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Device Analyzer Series

Programming Guide

Agilent Technologies

Notices

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For B1500A Users

Agilent B1500A supports the following modules. For reading this manual, ignore the information about the other modules.

- B1510A High power source/monitor unit (HPSMU)
- B1511A Medium power source/monitor unit (MPSMU)
- B1517A High resolution source/monitor unit (HRSMU)
- B1520A Multi frequency capacitance measurement unit (MFCMU or CMU)
- B1525A High voltage semiconductor pulse generator unit (HVSPGU or SPGU)

For B1505A Users

Agilent B1505A supports the following modules. For reading this manual, ignore the information about the other modules.

- B1510A High power source/monitor unit (HPSMU)
- B1512A High current source/monitor unit (HCSMU)
- B1513A High voltage source/monitor unit (HVSMU)
- B1520A Multi frequency capacitance measurement unit (MFCMU or CMU)

In This Manual

This manual provides the information to control the Agilent B1500 via GPIB interface using an external computer, and consists of the following chapters.

- "Programming Basics"

  This chapter provides basic information to control the Agilent B1500.

- "Remote Mode Functions"

  This chapter explains the functions of the Agilent B1500 in the remote mode.

- "Programming Examples"

  This chapter lists the GPIB commands and explains the programming examples for each measurement mode or function. The examples have been written in the Microsoft Visual Basic .NET or the HP BASIC language.

- "Command Reference"

  This chapter provides the complete reference of the GPIB commands of the Agilent B1500.

- "Error Messages"

  This chapter lists the error codes, and explains them.

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1. Programming Basics

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1 Programming Basics

This chapter describes basic information to control the Agilent B1500, and consists of the following sections.

- "Before Starting"
- "Getting Started"
- "Command Input Format"
- "Data Output Format"
- "GPIB Interface Capability"
- "Status Byte"
- "Programming Tips"

NOTE

About command execution examples

In this chapter, command execution examples are written in the HP BASIC language. See the following instructions for your guidance.

1. Use the ASSIGN statement to assign the I/O path.

   For example, enter the statement as shown below if the GPIB interface logial unit of controller is 7 and the GPIB interface address of instrument is 17.

   ```
   10 ASSIGN @B1500 TO 717
   ```

2. Use the OUTPUT statement to send commands to instruments, as shown below.

   ```
   OUTPUT @B1500;"*RST"
   ```

   It is available to send multiple commands as shown below.

   ```
   OUTPUT @B1500;"*CN;MM2,1"
   ```

3. Use the ENTER statement to get a query response or data from instruments.

Before Starting

Before starting the programming using the Agilent FLEX command, perform following.

1. Terminate the Agilent EasyEXPERT software as follows.
   a. Select *File* > *Exit* on the EasyEXPERT main window.
   b. Click [x] at the upper right corner of the Start EasyEXPERT button.
2. Open the Agilent Connection Expert window by clicking *Agilent IO Control* icon on the Windows task bar and selecting *Agilent Connection Expert*.
3. Change the following setup items as shown below. The setup window can be opened by highlighting *GPIB0* in the *Instrument I/O on this PC* area, and clicking *Change Properties*... button.

GPIB address	B1500’s GPIB address (ex: 17)
System Controller	No
Auto-discover	No

   The factory shipment initial values are 17, No, and No, respectively.
4. Reboot the B1500A if the System Controller setting is changed from Yes to No.

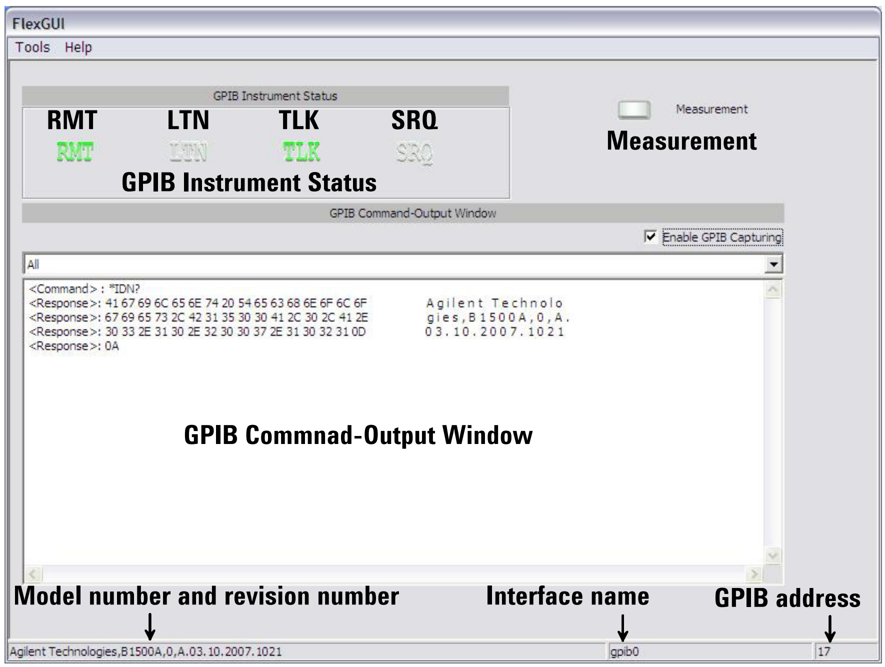
NOTE Start EasyEXPERT button

After rebooting the B1500A, leave the Start EasyEXPERT button on the B1500 screen. The button must be displayed on the screen or minimized to the Windows task bar. The Start EasyEXPERT service must be run to control the B1500 from an external computer.

FlexGUI Window

Once the Agilent B1500 receives a GPIB command, the Start EasyEXPERT button is minimized to the Windows task bar, and the FlexGUI window shown in Figure 1-1 is opened. The FlexGUI window is the status indicator of the B1500 in the GPIB remote state and provides the following GUI.

Figure 1-1 **FlexGUI Window**



Tools menu	**Go to Local & Close**	Returns the B1500 to the local state and closes the FlexGUI window. After that the Start EasyEXPERT button appears.
	Close	Substitution of Go to Local & Close when the B1500 is already in the local state. Closes the FlexGUI window. After that the Start EasyEXPERT button appears.
	Options > Enable GPIB Capturing	Enables or disables the GPIB log display function.
Help menu	**About FlexGUI**	Opens the About FlexGUI dialog box.

Model number and revision number

Shows “Agilent Technologies B1500A” and its firmware revision number.

Interface name

Shows the name of the B1500 internal GPIB interface.

GPIB address

Shows the GPIB address set to the B1500.

GPIB Instrument Status

Shows the B1500 remote status. Has the following indicators.

RMT	Turns green while the B1500 is in the GPIB remote state.
LTN	Turns green while the B1500 receives a GPIB command.
TLK	Turns green while the B1500 sends a response.
SRQ	Turns green since the service request occurs.

The last status display continues after the last communication.

Measurement

Measurement indicator. Turns green while measurement, self-test, self-calibration, program memory, or compensation data measurement is executed.

Enable GPIB Capturing

Enables or disables the GPIB log display function. This function can be set to ON by checking this check box.

The GPIB log display function is useful for debugging a program. For the normal remote operation, this function should be OFF.

GPIB Command-Output Window

Displays the following information as the communication log when the GPIB log display function is ON. No information is displayed when the function is OFF.

- GPIB commands sent to the B1500
- Response data sent from the B1500
- Error messages sent from the B1500

The display items can be selected by using the combo box.

All	Displays all of the above information.
Errors	Displays the error messages only.
Commands Sent	Displays the GPIB commands only.
Response Data	Displays the response data only.
Commands Sent & Response Data	Displays the GPIB commands and response data.

The right-click menu is available in the GPIB log display area.

Copy	Copies the highlighted data to the clipboard.
Select All	Highlights all of the displayed information.
Save to File	Saves the displayed information as the specified file which can be opened by using a text editor such as the Notepad.
Clear All	Deletes the displayed information.
Settings...	Available when the GPIB log display function is OFF. Opens the Settings dialog box.

Settings dialog box

This dialog box is opened by selecting Settings... of the right-click menu on the GPIB log display area, and is used to set the display update mode, the number of elements to be displayed in a line, and the display format.

GPIB Capturing Mode

Sets the display update mode to BYTE or BUFFER.

BYTE	Updates the log display every byte data which is one character of ASCII format.
BUFFER	Updates the log display every buffer data which is data to a terminator.

Elements(Response) in one Row

Sets the number of elements displayed in a line to 4, 8, 16, 32, 64, or 128 elements. One element is equivalent to one character of the ASCII format data.

Display Format

Sets the following function ON or OFF. The function can be set to ON by checking the check box.

Show Hex Data	Displays the values given in hexadecimal.
Show Ascii Data	Displays the values given in ASCII format.
Auto Clear	Clears the log display area automatically every display update. However, if an error occurs, the error message will be left in the log display area. Also, if the display update mode is BUFFER, the last log will be left in this area.

OK

Applies the setup changes and closes the dialog box.

Cancel

Cancels the setup changes and closes the dialog box.

Getting Started

This section explains the following basic operations. In this section, the HP BASIC language is used for the examples.

- "To Reset the Agilent B1500"
- "To Read Query Response"
- "To Perform Self-Test"
- "To Perform Self-Calibration"
- "To Perform Diagnostics"
- "To Enable Source/Measurement Channels"
- "To Select the Measurement Mode"
- "To Force Voltage/Current"
- "To Set the SMU Integration Time"
- "To Set the Measurement Range"
- "To Pause Command Execution"
- "To Start Measurement"
- "To Force 0 V"
- "To Disable Source/Measurement Channels"
- "To Control ASU"
- "To Control SCUU"
- "To Read Error Code/Message"
- "To Read Spot Measurement Data"
- "To Read Sweep Measurement Data"
- "To Read Time Stamp Data"
- "To Perform High Speed Spot Measurement"

To Reset the Agilent B1500

The B1500 returns to the initial settings by the *RST command.

Example

```
OUTPUT @B1500;"*RST"
```

For the initial settings, see “Initial Settings” on page 2-81.

To Read Query Response

If you enter a query command such as the *TST?, ERR? and so on, the B1500 puts an ASCII format response to the query buffer that can store only one response. Read the response as soon as possible after entering a query command.

Example

```
OUTPUT @B1500;"NUB?"
ENTER @B1500;A
```

This example returns the number of data stored in the data output buffer.

To Perform Self-Test

The B1500 starts the self-test by the *TST? command. The *TST? command also returns the test result.

Example

```
OUTPUT @B1500;"*TST?"
ENTER @B1500;Code
IF Code<>0 THEN DISP "FAIL: SELF-TEST"
```

This example starts the self-test, and reads the test result code. For the test result code, see “*TST?” on page 4-179.

To Perform Self-Calibration

The B1500 starts the self-calibration by the *CAL? command.

Example

```
OUTPUT @B1500;"*CAL?"
ENTER @B1500;Result
IF Result<>0 THEN DISP "FAIL: CALIBRATION"
```

This example starts the self-calibration, and reads the result, pass or fail. For details, see “*CAL?” on page 4-50.

To Perform Diagnostics

The B1500 starts the diagnostics by the DIAG? command, and returns the result. You must specify the diagnostics item by the command parameter. Available parameter values are:

1: Trigger In/Out diagnostics

3: High voltage LED diagnostics

4: Digital I/O diagnostics

To perform diagnostics 1, connect a BNC cable between the Ext Trig In terminal and the Ext Trig Out terminal before starting the diagnostics.

To perform diagnostics 4, disconnect any cable from the digital I/O port.

Example

```
OUTPUT @B1500;"DIAG? 1"
ENTER @B1500;Result
IF Result<>0 THEN DISP "FAIL: DIAGNOSTICS"
```

This example starts the Trigger In/Out diagnostics, and reads the result, pass or fail. For details, see “DIAG?” on page 4-66.

To Enable Source/Measurement Channels

The measurement channels or source channels can be enabled by closing the output switch. To close the switch, send the CN command. The B1500 closes the output switch of the specified channels.

Example

```
OUTPUT @B1500;"CN 1"
```

This example enables channel 1 (the module installed in slot 1 of the B1500). If you do not specify the channel, the CN command enables all channels.

To Select the Measurement Mode

The B1500 provides the measurement modes listed in Table 1-1. To select the measurement mode, send the MM command. In the table, the Mode No. means a command parameter of the MM command.

Syntax

```
MM Mode#[,Ch#[,Ch#] ... ]
```

where, Mode# specifies the Mode No., and Ch# specifies the measurement channel. The available number of measurement channels depends on the measurement mode. For details, see “MM” on page 4-112.

Table 1-1 **Measurement Mode**

Measurement Mode (measurement parameter)	Mode No.
Spot Measurement (current or voltage)	1
Staircase Sweep Measurement (current or voltage)	2
Pulsed Spot Measurement (current or voltage)	3
Pulsed Sweep Measurement (current or voltage)	4
Staircase Sweep with Pulsed Bias Measurement (current or voltage)	5
Quasi-Pulsed Spot Measurement (current or voltage)	9
Sampling Measurement (current or voltage)	10
Quasi-static CV Measurement (capacitance)	13
Linear Search Measurement (current or voltage)	14
Binary Search Measurement (current or voltage)	15
Multi Channel Sweep Measurement (current or voltage)	16
Spot C Measurement (impedance)	17
CV (DC bias) Sweep Measurement (impedance-DC voltage)	18
Pulsed Spot C Measurement (impedance)	19
Pulsed Sweep CV Measurement (impedance-voltage)	20
C-f Sweep Measurement (impedance-frequency)	22
CV (AC level) Sweep Measurement (impedance-AC voltage)	23
C-t Sampling Measurement (impedance)	26
Multi Channel Pulsed Spot Measurement (current or voltage)	27
Multi Channel Pulsed Sweep Measurement (current or voltage)	28
High Speed Spot Measurement (current, voltage, or impedance)	NA

Example

```
OUTPUT @B1500;"MM 2,1"
```

This example sets the staircase sweep measurement, and assigns channel 1 (the module installed in slot 1 of the B1500) as the measurement channel.

NOTE

The Mode No. is not assigned for the high speed spot measurement. See “To Perform High Speed Spot Measurement” on page 1-21. The high speed spot measurement does not need the MM command.

For the source output commands available for each measurement mode, see Table 1-2.

Table 1-2 Measurement Mode and Available Source Output Commands

Measurement Mode	Command
Staircase Sweep Measurement	WV or WI, WSV or WSI
Pulsed Spot Measurement	PT, PV or PI
Pulsed Sweep Measurement	PT, PWV or PWI, WSV or WSI
Staircase Sweep with Pulsed Bias Measurement	PT, PV or PI, WV or WI, WSV or WSI
Quasi-Pulsed Spot Measurement	BDV
Sampling Measurement	MV, MI, MSP
Quasi-static CV Measurement	QSV
Linear Search Measurement	LSV or LSI, LSSV or LSSI
Binary Search Measurement	BSV or BSI, BSSV or BSSI
Multi Channel Sweep Measurement	WNX, WV or WI
CV (DC bias) Sweep Measurement	WDCV
Pulsed Spot C Measurement	PTDCV, PDCV
Pulsed Sweep CV Measurement	PTDCV, PWDCV
C-f Sweep Measurement	WFC
CV (AC level) Sweep Measurement	WACV
C-t Sampling Measurement	MDCV
Multi Channel Pulsed Spot Measurement	MCPT, MCPNT, MCPNX
Multi Channel Pulsed Sweep Measurement	MCPT, MCPNT, MCPWS, WNX, MCPNX, MCPWNX

To Force Voltage/Current

The commands listed in Table 1-3 is used to force voltage or current. These commands start to force the voltage or current immediately when the command is executed. They can be used regardless of the measurement mode.

See Table 1-2 on page 1-11 for the commands available for each measurement mode. The commands just set the source channel condition, and the source channel starts the output by the start trigger, such as the XE command. For more details of the commands, see Chapter 4, “Command Reference.”

Table 1-3 **Voltage/Current Output Commands**

Command	Description
DV	Applies DC voltage from SMU immediately.
DI	Applies DC current from SMU immediately.
FC/ACV	Applies AC voltage from CMU immediately.
DCV	Applies DC bias from CMU immediately.
TDV	Applies DC voltage from SMU, and returns the time data.
TDI	Applies DC current from SMU, and returns the time data.
FC/TACV	Applies AC voltage from CMU, and returns the time data.
TDCV	Applies DC bias from CMU, and returns the time data.

Example

```
OUTPUT @B1500;"DV 1,0,5"
```

This example just forces 5 V using channel 1 (the module installed in slot 1 of the B1500) with auto ranging.

To Set the SMU Integration Time

To adjust the balance of the SMU’s measurement accuracy and speed, change the integration time or the number of averaging samples of the A/D converter (ADC) by using the AV command. The AV command is compatible with the AV command of the Agilent 4142B.

For accurate and reliable measurement, set the integration time longer or set the number of samples larger. For details about the integration time settings, see Chapter 4, “Command Reference.”

The following type of the ADC is available. Use the AAD command to select the type, and use the AIT command to set the integration time or the number of samples.

Type	Description
High-speed ADC	Effective for the high speed measurement. In the multi channel sweep measurement mode (MM16), multiple measurement channels can perform synchronous measurements. The number of averaging samples must be set by the AV or AIT command.
High-resolution ADC	Effective for the accurate measurement. Cannot be used for the pulsed measurement channel and the simultaneous measurement channel. The integration time must be set by the AIT command. Not available for the HCSMU and HVSMU.
Pulsed measurement ADC	Always used for the pulsed measurement. The number of averaging samples must be set by the AIT.

Example

The following example sets the number of samples to 10 for the high-speed A/D converter.

```
OUTPUT @B1500;"AV 10,1"
```

The following example sets the power line cycle mode (PLC) for both the high-speed ADC and the high-resolution ADC. And channel 1 uses the high-resolution ADC and other channels use the high-speed ADC.

```
OUTPUT @B1500;"*RST"
OUTPUT @B1500;"AIT 0,2"
OUTPUT @B1500;"AIT 1,2"
OUTPUT @B1500;"AAD 1,1"
```

To Set the Measurement Range

To set the measurement range, send the following command:

Command	Description
RI	Sets the current measurement range. Available for the current measurements that use the XE command. Not available for the high speed spot measurement.
RV	Sets the voltage measurement range. Available for the voltage measurements that use the XE command. Not available for the high speed spot measurement.
RC	Sets the impedance measurement range. Available for the CV sweep/spot C measurements.
TI, TTI	Sets the current measurement channel and range, and performs the high speed spot measurement.
TV, TTV	Sets the voltage measurement channel and range, and performs the high speed spot measurement.
TIV, TTIV	Sets the current and voltage measurement channel and ranges, and performs the high speed spot measurement.
TC, TTC	Sets the impedance measurement channel and range, and performs the high speed spot measurement.

For the current measurement with the auto ranging mode, you can specify the coverage of each measurement range. To specify the coverage, send the RM command.

For details, see Chapter 4, “Command Reference.”

Example

This example sets the voltage measurement ranging mode of channel 1 to auto.

```
OUTPUT @B1500;"RV 1,0"
```

This example sets the current measurement ranging mode of channel 1 to auto, and specifies coverage between 9 % and 90 % of the range value or between 90 mA and 180 mA for the 200 mA range.

```
OUTPUT @B1500;"RI 1,0"
OUTPUT @B1500;"RM 1,3,90"
```

NOTE

To use 1 pA range of ASU

Set the 1 pA limited auto ranging mode or the 1 pA fixed range mode. Or enable the 1 pA range for the auto ranging mode by using the SAR command. See “SAR” on page 4-147.

To Pause Command Execution

To pause command execution until the specified wait time elapses, send the PA command.

Example

```
OUTPUT @B1500;"PA 5"
```

If this command is sent, the B1500 waits 5 seconds before executing the next command.

To Start Measurement

To start measurement other than the high speed spot measurement, send the XE command.

Example

```
OUTPUT @B1500;"XE"
```

This starts the measurement specified by the MM command.

For the high speed spot measurement, see "To Perform High Speed Spot Measurement" on page 1-21.

To Force 0 V

To force 0 V immediately, send the DZ command. The B1500 memorizes the present source output settings of the specified channel, and changes the specified channel output to 0 V. If you do not specify the channel, the DZ command function is effective for all channels.

Example

```
OUTPUT @B1500;"DZ 1"
```

If this command is sent, the B1500 memorizes the current settings of channel 1 (the module installed in slot 1 of the B1500), and changes channel 1 output to 0 V.

To restore the settings stored by the DZ command, send the RZ command. For details, see Chapter 4, "Command Reference."

To Disable Source/Measurement Channels

To disable the channels, send the CL command. The B1500 opens the output switch of the specified channels. Opening the output switch disables the channel.

Example

```
OUTPUT @B1500;"CL 1"
```

This example disables channel 1 (the module installed in slot 1 of the B1500). If you do not specify the channel, the CL command disables all channels.

To Control ASU

This function is available for Agilent B1500A. ASU (atto sense and switch unit) has two inputs, SMU input for the HRSMU (high resolution SMU) and AUX input for the other instrument. And the ASU input to output connection can be controlled by the following commands. When the B1500 is turned on, the SMU input will be connected to the ASU output. However, the SMU output switch will be off at this time.

Table 1-4 ASU Input Output Connection Control

Previous Connection	Command	Subsequent Connection
SMU side, Output on/off	SAP *chnum*, 1	AUX side
SMU side, Output off	CN *chnum*	SMU side, Output on
	SAP *chnum*, 0	
AUX side	CN *chnum*	
	SAP *chnum*, 0	
	CL [*chnum*]	SMU side, Output off
SMU side, Output on	CL [*chnum*]	

where, *chnum* must be the channel number of the HRSMU connected to the ASU. See “SAL”, “SAP”, and “SAR” on page 4-147 for the other function and control commands of the ASU.

When the SMU side is connected to the ASU output, the source output on/off can be controlled by the CN/CL command. And then the SAP *chnum*, 1 command is used to change the output connection to the AUX side. When the AUX side is connected, the output of the instrument connected to the AUX input is appeared to the ASU output immediately.

To Control SCUU

This function is available for Agilent B1500A. SCUU (SMU CMU unify unit) can be used with one capacitance measurement unit (CMU) and two SMUs (MPSMU or HRSMU). The SCUU cannot be used with the HPSMU or when only one SMU is connected. The SCUU input to output connection can be controlled by the following commands. When the B1500 is turned on, the SCUU input to output connection is not made (open).

Table 1-5 SCUU Input Output Connection Control

Command	SCUU output connection after the command	
	CMUH/Force1/Sense1	**CMUL/Force2/Sense2**
SSP *chnum*, 1	Force1/Sense1	Open
SSP *chnum*, 2	Open	Force2/Sense2
SSP *chnum*, 3	Force1/Sense1	Force2/Sense2
SSP *chnum*, 4	CMUH	CMUL

Force1/Sense1 is connected to the SMU installed in the slot numbered *slot*-1.
Force2/Sense2 is connected to the SMU installed in the slot numbered *slot*-2.
where, *slot* is the slot number given by *chnum*. When the SCUU input to output connection is made, the measurement unit output switch will be automatically set to ON.

When the connection is changed from SMU to CMU, the SMU output will be set as follows. The other setup parameters are not changed.

Output voltage 0 V

Output range 100 V

Compliance 20 mA

Series resistance OFF

When the connection is changed from CMU to SMU, the SMU output will be set as follows. The other setup parameters are not changed.

Output voltage 0 V

Output range 20 V

Compliance 100 μA

Series resistance Condition before the connection is changed from SMU to CMU

To Read Error Code/Message

If any error occurs, the B1500 will not put the measurement data into the data output buffer. Hence, confirm that no error has occurred before reading the measurement data. To read the error code and the error message, enter the ERRX? command.

Example

```
OUTPUT @B1500;"ERRX?"
ENTER @B1500;Code,Msg$
IF Code<>0 THEN
  PRINT "ERROR: ";Msg$
ELSE
 :   :
```

This example checks the error buffer, and prints the error message on the computer screen if any error code is stored in the error buffer.

ERR? and EMG? commands are also available. These commands support the error codes 0 to 999.

To Read Spot Measurement Data

After the spot measurements, the B1500 puts the measurement data into its output data buffer. You can read the data as shown below. The examples read the header information and the measurement data included in the ASCII data set by the FMT5 command. For the data output format, see “Data Output Format” on page 1-25. The example uses the HP BASIC or Microsoft Visual Basic .NET language.

Example 1

For the HP BASIC users, use the ENTER statement.

```
ENTER @B1500 USING "#,3A,12D,X";Head$,Mdata
```

Example 2

For the VISA library users, use the viScanf, viRead, or another function.

```
Dim ret_rd As System.Text.StringBuilder = _
           New System.Text.StringBuilder(3 + 12 + 1)
ret = viScanf(vi, "%t", ret_rd)
ret_val = ret_rd.ToString()
head = Left(ret_val, 3)
mdata = Val(Mid(ret_val, 4, 12))
```

Example 3

For the VISA COM library users, use the ReadString or another method.

```
ret_val = B1500.ReadString(3 + 12 + 1)
head = Left(ret_val, 3)
mdata = Val(Mid(ret_val, 4, 12))
```

To Read Sweep Measurement Data

For the sweep measurements, the measurement data will be put into the data output buffer after every step measurement. You can read the data as shown below. The examples use the VISA COM library and Microsoft Visual Basic .NET language. For the data output format, see “Data Output Format” on page 1-25.

- To read data after sweep measurement

  This way waits for the measurement completion by using the *OPC? command after the XE command, and reads the sweep data (all step measurement data) at once after the sweep measurement is completed. For the specific example, see Table 3-5 on page 3-19.

  Example:

```
B1500.WriteString("FMT 5,0" & vbLf)    'terminator=comma
B1500.WriteString("XE" & vbLf)
B1500.WriteString("*OPC?" & vbLf)
rep = B1500.ReadString(1 + 2)          'Response+CRLF
ret_val = B1500.ReadString(16 * nop)
For i = 0 To nop - 1           'nop=number of sweep steps
  head = Mid(ret_val, 16 * i + 1, 3)
  mdata = Val(Mid(ret_val, 16 * i + 4, 12))
  ddata = "Data = " & mdata & ", Header = " & head
  Console.WriteLine(ddata)
Next i
```

- To read data after every step measurement

  This way starts to read the data after the XE command. You do not need to wait for the sweep measurement completion. So you can check the result data before the sweep measurement is completed. For the specific example, see Table 3-6 on page 3-22.

  Example:

```
B1500.WriteString("FMT 5,0" & vbLf)      'terminator=comma
B1500.TerminationCharacter = Chr(44)     'Chr(44)=comma
B1500.TerminationCharacterEnabled = True 'enables comma
B1500.WriteString("XE" & vbLf)
For i = 0 To nop - 1           'nop=number of sweep steps
  ret_val = B1500.ReadString(3 + 12 + 1)
  head = Left(ret_val, 3)
  mdata = Val(Mid(ret_val, 4, 12))
  ddata = "Data = " & mdata & ", Header = " & head
  Console.WriteLine(ddata)
Next i
```

To Read Time Stamp Data

NOTE

This function is *not* available for the quasi-pulsed spot measurement (MM 9), search measurement (MM 14 or 15), and the 4 byte binary data output (FMT 3 or 4).

To read the time data with the best resolution (100 μs), clear the timer every 100 s or less (for FMT 1, 2, or 5), or 1000 s or less (for FMT 11, 12, 15, 21, 22, or 25).

The time stamp function records the time from timer reset (*Time*=0 s) to the start of measurement. This function is enabled by the TSC command. The timer count is cleared/reset by the TSR command.

For example, the output data in the staircase sweep measurement will be as follows:

Block1 [,*Block2*] . . . . <terminator>

BlockN (*N*: integer) = *Time1*,*Data1* [,*Time2*,*Data2*] ... [,*Source_data*]

TimeN (*N*: integer) is the time from timer reset to the start of *DataN* measurement.

Without the TSC command, you can get the time data by the following commands:

- TDV / TDI (for voltage/current output by using a SMU),
  TDCV / TACV (for DC voltage/AC voltage output by using the CMU):

  Starts source output, and returns the time data from timer reset (TSR command) to the start of output.

  Example:
  ```
  OUTPUT @B1500;"TDV 1,0,20"
  ENTER @B1500 USING "#,5X,13D,X";Time
  PRINT "Time=";Time;"sec"
  ```

- TTV / TTI / TTIV (for voltage/current measurement by using a SMU),
  TTC (for impedance measurement by using the CMU):

  Executes high speed spot measurement, and returns the measurement data and the time data from timer reset (TSR command) to the start of measurement.

  Example:
  ```
  OUTPUT @B1500;"TTV 1,0"
  ENTER @B1500 USING "#,5X,13D,X";Time
  ENTER @B1500 USING "#,5X,13D,X";Mdata
  PRINT "Data=";Mdata;" at ";Time;"sec"
  ```

- TSQ: Returns the time data from timer reset (TSR command) to this command.

  Example:
  ```
  OUTPUT @B1500;"TSR"            !Resets count
        :
  OUTPUT @B1500;"TSQ"            !Returns time data
  ENTER @B1500 USING "#,5X,13D,X";Time
  PRINT "Time=";Time;"sec"
  ```

To Perform High Speed Spot Measurement

The high speed spot measurement does not need the MM and XE commands to set the measurement mode and start measurement. To start and perform the high speed spot measurement immediately, send the TI/TTI/TV/TTV/TIV/TTIV command to a SMU for the DC current or voltage measurement, or the TC/TTC command to the CMU for the impedance measurement. The following example program measures current by using the TI command, and displays the measurement result data on the computer screen.

Example

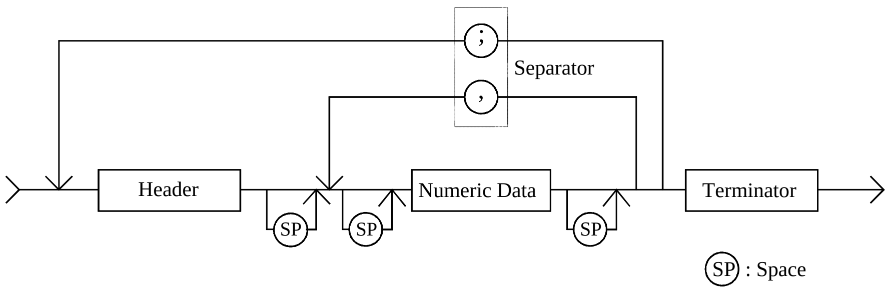
```
10    ASSIGN @B1500 TO 717
20    OUTPUT @B1500;"*RST"
30    OUTPUT @B1500;"FMT 5"
40    OUTPUT @B1500;"CN 1,2,3,4"
50    OUTPUT @B1500;"DV 1,0,0"
60    OUTPUT @B1500;"DV 2,0,0"
70    OUTPUT @B1500;"DV 3,0,2"
80    OUTPUT @B1500;"DV 4,0,5"
90    OUTPUT @B1500;"TI 4,0"
100   ENTER @B1500 USING "#,3A,12D,X";Head$,Data
110   PRINT Head$,Data
120   OUTPUT @B1500;"DZ"
130   OUTPUT @B1500;"CL"
140   END
```

Line Number	Description
10	Assigns the I/O path to control the B1500.
20	Initializes the B1500.
30	Sets the data output format (ASCII with header and <,>).
40	Enables channels 1, 2, 3, and 4.
50 to 80	Forces the DC voltage. Channel 1 and 2 force 0 V, channel 3 forces 2 V, and channel 4 forces 5 V with auto ranging.
90	Performs the high speed spot measurement using channel 4 with auto ranging.
100 to 110	Prints the header data and measurement data on the screen.
120	Forces 0 V. All channels force 0 V.
130	Disables all channels.

Command Input Format

Agilent FLEX commands (GPIB commands for the Agilent B1500) are composed of a header, numeric data, and terminator, as shown in the following syntax diagram.

B1500 Control Command Syntax Diagram



NOTE

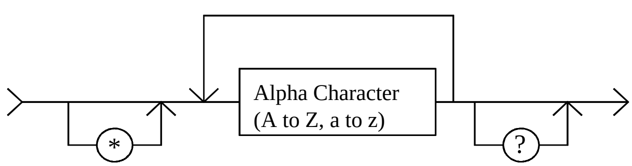
Terminator

Terminator is necessary to enter the command to the Agilent B1500. For the available terminators, see “Terminator” and “Special Terminator” on page 1-24.

Header

The header is the command name, always contains alpha characters, and is not upper or lowercase sensitive. Some command names also contain an asterisk (*) or question mark (?). The following figure shows the syntax diagram for a header.

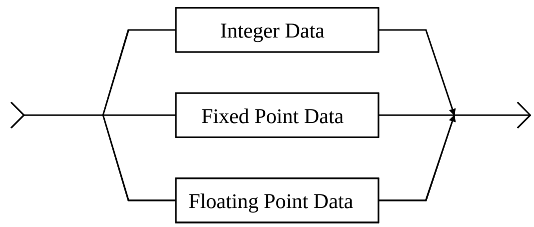
Header Syntax Diagram



Numeric Data

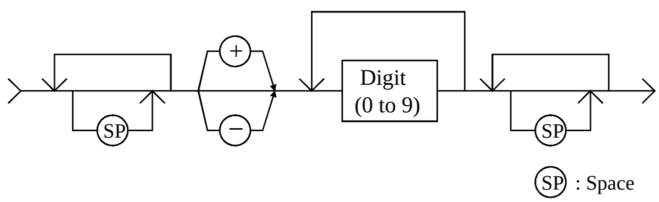
Numeric data are the command parameters. You can enter numeric data directly after the header or insert spaces between the header and numeric data. Some parameters require integer data. The following figure shows the syntax diagram for numeric data.

Numeric Data Syntax Diagram

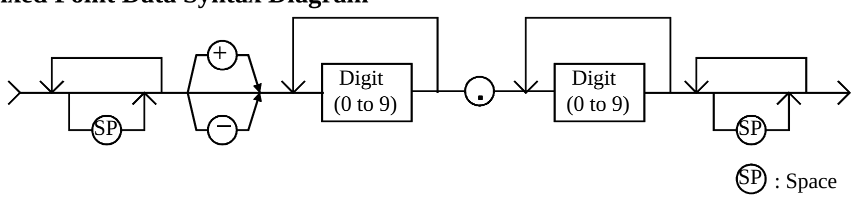


The following 3 figures show the syntax diagrams for integer, fixed point, and floating point data, respectively.

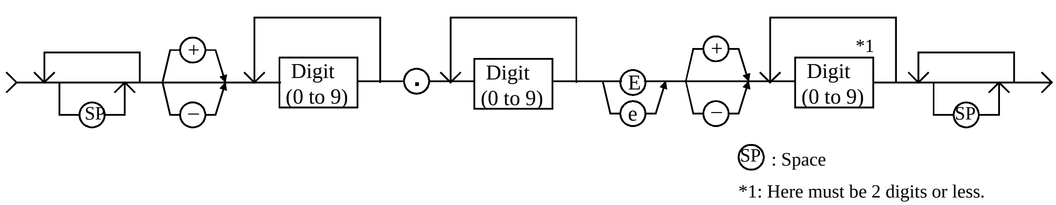
Integer Data Syntax Diagram



Fixed Point Data Syntax Diagram



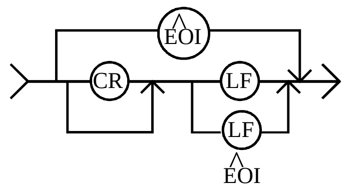
Floating Point Data Syntax Diagram



Terminator

The terminator completes the GPIB command entry and starts command execution. The following figure shows the terminator syntax diagram.

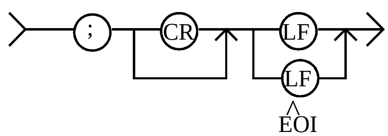
Terminator Syntax Diagram



Special Terminator

If a semicolon (;) is inserted before the terminator, as shown in the following figure, the preceding commands are not executed until the next command line is input and another terminator is input, without a preceding semicolon. The command lines are then executed together.

Special Terminator Syntax Diagram



Separator

If you enter multiple commands, use semicolons (;) to separate the commands. Spaces are allowed before and after the semicolons. Command execution starts when the terminator is received, not when the semicolon is received. You can input multiple commands of up to a total of 256 characters (including the terminator). If you input more than 256 characters, the input buffer overflows, and an error is indicated.

Use commas (,) to separate numeric data entries.

NOTE

Do not include the reset command (*RST) or the abort command (AB) in multiple command strings (example: `OUTPUT @B1500;"*RST;CN"`). If you do, the other commands in the string (example: `CN`) are not executed.

Data Output Format

Agilent B1500 provides the following data output formats:

- “ASCII Data Output Format”

  The B1500 supports the ASCII data format that is the common format for the instruments that support the Agilent FLEX command mode.

- “Binary Data Output Format”

  The B1500 supports the 4 bytes binary data format that is the common format for the instruments that support the Agilent FLEX command mode. The B1500 also supports the dedicated 8 bytes binary format. The binary format enables faster data transfer time than ASCII format. You need to calculate the data to get the measurement result.

To select the data output format, use the FMT command. See “FMT” on page 4-82.

For the query response, the returned data is always stored in the query buffer in ASCII format, regardless of the FMT command setting.

A minimum of 17×1001×2 (34034) measurement data can be stored in the data output buffer.

Conventions

The following conventions are used in this section.

Data Output data that the B1500 sends after a measurement.

[*Data*] Optional output data sent when there are multiple output data items.

For example, source data will be sent with measurement data after the staircase sweep measurements when the source data output is enabled by the FMT command.

<terminator> Terminator.

<CR/LF^EOI> (two bytes) or <,> (one byte) for ASCII data.

<CR/LF^EOI> (two bytes) or <^EOI> (0 byte) for binary data.

You can select by using the FMT command.

ASCII Data Output Format

This section describes the ASCII data output format, and the elements of the data.

- "Time Stamp"
- "Data Format"
- "Data Elements"

Time Stamp

The B1500 can record the time when the measurement is started, and sends the time data (*Time*). This function is enabled by the TSC command. The time data will be sent just before the measurement data.

For example, in the staircase sweep measurements, the data will be as shown below.

Block1 [,*Block2*] . . . . <terminator>

where, *BlockN* (*N*: integer) = *Time1*,*Data1* [,*Time2*,*Data2*] ... [,*Source_data*], then *TimeN* (*N*: integer) is the time from timer reset to the start of *DataN* measurement.

The timer count is cleared/reset by the TSR command (*Time*=0).

The time stamp function is *not* available for the following measurements.

- High speed spot measurement
- Quasi-pulsed spot measurement (MM9)
- Linear search measurement (MM14)
- Binary search measurement (MM15)

Data Format

The data output format depends on the measurement mode as shown below.

High speed spot

Data <terminator>	(by TI, TV, TMACV, or TMDCV command)
Time,*Data* <terminator>	(by TTI or TTV command)
Para1,*Para2* <terminator>	(by TIV or TC command)
Time,*Para1*,*Para2* <terminator>	(by TTIV or TTC command)

Data is the value measured by the channel you specify in the command. *Time* is the time from timer reset to the start of measurement. *Para1* and *Para2* are current (A) and voltage (V) respectively measured by the SMU or the primary and secondary parameters (ex: Cp and G) respectively measured by the CMU. The CMU measurement data is selected by the IMP command. See Table 4-12 on page 4-23.

TDI, TDV, TSQ, TACV, TDCV command

Time <terminator>

Time is the time from timer reset to the start of output.

Spot, Multi channel pulsed spot

Data1 [,*Data2*] . . . . <terminator>

DataN (*N*: integer) is the value measured by a channel. The order of *Data* is defined by the MM command.

Pulsed spot, Quasi-pulsed spot, Spot C, Pulsed spot C

Data <terminator>

Data is the value measured by the channel you specify by using the MM command.

For the spot C measurement, *Data* will be *Para1*,*Para2* [,*Osc_level*,*Dc_bias*].

For the pulsed spot C measurement, *Data* will be *Para1*,*Para2*.

Para1 and *Para2* are the primary and secondary parameters (ex: Cp and G). They are selected by the IMP command. See Table 4-12 on page 4-23. And *Osc_level* and *Dc_bias* are the monitor values of the oscillator level (AC signal level) and the DC bias respectively. They are sent if the data output is enabled by the LMN command.

Linear search, Binary search

Data_search [,*Data_sense*]<terminator>

This is the data at the measurement point closest to the search target. *Data_search* is the value forced by the search output channel. *Data_sense* is the value measured by the search monitor channel. It is sent if data output is enabled by the BSVM command for the binary search, or the LSVM command for the linear search.

Staircase sweep, Multi channel sweep, Multi channel pulsed sweep, CV (DC bias) sweep

Block1 [,*Block2*] . . . . <terminator>

Block1 is the block of data measured at the first sweep point.
Block2 is the block of data measured at the second sweep point.
where *Block* consists of the following data:

Data1 [,*Data2*] . . . . [,*Source_data*]

DataN (*N*: integer) is the value measured by a channel. The order of *Data* is defined by the MM command. *Source_data* is the sweep source output value. It is sent if the data output is enabled by the FMT command.

For the CMU measurement data, *DataN* will be *Para1*,*Para2* [,*Osc_level*,*Dc_bias*].

Para1 and *Para2* are the primary and secondary parameters (ex: Cp and G). They are selected by the IMP command. See Table 4-12 on page 4-23. And *Osc_level* and *Dc_bias* are the monitor values of the oscillator level (AC signal level) and the DC bias respectively. They are sent if the data output is enabled by the LMN command.

Pulsed sweep, Staircase sweep with pulsed bias, Pulsed sweep CV, CV (AC level) sweep, C-f sweep

Block1 [,*Block2*] . . . . <terminator>

Block1 is the block of data measured at the first sweep point.
Block2 is the block of data measured at the second sweep point.
where *Block* consists of the following data:

Data [,*Source_data*]

Data is the value measured by the channel you specify by using the MM command. *Source_data* is the sweep source output value. It is sent if the data output is enabled by the FMT command.

For the pulsed sweep CV measurement, *Data* will be *Para1*,*Para2*.

For the CV (AC level) and C-f, *Data* will be *Para1*,*Para2* [,*Osc_level*,*Dc_bias*].

Para1 and *Para2* are the primary and secondary parameters (ex: Cp and G). They are selected by the IMP command. See Table 4-12 on page 4-23. And *Osc_level* and *Dc_bias* are the monitor values of the oscillator level (AC signal level) and the DC bias respectively. They are sent if the data output is enabled by the LMN command.

Sampling, C-t sampling

Block1 [,*Block2*] . . . . <terminator>

Block1 is the block of the data measured at the first sampling point.
Block2 is the block of the data measured at the second sampling point.
where *Block* consists of the following data:

[*Sampling_no*,] *Data1* [,*Data2*] . . . .

Sampling_no is the sampling point index, and is returned by entering the FMT command with *mode*<>0. This value depends on the sampling interval setting and the measurement time. If the measurement time is shorter than the sampling interval, *Sampling_no* will be *N* of *BlockN* (*N*: 1, 2, 3 . . .).

DataN (*N*: integer) is the data measured by one unit. The order of *Data* is specified by the MM command. *Sampling_no* and *Data* values can be discarded when the range changing is occurred while the measurement with auto or limited auto ranging.

If the measurement time is longer than the sampling interval, *Sampling_no* is not *N* of *BlockN*. For example, if the measurement time is longer than the sampling interval and shorter than twice the sampling interval, then the *Sampling_no* is 2 for *Block1*, and 4 for *Block2*. In general, the measurement time depends on the measurement value and the A/D converter settings.

For the C-t sampling, *DataN* will be *Para1*,*Para2*.

Para1 and *Para2* are the primary parameter and the secondary parameter (ex: Cp and G). They are selected by the IMP command. See Table 4-12 on page 4-23.

Quasi-static CV

Block1 [,*Block2*] . . . . <terminator>

Block1 is the block of the data measured at the first sweep point.
Block2 is the block of the data measured at the second sweep point.
where *Block* consists of the following data:

[*DataL*,] *DataC* [,*Source_data*]

DataL is the leakage current measurement data. *DataC* is the capacitance measurement data. *Source_data* is the sweep source output value. *DataL* and *Source_data* are sent if the data output is enabled by the QSL or FMT command.

Data Elements

The data (*Data*, *Source_data*, *Time*, *Sampling_no*, *Data_search*, *Data_sense*, *Osc_level*, and *Dc_bias*) are the string as shown in Table 1-6.

The data elements depends on the FMT command setting. Details of the elements are described on the following pages.

A: Status. One character.

B: Channel number. One character.

C: Data type. One character.

D: Data. Twelve digits or 13 digits.

E: Status. Three digits.

F: Channel number. One character.

G: Data type. One character.

Table 1-6 **Data Elements**

Data	FMT command
ABCDDDDDDDDDDDD	FMT1 or FMT5
ABCDDDDDDDDDDDDD	FMT11 or FMT15
EEEFGDDDDDDDDDDDDD	FMT21 or FMT25
DDDDDDDDDDDD	FMT2
DDDDDDDDDDDDD	FMT12 or FMT22

A Status. One character.

- Status for *Source_data*: See Table 1-7 on page 1-32.

  Severity of a status is W<E.

- Status for measurement data: See Table 1-10 on page 1-33.

  For SMU, the severity of a status is as follows:

  - For the quasi-pulsed spot measurement: N<T<C<V<X<G or S
  - For other measurement: N<G<S<T<C<V<X

B Channel number of the measurement/source channel. One character. See Table 1-11 on page 1-34.

C Data type. One character. See Table 1-12 on page 1-35.

D Measurement data, output data, time data, or sampling index. Twelve or 13 digits depends on FMT setting, which may be one of the following:

- *sn.nnnnn*E*snn* or *sn.nnnnnn*E*snn*
- *snn.nnnn*E*snn* or *snn.nnnnn*E*snn*
- *snnn.nnn*E*snn* or *snnn.nnnn*E*snn*

where,

s: Sign, **+** or **-**.

n: Digit, 0 to 9.

E: Exponent symbol.

E Status. Three digits. Ignore status for the *Time* value.

- Status for *Source_data*: See Table 1-7 on page 1-32.

  Severity of a status is W<E.

- Status for measurement data:

  For SMU status, see Table 1-8 on page 1-32.

  For CMU status, see Table 1-9 on page 1-32.

  If multiple status conditions are found, the sum of the *EEE* values is returned. For example, if an A/D converter overflow occurred, and an SMU was oscillating during the measurements, the returned *EEE* value is 3 (=1+2).

F Channel number of the source/measurement module. One character. See Table 1-11 on page 1-34.

G Data type. One character. Also see Table 1-12 on page 1-35.

Table 1-7 **Source Data Status**

A or EEE	Explanation
W	Data is for the first or intermediate sweep step.
E	Data is for the last sweep step.

Table 1-8 **SMU Status**

EEE	Explanation
1	A/D converter overflowed.
2	Oscillation or force saturation occurred.
4	Another unit reached its compliance setting.
8	This unit reached its compliance setting.
16	Target value was not found within the search range.
32	Search measurement was automatically stopped.
64	Invalid data is returned. *D* is not used.
128	EOD (End of Data).

Table 1-9 **CMU Status**

EEE	Explanation
1	A/D converter overflowed.
2	CMU is in the NULL loop unbalance condition.
4	CMU is in the IV amplifier saturation condition.
8	Not assigned.
16	Not assigned.
32	Not assigned.
64	Invalid data is returned. *D* is not used.
128	EOD (End of Data).

Table 1-10 Status for Measurement Data

A	Explanation
N	No status error occurred.
T	Another channel reached its compliance setting.
C	This channel reached its compliance setting.
V	Measurement data is over the measurement range. Or the sweep measurement was aborted by the automatic stop function or power compliance. *D* will be 199.999E+99 (no meaning).
X	One or more channels are oscillating. Or source output did not settle before measurement.[a]
F	SMU is in the force saturation condition.
G	For linear or binary search measurement, the target value was not found within the search range. Returns the source output value.
	For quasi-pulsed spot measurement, the detection time was over the limit (3 s for Short mode, 12 s for Long mode).[b]
S	For linear or binary search measurement, the search measurement was stopped. Returns the source output value. See status of *Data_sense*.
	For quasi-pulsed spot measurement, output slew rate was too slow to perform the settling detection.[c] Or quasi-pulsed source channel reached the current compliance before the source output voltage changed 10 V from the start voltage.[d]
U	CMU is in the NULL loop unbalance condition.
D	CMU is in the IV amplifier saturation condition.

a. Make the wait time or delay time longer. Or make the current compliance larger. For pulsed measurement, make the pulse width longer, or make the pulse base value closer to the pulse peak value. For current output by limited auto ranging, make the output range lower.
b. Make the current compliance or start voltage larger. Or set the detection interval to Long. If this status occurs with the Long mode, perform the spot measurement.
c. Make the current compliance larger. Or set the detection interval to Long. If this status occurs with the Long mode, perform the spot measurement or pulsed spot measurement.
d. Perform the pulsed spot measurement or spot measurement.

Table 1-11 Channel Number

B or F	Explanation[a]
A	Subchannel 1 of the module installed in the slot 1
B	Subchannel 1 of the module installed in the slot 2
C	Subchannel 1 of the module installed in the slot 3
D	Subchannel 1 of the module installed in the slot 4
E	Subchannel 1 of the module installed in the slot 5
F	Subchannel 1 of the module installed in the slot 6
G	Subchannel 1 of the module installed in the slot 7
H	Subchannel 1 of the module installed in the slot 8
I	Subchannel 1 of the module installed in the slot 9
J	Subchannel 1 of the module installed in the slot 10
a	Subchannel 2 of the module installed in the slot 1
b	Subchannel 2 of the module installed in the slot 2
c	Subchannel 2 of the module installed in the slot 3
d	Subchannel 2 of the module installed in the slot 4
e	Subchannel 2 of the module installed in the slot 5
f	Subchannel 2 of the module installed in the slot 6
g	Subchannel 2 of the module installed in the slot 7
h	Subchannel 2 of the module installed in the slot 8
i	Subchannel 2 of the module installed in the slot 9
j	Subchannel 2 of the module installed in the slot 10
F	**Explanation**
V	Ground unit (GNDU)
Z	Status code for extraneous data in the channel. TSQ command response or invalid data is returned.

a. SMU and CMU do not have the subchannel 2.

Table 1-12 **Data Type**

C	Explanation
V	Voltage (V)
I	Current (A)
F	Frequency (Hz)
C or G	**Explanation**
Z	Impedance, resistance, or reactance (Ω)
Y	Admittance, conductance, or susceptance (S)
C	Capacitance (F)
L	Inductance (H)
R	Phase (radian)
P	Phase (degree)
D	Dissipation factor
Q	Quality factor
X	Sampling index
T	Time (second)
G	**Explanation**
V	Voltage measurement value (V)
I	Current measurement value (A)
v	Voltage output value (V)
i	Current output value (A)
f	Frequency (Hz)
z	invalid data

Binary Data Output Format

This section describes the binary data output format, and the elements of the data.

- "Time Stamp"
- "Data Resolution"
- "Data Format"
- "4 Bytes Data Elements"
- "8 Bytes Data Elements"

Time Stamp

The B1500 can record the time when the measurement is started, and sends the time data (*Time*). This function is enabled by the TSC command. The time data will be sent just before the measurement data.

For example, in the staircase sweep measurements, the data will be as shown below.

Block1 [*Block2*] . . . . <terminator>

where, *BlockN* (*N*: integer) = *Time1 Data1* [*Time2 Data2*] ... [*Source_data*], then *TimeN* (*N*: integer) is the time from timer reset to the start of *DataN* measurement.

The timer count is cleared/reset by the TSR command (*Time*=0).

The time stamp function is *not* available for the following measurements.

- 4 bytes binary data format (FMT3 or FMT4)
- High speed spot measurement
- Quasi-pulsed spot measurement (MM9)
- Linear search measurement (MM14)
- Binary search measurement (MM15)

Data Resolution

The 4 bytes binary data format provides the following data resolution. To use this data format, enter the FMT3 or FMT4 command. The resolution of the SMU measurement value will be larger than the measurement resolution of the B1500's high resolution A/D converter. For *Range* value, see "4 Bytes Data Elements" on page 1-41.

- SMU measurement value (voltage or current): *Range* / 50000
- SMU output value (voltage or current): *Range* / 20000
- CMU measurement value (resistance or reactance): *Range* / 2^{12}
- CMU measurement value (conductance or susceptance): 1 / (*Range* $\times 2^{12}$)
- CMU oscillator level monitor value (Vac), DC bias monitor value (Vdc), frequency (Hz): *Range* / 50000
- CMU DC bias output value: 2 mV

The 8 bytes binary data format provides the following data resolution. To use this data format, enter the FMT13 or FMT14 command. For *Range* value, see "8 Bytes Data Elements" on page 1-48.

- SMU measurement/output value (voltage or current): *Range* / 1000000
- CMU measurement value (resistance or reactance): *Range* / 2^{24}
- CMU measurement value (conductance or susceptance): 1 / (*Range* $\times 2^{24}$)
- CMU oscillator level monitor value (Vac), DC bias monitor value (Vdc), frequency (Hz): *Range* / 1000000
- CMU DC bias output value: 1 mV

Data Format

The data output format depends on the measurement mode as shown below.

High speed spot

Data <terminator>	(by TI, TV, TMACV, or TMDCV command)
Time Data <terminator>	(by TTI or TTV command)
Para1 Para2 <terminator>	(by TIV / TC command)
Time Para1 Para2 <terminator>	(by TTIV / TTC command)

Data is the value measured by the channel you specify in the command. *Time* is the time from timer reset to the start of measurement. *Para1* and *Para2* are current (A) and voltage (V) respectively measured by the SMU; or R (Ω) and X (Ω); or G (S) and B (S) respectively measured by the CMU. The CMU measurement data will be automatically selected by the B1500, and will be a couple without data overflow.

Time is available for the 8 bytes binary data format (FMT13 or FMT14) and *not* available for the 4 bytes binary data format (FMT3 or FMT4)

TDI, TDV, TSQ, TACV, TDCV command

Available for the 8 bytes binary data format (FMT13 or FMT14).

Time <terminator>

Time is the time from timer reset to the start of output.

Spot, Multi channel pulsed spot

Data1 [*Data2*] . . . . <terminator>

DataN (*N*: integer) is the value measured by a channel. The order of *Data* is defined by the MM command.

Pulsed spot, Quasi-pulsed spot, Spot C, Pulsed spot C

Data <terminator>

Data is the value measured by the channel you specify by using the MM command.

For the spot C, *Data* will be *Para1 Para2* [*Osc_level Dc_bias*].

For the pulsed spot C, *Data* will be *Para1 Para2*.

Para1 and *Para2* are R (Ω) and X (Ω), or G (S) and B (S) respectively. They will be automatically selected by the B1500, and will be a couple without data overflow. And *Osc_level* and *Dc_bias* are the monitor values of the oscillator level (AC signal level) and the DC bias respectively. They are sent if the data output is enabled by the LMN command.

Linear search, Binary search

Data_search [*Data_sense*]<terminator>

This is the data at the measurement point closest to the search target. *Data_search* is the value forced by the search output channel. *Data_sense* is the value measured by the search monitor channel. It is sent if data output is enabled by the BSVM command for the binary search, or the LSVM command for the linear search.

Staircase sweep, Multi channel sweep, Multi channel pulsed sweep, CV (DC bias) sweep

Block1 [*Block2*] . . . . <terminator>

Block1 is the block of data measured at the first sweep point. *Block2* is the block of data measured at the second sweep point. where *Block* consists of the following data:

Data1 [*Data2*] . . . . [*Source_data*]

DataN (*N*: integer) is the value measured by a channel. The order of *Data* is defined by the MM command. *Source_data* is the sweep source output value. It is sent if the data output is enabled by the FMT command.

For the CMU measurement data, *DataN* will be *Para1 Para2* [*Osc_level Dc_bias*].

Para1 and *Para2* are R (Ω) and X (Ω), or G (S) and B (S) respectively. They will be automatically selected by the B1500, and will be a couple without data overflow. And *Osc_level* and *Dc_bias* are the monitor values of the oscillator level (AC signal level) and the DC bias respectively. They are sent if the data output is enabled by the LMN command.

Pulsed sweep, Staircase sweep with pulsed bias, Pulsed sweep CV, CV (AC level) sweep, C-f sweep

Block1 [*Block2*] . . . . <terminator>

Block1 is the block of data measured at the first sweep point. *Block2* is the block of data measured at the second sweep point. *Block* consists of the following data:

Data [*Source_data*]

Data is the value measured by the channel you specify by using the MM command. *Source_data* is the sweep source output value. It is sent if the data output is enabled by the FMT command.

For the pulsed sweep CV measurement, *Data* will be *Para1 Para2*.

For the CV (AC level) and C-f, *Data* will be *Para1 Para2* [*Osc_level Dc_bias*].

Para1 and *Para2* are R (Ω) and X (Ω), or G (S) and B (S) respectively. They will be automatically selected by the B1500, and will be a couple without data overflow. And *Osc_level* and *Dc_bias* are the monitor values of the oscillator level (AC signal level) and the DC bias respectively. They are sent if the data output is enabled by the LMN command.

Sampling, C-t sampling

Available for the 8 bytes binary data format (FMT13 or FMT14).

Block1 [*Block2*] . . . . <terminator>

Block1 is the block of the data measured at the first sampling point. *Block2* is the block of the data measured at the second sampling point. where *Block* consists of the following data.

[*Sampling_no*] *Data1* [*Data2*] . . . .

Sampling_no is the sampling point index, and is returned by entering the FMT command with *mode*<>0. This value depends on the sampling interval setting and the measurement time. If the measurement time is shorter than the sampling interval, *Sampling_no* will be *N* of *BlockN* (*N*: 1, 2, 3 . . .).

DataN (*N*: integer) is the data measured by one unit. The order of *Data* is specified by the MM command. *Sampling_no* and *Data* values can be discarded when the range changing is occurred while the measurement with auto or limited auto ranging.

If the measurement time is longer than the sampling interval, *Sampling_no* is not *N* of *BlockN*. For example, if the measurement time is longer than the sampling interval and shorter than twice the sampling interval, then the *Sampling_no* is 2 for *Block1*, and 4 for *Block2*. In general, the measurement time depends on the measurement value and the A/D converter settings.

For the C-t sampling, *DataN* will be *Para1 Para2*.

Para1 and *Para2* are R (Ω) and X (Ω), or G (S) and B (S) respectively. They will be automatically selected by the B1500, and will be a couple without data overflow.

Quasi-static CV

Block1 [*Block2*] . . . . <terminator>

Block1 is the block of the data measured at the first sweep point.
Block2 is the block of the data measured at the second sweep point.
where *Block* consists of the following data:

[*DataL*] *DataC* [*Source_data*]

DataL is the leakage current measurement data. *DataC* is the capacitance measurement data. *Source_data* is the sweep source output value. *DataL* and *Source_data* are sent if the data output is enabled by the QSL or FMT command.

4 Bytes Data Elements

To use the 4 bytes binary data format, enter the FMT3 or FMT4 command.

The data (*Data*, *Source_data*, *Sampling_no*, *Data_search*, *Data_sense*, *Osc_level*, and *Dc_bias*) will be sent as the binary value shown in Figure 1-2.

Figure 1-2 **4 Bytes Binary Data Output Format**

<table>
<tr><td colspan="8">Byte 1</td><td colspan="8">Byte 2</td><td colspan="8">Byte 3</td><td colspan="8">Byte 4</td></tr>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>A</td><td>B</td><td colspan="5">C</td><td colspan="17">D</td><td colspan="3">E</td><td colspan="5">F</td></tr>
</table>

A: Type. One bit.

B: Parameter. One bit.

C: Range. Five bits. *Range* value used to calculate the data.

D: Data count. 17 bits.

E: Status. Three bits.

F: Channel number. Five bits.

These data elements are described in the following pages.

A Type. One bit.

A	Explanation
0	Data other than measurement data.
1	Measurement data.

B Parameter. One bit.

B	for SMU data	for CMU data
0	Voltage	Resistance or reactance
1	Current or Capacitance	Conductance or susceptance

C Range. Five bits. *Range* value used to calculate the data.

C	for SMU data			C	for CMU data			
	V	I	C		Z	AC	DC	F
01000 (8)	0.5 V	1 pA	1 pF	00000 (0)	1 Ω			
01001 (9)	5 V	10 pA	10 pF	00001 (1)	10 Ω			
01010 (10)		100 pA	100 pF	00010 (2)	100 Ω			
01011 (11)	2 V	1 nA	1 nF	00011 (3)	1 kΩ		8 V	1 kHz
01100 (12)	20 V	10 nA	10 nF	00100 (4)	10 kΩ	16 mV	12 V	10 kHz
01101 (13)	40 V	100 nA	100 nF	00101 (5)	100 kΩ	32 mV	25 V	100 kHz
01110 (14)	100 V	1 μA	1 μF	00110 (6)	1 MΩ	64 mV		1 MHz
01111 (15)	200 V	10 μA	10 μF	00111 (7)	10 MΩ	125 mV	100 V	
10000 (16)	500 V	100 μA	100 μF	01000 (8)	100 MΩ	250 mV		
10001 (17)	1500 V	1 mA	1 mF	01001 (9)	1 GΩ			
10010 (18)	3000 V	10 mA	10 mF	01010 (10)	10 GΩ			
10011 (19)		100 mA	100 mF	01011 (11)	100 GΩ			
10100 (20)		1 A	1 F					
10110 (22)		20 A						
11111 (31)	Invalid data is returned.							

D (SMU data)

Data count. This value is expressed in 17-bit binary data. The measurement data and the source data can be calculated by the following formula.

Measurement data = *Count* × *Range* / 50000

Source data = *Count* × *Range* / 20000

where, *Count* is the *D* value, and *Range* is the measurement range or output range given by *C*.

For the decimal value of *C*, the *Range* value of current and capacitance data will be 10^(*C*-20).

If the top bit of *D* is 0, *Count* is positive and equal to the value given by the following 16 bits.

If the top bit of *D* is 1, *Count* is negative. Calculate *Count* by subtracting 65536 (10000000000000000 in binary) from the value given by the following 16 bits.

Example:

If the output binary data is:

11010110000100111000100000000001

then,

Type:	Measurement data (*A*=1)
Parameter:	Current (*B*=1)
***Range*:**	1 nA=10^(11-20) A (*C*=01011 in binary, *C*=11 in decimal)
***Count*:**	5000 (*D*=00001001110001000)
Status:	Normal condition (*E*=000)
Channel:	SMU1 (channel number 1) (*F*=00001)

Measurement data = 5000 × 1E–9 / 5E+4 = 100 pA

NOTE

B=1 and *C*=10100 means that HPSMU used 1 A range or MPSMU used 200 mA range. Then use *Range*=1 to calculate the data for both HPSMU and MPSMU. *Range*=0.2 is not available even if the range value is 200 mA.

D (CMU data)

Data count. This value is expressed in 17-bit binary data. The measurement data and the output data can be calculated by the following formula.

Resistance or reactance = $Count \times Range / 2^{12}$

Conductance or susceptance = $Count / (2^{12} \times Range)$

OSC level monitor value = $Count \times Range$ / 50000

DC bias monitor value = $Count \times Range$ / 50000

DC bias output value = $Count$ / 500

Output signal frequency = $Count \times Range$ / 50000

where, *Count* is the *D* value, and *Range* is the measurement range or output range given by *C*.

For the decimal value of *C*, the *Range* value of resistance, reactance, conductance, and susceptance data will be 10^*C* Ω.

If the top bit of *D* is 0, *Count* is positive and equal to the value given by the following 16 bits.

If the top bit of *D* is 1, *Count* is negative. Calculate *Count* by subtracting 65536 (10000000000000000 in binary) from the value given by the following 16 bits.

Example:

If the output binary data is:

10001000000011111010000000001000

then,

Type:	Measurement data (*A*=1)
Parameter:	Resistance (or reactance) (*B*=0)
***Range*:**	10 kΩ =10^4 (*C*=00100 in binary, *C*=4 in decimal)
***Count*:**	4000 (*D*=000001111101000000)
Status:	Normal condition (*E*=000)
Channel:	8 (*F*=01000)

Measurement data = $4000 \times 10000 / 2^{12}$ = 9.76 kΩ

E

Status. Three bits.

- Status for *Source_data*:

  Severity of a status is 001<010.

E	Explanation
001	Data is for the first or intermediate sweep step.
010	Data is for the last sweep step.

- Status for measurement data. See Table 1-13 on page 1-46.

  For SMU, the severity of a status is as follows:

  - For the quasi-pulsed spot measurement: 0<1<2<3<4<6 or 7
  - For other measurement: 0<6<7<1<2<3<4

F

Channel number of the measurement/source channel. Five bits. See Table 1-14 on page 1-47.

Table 1-13 **Status for Measurement Data**

E	Explanation
000 (0)	No status error occurred.
001 (1)	For SMU: Another channel reached its compliance setting.
	For CMU: CMU is in the NULL loop unbalance condition.
010 (2)	For SMU: This channel reached its compliance setting.
	For CMU: CMU is in the IV amplifier saturation condition.
011 (3)	Measurement data is over the measurement range. Or the sweep measurement was aborted by the automatic stop function or power compliance. Meaningless value will be returned to *D*.
100 (4)	One or more channels are oscillating. Or source output did not settle before measurement.[a]
101 (5)	SMU is in the force saturation condition.
110 (6)	For linear or binary search measurement, the target value was not found within the search range. Returns the source output value.
	For quasi-pulsed spot measurement, the detection time was over the limit (3 s for Short mode, 12 s for Long mode).[b]
111 (7)	For linear or binary search measurement, the search measurement was stopped. Returns the source output value. See status of *Data_sense*.
	For quasi-pulsed spot measurement, output slew rate was too slow to perform the settling detection.[c] Or quasi-pulsed source channel reached the current compliance before the source output voltage changed 10 V from the start voltage.[d]

a. Make the wait time or delay time longer. Or make the current compliance larger. For pulsed measurement, make the pulse width longer, or make the pulse base value closer to the pulse peak value. For current output by limited auto ranging, make the output range lower.

b. Make the current compliance or start voltage larger. Or set the detection interval to Long. If this status occurs with the Long mode, perform the spot measurement.

c. Make the current compliance larger. Or set the detection interval to Long. If this status occurs with the Long mode, perform the spot measurement or pulsed spot measurement.

d. Perform the pulsed spot measurement or spot measurement.

Table 1-14 Channel Number

F	Explanation[a]
00001 (1)	Subchannel 1 of the module installed in the slot 1
00010 (2)	Subchannel 1 of the module installed in the slot 2
00011 (3)	Subchannel 1 of the module installed in the slot 3
00100 (4)	Subchannel 1 of the module installed in the slot 4
00101 (5)	Subchannel 1 of the module installed in the slot 5
00110 (6)	Subchannel 1 of the module installed in the slot 6
00111 (7)	Subchannel 1 of the module installed in the slot 7
01000 (8)	Subchannel 1 of the module installed in the slot 8
01001 (9)	Subchannel 1 of the module installed in the slot 9
01010 (10)	Subchannel 1 of the module installed in the slot 10
01011 (11)	Subchannel 2 of the module installed in the slot 1
01100 (12)	Subchannel 2 of the module installed in the slot 2
01101 (13)	Subchannel 2 of the module installed in the slot 3
01110 (14)	Subchannel 2 of the module installed in the slot 4
01111 (15)	Subchannel 2 of the module installed in the slot 5
10000 (16)	Subchannel 2 of the module installed in the slot 6
10001 (17)	Subchannel 2 of the module installed in the slot 7
10010 (18)	Subchannel 2 of the module installed in the slot 8
10011 (19)	Subchannel 2 of the module installed in the slot 9
10100 (20)	Subchannel 2 of the module installed in the slot 10
11010 (26)	Status code for extraneous data in the channel. TSQ command response or invalid data is returned.
11111 (31)	Invalid data is returned.

a. SMU and CMU do not have the subchannel 2.

8 Bytes Data Elements

To use the 8 bytes binary data format, enter the FMT13 or FMT14 command.

The data (*Data*, *Source_data*, *Sampling_no*, *Data_search*, *Data_sense*, *Osc_level*, and *Dc_bias*) will be sent as the binary value shown in Figure 1-3. The format of the time data (*Time*) will be different from the others.

Figure 1-3 8 Bytes Binary Data Output Format

For measurement data and source data:

<table>
<tr><td colspan="8">Byte 1</td><td colspan="8">Byte 2</td><td colspan="8">Byte 3</td><td colspan="8">Byte 4</td><td colspan="8">Byte 5</td><td colspan="8">Byte 6</td><td colspan="8">Byte 7</td><td colspan="8">Byte 8</td></tr>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>A</td><td colspan="7">B</td><td colspan="8">C</td><td colspan="32">D</td><td colspan="8">E</td><td colspan="3">G</td><td colspan="5">F</td></tr>
</table>

For time data:

<table>
<tr><td colspan="8">Byte 1</td><td colspan="8">Byte 2</td><td colspan="8">Byte 3</td><td colspan="8">Byte 4</td><td colspan="8">Byte 5</td><td colspan="8">Byte 6</td><td colspan="8">Byte 7</td><td colspan="8">Byte 8</td></tr>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>A</td><td colspan="7">B</td><td colspan="48">H</td><td></td><td></td><td></td><td colspan="5">F</td></tr>
</table>

A: Type. One bit.

B: Parameter. Seven bits.

C: Range. One byte. *Range* value used to calculate the data.

D: Data count. Four bytes.

E: Status. One byte.

F: Channel number. Five bits.

G: A/D converter. Three bits.

H: Time data count. Six bytes.

These data elements are described in the following pages.

A Type. One bit.

A	Explanation
0	Data other than measurement data.
1	Measurement data.

B Parameter. Seven bits.

B	Explanation
0000000 (0)	SMU voltage measurement or output data (V)
0000001 (1)	SMU current measurement or output data (A)
0000010 (2)	SMU QSCV capacitance measurement data (F)
0000011 (3)	Time data (second)
0000110 (6)	Sampling index
0000111 (7)	CMU output signal frequency data (Hz)
0001000 (8)	CMU oscillator level output data (Vac)
0001001 (9)	CMU DC bias output data (Vdc)
0001010 (10)	CMU oscillator level monitor data (Vac)
0001011 (11)	CMU DC bias monitor data (Vdc)
0001100 (12)	CMU resistance measurement data (Ω)
0001101 (13)	CMU reactance measurement data (Ω)
0001110 (14)	CMU conductance measurement data (S)
0001111 (15)	CMU susceptance measurement data (S)
0010000 (16)	SMU QSCV leakage current averaging value (A), in transition
0010001 (17)	SMU QSCV voltage V_0 (V), before voltage transition
0010010 (18)	SMU QSCV voltage V (V), after voltage transition
0010011 (19)	SMU QSCV leakage current IL_0 (A), before voltage transition
0010100 (20)	SMU QSCV leakage current IL (A), after voltage transition
0010101 (21)	SMU QSCV charge current I (A), in transition
0010110 (22)	SMU QSCV voltage averaging value (V), in transition
0010111 (23)	SMU QSCV sink SMU current setup value (A)

C Range. One byte. *Range* value used to calculate the data.

C	for SMU data			for CMU data			
	V	I	C	Z	AC	DC	F
00000000 (0)				1 Ω			
00000001 (1)				10 Ω			
00000010 (2)				100 Ω			
00000011 (3)				1 kΩ		8 V	1 kHz
00000100 (4)				10 kΩ	16 mV	12 V	10 kHz
00000101 (5)				100 kΩ	32 mV	25 V	100 kHz
00000110 (6)				1 MΩ	64 mV		1 MHz
00000111 (7)				10 MΩ	125 mV	100 V	
00001000 (8)	0.5 V	1 pA	1 pF	100 MΩ	250 mV		
00001001 (9)	5 V	10 pA	10 pF	1 GΩ			
00001010 (10)		100 pA	100 pF	10 GΩ			
00001011 (11)	2 V	1 nA	1 nF	100 GΩ			
00001100 (12)	20 V	10 nA	10 nF				
00001101 (13)	40 V	100 nA	100 nF				
00001110 (14)	100 V	1 μA	1 μF				
00001111 (15)	200 V	10 μA	10 μF				
00010000 (16)	500 V	100 μA	100 μF				
00010001 (17)	1500 V	1 mA	1 mF				
00010010 (18)	3000 V	10 mA	10 mF				
00010011 (19)		100 mA	100 mF				
00010100 (20)		1 A	1 F				
00010110 (22)		20 A					
00011111 (31)	Invalid data is returned.						

D

Data count. This value is expressed in 4 bytes binary data. The measurement data and the output data can be calculated by the following formula.

Resistance or reactance = *Count* × *Range* / 2^{24}

Conductance or susceptance = *Count* / (2^{24} × *Range*)

DC bias output value = *Count* / 1000

Data other than the above parameters = *Count* × *Range* / 1000000

where, *Count* is the *D* value, and *Range* is the measurement range or output range given by *C*.

For the decimal value of *C*, the *Range* value of current and capacitance data will be 10^(*C*-20), and the *Range* value of resistance, reactance, conductance, and susceptance data will be 10^*C* Ω.

If the top bit of *D* is 0, *Count* is positive and equal to the value given by the following 31 bits.

If the top bit of *D* is 1, *Count* is negative. Calculate *Count* by subtracting 2147483648 (10000000000000000000000000000000 in binary) from the value given by the following 31 bits.

Example:

If the output binary data is:

1000000100001011000000000000000011000011010100000000000000000001

then,

Type:	Measurement data (*A*=1)
Parameter:	Current (*B*=0000001)
***Range*:**	1 nA=10^(11-20) A (*C*=01011 in binary, *C*=11 in decimal)
***Count*:**	100000 (*D*=00000000000000011000011010100000)
Status:	Normal condition (*E*=00000000)
ADC:	High speed ADC (*G*=000)
Channel:	SMU1 (channel number 1) (*F*=00001)

Measurement data = 100000 × 1E–9/1E+6 = 100 pA

NOTE

B=0000001 and *C*=00010100 means that HPSMU used 1 A range or MPSMU used 200 mA range. Then use *Range*=1 to calculate the data for both HPSMU and MPSMU. *Range*=0.2 is not available even if the range value is 200 mA.

E Status. One byte. Meaningless for the *Time* data.

- Status for *Source_data*:

  Severity of a status is 001<010.

E	Explanation
00000001	Data is for the first or intermediate sweep step.
00000010	Data is for the last sweep step.

- Status for measurement data. See Table 1-15.

  For SMU, the severity of a status is as follows:

  - For the quasi-pulsed spot measurement: 0<1<2<4<8<16 or 32
  - For other measurement: 0<16<32<1<2<4<8

F Channel number of the measurement/source channel. Five bits. See Table 1-14 on page 1-47.

G A/D converter. Three bits. For the source data and time data, G=000.

G	Explanation
000 (0)	SMU High Speed ADC
001 (1)	SMU High Resolution ADC
010 (2)	CMU ADC

H

Data count for the time data. This value is expressed in 6 bytes binary data. The time data can be calculated by the following formula.

Time = *Count* / 1000000

where, *Count* is the decimal value of *H*.

If the top bit of *H* is 0, *Count* is positive and equal to the value given by the following 47 bits.

If the top bit of *H* is 1, *Count* is negative. Calculate *Count* by subtracting 140737488355328 (100000000000000000000000000000000000000000000000 in binary) from the value given by the following 47 bits.

H=100000000000000000000000000000000000000000000000 means invalid data.

Example:

If the output binary data is:

0000001100000000000000000000000000000001100001101010000000000001

then,

Type:	Data other than the measurement data (*A*=0)
Parameter:	Time (*B*=0000011)
***Count*:**	100000 (*H*= 000000000000000000000000000000011000011010100000)
Channel:	SMU1 (channel number 1) (*F*=00001)

Time data = 100000 / 1000000 = 0.1 second

Table 1-15 Status for Measurement Data

E	Explanation
00000000 (0)	No status error occurred.
00000001 (1)	Measurement data is over the measurement range. Or the sweep measurement was aborted by the automatic stop function or power compliance. Meaningless value will be returned to *D*.
00000010 (2)	For SMU: One or more channels are oscillating. Or source output did not settle before measurement.[a]
	For CMU: CMU is in the NULL loop unbalance condition.
00000100 (4)	For SMU: Another channel reached its compliance setting.
	For CMU: CMU is in the IV amplifier saturation condition.
00000101 (5)	SMU is in the force saturation condition.
00001000 (8)	This channel reached its compliance setting.
00010000 (16)	For linear or binary search measurement, the target value was not found within the search range. Returns the source output value.
	For quasi-pulsed spot measurement, the detection time was over the limit (3 s for Short mode, 12 s for Long mode).[b]
00100000 (32)	For linear or binary search measurement, the search measurement was stopped. Returns the source output value. See status of *Data_sense*.
	For quasi-pulsed spot measurement, output slew rate was too slow to perform the settling detection.[c] Or quasi-pulsed source channel reached the current compliance before the source output voltage changed 10 V from the start voltage.[d]

a. Make the wait time or delay time longer. Or make the current compliance larger. For pulsed measurement, make the pulse width longer, or make the pulse base value closer to the pulse peak value. For current output by limited auto ranging, make the output range lower.

b. Make the current compliance or start voltage larger. Or set the detection interval to Long. If this status occurs with the Long mode, perform the spot measurement.

c. Make the current compliance larger. Or set the detection interval to Long. If this status occurs with the Long mode, perform the spot measurement or pulsed spot measurement.

d. Perform the pulsed spot measurement or spot measurement.

GPIB Interface Capability

The following table lists the GPIB capabilities and functions of the Agilent B1500. These functions provide the means for an instrument to receive, process, and transmit, commands, data, and status over the GPIB bus.

Interface Function	Code	Description
Source Handshake	SH1	Complete capability
Acceptor Handshake	AH1	Complete capability
Talker	T6	Basic Talker: YES Serial Poll: YES Talk Only Mode: NO Unaddress if MLA (my listen address): YES
Listener	L4	Basic Listener: YES Unaddress if MTA (my talk address): YES Listen Only Mode: NO
Service Request	SR1	Complete capability
Remote/Local	RL1	Complete capability (with local lockout)
Parallel Poll	PP0	No capability
Device Clear	DC1	Complete capability
Device Trigger	DT1	Complete capability
Controller Function	C0	No capability
Driver Electronics	E1	Open Collector

The B1500 responds to the following HP BASIC statements:

- ABORT (IFC)
- CLEAR (DCL or SDC. same as AB command)
- LOCAL (GTL)
- LOCAL LOCKOUT (LL0)
- REMOTE
- SPOLL (Serial Poll)
- TRIGGER (GET. same as XE command)

Status Byte

Status byte bits are turned off or on (0 or 1) to represent the instrument operation status. When you execute a serial poll, an external computer (controller) reads the contents of the status byte, and responds accordingly. When an unmasked status bit is set to “1”, the instrument sends an SRQ to the controller, causing the controller to perform an interrupt service routine.

Bit	Decimal Value	Description
0	1	Data ready Indicates whether the output buffer is empty. If an unread data or query response exists, this bit is set to “1”. It is set to “0” when all the stored data has been transferred to the controller, or when the B1500 receives a *RST, BC, FMT, or device clear command.
1	2	Wait Indicates whether the instrument is in the wait status. This bit is set to “1” when the B1500 has been set to the wait state by the PA, WS, PAX, or WSX command. It is set to “0” when the waiting condition is complete, or when the B1500 receives a *RST or device clear command.
2	4	Not applicable. This bit is always set to “0”.
3	8	Interlock open If the interlock circuit is open, and a voltage output or voltage compliance setup value exceeds ±42 V, this bit is set to “1” . It is set to “0” when the B1500 receives a serial poll, *RST, or device clear command.
4	16	Set ready If the B1500 receives a GPIB command or a trigger signal, this bit is set to “0”. It is set to “1” when its operation is completed. This bit is also set to “0” when the self-test or calibration is started by front panel operation, and set to “1” when it is completed.

Bit	Decimal Value	Description
5	32	Error Indicates whether any error has occurred. If an error occurred, this bit is set to “1”. It is set to “0” when the B1500 receives a serial poll, *RST, ERR?, ERRX?, CA, *TST?, *CAL?, DIAG? or device clear command.
6	64	RQS (You cannot mask this bit.) Indicates whether an SRQ (Service Request) has occurred. This bit is set to “1” whenever any other unmasked bit is set to “1”. This causes the B1500 to send an SRQ to the controller. It is set to “0” when the B1500 receives a serial poll, *RST, or device clear command.
7	128	Not applicable. This bit is always set to “0”.

The status byte register can be read with either a serial poll or the *STB? query command. Serial poll is a low-level GPIB command that can be executed by the `SPOLL` command in HP BASIC, for example `Status=SPOLL(@B1500)`.

In general, use serial polling (not *STB?) inside interrupt service routines. Use *STB? in other cases (not in interrupt service routine) when you want to know the value of the Status Byte.

NOTE

If Bit 3 and Bit 5 are masked, they are not set to “0” by a serial poll. Also, if these bits are masked, set to “1”, and then unmasked, a serial poll does not set them to “0”.

After a masked bit is set to “1”, removing the mask does not set Bit 6 to “1”. That is, the B1500 does not send an SRQ to the controller. Therefore, if you remove a mask from a bit, it is usually best to do it at the beginning of the program.

Programming Tips

This section provides the following additional information on creating measurement programs. It is useful for checking the operation status, improving the measurement speed, and so on.

- “To Confirm the Operation”
- “To Confirm the Command Completion”
- “To Disable the Auto Calibration”
- “To Optimize the Measurement Range”
- “To Optimize the Integration Time”
- “To Disable the ADC Zero Function”
- “To Optimize the Source/Measurement Wait Time”
- “To Use the Internal Program Memory”
- “To Get Time Data with the Best Resolution”
- “To Use Sweep Source as a Constant Source”
- “To Start Measurements Simultaneously”
- “To Interrupt Command Execution”
- “To Use Programs for Agilent 4142B”
- “To Use Programs for Agilent 4155/4156”
- “To Use Programs for Agilent E5260/E5270”

To Confirm the Operation

To complete the measurement program, you can insert statements to check the B1500 operation status as shown below. This example starts the measurement, checks the status caused by the statements before the ERRX? command, reads and displays the measurement data without errors, or displays an error message when an error occurs.

```
OUTPUT @B1500;"XE"
OUTPUT @B1500;"ERRX?"
ENTER @B1500;Code,Msg$
IF Code=0 THEN
  ENTER @B1500 USING "#,3X,12D,X";Mdata
  PRINT "I(A)=";Mdata
ELSE
  PRINT "ERROR: ";Msg$
END IF
```

To Confirm the Command Completion

To check the completion of the previous command execution, use the *OPC? query command. Entering the *OPC command before sending a command to other equipment serves to delay its operation until the B1500 has completed its operation. The *OPC? command is useful to control equipments sequentially.

For example, the following program segment waits until the B1500 completes the DI command execution, and sends the *XYZ* command to equipment identified by *@Address*.

```
OUTPUT @B1500;"DI";1,0,1.0E-10,1
OUTPUT @B1500;"*OPC?"
ENTER @B1500; A$
OUTPUT @Address;"XYZ"
```

To Disable the Auto Calibration

The auto calibration function triggers self-calibration automatically every 30 minutes after measurement. When the function is enabled, open the measurement terminals frequently because calibration requires open terminals.

If you execute automatic measurements as a batch job that might leave the device connected for over 30 minutes after the measurements, disable auto calibration. Otherwise, the calibration might not be performed properly, or unexpected output might appear at the measurement terminals, and it could even damage the device. To disable auto calibration, send the `CM 0` command.

To Optimize the Measurement Range

The most effective way to improve measurement speed is to reduce the number of range changes. The limited auto ranging mode is more effective than the auto ranging mode. The fixed range mode is the most effective.

Check the typical value of the measurement data, select the optimum range, and perform measurement using the fixed range mode.

To Optimize the Integration Time

For best reliability and repeatability of the measurement data, the integration time or the number of averaging samples of the A/D converter must be increased. This increases the measurement time.

A long integration time and numerous samples are required for low current/ voltage measurements. However, the values can be decreased for medium or high current/voltage measurements. Enter the following commands:

AV Sets the number of averaging samples of the A/D converter. This command is compatible with the AV command of the Agilent 4142B.

AAD Selects the A/D converter type (high-resolution, high-speed, or high-speed for pulsed-measurement).

AIT Sets the integration time or the number of averaging samples. The AIT command covers the function of the AV command. The last command setting is available for the measurement.

For more information regarding these commands, see Chapter 4, “Command Reference.”

To Disable the ADC Zero Function

This information is effective only when the high resolution A/D converter is used for the measurement. If measurement speed is given top priority or is more important than reliability, disable the ADC zero function by sending the `AZ 0` command. This roughly halves integration time.

NOTE The ADC zero function is the function to cancel offset of the high resolution ADC. This function is especially effective for low voltage measurements.

To Optimize the Source/Measurement Wait Time

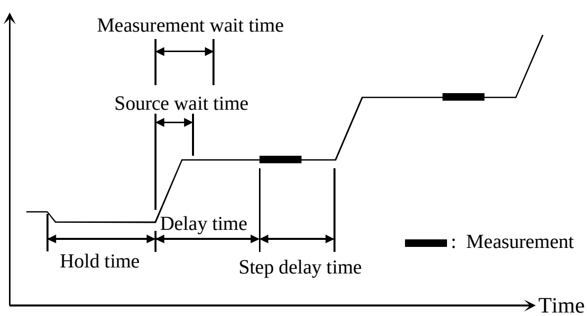
If measurement speed is given top priority or is more important than reliability, set the wait time shorter by using the WAT command. The source wait time is the time the source channel always waits before changing the source output value. The measurement wait time is the time the measurement channel always waits before starting measurement. The time is given by the following formula:

wait time = *initial wait time* × *A*+*B*

where, *initial wait time* is the time the B1500 automatically sets and you cannot change. The *initial source wait time* is not the same as the *initial measurement wait time*. *A* and *B* are the command parameters of the WAT command.

The wait time settings are effective for all modules.

Figure 1-4 **Source/Measurement Wait Time**



NOTE

The wait time can be ignored if it is shorter than the delay time.

It is not easy to determine the best wait time. If you specify it too short, the measurement may start before device characteristics stable. If too long, time will be wasted.

The initial wait time may be too short for measurements of high capacitance or slow response devices. Then set the wait time longer.

For measurements of low capacitance or fast response devices, if measurement speed has top priority or is more important than reliability and accuracy, set the wait time shorter.

To Use the Internal Program Memory

If your program repeats the setup and measurement for a number of devices, use the internal program memory. For these measurements, using the internal program memory reduces the command transfer time, and improves the program execution speed.

You can enter a maximum of 2,000 programs (total 40,000 commands) into the internal program memory. See Chapter 2, "Remote Mode Functions."

To Get Time Data with the Best Resolution

To read the time data with the best resolution (100 μs), the timer must be cleared within the following interval:

- 100 sec or less (for FMT1, 2, or 5 data output format)
- 1000 sec or less (for FMT 11, 12, 15, 21, 22, or 25 data output format)

Send the TSR command to clear the timer.

To Use Sweep Source as a Constant Source

The following setup enables sweep source to force a constant current or voltage.

- Sweep start value = Sweep stop value (for WI, WV, or WNX).

Also, setting number of sweep steps to 1 enables to perform a spot measurement.

To Start Measurements Simultaneously

Spot measurement, staircase sweep measurement, and multi channel sweep measurement enable to use multiple measurement channels. Then the measurement channels perform measurement in the order defined in the MM command. However, the measurement channels with the following setup start measurements simultaneously.

- To set the multi channel sweep measurement mode (MM 16).
- To set the measurement ranging mode to fixed (for RI or RV).
- To use the high-speed ADC (use AV).

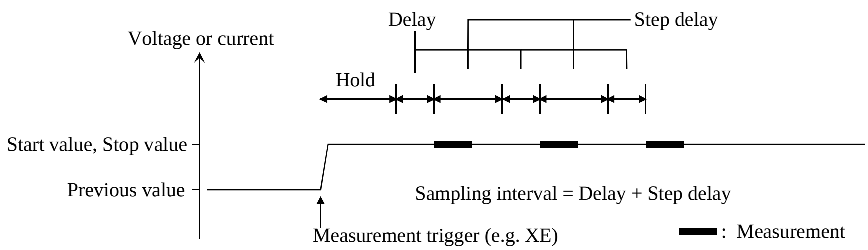
NOTE

Measurement setup is independent from source output setup. So, this simultaneous measurement cannot be broken by the source output setup. Any setting of the output ranging mode is effective for the simultaneous measurement.

To Perform Quasi-Sampling Measurement

The following setup enables to perform a quasi-sampling measurement. Then the sampling interval will be sum of delay time and step delay time.

- Sets the sweep measurement mode (MM 2 or MM 16).
- Sweep start value = Sweep stop value (for WI, WV, or WNX).
- Sets hold time, delay time, and step delay time (WT).



To Interrupt Command Execution

The B1500 executes commands in the received order. However, only the following commands can interrupt the command execution.

Table 1-16 **Interrupt Commands**

Command	Description
AV	Changes the number of averaging samples during the measurement.
AIT	Changes the A/D converter setting of the SMU during the measurement.
ACT	Changes the A/D converter setting of the CMU during the measurement.
AB	Aborts the command execution.
*RST	Resets the B1500 during the command execution.
XE	If the B1500 has been set to the wait status by the PA or PAX command, the XE command can be used to release the wait status. For details, see Chapter 4, “Command Reference.”

Programming Basics
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To Use Programs for Agilent 4142B

Agilent B1500 supports most of the commands and the data output format supported by the Agilent 4142B Modular DC Source/Monitor. To reuse the programs created for the Agilent 4142B, confirm the following and modify the programs if necessary.

- To remove all unsupported commands

  Some commands are not supported owing to differences in the modules supported by each instrument. See Table 1-17 that shows the commands not supported by the B1500. Do not use these commands.

  Perform the linear search or binary search measurement as a substitute for the analog search measurement that needs the analog feedback unit (AFU).

  Use a source/monitor unit (SMU) instead of the voltage source/voltage monitor unit (VS/VMU). Note that the SMU cannot perform the differential voltage measurements.

- FL command

  The initial setting of the FL command is different. It is ON for the Agilent 4142B, and OFF for the B1500.

  Add the FL1 command to use the filter.

- AV command

  This command is used to set the A/D converter of the B1500.

  To set the high resolution ADC installed in the B1500, use the AAD and AIT commands.

- *TST? command

  Use 11 to specify the B1500 mainframe instead of 9 that indicates the 4142B mainframe.

Table 1-17 **Modules and Commands Unsupported**

Plug-in Module	Commands
Analog Feedback Unit	ASM, AT, ASV, AIV, AVI
High Current Unit	PDM, PDI, PDV
High Voltage Unit	POL
Voltage Source/Voltage Monitor Unit	VM

To Use Programs for Agilent 4155/4156

Agilent B1500 supports commands similar to the FLEX command of the Agilent 4155B/4156B/4155C/4156C Parameter Analyzer. However, not all command sets are fully compatible. To reuse the programs created for the Agilent 4155/4156, the following modifications are required.

- To remove all unsupported commands

  Table 1-18 shows the commands not supported by the B1500. You cannot use these commands. The SCPI commands and 4145 syntax commands are not supported neither.

  The B1500 does not need the US and :PAGE commands that are necessary to change the control mode of the Agilent 4155/4156.

- To check and correct the command syntax

  Even if the command name is the same, the available parameters and values may be different. Check and correct the command parameters.

- To change the FMT command parameter

  Use the FMT 21, FMT 22, or FMT 25 command that sets the data output format compatible with the 4155/4156 ASCII format.

- To delete RMD?

  The B1500 does not need the RMD? command that is necessary to put the measurement data into the output data buffer of the Agilent 4155/4156.

- FL command

  The initial setting of the FL command is different. It is ON for the Agilent 4155/4156, and OFF for the B1500.

  Add the FL1 command to use the filter.

- AV command

  This command is used to set the A/D converter of the B1500.

  To set the high resolution ADC installed in the B1500, use the AAD and AIT commands.

- To replace TI?/TV?/TTI?/TTV? with TI/TV/TTI/TTV respectively
- To replace WM with LSM for the linear search measurement
- To replace TSQ? with TSQ

- If you reuse the built-in IBASIC programs:
    - Change the GPIB address.
    - Remove the statements to use the built-in flexible disk drive.

Table 1-18 4155/4156 FLEX Commands Unsupported

Category	Command
Control mode	:PAGE, US, US42
Measurement mode	VM, VMD
Staircase/pulsed sweep source setup	ESC
Sampling source setup	MP
Quasi-static CV measurement setup	QSZ?
PGU control	POR, SPG
Stress source setup	STC, STI, STM, STP, STT, STV
Integration time	SIT, SLI
Measurement execution	TI?, TTI?, TTV?, TV?
Time stamp	TSQ?
Output data	RMD?
Abort/pause/wait	*WAI
Zero offset cancel	GOC, SOC
SMU/PGU selector	SSP
R-box	RBC
External trigger	STG
Network operation	CLOSE, OPEN, PRN, RD?, SDSK, SPL, SPR, WR
Status byte	*CLS, *ESE(?), *ESR?
Query	CMD?, *OPT?, :SYST:ERR?

To Use Programs for Agilent E5260/E5270

Agilent B1500 supports most of the commands and the data output format supported by the Agilent E5260/E5270 Series of Parametric Measurement Solutions. To reuse the programs created for the Agilent E5260/E5270, confirm the following and modify the programs if necessary.

- To remove all unsupported commands

  Some commands are not supported owing to differences in the mainframe. See Table 1-19 that shows the commands not supported by the B1500. The commands will not cause errors because the B1500 will ignore these commands. However remove these commands to reduce the load.

- *CAL?, RCV, *TST? command

  Use 11 to specify the B1500 mainframe instead of 9 that indicates the E5260/E5270 mainframe.

- DIAG? command

  The B1500 does not support the front panel key test and the beeper test. So, do not use the parameter *item*=2 and 5.

Table 1-19 **E5260/E5270 FLEX Commands Unsupported**

Category	Command
Display Control	RED, DFM, SPA, MPA, SCH, MCH
Keyboard Control	KLC

Programming Basics
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2 Remote Mode Functions

This chapter describes the functions of the Agilent B1500 in the remote mode, and the initial settings.

- "Measurement Modes"
- "Synchronous Output"
- "Automatic Abort Function"
- "Parallel Measurement Function"
- "Program Memory"
- "SPGU Module"
- "Module Selector"
- "SMU/PG Selector"
- "Digital I/O Port"
- "Trigger Function"
- "Initial Settings"

NOTE

Synchronous Output

You can use synchronous output that will be synchronized to the output of the primary sweep or search source. The output is available for the following measurement modes:

- "Staircase Sweep Measurements"
- "Pulsed Sweep Measurements"
- "Staircase Sweep with Pulsed Bias Measurements"
- "Binary Search Measurements"
- "Linear Search Measurements"

The synchronous source supports the output mode (voltage or current) same as the primary source, and does not support the pulsed output.

Measurement Modes

The Agilent B1500 provides the following measurement modes.

- “Spot Measurements”
- “Pulsed Spot Measurements”
- “Multi Channel Pulsed Spot Measurements”
- “Staircase Sweep Measurements”
- “Staircase Sweep with Pulsed Bias Measurements”
- “Pulsed Sweep Measurements”
- “Multi Channel Sweep Measurements”
- “Multi Channel Pulsed Sweep Measurements”
- “Quasi-Pulsed Spot Measurements”
- “Binary Search Measurements”
- “Linear Search Measurements”
- “Sampling Measurements”
- “Quasi-static CV Measurements”
- “Spot C Measurements”
- “Pulsed Spot C Measurements”
- “CV (DC bias) Sweep Measurements”
- “Pulsed Sweep CV Measurements”
- “C-f Sweep Measurements”
- “CV (AC level) Sweep Measurements”
- “C-t Sampling Measurements”

NOTE

About Search Measurements

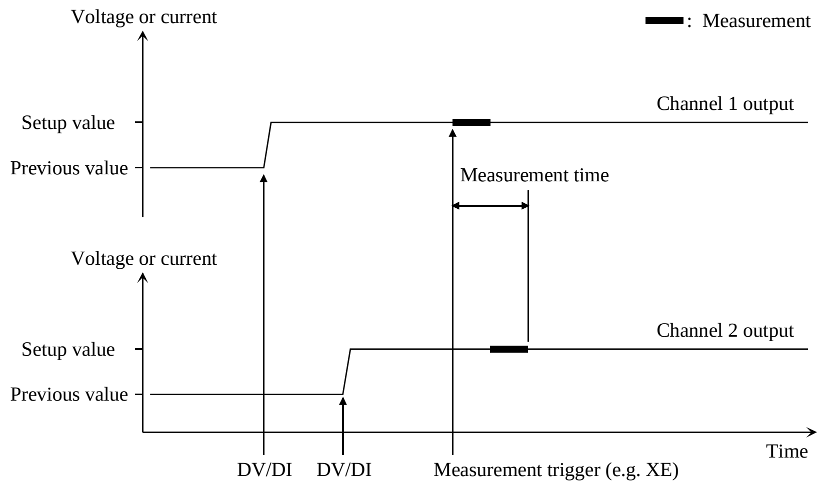
The B1500 supports search measurement to find a point on an I-V curve where a specified condition is satisfied. For example, it searches for a breakdown voltage or threshold voltage at a specified current.

Search measurements are performed by one or two SMUs. For two SMUs, one is the search channel, and the other is a sense channel. When one SMU is used, it serves as both search and sense channel. Basically, the search channel forces voltage or current until the search stop condition is satisfied.

Spot Measurements

Spot measurement is performed as shown below. The measurement channel performs one point measurement.

Figure 2-1 **Spot Measurements**



1. The source channel starts output by the DV or DI command. Multiple channels can be set.

2. The measurement channel starts measurement by a trigger, such as the XE command. If the trigger is received during the settling time of the source channels, measurement starts after the settling time.

   If you use multiple measurement channels, the channels perform measurement in the order defined in the MM command. Parallel measurement is also available, see "Parallel Measurement Function" on page 2-48.

3. After measurement, the source channels continue the source output.

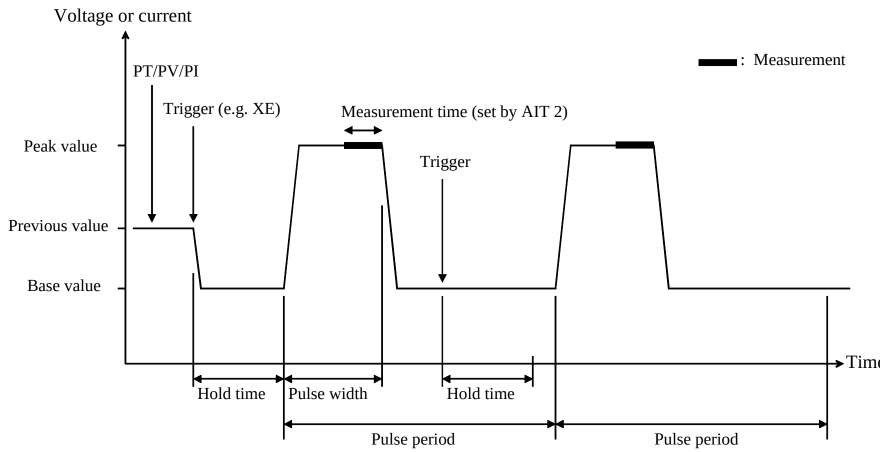
   For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the output to 0 V.

NOTE The DV command is used to force voltage, and the DI command is used to force current.

Pulsed Spot Measurements

Pulsed spot measurement is performed as shown below. The measurement channel performs one point measurement while the source channel is forcing a pulse.

Figure 2-2 **Pulsed Spot Measurements**



1. The pulse source channel sets output by the PT command and the PV or PI command. Only one channel can be used for the pulse source.
2. The pulse source channel starts output by a trigger, such as the XE command.
3. The measurement channel starts measurement as shown in Figure 2-2. Only one channel can be used for measurement. Measurement time is set by the AIT 2 command.
4. After measurement, the pulse source forces the pulse base value, and keeps it.

   If the next trigger occurs within the pulse period, pulse output is as follows.

   - If the rest of the pulse period is longer than the hold time as shown in Figure 2-2, the pulse source waits for the rest, then starts the pulse output.
   - If the rest of the pulse period is shorter than the hold time, the pulse source waits for the hold time since the last trigger, then starts the pulse output.

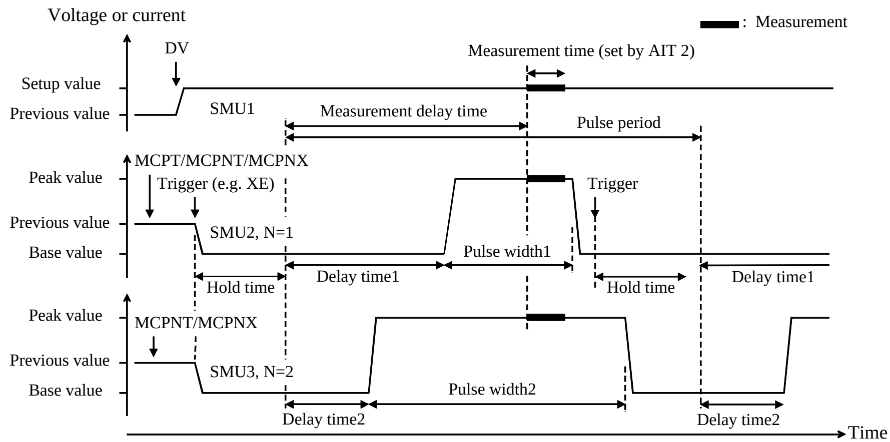
   For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the output to 0 V.

NOTE The PT command sets the pulse timing parameters, such as pulse width and pulse period. The PV command sets voltage pulse, and the PI command sets current pulse. The base and peak values must have the same polarity for the current pulse.

Multi Channel Pulsed Spot Measurements

Multi channel pulsed spot measurement is performed as shown below. The measurement channels perform one point measurement while a source channel is forcing a pulse. Up to ten channels can be used for both pulse source and measurement. Both voltage output mode and current output mode are available for the source channels.

Figure 2-3 **Multi Channel Pulsed Spot Measurements by MM27,SMU1,SMU2,SMU3**



1. Hold time, pulse period, measurement delay time, and number of measurements are set by the MCPT command.

2. The pulse source is set by the MCPNT and MCPNX commands with the source identification number *N* (*N*=1 to 10).

3. The DC bias output is started by the DV/DI command.

4. Pulse output is simultaneously started by a trigger, such as the XE command.

   For HR/MP/HPSMU, available delay time value is 0. Also, the pulse width value must be the same. If a different value is entered, the longest value is set.

5. The measurement channels perform measurements in parallel as shown in Figure 2-3. Measurement time is set by the AIT 2 command. This setting is effective for all measurement channels.

6. After the pulse width, the pulse source channels apply the pulse base value, and keep it.

   If the next trigger occurs within the pulse period, pulse output is as follows.

- If the rest of the pulse period is longer than the hold time as shown in Figure 2-3, the pulse source waits for the rest, then starts the pulse output.
- If the rest of the pulse period is shorter than the hold time, the pulse source waits for the hold time since the last trigger, then starts the pulse output.

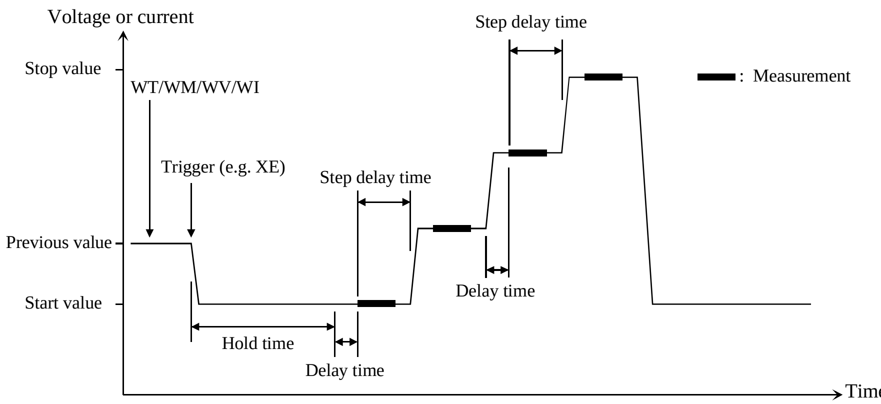
For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the output to 0 V.

NOTE The MCPNT command sets the delay time and pulse width. The MCPNX command sets the pulse output. The base and peak values must have the same polarity for the current pulse.

Staircase Sweep Measurements

Staircase sweep measurement is performed as shown below. The source channel forces staircase sweep voltage or current, and the measurement channel performs one point measurement at each sweep step.

Figure 2-4 **Staircase Sweep Measurements**



1. The staircase sweep source sets output by the WT, WM, and WV or WI commands. Only one channel can be used for the sweep source.
2. The sweep source starts output by a trigger, such as the XE command.
3. After the hold time, the sweep source waits for the delay time.
4. After the delay time, the measurement channel starts measurement.

   If you use multiple measurement channels, the channels perform measurement in the order defined in the MM command. Parallel measurement is also available, see “Parallel Measurement Function” on page 2-48.
5. After measurement, the sweep source waits for the rest of the step delay time if it is set, and the sweep source changes the output value.
6. The B1500 repeats 4 and 5 for all sweep steps.
7. After the sweep measurement, the sweep source forces the start or stop value, as specified by the WM command, and keeps it.

   For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the output to 0 V.

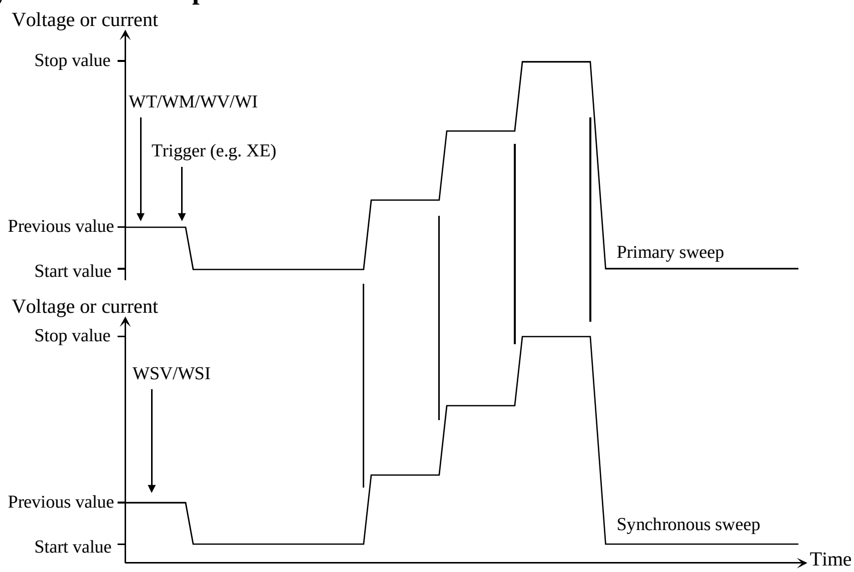
NOTE

The WT command sets the hold time, delay time, and step delay time. The WM command sets the automatic abort function and the output after measurement. The WV command sets the sweep voltage, and the WI command sets the sweep current. The start and stop values must have the same polarity for log sweep.

To Use Synchronous Sweep Source

One more channel can be set up as a staircase sweep source that has the output synchronized with the staircase sweep. Refer to “Synchronous Output” on page 2-44. After the measurement, the synchronous sweep source forces the start or stop value, as same as the primary sweep source, and keeps it.

Figure 2-5 **Synchronous Sweep**



NOTE

The WSV command sets the sweep voltage, and the WSI command sets the sweep current. You can use the same output mode (voltage or current) as the primary sweep. The start and stop values must have the same polarity for log sweep.

To Stop Sweep Output

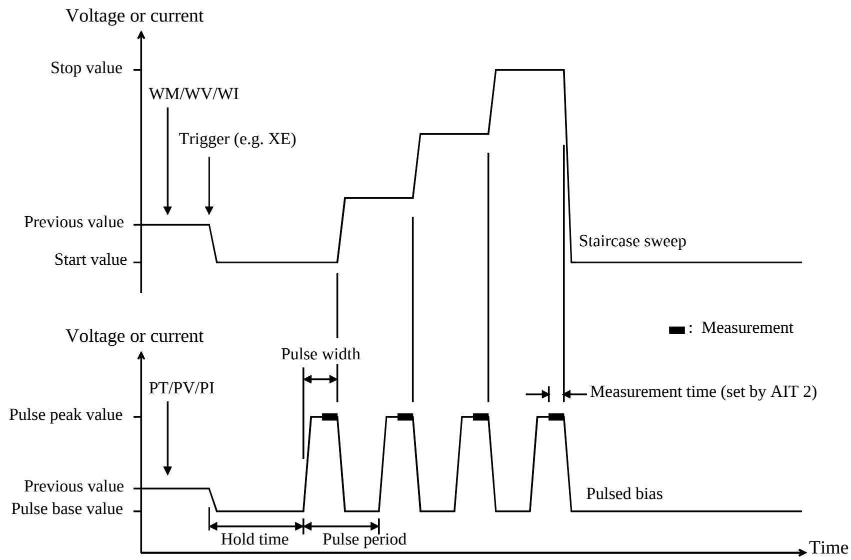
An automatic abort function is available. Refer to “Automatic Abort Function” on page 2-46.

Even if the automatic abort function is disabled, the B1500 automatically stops measurement if power compliance is enabled for the sweep source and the power compliance or an automatic abort condition is detected.

Staircase Sweep with Pulsed Bias Measurements

Staircase sweep with pulsed bias measurement is performed as shown below. The source channel forces staircase sweep voltage or current, the pulse channel forces pulsed bias, and the measurement channel performs one point measurement at each sweep step.

Figure 2-6 **Staircase Sweep with Pulsed Bias Measurements**



1. The staircase sweep source sets output by the WM, and WV or WI commands. Only one channel can be used for the sweep source.
2. The pulsed source sets output by the PT, and PV or PI commands. Only one channel can be used for the pulsed source.
3. The source channels start output by a trigger, such as the XE command.
4. After the hold time, the measurement channel starts measurement as shown in Figure 2-6. Only one channel can be used for measurement. Measurement time is set by the AIT 2 command.
5. After the measurement, the sweep source changes the output value. Then the pulsed source forces the pulse base value, and waits for the rest of the pulse period until the next pulse output.
6. The B1500 repeats measurement and 5 for all sweep steps.

7. After the sweep measurement, the pulsed source forces the pulse base value, and the sweep source forces the start or stop value, as specified by the WM command, and keeps it.

   For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the output to 0 V.

NOTE

The WM command sets the automatic abort function and the output after measurement. The WV command sets the sweep voltage, and the WI command sets the sweep current. The start and stop values must have the same polarity for log sweep.

The PT command sets the pulse timing parameters, such as pulse width and pulse period. The PV command sets voltage pulse, and the PI command sets current pulse. The base and peak values must have the same polarity for the current pulse.

To Use Synchronous Sweep Source

One more channel can be set up as a staircase sweep source that has the output synchronized with the staircase sweep. See Figure 2-5 and “Synchronous Output” on page 2-44. After the measurement, the synchronous sweep source forces the start or stop value, as same as the primary sweep source, and keeps it.

NOTE

The WSV command sets the sweep voltage, and the WSI command sets the sweep current. You can use the same output mode (voltage or current) as the primary sweep. The start and stop values must have the same polarity for log sweep.

To Stop Sweep Output

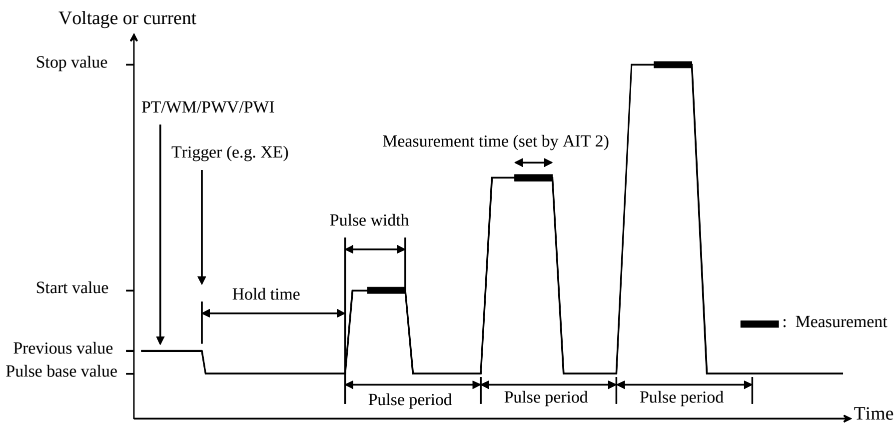
An automatic abort function is available. Refer to “Automatic Abort Function” on page 2-46.

Even if the automatic abort function is disabled, the B1500 automatically stops measurement if power compliance is enabled for the sweep source and the power compliance or an automatic abort condition is detected.

Pulsed Sweep Measurements

Pulsed sweep measurement is performed as shown below. The source channel forces pulsed sweep voltage or current, and the measurement channel performs one point measurement at each sweep step.

Figure 2-7 Pulsed Sweep Measurements



1. The pulsed sweep source sets output by the PT, WM, and PWV or PWI commands. Only one channel can be used for the pulsed sweep source.
2. The pulsed sweep source starts output by a trigger, such as the XE command.
3. After the hold time, the measurement channel starts measurement as shown in Figure 2-7. Only one channel can be used for measurement. Measurement time is set by the AIT 2 command.
4. After measurement, the pulsed sweep source forces the pulse base value, and waits for the rest of the pulse period. Then the pulsed sweep source changes the output value.
5. The B1500 repeats measurement and 4 for all sweep steps.
6. After the pulsed sweep measurement, the pulsed sweep source forces the pulse base value, and keeps it.

   For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the output to 0 V.

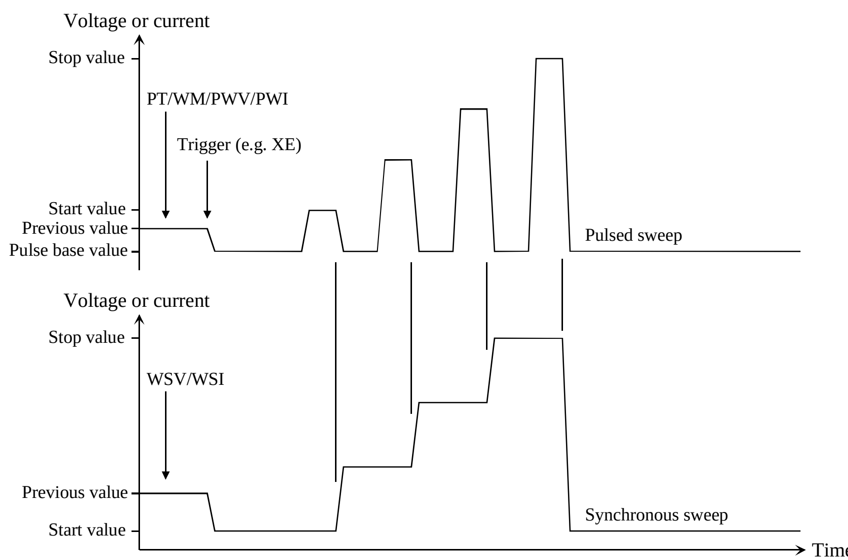
NOTE

The PT command sets the hold time, pulse width, and pulse period. The WM command sets the automatic abort function. The PWV sets the pulsed sweep voltage, and the PWI sets the pulsed sweep current. The base, start, and stop values must have the same polarity for current pulse or log sweep.

To Use Synchronous Sweep Source

One more channel can be set up as a staircase sweep source that has the output synchronized with the pulsed sweep. See “Synchronous Output” on page 2-44. After the measurement, the synchronous sweep source forces the start or stop value, as specified by the WM command, and keeps it.

Figure 2-8 **Synchronous Sweep**



NOTE

The WSV command sets the sweep voltage, and the WSI command sets the sweep current. You can use the same output mode (voltage or current) as the pulsed sweep. The start and stop values must have the same polarity for log sweep.

To Stop Sweep Output

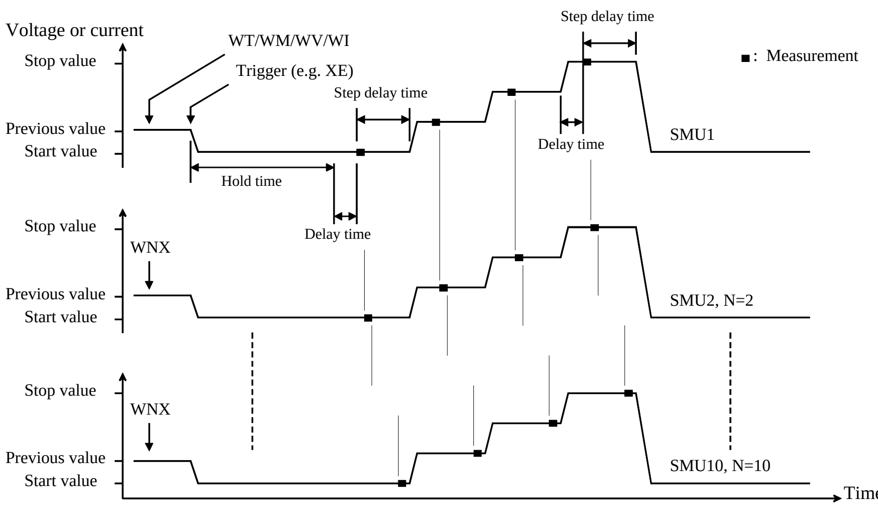
An automatic abort function is available. Refer to “Automatic Abort Function” on page 2-46.

Even if the automatic abort function is disabled, the B1500 automatically stops measurement if power compliance is enabled for the sweep source and the power compliance or an automatic abort condition is detected.

Multi Channel Sweep Measurements

Multi channel sweep measurement is performed as shown below. The source channels apply the staircase sweep or DC bias output, and the measurement channels perform one point measurement at each sweep step. Up to ten channels can be used for both sweep output and measurement. Both voltage output mode and current output mode are available for the source channels.

Figure 2-9 **Multi Channel Sweep Measurements using High-Resolution A/D Converter**



1. The primary sweep source is set by the WV or WI commands. And the synchronous sweep source is set by the WNX command with the source identification number *N* (*N*=2 to 10).
2. The sweep output is simultaneously started by a trigger, such as the XE command. However, if a sweep source sets power compliance or forces logarithmic sweep current, the sweep sources start output in the order specified by the *N* value. Then the first output is forced by the channel set by the WI or WV command.
3. After the hold time, the sweep sources wait for the delay time.
4. After the delay time, the measurement channel starts measurement. If you use multiple measurement channels, the channels that use the high speed ADC with the fixed ranging mode start measurement simultaneously, then other channels perform measurement in the order defined in the MM command.
5. After measurement, the sweep source waits for the rest of the step delay time if it is set, and the sweep source changes the output value.

6. The B1500 repeats 4 and 5 for all sweep steps.
7. After the sweep measurement, the sweep sources force the start or stop value, as specified by the WM command, and keep it.

   For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the output to 0 V.

NOTE

The WT command sets the hold time, delay time, and step delay time. The WM command sets the automatic abort function and the output after measurement. The WV command sets the sweep voltage, and the WI command sets the sweep current. The WNX command sets the synchronous sweep output. The start and stop values must have the same polarity for log sweep.

To Stop Sweep Output

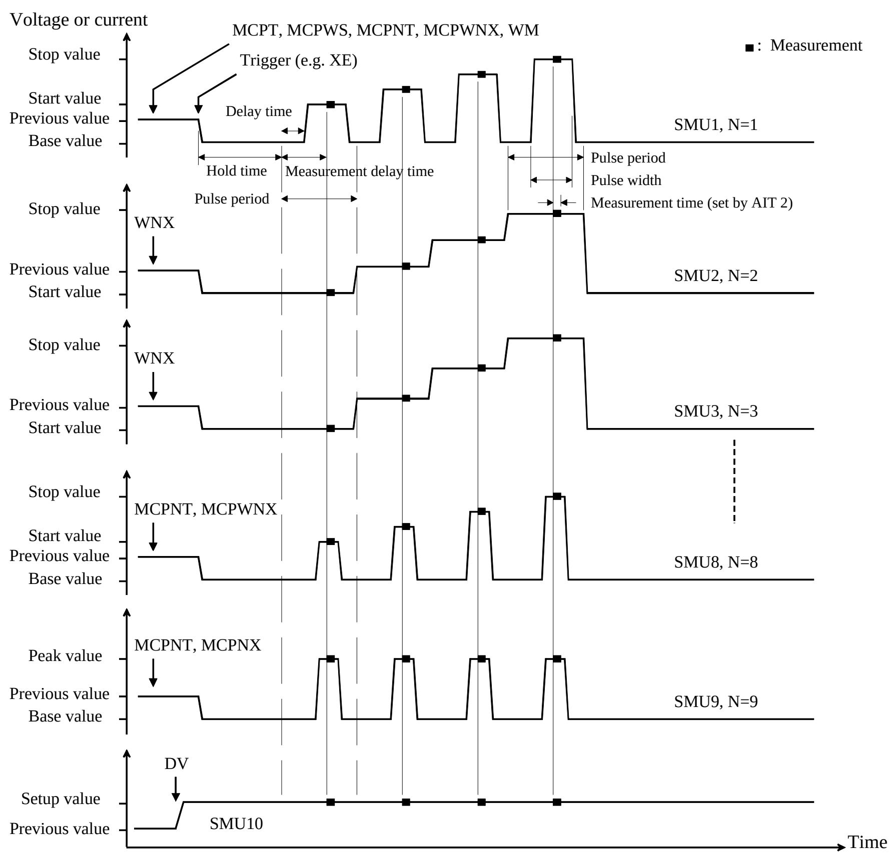
An automatic abort function is available. Refer to “Automatic Abort Function” on page 2-46.

Even if the automatic abort function is disabled, the B1500 automatically stops measurement if power compliance is enabled for the sweep source and the power compliance or an automatic abort condition is detected.

Multi Channel Pulsed Sweep Measurements

Multi channel pulsed sweep measurement is performed as shown below. The source channels apply the pulsed sweep, staircase sweep, pulsed bias, or DC bias output, and the measurement channels perform one point measurement at each sweep step. Up to ten channels can be used for both pulsed sweep output and measurement. Both voltage output mode and current output mode are available for the source channels.

Figure 2-10 Multi Channel Pulsed Sweep Measurements



1. Hold time, pulse period, measurement delay time, and number of measurements are set by the MCPT command.

   Sweep mode and number of sweep steps are set by the MCPWS command. They are the common parameters for all sweep sources.

2. The pulsed sweep source is set by the MCPNT and MCPWNX commands with the source identification number *N* (*N*=1 to 10).
3. The staircase sweep source is set by the WM and WNX commands with the source identification number *N* (*N*=1 to 10).
4. The pulsed bias source is set by the MCPNT and MCPNX commands with the source identification number *N* (*N*=1 to 10).
5. The DC bias output is started by the DV/DI command.
6. The source output is started by a trigger, such as the XE command. Then the staircase sweep sources start output in the order specified by the *N* value, after that the pulsed sweep sources and the pulsed bias sources start output simultaneously.
7. After the hold time, all pulse sources start the pulse output simultaneously.

   For HR/MP/HPSMU, available delay time value is 0. Also, the pulse width value must be the same. If a different value is entered, the longest value is set.
8. After the measurement delay time, the measurement channels perform measurements in parallel. Measurement time is set by the AIT 2 command. This setting is effective for all measurement channels.
9. The B1500 repeats the step output, the pulse output, and 8 for all sweep steps.
10. After the sweep measurement, the pulsed source forces the pulse base value, and the sweep source forces the start or stop value, as specified by the WM command, and keeps it.

    For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the output to 0 V.

NOTE

The MCPNT command sets the delay time and pulse width. The MCPWNX command sets the pulsed sweep output. The base, start, and stop values must have the same polarity for current pulse or log sweep. The WM command sets the automatic abort function and the output after measurement.

The MCPNX command sets the pulsed bias output. The base and peak values must have the same polarity for the current pulse.

The WNX command sets the staircase sweep output. The start and stop values must have the same polarity for log sweep.

To Stop Sweep Output

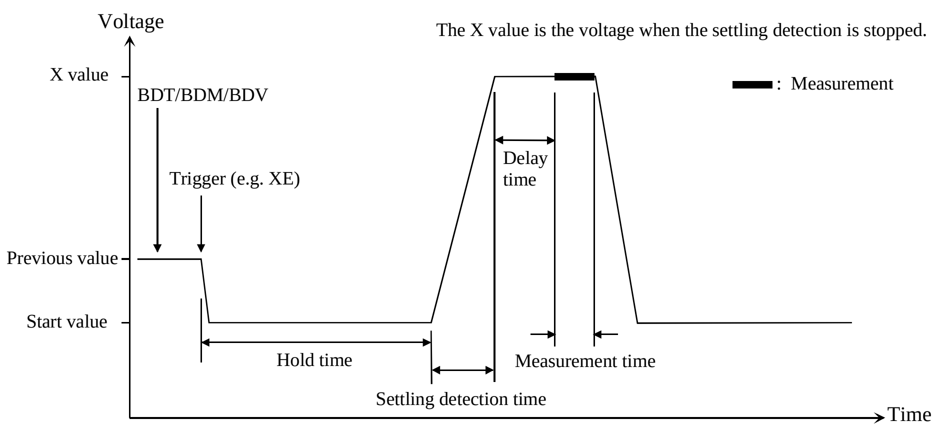
An automatic abort function is available. Refer to "Automatic Abort Function" on page 2-46.

Even if the automatic abort function is disabled, the B1500 automatically stops measurement if power compliance is enabled for the sweep source and the power compliance or an automatic abort condition is detected.

Quasi-Pulsed Spot Measurements

Quasi-pulsed spot measurement is performed as shown below. The measurement channel performs one point measurement while the source channel forces a quasi-pulse voltage. This measurement mode can minimize the output time of the measurement voltage. So it is effective for the breakdown voltage measurement and the reliability test.

Figure 2-11 **Quasi-Pulsed Spot Measurements**



1. The quasi-pulse source channel sets output by the BDT, BDM, and BDV commands. Only one channel can be used for the quasi-pulse source.
2. The quasi-pulse source starts output by a trigger, such as the XE command.
3. After the hold time, the quasi-pulse source starts the voltage transition to the stop value (settling detection time). Also, it performs voltage measurement (settling detection) in the interval set by the BDM command. The voltage transition and settling detection continue until the output voltage slew rate becomes half of the rate when settling detection started. The slew rate depends on the cabling and the characteristics of the device. You cannot define it directly. In normal operation, the slew rate will be slower in the following conditions:

- When the quasi-pulse source applies voltage close to the stop value.
- When the quasi-pulse source reaches its current compliance due to the breakdown condition of the device under test.

NOTE

If the slew rate was too slow when settling detection started or if the settling detection time was too long, an error occurs and the source returns its output to the start value immediately. See "BDM" on page 4-38.

4. After the settling detection stops, the quasi-pulse source keeps the output.
5. After the delay time, the measurement channel starts measurement.
   Only one channel can be used for measurement.
6. After measurement, the quasi-pulse source immediately returns the output to the start value and keeps it.

   For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the output to 0 V.

NOTE

If there is noise or skew on the output voltage, settling detection might stop at an unexpected voltage.

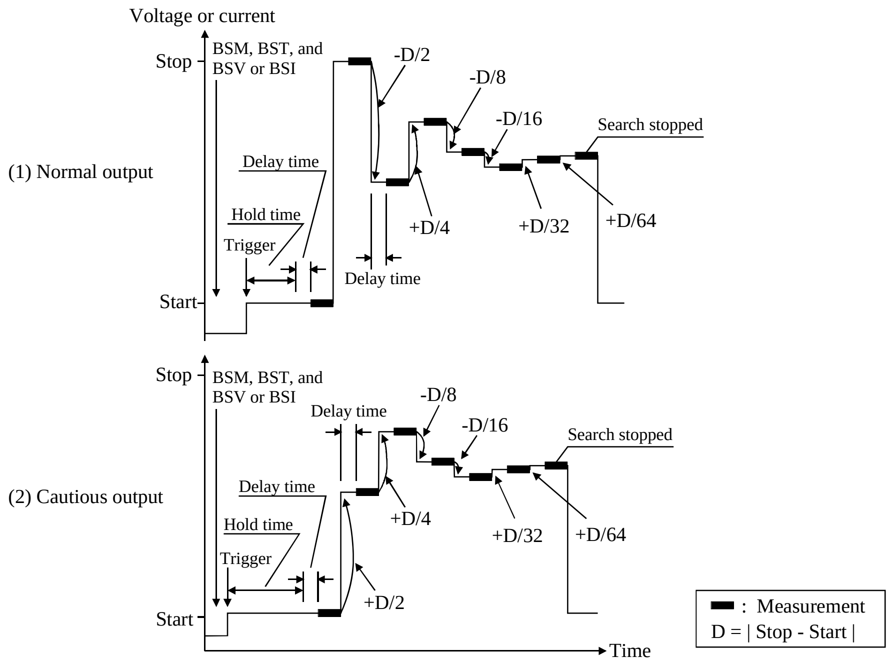
NOTE

The BDT command sets the hold time and delay time, and the BDM command sets the settling detection interval and measurement mode (voltage or current); the BDV command sets the output. Also |start - stop| must be 10 V or more.

Binary Search Measurements

Binary search measurement is performed as shown below. The source channel forces voltage or current, and the measurement channel performs one point measurement. The B1500 repeats this until the search stop condition is satisfied, and returns the source's last output value. The last measurement data is also returned if it is set by the BSVM command.

Figure 2-12 **Binary Search Measurements**



1. The search source sets output by the BSM, BST, and BSV or BSI commands. Only one channel can be used for the search source.
2. The search source starts output by a trigger, such as the XE command.
3. After the hold time, the measurement channel waits for the delay time, and starts measurement as shown in Figure 2-12. The measurement channel can be set by the BGI or BGV command. Only one channel can be used for measurement.
4. After measurement, the search source changes the output value. The output value depends on the output control mode, normal or cautious, selected by the BSM command. See Figure 2-12.

5. The B1500 repeats measurement and 4 until the search stop condition is satisfied. The search stop condition is one of the following conditions selected by the BGI or BGV command.

   - Measured value = Search target value ± limit
   - Number of measurement points > limit

6. After the search measurement, the search source forces the start value, the stop value, or the last output value, as specified by the BSM command, and keeps it.

   For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the output to 0 V.

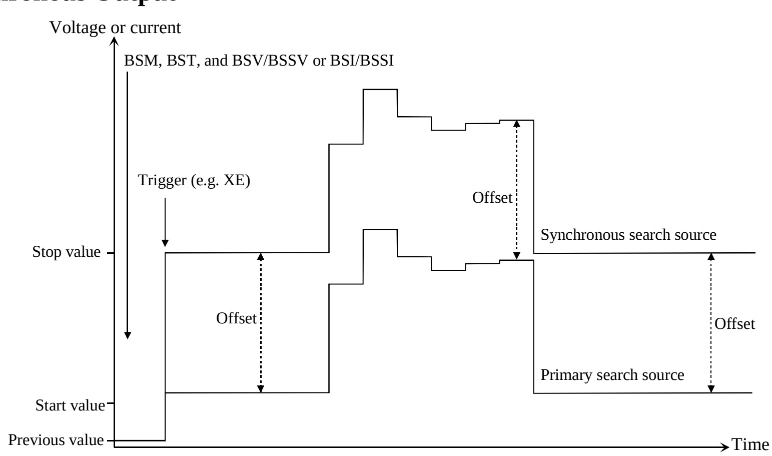
NOTE

The BSM command sets the search control mode, the automatic abort function, and the output after search. The BST command sets the hold time and delay time. The BSV/BSI command sets the search output, and the BGI/BGV command sets the measurement channel.

To Use Synchronous Output Channel

You can use the synchronous output channel that provides the output synchronized with the search source. Refer to “Synchronous Output” on page 2-44. After measurement, the synchronous channel forces the start+offset, stop+offset, or the last output value, as specified by the BSM command, and keeps it.

Figure 2-13 **Synchronous Output**



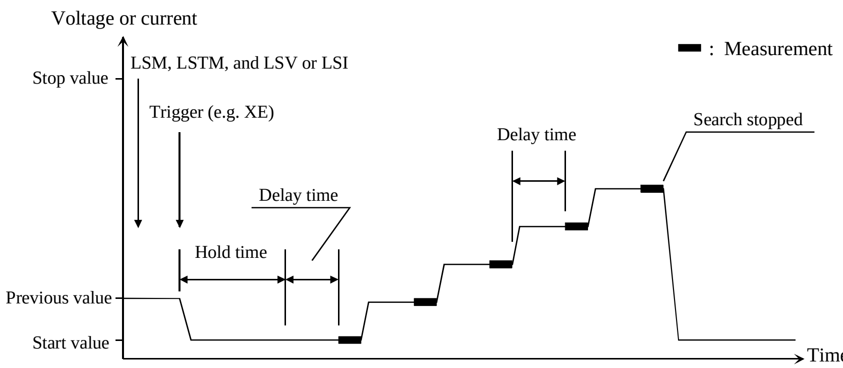
NOTE

The BSSV/BSSI command sets the synchronous output. You can use the same output mode (voltage or current) as the search source. All output values must be covered by the output range of the search source.

Linear Search Measurements

Linear search measurement is performed as shown below. The source channel sweeps voltage or current, and the measurement channel performs one point measurement at each sweep step. The B1500 stops sweep and measurement when the search stop condition is satisfied, and returns the source's last output value. The last measurement data is also returned if it is set by the LSVM command.

Figure 2-14 Linear Search Measurements



1. The search source sets output by the LSM, LSTM, and LSV or LSI commands. Only one channel can be used for the search source.
2. The search source starts output by a trigger, such as the XE command.
3. After the hold time, the measurement channel waits for the delay time, and starts measurement as shown in Figure 2-14. The measurement channel can be set by the LGI or LGV command. Only one channel can be used for the measurement.
4. After measurement, the search source changes the output value.
5. The B1500 repeats measurement and 4 until the search stop condition is satisfied. The search stop condition is one of the following conditions selected by the LGV or LGI command.
   - Measured value is over the search target value.
   - Measured value breaks the search target value.
6. After the search measurement, the search source forces the start value, the stop value, or the last output value, as specified by the LSM command, and keeps it.

   For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the output to 0 V.

NOTE

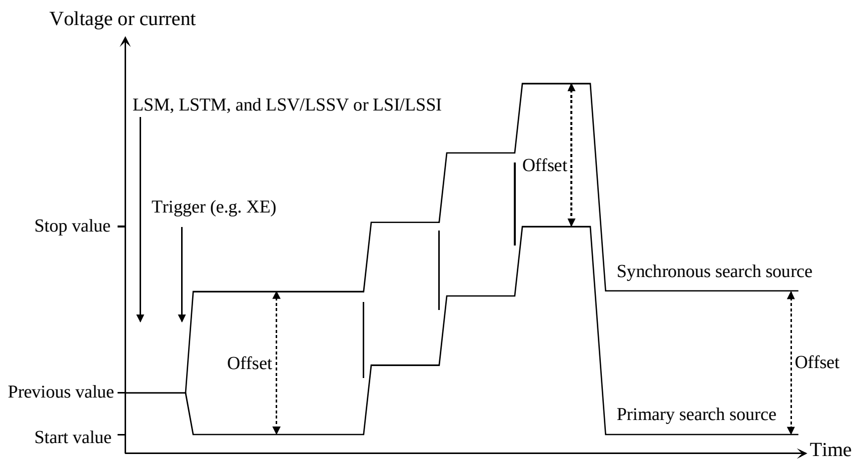
The LSM command sets the automatic abort function and the output after search. The LSTM command sets the hold time and delay time. The LSV/LSI command sets the search output, and the LGI/LGV command sets the measurement channel.

To Use Synchronous Output Channel

You can use the synchronous output channel that provides output synchronized with the search source. Refer to “Synchronous Output” on page 2-44.

After measurement, the synchronous channel forces the start+offset, stop+offset, or the last output value, as specified by the LSM command, and keeps it.

Figure 2-15 **Synchronous Output**



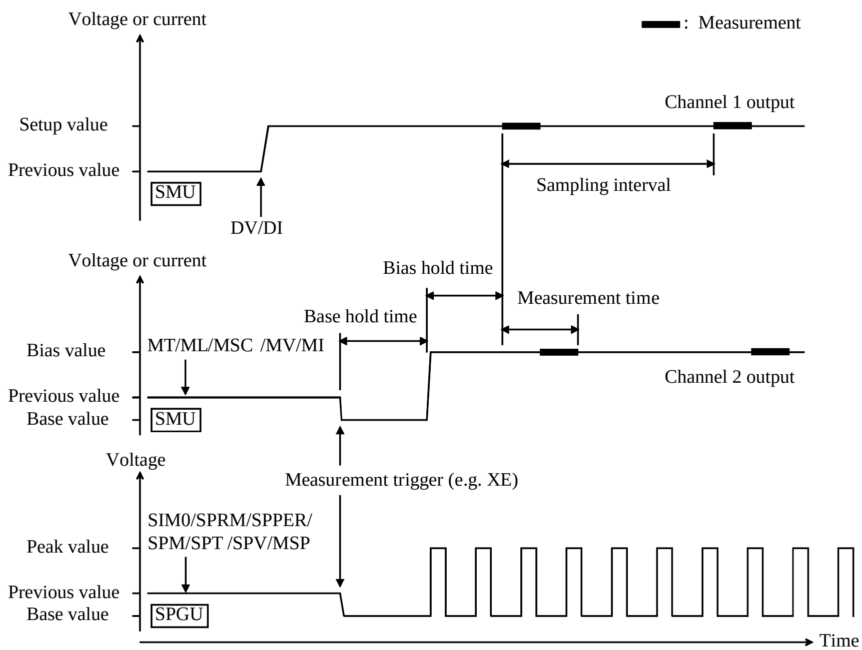
NOTE

The LSSV/LSSI command sets the synchronous output. You can use the same output mode (voltage or current) as the search source. All output values must be covered by the output range of the search source.

Sampling Measurements

Sampling measurement is performed as shown below. The sampling operation is performed in the specified time interval until the number of measurement result data reaches to the specified *number* of samples.

Figure 2-16 **Sampling Measurements**



1. The sampling condition is set by the MT, ML, and MSC commands.
2. The SMU synchronous source channels are set by the MV/MI commands. The channels will start output by a trigger, such as the XE command.
3. The SPGU synchronous source channels are set by the SIM 0, SPRM, SPPER, SPM, SPT, SPV, and MSP. The channels will start output by a trigger.
4. The source channels set by the DI/DV commands will start output at the timing of the DI/DV command execution.
5. The synchronous source channels force the base value by a trigger such as the XE command, as follows.

   The SPGUs start output in the order from lower to higher slot number, and then the SMUs start output simultaneously.

6. After the base hold time, the synchronous source channels force the bias value or the peak value as follows.

   The SMUs start output simultaneously, and then the SPGUs start output in the order from lower to higher slot number. However the SPGU pulse outputs are started simultaneously.

   The channels keep the output until the end of the sampling measurement.

7. And after the bias hold time, the measurement channels start measurement for the first sampling point.

   If you use multiple measurement channels, the channels perform measurement in the order defined in the MM command. Parallel measurement is also available, see “Parallel Measurement Function” on page 2-48.

8. After that, the following operation is repeated with *Sampling interval*.

   - Measurement channels start measurement if they are ready to measure.
   - Measurement channels keep the condition if they are busy.

   This operation is repeated until the number of measurement result data reaches to the specified *number* of samples.

   For the linear sampling with *interval* < 2 ms, if the total sampling time runs over *Bias hold time* + *Sampling interval* × *number*, the sampling measurement will be stopped even if the number of measured data is less than the specified *number*.

   For the log sampling, the B1500A holds only the data that can be plotted on the log scale in the same distance as close as possible. Only the held data is counted in the number of measured data.

9. After the sampling measurement, the synchronous source channels change the output value as follows.

   The SPGUs change the output in the order from higher to lower slot number, and then the SMUs change the output simultaneously. However the SPGU pulse outputs are stopped simultaneously.

   If the SPGU operation mode is not Free Run and the total time of pulse output is shorter than the sampling measurement time, the SPGU pulse outputs are stopped simultaneously before the measurement is completed.

   SPGU forces the post measurement output value set by the MSP command.

   SMU forces the post measurement output value set by the MSC command.

10. The source channel set by the DV or DI command continues the source output.

For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the output to 0 V.

The *index* data (max. 9999999) and the *time* data returned with the measurement data will be as shown in the following formula. However, long measurement or busy status may cause unexpected *time* and *index* data.

$time = t + Bias\ hold\ time + (index - 1) \times Sampling\ interval$

Where, *t* is the time of the sampling measurement time origin, and is the time when the output value is changed from *base* to *bias*.

NOTE

The MT command sets the bias hold time, sampling interval, number of samples, and base hold time. If the sampling interval is less than 2 ms, the SPGU cannot be used.

The MSC command sets the automatic abort function and the post measurement output value of SMU.

The ML command sets the linear sampling mode or the log sampling mode.

The MV and MI commands set the SMU synchronous voltage and current source respectively. The base and bias values must have the same polarity for MI output.

The SIM 0 command sets the pulse generator operation mode for all SPGU channels.

The SPRM command sets the output operation mode for all SPGU channels, free run (pulse output continues until SPP), pulse count, or duration.

The SPPER command sets the pulse period for all SPGU channels.

The SPM command sets the output mode of the SPGU channel, DC voltage, 2-level pulse using source 1, 2-level pulse using source 2, or 3-level pulse using sources 1 and 2.

The SPT command sets the delay time, pulse width, leading time, and trailing time of the SPGU channel.

The SPV command sets the pulse base and peak voltage or the DC bias voltage of the SPGU channel.

The MSP command sets the SPGU synchronous voltage source and its post measurement output value.

The MCC command clears the MV, MI, and MSP command setting.

To Stop Output

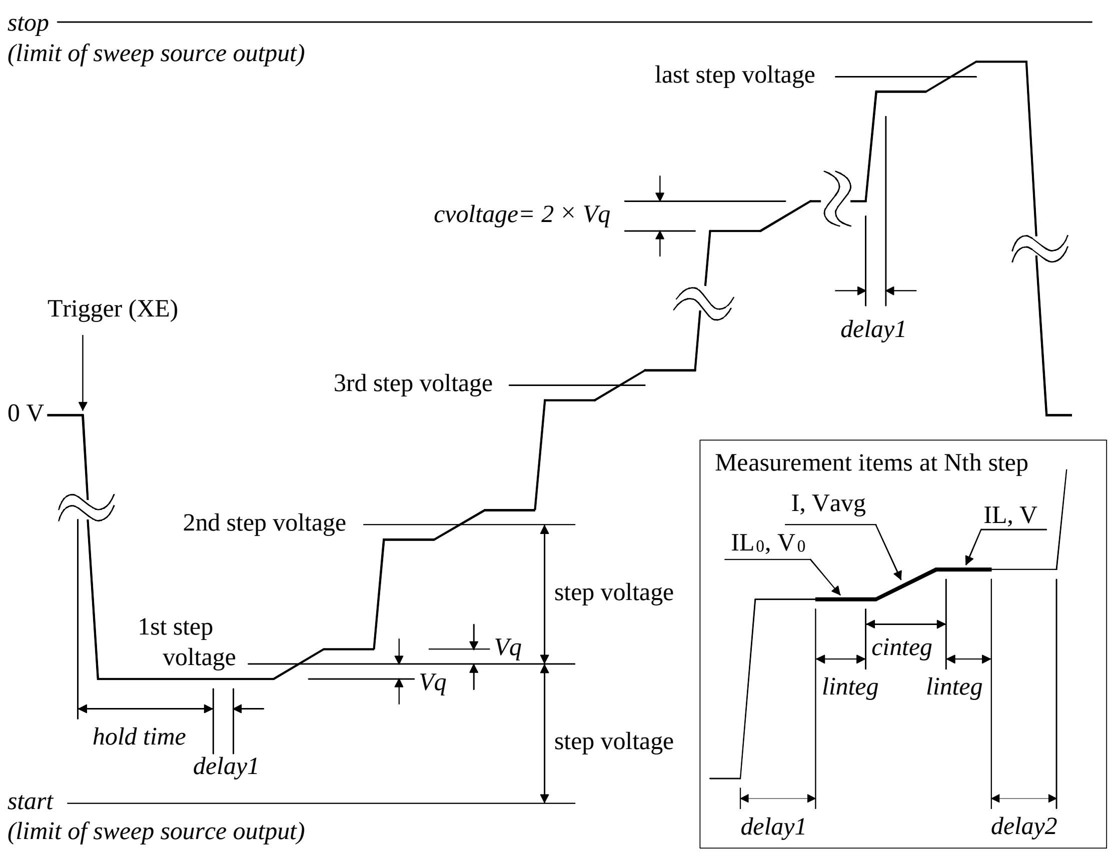
An automatic abort function is available. Refer to “Automatic Abort Function” on page 2-46.

Quasi-static CV Measurements

Quasi-static CV (QSCV) measurement is performed as shown. The specified SMU performs the measurement at the sweep steps except for the sweep start voltage and stop voltage. At each sweep step, current and voltage are measured during the voltage transition from *Nth step voltage*-*cvoltage*/2 to *Nth step voltage*+*cvoltage*/2, and capacitance is calculated by using the measured values. Where, *cvoltage* is the capacitance measurement voltage. For the measurement operation, see Figure 2-17. For the capacitance data calculation, see “Capacitance Data” on page 2-29.

Source parameters; *start*, *stop*, *cvoltage*, and *step* are set by the QSV command. Time parameters; *hold time*, *delay1*, *delay2*, *linteg*, and *cinteg* are set by the QST command. *linteg* and *cinteg* are the integration time for the leakage current measurement and the capacitance measurement, respectively.

Figure 2-17 Setting Parameters and Operation of QSCV Measurement



The operation of the quasi-static CV measurements is explained below. This is the case of *start* < *stop*.

1. Measurement trigger enables the sweep source output. The sweep source forces *1st step voltage*-*Vq*, and waits for *hold time*. where *Vq*=*cvoltage*/2.
2. Repeats 3 and 4 for the Nth sweep step. where N is integer, 1 to *step*.

   step is the number of sweep steps given by *step* = |*start*-*stop*| / |step voltage| -1.
3. The sweep source forces *Nth step voltage*-*Vq*, and waits for delay time (*delay1*).
4. The measurement unit measures the following items, and waits for delay time (*delay2*).

IL_0	Leakage current before the voltage transition
V_0	Voltage before the voltage transition
I	Charge current in the voltage transition to *Nth step voltage*+*Vq*
Vavg	Averaging voltage in the voltage transition to *Nth step voltage*+*Vq*. Not measured for the 4155C/4156C compatible operation mode set by the `QSC1` command.
IL	Leakage current after the voltage transition
V	Voltage after the voltage transition
5. After the sweep measurement, the sweep source forces the start or stop value, as specified by the QSM command, and keeps it.

NOTE

If the following condition is true, the measurement operation has the differences shown below.

- *delay2* is automatically set to 0.
- V_0 and IL_0 are not measured for the second step and later. The capacitance calculation uses the V and IL values at the previous sweep step, instead.

Condition:

|step voltage| = |*start*-*stop*| / (*step* + 1) = *cvoltage*

Capacitance Data

Capacitance data is given by the calculation. The calculation depends on the operation mode set by the QSC command. There is two operation modes, Normal and 4155C/4156C compatible.

Normal Mode

Normal operation mode for the B1500A

- Capacitance Data

  At each sweep step, the capacitance data is calculated by using the following formula.

  $C = (I - Leak) \times cinteg / (V - V_0)$

  The `QSL0,0` command disables the leakage current compensation and the leakage current data output. Then the leakage current measurement is not executed. The capacitance data is calculated by using the following formula.

  $C = I \times cinteg / (V - V_0)$

- Leakage Current Data

  At each sweep step, the leakage current data is calculated by using the following formula. This data output is enabled by the `QSL1,0` or `QSL1,1` command.

  $Leak = IL_0 + (IL - IL_0) \times (V_{avg} - V_0)/(V - V_0)$

4155C/4156C Compatible Mode

Operation mode that provides a good compatibility with the measurement results by the 4155C/4156C

- Capacitance Data

  At each sweep step, the capacitance data is calculated by using the following formula.

  $C = (I - Leak) \times cinteg / (V - V_0)$

  The `QSL0,0` command disables the leakage current compensation and the leakage current data output. Then the leakage current measurement is not executed. The capacitance data is calculated by using the following formula.

  $C = I \times cinteg / (V - V_0)$

- Leakage Current Data

  At each sweep step, the leakage current data is calculated by using the following formula. This data output is enabled by the `QSL1,0` or `QSL1,1` command.

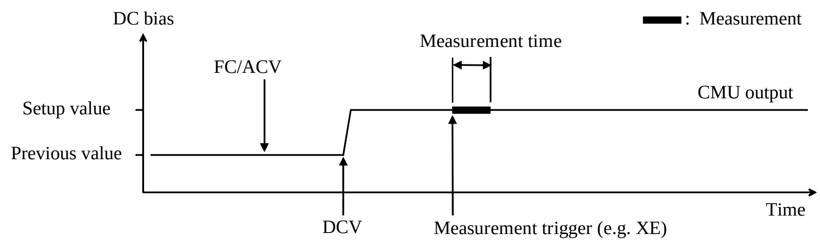
  $Leak = IL + \tau \times (IL_0 - IL)/(2 \times cinteg)$, where τ is the time for electrical charge

Spot C Measurements

Spot capacitance measurement is performed as shown below. The CMU (capacitance measurement unit) applies DC bias with AC signal, and performs one point measurement.

Before performing the measurement, select the measurement parameters by using the IMP command. And select the output data by using the LMN command.

Figure 2-18 **Spot C Measurements**



1. The CMU starts AC signal output by the FC and ACV commands.
2. The CMU starts DC bias output by the DCV command.
3. The CMU performs measurement by a trigger, such as the XE command. If the trigger is received during the settling time, the measurement starts after the time.
4. After the measurement, the CMU continue the DC bias output with AC signal.

   For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the CMU output to 0 V for both AC and DC.

NOTE

The FC command sets the AC signal frequency.

The ACV command specifies the oscillator level, and applies the AC signal.

The DCV command applies the specified DC bias.

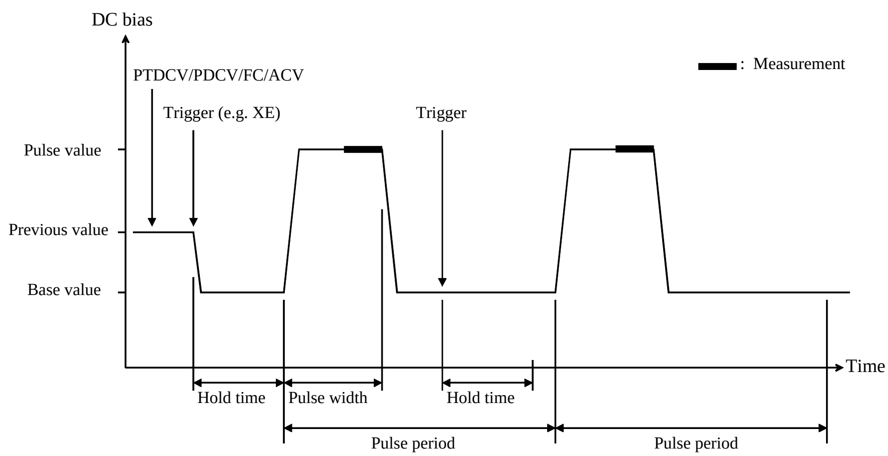
If the SCUU (SMU CMU Unify Unit) is connected to the 1 CMU and 2 MPSMUs/HRSMUs correctly, the source module is automatically selected by the DC bias setting. The CMU is selected if it is ±25 V or less (setting resolution: 0.001 V), or the SMU is selected if it is greater than ±25 V (setting resolution: 0.005 V).

Pulsed Spot C Measurements

Pulsed spot C measurement is performed as shown below. The CMU (capacitance measurement unit) applies pulsed DC bias with AC signal, and performs one point measurement.

Before performing the measurement, select the measurement parameters by using the IMP command. And select the output data by using the LMN command.

Figure 2-19 **Pulsed Spot C Measurements**



1. The CMU starts AC signal output by the FC and ACV commands.
2. The CMU sets the pulsed output by the PTDCV and PDCV commands.
3. The CMU starts output by a trigger, such as the XE command.
4. The CMU starts measurement as shown in Figure 2-19. The CMU performs measurement so that the pulse width and pulse period are kept.
5. After measurement, the CMU forces the pulse base value, and keeps it. The CMU also keeps the AC signal output.

   If the next trigger occurs within the pulse period, pulse output is as follows.

   - If the rest of the pulse period is longer than the hold time as shown in Figure 2-19, the CMU waits for the rest, then starts the pulse output.
   - If the rest of the pulse period is shorter than the hold time, the CMU waits for the hold time since the last trigger, then starts the pulse output.

   For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the CMU output to 0 V for both AC and DC.

NOTE

The PTDCV command sets the pulse timing parameters, such as pulse width and pulse period.

The PDCV command sets pulsed DC bias (voltage) with AC signal.

The FC command sets the AC signal frequency.

The ACV command specifies the oscillator level, and applies the AC signal.

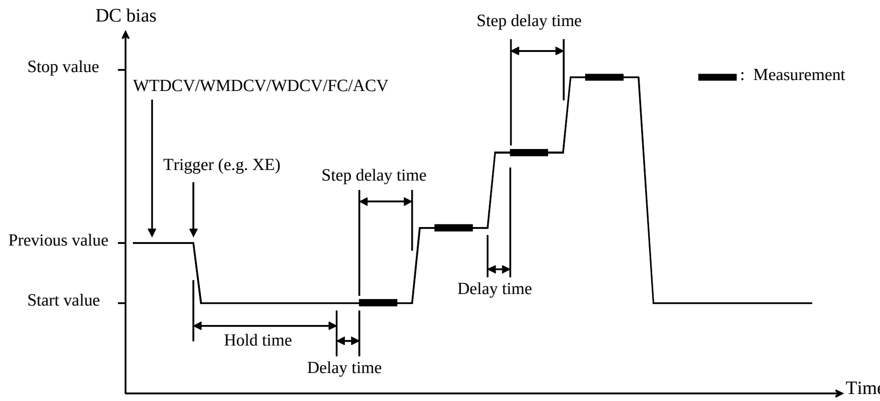
If the SCUU (SMU CMU Unify Unit) is connected to the 1 CMU and 2 MPSMUs/HRSMUs correctly, the source module is automatically selected by the DC bias setting. The CMU is selected if it is ±25 V or less (setting resolution: 0.001 V), or the SMU is selected if it is greater than ±25 V (setting resolution: 0.005 V).

CV (DC bias) Sweep Measurements

CV (DC bias) sweep measurement is performed as shown below. The CMU (capacitance measurement unit) applies DC bias with AC signal, and performs one point measurement at each step of DC bias sweep. While the sweep measurement, the AC signal level and frequency are constant.

Before performing the measurement, select the measurement parameters by using the IMP command. And select the output data by using the LMN command.

Figure 2-20 **CV (DC bias) Sweep Measurements**



1. The CMU starts AC signal output by the FC and ACV commands.
2. The CMU sets the DC bias sweep output by the WTDCV, WMDCV, and WDCV commands.
3. The CMU starts output by a trigger, such as the XE command.
4. After the hold time, the CMU waits for the delay time.
5. After the delay time, the CMU starts measurement.
6. After measurement, the CMU waits for the rest of the step delay time if it is set, and the CMU changes the output value.
7. The B1500 repeats 5 and 6 for all sweep steps.
8. After the sweep measurement, the CMU forces the start or stop value, as specified by the WMDCV command, and keeps it. The CMU also keeps the AC signal output.

   For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the CMU output to 0 V for both AC and DC.

NOTE

The WTDCV command sets the hold time, delay time, and step delay time.

The WMDCV command sets the automatic abort function and the output after measurement.

The WDCV command sets the DC bias sweep voltage. The start and stop values must have the same polarity for log sweep.

The FC command sets the AC signal frequency.

The ACV command specifies the oscillator level, and applies the AC signal.

If the SCUU (SMU CMU Unify Unit) is connected to the 1 CMU and 2 MPSMUs/HRSMUs correctly, the source module is automatically selected by the sweep range (from start to stop). The CMU is selected if it is ±25 V or less (setting resolution: 0.001 V), or the SMU is selected if it is greater than ±25 V (setting resolution: 0.005 V).

To Stop Sweep Output

An automatic abort function is available. Refer to "Automatic Abort Function" on page 2-46.

To Use SMU for Measurement

SMU can be used for current or voltage measurement in the CV (DC bias) sweep measurement mode by adding the SMU channel number after the CMU channel number of the MM18 command. See Figure 2-21 and Figure 2-22. For these measurements, the SMU starts measurement after the delay time and the CMU starts measurement after the measurement is completed by the SMU.

Figure 2-21 shows an example to use a SMU additionally to the above example shown in Figure 2-20. The SMU1 is used for the constant voltage output and the current or voltage measurement.

Figure 2-21 **CV (DC bias) Sweep Measurements by MM18,CMU,SMU1**

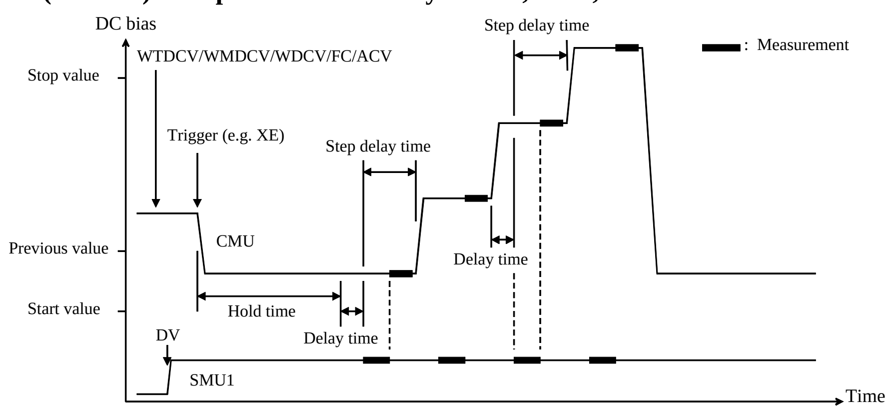


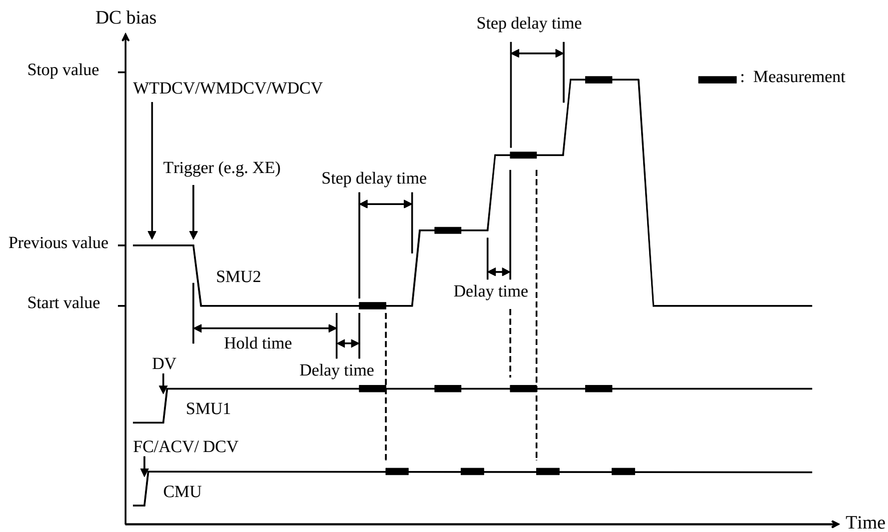
Figure 2-22 shows an example to use a SMU for the DC bias sweep source. This example uses the CMU for the constant voltage output and the capacitance measurement, the SMU1 for the constant voltage output and the current or voltage measurement, and the SMU2 for the DC bias sweep output and the current or voltage measurement. To perform this measurement, a bias-tee is required. And the CMU and the SMU2 must be connected as shown below.

- CMU: RF signal input of bias-tee
- SMU2: DC bias input of bias-tee

The output of the bias-tee must be connected to a DUT terminal.

This example uses the PAD1 command to perform the parallel measurement by the SMU. The SMU starts measurement simultaneously after the delay time and the CMU starts measurement after the measurement is completed by the SMU.

Figure 2-22 CV (DC bias) Sweep Measurements by MM18,CMU,SMU1,SMU2 and PAD1

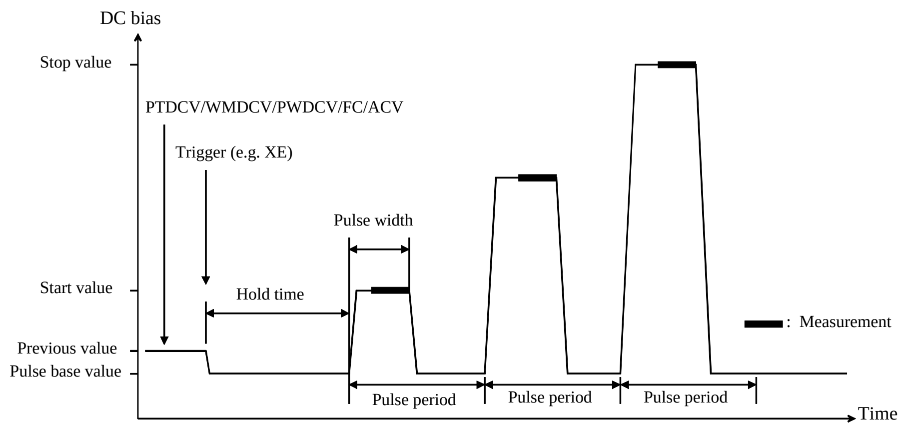


Pulsed Sweep CV Measurements

Pulsed sweep CV measurement is performed as shown below. The CMU (capacitance measurement unit) applies pulsed DC bias with AC signal, and performs one point measurement at each step of pulsed DC bias sweep. While the sweep measurement, the AC signal level and frequency are constant.

Before performing the measurement, select the measurement parameters by using the IMP command. And select the output data by using the LMN command.

Figure 2-23 **Pulsed Sweep CV Measurements**



1. The CMU starts AC signal output by the FC and ACV commands.
2. The CMU sets the pulsed bias sweep output by the PTDCV, WMDCV, and PWDCV commands.
3. The CMU starts output by a trigger, such as the XE command.
4. After the hold time, the CMU starts measurement as shown in Figure 2-23. The CMU performs measurement so that the pulse width and pulse period are kept.
5. After measurement, the CMU forces the pulse base value, and waits for the rest of the pulse period. Then the CMU changes the output value.
6. The B1500 repeats measurement and 5 for all sweep steps.
7. After the pulsed sweep measurement, the CMU forces the pulse base value, and keeps it. The CMU also keeps the AC signal output.

   For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the CMU output to 0 V for both AC and DC.

NOTE

The PTDCV command sets the pulse timing parameters, such as pulse width and pulse period.

The WMDCV command sets the automatic abort function.

The PWDCV command sets the pulsed bias sweep voltage. The base, start, and stop values must have the same polarity for log sweep.

The FC command sets the AC signal frequency.

The ACV command specifies the oscillator level, and applies the AC signal.

If the SCUU (SMU CMU Unify Unit) is connected to the 1 CMU and 2 MPSMUs/HRSMUs correctly, the source module is automatically selected by the sweep range (from start to stop). The CMU is selected if it is ±25 V or less (setting resolution: 0.001 V), or the SMU is selected if it is greater than ±25 V (setting resolution: 0.005 V).

To Stop Sweep Output

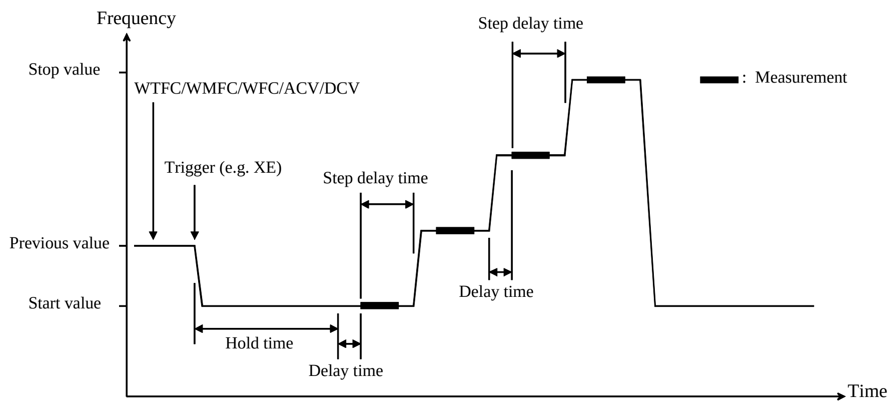
An automatic abort function is available. Refer to “Automatic Abort Function” on page 2-46.

C-f Sweep Measurements

C-f sweep measurement is performed as shown below. The CMU (capacitance measurement unit) applies AC signal with DC bias, and performs one point measurement at each step of AC signal frequency sweep. While the sweep measurement, the AC signal level and the DC bias are constant.

Before performing the measurement, select the measurement parameters by using the IMP command. And select the output data by using the LMN command.

Figure 2-24 **C-f Sweep Measurements**



1. The CMU sets the AC signal frequency sweep output by the WTFC, WMFC, and WFC commands.
2. The CMU starts AC signal/DC bias output by the ACV and DCV commands.
3. The CMU starts frequency sweep by a trigger, such as the XE command.
4. After the hold time, the CMU waits for the delay time.
5. After the delay time, the CMU starts measurement.
6. After measurement, the CMU waits for the rest of the step delay time if it is set, and the CMU changes the AC signal frequency.
7. The B1500 repeats 5 and 6 for all sweep steps.
8. After the sweep measurement, the CMU keeps the signal output of the AC signal frequency’s start or stop value as specified by the WMFC command.

   For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the CMU output to 0 V for both AC and DC.

NOTE

The WTFC command sets the hold time, delay time, and step delay time.

The WMFC command sets the automatic abort function and the output after measurement.

The WFC command sets the AC signal frequency sweep output.

The ACV command specifies the oscillator level, and applies the AC signal.

The DCV command applies the specified DC bias.

If the SCUU (SMU CMU Unify Unit) is connected to the 1 CMU and 2 MPSMUs/HRSMUs correctly, the source module is automatically selected by the DC bias setting. The CMU is selected if it is ±25 V or less (setting resolution: 0.001 V), or the SMU is selected if it is greater than ±25 V (setting resolution: 0.005 V).

To Stop Sweep Output

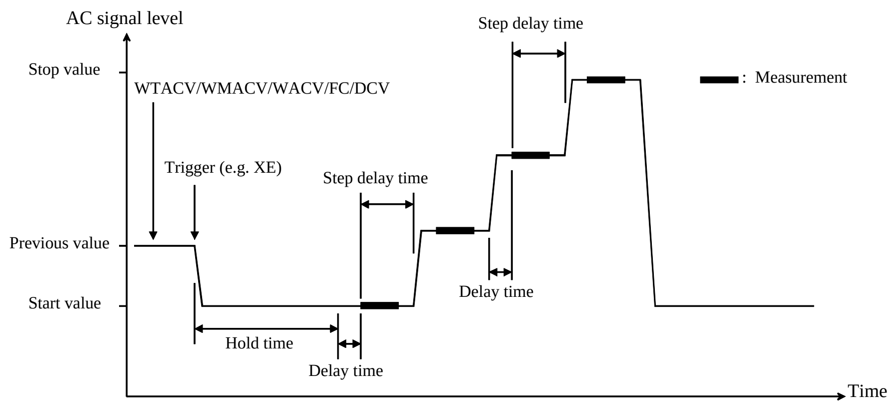
An automatic abort function is available. Refer to “Automatic Abort Function” on page 2-46.

CV (AC level) Sweep Measurements

CV (AC level) sweep measurement is performed as shown below. The CMU (capacitance measurement unit) applies AC signal with DC bias, and performs one point measurement at each step of AC signal level sweep. While the sweep measurement, the AC signal frequency and the DC bias are constant.

Before performing the measurement, select the measurement parameters by using the IMP command. And select the output data by using the LMN command.

Figure 2-25 **CV (AC level) Sweep Measurements**



1. The CMU sets the AC signal level sweep output by the WTACV, WMACV, WACV, and FC commands.
2. The CMU starts DC bias output by the DCV command.
3. The CMU starts AC signal level sweep by a trigger, such as the XE command.
4. After the hold time, the CMU waits for the delay time.
5. After the delay time, the CMU starts measurement.
6. After measurement, the CMU waits for the rest of the step delay time if it is set, and the CMU changes the AC signal level.
7. The B1500 repeats 5 and 6 for all sweep steps.
8. After the sweep measurement, the CMU keeps the signal output of the AC signal level's start or stop value as specified by the WMACV command.

   For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the CMU output to 0 V for both AC and DC.

NOTE

The WTACV command sets the hold time, delay time, and step delay time.

The WMACV command sets the automatic abort function and the output after measurement.

The WACV command sets the AC signal level sweep output.

The FC command sets the AC signal frequency.

The DCV command applies the specified DC bias.

If the SCUU (SMU CMU Unify Unit) is connected to the 1 CMU and 2 MPSMUs/HRSMUs correctly, the source module is automatically selected by the DC bias setting. The CMU is selected if it is ±25 V or less (setting resolution: 0.001 V), or the SMU is selected if it is greater than ±25 V (setting resolution: 0.005 V).

To Stop Sweep Output

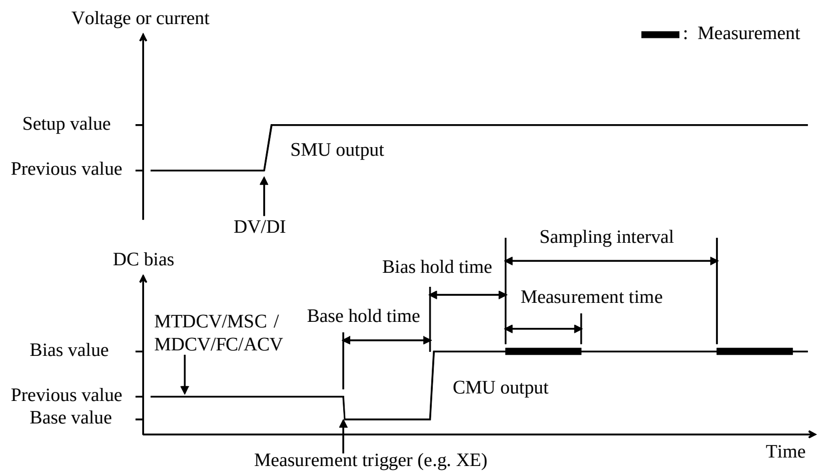
An automatic abort function is available. Refer to “Automatic Abort Function” on page 2-46.

C-t Sampling Measurements

C-t sampling measurement is performed as shown below. The sampling operation is performed in the specified time interval until when the total sampling time runs over *Bias hold time* + *Sampling interval* × *number* of samples.

Before performing the measurement, select the measurement parameters by using the IMP command. And select the output data by using the LMN command.

Figure 2-26 **C-t Sampling Measurements**



1. The sampling condition is set by the MTDCV and MSC commands.
2. The CMU sets the DC bias output by the MDCV command.
3. The CMU starts AC signal output by the FC and ACV commands.
4. (optional) The source channels set by the DI/DV commands will start output at the timing of the DI/DV command execution.
5. The CMU starts the base value output by a trigger, such as the XE command.
6. After the base hold time, the CMU changes the output to the bias value. The CMU keeps the value until the end of the sampling measurement.
7. And after the bias hold time, the CMU starts measurement for the first point.
8. After that, the following operation is repeated with *Sampling interval*.
   - CMU starts measurement if it is ready to measure.
   - CMU keeps the condition if it is busy.

This operation is repeated until when the total sampling time runs over *Bias hold time* + *Sampling interval* × *number* of samples. The sampling measurement will be stopped even if the number of measurement result data is less than *number*.

9. After the sampling measurement, the CMU forces the *base* or *bias* value specified by the MDCV command.

   The source channel set by the DV or DI command continues the source output.

   For 0 V output, enter the DZ command that is used to memorize the present settings of the channel and change the output to 0 V.

The *index* data (max. 10001) and the *time* data returned with the measurement data is given by the following formula. It depends on the measurement ranging mode set by the RC command. However, long measurement or busy status may cause unexpected *time* and *index* data.

- For the fixed range mode

  time = *Bias hold time* + *index* × *Sampling interval*

- For the auto range mode

  time = *Beginning time of one point measurement* - *t*

  Where, *t* is the time of the sampling measurement time origin, and is the time when the output value is changed from *base* to *bias*.

NOTE

The MTDCV command sets the bias hold time, sampling interval, number of samples, and base hold time.

The MSC command sets the automatic abort function.

The MDCV command sets the DC bias output and the output after measurement.

The FC command sets the AC signal frequency.

The ACV command specifies the oscillator level, and applies the AC signal.

If the SCUU (SMU CMU Unify Unit) is connected to the 1 CMU and 2 MPSMUs/HRSMUs correctly, the source module is automatically selected by the DC bias setting. The CMU is selected if it is ±25 V or less (setting resolution: 0.001 V), or the SMU is selected if it is greater than ±25 V (setting resolution: 0.005 V).

To Stop Output

An automatic abort function is available. Refer to “Automatic Abort Function” on page 2-46.

Synchronous Output

You can use synchronous output that will be synchronized to the output of the primary sweep or search source. See Figure 2-27 and Figure 2-28. Synchronous output is available for the following measurement modes and set by the following commands:

Measurement Mode	Command
“Staircase Sweep Measurements”	WSI or WSV
“Pulsed Sweep Measurements”	WSI or WSV
“Staircase Sweep with Pulsed Bias Measurements”	WSI or WSV
“Binary Search Measurements”	BSSI or BSSV
“Linear Search Measurements”	LSSI or LSSV

The synchronous source supports the same output mode (voltage or current) as the primary source, and does not support pulsed output.

Parameters

The following parameters are used to set up a synchronous output. For details of the commands, refer to Chapter 4, “Command Reference.”

- For the WSI and WSV commands:

  start Synchronous sweep start value.

  stop Synchronous sweep stop value.

  The start and stop values must have the same polarity for logarithmic sweep.

- For the BSSI, BSSV, LSSI, and LSSV commands:

  offset Offset value from the search source output.

  polarity Polarity (+ or `-`) of the synchronous source output.

  Synchronous output is given by one of the following formulas:

  - *Synchronous output* = *primary source output* + *offset*
  - *Synchronous output* = `-1`× *primary source output* + *offset*

  All output values must be covered by the output range of the search source.

Figure 2-27 **Synchronous Sweep Output Example for Staircase Sweep**

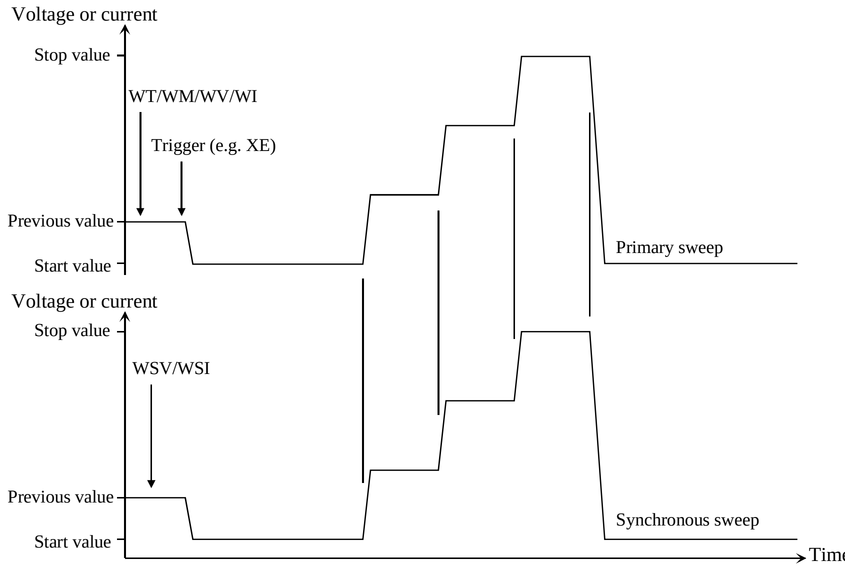
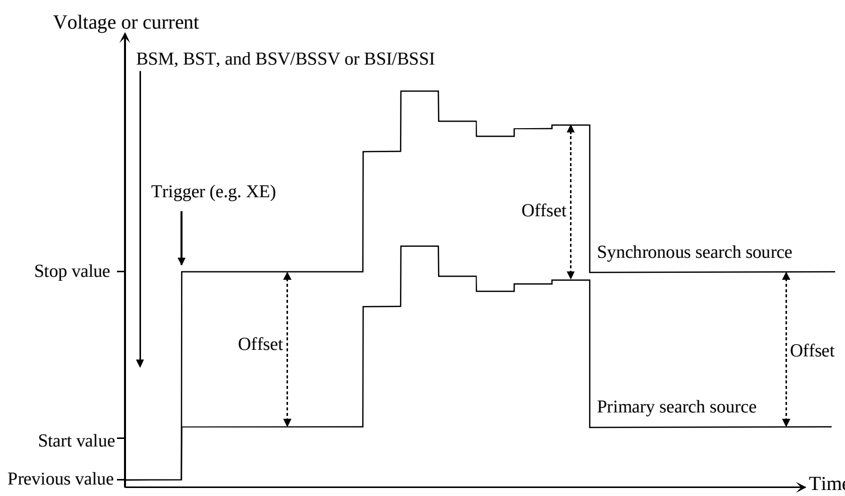


Figure 2-28 **Synchronous Output Example for Binary Search**



Automatic Abort Function

The automatic abort function stops measurement (increasing or decreasing source output value) when one of the following conditions occurs. This function is useful to reduce sweep time and to prevent damage to the device during measurement.

- The output reaches voltage compliance or current compliance
- A measurement value exceeds the specified measurement range
- An SMU oscillates, or an error is caused in the CMU

The automatic abort function is enabled by the following commands.

- WM: Staircase sweep, staircase sweep with pulsed bias, multi channel sweep, and pulsed sweep measurements
- BSM: Binary search measurement
- LSM: Linear search measurement
- MSC: Sampling measurement and C-t sampling measurement
- QSM: Quasi-static CV measurement
- WMDCV: CV (DC bias) sweep measurement
- WMFC: C-f sweep measurement
- WMACV: CV (AC level) sweep measurement

When abort occurs

After measurement is aborted, the source forces the following value. And then the dummy data (199.999E+99) is returned for measurement points not reached.

- Start value (for sweep source and search output source)
- Pulse base value (for pulsed source and pulsed sweep source)
- Base value (for synchronous source of sampling measurement)

Output after measurement

The commands listed above also can be used to set the source output after the measurement ends normally. The source output value can be one of the following values.

- Sweep measurement: Start value or stop value
- Search measurement: Start value, stop value, or last output value
- Sampling measurement: Base value or bias value

Exceptions:

- For the sampling measurement, the SPGU output value can be set by the MSP command, not the MSC command.
- For the C-t sampling measurement, the MFCMU output value can be set by the MDCV command, not the MSC command.
- This function is not effective for the pulsed sweep measurement and the pulsed sweep CV measurement.

NOTE

Even if the source output value is specified, the source forces the start value or the base value if the output is stopped by the automatic abort function, the power compliance, or the AB command.

Parallel Measurement Function

The following measurement modes allow to use the multiple measurement channels.

- Spot measurement (MM 1,*chnum*,*chnum*, . . . ,*chnum*)
- Staircase sweep measurement (MM 2,*chnum*,*chnum*, . . . ,*chnum*)
- Sampling measurement (MM 10,*chnum*,*chnum*, . . . ,*chnum*)
- Multi channel sweep measurement (MM 16,*chnum*,*chnum*, . . . ,*chnum*)

For the spot measurement, staircase sweep measurement, and sampling measurement, executing the PAD1 command before starting measurement enables the parallel measurement (simultaneous measurement).

For the multi channel sweep measurement and the sampling measurement of the sampling interval < 2 ms, the parallel measurement is always effective without the PAD1 command.

Measurement is performed as shown below.

1. Measurement channels that satisfy the following required conditions start measurement simultaneously (parallel measurement).
2. After the parallel measurement, the other channels perform measurement in the order defined in the MM command.

Required Conditions

The following conditions must be satisfied for the measurement channels to perform the parallel measurements.

- Use the high speed A/D converter

  AAD *chnum*,0 command

- Use the fixed ranging for the measurement

  RI *chnum*,*range* command (for current measurement)

  RV *chnum*,*range* command (for voltage measurement)

  Enter the negative value for *range* to use the fixed ranging.

Program Memory

The program memory is a volatile memory that is used to store command strings temporarily. The Agilent B1500 has a built-in program memory that can store 2,000 programs maximum, and a total of 40,000 commands.

The program memory can eliminate several processes in the program execution, such as transferring commands, checking command syntax, and converting commands to the internal codes. Thus, using the program memory speeds up program execution. If frequently used command strings are stored in the program memory, GPIB/computer activity is minimized.

Using Program Memory

You can store, execute, read, and delete programs in the program memory as shown below. For details on each command, refer to Chapter 4, "Command Reference."

To store programs

Send the ST and END commands to store a program. The following procedure stores a program (program number *n*) in the program memory. A multiple command string is also available.

1. `OUTPUT @B1500;"ST` *n*`"`

   where, *n* is the program number for the program now stored in the program memory. The value must be an integer, 1 to 2000.

2. `OUTPUT @B1500;"`*XXXX*`"`

   where, *XXXX* must be the command you want to store in the program memory. Repeat this until all required commands are stored.

   Table 2-1 lists the invalid commands for the program memory.

3. `OUTPUT @B1500;"END"`

NOTE

The program must be complete and free of errors.

An error occurs if the program memory overflows while a program is being stored.

If you store a new program using an existing program number, the old program is deleted and the new program is stored.

To call programs from a memory program

A memory program can invoke another memory program by storing the DO or RU command in the memory program. Up to eight levels of nesting are available. The first level is always the DO or RU command sent by the external computer.

To execute programs

Send the RU or DO command to execute the memory program.

- `OUTPUT @B1500;"RU 1,5"`

  This example executes the programs numbered 1 through 5 sequentially. These programs must be stored in the memory.

- `OUTPUT @B1500;"DO 1,2,3,4,5"`

  This example executes programs 1, 2, 3, 4, and 5 in this order. These programs must be stored in the memory. A maximum of eight numbers can be specified.

To use variables

You can use variables in the memory programs. To enter the value to the variable, send the VAR command. If the variable is referred by multiple programs or commands, set or change the value carefully so that the program works fine without errors. Format of the variable is %*tn* (*t*: integer I or real R, *n*: integer, 1 to 99).

In the following example, the first line stores a program (program 99) which uses the `%I50` variable. The second line enters 2 to `%I50`, and executes the program 99.

```
OUTPUT @B1500;"ST99;CN%I50;DV%I50,0,2;TI%I50;CL%I50;END"
OUTPUT @B1500;"VAR0,50,2;DO99"
```

To read programs

To read the program numbers of the memory programs, send the LST? command without a command parameter.

To read the contents of a memory program, send the LST? command with the program number as shown below. Up to 3000 commands can be read by one command execution.

```
OUTPUT @B1500;"LST? 100"
```

To delete programs

To delete all memory programs, send the SCR command without a parameter.

To delete a memory program, send the SCR command with the program number as shown below.

```
OUTPUT @B1500;"SCR 100"
```

NOTE

Turning off the instrument also clears the program memory. The device clear and *RST commands do not clear the program memory.

Table 2-1 **Invalid Commands for Program Memory**

Category	GPIB Command
Reset	*RST
Diagnostics	DIAG?
Self-test	*TST?
Self Calibration	CA, *CAL?, CM
Abort	AB
Channel Control	RCV, WZ?
Program Memory	ST, END, SCR, VAR?, LST?
SPGU Control	ALS, ALS?, ALW, ALW? CORRSER?, ODSW?, SER?, SIM?, SPM?, SPPER?, SPRM?, SPST?, SPT?, SPV?, STGP?
16440A Selector Control	ERMOD?, ERSSP?
16 bit Control Port	ERS?
Query	ERRX?, ERR?, EMG?, *IDN?, LOP?, *LRN?, NUB?, *OPC?, UNT?, WNU?
Status Byte	*SRE?, *STB?

SPGU Module

SPGU is the pulse generator module designed for the semiconductor parametric test application and provides the following key functions.

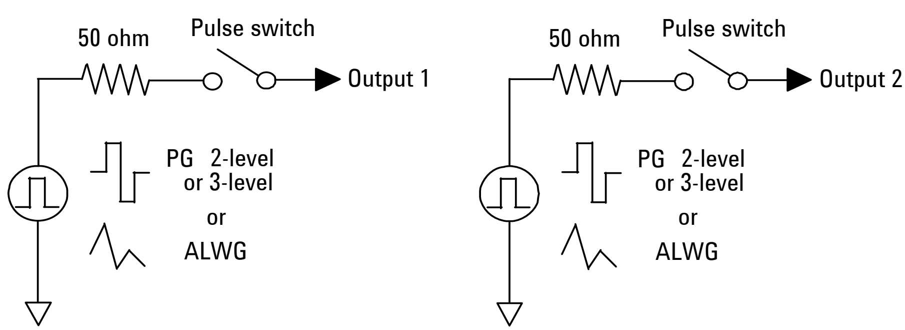
- Number of output channels: 2 channels per module
- Output impedance: 50 Ω
- Output level: 0 to ± 40 V (open load), ± 20 V (50 Ω load)
- SPGU operation mode (effective for all channels installed in B1500A):

  PG (pulse generator) or ALWG (arbitrary linear waveform generator)
- Channel output operation mode:

  Free run, count, or duration
- PG output mode:

  2-level pulse, 3-level pulse, or DC bias. For each channel.
- Terminal voltage measurement and load impedance calculation
- Automatic level adjustment by using load impedance measured or specified
- Pulse switch, which is more durable than mechanical relays, and better suited for frequent switching applications.

Figure 2-29 **SPGU Simplified Block Diagram**



NOTE

SPGU DC bias output

The SPGU offers the additional functionality of serving as a DC voltage source. However, it is not suitable for applications requiring an accurate DC bias voltage because of 50 Ω output impedance. For these applications, use the SMU.

NOTE

SPGU Channel Status

The SPGU status can be read with the SPST? command. The channel output will be active (SPST? response is 1) while the channel performs the pulse output or the ALWG sequence output. The status changes to the wait state (SPST? response is 0) when one of the following conditions occurs.

- SPP command
- Repeat count reaches the number specified by SPRM 1 (only for count mode)
- Output time specified by SPRM 2 elapses (only for duration mode)
- A command sets the output switch OFF
- The output operation mode is changed by the SPRM command

The SPGU output can be started by the SRP command, which will cause the status to change to active state.

NOTE

Terminal voltage measurement and load impedance calculation

SPGU performs voltage measurement and impedance calculation by executing the CORRSER? command. Followings are the recommended measurement conditions for the voltage measurement.

Output voltage: > 1 V

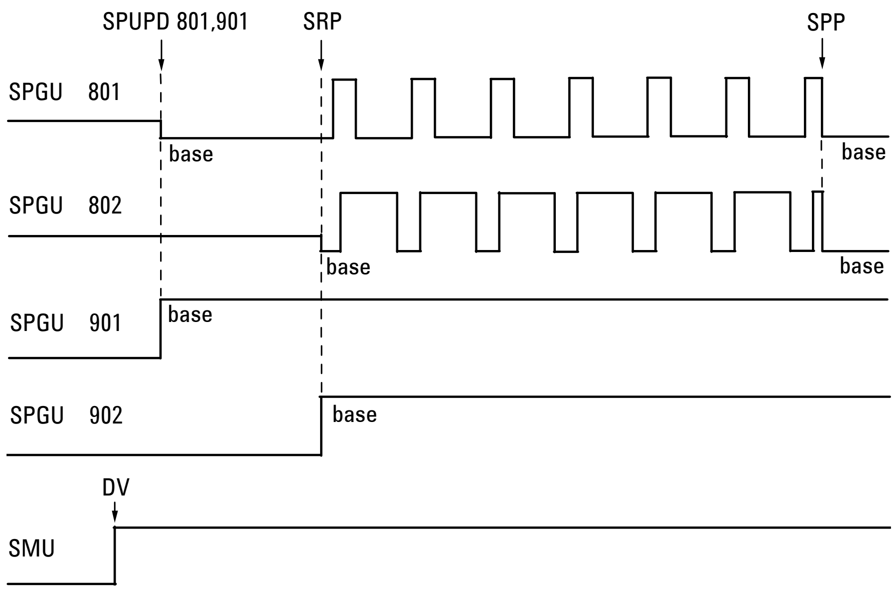
Minimum load impedance: 40 Ω

Maximum load impedance: 500 Ω (1 V), 2000 Ω (2 V), 5000 Ω (10 V)

PG Operation Mode

In the PG mode (pulse generator operation mode), the SPGU outputs normal 2- or 3-level pulse voltage or DC bias voltage. To set the PG mode, execute the SIM 0 command and use the commands listed in Table 2-2 to output pulse voltage or DC bias voltage. See Figure 2-30 for information on control commands and output timing.

Figure 2-30 **SPGU Pulse Output Control Commands and Output Timing**



In the example shown in Figure 2-30, channels 801 and 802 are used for pulse output, and channels 901 and 902 are used for DC bias output. Channels 801 and 901 output at base voltage level in the specified order when the SPUPD command is executed. Channels 802 and 902 start their output when the SRP command is executed in the order of their channel numbers, except for pulse outputs, which are always started simultaneously. Also note that pulse outputs stop simultaneously on one of the following stop conditions.

Stop conditions:

- SPP command
- Repeat count reaches the number specified by SPRM 1 (only for count mode)
- Output time specified by SPRM 2 elapses (only for duration mode)

Table 2-2 SPGU Control Commands for PG Mode

Command	Description
SIM 0	Sets the PG mode for all channels.
SPRM	Selects the output operation mode for all channels, free run (pulse output continues until SPP), pulse count, or duration.
SPPER	Sets the pulse period for all channels.
SPM	Selects the output mode of the channel, DC voltage, 2-level pulse using source 1, 2-level pulse using source 2, or 3-level pulse using sources 1 and 2. See Figure 2-33 for details on forming 3-level pulses.
SPT	Sets the delay time, pulse width, leading time, and trailing time of the channel. See Figure 2-31 for details on the pulse setup parameters.
SPV	Sets the pulse base and peak voltage or the DC bias voltage of the channel. See Figure 2-31 for details on the pulse setup parameters.
SER/SER?	Specifies/returns the load impedance connected to the channel.
CORRSER?	Measures the terminal voltage and returns the voltage and the calculated impedance. Also sets the impedance as same as SER.
SPUPD	Applies the channel setup to the specified SPGUs. The channel outputs the base voltage.
SRP	Starts all SPGU channel outputs.
SPP	Stops all SPGU pulse outputs. The channel outputs the base voltage.
ODSW	Sets the pulse switch to enable or disable, the normal state to open or close, the delay time for switching to start, and the state hold time.
STGP	Defines the trigger output for the SPGU channel and is effective for all channels in the same SPGU module. The trigger output is repeated at the timing of each pulse start by the specified channel. See Figure 2-32 for an example of the trigger output by the SPGU channel 801.
SPST?	Returns the status of the SPGU, run or wait.

Figure 2-31 **Pulse Setup Parameters**

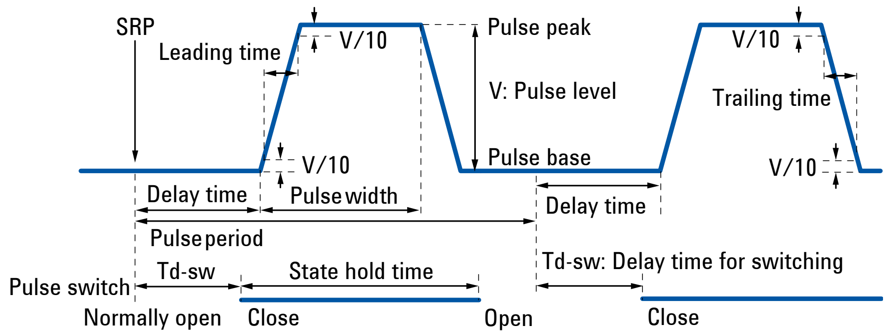


Figure 2-32 **Trigger Output in PG Mode**

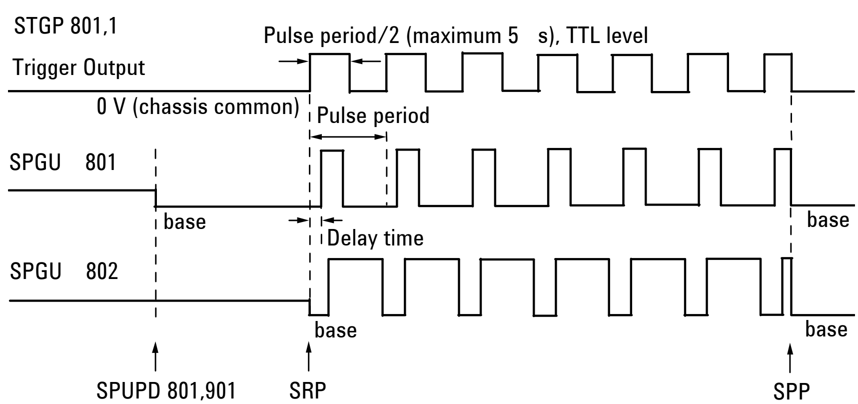
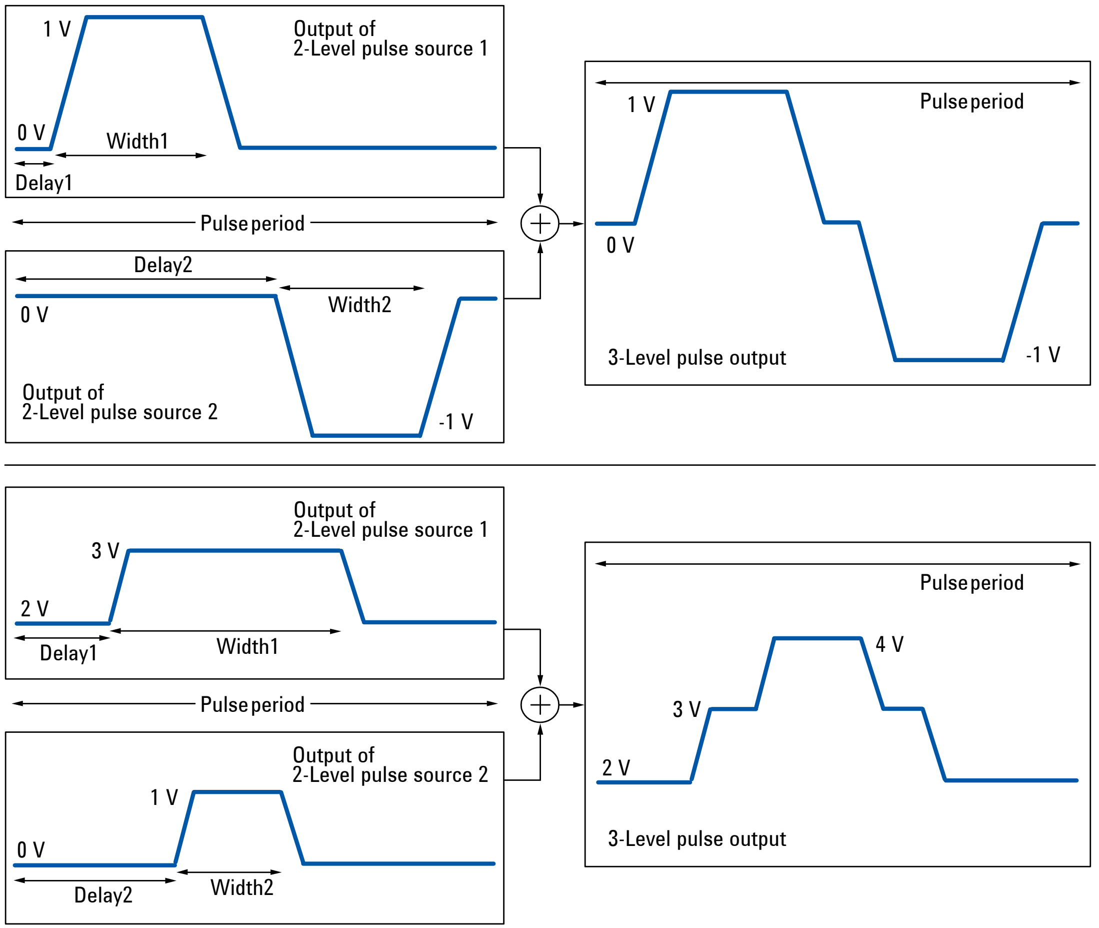


Figure 2-33 3-Level Pulse Output Examples



The SPGU output channels can be setup to be a 3-level pulse generator by using the SPM 3 command. A 3-level pulse source can be made by defining two 2-level pulse sources. For example, the upper example in Figure 2-33 can be made by the following command sequence.

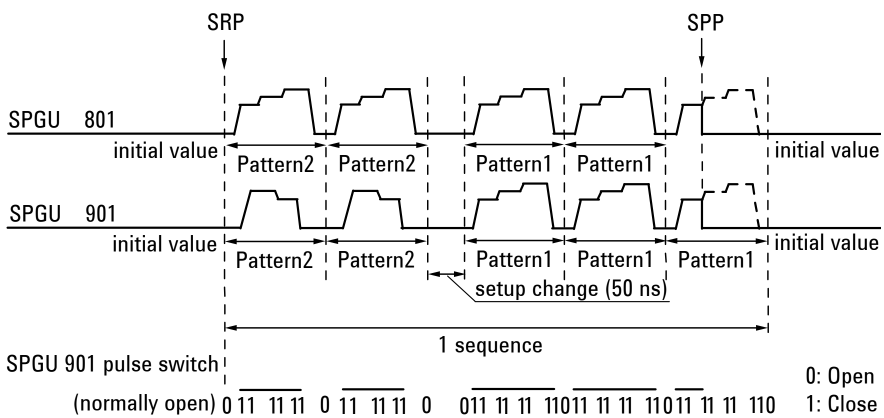
```
SPPER Period
SPM ch,3
SPT ch,1,Delay1,Width1,Leading1,Trailing1
SPV ch,1,0,1
SPT ch,2,Delay2,Width2,Leading2,Trailing2
SPV ch,2,0,-1
```

ALWG Operation Mode

The SPGU can output an arbitrary linear waveform voltage in the ALWG mode (arbitrary linear waveform generator operation mode). The waveform can be a voltage pattern sequence specified by both pattern data (Table 2-4) and sequence data (Table 2-5). You may specify a complicated pattern sequence or a simple pattern as shown in Figure 2-34.

To set the ALWG mode, execute the SIM 1 command. Then use the commands listed in Table 2-3 to output the voltage pattern sequence. See Figure 2-34 for details on the control commands and the output timing.

Figure 2-34 ALWG Output Control Commands and Output Timing



In the example shown in Figure 2-34, the SPGU channels 801 and 901 are used. Both channels output Pattern2 twice and Pattern1 three times in one sequence. Then the same pattern is set to the Pattern1 and Pattern2 of the channel 801, and two different patterns are set to the channel 901. Between two patterns of the different index, the setup change will cause delay time (50 ns).

The channels start their output when the SRP command is executed and repeat their output simultaneously. And the sequence will be repeated as same as the pulse period. The output can be stopped simultaneously by one of the following stop conditions.

Stop conditions:

- SPP command
- Repeat count reaches the number specified by SPRM 1 (only for count mode)
- Output time specified by SPRM 2 elapses (only for duration mode)

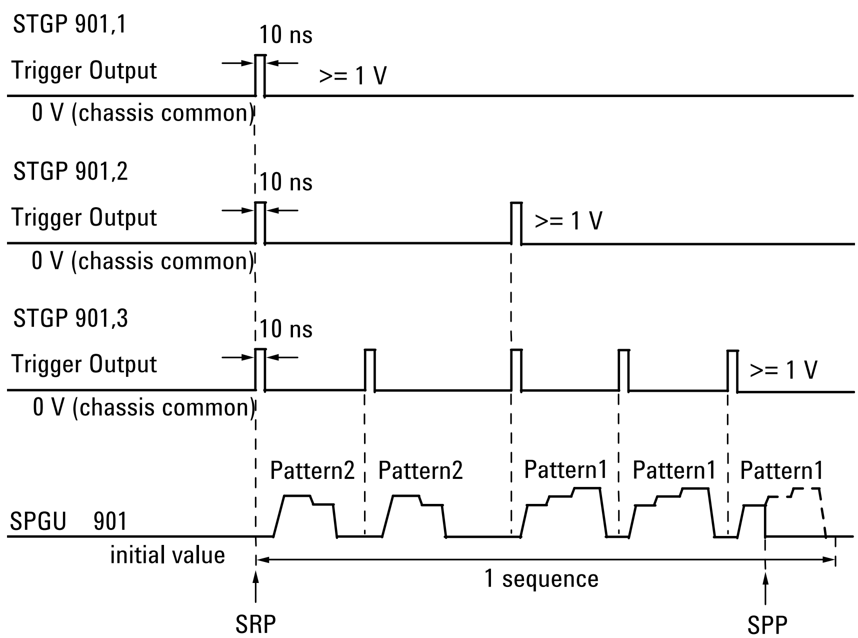
NOTE

Setup delay time and output voltage between the different patterns

When the pattern is changed to the pattern of the different index, 50 ns setup delay is always inserted. There are no delay between the patterns of the same index.

During the pattern change, the channel keeps the last output voltage of the previous pattern.

Figure 2-35 **Trigger Output in ALWG Mode**



NOTE

SPUPD, ALS, and SRP commands

If the command is executed while the ALWG output continues, the SPGU will stop the output and perform the channel setup operation again. After that, the SPGU will start the output again if the operation mode is set to free run, and wait for the SRP command if it is set to sequence count or duration.

Table 2-3 SPGU Control Commands for ALWG Mode

Command	Description
SIM 1	Sets the ALWG mode for all channels.
SPRM	Selects the operation mode, free run (output continues until SPP), sequence count, or duration for all channels.
ALW	Sets the ALWG pattern data (binary format, big endian) for each channel. See Table 2-4.
ALS	Sets the ALWG sequence data (binary format, big endian) for the B1500A mainframe. See Table 2-5.
SER/SER?	Specifies/returns the load impedance connected to the channel.
CORRSER?	Measures the terminal voltage and returns the voltage and the calculated impedance. Also sets the impedance as same as SER.
SPUPD	Applies the channel setup to the specified SPGUs. The channel outputs the initial voltage.
SRP	Starts all SPGU channel outputs.
SPP	Stops all SPGU channel outputs. The channel outputs the initial voltage.
ODSW	Sets the pulse switch enable or disable and the normal state open or close. Switch status (open or close) must be specified for each vector data in the ALWG pattern data. See Table 2-4.
STGP	Specifies the SPGU channel effective for the trigger output and enables the function. The trigger output is repeated at the timing of the sequence start, pattern change, or pattern start of the specified channel. See Figure 2-35 for an example of the trigger output by the SPGU channel 801.
SPST?	Returns the status of the SPGU, run or wait.

Table 2-4 ALWG Pattern Data (binary format, big endian)

<table>
<tr><th colspan="2"></th><th>Data</th><th>Data length</th><th colspan="2">Byte length</th></tr>
<tr><td colspan="2" rowspan="4">Header</td><td>Module type (ex: 0)</td><td>1 byte</td><td colspan="2" rowspan="4">20 bytes</td></tr>
<tr><td>Data format revision (ex: 0)</td><td>1 byte</td></tr>
<tr><td>Number of patterns [a] (ex: x)</td><td>2 bytes</td></tr>
<tr><td>Others (0 for all bit. Do not change.)</td><td>16 bytes</td></tr>
<tr><td rowspan="6">Pattern data</td><td rowspan="2">Initial data</td><td>Number of vector data in this pattern (ex: N_i)</td><td>2 bytes</td><td rowspan="2">6 bytes</td><td rowspan="7">$\Sigma(6+8\times N_i)$ bytes, i=1 to x</td></tr>
<tr><td>Initial voltage (1 μV/count) [b]</td><td>4 bytes</td></tr>
<tr><td rowspan="3">Vector data</td><td>Output level (1 μV/count) [b]</td><td>4 bytes</td><td rowspan="4">$8 \times N_i$ bytes</td></tr>
<tr><td>Pulse switch status (1: close, 0: open)</td><td>1 bit</td></tr>
<tr><td>Incremental time from previous point
(1 nsec/count) [c]</td><td>31 bits</td></tr>
<tr><td colspan="3">:
Vector data can be repeated until the N_i-th vector. (i: 1 to x, integer)</td></tr>
<tr><td colspan="5">:
Pattern data can be repeated until the x-th pattern. (x: number of patterns, integer)
(Total number of vector data must be $\leq 1024 - x$.)</td></tr>
</table>

a. Number of patterns must be 1 to 1000000000 (512).

b. Output level data must be 0 to 1001100010010110100000000 (40 V) or 11111111111111111111110000011000 (-1 mV) to 11111101100111011010011000000000 (-40 V) in 1111101000 (1 mV) resolution.

c. Incremental time data must be 1010 (10 nsec) to 1001111111111111111111111110110 (671.088630 msec, $(2^{26}-1)\times 10$ nsec) in 1010 (10 nsec) resolution.

Table 2-5 ALWG Sequence Data (binary format, big endian)

		Data	Data length	Byte length
Header		Module type (ex: 0)	1 byte	20 bytes
		Data format revision (ex: 0)	1 byte	
		Number of pattern cycles [a] (ex: *x*)	2 bytes	
		Others (0 for all bit. Do not change.)	16 bytes	
Sequence data	Pattern cycle data	Pattern index (ex: 1 for Pattern1)	2 bytes	6× *i* bytes, *i*=1 to *x*
		Repeat count [b] (ex: 5)	4 bytes	
	: Pattern cycle data can be repeated until the *x*-th pattern cycle. (*x*: number of pattern cycles, integer)			

a. Number of pattern cycles must be 1 to 1000000000 (512).
b. Repeat count must be 1 to 1000000000000000000000 (1048576).

In the example of Figure 2-34, the total byte length of the pattern data is as follows.

- SPGU 801 number of patterns: x=2 (Pattern1 and Pattern2)

  Number of vectors for Pattern1 and Pattern2: N_1=9, N_2=9

  Total byte length is 20+(6+8×9)+(6+8×9)=176 bytes.

- SPGU 901 number of patterns: x=2 (Pattern1 and Pattern2)

  Number of vectors for Pattern1 and Pattern2: N_1=9, N_2=7

  Total byte length is 20+(6+8×9)+(6+8×7)=160 bytes.

And, the total byte length of the sequence data is as follows.

Number of pattern cycles: x=2 (Pattern1 and Pattern2)

Total byte length is 20+6×2=32 bytes.

Module Selector

The Agilent N1258A Module Selector is used to switch the measurement resources (HPSMU, HCSMU, and HVSMU) connected to DUT (device under test). The Input ports must be connected to the HPSMU, HCSMU, HVSMU, and GNDU. And the Output port must be connected to the DUT interface. For the packaged devices, use the Agilent N1259A test fixture which can install the module selector.

Use the ERMOD, ERHPA, ERHPL, ERHPS, and ERHPP commands to control the module selector.

The ERMOD command sets the Digital IO control mode.

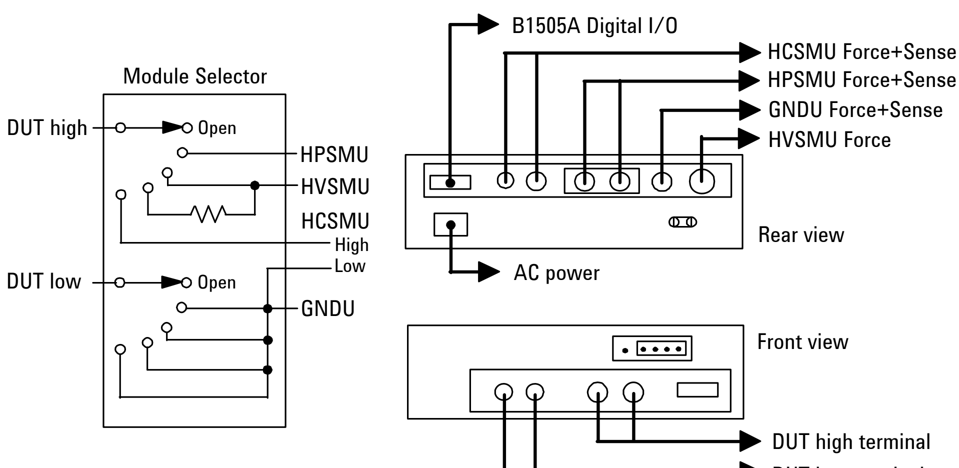
The ERHPA command specifies the modules connected to the input.

The ERHPL command sets the condition of the status indicator.

The ERHPP command sets the module selector input-output path to the HPSMU connect, HCSMU connect, HVSMU connect, or open (no connection).

The ERHPS command controls the connection of the HVSMU series resistor.

Figure 2-36 **Module Selector Block Diagram and Connections**



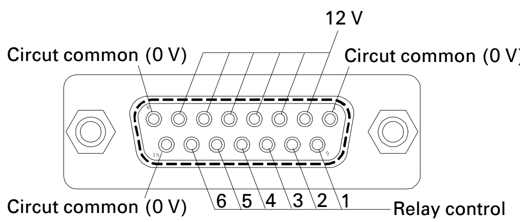
External Relay Control Output

The External Relay Control Output connector is designed for controlling an external relay switching. Use the ERHPE and ERHPR commands to use the external relay control.

The ERHPE command enables the external relay control function.

The ERHPR command controls the output level of the Relay control connector pin.

Figure 2-37 **External Relay Control Output Connector**



Connector type: D-sub 15 pin connector

External relay control signal output pins: Relay control 1 to 6

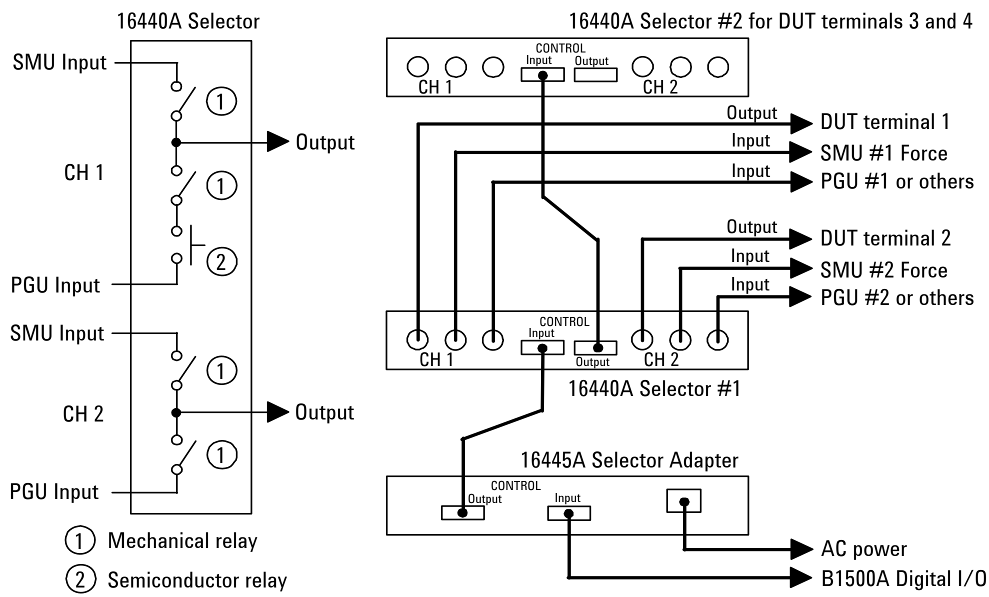
Control signal level: 0 V or 12 V, normally 0 V (circuit common)

SMU/PG Selector

The Agilent 16440A SMU/Pulse Generator Selector is used to switch the measurement resources connected to DUT (device under test). The Input ports must be connected to the measurement resources, an SMU and an SPGU or others, and the Output port must be connected to the DUT interface. For the SMU connection, connect the Force terminal only. The Sense terminal must be open.

Use the ERMOD and ERSSP commands to control the 16440A selector. The ERMOD command sets the Digital IO control mode. The ERSSP command sets the selector channel CH 1 or CH 2 input-output path to the SMU connect, PGU connect, or open (no connection).

Figure 2-38 **SMU/PG Selector Block Diagram and Connections**



The selector CH 1 additionally provides the PGU open status which is made by keeping the PGU side mechanical relay close and opening the semiconductor relay. This is effective for applications requiring frequent PGU open/connect switching because a semiconductor relay is durable compared to a mechanical relay.

The B1500A can use up to two selectors by connecting the selector control cable between the CONTROL Output connector of the first selector and the CONTROL Input connector of the second selector.

Digital I/O Port

The digital I/O port is used for the trigger input/output terminals or an interface to control an external relay circuit and so on. For the trigger input/output, refer to “Trigger Function”. For another usage, the following commands are available:

ERM Changes the digital I/O port assignments.

ERS? Returns the digital I/O port status.

ERC Changes the output status of the digital I/O port

Connector type of the digital I/O port is D-Sub 25-pin. The pin assignment is shown in Table 2-6. In the initial setting, all port forces TTL high level (approx. 2.4 V. TTL low is approx. 0.8 V). The above commands are available for non trigger ports from DIO 1 to DIO 16.

Table 2-6 **Digital I/O Pin Assignment**

Description	Pin Number		Description
GND	25	13	GND
Do not use	24	12	Do not use
Do not use	23	11	Do not use
DIO 15 (bit 15)	22	10	DIO 16 (bit 16)
DIO 13 (bit 13)	21	9	DIO 14 (bit 14)
DIO 11 (bit 11)	20	8	DIO 12 (bit 12)
DIO 9 (bit 9)	19	7	DIO 10 (bit 10)
DIO 7 (bit 7)	18	6	DIO 8 (bit 8)
DIO 5 (bit 5)	17	5	DIO 6 (bit 6)
DIO 3 (bit 3)	16	4	DIO 4 (bit 4)
DIO 1 (bit 1)	15	3	DIO 2 (bit 2)
Do not use	14	2	Do not use
		1	Do not use

Accessories

The following accessories are available to connect the Digital I/O port.

- Agilent 16493G Digital I/O connection cable

  Used to connect the Digital I/O port to a D-Sub (f) 25-pin connector. This cable should be connected between two B1500s, or between the B1500 and the N1253A-200 BNC box. Cable length depends on the following option items:

  16493G-001: Approx. 1.5 m

  16493G-002: Approx. 3 m

- Agilent N1253A-100 Digital I/O T-cable

  Used to connect the Digital I/O port to a D-Sub (f) 25-pin connector and a D-Sub (m) 25-pin connector. This cable must be used to connect three or more B1500s. Cable length is as following:

  - D-Sub (m) to D-Sub (m): Approximately 1.5 m

    Both connectors should be connected to the Digital I/O ports.

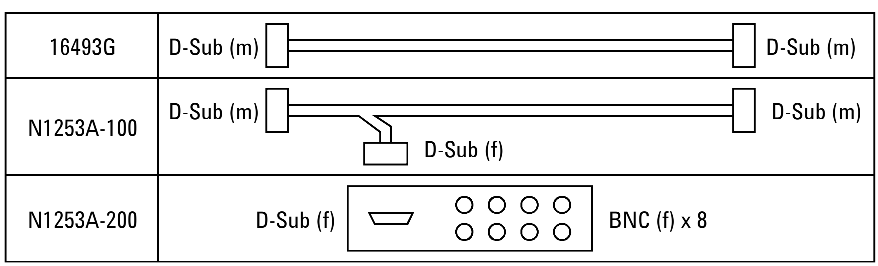
  - D-Sub (m) to D-Sub (f): Approximately 30 cm

    The D-Sub (f) connector should be connected to the additional N1253A-100 or the 16493G cable to connect the third or following B1500.

- Agilent N1253A-200 Digital I/O BNC box

  Used to convert the D-Sub connector to the BNC connectors. Only the DIO 1 to DIO 8 are connected to the BNC (f) connectors individually. To use the BNC box, connect the 16493G cable between the Digital I/O port and the BNC box.

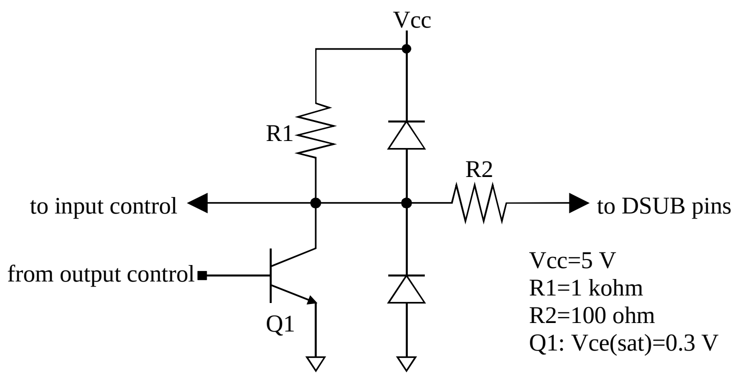
Figure 2-39 **Accessories for Digital I/O Port**



Digital I/O Internal Circuit

The following figure shows the input/output circuits internally connected to each port/pin of the Digital I/O connector.

Figure 2-40 **Digital I/O Internal Circuit**



Trigger Function

The Agilent B1500 can be synchronized with other equipment, such as capacitance meters, voltmeters, ammeters, probers, handlers and so on, by using the following terminals:

- Ext Trig In

  BNC connector. Only for trigger input (to receive trigger).

- Ext Trig Out

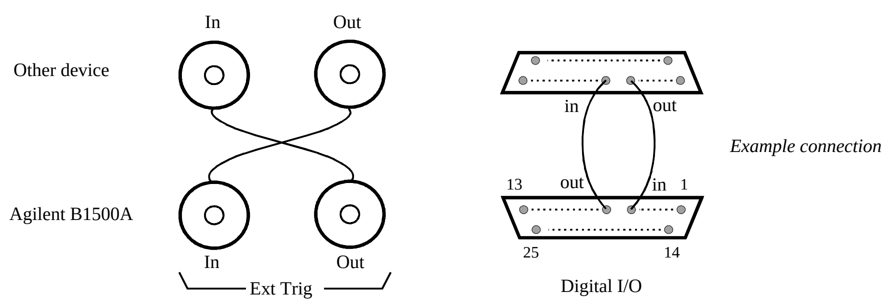
  BNC connector. Only for trigger output (to send trigger).

- Digital I/O

  D-Sub 25-pin connector. Sixteen paths are available for the trigger port. Each path can be used for either input or output. For the pin assignment and accessories, refer to “Digital I/O Port”.

Figure 2-41 shows a connection example of the B1500 and another device.

Figure 2-41 **Connecting Trigger Input/Output**



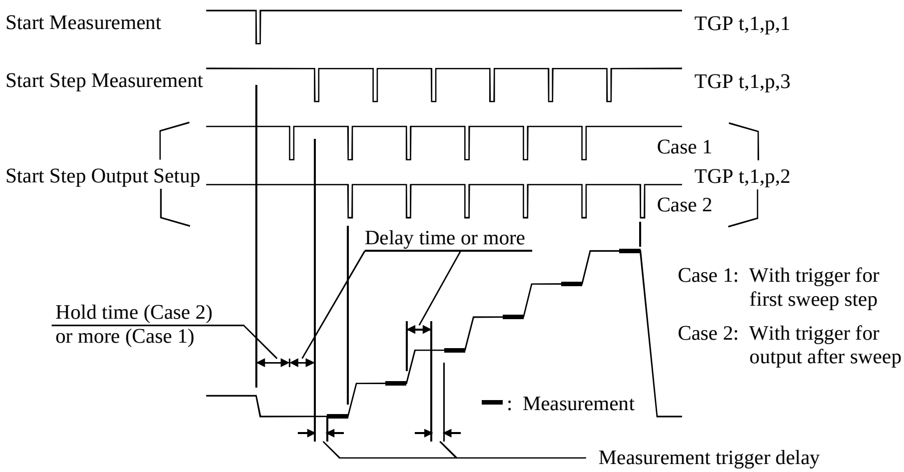
NOTE

To use the digital I/O port for the trigger input/output port, send the TGP command. DIO 1 to DIO 16 can be used for the trigger input/output port. See Table 2-6.

Trigger Input

A trigger input operation example is shown in Figure 2-42. Measurement or source output can be started by the input trigger sent through the port specified by the TGP command. See Table 2-7.

Figure 2-42 Trigger Input Example, Staircase Sweep Measurement, Negative Logic



Initial Settings

The following functions are available in the initial settings:

- Trigger port: Ext Trig In
- Trigger type: Start Measurement (type 1)
- Commands for the trigger wait: WS, TM3, or PA with TM3

Input Trigger

The B1500 responds to the input trigger (minimum pulse width 10 μs) that changes the signal level from high (approx. 2.4 V) to low (approx. 0.8 V). This is negative logic. You can change it to positive logic by using the third parameter of the TGP command.

Measurement Trigger Delay

Delay time from a trigger input to starting a step measurement. The delay time is available for the Start Step Measurement trigger (type 3). You can set the delay time value by using the WT command (WTDCV for the CV sweep measurement).

PA/PAX/WS/WSX Commands

The commands put the B1500 in the trigger wait state. The B1500 can recover from the wait state if an external trigger is sent to a trigger input port. You can use the commands regardless of the trigger type.

If you use the PA or PAX command to put the B1500 in the trigger wait state, send the TM3 command before the PA or PAX command.

Table 2-7 Type of Trigger Input

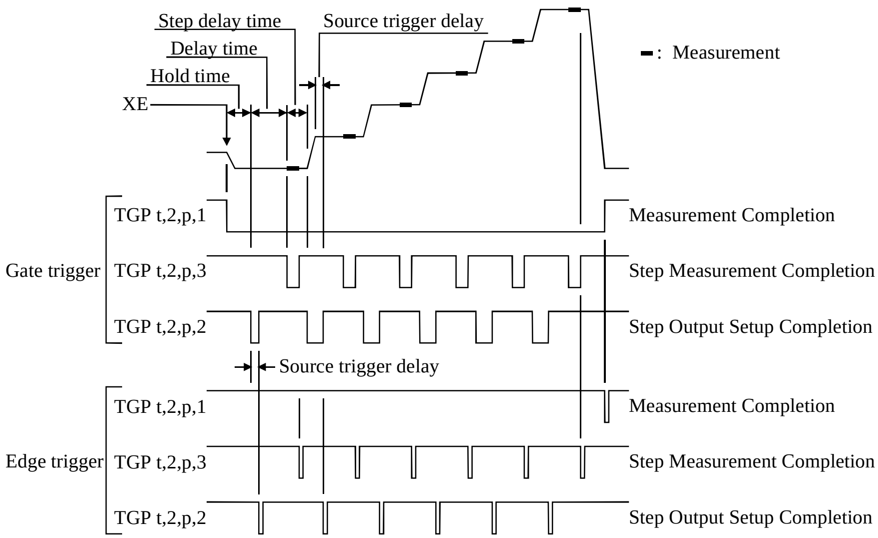
Type	B1500 Operation by Input Trigger	Command[a]
1	Starts the measurement specified by the MM command.	TGP *t*,1,*p*,1 TM3
2	The sweep source starts to set the sweep step output. The pulse source starts to set the pulsed output. This trigger type is available for the staircase sweep, pulsed spot, pulsed sweep, staircase sweep with pulsed bias, multi channel sweep, and CV sweep measurement.	TGP *t*,1,*p*,2 TGSI *m*
3	Waits for the measurement trigger delay, and starts the sweep step measurement. This trigger type is available for the staircase sweep, multi channel sweep, and CV sweep measurement.	TGP *t*,1,*p*,3

a. *t* selects trigger input terminal, Ext Trig In or a digital I/O path.
p selects positive or negative logic of the trigger.
m selects Case 1 or Case 2 of the trigger type 2 (see Figure 2-42).

Trigger Output

A trigger output operation example is shown in Figure 2-43. When the measurement or source output setup is completed, the output trigger is sent through the port specified by the TGP command. See Table 2-8.

Figure 2-43 **Trigger Output Example, Staircase Sweep Measurement, Negative Logic**



Initial Settings

The following functions are available in the initial settings:

- Trigger port: Ext Trig Out
- Trigger type: Measurement Completion (type 1)
- Commands for the trigger output: OS

Output Trigger

An edge trigger or a gate trigger will be sent when an operation is completed (see Figure 2-44). Initially, the negative edge trigger is sent.

Source Trigger Delay

Delay time from when the source output setup is completed until an edge trigger is sent or a gate trigger level is returned. The delay time is available for the Step Output Setup Completion trigger (type 2). You can set the delay time value by using the WT command (WTDCV for the CV sweep measurement).

OS/OSX Commands

The command is used to send a trigger immediately from a trigger output terminal. You can use the commands regardless of the trigger type.

Using Multiple Channels

If you use the multiple measurement channels, an edge trigger will be sent or a gate trigger level will be returned when the measurement is completed by all channels.

For the multi channel sweep measurement, an edge trigger will be sent or a gate trigger level will be returned when the source output setup is completed by all channels, or when the measurement is completed by all channels.

Figure 2-44 Output Trigger

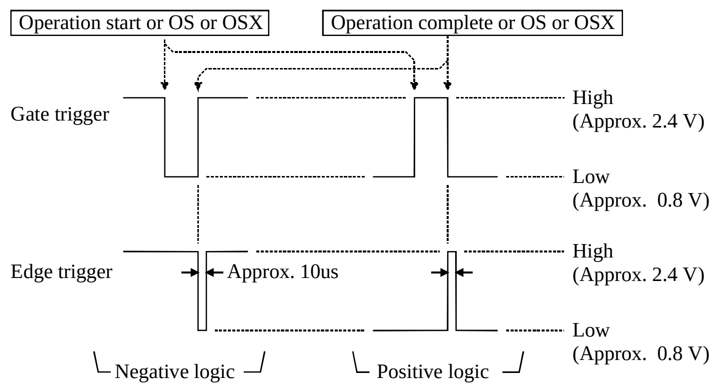


Table 2-8 Type of Trigger Output

Type	Timing of Trigger Output by B1500	Command[a]
1	When the measurement specified by the MM command is completed.	TGP *t*,2,*p*,1 TGXO *m* TM3
2	When the source trigger delay time elapses after the sweep step output setup or pulse output setup is completed. Available for the staircase sweep, pulsed spot, pulsed sweep, staircase sweep with pulsed bias, multi channel sweep, and CV sweep measurement.	TGP *t*,2,*p*,2 TGSO *m*
3	When the measurement is completed at each sweep step for the staircase sweep, multi channel sweep, and CV sweep measurement.	TGP *t*,2,*p*,3 TGMO *m*

a. *t* selects the trigger output terminal, Ext Trig Out or a digital I/O. *p* selects positive or negative logic. *m* selects edge or gate trigger.

Using Trigger Function

- "To Make Wait State Using PA/PAX"
- "To Make Wait State Using WS/WSX"
- "To Send Trigger Using OS/OSX"
- "To Receive Measurement Trigger"
- "To Specify Trigger Port and Receive Trigger"
- "To Control Measurement Timing Using External Trigger"

To Make Wait State Using PA/PAX

The PA or PAX command puts the B1500 into a wait state. The B1500 can be recovered from the wait state when the specified wait time elapses, or when an event selected by the TM command occurs. Then the B1500 executes the commands following the PA/PAX command. The event only releases the wait state set by the PA/PAX command.

The wait time parameter is available for the PA/PAX command. If you specify the wait time, the wait state continues until the time elapses or until the event occurs.

Available value: -99.9999 to 99.9999 s, in 100 μs resolution.

If you set a negative value, the wait state is kept until the event occurs.

You can select the event by using the TM command. If you want to use an external trigger as the event, enter the TM3 command. Then the PA/PAX command waits for the XE command execution, or:

- PA waits for a trigger sent to the Ext Trig In terminal.
- PAX waits for a trigger sent to the specified terminal.

In the initial setting, negative logic is available. To change it to positive, send the TGP command.

NOTE The TM command is used to select the event effective for starting measurement, or releasing the wait time set by the PA or PAX command. Enter the TM command before the PA or PAX command.

To Make Wait State Using WS/WSX

The WS or WSX command puts the B1500 into a wait state. The B1500 can be recovered from the wait state by an external trigger. Then the B1500 executes the commands following the WS/WSX command. The external trigger only releases the wait state set by the WS/WSX command.

- WS waits for a trigger sent to the Ext Trig In terminal.
- WSX waits for a trigger sent to the specified terminal.

In the initial setting, the negative logic is available. To change it to the positive, send the TGP command.

If you want to end a wait state before receiving an external trigger, enter the AB or *RST command, or use the device clear (HP BASIC CLEAR statement) if any other commands have already been entered.

NOTE

For easy programming, do not enter the TM command, or use the TM1, TM2, or TM4 event mode. The TM3 event mode will complicate programming.

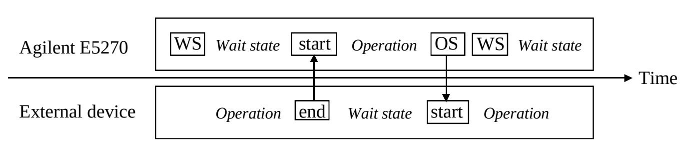
To Send Trigger Using OS/OSX

To trigger an external device from the B1500, use the OS or OSX command.

- OS sends an edge trigger to the Ext Trig Out terminal.
- OSX sends a trigger to the specified terminal.

In the initial setting, negative logic is available. To change it to positive, send the TGP command.

Enter the WS/WSX command immediately after the OS/OSX command. Then the B1500 triggers an external device to start its operation by the OS/OSX, and waits for an operation complete trigger from the external equipment. This scenario ensures that the B1500 and external equipment operations do not overlap.



To Receive Measurement Trigger

To use an external trigger just for starting measurement, instead of the XE command, perform the next step. This is not effective for the high speed spot measurement.

1. Connect a BNC cable between the Ext Trig In connector and a trigger output connector of an external device.

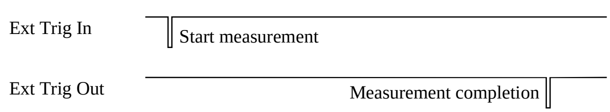
2. Create a control program. Then the TM3 command and HP BASIC ENTER statement should be entered as shown in the following example:

```
       :
OUTPUT @B1500;"MM1"     ! Sets spot measurement mode
       :                ! Sets measurement condition
       :
OUTPUT @B1500;"TM3"     ! Uses external trigger
ENTER @B1500 USING "#,3X,12D,2X";M_data
       :
```

3. Execute the control program.

   The B1500 sets the measurement conditions, and waits for an external trigger (negative trigger) sent to the Ext Trig In connector.

   When the trigger is received, the B1500 starts measurement. When measurement is completed, the B1500 sends a negative edge trigger to the Ext Trig Out connector, and puts the measurement data in the data output buffer.



NOTE

The HP BASIC ENTER statement pauses program execution until measurement data is put in the data buffer, reads the data from the buffer, and then continues program execution.

To Specify Trigger Port and Receive Trigger

To use an external trigger just for starting measurement, instead of the XE command, perform the next step. This is not effective for the high speed spot measurement.

This example specifies the trigger input/output ports and uses the gate trigger for the output trigger.

1. Connect a BNC cable between the Ext Trig In connector and a trigger output connector of an external device.

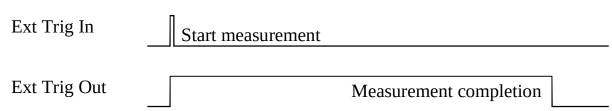
2. Create a control program. Then the TM3 and TGP commands and HP BASIC ENTER statement should be entered as shown in the following example:

```
       :
OUTPUT @B1500;"MM1"             ! Sets spot measurement mode
       :                        ! Sets measurement condition
       :
OUTPUT @B1500;"TM3"             ! Uses external trigger
OUTPUT @B1500;"TGP -1,1,1,1"    ! Sets trigger input
OUTPUT @B1500;"TGP -2,2,1,1"    ! Sets trigger output
OUTPUT @B1500;"TGXO 2"          ! Enables gate trigger
ENTER @B1500 USING "#,3X,12D,2X";M_data
       :
```

3. Execute the control program.

   The B1500 sets the measurement conditions, and waits for an external trigger (positive trigger) sent to the Ext Trig In connector.

   When the trigger is received, the B1500 starts measurement and sends a positive gate trigger to the Ext Trig Out connector. When measurement is completed, the B1500 returns the gate trigger level to logical low, and puts the measurement data in the data output buffer.



NOTE

The HP BASIC ENTER statement pauses program execution until measurement data is put in the data buffer, reads the data from the buffer, and then continues program execution.

To Control Measurement Timing Using External Trigger

Multiple trigger terminals will be used to control measurement timing. Refer to the following example that controls the staircase sweep measurement timing.

The example below uses the following triggers and terminals:

Trigger Name or Trigger Type	Terminal	TGP Command [a]
Start Measurement	Ext Trig In	`TGP -1,1,2,1`
Start Step Measurement	DIO 2	`TGP 2,1,2,3`
Start Step Output Setup	DIO 1	`TGP 1,1,2,2`
Measurement Completion	Ext Trig Out	`TGP -2,2,2,1`
Step Measurement Completion	DIO 12	`TGP 12,2,2,3`
Step Output Setup Completion	DIO 11	`TGP 11,2,2,2`

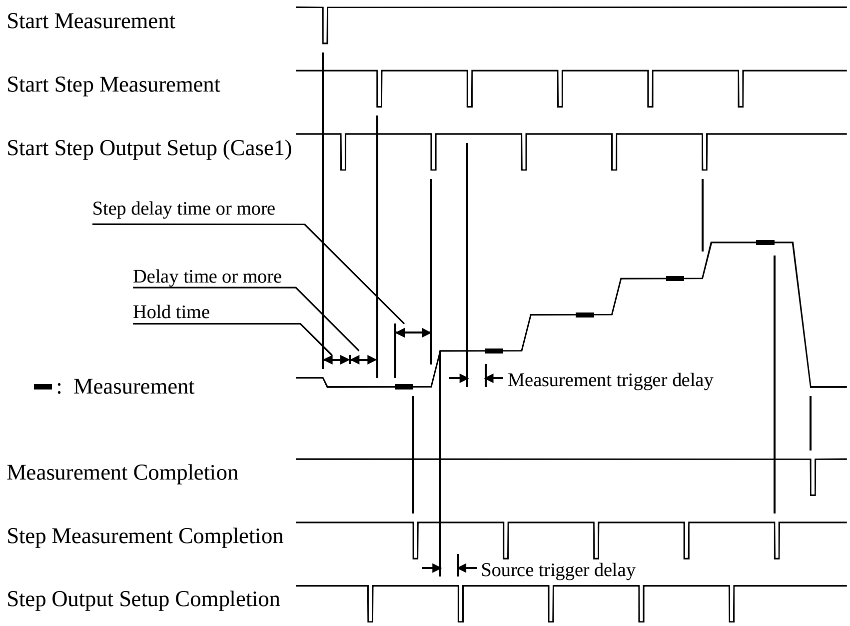
a. Parameters mean the port number, trigger input/output, positive/negative logic, and trigger type in this order from left.

Example

This example uses the negative edge trigger (set by the TGP and TGXO/TGMO/TGSO commands), and the Case 1 Start Step Output Setup trigger (set by the TGSI command). The WT command sets the hold time, delay time, step delay time, source trigger delay time, and the measurement trigger delay time.

```
       :
OUTPUT @B1500;"MM2"     ! Sets staircase sweep measurement mode
       :                ! Sets measurement condition
       :
OUTPUT @B1500;"TM3"          !Uses external trigger
OUTPUT @B1500;"TGP -1,1,2,1" !Start Measurement trigger
OUTPUT @B1500;"TGP 2,1,2,3"  !Start Step Measurement trigger
OUTPUT @B1500;"TGP 1,1,2,2"  !Start Step Output Setup trigger
OUTPUT @B1500;"TGP -2,2,2,1" !Measurement Completion trigger
OUTPUT @B1500;"TGP 12,2,2,3" !Step Measurement Completion trigger
OUTPUT @B1500;"TGP 11,2,2,2" !Step Output Setup Completion trigger
OUTPUT @B1500;"TGXO 1"       !1:Edge trigger
OUTPUT @B1500;"TGMO 1"       !1:Edge trigger
OUTPUT @B1500;"TGSO 1"       !1:Edge trigger
OUTPUT @B1500;"TGSI 1"       !1:Case 1
OUTPUT @B1500;"WT";Hold,Delay,Sdelay,Tdelay,Mdelay
       :
FOR N=1 TO No_step
  ENTER @B1500 USING "#,3X,12D,2X";M_data
  PRINT "DATA";N;"=";M_data
NEXT N
       :
```

Figure 2-45 **Trigger Input/Output Example, Staircase Sweep, Negative Logic**



The B1500 sets the measurement conditions, sets the trigger ports, and waits for a Start Measurement trigger.

By the Start Measurement trigger, the B1500 starts the staircase sweep measurement.

By the Start Step Output Setup trigger, the B1500 waits until the source trigger delay elapses, and sends the Step Output Setup Completion trigger. If the trigger is received during the hold time, the B1500 performs this after the hold time.

By the Start Step Measurement trigger, the B1500 waits until the measurement trigger delay elapses, executes a step measurement, and sends the Step Measurement Completion trigger. If the trigger is received during the delay time, the B1500 performs this after the delay time.

By the next Start Step Output Setup trigger, the B1500 changes the source output value, and waits until the source trigger delay elapses, and sends the Step Output Setup Completion trigger. If the trigger is received during the step delay time, the B1500 performs this after the step delay time.

After the staircase sweep measurement, the B1500 sends the Step Measurement Completion trigger and the Measurement Completion trigger, and puts the measurement data in the data output buffer.

Trig In/Out Internal Circuit

The following figures show the trigger input/output circuits internally connected to the Trig In/Out connectors.

Figure 2-46 **Trigger Input Internal Circuit**

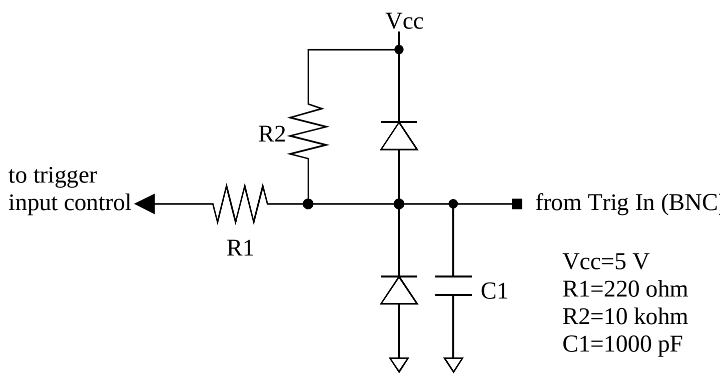
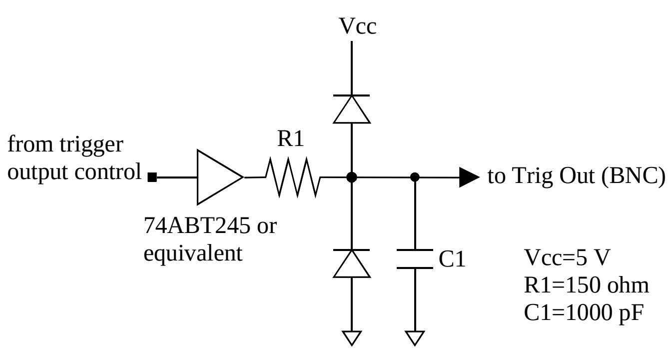


Figure 2-47 **Trigger Output Internal Circuit**



Initial Settings

Agilent B1500 is initialized by turning the B1500 on, the *RST command, or the device clear. Initial settings of the B1500 are shown in the following tables.

Table 2-9 **Mainframe Settings**

<table>
<tr><th>Setup Item</th><th colspan="2">Initial Setting</th><th>Commands</th></tr>
<tr><td>Auto calibration</td><td colspan="2">off</td><td>CM</td></tr>
<tr><td>Trigger mode</td><td colspan="2">XE, TV, TI, or GET</td><td>TM</td></tr>
<tr><td rowspan="3">Trigger port</td><td>Ext Trig In</td><td>Start Measurement trigger input</td><td>TGP</td></tr>
<tr><td>Ext Trig Out</td><td>Measurement Completion trigger output</td><td>TGP</td></tr>
<tr><td>Digital I/O</td><td>cleared</td><td>TGP</td></tr>
<tr><td>Trigger delay time</td><td colspan="2">0 s</td><td>WT, PT</td></tr>
<tr><td>Trigger condition of
Start Step Output Setup trigger</td><td colspan="2">with trigger for first sweep step</td><td>TGSI</td></tr>
<tr><td>Type of output trigger</td><td colspan="2">edge trigger</td><td>TGXO, TGSO, TGMO</td></tr>
<tr><td>Digital I/O port</td><td colspan="2">output for all port</td><td>ERM</td></tr>
<tr><td>Program memory</td><td colspan="2">cleared [a]</td><td>SCR</td></tr>
<tr><td>Value of internal variable (%In, %Rn)</td><td colspan="2">0</td><td>VAR</td></tr>
<tr><td>Data output format</td><td colspan="2">ASCII with header, CR/LF^EOI</td><td>FMT</td></tr>
<tr><td>Data output buffer</td><td colspan="2">cleared</td><td>BC</td></tr>
<tr><td>Status byte</td><td colspan="2">Only bit 6 is enabled.</td><td>*SRE</td></tr>
<tr><td>Error code register</td><td colspan="2">cleared</td><td>ERRX?, ERR?</td></tr>
</table>

a. Program memory is not cleared by the *RST command or the device clear.

Table 2-10 SMU Settings

Setup Item	Initial Setting		Commands
Output switch	open		CN, CL
Filter	off		FL
Series resistor	off		SSR
ASU path/1 pA auto range/indicator	SMU side/disable/enable		SAP/SAR/SAL
Current measurement range	with pulse	compliance range	RI
	without pulse	auto	
Voltage measurement range	with pulse	compliance range	RV
	without pulse	auto	
A/D converter	high speed ADC		AAD
ADC integration time	high speed ADC: auto, non parallel		AIT, PAD
	high resolution ADC: auto		AIT
ADC zero function	off		AZ
AV command parameter	*number*=1, *mode*=0		AV
Sweep source parameters	cleared		WV, WSV, WI, WSI
Pulse source parameters	cleared		PV, PI
Pulse sweep source parameters	cleared		PWV, PWI
Search source parameters	cleared		BSV, BSSV, BSI, BSSI, LSV, LSSV, LSI, LSSV
Search monitor parameters	cleared		BGV, BGI, LGV, LGI
Search measurement data	source output value only		BSVM, LSVM
Quasi-pulse source parameters	cleared		BDV
Quasi-pulsed spot measurement mode	voltage		BDM

Setup Item	Initial Setting	Commands
Quasi-pulse settling detection interval	short	BDM
Sampling source	cleared	MI, MV
Sampling interval, sampling point	2 ms, 1000 points	MT
Automatic abort function	off	WM, BSM, LSM, MSC
Output after measurement	start value (bias value for MSC)	
Hold time	0 s	WT, PT, BDT, BST, LSTM
Delay time	0 s	
Step delay time	0 s	WT
Trigger delay time	0 s	WT, PT
Pulse width	0.001 s	PT
Pulse period	0.01 s	PT

Table 2-11 CMU Settings

Setup Item	Initial Setting	Commands
SCUU path/indicator	open/enable	SSP/SSL
Measurement parameter	Cp-G	IMP
Measurement range	auto	RC
ADC integration time	auto	ACT
Open/short/load correction	off	OPEN/SHOR/LOAD
Phase compensation mode	auto	ADJ
AC signal	0 V, 1 kHz	ACV, FC
Sweep source parameters	cleared	WDCV
Automatic abort function	off	WMDCV
Output after measurement	start value	WMDCV
Hold time	0 s	WTDCV
Delay time	0 s	WTDCV
Step delay time	0 s	WTDCV
Trigger delay time	0 s	WTDCV

Table 2-12 SPGU Settings

Setup Item	Initial Setting	Commands
Operation mode	PG mode	SIM
Pulse period	1.0 μs	SPPER
Channel output operation mode	Free run	SPRM
Channel output mode	Pulse source 1, 2-level pulse output	SPM
DC source setup	0 V	SPV
Pulse source setup	Delay: 0 s, Width 100 ns, Leading: 20 ns, Trailing: 20 ns, Base: -0.5 V, Peak: 0.5 V	SPT, SPV
ALWG setup	Cleared	ALW, ALS
Pulse switch	Disable, Normally open, Delay: 0 s, Width: 100 ns	ODSW
DUT load impedance	50 Ω	SER
SPGU trigger output	Disable	STGP
SPGU setup in sampling measurement	Cleared	MSP

Table 2-13 Initial Settings of Mainframe, SMU, and CMU

Setup Item	Initial Setting		Commands
Auto calibration	off		CM
SMU output switch	open		CN, CL
SMU filter/series resistor	off/off		FL/SSR
ASU path/1 pA auto range/indicator	SMU side/disable/enable		SAP/SAR/SAL
SCUU path/indicator	open/enable		SSP/SSL
SMU current measurement range	with pulse	compliance range	RI
	without pulse	auto	
SMU voltage measurement range	with pulse	compliance range	RV
	without pulse	auto	
SMU A/D converter	high speed ADC		AAD
SMU ADC Integration time	high speed ADC: auto, non parallel		AIT, PAD
	high resolution ADC: auto		AIT
SMU ADC zero function	off		AZ
SMU AV command parameter	*number*=1, *mode*=0		AV
CMU measurement parameter	Cp-G		IMP
CMU measurement range	auto		RC
CMU ADC integration time	auto		ACT
CMU correction/compensation	Open/Short/Load: off/off/off, Phase compensation: auto		OPEN/SHOR/LOAD, ADJ
CMU AC signal	0 V, 1 kHz		ACV
Sweep source parameters	cleared		WV, WSV, WI, WSI, WDCV
Pulse source parameters	cleared		PV, PI
Pulse sweep source parameters	cleared		PWV, PWI
Search source parameters	cleared		BSV, BSSV, BSI, BSSI, LSV, LSSV, LSI, LSSV
Search monitor parameters	cleared		BGV, BGI, LGV, LGI
Search measurement data	source output value only		BSVM, LSVM
Quasi-pulse source parameters	cleared		BDV
Quasi-pulsed spot measurement mode	voltage		BDM
Quasi-pulse settling detection interval	short		BDM
Sampling source	cleared		MI, MV
Sampling interval, sampling point	2 ms, 1000 points		MT
Automatic abort function	off		WM, BSM, LSM, WMDCV, MSC
Output after measurement	start value (bias value for MSC)		WM, BSM, LSM, WMDCV, MSC
Pulse width	0.001 s		PT
Pulse period	0.01 s		PT
Hold time	0 s		WT, PT, BDT, BST, LSTM, WTDCV, MT
Delay time	0 s		WT, PT, BDT, BST, LSTM, WTDCV
Step delay time	0 s		WT, WTDCV
Trigger delay time	0 s		WT, PT, WTDCV
Trigger mode	XE, TV, TI, or GET		TM
Trigger port	Ext Trig In	Start Measurement trigger input	TGP
	Ext Trig Out	Measurement Completion trigger output	TGP
	Digital I/O	cleared	TGP
Trigger condition of Start Step Output Setup trigger	with trigger for first sweep step		TGSI
Type of output trigger	edge trigger		TGXO, TGSO, TGMO
Digital I/O port	output for all port		ERM
Program memory	cleared. Not cleared by *RST command or device clear.		SCR
Value of internal variable (%In, %Rn)	0		VAR
Data output format	ASCII with header, CR/LF^EOI		FMT
Data output buffer	cleared		BC
Status byte	Only bit 6 is enabled.		*SRE
Error code register	cleared		ERRX?, ERR?

3 Programming Examples

This chapter provides the following sections which show and explain programming example.

- “Programming Basics for Visual Basic .NET Users”
- “High-Speed Spot Measurements”
- “Spot Measurements”
- “Pulsed Spot Measurements”
- “Staircase Sweep Measurements”
- “Pulsed Sweep Measurements”
- “Staircase Sweep with Pulsed Bias Measurements”
- “Quasi Pulsed Spot Measurements”
- “Linear Search Measurements”
- “Binary Search Measurements”
- “Multi Channel Sweep Measurements”
- “Multi Channel Pulsed Spot Measurements”
- “Multi Channel Pulsed Sweep Measurements”
- “Sampling Measurements”
- “Quasi-static CV Measurements”
- “High-Speed Spot C Measurements”
- “Spot C Measurements”
- “CV (DC Bias) Sweep Measurements”
- “Pulsed Spot C Measurements”
- “Pulsed Sweep CV Measurements”
- “CV (AC Level) Sweep Measurements”
- “C-f Sweep Measurements”
- “C-t Sampling Measurements”
- “SPGU Pulse Output and Voltage Measurement”
- “Using Program Memory”
- “Using Trigger Function”
- “Reading Time Stamp Data”

- “Reading Binary Output Data”
- “Using Programs for 4142B”
- “Using Programs for 4155B/4156B/4155C/4156C”

Refer to Chapter 4, “Command Reference,” for the command syntax and descriptions of the Agilent B1500 FLEX commands.

The following command conventions are used in this chapter.

command	Required command for measurement execution.
[command]	Optional command for measurement execution.
parameter	Required command parameter. A value or variable *must* be specified.
[*parameter*]	Optional command parameter. A value may be specified.

NOTE

About Example Program Code

Example programs described in this section have been written in the Microsoft Visual Basic .NET or the HP BASIC language. Most of the examples written in the Visual Basic .NET are provided as a subprogram that can be run with the project template shown in Table 3-1. To run the program, insert the example subprogram or your subprogram instead of the perform_meas subprogram in the template.

NOTE

To Start Program

If you create the measurement program by using the example code shown in Table 3-1, the program can be run by clicking the Run button on the Visual Basic main window. Then a message box will appear. After that, click OK to continue.

NOTE

After the Automatic Measurement

After the automatic measurements, open the measurement terminals or disconnect the device under test from the measurement terminals. If you leave the connection with the device, the device may be damaged by unexpected operations.

Do not leave the connection over 30 minutes after measurement if the auto calibration is set to ON. Then, the Agilent B1500 performs the self-calibration automatically every 30 minutes after measurement. The calibration requires to open the measurement terminals.

To disable the auto calibration, enter the `CM 0` command.

Programming Basics for Visual Basic .NET Users

This section provides the basic information for programming of the automatic measurement using the Agilent B1500, Agilent IO Library, and Microsoft Visual Basic .NET.

- “To Create Your Project Template”
- “To Create Measurement Program”

NOTE To execute the example programs in this chapter, you need to install Agilent GPIB interface, Agilent IO Library, VISA COM Library, and Microsoft Visual Basic .NET on your computer. The VISA COM Library is included in the IO Library.

To Create Your Project Template

Before starting programming, create your project template, and keep it as your reference. It will remove the conventional task in the future programming. This section explains how to create a project template.

Step 1. Connect Agilent B1500 (ex. GPIB address 17) to the computer via GPIB.

Step 2. Launch Visual Basic .NET and create a new project. The project type should be Console Application to simplify the programming.

Step 3. Add VISA COM library (VisaComLib) to the reference.

Step 4. Open a module (e.g. Module1.vb) in the project. And enter a program code as template. See Table 3-1 for example.

Step 5. Save the project as your template (e.g. \test\my_temp).

To Create Measurement Program

Create the measurement program as shown below. The following procedure needs your project template. If the procedure does not fit your programming environment, arrange it to suit your environment.

Step 1. Plan the automatic measurements. Then decide the following items:

- Measurement devices

  Discrete, packaged, on-wafer, and so on.

- Parameters/characteristics to be measured

  h_{FE}, Vth, sheet resistance, and so on.

- Measurement method

  Spot measurement, staircase sweep measurement, and so on.

Step 2. Make a copy of your project template (e.g. \test\my_temp to \test\dev_a\my_temp).

Step 3. Rename the copy (e.g. \test\dev_a\my_temp to \test\dev_a\spot_id).

Step 4. Launch Visual Basic .NET.

Step 5. Open the project (e.g. \test\dev_a\spot_id).

Step 6. Open the module that contains the template code as shown in Table 3-1. On the code window, complete the perform_meas subprogram.

Step 7. Insert the code to display, store, or calculate data into the subprogram.

Step 8. Save the project (e.g. \test\dev_a\spot_id).

Table 3-1 Example Template Program Code for Visual Basic .NET

```
Imports Ivi.visa.interop

Module Module1

  Sub Main()                                                                          '5
    Dim B1500 As IResourceManager
    Dim session As IMessage
    B1500 = New ResourceManager
    session = B1500.Open("GPIB0::17::INSTR")
    session.WriteString("*RST" & vbLf)
    MsgBox("Click OK to start measurement.", vbOKOnly, "")
    Console.WriteLine("Measurement in progress. . ." & Chr(10))

    Dim t() As Integer = {5, 4, 3, 1}                                                '14
    Dim term As String = t(0) & "," & t(1) & "," & t(2) & "," & t(3)
    session.WriteString("CN " & term & vbLf)
    perform_meas(session, t)

    session.WriteString("CL" & vbLf)                                                 '19
    session.Close()
    MsgBox("Click OK to stop the program.", vbOKOnly, "")
    Console.WriteLine("Measurement completed." & Chr(10))
  End Sub                                                                            '23
```

Line	Description
1	This line is required to use the VISA COM library.
5 to 23	Main subprogram establishes the connection with the Agilent B1500, resets the B1500, opens a message box to confirm the start of measurement, and pauses program execution until OK is clicked on the message box. By clicking OK, the program displays a message on the console window, enables the SMUs, and calls the perform_meas subprogram that will be used to perform measurement. After the measurement, the program disables all SMUs, disables the connection with the B1500, and opens a message box to confirm the end of the program. Finally, by clicking OK on the message box, the program displays a message on the console window.
9	The above example is for the B1500 of the GPIB address 17 on the interface GPIB0. “GPIB0” is the VISA name. Confirm your GPIB settings, and set them properly.
14 to 15	The above example uses the SMUs installed in the B1500 slots 1, 3, 4, and 5. Change the slot numbers for matching your configuration.

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)          '25
  Dim i As Integer = 0 : Dim j As Integer = 0
  Dim nop1 As Integer = 1 : Dim nop2 As Integer = 1
  Dim data(nop2 - 1, nop1 - 1) As String
  Dim value As String = "Enter data header"
  Dim fname As String = "C:\enter_file_name.txt"
  Dim title As String = "Measurement Result"
  Dim msg As String = "No error." : Dim err As Integer = 0

  ' insert measurement program code                                          34

  session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
  If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err

  session.WriteString("DZ" & vbLf)
  save_data(fname, title, value, data, nop1, nop2, session, t)              '40
  Exit Sub

 Check_err:
  session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
  MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
End Sub                                                                      '46
```

Line	Description
25	Beginning of the perform_meas subprogram.
26 to 32	Declares variables used in this program template. The values are dummy. You must change the values to match your program. If you find unnecessary variables, delete them. *i* and *j*: Variables used to specify the element of the *data* array. *nop1* and *nop2*: Number of measurement steps. Also used to declare the *data* array. *data*: String data array used to store the measurement result data. *value*: String data variable to store the header (first line) of the displayed data. *fname*: Full path name of the measurement result data file. *title*: Title of the message box used to display the measurement result data. *msg* and *err*: Variables used to store an error message and an error code.
34	The line is placed as dummy. Remove the line and insert your program code to control the instruments and perform measurement.
36 to 37	Checks if the instrument causes an error, and goes to Check_err if an error is detected.
39 to 40	Applies 0 V from all channels and calls the save_data subprogram (lines 48 to 70).
43 to 45	Opens a message box to display error message if an error is detected.
46	End of the perform_meas subprogram.

```
  Sub save_data(ByVal fname As String, ByVal title As String, ByVal value As
String, ByVal data(,) As String, ByVal nop1 As Integer, ByVal nop2 As Integer,
ByVal session As IMessage, ByVal t() As Integer)                               '48
    Dim i As Integer = 0
    Dim j As Integer = 0
    FileOpen(1, fname, OpenMode.Output, OpenAccess.Write, OpenShare.LockReadWrite)
    Print(1, value)
    For j = 0 To nop2 - 1
        For i = 0 To nop1 - 1
            Print(1, data(j, i))
        Next i
    Next j
    FileClose(1)

    Dim rbx As Integer                                                         '60
    For j = 0 To nop2 - 1
        For i = 0 To nop1 - 1
            value = value & data(j, i)
        Next i
    Next j
    value = value & Chr(10) & Chr(10) & "Data save completed."
    value = value & Chr(10) & Chr(10) & "Do you want to perform measurement again?"
    rbx = MsgBox(value, vbYesNo, title)
    If rbx = vbYes Then perform_meas(session, t)
  End Sub                                                                      '70

End Module
```

Line	Description
48	Beginning of the save_data subprogram.
49 to 50	Declares loop counters used to specify the element of the *data* array.
51 to 58	Saves measurement result data into a file specified by the *fname* variable.
60 to 68	Displays the data and a message on a message box.
69	If Yes is clicked on the message box, calls the perform_meas subprogram again. If No is clicked, returns to the perform_meas subprogram.
70	End of the save_data subprogram.

High-Speed Spot Measurements

To perform high-speed spot measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets series resistor ON/OFF	[SSR]	*chnum*,*mode*
Sets integration time (Agilent B1500 can use AAD/AIT instead of AV.)	[AV]	*number*[,*mode*]
	[AAD]	*chnum*[,*type*]
	[AIT]	*type*,*mode*[,*N*]
Forces constant voltage	DV, TDV	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces constant current	DI, TDI	
Performs current measurement	TI	*chnum*[,*range*]
	TTI	*chnum*[,*range*]
Performs voltage measurement	TV	*chnum*[,*range*]
	TTV	*chnum*[,*range*]
Resets the time stamp	TSR	
Returns the time stamp at this time	TSQ	

You can use the above commands regardless of the measurement mode (MM command settings).

A program example of a high-speed spot measurement is shown below. This example measures MOSFET drain current. This program uses the TTI command to measure the current and read the time stamp data.

Table 3-2 High-Speed Spot Measurement Example

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)               '1
    Dim i As Integer = 0                            't(0): Drain
    Dim j As Integer = 0                            't(1): Gate
    Dim nop1 As Integer = 1                         't(2): Source
    Dim nop2 As Integer = 1                         't(3): Substrate
    Dim data(nop2 - 1, nop1 - 1) As String
    Dim value As String = "Id (uA), Status, Meas Time (msec)"
    Dim fname As String = "C:\Agilent\prog_ex\data1.txt"
    Dim title As String = "Measurement Result"
    Dim msg As String = "No error."
    Dim err As Integer = 0

    Dim vd As Double = 3                                                       '13
    Dim vg As Double = 1
    Dim idcomp As Double = 0.05
    Dim igcomp As Double = 0.01
    Dim orng As Integer = 0
    Dim mrng As Integer = 0

    session.WriteString("FMT 1" & vbLf)                                        '20
    session.WriteString("AV 10,1" & vbLf)     'sets number of samples for 1 data
    session.WriteString("FL 0" & vbLf)        'sets filter off
    session.WriteString("DV " & t(3) & ",0,0,0.1" & vbLf)   'out= 0 V, comp= 0.1 A
    session.WriteString("DV " & t(2) & ",0,0,0.1" & vbLf)   'out= 0 V, comp= 0.1 A
    session.WriteString("DV " & t(1) & "," & orng & "," & vg & "," & igcomp & vbLf)
    session.WriteString("DV " & t(0) & "," & orng & "," & vd & "," & idcomp & vbLf)
    session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
    If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err         '28
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 18	Declares variables and sets the value.
20 to 22	Sets the data output format and A/D converter. Also sets the SMU filter off.
23 to 28	Applies voltage to device and checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.

```
    session.WriteString("TSR" & vbLf)                                                  '30
    session.WriteString("TTI " & t(0) & "," & mrng & vbLf)
    session.WriteString("TSQ" & vbLf)
    Dim mret As String = session.ReadString(16 + 17)  'data+comma+data+terminator
    Dim tret As String = session.ReadString(17)       'data+terminator
    Dim tcal As String = Mid(mret, 4, 12)
    tret = Mid(tret, 4, 12)
    Dim mtime As Double = Val(tret) - Val(tcal)
    Dim status As String = Mid(mret, 17, 3)
    Dim meas As Double = Val(Mid(mret, 20, 12))

    data(j, i) = Chr(13) & Chr(10) & meas * 1000000 & ", " & status & ", " & mtime
* 1000

    session.WriteString("DZ" & vbLf)                                                   '43
    save_data(fname, title, value, data, nop1, nop2, session, t)
    Exit Sub

  Check_err:                                                                           '47
    session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
End Sub
```

Line	Description
30 to 41	Resets time stamp and performs the high-speed spot measurement. And stores the returned data into the *mret* and *tret* string variables. Finally, stores the measured data into the *data* array.
43 to 45	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
48 to 49	Displays a message box to show an error message if the error is detected.

Measurement Result Example

```
Id (uA), Status, Meas Time (msec)
23.69, NEI, 14.05

Data save completed.

Do you want to perform measurement again?
```

Spot Measurements

To perform spot measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets series resistor ON/OFF	[SSR]	*chnum*,*mode*
Sets integration time (Agilent B1500 can use AAD/AIT instead of AV.)	[AV]	*number*[,*mode*]
	[AAD]	*chnum*[,*type*]
	[AIT]	*type*,*mode*[,*N*]
Forces constant voltage	DV, TDV	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces constant current	DI, TDI	
Sets voltage measurement range	[RV]	*chnum*,*range*
Sets current measurement range	[RI]	*chnum*,*range*
	[RM]	*chnum*,*mode*[,*rate*]
Sets measurement mode	MM	1,*chnum*[,*chnum* ... [,*chnum*] ...]
Sets SMU operation mode	[CMM]	*chnum*,*mode*
Executes measurement	XE	

NOTE

If you use multiple measurement channels, the channels start measurement in the order defined in the MM command.

A program example of a spot measurement is shown below. This example measures MOSFET drain current.

Table 3-3 Spot Measurement Example

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)               '1
    Dim i As Integer = 0                            't(0): Drain
    Dim j As Integer = 0                            't(1): Gate
    Dim nop1 As Integer = 1                         't(2): Source
    Dim nop2 As Integer = 1                         't(3): Substrate
    Dim data(nop2 - 1, nop1 - 1) As String
    Dim value As String = "Id (uA), Time (sec), Status"
    Dim fname As String = "C:\Agilent\prog_ex\data2.txt"
    Dim title As String = "Measurement Result"
    Dim msg As String = "No error."
    Dim err As Integer = 0

    Dim vd As Double = 3                                                       '13
    Dim vg As Double = 1
    Dim idcomp As Double = 0.05
    Dim igcomp As Double = 0.01
    Dim orng As Integer = 0
    Dim mrng As Integer = 0
    session.WriteString("FMT 1" & vbLf)                                        '19
    session.WriteString("TSC 1" & vbLf)        'enables time stamp output
    session.WriteString("FL 0" & vbLf)         'sets filter off
    session.WriteString("AV 10,1" & vbLf)      'sets number of samples for 1 data
    session.WriteString("DV " & t(3) & ",0,0,0.1" & vbLf)   'out= 0 V, comp= 0.1 A
    session.WriteString("DV " & t(2) & ",0,0,0.1" & vbLf)   'out= 0 V, comp= 0.1 A
    session.WriteString("DV " & t(1) & "," & orng & "," & vg & "," & igcomp & vbLf)
    session.WriteString("DV " & t(0) & "," & orng & "," & vd & "," & idcomp & vbLf)
    session.WriteString("MM 1," & t(0) & vbLf)          '1: spot measurement
    session.WriteString("CMM " & t(0) & ",1" & vbLf)    '1: current measurement
    session.WriteString("RI " & t(0) & "," & mrng & vbLf)                      '29
    session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
    If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 18	Declares variables and sets the value.
19 to 22	Sets the data output format, time stamp data output mode, and A/D converter. Also sets the SMU filter off.
23 to 26	Applies voltage to device.
27 to 29	Sets the measurement mode, channel measurement mode, and measurement range.
30 to 31	Checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.

```
    session.WriteString("TSR" & vbLf)                                         '33
    session.WriteString("XE" & vbLf)
    session.WriteString("TSQ" & vbLf)
    Dim mret As String = session.ReadString(16 + 17)   'data+comma+data+terminator
    Dim tret As String = session.ReadString(17)        'data+terminator
    Dim tcal As String = Mid(mret, 4, 12)
    tret = Mid(tret, 4, 12)
    Dim mtime As Double = Val(tret) - Val(tcal)
    Dim status As String = Mid(mret, 17, 3)
    Dim meas As Double = Val(Mid(mret, 20, 12))

    data(j, i) = Chr(13) & Chr(10) & meas * 1000000 & ", " & status & ", " & mtime
* 1000

    session.WriteString("DZ" & vbLf)                                          '46
    save_data(fname, title, value, data, nop1, nop2, session, t)
    Exit Sub

  Check_err:                                                                  '50
    session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
End Sub
```

Line	Description
33 to 44	Resets time stamp and performs the spot measurement. And stores the returned data into the *mret* and *tret* string variables. Finally, stores the measured data into the *data* array.
46 to 48	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
51 to 52	Displays a message box to show an error message if the error is detected.

Measurement Result Example

```
Id (uA), Status, Meas Time (msec)
23.495, NEI, 14.28

Data save completed.

Do you want to perform measurement again?
```

Pulsed Spot Measurements

To perform pulsed spot measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets series resistor ON/OFF	[SSR]	*chnum*,*mode*
Measurement time	AIT	2,*mode*[,*N*]
Forces constant voltage	DV, TDV	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces constant current	DI, TDI	
Sets pulse timing parameters	PT	*hold*,*width*[,*period* [,*tdelay*]]
Sets pulse voltage	PV	*chnum*,*range*,*base*,*pulse*[,*comp*]
Sets pulse current	PI	*chnum*,*range*,*base*,*pulse* [,*comp*]
Sets voltage measurement range	[RV]	*chnum*,*range*
Sets current measurement range	[RI]	*chnum*,*range*
	[RM]	*chnum*,*mode*[,*rate*]
Sets measurement mode	MM	3,*chnum*
Sets SMU operation mode	[CMM]	*chnum*,*mode*
Executes measurement	XE	

A program example of a pulsed spot measurement is shown below. This example measures MOSFET drain current.

Table 3-4 Pulsed Spot Measurement Example

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)               '1
    Dim i As Integer = 0                         't(0): Drain
    Dim j As Integer = 0                         't(1): Gate
    Dim nop1 As Integer = 1                      't(2): Source
    Dim nop2 As Integer = 1                      't(3): Substrate
    Dim data(nop2 - 1, nop1 - 1) As String
    Dim value As String = "Id (uA), Status, Meas Time (msec)"
    Dim fname As String = "C:\Agilent\prog_ex\data3.txt"
    Dim title As String = "Measurement Result"
    Dim msg As String = "No error."
    Dim err As Integer = 0

    Dim vd As Double = 3                                                       '13
    Dim vg As Double = 1
    Dim idcomp As Double = 0.05
    Dim igcomp As Double = 0.01
    Dim orng As Integer = 0
    Dim mrng As Integer = 0
    session.WriteString("FMT 1" & vbLf)                                        '19
    session.WriteString("TSC 1" & vbLf)       'enables time stamp output
    session.WriteString("FL 0" & vbLf)        'sets filter off
    session.WriteString("AV 1,1" & vbLf)      'sets number of samples for 1 data
    session.WriteString("DV " & t(3) & ",0,0,0.1" & vbLf)   'out= 0 V, comp= 0.1 A
    session.WriteString("DV " & t(2) & ",0,0,0.1" & vbLf)   'out= 0 V, comp= 0.1 A
    Dim g_pt As String = "0.1,0.01,0.02"      'hold, width, period in sec
    session.WriteString("PT " & g_pt & vbLf)
    Dim v0 As Double = 0                      '0 V: pulse base voltage
    session.WriteString("PV " & t(1) & "," & orng & "," & v0 & "," & vg & "," &
igcomp & vbLf)
    session.WriteString("DV " & t(0) & "," & orng & "," & vd & "," & idcomp & vbLf)
    session.WriteString("MM 3," & t(0) & vbLf)         '3: pulsed spot measurement
    session.WriteString("CMM " & t(0) & ",1" & vbLf)   '1: current measurement
    session.WriteString("RI " & t(0) & "," & mrng & vbLf)                      '32
    session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
    If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 18	Declares variables and sets the value.
19 to 22	Sets the data output format, time stamp data output mode, SMU filter, and averaging.
23 to 29	Applies DC voltage to device, and sets the voltage pulse source.
30 to 32	Sets the measurement mode, channel measurement mode, and measurement range.
33 to 34	Checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.

```
    session.WriteString("TSR" & vbLf)                                     '35
    session.WriteString("XE" & vbLf)
    session.WriteString("TSQ" & vbLf)
    Dim mret As String = session.ReadString(16 + 17)   'data+comma+data+terminator
    Dim tret As String = session.ReadString(17)        'data+terminator
    Dim tcal As String = Mid(mret, 4, 12)
    tret = Mid(tret, 4, 12)
    Dim mtime As Double = Val(tret) - Val(tcal)
    Dim status As String = Mid(mret, 17, 3)
    Dim meas As Double = Val(Mid(mret, 20, 12))

    data(j, i) = Chr(13) & Chr(10) & meas * 1000000 & ", " & status & ", " & mtime
* 1000

    session.WriteString("DZ" & vbLf)                                      '48
    save_data(fname, title, value, data, nop1, nop2, session, t)
    Exit Sub

  Check_err:                                                              '52
    session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
End Sub
```

Line	Description
35 to 46	Resets time stamp and performs the pulsed spot measurement. And stores the returned data into the *mret* and *tret* string variables. Finally, stores the measured data into the *data* array.
48 to 50	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
53 to 54	Displays a message box to show an error message if the error is detected.

Measurement Result Example

```
Id (uA), Status, Meas Time (msec)
25, NEI, 17.58

Data save completed.

Do you want to perform measurement again?
```

Staircase Sweep Measurements

To perform staircase sweep measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets series resistor ON/OFF	[SSR]	*chnum*,*mode*
Sets integration time (Agilent B1500 can use AAD/AIT instead of AV.)	[AV]	*number*[,*mode*]
	[AAD]	*chnum*[,*type*]
	[AIT]	*type*,*mode*[,*N*]
Sets sweep source timing parameter	[WT]	*hold*,*delay* [,*sdelay*[,*tdelay*[,*mdelay*]]]
Sets auto abort function	[WM]	*abort*[,*post*]
Sets voltage sweep source	WV	*chnum*,*mode*,*range*,*start*,*stop*,*step* [,*comp*[,*Pcomp*]]
Sets current sweep source	WI	
Sets synchronous sweep source [a]	[WSV]	*chnum*,*range*,*start*,*stop* [,*comp*[,*Pcomp*]]
	[WSI]	
Forces constant voltage	DV, TDV	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces constant current	DI, TDI	
Sets voltage measurement range	[RV]	*chnum*,*range*
Sets current measurement range	[RI]	*chnum*,*range*
	[RM]	*chnum*,*mode*[,*rate*]
Sets measurement mode	MM	2,*chnum*[,*chnum* ... [,*chnum*] ...]
Sets SMU operation mode	[CMM]	*chnum*,*mode*
Executes measurement	XE	

a. The WSV/WSI command must be entered after the WV/WI command.

NOTE

If you use multiple measurement channels, the channels start measurement in the order defined in the MM command.

A program example of a staircase sweep measurement is shown below. This example measures MOSFET Id-Vd characteristics.

Table 3-5 Staircase Sweep Measurement Example 1

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)              '1
    Dim i As Integer = 0                         't(0): Drain
    Dim j As Integer = 0                         't(1): Gate
    Dim nop1 As Integer = 11                     't(2): Source
    Dim nop2 As Integer = 3                      't(3): Substrate
    Dim data(nop2 - 1, nop1 - 1) As String
    Dim value As String = "Vg (V), Vd (V), Id (mA), Time (sec), Status"
    Dim fname As String = "C:\Agilent\prog_ex\data4.txt"
    Dim title As String = "Measurement Result"
    Dim msg As String = "No error."
    Dim err As Integer = 0

    Dim vd1 As Double = 0                                                     '13
    Dim vd2 As Double = 3
    Dim idcomp As Double = 0.05
    Dim vg1 As Double = 1
    Dim vg2 As Double = 3
    Dim igcomp As Double = 0.01
    Dim vg As Double = vg1              'secondary sweep output value
    Dim d_vg As Double = 0              'secondary sweep step value (delta)
    If nop2 <> 1 Then d_vg = (vg2 - vg1) / (nop2 - 1)
    Dim hold As Double = 0
    Dim delay As Double = 0
    Dim s_delay As Double = 0
    Dim p_comp As Double = 0.3
    Dim rep As Integer = nop1
    Dim mret As String                                                        '27
    Dim sc(nop1) As Double
    Dim md(nop1) As Double
    Dim st(nop1) As String
    Dim tm(nop1) As Double
    session.WriteString("FMT 1,1" & vbLf)'ASCII,<CRLF EOI>,w/sweep source data '32
    session.WriteString("TSC 1" & vbLf)       'enables time stamp output
    session.WriteString("FL 0" & vbLf)        'sets filter off
    session.WriteString("AV 10,1" & vbLf)     'sets number of samples for 1 data
    session.WriteString("DV " & t(3) & ",0,0,0.1" & vbLf)   'out= 0 V, comp= 0.1 A
    session.WriteString("DV " & t(2) & ",0,0,0.1" & vbLf)   'out= 0 V, comp= 0.1 A
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 26	Declares variables used to set the source output, and sets the value.
27 to 31	Declares variables used to read the measurement data.
32 to 35	Sets the data output format, time stamp data output mode, SMU filter, and averaging.
36 to 37	Applies voltage to device.

```
    session.WriteString("MM 2," & t(0) & vbLf)   '2: staircase sweep measurement
    session.WriteString("CMM " & t(0) & ",1" & vbLf) '1: current measurement
    session.WriteString("RI " & t(0) & ",0" & vbLf)  '0: auto ranging
    session.WriteString("WT " & hold & "," & delay & "," & s_delay & vbLf)     '41
    session.WriteString("WM 2,1" & vbLf)             'stops any abnormal
    session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
    If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err

    For j = 0 To nop2 - 1                                                      '46
      session.WriteString("WV " & t(0) & ",1,0," & vd1 & "," & vd2 & "," & nop1 &
"," & idcomp & "," & p_comp & vbLf)
      session.WriteString("DV " & t(1) & ",0" & "," & vg & "," & igcomp & vbLf)
      session.WriteString("TSR" & vbLf)
      session.WriteString("XE" & vbLf)
      session.WriteString("*OPC?" & vbLf) : rep = session.ReadString(1 + 2)
      session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
      If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
      session.WriteString("NUB?" & vbLf) : rep = session.ReadString(3 + 2)     '54
      If rep <> nop1 * 3 Then session.WriteString("DZ" & vbLf) : GoTo Check_nop

      mret = session.ReadString(16 * 3 * nop1 + 1)
      For i = 0 To nop1 - 1
        tm(i) = Val(Mid(mret, 4 + 16 * 3 * i, 12))
        st(i) = Mid(mret, 17 + 16 * 3 * i, 3)
        md(i) = Val(Mid(mret, 20 + 16 * 3 * i, 12))
        sc(i) = Val(Mid(mret, 36 + 16 * 3 * i, 12))
        data(j, i) = Chr(13) & Chr(10) & vg & ", " & sc(i) & ", " & md(i) * 1000 &
", " & tm(i) & ", " & st(i)                                                    '63
      Next i
      vg = vg + d_vg
    Next j
    session.WriteString("DZ" & vbLf)                                           '67
    save_data(fname, title, value, data, nop1, nop2, session, t)
    Exit Sub
```

Line	Description
38 to 40	Sets the measurement mode, channel measurement mode, and measurement range.
41 to 44	Sets the timing parameters and sweep mode of the staircase sweep source. And checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.
46 to 66	Sets the sweep source, applies voltage to device, resets time stamp, and performs the staircase sweep measurement. And stores the returned data into the *mret* string variable. Finally, stores the measured data into the *data* array.
54 to 55	Checks number of returned data. If it is not correct, forces 0 V and goes to Check_nop.
63	Stores the measured data into the *data* array.
67 to 69	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.

```
  Check_err:                                                                  '71
    session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
    Exit Sub

  Check_nop:                                                                  '76
    MsgBox("No. of data: " & rep & " (not " & nop1 * 3 & ")", vbOKOnly, "")
End Sub
```

Line	Description
71 to 74	Displays a message box to show an error message if the error is detected.
76 to 77	Displays a message box to show an error message if the number of returned data is not correct.

Measurement Result Example

```
Vg (V), Vd (V), Id (mA), Time (sec), Status
1, 0, 0.0001123, 0.05631, NEI
1, 0.3, 0.02327, 0.09489, NEI
1, 0.6, 0.0235, 0.12746, NEI
1, 0.9, 0.0235, 0.16004, NEI
1, 1.2, 0.0235, 0.19262, NEI
1, 1.5, 0.0235, 0.22518, NEI
1, 1.8, 0.02351, 0.25775, NEI
1, 2.1, 0.0235, 0.29032, NEI
1, 2.4, 0.02353, 0.32288, NEI
1, 2.7, 0.02351, 0.35545, NEI
1, 3, 0.02353, 0.38802, NEI
2, 0, 0.001794, 0.03458, NEI
2, 0.3, 2.085, 0.05779, NEI
2, 0.6, 3.5975, 0.07353, NEI
2, 0.9, 4.5655, 0.08926, NEI
2, 1.2, 5.0875, 0.10499, NEI
2, 1.5, 5.316, 0.12073, NEI
2, 1.8, 5.4045, 0.13646, NEI
2, 2.1, 5.4455, 0.15219, NEI
2, 2.4, 5.474, 0.16794, NEI
2, 2.7, 5.4935, 0.18367, NEI
2, 3, 5.513, 0.19941, NEI
3, 0, 0.0027225, 0.03542, NEI
3, 0.3, 3.4465, 0.05861, NEI
3, 0.6, 6.4185, 0.07436, NEI
3, 0.9, 8.904, 0.09011, NEI
3, 1.2, 10.9, 0.10008, NEI
3, 1.5, 12.425, 0.10527, NEI
3, 1.8, 13.51, 0.11046, NEI
3, 2.1, 14.215, 0.11566, NEI
3, 2.4, 14.63, 0.12085, NEI
3, 2.7, 14.875, 0.12605, NEI
3, 3, 15.04, 0.13124, NEI
Data save completed.
Do you want to perform measurement again?
```

The following program performs the same measurement as the previous program (Table 3-5). This program starts to read measurement data before the sweep measurement is completed.

Table 3-6 Staircase Sweep Measurement Example 2

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)              ’1
    Dim i As Integer = 0                          ’t(0): Drain
    Dim j As Integer = 0                          ’t(1): Gate
    Dim nop1 As Integer = 11                      ’t(2): Source
    Dim nop2 As Integer = 3                       ’t(3): Substrate
    Dim data(nop2 - 1, nop1 - 1) As String
    Dim value As String = "Vg (V), Vd (V), Id (mA), Time (sec), Status"
    Dim fname As String = "C:\Agilent\prog_ex\data4r.txt"
    Dim title As String = "Measurement Result"
    Dim msg As String = "No error."
    Dim err As Integer = 0

    Dim vd1 As Double = 0                                                     ’13
    Dim vd2 As Double = 3
    Dim idcomp As Double = 0.05
    Dim vg1 As Double = 1
    Dim vg2 As Double = 3
    Dim igcomp As Double = 0.01
    Dim vg As Double = vg1               ’secondary sweep output value
    Dim d_vg As Double = 0               ’secondary sweep step value (delta)
    If nop2 <> 1 Then d_vg = (vg2 - vg1) / (nop2 - 1)
    Dim hold As Double = 0
    Dim delay As Double = 0
    Dim s_delay As Double = 0
    Dim p_comp As Double = 0.3

    session.WriteString("FMT 5,1" & vbLf)  ’ASCII,<comma>,w/sweep source data  ’27
    session.WriteString("TSC 1" & vbLf)       ’enables time stamp output
    session.WriteString("FL 0" & vbLf)        ’sets filter off
    session.WriteString("AV 10,1" & vbLf)     ’sets number of samples for 1 data
    session.WriteString("DV " & t(3) & ",0,0,0.1" & vbLf)   ’out= 0 V, comp= 0.1 A
    session.WriteString("DV " & t(2) & ",0,0,0.1" & vbLf)   ’out= 0 V, comp= 0.1 A
    session.WriteString("MM 2," & t(0) & vbLf)    ’2: staircase sweep measurement
    session.WriteString("CMM " & t(0) & ",1" & vbLf) ’1: current measurement
    session.WriteString("RI " & t(0) & ",0" & vbLf)  ’0: auto ranging
    session.WriteString("WT " & hold & "," & delay & "," & s_delay & vbLf)
    session.WriteString("WM 2,1" & vbLf)             ’stops any abnormal
    session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
    If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err        ’39
```

Line	Description
1 to 25	Declares variables and set the value. Almost same as the previous program. Only the fname value is different.
27	Sets the data output format. A comma will be sent as the data terminator.
28 to 39	Sets the measurement condition. Same as the lines 33 to 44 of the previous program.

```
    Dim ret_val As String : Dim status As String : Dim chan As String          '41
    Dim type As String : Dim rdata As Double : Dim tdata As Double
    Dim sdata As Double : Dim mdata As Double : Dim mstat As String
    Dim disp_data As String : Dim k As Integer = 0
    session.TerminationCharacter = 44           'terminator=comma              '45
    session.TerminationCharacterEnabled = True

    For j = 0 To nop2 - 1                                                      '48
       session.WriteString("WV " & t(0) & ",1,0," & vd1 & "," & vd2 & "," & nop1 &
"," & idcomp & "," & p_comp & vbLf)
       session.WriteString("DV " & t(1) & ",0" & "," & vg & "," & igcomp & vbLf)
       session.WriteString("TSR" & vbLf)
       session.WriteString("XE" & vbLf)
       For i = 0 To nop1 - 1
          For k = 0 To 2                                                       '54
             ret_val = session.ReadString(16)
             status = Left(ret_val, 1)        'status
             chan = Mid(ret_val, 2, 1)        'channel
             type = Mid(ret_val, 3, 1)        'data type
             rdata = Val(Mid(ret_val, 4, 12)) 'data
             If type = "T" Then tdata = rdata                   'time data
             If type = "I" Then mdata = rdata : mstat = status  'meas data, status
             If type = "V" Then sdata = rdata                   'source data
          Next k                                                               '63
          If mstat <> "N" Then session.WriteString("DZ" & vbLf) : GoTo Check_err
          disp_data = "Vg = " & vg & " (V),  "
          disp_data = disp_data & "Vd = " & sdata & " (V),  "
          disp_data = disp_data & "Id = " & mdata * 1000 & " (mA),  "
          disp_data = disp_data & "Time = " & tdata & " (sec),  "
          disp_data = disp_data & "Status = " & mstat
          Console.WriteLine(disp_data)
          data(j, i) = Chr(13) & Chr(10) & vg & ", " & sdata & ", " & mdata * 1000
& ", " & tdata & ", " & mstat                                                  '71
       Next i
       vg = vg + d_vg
    Next j
```

Line	Description
41 to 44	Declares the variables used to read and save the measurement data.
45 to 46	Declares that a comma is the data terminator needed to read data, and enables it.
49 to 52	Sets the sweep source, applies voltage to device, resets time stamp, and triggers the staircase sweep measurement. Same as the lines 47 to 50 of the previous program.
54 to 63	Reads data and picks up the status, channel, data type, and data. And stores the time data, measurement data, and source data into the variables, *tdata*, *mdata*, and *sdata*.
64	Checks the status of the measurement channel. And applies 0 V and goes to Check_err if an error is detected.
65 to 71	Displays the data on the console window. And stores the data into the *data* array.

```
    session.WriteString("DZ" & vbLf)                                        '76
    save_data(fname, title, value, data, nop1, nop2, session, t)
    Exit Sub

  Check_err:                                                                '80
    session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
End Sub
```

Line	Description
76 to 78	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
80 to 82	Displays a message box to show an error message if the error is detected.

Measurement Result Example

```
Vg (V), Vd (V), Id (mA), Time (sec), Status
1, 0, 0.00011485, 0.0595, N
1, 0.3, 0.02333, 0.09706, N
1, 0.6, 0.02351, 0.12941, N
1, 0.9, 0.023545, 0.16096, N
1, 1.2, 0.02356, 0.19251, N
1, 1.5, 0.02357, 0.22487, N
1, 1.8, 0.02356, 0.25643, N
1, 2.1, 0.02356, 0.28798, N
1, 2.4, 0.02356, 0.31978, N
1, 2.7, 0.02359, 0.35134, N
1, 3, 0.02357, 0.3829, N
2, 0, 0.001744, 0.0327, N
2, 0.3, 2.085, 0.05511, N
2, 0.6, 3.597, 0.07008, N
2, 0.9, 4.5645, 0.08505, N
2, 1.2, 5.0875, 0.10057, N
2, 1.5, 5.3175, 0.11609, N
2, 1.8, 5.4055, 0.131, N
2, 2.1, 5.4445, 0.14653, N
2, 2.4, 5.4725, 0.16147, N
2, 2.7, 5.4925, 0.17629, N
2, 3, 5.512, 0.19182, N
3, 0, 0.002838, 0.04035, N
3, 0.3, 3.445, 0.06253, N
3, 0.6, 6.416, 0.07754, N
3, 0.9, 8.8995, 0.09331, N
3, 1.2, 10.895, 0.10238, N
3, 1.5, 12.425, 0.10732, N
3, 1.8, 13.51, 0.11182, N
3, 2.1, 14.215, 0.11484, N
3, 2.4, 14.63, 0.11813, N
3, 2.7, 14.88, 0.12139, N
3, 3, 15.045, 0.12469, N
Data save completed.
Do you want to perform measurement again?
```

The following program example executes the synchronous sweep measurement using two sweep sources. This example measures MOSFET Id-Vg characteristics.

Table 3-7 Staircase Sweep Measurement Example 3

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)              '1
    Dim i As Integer = 0                          't(0): Drain
    Dim j As Integer = 0                          't(1): Gate
    Dim nop1 As Integer = 11                      't(2): Source
    Dim nop2 As Integer = 1                       't(3): Substrate
    Dim data(nop2 - 1, nop1 - 1) As String
    Dim value As String = "Vg (V), Id (mA), Time (sec), Status"
    Dim fname As String = "C:\Agilent\prog_ex\data5.txt"
    Dim title As String = "Measurement Result"
    Dim msg As String = "No error."
    Dim err As Integer = 0

    Dim vd1 As Double = 0                                                      '13
    Dim vd2 As Double = 2
    Dim idcomp As Double = 0.05
    Dim pd_comp As Double = 0.1
    Dim vg1 As Double = vd1
    Dim vg2 As Double = vd2
    Dim igcomp As Double = 0.01
    Dim pg_comp As Double = 0.05
    Dim hold As Double = 0
    Dim delay As Double = 0
    Dim s_delay As Double = 0
    Dim rep As Integer = nop1
    Dim mret As String                                                         '25
    Dim sc(nop1) As Double
    Dim md(nop1) As Double
    Dim st(nop1) As String
    Dim tm(nop1) As Double
    session.WriteString("FMT 1,1" & vbLf)'ASCII,<CRLF EOI>,w/sweep source data '30
    session.WriteString("TSC 1" & vbLf)       'enables time stamp output
    session.WriteString("FL 0" & vbLf)        'sets filter off
    session.WriteString("AV 10,1" & vbLf)     'sets number of samples for 1 data
    session.WriteString("DV " & t(3) & ",0,0,0.1" & vbLf)   'out= 0 V, comp= 0.1 A
    session.WriteString("DV " & t(2) & ",0,0,0.1" & vbLf)   'out= 0 V, comp= 0.1 A
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 24	Declares variables used to set the source output, and sets the value.
25 to 29	Declares variables used to read the measurement data.
30 to 33	Sets the data output format, time stamp data output mode, SMU filter, and averaging.
34 to 35	Applies voltage to device.

```
    session.WriteString("MM 2," & t(0) & vbLf)    '2: staircase sweep measurement
    session.WriteString("CMM " & t(0) & ",1" & vbLf) '1: current measurement
    session.WriteString("RI " & t(0) & ",0" & vbLf)  '0: auto ranging
    session.WriteString("WT " & hold & "," & delay & "," & s_delay & vbLf)     '40
    session.WriteString("WM 2,1" & vbLf)             'stops any abnormal
    session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
    If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err

    session.WriteString("WV " & t(0) & ",1,0," & vd1 & "," & vd2 & "," & nop1 & ","
& idcomp & "," & pd_comp & vbLf)                                                  '45
    session.WriteString("WSV " & t(1) & ",0," & vg1 & "," & vg2 & "," & igcomp & ","
& pg_comp & vbLf)
    session.WriteString("TSR" & vbLf)
    session.WriteString("XE" & vbLf)
    session.WriteString("*OPC?" & vbLf) : rep = session.ReadString(1 + 2)
    session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
    If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
    session.WriteString("NUB?" & vbLf) : rep = session.ReadString(3 + 2)       '52
    If rep <> nop1 * 3 Then session.WriteString("DZ" & vbLf) : GoTo Check_nop

    mret = session.ReadString(16 * 3 * nop1 + 1)                               '55
    For i = 0 To nop1 - 1
      tm(i) = Val(Mid(mret, 4 + 16 * 3 * i, 12))
      st(i) = Mid(mret, 17 + 16 * 3 * i, 3)
      md(i) = Val(Mid(mret, 20 + 16 * 3 * i, 12))
      sc(i) = Val(Mid(mret, 36 + 16 * 3 * i, 12))
      data(j, i) = Chr(13) & Chr(10) & sc(i) & ", " & md(i) * 1000 & ", " & tm(i) &
", " & st(i)
    Next i

    session.WriteString("DZ" & vbLf)                                           '64
    save_data(fname, title, value, data, nop1, nop2, session, t)
    Exit Sub
```

Line	Description
37 to 39	Sets the measurement mode, channel measurement mode, and measurement range.
40 to 43	Sets the timing parameters and sweep mode of the staircase sweep source. And checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.
45 to 62	Sets the sweep sources, applies voltage to device, resets time stamp, and performs the staircase sweep measurement. And stores the returned data into the *mret* string variable. Finally, stores the measured data into the *data* array.
52 to 53	Checks number of returned data. If it is not correct, forces 0 V and goes to Check_nop.
61	Stores the measured data into the *data* array.
64 to 66	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.

```
  Check_err:                                                             '68
    session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
    Exit Sub

  Check_nop:                                                             '73
    MsgBox("No. of data: " & rep & " (not " & nop1 * 3 & ")", vbOKOnly, "")
End Sub
```

Line	Description
68 to 70	Displays a message box to show an error message if the error is detected.
73 to 74	Displays a message box to show an error message if the number of returned data is not correct.

Measurement Result Example

```
Vg (V), Id (mA), Time (sec), Status
0, -3.685E-10, 5.44653, NEI
0.2, 1.6695E-08, 5.67838, NEI
0.4, 5.2305E-07, 5.77096, NEI
0.6, 1.8995E-05, 5.84304, NEI
0.8, 0.00078485, 5.90087, NEI
1, 0.023885, 5.94082, NEI
1.2, 0.2708, 5.96907, NEI
1.4, 1.035, 5.98927, NEI
1.6, 2.261, 6.00637, NEI
1.8, 3.7695, 6.02346, NEI
2, 5.43, 6.04055, NEI
Data save completed.
Do you want to perform measurement again?
```

Pulsed Sweep Measurements

To perform pulsed sweep measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets series resistor ON/OFF	[SSR]	*chnum*,*mode*
Measurement time	AIT	2,*mode*[,*N*]
Sets pulse timing parameters	PT	*hold*,*width*,*period* [,*tdelay*]
Sets auto abort function	[WM]	*abort*[,*post*]
Sets pulsed sweep source	PWV	*chnum*,*mode*,*range*,*base*,*start*, *stop*, *step*[,*comp*]
	PWI	
Sets synchronous sweep source [a]	[WSV]	*chnum*,*range*,*start*,*stop* [,*comp*[,*Pcomp*]]
	[WSI]	
Forces constant voltage	DV, TDV	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces constant current	DI, TDI	
Sets voltage measurement range	[RV]	*chnum*,*range*
Sets current measurement range	[RI]	*chnum*,*range*
	[RM]	*chnum*,*mode*[,*rate*]
Sets measurement mode	MM	4,*chnum*
Sets SMU operation mode	[CMM]	*chnum*,*mode*
Executes measurement	XE	

a. The WSV/WSI command must be entered after the PWV/PWI command.

A program example of a pulsed sweep measurement is shown below. This example measures the bipolar transistor Ic-Vc characteristics.

Table 3-8 Pulsed Sweep Measurement Example

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)              ’1
    Dim i As Integer = 0                            ’t(0): Emitter
    Dim j As Integer = 0                            ’t(1): Base
    Dim nop1 As Integer = 11                        ’t(2): Collector
    Dim nop2 As Integer = 3                         ’t(3): not use
    Dim data(nop2 - 1, nop1 - 1) As String
    Dim value As String = "Ib (mA), Vc (V), Ic (mA), Time (sec), Status"
    Dim fname As String = "C:\Agilent\prog_ex\data6.txt"
    Dim title As String = "Measurement Result"
    Dim msg As String = "No error."
    Dim err As Integer = 0

    Dim v0 As Double = 0                                                       ’13
    Dim vc1 As Double = 0
    Dim vc2 As Double = 5
    Dim iccomp As Double = 0.05
    Dim ib1 As Double = 0.003
    Dim ib2 As Double = 0.007
    Dim vbcomp As Double = 5
    Dim ib As Double = ib1              ’secondary sweep output value
    Dim d_ib As Double = 0              ’secondary sweep step value (delta)
    If nop2 <> 1 Then d_ib = (ib2 - ib1) / (nop2 - 1)
    Dim hold As Double = 0
    Dim delay As Double = 0
    Dim s_delay As Double = 0
    Dim rep As Integer = nop1
    Dim mret As String                                                         ’27
    Dim sc(nop1) As Double
    Dim md(nop1) As Double
    Dim st(nop1) As String
    Dim tm(nop1) As Double
    session.WriteString("FMT 1,1" & vbLf)   ’ASCII, <CRLF EOI>, w/sweep source data
    session.WriteString("TSC 1" & vbLf)     ’enables time stamp output
    session.WriteString("FL 0" & vbLf)      ’sets filter off
    session.WriteString("AV 10,1" & vbLf)   ’sets number of samples for 1 data
    session.WriteString("CL " & t(3) & vbLf)                                   ’36
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 26	Declares variables used to set the source output, and sets the value.
27 to 31	Declares variables used to read the measurement data.
32 to 35	Sets the data output format, time stamp data output mode, SMU filter, and averaging.
36	Disables SMU assigned to t(3) that is not needed.

```
    session.WriteString("DV " & t(0) & ",0,0,0.1" & vbLf) 'out=0 V, comp=0.1 A '38
    Dim b_pt As String = "0.1,0.01,0.02"       'hold, width, period in sec
    session.WriteString("PT " & b_pt & vbLf)
    session.WriteString("MM 4," & t(2) & vbLf) '4: pulsed sweep measurement
    session.WriteString("CMM " & t(2) & ",1" & vbLf)
    session.WriteString("RI " & t(2) & ",0" & vbLf)
    session.WriteString("WT " & hold & "," & delay & "," & s_delay & vbLf)
    session.WriteString("WM 2,1" & vbLf)             'stops any abnormal
    session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)     '46
    If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err

    For j = 0 To nop2 - 1                                                      '49
      session.WriteString("PWV " & t(2) & ",1,0," & v0 & "," & vc1 & "," & vc2 & ","
& nop1 & "," & iccomp & vbLf)
      session.WriteString("DI " & t(1) & ",0," & ib & "," & vbcomp & vbLf)
      session.WriteString("TSR" & vbLf)
      session.WriteString("XE" & vbLf)
      session.WriteString("*OPC?" & vbLf) : rep = session.ReadString(1 + 2)
      session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
      If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
      session.WriteString("NUB?" & vbLf) : rep = session.ReadString(3 + 2)     '57
      If rep <> nop1 * 3 Then session.WriteString("DZ" & vbLf) : GoTo Check_nop

      mret = session.ReadString(16 * 3 * nop1 + 1)                             '60
      For i = 0 To nop1 - 1
        tm(i) = Val(Mid(mret, 4 + 16 * 3 * i, 12))
        st(i) = Mid(mret, 17 + 16 * 3 * i, 3)
        md(i) = Val(Mid(mret, 20 + 16 * 3 * i, 12))
        sc(i) = Val(Mid(mret, 36 + 16 * 3 * i, 12))
        data(j, i) = Chr(13) & Chr(10) & ib * 1000 & ", " & sc(i) & ", " & md(i) *
1000 & ", " & tm(i) & ", " & st(i)
      Next i
      ib = ib + d_ib
    Next j                                                                     '69
```

Line	Description
38 to 45	Applies voltage to device. And sets the pulse timing parameters, measurement mode, channel measurement mode, measurement range, and sweep mode.
46 to 47	Checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.
49 to 69	Sets the pulsed sweep source, applies voltage to device, resets time stamp, and performs the pulsed sweep measurement. And stores the returned data into the *mret* string variable. Finally, stores the measured data into the *data* array.
57 to 58	Checks number of returned data. If it is not correct, forces 0 V and goes to Check_nop.

```
    session.WriteString("DZ" & vbLf)                                        '71
    save_data(fname, title, value, data, nop1, nop2, session, t)
    Exit Sub

  Check_err:                                                                '75
    session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
    Exit Sub

  Check_nop:                                                                '80
    MsgBox("No. of data: " & rep & " (not " & nop1 * 3 & ")", vbOKOnly, "")
End Sub
```

Line	Description
71 to 72	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
75 to 77	Displays a message box to show an error message if the error is detected.
80 to 81	Displays a message box to show an error message if the number of returned data is not correct.

Measurement Result Example

```
Ib (mA), Vc (V), Ic (mA), Time (sec), Status
3, 0, -0.375, 0.1437, NCI
3, 0.5, 5.28, 0.1637, NCI
3, 1, 5.39, 0.1837, NCI
3, 1.5, 5.48, 0.2037, NCI
3, 2, 5.57, 0.2237, NCI
3, 2.5, 5.66, 0.2437, NCI
3, 3, 5.785, 0.2637, NCI
3, 3.5, 5.97, 0.2837, NCI
3, 4, 6.305, 0.3037, NCI
3, 4.5, 6.895, 0.3237, NCI
3, 5, 7.97, 0.3437, NCI
5, 0, -0.985, 0.12189, NCI
5, 0.5, 9.68, 0.14189, NCI
5, 1, 9.845, 0.16189, NCI
5, 1.5, 9.985, 0.18189, NCI
5, 2, 10.12, 0.20189, NCI
5, 2.5, 10.255, 0.22189, NCI
5, 3, 10.46, 0.24189, NCI
5, 3.5, 10.775, 0.26189, NCI
5, 4, 11.375, 0.28189, NCI
5, 4.5, 12.46, 0.30189, NCI
5, 5, 14.47, 0.32189, NCI
7, 0, -1.565, 0.12387, NCI
7, 0.5, 13.8, 0.14387, NCI
7, 1, 14.005, 0.16387, NCI
7, 1.5, 14.18, 0.18387, NCI
7, 2, 14.34, 0.20387, NCI
7, 2.5, 14.53, 0.22387, NCI
7, 3, 14.785, 0.24387, NCI
7, 3.5, 15.22, 0.26387, NCI
7, 4, 16.045, 0.28387, NCI
7, 4.5, 17.565, 0.30387, NCI
7, 5, 20.355, 0.32387, NCI

Data save completed.

Do you want to perform measurement again?
```

Staircase Sweep with Pulsed Bias Measurements

To perform staircase sweep with pulsed bias measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets series resistor ON/OFF	[SSR]	*chnum*,*mode*
Measurement time	AIT	2,*mode*[,*N*]
Sets auto abort function	[WM]	*abort*[,*post*]
Sets voltage sweep source	WV	*chnum*,*mode*,*range*,*start*,*stop*, *step*[,*comp*[,*Pcomp*]]
Sets current sweep source	WI	
Sets synchronous sweep source [a]	[WSV]	*chnum*,*range*,*start*,*stop* [,*comp*[,*Pcomp*]]
	[WSI]	
Sets pulse timing parameters	PT	*hold*,*width*,*period* [,*tdelay*]
Forces pulse voltage	PV	*chnum*,*range*,*base*,*pulse*[,*comp*]
Forces pulse current	PI	*chnum*,*range*,*base*,*pulse* [,*comp*]
Forces constant voltage	DV, TDV	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces constant current	DI, TDI	
Sets voltage measurement range	[RV]	*chnum*,*range*
Sets current measurement range	[RI]	*chnum*,*range*
	[RM]	*chnum*,*mode*[,*rate*]
Sets measurement mode	MM	5,*chnum*
Sets SMU operation mode	[CMM]	*chnum*,*mode*
Executes measurement	XE	

a. The WSV/WSI command must be entered after the WV/WI command.

A program example of a staircase sweep with pulsed bias measurement is shown below. This example measures the bipolar transistor Ic-Vc characteristics.

Table 3-9 Staircase Sweep with Pulsed Bias Measurement Example

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)              '1
    Dim i As Integer = 0                              't(0): Emitter
    Dim j As Integer = 0                              't(1): Base
    Dim nop1 As Integer = 11                          't(2): Collector
    Dim nop2 As Integer = 3                           't(3): not use
    Dim data(nop2 - 1, nop1 - 1) As String
    Dim value As String = "Ib (mA), Vc (V), Ic (mA), Time (sec), Status"
    Dim fname As String = "C:\Agilent\prog_ex\data7.txt"
    Dim title As String = "Measurement Result"
    Dim msg As String = "No error."
    Dim err As Integer = 0
    Dim vc1 As Double = 0                                                      '12
    Dim vc2 As Double = 5
    Dim iccomp As Double = 0.05
    Dim pccomp As Double = 0.2
    Dim i0 As Double = 0
    Dim ib1 As Double = 0.003
    Dim ib2 As Double = 0.007
    Dim vbcomp As Double = 5
    Dim ib As Double = ib1              'secondary sweep output value
    Dim d_ib As Double = 0              'secondary sweep step value (delta)
    If nop2 <> 1 Then d_ib = (ib2 - ib1) / (nop2 - 1)
    Dim hold As Double = 0
    Dim delay As Double = 0
    Dim s_delay As Double = 0
    Dim rep As Integer = nop1
    Dim mret As String                                                         '27
    Dim sc(nop1) As Double
    Dim md(nop1) As Double
    Dim st(nop1) As String
    Dim tm(nop1) As Double
    session.WriteString("FMT 1,1" & vbLf)   'ASCII, <CRLF EOI>, w/sweep source data
    session.WriteString("TSC 1" & vbLf)     'enables time stamp output
    session.WriteString("FL 0" & vbLf)      'sets filter off
    session.WriteString("AV 10,1" & vbLf)   'sets number of samples for 1 data
    session.WriteString("CL " & t(3) & vbLf)                                   '36
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
12 to 26	Declares variables used to set the source output, and sets the value.
27 to 31	Declares variables used to read the measurement data.
32 to 35	Sets the data output format, time stamp data output mode, SMU filter, and averaging.
36	Disables SMU assigned to t(3) that is not needed.

```
    session.WriteString("DV " & t(0) & ",0,0,0.1" & vbLf)                      '37
    Dim b_pt As String = "0.1,0.01,0.02"       'hold, width, period in sec
    session.WriteString("PT " & b_pt & vbLf)
    session.WriteString("MM 5," & t(2) & vbLf) '5: staircase sweep w/pulsed bias
    session.WriteString("CMM " & t(2) & ",1" & vbLf)
    session.WriteString("RI " & t(2) & ",0" & vbLf)
    session.WriteString("WT " & hold & "," & delay & "," & s_delay & vbLf)
    session.WriteString("WM 2,1" & vbLf)
    session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)     '45
    If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err

    For j = 0 To nop2 - 1                                                      '48
      session.WriteString("WV " & t(2) & ",1,0," & vc1 & "," & vc2 & "," & nop1 &
"," & iccomp & "," & pccomp & vbLf)
      session.WriteString("PI " & t(1) & ",0," & i0 & "," & ib & "," & vbcomp &
vbLf)
      session.WriteString("TSR" & vbLf)
      session.WriteString("XE" & vbLf)
      session.WriteString("*OPC?" & vbLf) : rep = session.ReadString(1 + 2)
      session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
      If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
      session.WriteString("NUB?" & vbLf) : rep = session.ReadString(3 + 2)     '56
      If rep <> nop1 * 3 Then session.WriteString("DZ" & vbLf) : GoTo Check_nop

      mret = session.ReadString(16 * 3 * nop1 + 1)                             '59
      For i = 0 To nop1 - 1
        tm(i) = Val(Mid(mret, 4 + 16 * 3 * i, 12))
        st(i) = Mid(mret, 17 + 16 * 3 * i, 3)
        md(i) = Val(Mid(mret, 20 + 16 * 3 * i, 12))
        sc(i) = Val(Mid(mret, 36 + 16 * 3 * i, 12))
        data(j, i) = Chr(13) & Chr(10) & ib * 1000 & ", " & sc(i) & ", " & md(i) *
1000 & ", " & tm(i) & ", " & st(i)
      Next i
      ib = ib + d_ib
    Next j                                                                     '68
```

Line	Description
37 to 44	Applies voltage to device. And sets the pulse timing parameters, measurement mode, channel measurement mode, measurement range, and sweep mode.
45 to 46	Checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.
48 to 68	Sets the sweep source and the pulsed bias source, resets time stamp, and performs the staircase sweep with pulsed bias measurement. And stores the returned data into the *mret* string variable. Finally, stores the measured data into the *data* array.
56 to 57	Checks number of returned data. If it is not correct, forces 0 V and goes to Check_nop.

```
    session.WriteString("DZ" & vbLf)                                        '70
    save_data(fname, title, value, data, nop1, nop2, session, t)
    Exit Sub

  Check_err:
    session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)  '75
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
    Exit Sub

  Check_nop:
    MsgBox("No. of data: " & rep & " (not " & nop1 * 3 & ")", vbOKOnly, "")    '80
End Sub
```

Line	Description
70 to 72	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
75 to 76	Displays a message box to show an error message if the error is detected.
80	Displays a message box to show an error message if the number of returned data is not correct.

Measurement Result Example

```
Ib (mA), Vc (V), Ic (mA), Time (sec), Status
3, 0, -0.39, 0.14938, NCI
3, 0.5, 5.28, 0.16938, NCI
3, 1, 5.39, 0.18938, NCI
3, 1.5, 5.48, 0.20938, NCI
3, 2, 5.57, 0.22938, NCI
3, 2.5, 5.66, 0.24938, NCI
3, 3, 5.78, 0.26938, NCI
3, 3.5, 5.97, 0.28938, NCI
3, 4, 6.305, 0.30938, NCI
3, 4.5, 6.89, 0.32938, NCI
3, 5, 7.97, 0.34938, NCI
5, 0, -0.98, 0.12291, NCI
5, 0.5, 9.685, 0.14291, NCI
5, 1, 9.845, 0.16291, NCI
5, 1.5, 9.985, 0.18291, NCI
5, 2, 10.12, 0.20291, NCI
5, 2.5, 10.26, 0.22291, NCI
5, 3, 10.455, 0.24291, NCI
5, 3.5, 10.78, 0.26291, NCI
5, 4, 11.37, 0.28291, NCI
5, 4.5, 12.46, 0.30291, NCI
5, 5, 14.47, 0.32291, NCI
7, 0, -1.59, 0.12552, NCI
7, 0.5, 13.795, 0.14552, NCI
7, 1, 14.005, 0.16552, NCI
7, 1.5, 14.18, 0.18552, NCI
7, 2, 14.345, 0.20552, NCI
7, 2.5, 14.53, 0.22552, NCI
7, 3, 14.785, 0.24552, NCI
7, 3.5, 15.22, 0.26552, NCI
7, 4, 16.045, 0.28552, NCI
7, 4.5, 17.56, 0.30552, NCI
7, 5, 20.365, 0.32552, NCI

Data save completed.

Do you want to perform measurement again?
```

Quasi Pulsed Spot Measurements

To perform quasi-pulsed spot measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets series resistor ON/OFF	[SSR]	*chnum*,*mode*
Sets integration time (Agilent B1500 can use AAD/AIT instead of AV.)	[AV]	*number*[,*mode*]
	[AAD]	*chnum*[,*type*]
	[AIT]	*type*,*mode*[,*N*]
Sets detection interval	[BDM]	*interval*[,*mode*]
Sets timing parameters	[BDT]	*hold*,*delay*
Sets quasi-pulsed source	BDV	*chnum*,*range*,*start*,*stop*[,*comp*]
Forces constant voltage	DV, TDV	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces constant current	DI, TDI	
Sets voltage measurement range	[RV]	*chnum*,*range*
Sets current measurement range	[RI]	*chnum*,*range*
	[RM]	*chnum*,*mode*[,*rate*]
Sets measurement mode	MM	9[,*chnum*]
Sets SMU operation mode	[CMM]	*chnum*,*mode*
Executes measurement	XE	

A program example of a spot measurement is shown below. This measures the breakdown voltage of bipolar transistor.

Table 3-10 Quasi Pulsed Spot Measurement Example

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)              '1
    Dim i As Integer = 0                             't(0): Emitter
    Dim j As Integer = 0                             't(1): Base
    Dim nop1 As Integer = 1                          't(2): Collector
    Dim nop2 As Integer = 1                          't(3): not use
    Dim data(nop2 - 1, nop1 - 1) As String
    Dim value As String = "BVceo (V), Status"
    Dim fname As String = "C:\Agilent\prog_ex\data8.txt"
    Dim title As String = "Measurement Result"
    Dim msg As String = "No error."
    Dim err As Integer = 0

    Dim vc1 As Double = 0                                                     '13
    Dim vc2 As Double = 100
    Dim iccomp As Double = 0.005
    Dim hold As Double = 0
    Dim delay As Double = 0
    Dim interval As Double = 0
    Dim mmode As Double = 0
    Dim mrng As Integer = 0

    session.WriteString("FMT 1" & vbLf)                                       '22
    session.WriteString("CL " & t(1) & "," & t(3) & vbLf)
    session.WriteString("MM 9," & t(2) & vbLf)           '9: quasi pulsed spot
    session.WriteString("BDT " & hold & "," & delay & vbLf)
    session.WriteString("BDM " & interval & "," & mmode & vbLf)
    session.WriteString("BDV " & t(2) & "," & mrng & "," & vc1 & "," & vc2 & "," &
iccomp & vbLf)
    session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)     '28
    If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
    session.WriteString("DV " & t(0) & ",0,0,0.1" & vbLf)   'out= 0 V, comp= 0.1 A
    session.WriteString("XE" & vbLf)
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 20	Declares variables, and sets the value.
22 to 23	Sets the data output format. And disables SMUs assigned to t(1) and t(3) that are not needed.
24 to 27	Sets the measurement mode, measurement timing parameters, measurement conditions, and source output conditions.
28 to 29	Checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.
30 to 31	Applies voltage to device, and performs the quasi pulsed spot measurement.

```
    Dim data1 As String = session.ReadString(17)                                    '33
    Dim status As String = Left(data1, 3)
    data1 = Mid(data1, 4, 12)
    Dim meas As Double = Val(data1)
    data(j, i) = Chr(13) & Chr(10) & meas & ", " & status

    session.WriteString("DZ" & vbLf)                                                '39
    save_data(fname, title, value, data, nop1, nop2, session, t)
    Exit Sub

  Check_err:                                                                        '43
    session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
End Sub
```

Line	Description
33 to 37	Reads the returned data and stores it into the *data1* string variable. Finally, stores the measured data into the *data* array.
39 to 41	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
43 to 45	Displays a message box to show an error message if the error is detected.

Measurement Result Example

```
BVceo (V), Status
7.759, CCV

Data save completed.

Do you want to perform measurement again?
```

Linear Search Measurements

To perform linear search measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets series resistor ON/OFF	[SSR]	*chnum*,*mode*
Sets integration time (Agilent B1500 can use AAD/AIT instead of AV.)	[AV]	*number*[,*mode*]
	[AAD]	*chnum*[,*type*]
	[AIT]	*type*,*mode*[,*N*]
Sets measurement mode	MM	14
Selects output data	[LSVM]	*output_data*
Sets timing parameters	[LSTM]	*hold*,*delay*
Sets auto abort function	[LSM]	*abort*[,*post*]
Sets current search or voltage search condition	LGI or LGV	*chnum*,*mode*,*range*,*target*
Sets voltage source or current source	LSV or LSI	*chnum*,*range*,*start*,*stop*,*step* [,*comp*]
Sets synchronous voltage source or current source	[LSSV] or [LSSI]	*chnum*,*polarity*,*offset*[,*comp*]
Forces constant voltage	DV, TDV	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces constant current	DI, TDI	
Executes measurement	XE	

The LSV and LSI commands clear the previous source settings.

Send the LSI command before sending the LSSI command.

Send the LSV command before sending the LSSV command.

The LSI/LSSV commands or LSV/LSSI commands cannot be used together.

A program example of a linear search measurement is shown below. This example measures the MOSFET threshold voltage.

Table 3-11 **Linear Search Measurement Example**

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)                '1
    Dim i As Integer = 0                              't(0): Drain
    Dim j As Integer = 0                              't(1): Gate
    Dim nop1 As Integer = 1                           't(2): Source
    Dim nop2 As Integer = 1                           't(3): Substrate
    Dim data(nop2 - 1, nop1 - 1) As String
    Dim value As String = "Vth (V), Id (mA), Status"
    Dim fname As String = "C:\Agilent\prog_ex\data9.txt"
    Dim title As String = "Measurement Result"
    Dim msg As String = "No error."
    Dim err As Integer = 0

    Dim vd1 As Double = 0                                                       '13
    Dim vd2 As Double = 3
    Dim vdel As Double = 0.01
    Dim idcomp As Double = 0.01
    Dim igcomp As Double = 0.01
    Dim orng As Integer = 12    '12: 20 V limited auto ranging
    Dim mrng As Integer = 13    '13: 100 nA limited auto ranging
    Dim hold As Double = 0
    Dim delay As Double = 0
    Dim judge As Integer = 1    ' 1: result>=target
    Dim tgt As Double = 0.001   ' target current
    Dim posneg As Integer = 1   ' 1: positive
    Dim offset As Double = 0    ' offset voltage

    session.WriteString("FMT 1" & vbLf)                                         '27
    session.WriteString("MM 14" & vbLf)     'linear search measurement
    session.WriteString("LSM 2,3" & vbLf)   'stops by any abnormal
    session.WriteString("LSVM 1" & vbLf)    'returns search data and sense data
    session.WriteString("LSTM " & hold & "," & delay & vbLf)
    session.WriteString("LGI " & t(0) & "," & judge & "," & mrng & "," & tgt & vbLf)
    session.WriteString("LSV " & t(1) & "," & orng & "," & vd1 & "," & vd2 & "," &
vdel & "," & idcomp & vbLf)
    session.WriteString("LSSV " & t(0) & "," & posneg & "," & offset & "," & igcomp
& vbLf)                                                                         '34
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 25	Declares variables, and sets the value.
27 to 28	Sets the data output format and the measurement mode.
29 to 32	Sets the linear search measurement conditions.
33 to 34	Sets the linear search sources, primary source and synchronous source.

```
    session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)     '36
    If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
    session.WriteString("DV " & t(3) & ",0,0,0.1" & vbLf) 'out= 0 V, comp= 0.1 A
    session.WriteString("DV " & t(2) & ",0,0,0.1" & vbLf)
    session.WriteString("XE" & vbLf)                                            '40

    Dim mret As String = session.ReadString(16 + 17)    'data+comma+data+terminator
    Dim dsearch As Double = Val(Mid(mret, 4, 12))
    Dim status As String = Mid(mret, 17, 3)
    Dim dsense As Double = Val(Mid(mret, 20, 12))
    data(j, i) = Chr(13) & Chr(10) & dsearch & ", " & dsense * 1000 & ", " & status

    session.WriteString("DZ" & vbLf)                                            '48
    save_data(fname, title, value, data, nop1, nop2, session, t)
    Exit Sub

  Check_err:                                                                    '52
    session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
End Sub
```

Line	Description
36 to 37	Checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.
38 to 40	Applies voltage to device, and performs the linear search measurement.
42 to 46	Reads the returned data and stores it into the *mret* string variable. Finally, stores the measured data into the *data* array.
48 to 50	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
52 to 54	Displays a message box to show an error message if the error is detected.

Measurement Result Example

```
Vth (V), Id (mA), Status
1.4, 1.03545, NEI

Data save completed.

Do you want to perform measurement again?
```

Binary Search Measurements

To perform binary search measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets series resistor ON/OFF	[SSR]	*chnum*,*mode*
Sets integration time (Agilent B1500 can use AAD/AIT instead of AV.)	[AV]	*number*[,*mode*]
	[AAD]	*chnum*[,*type*]
	[AIT]	*type*,*mode*[,*N*]
Sets measurement mode	MM	15
Selects output data	[BSVM]	*output_data*
Sets timing parameters	[BST]	*hold*,*delay*
Sets source control mode	BSM	*mode*,*abort*[,*post*]
Sets current search or voltage search condition	BGI or BGV	*chnum*,*mode*,*condition*,*range*, *target*
Sets voltage source or current source	BSV or BSI	*chnum*,*range*,*start*,*stop*[,*comp*]
Sets synchronous voltage source or current source	[BSSV] or [BSSI]	*chnum*,*polarity*,*offset*[,*comp*]
Forces constant voltage	DV, TDV	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces constant current	DI, TDI	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Executes measurement	XE	

The BSV and BSI commands clear the previous source settings.

Send the BSI command before sending the BSSI command.

Send the BSV command before sending the BSSV command.

The BSI/BSSV commands or BSV/BSSI commands cannot be used together.

A program example of a binary search measurement is shown below. This example measures the MOSFET threshold voltage.

Table 3-12 Binary Search Measurement Example

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)                 '1
    Dim i As Integer = 0                              't(0): Drain
    Dim j As Integer = 0                              't(1): Gate
    Dim nop1 As Integer = 1                           't(2): Source
    Dim nop2 As Integer = 1                           't(3): Substrate
    Dim data(nop2 - 1, nop1 - 1) As String
    Dim value As String = "Vth (V), Id (mA), Status"
    Dim fname As String = "C:\Agilent\prog_ex\data10.txt"
    Dim title As String = "Measurement Result"
    Dim msg As String = "No error."
    Dim err As Integer = 0

    Dim vd1 As Double = 0                                                        '13
    Dim vd2 As Double = 3
    Dim idcomp As Double = 0.01
    Dim igcomp As Double = 0.01
    Dim orng As Integer = 12        '12: 20 V limited auto ranging
    Dim mrng As Integer = 13        '13: 100 nA limited auto ranging
    Dim hold As Double = 0
    Dim delay As Double = 0
    Dim mode As Integer = 0         ' 0: limit, 1: repeat
    Dim judge As Double = 0.000001  ' limit value in A
    Dim tgt As Double = 0.001       ' target current
    Dim posneg As Integer = 1       ' 1: positive
    Dim offset As Double = 0        ' offset voltage

    session.WriteString("FMT 1" & vbLf)                                          '27
    session.WriteString("MM 15" & vbLf)    'binary search measurement
    session.WriteString("BSM 1,1" & vbLf)  'cautious mode, abort off
    session.WriteString("BSVM 1" & vbLf)   'returns search data and sense data
    session.WriteString("BST " & hold & "," & delay & vbLf)
    session.WriteString("BGI " & t(0) & "," & mode & "," & judge & "," & mrng & ","
& tgt & vbLf)
    session.WriteString("BSV " & t(1) & "," & orng & "," & vd1 & "," & vd2 & "," &
idcomp & vbLf)
    session.WriteString("BSSV " & t(0) & "," & posneg & "," & offset & "," & igcomp
& vbLf)
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 25	Declares variables, and sets the value.
27 to 28	Sets the data output format and the measurement mode.
29 to 32	Sets the binary search measurement conditions.
33 to 34	Sets the binary search sources, primary source and synchronous source.

```
    session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)     '36
    If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
    session.WriteString("DV " & t(3) & ",0,0,0.1" & vbLf)   'out= 0 V, comp= 0.1 A
    session.WriteString("DV " & t(2) & ",0,0,0.1" & vbLf)   'out= 0 V, comp= 0.1 A
    session.WriteString("XE" & vbLf)                                           '40

    Dim mret As String = session.ReadString(16 + 17)    'data+comma+data+terminator
    Dim dsearch As Double = Val(Mid(mret, 4, 12))
    Dim status As String = Mid(mret, 17, 3)
    Dim dsense As Double = Val(Mid(mret, 20, 12))
    data(j, i) = Chr(13) & Chr(10) & dsearch & ", " & dsense * 1000 & ", " & status

    session.WriteString("DZ" & vbLf)                                           '48
    save_data(fname, title, value, data, nop1, nop2, session, t)
    Exit Sub

  Check_err:                                                                   '52
    session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
End Sub
```

Line	Description
36 to 37	Checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.
38 to 40	Applies voltage to device, and performs the binary search measurement.
42 to 46	Reads the returned data and stores it into the *mret* string variable. Finally, stores the measured data into the *data* array.
48 to 50	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
52 to 54	Displays a message box to show an error message if the error is detected.

Measurement Result Example

```
Vth (V), Id (mA), Status
1.393, 1.0004, NEI

Data save completed.

Do you want to perform measurement again?
```

Multi Channel Sweep Measurements

To perform multi channel sweep measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets series resistor ON/OFF	[SSR]	*chnum*,*mode*
Sets integration time (Agilent B1500 can use AAD/AIT instead of AV.)	[AV]	*number*[,*mode*]
	[AAD]	*chnum*[,*type*]
	[AIT]	*type*,*mode*[,*N*]
Sets sweep source timing parameter	[WT]	*hold*,*delay* [,*sdelay*[,*tdelay*[,*mdelay*]]]
Sets auto abort function	[WM]	*abort*[,*post*]
Sets voltage sweep source	WV	*chnum*,*mode*,*range*,*start*,*stop*,*step* [,*comp*[,*Pcomp*]]
Sets current sweep source	WI	
Sets synchronous sweep source [a]	[WNX]	*N*,*chnum*,*mode*,*range*,*start*,*stop* [,*comp*[,*Pcomp*]]
Forces constant voltage	DV, TDV	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces constant current	DI, TDI	
Sets voltage measurement range	[RV]	*chnum*,*range*
Sets current measurement range	[RI]	*chnum*,*range*
	[RM]	*chnum*,*mode*[,*rate*]
Sets measurement mode	MM	16,*chnum*[,*chnum* ... [,*chnum*] ...]
Sets SMU operation mode	[CMM]	*chnum*,*mode*
Executes measurement	XE	

a. The WNX command must be entered after the WV/WI command.

NOTE

Sweep sources simultaneously start output by a trigger such as the XE command. However, if a sweep source sets power compliance or forces logarithmic sweep current, the sweep sources start output in the order specified by the WNX's *N* value. Then the first output is forced by the channel set by the WI or WV command.

If you use multiple measurement channels, the channels that use the high speed ADC with the fixed ranging mode start measurement simultaneously, then other channels start measurement in the order defined in the MM command.

A program example of a multi channel sweep measurement is shown below. This measures the bipolar transistor Ib-Vb and Ic-Vb characteristics simultaneously.

Table 3-13 **Multi Channel Sweep Measurement Example**

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)               '1
    Dim i As Integer = 0                               't(0): Emitter
    Dim j As Integer = 0                               't(1): Base
    Dim nop1 As Integer = 11                           't(2): Collector
    Dim nop2 As Integer = 1                            't(3): not use
    Dim data(nop2 - 1, nop1 - 1) As String
    Dim value As String = "Vb (V), Ib (mA), Tb (sec), Stat_b, Ic (mA), Tc (sec),
Stat_c"
    Dim fname As String = "C:\Agilent\prog_ex\data11.txt"
    Dim title As String = "Measurement Result"
    Dim msg As String = "No error."
    Dim err As Integer = 0

    Dim vc As Double = 3                                                       '13
    Dim vb1 As Double = 0.1
    Dim vb2 As Double = 0.9
    Dim ibcomp As Double = 0.1
    Dim pbcomp As Double = 0.1
    Dim hold As Double = 0
    Dim delay As Double = 0
    Dim s_delay As Double = 0
    Dim rep As Integer = nop1
    Dim mret As String                                                         '22
    Dim sc(nop1) As Double
    Dim md1(nop1) As Double
    Dim st1(nop1) As String
    Dim tm1(nop1) As Double
    Dim md2(nop1) As Double
    Dim st2(nop1) As String
    Dim tm2(nop1) As Double                                                    '29
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 21	Declares variables used to set the source output, and sets the value.
22 to 29	Declares variables used to read the measurement data.

```
    session.WriteString("FMT 1,1" & vbLf)’ASCII,<CRLF EOI>,w/sweep source data ’31
    session.WriteString("TSC 1" & vbLf)  ’enables time stamp output
    session.WriteString("FL 1" & vbLf)   ’sets filter on
    session.WriteString("AV 10,1" & vbLf)’sets number of samples for 1 data
    session.WriteString("MM 16," & t(1) & "," & t(2) & vbLf) ’16: m-ch sweep
    session.WriteString("CMM" & t(1) & ",1" & vbLf)
    session.WriteString("CMM" & t(2) & ",1" & vbLf)
    session.WriteString("RI" & t(1) & ",-19" & vbLf) ’-19: 100 mA fixed range
    session.WriteString("RI" & t(2) & ",-19" & vbLf)
    session.WriteString("WT " & hold & "," & delay & "," & s_delay & vbLf)
    session.WriteString("WM 2,1" & vbLf) ’stops any abnormal
    session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
    If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err         ’43

    session.WriteString("WV" & t(1) & ",1,0," & vb1 & "," & vb2 & "," & nop1 & ","
& ibcomp & "," & pbcomp & vbLf)
    session.WriteString("DV" & t(2) & ",0," & vc & ",0.1" & vbLf)
    session.WriteString("DV" & t(0) & ",0,0,0.1" & vbLf)    ’out= 0 V, comp= 0.1 A
    session.WriteString("TSR" & vbLf)
    session.WriteString("XE" & vbLf)
    session.WriteString("*OPC?" & vbLf) : rep = session.ReadString(1 + 2)      ’50
    session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
    If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
    session.WriteString("NUB?" & vbLf) : rep = session.ReadString(3 + 2)
    If rep <> nop1 * 5 Then session.WriteString("DZ" & vbLf) : GoTo Check_nop

    mret = session.ReadString(16 * 5 * nop1 + 1)                              ’56
```

Line	Description
31 to 43	Sets the data output format, time stamp data output mode, A/D converter, SMU filter, measurement mode, channel measurement mode, and measurement range. Also sets the timing parameters and sweep mode of the staircase sweep source. And checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.
45 to 49	Sets the sweep source, applies voltage to device, resets time stamp, and performs the multi channel sweep measurement.
50 to 54	Waits until the measurement is completed, and checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err. Also checks number of returned data. If it is not correct, forces 0 V and goes to Check_nop.
56	Stores the returned data into the *mret* string variable.

```
    For i = 0 To nop1 - 1                                                      '58
    tm1(i) = Val(Mid(mret, 4 + 16 * 5 * i, 12))
    st1(i) = Mid(mret, 17 + 16 * 5 * i, 3)
    md1(i) = Val(Mid(mret, 20 + 16 * 5 * i, 12))
    tm2(i) = Val(Mid(mret, 36 + 16 * 5 * i, 12))
    st2(i) = Mid(mret, 49 + 16 * 5 * i, 3)
    md2(i) = Val(Mid(mret, 52 + 16 * 5 * i, 12))
    sc(i) = Val(Mid(mret, 68 + 16 * 5 * i, 12))
    data(j, i) = Chr(13) & Chr(10) & sc(i) & ", " & md1(i) * 1000 & ", " & tm1(i) &
", " & st1(i) & ", " & md2(i) * 1000 & ", " & tm2(i) & ", " & st2(i)
    Next

    session.WriteString("DZ" & vbLf)                                           '69
    save_data(fname, title, value, data, nop1, nop2, session, t)
    Exit Sub

  Check_err:                                                                   '73
    session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
    Exit Sub

  Check_nop:
    MsgBox("No. of data: " & rep & " (not " & nop1 * 5 & ")", vbOKOnly, "")    '79
End Sub
```

Line	Description
58 to 67	Picks the measurement data out and stores it into the *data* array.
69 to 71	Applies 0 V from all channels and transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
73 to 79	Displays a message box to show an error message if the error is detected. Also displays a message box to show an error message if the number of returned data is not correct.

Measurement Result Example

```
Vb (V), Ib (mA), Tb (sec), Stat_b, Ic (mA), Tc (sec), Stat_c
0.1, 0.01, 0.02949, NDI, -0.025, 0.02949, NCI
0.18, 0.01, 0.03788, NDI, -0.03, 0.03788, NCI
0.26, 0.01, 0.04628, NDI, -0.03, 0.04628, NCI
0.34, 0.01, 0.05468, NDI, -0.025, 0.05468, NCI
0.42, 0.01, 0.06308, NDI, -0.025, 0.06308, NCI
0.5, 0.02, 0.07148, NDI, -0.025, 0.07148, NCI
0.58, 0.105, 0.07987, NDI, 0.005, 0.07987, NCI
0.66, 0.585, 0.08825, NDI, 0.5, 0.08825, NCI
0.74, 2.635, 0.09664, NDI, 4.885, 0.09664, NCI
0.82, 9.96, 0.10505, NDI, 20.5, 0.10505, NCI
0.9, 27.84, 0.11345, NDI, 45.75, 0.11345, NCI
Data save completed.
Do you want to perform measurement again?
```

Multi Channel Pulsed Spot Measurements

To perform multi channel pulsed spot measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets series resistor ON/OFF	[SSR]	*chnum*,*mode*
Measurement time	[AIT]	2,*mode*[,*N*]
Sets pulse common parameters	MCPT	*hold*[,*period*[,*Mdelay* [,*average*]]]
Sets pulse timing parameters	MCPNT	*chnum*,*delay*,*width*
Sets pulse output	MCPNX	*N*,*chnum*,*mode*,*range*,*base*,*pulse* [,*comp*]
Forces constant voltage	DV, TDV	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces constant current	DI, TDI	
Sets voltage measurement range	[RV]	*chnum*,*range*
Sets current measurement range	[RI]	*chnum*,*range*
	[RM]	*chnum*,*mode*[,*rate*]
Sets measurement mode	MM	27,*chnum*[,*chnum* ...[,*chnum*] ...]
Sets SMU operation mode	[CMM]	*chnum*,*mode*
Executes measurement	XE	

A program example of a multi channel pulsed spot measurement is shown below. This example measures MOSFET drain current and gate current simultaneously.

Table 3-14 Multi Channel Pulsed Spot Measurement Example

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)               ’1
    Dim i As Integer = 0                         ’t(0): Drain
    Dim j As Integer = 0                         ’t(1): Gate
    Dim nop1 As Integer = 1                      ’t(2): Source
    Dim nop2 As Integer = 1                      ’t(3): Substrate
    Dim data(nop2 - 1, nop1 - 1) As String
    Dim value As String = "Id (uA), Stat, Time (msec),Ig (uA), Stat, Time (msec)"
    Dim fname As String = "C:\Agilent\prog_ex\data30.txt"
    Dim title As String = "Measurement Result"
    Dim msg As String = "No error."
    Dim err As Integer = 0

    Dim vd As Double = 3                                                        ’13
    Dim vg As Double = 1
    Dim idcomp As Double = 0.05
    Dim igcomp As Double = 0.01
    Dim orng As Integer = 0
    Dim mrng As Integer = 0
    Dim mtm As Double = 0.01                      ’measurement time in sec
    Dim pcom As String = "0.1,0.05,0.01"          ’hold,period,Mdelay in sec
    Dim g_pt As String = ",0,0.03"                ’gate delay,width in sec
    Dim d_pt As String = ",0,0.03"                ’drain delay,width in sec
    session.WriteString("FMT 1" & vbLf)                                         ’23
    session.WriteString("TSC 1" & vbLf)           ’enables time stamp output
    session.WriteString("FL 0" & vbLf)            ’sets filter off
    session.WriteString("AIT 2,3," & mtm & vbLf)  ’sets measurement time
    session.WriteString("MCPT " & pcom & vbLf)                                  ’27
    session.WriteString("MCPNT " & t(1) & g_pt & vbLf)
    session.WriteString("MCPNX 2," & t(1) & ",1," & orng & ",0," & vg & "," &
igcomp & vbLf)
    session.WriteString("MCPNT " & t(0) & d_pt & vbLf)
    session.WriteString("MCPNX 1," & t(0) & ",1," & orng & ",0," & vd & "," &
idcomp & vbLf)
    session.WriteString("DV " & t(3) & ",0,0,0.1" & vbLf)   ’out= 0 V, comp= 0.1 A
    session.WriteString("DV " & t(2) & ",0,0,0.1" & vbLf)   ’out= 0 V, comp= 0.1 A
    session.WriteString("MM27," & t(0) & "," & t(1) & vbLf) ’multi ch pulsed spot
    session.WriteString("CMM " & t(0) & ",1" & vbLf)   ’1: current measurement
    session.WriteString("RI " & t(0) & "," & mrng & vbLf)                       ’36
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 22	Declares variables and sets the value.
23 to 26	Sets the data output format, time data output mode, SMU filter, and measurement time.
27 to 33	Sets the voltage pulse sources, and applies DC voltage to device.
34 to 36	Sets the measurement mode, channel measurement mode, and measurement range.

```
    session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)     '38
    If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err

    session.WriteString("TSR" & vbLf)
    session.WriteString("XE" & vbLf)
    Dim mret As String = session.ReadString(16 + 16)   'data+comma+data+comma
    Dim mret1 As String = session.ReadString(16 + 17)  'data+comma+data+terminator
    Dim mtime As Double = Val(Mid(mret, 4, 12))
    Dim status As String = Mid(mret, 17, 3)
    Dim meas As Double = Val(Mid(mret, 20, 12))
    Dim mtime1 As Double = Val(Mid(mret1, 4, 12))
    Dim status1 As String = Mid(mret1, 17, 3)
    Dim meas1 As Double = Val(Mid(mret1, 20, 12))

    data(j, i) = Chr(13) & Chr(10) & meas * 1000000 & ", " & status & ", " & mtime
* 1000 & ", " & meas1 * 1000000 & ", " & status1 & ", " & mtime1 * 1000

    session.WriteString("DZ" & vbLf)                                            '54
    save_data(fname, title, value, data, nop1, nop2, session, t)
    Exit Sub

  Check_err:                                                                    '58
    session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
End Sub
```

Line	Description
38 to 39	Checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.
41 to 52	Resets time stamp and performs measurement. And stores the returned data into the *mret* and *tret* string variables. Finally, stores the measured data into the *data* array.
54 to 56	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
59 to 60	Displays a message box to show an error message if the error is detected.

Measurement Result Example

```
Id (uA), Stat, Time (msec),Ig (uA), Stat, Time (msec)
45, NEI, 160.44, 0, NDI, 160.44

Data save completed.

Do you want to perform measurement again?
```

Multi Channel Pulsed Sweep Measurements

To perform multi channel pulsed sweep measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets series resistor ON/OFF	[SSR]	*chnum*,*mode*
Measurement time	[AIT]	2,*mode*[,*N*]
Sets auto abort function	[WM]	*abort*[,*post*]
Sets pulse common parameters	MCPT	*hold*[,*period*[,*Mdelay* [,*average*]]]
Sets pulse timing parameters	MCPNT	*chnum*,*delay*,*width*
Sets sweep mode and steps	MCPWS	*mode*,*numberOfSteps*
Sets pulsed sweep output	MCPWNX	*N*,*chnum*,*mode*,*range*,*base*,*start*,*stop*[,*comp*[,*Pcomp*]]
Sets pulse output	[MCPNX]	*N*,*chnum*,*mode*,*range*,*base*,*pulse* [,*comp*]
Sets synchronous staircase sweep source	[WNX]	*N*,*chnum*,*mode*,*range*,*start*,*stop* [,*comp*[,*Pcomp*]]
Forces constant voltage	DV, TDV	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces constant current	DI, TDI	
Sets voltage measurement range	[RV]	*chnum*,*range*
Sets current measurement range	[RI]	*chnum*,*range*
	[RM]	*chnum*,*mode*[,*rate*]
Sets measurement mode	MM	28,*chnum*[,*chnum* ...[,*chnum*] ...]
Sets SMU operation mode	[CMM]	*chnum*,*mode*
Executes measurement	XE	

NOTE

By a trigger such as the XE command, the source channels set by the WNX commands start output in the order specified by the *N* value, and then the source channels set by the MCPNX and MCPWNX commands start output simultaneously.

If you use multiple measurement channels, all measurement channels start measurement simultaneously.

A program example of a multi channel pulsed sweep measurement is shown below. This measures the bipolar transistor Ib-Vb and Ic-Vb characteristics simultaneously.

Table 3-15 Multi Channel Pulsed Sweep Measurement Example

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)              '1
    Dim i As Integer = 0                              't(0): Emitter
    Dim j As Integer = 0                              't(1): Base
    Dim nop1 As Integer = 11                          't(2): Collector
    Dim nop2 As Integer = 1                           't(3): not use
    Dim data(nop2 - 1, nop1 - 1) As String
    Dim value As String = "Vb (V), Ib (mA), Tb (sec), Stat_b, Ic (mA), Tc (sec),
Stat_c"
    Dim fname As String = "C:\Agilent\prog_ex\data31.txt"
    Dim title As String = "Measurement Result"
    Dim msg As String = "No error."
    Dim err As Integer = 0

    Dim vc As Double = 3                                                       '13
    Dim vb1 As Double = 0.1
    Dim vb2 As Double = 0.9
    Dim ibcomp As Double = 0.1
    Dim iccomp As Double = 0.5
    Dim rep As Integer = nop1
    Dim mret As String                                                         '19
    Dim sc(nop1) As Double
    Dim md1(nop1) As Double
    Dim st1(nop1) As String
    Dim tm1(nop1) As Double
    Dim md2(nop1) As Double
    Dim st2(nop1) As String
    Dim tm2(nop1) As Double                                                    '26
    Dim mtm As Double = 0.001                      'measurement time in sec
    Dim pcom As String = "0,0.01,0.001"            'hold,period,Mdelay in sec
    Dim b_pt As String = ",0,0.005"                'base delay,width in sec
    Dim c_pt As String = ",0,0.005"                 'collector delay,width in sec
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 18	Declares variables used to set the source output, and sets the value.
19 to 26	Declares variables used to read the measurement data.
27 to 30	Declares variables used to set the pulse and measurement timing, and sets the value.

```
    session.WriteString("FMT 1,1" & vbLf)'ASCII,<CRLF EOI>,w/sweep source data '31
    session.WriteString("TSC 1" & vbLf)  'enables time stamp output
    session.WriteString("FL 0" & vbLf)   'sets filter off
    session.WriteString("AIT 2,3," & mtm & vbLf)   'sets measurement time
    session.WriteString("MCPT " & pcom & vbLf)
    session.WriteString("MCPNT " & t(1) & b_pt & vbLf)
    session.WriteString("MCPNT " & t(2) & c_pt & vbLf)
    session.WriteString("MM 28," & t(1) & "," & t(2) & vbLf) '28: m-ch p-sweep
    session.WriteString("CMM" & t(1) & ",1" & vbLf)
    session.WriteString("CMM" & t(2) & ",1" & vbLf)
    session.WriteString("RI" & t(1) & ",0" & vbLf)          '0: auto range
    session.WriteString("RI" & t(2) & ",0" & vbLf)
    session.WriteString("WM 2,1" & vbLf) 'stops any abnormal
    session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
    If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err         '45

    session.WriteString("MCPWS 1," & nop1 & vbLf)
    session.WriteString("MCPWNX 1," & t(1) & ",1,0,0," & vb1 & "," & vb2 & "," &
ibcomp & vbLf)
    session.WriteString("MCPNX 2," & t(2) & ",1,0,0," & vc & "," & iccomp & vbLf)
    session.WriteString("DV" & t(0) & ",0,0,0.1" & vbLf)    'out= 0 V, comp= 0.1 A
    session.WriteString("TSR" & vbLf)
    session.WriteString("XE" & vbLf)
    session.WriteString("*OPC?" & vbLf) : session.Timeout = 10000 : rep =
session.ReadString(1 + 2)
    session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
    If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
    session.WriteString("NUB?" & vbLf) : rep = session.ReadString(3 + 2)
    If rep <> nop1 * 5 Then session.WriteString("DZ" & vbLf) : GoTo Check_nop

    mret = session.ReadString(16 * 5 * nop1 + 1)                               '59
```

Line	Description
31 to 45	Sets the data output format, time data output mode, SMU filter, measurement time, pulse time parameters, measurement mode, channel measurement mode, and measurement range. Also sets the automatic sweep abort function. And checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.
47 to 53	Sets the pulsed sweep source, sets the pulsed bias source, applies voltage to device, resets time stamp, and performs measurement.
54 to 57	Waits until the measurement is completed, and checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err. Also checks number of returned data. If it is not correct, forces 0 V and goes to Check_nop.
59	Stores the returned data into the *mret* string variable.

```
    For i = 0 To nop1 - 1                                                       '61
      tm1(i) = Val(Mid(mret, 4 + 16 * 5 * i, 12))
      st1(i) = Mid(mret, 17 + 16 * 5 * i, 3)
      md1(i) = Val(Mid(mret, 20 + 16 * 5 * i, 12))
      tm2(i) = Val(Mid(mret, 36 + 16 * 5 * i, 12))
      st2(i) = Mid(mret, 49 + 16 * 5 * i, 3)
      md2(i) = Val(Mid(mret, 52 + 16 * 5 * i, 12))
      sc(i) = Val(Mid(mret, 68 + 16 * 5 * i, 12))
      data(j, i) = Chr(13) & Chr(10) & sc(i) & ", " & md1(i) * 1000 & ", " & tm1(i)
& ", " & st1(i) & ", " & md2(i) * 1000 & ", " & tm2(i) & ", " & st2(i)
    Next

    session.WriteString("DZ" & vbLf)                                            '72
    save_data(fname, title, value, data, nop1, nop2, session, t)
    Exit Sub

  Check_err:                                                                    '76
    session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
    Exit Sub

  Check_nop:
    MsgBox("No. of data: " & rep & " (not " & nop1 * 5 & ")", vbOKOnly, "")    '82
End Sub
```

Line	Description
61 to 70	Picks the measurement data out and stores it into the *data* array.
72 to 74	Applies 0 V from all channels and transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
76 to 82	Displays a message box to show an error message if the error is detected. Also displays a message box to show an error message if the number of returned data is not correct.

Measurement Result Example

```
Vb (V), Ib (mA), Tb (sec), Stat_b, Ic (mA), Tc (sec), Stat_c
0.1, 0, 0.05717, NDI, -0.005, 0.05717, NCI
0.18, 0, 0.06927, NDI, -0.005, 0.06927, NCI
0.26, 0, 0.08134, NDI, -0.005, 0.08134, NCI
0.34, 0, 0.09343, NDI, -0.005, 0.09343, NCI
0.42, 0, 0.10551, NDI, -0.005, 0.10551, NCI
0.5, 0, 0.11759, NDI, 0.005, 0.11759, NCI
0.58, 0, 0.12966, NDI, 0.215, 0.12966, NCI
0.66, 0.045, 0.14173, NDI, 3.815, 0.14173, NCI
0.74, 0.385, 0.15382, NDI, 22.63, 0.15382, NCI
0.82, 2.225, 0.1659, NDI, 51.03, 0.1659, NCI
0.9, 7.86, 0.17795, NDI, 87.535, 0.17795, NCI
Data save completed.
Do you want to perform measurement again?
```

Sampling Measurements

To make sampling measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets series resistor ON/OFF	[SSR]	*chnum*,*mode*
Sets integration time (Agilent B1500 can use AAD/AIT instead of AV.)	[AV]	*number*[,*mode*]
	[AAD]	*chnum*[,*type*]
	[AIT]	*type*,*mode*[,*N*]
Sets sampling mode	[ML]	*mode*
Sets timing parameters	MT	*h_bias*,*interval*,*points*[,*h_base*]
Sets constant voltage source	MV	*chnum*,*range*,*base*,*bias*[,*comp*]
Sets constant current source	MI	
Sets pulse voltage source	MSP	*chnum*[,*post*[,*base*]]
Clears sampling source setup	[MCC]	[*chnum* ... [,*chnum*] ...]
Sets automatic abort function	[MSC]	*abort*[,*post*]
Forces constant voltage	[DV, TDV]	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces constant current	[DI, TDI]	
Sets voltage measurement range	[RV]	*chnum*,*range*
Sets current measurement range	[RI]	*chnum*,*range*
	[RM]	*chnum*,*mode*[,*rate*]
Sets measurement mode	MM	10,*chnum*[,*chnum* ..[,*chnum*] ..]
Sets SMU measurement mode	[CMM]	*chnum*,*mode*
Executes measurement	XE	

Table 3-16 explains example subprogram that performs linear sampling measurement. This example measures current that flows to resistors R1 and R2, and then calculates the resistance.

Table 3-16 Sampling Measurement Example

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)          '1
 Dim i As Integer = 0                           't(0): Low1
 Dim j As Integer = 0                           't(1): High1
 Dim nop1 As Integer = 30                       't(2): High2
 Dim nop2 As Integer = 1                        't(3): Low2
 Dim data(nop2 - 1, nop1 - 1) As String
 Dim value As String = "Index, I1 (mA), R1 (ohm), St1, I2 (mA), R2 (ohm), St2"
 Dim fname As String = "C:\Agilent\prog_ex\data17.txt"
 Dim title As String = "Sampling Measurement Result"
 Dim msg As String = "No error."
 Dim err As Integer = 0

 Dim base As Double = 0                                                    '13
 Dim bias As Double = 0.1
 Dim icomp As Double = 0.1
 Dim vlout As Double = 0
 Dim ilcomp As Double = 0.1
 Dim base_h As Double = 0
 Dim bias_h As Double = 0.1
 Dim interval As Double = 0.05
 Dim mch() As Integer = {t(1), t(2), 0}
 Dim range() As Double = {0, 0}
 Dim rep As Integer = nop1
 Dim mret As String                                                        '24
 Dim id(nop1) As Double
 Dim d1(nop1) As Double
 Dim d2(nop1) As Double
 Dim r1(nop1) As Double
 Dim r2(nop1) As Double
 Dim s1(nop1) As String
 Dim s2(nop1) As String                                                    '31

 session.WriteString("FMT 1,1" & vbLf) 'ASCII, <CRLF EOI>, w/sweep source data
 session.WriteString("FL 1" & vbLf)    'sets filter on
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 23	Declares variables used to set the source output, and sets the value.
24 to 31	Declares variables used to read the measurement data.
33	Sets the data output format. The source output data will be also returned.
34	Sets the SMU filter on.

```
session.WriteString("AAD " & t(1) & ", 1" & vbLf) ’sets HR ADC for t(1)       ’36
session.WriteString("AAD " & t(2) & ", 1" & vbLf) ’sets HR ADC for t(2)
session.WriteString("AIT 1,1,2" & vbLf) ’number of averaging samples for 1 data
session.WriteString("AZ 0" & vbLf)      ’sets auto zero off                  ’39
session.WriteString("MT " & bias_h & "," & interval & "," & nop1 & "," & base_h &
vbLf)
session.WriteString("MV " & t(1) & ",0," & base & "," & bias & "," & icomp & vbLf)
session.WriteString("MV " & t(2) & ",0," & base & "," & bias & "," & icomp & vbLf)
session.WriteString("MM 10," & mch(0) & "," & mch(1) & vbLf)
session.WriteString("RI " & mch(0) & "," & range(0) & vbLf)
session.WriteString("RI " & mch(1) & "," & range(1) & vbLf)
session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err          ’47
session.WriteString("DV " & t(0) & ",0," & vlout & "," & ilcomp & ", 0" & vbLf)
session.WriteString("DV " & t(3) & ",0," & vlout & "," & ilcomp & ", 0" & vbLf)
session.WriteString("TSR" & vbLf)
session.WriteString("XE" & vbLf)

session.WriteString("*OPC?" & vbLf) : rep = session.ReadString(1 + 2)        ’53
session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
session.WriteString("NUB?" & vbLf) : rep = session.ReadString(3 + 2)
If rep <> nop1 * 3 Then session.WriteString("DZ") : GoTo Check_nop
```

Line	Description
36 to 38	Sets the A/D converter.
39	Sets the SMU auto zero function off.
40 to 42	Sets the sampling timing parameters and the constant voltage sources.
43 to 47	Sets the sampling measurement mode, and sets the current measurement range. And checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.
48 to 51	Applies 0 V to the device low terminal, resets the time stamp, and performs the sampling measurement.
53 to 57	Waits until the measurement is completed, and checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err. Also checks number of returned data. If it is not correct, forces 0 V and goes to Check_nop.

```
 mret = session.ReadString(16 * 3 * nop1 + 1)                                   '59
 For i = 0 To nop1 - 1
   id(i) = Val(Mid(mret, 4 + 16 * 3 * i, 12))
   d1(i) = Val(Mid(mret, 16 + 4 + 16 * 3 * i, 12))
   d2(i) = Val(Mid(mret, 16 * 2 + 4 + 16 * 3 * i, 12))
   s1(i) = Mid(mret, 16 + 1 + 16 * 3 * i, 3)
   s2(i) = Mid(mret, 16 * 2 + 1 + 16 * 3 * i, 3)
   r1(i) = Math.Round(bias / d1(i), 3)
   r2(i) = Math.Round(bias / d2(i), 3)
   data(j, i) = Chr(13) & Chr(10) & id(i) & ", " & d1(i) * 1000 & ", " & r1(i) & ",
" & s1(i) & ", " & d2(i) * 1000 & ", " & r2(i) & ", " & s2(i)
 Next i

 session.WriteString("DZ" & vbLf)                                               '71
 save_data(fname, title, value, data, nop1, nop2, session, t)
 Exit Sub

Check_err:                                                                      '75
 session.WriteString("EMG? " & err) : msg = session.ReadString(256)
 MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
 Exit Sub

Check_nop:                                                                      '80
 MsgBox("No. of data: " & rep & " (not " & nop1 * 3 & ")", vbOKOnly, "")
End Sub
```

Line	Description
59 to 69	Reads the returned data and stores it into the *mret* string variable. Finally, stores the measured data into the *data* array.
71 to 73	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
74 to 78	Displays a message box to show an error message if the error is detected.
80 to 81	Displays a message box to show an error message if the number of returned data is not correct (nop1).

Measurement Result Example

```
Index, I1 (mA), R1 (ohm), St1, I2 (mA), R2 (ohm), St2
1, 69.17, 1.446, NDI, 66, 1.515, NCI
2, 69.18, 1.446, NDI, 66.03, 1.514, NCI
3, 69.18, 1.446, NDI, 66.03, 1.514, NCI
4, 69.15, 1.446, NDI, 66.02, 1.515, NCI
5, 69.16, 1.446, NDI, 66, 1.515, NCI
6, 69.16, 1.446, NDI, 66.01, 1.515, NCI
7, 69.16, 1.446, NDI, 66.02, 1.515, NCI
8, 69.19, 1.445, NDI, 66.01, 1.515, NCI
9, 69.16, 1.446, NDI, 66.03, 1.514, NCI
10, 69.15, 1.446, NDI, 66.02, 1.515, NCI
11, 69.17, 1.446, NDI, 66.02, 1.515, NCI
12, 69.17, 1.446, NDI, 66.02, 1.515, NCI
13, 69.15, 1.446, NDI, 66.03, 1.514, NCI
14, 69.17, 1.446, NDI, 66.01, 1.515, NCI
15, 69.17, 1.446, NDI, 66.02, 1.515, NCI
16, 69.16, 1.446, NDI, 66.05, 1.514, NCI
17, 69.16, 1.446, NDI, 66.01, 1.515, NCI
18, 69.17, 1.446, NDI, 66, 1.515, NCI
19, 69.15, 1.446, NDI, 65.99, 1.515, NCI
20, 69.17, 1.446, NDI, 66.01, 1.515, NCI
21, 69.17, 1.446, NDI, 66.02, 1.515, NCI
22, 69.15, 1.446, NDI, 66.03, 1.514, NCI
23, 69.18, 1.446, NDI, 66.02, 1.515, NCI
24, 69.16, 1.446, NDI, 66.03, 1.514, NCI
25, 69.18, 1.446, NDI, 66.03, 1.514, NCI
26, 69.16, 1.446, NDI, 66.03, 1.514, NCI
27, 69.16, 1.446, NDI, 66.02, 1.515, NCI
28, 69.17, 1.446, NDI, 66.03, 1.514, NCI
29, 69.18, 1.446, NDI, 66, 1.515, NCI
30, 69.16, 1.446, NDI, 66.04, 1.514, NCI
Data save completed.
Do you want to perform measurement again?
```

Quasi-static CV Measurements

To make quasi-static CV measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets QSCV operation mode	[QSC]	*mode*
Sets offset cancel ON/OFF or performs capacitance offset measurement	[QSZ]	*mode*
Sets voltage sweep source	QSV	*chnum*,*mode*,*vrange*,*start*,*stop* ,*cvoltage*,*step*[,*Icomp*]
Sets time parameters	QST	*cinteg*,*linteg*,*hold*,*delay1*[,*delay2*]
Sets leak current data output and compensation ON/OFF	[QSL]	*data*,*compen*
Sets measurement range	[QSR]	*range*
Sets QSCV smart operation	[QSO]	*mode*[,*chnum*[,*Vcomp*]]
Sets automatic abort function	[QSM]	*abort*[,*post*]
Sets measurement mode	MM	13[,*chnum*]
Forces constant voltage	[DV, TDV]	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces constant current	[DI, TDI]	
Executes measurement	XE	

A program example of quasi-static CV measurement is shown below. This example measures the gate capacitance of MOSFET. This program example uses three SMUs directly connected to the DUT and a SMU connected to the DUT through the SMU/CMU unify unit (SCUU).

Table 3-17 **Quasi-static CV Measurement Example**

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)              '1
 Dim i As Integer = 0                                     't(0): Drain
 Dim j As Integer = 0                                     't(1): Gate
 Dim nop1 As Integer = 1                                  't(2): Source
 Dim nop2 As Integer = 1                                  't(3): Substrate
 Dim value As String = "Vg (V), Cgb (pF), C-status, Ileak (pA), I-status, Time
(sec)"
 Dim fname As String = "C:\Agilent\prog_ex\data21.txt"
 Dim title As String = "QSCV Measurement Result"
 Dim msg As String = "No error."
 Dim err As Integer = 0

 Dim vg1 As Double = 3.2                                                        '12
 Dim vg2 As Double = -7.2
 Dim vstep As Double = 0.2
 Dim gstep As Integer = Math.Round(Math.Abs(vg2 - vg1) / Math.Abs(vstep)) - 1
 Dim cvoltage As Double = 0.25
 Dim icomp As Double = 0.1
 Dim swp As Integer = 1
 Dim hold As Double = 5
 Dim delay1 As Double = 0.0
 Dim delay2 As Double = 0.0
 Dim cinteg As Double = 0.1
 Dim linteg As Double = 0.1
 Dim range As Integer = -10
 nop1 = gstep
 Dim data(nop2-1, nop1-1) As String                                             '26
 Dim rep As Integer
 Dim mret As String
 Dim sc(nop1) As Double
 Dim md1(nop1) As Double
 Dim st1(nop1) As String
 Dim md2(nop1) As Double
 Dim st2(nop1) As String
 Dim tm(nop1) As Double                                                         '34
```

Line	Description
2 to 10	Declares variables used through the project. And sets the proper values.
12 to 25	Declares variables used to set the source output, and sets the value.
26 to 34	Declares variables used to read the measurement data.

```
 session.Timeout = 60000                             'timeout = 60 seconds     '36

 session.WriteString("FMT 1,1" & vbLf)
 session.WriteString("TSC 1" & vbLf)                 'enables time stamp output

 session.WriteString("MM 13," & t(1) & vbLf)         'QSCV measurement         '41
 session.WriteString("QSC 0" & vbLf)                 'Normal QSCV operation
 session.WriteString("QSL 1,1" & vbLf)               'Ileak DataOn, CompenOn
 session.WriteString("QSM 2,1" & vbLf)               'AbortOn, StartValue
 session.WriteString("QSR " & range & vbLf)
 session.WriteString("QST " & cinteg & "," & linteg & "," & hold & "," & delay1 &
"," & delay2 & vbLf)
 session.WriteString("QSV " & t(1) & "," & swp & ",0," & vg1 & "," & vg2 & "," &
cvoltage & "," & gstep & "," & icomp & vbLf)
 session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
 If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err

 session.WriteString("QSZ 0" & vbLf)                                           '51

 Dim rbx As Integer
 rbx = MsgBox("Do you want to perform offset cancel?", vbYesNo, "")
 If rbx = vbYes Then
  MsgBox("Open measurement terminal.  Then click OK.", vbOKOnly, "")
  Console.WriteLine("Wait a minute . . ." & Chr(10))
  session.WriteString("QSZ 2" & vbLf)
  session.WriteString("*OPC?" & vbLf) : rep = session.ReadString(1 + 2)
  session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
  If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
  mret = session.ReadString(16 + 2)
  md1(0) = Val(Mid(mret, 4, 12))
  Console.WriteLine("Offset data = " & md1(0) * 1000000000000.0 & "pF" & Chr(10))
  MsgBox("Offset data = " & md1(0) * 1000000000000.0 & "pF", vbOKOnly, "")
  session.WriteString("QSZ 1" & vbLf)
 End If                                                                        '67
```

Line	Description
38 to 39	Sets the data output format and the time stamp data output mode.
41 to 49	Sets the quasi-static CV measurement condition. And checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.
51	Sets the capacitance offset cancel to OFF.
53 to 67	Displays a message box that asks if you perform the offset cancel. If you click Yes, the program displays a message box that prompts you to open the measurement terminals. Clicking OK starts the offset measurement. After the measurement, the offset data is displayed on the console window and the message box. Finally, the capacitance offset cancel is set to ON.

```
 MsgBox("Connect DUT.  Then click OK.", vbOKOnly, "")                         '69
 Console.WriteLine("Wait a minute . . ." & Chr(10))
 session.WriteString("DV " & t(0) & ",0,0,0.1,0" & vbLf)    'Drain
 session.WriteString("DV " & t(2) & ",0,0,0.1,0" & vbLf)    'Source
 session.WriteString("DV " & t(3) & ",0,0,0.1,0" & vbLf)    'Substrate
 session.WriteString("TSR" & vbLf)
 session.WriteString("XE" & vbLf)

 session.WriteString("*OPC?" & vbLf) : rep = session.ReadString(1 + 2)         '77
 session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
 If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
 session.WriteString("NUB?" & vbLf) : rep = session.ReadString(3 + 2)
 If rep <> nop1 * 4 Then session.WriteString("DZ" & vbLf) : GoTo Check_nop

 mret = session.ReadString(16 * 4 * nop1 + 2)    '4*nop1 data + terminator     '83

 For i = 0 To nop1 - 1
   st1(i) = Mid(mret, i * 16 * 4 + 16 * 1 + 1, 3)
   st2(i) = Mid(mret, i * 16 * 4 + 16 * 2 + 1, 3)
   tm(i) = Val(Mid(mret, i * 16 * 4 + 4, 12))
   md1(i) = Val(Mid(mret, i * 16 * 4 + 16 * 1 + 4, 12))
   md2(i) = Val(Mid(mret, i * 16 * 4 + 16 * 2 + 4, 12))
   sc(i) = Val(Mid(mret, i * 16 * 4 + 16 * 3 + 4, 12))
   data(j, i) = Chr(13) & Chr(10) & sc(i) & ", " & md2(i) * 1000000000000.0 & ", "
& st2(i) & ", " & md1(i) * 1000000000000.0 & ", " & st1(i) & ", " & tm(i)
 Next i

 session.WriteString("DZ" & vbLf)                                              '95
 save_data(fname, title, value, data, nop1, nop2, session, t)
 Exit Sub

Check_err:                                                                     '99
 session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
 MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
 Exit Sub

Check_nop:                                                                    '104
 MsgBox("No. of data: " & rep & " (not " & nop1 * 4 & ")", vbOKOnly, "")
End Sub
```

Line	Description
69 to 75	Displays a message box that prompts you to connect DUT. Clicking OK applies voltage to the device, resets the time stamp, and performs the quasi-static CV measurement.
77 to 81	Waits until the measurement is completed. If an error is detected, applies 0 V and goes to Check_err. Also if number of data is not correct, applies 0 V and goes to Check_nop.
83 to 93	Stores the returned data into the *mret* string variable. Finally, stores the measured data into the *data* array.
95 to 105	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.

Measurement Result Example

```
Vg (V), Cgb (pF), C-status, Ileak (pA), I-status, Time (sec)
3, 2.3085, NCC, -0.259, NCI, 5.10526
2.8, 3.1277, NCC, 0.298, NCI, 5.41159
2.6, 3.1034, NCC, 0.241, NCI, 5.71947
2.4, 3.1334, NCC, 0.278, NCI, 6.02741
2.2, 3.1314, NCC, 0.255, NCI, 6.33532
2, 3.116, NCC, 0.232, NCI, 6.64316
1.8, 3.1193, NCC, 0.215, NCI, 6.95102
1.6, 3.1218, NCC, 0.222, NCI, 7.25891
1.4, 3.106, NCC, 0.18, NCI, 7.56681
1.2, 3.1303, NCC, 0.171, NCI, 7.87471
1, 3.1317, NCC, 0.184, NCI, 8.18262
0.8, 3.1096, NCC, 0.168, NCI, 8.49048
0.6, 3.1235, NCC, 0.185, NCI, 8.79832
0.4, 3.085, NCC, 0.148, NCI, 9.10628
0.2, 3.1028, NCC, 0.164, NCI, 9.41414
0, 3.1023, NCC, 0.149, NCI, 9.72198
-0.2, 3.0651, NCC, 0.117, NCI, 10.0301
-0.4, 3.0723, NCC, 0.141, NCI, 10.338
-0.6, 3.0654, NCC, 0.115, NCI, 10.6459
-0.8, 3.0375, NCC, 0.141, NCI, 10.9538
-1, 3.0117, NCC, 0.132, NCI, 11.2617
-1.2, 2.9459, NCC, 0.115, NCI, 11.5696
-1.4, 2.8877, NCC, 0.079, NCI, 11.8775
-1.6, 2.7965, NCC, 0.036, NCI, 12.1854
-1.8, 2.7727, NCC, 0.056, NCI, 12.4933
-2, 2.7219, NCC, 0.061, NCI, 12.8011
-2.2, 2.6781, NCC, 0.044, NCI, 13.109
-2.4, 2.6496, NCC, 0.032, NCI, 13.4169
-2.6, 2.6694, NCC, 0.076, NCI, 13.7248
-2.8, 2.6174, NCC, 0.053, NCI, 14.0327
-3, 2.5789, NCC, 0.041, NCI, 14.3406
-3.2, 2.5974, NCC, 0.046, NCI, 14.6484
-3.4, 2.6325, NCC, 0.042, NCI, 14.9564
-3.6, 2.6338, NCC, 0.002, NCI, 15.2643
-3.8, 2.706, NCC, 0.031, NCI, 15.5722
-4, 2.7984, NCC, 0.069, NCI, 15.8801
-4.2, 2.8384, NCC, 0.036, NCI, 16.188
-4.4, 2.8908, NCC, 0.044, NCI, 16.4959
-4.6, 2.9477, NCC, 0.043, NCI, 16.8038
-4.8, 2.9606, NCC, 0.034, NCI, 17.1117
-5, 2.9836, NCC, 0.012, NCI, 17.4196
-5.2, 3.0091, NCC, 0.017, NCI, 17.7275
-5.4, 3.0256, NCC, 0.039, NCI, 18.0353
-5.6, 3.0433, NCC, 0.035, NCI, 18.3433
-5.8, 3.0888, NCC, 0.068, NCI, 18.6512
-6, 3.08, NCC, 0.056, NCI, 18.9591
-6.2, 3.0803, NCC, 0.041, NCI, 19.267
-6.4, 3.0658, NCC, 0.024, NCI, 19.5749
-6.6, 3.0757, NCC, 0.014, NCI, 19.8828
-6.8, 3.0961, NCC, 0.028, NCI, 20.1907
-7, 3.0894, NCC, 0.009, NCI, 20.4986

Data save completed.

Do you want to perform measurement again?
```

High-Speed Spot C Measurements

To perform high-speed spot C measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets SMU filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets SMU series resistor ON/OFF	[SSR]	*chnum*,*mode*
Disables SCUU status indicator	[SSL]	*chnum*,*mode*
Controls SCUU input-output path	[SSP]	*chnum*,*path*
Sets MFCMU A/D converter	[ACT]	*mode*[,*N*]
Sets MFCMU measurement mode	[IMP]	*mode*
Sets AC/DC voltage monitor ON/OFF	[LMN]	*mode*
Sets MFCMU output frequency	FC	*chnum*,*freq*
Forces AC voltage by using MFCMU	ACV	*chnum*,*ac_level*
Forces DC voltage by using MFCMU	DCV	*chnum*,*voltage*
Forces DC voltage by using SMU	[DV, TDV]	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces DC current by using SMU	[DI, TDI]	
Performs capacitance measurement	TC	*chnum*,*mode*[,*range*]
	TTC	*chnum*,*mode*[,*range*]
Resets the time stamp	TSR	
Returns the time stamp at this time	TSQ	

You can use the above commands regardless of the measurement mode (MM command settings). The TTC command returns the time data and the measurement data.

The following program performs a high-speed spot capacitance measurement by using the TTC command. This example uses the multi frequency capacitance measurement unit (MFCMU) and the SMU/CMU unify unit (SCUU).

Before performing the capacitance (impedance) measurement, you need to perform the phase compensation and data correction. See “Data Correction” on page 3-71.

Table 3-18 High-Speed Spot C Measurement Example

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)              '1
 Dim i As Integer = 0                                 't(0): Drain
 Dim j As Integer = 0                                 't(1): Gate
 Dim nop1 As Integer = 1                              't(2): Source
 Dim nop2 As Integer = 1                              't(3): Substrate
 Dim data(nop2 - 1, nop1 - 1) As String
 Dim value As String = "Cp (pF), C_st, G (uS), G_st, OSC (mV), Osc_st, DC (V),
Dc_st, Time (s)"
 Dim fname As String = "C:\Agilent\prog_ex\data18.txt"
 Dim title As String = "High Speed Spot C Measurement Result"
 Dim msg As String = "No error."
 Dim err As Integer = 0

 Dim freq As Double = 1000000                                                 '13
 Dim ref_cp As Double = 0
 Dim ref_g As Double = 0
 Dim osc_level As Double = 0.03
 Dim dc_bias As Double = -5
 Dim range As Integer = 0
 Dim md(nop1) As Double
 Dim st(nop1) As String
 Dim mon(nop1) As Double
 Dim st_mon(nop1) As String
 Dim mt As Double

 session.Timeout = 60000            'timeout = 60 seconds                     '25
 session.WriteString("FMT 1" & vbLf)
 session.WriteString("TSC 1" & vbLf) 'enables time stamp output
 session.WriteString("DV " & t(0) & ",0,0,0.1,0" & vbLf)
 session.WriteString("DV " & t(2) & ",0,0,0.1,0" & vbLf)
 session.WriteString("SSP " & t(1) & ", 4" & vbLf)   'CMU to SCUU output
 session.WriteString("ACT 0, 2" & vbLf)              'auto, 2 samples
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 23	Declares variables and sets the value.
25 to 27	Sets timeout and data output format. And enables time stamp output.
28 to 29	Applies 0 V to the drain and source terminals.
30 to 31	Makes the SCUU connection path, and sets the A/D converter of the MFCMU.

```
 Dim rbx As Integer                                                           '33
 rbx = MsgBox("Do you want to perform Phase compensation?", vbYesNo, "")
 If rbx = vbYes Then
    MsgBox("Open measurement terminal.  Then click OK.", vbOKOnly, "")
    Console.WriteLine("Wait a minute . . ." & Chr(10))
    session.WriteString("ADJ " & t(1) & ",1" & vbLf)
    session.WriteString("ADJ? " & t(1) & vbLf) : err = session.ReadString(1 + 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbLf) : err =
session.ReadString(4 + 2) : session.WriteString("DZ" & vbLf) : GoTo Check_err
 End If

 session.WriteString("FC " & t(1) & "," & freq & vbLf)                        '43
 session.WriteString("ACV " & t(1) & "," & osc_level & vbLf)

 rbx = MsgBox("Do you want to perform Open correction?", vbYesNo, "")
 If rbx = vbYes Then
    session.WriteString("CLCORR " & t(1) & ",2" & vbLf)
    MsgBox("Open measurement terminal.  Then click OK.", vbOKOnly, "")
    Console.WriteLine("Wait a minute . . ." & Chr(10) & vbLf)
    session.WriteString("DCORR " & t(1) & ",1,100," & ref_cp & "," & ref_g & vbLf)
    session.WriteString("CORR? " & t(1) & ",1" & vbLf) : err = session.ReadString(1
+ 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbLf) : err =
session.ReadString(4 + 2) : session.WriteString("DZ" & vbLf) : GoTo Check_err
    session.WriteString("CORRST " & t(1) & ",1,1" & vbLf)    'open correction ON
    session.WriteString("CORRST " & t(1) & ",2,0" & vbLf)    'short correction OFF
    session.WriteString("CORRST " & t(1) & ",3,0" & vbLf)    'load correction OFF
 End If

 MsgBox("Connect DUT.  Then click OK.", vbOKOnly, "")                          '59
```

Line	Description
33 to 41	Displays a message box that asks if you perform the phase compensation. If you click Yes, the phase compensation will be performed. It will take about 30 seconds.
43 to 44	Sets the frequency and the oscillator level of the MFCMU output signal.
46 to 57	Displays a message box that asks if you perform the open correction. If you click Yes, the open correction will be performed. It does not need a long time. The short correction and the load correction are not performed in this example.
59	Displays a message box that asks you to connect the device to the measurement terminal. Then the CMUH and CMUL must be connected to the gate terminal and the substrate terminal respectively.

```
 session.WriteString("IMP 100" & vbLf)                                                   '60
 session.WriteString("LMN 1" & vbLf)
 session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
 If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
 session.WriteString("DCV " & t(1) & "," & dc_bias & vbLf)
 session.WriteString("TSR" & vbLf)
 session.WriteString("TTC " & t(1) & "," & range & vbLf)
 session.WriteString("TSQ" & vbLf)

 Dim mret As String = session.ReadString(16 * 5 + 2)  '5 data + terminator     '69
 Dim tret As String = session.ReadString(15 + 2)      '1 data + terminator
 Dim tcal As String = Mid(mret, 4, 12)
 tret = Mid(tret, 4, 12)
 mt = Val(tret) - Val(tcal)
 st(0) = Mid(mret, 16 * 1 + 1, 3)
 st(1) = Mid(mret, 16 * 2 + 1, 3)
 st_mon(0) = Mid(mret, 16 * 3 + 1, 3)
 st_mon(1) = Mid(mret, 16 * 4 + 1, 3)
 md(0) = Val(Mid(mret, 16 * 1 + 4, 12))
 md(1) = Val(Mid(mret, 16 * 2 + 4, 12))
 mon(0) = Val(Mid(mret, 16 * 3 + 4, 12))
 mon(1) = Val(Mid(mret, 16 * 4 + 4, 12))
 data(j, i) = Chr(13) & Chr(10) & md(0) * 1000000000000.0 & "," & st(0) & "," &
md(1) * 1000000.0 & "," & st(1)
 data(j, i) = data(j, i) & "," & mon(0) * 1000 & "," & st_mon(0) & "," & mon(1) &
"," & st_mon(1) & "," & mt

 session.WriteString("DZ" & vbLf)                                                        '85
 save_data(fname, title, value, data, nop1, nop2, session, t)
 Exit Sub

Check_err:                                                                               '89
 session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
 MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
End Sub
```

Line	Description
60 to 67	Sets the measurement condition, resets the time stamp, and performs the high-speed spot C measurement.
69 to 83	Stores the returned data into the *mret* and *tret* string variables. Finally, stores the measured data into the *data* array.
85 to 87	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
89 to 91	Displays a message box to show an error message if the error is detected.

Measurement Result Example

```
Cp (pF), C_st, G (uS), G_st, OSC (mV), Osc_st, DC (V), Dc_st, Time
(s)
4.96641,NJC,26.1348,NJY,28.7814,NJV,4.7239,NJV,0.0146

Data save completed.

Do you want to perform measurement again?
```

Table 3-19 Phase Compensation and Data Correction Commands for MFCMU

Function	Command	Parameters
Sets the phase compensation mode, auto or manual	ADJ	*slot*,*mode*
Performs phase compensation data measurement	ADJ?	*slot*
Clears the frequency list for data correction	CLCORR	*slot*,*mode*
Adds the specified frequency to the frequency list	CORRL	*slot*,*freq*
Returns the frequency defined in the frequency list	CORRL?	*slot*[,*index*]
Sets the reference value of open/short/load standard	DCORR	*slot*,*corr*,*mode*,*primary*,*secondary*
Returns the reference value of the specified standard	DCORR?	*slot*,*corr*
Performs the specified correction (open, short, or load) data measurement	CORR?	*slot*,*corr*
Sets the specified correction ON or OFF	CORRST	*slot*,*corr*,*state*
Returns the status ON or OFF of the specified correction	CORRST?	*slot*,*corr*

Data Correction

Table 3-19 lists the Agilent B1500A FLEX commands used for the phase compensation and the open/short/load correction. Before performing the capacitance (impedance) measurement, perform the phase compensation to adjust the phase zero, and perform the corrections you desire.

NOTE

Before executing CORR? command

- Execute DCORR command to set the calibration value or reference value of the open/short/load standard.
- Execute CLCORRL and CORRL commands to define the MFCMU output frequency for the data correction.
- Execute ACV command to set the AC signal level.

These setups must be done before executing the CORR? command.

- Phase Compensation
  1. Open the measurement terminals at the end of the device side.
  2. Execute ADJ command to set the compensation mode to manual.
  3. Execute ADJ? command to perform phase compensation data measurement. This operation will take about 30 seconds.
- Open Correction
  1. Connect the open standard. Or open the measurement terminals at the end of the device side.
  2. Execute CORR? command to perform open correction data measurement.
  3. Execute CORRST command to set the open correction ON.
- Short Correction
  1. Connect the short standard. Or connect the measurement terminals together at the end of the device side.
  2. Execute CORR? command to perform short correction data measurement.
  3. Execute CORRST command to set the short correction ON.
- Load Correction
  1. Connect the load standard.
  2. Execute CORR? command to perform load correction data measurement.
  3. Execute CORRST command to set the load correction ON.

Spot C Measurements

To perform capacitance spot measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets SMU filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets SMU series resistor ON/OFF	[SSR]	*chnum*,*mode*
Disables SCUU status indicator	[SSL]	*chnum*,*mode*
Controls SCUU input-output path	[SSP]	*chnum*,*path*
Sets MFCMU A/D converter	[ACT]	*mode*[,*N*]
Sets MFCMU measurement mode	[IMP]	*mode*
Sets AC/DC voltage monitor ON/OFF	[LMN]	*mode*
Sets MFCMU output frequency	FC	*chnum*,*freq*
Forces AC voltage by using MFCMU	ACV	*chnum*,*ac_level*
Forces DC voltage by using MFCMU	DCV	*chnum*,*voltage*
Forces DC voltage by using SMU	[DV, TDV]	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces DC current by using SMU	[DI, TDI]	
Sets MFCMU measurement range	[RC]	*chnum*,*mode*[,*range*]
Sets measurement mode	MM	17,*chnum*
Executes measurement	XE	

Measurement Result Example

```
Cp (pF), C_st, G (uS), G_st, OSC (mV), Osc_st, DC (V), Dc_st, Time
(s)
4.96981,NJC,26.1577,NJY,28.7737,NJV,4.72556,NJV,0.0259

Data save completed.
Do you want to perform measurement again?
```

The following program performs a spot capacitance measurement. This example uses the multi frequency capacitance measurement unit (MFCMU) and the SMU/CMU unify unit (SCUU).

Before performing the capacitance (impedance) measurement, you need to perform the phase compensation and data correction. See “Data Correction” on page 3-71.

Table 3-20 Spot C Measurement Example

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)              ’1
 Dim i As Integer = 0                             ’t(0): Drain
 Dim j As Integer = 0                             ’t(1): Gate
 Dim nop1 As Integer = 1                          ’t(2): Source
 Dim nop2 As Integer = 1                          ’t(3): Substrate
 Dim data(nop2 - 1, nop1 - 1) As String
 Dim value As String = "Cp (pF), C_st, G (uS), G_st, OSC (mV), Osc_st, DC (V),
Dc_st, Time (s)"
 Dim fname As String = "C:\Agilent\prog_ex\data19.txt"
 Dim title As String = "Spot C Measurement Result"
 Dim msg As String = "No error."
 Dim err As Integer = 0

 Dim freq As Double = 1000000                                                 ’13
 Dim ref_cp As Double = 0
 Dim ref_g As Double = 0
 Dim osc_level As Double = 0.03
 Dim dc_bias As Double = -5
 Dim range As Integer = 0
 Dim md(nop1) As Double
 Dim st(nop1) As String
 Dim mon(nop1) As Double
 Dim st_mon(nop1) As String
 Dim mt As Double
 Dim rep As Integer = nop1
 session.Timeout = 60000            ’timeout = 60 seconds                     ’25
 session.WriteString("FMT 1" & vbLf)
 session.WriteString("TSC 1" & vbLf) ’enables time stamp output
 session.WriteString("DV " & t(0) & ",0,0,0.1,0" & vbLf)
 session.WriteString("DV " & t(2) & ",0,0,0.1,0" & vbLf)
 session.WriteString("SSP " & t(1) & ", 4" & vbLf)  ’CMU to SCUU output
 session.WriteString("ACT 0, 2" & vbLf)             ’auto, 2 samples
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 24	Declares variables and sets the value.
25 to 27	Sets timeout and data output format. And enables the time stamp output.
28 to 29	Applies 0 V to the drain and source terminals.
30 to 31	Makes the SCUU connection path, and sets the A/D converter of the MFCMU.

```
 Dim rbx As Integer                                                          '33
 rbx = MsgBox("Do you want to perform Phase compensation?", vbYesNo, "")
 If rbx = vbYes Then
    MsgBox("Open measurement terminal.  Then click OK.", vbOKOnly, "")
    Console.WriteLine("Wait a minute . . ." & Chr(10))
    session.WriteString("ADJ " & t(1) & ",1" & vbLf)
    session.WriteString("ADJ? " & t(1) & vbLf) : err = session.ReadString(1 + 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbLf) : err =
session.ReadString(4 + 2) : session.WriteString("DZ" & vbLf) : GoTo Check_err
 End If

 session.WriteString("FC " & t(1) & "," & freq & vbLf)                       '43
 session.WriteString("ACV " & t(1) & "," & osc_level & vbLf)

 rbx = MsgBox("Do you want to perform Open correction?", vbYesNo, "")
 If rbx = vbYes Then
    session.WriteString("CLCORR " & t(1) & ",2" & vbLf)
    MsgBox("Open measurement terminal.  Then click OK.", vbOKOnly, "")
    Console.WriteLine("Wait a minute . . ." & Chr(10) & vbLf)
    session.WriteString("DCORR " & t(1) & ",1,100," & ref_cp & "," & ref_g & vbLf)
    session.WriteString("CORR? " & t(1) & ",1" & vbLf) : err = session.ReadString(1
+ 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbLf) : err =
session.ReadString(4 + 2) : session.WriteString("DZ" & vbLf) : GoTo Check_err
    session.WriteString("CORRST " & t(1) & ",1,1" & vbLf)    'open correction ON
    session.WriteString("CORRST " & t(1) & ",2,0" & vbLf)    'short correction OFF
    session.WriteString("CORRST " & t(1) & ",3,0" & vbLf)    'load correction OFF
 End If

 MsgBox("Connect DUT.  Then click OK.", vbOKOnly, "")                         '59
```

Line	Description
33 to 41	Displays a message box that asks if you perform the phase compensation. If you click Yes, the phase compensation will be performed. It will take about 30 seconds.
43 to 44	Sets the frequency and the oscillator level of the MFCMU output signal.
46 to 57	Displays a message box that asks if you perform the open correction. If you click Yes, the open correction will be performed. It does not need a long time. The short correction and the load correction are not performed in this example.
59	Displays a message box that asks you to connect the device to the measurement terminal. Then the CMUH and CMUL must be connected to the gate terminal and the substrate terminal respectively.

```
 session.WriteString("MM 17," & t(1) & vbLf)                                      '60
 session.WriteString("IMP 100" & vbLf)
 session.WriteString("LMN 1" & vbLf)
 session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
 If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
 session.WriteString("DCV " & t(1) & "," & dc_bias & vbLf)
 session.WriteString("TSR" & vbLf)
 session.WriteString("XE" & vbLf)

 session.WriteString("*OPC?" & vbLf) : rep = session.ReadString(1 + 2)          '69
 session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
 If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err

 Dim mret As String = session.ReadString(16 * 5 + 2)  '5 data + terminator     '73
 mt = Mid(mret, 4, 12)
 st(0) = Mid(mret, 16 * 1 + 1, 3)
 st(1) = Mid(mret, 16 * 2 + 1, 3)
 st_mon(0) = Mid(mret, 16 * 3 + 1, 3)
 st_mon(1) = Mid(mret, 16 * 4 + 1, 3)
 md(0) = Val(Mid(mret, 16 * 1 + 4, 12))
 md(1) = Val(Mid(mret, 16 * 2 + 4, 12))
 mon(0) = Val(Mid(mret, 16 * 3 + 4, 12))
 mon(1) = Val(Mid(mret, 16 * 4 + 4, 12))
 data(j, i) = Chr(13) & Chr(10) & md(0) * 1000000000000.0 & "," & st(0) & "," &
md(1) * 1000000.0 & "," & st(1)
 data(j, i) = data(j, i) & "," & mon(0) * 1000 & "," & st_mon(0) & "," & mon(1) &
"," & st_mon(1) & "," & mt

 session.WriteString("DZ" & vbLf)                                                  '86
 save_data(fname, title, value, data, nop1, nop2, session, t)
 Exit Sub

Check_err:                                                                          '90
 session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
 MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
End Sub
```

Line	Description
60 to 67	Sets the measurement condition, resets the time stamp, and performs the measurement.
69 to 71	Waits until the measurement is completed. If an error is detected, applies 0 V and goes to Check_err.
73 to 84	Stores the returned data into the *mret* string variable. Finally, stores the measured data into the *data* array.
86 to 88	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
90 to 92	Displays a message box to show an error message if the error is detected.

CV (DC Bias) Sweep Measurements

To perform capacitance-voltage (DC bias) sweep measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets SMU filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets SMU series resistor ON/OFF	[SSR]	*chnum*,*mode*
Disables SCUU status indicator	[SSL]	*chnum*,*mode*
Controls SCUU input-output path	[SSP]	*chnum*,*path*
Sets MFCMU A/D converter	[ACT]	*mode*[,*N*]
Sets MFCMU measurement mode	[IMP]	*mode*
Sets AC/DC voltage monitor ON/OFF	[LMN]	*mode*
Sets MFCMU output frequency	FC	*chnum*,*freq*
Forces AC voltage by using MFCMU	ACV	*chnum*,*level*
Sets CV sweep timing parameter	WTDCV	*hold*,*delay* [,*sdelay*[,*tdelay*[,*mdelay*]]]
Sets auto abort function	[WMDCV]	*abort*[,*post*]
Sets DC bias sweep source	WDCV	*chnum*,*mode*,*start*,*stop*,*step*
Forces constant voltage	[DV, TDV]	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces constant current	[DI, TDI]	
Sets MFCMU measurement range	[RC]	*chnum*,*mode*[,*range*]
Sets measurement mode	MM	18,*chnum*
Executes measurement	XE	

The following program performs a capacitance vs voltage measurement by the DC bias sweep. This example uses the multi frequency capacitance measurement unit (MFCMU) and the SMU/CMU unify unit (SCUU).

Before performing the capacitance (impedance) measurement, you need to perform the phase compensation and data correction. See “Data Correction” on page 3-71.

Table 3-21 CV (DC bias) Sweep Measurement Example

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)               '1
 Dim i As Integer = 0                                  't(0): Drain
 Dim j As Integer = 0                                  't(1): Gate
 Dim nop1 As Integer = 21                              't(2): Source
 Dim nop2 As Integer = 1                               't(3): Substrate
 Dim data(nop2 - 1, nop1 - 1) As String
 Dim value As String = "Vg (V), Cp (pF), C_st, G (uS), G_st, OSC (mV), Osc_st, DC
(V), Dc_st, Time (s)"
 Dim fname As String = "C:\Agilent\prog_ex\data20.txt"
 Dim title As String = "CV Sweep Measurement Result"
 Dim msg As String = "No error."
 Dim err As Integer = 0

 Dim freq As Double = 1000000                                                   '13
 Dim ref_cp As Double = 0
 Dim ref_g As Double = 0
 Dim osc_level As Double = 0.03
 Dim vg1 As Double = -5
 Dim vg2 As Double = 5
 Dim hold As Double = 0
 Dim delay As Double = 0
 Dim s_delay As Double = 0
 Dim range As Integer = 0
 Dim rep As Integer = nop1
 Dim sc(nop1) As Double
 Dim md(nop1 * 2) As Double
 Dim st(nop1 * 2) As String
 Dim mon(nop1 * 2) As Double
 Dim st_mon(nop1 * 2) As String
 Dim tm(nop1) As Double

 session.Timeout = 60000                'timeout = 60 seconds                   '31
 session.WriteString("FMT 1,1" & vbLf)  'data w/source data
 session.WriteString("TSC 1" & vbLf)    'enables time stamp output
 session.WriteString("DV " & t(0) & ",0,0,0.1,0" & vbLf)
 session.WriteString("DV " & t(2) & ",0,0,0.1,0" & vbLf)
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 29	Declares variables and sets the value.
31 to 33	Sets timeout and data output format. And enables the time stamp output.
34 to 35	Applies 0 V to the drain and source terminals.

```
 session.WriteString("SSP " & t(1) & ", 4" & vbLf)  'CMU to SCUU output      '37
 session.WriteString("ACT 2, 4" & vbLf)             'CMU integration, 4 PLC

 Dim rbx As Integer                                                         '40
 rbx = MsgBox("Do you want to perform Phase compensation?", vbYesNo, "")
 If rbx = vbYes Then
    MsgBox("Open measurement terminal.  Then click OK.", vbOKOnly, "")
    Console.WriteLine("Wait a minute . . ." & Chr(10))
    session.WriteString("ADJ " & t(1) & ",1" & vbLf)
    session.WriteString("ADJ? " & t(1) & vbLf) : err = session.ReadString(1 + 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbLf) : err =
session.ReadString(4 + 2) : session.WriteString("DZ" & vbLf) : GoTo Check_err
 End If

 session.WriteString("FC " & t(1) & "," & freq & vbLf)                      '50
 session.WriteString("ACV " & t(1) & "," & osc_level & vbLf)

 rbx = MsgBox("Do you want to perform Open correction?", vbYesNo, "")
 If rbx = vbYes Then
    session.WriteString("CLCORR " & t(1) & ",2" & vbLf)
    MsgBox("Open measurement terminal.  Then click OK.", vbOKOnly, "")
    Console.WriteLine("Wait a minute . . ." & Chr(10) & vbLf)
    session.WriteString("DCORR " & t(1) & ",1,100," & ref_cp & "," & ref_g & vbLf)
    session.WriteString("CORR? " & t(1) & ",1" & vbLf) : err = session.ReadString(1
+ 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbLf) : err =
session.ReadString(4 + 2) : session.WriteString("DZ" & vbLf) : GoTo Check_err
    session.WriteString("CORRST " & t(1) & ",1,1" & vbLf)    'open correction ON
    session.WriteString("CORRST " & t(1) & ",2,0" & vbLf)    'short correction OFF
    session.WriteString("CORRST " & t(1) & ",3,0" & vbLf)    'load correction OFF
 End If

 MsgBox("Connect DUT.  Then click OK.", vbOKOnly, "")                        '66
```

Line	Description
37 to 38	Makes the SCUU connection path, and sets the A/D converter of the MFCMU.
40 to 48	Displays a message box that asks if you perform the phase compensation. If you click Yes, the phase compensation will be performed. It will take about 30 seconds.
50 to 51	Sets the frequency and the oscillator level of the MFCMU output signal.
53 to 64	Displays a message box that asks if you perform the open correction. If you click Yes, the open correction will be performed. It does not need a long time. The short correction and the load correction are not performed in this example.
66	Displays a message box that asks you to connect the device to the measurement terminal. Then the CMUH and CMUL must be connected to the gate terminal and the substrate terminal respectively.

```
 session.WriteString("WMDCV 2, 1" & vbLf)                                           '68
 session.WriteString("WTDCV " & hold & "," & delay & "," & s_delay & vbLf)
 session.WriteString("WDCV " & t(1) & ",1," & vg1 & "," & vg2 & "," & nop1 & vbLf)
 session.WriteString("MM 18," & t(1) & vbLf)
 session.WriteString("IMP 100" & vbLf)
 session.WriteString("LMN 1" & vbLf)
 session.WriteString("RC " & t(1) & "," & range & vbLf)
 session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
 If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
 session.WriteString("TSR" & vbLf)
 session.WriteString("XE" & vbLf)
 session.WriteString("*OPC?" & vbLf) : rep = session.ReadString(1 + 2)            '79
 session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
 If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
 session.WriteString("NUB?" & vbLf) : rep = session.ReadString(3 + 2)
 If rep <> nop1 * 6 Then session.WriteString("DZ" & vbLf) : GoTo Check_nop     '83

 Dim mret As String = session.ReadString(16 * 6 * nop1 + 2) '6*nop1 data +
terminator
 For i = 0 To nop1 - 1
    st(i * 2) = Mid(mret, i * 16 * 6 + 16 * 1 + 1, 3)
    st(i * 2 + 1) = Mid(mret, i * 16 * 6 + 16 * 2 + 1, 3)
    st_mon(i * 2) = Mid(mret, i * 16 * 6 + 16 * 3 + 1, 3)
    st_mon(i * 2 + 1) = Mid(mret, i * 16 * 6 + 16 * 4 + 1, 3)
    tm(i) = Val(Mid(mret, i * 16 * 6 + 4, 12))
    md(i * 2) = Val(Mid(mret, i * 16 * 6 + 16 * 1 + 4, 12))
    md(i * 2 + 1) = Val(Mid(mret, i * 16 * 6 + 16 * 2 + 4, 12))
    mon(i * 2) = Val(Mid(mret, i * 16 * 6 + 16 * 3 + 4, 12))
    mon(i * 2 + 1) = Val(Mid(mret, i * 16 * 6 + 16 * 4 + 4, 12))
    sc(i) = Val(Mid(mret, i * 16 * 6 + 16 * 5 + 4, 12))
    data(j, i) = Chr(13) & Chr(10) & sc(i) & "," & md(i * 2) * 1000000000000.0 & ","
& st(i * 2)
    data(j, i) = data(j, i) & "," & md(i * 2 + 1) * 1000000.0 & "," & st(i * 2 + 1)
    data(j, i) = data(j, i) & "," & mon(i * 2) * 1000 & "," & st_mon(i * 2)
    data(j, i) = data(j, i) & "," & mon(i * 2 + 1) & "," & st_mon(i * 2 + 1) & ","
& tm(i)
 Next i                                                                            '101
```

Line	Description
68 to 78	Sets the measurement condition, resets the time stamp, and performs the measurement.
68	Sets the automatic abort function to ON, and sets the post measurement output value to vg1.
69	Sets the MFCMU sweep output timing.
70	Sets the MFCMU DC bias sweep output.
79 to 83	Waits until the measurement is completed. After that, if an error is detected, forces 0 V and goes to Check_err. Also if the number of returned data is not correct, forces 0 V and goes to Check_nop.
85 to 101	Stores the returned data into the *mret* string variable. Finally, stores the measured data into the *data* array.

```
 session.WriteString("DZ" & vbLf)                                                    '103
 save_data(fname, title, value, data, nop1, nop2, session, t)
 Exit Sub

Check_err:                                                                           '107
 session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
 MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
 Exit Sub

Check_nop:                                                                           '112
 MsgBox("No. of data: " & rep & " (not " & nop1 * 6 & ")", vbOKOnly, "")
End Sub
```

Line	Description
103 to 105	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
107 to 110	Displays a message box to show an error message if the error is detected.
112 to 113	Displays a message box to show an error message if the number of returned data is not correct.

Measurement Result Example

```
Vg (V), Cp (pF), C_st, G (uS), G_st, OSC (mV), Osc_st, DC (V),
Dc_st, Time (s)
-5,4.96677,NJC,26.155,NJY,28.7732,NJV,-4.72468,NJV,0.0547
-4.5,4.66524,NJC,26.3993,NJY,28.6384,NJV,-4.2384,NJV,0.0884
-4,4.2986,NJC,26.2738,NJY,28.4891,NJV,-3.75442,NJV,0.1228
-3.5,3.88182,NJC,25.5785,NJY,28.3222,NJV,-3.27358,NJV,0.1535
-3,3.43272,NJC,24.1992,NJY,28.1426,NJV,-2.79417,NJV,0.1878
-2.5,2.99286,NJC,21.9946,NJY,27.9503,NJV,-2.31792,NJV,0.2294
-2,2.57856,NJC,18.7458,NJY,27.7505,NJV,-1.84498,NJV,0.2709
-1.5,2.20793,NJC,14.2867,NJY,27.5502,NJV,-1.37609,NJV,0.3125
-1,1.92563,NJC,7.57546,NJY,27.3772,NJV,-0.91155,NJV,0.3541
-0.5,1.79915,NJC,-1.83967,NJY,27.494,NJV,-0.45241,NJV,0.3957
0,1.77613,NJC,-2.50329,NJY,27.4588,NJV,0.0041,NJV,0.4375
0.5,1.78246,NJC,-2.73976,NJY,27.488,NJV,0.46025,NJV,0.4789
1,1.7831,NJC,-2.66401,NJY,27.6511,NJV,0.92066,NJV,0.5205
1.5,1.78149,NJC,-2.52984,NJY,27.8257,NJV,1.38437,NJV,0.5621
2,1.77384,NJC,-2.39091,NJY,27.9928,NJV,1.85152,NJV,0.6037
2.5,1.77054,NJC,-2.22722,NJY,28.1473,NJV,2.32111,NJV,0.6453
3,1.76359,NJC,-2.03388,NJY,28.283,NJV,2.79339,NJV,0.6867
3.5,1.75959,NJC,-1.58516,NJY,28.3958,NJV,3.26736,NJV,0.7281
4,1.75883,NJC,-0.542666,NJY,28.481,NJV,3.74189,NJV,0.7697
4.5,1.73431,NJC,1.73765,NJY,28.5416,NJV,4.2182,NJV,0.8113
5,1.60909,NJC,6.23405,NJY,28.5737,NJV,4.69593,NJV,0.8529

Data save completed.

Do you want to perform measurement again?
```

Pulsed Spot C Measurements

To perform capacitance pulsed spot measurement, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets SMU filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets SMU series resistor ON/OFF	[SSR]	*chnum*,*mode*
Disables SCUU status indicator	[SSL]	*chnum*,*mode*
Controls SCUU input-output path	[SSP]	*chnum*,*path*
Sets MFCMU A/D converter	[ACT]	*mode*[,*N*]
Sets MFCMU measurement mode	[IMP]	*mode*
Sets MFCMU output frequency	FC	*chnum*,*freq*
Forces AC voltage by using MFCMU	ACV	*chnum*,*ac_level*
Sets pulse timing parameters	PTDCV	*hold*,*width*[,*period* [,*tdelay*]]
Sets pulse voltage	PDCV	*chnum*,*base*,*pulse*
Forces DC voltage by using SMU	[DV, TDV]	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces DC current by using SMU	[DI, TDI]	
Sets MFCMU measurement range	[RC]	*chnum*,*mode*[,*range*]
Sets measurement mode	MM	19,*chnum*
Executes measurement	XE	

Measurement Result Example

```
Cp (pF), C_st, G (uS), G_st, Time (s)
0.101969,NGC,0.258706,NGY,0.59655

Data save completed.
Do you want to perform measurement again?
```

The following program performs a pulsed spot capacitance measurement. This example uses the multi frequency capacitance measurement unit (MFCMU) and the SMU/CMU unify unit (SCUU).

Before performing the capacitance (impedance) measurement, you need to perform the phase compensation and data correction. See “Data Correction” on page 3-71.

Table 3-22 Pulsed Spot C Measurement Example

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)               '1
 Dim i As Integer = 0                                 't(0): Drain
 Dim j As Integer = 0                                 't(1): Gate
 Dim nop1 As Integer = 1                              't(2): Source
 Dim nop2 As Integer = 1                              't(3): Substrate
 Dim data(nop2 - 1, nop1 - 1) As String
 Dim value As String = "Cp (pF), C_st, G (uS), G_st, Time (s)"
 Dim fname As String = "C:\Agilent\prog_ex\data22.txt"
 Dim title As String = "Pulsed Spot C Measurement Result"
 Dim msg As String = "No error."
 Dim err As Integer = 0

 Dim freq As Double = 1000000                                                  '13
 Dim ref_cp As Double = 0
 Dim ref_g As Double = 0
 Dim osc_level As Double = 0.03
 Dim dc_bias As Double = -5
 Dim range As Integer = 0
 Dim md(nop1) As Double
 Dim st(nop1) As String
 Dim mt As Double

 session.Timeout = 60000             'timeout = 60 seconds                     '23
 session.WriteString("FMT 1" & vbLf)
 session.WriteString("TSC 1" & vbLf) 'enables time stamp output
 session.WriteString("DV " & t(0) & ",0,0,0.1,0" & vbLf)
 session.WriteString("DV " & t(2) & ",0,0,0.1,0" & vbLf)
 session.WriteString("SSP " & t(1) & ", 4" & vbLf)  'CMU to SCUU output
 session.WriteString("ACT 0, 2" & vbLf)             'auto, 2 samples
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 21	Declares variables and sets the value.
23 to 25	Sets timeout and data output format. And enables the time stamp output.
26 to 27	Applies 0 V to the drain and source terminals.
28 to 29	Makes the SCUU connection path, and sets the A/D converter of the MFCMU.

```
 Dim rbx As Integer                                                          '31
 rbx = MsgBox("Do you want to perform Phase compensation?", vbYesNo, "")
 If rbx = vbYes Then
    MsgBox("Open measurement terminal.  Then click OK.", vbOKOnly, "")
    Console.WriteLine("Wait a minute . . ." & Chr(10))
    session.WriteString("ADJ " & t(1) & ",1" & vbLf)
    session.WriteString("ADJ? " & t(1) & vbLf) : err = session.ReadString(1 + 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbLf) : err =
session.ReadString(4 + 2) : session.WriteString("DZ" & vbLf) : GoTo Check_err
 End If

 session.WriteString("FC " & t(1) & "," & freq & vbLf)                       '41
 session.WriteString("ACV " & t(1) & "," & osc_level & vbLf)

 rbx = MsgBox("Do you want to perform Open correction?", vbYesNo, "")
 If rbx = vbYes Then
    session.WriteString("CLCORR " & t(1) & ",2" & vbLf)
    MsgBox("Open measurement terminal.  Then click OK.", vbOKOnly, "")
    Console.WriteLine("Wait a minute . . ." & Chr(10) & vbLf)
    session.WriteString("DCORR " & t(1) & ",1,100," & ref_cp & "," & ref_g & vbLf)
    session.WriteString("CORR? " & t(1) & ",1" & vbLf) : err = session.ReadString(1
+ 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbLf) : err =
session.ReadString(4 + 2) : session.WriteString("DZ" & vbLf) : GoTo Check_err
    session.WriteString("CORRST " & t(1) & ",1,1" & vbLf)    'open correction ON
    session.WriteString("CORRST " & t(1) & ",2,0" & vbLf)    'short correction OFF
    session.WriteString("CORRST " & t(1) & ",3,0" & vbLf)    'load correction OFF
 End If

 MsgBox("Connect DUT.  Then click OK.", vbOKOnly, "")                        '57

 Dim g_pt As String = "0.5, 0.1, 0.2" 'hold, width, period in sec
 session.WriteString("PTDCV " & g_pt & vbLf)
 Dim v0 As Double = 0                 '0 V: pulse base voltage
 session.WriteString("PDCV " & t(1) & "," & v0 & "," & dc_bias & vbLf)       '62
```

Line	Description
31 to 39	Displays a message box that asks if you perform the phase compensation. If you click Yes, the phase compensation will be performed. It will take about 30 seconds.
41 to 42	Sets the frequency and the oscillator level of the MFCMU output signal.
44 to 55	Displays a message box that asks if you perform the open correction. If you click Yes, the open correction will be performed. It does not need a long time. The short correction and the load correction are not performed in this example.
57	Displays a message box that asks you to connect the device to the measurement terminal. Then the CMUH and CMUL must be connected to the gate terminal and the substrate terminal respectively.
59 to 62	Sets the pulse timing parameters and the pulse voltage output of MFCMU.

```
 session.WriteString("MM 19," & t(1) & vbLf)                                     ’63
 session.WriteString("IMP 100" & vbLf)
 session.WriteString("RC " & t(1) & "," & range & vbLf)
 session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
 If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
 session.WriteString("TSR" & vbLf)
 session.WriteString("XE" & vbLf)
 session.WriteString("*OPC?" & vbLf) : err = session.ReadString(1 + 2)         ’70
 session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
 If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err

 Dim mret As String = session.ReadString(16 * 3 + 2)  ’3 data + terminator     ’74
 mt = Mid(mret, 4, 12)
 st(0) = Mid(mret, 16 * 1 + 1, 3)
 st(1) = Mid(mret, 16 * 2 + 1, 3)
 md(0) = Val(Mid(mret, 16 * 1 + 4, 12))
 md(1) = Val(Mid(mret, 16 * 2 + 4, 12))
 data(j, i) = Chr(13) & Chr(10) & md(0) * 1000000000000.0 & "," & st(0) & "," &
md(1) * 1000000.0 & "," & st(1) & "," & mt

 session.WriteString("DZ" & vbLf)                                                ’82
 save_data(fname, title, value, data, nop1, nop2, session, t)
 Exit Sub

Check_err:                                                                        ’86
 session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
 MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
End Sub
```

Line	Description
63 to 69	Sets the measurement condition, resets the time stamp, and performs the measurement.
70 to 72	Waits until the measurement is completed. If an error is detected, applies 0 V and goes to Check_err.
74 to 80	Stores the returned data into the *mret* string variable. Finally, stores the measured data into the *data* array.
82 to 84	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
86 to 88	Displays a message box to show an error message if the error is detected.

Pulsed Sweep CV Measurements

To perform capacitance-voltage pulsed sweep measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets SMU filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets SMU series resistor ON/OFF	[SSR]	*chnum*,*mode*
Disables SCUU status indicator	[SSL]	*chnum*,*mode*
Controls SCUU input-output path	[SSP]	*chnum*,*path*
Sets MFCMU A/D converter	[ACT]	*mode*[,*N*]
Sets MFCMU measurement mode	[IMP]	*mode*
Sets MFCMU output frequency	FC	*chnum*,*freq*
Forces AC voltage by using MFCMU	ACV	*chnum*,*level*
Sets pulse timing parameters	PTDCV	*hold*,*width*,*period* [,*tdelay*]
Sets auto abort function	[WMDCV]	*abort*[,*post*]
Sets pulse voltage sweep source	PWDCV	*chnum*,*mode*,*base*,*start*,*stop*,*step*
Forces constant voltage	[DV, TDV]	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces constant current	[DI, TDI]	
Sets MFCMU measurement range	[RC]	*chnum*,*mode*[,*range*]
Sets measurement mode	MM	20,*chnum*
Executes measurement	XE	

The following program performs a capacitance vs voltage measurement by the pulsed bias sweep. This example uses the multi frequency capacitance measurement unit (MFCMU) and the SMU/CMU unify unit (SCUU).

Before performing the capacitance (impedance) measurement, you need to perform the phase compensation and data correction. See “Data Correction” on page 3-71.

Table 3-23 Pulsed Sweep CV Measurement Example

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)               '1
 Dim i As Integer = 0                            't(0): Drain
 Dim j As Integer = 0                            't(1): Gate
 Dim nop1 As Integer = 21                        't(2): Source
 Dim nop2 As Integer = 1                         't(3): Substrate
 Dim data(nop2 - 1, nop1 - 1) As String
 Dim value As String = "Vg (V), Cp (pF), C_st, G (uS), G_st, Time (s)"
 Dim fname As String = "C:\Agilent\prog_ex\data23.txt"
 Dim title As String = "Pulsed Sweep CV Sweep Measurement Result"
 Dim msg As String = "No error."
 Dim err As Integer = 0

 Dim freq As Double = 1000000                                                  '13
 Dim ref_cp As Double = 0
 Dim ref_g As Double = 0
 Dim osc_level As Double = 0.03
 Dim vg1 As Double = -5
 Dim vg2 As Double = 5
 Dim range As Integer = 0
 Dim rep As Integer = nop1
 Dim sc(nop1) As Double
 Dim md(nop1 * 2) As Double
 Dim st(nop1 * 2) As String
 Dim tm(nop1) As Double

 session.Timeout = 60000                'timeout = 60 seconds                  '26
 session.WriteString("FMT 1,1" & vbLf)  'data w/source data
 session.WriteString("TSC 1" & vbLf)    'enables time stamp output
 session.WriteString("DV " & t(0) & ",0,0,0.1,0" & vbLf)
 session.WriteString("DV " & t(2) & ",0,0,0.1,0" & vbLf)
 session.WriteString("SSP " & t(1) & ", 4" & vbLf)  'CMU to SCUU output
 session.WriteString("ACT 0, 2" & vbLf)             'auto, 2 samples
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 24	Declares variables and sets the value.
26 to 28	Sets timeout and data output format. And enables the time stamp output.
29 to 30	Applies 0 V to the drain and source terminals.
31 to 32	Makes the SCUU connection path, and sets the A/D converter of the MFCMU.

```
 Dim rbx As Integer                                                            '34
 rbx = MsgBox("Do you want to perform Phase compensation?", vbYesNo, "")
 If rbx = vbYes Then
    MsgBox("Open measurement terminal.  Then click OK.", vbOKOnly, "")
    Console.WriteLine("Wait a minute . . ." & Chr(10))
    session.WriteString("ADJ " & t(1) & ",1" & vbLf)
    session.WriteString("ADJ? " & t(1) & vbLf) : err = session.ReadString(1 + 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbLf) : err =
session.ReadString(4 + 2) : session.WriteString("DZ" & vbLf) : GoTo Check_err
 End If

 session.WriteString("FC " & t(1) & "," & freq & vbLf)                         '44
 session.WriteString("ACV " & t(1) & "," & osc_level & vbLf)

 rbx = MsgBox("Do you want to perform Open correction?", vbYesNo, "")
 If rbx = vbYes Then
    session.WriteString("CLCORR " & t(1) & ",2" & vbLf)
    MsgBox("Open measurement terminal.  Then click OK.", vbOKOnly, "")
    Console.WriteLine("Wait a minute . . ." & Chr(10) & vbLf)
    session.WriteString("DCORR " & t(1) & ",1,100," & ref_cp & "," & ref_g & vbLf)
    session.WriteString("CORR? " & t(1) & ",1" & vbLf) : err = session.ReadString(1
+ 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbLf) : err =
session.ReadString(4 + 2) : session.WriteString("DZ" & vbLf) : GoTo Check_err
    session.WriteString("CORRST " & t(1) & ",1,1" & vbLf)    'open correction ON
    session.WriteString("CORRST " & t(1) & ",2,0" & vbLf)    'short correction OFF
    session.WriteString("CORRST " & t(1) & ",3,0" & vbLf)    'load correction OFF
 End If

 MsgBox("Connect DUT.  Then click OK.", vbOKOnly, "")                          '60
```

Line	Description
34 to 42	Displays a message box that asks if you perform the phase compensation. If you click Yes, the phase compensation will be performed. It will take about 30 seconds.
44 to 45	Sets the frequency and the oscillator level of the MFCMU output signal.
47 to 58	Displays a message box that asks if you perform the open correction. If you click Yes, the open correction will be performed. It does not need a long time. The short correction and the load correction are not performed in this example.
60	Displays a message box that asks you to connect the device to the measurement terminal. Then the CMUH and CMUL must be connected to the gate terminal and the substrate terminal respectively.

```
 Dim g_pt As String = "0.5, 0.1, 0.2" 'hold, width, period in sec              '61
 Dim v0 As Double = 0                 '0 V: pulse base voltage
 session.WriteString("WMDCV 2, 1" & vbLf)
 session.WriteString("PTDCV " & g_pt & vbLf)
 session.WriteString("PWDCV " & t(1) & ",1," & v0 & "," & vg1 & "," & vg2 & "," &
nop1 & vbLf)
 session.WriteString("MM 20," & t(1) & vbLf)
 session.WriteString("IMP 100" & vbLf)
 session.WriteString("LMN 1" & vbLf)
 session.WriteString("RC " & t(1) & "," & range & vbLf)
 session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
 If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
 session.WriteString("TSR" & vbLf)
 session.WriteString("XE" & vbLf)
 session.WriteString("*OPC?" & vbLf) : rep = session.ReadString(1 + 2)         '74
 session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
 If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
 session.WriteString("NUB?" & vbLf) : rep = session.ReadString(3 + 2)
 If rep <> nop1 * 4 Then session.WriteString("DZ" & vbLf) : GoTo Check_nop     '78

 Dim mret As String = session.ReadString(16 * 4 * nop1 + 2) '4*nop1 + terminator
 For i = 0 To nop1 - 1
    st(i * 2) = Mid(mret, i * 16 * 4 + 16 * 1 + 1, 3)
    st(i * 2 + 1) = Mid(mret, i * 16 * 4 + 16 * 2 + 1, 3)
    tm(i) = Val(Mid(mret, i * 16 * 4 + 4, 12))
    md(i * 2) = Val(Mid(mret, i * 16 * 4 + 16 * 1 + 4, 12))
    md(i * 2 + 1) = Val(Mid(mret, i * 16 * 4 + 16 * 2 + 4, 12))
    sc(i) = Val(Mid(mret, i * 16 * 4 + 16 * 3 + 4, 12))
    data(j, i) = Chr(13) & Chr(10) & sc(i) & "," & md(i * 2) * 1000000000000.0 & ","
& st(i * 2)
    data(j, i) = data(j, i) & "," & md(i * 2 + 1) * 1000000.0 & "," & st(i * 2 + 1)
& "," & tm(i)
 Next i                                                                          '90
```

Line	Description
61 to 73	Sets the measurement condition, resets the time stamp, and performs the measurement.
63	Sets the automatic abort function to ON, and sets the post measurement output value to vg1.
64	Sets the pulsed sweep timing parameters of MFCMU.
65	Sets the pulsed sweep voltage output of MFCMU.
74 to 78	Waits until the measurement is completed. After that, if an error is detected, forces 0 V and goes to Check_err. Also if the number of returned data is not correct, forces 0 V and goes to Check_nop.
80 to 90	Stores the returned data into the *mret* string variable. Finally, stores the measured data into the *data* array.

```
 session.WriteString("DZ" & vbLf)                                                        '92
 save_data(fname, title, value, data, nop1, nop2, session, t)
 Exit Sub

Check_err:                                                                               '96
 session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
 MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
 Exit Sub

Check_nop:                                                                              '101
 MsgBox("No. of data: " & rep & " (not " & nop1 * 4 & ")", vbOKOnly, "")
End Sub
```

Line	Description
92 to 94	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
96 to 99	Displays a message box to show an error message if the error is detected.
101 to 102	Displays a message box to show an error message if the number of returned data is not correct.

Measurement Result Example

```
Vg (V), Cp (pF), C_st, G (uS), G_st, Time (s)
-5,0.133441,NGC,-0.334621,NGY,0.11755
-4.5,0.11202,NGC,-0.301203,NGY,0.13873
-4,0.137815,NGC,-0.151185,NGY,0.15973
-3.5,0.103693,NGC,-0.0974783,NGY,0.18053
-3,0.0877819,NGC,0.0884008,NGY,0.20112
-2.5,0.0523748,NGC,0.697226,NGY,0.22152
-2,0.0487233,NGC,0.0480156,NGY,0.24172
-1.5,0.118844,NGC,-0.322665,NGY,0.26172
-1,0.109541,NGC,-0.488218,NGY,0.28155
-0.5,0.0792613,NGC,0.232565,NGY,0.30135
0,0.0580278,NGC,0.240967,NGY,0.32115
0.5,0.110523,NGC,-0.0462759,NGY,0.34094
1,0.082289,NGC,0.156317,NGY,0.36075
1.5,0.102956,NGC,0.175315,NGY,0.38055
2,0.188602,NGC,-0.463437,NGY,0.40045
2.5,0.0818513,NGC,-0.620362,NGY,0.42064
3,0.0739288,NGC,-0.084286,NGY,0.44104
3.5,0.0476039,NGC,0.287456,NGY,0.46164
4,0.0910013,NGC,0.0407421,NGY,0.48244
4.5,0.0745168,NGC,0.170635,NGY,0.50344
5,0.0627603,NGC,0.144463,NGY,0.52464

Data save completed.

Do you want to perform measurement again?
```

CV (AC Level) Sweep Measurements

To perform capacitance-voltage (AC level) sweep measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets SMU filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets SMU series resistor ON/OFF	[SSR]	*chnum*,*mode*
Disables SCUU status indicator	[SSL]	*chnum*,*mode*
Controls SCUU input-output path	[SSP]	*chnum*,*path*
Sets MFCMU A/D converter	[ACT]	*mode*[,*N*]
Sets MFCMU measurement mode	[IMP]	*mode*
Sets AC/DC voltage monitor ON/OFF	[LMN]	*mode*
Sets MFCMU output frequency	FC	*chnum*,*freq*
Forces AC voltage by using MFCMU	ACV	*chnum*,*level*
Sets CV sweep timing parameter	WTACV	*hold*,*delay* [,*sdelay*[,*tdelay*[,*mdelay*]]]
Sets auto abort function	[WMACV]	*abort*[,*post*]
Sets AC level sweep source	WACV	*chnum*,*mode*,*start*,*stop*,*step*
Forces DC voltage by using MFCMU	DCV	*chnum*,*voltage*
Forces constant voltage	[DV, TDV]	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces constant current	[DI, TDI]	
Sets MFCMU measurement range	[RC]	*chnum*,*mode*[,*range*]
Sets measurement mode	MM	23,*chnum*
Executes measurement	XE	

The following program performs a capacitance vs voltage measurement by the AC level sweep. This example uses the multi frequency capacitance measurement unit (MFCMU) and the SMU/CMU unify unit (SCUU).

Before performing the capacitance (impedance) measurement, you need to perform the phase compensation and data correction. See “Data Correction” on page 3-71.

Table 3-24 CV (AC level) Sweep Measurement Example

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)             '1
 Dim i As Integer = 0                                ’t(0): Drain
 Dim j As Integer = 0                                ’t(1): Gate
 Dim nop1 As Integer = 10                            ’t(2): Source
 Dim nop2 As Integer = 1                             ’t(3): Substrate
 Dim data(nop2 - 1, nop1 - 1) As String
 Dim value As String = "Level (mV), Cp (pF), C_st, G (uS), G_st, OSC (mV), Osc_st,
DC (V), Dc_st, Time (s)"
 Dim fname As String = "C:\Agilent\prog_ex\data24.txt"
 Dim title As String = "CV (AC) Sweep Measurement Result"
 Dim msg As String = "No error."
 Dim err As Integer = 0

 Dim freq As Double = 1000000                                                ’13
 Dim ref_cp As Double = 0
 Dim ref_g As Double = 0
 Dim osc_level As Double = 0.03
 Dim dc_bias As Double = 5
 Dim v1 As Double = 0.01
 Dim v2 As Double = 0.1
 Dim hold As Double = 0
 Dim delay As Double = 0
 Dim s_delay As Double = 0
 Dim range As Integer = 0
 Dim rep As Integer = nop1
 Dim sc(nop1) As Double
 Dim md(nop1 * 2) As Double
 Dim st(nop1 * 2) As String
 Dim mon(nop1 * 2) As Double
 Dim st_mon(nop1 * 2) As String
 Dim tm(nop1) As Double

 session.Timeout = 60000                  ’timeout = 60 seconds              ’32
 session.WriteString("FMT 1,1" & vbLf)    ’data w/source data
 session.WriteString("TSC 1" & vbLf)      ’enables time stamp output
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 30	Declares variables and sets the value.
32 to 34	Sets the B1500A timeout and the data output format (data with source data). And enables the time stamp output.

```
 session.WriteString("DV " & t(0) & ",0,0,0.1,0" & vbLf)                        '35
 session.WriteString("DV " & t(2) & ",0,0,0.1,0" & vbLf)
 session.WriteString("SSP " & t(1) & ", 4" & vbLf)  'CMU to SCUU output
 session.WriteString("ACT 0, 2" & vbLf)             'auto, 2 samples

 Dim rbx As Integer                                                             '40
 rbx = MsgBox("Do you want to perform Phase compensation?", vbYesNo, "")
 If rbx = vbYes Then
    MsgBox("Open measurement terminal.  Then click OK.", vbOKOnly, "")
    Console.WriteLine("Wait a minute . . ." & Chr(10))
    session.WriteString("ADJ " & t(1) & ",1" & vbLf)
    session.WriteString("ADJ? " & t(1) & vbLf) : err = session.ReadString(1 + 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbLf) : err =
session.ReadString(4 + 2) : session.WriteString("DZ" & vbLf) : GoTo Check_err
 End If

 session.WriteString("FC " & t(1) & "," & freq & vbLf)                          '50
 session.WriteString("ACV " & t(1) & "," & osc_level & vbLf)

 rbx = MsgBox("Do you want to perform Open correction?", vbYesNo, "")
 If rbx = vbYes Then
    session.WriteString("CLCORR " & t(1) & ",2" & vbLf)
    MsgBox("Open measurement terminal.  Then click OK.", vbOKOnly, "")
    Console.WriteLine("Wait a minute . . ." & Chr(10) & vbLf)
    session.WriteString("DCORR " & t(1) & ",1,100," & ref_cp & "," & ref_g & vbLf)
    session.WriteString("CORR? " & t(1) & ",1" & vbLf) : err = session.ReadString(1
+ 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbLf) : err =
session.ReadString(4 + 2) : session.WriteString("DZ" & vbLf) : GoTo Check_err
    session.WriteString("CORRST " & t(1) & ",1,1" & vbLf)    'open correction ON
    session.WriteString("CORRST " & t(1) & ",2,0" & vbLf)    'short correction OFF
    session.WriteString("CORRST " & t(1) & ",3,0" & vbLf)    'load correction OFF
 End If

 MsgBox("Connect DUT.  Then click OK.", vbOKOnly, "")                           '66
```

Line	Description
35 to 36	Applies 0 V to the drain and source terminals.
37 to 38	Makes the SCUU connection path, and sets the A/D converter of the MFCMU.
40 to 48	Displays a message box that asks if you perform the phase compensation. If you click Yes, the phase compensation will be performed. It will take about 30 seconds.
50 to 51	Sets the frequency and the oscillator level of the MFCMU output signal.
53 to 64	Displays a message box that asks if you perform the open correction. If you click Yes, the open correction will be performed. It does not need a long time. The short correction and the load correction are not performed in this example.
66	Displays a message box that asks you to connect the device to the measurement terminal. Then the CMUH and CMUL must be connected to the gate terminal and the substrate terminal respectively.

```
 session.WriteString("WMACV 2, 1" & vbLf)                                              '68
 session.WriteString("WTACV " & hold & "," & delay & "," & s_delay & vbLf)
 session.WriteString("WACV " & t(1) & ",1," & v1 & "," & v2 & "," & nop1 & vbLf)
 session.WriteString("MM 23," & t(1) & vbLf)
 session.WriteString("IMP 100" & vbLf)
 session.WriteString("LMN 1" & vbLf)
 session.WriteString("RC " & t(1) & "," & range & vbLf)
 session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
 If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
 session.WriteString("DCV " & t(1) & "," & dc_bias & vbLf)
 session.WriteString("TSR" & vbLf)
 session.WriteString("XE" & vbLf)
 session.WriteString("*OPC?" & vbLf) : rep = session.ReadString(1 + 2)             '80
 session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
 If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
 session.WriteString("NUB?" & vbLf) : rep = session.ReadString(3 + 2)
 If rep <> nop1 * 6 Then session.WriteString("DZ" & vbLf) : GoTo Check_nop     '84

 Dim mret As String = session.ReadString(16 * 6 * nop1 + 2) '6*nop1 + terminator
 For i = 0 To nop1 - 1
    st(i * 2) = Mid(mret, i * 16 * 6 + 16 * 1 + 1, 3)
    st(i * 2 + 1) = Mid(mret, i * 16 * 6 + 16 * 2 + 1, 3)
    st_mon(i * 2) = Mid(mret, i * 16 * 6 + 16 * 3 + 1, 3)
    st_mon(i * 2 + 1) = Mid(mret, i * 16 * 6 + 16 * 4 + 1, 3)
    tm(i) = Val(Mid(mret, i * 16 * 6 + 4, 12))
    md(i * 2) = Val(Mid(mret, i * 16 * 6 + 16 * 1 + 4, 12))
    md(i * 2 + 1) = Val(Mid(mret, i * 16 * 6 + 16 * 2 + 4, 12))
    mon(i * 2) = Val(Mid(mret, i * 16 * 6 + 16 * 3 + 4, 12))
    mon(i * 2 + 1) = Val(Mid(mret, i * 16 * 6 + 16 * 4 + 4, 12))
    sc(i) = Val(Mid(mret, i * 16 * 6 + 16 * 5 + 4, 12))
    data(j, i) = Chr(13) & Chr(10) & sc(i) & "," & md(i * 2) * 1000000000000.0 & ","
& st(i * 2)
    data(j, i) = data(j, i) & "," & md(i * 2 + 1) * 1000000.0 & "," & st(i * 2 + 1)
    data(j, i) = data(j, i) & "," & mon(i * 2) * 1000 & "," & st_mon(i * 2)
    data(j, i) = data(j, i) & "," & mon(i * 2 + 1) & "," & st_mon(i * 2 + 1) & ","
& tm(i)
 Next i                                                                                '102
```

Line	Description
68 to 79	Sets the measurement condition, resets the time stamp, and performs the measurement.
68	Sets the automatic abort function to ON, and sets the post measurement output value to v1.
69	Sets the MFCMU sweep output timing.
70	Sets the MFCMU AC level sweep output.
80 to 84	Waits until the measurement is completed. After that, if an error is detected, forces 0 V and goes to Check_err. Also if the number of returned data is not correct, forces 0 V and goes to Check_nop.
86 to 102	Stores the returned data into the *mret* string variable. Finally, stores the measured data into the *data* array.

```
 session.WriteString("DZ" & vbLf)                                        '104
 save_data(fname, title, value, data, nop1, nop2, session, t)
 Exit Sub

Check_err:                                                               '108
 session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
 MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
 Exit Sub

Check_nop:                                                               '113
 MsgBox("No. of data: " & rep & " (not " & nop1 * 6 & ")", vbOKOnly, "")
End Sub
```

Line	Description
104 to 106	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
108 to 111	Displays a message box to show an error message if the error is detected.
113 to 114	Displays a message box to show an error message if the number of returned data is not correct.

Measurement Result Example

```
Level (mV), Cp (pF), C_st, G (uS), G_st, OSC (mV), Osc_st, DC (V),
Dc_st, Time (s)
10,0.101413,NGC,0.023601,NGY,9.9799,NGV,5.00485,NGV,0.0714
20,0.102654,NGC,0.0450136,NGY,19.963,NGV,5.0049,NGV,0.13921
30,0.100627,NGC,0.0522385,NGY,29.9446,NGV,5.00488,NGV,0.15706
40,0.10053,NGC,0.0529098,NGY,39.926,NGV,5.00491,NGV,0.22501
50,0.10008,NGC,0.0562029,NGY,49.8853,NGV,5.00495,NGV,0.24298
60,0.0982925,NGC,0.0492554,NGY,59.8801,NGV,5.00515,NGV,0.26092
70,0.0992213,NGC,0.0548534,NGY,69.899,NGV,5.00502,NGV,0.32885
80,0.099067,NGC,0.0501863,NGY,79.915,NGV,5.00514,NGV,0.34679
90,0.100248,NGC,0.0512628,NGY,89.892,NGV,5.00487,NGV,0.36446
100,0.0996081,NGC,0.0519715,NGY,99.869,NGV,5.00486,NGV,0.38241

Data save completed.

Do you want to perform measurement again?
```

C-f Sweep Measurements

To perform capacitance-frequency sweep measurements, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets SMU filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets SMU series resistor ON/OFF	[SSR]	*chnum*,*mode*
Disables SCUU status indicator	[SSL]	*chnum*,*mode*
Controls SCUU input-output path	[SSP]	*chnum*,*path*
Sets MFCMU A/D converter	[ACT]	*mode*[,*N*]
Sets MFCMU measurement mode	[IMP]	*mode*
Sets AC/DC voltage monitor ON/OFF	[LMN]	*mode*
Sets C-f sweep timing parameter	WTFC	*hold*,*delay* [,*sdelay*[,*tdelay*[,*mdelay*]]]
Sets auto abort function	[WMFC]	*abort*[,*post*]
Sets frequency sweep source	WFC	*chnum*,*mode*,*start*,*stop*,*step*
Forces AC voltage by using MFCMU	ACV	*chnum*,*level*
Forces DC voltage by using MFCMU	DCV	*chnum*,*voltage*
Forces constant voltage	[DV, TDV]	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces constant current	[DI, TDI]	
Sets MFCMU measurement range	[RC]	*chnum*,*mode*[,*range*]
Sets measurement mode	MM	22,*chnum*
Executes measurement	XE	

The following program performs a capacitance vs frequency sweep measurement. This example uses the multi frequency capacitance measurement unit (MFCMU) and the SMU/CMU unify unit (SCUU).

Before performing the capacitance (impedance) measurement, you need to perform the phase compensation and data correction. See “Data Correction” on page 3-71.

Table 3-25 C-f Sweep Measurement Example

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)              '1
 Dim i As Integer = 0                                        't(0): Drain
 Dim j As Integer = 0                                        't(1): Gate
 Dim nop1 As Integer = 10                                    't(2): Source
 Dim nop2 As Integer = 1                                     't(3): Substrate
 Dim data(nop2 - 1, nop1 - 1) As String
 Dim value As String = "Freq (MHz), Cp (pF), C_st, G (uS), G_st, OSC (mV), Osc_st,
DC (V), Dc_st, Time (s)"
 Dim fname As String = "C:\Agilent\prog_ex\data25.txt"
 Dim title As String = "C-f Sweep Measurement Result"
 Dim msg As String = "No error."
 Dim err As Integer = 0

 Dim freq As Double = 1000000                                                  '13
 Dim ref_cp As Double = 0
 Dim ref_g As Double = 0
 Dim osc_level As Double = 0.03
 Dim dc_bias As Double = 5
 Dim f1 As Double = 500000.0
 Dim f2 As Double = 5000000.0
 Dim hold As Double = 0
 Dim delay As Double = 0
 Dim s_delay As Double = 0
 Dim range As Integer = 0
 Dim rep As Integer = nop1
 Dim sc(nop1) As Double
 Dim md(nop1 * 2) As Double
 Dim st(nop1 * 2) As String
 Dim mon(nop1 * 2) As Double
 Dim st_mon(nop1 * 2) As String
 Dim tm(nop1) As Double

 session.Timeout = 120000                        'B1500 timeout = 120 seconds   '32
 session.WriteString("FMT 1,1" & vbLf)
 session.WriteString("TSC 1" & vbLf)             'enables time stamp output
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 30	Declares variables and sets the value.
32 to 34	Sets the B1500A timeout and the data output format (data with source data). And enables the time stamp output.

```
 session.WriteString("DV " & t(0) & ",0,0,0.1,0" & vbLf)                      '35
 session.WriteString("DV " & t(2) & ",0,0,0.1,0" & vbLf)
 session.WriteString("SSP " & t(1) & ", 4" & vbLf)  'CMU to SCUU output
 session.WriteString("ACT 0, 2" & vbLf)             'auto, 2 samples

 Dim rbx As Integer                                                            '40
 rbx = MsgBox("Do you want to perform Phase compensation?", vbYesNo, "")
 If rbx = vbYes Then
    MsgBox("Open measurement terminal.  Then click OK.", vbOKOnly, "")
    Console.WriteLine("Wait a minute . . ." & Chr(10))
    session.WriteString("ADJ " & t(1) & ",1" & vbLf)
    session.WriteString("ADJ? " & t(1) & vbLf) : err = session.ReadString(1 + 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbLf) : err =
session.ReadString(4 + 2) : session.WriteString("DZ" & vbLf) : GoTo Check_err
 End If

 session.WriteString("ACV " & t(1) & "," & osc_level & vbLf)                   '50

 rbx = MsgBox("Do you want to perform Open correction?", vbYesNo, "")
 If rbx = vbYes Then
    session.WriteString("CLCORR " & t(1) & ",1" & vbLf)  'clears frequency list
    For i = 0 To nop1 - 1
      freq = f1 + i * (f2 - f1) / (nop1 - 1)
      session.WriteString("CORRL " & t(1) & "," & freq & vbLf)
      session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
      If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
    Next i
    MsgBox("Open measurement terminal.  Then click OK.", vbOKOnly, "")
    Console.WriteLine("Wait a minute . . ." & Chr(10) & vbLf)
    session.WriteString("DCORR " & t(1) & ",1,100," & ref_cp & "," & ref_g & vbLf)
    session.WriteString("CORR? " & t(1) & ",1" & vbLf) : err = session.ReadString(1
+ 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbLf) : err =
session.ReadString(4 + 2) : session.WriteString("DZ" & vbLf) : GoTo Check_err
    session.WriteString("CORRST " & t(1) & ",1,1" & vbLf)    'open correction ON
    session.WriteString("CORRST " & t(1) & ",2,0" & vbLf)    'short correction OFF
    session.WriteString("CORRST " & t(1) & ",3,0" & vbLf)    'load correction OFF
 End If                                                                        '69
```

Line	Description
35 to 36	Applies 0 V to the drain and source terminals.
37 to 38	Makes the SCUU connection path, and sets the A/D converter of the MFCMU.
40 to 48	Displays a message box that asks if you perform the phase compensation. If you click Yes, the phase compensation will be performed. It will take about 30 seconds.
50	Sets the oscillator level of the MFCMU output signal.
52 to 69	Displays a message box that asks if you perform the open correction. If you click Yes, the open correction will be performed. It does not need a long time. The short correction and the load correction are not performed in this example.

```
MsgBox("Connect DUT.  Then click OK.", vbOKOnly, "")                            '71
session.WriteString("WMFC 2, 1" & vbLf)
session.WriteString("WTFC " & hold & "," & delay & "," & s_delay & vbLf)
session.WriteString("WFC " & t(1) & ",1," & f1 & "," & f2 & "," & nop1 & vbLf)
session.WriteString("MM 22," & t(1) & vbLf)        'Sets measurement mode
session.WriteString("IMP 100" & vbLf)
session.WriteString("LMN 1" & vbLf)
session.WriteString("RC " & t(1) & "," & range & vbLf)
session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
session.WriteString("DCV " & t(1) & "," & dc_bias & vbLf)
session.WriteString("TSR" & vbLf)
session.WriteString("XE" & vbLf)
session.WriteString("*OPC?" & vbLf) : rep = session.ReadString(1 + 2)           '84
session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
session.WriteString("NUB?" & vbLf) : rep = session.ReadString(3 + 2)
If rep <> nop1 * 6 Then session.WriteString("DZ" & vbLf) : GoTo Check_nop     '88

Dim mret As String = session.ReadString(16 * 6 * nop1 + 2) '6*nop1 + terminator
For i = 0 To nop1 - 1
   st(i * 2) = Mid(mret, i * 16 * 6 + 16 * 1 + 1, 3)
   st(i * 2 + 1) = Mid(mret, i * 16 * 6 + 16 * 2 + 1, 3)
   st_mon(i * 2) = Mid(mret, i * 16 * 6 + 16 * 3 + 1, 3)
   st_mon(i * 2 + 1) = Mid(mret, i * 16 * 6 + 16 * 4 + 1, 3)
   tm(i) = Val(Mid(mret, i * 16 * 6 + 4, 12))
   md(i * 2) = Val(Mid(mret, i * 16 * 6 + 16 * 1 + 4, 12))
   md(i * 2 + 1) = Val(Mid(mret, i * 16 * 6 + 16 * 2 + 4, 12))
   mon(i * 2) = Val(Mid(mret, i * 16 * 6 + 16 * 3 + 4, 12))
   mon(i * 2 + 1) = Val(Mid(mret, i * 16 * 6 + 16 * 4 + 4, 12))
   sc(i) = Val(Mid(mret, i * 16 * 6 + 16 * 5 + 4, 12))
   data(j, i) = Chr(13) & Chr(10) & sc(i) / 1000000
   data(j, i) = data(j, i) & "," & md(i * 2) * 1000000000000.0 & "," & st(i * 2)
   data(j, i) = data(j, i) & "," & md(i * 2 + 1) * 1000000.0 & "," & st(i * 2 + 1)
   data(j, i) = data(j, i) & "," & mon(i * 2) * 1000 & "," & st_mon(i * 2)
   data(j, i) = data(j, i) & "," & mon(i * 2 + 1) & "," & st_mon(i * 2 + 1)
   data(j, i) = data(j, i) & "," & tm(i)
Next i                                                                         '108
```

Line	Description
71	Displays a message box that asks you to connect the device to the measurement terminal. Then the CMUH and CMUL must be connected to the gate terminal and the substrate terminal respectively.
72 to 83	Sets the measurement condition, resets the time stamp, and performs the measurement.
84 to 88	Waits until the measurement is completed. After that, if an error is detected, forces 0 V and goes to Check_err. Also if the number of returned data is not correct, forces 0 V and goes to Check_nop.
90 to 108	Stores the returned data into the *mret* string variable. Finally, stores the measured data into the *data* array.

```
 session.WriteString("DZ" & vbLf)                                     '110
 save_data(fname, title, value, data, nop1, nop2, session, t)
 Exit Sub

Check_err:                                                            '114
 session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
 MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
 Exit Sub

Check_nop:                                                            '119
 MsgBox("No. of data: " & rep & " (not " & nop1 * 6 & ")", vbOKOnly, "")
End Sub
```

Line	Description
110 to 112	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
114 to 117	Displays a message box to show an error message if the error is detected.
119 to 120	Displays a message box to show an error message if the number of returned data is not correct.

Measurement Result Example

```
Freq (MHz), Cp (pF), C_st, G (uS), G_st, OSC (mV), Osc_st, DC (V),
Dc_st, Time (s)
0.5,0.102504,NGC,-0.00489649,NGY,29.9602,NGV,5.00364,NGV,0.01205
1,0.103028,NGC,0.00752516,NGY,29.9472,NGV,5.00362,NGV,0.03098
1.5,0.0941827,NGC,0.0385718,NGY,29.914,NGV,5.00384,NGV,0.04993
2,0.0925777,NGC,0.00978407,NGY,29.8359,NGV,5.00383,NGV,0.06891
2.5,0.0936848,NGC,0.0741706,NGY,29.7236,NGV,5.00383,NGV,0.08851
3,0.0926532,NGC,0.0838099,NGY,29.6289,NGV,5.00396,NGV,0.10756
3.5,0.098542,NGC,0.0313031,NGY,29.4926,NGV,5.00391,NGV,0.12654
4,0.0985281,NGC,0.0103357,NGY,29.3519,NGV,5.00376,NGV,0.14551
4.5,0.101377,NGC,0.0136298,NGY,29.1433,NGV,5.004,NGV,0.1644
5,0.100967,NGC,0.10801,NGY,28.9145,NGV,5.0038,NGV,0.1833

Data save completed.

Do you want to perform measurement again?
```

C-t Sampling Measurements

To perform C-t sampling measurements, use the following commands.

Function	Command	Parameters
Enables Measurement Units	CN	[*chnum* ... [,*chnum*] ...]
Disables Measurement Units	CL	[*chnum* ... [,*chnum*] ...]
Sets Filter ON/OFF	[FL]	*mode*[,*chnum* ... [,*chnum*] ...]
Sets series resistor ON/OFF	[SSR]	*chnum*,*mode*
Disables SCUU status indicator	[SSL]	*chnum*,*mode*
Controls SCUU input-output path	[SSP]	*chnum*,*path*
Sets MFCMU A/D converter	[ACT]	*mode*[,*N*]
Sets MFCMU measurement mode	[IMP]	*mode*
Sets timing parameters	MTDCV	*h_bias*,*interval*,*points*[,*h_base*]
Sets constant voltage source	MDCV	*chnum*,*base*,*bias*[,*post*]
Sets MFCMU output frequency	FC	*chnum*,*freq*
Forces AC voltage by using MFCMU	ACV	*chnum*,*ac_level*
Forces DC voltage by using SMU	[DV, TDV]	*chnum*,*range*,*output* [,*comp*[,*polarity*[,*crange*]]]
Forces DC current by using SMU	[DI, TDI]	
Sets MFCMU measurement range	[RC]	*chnum*,*mode*[,*range*]
Sets measurement mode	MM	26,*chnum*
Executes measurement	XE	

The following program performs sampling measurement which repeats capacitance measurement in the specified time interval when a constant voltage is applied to the DUT. This example uses the multi frequency capacitance measurement unit (MFCMU) and the SMU/CMU unify unit (SCUU).

Before performing the capacitance (impedance) measurement, you need to perform the phase compensation and data correction. See “Data Correction” on page 3-71.

Table 3-26 C-t Sampling Measurement Example

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)               '1
 Dim i As Integer = 0                                 't(0): Drain
 Dim j As Integer = 0                                 't(1): Gate
 Dim nop1 As Integer = 30                             't(2): Source
 Dim nop2 As Integer = 1                              't(3): Substrate
 Dim data(nop2 - 1, nop1 - 1) As String
 Dim value As String = "Index, Cp (pF), C_st, G (uS), G_st, Time (s)"
 Dim fname As String = "C:\Agilent\prog_ex\data26.txt"
 Dim title As String = "C-t Sampling Measurement Result"
 Dim msg As String = "No error."
 Dim err As Integer = 0

 Dim freq As Double = 1000000                                                  '13
 Dim ref_cp As Double = 0
 Dim ref_g As Double = 0
 Dim osc_level As Double = 0.03
 Dim base As Double = 0
 Dim bias As Double = 5
 Dim base_h As Double = 0
 Dim bias_h As Double = 0.1
 Dim interval As Double = 0.05
 Dim range As Integer = 0
 Dim rep As Integer = nop1
 Dim sc(nop1) As Double
 Dim md(nop1 * 2) As Double
 Dim st(nop1 * 2) As String
 Dim tm(nop1) As Double

 session.Timeout = 120000                            'B1500 timeout = 120 seconds   '29
 session.WriteString("FMT 1,1" & vbLf)
 session.WriteString("TSC 1" & vbLf)                 'enables time stamp output
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 27	Declares variables and sets the value.
29	Sets timeout for the B1500A.
30 to 31	Sets the data output format (data with source data). And enables the time stamp output.

```
 session.WriteString("DV " & t(0) & ",0,0,0.1,0" & vbLf)                       '32
 session.WriteString("DV " & t(2) & ",0,0,0.1,0" & vbLf)
 session.WriteString("SSP " & t(1) & ", 4" & vbLf)  'CMU to SCUU output
 session.WriteString("ACT 0, 2" & vbLf)             'auto, 2 samples

 Dim rbx As Integer                                                            '37
 rbx = MsgBox("Do you want to perform Phase compensation?", vbYesNo, "")
 If rbx = vbYes Then
    MsgBox("Open measurement terminal.  Then click OK.", vbOKOnly, "")
    Console.WriteLine("Wait a minute . . ." & Chr(10))
    session.WriteString("ADJ " & t(1) & ",1" & vbLf)
    session.WriteString("ADJ? " & t(1) & vbLf) : err = session.ReadString(1 + 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbLf) : err =
session.ReadString(4 + 2) : session.WriteString("DZ" & vbLf) : GoTo Check_err
 End If

 session.WriteString("FC " & t(1) & "," & freq & vbLf)                         '47
 session.WriteString("ACV " & t(1) & "," & osc_level & vbLf)

 rbx = MsgBox("Do you want to perform Open correction?", vbYesNo, "")
 If rbx = vbYes Then
    session.WriteString("CLCORR " & t(1) & ",2" & vbLf)
    MsgBox("Open measurement terminal.  Then click OK.", vbOKOnly, "")
    Console.WriteLine("Wait a minute . . ." & Chr(10) & vbLf)
    session.WriteString("DCORR " & t(1) & ",1,100," & ref_cp & "," & ref_g & vbLf)
    session.WriteString("CORR? " & t(1) & ",1" & vbLf) : err = session.ReadString(1
+ 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbLf) : err =
session.ReadString(4 + 2) : session.WriteString("DZ" & vbLf) : GoTo Check_err
    session.WriteString("CORRST " & t(1) & ",1,1" & vbLf)    'open correction ON
    session.WriteString("CORRST " & t(1) & ",2,0" & vbLf)    'short correction OFF
    session.WriteString("CORRST " & t(1) & ",3,0" & vbLf)    'load correction OFF
 End If                                                                        '61
```

Line	Description
32 to 33	Applies 0 V to the drain and source terminals.
34 to 35	Makes the SCUU connection path, and sets the A/D converter of the MFCMU.
37 to 45	Displays a message box that asks if you perform the phase compensation. If you click Yes, the phase compensation will be performed. It will take about 30 seconds.
47 to 48	Sets the frequency and the oscillator level of the MFCMU output signal.
50 to 61	Displays a message box that asks if you perform the open correction. If you click Yes, the open correction will be performed. It does not need a long time. The short correction and the load correction are not performed in this example.

```
 MsgBox("Connect DUT.  Then click OK.", vbOKOnly, "")                                  '63
 session.WriteString("MTDCV " & bias_h & "," & interval & "," & nop1 & "," & base_h
& vbLf)
 session.WriteString("MDCV " & t(1) & "," & base & "," & bias & ",0" & vbLf)
 session.WriteString("MM 26," & t(1) & vbLf)
 session.WriteString("IMP 100" & vbLf)
 session.WriteString("RC " & t(1) & "," & range & vbLf)
 session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
 If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
 session.WriteString("TSR" & vbLf)
 session.WriteString("XE" & vbLf)
 session.WriteString("*OPC?" & vbLf) : rep = session.ReadString(1 + 2)         '73
 session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
 If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
 session.WriteString("NUB?" & vbLf) : rep = session.ReadString(3 + 2)
 If rep <> nop1 * 4 Then session.WriteString("DZ" & vbLf) : GoTo Check_nop     '77

 Dim mret As String = session.ReadString(16 * 4 * nop1 + 2) '4*nop1 + terminator
 For i = 0 To nop1 - 1
    st(i * 2) = Mid(mret, i * 16 * 4 + 16 * 2 + 1, 3)
    st(i * 2 + 1) = Mid(mret, i * 16 * 4 + 16 * 3 + 1, 3)
    sc(i) = Val(Mid(mret, i * 16 * 4 + 4, 12))
    tm(i) = Val(Mid(mret, i * 16 * 4 + 16 * 1 + 4, 12))
    md(i * 2) = Val(Mid(mret, i * 16 * 4 + 16 * 2 + 4, 12))
    md(i * 2 + 1) = Val(Mid(mret, i * 16 * 4 + 16 * 3 + 4, 12))
    data(j, i) = Chr(13) & Chr(10) & sc(i) & "," & md(i * 2) * 1000000000000.0 & ","
& st(i * 2)
    data(j, i) = data(j, i) & "," & md(i * 2 + 1) * 1000000.0 & "," & st(i * 2 + 1)
& "," & tm(i)
 Next i                                                                                '89
 session.WriteString("DZ" & vbLf)
 save_data(fname, title, value, data, nop1, nop2, session, t)
 Exit Sub
```

Line	Description
63	Displays a message box that asks you to connect the device to the measurement terminal. Then the CMUH and CMUL must be connected to the gate terminal and the substrate terminal respectively.
64 to 72	Sets the measurement condition, resets the time stamp, and performs the measurement.
73 to 77	Waits until the measurement is completed. After that, if an error is detected, forces 0 V and goes to Check_err. Also if the number of returned data is not correct, forces 0 V and goes to Check_nop.
79 to 89	Stores the returned data into the *mret* string variable. Finally, stores the measured data into the *data* array.
90 to 92	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.

```
Check_err:                                                              '94
 session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
 MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
 Exit Sub

Check_nop:                                                              '99
 MsgBox("No. of data: " & rep & " (not " & nop1 * 4 & ")", vbOKOnly, "")
End Sub
```

Line	Description
94 to 97	Displays a message box to show an error message if the error is detected.
99 to 100	Displays a message box to show an error message if the number of returned data is not correct.

Measurement Result Example

```
Index, Cp (pF), C_st, G (uS), G_st, Time (s)
1,0.100051,NGC,0.0579184,NGY,0.10199
2,0.0989954,NGC,0.0510581,NGY,0.152
3,0.101344,NGC,0.0603764,NGY,0.20199
4,0.0988522,NGC,0.058593,NGY,0.252
5,0.0990403,NGC,0.0514987,NGY,0.30199
6,0.10049,NGC,0.0588621,NGY,0.35199
7,0.0997872,NGC,0.0505812,NGY,0.40199
8,0.0990492,NGC,0.0449747,NGY,0.452
9,0.0999805,NGC,0.0460361,NGY,0.50199
10,0.0972752,NGC,0.0518454,NGY,0.552
11,0.100533,NGC,0.0604562,NGY,0.60199
12,0.0979196,NGC,0.0573212,NGY,0.65199
13,0.0984623,NGC,0.0589873,NGY,0.70199
14,0.0991157,NGC,0.0501881,NGY,0.752
15,0.0985757,NGC,0.0550837,NGY,0.80199
16,0.0972,NGC,0.0564537,NGY,0.852
17,0.0993272,NGC,0.0596557,NGY,0.90199
18,0.0986133,NGC,0.0542398,NGY,0.952
19,0.0992744,NGC,0.0634103,NGY,1.00199
20,0.0990222,NGC,0.0627697,NGY,1.052
21,0.0985357,NGC,0.0446665,NGY,1.102
22,0.0997336,NGC,0.060945,NGY,1.152
23,0.0993864,NGC,0.0538741,NGY,1.202
24,0.0986702,NGC,0.04196,NGY,1.25199
25,0.099164,NGC,0.0535988,NGY,1.30199
26,0.100364,NGC,0.0378016,NGY,1.352
27,0.100047,NGC,0.0534552,NGY,1.402
28,0.100995,NGC,0.0550804,NGY,1.452
29,0.100044,NGC,0.0452834,NGY,1.50199
30,0.101213,NGC,0.0538826,NGY,1.552

Data save completed.

Do you want to perform measurement again?
```

SPGU Pulse Output and Voltage Measurement

To control the SPGU channel, use the following commands.

Function	Command	Parameters
Enables channels	CN	[*chnum* ... [,*chnum*] ...]
Disables channels	CL	[*chnum* ... [,*chnum*] ...]
Sets SPGU pulse output mode	SIM	0
Sets output operation mode	SPRM	*mode*[,*condition*]
Sets pulse period for all of SPGU channels	SPPER	*period*
Sets channel output mode	SPM	*chnum*,*mode*
Sets pulse timing parameters	SPT	*chnum*,*src*,*delay*,*width*,*leading* [,*trailing*]
Sets pulse level parameters	SPV	*chnum*,*src*,*base*[,*peak*]
Sets load impedance	SER	*chnum*,*loadZ*
Measures terminal voltage, calculates and sets load impedance	[CORRSER?]	*chnum*,*mode*,*delay*,*interval*, *count*
Sets pulse switch	[ODSW]	*chnum*,*state*[,*normal*[,*delay*, *width*]]
Sets SPGU trigger output	[STGP]	*chnum*,*state*
Applies SPGU channel setup	SPUPD	*chnum*[,*chnum* ... [,*chnum*] ...]
Starts SPGU pulse output	SRP	
Stops SPGU pulse output	[SPP]	
Returns SPGU output status	[SPST?]	

The following program controls a SPGU to output 2-level pulse from the channel 1 and 3-level pulse from the channel 2. This program can run without the project template (Table 3-1).

Table 3-27 **SPGU Pulse Output Example**

```
Imports Ivi.visa.interop                                                   '1

Module Module1

Sub Main()
 Dim B1500 As IResourceManager                                             '6
 Dim session As IMessage
 B1500 = New ResourceManager
 session = B1500.Open("GPIB0::17::INSTR")
 session.WriteString("*RST" & vbLf)                                        '10
 MsgBox("Click OK to start measurement.", vbOKOnly, "")
 Console.WriteLine("SPGU setup." & Chr(10))

 Dim sp_ch() As Integer = {101, 102}                                       '14
 Dim duration As Double = 10
 Dim loadz As Double = 1000000.0
 Dim period As Double = 0.0001
 Dim p1_del As Double = 0.00001
 Dim p1_wid As Double = 0.00008
 Dim p2_del1 As Double = 0.00001
 Dim p2_del2 As Double = 0.00006
 Dim p2_wid1 As Double = 0.00003
 Dim p2_wid2 As Double = 0.00003
 Dim p_lead As Double = 0.00000002
 Dim p_trail As Double = 0.00000002
 Dim p1_base As Double = 0
 Dim p1_peak As Double = 3
 Dim p2_base1 As Double = 0
 Dim p2_base2 As Double = 0
 Dim p2_peak1 As Double = 3
 Dim p2_peak2 As Double = -3
 Dim p_stat As Integer = 0                                                 '32
```

Line	Description
1	This line is required to use the VISA COM library.
6 to 9	Establishes the connection with the Agilent B1500 of the GPIB address 17 on the interface GPIB0. “GPIB0” is the VISA name. Confirm your GPIB settings, and set them properly.
10	Resets the B1500.
14 to 32	Declares variables and sets the value. This program uses the SPGU installed in the slot 1 of the B1500.

```
 Dim msg As String = "No error."                                          '34
 Dim err As Integer = 0

 session.WriteString("CN " & sp_ch(0) & "," & sp_ch(1) & vbLf)  'SPGU ch on    '37
 session.WriteString("SIM 0" & vbLf)                            'PG mode
 session.WriteString("SPRM 2," & duration & vbLf)               'Duration mode
 session.WriteString("ODSW " & sp_ch(0) & ", 0" & vbLf) 'Disables pulse switch '40
 session.WriteString("ODSW " & sp_ch(1) & ", 0" & vbLf)
 session.WriteString("SER " & sp_ch(0) & "," & loadz & vbLf)    'Load impedance
 session.WriteString("SER " & sp_ch(1) & "," & loadz & vbLf)
 session.WriteString("SPPER " & period & vbLf)                  'Pulse period
 session.WriteString("SPM " & sp_ch(0) & ",1" & vbLf)   '2-level pulse setup   '45
 session.WriteString("SPT " & sp_ch(0) & ",1," & p1_del & "," & p1_wid & "," &
p_lead & "," & p_trail & vbLf)
 session.WriteString("SPV " & sp_ch(0) & ",1," & p1_base & "," & p1_peak & vbLf)
 session.WriteString("SPM " & sp_ch(1) & ",3" & vbLf)   '3-level pulse setup   '48
 session.WriteString("SPT " & sp_ch(1) & ",1," & p2_del1 & "," & p2_wid1 & "," &
p_lead & "," & p_trail & vbLf)
 session.WriteString("SPT " & sp_ch(1) & ",2," & p2_del2 & "," & p2_wid2 & "," &
p_lead & "," & p_trail & vbLf)
 session.WriteString("SPV " & sp_ch(1) & ",1," & p2_base1 & "," & p2_peak1 & vbLf)
 session.WriteString("SPV " & sp_ch(1) & ",2," & p2_base2 & "," & p2_peak2 & vbLf)
 session.WriteString("SPUPD" & sp_ch(0) & "," & sp_ch(1) & vbLf) 'Apply setup  '53
```

Line	Description
34 to 35	Declares variables used for error check.
37	Enables the SPGU channels specified by sp_ch(0) and sp_ch(1).
38	Sets the pulse generator mode to all of the SPGU channels.
39	Selects the duration output mode.
40 to 41	Disables the pulse switch.
42 to 43	Sets the load impedance value.
44	Sets the pulse period for all of the SPGU channels.
45 to 47	Sets the channel specified by sp_ch(0) to the 2-level pulse output channel using the source 1, sets the pulse timing parameters, and sets the pulse level parameters.
48 to 52	Sets the channel specified by sp_ch(1) to the 3-level pulse output channel using the source 1 and 2, sets the pulse timing parameters, and sets the pulse level parameters.
53	Applies the setup to the channels specified by sp_ch(0) and sp_ch(1). The channels start the pulse base output.

```
 session.WriteString("ERRX? 0" & vbLf) : msg = session.ReadString(256)        '55
 err = Val(Left(msg, 2))
 If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err

 session.WriteString("SRP" & vbLf)        'starts pulse output                 '59
 Console.Write("SPGU output in progress")

Spgu_stat:                                                                    '62
 Console.Write(".")
 session.WriteString("SPST?" & vbLf) : p_stat = session.ReadString(1 + 2)
 If p_stat = 1 Then GoTo Spgu_stat
 If p_stat = 0 Then GoTo Close

Check_err:                                                                    '68
 MsgBox("Instrument error: " & Chr(10) & msg, vbOKOnly, "")

Close:                                                                        '71
 Console.WriteLine(Chr(10) & "SPGU output stopped.")
 session.WriteString("CL" & vbLf)
 session.Close()
 MsgBox("Click OK to stop the program.", vbOKOnly, "")
 Console.WriteLine("Program completed." & Chr(10))                            '76

End Sub

End Module
```

Line	Description
55 to 57	Reads error buffer. If an error is detected, changes the channel output to 0 V and goes to Check_err.
59	Starts the SPGU pulse output.
62 to 66	Checks the SPGU pulse output status. And waits for the end status.
68 to 69	Clears the error buffer. And displays a message box to show an error message.
71 to 76	Disables all channels, and closes the connection with the Agilent B1500.

Measurement Result Example

```
SPGU setup.

SPGU output in progress.....................................
...............................................................
SPGU output stopped.
```

The following program controls a SPGU to measure the terminal voltage, calculate the load impedance, set it for the automatic output level adjustment, and output 2-level pulse voltage. This program can run without the project template (Table 3-1).

Table 3-28 SPGU Voltage Measurement and Pulse Output Example

```
Imports Ivi.visa.interop                                                    '1

Module Module1

Sub Main()
 Dim B1500 As IResourceManager                                              '6
 Dim session As FormattedIO488
 B1500 = New ResourceManager
 session = New FormattedIO488
 session.IO = B1500.Open("GPIB0::17::INSTR")
 session.IO.Timeout = 10000

 session.WriteString("*RST" & vbLf)                                         '13
 MsgBox("Click OK to start measurement.", vbOKOnly, "")
 Console.Write("SPGU setup...   ")

 Dim sp_ch() As Integer = {101, 102}                                        '17
 Dim duration As Double = 5
 Dim loadz As Double = 50.0
 Dim period As Double = 0.0001
 Dim p1_del As Double = 0.00001
 Dim p1_wid As Double = 0.00008
 Dim p_lead As Double = 0.0000001
 Dim p_trail As Double = 0.0000001
 Dim p1_base As Double = 0
 Dim p1_peak As Double = 3
 Dim p_stat As Integer = 0
 Dim delay As Double = p1_wid / 8
 Dim count As Double = 3
 Dim interval As Double = (p1_wid - delay * 2) / count
 Dim measv As Double = 3.0
 Dim rval As String = ""                                                    '32
```

Line	Description
1	This line is required to use the VISA COM library.
6 to 11	Establishes the connection with the Agilent B1500 of the GPIB address 17 on the interface GPIB0. “GPIB0” is the VISA name. Confirm your GPIB settings, and set them properly. Also sets the B1500 GPIB IO timeout.
13	Resets the B1500.
17 to 32	Declares variables and sets the value. This program uses the SPGU installed in the slot 1 of the B1500.

```
 Dim msg As String = "No error."                                                '34
 Dim err As Integer = 0

 session.WriteString("CN " & sp_ch(0) & vbLf)                                   '37
 session.WriteString("SIM 0" & vbLf)                        ' PG mode
 session.WriteString("SPRM 2," & duration & vbLf)           ' Duration mode
 session.WriteString("ODSW " & sp_ch(0) & ", 0" & vbLf)  ' Disables pulse switch
 session.WriteString("SPPER " & period & vbLf)              ' Pulse period
 session.WriteString("SPM " & sp_ch(0) & ",1" & vbLf)     ' 2-level pulse setup
 session.WriteString("SPT " & sp_ch(0) & ",1," & p1_del & "," & p1_wid & "," &
p_lead & "," & p_trail & vbLf)
 session.WriteString("SPV " & sp_ch(0) & ",1," & p1_base & "," & p1_peak & vbLf)
 session.WriteString("SPUPD" & sp_ch(0) & vbLf)             ' Apply setup       '45
 session.WriteString("ERRX? 0" & vbLf) : msg = session.ReadString() : err =
Val(Left(msg, 2))
 If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
 Console.Write("Completed." & Chr(10) & Chr(10))                                '48

 session.WriteString("CORRSER? " & sp_ch(0) & ", 1," & delay & "," & interval & ","
& count & vbLf)
 rval = session.ReadString()
 Console.WriteLine("Before compensation: LoadZ, TermV = " & rval)
 session.WriteString("CORRSER? " & sp_ch(0) & ", 1," & delay & "," & interval & ","
& count & vbLf)
 rval = session.ReadString()
 Console.WriteLine("After compensation:  LoadZ, TermV = " & rval)
 session.WriteString("SRP" & vbLf) ' Start pulse output                         '56
 Console.Write("SPGU output in progress")

Spgu_stat:
 Console.Write(".")
 session.WriteString("SPST?" & vbLf) : p_stat = session.ReadString()
 If p_stat = 1 Then GoTo Spgu_stat                                              '62
```

Line	Description
34 to 35	Declares variables used for error check.
37	Enables the SPGU channels specified by sp_ch(0).
38 to 45	Defines the channel setup and applies them to the channel specified by sp_ch(0). The channels start the pulse base output.
46 to 47	Reads error buffer. If an error is detected, changes the channel output to 0 V and goes to Check_err.
50 to 55	Measures the terminal voltage, calculates the impedance, sets it to the channel specified by sp_ch(0), and displays the voltage and impedance. This is performed twice.
56 to 62	Starts the SPGU pulse output and checks the SPGU pulse output status. And waits for the end status.

```
 Dim i, n As Integer                                                           '64
 session.WriteString("CORRSER? " & sp_ch(0) & ", 0," & delay & "," & interval & ","
& count & vbLf)
 rval = session.ReadString()
 n = Len(rval)
 i = InStr(rval, ",")
 loadz = Val(Left(rval, i - 1))
 measv = Val(Right(rval, n - i))
 Console.WriteLine(Chr(10) & Chr(10) & "After SPGU output:")
 Console.WriteLine("Load impedance   = " & loadz & " ohm")
 Console.WriteLine("Terminal voltage = " & measv & " V")
 GoTo Close

Check_err:                                                                     '76
 MsgBox("Instrument error: " & Chr(10) & msg, vbOKOnly, "")

Close:                                                                         '79
 Console.WriteLine(Chr(10) & "SPGU output stopped." & vbLf)
 session.WriteString("CL" & vbLf)
 session.IO.Close()
 MsgBox("Click OK to stop the program.", vbOKOnly, "")
 Console.WriteLine("Program completed." & Chr(10))                             '84

End Sub

End Module
```

Line	Description
64 to 74	Measures the terminal voltage, calculates the impedance, and displays the result.
76 to 77	Clears the error buffer. And displays a message box to show an error message.
79 to 84	Disables all channels, and closes the connection with the Agilent B1500.

Measurement Result Example

```
SPGU setup...   Completed.

Before compensation: LoadZ, TermV = +3.02579E+05,+6.029515

After compensation:  LoadZ, TermV = +1.50844E+05,+3.004060

SPGU output in progress..........................................
................................................................

After SPGU output:
Load impedance   = 150865 ohm
Terminal voltage = 3.003394 V

SPGU output stopped.
```

Using Program Memory

The program memory can store approximately 2,000 programs or 40,000 commands. Storing programs and executing them will improve the program execution speed. The following commands are available to use program memory.

Command	Function and Syntax

ST and END	Stores the program in the memory.
	
	`ST` *pnum*`;`*command*`[ ... [;`*command*`] ..];END`
	
	or
	
	`ST` *pnum*
	`[`*command*`]`
	`:`
	`[`*command*`]`
	`END`

[SCR]	Scratches the program. `SCR [`*pnum*`]`
[LST?]	Gets a catalog of program numbers or a specific program listing (up to 3000 commands). `LST? [`*pnum*`[,`*index*`[,`*size*`]]]`
DO	Executes specified programs. `DO` *pnum*`[,`*pnum* ... `[,`*pnum*`] ...]`
RU	Executes programs sequentially. `RU` *start*`,`*stop*
[PA]	Pauses command execution or internal memory program execution. `PA [`*wait*`]`
[VAR]	Defines an internal memory variable, and sets the value. `VAR` *Type*`,`*N*`,`*Value*
[VAR?]	Reads the value of the internal memory variable. `VAR?` *Type*`,`*N*

Table 3-29 and Table 3-30 show the example program that uses the internal program memory, and does the following:

- stores a high-speed spot measurement program in the memory 1, and displays it.
- stores a pulsed spot measurement program in the memory 2, and displays it.
- executes the internal memory program 1 and 2.
- displays the measurement results on the console window.

The example program shown in Table 3-30 uses the internal variables available for the internal program memory. The program code is given as the replaceable code of the lines 12 to 38 shown in Table 3-29. To run the program, delete the lines 12 to 38 from the program of Table 3-29, and insert the program lines 1 to 37 of Table 3-30. Also insert Table 3-30's lines 39 to 49 between Table 3-29's lines 52 and 53. The code shown in Table 3-30 cannot run by itself.

NOTE

Running example programs in this section

To run the programs, the project template (Table 3-1) is not needed. To run the program of Table 3-30, see the above paragraph.

Tips to use program memory

1. Completes program:

   Before storing the program in the program memory, verify that the program is complete and free of errors. Command parameter check will be performed when the program is executed.

   If the program being stored makes changes to the present measurement setup, verify that these changes are correct and compatible with the present setup.

2. For the invalid commands in the internal memory program, refer to Table 2-1 on page 2-51.

Table 3-29 Program Memory Programming Example 1

```
Imports Ivi.visa.interop                                                    '1

Module Module1
Sub Main()
    Dim B1500 As IResourceManager                                           '5
    Dim session As IMessage
    B1500 = New ResourceManager
    session = B1500.Open("GPIB0::17::INSTR")
    session.WriteString("*RST" & vbLf)
    Dim fmt As Integer = 1 : session.WriteString("FMT" & fmt & vbLf)
    Dim t() As Integer = {5, 4, 3, 1}  'Drain, Gate, Source, Substrate
    Dim v0 As Double = 0 : Dim vd As Double = 1 : Dim idcomp As Double = 0.1   '12
    Dim vg As Double = 0.8 : Dim igcomp As Double = 0.05
    Dim orng As Integer = 0 : Dim mrng As Integer = 0 : Dim hold As Double = 0.1
    Dim width As Double = 0.01 : Dim period As Double = 0.02

    Dim mem As Integer = 1                                                  '17
    session.WriteString("ST" & mem & vbLf)
    session.WriteString("DV" & t(3) & ",0,0,0.1" & vbLf)
    session.WriteString("DV" & t(2) & ",0,0,0.1" & vbLf)
    session.WriteString("DV" & t(1) & "," & orng & "," & vg & "," & igcomp & vbLf)
    session.WriteString("DV" & t(0) & "," & orng & "," & vd & "," & idcomp & vbLf)
    session.WriteString("TI" & t(0) & "," & mrng & vbLf)
    session.WriteString("END" & vbLf)
    display_mem(session, mem)

    mem = 2                                                                 '27
    session.WriteString("ST" & mem & vbLf)
    session.WriteString("PT" & hold & "," & width & "," & period & vbLf)
    session.WriteString("DV" & t(3) & ",0,0,0.1" & vbLf)
    session.WriteString("DV" & t(2) & ",0,0,0.1" & vbLf)
    session.WriteString("PV" & t(1) & "," & orng & "," & v0 & "," & vg & "," &
igcomp & vbLf)
    session.WriteString("DV" & t(0) & "," & orng & "," & vd & "," & idcomp & vbLf)
    session.WriteString("MM3," & t(0) & vbLf)
    session.WriteString("RI" & t(0) & "," & mrng & vbLf)
    session.WriteString("XE" & vbLf)
    session.WriteString("END" & vbLf)
    display_mem(session, mem)                                               '38
```

Line	Description
1	This line is required to use the VISA COM library.
5 to 11	Establishes the connection with the Agilent B1500, resets the B1500, and sets the data output format. Also declares the SMUs used for measurement.
12 to 15	Declares variables used to set measurement conditions and sets the value.
17 to 25	Stores program in the internal memory 1, and displays it on the console window.
27 to 38	Stores program in the internal memory 2, and displays it on the console window.

```
    Dim term As String = t(0) & "," & t(1) & "," & t(2) & "," & t(3)        '40
    session.WriteString("CN" & term & vbLf)
    Dim i As Integer : Dim ret As Integer : Dim msg As String
    Dim value As String : Dim status As String : Dim meas As Double
    For i = 1 To 2
     session.WriteString("DO" & i & vbLf)
     session.WriteString("*OPC?" & vbLf) : ret = session.ReadString(1 + 2)
     session.WriteString("ERR? 1" & vbLf) : ret = session.ReadString(4 + 2)
     If ret <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
     value = session.ReadString(17) : status = Left(value, 3)
     value = Mid(value, 4, 12) : meas = Val(value)
     Console.WriteLine("Memory " & i & ": Id = " & meas & " (A), Status = " & status
& Chr(10))
    Next
    session.WriteString("DZ" & vbLf)                                         '53
    session.WriteString("CL" & vbLf)
    session.Close()
    Exit Sub

Check_err:                                                                   '58
    session.WriteString("EMG? " & ret & vbLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & ret & Chr(10) & msg, vbOKOnly, "")
    Exit Sub
End Sub

Sub display_mem(ByVal session As IMessage, ByVal mem As Integer)            '64
    session.WriteString("LST?" & mem & vbLf)
    Dim prog_list As String = session.ReadString(256)
    Console.WriteLine("Memory " & mem & ":")
    Console.WriteLine(prog_list & Chr(10))
End Sub

End Module
```

Line	Description
40 to 52	Enables SMUs and performs the measurement. After that, checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err. Also reads the measured data and displays it on the console window.
53 to 56	Applies 0 V from all channels, disables SMUs, and closes the connection with the Agilent B1500.
58 to 62	Displays a message box to show an error message if the error is detected.
64 to 69	Reads the program lists stored in the internal program memory, and displays it on the console window.

Measurement Result Example

```
Memory 1: Id = 0.021945 (A), Status = NAI

Memory 2: Id = 0.022095 (A), Status = NAI

Press any key to continue
```

Table 3-30 Program Memory Programming Example 2

```
session.WriteString("VAR0,0," & t(0) & vbLf) '%I0=t(0)                         '1
session.WriteString("VAR0,1," & t(1) & vbLf) '%I1=t(1)
session.WriteString("VAR0,2," & t(2) & vbLf) '%I2=t(2)
session.WriteString("VAR0,3," & t(3) & vbLf) '%I3=t(3)
session.WriteString("VAR0,4,0" & vbLf)       '%I4=mrng
session.WriteString("VAR0,5,0" & vbLf)       '%I5=orng
session.WriteString("VAR1,0,1" & vbLf)       '%R0=vd
session.WriteString("VAR1,1,0.8" & vbLf)     '%R1=vg
session.WriteString("VAR1,2,0.1" & vbLf)     '%R2=idcomp
session.WriteString("VAR1,3,0.05" & vbLf)    '%R3=igcomp
session.WriteString("VAR1,4,0" & vbLf)       '%R4=v0
session.WriteString("VAR1,5,0.1" & vbLf)     '%R5=hold
session.WriteString("VAR1,6,0.01" & vbLf)    '%R6=width
session.WriteString("VAR1,7,0.02" & vbLf)    '%R7=period

Dim mem As Integer = 1                                                         '16
session.WriteString("ST" & mem & vbLf)
session.WriteString("DV %I3,0,0,0.1" & vbLf)
session.WriteString("DV %I2,0,0,0.1" & vbLf)
session.WriteString("DV %I1,%I5,%R1,%R3" & vbLf)
session.WriteString("DV %I0,%I5,%R0,%R2" & vbLf)
session.WriteString("TI %I0,%I4" & vbLf)
session.WriteString("END" & vbLf)
display_mem(session, mem)

mem = 2                                                                        '26
session.WriteString("ST" & mem & vbLf)
session.WriteString("PT %R5,%R6,%R7" & vbLf)
session.WriteString("DV %I3,0,0,0.1" & vbLf)
session.WriteString("DV %I2,0,0,0.1" & vbLf)
session.WriteString("PV %I1,%I5,%R4,%R1,%R3" & vbLf)
session.WriteString("DV %I0,%I5,%R0,%R2" & vbLf)
session.WriteString("MM3,%I0" & vbLf)
session.WriteString("RI %I0,%I4" & vbLf)
session.WriteString("XE" & vbLf)
session.WriteString("END" & vbLf)
display_mem(session, mem)                                                      '37
```

Line	Description
1 to 14	Declares variables used to set measurement conditions and sets the value. To run the program, replace the code with the lines 12 to 15 of the program shown in Table 3-29.
16 to 24	Stores program in the internal memory 1, and displays it on the console window. To run the program, replace the code with the lines 17 to 25 of the program shown in Table 3-29.
26 to 37	Stores program in the internal memory 2, and displays it on the console window. To run the program, replace the code with the lines 27 to 38 of the program shown in Table 3-29.

```
'changes vd and vg and performs measurement again                              '39
session.WriteString("VAR1,0,3" & vbLf)      '%R0=vd
For i = 1 To 2
session.WriteString("DO" & i & vbLf)
session.WriteString("*OPC?" & vbLf) : ret = session.ReadString(1 + 2)
session.WriteString("ERR? 1" & vbLf) : ret = session.ReadString(4 + 2)
If ret <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
value = session.ReadString(17) : status = Left(value, 3)
value = Mid(value, 4, 12) : meas = Val(value)
Console.WriteLine("Memory " & i & ": Id = " & meas & " (A), Status = " & status &
Chr(10))
Next                                                                           '49
```

Line	Description
39 to 49	Changes the value of the internal variable %R0, and performs measurement again. Can be inserted between line 52 and line 53 of the program shown in Table 3-29.

Measurement Result Example

```
Memory 1: Id = 0.021955 (A), Status = NAI

Memory 2: Id = 0.021975 (A), Status = NAI

Memory 1: Id = 0.023085 (A), Status = NAI

Memory 2: Id = 0.023335 (A), Status = NAI

Press any key to continue
```

Using Trigger Function

The Agilent B1500 can be equipped with eight trigger ports that will be used for different purpose individually. The Agilent B1500 can synchronize the operation with other equipment by using the trigger function. For details about the trigger input/output operation, see “Trigger Function” on page 2-69. The following commands are available for the trigger function.

Command	Function and Syntax
TGP	Sets the trigger port for the specified terminal. `TGP` *port*`,`*terminal*`,`*polarity*`[,`*type*`]`
TGPC	Clears the trigger setting of the specified ports. `TGPC [`*port* `... [,`*port*`] ... ]`
TGSI	Selects the sweep step first or last that ignores the Start Step Output Setup trigger input set by the `TGP` *port*`,1,`*polarity*`,2` command. `TGSI` *mode*
TGSO	Selects the trigger type, edge or gate, for the Step Output Setup Completion trigger output set by the `TGP` *port*`,2,`*polarity*`,2` command. `TGSO` *mode*
TGXO	Selects the trigger type, edge or gate, for the Measurement Completion trigger output set by the `TGP` *port*`,2,`*polarity*`,1` command. `TGXO` *mode*
TGMO	Selects the trigger type, edge or gate, for the Step Measurement Completion trigger output set by the `TGP` *port*`,2,`*polarity*`,3` command. `TGMO` *mode*
TM3	Enables the trigger set by the `TGP` *port*`,`*terminal*`,`*polarity*`,1` command.

The following commands are also available to send a trigger or wait for an external trigger input. Refer to “Using Trigger Function” on page 2-74.

Command	Function and Syntax
OS	Causes the Agilent B1500 to send a trigger signal from the Ext Trig Out terminal. `OS`
OSX [a]	Causes the Agilent B1500 to send a trigger signal from the specified port. `OSX` *port*`[,`*level*`]`
WS	Enters a wait state until the Agilent B1500 receives an external trigger via the Ext Trig In terminal. `WS [`*mode*`]`
WSX [a]	Enters a wait state until the Agilent B1500 receives an external trigger via the specified port. `WSX` *port*`[,`*mode*`]`
PA	Pauses command execution or internal memory program execution until the specified wait time has elapsed, or until a trigger is received from the Ext Trig In terminal if the TM3 command has been entered. `PA [`*wait*`]`
PAX [a]	Pauses command execution or internal memory program execution until the specified wait time has elapsed, or until a trigger is received from the specified port if the TM3 command has been entered. `PAX` *port*`[,`*wait*`]`
TGP	Sets trigger port to the specified terminal. `TGP` *port*`,`*terminal*`,`*polarity*`[,`*type*`]`
TM3	Uses an external trigger to release the PA/PAX command state or to start measurement when the B1500 is not in the PA/PAX/WS/WSX command state.

a. Enter the TGP command to set the trigger port.

Programming examples using the trigger function are explained below. The examples use a couple within the available couples of the Agilent B1500A and the Agilent E5260/E5270 series. In this section, they are assigned as Unit1 (address 717) and Unit2 (address 722).

NOTE To run the programs shown in this section, you do not need the example code shown in Table 3-1 (template of a project).

The following program performs a MOSFET drain current measurement. Unit2 applies voltage to the source and substrate terminals. Unit1 applies voltage to the gate and drain terminals, and measures the drain current. Before running the program, connect a BNC cable between the following terminals.

- Unit2's Ext Trig Out to Unit1's Ext Trig In

Table 3-31 Trigger Programming Example 1

```
Imports Ivi.visa.interop                                                       '1

Module Module1
Sub Main()
 Dim B1500 As IResourceManager : Dim unit1 As IMessage                         '5
 B1500 = New ResourceManager
 unit1 = B1500.Open("GPIB0::17::INSTR")
 Dim E5270 As IResourceManager : Dim unit2 As IMessage
 E5270 = New ResourceManager
 unit2 = E5270.Open("GPIB0::22::INSTR")
 unit1.WriteString("*RST" & vbLf)
 unit2.WriteString("*RST" & vbLf)
 MsgBox("Click OK to start measurement.", vbOKOnly, "")
 Console.WriteLine("Measurement in progress. . ." & Chr(10))
 Dim t() As Integer = {1, 2, 1, 2}              'unit1[1,2], unit2[1,2]
 Dim term1 As String = t(0) & "," & t(1)
 Dim term2 As String = t(2) & "," & t(3)
 unit1.WriteString("CN " & term1 & vbLf)
 unit2.WriteString("CN " & term2 & vbLf)
 perform_meas(unit1, unit2, t)                                                 '20
```

Line	Description
1	This line is required to use the VISA COM library.
5 to 20	Main subprogram establishes the connection with Unit1 and Unit2, resets them, opens a message box to confirm the start of measurement, and pauses program execution until OK is clicked on the message box. By clicking OK, the program displays a message on the console window, enables the SMUs (in the slots 1 and 2 of both Unit1 and Unit2), and calls the perform_meas subprogram that will be used to perform measurement.

```
 unit1.WriteString("CL" & vbLf)                                              '22
 unit2.WriteString("CL" & vbLf)
 unit1.Close()
 unit2.Close()
 MsgBox("Click OK to stop the program.", vbOKOnly, "")
 Console.WriteLine("Measurement completed." & Chr(10))
 End Sub                                                                     '28

Sub perform_meas(ByVal unit1 As IMessage, ByVal unit2 As IMessage, ByVal t() As
Integer)                                                                     '30
 Dim i As Integer = 0                          't(0): Drain
 Dim j As Integer = 0                          't(1): Gate
 Dim nop1 As Integer = 1                       't(2): Source
 Dim nop2 As Integer = 1                       't(3): Substrate
 Dim data(nop2 - 1, nop1 - 1) As String
 Dim value As String = "Id (mA), Status"
 Dim fname As String = "C:\Agilent\prog_ex\data14.txt"
 Dim title As String = "Measurement Result"
 Dim msg As String = "No error."
 Dim err As Integer = 0

 Dim vg As Double = 0.8 : Dim igcomp As Double = 0.05                        '42
 Dim vd As Double = 2.5 : Dim vs As Double = 0 : Dim icomp As Double = 0.1
 Dim ret As Integer

 unit1.WriteString("FMT 1" & vbLf)
 unit1.WriteString("TM 1" & vbLf)
 unit1.WriteString("AV -1" & vbLf)
 unit1.WriteString("MM 1," & t(0) & vbLf)
 unit2.WriteString("DV" & t(3) & ",0," & vs & "," & icomp & vbLf)
 unit2.WriteString("DV" & t(2) & ",0," & vs & "," & icomp & vbLf)
 unit1.WriteString("DV" & t(0) & ",0," & vd & "," & icomp & vbLf)
 unit1.WriteString("DV" & t(1) & ",0," & vg & "," & igcomp & vbLf)           '53
```

Line	Description
22 to 28	After the measurement, the program disables all SMUs, closes the connection with Unit1 and Unit2, and opens a message box to confirm the end of the program. Finally, by clicking OK on the message box, the program displays a message on the console window.
31 to 40	Declares variables used through the project. And sets the proper values.
42 to 44	Declares variables used to perform measurement, and sets the value.
46 to 49	Sets the data output format, trigger mode, A/D converter, and measurement mode.
50 to 51	Unit2 applies voltage to the source and substrate terminals of a device.
52 to 53	Unit1 applies voltage to the gate and drain terminals of a device.

```
unit1.WriteString("WS 2" & vbLf)                                                         '55
unit1.WriteString("XE" & vbLf)
unit2.WriteString("OS" & vbLf)

'unit1.WriteString("TM 3" & vbLf)                                                        '59
'unit1.WriteString("*OPC?" & vbLf) : ret = unit1.ReadString(1 + 2)
'unit2.WriteString("OS" & vbLf)
'unit1.WriteString("PA" & vbLf)                                                          '62
'unit2.WriteString("OS" & vbLf)
'unit1.WriteString("XE" & vbLf)

unit1.WriteString("*OPC?" & vbLf) : ret = unit1.ReadString(1 + 2)                        '66
unit1.WriteString("ERR? 1" & vbLf) : err = unit1.ReadString(4 + 2)
If err <> 0 Then
   unit1.WriteString("DZ" & vbLf) : unit2.WriteString("DZ" & vbLf)
   GoTo Check_err
End If

Dim mret As String = unit1.ReadString(17)                                                '73
Dim status As String = Left(mret, 3)
Dim meas As Double = Val(Mid(mret, 4, 12))

data(j, i) = Chr(13) & Chr(10) & meas * 1000 & ", " & status

unit1.WriteString("DZ" & vbLf) : unit2.WriteString("DZ" & vbLf)                          '79
save_data(fname, title, value, data, nop1, nop2, unit1, unit2, t)
Exit Sub
```

Line	Description
55 to 57	Unit1 waits for a trigger sent to the Ext Trig In terminal, and starts measurement by receiving a trigger sent by Unit2.
59 to 61	The lines can be replaced with 55 to 57. Delete ’ at the top of the lines 59 to 61, and delete lines 55 to 57, then run the program. Unit1 will start measurement when a trigger is received via the Ext Trig In terminal.
62 to 64	The lines can be replaced with 55 to 57. Delete ’ at the top of the lines 59 to 64, and delete lines 55 to 57, and 61, then run the program. Unit1 will start measurement when a trigger is received via the Ext Trig In terminal.
66 to 71	Waits for the operation complete and checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.
73 to 77	Reads measurement data and stores it into the *data* array.
79 to 81	Applies 0 V from all channels and transfers the data stored in the *data* variable to the save_data subprogram. And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.

```
Check_err:                                                                    '83
 unit1.WriteString("EMG? " & err & vbLf) : msg = unit1.ReadString(256)
 MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
 Exit Sub

End Sub                                                                       '88

Sub save_data(ByVal fname As String, ByVal title As String, ByVal value As String,
ByVal data(,) As String, ByVal nop1 As Integer, ByVal nop2 As Integer, ByVal unit1
As IMessage, ByVal unit2 As IMessage, ByVal t() As Integer)                   '90
 Dim i As Integer = 0
 Dim j As Integer = 0
 FileOpen(1, fname, OpenMode.Output, OpenAccess.Write, OpenShare.LockReadWrite)
 Print(1, value)
 For j = 0 To nop2 - 1
    'Print(1, Chr(13) & Chr(10) & "Unit" & j + 1)                             '96
    For i = 0 To nop1 - 1
       Print(1, data(j, i))
    Next i
 Next j
 FileClose(1)

 Dim rbx As Integer
 For j = 0 To nop2 - 1
    'value = value & Chr(10) & "Unit" & j + 1                                '105
    For i = 0 To nop1 - 1
       value = value & data(j, i)
    Next i
 Next j
 value = value & Chr(10) & Chr(10) & "Data save completed."
 value = value & Chr(10) & Chr(10) & "Do you want to perform measurement again?"
 rbx = MsgBox(value, vbYesNo, title)
 If rbx = vbYes Then perform_meas(unit1, unit2, t)
End Sub                                                                      '114

End Module
```

Line	Description
83 to 86	Displays a message box to show an error message if the error is detected.
90 to 114	Save_data subprogram saves measurement result data into a file specified by the *fname* variable and displays the data and a message on a message box. If Yes is clicked on the message box, calls the perform_meas subprogram again. If No is clicked, returns to the perform_meas subprogram.

Measurement Result Example

```
Id (mA), Status
22.475, NAI

Data save completed.

Do you want to perform measurement again?
```

The following program controls two units and performs I-V measurement of two-terminal devices. Each unit measures a different device and performs one point measurement alternately at each sweep step. Before running the program, connect a BNC cable between the following terminals.

- Unit1’s Ext Trig Out to Unit2’s Ext Trig In
- Unit2’s Ext Trig Out to Unit1’s Ext Trig In

NOTE The program needs the example code shown in Table 3-31 to run. Delete apostrophe (’) at the beginning of the lines 96 and 105 shown in Table 3-31. And delete the lines 30 to 88 shown in Table 3-31, and insert the code shown in Table 3-32 into there.

Table 3-32 Trigger Programming Example 2

```
Sub perform_meas(ByVal unit1 As IMessage, ByVal unit2 As IMessage, ByVal t() As
Integer)                                                                         ’1
 Dim i As Integer = 0                            ’t(0): Low1
 Dim j As Integer = 0                            ’t(1): High1
 Dim nop1 As Integer = 5                         ’t(2): High2
 Dim nop2 As Integer = 2                         ’t(3): Low2
 Dim data(nop2 - 1, nop1 - 1) As String
 Dim value As String = "I (mA), Time (msec), Status"
 Dim fname As String = "C:\Agilent\prog_ex\data15.txt"
 Dim title As String = "Measurement Result"
 Dim msg As String = "No error."
 Dim err As Integer = 0
 Dim v1 As Double = 0.1 : Dim v2 As Double = 0.5                                 ’12
 Dim vs As Double = 0 : Dim icomp As Double = 0.1
 Dim ret As Integer
 unit1.WriteString("FMT 1" & vbLf)
 unit1.WriteString("AV -1" & vbLf)
 unit1.WriteString("WT 0, 0.01" & vbLf)
 unit1.WriteString("TM 3" & vbLf)
 unit1.WriteString("TGP -1, 1, 2, 1" & vbLf)
 unit1.WriteString("TGP -2, 2, 2, 3" & vbLf)
 unit1.WriteString("TGMO 1" & vbLf)                                              ’21
```

Line	Description
1 to 11	Declares variables used in the Main of Table 3-31. And sets the proper values.
12 to 14	Declares variables used to perform measurement, and sets the value.
15 to 17	Unit1 sets the data output format, A/D converter, and sweep delay time.
18 to 19	Unit1 sets the Start Measurement trigger input for the Ext Trig In terminal.
20 to 21	Unit1 sets the Step Measurement Completion trigger output for the Ext Trig Out terminal.

```
 unit1.WriteString("DV" & t(1) & ",0," & vs & "," & icomp & vbLf)              '22
 unit1.WriteString("WV" & t(0) & ",1,0," & v1 & "," & v2 & "," & nop1 & "," & icomp
& vbLf)
 unit1.WriteString("MM 2," & t(0) & vbLf)
 unit1.WriteString("TSC 1" & vbLf)

 unit2.WriteString("FMT 1" & vbLf)                                             '27
 unit2.WriteString("AV -1" & vbLf)
 unit2.WriteString("WT 0, 0.01" & vbLf)
 unit2.WriteString("TM 3" & vbLf)                                              '30
 unit2.WriteString("TGP -2, 2, 2, 1" & vbLf)
 unit2.WriteString("TGXO 2" & vbLf)
 unit2.WriteString("TGP -1, 1, 2, 2" & vbLf)
 unit2.WriteString("TGSI 2" & vbLf)                                            '34
 unit2.WriteString("DV" & t(3) & ",0," & vs & "," & icomp & vbLf)
 unit2.WriteString("WV" & t(2) & ",1,0," & v1 & "," & v2 & "," & nop1 & "," & icomp
& vbLf)
 unit2.WriteString("MM 2," & t(2) & vbLf)
 unit2.WriteString("TSC 1" & vbLf)
 unit1.WriteString("TSR" & vbLf) : unit2.WriteString("TSR" & vbLf)
 unit2.WriteString("XE" & vbLf)

 unit1.WriteString("*OPC?" & vbLf) : ret = unit1.ReadString(1 + 2)             '42
 unit1.WriteString("ERR? 1" & vbLf) : err = unit1.ReadString(4 + 2) : ret = 1
 If err <> 0 Then GoTo Check_err
 unit2.WriteString("ERR? 1" & vbLf) : err = unit2.ReadString(4 + 2) : ret = 2
 If err <> 0 Then GoTo Check_err
```

Line	Description
22 to 25	Unit1 applies voltage to device, and sets the sweep source, the measurement mode, and the time stamp data output.
27 to 29	Unit2 sets the data output format, A/D converter, and sweep delay time.
30 to 32	Unit2 sets the Measurement Completion trigger output for the Ext Trig Out terminal, and specifies the gate trigger. Unit1 will start measurement when this trigger is sent to its Ext Trig In terminal.
33 to 34	Unit2 sets the Start Step Output Setup trigger input for the Ext Trig In terminal. Unit2 will start step output setup when the Step Measurement Completion trigger is sent by Unit1.
35 to 38	Unit2 applies voltage to device, and sets the sweep source, the measurement mode, and the time stamp data output.
39	Resets the time stamp.
40	Unit2 starts measurement, and sends a gate trigger to the Ext Trig Out terminal. Then Unit1 starts measurement.
42 to 46	Waits for the operation complete. Goes to Check_err if an error is detected.

```
 Dim mret1 As String = unit1.ReadString(16 * 2 * nop1 + 1)                       '48
 Dim mret2 As String = unit2.ReadString(16 * 2 * nop1 + 1)
 Dim time As Double : Dim status As String : Dim meas As Double
 For i = 0 To nop1 - 1
   time = Val(Mid(mret1, 4 + i * 16 * 2, 12))
   status = Mid(mret1, 17 + i * 16 * 2, 3)
   meas = Val(Mid(mret1, 20 + i * 16 * 2, 12))
   data(0, i) = Chr(13) & Chr(10) & meas * 1000 & ", " & time * 1000 & ", " & status
 Next i
 For i = 0 To nop1 - 1
   time = Val(Mid(mret2, 4 + i * 16 * 2, 12))
   status = Mid(mret2, 17 + i * 16 * 2, 3)
   meas = Val(Mid(mret2, 20 + i * 16 * 2, 12))
   data(1, i) = Chr(13) & Chr(10) & meas * 1000 & ", " & time * 1000 & ", " & status
 Next i

 unit1.WriteString("DZ" & vbLf) : unit2.WriteString("DZ" & vbLf)                 '64
 save_data(fname, title, value, data, nop1, nop2, unit1, unit2, t)
 Exit Sub

Check_err:                                                                        '68
 unit1.WriteString("DZ" & vbLf) : unit2.WriteString("DZ" & vbLf)
 If ret = 1 Then unit1.WriteString("EMG? " & err & vbLf) : msg =
unit1.ReadString(256)
 If ret = 2 Then unit2.WriteString("EMG? " & err & vbLf) : msg =
unit2.ReadString(256)
 MsgBox("Unit" & ret & " error: " & err & Chr(10) & msg, vbOKOnly, "")
 Exit Sub
End Sub
```

Line	Description
48 to 62	Reads measurement data and stores it into the *data* array.
64 to 65	Applies 0 V from all channels and transfers the data stored in the *data* variable to the save_data subprogram. And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
68 to 73	Applies 0 V from all channels and displays a message box to show an error message.

Measurement Result Example

```
I (mA), Time (msec), Status
Unit1
11.345, 18.8, NAI
22.685, 50, NAI
34.035, 81.2, NAI
45.385, 112.4, NAI
56.73, 143.5, NAI
Unit2
10.98, 13.6, NAI
21.98, 47.1, NAI
32.98, 78.2, NAI
43.965, 109.6, NAI
54.965, 140.7, NAI
```

This is a program written in the HP BASIC language, and performs the following.

1. Sets the Agilent B1500 for the bipolar transistor Ib-Ic measurement
2. Triggers a sweep measurement
3. Performs a step measurement and sends the Step Measurement Completion output gate trigger
4. Waits for the Start Step Output Setup input trigger
5. Displays a measurement data (Ic)
6. Repeats 3 to 5 the number of times specified by Ib_num
7. Disables the Agilent B1500 channel output

This is a part of the program used to synchronize the Agilent B1500 operation with the other instrument. However this program does not include the program code to control the instrument. So add the program code to control it before running the program. For the timing of the trigger, refer to the comments in the following program listing.

```
10      ASSIGN @B1500 TO 717
20      OPTION BASE 1
30      INTEGER Collector,Base,Ib_num,Vc_num
40     !
50      Collector=2
60      Base=1
70      Ib_start=.0001
80      Ib_stop=.001
90      Ib_num=10
100     Ib_step=(Ib_stop-Ib_start)/(Ib_num-1)
110     Vb_comp=1
120     Vc=2.5
130     Ic_comp=.1
140    !
150    !Other instrument should be initialized and set up.
160    !
```

Line No.	Description
10	Assigns the I/O path to control the B1500.
50 to 130	Sets the value of the variables for source setup and so on.
140 to 160	Add program lines to perform initialization and measurement setup of the other instrument.

```
170    OUTPUT @B1500;"FMT 5"        ! ASCII w/header<,>
180    OUTPUT @B1500;"AV -1"        ! Averaging=1PLC
190    OUTPUT @B1500;"WT 0,.01"     ! Hold Time, Delay Time
200    OUTPUT @B1500;"CN";Collector,Base
210    OUTPUT @B1500;"TGP -2,2,2,3" ! StepMeasEndTrg Output
220    OUTPUT @B1500;"TGMO 2"       ! Gate Trigger
230    OUTPUT @B1500;"TGP -1,1,2,2" ! StartStepSetupTrg Input
240    OUTPUT @B1500;"TGSI 2" ! Ignore TRG for 1st step setup
250    OUTPUT @B1500;"DV";Collector,0,Vc,Ic_comp
260    OUTPUT @B1500;"WI";Base,1,0,Ib_start,Ib_stop,Ib_num,Vb_comp
270    OUTPUT @B1500;"MM";2,Collector
280   !
290   !Other instrument must be set to the measurement ready and
300   !trigger wait condition.
310   !
```

Line No.	Description
170	Specifies the data output format.
180	Sets the number of averaging samples of the ADC.
190	Sets the hold time and delay time.
200	Enables the source/measurement channels.
210 to 220	Sets the Step Measurement Completion trigger output for the Ext Trig Out terminal, and specifies the gate trigger.
230 to 240	Sets the Start Step Output Setup trigger input for the Ext Trig In terminal, also disables the input trigger for the first sweep step.
250	Forces voltage.
260	Sets the staircase sweep source.
270	Sets the measurement mode and the measurement channel.
280 to 310	To synchronize the Agilent B1500 operation with the operation of the other instrument, add program lines to set it to the measurement ready and trigger wait condition.

```
320    OUTPUT @B1500;"XE"
330   !
340   !B1500 starts measurement. Then B1500 sends negative gate
350   !trigger to the other instrument.
360   !Then the instrument should start measurement.
370   !
380    FOR I=1 TO Ib_num
390      ENTER @B1500 USING "#,3X,12D,X";Ic
400      PRINT "Ic= ";Ic*1000;" [mA]"
410   !
420   !Measurement data of the other instrument should be read.
430   !And the data should be displayed.
440   !
450   !The instrument must be set to the measurement ready and
460   !trigger wait condition.
470   !
480   !The instrument must send trigger to B1500. B1500 will
490   !start a step source output by the trigger, and perform
500   !a step measurement.
510   !
520    NEXT I
530   !
540    OUTPUT @B1500;"CL"
550    END
```

Line No.	Description
320	Starts sweep measurement, and performs a step measurement. When the Agilent B1500 starts a step measurement, it sends a negative gate trigger. Then the other instrument should start measurement.
390 to 400	Reads the measurement data, and displays the measurement data.
410 to 510	To synchronize the Agilent B1500 operation with the operation of other instrument, add program lines to do following: • To read and display the data measured by the instrument • To set it to the measurement ready and trigger wait condition • To send a trigger from the instrument When the Agilent B1500 receives the trigger, it starts a step measurement and sends negative gate trigger.
520	Repeats 390 to 510 the number of times specified by Ib_num.
540	Disables the source/measurement channels.

Reading Time Stamp Data

Time stamp function outputs a time data with a measurement result data. For example of reading the time stamp data, see programs in the previous sections.

NOTE

This function is not available for binary data output format (FMT 3 and 4).

This function is not available for the quasi-pulsed spot measurement (MM 9) and the search measurement (MM 14 and 15).

To read the time data with the best resolution (100 μs), reset the time stamp every 100 sec or less for the FMT 1, 2, or 5 data output format, or every 1000 sec or less for the FMT 11, 12, 15, 21, 22, or 25 data output format.

Enter the MM command to define the measurement mode and enter the TSC command to set the time stamp function ON. You can get the time data with the measurement data. The time data is the time from timer reset to the start of measurement. To clear/reset the time stamp, enter the TSR command.

Function	Command	Parameters
Sets the time stamp function	TSC	*onoff*

The following commands returns the time data regardless of the TSC command setting. The time data is the time from when the time stamp is cleared until the following command is entered.

Function	Command	Parameters
Forces DC voltage from SMU	TDV	*chnum*,*range*,*output*[,*Icomp*]
Forces DC current from SMU	TDI	*chnum*,*range*,*output*[,*Vcomp*]
Forces DC bias from CMU	TDCV	*chnum*,*output*
Forces AC signal from CMU	TACV	*chnum*,*output*
Performs high speed spot current measurement	TTI	*chnum*,*range*
Performs high speed spot voltage measurement	TTV	*chnum*,*range*
Performs high speed spot C measurement	TTC	*chnum*,*mode*[,*range*]
Just returns the time data	TSQ	

Reading Binary Output Data

This section provides the example to read binary data. The following program example:

1. executes high-speed spot measurements
2. reads the measurement data in binary data format
3. rearranges the data and calculates the measured data
4. prints the measured data on the screen

NOTE

Data resolution

The resolution of binary data is as shown below.

- Measurement data: Measurement range / 50000
- Output data: Output range / 20000

Note that the resolution of the measurement data is larger than the resolution of the high resolution A/D converter.

Measurement Result Example

```
Id (uA), Status
status = 0
type = 1
mode = 1
channel = 5
sign = 0
range = 0.0001
count = 12010

24.02, 0

Data save completed.

Do you want to perform measurement again?
```

Table 3-33 High-Speed Spot Measurement Example to read binary data

```
Sub perform_meas(ByVal session As IMessage, ByVal t() As Integer)                   '1
    Dim i As Integer = 0                         't(0): Drain
    Dim j As Integer = 0                         't(1): Gate
    Dim nop1 As Integer = 1                      't(2): Source
    Dim nop2 As Integer = 1                      't(3): Substrate
    Dim data(nop2 - 1, nop1 - 1) As String
    Dim value As String = "Id (mA), Status"
    Dim fname As String = "C:\Agilent\prog_ex\data16.txt"
    Dim title As String = "Measurement Result"
    Dim msg As String = "No error."
    Dim err As Integer = 0

    Dim vd As Double = 3                                                             '13
    Dim vg As Double = 1
    Dim idcomp As Double = 0.05
    Dim igcomp As Double = 0.01
    Dim orng As Integer = 0
    Dim mrng As Integer = 0

    session.WriteString("FMT 3" & vbLf)
    session.WriteString("AV 10,1" & vbLf)     'sets number of samples for 1 data
    session.WriteString("FL 0" & vbLf)        'sets filter off
    session.WriteString("DV " & t(3) & ",0,0,0.1" & vbLf)   'out= 0 V, comp= 0.1 A
    session.WriteString("DV " & t(2) & ",0,0,0.1" & vbLf)   'out= 0 V, comp= 0.1 A
    session.WriteString("DV " & t(1) & "," & orng & "," & vg & "," & igcomp & vbLf)
    session.WriteString("DV " & t(0) & "," & orng & "," & vd & "," & idcomp & vbLf)
    session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)          '28
    If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
    session.WriteString("TI " & t(0) & "," & mrng & vbLf)
    Dim dat() As Byte = session.Read(4 + 2) '4 byte data + terminator               '31

    Dim status As Integer = dat(3) And 224 : status = status / 32  '224=128+64+32
    If status <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
    Dim type As Integer = dat(0) And 128 : type = type / 128  '0:source, 1:meas
    Dim mode As Integer = dat(0) And 64 : mode = mode / 64    '0:voltage, 1:current
    Dim sign As Integer = dat(0) And 1                        '0:positive, 1:negative
    Dim rng As Integer = dat(0) And 62 : rng = rng / 2        '62=32+16+8+4+2
    Dim count As Integer = dat(1) * 256 + dat(2)
    Dim chan As Integer = dat(3) And 31                       '31=16+8+4+2+1
    If sign = 1 Then count = count - 65536 '65536 = 10000000000000000 (17 bits)
```

Line	Description
2 to 11	Declares variables used through the project. And sets the proper values.
13 to 18	Declares variables and sets the value.
20 to 22	Sets the data output format and A/D converter. Also sets the SMU filter off.
23 to 26	Applies voltage to device.
28 to 29	Checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.
30 to 31	Performs the high-speed spot measurement. And stores the returned binary data (four bytes) into the *dat* array variable.
33 to 41	Picks up the elements, status, type, mode, sign, rng, count, and chan, included in the returned binary data.

```
 Dim range As Double                                                         '43
 If mode = 1 Then              ' current range
   range = 10 ^ (rng - 20)
   If rng = 20 Then
     session.WriteString("UNT? 1" & vbLf)
     Dim unt As String = session.ReadString(256)
     Dim mdl(8) As String : Dim c As String
     Dim a As Integer : Dim b As Integer = 0 : Dim d As Integer = 0
     For a = 1 To Len(unt)
       c = Mid(unt, a, 1)
       If c = "," Then mdl(d) = Mid(unt, b + 1, a - b - 1) : d = d + 1
       If c = ";" Then b = a
     Next
     If mdl(chan) = "E5291A" Then range = 0.2   'for E5260/E5270
   End If
 Else                          ' voltage range
   If rng = 8 Then range = 0.5
   If rng = 9 Then range = 5
   If rng = 11 Then range = 2
   If rng = 12 Then range = 20
   If rng = 13 Then range = 40
   If rng = 14 Then range = 100
   If rng = 15 Then range = 200
 End If                                                                      '66

   'value = value & Chr(13) & Chr(10) & "status = " & status                 '68
   'value = value & Chr(13) & Chr(10) & "type = " & type
   'value = value & Chr(13) & Chr(10) & "mode = " & mode
   'value = value & Chr(13) & Chr(10) & "channel = " & chan
   'value = value & Chr(13) & Chr(10) & "sign = " & sign
   'value = value & Chr(13) & Chr(10) & "range = " & range
   'value = value & Chr(13) & Chr(10) & "count = " & count & Chr(13) & Chr(10)

   Dim meas As Double                                                        '76
   If type = 0 Then meas = count * range / 20000 'source data
   If type = 1 Then meas = count * range / 50000 'measurement data

   data(j, i) = Chr(13) & Chr(10) & meas * 1000 & ", " & status              '80

   session.WriteString("DZ" & vbLf)                                          '82
   save_data(fname, title, value, data, nop1, nop2, session, t)
   Exit Sub

Check_err:                                                                   '86
   session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
   MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
   Exit Sub

End Sub
```

Line	Description
43 to 66	Checks the measurement range or output range setting.
68 to 74	If you want to display and save the binary data elements, delete ' at the top of the lines.
76 to 80	Calculates the measurement data or source output data. And, stores the data into the *data* array.
82 to 84	Applies 0 V from all channels. And transfers the data stored in the *data* variable to the save_data subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the *fname* variable and displays the data on a message box.
86 to 89	Displays a message box to show an error message if the error is detected.

Using Programs for 4142B

This section describes the program modification example to use a program created for the Agilent 4142B Modular DC Source/Monitor. To use the program:

1. change the GPIB address, if necessary.
2. enter the ACH command to translate the channel numbers, if necessary.
3. remove the unsupported command, or replace it with the command supported by the B1500.

For more information, refer to “To Use Programs for Agilent 4142B” on page 1-64.

The following program examples show a modified measurement program, which performs a high-speed spot measurement.

The original 4142B program:

```
10      ASSIGN @Hp4142 TO 717
20      INTEGER G_ch,D_ch,S_ch
30    !
40    !         !Source:    GNDU
50      G_ch=2  !Gate:      HPSMU (SLOT2)
60      D_ch=3  !Drain:     MPSMU (SLOT3)
70      S_ch=4  !Substrate: MPSMU (SLOT4)
80    !
90      OUTPUT @Hp4142;"FMT5"
100     OUTPUT @Hp4142;"CN";D_ch,G_ch,S_ch
110     OUTPUT @Hp4142;"DV";S_ch;",0,0,.1"
120     OUTPUT @Hp4142;"DV";G_ch;",0,3,.01"
130     OUTPUT @Hp4142;"DV";D_ch;",0,5,.1"
140     OUTPUT @Hp4142;"TI";D_ch;",0"
150     ENTER @Hp4142 USING "#,3X,12D,X";Mdata
160     PRINT "Id(A)=";Mdata
170     OUTPUT @Hp4142;"CL"
180     END
```

Line No.	Description
10	Assigns the I/O path to control the 4142B.
90	Specifies the data output format.
100 to 130	Enables the source/measurement channels, and forces voltage.
140 to 180	Executes the measurement, reads and displays the measurement data, and disables channels.

The program modified to control the B1500:

```
10     ASSIGN @Hp4142 TO 717                  !<<<<
20     INTEGER G_ch,D_ch,S_ch
21     INTEGER Sub                            !<<<<
30    !
40    !        !Source:    GNDU
50     G_ch=2  !Gate:      HPSMU (SLOT2)
60     D_ch=3  !Drain:     MPSMU (SLOT3)
70     S_ch=4  !Substrate: MPSMU (SLOT4)
80    !
81     Sub=5                                  !<<<<
82     OUTPUT @Hp4142;"ACH";Sub,S_ch          !<<<<
83     OUTPUT @Hp4142;"*OPC?"                 !<<<<
84     ENTER @Hp4142;A                        !<<<<
85    !
90     OUTPUT @Hp4142;"FMT5"
100    OUTPUT @Hp4142;"CN";D_ch,G_ch,S_ch
110    OUTPUT @Hp4142;"DV";S_ch;",0,0,.1"
120    OUTPUT @Hp4142;"DV";G_ch;",0,3,.01"
130    OUTPUT @Hp4142;"DV";D_ch;",0,5,.1"
140    OUTPUT @Hp4142;"TI";D_ch;",0"
150    ENTER @Hp4142 USING "#,3X,12D,X";Mdata
160    PRINT "Id(A)=";Mdata
170    OUTPUT @Hp4142;"CL"
180    END
```

Line No.	Note
10	Change GPIB address, if necessary.
21, 81	Add program lines if the module configuration is different from the 4142B. This example adds the variable Sub, and uses the SMU in slot 5 instead of slot 4 for substrate.
82 to 84	Add program line to set the channel map. This example transfers the Sub value to the variable S_ch used in the original program.

Using Programs for 4155B/4156B/4155C/4156C

This section describes the program modification example to use a FLEX command program created for the Agilent 4155B/4156B/4155C/4156C Parameter Analyzer. To use the program:

1. change the GPIB address, if necessary.
2. enter the ACH command to translate the channel numbers, if necessary.
3. change the FMT command parameter value to use the data output format compatible with the 4155/4156 output data, or change the program lines to read the measurement data.
4. remove the US command.
5. remove the RMD? command.
6. remove the unsupported command, or replace the command with the corresponding command supported by the B1500.

For more information, refer to "To Use Programs for Agilent 4155/4156" on page 1-65.

The following program examples show a modified measurement program, which performs a high-speed spot measurement.

The original 4156C program:

```
10     ASSIGN @Hp415x TO 717
20     INTEGER G_ch,D_ch,S_ch,B_ch
30    !
40     S_ch    !Source:    SMU1
50     G_ch=2  !Gate:      SMU2
60     D_ch=3  !Drain:     SMU3
70     B_ch=4  !Substrate: SMU4
80    !
90     OUTPUT @Hp415x;"US"
100    OUTPUT @Hp415x;"FMT 5"
110    OUTPUT @Hp415x;"CN ";D_ch,G_ch,S_ch,B_ch
120    OUTPUT @Hp415x;"DV ";S_ch;",0,0,.1"
130    OUTPUT @Hp415x;"DV ";B_ch;",0,0,.1"
140    OUTPUT @Hp415x;"DV ";G_ch;",0,3,.01"
150    OUTPUT @Hp415x;"DV ";D_ch;",0,5,.1"
160    OUTPUT @Hp415x;"TI ";D_ch;",0"
170    OUTPUT @Hp415x;"RMD? 1"
180    ENTER @Hp415x USING "#,5X,13D,X";Mdata
190    PRINT "Id(A)=";Mdata
200    OUTPUT @Hp415x;"CL"
210    END
```

Line No.	Description
10	Assigns the I/O path to control the 4155/4156.
90	Enters the FLEX command mode.
100	Specifies the data output format.
110 to 150	Enables the source/measurement channels, and forces voltage.
160 to 210	Executes the measurement, reads and displays the measurement data, and disables channels.

The program modified to control the B1500:

```
10     ASSIGN @Hp415x TO 717                      !<<<<
20     INTEGER G_ch,D_ch,S_ch,B_ch
21     INTEGER Sub                                !<<<<
30   !
40   ! S_ch=1  !Source:    SMU1 <<<< replaced with GNDU
50     G_ch=2  !Gate:      SMU2
60     D_ch=3  !Drain:     SMU3
70     B_ch=4  !Substrate: SMU4
80   !
81     Sub=5                                      !<<<<
82     OUTPUT @Hp415x;"ACH ";Sub,B_ch             !<<<<
83   !
90   ! OUTPUT @Hp415x;"US"                         <<<<
100    OUTPUT @Hp415x;"FMT 25"                    !<<<<
110    OUTPUT @Hp415x;"CN ";D_ch,G_ch,B_ch        !<<<<
120  ! OUTPUT @Hp415x;"DV ";S_ch;",0,0,.1"         <<<<
130    OUTPUT @Hp415x;"DV ";B_ch;",0,0,.1"
140    OUTPUT @Hp415x;"DV ";G_ch;",0,3,.01"
150    OUTPUT @Hp415x;"DV ";D_ch;",0,5,.1"
160    OUTPUT @Hp415x;"TI ";D_ch;",0"
170  ! OUTPUT @Hp415x;"RMD? 1"                      <<<<
180    ENTER @Hp415x USING "#,5X,13D,X";Mdata
190    PRINT "Id(A)=";Mdata
200    OUTPUT @Hp415x;"CL"
210    END
```

Line No.	Note
10	Change GPIB address, if necessary.
21, 81	Add program lines if the module configuration is different from the 415x. This example adds the Sub variable, and uses the SMU in slot 5 instead of slot 4 for substrate.
82	Add program line to set the channel map. This example transfers the Sub value to the variable B_ch used in the original program.
90	Remove the US command. This command is not required.
100	Change the FMT command parameter value.
40, 110, 120	This example uses the GNDU instead of the SMU1. So remove the program lines that include the variable S_ch (SMU1).
170	Remove the RMD? command. This command is not required.

4 Command Reference

This chapter is the complete reference of the GPIB commands of the Agilent B1500:

- "Command Summary"
- "Command Parameters"
- "Command Reference"

NOTE

Module model number and description

In this chapter, plug-in modules and accessory for the Agilent B1500 will be expressed by the model number or the following abbreviation as shown below.

B1510A: HPSMU (high power SMU)

B1511A: MPSMU (medium power SMU)

B1512A: HCSMU (high current SMU)

B1513A: HVSMU (high voltage SMU)

B1517A: HRSMU (high resolution SMU)

E5288A: ASU (atto sense and switch unit)

B1520A: MFCMU (multi frequency capacitance measurement unit) or CMU

B1525A: HVSPGU (high voltage semiconductor pulse generator unit) or SPGU

N1301A: SCUU (SMU CMU unify unit)

Command Summary

The following table summarizes the Agilent B1500 GPIB commands.

Category	Command	Summary
Reset	*RST	Resets the B1500 to the initial settings.
Diagnostics	DIAG?	Performs diagnostics, and returns the result.
Self-test	*TST?	Performs the self-test, and returns the result.
	RCV	Enables the channels fail self-test.
Self Calibration	CA	Performs self-calibration.
	*CAL?	Performs self-calibration, and returns the result.
	CM	Sets SMU auto-calibration ON or OFF.
MFCMU Data Correction	ADJ/ADJ?	Sets the phase compensation data.
	CLCORR	Clears the frequency list for the correction data measurement.
	CORRL/CORRL? adds or returns the frequency for the correction data measurement.	
	DCORR/DCORR? sets or returns the calibration/reference value of the standard.	
	CORR?	Performs the open/short/load correction data measurement.
	CORRST/CORRST? sets or returns the open/short/load correction function ON/OFF.	
	CORRDT/CORRDT? sets or returns the open/short/load correction data.	
Abort	AB	Aborts the present operation and subsequent command execution.
Pause/ Continue	PA/PAX	Pauses command execution or internal memory program execution, until the specified wait time elapses or until an event specified by the TM command is received.
	TM	Sets the event to start measurement or to release the B1500 from the paused status set by the PA or PAX command.
Data Output	FMT	Specifies the measurement data output format and the data terminator.
	BC	Clears the B1500 output data buffer that stores measurement data and/or query command response data.
Timer Clear	TSR	Clears the timer count.

Category	Command	Summary
Time Stamp	TSC	Enables the time stamp function. This function is *not* available for the 4 bytes binary data format (FMT3 or FMT4), the high speed spot, quasi-pulsed spot (MM9), and search (MM14 and MM15) measurements.
	TSQ	Returns the time data from timer reset (TSR) to this command.
ASU Control	SAL	Disables the connection status indicator of the ASU.
	SAP	Controls the input-output path of the ASU.
	SAR	Enables 1 pA range for the auto ranging operation.
SCUU Control	SSL	Disables the connection status indicator of the SCUU.
	SSP	Controls the input-output path of the SCUU.
SMU Series Resistor	SSR	Sets the internal series resistor of the specified SMU to ON or OFF.
SMU Filter	FL	Sets the internal filter of the specified SMUs to ON or OFF.
SMU Max. Output	LIM/LIM?	Sets/returns the maximum output limit value effective for all SMU.
Channel Control	ACH	Translates a channel number to another channel number.
	CN/CNX	Enables the specified channels by setting the output switches to ON.
	CL	Disables the specified channels by setting the output switches to OFF.
	IN	Sets the specified channels to 0 V.
	DZ	Stores the setup of the channels, and sets the output to 0 V.
	RZ	Returns the channel to the settings that are stored by the DZ command and clears the stored channel settings.
	WAT	Sets the source wait time and the measurement wait time.
SMU Integration Time and Averaging	AV	Sets the number of samples for averaging of the high-speed ADC (A/D converter). Not effective for the high-resolution ADC.
	AAD	Selects the type of A/D converter.
	AIT	Sets the operation mode and the setup parameter of the ADC.
	AZ	Enables or disables the ADC zero function.

Category	Command	Summary
High Speed Spot Measurement	TC	Measures impedance (TC), current (TI), current and voltage (TIV), voltage (TV), AC level (TMACV), or DC bias (TMDCV), and returns the measured data.
	TI	
	TIV	
	TV	
	TMACV	
	TMDCV	
	TTC	Measures impedance (TTC), current (TTI), current and voltage (TTIV), or voltage (TTV), and returns the measurement data and the time data from timer reset to the start of measurement.
	TTI	
	TTIV	
	TTV	
Source Output	DI	Forces DC current from the specified SMU.
	DV	Forces DC voltage from the specified SMU.
	TDI	Forces DC current (TDI) or voltage (TDV) from the specified SMU, and returns the time data from timer reset to the start of output.
	TDV	
	FC	Sets the output signal frequency of the MFCMU.
	ACV	Sets the output signal level of the MFCMU, and starts AC voltage output.
	DCV	Forces DC voltage from the MFCMU.
	TACV	Forces AC (TACV) or DC (TDCV) voltage from the MFCMU, and returns the time data from timer reset to the start of output.
	TDCV	
MFCMU Setup	FC	Sets the frequency of the AC voltage output. Used with ACV or TACV.
	ACT	Sets the A/D converter of the MFCMU.
	IMP	Specifies the impedance measurement parameters. For the ASCII data output. Not available for FMT 3/4/13/14.
	LMN	Enables or disables data output of the OSC level/DC bias monitor values.
Measurement Mode	MM	Sets the measurement mode and measurement channels.

Category	Command	Summary
Measurement Execution	XE	Performs measurements, and returns the measurement data; or recovers from the paused state if the PA/PAX command has been sent. Not available for the high speed spot measurement.
Measurement Setup	CMM	Sets the SMU measurement operation mode.
	PAD	Enables or disables the SMU parallel measurements. This is effective for the spot (MM1), sweep (MM2), and sampling (MM10) measurements.
	RC	Specifies the impedance (RC), current (RI), or voltage (RV) measurement ranging mode for the measurement other than the high speed spot measurement.
	RI	
	RV	
	RM	Sets the range selection rule for the auto ranging current measurement.
Staircase Sweep Source Setup	WT	Sets the hold time, delay time, step delay time, and trigger delay time.
	WI	Sets the staircase current sweep source.
	WV	Sets the staircase voltage sweep source.
Automatic Sweep Stop	WM	Sets the automatic abort function.
Synchronous Sweep Source Setup	WSI	Sets the synchronous current sweep source used with the WI or PWI command.
	WSV	Sets the synchronous voltage sweep source used with the WV or PWV command.
Multi channel Sweep Source Setup	WNX	Sets the synchronous current sweep source or synchronous voltage sweep source used with the WI or WV command.
Pulsed Source Setup	PT	Sets the hold time, pulse width, pulse period, and trigger delay time.
	PI	Sets the pulsed current source.
	PV	Sets the pulsed voltage source.
Pulsed Sweep Source Setup	PT	Sets the hold time, pulse width, pulse period, and trigger delay time.
	PWI	Sets the pulsed current sweep source.
	PWV	Sets the pulsed voltage sweep source.

Category	Command	Summary
Multi channel Setup Clear	WNCC	Clears setup of all channels defined for the multi channel measurement.
Multi channel Pulsed Source and Multi channel Pulsed Sweep Source Setup	MCPT	Sets the hold time, pulse width, measurement timing, etc.
	MCPNT	Sets the pulse width and the delay time.
	MCPNX	Sets the pulsed bias source.
	MCPWS	Sets the sweep mode and the number of sweep steps.
	MCPWNX	Sets the pulsed sweep source.
Quasi-pulsed Spot Measurement /Source Setup	BDM	Specifies the detection interval, and either voltage or current measurement.
	BDT	Specifies the hold time and delay time.
	BDV	Sets the quasi-pulsed voltage source.
Sampling Measurement /Source Setup	MCC	Clears the settings of the constant sources defined by MI, MV, or MSP.
	MI	Sets the current source synchronized with the sampling measurement.
	MSC	Sets the automatic abort function.
	ML	Sets the sampling mode, linear or logarithm.
	MT	Sets the timing parameters.
	MV	Sets the voltage source synchronized with the sampling measurement.
	MSP	Sets the SPGU channel synchronized with the sampling measurement, and its output after the measurement.
Binary Search Measurement /Source Setup	BSM	Sets the source output control mode and the automatic abort function.
	BST	Specifies the hold time and delay time.
	BSVM	Selects the data output mode.
	BSI	Sets the current source channel.
	BSSI	Sets the synchronous current source channel.
	BGV	Sets the voltage monitor channel.
	BSV	Sets the voltage source channel.
	BSSV	Sets the synchronous voltage source channel.
	BGI	Sets the current monitor channel.

Category	Command	Summary
Linear Search Measurement /Source Setup	LSTM	Specifies the hold time and delay time.
	LSVM	Selects the data output mode.
	LSI	Sets the current source channel.
	LSSI	Sets the synchronous current source channel.
	LGV	Sets the voltage monitor channel.
	LSV	Sets the voltage source channel.
	LSSV	Sets the synchronous voltage source channel.
	LGI	Sets the current monitor channel.
	LSM	Sets the automatic abort function.
Quasi-static CV Measurement /Source Setup	QSC	Sets the QSCV measurement operation.
	QSO	Enables or disables the QSCV smart operation.
	QSM	Sets the automatic abort function and the post measurement condition.
	QSL	Enables or disables the data output and compensation for the leakage current.
	QSZ	Enables or disables the capacitance offset cancel function. Or executes the capacitance offset measurement.
	QST	Sets the integration time, hold time, and delay time.
	QSR	Sets the current measurement range.
	QSV	Specifies the voltage output channel and its source parameters.
MFCMU DC Bias Sweep Source Setup	WDCV	Sets the DC bias sweep source by the MFCMU or SMU.
	WMDCV	Sets the automatic abort function, also sets the post sweep condition.
	WTDCV	Sets the hold time, delay time, step delay time, and trigger delay time.
MFCMU Frequency Sweep Source Setup	WFC	Sets the frequency sweep source of the MFCMU.
	WMFC	Sets the automatic abort function, also sets the post sweep condition.
	WTFC	Sets the hold time, delay time, step delay time, and trigger delay time.

Category	Command	Summary
MFCMU Sweep Source Setup	WACV	Sets the AC level sweep source of the MFCMU.
	WMACV	Sets the automatic abort function, also sets the post sweep condition.
	WTACV	Sets the hold time, delay time, step delay time, and trigger delay time.
MFCMU Pulsed Source Setup	PDCV	Sets the pulsed voltage source of the MFCMU.
	PTDCV	Sets the hold time, pulse width, pulse period, and trigger delay time.
MFCMU Pulsed Sweep Source Setup	PWDCV	Sets the pulsed voltage sweep source of the MFCMU.
	PTDCV	Sets the hold time, pulse width, pulse period, and trigger delay time.
MFCMU Sampling Measurement /Source Setup	MSC	Sets the automatic abort function.
	MTDCV	Sets the timing parameters.
	MDCV	Sets the voltage source synchronized with the sampling measurement.
SPGU Control	SIM/SIM?	Sets/returns the SPGU operation mode, PG or ALWG.
	SPRM/SPRM?	Sets/returns the output operating mode (free run, duration, count).
	SRP	Starts the SPGU output.
	SPP	Stops all channel outputs and all trigger outputs of the SPGU.
	SPUPD	Applies the setup of the specified SPGU channels.
	SPST?	Returns the waveform output state of the SPGU.
	ODSW/ODSW?	Sets/returns the pulse switch condition of the specified channel.
	SER/SER?	Specifies/returns the load impedance connected to the channel.
	CORRSER?	Measures the terminal voltage and returns the voltage and the calculated impedance. Also sets the impedance as same as SER.
	STGP/STGP?	Sets/returns the trigger output condition of the specified channel.
SPGU Pulse Setup	SPPER/SPPER?	Sets/returns the pulse period for all SPGU channels.
	SPM/SPM?	Sets/returns the output mode (2-level pulse, 3-level pulse, or DC bias) of the specified channel.
	SPT/SPT?	Sets/returns the pulse timing parameter of the specified channel.
	SPV/SPV?	Sets/returns the voltage parameter for the DC bias source or pulse signal source of the specified channel.

Category	Command	Summary
SPGU ALWG Setup	ALW/ALW?	Sets/returns the ALWG pattern data.
	ALS/ALS?	Sets/returns the ALWG sequence data.
External Trigger	TGP	Enables the trigger function for a terminal.
	TGPC	Clears the trigger setting of the specified ports.
	TGSI	Selects the sweep step first or last that ignores the Start Step Output Setup trigger input set by the `TGP` *port*`,1,`*polarity*`,2` command.
	TGSO	Selects the trigger type, edge or gate, for the Step Output Setup Completion trigger output set by the `TGP` *port*`,2,`*polarity*`,2` command.
	TGXO	Selects the trigger type, edge or gate, for the Measurement Completion trigger output set by the `TGP` *port*`,2,`*polarity*`,1` command.
	TGMO	Selects the trigger type, edge or gate, for the Step Measurement Completion trigger output set by the `TGP` *port*`,2,`*polarity*`,3` command.
	OS/OSX	Causes the B1500 to send a trigger signal from a trigger output terminal.
	WS/WSX	Enters a wait state until the B1500 receives an external trigger via a trigger input terminal.
	TM3	Enables use of an external trigger to release the PA/PAX state, or to start measurement if the B1500 has not been set to the PA/PAX/WS/WSX state. Or enables trigger set by the TGP *port*,*terminal*,*polarity*,1.
Digital I/O port	ERM	Changes the digital I/O port assignments.
	ERS?	Returns the digital I/O port status.
	ERC	Changes the output status of the digital I/O port.
	ERMOD/ ERMOD?	Sets/returns the digital I/O control mode, direct control (normal), 16440A control, or N1258A/N1259A control.
16440A Selector Control	ERSSP/ERSSP?	Sets/returns the input output connection path of the selector.

Category	Command	Summary
N1258A/ N1259A Module Selector Control	ERHPA/ ERHPA?	Specifies/returns the module connected to the module selector input.
	ERHPL/ ERHPL?	Sets/returns the LED status indicator operation status.
	ERHPS/ ERHPS?	Sets/returns the HVSMU series resistor connection status.
	ERHPP/ ERHPP?	Specifies/returns the input output connection path.
	ERHPE/ ERHPE?	Sets/returns the External Relay Control status.
	ERHPR/ ERHPR?	Sets/returns the signal level applied to the External Relay Control connector pin.
Internal Variable	VAR	Sets the value to the internal variable.
	VAR?	Returns the value set to the internal variable.
Program Memory	ST	Used with END command to store a program in the internal program memory. The ST command indicates the beginning of the program.
	END	Used with the ST command to store a program in the internal program memory. The END command indicates the end of the program.
	SCR	Scratches the specified program from the internal program memory.
	LST?	Returns a catalog of internal memory programs or a specific program listing (3000 commands maximum).
	DO	Executes internal memory programs in the order specified.
	RU	Executes internal memory programs sequentially.
Error Management	ERRX?	Returns error code and error message.
	ERR?	Returns error codes. Supports error code 0 to 999.
	EMG?	Returns error message for the specified error code. Supports error code 0 to 999.

Category	Command	Summary
Query	*IDN?	Returns the instrument model number and the ROM version number.
	LOP?	Returns the operation status of all modules.
	*LRN?	Returns channel settings or the B1500 command parameter settings.
	NUB?	Returns the number of measurement data items in the output data buffer.
	*OPC?	Starts to monitor pending operations, or asks the OPC bit setting.
	UNT?	Returns the model and revision numbers of all modules.
	WNU?	Returns the number of sweep steps specified by the sweep command.
	WZ?	Returns 0 if all channel output is ± 2 V or less, or 1 if any channel applies more than ± 2 V.
Status Byte	*SRE	Enables the specified bits of the status byte register.
	*SRE?	Returns which bits of the status byte register are enabled.
	*STB?	Returns the status byte setting.

Command Parameters

The parameters used by several commands are explained in this section.

- Channel Number
- Measurement Ranging Type
- Output Ranging Type
- MP/HR/HPSMU Source Setup Parameters
- HCSMU Source Setup Parameters
- HVSMU Source Setup Parameters
- MFCMU Measurement Parameters and Setup Parameters

NOTE

Command Parameters

In this section, the command parameters are put in italics such as *chnum*.

NOTE

Slot Numbers

Agilent B1500 provides ten module slots. And the slot numbers 1 to 10 have been assigned from the bottom slot to the top slot sequentially.

NOTE

Number of Channels in a Module and Subchannel Numbers

Agilent B1500 plug-in modules have one or two channels. The subchannel number is always 1 for one-channel modules (SMU and MFCMU). And the subchannel number is 1 or 2 for two-channel modules. For example, the subchannel number 1 is assigned to the SPGU Output 1, and 2 is assigned to the SPGU Output 2.

Table 4-1 Channel Number

chnum [a]	Description
101 or 1	Subchannel 1 of the module installed in slot 1
201 or 2	Subchannel 1 of the module installed in slot 2
301 or 3	Subchannel 1 of the module installed in slot 3
401 or 4	Subchannel 1 of the module installed in slot 4
501 or 5	Subchannel 1 of the module installed in slot 5
601 or 6	Subchannel 1 of the module installed in slot 6
701 or 7	Subchannel 1 of the module installed in slot 7
801 or 8	Subchannel 1 of the module installed in slot 8
901 or 9	Subchannel 1 of the module installed in slot 9
1001 or 10	Subchannel 1 of the module installed in slot 10
102	Subchannel 2 of the module installed in slot 1
202	Subchannel 2 of the module installed in slot 2
302	Subchannel 2 of the module installed in slot 3
402	Subchannel 2 of the module installed in slot 4
502	Subchannel 2 of the module installed in slot 5
602	Subchannel 2 of the module installed in slot 6
702	Subchannel 2 of the module installed in slot 7
802	Subchannel 2 of the module installed in slot 8
902	Subchannel 2 of the module installed in slot 9
1002	Subchannel 2 of the module installed in slot 10

a. The HPSMU, HCSMU, and HVSMU occupy two slots. To specify these module, use the channel number given by the smaller slot number. For example, use the channel number 301 or 3 to specify the HPSMU installed in slots 3 to 4.

Table 4-2 SMU Voltage Measurement Ranging Type

range [a]	Module type					Ranging type	
	MP	HR	HP	HC	HV	for measurement mode without pulse	for measurement mode that uses pulse
0	Yes	Yes	Yes	Yes	Yes	Auto ranging	Measurement channel uses the minimum range that covers the compliance value.
2				Yes		0.2 V limited auto ranging	
5	Yes	Yes				0.5 V limited auto ranging	
20 or 11	Yes	Yes	Yes	Yes		2 V limited auto ranging	
50	Yes	Yes				5 V limited auto ranging	
200 or 12	Yes	Yes	Yes	Yes		20 V limited auto ranging	
400 or 13	Yes	Yes	Yes	Yes		40 V limited auto ranging	
1000 or 14	Yes	Yes	Yes			100 V limited auto ranging	
2000 or 15			Yes		Yes	200 V limited auto ranging	
5000					Yes	500 V limited auto ranging	
15000					Yes	1500 V limited auto ranging	
30000					Yes	3000 V limited auto ranging	
-2				Yes		0.2 V range fixed	
-5	Yes	Yes				0.5 V range fixed	
-20 or -11	Yes	Yes	Yes	Yes		2 V range fixed	
-50	Yes	Yes				5 V range fixed	
-200 or -12	Yes	Yes	Yes	Yes		20 V range fixed	
-400 or -13	Yes	Yes	Yes	Yes		40 V range fixed	
-1000 or -14	Yes	Yes	Yes			100 V range fixed	
-2000 or -15			Yes		Yes	200 V range fixed	
-5000					Yes	500 V range fixed	
-15000					Yes	1500 V range fixed	
-30000					Yes	3000 V range fixed	

a. If the measurement channel forces voltage, the channel uses the voltage output range regardless of the *range* value.

Table 4-3 SMU Current Measurement Ranging Type

range [a]	Module type					Ranging type	
	MP	HR	HP	HC	HV	for measurement mode without pulse	for measurement mode that uses pulse
0	Yes	Yes	Yes	Yes	Yes	Auto ranging	Measurement channel uses the minimum range that covers the compliance value.
8, for ASU		Yes				1 pA limited auto ranging	
9		Yes				10 pA limited auto ranging	
10		Yes				100 pA limited auto ranging	
11	Yes	Yes	Yes		Yes	1 nA limited auto ranging	
12	Yes	Yes	Yes		Yes	10 nA limited auto ranging	
13	Yes	Yes	Yes		Yes	100 nA limited auto ranging	
14	Yes	Yes	Yes		Yes	1 μA limited auto ranging	
15	Yes	Yes	Yes	Yes	Yes	10 μA limited auto ranging	
16	Yes	Yes	Yes	Yes	Yes	100 μA limited auto ranging	
17	Yes	Yes	Yes	Yes	Yes	1 mA limited auto ranging	
18	Yes	Yes	Yes	Yes	Yes	10 mA limited auto ranging	
19	Yes	Yes	Yes	Yes		100 mA limited auto ranging	
20			Yes	Yes		1 A limited auto ranging	
22				Yes		20 A limited auto ranging	
-8		Yes				1 pA range fixed	
-9		Yes				10 pA range fixed	
-10		Yes				100 pA range fixed	
-11	Yes	Yes	Yes		Yes	1 nA range fixed	
-12	Yes	Yes	Yes		Yes	10 nA range fixed	
-13	Yes	Yes	Yes		Yes	100 nA range fixed	
-14	Yes	Yes	Yes		Yes	1 μA range fixed	
-15	Yes	Yes	Yes	Yes	Yes	10 μA range fixed	
-16	Yes	Yes	Yes	Yes	Yes	100 μA range fixed	
-17	Yes	Yes	Yes	Yes	Yes	1 mA range fixed	
-18	Yes	Yes	Yes	Yes	Yes	10 mA range fixed	
-19	Yes	Yes	Yes	Yes		100 mA range fixed	
-20			Yes	Yes		1 A range fixed	
-22				Yes		20 A range fixed	

a. If the measurement channel forces current, the channel uses the current output range regardless of the *range* value.

NOTE

Measurement ranging (auto and limited auto)

The instrument automatically selects the minimum range that covers the measurement value, and performs the measurement by using the range. For the limited auto ranging, the instrument does not use the range lower than the specified range value. For example, if you select the 100 nA limited auto ranging, the instrument never uses the 10 nA range and below.

NOTE

Before using 1 pA range

The measurement channel connected to the ASU (Atto Sense and Switch Unit) supports the 1 pA range. To use the 1 pA range, set the 1 pA fixed range or the 1 pA limited auto ranging.

To enable the 1 pA range for the auto ranging mode, execute the SAR command.

The Agilent B1500 automatically performs the compensation of the data measured by the 1 pA range and returns the compensated data. You can use either the pre-stored offset data or the pre-measured offset data.

To measure the offset data, execute the CA command before starting the measurement for a DUT. The offset data is temporarily memorized until the B1500 is turned off.

NOTE

Output ranging

The instrument automatically selects the minimum range that covers the output value, and applies voltage or current by using the range. For the limited auto ranging, the instrument does not use the range lower than the specified range value. For example, if you select the 100 nA limited auto ranging, the instrument never uses the 10 nA range and below.

Table 4-4 **SMU Voltage Output Ranging Type**

range or *vrange*	Module type					Ranging type
	MP	HR	HP	HC	HV	
0	Yes	Yes	Yes	Yes	Yes	Auto ranging
2				Yes		0.2 V limited auto ranging
5	Yes	Yes				0.5 V limited auto ranging
20 or 11	Yes	Yes	Yes	Yes		2 V limited auto ranging
50	Yes	Yes				5 V limited auto ranging
200 or 12	Yes	Yes	Yes	Yes		20 V limited auto ranging
400 or 13	Yes	Yes	Yes	Yes		40 V limited auto ranging
1000 or 14	Yes	Yes	Yes			100 V limited auto ranging
2000 or 15			Yes		Yes	200 V limited auto ranging
5000					Yes	500 V limited auto ranging
15000					Yes	1500 V limited auto ranging
30000					Yes	3000 V limited auto ranging

Table 4-5 **SMU Current Output Ranging Type**

range or *irange*	Module type					Ranging type
	MP	HR	HP	HC	HV	
0	Yes	Yes	Yes	Yes	Yes	Auto ranging
8, for ASU		Yes				1 pA limited auto ranging
9		Yes				10 pA limited auto ranging
10		Yes				100 pA limited auto ranging
11	Yes	Yes	Yes		Yes	1 nA limited auto ranging
12	Yes	Yes	Yes		Yes	10 nA limited auto ranging
13	Yes	Yes	Yes		Yes	100 nA limited auto ranging
14	Yes	Yes	Yes		Yes	1 μA limited auto ranging
15	Yes	Yes	Yes	Yes	Yes	10 μA limited auto ranging
16	Yes	Yes	Yes	Yes	Yes	100 μA limited auto ranging
17	Yes	Yes	Yes	Yes	Yes	1 mA limited auto ranging
18	Yes	Yes	Yes	Yes	Yes	10 mA limited auto ranging
19	Yes	Yes	Yes	Yes		100 mA limited auto ranging
20			Yes	Yes		1 A limited auto ranging
22				Yes		20 A limited auto ranging

Table 4-6 MP/HR/HPSMU Voltage Source Setup Parameters

Output range (actually used)	Setting resolution in V	*voltage*, *start*, *stop*, *base*, *bias*, or *pulse* in V	Pulse	DC	Maximum *Icomp* value in A		
					HPSMU	MPSMU	HRSMU
0.5 V	25E-6	0 to ± 0.5	Yes	Yes	NA	±100E-3	±100E-3
2 V	100E-6	0 to ± 2	Yes	Yes	±1	±100E-3	±100E-3
5 V	250E-6	0 to ± 5	Yes	Yes	NA	±100E-3	±100E-3
20 V	1E-3	0 to ± 20	Yes	Yes	±1	±100E-3	±100E-3
40 V	2E-3	0 to ± 20	Yes	Yes	±500E-3	±100E-3	±100E-3
		to ± 40				±50E-3	±50E-3
100 V	5E-3	0 to ± 20	Yes	Yes	±125E-3	±100E-3	±100E-3
		to ± 40				±50E-3	±50E-3
		to ± 100				±20E-3	±20E-3
200 V	10E-3	0 to ± 200	Yes	Yes	±50E-3	NA	

The following commands are used for setting the MP/HR/HPSMU to the voltage source.

DV, TDV, BDV, WV, WSV, WNX, PV, PWV, QSV, LSV, LSSV, BSV, BSSV, MV, MCPNX, MCPWNX, MDCV, PDCV, WDCV, PWDCV

Table 4-7 MP/HR/HPSMU Current Source Setup Parameters

Output range (actually used)	Setting resolution in A	*current*, *start*, *stop*, *base*, *bias*, or *pulse* in A	Pulse	DC	Maximum *Vcomp* value in V		
					HPSMU	MPSMU	HRSMU
1 pA	1E-15	0 to ± 1.15 E-12	No	Yes	NA		±100
10 pA	5E-15	0 to ± 11.5 E-12	No	Yes			±100
100 pA	5E-15	0 to ± 115 E-12	No	Yes			±100
1 nA	50E-15	0 to ± 1.15 E-9	No	Yes	±200	±100	±100
10 nA	500E-15	0 to ± 11.5 E-9	Yes	Yes	±200	±100	±100
100 nA	5E-12	0 to ± 115 E-9	Yes	Yes	±200	±100	±100
1 μA	50E-12	0 to ± 1.15E-6	Yes	Yes	±200	±100	±100
10 μA	500E-12	0 to ± 11.5E-6	Yes	Yes	±200	±100	±100
100 μA	5E-9	0 to ± 115E-6	Yes	Yes	±200	±100	±100
1 mA	50E-9	0 to ± 1.15E-3	Yes	Yes	±200	±100	±100
10 mA	500E-9	0 to ± 11.5E-3	Yes	Yes	±200	±100	±100
100 mA	5E-6	0 to ± 20E-3	Yes	Yes	±200	±100	±100
		to ± 50E-3			±200	±40	±40
		to ± 100E-3			±100	±20	±20
		to ± 115E-3			±100	NA	
1 A	50E-6	0 to ± 50E-3	Yes	Yes	±200		
		to ± 125E-3			±100		
		to ± 500E-3			±40		
		to ± 1			±20		

The following commands are used for setting the MP/HR/HPSMU to the current source.

DI, TDI, WI, WSI, WNX, PI, PWI, LSI, LSSI, BSI, BSSI, MI, MCPNX, MCPWNX

Table 4-8 **HCSMU Voltage Source Setup Parameters**

Output range (actually used)	Setting resolution in V	*voltage*, *start*, *stop*, *base*, *bias*, or *pulse* in V	Maximum *Icomp* value in A	
			Pulse output	DC output
0.2 V	2E-7	0 to ± 0.2	±20	±1
2 V	2E-6	0 to ± 2	±20	±1
20 V	2E-5	0 to ± 20	±20	±1
40 V	4E-5	0 to ± 40	±1	±1

The following commands are used for setting the HCSMU to the voltage source.

DV, TDV, WV, WSV, WNX, PV, PWV, LSV, LSSV, BSV, BSSV, MV, MCPNX, MCPWNX, MDCV, PDCV, WDCV, PWDCV

Table 4-9 **HCSMU Current Source Setup Parameters**

Output range (actually used)	Setting resolution in A	*current*, *start*, *stop*, *base*, *bias*, or *pulse* in A	Maximum *Vcomp* value in V	
			Pulse output	DC output
10 μA	1E-11	0 to ± 1E-5	±40	±40
100 μA	1E-10	0 to ± 1E-4	±40	±40
1 mA	1E-9	0 to ± 1E-3	±40	±40
10 mA	1E-8	0 to ± 1E-2	±40	±40
100 mA	1E-7	0 to ± 1E-1	±40	±40
1 A	1E-6	0 to ± 1	±40	±40
20 A	2E-5	peak: 0 to ± 20	±20	NA
		base: 0 to ± 1E-1		

The following commands are used for setting the HCSMU to the current source.

DI, TDI, WI, WSI, WNX, PI, PWI, LSI, LSSI, BSI, BSSI, MI, MCPNX, MCPWNX

Table 4-10 HVSMU Voltage Source Setup Parameters

Output range (actually used)	Setting resolution in V	*voltage*, *start*, *stop*, *base*, *bias*, or *pulse* in V	Pulse	DC	*Icomp* value in A	
					Negative output	Positive output
200 V	2E-4	0 to ± 200	Yes	Yes	-8E-3 to 0	0 to +8E-3
500 V	5E-4	0 to ± 500	Yes	Yes		
1500 V	15E-4	0 to ± 1500	Yes	Yes		
3000 V	3E-3	0 to ± 3000	Yes	Yes	-4E-3 to 0	0 to +4E-3

The following commands are used for setting the HVSMU to the voltage source.
DV, TDV, WV, WSV, WNX, PV, PWV, LSV, LSSV, BSV, BSSV, MV, MCPNX, MCPWNX, MDCV, PDCV, WDCV, PWDCV

Table 4-11 HVSMU Current Source Setup Parameters

Output range (actually used)	Setting resolution in A	*current*, *start*, *stop*, *base*, *bias*, or *pulse* in A	Pulse	DC	*Vcomp* value in V	
					Negative output	Positive output
1 nA	1E-14	0 to ± 1E-9	Yes	Yes	-3000 to 0	0 to +3000
10 nA	1E-13	0 to ± 1E-8	Yes	Yes		
100 nA	1E-13	0 to ± 1E-7	Yes	Yes		
1 μA	1E-12	0 to ± 1E-6	Yes	Yes		
10 μA	1E-11	0 to ± 1E-5	Yes	Yes		
100 μA	1E-10	0 to ± 1E-4	Yes	Yes		
1 mA	1E-9	0 to ± 1E-3	Yes	Yes		
10 mA	1E-8	0 to ± 4E-3	Yes	Yes		
		to ± 8E-3			-1500 to 0	0 to +1500

The following commands are used for setting the HVSMU to the current source.
DI, TDI, WI, WSI, WNX, PI, PWI, LSI, LSSI, BSI, BSSI, MI, MCPNX, MCPWNX

Table 4-12 **MFCMU Measurement Parameters**

mode	Primary Parameter	Secondary Parameter
1	R (resistance, Ω)	X (reactance, Ω)
2	G (conductance, S)	B (susceptance, S)
10	Z (impedance, Ω)	θ (phase, radian)
11	Z (impedance, Ω)	θ (phase, degree)
20	Y (admittance, S)	θ (phase, radian)
21	Y (admittance, S)	θ (phase, degree)
100	Cp (parallel capacitance, F)	G (conductance, S)
101	Cp (parallel capacitance, F)	D (dissipation factor)
102	Cp (parallel capacitance, F)	Q (quality factor)
103	Cp (parallel capacitance, F)	Rp (parallel resistance, Ω)
200	Cs (series capacitance, F)	Rs (series resistance, Ω)
201	Cs (series capacitance, F)	D (dissipation factor)
202	Cs (series capacitance, F)	Q (quality factor)
300	Lp (parallel inductance, H)	G (conductance, S)
301	Lp (parallel inductance, H)	D (dissipation factor)
302	Lp (parallel inductance, H)	Q (quality factor)
303	Lp (parallel inductance, H)	Rp (parallel resistance, Ω)
400	Ls (series inductance, H)	Rs (series resistance, Ω)
401	Ls (series inductance, H)	D (dissipation factor)
402	Ls (series inductance, H)	Q (quality factor)

Table 4-13 **MFCMU Measurement Range for Fixed Ranging Mode**

range	Measurement range (impedance range) [a]		
	1 kHz ≤ f ≤ 200 kHz	**200 kHz < f ≤ 2 MHz**	**2 MHz < f ≤ 5 MHz**
0 ≤ *range* < 100	50 Ω	50 Ω	50 Ω
100 ≤ *range* < 300	100 Ω	100 Ω	100 Ω
300 ≤ *range* < 1000	300 Ω	300 Ω	300 Ω
1000 ≤ *range* < 3000	1 kΩ	1 kΩ	1 kΩ
3000 ≤ *range* < 10000	3 kΩ	3 kΩ	3 kΩ
10000 ≤ *range* < 30000	10 kΩ	10 kΩ	
30000 ≤ *range* < 100000	30 kΩ	30 kΩ	
100000 ≤ *range* < 300000	100 kΩ		
300000 ≤ *range*	300 kΩ		

a. Available measurement ranges depend on the output signal frequency. MFCMU performs impedance measurement and returns the specified measurement parameters such as Cp-G. Then capacitance C will be given by $C = 1 / (2\pi f Z)$ where f is frequency (Hz) and Z is impedance (Ω). To decide the measurement range, also see Figure 4-1.

Table 4-14 **MFCMU Output Signal Frequency**

freq	Setting resolution
1000 ≤ *freq* < 10000	0.001 Hz
10000 ≤ *freq* < 100000	0.01 Hz
100000 ≤ *freq* < 1000000	0.1 Hz
1000000 ≤ *freq* ≤ 5000000	1 Hz

Table 4-15 **MFCMU AC Level Measurement Range**

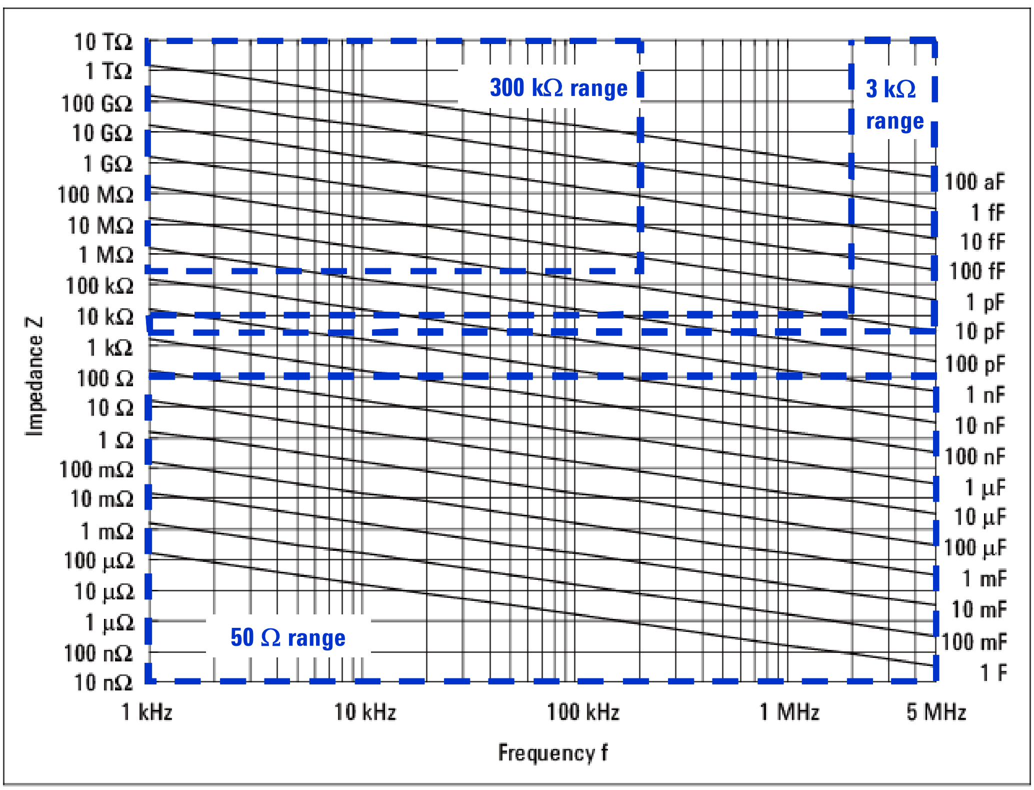
range	Maximum measurement value, absolute value
0.016	0.016 V
0.032	0.032 V
0.064	0.064 V
0.125	0.125 V
0.250	0.250 V

Table 4-16 **MFCMU DC Bias Measurement Range**

range [a]	Maximum measurement value, absolute value	
8	100 V (SMU)	8 V (MFCMU)
12		12 V (MFCMU)
25		25 V (MFCMU)
100		

a. SMU (MPSMU or HRSMU) connected to the SCUU (SMU CMU Unify Unit) always performs the 100 V limited auto ranging operation. The MFCMU uses the 25V range even if *range*=100 is specified.

Figure 4-1 **Impedance vs Frequency Characteristics of Capacitive Load, Calculation Example**



Command Reference

This section contains detailed descriptions of all GPIB commands. The commands are listed in alphabetical order. Each entry:

1. Defines one GPIB command
2. Describes the execution conditions, if any exist
3. Describes the syntax
4. Lists the parameters
5. Shows the query response after command execution, if there is a query command
6. Explains any additional information
7. Provides examples

The following conventions are used in this section.

parameter	Required command parameters, for which you must substitute a value or variable.
[*parameter*]	Optional command parameters, for which you may substitute a value or omit it.

AAD

This command is used to specify the type of the A/D converter (ADC) for each measurement channel.

Execution Conditions

Enter the AIT command to set up the ADC.

Syntax

AAD *chnum*,*type*

Parameters

***chnum* :** SMU measurement channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***type* :** Type of the A/D converter. Integer expression. 0, 1, or 2.

0: High-speed ADC for high speed DC measurement. Initial setting.

1: High-resolution ADC. For high accurate DC measurement.
Not available for the HCSMU and HVSMU.

2: High-speed ADC for pulsed-measurement

The pulsed-measurement ADC is automatically used for the pulsed spot, pulsed sweep, multi channel pulsed spot, multi channel pulsed sweep, or staircase sweep with pulsed bias measurement, even if the AAD *chnum*,2 command is not executed.

The pulsed-measurement ADC is never used for the DC measurement. Even if the AAD *chnum*,2 command is executed, the previous setting is still effective.

Example Statements

```
OUTPUT @B1500;"AAD 1,0"
OUTPUT @B1500;"AAD 1,1"
```

AB

The AB command aborts the present operation and subsequent command execution.

This command stops the operation now in progress, such as the measurement execution, source setup changing, and so on. But this command does not change the present condition. For example, if the B1500 just keeps to force the DC bias, the AB command does not stop the DC bias output.

Syntax

AB

Example Statements

```
OUTPUT @B1500;"AB"
```

Remarks

If you start an operation that you may want to abort, do not send any command after the command or command string that starts the operation. If you do, the AB command cannot enter the command input buffer until the intervening command execution starts, so the operation cannot be aborted. In this case, use the device clear (HP BASIC CLEAR command) to end the operation.

If the AB command is entered in a command string, the other commands in the string are not executed. For example, the CN command in the following command string is not executed.

```
OUTPUT @B1500;"AB;CN"
```

During sweep measurement, if the B1500 receives the AB command, it returns only the measurement data obtained before abort. Then the dummy data is not returned.

For the quasi-pulsed spot measurement, the B1500 cannot receive any command during the settling detection. So the AB command cannot abort the operation, and it will be performed after the settling detection.

Conditions after Execution

The AB command sets the B1500 as listed in the following table.

Operation before AB	Setting after AB
Staircase sweep output	Sets specified start value.
Pulse output	Sets specified base value.
Quasi-pulsed spot measurement	Sets specified start value.
Sampling measurement	Sets specified base value.
Quasi-static CV measurement	Sets specified start value.
Linear search measurement	Sets specified start value.
Binary search measurement	Sets specified start value.
Multi channel sweep measurement	Sets specified start value.
MFCMU DC/AC/frequency sweep measurement	Sets specified start value.
Self-test	Same as set by CL command.
Self-calibration	Same as set by CL command.
Wait state (PA/PAX/WS/WSX command)	Settings do not change.
Program execution (RU or DO command)	Settings do not change.

ACH

The ACH command translates the specified *program* channel number to the specified *actual* channel number at the program execution. This command is useful when you use a control program created for an instrument, such as the 4142B, 4155B/4155C/4156B/4156C/E5260/E5270, and B1500, that has a module configuration different from the B1500 actually you use. After the ACH command, enter the *OPC? command to confirm that the command execution is completed.

Syntax

ACH [*actual*[,*program*]]

Parameter

***actual* :** Channel number actually set to the B1500 instead of *program*. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1 on page 4-14.

***program* :** Channel number used in a program and will be replaced with *actual*. Integer expression.

If you do not set *program*, this command is the same as ACH *n*,*n*.

If you do not set *actual* and *program*, all channel number mapping is cleared.

For parameter settings, you cannot use the variables set by the VAR command.

Remarks

The ACH commands must be put at the beginning of the program or before the command line that includes a *program* channel number. In the program lines that follow the ACH command, you must leave the *program* channel numbers. The measurement data is returned as the data of the channel *program*, not *actual*.

Example Statements

If you want to use channels 1 to 3 instead of channels 5 to 7 respectively, enter the following statements. The measurement data is returned as the data of channel 5, not channel 1.

```
OUTPUT @B1500;"ACH 1,5"    !uses ch1 instead of ch5
OUTPUT @B1500;"ACH 2,6"    !     ch2            ch6
OUTPUT @B1500;"ACH 3,7"    !     ch3            ch7
OUTPUT @B1500;"*OPC?"
ENTER @B1500;A
!
OUTPUT @B1500;"CN 5,6,7"            !leave prog ch No.
!                                           |
OUTPUT @B1500;"DV 5,0,3"            !       |
OUTPUT @B1500;"DV 6,0,0"            !       |
OUTPUT @B1500;"DV 7,0,0"            !       |
!                                           |
OUTPUT @B1500;"TI 5,0"              !       |
ENTER @B1500 USING "#,3X,13D,X";Data!       |
PRINT "I=";Data                     !       |
!                                           |
OUTPUT @B1500;"CL 5,6,7"            !       V
```

ACT

This command sets the number of averaging samples or the averaging time set to the A/D converter of the MFCMU.

Syntax

`ACT mode[,N]`

Parameters

***mode* :** Averaging mode. Integer expression. 0 (initial setting) or 2.

- 0: Auto mode.

  Defines the number of averaging samples given by the following formula. Then *initial averaging* is the number of averaging samples automatically set by the B1500 and you cannot change.

  $\textit{Number of averaging samples} = N \times \textit{initial averaging}$

- 2: Power line cycle (PLC) mode.

  Defines the averaging time given by the following formula.

  $\textit{Averaging time} = N / \textit{power line frequency}$

***N* :** Coefficient used to define the number of averaging samples or the averaging time. Integer expression.

- For *mode*=0: 1 to 1023. Initial setting/default setting is 2.
- For *mode*=2: 1 to 100. Initial setting/default setting is 1.

Example Statements

```
OUTPUT @B1500;"ACT 0,1"
OUTPUT @B1500;"ACT 2,2"
```

ACV

This command sets the output signal level of the MFCMU, and starts the AC voltage output. Output signal frequency is set by the FC command.

Execution Conditions

The CN/CNX command has been executed for the specified channel.

Syntax

`ACV chnum,voltage`

Parameters

***chnum* :** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***voltage* :** Oscillator level of the output AC voltage (in V). Numeric expression.

0 mV (initial setting) to 250 mV, 1 mV step.

Example Statements

```
OUTPUT @B1500;"ACV 7,0.01"
```

ADJ

This command selects the MFCMU phase compensation mode. This command initializes the MFCMU.

Syntax

ADJ *chnum*,*mode*

Parameters

chnum **:** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

mode **:** Phase compensation mode. Integer expression. 0 or 1.

0: Auto mode. Initial setting.

1: Manual mode.

For *mode*=0, the B1500 sets the compensation data automatically.

For *mode*=1, execute the ADJ? command to perform the phase compensation and set the compensation data.

Example Statements

```
OUTPUT @B1500;"ADJ 9,1"
```

ADJ?

This command performs the MFCMU phase compensation, and sets the compensation data to the B1500. This command also returns the execution results.

This command resets the MFCMU.

Before executing this command, set the phase compensation mode to manual by using the ADJ command. During this command, open the measurement terminals at the end of the device side. This command execution will take about 30 seconds.

The compensation data is cleared by turning the B1500 off.

Syntax

ADJ? *chnum*[,*mode*]

Parameters

chnum **:** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

mode **:** Command operation mode.

0: Use the last phase compensation data without measurement.

1: Perform the phase compensation data measurement.

If the *mode* parameter is not set, *mode*=1 is set.

Query Response

`results<CR/LF^EOI>`

results returns the following value.

results	Meaning
0	Phase compensation measurement was normally completed.
1	Phase compensation measurement failed.
2	Phase compensation measurement was aborted.
3	Phase compensation measurement has not been performed.

If the phase compensation measurement has never been performed, *result*=3 is returned.

Example Statements

```
OUTPUT @B1500;"ADJ?"
ENTER @B1500;A
```

AIT

This command is used to set the operation mode and the setup parameter of the A/D converter (ADC) for each ADC type.

Execution Conditions

Enter the AAD command to specify the ADC type for each measurement channel.

Syntax

`AIT type,mode[,N]`

Parameters

***type* :** Type of the A/D converter. Integer expression. 0, 1, or 2.

0: High-speed ADC

1: High-resolution ADC. Not available for the HCSMU and HVSMU.

2: High-speed ADC for pulsed-measurement

***mode* :** ADC operation mode. Integer expression. 0, 1, 2, or 3.

0: Auto mode. Initial setting.

1: Manual mode

2: Power line cycle (PLC) mode

3: Measurement time mode. Not available for the high-resolution ADC.

N **:** Coefficient used to define the integration time or the number of averaging samples, integer expression, for *mode*=0, 1, and 2. Or the actual measurement time, numeric expression, for *mode*=3. See Table 4-17.

The pulsed-measurement ADC (*type*=2) is available for the all measurement channels used for the pulsed spot, pulsed sweep, multi channel pulsed spot, multi channel pulsed sweep, or staircase sweep with pulsed bias measurement.

Table 4-17 **Available Parameter Values**

type	*mode*	*N*
0	0	Value that defines the number of averaging samples given by the following formula. *N*=1 to 1023. Default setting is 1. *Number of averaging samples* = *N* × *initial averaging* where *initial averaging* is the number of averaging samples automatically set by Agilent B1500 and you cannot change.
	1	Number of averaging samples. *N*=1 to 1023. Default setting is 1.
	2	Value that defines the number of averaging samples given by the following formula. *N*=1 to 100. Default setting is 1. *Number of averaging samples* = *N* × 128 The Agilent B1500 gets 128 samples in a power line cycle, repeats this for the times you specify, and performs averaging to get the measurement data.
	3	Actual measurement time, in seconds. *N*=2 μs to 20 ms, 2 μs resolution. Default setting is 2 μs. For HR/MP/HPSMU, it performs the operation of *mode*=1. Then the number of averaging samples is automatically set to the following value. *Number of averaging samples* = *N* / *Tm* *Tm*: Required time for one sample measurement If *N* / *Tm* < 1, *Number of averaging samples* =1.

type	*mode*	*N*
1	0	Value that defines the integration time given by the following formula. *N*=1 to 127. Default setting is 6. *Integration time* = *N* × *initial integration time* where *initial integration time* is the integration time automatically set by Agilent B1500 and you cannot change.
	1	Value that defines the integration time given by the following formula. *N*=1 to 127. Default setting is 3. *Integration time* = *N* × 80 μsec
	2	Value that defines the integration time given by the following formula. *N*=1 to 100. Default setting is 1. *Integration time* = *N* / *power line frequency*
	3	Not applicable.
2	0	Not applicable.
	1	Not applicable.
	2	Value that defines the number of averaging samples given by the following formula. *N*=1 to 100. Default setting is 1. *Number of averaging samples* = *N* × 128 The Agilent B1500 gets 128 samples in a power line cycle, repeats this for the times you specify, and performs averaging to get the measurement data.
	3	Actual measurement time, in seconds. *N*=2 μs to 20 ms, 2 μs resolution. Default setting is 2 μs. For HR/MP/HPSMU, it performs the operation of *type*=0 and *mode*=1. Then the number of averaging samples is automatically set to the following value. *Number of averaging samples* = *N* / *Tm* *Tm*: Required time for one sample measurement If *N* / *Tm* < 1, *Number of averaging samples* =1.

Example Statements

```
OUTPUT @B1500;"AIT 2,3,.001"
```

ALS

This command sets the ALWG sequence data.

To generate an arbitrary linear waveform, the SPGU channels need both sequence data and pattern data. The sequence data must be used by and in common with all SPGU channels installed in the B1500. And the pattern data must be set to each SPGU channel.

See “SPGU Module” on page 2-52 for details on the ALWG output and the data format.

Execution Conditions

The SPGU operating mode must be set to ALWG with the SIM 1 command.

Syntax

`ALS` *`chnum,bytes block`*

Parameters

chnum **:** SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1.

bytes **:** Total number of bytes of the ALWG sequence data. Numeric expression.

block **:** ALWG sequence data (binary format, big endian).

ALS?

This query command returns the ALWG sequence data of the specified SPGU channel.

Syntax

`ALS?` *`chnum`*

Parameters

chnum **:** SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1.

Query Response

`block``<^EOI>`

Returns the ALWG sequence data (binary format, big endian).

ALW

This command sets the ALWG pattern data.

To generate an arbitrary linear waveform, the SPGU channels need both sequence data and pattern data. The sequence data must be used by and in common with all SPGU channels installed in the B1500. And the pattern data must be set to each SPGU channel.

See "SPGU Module" on page 2-52 for details on the ALWG output and the data format.

Execution Conditions The SPGU operating mode must be set to ALWG with the SIM 1 command.

Syntax `ALW` *chnum*,*bytes block*

Parameters

***chnum* :** SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1.

***bytes* :** Total number of bytes of the ALWG pattern data. Numeric expression.

***block* :** ALWG pattern data (binary format, big endian).

ALW?

This query command returns the ALWG pattern data of the specified SPGU channel.

Syntax `ALW?` *chnum*

Parameters

***chnum* :** SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1.

Query Response *block*<^EOI>

Returns the ALWG pattern data (binary format, big endian).

AV

This command sets the number of averaging samples of the high-speed ADC (A/D converter). This command is not effective for the high-resolution ADC.

This command is not effective for the measurements using pulse.

Syntax `AV` *number*[,*mode*]

Parameters

***number* :** 1 to 1023, or –1 to –100. Initial setting is 1.

For *positive* number input, this value specifies the number of samples depended on the *mode* value. See below.

For *negative* number input, this parameter specifies the number of power line cycles (PLC) for one point measurement. The Agilent B1500 gets 128 samples in 1 PLC. Ignore the *mode* parameter.

***mode* :** Averaging mode. Integer expression. This parameter is meaningless for negative *number*.

0: Auto mode (default setting).

Number of samples = *number* × *initial number*

1: Manual mode.

Number of samples = *number*

where *initial number* means the number of samples the Agilent B1500 automatically sets and you cannot change. For voltage measurement, *initial number*=1. For current measurement, see Table 4-18.

If you select the manual mode, *number* must be *initial number* or more to satisfy the specifications.

Table 4-18 Initial Number for Current Measurement

Current Measurement Range	Voltage Output Range [a]		
	to 40 V	100 V	200 V
to 10 μA	4	10	25
100 μA to 1 A	1	1	1

a. For measurement channels that force current, this is the minimum range that covers the voltage compliance value.

Example Statements

```
OUTPUT @B1500;"AV 10"
OUTPUT @B1500;"AV -50"
OUTPUT @B1500;"AV 100,1"
```

AZ

This command is used to enable or disable the ADC zero function that is the function to cancel offset of the high-resolution A/D converter. This function is especially effective for low voltage measurements. Power on, *RST command, and device clear disable the function.

This command is effective for the high-resolution A/D converter, not effective for the high-speed A/D converter.

Syntax `AZ` *`mode`*

Parameters ***mode*** **:** Mode ON or OFF.

0: OFF. Disables the function. Initial setting.

1: ON. Enables the function.

Remarks Set the function to OFF in cases that the measurement speed is more important than the measurement accuracy. This roughly halves the integration time.

Example Statements

```
OUTPUT @B1500;"AZ 0"
```

BC

The BC command clears the output data buffer that stores measurement data and query command response data. This command does not change the measurement settings.

NOTE Multi command statement is not allowed for this command.

Syntax `BC`

Example Statements

```
OUTPUT @B1500;"BC"
```

BDM

The BDM command specifies the settling detection interval and the measurement mode; voltage or current, for the quasi-pulsed measurements.

Syntax `BDM` *`interval`*`[,`*`mode`*`]`

Parameters ***interval*** **:** Settling detection interval. Numeric expression.

0: Short. Initial setting.
1: Long. For measurements of the devices that have the stray capacitance, or the measurements with the compliance less than 1 μA

***mode* :** Measurement mode. Numeric expression.

0: Voltage measurement mode. Default setting.
1: Current measurement mode.

Remarks

The following conditions must be true to perform the measurement successfully:

When *interval*=0: A > 1 V/ms and B ≤ 3 s

When *interval*=1: A > 0.1 V/ms and B ≤ 12 s

where A means the slew rate when source output sweep was started, and B means the settling detection time. See "Quasi-Pulsed Spot Measurements" on page 2-18. These values depend on the conditions of cabling and device characteristics. And you cannot specify the values directly.

Example Statements

```
OUTPUT @B1500;"BDM 0,1"
```

BDT

The BDT command specifies the hold time and delay time for the quasi-pulsed measurements.

Syntax

BDT *hold*,*delay*

Parameters

***hold* :** Hold time (in sec). Numeric expression.
0 to 655.35 s, 0.01 s resolution. Initial setting is 0.

***delay* :** Delay time (in sec). Numeric expression.
0 to 6.5535 s, 0.0001 s resolution. Initial setting is 0.

Example Statements

```
OUTPUT @B1500;"BDT 0.1,1E-3"
```

BDV

The BDV command specifies the quasi-pulsed voltage source and its parameters.

If the output voltage is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

BDV *chnum*,*range*,*start*,*stop*[,*Icomp*]

Parameters

***chnum* :** SMU source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***range* :** Ranging type for quasi-pulsed source. Integer expression. The output range will be set to the minimum range that covers both *start* and *stop* values. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-4 on page 4-18.

***start, stop* :** Start or stop voltage (in V). Numeric expression. See Table 4-6 on page 4-19.

0 to ± 100 for MPSMU/HRSMU, or 0 to ± 200 for HPSMU

|*start* - *stop*| must be 10 V or more.

***Icomp* :** Current compliance (in A). Numeric expression. See Table 4-6 on page 4-19.

If you do not set *Icomp*, the previous value is used.

The compliance polarity is automatically set to the same polarity as the *stop* value, regardless of the specified *Icomp* value. If *stop*=0, the polarity is positive.

Remarks

The time forcing the *stop* value will be approximately 1.5 ms to 1.8 ms with the following settings:

- BDM, BDT command parameters: *interval*=0, *mode*=0, *delay*=0
- AV or AAD/AIT command parameters: initial setting

Example Statements

```
OUTPUT @B1500;"BDV 1,0,0,100,0.01"
```

BGI

The BGI command sets the current monitor channel for the binary search measurement (MM15). This command setting clears, and is cleared by, the BGV command setting.

This command ignores the RI command setting.

Syntax

BGI *chnum*,*mode*,*condition*,*range*,*target*

Parameters

***chnum* :** SMU search monitor channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***mode*, *condition* :** Search mode (0: limit mode or 1: repeat mode) and search stop condition. The meaning of *condition* depends on the *mode* setting.

mode	*condition*
0	Limit value for the search target (*target*). The search stops when the monitor data reaches *target* ± *condition*. Numeric expression. Positive value. in A. Setting resolution: *range*/20000. where *range* means the measurement range actually used for the measurement.
1	Repeat count. The search stops when the repeat count of the operation that changes the source output value is over the specified value. Numeric expression. 1 to 16.

***range* :** Measurement ranging type. Integer expression. The measurement range will be set to the minimum range that covers the *target* value. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-3 on page 4-16.

***target* :** Search target current (in A). Numeric expression.

0 to ± 0.1 for MPSMU/HRSMU, or 0 to ± 1 for HPSMU

Remarks

In the limit search mode, if search cannot find the search target and the following two conditions are satisfied, the B1500 repeats the binary search between the last source value and the source *start* value.

- *target* is between the data at source *start* value and the last measurement data.
- *target* is between the data at source *stop* value and the data at:
  source value = | *stop* – *start* | / 2.

If the search cannot find the search target and the following two conditions are satisfied, the B1500 repeats the binary search between the last source value and the source *stop* value.

- *target* is between the data at source *stop* value and the last measurement data.
- *target* is between the data at source *start* value and the data at:
  source value = | *stop* – *start* | / 2.

Example Statements

```
OUTPUT @B1500;"BGI 1,0,1E-8,14,1E-6"
```

See Also

“BSM”

BGV

The BGV command specifies the voltage monitor channel and its search parameters for the binary search measurement (MM15). This command setting clears, and is cleared by, the BGI command setting.

This command ignores the RV command setting.

Syntax

```
BGV chnum,mode,condition,range,target
```

Parameters

***chnum* :** SMU search monitor channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***mode*, *condition* :** Search mode (0: limit mode or 1: repeat mode) and search stop condition. The meaning of *condition* depends on the *mode* setting.

mode	*condition*
0	Limit value for the search target (*target*). The search stops when the monitor data reaches *target* ± *condition*. Numeric expression. Positive value. in V. Setting resolution: *range*/20000. where *range* means the measurement range actually used for the measurement.
1	Repeat count. The search stops when the repeat count of the operation that changes the source output value is over the specified value. Numeric expression. 1 to 16.

***range* :** Measurement ranging type. Integer expression. The measurement range will be set to the minimum range that covers the *target* value. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-2 on page 4-15.

***target* :** Search target voltage (in V). Numeric expression.

0 to ± 100 for MPSMU/HRSMU, or 0 to ± 200 for HPSMU

Remarks

In the limit search mode, if search cannot find the search target and the following two conditions are satisfied, the B1500 repeats the binary search between the last source value and the source *start* value.

- *target* is between the data at source *start* value and the last measurement data.
- *target* is between the data at source *stop* value and the data at:
  source value = | *stop* – *start* | / 2.

If the search cannot find the search target and the following two conditions are satisfied, the B1500 repeats the binary search between the last source value and the source *stop* value.

- *target* is between the data at source *stop* value and the last measurement data.
- *target* is between the data at source *start* value and the data at: source value = | *stop* – *start* | / 2.

Example Statements

```
OUTPUT @B1500;"BGV 1,0,0.1,12,5"
```

See Also

"BSM"

BSI

The BSI command sets the current search source for the binary search measurement (MM15). After search stops, the search channel forces the value specified by the BSM command.

This command clears the BSV, BSSI, and BSSV command settings.

This command setting is cleared by the BSV command.

If *Vcomp* value is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

BSI *chnum*,*range*,*start*,*stop*[,*Vcomp*]

Parameters

chnum **:** SMU search source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

range **:** Output ranging type. Integer expression. The output range will be set to the minimum range that covers both *start* and *stop* values. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-5 on page 4-18.

start, stop **:** Search start or stop current (in A). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type. The *start* and *stop* must have different values.

Vcomp **:** Voltage compliance value (in V). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type. If you do not specify *Vcomp*, the previous value is set.

Example Statements

```
OUTPUT @B1500;"BSI 1,0,1E-12,1E-6,10"
```

BSM

The BSM command specifies the search source control mode in the binary search measurement (MM15), and enables or disables the automatic abort function. The automatic abort function stops the search operation when one of the following conditions occurs:

- Compliance on the measurement channel
- Compliance on the non-measurement channel
- Overflow on the AD converter
- Oscillation on any channel

This command also sets the post search condition for the binary search sources. After the search measurement is normally completed, the binary search sources force the value specified by the *post* parameter.

If the search operation is stopped by the automatic abort function, the binary search sources force the start value after search.

Syntax

`BSM mode,abort[,post]`

Parameters

mode **:** Source output control mode, 0 (normal mode) or 1 (cautious mode). If you do not enter this command, the normal mode is set. See Figure 4-2.

abort **:** Automatic abort function. Integer expression.

1: Disables the function. Initial setting.

2: Enables the function.

post **:** Source output value after the search operation is normally completed. Integer expression.

1: Start value. Initial setting.

2: Stop value.

3: Output value when the search target value is get.

If this parameter is not set, the search source forces the start value.

Normal mode

The operation of the normal mode is explained below:

1. The source channel forces the Start value, and the monitor channel executes a measurement.

2. The source channel forces the Stop value, and the monitor channel executes a measurement.

   If the search target value is out of the range between the measured value at the Start value and the measured value at the Stop value, the search stops.

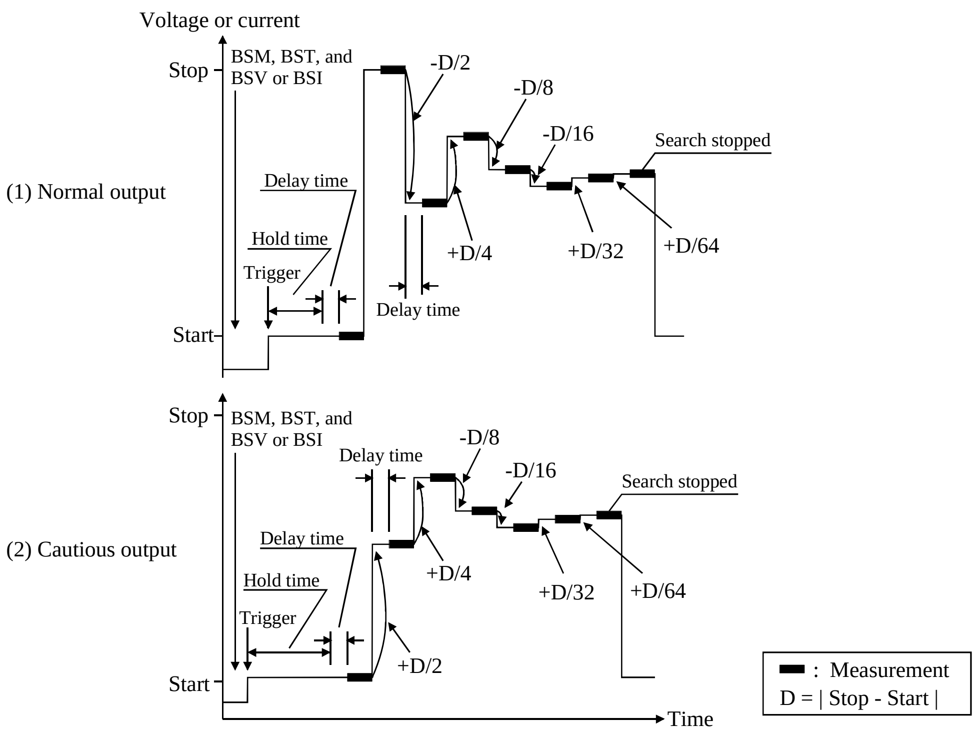
3. The source channel forces the Stop - D/2 value (or Stop+D/2 if Start>Stop), and the monitor channel executes a measurement.

   If the search stop condition is not satisfied, the measured data is used to decide the direction (+ or –) of the next output change. The value of the change is always half of the previous change.

4. Repeats the output change and measurement until the search stop condition is satisfied.

   For information on the search stop condition, see “BGI” or “BGV”. If the output change value is less than the setting resolution, the search stops.

Figure 4-2 **Binary Search Source Output Control Mode**



Cautious mode

The operation of the cautious mode is explained below:

1. The source channel forces the Start value, and the monitor channel executes a measurement.
2. The source channel forces the Start+D/2 value (or Start-D/2 if Start>Stop), and the monitor channel executes a measurement.

   If the search stop condition is not satisfied, the measured data is used to decide the direction (+ or –) of the next output change. The value of the change is always half of the previous change.
3. Repeats the output change and measurement until the search stop condition is satisfied.

   For information on the search stop condition, see “BGI” or “BGV”. If the output change value is less than the setting resolution, the search stops.

Example Statements

```
OUTPUT @B1500;"BSM 1,2,3"
```

BSSI

The BSSI command sets the synchronous current source for the binary search measurement (MM15). The synchronous source output will be:

Synchronous source output = *polarity* × BSI source output + *offset*

where BSI source output means the output set by the BSI command.

This command setting is cleared by the BSV/BSI command.

Execution Conditions

The BSI command must be sent *before* sending this command.

Syntax

BSSI *chnum*,*polarity*,*offset*[,*Vcomp*]

Parameters

chnum **:** SMU synchronous source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

polarity **:** Polarity of the BSSI output for the BSI output.

0: Negative. BSSI output = –BSI output + *offset*

1: Positive. BSSI output = BSI output + *offset*

offset **:** Offset current (in A). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type.

Both primary and synchronous search sources will use the same output range. So check the output range set to the BSI command to determine the synchronous source outputs.

***Vcomp* :** Voltage compliance value (in V). Numeric expression. If you do not specify *Vcomp*, the previous value is set.

Example Statements

```
OUTPUT @B1500;"BSSI 1,0,1E-6,10"
```

See Also

For the source output value, output range, and the available compliance values, see Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type.

BSSV

The BSSV command sets the synchronous voltage source for the binary search measurement (MM15). The synchronous source output will be:

Synchronous source output = *polarity* × BSV source output + *offset*

where BSV source output means the output set by the BSV command.

This command setting is cleared by the BSI/BSV command.

Execution Conditions

The BSV command must be sent *before* sending this command.

Syntax

BSSV *chnum*,*polarity*,*offset*[,*Icomp*]

Parameters

***chnum* :** SMU synchronous source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***polarity* :** Polarity of the BSSV output for the BSV output.

0: Negative. BSSV output = –BSV output + *offset*

1: Positive. BSSV output = BSV output + *offset*

***offset* :** Offset voltage (in V). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type.

Both primary and synchronous search sources will use the same output range. So check the output range set to the BSV command to determine the synchronous source outputs.

***Icomp* :** Current compliance value (in A). Numeric expression. If you do not specify *Icomp*, the previous value is set. Zero amps (0 A) is not a valid value for the *Icomp* parameter.

Example Statements

```
OUTPUT @B1500;"BSSV 1,0,5,1E-6"
```

See Also

For the source output value, output range, and the available compliance values, see Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type.

BST

The BST command sets the hold time and delay time for the binary search measurement (MM15). If you do not enter this command, all parameters are set to 0.

Syntax

BST *hold*,*delay*

Parameters

***hold* :** Hold time (in seconds) that is the wait time after starting the search measurement and before starting the delay time for the first search point. Numeric expression.

0 to 655.35 sec. 0.01 sec resolution.

***delay* :** Delay time (in seconds) that is the wait time after starting to force a step output value and before starting a step measurement. Numeric expression.

0 to 65.535 sec. 0.0001 sec resolution.

Example Statements

```
OUTPUT @B1500;"BST 5,0.1"
```

BSV

The BSV command sets the voltage search source for the binary search measurement (MM15). After search stops, the search channel forces the value specified by the BSM command.

This command clears the BSI, BSSI, and BSSV command settings.

This command setting is cleared by the BSI command.

If the output voltage is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

BSV *chnum*,*range*,*start*,*stop*[,*Icomp*]

Parameters

***chnum* :** SMU search source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***range* :** Output ranging type. Integer expression. The output range will be set to the minimum range that covers both *start* and *stop* values. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-4 on page 4-18.

***start, stop* :** Search start or stop voltage (in V). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. The *start* and *stop* parameters must have different values.

***Icomp* :** Current compliance value (in A). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. If you do not specify *Icomp*, the previous value is set. Zero amps (0 A) is not allowed for *Icomp*.

Example Statements

```
OUTPUT @B1500;"BSV 1,0,0,20,1E-6"
```

BSVM

The BSVM command selects the data output mode for the binary search measurement (MM15).

Syntax

`BSVM *mode*`

Parameters

***mode* :** Data output mode. Integer expression.

0 : Returns *Data_search* only (initial setting).

1 : Returns *Data_search* and *Data_sense*.

Data_search is the value forced by the search output channel set by BSI or BSV.

Data_sense is the value measured by the monitor channel set by BGI or BGV.

For data output format, refer to “Data Output Format” on page 1-25.

Example Statements

```
OUTPUT @B1500;"BSVM 1"
```

CA

This command performs the self-calibration.

The *OPC? command should be entered after this command to confirm the completion of the self-calibration.

Module condition after this command is the same as the condition by the CL command.

Execution Conditions

No SMU may be in the high voltage state (forcing more than ± 42 V, or voltage compliance set to more than ± 42 V).

Before starting the calibration, open the measurement terminals.

Syntax

`CA [slot]`

Parameters

slot **:** Slot number where the module under self-calibration has been installed. 1 to 10. Integer expression. If *slot* is not specified, the self-calibration is performed for the mainframe and all modules.

If *slot* specifies the slot that installs no module, this command causes an error.

Example Statements

```
OUTPUT @B1500;"CA"
OUTPUT @B1500;"*OPC?"
ENTER @B1500;A
```

NOTE

To send CA command to Agilent B1500 installed with ASU

If you send the CA command to the B1500 installed with the ASU (Atto Sense and Switch Unit), the B1500 executes the self-calibration and the 1 pA range offset measurement for the measurement channels connected to the ASUs. The offset data is temporarily memorized until the B1500 is turned off, and is used for the compensation of the data measured by the 1 pA range of the channels. The B1500 performs the data compensation automatically and returns the compensated data.

Since the B1500 is turned on, if you do not send the CA command, the B1500 performs the data compensation by using the pre-stored offset data.

Remarks

Failed modules are disabled, and can only be enabled by the RCV command.

*CAL?

This query command performs the self-calibration, and returns the results. After this command, read the results soon.

Module condition after this command is the same as the condition by the CL command.

Execution Conditions

No SMU may be in the high voltage state (forcing more than ± 42 V, or voltage compliance set to more than ± 42 V).

Before starting the calibration, open the measurement terminals.

Syntax

```
*CAL? [slot]
```

Parameters

***slot* :** Slot number where the module under self-calibration has been installed. 1 to 10. Or 0 or 11. Integer expression.

0: All modules and mainframe. Default setting.

11: Mainframe.

If *slot* specifies the slot that installs no module, this command causes an error.

Query Response

results<CR/LF^EOI>

results returns the sum of the following values corresponding to the failures.

results	Description	*results*	Description
0	Passed. No failure detected.	32	Slot 6 module failed.
1	Slot 1 module failed.	64	Slot 7 module failed.
2	Slot 2 module failed.	128	Slot 8 module failed.
4	Slot 3 module failed.	256	Slot 9 module failed.
8	Slot 4 module failed.	512	Slot 10 module failed.
16	Slot 5 module failed.	1024	Mainframe failed.

Example Statements

```
OUTPUT @B1500;"*CAL?"
ENTER @B1500;A
```

Remarks

If a SMU connected to SCUU fails the self-calibration, the SCUU cannot be controlled. And the SSP and SSL commands are not available.

Failed modules are disabled, and can only be enabled by the RCV command.

CL

The CL command disables the specified channels.

Execution Conditions

No channel may be in the high voltage state (forcing more than ± 42 V, or voltage compliance set to more than ± 42 V). However, if you do not specify *chnum* for CL command, there are no restrictions on the execution conditions.

Syntax

`CL [`*`chnum`*`[,`*`chnum`*`...[,`*`chnum`*`]...]]`

A maximum of 15 channels can be set.

Parameters

***chnum* :** Channel number. Integer expression. See Table 4-1 on page 4-14.

If you specify multiple *chnum*s, the channels will be disabled in the specified order.

If you do not specify *chnum*, this command disables all SMU, all SPGU, and CMU in this order. Then, SMU will be disabled in the order from higher to lower output range and SPGU will be disabled in the order from higher to lower setup voltage.

Remarks

The CL command sets the specified module to the following conditions:

SMU setup parameter	Value	MFCMU setup parameter	Value
Output switch	OFF	DC bias	0 V
Source mode	Voltage	AC level	0 V
Output voltage	0 V	Output signal frequency	1 kHz
V range	20 V	Measurement range	50 Ω
I compliance	100 μA	**SPGU setup parameter**	**Value**
I range	100 μA	Output switch	OFF
Filter	OFF	Output mode	DC
Series resistor	Not changed	Output voltage	0 V

After this command, there is no additional power consumption for the idle state.

Example Statements

```
OUTPUT @B1500;"CL"
OUTPUT @B1500;"CL 1,2,3,5"
```

CLCORR

This command disables the MFCMU open/short/load correction function and clears the frequency list for the correction data measurement. This command also clears the correction data.

Syntax

`CLCORR `*`chnum,mode`*

Parameters

***chnum* :** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***mode* :** Command option. Integer expression. 1 or 2.

1: Just clears the frequency list.

2: Clears the frequency list and sets the default frequencies, 1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz.

Example Statements

```
OUTPUT @B1500;"CLCORR 9,1"
```

CM

The CM command sets the SMU auto-calibration function to ON or OFF. If the following two conditions are satisfied, the B1500 automatically calibrates all modules every 30 minutes.

- Auto-calibration is ON.
- For all SMUs, the output switch has been OFF for 30 minutes.

Syntax

CM *mode*

Parameters

***mode* :** Auto-calibration ON or OFF. Integer expression.

0: OFF (initial setting)

1: ON

Remarks

Before starting the calibration, open the measurement terminals.

If the auto-calibration is enabled, do not forget to open the measurement terminals after measurements.

Example Statements

```
OUTPUT @B1500;"CM 0"
OUTPUT @B1500;"CM 1"
```

CMM

The CMM command sets the SMU measurement operation mode. This command is not available for the high speed spot measurement.

Syntax

CMM *chnum*,*mode*

Parameters

***chnum* :** SMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***mode* :** SMU measurement operation mode. Integer expression. 0 to 4.

0: Compliance side measurement. Initial setting.

1: Current measurement

2: Voltage measurement

3: Force side measurement

4: Current and voltage synchronous measurement. Available for the HCSMU and HVSMU.

If *mode*=0, SMU measures current when it forces voltage, or measures voltage when it forces current.

If *mode*=3, SMU measures current when it forces current, or measures voltage when it forces voltage.

The *mode* setting is kept until the *mode* is changed by this command. If you want to return it to the initial setting, enter the CMM command with *mode*=0.

Example Statements

```
OUTPUT @B1500;"CMM 1,1"
```

CN/CNX

This command enables the specified channels. See Table 4-19 for the difference between the CN command and the CNX command.

WARNING

THIS COMMAND ENABLES SMU TO FORCE DANGEROUS VOLTAGES. WHEN THE CHANNEL IS NOT IN USE, SET THE OUTPUT SWITCH TO "OFF" WHENEVER POSSIBLE.

Execution Conditions

No channel may be in the high voltage state (forcing more than ± 42 V, or voltage compliance set to more than ± 42 V).

Syntax

```
CN [chnum[,chnum...[,chnum]...]]
CNX [chnum[,chnum...[,chnum]...]]
```

A maximum of 15 channels can be set.

Parameters

***chnum* :** Channel number. Integer expression. See Table 4-1 on page 4-14.

If the output switch of the specified SMU is already set to ON, no action is performed by this command.

If you specify multiple *chnum*s, the channels will be enabled in the specified order.

If you do not specify *chnum*, this command enables all SMU, all SPGU, and CMU in this order. Then, the modules of same kind will be enabled in the order from lower to higher channel number 101 to 1002. The channel numbers 1 to 10 correspond to the channel numbers 101 to 1001 respectively. See Table 4-1 on page 4-14.

If you specify the HRSMU connected to the ASU, this command enables the HRSMU and connects the path to the ASU output.

If you specify a SMU connected to the SCUU, this command enables the SMU and connects the path to the SCUU output.

If you specify the MFCMU connected to the SCUU, this command enables the MFCMU and connects the path to the SCUU output.

If you specify both MFCMU and SMU connected to the SCUU, this command causes an error.

If you enter the CN/CNX command without *chnum* parameter to the B1500 installed with the SCUU, this command enables the SMUs except for the SMUs connected to the SCUU, enables the MFCMU, and connects the path to the SCUU output.

Remarks

The CN/CNX command sets the specified module to the following conditions:

SMU setup parameter	**Value**	**MFCMU setup parameter**	**Value**
Output switch	ON	DC bias	0 V
Source mode	Voltage	AC level	0 V
Output voltage	0 V	Output signal frequency	1 kHz
V range	20 V	Measurement range	50 Ω
I compliance	100 μA	**SPGU setup parameter**	**Value**
I range	100 μA	Output switch	ON
Filter	Not changed	Output mode	DC
Series resistor	Not changed	Output voltage	0 V

After this command, there is no additional power consumption for the idle state.

Table 4-19 Differences between CN and CNX

<table>
<tr><th colspan="2">Previous status</th><th colspan="2">Command execution result</th></tr>
<tr><th>Module status</th><th>Output switch</th><th>CN</th><th>CNX</th></tr>
<tr><td>Normal</td><td>Open/Close</td><td colspan="2">Close with no error</td></tr>
<tr><td rowspan="2">High voltage</td><td>Open</td><td colspan="2">Open with an error</td></tr>
<tr><td>Close</td><td>Close with an error</td><td>Close with no error</td></tr>
</table>

Example Statements

```
OUTPUT @B1500;"CN"
OUTPUT @B1500;"CN 1,2,3,5"
OUTPUT @B1500;"CNX"
OUTPUT @B1500;"CNX 1,2,3,5"
```

CORR?

This command performs the MFCMU open, short. or load correction data measurement, and set the correction data to the B1500.

Before executing this command, set the oscillator level of the MFCMU output signal by using the ACV command.

If you use the correction standard, execute the DCORR command before this command. The calibration value or the reference value of the standard must be defined before executing this command.

The correction function is set to OFF by turning off power or by the CORRST or *RST command. The correction data is cleared by turning off power or by the CLCORR, CORRL, or DCORR command. If the correction function is set to ON after the *RST command, the correction function uses the memorized correction data.

Execution Conditions

To measure the open correction data, connect the open standard that has the calibration value or reference value, or open the measurement terminals at the end of the device side.

To measure the short correction data, connect the short standard that has the calibration value or reference value, or connect the measurement terminals together at the end of the device side.

To measure the load correction data, connect the load standard that has the calibration value or reference value.

Syntax `CORR? chnum,corr`

Parameters

chnum **:** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

corr **:** Correction data to measure. Integer expression. 1, 2, or 3.

1: Open correction data

2: Short correction data

3: Load correction data

Query Response *result*<CR/LF^EOI>

0: Correction data measurement completed successfully.

1: Correction data measurement failed.

2: Correction data measurement aborted.

Example Statements

```
OUTPUT @B1500;"CORR? 9,3"
ENTER @B1500;Result
```

CORRDT

This command sets the MFCMU open/short/load correction data to the B1500.

The correction data is cleared by the CORR? command which performs the correction data measurement and set it to the B1500.

Syntax `CORRDT chnum,freq,open_r,open_i,short_r,short_i,load_r,load_i`

Parameters

chnum **:** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

freq **:** Frequency to be added. Numeric expression in Hz. See Table 4-14 on page 4-24.

open_r **:** Open correction data (G). Numeric expression in S.

open_i **:** Open correction data (B). Numeric expression in S.

short_r **:** Short correction data (R). Numeric expression in Ω.

short_i **:** Short correction data (X). Numeric expression in Ω.

load_r **:** Load correction data (R). Numeric expression in Ω.

load_i **:** Load correction data (X). Numeric expression in Ω.

Example Statements

```
OUTPUT @B1500;"CORRDT 9,3000000,0,0,0,0,0,0"
```

CORRDT?

This command returns the MFCMU open/short/load correction data.

Syntax

`CORRDT? chnum,index`

Parameters

chnum **:** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

index **:** Index number of the list. Integer expression.

Query Response

`freq,open_r,open_i,short_r,short_i,load_r,load_i<CR/LF^EOI>`

freq **:** Frequency of the correction data. Numeric expression in Hz.

open_r **:** Open correction data (G). Numeric expression in S.

open_i **:** Open correction data (B). Numeric expression in S.

short_r **:** Short correction data (R). Numeric expression in Ω.

short_i **:** Short correction data (X). Numeric expression in Ω.

load_r **:** Load correction data (R). Numeric expression in Ω.

load_i **:** Load correction data (X). Numeric expression in Ω.

Example Statements

```
OUTPUT @B1500;"CORRDT 9,3000000,0,0,0,0,0,0"
OUTPUT @B1500;"CORRDT? 9,1"
ENTER @B1500;Freq,Open_r,Open_i,Short_r,Short_i,Load_r,
Load_i
```

CORRL

This command disables the MFCMU open/short/load correction function and adds the specified frequency to the frequency list for the correction data measurement. This command also clears the correction data.

Syntax

`CORRL chnum,freq`

Parameters

chnum **:** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

freq **:** Frequency to be added. Numeric expression. in Hz. See Table 4-14 on page 4-24.

Example Statements

```
OUTPUT @B1500;"CORRL 9,3000000"
```

CORRL?

This command returns the frequency stored in the frequency list for the MFCMU correction data measurement.

Syntax

`CORRL? chnum[,index]`

Parameters

***chnum* :** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***index* :** Index number of the list. Integer expression.

Query Response

- CORRL? *chnum* returns:

  number_of_frequencies<CR/LF^EOI>

  This value is the number of frequencies stored in the list.

- CORRL? *chnum*,*index* returns:

  frequency<CR/LF^EOI>

  This value is the frequency corresponding to the specified index.

Example Statements

```
OUTPUT @B1500;"CLCORR 9,2"
OUTPUT @B1500;"CORRL? 9"
ENTER @B1500;Number
OUTPUT @B1500;"CORRL? 9,4"
ENTER @B1500;Freq
```

This example returns Number=12 and Freq=10000.

CORRSER?

This query command measures the SPGU terminal voltage and returns the measurement data and the calculated impedance data. Setting *mode*=1 automatically executes the SER command using this impedance data as the input parameter. Only one channel can be specified in this command. So the voltage monitor cannot be performed by using multiple channels simultaneously.

Execution Conditions

The SPGU output channel must be set up by using the following commands before executing this command.

- SPPER, SPM, SPT, and SPV commands, in PG mode
- ALW and ALS commands, in ALWG mode

The voltage must be measured in the first pulse or ALWG sequence output. In the PG mode, the pulse period must be more than *delay* + *interval* × *count* value.

Set the command parameters properly. The voltage must be measured at the output timing of the voltage effective for the automatic adjustment of the SPGU output voltage.

Syntax `CORRSER? chnum,mode,delay,interval,count`

Parameters

***chnum* :** SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1 on page 4-14.

***mode* :** Automatic execution modes of SER. Integer expression.

0: Does not execute the SER command (set the load impedance)

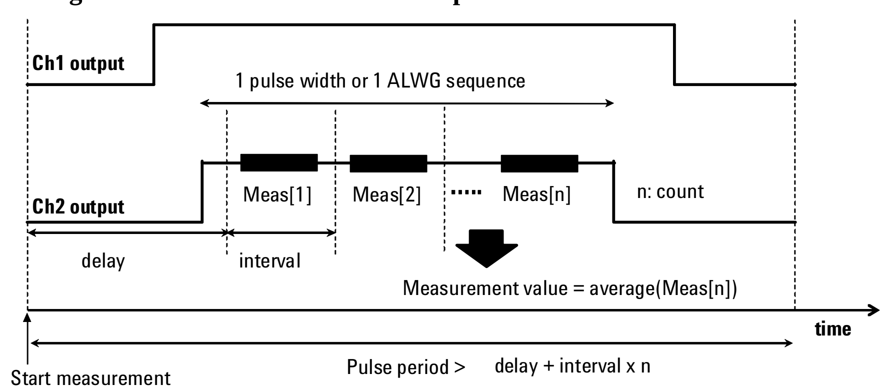
1: Executes the SER command (set the load impedance)

***delay* :** Delay till start of measurement (seconds). Numeric expression. 0 (initial setting) to pulse period -5E-6 seconds, setting resolution 1E-8 seconds.

***interval* :** Measuring interval (seconds). Numeric expression. 5E-6 (initial setting) to 0.001 seconds, setting resolution 2E-8 seconds.

***count* :** Measurement repetitions (times). Integer expression. 1 (initial setting) to 65535 times.

Figure 4-3 Voltage Monitor and CORRSER? Setup Parameters



Query Response `loadZ,voltage<CR/LF^EOI>`

***loadZ* :** Returns the impedance calculation data (Ω).

***voltage* :** Returns the voltage measurement data (V).

Remarks

Active SPGU outputs are stopped by the CORRSER? command.

Any other channels specified as SPGU output channels, but not specified in this command, will output synchronized to the CORRSER? command.

After executing the CORRSER? command, all SPGU channel outputs are changed to the following value.

- *base* value set by the SPV command, in PG mode
- initial value of waveform, in ALWG mode

Example Statements

```
OUTPUT @B1500;"SPPER 10E-6"
OUTPUT @B1500;"SPM 101,1"
OUTPUT @B1500;"SPT 101,1,0,5E-7,20E-9"
OUTPUT @B1500;"SPV 101,1,-0.5,0.5"
OUTPUT @B1500;"CORRSER? 101,1,1E-7,1E-8,10"
ENTER @B1500;A,B
```

In this example, the voltage measurement data is returned to the variable B, and the load impedance calculation data is returned to the variable A.

See Also

"SER", "SER?"

NOTE

Terminal voltage measurement and load impedance calculation

SPGU performs voltage measurement and impedance calculation by executing the CORRSER? command. Followings are the recommended measurement conditions for the voltage measurement.

Output voltage: > 1 V

Minimum load impedance: 40 Ω

Maximum load impedance: 500 Ω (1 V), 2000 Ω (2 V), 5000 Ω (10 V)

CORRST

This command enables or disables the MFCMU open/short/load correction function. Before setting a function to ON, perform the corresponding correction data measurement by using the CORR? command.

The correction function is set to OFF by turning off power or by the CORRST or *RST command. The correction data is cleared by turning off power or by the CLCORR, CORRL, or DCORR command. If the correction function is set to ON after the *RST command, the correction function uses the memorized correction data.

Syntax `CORRST` *`chnum,corr,state`*

Parameters

chnum **:** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

corr **:** Correction mode. Integer expression. 1, 2, or 3.

1: Open correction

2: Short correction

3: Load correction

state **:** Correction function state. Integer expression. 0 (OFF) or 1 (ON).

CORRST?

This command returns the MFCMU open/short/load correction function ON or OFF.

Syntax `CORRST?` *`chnum,corr`*

Parameters

chnum **:** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

corr **:** Correction mode. Integer expression. 1, 2, or 3.

1: Open correction

2: Short correction

3: Load correction

Query Response *`status`*`<CR/LF^EOI>`

0: Disable (correction OFF)

1: Enable (correction ON)

Example Statements

```
OUTPUT @B1500;"CORRST 9,3,1"
OUTPUT @B1500;"CORRST? 9,3"
ENTER @B1500;Status
```

The above example returns Status=1.

DCORR

This command disables the MFCMU open/short/load correction function and sets the open/short/load standard calibration value or reference value to the B1500. This command also clears the correction data.

The reference values set by this command are cleared by turning off power.

Syntax

`DCORR` *`chnum`*`,`*`corr`*`,`*`mode`*`,`*`primary`*`,`*`secondary`*

Parameters

***chnum* :** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***corr* :** Correction mode. Integer expression. 1, 2, or 3.

1: Open correction

2: Short correction

3: Load correction

***mode* :** Measurement mode. Integer expression. 100 or 400.

100: Cp-G (for open correction)

400: Ls-Rs (for short or load correction)

***primary* :** Primary reference value of the standard. Numeric expression.

Cp value for the open standard. in F.

Ls value for the short or load standard. in H.

***secondary* :** Secondary reference value of the standard. Numeric expression.

G value for the open standard. in S.

Rs value for the short or load standard. in Ω.

Example Statements

```
OUTPUT @B1500;"DCORR 9,3,400,0.00001,49.8765"
```

DCORR?

This command returns the calibration value or the reference value of the standard used for the MFCMU open/short/load correction.

Syntax

`DCORR?` *`chnum`*`,`*`corr`*

Parameters

***chnum* :** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***corr* :** Correction mode. Integer expression. 1, 2, or 3.

1: Open correction

2: Short correction

3: Load correction

Query Response

mode,*primary*,*secondary*<CR/LF^EOI>

mode : Measurement mode. Integer expression. 100 or 400.

100: Cp-G (for open correction)

400: Ls-Rs (for short or load correction)

primary : Primary reference value of the standard. Numeric expression.

Cp value for the open standard. in F.

Ls value for the short or load standard. in H.

secondary : Secondary reference value of the standard. Numeric expression.

G value for the open standard. in S.

Rs value for the short or load standard. in Ω.

Example Statements

```
OUTPUT @B1500;"DCORR 9,3,400,0.00001,49.8765"
OUTPUT @B1500;"DCORR? 9,3"
ENTER @B1500;Mode,Primary,Secondary
```

This example returns Mode=400, Priamry=0.00001, Secondary=49.8765.

DCV

This command forces DC bias (voltage, up to ± 25 V) from the MFCMU. When the SCUU (SMU CMU unify unit) is connected, output up to ± 100 V is available by using the SMU that can be connected to the Force1/Sense1 terminals.

Execution Conditions

The CN/CNX command has been executed for the specified channel.

If you want to apply DC voltage over ± 25 V, the SCUU must be connected correctly. The SCUU can be used with the MFCMU and two SMUs (MPSMU or HRSMU). The SCUU cannot be used if the HPSMU is connected to the SCUU or if the number of SMUs connected to the SCUU is only one.

If the output voltage is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

DCV *chnum*,*voltage*

Parameters

chnum : MFCMU source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

voltage : DC voltage (in V). Numeric expression.

0 (initial setting) to ± 25 V (MFCMU) or ± 100 V (with SCUU)

With the SCUU, the source module is automatically selected by the setting value. The MFCMU is used if *voltage* is below ± 25 V (setting resolution: 0.001 V), or the SMU is used if *voltage* is greater than ± 25 V (setting resolution: 0.005 V).

The SMU will operate with the 100 V limited auto ranging and 20 mA compliance settings.

Example Statements

```
OUTPUT @B1500;"DCV 7,1"
```

DI

The DI command forces DC current from the specified SMU.

Execution Conditions

The CN/CNX command has been executed for the specified channel.

If *Vcomp* value is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

DI *chnum*,*irange*,*current*[,*Vcomp*[,*comp_polarity*[,*vrange*]]]

Parameters

***chnum* :** SMU source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***irange* :** Ranging type for current output. Integer expression. The output range will be set to the minimum range that covers *current* value. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-5 on page 4-18.

***current* :** Output current value (in A). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type.

***Vcomp* :** Voltage compliance value (in V). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type. If you do not specify this parameter, *Vcomp* is set to the previous setting.

***comp_polarity* :** Polarity of voltage compliance. Integer expression.

0: Auto mode (default setting). The compliance polarity is automatically set to the same polarity as *current*, regardless of the specified *Vcomp*. If *current*=0 A, the polarity is set to positive.

1: Manual mode. Uses the polarity of *Vcomp* you specified.

vrange **:** Voltage compliance ranging type. Integer expression. The compliance range will be set to the minimum range that covers *Vcomp* value. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-4 on page 4-18.

Example Statements

```
OUTPUT @B1500;"DI 1,0,1E-6"
OUTPUT @B1500;"DI 3,14,5E-7,20,0,0"
```

DIAG?

The DIAG? command starts the diagnostics, and returns the results.

Before starting the diagnostics, refer to Remarks below.

After the DIAG? command, read the results soon.

Syntax

DIAG? *item*[,*pause*]

Parameters

item **:** Diagnostics item. Integer expression. 1 to 5.

item	Description
1	Trigger In/Out diagnostics.
3	High voltage LED diagnostics.
4	Digital I/O diagnostics.
6	Interlock open diagnostics.
7	Interlock close diagnostics.

pause **:** Place holder to keep the compatibility with the FLEX command of other instruments.

Query Response

result<CR/LF^EOI>

0: Passed.

1: Failed.

2: Aborted.

Remarks

- Before executing DIAG? 1, connect a BNC cable between the Ext Trig In and Out connectors.

- After executing DIAG? 3, confirm the status of LED. Then enter the AB command. *result* returns 2.

  If the LED does not blink, the B1500 must be repaired.
- Before executing DIAG? 4, disconnect any cable from the digital I/O port.
- Before executing DIAG? 6, open interlock circuit.
- Before executing DIAG? 7, close interlock circuit.

Example Statements

```
OUTPUT @B1500;"DIAG? 1"
ENTER @B1500;A
```

DO

The DO command executes the B1500 internal memory programs (up to 8 programs) in the order specified.

Execution Conditions

The specified programs have been stored by using the ST and END commands.

Syntax

DO *pnum*[,*pnum*[,*pnum*[,*pnum*[,*pnum*[,*pnum*[,*pnum*[,*pnum*]]]]]]]

Parameters

pnum **:** Internal memory program number. Numeric expression. 1 to 2000.

Example Statements

```
OUTPUT @B1500;"DO 1,2,3,4,5,6,7,8"
OUTPUT @B1500;"DO 98,99"
```

DV

The DV command forces DC voltage from the specified SMU.

Execution Conditions

The CN/CNX command has been executed for the specified channel.

If the output voltage is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

DV *chnum*,*vrange*,*voltage*[,*Icomp*[,*comp_polarity*[,*irange*]]]

Parameters

chnum **:** SMU source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

vrange **:** Ranging type for voltage output. Integer expression. The output range will be set to the minimum range that covers *voltage* value. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-4 on page 4-18.

voltage **:** Output voltage value (in V). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type.

Icomp **:** Current compliance value (in A). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. If you do not set *Icomp*, the previous value is used. 0 A is not allowed for *Icomp*.

comp_ polarity **:** Polarity of current compliance. Integer expression.

0: Auto mode (default setting). The compliance polarity is automatically set to the same polarity as *voltage*, regardless of the specified *Icomp*. If *voltage*=0 V, the polarity is set to positive.

1: Manual mode. Uses the polarity of *Icomp* you specified.

irange **:** Current compliance ranging type. Integer expression. The compliance range will be set to the minimum range that covers *Icomp* value. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-5 on page 4-18.

Example Statements

```
OUTPUT @B1500;"DV 1,0,20,1E-6,0,15"
OUTPUT @B1500;"DV 2,12,10"
```

DZ

The DZ command stores the settings (V/I output values, V/I output ranges, V/I compliance values, and so on) of the specified channels, and sets the channels to 0 V. The settings can be recovered by using the RZ command. The stored settings are cleared by using a device clear (HP BASIC CLEAR) command, *RST, RZ, CL, CA, or *TST?.

Syntax

DZ [*chnum*[,*chnum*...[,*chnum*]...]]

A maximum of 15 channels can be set.

Parameters

chnum **:** Channel number. Integer expression. See Table 4-1 on page 4-14.

If you specify multiple *chnum*s, the channel outputs will be set to 0 V in the specified order.

If you do not specify *chnum*, all SMU, all SPGU, and CMU with the output switch ON will be set to 0 V in this order. Then, SMU will be set to 0 V in the order from higher to lower output range and SPGU will be set to 0 V in the order from higher to lower setup voltage.

Remarks

The DZ command sets the specified module to the following conditions:

SMU setup parameter	Value	MFCMU setup parameter	Value
Source mode	Voltage	DC bias	0 V
Output voltage	0 V	AC level	0 V
V range	Not changed	Output signal frequency	Not changed
I compliance	See next table	Measurement range	50 Ω
I range	See next table	**SPGU setup parameter**	**Value**
Filter	Not changed	Output mode	Not changed
Series resistor	Not changed	Output voltage	0 V

Previous range [a]	I Range	I Compliance
1 nA to 100 μA	same as previous range	range value
over 100 μA	100 μA	100 μA

a. Range value that was set before the DZ command.

Example Statements

```
OUTPUT @B1500;"DZ 1,2,3"
```

EMG?

The EMG? query command returns error message corresponding to the specified error code.

Syntax

`EMG? `*`errcode`*

Parameters

***errcode* :** Error code returned by the ERR? command. Numeric expression.

Query Response

`error_message``<CR/LF^EOI>`

See Chapter 5, “Error Messages” for the error codes and error messages.

Remarks

Use the ERRX? command to support all errors. The EMG? command supports the error code 0 to 999 only.

If unsupported error is detected, 999 is returned by the ERR? command.
The EMG? 999 command returns the message associated with the last error.

Example Statements

```
OUTPUT @B1500;"EMG? 100"
ENTER @B1500;A$
```

See Also

"ERR?"

END

The END command is used with the ST command to store a program in the internal program memory. See "ST" on page 4-161.

Syntax

`END`

Example Statements

```
OUTPUT @B1500;"ST1;CN1;DV1,0,5,1E-4;TI1,0;CL1"
OUTPUT @B1500;"END"
```

ERC

The ERC command changes the output status of the digital I/O port. This command does not change the status of the trigger ports and the input ports set by the ERM command.

The *RST command or the device clear sets the digital I/O port (total 16 paths) to the output port, and sets the port output level to TTL high.

Execution Conditions

The digital I/O control mode must be the direct control (ERMOD 0).

Syntax

ERC *mode*,*value*[,*rule*]

Parameters

mode : Control mode. Integer expression. Set *mode* to 2.

2: Controls the digital I/O port.

If you set 1 that is effective for the Agilent 4142B, an error occurs.

value : Decimal value of the output status bit pattern. Integer expression. 0 to 65535. The bit pattern must comply with the following rule:

Bit value 0: TTL high level (approx. 2.4 V)

Bit value 1: TTL low level (approx. 0.8 V)

rule **:** Place holder to keep the same syntax as the ERC command of the Agilent 4142B. Input value is ignored.

Example Statements

If you want to set TTL low level for the output ports of the digital I/O port bit 0 to 7, enter the following command.

```
OUTPUT @B1500;"ERC 2,255"
```

where the decimal value 255 means binary bit pattern `0000000011111111`. This command does not change the status of the trigger ports and the input ports.

See Also

“ERMOD”, “ERM”, “ERS?”

ERHPA

The ERHPA command specifies the modules connected to the input ports of Agilent N1258A/N1259A module selector.

Execution Conditions

Digital I/O port must be set for N1258A/N1259A control mode using the ERMOD 2 command.

Syntax

`ERHPA` *`hvsmu,hcsmu,hpsmu`*

Parameters

hvsmu **:** HVSMU channel number

hcsmu **:** HCSMU channel number

hpsmu **:** HPSMU channel number

Effective channel numbers are 1 to 10, or 101 to 1001. Integer expression. See Table 4-1 on page 4-14.

Enter 0 if the associated module is not installed.

Example Statements

```
OUTPUT @B1500;"ERHPA 7,5,3"
```

ERHPA?

The ERHPA? command returns the channel numbers of the modules connected to the input ports of Agilent N1258A/N1259A module selector.

Syntax

`ERHPA?`

Query Response

`hvsmu,hcsmu,hpsmu``<CR/LF^EOI>`

***hvsmu* :** HVSMU channel number

***hcsmu* :** HCSMU channel number

***hpsmu* :** HPSMU channel number

Channel number will be 1 to 10, or 101 to 1001. Integer expression. Or 0 is returned if the associated module has not been installed.

Example Statements

```
OUTPUT @B1500;"ERHPA?"
ENTER @B1500;A,B,C
```

ERHPE

The ERHPE command enables or disables the External Relay Control of Agilent N1258A module selector.

Execution Conditions

Digital I/O port must be set for N1258A/N1259A control mode using the ERMOD 2 command.

Syntax

ERHPE *onoff*

Parameters

***onoff* :** 1 (enable) or 0 (disable, initial setting). Integer expression.

Example Statements

```
OUTPUT @B1500;"ERHPE 1"
```

ERHPE?

The ERHPE? command returns the condition of the External Relay Control of Agilent N1258A module selector.

Syntax

ERHPE?

Query Response

onoff<CR/LF^EOI>

1 (enable) or 0 (disable). Integer expression.

Example Statements

```
OUTPUT @B1500;"ERHPE?"
ENTER @B1500;A
```

ERHPL

The ERHPL command enables or disables the LED status indicator of Agilent N1258A/N1259A module selector.

Execution Conditions

Digital I/O port must be set for N1258A/N1259A control mode using the ERMOD 2 command.

Syntax

`ERHPL` *`onoff`*

Parameters

onoff **:** 1 (enable, initial setting) or 0 (disable, always off). Integer expression.

Example Statements

```
OUTPUT @B1500;"ERHPL 0"
```

ERHPL?

The ERHPL? command returns the condition of the LED status indicator of Agilent N1258A/N1259A module selector.

Syntax

`ERHPL?`

Query Response

`onoff``<CR/LF^EOI>`

1 (enable) or 0 (disable, always off). Integer expression.

Example Statements

```
OUTPUT @B1500;"ERHPL?"
ENTER @B1500;A
```

ERHPP

The ERHPP command specifies the input output connection path of Agilent N1258A/N1259A module selector.

Execution Conditions

Digital I/O port must be set for N1258A/N1259A control mode using the ERMOD 2 command.

Syntax

`ERHPP` *`path`*

Parameters

path **:** Input output connection path. Integer expression. 0, 1, 2, 3, or 4.

0: Open, no module is connected, initial setting

1: Connects to HVSMU

2: Connects to HCSMU

3: Connects to HPSMU

4: Connects to HVSMU, also connects the series resistor

Example Statements

```
OUTPUT @B1500;"ERHPP 3"
```

ERHPP?

The ERHPP? command returns the input output connection path of Agilent N1258A/N1259A module selector.

Syntax

`ERHPP?`

Query Response

path`<CR/LF^EOI>`

Input output connection path. Integer expression. 0, 1, 2, 3, or 4.

0: Open, no module is connected

1: Connects to HVSMU

2: Connects to HCSMU

3: Connects to HPSMU

4: Connects to HVSMU, also connects the series resistor

Example Statements

```
OUTPUT @B1500;"ERHPP?"
ENTER @B1500;A
```

ERHPR

The ERHPR command specifies the signal level applied to the External Relay Control connector pin of Agilent N1258A module selector.

Execution Conditions

Digital I/O port must be set for N1258A/N1259A control mode using the ERMOD 2 command.

External Relay Control must be enabled using the ERHPE 1 command.

Syntax

`ERHPR` *`pin`*`,`*`level`*

Parameters

pin **:** External Relay Control pin number. Integer expression. 1 to 6.

level **:** Signal level. Integer expression. 0 or 1.

0: 0 V, circuit common, initial setting

1: 12 V

Example Statements

```
OUTPUT @B1500;"ERHPR 1,1"
OUTPUT @B1500;"ERHPR 2,1"
```

ERHPR?

The ERHPR? command returns the signal level applied to the External Relay Control connector pin of Agilent N1258A module selector.

Syntax `ERHPR? pin`

Parameters ***pin* :** External Relay Control pin number. Integer expression. 1 to 6.

Query Response `level<CR/LF^EOI>`

Signal level. Integer expression. 0 (0 V) or 1 (12 V)

Example Statements

```
OUTPUT @B1500;"ERHPR? 1"
ENTER @B1500;A
```

ERHPS

The ERHPS command connects or disconnects the series resistor installed in the HVSMU path of Agilent N1258A/N1259A module selector.

Execution Conditions Digital I/O port must be set for N1258A/N1259A control mode using the ERMOD 2 command.

Syntax `ERHPS onoff`

Parameters ***onoff* :** 1 (connect) or 0 (disconnect, initial setting). Integer expression.

Example Statements

```
OUTPUT @B1500;"ERHPS 1"
```

ERHPS?

The ERHPS? command returns the condition of the HVSMU series resistor of Agilent N1258A/N1259A module selector.

Syntax `ERHPS?`

Query Response `onoff<CR/LF^EOI>`

HVSMU series resistor status. 1 (connect) or 0 (disconnect). Integer expression.

Example Statements

```
OUTPUT @B1500;"ERHPS?"
ENTER @B1500;A
```

ERM

The ERM command changes the input/output assignments of the digital I/O port (total 16 paths). This command does not change the trigger port assignments and settings.

The *RST command or the device clear sets the digital I/O port to the output port, and sets the port output level to TTL high.

Execution Conditions

The digital I/O control mode must be the direct control (ERMOD 0).

Syntax

`ERM` *`iport`*

Parameters

***iport* :** Decimal value of the port setting. Integer expression. 0 to 65535.

The setting of each port must be designated by 0 or 1 that has the following meaning:

0: Output port

1: Input port

Example Statements

If you want to use the non-trigger ports of the digital I/O ports 0 to 7 as the input port, enter the following statement.

```
OUTPUT @B1500;"ERM 255"
```

where the decimal value 255 means binary bit pattern `0000000011111111`.

Remarks

The ERM command sets the port level to TTL high for all ports where the port assignment is changed from output to input or from input to output.

The ERM command does not change the port assignment of the trigger ports.

See Also

“ERMOD”, “ERC”, “ERS?”

ERMOD

This command selects the control mode for the digital I/O ports.

Syntax `ERMOD mode`

Parameters ***mode* :** Control mode. Integer expression. 0, 1, or 2.

0: General purpose control mode, initial setting.

1: 16440A control mode

2: N1258A/N1259A control mode

The 16440A control mode offers easy control over the Agilent 16440A SMU/PG selector connected to the digital I/O port via the Agilent 16445A selector adapter. Use ERSSP and ERSSP?.

The N1258A/N1259A control mode offers easy control over the Agilent N1258A module selector or the module selector installed in the Agilent N1259A test fixture. Use ERHPA, ERHPP, and ERHPP?.

The general purpose control mode is for controlling the other equipments. Use ERM, ERS?, ERC, and TGP.

Example Statements

```
OUTPUT @B1500;"ERMOD 1"
```

ERMOD?

This query command returns the control mode for the digital I/O ports.

Syntax `ERMOD?`

Query Response *mode*<CR/LF^EOI>

0: General purpose control mode

1: 16440A control mode

2: N1258A/N1259A control mode

Example Statements

```
OUTPUT @B1500;"ERMOD?"
ENTER @B1500;A
```

ERR?

The ERR? query command returns error code.

Syntax `ERR? [mode]`

Parameters ***mode* :** Error code output mode. Integer expression. 0 (default setting) or 1.

0: Reads the contents of the error queue, and clears the queue. This returns four error codes in order from their occurrence.

1: Reads one error code from the head of the error queue and removes that code from the queue. This returns one error code.

Query Response

error_code,*error_code*,*error_code*,*error_code*<CR/LF^EOI>

or

error_code<CR/LF^EOI>

See Chapter 5, “Error Messages” for the error codes and error messages.

If no error occurred, `0` is returned.

Remarks

Use the ERRX? command to support all errors. The ERR? command supports the error code 0 to 999 only.

If unsupported error is detected, 999 is returned. The EMG? 999 command returns the message associated with the last error.

This command uses the error queue which can store four error codes. This error queue is cleared by executing the ERRX? command.

Example Statements

```
OUTPUT @B1500;"ERR?"
ENTER @B1500;A$

OUTPUT @B1500;"ERR? 1"
ENTER @B1500;A
```

See Also

“EMG?”, “ERRX?”

ERRX?

This query command reads one error code from the head of the error queue and removes that code from the queue.

Syntax

ERRX? [*mode*]

Parameters

mode **:** Error code output mode. Integer expression. 0 (default setting) or 1.

0: Returns the error code and the corresponding message.

1: Returns the error code only.

Query response

error_code,*message*<CR/LF^EOI>

or

error_code<CR/LF^EOI>

Message contains an error message similar to the EMG? response and a custom message containing additional information such as the channel number. They are separated by a semicolon (;).

See Chapter 5, "Error Messages" for the error codes and error messages.

If no error occurred, *Error Code* is `0` and *Message* is `"No Error."`

Remarks This command uses the error queue which can store 30 error codes. This error queue is cleared by executing the ERR? command.

Example

```
OUTPUT @B1500;"ERRX?"
ENTER @B1500;A,B$

OUTPUT @B1500;"ERRX? 1"
ENTER @B1500;A
```

See Also "EMG?", "ERR?"

ERS?

The ERS? command returns the status of the digital I/O port (16 paths).

Execution Conditions The digital I/O control mode must be the direct control (ERMOD 0).

Syntax `ERS?`

Query Response *pattern*<CR/LF^EOI>

pattern returns the decimal value of the port status.

The status of each port is designated by 0 or 1 that has the following meaning:

0: TTL high level (approx. 2.4 V)

1: TTL low level (approx. 0.8 V)

Example Statements

```
OUTPUT @B1500;"ERS?"
ENTER @B1500;A
PRINT "Port Status=";A
```

For example, 255 (`0000000011111111`) is returned when the port 0 to 7 have been set to the TTL low level and the port 8 to 15 have been set to the TTL high level.

See Also “ERMOD”, “ERC”, “ERM”

ERSSP

This command sets the connection state of the I/O path for the Agilent 16440A SMU/PG selector. Set for each output port on the selector.

Execution Conditions Digital I/O port must be set for 16440A control mode using the ERMOD 1 command.

Syntax `ERSSP` *`port,status`*

Parameters

port: Output port of SMU/PG selector. Integer expression.

0: Output 1 on selector of first module

1: Output 2 on selector of first module

2: Output 1 on selector of second module

3: Output 2 on selector of second module

status: Connection status of I/O path. Integer expression.

0: Open. Normally open mechanical relay contact.

1: SMU connect. Connected to the SMU input.

2: PGU connect. Connected to the PGU input.

3: PGU open. Open semiconductor relay contact installed on the PGU connect path.

Example Statements

```
OUTPUT @B1500;"ERMOD 1"
OUTPUT @B1500;"ERSSP 0,2"
```

See Also “ERMOD”

ERSSP?

This query command returns the connection state of the I/O path for the Agilent 16440A SMU/PG selector.

Syntax `ERSSP?` *`port`*

Parameters

port: Output port of SMU/PG selector. Integer expression.

0: Output 1 on selector of first module

1: Output 2 on selector of first module

2: Output 1 on selector of second module

3: Output 2 on selector of second module

Query Response

status<CR/LF^EOI>

0: Open. Normally open mechanical relay contact.

1: SMU connect. Connected to the SMU input.

2: PGU connect. Connected to the PGU input.

3: PGU open. Open semiconductor relay contact installed on the PGU connect path.

Example Statements

```
OUTPUT @B1500;"ERSSP? 1"
ENTER @B1500;A
```

See Also

"ERMOD"

FC

This command sets the output signal frequency of the MFCMU.

Execution Conditions

The CN/CNX command has been executed for the specified channel (MFCMU).

Syntax

FC *chnum*,*freq*

Parameters

chnum **:** MFCMU source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

freq **:** Frequency (in Hz). Numeric expression. in Hz. See Table 4-14 on page 4-24.

Example Statements

```
OUTPUT @B1500;"FC 7,1000000"
```

FL

This command sets the connection mode of a SMU filter for each channel.

A filter is mounted on the SMU. It assures clean source output with no spikes or overshooting.

Syntax

`FL mode[,chnum[,chnum...[,chnum]...]]`

A maximum of ten channels can be set.

Parameters

mode **:** Status of the filter. Integer expression.

0: Disconnect (initial setting).

1: Connect.

chnum **:** SMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

If you do not specify *chnum*, the FL command sets the same *mode* for all channels.

Example Statements

```
OUTPUT @B1500;"FL 1"
OUTPUT @B1500;"FL 0,1,3,5"
```

FMT

This command clears the B1500 output data buffer, and specifies the data output format. For details about data output format, see "Data Output Format" on page 1-25. Without this command, the data output format is same as the format by the FMT1,0 command.

Query command output data is always stored in the query buffer in ASCII format, regardless of this command.

NOTE Multi command statement is not allowed for this command.

Syntax

`FMT format[,mode]`

Parameters

format **:** Data output format. Integer expression. 1 to 25. See Table 4-20.

mode **:** Data output mode. Integer expression. 0 to 10. See Table 4-21. Without setting the *mode* value, only the measurement data is returned.

For the sampling measurement, the sampling index is also returned if no zero value is set to *mode*.

Example Statements

```
OUTPUT @B1500;"FMT 1"
OUTPUT @B1500;"FMT 2,1"
```

Table 4-20 **FMT format parameter**

format	**Data format**	**Terminator**
1 [a]	ASCII (12 digits data with header)	<CR/LF^EOI>
2 [a]	ASCII (12 digits data without header)	<CR/LF^EOI>
3 [a]	4 byte binary	<CR/LF^EOI>
4 [a]	4 byte binary	<^EOI>
5 [a]	ASCII (12 digits data with header)	,
11	ASCII (13 digits data with header)	<CR/LF^EOI>
12	ASCII (13 digits data without header) [b]	<CR/LF^EOI>
13	8 byte binary	<CR/LF^EOI>
14	8 byte binary	<^EOI>
15	ASCII (13 digits data with header)	,
21	ASCII (13 digits data with header) [b]	<CR/LF^EOI>
22	ASCII (13 digits data without header) [b]	<CR/LF^EOI>
25	ASCII (13 digits data with header) [b]	,

a. Compatible with the Agilent 4142B data output format.
b. Compatible with the Agilent 4155/4156 FLEX mode ASCII data.

12 digits data will be `sn.nnnnnEsnn`, `snn.nnnnEsnn`, or `snnn.nnnEsnn`.

13 digits data will be `sn.nnnnnnEsnn`, `snn.nnnnnEsnn`, or `snnn.nnnnEsnn`.

where, `s` is `+` or `-`, `E` is exponent symbol, and `n` means one digit number.

NOTE

For the 4 byte binary data output format, the time stamp function is not available. Refer to "Data Output Format" on page 1-25.

Table 4-21 **FMT mode parameter**

mode	Source data returned with measurement data
0	None (default setting). Only the measurement data is returned.
1	Source output data of the primary sweep source.
2	For MM2 and MM5: Source output data of the synchronous sweep source set by the WSI/WSV command.
1 to 10	For MM16, MM27, and MM28: Source output data of the sweep source set by the WNX, MCPNX, or MCPWNX command. The *mode* value must be the source number (1 to 10) you want to get data. For the source number, see description of the above commands.

*IDN?

The *IDN? query command returns the instrument model number and the firmware revision number.

Syntax `*IDN?`

Query Response `Agilent Technologies,`*`model`*`,0,`*`revision`*`<CR/LF^EOI>`

Response	Explanation
model	`B1500A`
revision	Firmware revision number. Example: `A.01.00`

Example Statements

```
OUTPUT @B1500;"*IDN?"
ENTER @B1500;A$
```

Example Response `Agilent Technologies,B1500A,0,A.01.00`

IMP

The IMP command specifies the parameter measured by the MFCMU. This command is effective for the following commands and the following measurement mode. The MFCMU can measure two parameters.

- TC command
- TTC command
- Spot C measurement (MM17)
- CV (DC bias) sweep measurement (MM18)
- Pulsed spot C measurement (MM19)
- Pulsed sweep CV measurement (MM20)
- C-f sweep measurement (MM22)
- CV (AC level) sweep measurement (MM23)
- C-t sampling measurement (MM26)

Execution Conditions

This command is not effective for the binary data output format (FMT3, FMT4, FMT13, and FMT14). Then one of the following couples will be measured. They will be automatically selected by the B1500, and will be a couple without data overflow.

- R (resistance, Ω) and X (reactance, Ω)
- G (conductance, S) and B (susceptance, S)

Syntax

`IMP` *`mode`*

Parameters

mode **:** Measurement mode. 1 to 402. Integer expression. See Table 4-12 on page 4-23.

Initial setting: *mode*=100 (Cp-G measurement)

Example Statements

```
OUTPUT @B1500;"IMP 10"
```

IN

The IN command sets the specified channel to 0 V with an output range change.

Remarks

The IN command sets the specified module to the following conditions:

SMU setup parameter	Value	MFCMU setup parameter	Value
Source mode	Voltage	DC bias	0 V
Output voltage	0 V	AC level	0 V
V range	20 V	Output signal frequency	1 kHz
I compliance	100 μA	Measurement range	50 Ω
I range	100 μA	**SPGU setup parameter**	**Value**
Filter	Not changed	Output mode	DC
Series resistor	Not changed	Output voltage	0 V

After this command, there is no additional power consumption for the idle state.

Syntax

IN [*chnum*[,*chnum*...[,*chnum*]...]]

A maximum of 15 channels can be set.

Parameters

chnum **:** Channel number. Integer expression. See Table 4-1 on page 4-14.

If you specify multiple *chnum*s, the channel outputs will be set to 0 V in the specified order.

If you do not specify *chnum*, all SMU, all SPGU, and CMU will be set to 0 V in this order. Then, SMU will be set to 0 V in the order from higher to lower output range and SPGU will be set to 0 V in the order from higher to lower setup voltage.

Example Statements

```
OUTPUT @B1500;"IN"
OUTPUT @B1500;"IN 1,2,3,5,6"
```

LGI

The LGI command sets the current monitor channel for the linear search measurement (MM14). This command setting clears, and is cleared by, the LGV command setting.

This command ignores the RI command setting.

Syntax

LGI *chnum*,*mode*,*range*,*target*

Parameters

***chnum* :** SMU search monitor channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***mode* :** Search mode. Integer expression.

0 : If the measured value ≤ *target*, it is the search result data.

1 : If the measured value ≥ *target*, it is the search result data.

***range* :** Measurement ranging type. Integer expression. The measurement range will be set to the minimum range that covers the *target* value. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-3 on page 4-16.

***target*:** Search target current (in A). Numeric expression.

0 to ± 0.1 for MPSMU/HRSMU, or 0 to ± 1 for HPSMU

Example Statements

```
OUTPUT @B1500;"LGI 0,1,14,1E-6"
```

LGV

The LGV command sets the voltage monitor channel for the linear search measurement (MM14). This command setting clears, and is cleared by, the LGI command setting.

This command ignores the RV command setting.

Syntax

`LGV` *`chnum,mode,range,target`*

Parameters

***chnum* :** SMU search monitor channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***mode* :** Search mode. Integer expression.

0 : If the measured value ≤ *target*, it is the search result data.

1 : If the measured value ≥ *target*, it is the search result data.

***range* :** Measurement ranging type. Integer expression. The measurement range will be set to the minimum range that covers the *target* value. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-2 on page 4-15.

***target* :** Search target voltage (in V). Numeric expression.

0 to ± 100 for MPSMU/HRSMU, or 0 to ± 200 for HPSMU

Example Statements

```
OUTPUT @B1500;"LGV 1,2,12,3"
```

LIM

The LIM command sets the maximum output limit of the voltage or current applied by SMU. The setting value is effective for all of the SMU and memorized until the LIM command is executed again. The value is not initialized by the *RST command or power off.

Syntax

`LIM mode,limit`

Parameters

mode **:** Limit setup mode. 1 or 2. Integer expression.

1: Voltage output limit

2: Current output limit

limit **:** Maximum output limit value, in V or A. Numeric expression.

For voltage limit: 200 V to 3000 V (initial value), 100 V resolution.

For current limit: 1 A to 20 A (initial value), in 1 A resolution.

Example Statements

```
OUTPUT @B1500;"LIM 1,1500"
```

LIM?

This query command returns the voltage or current maximum output limit value of SMU.

Syntax

`LIM? mode`

Parameters

mode **:** Type of the output limit value to read. 1 or 2. Integer expression.

1: Voltage limit value

2: Current limit value

Query Response

`limit<CR/LF^EOI>`

This value returns the voltage output limit (V) or current output limit (A).

Example Statements

```
OUTPUT @B1500;"LIM? 1"
ENTER @B1500;Limit
```

LMN

This command enables or disables the data monitor and data output of the MFCMU AC voltage and DC voltage.

This command is effective for the spot C (MM17), DC bias sweep (MM18), and frequency sweep (MM22), and AC level sweep (MM23).

Syntax

`LMN` *`mode`*

Parameters

mode **:** Data monitor and output mode. Integer expression. 0 or 1.

0: Disables the data monitor and output. Initial setting.

1: Enables the data monitor and output.

Example Statements

```
OUTPUT @B1500;"LMN 1"
```

LOP?

The LOP? query command returns the operation status of all modules and stores the results in the output data buffer (query buffer).

Syntax

`LOP?`

Query Response

`LOP` *`stat1,stat2,stat3,stat4,stat5,stat6,stat7,stat8,stat9,stat10`*`<CR/LF^EOI>`

The variables *stat1* to *stat10* will indicate the status of the module installed in the slot 1 to 10 respectively, and will be the two-digit status code shown in Table 4-22.

For the HPSMU that occupies two slots, two variables will be returned. Then the first one is always 00, and the last one indicates the module status. For example, `LOP00,11,00,00,00,00,00,00,00,00` will be returned when only the HPSMU installed in the slot 1-2 is used and is in the voltage compliance condition.

Example Statements

```
OUTPUT @B1500;"LOP?"
ENTER @B1500;A$
```

Table 4-22 **LOP? Response**

Status code	Description
00	No module is installed, or the output switch is OFF.
01	SMU forces voltage, and does not reach current compliance.
02	SMU forces positive current, and does not reach voltage compliance.
03	SMU forces negative current, and does not reach voltage compliance.
10	Not applicable.
11	SMU reaches voltage compliance.
12	SMU reaches positive current compliance.
13	SMU reaches negative current compliance.
20	SMU is oscillating.
30	Not applicable.
40	MFCMU applies DC bias.
51	MFCMU is in the NULL loop unbalance condition.
52	MFCMU is in the IV amplifier saturation condition.

*LRN?

The *LRN? (learn) query command returns the B1500 command parameter settings.

Syntax

```
*LRN? type
```

Example Statements

```
DIM A$[200]
OUTPUT @B1500;"*LRN? 1"
ENTER @B1500;A$
```

Parameters and Query Response

type **:** This parameter selects the type of query response. Available values are 0 to 110, but some numbers are not used. See below. Integer expression.

A description and the query response of each *type* is described below.

0 : Returns the output switch ON/OFF status:

CN[*chnum*[,*chnum* . . . [,*chnum*] . . .]]<CR/LF^EOI>

where *chnum* is the channel number for the channel whose output switch is set to ON.

If no output switches are ON, the query response is:

CL<CR/LF^EOI>

1 to 10: Returns the source status of SMU or MFCMU.

The *type* parameter corresponds to slot number where the module is installed.

For the SMU when the output switch is ON, the query response is:

DV *chnum*,*range*,*voltage*[,*Icomp*[,*comp polarity*[,*irange*]]]
<CR/LF^EOI>

or

DI *chnum*,*range*,*current*[,*Vcomp*[,*comp polarity*[,*vrange*]]]
<CR/LF^EOI>

where *range* is the present setting of the output range.

For the SMU when the output switch is OFF, the query response is:

CL *chnum*<CR/LF^EOI>

For the MFCMU, the query response is:

DCV *chnum*,*voltage*;ACV *chnum*,*voltage*;FC *chnum*,*frequency*
<CR/LF^EOI>

For the SPGU, the query response is:

CNX *chnum*[,*chnum*][;CL *chnum*]<CR/LF^EOI>

or

CL *chnum*[,*chnum*][;CNX *chnum*]<CR/LF^EOI>

where *chnum* of CNX is the channel number for the channel whose output switch is set to ON, and *chnum* of CL is the channel number for the channel whose output switch is set to OFF.

30 : Returns the filter ON/OFF status:

FL0 [*off ch*[,*off ch* . . . [,*off ch*] . . .];
FL1 [*on ch*[,*on ch* . . . [,*on ch*] . .] <CR/LF^EOI>

If all modules are Filter OFF, the query response is:

FL0<CR/LF^EOI>

If all modules are Filter ON, the query response is:

FL1<CR/LF^EOI>

31 : Returns the parameter values of the TM, AV, CM, FMT, and MM commands:

TM *trigger mode*;AV *number*[,*mode*];CM *auto calibration mode*;
FMT *output data format*,*output data mode*
[;MM *measurement mode*[,*chnum*[,*chnum*...[,*chnum*]...]]]
<CR/LF^EOI>

32 : Returns the measurement ranging status:

RI *chnum*,*Irange*;RV *chnum*,*Vrange*
[;RI *chnum*,*Irange*;RV *chnum*,*Vrange*] . . . .
[;RI *chnum*,*Irange*;RV *chnum*,*Vrange*]<CR/LF^EOI>

33 : Returns the staircase sweep measurement settings:

WM *automatic sweep abort function*,*output after sweep*;
WT *hold time*,*delay time*[,*step delay time*[,*S trig delay*[,*M trig delay*]]]
[;WV *chnum*,*mode*,*range*,*start*,*stop*,*nop*[,*Icomp* [,*pcomp*]]] or
[;WI *chnum*,*mode*,*range*,*start*,*stop*,*nop*[,*Vcomp*[,*pcomp*]]]
[;WSV *chnum*,*range*,*start*,*stop*[,*Icomp*[,*pcomp*]]] or
[;WSI *chnum*,*range*,*start*,*stop*[,*Vcomp*[,*pcomp*]]]<CR/LF^EOI>

34 : Returns the pulsed source settings:

PT *hold time*,*pulse width*[,*pulse period*[,*trig delay*]]
[;PV *chnum*,*output range*,*base voltage*,*pulse voltage* [,*Icomp*]] or
[;PI *chnum*,*output range*,*base current*,*pulse current* [,*Vcomp*]]
[;PWV *chnum*,*mode*,*range*,*base*,*start*,*stop*,*nop*[,*Icomp*]] or
[;PWI *chnum*,*mode*,*range*,*base*,*start*,*stop*,*nop*[,*Vcomp*]]<CR/LF^EOI>

37 : Returns the quasi-pulsed source settings:

BDM *detection interval*[,*mode*];
BDT *hold time*,*delay time*
[;BDV *chnum*,*range*,*start*,*stop*[,*Icomp*]]<CR/LF^EOI>

38 : Returns the digital I/O port information:

ERM *input pin*;ERC2,*value* <CR/LF^EOI>

40 : Returns channel mapping information:

If multiple channel numbers are translated to another numbers.

ACH *actual*,*program*[;ACH *actual*,*program*] . . . .
[;ACH *actual*,*program*]<CR/LF^EOI>

If no channel number is defined by the ACH command.

ACH<CR/LF^EOI>

46 : Returns SMU measurement operation mode settings:

CMM *chnum*,*mode*[;CMM *chnum*,*mode*] . . . .
[;CMM *chnum*,*mode*]<CR/LF^EOI>

47 : Returns the sampling measurement settings:

MSC *abort*,*post*;MT *h_bias*,*interval*,*number*,*h_base*;ML *mode*
[;MV *chnum*,*range*,*base*,*bias*,*comp*] or
[;MI *chnum*,*range*,*base*,*bias*,*comp*] or
[;MSP *chnum*[,*post* [,*base*]]]
:
<CR/LF^EOI>

49 : Returns the quasi-static CV measurement settings:

QSM *abort*,*post*;QSL *data*,*compen*;QSZ *mode*
;QSO *mode*[,*chnum*[,*Vcomp*]]
;QSC *mode*
;QST *cinteg*,*linteg*,*hold*,*delay1*[,*delay2*]
;QSR *range*
[;QSV *chnum*,*mode*,*range*,*start*,*stop*,*cvoltage*,*step*[,*Icomp*]]
:
<CR/LF^EOI>

50 : Returns the linear search measurement settings:

LSM *abort*,*post*;LSTM *hold*,*delay*;LSVM *mode*
[;LGI *chnum*,*mode*,*Irange*,*Itarget*] or
[;LGV *chnum*,*mode*,*Vrange*,*Vtarget*]
[;LSV *chnum*,*range*,*start*,*stop*,*step*[,*Icomp*]] or
[;LSI *chnum*,*range*,*start*,*stop*,*step*[,*Vcomp*]]
[;LSSV *chnum*,*polarity*,*offset*[,*Icomp*]] or
[;LSSI *chnum*,*polarity*,*offset*[,*Vcomp*]]
<CR/LF^EOI>

51 : Returns the binary search measurement settings:

BSM *mode*,*past*;BST *hold*,*delay*;BSVM *mode*
[;BGI *chnum*,*mode*,*condition*,*Irange*,*Itarget*] or
[;BGV *chnum*,*mode*,*condition*,*Vrange*,*Vtarget*]

[;BSV *chnum*,*range*,*start*,*stop*[,*Icomp*]] or
[;BSI *chnum*,*range*,*start*,*stop*[,*Vcomp*]]
[;BSSV *chnum*,*polarity*,*offset*[,*Icomp*]] or
[;BSSI *chnum*,*polarity*,*offset*[,*Vcomp*]]
<CR/LF^EOI>

53 : Returns the SMU series resistor ON/OFF status:

SSR *chnum*,*mode*[;SSR *chnum*,*mode*] . . . .
[;SSR *chnum*,*mode*]<CR/LF^EOI>

54 : Returns the auto ranging mode status:

RM *chnum*,*mode*[,*rate*][;RM *chnum*,*mode*[,*rate*]] . . . .
[;RM *chnum*,*mode*[,*rate*]]<CR/LF^EOI>

55 : Returns the A/D converter settings:

AAD *chnum*,*type*;AAD *chnum*,2[;AAD *chnum*,*type*;AAD *chnum*,2] . . . .[;AAD *chnum*,*type*;AAD *chnum*,2]<CR/LF^EOI>

56 : Returns the ADC averaging or integration time setting:

AIT0,*mode*,*time*;AIT1,*mode*,*time*;AIT2,*mode*,*time*;AZ *mode*<CR/LF^EOI>

57 : Returns the source/measurement wait time settings:

WAT0,*set_set*;WAT1,*set_meas*<CR/LF^EOI>

58 : Returns the trigger settings:

[TGP *port*,*terminal*,*polarity*,*type*]
[;TGP *port*,*terminal*,*polarity*,*type*] . . . .
[;TGP *port*,*terminal*,*polarity*,*type*]
TGSI *mode*;TGXO *mode*;TGSO *mode*;TGMO *mode*<CR/LF^EOI>

59 : Returns the multi channel sweep source settings:

WNX *n*,*chnum*,*mode*,*range*,*start*,*stop*[,*comp*[,*pcomp*]]
[;WNX *n*,*chnum*,*mode*,*range*,*start*,*stop*[,*comp*[,*pcomp*]]] . . . .
[;WNX *n*,*chnum*,*mode*,*range*,*start*,*stop*[,*comp*[,*pcomp*]]]
<CR/LF^EOI>

If no multi channel sweep source is set, the query response is:

WNX<CR/LF^EOI>

60 : Returns the time stamp setting:

TSC *enable*<CR/LF^EOI>

61 : Returns the display settings:

RED *enable*;
KLC *lock*;
DFM *format*;
SPA1,*param*;
SPA2,*param*;
MPA *param*;
SCH *chnum*;
MCH *chnum*<CR/LF^EOI>

62 : Returns the ASU connection path:

SAP *chnum*,*path*[;SAP *chnum*,*path*] . . . .
[;SAP *chnum*,*path*]<CR/LF^EOI>

63 : Returns the 1 pA auto ranging operation mode:

SAR *chnum*,*mode*[;SAR *chnum*,*mode*] . . . .
[;SAR *chnum*,*mode*]<CR/LF^EOI>

64 : Returns the operation mode of the ASU connection status indicator:

SAL *chnum*,*mode*[;SAL *chnum*,*mode*] . . . .
[;SAL *chnum*,*mode*]<CR/LF^EOI>

70 : Returns the MFCMU measurement mode:

IMP *mode*<CR/LF^EOI>

71 : Returns the MFCMU data output mode:

LMN *mode*<CR/LF^EOI>

72 : Returns the MFCMU’s ADC setting:

ACT *mode*, *number*<CR/LF^EOI>

73 : Returns the MFCMU measurement range:

RC *chnum*,*mode*,*range*<CR/LF^EOI>

80 : Returns the operation mode of the SCUU connection status indicator:

SSL *chnum*,*mode*<CR/LF^EOI>

81 : Returns the SCUU connection path:

SSP *chnum*,*mode*<CR/LF^EOI>

90 : Returns the MFCMU adjustment mode setting:

ADJ *chnum*,*mode*<CR/LF^EOI>

100 : Returns the CV (DC bias) sweep measurement settings:

WMDCV *abort function*[,*output after sweep*];
WTDCV *hold*,*delay*[,*step delay*[,*S trig delay*[,*M trig delay*]]]
[;WDCV *chnum*,*mode*,*start*,*stop*,*step*]<CR/LF^EOI>

101 : Returns the pulsed spot C measurement or pulsed sweep CV measurement settings:

PTDCV *hold*,*width*[,*period*[,*trig delay*]]
[;PDCV *chnum*,*base*,*peak*] or
[;PWDCV *chnum*,*mode*,*base*,*start*,*stop*,*step*]<CR/LF^EOI>

102 : Returns the C-f sweep measurement settings:

WMFC *abort post*;
WTFC *hold*,*delay*[,*step delay*[,*S trig delay*[,*M trig delay*]]]
[;WFC *chnum*,*mode*,*start*,*stop*,*step*]<CR/LF^EOI>

103 : Returns the CV (AC level) sweep measurement settings:

WMACV *abort post*;
WTACV *hold*,*delay*[,*step delay*[,*S trig delay*[,*M trig delay*]]]
[;WACV *chnum*,*mode*,*start*,*stop*,*step*]<CR/LF^EOI>

104 : Returns the C-t sampling measurement settings:

MTDCV *h_bias*,*interval*,*number*,*h_base*
[;MDCV *chnum*,*base*,*bias*,*post*]<CR/LF^EOI>

105 : Returns the multi channel pulsed spot measurement settings:

MCPT *hold*,*period*,*Mdelay*,*average*[[;MCPNT *chnum*,*delay*,*width*]
. . . . [;MCPNX *n*,*chnum*,*mode*,*range*,*base*,*peak*[,*comp*]]] . . . .
<CR/LF^EOI>

106 : Returns the multi channel pulsed sweep measurement settings:

MCPT *hold*,*period*,*Mdelay*,*average*;MCPWS *mode*,*numOfStep*[
[;MCPNT *chnum*,*delay*,*width*] . . . .
[;WNX *n*,*chnum*,*mode*,*range*,*start*,*stop*[,*comp*[,*pcomp*]]] . . . .
[;MCPNX *n*,*chnum*,*mode*,*range*,*base*,*peak*[,*comp*]] . . . .
[;MCPWNX *n*,*chnum*,*mode*,*range*,*base*,*start*,*stop*[,*comp*[,*pcomp*]]]]
. . . . <CR/LF^EOI>

110 : Returns the parallel measurement mode setting:

PAD *mode*<CR/LF^EOI>

LSI

The LSI command sets the current search source for the linear search measurement (MM14). After search stops, the search channel forces the value specified by the LSM command.

This command clears the LSV, LSSI, and LSSV command settings.

This command setting is cleared by the LSV command.

If *Vcomp* value is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

`LSI chnum,range,start,stop,step[,Vcomp]`

Parameters

chnum **:** SMU search source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

range **:** Output ranging type. Integer expression. The output range will be set to the minimum range that covers both *start* and *stop* values. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-5 on page 4-18.

start, stop **:** Search start or stop current (in A). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type. The *start* and *stop* must have different values.

step**:** Step current (in A). Numeric expression.

If *start* < *stop*, *step* must be positive, and if *start* > *stop*, *step* must be negative. Maximum number of search steps is 1001.

Vcomp**:** Voltage compliance value (in V). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type. If you do not specify *Vcomp*, the previous value is set.

Example Statements

```
OUTPUT @B1500;"LSI 1,0,0,1E-6,1E-8,10"
```

LSM

The LSM command enables or disables the automatic abort function for the linear search measurement (MM14). The automatic abort function stops the search operation when one of the following conditions occurs:

- Compliance on the measurement channel
- Compliance on the non-measurement channel
- Overflow on the AD converter

- Oscillation on any channel

This command also sets the post search condition for the linear search sources. After the search measurement is normally completed, the linear search sources force the value specified by the *post* parameter.

If the search operation is stopped by the automatic abort function, the linear search sources force the start value after search.

Syntax

```
LSM abort[,post]
```

Parameters

abort **:** Automatic abort function. Integer expression.

1: Disables the function. Initial setting.

2: Enables the function.

post **:** Source output value after the search operation is normally completed. Integer expression.

1: Start value. Initial setting.

2: Stop value.

3: Output value when the search target value is obtained.

If this parameter is not set, the search source forces the start value.

Example Statements

```
OUTPUT @B1500;"LSM 2"
OUTPUT @B1500;"LSM 2,3"
```

LSSI

The LSSI command sets the synchronous current source for the linear search measurement (MM14). The synchronous source output will be:

Synchronous source output = *polarity* × LSI source output + *offset*

where the LSI source output is the output set by the LSI command.

This command setting is cleared by the LSV/LSI command.

Execution Conditions

The LSI command must be entered before this command.

If *Vcomp* value is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

```
LSSI chnum,polarity,offset[,Vcomp]
```

Parameters

chnum **:** SMU synchronous source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***polarity*:** Polarity of the LSSI output for the LSI output.

0 (negative): LSSI output = –LSI output + *offset*

1 (positive): LSSI output = LSI output + *offset*

***offset*:** Offset current (in A). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type.

Both primary and synchronous search sources will use the same output range. So check the output range set to the LSI command to determine the synchronous source outputs.

***Vcomp*:** Voltage compliance value (in V). Numeric expression. If you do not specify *Vcomp*, the previous value is set.

Example Statements

```
OUTPUT @B1500;"LSSI 1,1,1E-6,5"
```

See Also

For the source output value, output range, and the available compliance values, see Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type.

LSSV

The LSSV command sets the synchronous voltage source for the linear search measurement (MM14). The synchronous source output will be:

Synchronous source output = *polarity* × LSV source output + *offset*

where the LSV source output is the value set by the LSV command.

This command setting is cleared by the LSI/LSV command.

Execution Conditions

The LSV command must be entered before this command.

If the output voltage is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

LSSV *chnum*,*polarity*,*offset*[,*Icomp*]

Parameters

chnum **:** SMU synchronous source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***polarity*:** Polarity of the LSSV output for the LSV output.

0 (negative): LSSV output = –LSV output + *offset*

1 (positive): LSSV output = LSV output + *offset*

***offset*:** Offset voltage (in V). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type.

Both primary and synchronous search sources will use the same output range. So check the output range set to the LSV command to determine the synchronous source outputs.

***Icomp*:** Current compliance value (in A). Numeric expression. If you do not specify *Icomp*, the previous value is set. Zero amps (0 A) is not a valid value for the *Icomp* parameter.

Example Statements

```
OUTPUT @B1500;"LSSV 1,0,5,1E-6"
```

See Also

For the source output value, output range, and the available compliance values, see Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type.

LST?

The LST? query command stores a catalog of internal memory programs or a specific program listing in the output data buffer (query buffer) of the B1500.

Syntax

LST? [*pnum*[,*index*[,*size*]]]

Parameters

***pnum* :** Memory program number. Numeric expression. 0 to 2000. If you do not specify the value, 0 is set.

LST? 0 returns the catalog of the memory programs. This is same as the LST? command results. Then *index* and *size* are not required.

***index* :** Command index that is the number of top command to read. Numeric expression. If you do not specify the value, 1 is set.

index=1 specifies the first command stored in the memory program. This command is always the ST command. And the last command is always the END command. If the *index* value is greater than the number of commands, the LST? returns the END only.

If you set *index*=0, the LST? returns the number of commands stored in the memory program. For empty memory programs, the LST? returns 2 (ST and END).

***size* :** Number of commands to read. Numeric expression. 1 to 3000. If you do not specify the value, 3000 is set.

If you set the value greater than the number of commands from the command specified by *index* to the last command (END), the LST? command stops operation after reading the END command.

Query Response

Response by LST? or LST? 0:

```
number_of_programs[,pnum[,pnum ... [,pnum]...]]<CR/LF^EO
I>
```

Response by LST? *pnum*[, *index*[, *size*]]:

```
ST pnum<CR/LF>
[saved_command<CR/LF>]
[saved_command<CR/LF>]
          :
[saved_command<CR/LF>]
END<CR/LF^EOI>
```

The LST? command reads the command specified by the *index*, reads the command stored next, and repeats this operation until the *size* each of commands are read. If you do not specify the *index* and *size* values, the LST? command reads the first stored command (ST *pnum*) to the 3000th stored command. If the number of commands are less than 3000, the LST? command reads the commands from ST to END. See Example Statements that show an HP BASIC programming example.

Example Statements

Example of LST? :

```
DIM A$[100]
OUTPUT @B1500;"LST?"
ENTER @B1500;A$
PRINT A$
```

Example of LST? *pnum*[, *index*[, *size*]] :

```
DIM A$[100]
P_num=1
!
OUTPUT @B1500;"LST?";P_num,0
ENTER @B1500;Num_c
Num_l=Num_c/3000
!
IF Num_c>3000 THEN
 C_index=1
```

```
  FOR I=1 TO INT(Num_l)
    OUTPUT @B1500;"LST?";P_num,C_index
    FOR N=1 TO 3000
      ENTER @B1500;A$
      PRINT A$
      C_index=C_index+1
    NEXT N
  NEXT I
  OUTPUT @B1500;"LST?";P_num,C_index
  LOOP
    ENTER @B1500;A$
    PRINT A$
  EXIT IF A$="END"
  END LOOP
ELSE
  OUTPUT @B1500;"LST?";P_num
  LOOP
    ENTER @B1500;A$
    PRINT A$
  EXIT IF A$="END"
  END LOOP
END IF
```

LSTM

The LSTM command sets the timing parameters for the linear search measurement (MM14). If you do not enter this command, all parameters are set to 0.

Syntax `LSTM` *`hold,delay`*

Parameters

hold **:** Hold time (in seconds) that is the wait time after starting the search measurement and before starting the delay time for the first search point. Numeric expression.

0 to 655.35 sec. 0.01 sec resolution.

delay **:** Delay time (in seconds) that is the wait time after starting to force a step output value and before starting a step measurement. Numeric expression.

0 to 65.535 sec. 0.0001 sec resolution.

Example Statements

```
OUTPUT @B1500;"LSTM 5,0.1"
```

LSV

The LSV command sets the voltage search source for the linear search measurement (MM14). After search stops, the search channel forces the value specified by the LSM command.

This command clears the LSI, LSSI, and LSSV command settings.

This command setting is cleared by the LSI command.

If the output voltage is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

`LSV chnum,range,start,stop,step[,Icomp]`

Parameters

***chnum* :** SMU search source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***range* :** Output ranging type. Integer expression. The output range will be set to the minimum range that covers both *start* and *stop* values. Range changing may cause 0 V output in a moment. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-4 on page 4-18.

***start, stop* :** Search start or stop voltage (in V). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. The *start* and *stop* parameters must have different values.

***step* :** Step voltage (in V). Numeric expression.

If *start* < *stop*, *step* must be positive, and if *start* > *stop*, *step* must be negative. Maximum number of search steps is 1001.

***Icomp*:** Current compliance value (in A). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. If you do not specify *Icomp*, the previous value is set. Zero amps (0 A) is not allowed for *Icomp*.

Example Statements

```
OUTPUT @B1500;"LSV 1,0,0,20,.5,1E-6"
```

LSVM

The LSVM command selects the data output mode for the linear search measurement (MM14).

Syntax

`LSVM mode`

Parameters

***mode* :** Data output mode. Integer expression. 0 (initial setting) or 1.

0 : Returns *Data_search* only.

1 : Returns *Data_search* and *Data_sense*.

Data_search is the value forced by the search output channel set by LSI or LSV.

Data_sense is the value measured by the search monitor channel set by LGI or LGV.

For data output format, refer to “Data Output Format” on page 1-25.

Example Statements

```
OUTPUT @B1500;"LSVM 1"
```

MCC

The MCC command clears the settings of the sampling output channels defined by the MV, MI, or MSP command. This command is available for the sampling measurement (MM10).

Syntax

MCC [*chnum*[,*chnum*...[,*chnum*[,*chnum*]]...]]

A maximum of 15 channels can be set.

Parameters

chnum **:** Channel number of the unit to clear the settings. Integer expression. See Table 4-1 on page 4-14.

If you do not specify *chnum*, the MCC command clears the settings of all sampling channels.

Example Statements

```
OUTPUT @B1500;"MCC"
OUTPUT @B1500;"MCC 1,2,3"
```

MCPNT

The MCPNT command sets the delay time and the pulse width of the pulse output channels. This command is effective for the multi channel pulsed spot or sweep measurement set by MM 27 or MM 28.

Syntax

MCPNT *chnum*,*delay*,*width*

Parameters

chnum **:** SMU pulsed source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

delay **:** Delay time (in seconds) from the beginning of the pulse period to the beginning of the transition from base to peak. Numeric expression. Effective value depends on the module type. See Table 4-23 on page 4-105.

width **:** Pulse width (in seconds). Numeric expression. Effective value depends on the module type. See Table 4-23 on page 4-105.

For HR/MP/HPSMU, available delay time value is 0. Also, the pulse width value must be the same. If a different value is entered, the longest value is set.

Table 4-23 **Effective value for *delay* and *width***

	HR/MP/HPSMU	HCSMU	HVSMU
delay	0	0 to *period*-*width* *period* is set by MCPT command. Resolution: 2 μs, Initial value: 0	
width	500 μs to 2 s Resolution: 2 μs Initial setting: 1 ms Same value for all HR/MP/HPSMU.	50 μs to 1 ms, duty ratio maximum 1 %, for 20 A range 50 μs to 2 s for other range Resolution: 2 μs Initial setting: 1 ms	500 μs to 2 s Resolution: 2 μs Initial setting: 1 ms

MCPNX

The MCPNX command specifies the pulsed bias source and its parameters. This command is effective for the multi channel pulsed spot or sweep measurement set by MM 27 or MM 28.

To set the timing of output pulse and measurement, use the MCPT, MCPNT, and AIT commands.

Syntax

```
MCPNX N,chnum,mode,range,base,pulse[,comp]
```

Parameters

N **:** Source number. Integer expression. 1 to 10. See Remarks below.

chnum **:** SMU pulsed source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

mode **:** Source type. Integer expression. 1 or 2.

1: Voltage source

2: Current source

range **:** Ranging type. Integer expression.

- For voltage source (*mode*=1): See Table 4-4 on page 4-18.
- For current source (*mode*=2): See Table 4-5 on page 4-18.

The B1500 usually uses the minimum range that covers both *base* and *pulse* values to perform pulse output. For the limited auto ranging, the instrument never uses the range less than the specified range.

***base*, *pulse*:** Pulse base or peak value (in V or A). Numeric expression.

- For voltage source (*mode*=1): See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. For using 3000 V range of HVSMU, *base* and *peak* must have the same polarity.
- For current source (*mode*=2): See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type. *base* and *peak* must have the same polarity.

***comp* :** Compliance (in A or V). Numeric expression. If you do not set *comp*, the previous value is used.

- For voltage source (*mode*=1): See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type.
- For current source (*mode*=2): See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type.

Compliance polarity is automatically set to the same polarity as the output value, regardless of the specified *comp*. If the output value is 0, the polarity is set to positive.

Remarks

The *N* value and the *chnum* value set to the MCPNX, MCPWNX, and WNX commands must be unique for each command execution. If you set the value used to the previous command, the previous command setting is cleared, and the last command setting is effective.

Source channels set by the WNX commands start output in the order specified by the *N* value, and then the source channels set by the MCPNX and MCPWNX commands start output simultaneously.

If you use multiple measurement channels, all measurement channels start measurement simultaneously.

Example Statements

```
OUTPUT @B1500;"AIT 2,3,1E-3"
OUTPUT @B1500;"MCPT 1,5E-2,2E-2,1"
OUTPUT @B1500;"MCPNT 3,1E-2,2E-2"
OUTPUT @B1500;"MCPNX 1,3,1,0,0,5,1E-1"
```

MCPT

The MCPT command sets the hold time, pulse period, measurement timing, and number of measurements, which are the parameters for the multi channel pulsed spot or sweep measurement set by MM 27 or MM 28.

Syntax

`MCPT hold[,period[,Mdelay[,average]]]`

Parameters

***hold* :** Hold time (in seconds). Numeric expression. 0 to 655.35 sec. 10 ms resolution. Initial setting = 0.

***period* :** Pulse period (in seconds). Numeric expression. 0, -1, or 5 ms to 5.0 s. 0.1 ms resolution. Initial setting = 10 ms. Default setting = 0. t_0 = *delay* + *width*, where *delay* and *width* are the parameters set by the MCPNT command.

- *period* ≥ t_0 + 2 ms (for t_0 ≤ 100 ms)
- *period* ≥ t_0 + 10 ms (for 100 ms < t_0)
- *period* =0: Pulse period is automatically set as follows.
  - Pulse period = 5 ms (for t_0 ≤ 3 ms)
  - Pulse period = t_0 + 2 ms (for 3 ms < t_0 ≤ 100 ms)
  - Pulse period = t_0 + 10 ms (for 100 ms < t_0)
- *period* =-1: Pulse period is automatically set to the minimum effective value longer than the pulse width.

***Mdelay* :** Measurement timing (in seconds) from the beginning of the pulse period to the beginning of the measurement. Numeric expression. 2 μs to *period*-*N*-2 ms. 2 μs resolution. where *N* is the actual measurement time set to the AIT command. Initial and default setting = 0. Entering 0 sets the optimum value automatically so that the measurement is completed when the transition from peak to base is started by the pulse output channel which starts the transition at first.

***average* :** Number of measurements for averaging to get a measurement data. Integer expression. 1 to 1023. Initial and default setting = 1.

MCPWS

The MCPWS command sets the sweep mode and the number of sweep steps effective for the multi channel pulsed sweep measurement set by MM 28.

Syntax `MCPWS mode,step`

Parameters

mode **:** Sweep mode. Integer expression. 1 to 4.

1: Linear sweep (single stair, start to stop.)

2: Log sweep (single stair, start to stop.)

3: Linear sweep (double stair, start to stop to start.)

4: Log sweep (double stair, start to stop to start.)

step **:** Number of sweep steps. Numeric expression. 1 to 1001.

MCPWNX

The MCPWNX command specifies the pulsed sweep source and its parameters. This command is effective for the multi channel pulsed sweep measurement set by MM 28.

To set the timing of output pulse and measurement, use the MCPT, MCPNT, and AIT commands. To set the sweep mode and the number of sweep steps, use the MCPWS command.

Syntax `MCPWNX N,chnum,mode,range,base,start,stop[,comp[,Pcomp]]`

Parameters

N **:** Source number. Integer expression. 1 to 10. See Remarks below.

chnum **:** SMU pulsed source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

mode **:** Source type. Integer expression. 1 or 2.

1: Voltage source

2: Current source

range **:** Ranging type. Integer expression.

- For voltage source (*mode*=1): See Table 4-4 on page 4-18.
- For current source (*mode*=2): See Table 4-5 on page 4-18.

The B1500 usually uses the minimum range that covers *base*, *start*, and *stop* values to perform pulse output. For the limited auto ranging, the instrument never uses the range less than the specified range.

***base*, *start*, *stop*:** Pulse base, pulse sweep start, or pulse sweep stop value (in V or A). Numeric expression. Setting *start*=*stop* sets the SMU to a pulsed bias source.

- For voltage source (*mode*=1): See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. For the log sweep or using 3000 V range of HVSMU, *base*, *start*, and *stop* must have the same polarity.
- For current source (*mode*=2): See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type. *base*, *start*, and *stop* must have the same polarity.

***comp* :** Compliance (in A or V). Numeric expression. If you do not set *comp*, the previous value is used.

- For voltage source (*mode*=1): See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type.
- For current source (*mode*=2): See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type.

  For the log sweep and without *Pcomp*, set the value available for the minimum range that covers *base*, *start*, and *stop* values.

Compliance polarity is automatically set to the same polarity as the output value, regardless of the specified *comp*. If the output value is 0, the polarity is set to positive.

If you set *Pcomp*, the maximum *comp* value for the module is allowed, regardless of the output range setting.

***Pcomp* :** Power compliance (in W). Numeric expression. Resolution: 0.001 W. If the *Pcomp* value is not entered, the power compliance is not set. The power compliance operation is based on the large one either pulse peak or base. This parameter is not available for HVSMU.

0.001 to 2 for MPSMU/HRSMU, 0.001 to 20 for HPSMU, 0.001 to 400 for HCSMU

Remarks

The *N* value and the *chnum* value set to the MCPNX, MCPWNX, and WNX commands must be unique for each command execution. If you set the value used to the previous command, the previous command setting is cleared, and the last command setting is effective.

Source channels set by the WNX commands start output in the order specified by the *N* value, and then the source channels set by the MCPNX and MCPWNX commands start output simultaneously.

If you use multiple measurement channels, all measurement channels start measurement simultaneously.

Example Statements

```
OUTPUT @B1500;"AIT 2,3,1E-3"
OUTPUT @B1500;"MCPT 1,5E-2,2E-2,1"
OUTPUT @B1500;"MCPNT 3,1E-2,2E-2"
OUTPUT @B1500;"MCPNX 1,3,1,0,0,5,1E-1"
OUTPUT @B1500;"MCPWS 1,101"
OUTPUT @B1500;"MCPNT 4,1E-2,2E-2"
OUTPUT @B1500;"MCPWNX 2,4,1,0,0,0,5,1E-1"
```

MDCV

This command sets the DC bias source (MFCMU, up to ± 25 V) used for the C-t sampling measurement (MM26). When the SCUU (SMU CMU unify unit) is connected, output up to ± 100 V is available by using the SMU that can be connected to the Force1/Sense1 terminals.

This command setting clears the previous MDCV command setting.

Execution Conditions

The CN/CNX command has been executed for the specified channel.

If you want to apply DC voltage over ± 25 V, the SCUU must be connected correctly. The SCUU can be used with the MFCMU and two SMUs (MPSMU or HRSMU). The SCUU cannot be used if the HPSMU is connected to the SCUU or if the number of SMUs connected to the SCUU is only one.

If the output voltage is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

MDCV *chnum*,*base*,*bias*[,*post*]

Parameters

***chnum* :** MFCMU source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***base*, *bias*:** Base or bias voltage (in V). Numeric expression. See NOTE below. For using 3000 V range of HVSMU, *base* and *bias* must have the same polarity.

0 (initial setting) to ± 25 V (MFCMU) or ± 100 V (with SCUU)

***post* :** Source output value after the measurement is normally completed. Numeric expression. See NOTE below. If you do not specify *post*, the previous value is set.

0 to ± 25 V (MFCMU) or ± 100 V (with SCUU)

Example Statements

```
OUTPUT @B1500;"MDCV 9,0,5"
```

NOTE

With the SCUU, the source module is automatically selected by the setting value. The MFCMU is used if the *base*, *bias*, and *post* values are below ± 25 V (setting resolution: 0.001 V), or the SMU is used if they are greater than ± 25 V (setting resolution: 0.005 V).
The SMU will operate with the 100 V limited auto ranging and 20 mA compliance settings.

MI

The MI command sets the DC current source (SMU) for the sampling measurement (MM10). This command setting clears, and is cleared by, the MV command setting.

The specified channel starts the *base* current output by the measurement trigger (XE command and so on), and changes the output value to *bias* after the hold time elapses. The hold time is set by the *h_base* parameter of the MT command.

When multiple channels are used, channel outputs start in the order from lower to higher channel number 101 to 1001. The channel numbers 1 to 10 correspond to the channel numbers 101 to 1001 respectively. See Table 4-1 on page 4-14.

If the DI command is executed for this channel, the channel works as the DC current source set by the DI command.

Execution Conditions

If *Vcomp* value is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

MI *chnum*,*irange*,*base*,*bias*[,*Vcomp*]

Parameters

***chnum* :** SMU source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***irange* :** Ranging type. Integer expression. The output range will be set to the minimum range that covers both *base* and *bias* values. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-5 on page 4-18.

***base, bias* :** Base current and bias current (in A). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type. *base* and *bias* must have the same polarity.

***Vcomp* :** Voltage compliance value (in V). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type. If you do not specify this parameter, *Vcomp* is set to the previous setting.

Example Statements

```
OUTPUT @B1500;"MI 1,18,0,5E-5,10"
```

See Also “MT”, “MCC”, “MSC”

ML

The ML command sets the sampling mode, linear or logarithmic. For the logarithmic sampling, this command also specify the number of measurement data to be returned.

If you do not execute this command, the last sampling mode is effective. Initialization such as the *RST command sets the linear sampling mode.

Syntax

`ML *mode*`

Parameters

mode Sampling mode, linear or logarithm.

1: linear sampling, initial setting.

2: logarithmic sampling, 10 data/decade.

3: logarithmic sampling, 25 data/decade.

4: logarithmic sampling, 50 data/decade.

5: logarithmic sampling, 100 data/decade.

6: logarithmic sampling, 250 data/decade.

7: logarithmic sampling, 500 data/decade.

Example Statements

```
OUTPUT @B1500;"ML 2"
```

MM

The MM command specifies the measurement mode and the channels used for measurements. This command must be entered to specify the measurement mode. For the high speed spot measurements, do not enter the MM command.

Syntax

- *mode*= 1, 2, 10, 16, 18, 27, or 28:

`MM mode,chnum[,chnum[,chnum...[,chnum]...]]`

A maximum of ten channels can be set. For *mode*=18, the first *chnum* must be MFCMU.

- *mode*= 3, 4, 5, 17, 19, 20, 22, 23, or 26:

  `MM mode,chnum`

- *mode*= 9 or 13:

  `MM mode[,chnum]`

- *mode*= 14 or 15:

  `MM mode`

Parameters

mode **:** Measurement mode. Integer expression. 1 to 28. See Table 4-24.

***chnum*:** Measurement channel number. Integer expression. See Table 4-1 on page 4-14.

Remarks

The SMU operation mode is defined by the CMM command.

The measurement range is defined by the RI or RV command (for SMU), or the RC command (for MFCMU).

To execute the measurement, enter the XE command.

For *mode*=1, 2, or 10, if you use multiple measurement channels, the channels start measurement in the order defined in the MM command.

For *mode*=16, if you use multiple measurement channels, the channels that use the high speed ADC with the fixed ranging mode start measurement simultaneously, then other channels start measurement in the order defined in the MM command.

For *mode*=9 or 13, if you do not specify *chnum*, the B1500 uses the channel specified by the BDV or QSV command to execute measurement.

For *mode*=9, 14, or 15, the time stamp function is not available. See “Data Output Format” on page 1-25.

For *mode*=18, MFCMU must be specified for the first *chnum*. Also SMU can be used for the additional measurement channels. Then the SMU will execute the measurement simultaneously or in the order specified by the MM command, and finally the MFCMU will execute the measurement. The *chnum* parameter must not specify the SMU connected to the SCUU.

Example Statements

```
OUTPUT @B1500;"MM 1,1"
OUTPUT @B1500;"MM 2,1,3"
```

Table 4-24 Measurement Mode

mode	Measurement mode	Related source setup command	SMU		MF CMU
			HP/ MP/ HR	HC/ HV	
1	Spot	DI, DV	Yes	Yes	
2	Staircase sweep	WI, WV, WT, WM, WSI, WSV	Yes	Yes	
3	Pulsed spot	PI, PV, PT	Yes	Yes	
4	Pulsed sweep	PWI, PWV, PT, WM, WSI, WSV	Yes	Yes	
5	Staircase sweep with pulsed bias	WI, WV, WM, WSI, WSV, PI, PV, PT	Yes	Yes	
9	Quasi-pulsed spot	BDV, BDT, BDM	Yes		
10	Sampling	MCC, MSC, ML, MT, MI, MV	Yes	Yes	
13	Quasi-static CV	QSV, QST, QSM	Yes		
14	Linear search	LSV, LSI, LGV, LGI, LSM, LSTM, LSSV, LSSI, LSVM	Yes	Yes	
15	Binary search	BSV, BSI, BGV, BGI, BSM, BST, BSSV, BSSI, BSVM	Yes	Yes	
16	Multi channel sweep	WI, WV, WT, WM, WNX	Yes	Yes	
17	Spot C	FC, ACV, DCV			Yes
18	CV (DC bias) sweep	FC, ACV, WDCV, WMDCV, WTDCV	Yes	Yes	Yes
19	Pulsed spot C	PDCV, PTDCV			Yes
20	Pulsed sweep CV	PWDCV, PTDCV			Yes
22	C-f sweep	WFC, ACV, DCV, WMFC, WTFC			Yes
23	CV (AC level) sweep	FC, WACV, DCV, WMACV, WTACV			Yes
26	C-t sampling	MSC, MDCV, MTDCV			Yes
27	Multi channel pulsed spot	MCPT, MCPNT, MCPNX	Yes	Yes	
28	Multi channel pulsed sweep	MCPT, MCPNT, MCPNX, MCPWS, MCPWNX, WNX	Yes	Yes	

MSC

The MSC command enables or disables the automatic abort function for the sampling measurement (MM10 and MM26). The automatic abort function stops the measurement when one of the following conditions occurs:

- Compliance on the measurement channel (MM10)
- Compliance on the non-measurement channel (MM10)
- Oscillation on any channel (MM10)
- NULL loop unbalance condition (MM26)
- IV amplifier saturation condition (MM26)
- Overflow on the AD converter (MM10 and MM26)

This command also sets the post measurement condition for the sources. After the measurement is normally completed, the voltage/current sources force the value specified by the *post* parameter. The *post* parameter is effective only for the DC output channels in MM10.

If the measurement is stopped by the automatic abort function, the voltage/current sources force the *base* value.

Syntax

```
MSC abort[,post]
```

Parameters

abort **:** Automatic abort function. Integer expression.

1: Disables the function. Initial setting.

2: Enables the function.

post **:** Source output value after the measurement is normally completed. Integer expression.

1: Base value.

2: Bias value. Initial setting.

If this parameter is not set, the sources force the bias value.

Output Data

The B1500 returns the data measured before any abort condition is detected. Dummy data 199.999E+99 will be returned for the data after abort.

Example Statements

```
OUTPUT @B1500;"MSC 2"
OUTPUT @B1500;"MSC 2,2"
```

MSP

The MSP command specifies the SPGU channel synchronized with the sampling measurements (MM10), and the channel output after the sampling measurement. You can also specify the channel output before the sampling measurement for the channel which is set to the DC bias output by the SPM command.

Using the measurement trigger (XE command, etc.), the specified channel's output changes to the base value (set by the SPV command) and then changes to the pulse peak value or the DC bias value (set by the SPV command) after the base hold time elapses (which is set by the MT command). Finally the output is changed to the *post* value (set by the MSP command) after the sampling measurement.

Execution Conditions

Sampling interval (*interval* of MT command) must be ≥ 2 ms.

Syntax

`MSP chnum[,post[,base]]`

Parameters

chnum **:** SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1 on page 4-14.

post **:** Output voltage after completing sampling measurement. Numeric expression. If this parameter is not set, the SPGU channel outputs the *base* value set by the SPV command.

0 to ± 40 V, in 1 mV resolution

base **:** Output voltage before starting sampling measurement. Numeric expression. This parameter is available only for the SPGU channel which is set to the DC bias output by the SPM command. If this parameter is not set, the SPGU channel outputs the *base* value set by the SPV command.

0 to ± 40 V, in 1 mV resolution

Remarks

The MSC command's *post* parameter is not effective for the SPGU channel synchronized with the sampling measurements (MM10).

Example Statements

```
OUTPUT @B1500;"MSP 101,0,0"
OUTPUT @B1500;"MSP 1,0"
```

See Also

"SPT", "SPV", "SPM"

MT

This command sets the timing parameters of the sampling measurement (MM10).

NOTE

If you set interval < 0.002 s

Sampling mode must be linear. This setting is not permitted for the log sampling. Also SPGU is not available.

The following conditions are automatically set to the all measurement channels. And the all channels start measurement simultaneously. After the measurement, they are returned to the previous conditions automatically.

- High speed A/D converter (ADC)
- Minimum measurement range that covers compliance value, fixed ranging

If the measurement time is expected to be longer than *interval*, the measurement channels automatically adjust the number of averaging samples (AIT or AV command settings) to keep the sampling interval. After the measurement, it is returned to the previous setting automatically.

Syntax

```
MT h_bias,interval,number[,h_base]
```

Parameters

***h_bias* :** Time since the *bias* value output until the first sampling point. Numeric expression. in seconds. 0 (initial setting) to 655.35 s, resolution 0.01 s.

The following values are also available for *interval* < 0.002 s. |*h_bias*| will be the time since the sampling start until the *bias* value output.

-0.09 to -0.0001 s, resolution 0.0001 s.

***interval* :** Interval of the sampling. Numeric expression, 0.0001 to 65.535, in seconds. Initial value is 0.002. Resolution is 0.001 at *interval* ≥ 0.002.

Linear sampling of *interval* < 0.002 in 0.00001 resolution is available only when the following formula is satisfied. Also see NOTE above.

$interval \geq 0.0001 + 0.00002 \times (\text{number of measurement channels} - 1)$

***number* :** Number of samples. Integer expression. 1 to the following value. Initial value is 1000.

For the linear sampling: 100001 / (number of measurement channels)

For the log sampling: 1 + (number of data for 11 decades)

h_base Hold time of the *base* value output until the *bias* value output. Numeric expression. in seconds. 0 (initial setting) to 655.35 s, resolution 0.01 s.

Sampling Operation

Sampling measurement will be started by a measurement trigger such as the XE command or an external trigger, and performed as shown below. Before the measurement trigger, the source channels set by the DI/DV commands will start output at the timing of the DI/DV command execution.

1. By the measurement trigger, source channels set by the MI/MV commands start the *base* value output. Each source channel controls the output simultaneously.
2. *h_base* seconds later, the source channels change the output to the *bias* value. The channels keep the value until the end of the sampling measurement.
3. Another *h_bias* seconds later, the measurement channels start measurement for the first sampling point. The measurement channels perform the measurement in series by the order set to the MM command.
4. After that, the following operation is repeated with the specified time *interval*.

   - Measurement channels start measurement if they are ready to measure.
   - Measurement channels keep the condition if they are busy.

   This operation is repeated until the number of measurement result data reaches to the specified *number* of measurement data.

   For the linear sampling with *interval* < 2 ms, if the total measurement time runs over the specified time *interval* × *number*, the sampling measurement will be stopped even if the number of measurement result data is less than the specified *number*.

   For the log sampling, the B1500 holds only the data that can be plotted on the log scale in the same distance as close as possible. Only the held data is counted in the number of measurement result data.

5. The sampling measurement is completed. And the source channel set by the MI/MV command forces the *base* or *bias* value specified by the MSC command. The source channel set by the DI/DV command keeps its output.

The index data (max. 9999999) and the time data returned with the measurement data will be as shown in the following formula. However, long measurement or busy status may cause unexpected time data.

time data = t + *h_bias* + (index data -1) × *interval*

Where, t is the time of the sampling measurement time origin, and is the time when the output value is changed from *base* to *bias*.

Example Statements

```
OUTPUT @B1500;"MT 0,0.0001,5000,0"
OUTPUT @B1500;"MT 0.01,0.001,101,0.1"
```

MTDCV

This command sets the timing parameters of the C-t sampling measurement (MM26).

Syntax

`MTDCV` *`h_bias`*`,`*`interval`*`,`*`number`*`[,`*`h_base`*`]`

Parameters

***h_bias* :** Time since the *bias* value output until the first sampling point. Numeric expression. in seconds. 0 (initial setting) to 655.35 s, resolution 0.01 s.

***interval* :** Interval of the sampling. Numeric expression. in seconds. 0.008 to 655.35 s, 0.001 s resolution. Initial setting is 0.01.

***number* :** Number of samples. Integer expression. 1 to 10001. Initial setting = 1000.

***h_base*:** Hold time of the *base* value output until the *bias* value output. Numeric expression. in seconds. 0 (initial setting) to 655.35 s, resolution 0.01 s.

Example Statements

```
OUTPUT @B1500;"MTDCV 0,0.008,5000,0"
OUTPUT @B1500;"MTDCV 0.01,0.008,101,0.1"
```

MV

The MV command sets the DC voltage source (SMU) for the sampling measurement (MM10). This command setting clears, and is cleared by, the MI command setting.

The specified channel starts the *base* voltage output by the measurement trigger (XE command and so on), and changes the output value to *bias* after the hold time elapses. The hold time is set by the *h_base* parameter of the MT command.

When multiple channels are used, channel outputs start in the order from lower to higher channel number 101 to 1001. The channel numbers 1 to 10 correspond to the channel numbers 101 to 1001 respectively. See Table 4-1 on page 4-14.

If the DV command is executed for this channel, the channel works as the DC voltage source set by the DV command.

Execution Conditions

If the output voltage is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

`MV` *`chnum`*`,`*`vrange`*`,`*`base`*`,`*`bias`*`[,`*`Icomp`*`]`

Parameters

***chnum* :** SMU source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***vrange* :** Ranging type. Integer expression. The output range will be set to the minimum range that covers both *base* and *bias* values. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-4 on page 4-18.

***base*, *bias* :** Base voltage and bias voltage (in V). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. For using 3000 V range of HVSMU, *base* and *bias* must have the same polarity.

***Icomp* :** Current compliance value (in A). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. If you do not set *Icomp*, the previous value is used. 0 A is not allowed for *Icomp*.

Example Statements

```
OUTPUT @B1500;"MV 1,12,0,5,1E-3"
```

See Also "MT", "MCC", "MSC"

NUB?

The NUB? query command checks the number of measurement data in the output data buffer, and stores the results in the output data buffer (query buffer).

Syntax `NUB?`

Query Response *number_of_measurement_data*<CR/LF^EOI>

Example Statements

```
OUTPUT @B1500;"NUB?"
ENTER @B1500;A
```

ODSW

This command specifies the operation of the pulse switch for the specified SPGU channel. Set for each channel. See "SPGU Module" on page 2-52 for details on the operation of the pulse switch.

Syntax ODSW *chnum*,*state*[,*normal*,[*delay*,*width*]]

Parameters

***chnum* :** SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1.

***state* :** 0: pulse switch disabled (initial setting)

1: pulse switch enabled

normal: 0: normally open (switch is normally open, initial setting)

1: normally closed (switch is normally closed)

delay: Only for the PG mode. Delay time (seconds) from start of pulse output to changeover of pulse switch. Numeric expression. 0 (initial setting) to *pulse period*-1E-7 seconds, setting resolution 1E-8 seconds.

width: Only for the PG mode. Duration (seconds) to hold the switched state of the pulse switch. Numeric expression. 1E-7 (initial setting) to *pulse period*-*delay* seconds, setting resolution 1E-8 seconds.

The *delay* and *width* parameters are ignored in ALWG mode.

Example Statements

```
OUTPUT @B1500;"ODSW 101,1,1,1E-6,2E-6"
```

ODSW?

This query command returns the pulse switch settings for the specified SPGU channel.

Syntax

`ODSW? chnum`

Parameters

chnum **:** SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table Table 4-1.

Query Response

state[,*normal*,[*delay*,*width*]]<CR/LF^EOI>

state **:** 0: pulse switch disabled

1: pulse switch enabled

normal **:** 0: normally open (switch is normally open)

1: normally closed (switch is normally closed)

delay **:** Delay time (seconds) from start of pulse output to changeover of pulse switch.

width **:** Duration (seconds) to hold the switched state of the pulse switch

Example Statements

```
OUTPUT @B1500;"ODSW? 101"
ENTER @B1500;A,B,C,D
```

*OPC?

The *OPC? command monitors the pending operations, and places ASCII character `1` into the output queue when all pending operations are completed. Also this command sets/clears the operation complete (OPC) bit in the standard event status register as follows:

- If there are no pending operations, sets the OPC bit to 1.
- If there are any pending operations, sets the OPC bit to 0.
  The bit will be set to 1 when all pending operations are completed.

Syntax `*OPC?`

Query Response `1<CR/LF^EOI>`

No response will be returned until all pending operations are completed.

Example Statements

```
OUTPUT @B1500;"*OPC?"
ENTER @B1500;A
```

OS

The OS command causes the B1500 to send a edge trigger from the Ext Trig Out terminal. To set the trigger logic (initial setting: negative), send the TGP command for the Ext Trig Out terminal.

Syntax `OS`

Example Statements

```
OUTPUT @B1500;"OS"
```

OSX

The OSX command causes the B1500 to send a trigger from a trigger output terminal specified by the *port* parameter. To set the trigger logic (initial setting: negative), send the TGP command for the specified port.

Syntax `OSX` *`port`*`[,`*`level`*`]`

Parameters

port **:** External trigger output port number. Integer expression. -2, or 1 to 16.

-2: Ext Trig Out terminal.

1 to 16: Port 1 to 16 of the digital I/O terminal.

To use a digital I/O port, send the TGP command. The *port* value must be same as the *port* value set to the TGP command.

***level* :** Trigger output level. Integer expression. 0, 1, or 2.

0: Logical low.

1: Logical high.

2: Edge trigger (default setting).

If *level* is not specified, the B1500 sends the edge trigger. For the gate trigger output, send OSX *port*,1 when starting trigger output, and send OSX *port*,0 when stopping trigger output.

Example Statements

```
OUTPUT @B1500;"OSX 1,1"
OUTPUT @B1500;"TI";1
ENTER @B1500 USING "#,3X,13D,X";Idata
OUTPUT @B1500;"OSX 1,0"
```

See Also "TGP" and "TGPC"

PA

The PA command pauses the command execution or internal memory program execution, until the specified wait time elapses or until an event specified by the TM command is received. The event set by the TM command only releases the paused status. It does not start the measurement.

Syntax `PA [`*`wait time`*`]`

Parameters

***wait time* :** -99.9999 to 99.9999 seconds, with 100 μsec resolution. Numeric expression. If *wait time* is not specified or negative *wait time* is set, the paused status is kept until receiving an event specified by the TM command.

Remarks

The TM3 command enables an external trigger from the Ext Trig In terminal as an event used to break the pause state set by the PA command.

The B1500 counts the *wait time* independent of the source wait time and the measurement wait time set by the WAT command. So the *wait time* can cover them as shown in the following program example:

```
OUTPUT @B1500;"CN";1
OUTPUT @B1500;"WAT";1,0,1E-3  !Source Wait Time =1ms
OUTPUT @B1500;"WAT";2,0,1E-3  !Meas Wait Time =1ms
OUTPUT @B1500;"DV";1,0,5,1E-2
```

```
OUTPUT @B1500;"PA";1E-3       !Wait Time =1ms
OUTPUT @B1500;"TI";1
ENTER @B1500 USING "#,3X,13D,X";Idata
```

Example Statements

```
OUTPUT @B1500;"PA 10"
```

See Also “TM”

PAD

Enables or disables parallel measurements by the multiple channels (SMU). This command is effective for the SMUs that use the high speed A/D converter (ADC) and for the spot measurement (MM1), staircase sweep measurement (MM2), sampling measurement (MM10), or CV (DC bias) sweep measurement (MM18).

The parallel measurements are performed at first by using the SMUs that use the high speed ADC. And the other SMUs perform measurements in series as defined in the MM command by using the high resolution ADC.

Syntax `PAD` *`mode`*

Parameters

mode **:** 1 (enable) or 0 (disable, initial setting). Integer expression.

Example Statements

```
OUTPUT @B1500;"PAD 1"
```

PAX

The PAX command pauses the command execution or internal memory program execution, until the specified wait time elapses or until an event specified by the TM command is received. The event set by the TM command only releases the paused status. It does not start the measurement.

Execution Conditions

The *port* parameter is meaningful only for the event (trigger input) set by the TM3 command. Set 1 (dummy) for the event set by the TM1, TM2, or TM4 command.

Syntax `PAX` *`port`*`[,`*`wait time`*`]`

Parameters

port **:** External trigger input port number. Integer expression. -1, or 1 to 16.

-1: Ext Trig In terminal.

1 to 16: Port 1 to 16 of the digital I/O terminal.

To use a digital I/O port, send the TGP command. The *port* value must be same as the *port* value set to the TGP command.

***wait time* :** -99.9999 to 99.9999 seconds, with 100 μsec resolution. Numeric expression.

If *wait time* is not specified or negative *wait time* is set, the paused status is kept until receiving an event specified by the TM command.

Remarks

The TM3 command enables an external trigger from a trigger input terminal specified by the *port* parameter as an event used to break the pause state set by the PA command.

The B1500 counts the *wait time* independent of the source wait time and the measurement wait time set by the WAT command. So the *wait time* can cover them as shown in the following program example:

```
OUTPUT @B1500;"CN";1
OUTPUT @B1500;"WAT";1,0,1E-3  !Source Wait Time =1ms
OUTPUT @B1500;"WAT";2,0,1E-3  !Meas Wait Time =1ms
OUTPUT @B1500;"DV";1,0,5,1E-2
OUTPUT @B1500;"PAX";-1,1E-3   !Wait Time =1ms
OUTPUT @B1500;"TI";1
ENTER @B1500 USING "#,3X,13D,X";Idata
```

Example Statements

```
OUTPUT @B1500;"PAX 1,10"
```

See Also

"TM", "TGP", and "TGPC"

PDCV

This command sets the pulsed voltage source used for the pulsed spot C measurement (MM19). The source will be the MFCMU, or the SMU that can be connected to the Force1/Sense1 terminals of the SCUU (SMU CMU unify unit).

Execution Conditions

The CN/CNX command has been executed for the specified channel.

If you want to apply DC voltage over ± 25 V, the SCUU must be connected correctly. The SCUU can be used with the MFCMU and two SMUs (MPSMU or HRSMU). The SCUU cannot be used if the HPSMU is connected to the SCUU or if the number of SMUs connected to the SCUU is only one.

If the output voltage is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

PDCV *chnum*,*base*,*pulse*

Parameters

***chnum* :** MFCMU source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***base*, *pulse*:** Pulse base voltage or pulse peak voltage (in V). Numeric expression. For using 3000 V range of HVSMU, *base* and *pulse* must have the same polarity.

0 (initial setting) to ± 100 V.

With the SCUU, the source module is automatically selected by the setting value. The MFCMU is used if the *base* and *pulse* values are below ± 25 V (setting resolution: 0.001 V), or the SMU is used if they are greater than ± 25 V (setting resolution: 0.005 V).

The SMU will operate with the 100 V limited auto ranging and 20 mA compliance settings.

Example Statements

```
OUTPUT @B1500;"PTDCV 1,0.01"
OUTPUT @B1500;"PDCV 9,0,1"
```

PI

The PI command specifies the pulse current source and its parameters. This command also clears, and is cleared by, the PV command setting.

To set the timing of output pulse and measurement, use the PT and AIT2 commands.

In the staircase sweep with pulsed bias measurement mode (set by the MM 5 command), the pulsed bias output will be synchronized with the staircase sweep outputs set by the WI or WV command.

If *Vcomp* value is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

PI *chnum*,*irange*,*base*,*pulse*[,*Vcomp*]

Parameters

***chnum* :** SMU pulsed source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***irange*:** Ranging type for pulse current output. Integer expression. The output range will be set to the minimum range that covers both *base* and *pulse* values. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-5 on page 4-18.

***base*,**
***pulse* :** Pulse base current or peak current (in A). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type. *base* and *pulse* must have the same polarity.

***Vcomp*:** Voltage compliance value (in V). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type. If *Vcomp* is not specified, the previous value is set.

Compliance polarity is automatically set to the same polarity as the output value, regardless of the specified *Vcomp*. If the output value is 0, the polarity is set to positive.

Example Statements

```
OUTPUT @B1500;"PT 1,0.01"
OUTPUT @B1500;"PI 1,16,0,5E-5,5"

OUTPUT @B1500;"PT 1,0.01"
OUTPUT @B1500;"PI 3,0,0,5E-6"
```

PT

The PT command sets the hold time, pulse width, and pulse period for a pulse source set by the PI, PV, PWI or PWV command. This command also sets the trigger delay time.

Syntax

For pulsed spot measurements:

PT *hold*,*width*[,*period*[,*Tdelay*]]

For pulsed sweep or staircase sweep with pulsed bias measurements:

PT *hold*,*width*,*period*[,*Tdelay*]

Parameters

***hold* :** Hold time (in seconds). Numeric expression. 0 to 655.35 sec. 10 ms resolution. Initial setting = 0.

***width* :** Pulse width (in seconds). Numeric expression. Initial setting = 1 ms.

HR/HP/MP/HVSMU: 500 μs to 2 s, 2 μs resolution

HCSMU: 50 μs to 2 s, 2 μs resolution. Maximum 1 ms and duty ratio ≤ 1 % for using 20 A range.

***period* :** Pulse period (in seconds). Numeric expression. 0, -1, or 5 ms to 5.0 s. 0.1 ms resolution. Initial setting = 10 ms. Default setting = 0.

- *period* ≥ *width* + 2 ms (for *width* ≤ 100 ms)
- *period* ≥ *width* + 10 ms (for 100 ms < *width*)

- *period* =0: Pulse period is automatically set as follows.
  - Pulse period = 5 ms (for *width* ≤ 3 ms)
  - Pulse period = *width* + 2 ms (for 3 ms < *width* ≤ 100 ms)
  - Pulse period = *width* + 10 ms (for 100 ms < *width*)
- *period* =`-1`: Pulse period is automatically set to the minimum effective value longer than the pulse width.

***Tdelay* :** Trigger output delay time (in seconds). Numeric expression. 0 to *width*. 0.1 ms resolution. Initial or default setting = 0.

This parameter is the time from pulse leading edge to timing of trigger output from a trigger output terminal.

PTDCV

This command sets the hold time, pulse width, pulse period, and trigger output delay time of the pulsed spot C measurement (MM19) or pulsed sweep CV measurement (MM20).

Syntax

For pulsed spot C measurement:

`PTDCV` *`hold`*`,`*`width`*`[,`*`period`*`[,`*`Tdelay`*`]]`

For pulsed sweep CV measurement:

`PTDCV` *`hold`*`,`*`width`*`,`*`period`*`[,`*`Tdelay`*`]`

Parameters

***hold* :** Hold time (in seconds). Numeric expression. 0 to 655.35 sec. 10 ms resolution. Initial setting = 0 sec.

***width* :** Pulse width (in seconds). Numeric expression. 8 ms to 655.35 sec. 0.1 ms resolution. Initial setting = 8 ms.

- *width* ≥ 50 ms (for 1 kHz ≤ MFCMU frequency ≤ 10 kHz)
- *width* ≥ 10 ms (for 10 kHz < MFCMU frequency ≤ 200 kHz)
- *width* ≥ 8 ms (for 200 kHz < MFCMU frequency ≤ 5 MHz)

***period* :** Pulse period (in seconds). Numeric expression. 0, or 10 ms to 655.35 sec. 0.1 ms resolution. Initial or default setting = 10 ms.

- *period* ≥ *width* + 2 ms (for *width* ≤ 100 ms)
- *period* ≥ *width* + 10 ms (for 100 ms < *width*)

- *period* =0: Pulse period is automatically set as follows.
  - Pulse period = *width* + 2 ms (for *width* ≤ 100 ms)
  - Pulse period = *width* + 10 ms (for 100 ms < *width*)

***Tdelay* :** Trigger output delay time (in seconds). Numeric expression.

0 to *width*. 0.1 ms resolution. Initial or default setting = 0.

This parameter is the time from pulse leading edge to timing of trigger output from a trigger output terminal.

PV

The PV command specifies the pulsed voltage source and its parameters. This command also clears, and is cleared by, the PI command setting.

To set the timing of output pulse and measurement, use the PT and AIT2 commands.

In the staircase sweep with pulsed bias measurement mode (MM 5 command), the pulsed bias output will be synchronized with the staircase sweep outputs set by the WI or WV command.

If the output voltage is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

`PV chnum,vrange,base,pulse[,Icomp]`

Parameters

***chnum* :** SMU pulsed source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***vrange*:** Ranging type for the pulsed voltage output. Integer expression. The output range will be set to the minimum range that covers both *base* and *pulse* values. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-4 on page 4-18.

***base*, *pulse* :** Pulse base voltage or pulse peak voltage (in V). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. For using 3000 V range of HVSMU, *base* and *pulse* must have the same polarity.

***Icomp*:** Current compliance value (in A). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. If you do not set *Icomp*, the previous value is used.

Compliance polarity is automatically set to the same polarity as the output value, regardless of the specified *Icomp*. If the output value is 0, the polarity is set to positive.

Example Statements

```
OUTPUT @B1500;"PT 1,0.01"
OUTPUT @B1500;"PV 1,12,0,5,1E-3"

OUTPUT @B1500;"PT 1,0.01"
OUTPUT @B1500;"PV 2,0,0,3"
```

PWDCV

This command sets the pulsed voltage sweep source used for the pulsed sweep CV measurement (MM20). The sweep source will be the MFCMU, or the SMU that can be connected to the Force1/Sense1 terminals of the SCUU (SMU CMU unify unit).

Execution Conditions

The CN/CNX command has been executed for the specified channel.

If you want to apply DC voltage over ± 25 V, the SCUU must be connected correctly. The SCUU can be used with the MFCMU and two SMUs (MPSMU or HRSMU). The SCUU cannot be used if the HPSMU is connected to the SCUU or if the number of SMUs connected to the SCUU is only one.

If the output voltage is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

`PWDCV` *`chnum,mode,base,start,stop,step`*

Parameters

chnum **:** MFCMU source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

mode **:** Sweep mode. Integer expression. 1 or 3.

1: Linear sweep (single stair, start to stop.)

3: Linear sweep (double stair, start to stop to start.)

base, start, stop **:** Pulse base, start or stop voltage (in V). Numeric expression. For the log sweep or using 3000 V range of HVSMU, *base*, *start*, and *stop* must have the same polarity.

0 (initial setting) to ± 100 V.

With the SCUU, the source module is automatically selected by the setting value. The MFCMU is used if the *base*, *start*, and *stop* values are below ± 25 V (setting resolution: 0.001 V), or the SMU is used if they are greater than ± 25 V (setting resolution: 0.005 V).

The SMU will operate with the 100 V limited auto ranging and 20 mA compliance settings.

***step* :** Number of steps for the pulsed sweep. Numeric expression. 1 to 1001.

Example Statements

```
OUTPUT @B1500;"PTDCV 1,0.01,0.02"
OUTPUT @B1500;"PWDCV 9,1,0,-5,5,101"
```

PWI

The PWI command specifies the pulsed current sweep source and its parameters. This command clears the settings of the PWV, WSV and WSI commands. The settings specified by this command are cleared by the PWV command.

To set the timing of output pulse and measurement, use the PT and AIT2 commands.

Syntax

PWI *chnum*,*mode*,*range*,*base*,*start*,*stop*,*step*[,*Vcomp*[,*Pcomp*]
]

Parameters

***chnum* :** SMU pulsed sweep source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***mode* :** Sweep mode. Integer expression. 1 to 4.

1: Linear sweep (single stair, start to stop.)

2: Log sweep (single stair, start to stop.)

3: Linear sweep (double stair, start to stop to start.)

4: Log sweep (double stair, start to stop to start.)

***range* :** Ranging type for pulsed current sweep. Integer expression. The output range will be set to the minimum range that covers *base*, *start*, and *stop* values. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-5 on page 4-18.

***base*, *start*, *stop* :** Pulse base, start, or stop current (in A). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type. *base*, *start* and *stop* must have the same polarity.

step **:** Number of steps for pulsed sweep. Numeric expression. 1 to 1001.

Vcomp **:** Voltage compliance (in V). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type. If you do not specify *Vcomp*, the previous value is set. If *Vcomp* value is greater than ± 42 V, the interlock circuit must be shorted.

Compliance polarity is automatically set to the same polarity as the output value, regardless of the specified *Vcomp*. If the output value is 0, the polarity is set to positive.

Pcomp **:** Power compliance (in W). Numeric expression. Resolution: 0.001 W. If the *Pcomp* value is not entered, the power compliance is not set. The power compliance operation is based on the large one either pulse peak or base. This parameter is not available for HVSMU.

0.001 to 2 for MPSMU/HRSMU, 0.001 to 20 for HPSMU, 0.001 to 400 for HCSMU

Example Statements

```
OUTPUT @B1500;"PT 1,0.01"
OUTPUT @B1500;"PWI 1,1,0,0,0,0.1,101"
OUTPUT @B1500;"PT 1,0.01"
OUTPUT @B1500;"PWI 2,3,13,0,1E-7,1E-2,100,10"
```

PWV

The PWV command specifies the pulsed voltage sweep source and its parameters. This command also clears the settings of the PWI, WSV and WSI commands. The settings specified by this command are cleared by the PWI command.

To set the timing of output pulse and measurement, use the PT and AIT2 commands.

Syntax

PWV *chnum*,*mode*,*range*,*base*,*start*,*stop*,*step*[,*Icomp*[,*Pcomp*]]

Parameters

chnum **:** SMU pulsed sweep source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

mode **:** Sweep mode. Integer expression. 1 to 4.

1: Linear sweep (single stair, start to stop.)

2: Log sweep (single stair, start to stop.)

3: Linear sweep (double stair, start to stop to start.)

4: Log sweep (double stair, start to stop to start.)

***range*:** Ranging type for pulsed voltage sweep. Integer expression. The output range will be set to the minimum range that covers *base*, *start*, and *stop* values. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-4 on page 4-18.

***base*, *start*, *stop* :** Pulse base, start, or stop voltage (in V). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. If the output voltage is greater than ± 42 V, the interlock circuit must be shorted. For the log sweep or using 3000 V range of HVSMU, *base*, *start*, and *stop* must have the same polarity.

***step* :** Number of steps for pulsed sweep. Numeric expression. 1 to 1001.

***Icomp* :** Current compliance (in A). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. If you do not specify *Icomp*, the previous value is set.

Compliance polarity is automatically set to the same polarity as the output value, regardless of the specified *Icomp*. If the output value is 0, the polarity is set to positive.

***Pcomp* :** Power compliance (in W). Numeric expression. Resolution: 0.001 W. If the *Pcomp* value is not entered, the power compliance is not set. The power compliance operation is based on the large one either pulse peak or base. This parameter is not available for HVSMU.

0.001 to 2 for MPSMU/HRSMU, 0.001 to 20 for HPSMU, 0.001 to 400 for HCSMU

Example Statements

```
OUTPUT @B1500;"PT 1,0.01"
OUTPUT @B1500;"PWV 1,1,0,0,0,10,101"

OUTPUT @B1500;"PT 1,0.01"
OUTPUT @B1500;"PWV 2,3,14,0,1,10,100,0.1"
```

QSC

This command sets the QSCV measurement operation for the quasi-static CV measurement (MM13). For the QSCV measurement operation, see “Quasi-static CV Measurements” on page 2-27.

Syntax

`QSC` *`mode`*

Parameters

***mode* :** Operation mode of the QSCV measurement. Integer expression. 0 or 1.

0: Normal. Initial setting.

1: 4155C/4156C compatible.

Use the 4155C/4156C compatible mode (*mode*=1) to have a good compatibility with the measurement results by the 4155C/4156C.

Example Statements

```
OUTPUT @B1500;"QSC 1"
```

QSL

This command enables or disables the leakage current data output, and enables or disables the leakage current compensation for the quasi-static CV measurement (MM13).

Syntax

QSL *data,compen*

Parameters

data **:** Leakage current data output. Integer expression. 0 or 1.

0 : Disables data output. Initial setting.

1: Enables data output.

compen **:** Leakage current compensation. Integer expression. 0 or 1.

0 : Disables compensation. Initial setting.

1: Enables compensation.

Example Statements

```
OUTPUT @B1500;"QSL 0,0"
```

If you send the above command, the leakage current is not measured during the quasi-static CV measurements.

QSM

This command enables or disables the automatic abort function for the quasi-static CV measurement (MM13). The automatic abort function stops the measurement when one of the following conditions occurs.

- Compliance on the measurement channel
- Compliance on the non-measurement channel
- Overflow on the AD converter
- Oscillation on any channel

This command also sets the post measurement condition for the sweep source. After the measurement is normally completed, the sweep source forces the value specified by the *post* parameter.

If the measurement is stopped by the automatic abort function, the sweep source forces the start value.

Syntax

`QSM abort[,post]`

Parameters

***abort* :** Automatic abort function. Integer expression. 1 or 2.

1: Disables the function. Initial setting.

2: Enables the function.

***post* :** Source output value after the measurement is normally completed. Integer expression. 1 or 2.

1: Start value. Initial setting.

2: Stop value.

If this parameter is not set, the sweep sources force the start value.

Output Data

The B1500 returns the data measured before an abort condition is detected. Dummy data 199.999E+99 will be returned for the data after abort.

Example Statements

```
OUTPUT @B1500;"QSM 2"
OUTPUT @B1500;"QSM 2,2"
```

QSO

This command enables or disables the QSCV smart operation for the quasi-static CV measurement (MM13).

Execution Conditions

The QSCV measurement operation must be Normal (QSC 0).

Syntax

`QSO mode[,chnum[,Vcomp]]`

Parameters

***mode* :** QSCV smart operation. Integer expression. 0 or 1.

0: Disables the smart operation. Initial setting.

1: Enables the smart operation.

The QSCV smart operation is effective for the quasi-static CV measurement with large leakage current, and needs an additional SMU. The SMU must be specified by *chnum*.

Do not specify the following parameters when *mode*=0.

***chnum* :** SMU source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

The specified SMU is used to perform the QSCV smart operation. The SMU performs the current force operation to minimize the measurement error caused by an offset current.

***Vcomp* :** Voltage compliance (in V). Numeric expression. See Table 4-7 on page 4-20. If you do not specify *Vcomp*, the previous value is set.

This value is set to the SMU specified by *chnum*.

Example Statements

```
OUTPUT @B1500;"QSO 1,5,20"
```

QSR

This command sets the current measurement range used for the quasi-static CV measurement (MM13).

Syntax

QSR *range*

Parameters

***range* :** Current measurement range. Integer expression. -9 to -14.

-9: 10 pA range fixed.

-10: 100 pA range fixed.

-11: 1 nA range fixed. Initial setting.

-12: 10 nA range fixed.

-13: 100 nA range fixed.

-14: 1 μA range fixed.

Remarks

The range set by this command is used for both the leakage current measurement and the capacitance measurement.

Use the QST command to set the integration time of the capacitance measurement and the leakage current measurement.

Example Statements

```
OUTPUT @B1500;"QSR -10"
```

QST

This command sets the integration time, hold time, and delay time of the quasi-static CV measurement (MM13).

Syntax

QST *cinteg*,*linteg*,*hold*,*delay1*[,*delay2*]

Parameters

***cinteg* :** Integration time for the capacitance measurement, in seconds. Numeric expression. The available values are 0.02 to 400 s for a 50 Hz line frequency, and 0.016667 to 333.33 s for 60 Hz. But the value is rounded as follows:

cinteg = *n* / *selected line frequency* (*n* : integer. 1 to 20000.)

The initial setting is 5/ *selected line frequency*. So this value is 0.1 s for a 50 Hz line frequency, and approximately 0.083 s for 60 Hz.

***linteg* :** Integration time for the leakage current measurement, in seconds. Numeric expression. The available values are 0.02 to 2 s for a 50 Hz line frequency, and 0.016667 to 1.6667 s for 60 Hz. But the value is rounded as follows:

linteg = *n* / *selected line frequency* (*n* : integer. 1 to 100.)

The initial setting is 5/ *selected line frequency*. So this value is 0.1 s for a 50 Hz line frequency, and approx. 0.083 s for 60 Hz.

***hold* :** Hold time (in seconds). Numeric expression. This is the time from the start of the first sweep step to the beginning of the delay time (*delay1*).

0 to 655.35 sec. 0.01 sec resolution. Initial setting = 0.

***delay1* :** Delay time (in seconds). Numeric expression. This is the time from the start of each sweep step to the start of the measurement.

0 to 65.535 sec. 0.0001 sec resolution. Initial setting = 0.

***delay2* :** Delay time (in seconds). Numeric expression. This is the time from the end of the each sweep step to the start of the next sweep step or the end of the sweep. *delay2* is not effective for the spot measurement.

0 to 65.535 sec. 0.0001 sec resolution. Initial setting = 0.

Example Statements

```
OUTPUT @B1500;"QST 0.35,0.1,5,0.2,0.2"
```

This example sets a hold time of 5 s and a delay time of 0.2 s for *delay1* and *delay2*. The integration time for the capacitance measurement is 0.35 s for a line frequency of 60 Hz, and 0.36 s for 50 Hz. The integration time for the leakage current is 0.1 s for 50 Hz and 60 Hz.

Where, 0.35 is equal to 21 / 60 and 17.5 / 50. This means 0.35 s is not a suitable value for the integration time at 50 Hz. Because *n* must be integer. In this case, the integration time is automatically set to 0.36 s (=18 / 50). *n* is rounded to 18, not 17.

QSV

This command specifies the voltage sweep source and its parameters for the quasi-static CV measurement (MM13).

Execution Conditions

If you do not specify the channel number for the MM command, the channel specified by the QSV command forces the sweep voltage, and measures the capacitance.

Syntax

`QSV chnum,mode,vrange,start,stop,cvoltage,step[,Icomp]`

Parameters

***chnum* :** SMU source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***mode* :** Sweep mode. Integer expression. 1 or 3.

1: Linear sweep (single stair, start to stop.)

3: Linear sweep (double stair, start to stop to start.)

***vrange* :** Ranging type. Integer expression. The output range will be set to the minimum range that covers both *start* and *stop* values. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-4 on page 4-18.

***start, stop* :** Start or stop voltage (in V). Numeric expression. See Table 4-6 on page 4-19.

0 to ± 100 for MPSMU/HRSMU, or 0 to ± 200 for HPSMU

This value is the upper or lower limit of the sweep output voltage.

***cvoltage* :** Capacitance measurement voltage (in V).

The minimum value is double the resolution of the output range, and the maximum value is 10 V. The value must be ≤ |sweep step voltage| you desire. If you set the value greater than |sweep step voltage|, the *cvoltage* is automatically set to the same value as |sweep step voltage|. See *step*.

NOTE

In the QSCV measurement, the B1500 executes the capacitance measurement at the sweep steps except for the sweep start voltage and stop voltage. At each sweep step, the capacitance measurement is executed over the voltage range: output voltage ± *cvoltage*/2 (V).

step **:** The number of steps for the voltage sweep. 1 to 1001. Integer expression. Define the sweep step voltage at first, then calculate the *step* value by using the following formula.

step = |*start* - *stop*| / |sweep step voltage| - 1

If you set *step*=1 and |*stop*–*start*| ≤ 10, the B1500 executes a one-point capacitance measurement between the *start* and *stop* values. Then *cvoltage* value is ignored.

Icomp **:** Current compliance (in A). Numeric expression. See Table4-6 on page 4-14. If you do not set *Icomp*, the previous value is used.

The current compliance polarity is automatically set to the same polarity value as the output voltage, regardless of polarity of the specified *Icomp*.

Example Statements

```
OUTPUT @B1500;"QSV 1,1,0,0,5,1,4,0.1"
```

This example sets the following parameter values:

start=0 V, *stop*=5 V, *cvoltage*=1 V, *step*=4

This sets the sweep step voltage to 1 V. And the capacitance measurement is then executed over the following voltage ranges:

1st sweep step: 0.5 to 1.5 V

2nd sweep step: 1.5 to 2.5 V

3rd sweep step: 2.5 to 3.5 V

4th sweep step: 3.5 to 4.5 V

For easy definition, use variables to set the parameters as shown below:

```
Start=0     !Start voltage (V)
Stop=5      !Stop voltage (V)
Cvolt=1     !C meas voltage (V)
Svolt=1     !Sweep step voltage (V)
Nop=ABS(Start-Stop)/Svolt-1 ! Number of steps
!
OUTPUT @B1500;"QSV 1,1,0,Start,Stop,Cvolt,Nop,0.1"
```

QSZ

This command enables/disables the capacitance offset cancel function for the quasi-static CV measurement (MM13). Or this command triggers the capacitance offset measurement, and returns the measurement result.

Execution Conditions

The quasi-static CV measurement setup must be completed before executing the offset measurement.

To execute the offset measurement, open the measurement terminals at the end of the device side.

Syntax

`QSZ` *`mode`*

Parameters

mode **:** Capacitance offset cancel function. Integer expression. 0 to 2.

0: Disables the function. Initial setting.

1: Enables the function.

2: Performs a capacitance offset measurement, and returns the result.

The `QSZ 2` command does not enable the capacitance offset cancel function.

Example Statements

```
OUTPUT @B1500;"QSZ 2"
OUTPUT @B1500;"*OPC?"
ENTER @B1500;A
ENTER @B1500 USING "#,3X,13D,X";Offset
```

```
OUTPUT @B1500;"QSZ 1"
```

RC

The RC command specifies the measurement range or the measurement ranging type of the MFCMU. In the initial setting, the auto ranging is set. The range changing occurs immediately after the trigger (that is, during the measurements).

For the high speed spot measurement, use the TC/TTC command.

The range setting is cleared by the CL, CA, IN, *TST?, *RST or a device clear (HP BASIC CLEAR) command.

Syntax

`RC chnum,mode[,range]`

Parameters

***chnum* :** MFCMU measurement channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***mode* :** Ranging mode. 0 (auto ranging. initial setting) or 2 (fixed range).

***range* :** Measurement range. Needs to set when *mode*=2. Integer (0 or more). 50 Ω, 100 Ω, 300 Ω, 1 kΩ, 3 kΩ, 10 kΩ, 30 kΩ, 100 kΩ, and 300 kΩ are selectable. See Table 4-13 on page 4-24. Available measurement ranges depend on the output signal frequency set by the FC command.

Example Statements

```
OUTPUT @B1500;"RC 8,0"
OUTPUT @B1500;"RC 8,2,10000"
```

RCV

This command enables the modules that fail the self-test or self-calibration so that it can receive commands again.

The *OPC? command should be entered to confirm the completion of the module recovery.

This command should only be used for servicing the B1500.

Syntax

`RCV [slot]`

Parameters

***slot* :** Slot number where the failed module to enable has been installed. 1 to 10. Or 0 or 11. Integer expression.

0: All failed modules. Default setting.

11: Mainframe.

If *slot* specifies the slot that installs no module, this command causes an error.

Example Statements

```
OUTPUT @B1500;"RCV 1"
OUTPUT @B1500;"*OPC?"
ENTER @B1500;A
```

Remarks

When a SMU connected to SCUU is recovered, the MFCMU is also recovered. The SCUU cannot be controlled if a failed module is connected.

RI

The RI command specifies the current measurement range or ranging type. In the initial setting, the auto ranging is set. The range changing occurs immediately after the trigger (that is, during the measurements). Current measurement channel can be decided by the CMM command setting and the channel output mode (voltage or current).

For the high speed spot measurement, use the TI/TTI command.

The range setting is cleared by the CL, CA, IN, *TST?, *RST or a device clear (HP BASIC CLEAR) command.

Syntax

```
RI chnum,range
```

Parameters

***chnum* :** SMU current measurement channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***range* :** Measurement range or ranging type. Integer expression. See Table 4-3 on page 4-16.

If you select the fixed range, the instrument performs measurement by using the specified range.

For the auto or limited auto ranging, the measurement range will be set to the minimum range that covers the measured values. However, the instrument never uses the range less than the specified range for the limited auto ranging.

For the measurement mode that uses pulse source, if you select the auto or limited auto ranging, the measurement channel uses the minimum range that covers the compliance value or current output range.

NOTE

To use 1 pA range

The measurement channel connected to the ASU (Atto Sense and Switch Unit) supports the 1 pA range. To use the 1 pA range, set the 1 pA fixed range or the 1 pA limited auto ranging.

To enable the 1 pA range for the auto ranging mode, execute the SAR command.

Example Statements

```
OUTPUT @B1500;"RI 1,0"
OUTPUT @B1500;"RI 2,-20"
```

RM

This command specifies the auto range operation for the current measurement.

Syntax

`RM chnum,mode[,rate]`

where the *rate* parameter is available for *mode*=2 or 3.

Parameters

***chnum* :** SMU current measurement channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***mode* :** Range changing operation mode. Integer expression. 1, 2 or 3.

mode	Description
1	Initial setting. If you set *mode*=1, do not set *rate*.
2	If measured data ≥ *current1*, the range changes up after measurement.
3	If measured data ≤ *current2*, the range changes down immediately, and if measured data ≥ *current1*, the range changes up after measurement.

where *current1* and *current2* are given by the following formula:

current1 = *measurement range* × *rate* /100
current2 = *measurement range* × *rate* /1000

For example, if *measurement range*=10 mA and *rate*=90, these values are as follows:

current1 = 9 mA
current2 = 0.9 mA

***rate*:** Parameter used to calculate the *current* value. Numeric expression. 11 to 100. Default setting is 50.

Example Statements

```
OUTPUT @B1500;"RM 1,2"
OUTPUT @B1500;"RM 2,3,60"
```

*RST

The *RST command resets the B1500 to the initial settings.

Syntax

`*RST`

Remarks

If you want to reset channels while a sweep measurement is being performed, you must first send the AB command, then the *RST command.

The *RST command does not clear the following data.

- Program memory setup data
- Self-calibration data
- MFCMU phase compensation data
- MFCMU open/short/load correction data

Example Statement

```
OUTPUT @B1500;"*RST"
```

RU

The RU command sequentially executes the internal memory programs.

Execution Conditions

The specified programs have been stored by using the ST and END commands, from the start program number through the stop program number.

Syntax

RU *start*,*stop*

Parameters

***start* :** Start program number. Numeric expression. 1 to 2000.

***stop* :** Stop program number. Numeric expression. 1 to 2000.

where *stop* value must be greater than or equal to the *start* value.

Example Statements

```
OUTPUT @B1500;"RU 1,10"
OUTPUT @B1500;"RU 3,6"
```

RV

The RV command specifies the voltage measurement range or ranging type. In the initial setting, the auto ranging is set. The range changing occurs immediately after the trigger (that is, during the measurements). Voltage measurement channel can be decided by the CMM command setting and the channel output mode (voltage or current).

For the high speed spot measurement, use the TV/TTV command.

The range setting is cleared by the CL, CA, IN, *TST?, *RST or a device clear (HP BASIC CLEAR) command.

Syntax

RV *chnum*,*range*

Parameters

***chnum* :** SMU voltage measurement channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***range* :** Measurement range or ranging type. Integer expression. See Table 4-2 on page 4-15.

If you select the fixed range, the instrument performs measurement by using the specified range.

For the auto or limited auto ranging, the measurement range will be set to the minimum range that covers the measured values. However, the instrument never uses the range less than the specified range for the limited auto ranging.

For the measurement mode that uses pulse source, if you select the auto or limited auto ranging, the measurement channel uses the minimum range that covers the compliance value or voltage output range.

Example Statements

```
OUTPUT @B1500;"RV 2,-15"
OUTPUT @B1500;"RV 1,12"
```

RZ

The RZ command returns the channel to the settings that are stored by the DZ command and clears the stored settings.

The DZ command stores the channel settings (V/I output values, V/I output ranges, V/I compliance values, and so on), then sets the channel to 0 V.

Execution Conditions

The channel setup has not been changed since the DZ command has been executed for the specified channel. And the CL, CA, *TST?, *RST or a device clear (HP BASIC CLEAR) command has not been executed for the specified channel.

Syntax

RZ [*chnum*[,*chnum*...[,*chnum*]...]]

A maximum of 15 channels can be set.

Parameters

***chnum* :** Channel number. Integer expression. See Table 4-1 on page 4-14.

If you specify multiple *chnum*s, the B1500 returns the stored settings in the order specified.

If you do not specify *chnum*, this command returns the settings for all SMU, all SPGU, and CMU that satisfy the conditions described in “Execution Conditions” above, in this order. For the modules of same kind, the settings will be restored in reverse order from their storage by the DZ command.

Example Statements

```
OUTPUT @B1500;"RZ"
OUTPUT @B1500;"RZ 1,2,3"
```

SAL

This function is available for the Agilent B1500 installed with the high resolution SMU (HRSMU) and the atto sense and switch unit (ASU).

Disables or enables the connection status indicator (LED) of the ASU. This command is effective for the specified channel.

Syntax

SAL *chnum*,*mode*

Parameters

***chnum* :** Channel number of the HRSMU connected to the ASU. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***mode* :** 0: Disables the indicator.

1: Enables the indicator. Default setting.

Example Statements

```
OUTPUT @B1500;"SAL 1,0"
```

SAP

This function is available for the Agilent B1500 installed with the high resolution SMU (HRSMU) and the atto sense and switch unit (ASU). This command is not effective when the High Voltage indicator of the Agilent B1500 has been lighted.

Controls the connection path of the ASU. Switches the ASU input resource (HRSMU or the instrument connected to the AUX input) to be connected to the ASU output. This command is effective for the specified channel.

After the Agilent B1500 is turned on or the CL command is entered, the ASU output will be connected to the SMU connector side, but the HRSMU will not be enabled yet. After this command is entered with *path*=1, the HRSMU specified by *chnum* cannot be used. After this command is entered with *path*=0 or the CN command is entered, the HRSMU output will appear on the ASU output.Then the HRSMU output will be 0 V.

NOTE

To use ASU

To use the ASU, connect it to the correct HRSMU properly before turning the Agilent B1500 on. For the connection, see *User's Guide*.

The ASU will add the connection switch function described above to the B1500 and the 1 pA measurement range to the HRSMU. Use the SAR function to enable/disable the 1 pA range for the auto ranging operation.

Remember that the series resistor in the HRSMU connected to the ASU cannot be used.

Syntax

`SAP` *`chnum,path`*

Parameters

chnum **:** Channel number of the HRSMU connected to the ASU. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

path **:** 0: The ASU output will be connected to the SMU connector side.

1: The ASU output will be connected to the AUX connector side.

Example Statements

```
OUTPUT @B1500;"SAP 1,1"
```

SAR

This function is available for the Agilent B1500 installed with the high resolution SMU (HRSMU) and the atto sense and switch unit (ASU).

Enables or disables the 1 pA range for the auto ranging operation. This command is effective for the specified channel.

Syntax

`SAR` *`chnum,mode`*

Parameters

chnum **:** Channel number of the HRSMU connected to the ASU. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

mode **:** 0: Enables 1 pA range for the auto ranging operation.

1: Disables 1 pA range for the auto ranging operation. Initial setting

Example Statements

```
OUTPUT @B1500;"SAR 1,0"
```

SCR

The SCR command scratches the specified program from the internal program memory.

Syntax

`SCR [`*`pnum`*`]`

Parameters

pnum : Program number. Numeric expression. 1 to 2000.
If you do not specify this parameter, this command scratches all programs stored in the internal program memory.

Example Statements

```
OUTPUT @B1500;"SCR"
OUTPUT @B1500;"SCR 5"
```

SER

This command sets the load impedance connected to the specified SPGU channel. Set for each channel.

This load impedance value is used for automatic adjustment of the SPGU output voltage. Setting the correct value will make the voltage applied to the DUT close to the voltage set with the SPV command. To automatically set the load impedance, execute the CORRSER? command.

Syntax

SER *chnum*, *loadZ*

Parameters

mode : SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1.

loadZ : Load impedance value (Ω). Numeric expression. 0.1 Ω to 1 MΩ. Initial setting: 50 Ω.

Remarks

The recommended load impedance ranges are shown below.

Measured voltage: 1 V or more

Minimum load: 40 Ω

Maximum load: 500 Ω (at 1 V), 2 kΩ (at 5 V), 5 kΩ (at 10 V)

Example Statements

```
OUTPUT @B1500;"SER 101,1000000"
```

See Also

“CORRSER?”

SER?

This query command returns the load impedance value set for the specified SPGU channel.

Syntax

SER? *chnum*

Parameters ***chnum*** **:** SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1.

Query Response `loadZ<CR/LF^EOI>`

Returns the load impedance value (Ω).

Example Statements

```
OUTPUT @B1500;"SER? 101"
ENTER @B1500;A
```

SIM

The SIM command sets the SPGU operation mode, PG or ALWG. The setting is effective for the all SPGU modules installed in the B1500. This command also triggers 0 V output of the SPGU channels which output switch has been ON.

Syntax `SIM mode`

Parameters ***mode*** **:** SPGU operation mode. Integer expression. 0 or 1.

0: PG (pulse output) mode

1: ALWG (arbitrary linear wave output) mode

Example Statements

```
OUTPUT @B1500;"SIM 1"
```

SIM?

This query command returns the present SPGU operation mode of the B1500.

Syntax `SIM?`

Response `mode<CR/LF^EOI>`

0: PG (pulse output) mode

1: ALWG (Arbitrary linear wave output) mode

Example Statements

```
OUTPUT @B1500;"SIM?"
ENTER @B1500;A
```

SPM

This command specifies the output mode of the specified SPGU channel. Set for each channel.

Execution Conditions

The SPGU operating mode must be set to PG with the SIM 0 command.

Syntax

`SPM chnum,mode`

Parameters

***chnum* :** SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1.

***mode* :** Settings for the output signal source. Integer expression.

0: DC voltage output mode.

1: 2-level pulse output mode using pulse signal source 1.

2: 2-level pulse output mode using pulse signal source 2.

3: 3-level pulse output mode using pulse signal source 1 and 2.

Example Statements

```
OUTPUT @B1500;"SPM 101,3"
```

SPM?

This query command returns the output mode of the specified SPGU channel.

Syntax

`SPM? chnum`

Parameters

***chnum* :** SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1.

Query Response

`mode<CR/LF^EOI>`

0: DC voltage output mode.

1: 2-level pulse output mode using pulse signal source 1.

2: 2-level pulse output mode using pulse signal source 2.

3: 3-level pulse output mode using pulse signal source 1 and 2.

Example Statements

```
OUTPUT @B1500;"SPM? 101"
ENTER @B1500;A
```

SPP

This command stops all channel outputs and all trigger outputs of the SPGU simultaneously. The output goes to the following value.

- *base* value set by the SPV command, in PG mode

- initial value of waveform, in ALWG mode

This command does not stop the SPGU DC bias output.

Syntax

```
SPP
```

Example Statements

```
OUTPUT @B1500;"SPP"
```

SPPER

This command sets the pulse period for the SPGU channel. This setting applies to all SPGU modules installed in the B1500. See “SPGU Module” on page 2-52.

Syntax

SPPER *period*

Parameters

period **:** Pulse period. Numeric expression. 2E-8 to 10 seconds, setting resolution 1E-8 seconds. Initial setting 1E-6 seconds.

Example Statements

```
OUTPUT @B1500;"SPPER 20E-6"
```

SPPER?

This query command returns the pulse period for the SPGU channel.

Syntax

```
SPPER?
```

Query Response

period<CR/LF^EOI>

Returns the pulse period (seconds).

Example Statements

```
OUTPUT @B1500;"SPPER?"
ENTER @B1500;A
```

SPRM

This command specifies the operating mode for SPGU channel outputs. This setting applies to all SPGU modules installed in the B1500.

Syntax

SPRM *mode*[,*condition*]

Parameters

mode **:** Operating mode of the SPGU channel output. Integer expression. 0, 1, or 2. Initial setting 0.

0: Free Run mode. Continues outputting until the SPP command is executed. The *condition* parameter is not required.

1: Count mode. Outputs the number of pulses (when set to PG mode with the SIM 0 command), or the number of sequences (when set to ALWG mode with the SIM 1 command) specified by the *condition* parameter.

2: Duration mode. Outputs for a duration specified by the *condition* parameter.

condition **:** Number of pulses or sequences to output, or output duration (seconds). Numeric expression. The following values are valid for the *condition* parameter.

When *mode* = 1, 1 (initial value) to 1,000,000 times.

When *mode* = 2, IE-6 (initial setting) to 31,556,926 seconds (1 year), setting resolution 1E-8 seconds.

Example Statements

```
OUTPUT @B1500;"SPRM 1,300"
```

SPRM?

This query command returns the operating mode and settings of the SPGU channel output.

Syntax

```
SPRM?
```

Query Response

mode[,*condition*]<CR/LF^EOI>

mode **:** Returns the operating mode of the SPGU channel output. Integer expression.

0: Free run mode. *condition* is not returned.

1: Count mode.

2: Duration mode.

condition **:** Returns the number of pulses or sequences to output, or output duration (seconds). Numeric expression.

When *mode* = 1, returns the number of outputs (times).

When *mode* = 2, returns the duration of the output (seconds).

Example Statements

```
OUTPUT @B1500;"SPRM?"
ENTER @B1500;A,B
```

SPST?

This query command returns the waveform output state of the SPGU.

Syntax

`SPST?`

Query Response

state<CR/LF^EOI>

0: Pulse output inactive or ALWG sequence output inactive

1: Pulse output active or ALWG sequence active

Example Statements

```
OUTPUT @B1500;"SPST?"
ENTER @B1500;A
```

SPT

This command sets the pulse timing parameter for the specified SPGU channel. Set for each channel. For the parameters, see Figure 2-31 on page 2-56.

Execution Conditions

The SPGU operating mode must be set to PG with the SIM 0 command.

Syntax

SPT *chnum*,*src*,*delay*,*width*,*leading*[,*trailing*]

Parameters

chnum **:** SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1.

src **:** Channel signal source. Integer expression.

1: Pulse signal source 1

2: Pulse signal source 2

delay **:** Pulse delay time. Numeric expression. 0 to *pulse period*-2E-8 seconds, setting resolution 2.5E-9 seconds. Initial setting 0 second.

Setting resolution becomes 1E-8 when *leading* > 8E-6 seconds or *trailing* > 8E-6 seconds.

width **:** Pulse width. Numeric expression.1E-8 to *pulse period*-1E-8 seconds, setting resolution 2.5E-9 seconds. Initial setting 1E-7 seconds.

Setting resolution becomes 1E-8 when *leading* > 8E-6 seconds or *trailing* > 8E-6 seconds.

leading **:** Pulse leading time. Numeric expression. 8E-9 to 0.4 seconds, setting resolution 2E-9 seconds. Initial setting 2E-8 seconds.

Setting resolution becomes 8E-9 when *leading* > 8E-6 seconds or trailing > 8E-6 seconds.

***trailing* :** Pulse trailing time. Numeric expression. 8E-9 to 0.4 seconds, setting resolution 2E-9 seconds. Initial setting 2E-8 seconds.

Setting resolution becomes 8E-9 when *leading* > 8E-6 seconds or *trailing* > 8E-6 seconds.

If no value is set for *trailing*, the *leading* value will be used for both parameters.

Example Statements

```
OUTPUT @B1500;"SPT 101,1,0,5E-7,20E-9"
```

SPT?

This query command returns the pulse timing parameter of the specified SPGU channel signal source.

Syntax

SPT? *chnum*,*src*

Parameters

***chnum* :** SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1.

***src* :** Channel signal source. Integer expression.

1: Pulse signal source 1

2: Pulse signal source 2

Query Response

delay,*width*,*leading*,*trailing*<CR/LF^EOI>

***delay* :** returns the pulse delay time (seconds).

***width* :** returns the pulse width (seconds).

***leading* :** returns the pulse leading time (seconds).

***trailing* :** returns the pulse trailing time (seconds).

Example Statements

```
OUTPUT @B1500;"SPT? 101,1"
ENTER @B1500;A,B,C,D
```

SPUPD

The SPUPD command applies the setup of the specified SPGU channels.

The channel output is changed to the following value by this command. And the waveform or pulse output is started by the SRP command.

- *base* value set by the SPV command, in PG mode
- initial value of waveform, in ALWG mode

If a DC bias output channel is specified in the SPUPD command, the channel starts the DC bias voltage output. And the output is not changed by the SRP command.

Syntax

`SPUPD chnum[,chnum...[,chnum[,chnum]]...]`

A maximum of ten channels can be set.

Parameters

chnum **:** SPGU channel number. Integer expression. 1 to 10 or 101 to 1002.

If multiple *chnum*s are specified, all outputs are started in the specified order. The channel numbers 1 to 10 correspond to the channel numbers 101 to 1001 respectively. See Table 4-1 on page 4-14.

Example Statements

```
OUTPUT @B1500;"CN 101,102,201,202"
OUTPUT @B1500;"SPUPD 101,102,201,202"
OUTPUT @B1500;"SRP"
```

SPV

This command sets the output voltage of the specified SPGU channel. Set for each channel. For the parameters, see Figure 2-31 on page 2-56.

Execution Conditions

The SPGU operating mode must be set to PG with the SIM 0 command.

Syntax

`SPV chnum,src,base[,peak]`

Parameters

chnum **:** SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1.

src **:** Channel signal source. Integer expression. Initial setting 1.

0: DC bias source

1: Pulse signal source 1

2: Pulse signal source 2

base **:** Pulse base voltage or DC output voltage. Numeric expression. -40 V to 40 V, setting resolution 1 mV. Initial setting 0 V.

***peak* :** Pulse peak voltage. Numeric expression. -40 V to 40 V, setting resolution 1 mV. Initial setting 0 V.

If no value is set for *peak*, the *base* value will be used for both parameters.

The *peak* parameter has no effect on DC bias sources.

Example Statements

```
OUTPUT @B1500;"SPV 101,1,-0.5,0.5"
```

SPV?

This query command returns the voltage parameter of the specified SPGU channel signal source.

Syntax

SPV? *chnum*,*src*

Parameters

***chnum* :** SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1.

***src* :** Channel signal source. Integer expression.

0: DC bias source

1: Pulse signal source 1

2: Pulse signal source 2

Query Response

base,*peak*<CR/LF^EOI>

***base* :** pulse base voltage (V) or DC output voltage (V)

***peak* :** pulse peak voltage (V) or DC output voltage (V)

Example Statements

```
OUTPUT @B1500;"SPV? 101,1"
ENTER @B1500;A,B
```

*SRE

The *SRE command enables the specified bits of the status byte register for SRQ (service requests), and masks (disables) the bits that are not specified.

Syntax

*SRE *bit*

Parameters

***bit* :** Sum of the decimal values corresponding to the bits to be enabled. Integer expression. 0 to 255. See Table 4-25.

For example, to enable Bit 0 and 4 for the SRQ, the *bit* value must be 17 (1+16).

If *bit*=0, all bits, except for Bit 6, will be masked (disabled for the SRQ). You cannot mask bit 6.

Example Statements

```
OUTPUT @B1500;"*SRE 6"
OUTPUT @B1500;"*SRE 32"
```

Table 4-25 **Status Byte Register**

Decimal Value	Bit Number	Description
1	Bit 0	data ready
2	Bit 1	wait
4	Bit 2	not used
8	Bit 3	interlock open
16	Bit 4	set ready
32	Bit 5	error
64	Bit 6	RQS
128	Bit 7	not used

*SRE?

The *SRE? query command returns information about which bits of the status byte register are enabled for the SRQ (service requests), and stores the results in the output data buffer (query buffer).

Syntax `*SRE?`

Query Response *enabled_bits*<CR/LF^EOI>

enabled_bits are represented by the corresponding decimal values shown in Table 4-25. For example, if Bit 0, 3, and 4 are enabled for the SRQ, 25 (1 + 8 + 16) will be returned.

If all bits, except for Bit 6, are masked, *enabled_bits* will be 0.

Example Statements

```
OUTPUT @B1500;"*SRE?"
ENTER @B1500;A
```

SRP

The SRP command starts the SPGU output. If multiple outputs are defined, all outputs are started in the order from lower to higher channel number 101 to 1002. And all waveform or pulse outputs are started simultaneously.

Syntax

```
SRP
```

Example Statements

```
OUTPUT @B1500;"SRP"
```

SSL

This function is available for the Agilent B1500 installed with the multi frequency capacitance measurement unit (MFCMU) and the SMU CMU unify unit (SCUU). To use the SCUU, connect it to the MFCMU and two SMUs (MPSMU or HRSMU) correctly. The SCUU cannot be used with the HPSMU or when only one SMU is connected.

Disables or enables the connection status indicator (LED) of the SCUU.

Syntax

SSL *chnum*,*mode*

Parameters

***chnum* :** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***mode* :** 0: Disables the indicator.

1: Enables the indicator. Initial setting.

Example Statements

```
OUTPUT @B1500;"SSL 9,0"
```

NOTE

To use SCUU

Before turn the Agilent B1500 on, connect the SCUU to the MFCMU and two MPSMU/HRSMUs properly. The SCUU is used to switch the module (SMU or MFCMU) connected to the DUT.

SSP

This function is available for the Agilent B1500 installed with the multi frequency capacitance measurement unit (MFCMU) and the SMU CMU unify unit (SCUU). To use the SCUU, connect it to the MFCMU and two SMUs (MPSMU or HRSMU) correctly. The SCUU cannot be used with the HPSMU or when only one SMU is connected.

Controls the connection path of the SCUU. Switches the SCUU input resource (MFCMU or SMU) to be connected to the SCUU output.

When the B1500 is turned on, the SCUU input to output connection is not made (open). When the SCUU input to output connection is made, the measurement unit output switch will be automatically set to ON.

Syntax

`SSP chnum,path`

Parameters

***chnum* :** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***path* :** Path connected to the SCUU output. 1 to 4. See Table 4-26.

Example Statements

```
OUTPUT @B1500;"SSP 9,4"
```

Remarks

When the connection is changed from SMU to MFCMU, the SMU output will be set as follows. The other setup parameters are not changed.

Output voltage	0 V
Output range	100 V
Compliance	20 mA
Series resistance	OFF

When the connection is changed from MFCMU to SMU, the SMU output will be set as follows. The other setup parameters are not changed.

Output voltage	0 V
Output range	20 V
Compliance	100 μA
Series resistance	Condition before the connection is changed from SMU to MFCMU

Table 4-26 **SCUU Input Output Connection Control**

Command	SCUU output connection after the command	
	CMUH/Force1/Sense1	CMUL/Force2/Sense2
SSP *chnum*, 1	Force1/Sense1	Open
SSP *chnum*, 2	Open	Force2/Sense2
SSP *chnum*, 3	Force1/Sense1	Force2/Sense2
SSP *chnum*, 4	CMUH	CMUL

Force1/Sense1 is connected to the SMU installed in the slot numbered *slot*-1.

Force2/Sense2 is connected to the SMU installed in the slot numbered *slot*-2.

where, *slot* is the slot number given by *chnum*.

NOTE

To use SCUU

Before turn the Agilent B1500 on, connect the SCUU to the MFCMU and two MPSMU/HRSMUs properly. The SCUU is used to switch the module (SMU or MFCMU) connected to the DUT.

SSR

This command sets the connection mode of a SMU series resistor (approx. 1 MΩ) for each channel.

If the output switch is opened, the SSR command just sets the mode, and the CN command connects or disconnects the series resistor.

If the output switch is already closed, the SSR command connects the series resistor to the SMU output. Then the output forces 0 V one moment.

A series resistor is mounted on each module. If you use a series resistor, the voltage you set is applied to the near side of the series resistor. Thus, the voltage will be divided by the series resistor and the device under test.

Execution Conditions

The series resistor cannot be used for the measurements that use the HCSMU, the HVSMU, the HRSMU connected to the atto sense and switch unit (ASU), or the measurements that use 1 A range of the HPSMU.

The channel must not be in the high voltage state (forcing more than ± 42 V, or voltage compliance set to more than ± 42 V).

Syntax

`SSR chnum,mode`

Parameters

chnum **:** SMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

mode **:** Status of the series resistor. Integer expression.

0: Disconnect (initial setting).

1: Connect.

Example Statements

```
OUTPUT @B1500;"SSR 1,1"
OUTPUT @B1500;"SSR 2,1"
```

ST

The ST command is used with the END command to store a program in the internal program memory that can store 2,000 programs maximum, and a total of 40,000 commands.

The ST command indicates the start of the program, and assigns the program number. If the assigned program number already exists, the B1500 deletes the old program, and stores the new one.

The END command indicates the end of the program. If the END command is not included, the B1500 stores the commands until the program memory is full.

Use the DO or RU command to execute stored programs.

Syntax

`STpnum[;command[;command...[;command]...];END`

or

```
ST pnum
[command]
[command]
    :
[command]
END
```

Parameters

pnum **:** Program number. Integer expression. 1 to 2000.

command **:** Command stored in the internal program memory. Specify commands according to normal syntax – no special syntax is necessary.

For the commands that cannot stored in the program memory, refer to Table 2-1 on page 2-51.

Example Statements

Example 1:

```
OUTPUT @B1500;"ST1;CN1;DV1,0,5,1E-4;TI1,0;CL1"
OUTPUT @B1500;"END"
```

Example 2:

```
OUTPUT @B1500;"ST 1"
OUTPUT @B1500;"CN 1"
OUTPUT @B1500;"DV 1,0,5,1E-4"
OUTPUT @B1500;"TI 1,0"
OUTPUT @B1500;"CL 1"
OUTPUT @B1500;"END"
```

*STB?

The *STB? query command stores the decimal representation of the status byte in the output data buffer (query buffer).

The *STB? command is functionally identical to the SPOLL command of BASIC, however this command does not clear the status byte (the SPOLL command clears the status byte).

Syntax

```
*STB?
```

Example Statements

```
OUTPUT @B1500;"*STB?"
ENTER @B1500;A
```

Query Response

`*status_byte*<CR/LF^EOI>`

status_byte value is a decimal number that indicates which bits of the status byte are ON (“1”). See Table 4-25.

For example, if *status_byte* is 40 (8 + 32), then Bit 3 and 5 are set to 1.

STGP

This command specifies the trigger output timing for the specified SPGU channel. This setting applies commonly to all channels in the same SPGU module. See “SPGU Module” on page 2-52 for details on the SPGU trigger.

Syntax

STGP *chnum*,*state*

Parameters

***chnum* :** SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1.

state **:** Trigger output state. Integer expression. Initial setting 0.

- **0** trigger output disabled.
- **1** Output trigger signals synchronized to the pulses (PG mode), or to the start of the ALWG sequence.
- **2** Output a trigger when the ALWG pattern changes, or at start of the first pattern.
- **3** Output triggers at the start of every ALWG pattern.

Example Statements

```
OUTPUT @B1500;"STGP 101,1"
```

STGP?

This query command returns the trigger output state of the specified SPGU channel.

Syntax

STGP? *chnum*

Parameters

chnum **:** SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1.

Query Response

state<CR/LF^EOI>

- **0** Trigger output disabled.
- **1** Output trigger signals synchronized to the pulses (PG mode), or to the start of the ALWG sequence.
- **2** Output a trigger when the ALWG pattern changes, or at start of the first pattern.
- **3** Output triggers at the start of every ALWG pattern.

Example Statements

```
OUTPUT @B1500;"STGP? 101"
ENTER @B1500;A
```

TACV

This command forces AC voltage from the MFCMU, and returns the time data from timer reset to the start of output.

Execution Conditions

The CN/CNX command has been executed for the specified channel.

The FC command has been executed to set the frequency of the AC voltage.

This command is not effective for the 4 byte binary data output format (FMT3 and FMT4).

Syntax

```
TACV chnum,voltage
```

Parameters

chnum **:** MFCMU source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

voltage **:** Oscillator level of the output AC voltage (in V). Numeric expression.

0 (initial setting) to 0.25 V, 0.001 V step.

Remarks

To read the time data with the best resolution (100 μs), the timer must be cleared every 100 sec or less for the FMT1, 2, or 5 data output format, or every 1000 sec or less for the FMT 11, 12, 15, 21, 22, or 25 data output format.

Example Statements

```
OUTPUT @B1500;"TACV 7,0.01"
ENTER @B1500 USING "#,3X,13D,X";Time
```

TC

The TC command performs the high speed spot measurement by using the MFCMU, and returns the measurement data. The command starts a measurement regardless of the trigger mode (TM command) and the measurement mode (MM command).

The MFCMU measures the primary parameter and the secondary parameter (for example, Cp and G). Use the IMP command to select the measurement parameters. See “IMP” on page 4-84.

Execution Conditions

The CN/CNX command has been executed for the specified channel.

The IMP command has been executed.

Syntax

```
TC chnum,mode[,range]
```

Parameters

chnum **:** MFCMU measurement channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

mode **:** Ranging mode. 0 (auto ranging. initial setting) or 2 (fixed range).

range **:** Measurement range. Needs to set when *mode*=2. Integer (0 or more). 50 Ω, 100 Ω, 300 Ω, 1 kΩ, 3 kΩ, 10 kΩ, 30 kΩ, 100 kΩ, and 300 kΩ are selectable. See Table 4-13 on page 4-24. Available measurement ranges depend on the output signal frequency set by the FC command.

Example Statements

```
OUTPUT @B1500;"TC 8,2,1000"
ENTER @B1500 USING "#,3X,13D,X";Cdata
ENTER @B1500 USING "#,3X,13D,X";Gdata
```

TDCV

Forces DC voltage from the MFCMU or the SMU connected to the Force1/Sense1 terminals of the SCUU (SMU CMU unify unit), and returns the time data from timer reset to the start of output.

Execution Conditions

The CN/CNX command has been executed for the specified channel (MFCMU).

If you want to apply DC voltage over ± 25 V, the SCUU must be connected correctly. The SCUU can be used with the MFCMU and two SMUs (MPSMU or HRSMU). The SCUU cannot be used if the HPSMU is connected to the SCUU or if the number of SMUs connected to the SCUU is only one.

This command is not effective for the 4 byte binary data output format (FMT3 and FMT4).

Syntax

`TDCV` *`chnum,voltage`*

Parameters

chnum **:** MFCMU source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

voltage **:** DC voltage (in V). Numeric expression.

0 (initial setting) to ± 100 V.

Source module is automatically selected by the setting value. The MFCMU is selected if *voltage* is ± 25 V or less (setting resolution: 0.001 V), or the SMU is selected if *voltage* is greater than ± 25 V (setting resolution: 0.005 V).

The SMU will operate with the 100 V limited auto ranging and 20 mA compliance settings.

If the output voltage is greater than ± 42 V, the interlock circuit must be shorted.

Remarks

To read the time data with the best resolution (100 µs), the timer must be cleared every 100 sec or less for the FMT1, 2, or 5 data output format, or every 1000 sec or less for the FMT 11, 12, 15, 21, 22, or 25 data output format.

Example Statements

```
OUTPUT @B1500;"TDCV 7,1"
ENTER @B1500 USING "#,3X,13D,X";Time
```

TDI

Forces current and returns the time data from timer reset to the start of output. This command is not effective for the 4 byte binary data output format (FMT3 and FMT4).

Execution Conditions

The CN/CNX command has been executed for the specified channel.

If the compliance value is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

`TDI chnum,irange,current[,Vcomp[,polarity[,vrange]]]`

Parameters

***chnum* :** SMU source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***irange*:** Ranging type for current output. Integer expression. The output range will be set to the minimum range that covers *current* value. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-5 on page 4-18.

***current*:** Output current (in A). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type.

***Vcomp*:** Voltage compliance value (in V). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type. If you do not specify this parameter, *Vcomp* is set to the previous setting.

***polarity*:** Polarity of voltage compliance. Numeric expression.

- **0:** Auto mode (default setting). The compliance polarity is automatically set to the same polarity as *current*, regardless of the specified *Vcomp*. If *current*=0 A, the polarity is set to positive.
- **1:** Manual mode. Uses the polarity of *Vcomp* you specified.

***vrange*:** Voltage compliance ranging type. Integer expression. The compliance range will be set to the minimum range that covers *Vcomp* value. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-4 on page 4-18.

Remarks

To read the time data with the best resolution (100 μs), the timer must be cleared every 100 sec or less for the FMT1, 2, or 5 data output format, or
every 1000 sec or less for the FMT 11, 12, 15, 21, 22, or 25 data output format.

Example Statements

```
OUTPUT @B1500;"TDI 1,0,1E-6"
ENTER @B1500 USING "#,3X,13D,X";Time
```

TDV

Forces voltage and returns the time data from timer reset to the start of output. This command is not effective for the 4 byte binary data output format (FMT3 and FMT4).

Execution Conditions

The CN/CNX command has been executed for the specified channel.

If the output voltage is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

`TDV chnum,vrange,voltage[,Icomp[,polarity[,irange]]`

Parameters

chnum **:** SMU source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

vrange**:** Ranging type for voltage output. Integer expression. The output range will be set to the minimum range that covers *voltage* value. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-4 on page 4-18.

voltage**:** Output voltage (V). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type.

Icomp**:** Current compliance value (in A). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. If you do not set *Icomp*, the previous value is used. 0 A is not allowed for *Icomp*.

polarity**:** Polarity of current compliance. Integer expression.

- **0:** Auto mode (default setting). The compliance polarity is automatically set to the same polarity as *voltage*, regardless of the specified *Icomp*. If *voltage*=0 V, the polarity is set to positive.
- **1:** Manual mode. Uses the polarity of *Icomp* you specified.

irange**:** Current compliance ranging type. Integer expression. The compliance range will be set to the minimum range that covers *Icomp* value. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-5 on page 4-18.

Remarks

To read the time data with the best resolution (100 μs), the timer must be cleared every 100 sec or less for the FMT1, 2, or 5 data output format, or every 1000 sec or less for the FMT 11, 12, 15, 21, 22, or 25 data output format.

Example Statements

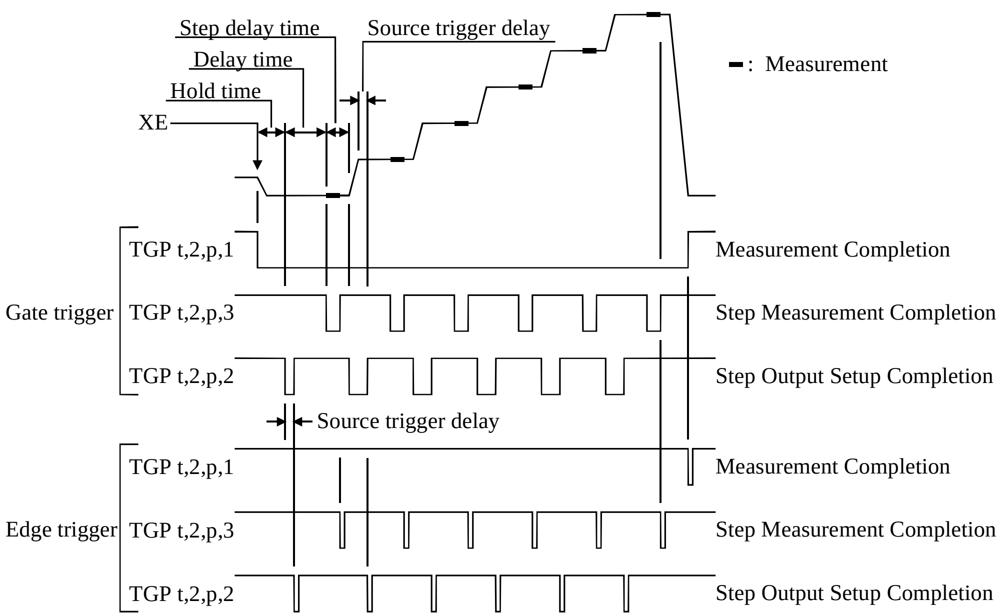
```
OUTPUT @B1500;"TDV 1,0,20,1E-6,0,15"
ENTER @B1500 USING "#,3X,13D,X";Time
```

TGMO

The TGMO command selects the edge trigger or the gate trigger for the Step Measurement Completion trigger output set by the `TGP` *port*`,2,`*polarity*`,3` command. See Figure 4-4.

This command is available for the staircase sweep, multi channel sweep, and MFCMU DC/AC/frequency sweep measurements.

Figure 4-4 **Trigger Output Example, Staircase Sweep Measurement, Negative Logic**



Syntax

`TGMO` *`mode`*

Parameters

***mode* :** Edge trigger or gate trigger. Integer expression. 1 or 2.

1: Edge trigger (initial setting).

2: Gate trigger.

Example Statements

```
OUTPUT @B1500;"TGMO 2"
```

See Also

"TGP" and "TGPC"

TGP

The TGP command enables the trigger function for the terminal specified by the *port* parameter. For the trigger function, refer to "Trigger Function" on page 2-69.

Syntax

TGP *port*,*terminal*,*polarity*[,*type*]

Parameters

port **:** Trigger port number. Integer expression. -1, -2, or 1 to 16.

-1: Ext Trig In terminal.

-2: Ext Trig Out terminal.

1 to 16: Port 1 to 16 of the digital I/O terminal.

terminal **:** Terminal type. Integer expression. 1 or 2.

1: Trigger input. Not available for *port*=-2.

2: Trigger output. Not available for *port*=-1.

polarity **:** Trigger logic. Integer expression. 1 or 2.

1: Positive logic.

2: Negative logic.

type **:** Trigger type. Integer expression. 0, 1, 2, or 3. Selects the function of the trigger port. See Table 4-27.

If this parameter is not specified, *type* is set to 0.

Remarks

The function of type=0 is effective for all trigger ports regardless of the *type* value. Then the PA and WS commands are used for the Ext Trig In terminal, and the OS command is used for the Ext Trig Out terminal. Also the PAX and WSX commands are used for the trigger input ports set by the TGP command, and the OSX command is used for the trigger output ports set by the TGP command.

type=1 to 3 is available for a port only. If you send the command with the same *type* more than once, only the last command is effective. *type*=0 is set for another ports.

If you send the TGP command with *terminal*=1 and *port*=1 to 16, the signal level of the trigger input terminal is set to physical high.

If you send the TGP command with *terminal*=2, the signal level of the trigger output terminal is set to logical low.

Table 4-27 Trigger Type

type	*terminal*	Description
0	1	When a trigger is received, the B1500 recovers from the wait state set by the PA, PAX, WS, or WSX command.
	2	The B1500 sends a trigger by the OS or OSX command.
1 [a]	1	Start measurement trigger When a trigger is received, the B1500 starts the measurement.
	2	Measurement completion trigger The B1500 sends a trigger after measurement.
2	1	Start step output setup trigger When a trigger is received, the B1500 starts the output setup at each sweep step or the pulsed output setup. This function is available for the staircase sweep, multi channel sweep, pulsed spot, pulsed sweep, staircase sweep with pulsed bias, and MFCMU DC/AC/frequency sweep measurements.
	2	Step output setup completion trigger The B1500 sends a trigger when the output setup is completed at each sweep step or the pulsed output setup is completed. This function is available for the staircase sweep, multi channel sweep, pulsed spot, pulsed sweep, staircase sweep with pulsed bias, and MFCMU DC/AC/frequency sweep measurements.
3	1	Start step measurement trigger When a trigger is received, the B1500 starts the measurement at each sweep step. This function is available for the staircase sweep, multi channel sweep, and MFCMU DC/AC/frequency sweep measurements.
	2	Step measurement completion trigger The B1500 sends a trigger after measurement at each sweep step. This function is available for the staircase sweep, multi channel sweep, and MFCMU DC/AC/frequency sweep measurements.

a. TM3 command must be entered to use this trigger type.

Example Statements

```
OUTPUT @B1500;"TGP 1,1,1,2"
```

See Also

See Figure 4-4 on page 4-168 for a trigger output example and Figure 4-5 on page 4-172 for a trigger input example.

TGPC

The TGPC command clears the trigger setting of the specified ports.

Syntax

`TGPC [`*`port`*`[,`*`port`*`...[,`*`port`*`]...]]`

A maximum of 18 ports can be set. If no port is specified, the TGPC command clears the setting of all ports; Ext Trig In, Ext Trig Out, and digital I/O ports 1 to 16.

Parameters

***port* :** Trigger port number. Integer expression. -1, -2, or 1 to 16.

-1: Ext Trig In terminal.

-2: Ext Trig Out terminal.

1 to 16: Port 1 to 16 of the digital I/O terminal.

Remarks

The TGPC command sets the trigger ports as shown below.

Ext Trig In	Same as after TGP -1,1,2,0 command execution.
Ext Trig Out	Same as after TGP -2,2,2,0 command execution.
Digital I/O Ports	No trigger function is available. The ERS? and ERC commands are available for the port control.

This is not same as the condition set by the *RST command that sets the ports as shown below.

Ext Trig In	Same as after TGP -1,1,2,1 command execution.
Ext Trig Out	Same as after TGP -2,2,2,1 command execution.
Digital I/O Ports	No trigger function is available. The ERS? and ERC commands are available for the port control.

Example Statements

```
OUTPUT @B1500;"TGPC -1,-2,1,2"
```

See Also

"TGP"

TGSI

The TGSI command selects Case 1 or Case 2 effective for the Start Step Output Setup trigger input set by the `TGP` *port*`,1,`*polarity*`,2` command.

This command is available for the staircase sweep, multi channel sweep, pulsed spot, pulsed sweep, staircase sweep with pulsed bias, and MFCMU DC/AC/frequency sweep measurements.

Syntax `TGSI` *mode*

Parameters

mode **:** Case 1 or Case 2. Integer expression. See Figure 4-5.

1: Case 1 (initial setting).

2: Case 2.

Case 1 waits for a trigger for the first sweep step, and does not wait for a trigger for the source output after sweep.

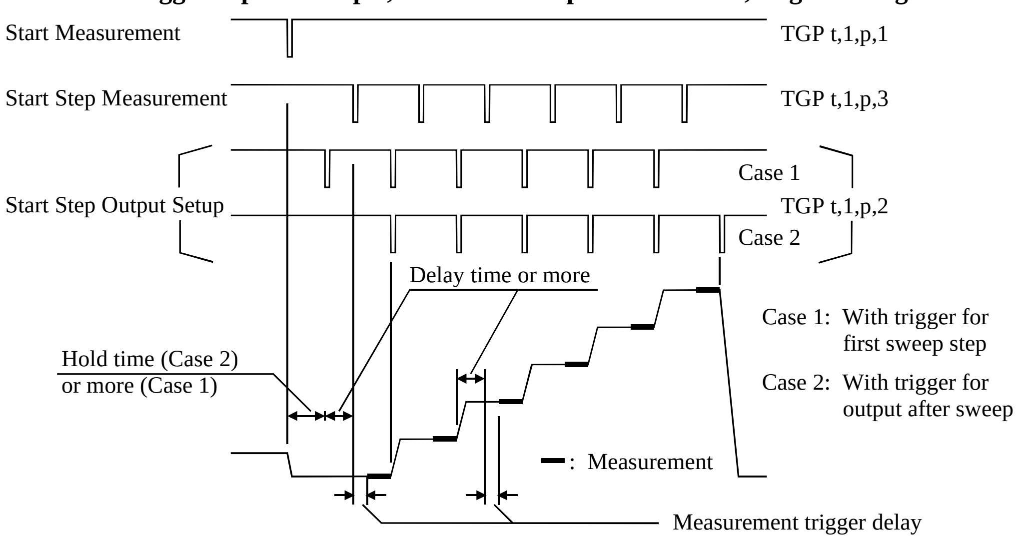
Case 2 does not wait for a trigger for the first sweep step, and waits for a trigger for the source output after sweep.

Example Statements

```
OUTPUT @B1500;"TGSI 2"
```

See Also "TGP" and "TGPC"

Figure 4-5 Trigger Input Example, Staircase Sweep Measurement, Negative Logic



TGSO

The TGSO command selects the edge trigger or the gate trigger for the Step Output Setup Completion trigger output set by the `TGP` *port*`,2,`*polarity*`,2` command. See Figure 4-4 on page 4-168

This command is available for the staircase sweep, multi channel sweep, pulsed spot, pulsed sweep, staircase sweep with pulsed bias, and MFCMU DC/AC/frequency sweep measurements.

Syntax

`TGSO` *mode*

Parameters

***mode* :** Edge trigger or gate trigger. Integer expression.

1: Edge trigger (initial setting).

2: Gate trigger.

Example Statements

```
OUTPUT @B1500;"TGSO 2"
```

See Also

"TGP" and "TGPC"

TGXO

The TGXO command selects the edge trigger or the gate trigger for the Measurement Completion trigger output set by the `TGP` *port*`,2,`*polarity*`,1` command. See Figure 4-4 on page 4-168

Syntax

`TGXO` *mode*

Parameters

***mode* :** Edge trigger or gate trigger. Integer expression.

1: Edge trigger (initial setting).

2: Gate trigger.

Example Statements

```
OUTPUT @B1500;"TGXO 2"
```

See Also

"TGP" and "TGPC"

TI

The TI command performs the high speed spot measurement, and returns the measurement data. The command starts a current measurement regardless of the SMU operation mode, trigger mode (TM command), and measurement mode (MM command).

Execution Conditions

The CN/CNX command has been executed for the specified channel.

Syntax

`TI chnum[,range]`

Parameters

chnum **:** SMU measurement channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

range **:** Measurement range or ranging type. Integer expression. See Table 4-3 on page 4-16.

If you select the fixed range, the instrument performs measurement by using the specified range.

For the auto or limited auto ranging, the measurement range will be set to the minimum range that covers the measured values. However, the instrument never uses the range less than the specified range for the limited auto ranging.

The *range* parameter is meaningless for current output channels. The measurement ranging type is always same as the output ranging type.

If you do not specify the *range* parameter for voltage output channels, the channel uses the minimum range that covers the compliance value.

Example Statements

```
OUTPUT @B1500;"TI 1"
ENTER @B1500 USING "#,3X,13D,X";Idata
```

NOTE

To use 1 pA range

The measurement channel connected to the ASU (Atto Sense and Switch Unit) supports the 1 pA range. To use the 1 pA range, set the 1 pA fixed range or the 1 pA limited auto ranging.

To enable the 1 pA range for the auto ranging mode, execute the SAR command.

TIV

The TIV command performs the high speed spot measurement, and returns the measurement data. The command starts a current and voltage measurement regardless of the SMU operation mode, trigger mode (TM command), and measurement mode (MM command).

The HCSMU and HVSMU perform the current measurement and the voltage measurement simultaneously.

The HRSMU, MPSMU, and HPSMU perform the compliance side measurement and the force side measurement in this order.

Execution Conditions

The CN/CNX command has been executed for the specified channel.

Syntax

`TIV` *`chnum`*`[,`*`irange`*`,`*`vrange`*`]`

Parameters

chnum **:** SMU measurement channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

irange **:** Current measurement range or ranging type. Integer expression. See Table 4-3 on page 4-16.

vrange **:** Voltage measurement range or ranging type. Integer expression. See Table 4-2 on page 4-15.

If you select the fixed range, the instrument performs measurement by using the specified range.

For the auto or limited auto ranging, the measurement range will be set to the minimum range that covers the measured values. However, the instrument never uses the range less than the specified range for the limited auto ranging.

The *irange* parameter is meaningless for current output channels. The measurement ranging type is always same as the output ranging type.

The *vrange* parameter is meaningless for voltage output channels. The measurement ranging type is always same as the output ranging type.

If you do not specify the *irange* and *vrange* parameters, the channel uses the minimum range that covers the compliance value and the minimum range that covers the output value.

Example Statements

```
OUTPUT @B1500;"TIV 1"
ENTER @B1500 USING "#,3X,12D,X";Idata
ENTER @B1500 USING "#,3X,12D,X";Vdata
PRINT "I=";Idata*1000;"mA, V=";Vdata*1000;"mV"
```

NOTE

To use 1 pA range

The measurement channel connected to the ASU (Atto Sense and Switch Unit) supports the 1 pA range. To use the 1 pA range, set the 1 pA fixed range or the 1 pA limited auto ranging.

To enable the 1 pA range for the auto ranging mode, execute the SAR command.

TM

The TM command specifies how events are effective for the following actions:

- Releasing the B1500 from the paused status set by the PA or PAX command
- Starting the measurement except for high speed spot measurement (when the B1500 is not in the paused status set by the PA, PAX, WS, or WSX command)

Syntax

`TM mode`

Parameters

mode **:** Event mode. Integer expression. See below.

mode	Events
1	XE command and GPIB GET (Group Execute Trigger, TRIGGER command in HP BASIC). Initial setting.
2	XE command
3	XE command and external trigger
4	XE command and MM command (automatic trigger after the MM command execution)

To enable the trigger function set by the TGP *port*,*terminal*,*polarity*,1 command, the *mode* value must be 3.

Remarks

In the TM3 event mode, if the B1500 is not in the wait status set by the PA, PAX, WS, or WSX command, the B1500 can start the measurement by an external trigger input. After measurement, the B1500 sends a trigger to a trigger output terminal. In the initial setting, you can use the Ext Trig In and Out terminals. To use the digital I/O port, enter the TGP command to set the trigger input or output terminal.

To set the trigger logic (initial setting: negative), send the TGP command for the trigger input terminal.

Example Statements

```
OUTPUT @B1500;"TM 1"
OUTPUT @B1500;"TM 3"
```

See Also

“PA”, “PAX”, “TGP”, “TGPC”, “WS”, and “WSX”

TMACV

This command monitors the MFCMU AC voltage output signal level, and returns the measurement data.

Execution Conditions

The CN/CNX command has been executed for the specified channel.

Syntax

TMACV *chnum*,*mode*[,*range*]

Parameters

***chnum* :** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***mode* :** Ranging mode. Integer expression. 0 or 2.

0: Auto ranging. Initial setting.

2: Fixed range.

***range* :** Measurement range. This parameter must be set if *mode*=2. See Table 4-15 on page 4-24.

Example Statements

```
OUTPUT @B1500;"TMACV 9,0"
ENTER @B1500 USING "#,3X,13D,X";Aclevel
```

TMDCV

This command monitors the MFCMU DC bias output, and returns the measurement data.

Execution Conditions

The CN/CNX command has been executed for the specified channel.

If you want to apply DC voltage over ± 25 V, the SCUU must be connected correctly. The SCUU can be used with the MFCMU and two SMUs (MPSMU or HRSMU). The SCUU cannot be used if the HPSMU is connected to the SCUU or if the number of SMUs connected to the SCUU is only one.

If the output voltage is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

TMDCV *chnum*,*mode*[,*range*]

Parameters

***chnum* :** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***mode* :** Ranging mode. Integer expression. 0 or 2.

0: Auto ranging. Initial setting.

2: Fixed range.

***range* :** Measurement range. This parameter must be set if *mode*=2. See Table 4-16 on page 4-25.

Example Statements

```
OUTPUT @B1500;"TMDCV 9,0"
ENTER @B1500 USING "#,3X,13D,X";Dcbias
```

TSC

The TSC command enables or disables the time stamp function.

Execution Conditions

Time stamp function is not available for the following measurement modes:

- Quasi-pulsed spot measurement (MM 9)
- Linear search measurement (MM 14)
- Binary search measurement (MM 15)

This command is not effective for the 4 byte binary data output format (FMT3 and FMT4).

Syntax

`TSC mode`

Parameters

***mode* :** Time stamp function mode. Integer expression.

mode	Description
0	Disables the time stamp function. Initial setting.
1	Enables the time stamp function.

When the function is enabled, the B1500 returns the time data with the measurement data. The time data is the time from timer reset to the start of measurement. Refer to “Data Output Format” on page 1-25.

Remarks

To read the time data with the best resolution (100 μs), the timer must be cleared every 100 sec or less for the FMT1, 2, or 5 data output format, or
every 1000 sec or less for the FMT 11, 12, 15, 21, 22, or 25 data output format.

Example Statements

```
OUTPUT @B1500;"TSC 1"
```

TSQ

The TSQ command returns the time data from when the TSR command is sent until this command is sent. The time data will be put in the data output buffer as same as the measurement data.

This command is effective for all measurement modes, regardless of the TSC setting.

This command is not effective for the 4 byte binary data output format (FMT3 and FMT4).

Syntax

```
TSQ
```

Example Statements

```
OUTPUT @B1500;"TSQ"
ENTER @B1500 USING "#,3X,13D,X";Time
PRINT "Time=";Time;"s"
```

TSR

This command clears the timer count. This command is effective for all measurement modes, regardless of the TSC setting. This command is not effective for the 4 byte binary data output format (FMT3 and FMT4).

Syntax

TSR [*chnum*]

Parameters

chnum **:** SMU or MFCMU channel number. Integer expression. 1 to 10. See Table 4-1 on page 4-14.

If *chnum* is specified, this command clears the timer count once at the source output start by the DV, DI, or DCV command for the specified channel. The channel output switch of the specified channel must be ON when the timer count is cleared. This command setting is disabled by the CL command. If multiple TSR *chnum* commands are entered before timer clear, only the last command is effective.

If *chnum* is abbreviated, this command clears the timer count immediately.

Example Statements

```
OUTPUT @B1500;"TSR"
OUTPUT @B1500;"TSR 1"
```

Remarks

To read the time data with the best resolution (100 μs), the timer must be cleared every 100 sec or less for the FMT1, 2, or 5 data output format, or
every 1000 sec or less for the FMT 11, 12, 15, 21, 22, or 25 data output format.

*TST?

This query command performs the self-test and self-calibration, and returns the execution results. After this command, read the results soon.

Module condition after this command is the same as the condition by the CL command.

Execution Conditions

No SMU may be in the high voltage state (forcing more than ± 42 V, or voltage compliance set to more than ± 42 V).

Before this command, open the measurement terminals.

Syntax

`*TST? [slot[,option]]`

Parameters

slot **:** Slot number where the module under self-test and self-calibration has been installed. 1 to 10. Or 0 or 11. Integer expression.

0: All modules and mainframe. Default setting.

11: Mainframe.

option **:** Execution option. Integer expression. 0 or 1.

0: Returns the pass/fail result.

1: Performs the self-test and returns the result. Default setting.

The *TST? *slot*,0 command just returns the pass/fail result of the latest *TST?/CA/*CAL? command or the auto calibration.

The *TST? 0,0 command returns the memorized latest pass/fail result of all modules.

If *slot* specifies the slot that installs no module, this command causes an error.

Remarks

If a SMU connected to SCUU fails this command, the SCUU cannot be controlled. And the SSP and SSL commands are not available.

If the MFCMU connected to SCUU fails this command, all modules connected to SCUU cannot be used.

Failed modules are disabled, and can only be enabled by the RCV command. To recover the modules connected to SCUU, recover MFCMU and SMU in this order.

Query Response

`results<CR/LF^EOI>`

See Table 4-28. *results* returns the sum of the values corresponding to the failures.

Example Statements

```
OUTPUT @B1500;"*TST?"
ENTER @B1500;A
```

Table 4-28 ***TST? Response**

results	Description	*results*	Description
0	Passed. No failure detected.	32	Slot 6 module failed.
1	Slot 1 module failed.	64	Slot 7 module failed.
2	Slot 2 module failed.	128	Slot 8 module failed.
4	Slot 3 module failed.	256	Slot 9 module failed.
8	Slot 4 module failed.	512	Slot 10 module failed.
16	Slot 5 module failed.	1024	Mainframe failed.

TTC

The TTC command performs the high speed spot measurement by using the MFCMU, and returns the measurement data and the time data from timer reset to the start of measurement. The command starts a current measurement regardless of the trigger mode (TM command) and the measurement mode (MM command).

The MFCMU measures the primary parameter and the secondary parameter (for example, Cp and G). Use the IMP command to select the measurement parameters. See “IMP” on page 4-84.

Execution Conditions

The CN/CNX command has been executed for the specified channel.

The IMP command has been executed.

This command is not effective for the 4 byte binary data output format (FMT3 and FMT4).

Syntax

TTC *chnum*,*mode*[,*range*]

Parameters

***chnum* :** MFCMU measurement channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***mode* :** Ranging mode. 0 (auto ranging. initial setting) or 2 (fixed range).

***range* :** Measurement range. Needs to set when *mode*=2. Integer (0 or more). 50 Ω, 100 Ω, 300 Ω, 1 kΩ, 3 kΩ, 10 kΩ, 30 kΩ, 100 kΩ, and 300 kΩ are selectable. See Table 4-13 on page 4-24. Available measurement ranges depend on the output signal frequency set by the FC command.

Remarks

To read the time data with the best resolution (100 μs), the timer must be cleared every 100 sec or less for the FMT1, 2, or 5 data output format, or every 1000 sec or less for the FMT 11, 12, 15, 21, 22, or 25 data output format.

Example Statements

```
OUTPUT @B1500;"IMP 101"
OUTPUT @B1500;"TTC 8,2,1000"
ENTER @B1500 USING "#,3X,13D,X";Time
ENTER @B1500 USING "#,3X,13D,X";Cdata
ENTER @B1500 USING "#,3X,13D,X";Ddata
PRINT "Data=";Cdata*1000000;" uF, D=";Ddata;
", at ";Time;" s"
```

TTI

The TTI command performs the high speed spot measurement, and returns the measurement data and the time data from timer reset to the start of measurement. The command starts a current measurement regardless of the SMU operation mode, trigger mode (TM command), and measurement mode (MM command).

Execution Conditions

The CN/CNX command has been executed for the specified channel.

This command is not effective for the 4 byte binary data output format (FMT3 and FMT4).

Syntax

`TTI` *`chnum`*`[,`*`range`*`]`

Parameters

***chnum* :** SMU measurement channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***range* :** Measurement range or ranging type. Integer expression. See Table 4-3 on page 4-16.

If you select the fixed range, the instrument performs measurement by using the specified range.

For the auto or limited auto ranging, the measurement range will be set to the minimum range that covers the measured values. However, the instrument never uses the range less than the specified range for the limited auto ranging.

The *range* parameter is meaningless for current output channels. The measurement ranging type is always same as the output ranging type.

If you do not specify the *range* parameter for voltage output channels, the channel uses the minimum range that covers the compliance value.

NOTE

To use 1 pA range

The measurement channel connected to the ASU (Atto Sense and Switch Unit) supports the 1 pA range. To use the 1 pA range, set the 1 pA fixed range or the 1 pA limited auto ranging.

To enable the 1 pA range for the auto ranging mode, execute the SAR command.

Remarks

To read the time data with the best resolution (100 μs), the timer must be cleared every 100 sec or less for the FMT1, 2, or 5 data output format, or
every 1000 sec or less for the FMT 11, 12, 15, 21, 22, or 25 data output format.

Example Statements

```
OUTPUT @B1500;"TTI 1"
ENTER @B1500 USING "#,3X,13D,X";Time
ENTER @B1500 USING "#,3X,13D,X";Idata
PRINT "Data=";Idata*1000;"mA, at";Time;"s"
```

TTIV

The TTIV command performs the high speed spot measurement, and returns the measurement data and the time data from timer reset to the start of measurement. The command starts a current and voltage measurement regardless of the SMU operation mode, trigger mode (TM command), and measurement mode (MM command).

The HCSMU and HVSMU perform the current measurement and the voltage measurement simultaneously.

The HRSMU, MPSMU, and HPSMU perform the compliance side measurement and the force side measurement in this order.

Execution Conditions

The CN/CNX command has been executed for the specified channel.

This command is not effective for the 4 byte binary data output format (FMT3 and FMT4).

Syntax

TTIV *chnum*[,*irange*,*vrange*]

Parameters

chnum **:** SMU measurement channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***irange* :** Current measurement range or ranging type. Integer expression. See Table 4-3 on page 4-16.

***vrange* :** Voltage measurement range or ranging type. Integer expression. See Table 4-2 on page 4-15.

If you select the fixed range, the instrument performs measurement by using the specified range.

For the auto or limited auto ranging, the measurement range will be set to the minimum range that covers the measured values. However, the instrument never uses the range less than the specified range for the limited auto ranging.

The *irange* parameter is meaningless for current output channels. The measurement ranging type is always same as the output ranging type.

The *vrange* parameter is meaningless for voltage output channels. The measurement ranging type is always same as the output ranging type.

If you do not specify the *irange* and *vrange* parameters, the channel uses the minimum range that covers the compliance value and the minimum range that covers the output value.

NOTE

To use 1 pA range

The measurement channel connected to the ASU (Atto Sense and Switch Unit) supports the 1 pA range. To use the 1 pA range, set the 1 pA fixed range or the 1 pA limited auto ranging.

To enable the 1 pA range for the auto ranging mode, execute the SAR command.

Remarks

To read the time data with the best resolution (100 μs), the timer must be cleared every 100 sec or less for the FMT1, 2, or 5 data output format, or every 1000 sec or less for the FMT 11, 12, 15, 21, 22, or 25 data output format.

Example Statements

```
OUTPUT @B1500;"TTIV 1"
ENTER @B1500 USING "#,3X,13D,X";Time
ENTER @B1500 USING "#,3X,12D,X";Idata
ENTER @B1500 USING "#,3X,12D,X";Vdata
PRINT "I=";Idata*1000;"mA, V=";Vdata*1000;"mV,
at";Time;"s"
```

TTV

The TTV command performs the high speed spot measurement, and returns the measurement data and the time data from timer reset to the start of measurement. The command starts a voltage measurement regardless of the SMU operation mode, trigger mode (TM command), and measurement mode (MM command).

Execution Conditions

The CN/CNX command has been executed for the specified channel.

This command is not effective for the 4 byte binary data output format (FMT3 and FMT4).

Syntax

TTV *chnum*[,*range*]

Parameters

chnum **:** SMU measurement channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

range **:** Measurement range or ranging type. Integer expression. See Table 4-2 on page 4-15.

If you select the fixed range, the instrument performs measurement by using the specified range.

For the auto or limited auto ranging, the measurement range will be set to the minimum range that covers the measured values. However, the instrument never uses the range less than the specified range for the limited auto ranging.

The *range* parameter is meaningless for voltage output channels. The measurement ranging type is always same as the output ranging type.

If you do not specify the *range* parameter for current output channels, the channel uses the minimum range that covers the compliance value.

Remarks

To read the time data with the best resolution (100 μs), the timer must be cleared every 100 sec or less for the FMT1, 2, or 5 data output format, or
every 1000 sec or less for the FMT 11, 12, 15, 21, 22, or 25 data output format.

Example Statements

```
OUTPUT @B1500;"TTV 1"
ENTER @B1500 USING "#,3X,13D,X";Time
ENTER @B1500 USING "#,3X,13D,X";Vdata
PRINT "Data=";Vdata*1000;"mV, at";Time;"s"
```

TV

The TV command performs the high speed spot measurement, and returns the measurement data. The command starts a voltage measurement regardless of the SMU operation mode, trigger mode (TM), and measurement mode (MM).

Execution Conditions

The CN/CNX command has been executed for the specified channel.

Syntax

TV *chnum*[,*range*]

Parameters

***chnum* :** SMU measurement channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***range* :** Measurement range or ranging type. Integer expression. See Table 4-2 on page 4-15.

If you select the fixed range, the instrument performs measurement by using the specified range. For the auto or limited auto ranging, the measurement range will be set to the minimum range that covers the measured values. However, the instrument never uses the range less than the specified range for the limited auto ranging.

The *range* parameter is meaningless for voltage output channels. The measurement ranging type is always same as the output ranging type.

If you do not specify the *range* parameter for current output channels, the channel uses the minimum range that covers the compliance value.

Example Statements

```
OUTPUT @B1500;"TV 1"
ENTER @B1500 USING "#,3X,13D,X";Vdata
```

UNT?

This command returns the model and revision numbers of mainframe and modules.

Syntax

UNT? [*mode*]

Parameters

***mode* :** Integer expression. 0 (returns information for all modules, default setting) or 1 (returns information for mainframe and all modules).

Query Response

[*FrameModel*,*FrameRevision*;]*Slot1Model*,*Slot1Revision*; ....*Slot9Model*,*Slot9Revision*;*Slot10Model*,*Slot10Revision*<CR/LF^EOI>

Example Statements

```
DIM A$[50]
OUTPUT @B1500;"UNT?"
ENTER @B1500;A$
```

VAR

This command defines the Agilent B1500 internal variable, and sets the value. The variable name is automatically assigned by using the parameters you specify.

Syntax `VAR` *`type,n,value`*

Parameters

type **:** Variable type. Integer expression. 0 or 1.

0: Integer variable. Variable name will be %I*n*.

1: Real variable. Variable name will be %R*n*.

n **:** Number *n* added to the variable name. Integer expression. 0 to 99.

value **:** Value entered in the variable. Numeric value. The value must be 6 digits or less. Available values are as follows:

For integer variables: -999999 to 999999

For real variables: -9999.9 to 9999.9

Example Statements

```
OUTPUT @B1500;"ST1;CN1;DV1,0,%R99,1E-4;TI1,0"
OUTPUT @B1500;"END"
OUTPUT @B1500;"VAR 1,99,2.5"
```

This example sets 2.5 to the real variable %R99.

VAR?

Returns the value of the variable set by the VAR command.

Syntax `VAR?` *`type,n`*

Parameters

type **:** Variable type. Integer expression. 0 or 1.

0: Integer variable. For the variable %I*n*.

1: Real variable. For the variable %R*n*.

n **:** Number *n* added to the variable name. Integer expression. 0 to 99.

Query Response *value*<CR/LF^EOI>

Example Statements

```
OUTPUT @B1500;"VAR? 1,99"
ENTER @B1500;A$
```

This example reads the %R99 real variable value.

WACV

This command sets the AC level sweep source used for the CV (AC level) sweep measurement (MM23). The sweep source will be the MFCMU.

Execution Conditions

The CN/CNX command has been executed for the specified channel.

Syntax

`WACV` *`chnum,mode,start,stop,step`*

Parameters

chnum **:** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

mode **:** Sweep mode. Integer expression. 1 to 4.

1: Linear sweep (single stair, start to stop.)

2: Log sweep (single stair, start to stop.)

3: Linear sweep (double stair, start to stop to start.)

4: Log sweep (double stair, start to stop to start.)

start, stop **:** Start or stop value of the AC level sweep (in V). Numeric expression.

0 (initial setting) to 0.250 V, 0.001 V step.

step **:** Number of steps for staircase sweep. Numeric expression. 1 to 1001.

Example Statements

```
OUTPUT @B1500;"WACV 9,1,0.001,0.100,100"
```

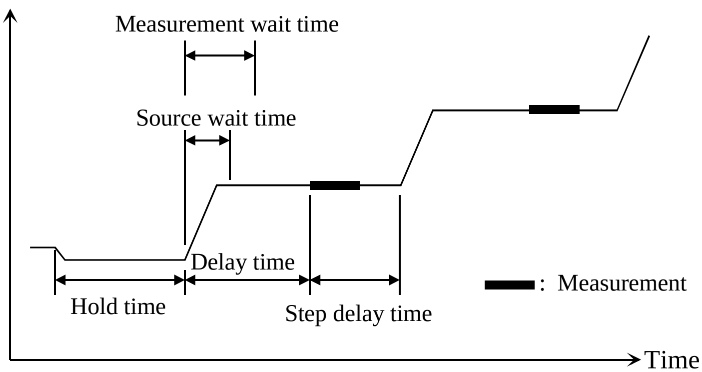
WAT

This command sets the source wait time and the measurement wait time as shown in Figure 4-6. The wait time is given by the following formula:

wait time = *N* × *initial wait time* + *offset*

where *initial wait time* is the time the Agilent B1500 initially sets and you cannot change. The *initial source wait time* is not same as the *initial measurement wait time*. The SMU wait time settings are effective for all SMUs.

Figure 4-6 **Source/Measurement Wait Time**



Syntax

`WAT type,N[,offset]`

Parameters

type Type of the wait time. Integer expression. 1 or 2.

1: SMU source wait time (before changing the output value).

2: SMU measurement wait time (before starting the measurement).

3: MFCMU measurement wait time (before starting the measurement).

N Coefficient for *initial wait time*. Numeric expression.
0 to 10, resolution 0.1. Initial setting is 1.

offset Offset for the wait time. Numeric expression.
0 to 1 sec, resolution 0.0001. Default setting is 0.

NOTE

The wait time can be ignored if it is shorter than the delay time.

NOTE

It is not easy to determine the best wait time. If you specify it too short, the measurement may start before device characteristics stable. If too long, time will be wasted.

The initial wait time may be too short for measurements of high capacitance or slow response devices. Then set the wait time longer.

For measurements of low capacitance or fast response devices, if measurement speed has top priority or is more important than reliability and accuracy, set the wait time shorter.

Example Statements

```
OUTPUT @B1500;"WAT 1,.7"
OUTPUT @B1500;"WAT 2,0,.01"
```

WDCV

This command sets the DC bias sweep source used for the CV (DC bias) sweep measurement (MM18). The sweep source will be MFCMU or SMU.

Execution Conditions

The CN/CNX command has been executed for the specified channel.

If you want to apply DC voltage over ± 25 V using the MFCMU, the SCUU must be connected correctly. The SCUU can be used with the MFCMU and two SMUs (MPSMU or HRSMU). The SCUU cannot be used if the HPSMU is connected to the SCUU or if the number of SMUs connected to the SCUU is only one.

If the output voltage is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

`WDCV chnum,mode,start,stop,step[,comp]`

Parameters

chnum **:** MFCMU or SMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

mode **:** Sweep mode. Integer expression.

1: Linear sweep (single stair, start to stop.)

2: Log sweep (single stair, start to stop.)

3: Linear sweep (double stair, start to stop to start.)

4: Log sweep (double stair, start to stop to start.)

start, stop **:** Start or stop value of the DC bias sweep (in V). Numeric expression. For the log sweep, *start* and *stop* must have the same polarity.

For SMU, see Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type.

For MFCMU, 0 (initial setting) to ± 25 V (MFCMU) or ± 100 V (with SCUU)

With the SCUU, the source module is automatically selected by the setting value. The MFCMU is used if the *start* and *stop* values are below ± 25 V (setting resolution: 0.001 V), or the SMU is used if they are greater than ± 25 V (setting resolution: 0.005 V).

The SMU connected to the SCUU will operate with the 100 V limited auto ranging and 20 mA compliance settings.

step **:** Number of steps for staircase sweep. Numeric expression. 1 to 1001.

***Icomp* :** Available only for SMU. An error occurs if the *Icomp* value is specified for the MFCMU.

Current compliance (in A). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. If you do not set *Icomp*, the previous value is used.

Compliance polarity is automatically set to the same polarity as the output value, regardless of the specified *Icomp*. If the output value is 0, the compliance polarity is positive.

Example Statements

```
OUTPUT @B1500;"WDCV 8,1,5,-5,101"
```

WFC

This command sets the frequency sweep source used for the C-f sweep measurement (MM22). The sweep source will be the MFCMU.

Execution Conditions

The CN/CNX command has been executed for the specified channel.

Syntax

WFC *chnum*,*mode*,*start*,*stop*,*step*

Parameters

***chnum* :** MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***mode* :** Sweep mode. Integer expression. 1 to 4.

1: Linear sweep (single stair, start to stop.)

2: Log sweep (single stair, start to stop.)

3: Linear sweep (double stair, start to stop to start.)

4: Log sweep (double stair, start to stop to start.)

***start, stop* :** Start or stop value of the frequency sweep (in Hz). Numeric expression. See Table 4-14 on page 4-24.

1000 (1 kHz, initial setting) to 5000000 Hz (5 MHz).

Setting resolution: 1 mHz (1 kHz to), 10 mHz (10 kHz to), 100 mHz (100 kHz to), 1 Hz (1 MHz to 5 MHz).

***step* :** Number of steps for staircase sweep. Numeric expression. 1 to 1001.

Example Statements

```
OUTPUT @B1500;"WFC 9,1,100000,5000000,50"
```

WI

The WI command specifies the staircase sweep current source and its parameters. This command also clears the WV, WSV, WSI, and WNX command settings.

This command setting is cleared by the WV command.

Syntax

- For Staircase Sweep Measurement:

  `WI chnum,mode,range,start,stop,step[,Vcomp[,Pcomp]]`

- For Staircase Sweep with Pulsed Bias Measurement:

  `WI chnum,mode,range,start,stop,step[,Vcomp]`

Parameters

chnum **:** SMU sweep source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

mode **:** Sweep mode. Integer expression. Only linear sweep (*mode*=1 or 3) is available for the staircase sweep with pulsed bias.

1: Linear sweep (single stair, start to stop.)

2: Log sweep (single stair, start to stop.)

3: Linear sweep (double stair, start to stop to start.)

4: Log sweep (double stair, start to stop to start.)

range **:** Ranging type for staircase sweep current output. Integer expression. See Table 4-5 on page 4-18.

For the linear sweep, the B1500 uses the minimum range that covers both *start* and *stop* values to force the staircase sweep current.

For the log sweep, the B1500 uses the minimum range that covers the output value, and changes the output range dynamically.

For the limited auto ranging, the instrument never uses the range less than the specified range.

start, stop **:** Start or stop current (in A). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type. *start* and *stop* must have the same polarity for *log* sweep.

step **:** Number of steps for staircase sweep. Numeric expression. 1 to 1001.

***Vcomp* :** Voltage compliance (in V). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type.

If you do not set *Vcomp*, the previous value is used. If *Vcomp* value is greater than ± 42 V, the interlock circuit must be shorted.

Compliance polarity is automatically set to the same polarity as the output value, regardless of the specified *Vcomp*. If the output value is 0, the polarity is set to positive.

If you set *Pcomp*, the maximum *Vcomp* value for the module is allowed, regardless of the output range setting.

For the log sweep and without *Pcomp*, set the value available for the minimum range that covers *start* and *stop* values.

***Pcomp* :** Power compliance (in W). Numeric expression. Resolution: 0.001 W. If the *Pcomp* value is not entered, the power compliance is not set. This parameter is not available for HVSMU.

0.001 to 2 for MPSMU/HRSMU, 0.001 to 20 for HPSMU, 0.001 to 40 for HCSMU

Example Statements

```
OUTPUT @B1500;"WI 1,1,11,0,0.1,100,10,1"
OUTPUT @B1500;"WI 2,2,15,1E-6,0.1,100"
```

WM

The WM command enables or disables the automatic abort function for the staircase sweep sources and the pulsed sweep source. The automatic abort function stops the measurement when one of the following conditions occurs:

- Compliance on the measurement channel
- Compliance on the non-measurement channel
- Overflow on the AD converter
- Oscillation on any channel

This command also sets the post measurement condition for the sweep sources. After the measurement is normally completed, the staircase sweep sources force the value specified by the *post* parameter, and the pulsed sweep source forces the pulse base value.

If the measurement is stopped by the automatic abort function, the staircase sweep sources force the start value, and the pulsed sweep source forces the pulse base value after sweep.

Syntax

`WM abort[,post]`

Parameters

***abort* :** Automatic abort function. Integer expression.

1: Disables the function. Initial setting.

2: Enables the function.

***post* :** Source output value after the measurement is normally completed. Integer expression.

1: Start value. Initial setting.

2: Stop value.

If this parameter is not set, the sweep sources force the start value.

Output Data

The B1500 returns the data measured before an abort condition is detected. Dummy data 199.999E+99 will be returned for the data after abort.

Example Statements

```
OUTPUT @B1500;"WM 2"
OUTPUT @B1500;"WM 2,2"
```

WMACV

This command enables or disables the automatic abort function for the CV (AC level) sweep measurement (MM23). The automatic abort function stops the measurement when one of the following conditions occurs.

- NULL loop unbalance condition
- IV amplifier saturation condition
- Overflow on the AD converter

This command also sets the post measurement condition of the MFCMU. After the measurement is normally completed, the MFCMU forces the value specified by the *post* parameter.

If the measurement is stopped by the automatic abort function, the MFCMU forces the start value.

Syntax

`WMACV abort[,post]`

Parameters

***abort* :** Automatic abort function. Integer expression. 1 or 2.

1: Disables the function. Initial setting.

2: Enables the function.

***post* :** AC level value after the measurement is normally completed. Integer expression. 1 or 2.

1: Start value. Initial setting.

2: Stop value.

If this parameter is not set, the MFCMU forces the start value.

Output Data

The B1500 returns the data measured before an abort condition is detected. Dummy data 199.999E+99 will be returned for the data after abort.

Example Statements

```
OUTPUT @B1500;"WMACV 2"
OUTPUT @B1500;"WMACV 2,2"
```

WMDCV

This command enables or disables the automatic abort function for the CV (DC bias) sweep measurement (MM18) and the pulsed bias sweep measurement (MM20). The automatic abort function stops the measurement when one of the following conditions occurs:

- NULL loop unbalance condition
- IV amplifier saturation condition
- Overflow on the AD converter

This command also sets the post measurement condition of the MFCMU. After the measurement is normally completed, the DC bias sweep source forces the value specified by the *post* parameter, and the pulsed bias sweep source forces the pulse base value.

If the measurement is stopped by the automatic abort function, the DC bias sweep source forces the start value, and the pulsed bias sweep source forces the pulse base value after sweep.

Syntax

WMDCV *abort*[,*post*]

Parameters

***abort* :** Automatic abort function. Integer expression.

1: Disables the function. Initial setting.

2: Enables the function.

***post* :** Source output value after the measurement is normally completed. Integer expression.

1: Start value. Initial setting.

2: Stop value.

If this parameter is not set, the MFCMU forces the start value.

Output Data The B1500 returns the data measured before an abort condition is detected. Dummy data 199.999E+99 will be returned for the data after abort.

Example Statements

```
OUTPUT @B1500;"WMDCV 2"
OUTPUT @B1500;"WMDCV 2,2"
```

WMFC

This command enables or disables the automatic abort function for the C-f sweep measurement (MM22). The automatic abort function stops the measurement when one of the following conditions occurs.

- NULL loop unbalance condition
- IV amplifier saturation condition
- Overflow on the AD converter

This command also sets the post measurement condition of the MFCMU. After the measurement is normally completed, the MFCMU forces the value specified by the *post* parameter.

If the measurement is stopped by the automatic abort function, the MFCMU forces the start value.

Syntax `WMFC` *`abort`*`[,`*`post`*`]`

Parameters

***abort* :** Automatic abort function. Integer expression. 1 or 2.

1: Disables the function. Initial setting.

2: Enables the function.

***post* :** Signal frequency value after the measurement is normally completed. Integer expression. 1 or 2.

1: Start value. Initial setting.

2: Stop value.

If this parameter is not set, the MFCMU forces the start value.

Output Data

The B1500 returns the data measured before an abort condition is detected. Dummy data 199.999E+99 will be returned for the data after abort.

Example Statements

```
OUTPUT @B1500;"WMFC 2"
OUTPUT @B1500;"WMFC 2,2"
```

WNCC

The WNCC command clears the multi channel sweep setup. This command is effective for the measurement modes 16, 27, and 28, and clears the setup of the following commands.

WNX, MCPT, MCPNT, MCPNX, MCPWS, and MCPWNX

Syntax

`WNCC`

Example Statement

```
OUTPUT @B1500;"WNCC"
```

WNU?

The WNU? query command returns the number of sweep steps specified by the sweep command (WI, WV, PWI or PWV), and stores the results in the output data buffer (query buffer).

Execution Conditions

If you want to know the number of steps for a pulsed sweep, you must execute an “MM 4” command before using this command, otherwise the number of steps for the staircase sweep is reported.

Syntax

`WNU?`

Query Response

number_of_sweep_steps<CR/LF^EOI>

Example Statement

```
OUTPUT @B1500;"WNU?"
ENTER @B1500;A
```

WNX

The WNX command specifies the staircase sweep source (synchronous sweep source) that will be synchronized with the primary sweep source. Including the primary sweep source, the maximum of ten sweep sources can be used for a measurement. There is no restrictions for the output mode (voltage or current) of the sweep sources. This command is available for the multi channel sweep measurement (MM16 and MM28).

For MM16, the primary sweep source is set by the WI or WV command.

For MM28, the primary sweep source is set by the WNX or MCPWNX command defined with the parameter *N*=1.

Sweep mode, linear or log, and the number of sweep steps are set by the WI or WV command for MM16, or the MCPWS command for MM28.

This command setting is cleared by the WI, WV, or WNCC command.

Execution Conditions

For MM16, the WI or WV command must be entered before the WNX command.

If the output voltage is greater than ± 42 V, the interlock circuit must be shorted.

Syntax

`WNX N,chnum,mode,range,start,stop[,comp[,Pcomp]]`

Parameters

N **:** Source number. Integer expression. 2 to 10 for MM16. 1 to 10 for MM28. See Remarks below.

chnum **:** SMU sweep source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

mode **:** Sweep source type. Integer expression. 1 or 2.

1: Voltage sweep source

2: Current sweep source

range **:** Ranging type for synchronous sweep output. Integer expression.

- For voltage source (*mode*=1): See Table 4-4 on page 4-18.

  The B1500 usually uses the minimum range that covers both *start* and *stop* values to force the staircase sweep voltage. However, if you set *Pcomp* and if the following formulas are true, the B1500 changes the output range dynamically (20 V range or above). Range changing may cause 0 V output in a moment. For the limited auto ranging, the instrument never uses the range less than the specified range.

  - *comp* > maximum current for the output range
  - *Pcomp*/output value > maximum current for the output range

- For current source (*mode*=2): See Table 4-5 on page 4-18.

For the linear sweep, the B1500 uses the minimum range that covers both *start* and *stop* values to force the staircase sweep current.

For the log sweep, the B1500 changes the output range dynamically.

For the limited auto ranging, the instrument never uses the range less than the specified range.

***start, stop* :** Start or stop value (in V or A). Numeric expression. Setting *start*=*stop* sets the SMU to a constant source. For the log sweep, *start* and *stop* must have the same polarity.

- For voltage source (*mode*=1): See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type.
- For current source (*mode*=2): See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type.

***comp* :** Compliance (in A or V). Numeric expression. If you do not set *comp*, the previous value is used.

- For voltage source (*mode*=1): See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type.
- For current source (*mode*=2): See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type.

For the log sweep and without *Pcomp*, set the value available for the minimum range that covers *start* and *stop* values.

Compliance polarity is automatically set to the same polarity as the output value, regardless of the specified *comp*. If the output value is 0, the polarity is set to positive.

If you set *Pcomp*, the maximum *comp* value for the module is allowed, regardless of the output range setting.

***Pcomp* :** Power compliance (in W). Numeric expression. Resolution: 0.001 W. If the *Pcomp* value is not entered, the power compliance is not set. This parameter is not available for HVSMU.

0.001 to 2 for MPSMU/HRSMU, 0.001 to 20 for HPSMU, 0.001 to 40 for HCSMU

Remarks

The *N* value and the *chnum* value set to the MCPNX, MCPWNX, and WNX commands must be unique for each command execution. If you set the value used to the previous command, the previous command setting is cleared, and the last command setting is effective.

For MM16, the sweep sources simultaneously start output by a trigger such as the XE command. However, if a sweep source sets power compliance or forces logarithmic sweep current, the sweep sources start output in the order specified by the *N* value. Then the first output is forced by the primary sweep source.

For MM16, if you use multiple measurement channels, the channels that use the high-speed A/D converter with the fixed ranging mode start measurement simultaneously, then other channels start measurement in the order defined in the MM command.

For MM28, the source channels set by the WNX commands start output in the order specified by the *N* value, and then the source channels set by the MCPNX and MCPWNX commands start output simultaneously.

For MM28, if you use multiple measurement channels, all measurement channels start measurement simultaneously.

Example Statements

```
OUTPUT @B1500;"WNX 2,3,1,12,0,3,1E-3,2E-3"
OUTPUT @B1500;"WNX 3,4,2,0,1E-3,1E-2,3"
```

WS

The WS command causes the B1500 to enter a wait state until the B1500 receives an external trigger from the Ext Trig In terminal. To set the trigger logic (initial setting: negative), send the TGP command for the Ext Trig In terminal.

To end a wait state before the trigger, execute the AB or *RST command.

Syntax

`WS [`*`mode`*`]`

Parameters

mode **:** Waiting mode. Integer expression. 1 or 2. If this parameter is not specified, *mode* is set to 1.

1: Continues the operation if an external trigger was already received. Otherwise, the B1500 immediately goes into a wait state for an external trigger.

2: In any condition, the B1500 immediately goes into a wait state for an external trigger.

Remarks

The B1500 checks its trigger flag to confirm the present trigger status, received or none. To clear the trigger flag:

- Enter the *RST or device clear command (HP BASIC CLEAR statement).
- Enter the TM3 command.
- Enter the TM1, TM2, or TM4 command to change the mode from TM3.
- Enter the OS command.
- Trigger the B1500 to start measurement via the Ext Trig In terminal.
- Trigger the B1500 to recover from wait state set by the WS command via the Ext Trig In terminal.

Example Statements

```
OUTPUT @B1500;"WS 2"
```

WSI

The WSI command specifies the staircase sweep current source (synchronous sweep source) that will be synchronized with the staircase sweep current source (primary sweep source) set by the WI command, or the pulsed sweep current source (primary sweep source) set by the PWI command.

Execution Conditions

Available for the staircase sweep (MM 2), pulsed sweep (MM 4), or staircase sweep with pulsed bias (MM5) measurement.

This command must be entered after the WI or PWI command that clears the WSI command setting. The WV and PWV command also clears the WSI setting.

Syntax

`WSI` *`chnum`*`,`*`range`*`,`*`start`*`,`*`stop`*`[,`*`Vcomp`*`[,`*`Pcomp`*`]]`

Parameters

chnum **:** SMU synchronous sweep source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

range **:** Ranging type for synchronous sweep current output. Integer expression. See Table 4-5 on page 4-18.

For the linear sweep, the B1500 uses the minimum range that covers both *start* and *stop* values to force the staircase sweep current.

For the log sweep, the B1500 uses the minimum range that covers the output value, and changes the output range dynamically.

Sweep mode, linear or log, is set by the WI or PWI command.

For the limited auto ranging, the instrument never uses the range less than the specified range.

start, stop **:** Start or stop current (in A). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type. *start* and *stop* must have the same polarity for *log* sweep. Sweep mode, linear or log, and the number of sweep steps are set by the WI or PWI command.

Vcomp **:** Voltage compliance (in V). Numeric expression. See Table 4-7 on page 4-20, Table 4-9 on page 4-21, or Table 4-11 on page 4-22 for each module type. If you do not set *Vcomp*, the previous value is used. If *Vcomp* value is greater than ± 42 V, the interlock circuit must be shorted.

Compliance polarity is automatically set to the same polarity as the output value, regardless of the specified *Vcomp*. If the output value is 0, the compliance polarity is positive.

If you set *Pcomp*, the maximum *Vcomp* value for the module is allowed, regardless of the output range setting.

For the log sweep and without *Pcomp*, set the value available for the minimum range that covers *start* and *stop* values.

Pcomp **:** Power compliance (in W). Numeric expression. Resolution: 0.001 W. If the *Pcomp* value is not entered, the power compliance is not set. This parameter is not available for HVSMU.

0.001 to 2 for MPSMU/HRSMU, 0.001 to 20 for HPSMU, 0.001 to 40 for HCSMU

Example Statements

```
OUTPUT @B1500;"WSI 1,16,0,4E-5"
OUTPUT @B1500;"WSI 2,0,1E-3,1E-2,5,5E-2"
```

WSV

The WSV command specifies the staircase sweep voltage source (synchronous sweep source) that will be synchronized with the staircase sweep voltage source (primary sweep source) set by the WV command, or the pulsed sweep voltage source (primary sweep source) set by the PWV command.

Execution Conditions

Available for the staircase sweep (MM 2), pulsed sweep (MM 4), or staircase sweep with pulsed bias (MM5) measurement.

This command must be entered after the WV or PWV command that clears the WSV command setting. The WI and PWI command also clears the WSV setting.

Syntax

`WSV chnum,range,start,stop[,Icomp[,Pcomp]]`

Parameters

***chnum* :** SMU synchronous sweep source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***range* :** Ranging type for synchronous sweep voltage output. Integer expression. See Table 4-4 on page 4-18.

The B1500 usually uses the minimum range that covers both *start* and *stop* values to force the staircase sweep voltage. However, if you set *Pcomp* and if the following formulas are true, the B1500 changes the output range dynamically (20 V range or above). Range changing may cause 0 V output in a moment. For the limited auto ranging, the instrument never uses the range less than the specified range.

- *Icomp* > maximum current for the output range
- *Pcomp*/output voltage > maximum current for the output range

***start, stop* :** Start or stop voltage (in V). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. *start* and *stop* must have the same polarity for *log* sweep. Sweep mode, linear or log, and the number of sweep steps are set by the WV or PWV command. If the output voltage is greater than ± 42 V, the interlock circuit must be shorted.

***Icomp* :** Current compliance (in A). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. If you do not set *Icomp*, the previous value is used.

Compliance polarity is automatically set to the same polarity as the output value, regardless of the specified *Icomp*. If the output value is 0, the compliance polarity is positive.

If you set *Pcomp*, the maximum *Icomp* value for the module is allowed, regardless of the output range setting.

***Pcomp* :** Power compliance (in W). Numeric expression. Resolution: 0.001 W. If the *Pcomp* value is not entered, the power compliance is not set. This parameter is not available for HVSMU.

0.001 to 2 for MPSMU/HRSMU, 0.001 to 20 for HPSMU, 0.001 to 40 for HCSMU

Example Statements

```
OUTPUT @B1500;"WSV 1,0,1,100,0.01,1"
OUTPUT @B1500;"WSV 2,12,0,10"
```

WSX

The WSX command causes the B1500 to enter a wait state until the B1500 receives an external trigger from a trigger input terminal specified by the *port* parameter. To set the trigger logic (initial setting: negative), send the TGP command for the specified terminal. To end a wait state before the trigger, execute the AB or *RST command.

Syntax

WSX *port*[,*mode*]

Parameters

***port* :** External trigger input port number. Integer expression. -1, or 1 to 16.

-1: Ext Trig In terminal.

1 to 16: Port 1 to 16 of the digital I/O terminal.

To use a digital I/O port, send the TGP command. The *port* value must be same as the *port* value set to the TGP command.

***mode* :** Waiting mode. Integer expression. 1 or 2. If this parameter is not specified, *mode* is set to 1.

1: Continues the operation if an external trigger was already received. Otherwise, the B1500 immediately goes into a wait state for an external trigger.

2: In any condition, the B1500 immediately goes into a wait state for an external trigger.

Remarks

The B1500 checks its trigger flag to confirm the present trigger status, received or none. To clear the trigger flag:

- Enter the *RST or device clear command (HP BASIC CLEAR statement).
- Enter the TM3 command.
- Enter the TM1, TM2, or TM4 command to change the mode from TM3.
- Enter the OS command.
- Trigger the B1500 to start measurement via the trigger input terminal.
- Trigger the B1500 to recover from wait state set by the WS command via the trigger input terminal.

Example Statements

```
OUTPUT @B1500;"WSX 2"
```

WT

The WT command sets the hold time, delay time, and step delay time for the staircase sweep or multi channel sweep measurement. This command is also used to set the step source trigger delay time effective for the step output setup completion trigger and the step measurement trigger delay time effective for the start step measurement trigger. For the trigger function, refer to “Trigger Function” on page 2-69.

If you do not enter this command, all parameters are set to 0.

This command is not effective for the measurements using pulse.

Syntax

WT *hold*,*delay*[,*Sdelay*[,*Tdelay*[,*Mdelay*]]]

Parameters

***hold* :** Hold time (in seconds) that is the wait time after starting the sweep measurement and before starting the delay time for the first step.

0 to 655.35, with 10 ms resolution. Numeric expression.

***delay* :** Delay time (in seconds) that is the wait time after starting to force a step output and before starting a step measurement.

0 to 65.535, with 0.1 ms resolution. Numeric expression.

***Sdelay* :** Step delay time (in seconds) that is the wait time after starting a step measurement and before starting to force the next step output value.

0 to 1.0, with 0.1 ms resolution. Numeric expression.

If this parameter is not set, *Sdelay* will be 0.

If *Sdelay* is shorter than the measurement time, the B1500 waits until the measurement completes, then forces the next step output.

***Tdelay* :** Step source trigger delay time (in seconds) that is the wait time after completing a step output setup and before sending a step output setup completion trigger.

0 to *delay*, with 0.1 ms resolution. Numeric expression.

If this parameter is not set, *Tdelay* will be 0.

***Mdelay* :** Step measurement trigger delay time (in seconds) that is the wait time after receiving a start step measurement trigger and before starting a step measurement.

0 to 65.535, with 0.1 ms resolution. Numeric expression.

If this parameter is not set, *Mdelay* will be 0.

Example Statements

```
OUTPUT @B1500;"WT 5,0.1,0.1,0.1,0.1"
OUTPUT @B1500;"WT 5,0.2"
```

WTACV

This command sets the hold time, delay time, and step delay time for the CV (AC level) sweep measurement (MM23). This command is also used to set the step source trigger delay time effective for the step output setup completion trigger and the step measurement trigger delay time effective for the start step measurement trigger. For the trigger function, refer to “Trigger Function” on page 2-69. If you do not enter this command, all parameters are set to 0.

Syntax

WTACV *hold*,*delay*[,*Sdelay*[,*Tdelay*[,*Mdelay*]]]

Parameters

hold **:** Hold time (in seconds) that is the wait time after starting measurement and before starting delay time for the first step.

0 (initial setting) to 655.35, with 10 ms resolution. Numeric expression.

delay **:** Delay time (in seconds) that is the wait time after starting to force a step output and before starting a step measurement.

0 (initial setting) to 655.35, with 0.1 ms resolution. Numeric expression.

Sdelay **:** Step delay time (in seconds) that is the wait time after starting a step measurement and before starting to force the next step output.

0 (initial setting) to 1, with 0.1 ms resolution. Numeric expression. If this parameter is not set, *Sdelay* will be 0. If *Sdelay* is shorter than the measurement time, the B1500 waits until the measurement completes, then forces the next step output.

Tdelay **:** Step source trigger delay time (in seconds) that is the wait time after completing a step output setup and before sending a step output setup completion trigger.

0 (initial setting) to *delay* or 65.535, with 0.1 ms resolution. Numeric expression. If this parameter is not set, *Tdelay* will be 0.

***Mdelay* :** Step measurement trigger delay time (in seconds) that is the wait time after receiving a start step measurement trigger and before starting a step measurement.

0 (initial setting) to 65.535, with 0.1 ms resolution. Numeric expression. If this parameter is not set, *Mdelay* will be 0.

Example Statements

```
OUTPUT @B1500;"WTACV 5,0.1,0.1,0.1,0.1"
OUTPUT @B1500;"WTACV 5,0.2"
```

WTDCV

This command sets the hold time, delay time, and step delay time for the CV (DC bias) sweep measurement (MM18). This command is also used to set the step source trigger delay time effective for the step output setup completion trigger and the step measurement trigger delay time effective for the start step measurement trigger. For the trigger function, refer to “Trigger Function” on page 2-69. If you do not enter this command, all parameters are set to 0.

Syntax

WTDCV *hold*,*delay*[,*Sdelay*[,*Tdelay*[,*Mdelay*]]]

Parameters

***hold* :** Hold time (in seconds) that is the wait time after starting measurement and before starting delay time for the first step.

0 to 655.35, with 10 ms resolution. Numeric expression.

***delay* :** Delay time (in seconds) that is the wait time after starting to force a step output and before starting a step measurement.

0 to 65.535, with 0.1 ms resolution. Numeric expression.

***Sdelay* :** Step delay time (in seconds) that is the wait time after starting a step measurement and before starting to force the next step output.

0 to 1, with 0.1 ms resolution. Numeric expression.

If this parameter is not set, *Sdelay* will be 0.

If *Sdelay* is shorter than the measurement time, the B1500 waits until the measurement completes, then forces the next step output.

***Tdelay* :** Step source trigger delay time (in seconds) that is the wait time after completing a step output setup and before sending a step output setup completion trigger.

0 to *delay*, with 0.1 ms resolution. Numeric expression.

If this parameter is not set, *Tdelay* will be 0.

Mdelay **:** Step measurement trigger delay time (in seconds) that is the wait time after receiving a start step measurement trigger and before starting a step measurement.

0 to 65.535, with 0.1 ms resolution. Numeric expression.

If this parameter is not set, *Mdelay* will be 0.

Example Statements

```
OUTPUT @B1500;"WTDCV 5,0.1,0.1,0.1,0.1"
OUTPUT @B1500;"WTDCV 5,0.2"
```

WTFC

This command sets the hold time, delay time, and step delay time for the C-f sweep measurement (MM22). This command is also used to set the step source trigger delay time effective for the step output setup completion trigger and the step measurement trigger delay time effective for the start step measurement trigger. For the trigger function, refer to “Trigger Function” on page 2-69. If you do not enter this command, all parameters are set to 0.

Syntax

WTFC *hold*,*delay*[,*Sdelay*[,*Tdelay*[,*Mdelay*]]]

Parameters

hold **:** Hold time (in seconds) that is the wait time after starting measurement and before starting delay time for the first step.

0 (initial setting) to 655.35, with 10 ms resolution. Numeric expression.

delay **:** Delay time (in seconds) that is the wait time after starting to force a step output and before starting a step measurement.

0 (initial setting) to 655.35, with 0.1 ms resolution. Numeric expression.

Sdelay **:** Step delay time (in seconds) that is the wait time after starting a step measurement and before starting to force the next step output.

0 (initial setting) to 1, with 0.1 ms resolution. Numeric expression. If this parameter is not set, *Sdelay* will be 0. If *Sdelay* is shorter than the measurement time, the B1500 waits until the measurement completes, then forces the next step output.

Tdelay **:** Step source trigger delay time (in seconds) that is the wait time after completing a step output setup and before sending a step output setup completion trigger.

0 (initial setting) to *delay* or 65.535, with 0.1 ms resolution. Numeric expression. If this parameter is not set, *Tdelay* will be 0.

***Mdelay* :** Step measurement trigger delay time (in seconds) that is the wait time after receiving a start step measurement trigger and before starting a step measurement.

0 (initial setting) to 65.535, with 0.1 ms resolution. Numeric expression. If this parameter is not set, *Mdelay* will be 0.

Example Statements

```
OUTPUT @B1500;"WTFC 5,0.1,0.1,0.1,0.1"
OUTPUT @B1500;"WTFC 5,0.2"
```

WV

The WV command specifies the staircase sweep voltage source and its parameters. This command also clears the WI, WSI, WSV, and WNX command settings.

This command setting is cleared by the WI command. If the output voltage is greater than ±42 V, the interlock circuit must be shorted.

Syntax

- For Staircase Sweep Measurement:

  `WV` ***`chnum`***`,`***`mode`***`,`***`range`***`,`***`start`***`,`***`stop`***`,`***`step`***`[,`***`Icomp`***`[,`***`Pcomp`***`]]`

- For Staircase Sweep with Pulsed Bias Measurement:

  `WV` ***`chnum`***`,`***`mode`***`,`***`range`***`,`***`start`***`,`***`stop`***`,`***`step`***`[,`***`Icomp`***`]`

Parameters

***chnum* :** SMU sweep source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 4-14.

***mode* :** Sweep mode. Integer expression. Only linear sweep (*mode*=1 or 3) is available for the staircase sweep with pulsed bias.

1: Linear sweep (single stair, start to stop.)

2: Log sweep (single stair, start to stop.)

3: Linear sweep (double stair, start to stop to start.)

4: Log sweep (double stair, start to stop to start.)

***range* :** Ranging type for staircase sweep voltage output. Integer expression. See Table 4-4 on page 4-18.

The B1500 usually uses the minimum range that covers both *start* and *stop* values to force the staircase sweep voltage. However, if you set *Pcomp* and if the following formulas are true, the B1500 uses the minimum range that covers the output value, and changes the output range dynamically (20 V range or above). Range changing may cause 0 V output in a moment. For the limited auto ranging, the instrument never uses the range less than the specified range.

- *Icomp* > maximum current for the output range
- *Pcomp*/output voltage > maximum current for the output range

start, stop **:** Start or stop voltage (in V). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. *start* and *stop* must have the same polarity for *log* sweep.

step **:** Number of steps for staircase sweep. Numeric expression. 1 to 1001.

Icomp **:** Current compliance (in A). Numeric expression. See Table 4-6 on page 4-19, Table 4-8 on page 4-21, or Table 4-10 on page 4-22 for each module type. If you do not set *Icomp*, the previous value is used.

Compliance polarity is automatically set to the same polarity as the output value, regardless of the specified *Icomp*. If the output value is 0, the compliance polarity is positive.

If you set *Pcomp*, the maximum *Icomp* value for the module is allowed, regardless of the output range setting.

Pcomp **:** Power compliance (in W). Numeric expression. Resolution: 0.001 W. If the *Pcomp* value is not entered, the power compliance is not set. This parameter is not available for HVSMU.

0.001 to 2 for MPSMU/HRSMU, 0.001 to 20 for HPSMU, 0.001 to 40 for HCSMU

Example Statements

```
OUTPUT @B1500;"WV 1,2,12,1E-6,10,100,0.1,1"
OUTPUT @B1500;"WV 2,1,0,0,20,101"
```

WZ?

This query command immediately confirms all channel output, and returns the status 0 if it is within ± 2 V or 1 if it is more than ± 2 V.

Syntax

WZ? [*timeout*]

Parameters

timeout **:** Timeout. Numeric expression.

0 to 655.35 sec, with 0.01 sec resolution.

With *timeout* parameter, this command waits until all channel output becomes within ± 2 V or until the specified *timeout* elapses, and returns 0 or 1.

The `WZ? 0` command has the same effect as the `WZ?` command.

Query Response *state*<CR/LF^EOI>

0: All channel output is within ± 2 V.

1: Any output channel applies more than ± 2 V.

Example Statement

```
OUTPUT @B1500;"WZ? 5.0"
ENTER @B1500;A
```

XE

The XE command triggers the B1500 to start measurement, or causes the B1500 to recover from the wait state set by the PA command. This command is not available for the high-speed spot measurement.

Syntax XE

Example Statement

```
OUTPUT @B1500;"XE"
```

NOTE After measurement, the measurement data will be entered to the output data buffer. For data output format, refer to “Data Output Format” on page 1-25.

Table 4-29 Required Commands before XE, by Measurement Mode

Measurement Mode	Commands
Spot	CN, MM, DV or DI
Staircase sweep	CN, MM, WV or WI
Pulsed spot	CN, MM, PT, PV or PI
Pulsed sweep	CN, MM, PT, PWV or PWI
Staircase sweep with pulsed bias	CN, MM, PT, WV or WI, PV or PI
Quasi-pulsed spot	CN, MM, BDV

Measurement Mode	Commands
Sampling	CN, MM, MCC, ML, MT, MSC, MI, MV, MSP
Quasi-static CV	CN, MM, QST, QSV
Liner search	CN, MM, LSV or LSI, LGV or LGI
Binary search	CN, MM, BSV or BSI, BGV or BGI
Multi channel sweep	CN, MM, WI or WV, WNX
Spot C	CN, MM, IMP, FC, ACV, DCV
CV (DC bias) sweep	CN, MM, IMP, FC, ACV, WDCV
CV (AC level) sweep	CN, MM, IMP, FC, DCV, WACV
C-f sweep	CN, MM, IMP, DCV, ACV, WFC
Pulsed spot C	CN, MM, IMP, FC, ACV, PTDCV, PDCV
Pulsed sweep CV	CN, MM, IMP, FC, ACV, PTDCV, PWDCV
C-t sampling	CN, MM, IMP, FC, ACV, MDCV, MTDCV
Multi channel pulsed spot	CN, MM, MCPT, MCPNT, MCPNX
Multi channel pulsed sweep	CN, MM, MCPT, MCPNT, MCPWS, MCPWNX

Execution Conditions

The following execution conditions are for you who use the XE command to start measurement. There is no execution condition when you use the XE command to recover from the wait state.

- If any channel is set to the high voltage state (forcing more than ± 42 V, or voltage compliance set to more than ± 42 V) after the trigger (XE), the interlock terminal must be shorted.
- The commands shown in Table 4-29 must be entered before the XE command.

5 Error Messages

This chapter lists the error code of the Agilent B1500.

If error occurs, find solutions in this section and solve problems. However, if problems still remain, perform self-test.

If the Agilent B1500 fails self-test, contact your nearest Agilent Technologies Service Center.

If errors occur, error codes are stored in the error buffer. To read the error code and the error message, use the “ERRX?”/“ERR?”/“EMG?” command. The output of the error codes is in the order that they occurred.

The “ERR?”/“EMG?” command supports the error codes 0 to 999.

Operation Error

100 Undefined GPIB command.

Send the correct command.

102 Incorrect numeric data syntax.

Correct the data syntax.

103 Incorrect terminator position.

Correct the command syntax. The number of parameters will be incorrect.

104 Incorrect serial data syntax.

120 Incorrect parameter value.

Correct the parameter value.

121 Channel number must be 1 to 10.

Correct the channel number. The channel number must be 1 to 10 for Agilent B1500.

122 Number of channels must be corrected.

Check the MM, FL, CN, CL, IN, DZ, or RZ command, and correct the number of channels.

123 Compliance must be set correctly.

Incorrect compliance value was set. Set the compliance value correctly.

124 Incorrect range value for this channel.

Check the range value available for the channel, and correct the range value.

125 Search goal value must be less than compliance value.

126 Pulse base and peak must be same polarity.

The polarity of the base and peak values must be the same in the PI command. Also the polarity of the base, start, and stop values must be the same in the PWI command.

130 Start and stop must be same polarity.

For a log sweep, the polarity of the start and stop values must be the same in the WV, WI, WSV, WSI, or WNX command. Also, 0 is not allowed for the start and stop values.

140 Invalid setup

Check the setup required for the specified function and set it properly.

150 Command input buffer is full.

Agilent B1500 can receive 256 characters maximum including the terminator at one time.

151 This command is not allowed to this channel.

152 Cannot use failed module.

The channel number specifying the module failed the self-test or calibration. Specify another module that passed the self-test or calibration. For the service purpose, execute the RCV command to enable the module.

153 No module for the specified channel.

Module is not installed in the slot specified by the channel number.

154 Cannot recover this module.

The specified module cannot recover from the fail status. It may be defective.

155 Module initialization failed.

The specified module failed the initialization. It may be defective.

160 Incorrect ST execution.

The internal memory programming can be started by the ST command and completed by the END command. Do not enter the ST command between the ST command and the END command.

161 Incorrect END execution.

The internal memory programming can be started by the ST command and completed by the END command. Do not send the END command before starting the programming.

162 Incorrect command for program memory.

Specified command cannot be stored in the program memory. For the incorrect commands, see Programming Guide.

170 Incorrect usage of internal variable.

The internal variable must be %I*n* for integer data, or %R*n* for real data. where *n* is an integer, 0 to 99. Use %I*n* for the integer type command parameters; and use %R*n* for the real type command parameters. For the internal variables, see the VAR command of Programming Guide.

171 Internal variable is not allowed.

The internal variables %I*n* and %R*n* are not available for the ACH, VAR, and VAR? commands. Do not use the internal variables for the commands.

200 Channel output switch must be ON.

To enter the specified command, set the channel output switch to ON.

201 Compliance must be set.

To change the source output mode (voltage or current), set the compliance value.

202 Interlock circuit must be closed.

To set the output voltage or the voltage compliance to more than ±42 V (high voltage state), close the interlock circuit. If the interlock circuit is opened in the high voltage state, outputs of all units will be set to 0 V.

203 Cannot enable channel.

The channel output switch cannot be set to ON in the high voltage state. Set the output voltage or the voltage compliance to ±42 V or less to set the switch to ON.

204 Cannot disable channel.

The channel output switch cannot be set to OFF in the high voltage state. Set the output voltage or the voltage compliance to ±42 V or less to set the switch to OFF. Or send the CL command with no parameter to set switches of all channels to OFF immediately.

205 DZ must be sent before RZ.

The RZ command is effective for the channels set to 0 V output by the DZ command.

206 Do not specify the channel recovered by RZ.

Specify the channels that have not been recovered yet by the RZ command after the DZ command. The RZ command cannot be executed if the specified channels include a channel that has already been recovered by the RZ command.

210 Ext trigger could not start measurement.

External trigger cannot start measurement because of busy condition.

211 TM1 must be sent to use GET.

Send the TM1 command to use the GPIB GET command (TRIGGER statement in HP BASIC).

212 Compliance must be set correctly.

Compliance was not set or an incorrect compliance value was set in the DV, DI, PV, PI, PWV, PWI, TDV, TDI, LSV, LSI, LSSV, LSSI, BSV, BSI, BSSV, or BSSI command. Set the compliance value correctly.

213 Cannot perform self-test or calibration.

Self-test and calibration cannot be performed in the high voltage state. Set the output voltage or the voltage compliance to ±42 V or less to perform the self-test or calibration.

214 Send MM before measurement trigger.

Before sending the measurement trigger, the MM command must be sent to set the measurement mode.

217 Self-test is not defined for this module.

218 Cannot change output range.

The specified module failed the output range change. The output is set to the initial condition 0 V and 100 μA.

219 Channel output switch must be OFF.

The channel output switch must be OFF before executing the specified command.

220 Send WV or WI to set primary sweep source.

Before triggering the staircase sweep measurement, triggering the staircase sweep with pulsed bias measurement, or sending the WSV, WSI, or WNX command to set the synchronous sweep source, send the WV or WI command to set the primary sweep source.

221 Send PWV or PWI to set pulse sweep source.

Before triggering the pulsed sweep measurement, or sending the WSV or WSI command to set the synchronous sweep source, send the PWV or PWI command to set the pulse sweep source.

222 Send PV or PI to set pulse source.

Before triggering the staircase sweep with pulsed bias measurement, send the PV or PI command to set the pulse source.

223 Compliance must be set correctly.

Compliance was not set or an incorrect compliance value was set in the WV, WI, WSV, WSI, WNX, or BDV command. Set the compliance value correctly.

224 Sweep and sync output modes must be the same.

The primary sweep channel and the synchronous sweep channel must be different, and they must be set to the same output mode (voltage or current).

225 Send WSV, WSI, or WNX to get sync sweep data.

If you enable data output of the synchronous sweep source, do not forget to set the synchronous sweep source by the WSV, WSI, or WNX command. For data output, see the FMT command of Programming Guide.

226 Set linear sweep for MM4 or MM5.

Only the linear sweep is available for the PWV or PWI command for the pulsed sweep measurement (MM4) or the WV or WI command for the staircase sweep with pulsed bias measurement (MM5).

227 Sweep measurement was aborted.

Sweep measurement was aborted by the automatic abort function or the power compliance.

228 Pulse period is not set for pulse measurements.

230 Pulse source must be set.

To perform the pulsed spot measurement (MM3), send the PV or PI command to set the pulse source.

231 Compliance must be set correctly.

Compliance was not set or an incorrect compliance value was set in the PV, PI, PWV, or PWI command. Set the correct compliance value effective for the pulse output.

232 Invalid pulse output setup

Check the pulse output setup and set the correct value.

233 Invalid pulse timing setup

Check the pulse timing parameters and set the correct values.

238 Too large pulse width (max. 2 s).

The maximum value of the pulse width is 2 s. And the available value depends on the pulse period value. See the PT command of Programming Guide.

239 Pulse width must be 0.5 ms or more.

Set the pulse width to 0.5 ms or more. See the PT command of Programming Guide.

240 Enter QSV to set QSCV sweep source.

The QSV command must be entered to set the sweep source of the quasi-static CV measurement.

241 QSR range value must be -9 to -14.

The *range* values available for the QSR command are -9 to -14. Set one of the available values.

242 QSCV measurement was aborted.

Quasi-static CV measurement was aborted by the automatic abort function.

243 Enter MM13 before QSZ.

Before the QSZ command, the MM13 command must be entered to set the measurement mode.

244 Set a longer integration time to QST.

The integration time is too short to perform the offset measurement. Set a longer value to the integration time parameter of the QST command.

245 Specify a higher measurement range to QSR.

Too large offset current was measured. Specify the next higher measurement range to the QSR command.

246 QSV mode value must be 1 or 3.

The *mode* values available for the QSV command are 1 (single linear) and 3 (double linear). Set one of the available values.

247 Dedicated channel must be specified by QSO.

Specify the dedicated channel to the QSO command. It must be the channel other than the measurement channel set by the MM13 command or the sweep output channel set by the QSV command.

253 Program memory is full.

Maximum of 2000 programs or 40000 commands can be stored in the program memory. See the ST command of Programming Guide.

254 Invalid input for a memory program.

The GPIB GET command (TRIGGER statement in HP BASIC) and an external trigger input are not allowed in a memory program (between the ST and END commands).

255 Maximum nesting level is eight.

Nesting (one program calling another) of a memory program must be eight levels or less.

260 Data output buffer is full.

Maximum 34034 measurement data items can be stored in the data output buffer.

270 Search source channel must be set.

Before triggering the search measurement or sending the LSSV, LSSI, BSSV, or BSSI command to set the synchronous search source, send the LSV, LSI, BSV, or BSI command to set the primary search source.

271 Search monitor channel must be set.

Before triggering the search measurement, send the LGV, LGI, BGV, or BGI command to set the search monitor channel.

273 Search and sync output modes must be the same.

The primary search source channel and the synchronous source channel must be different, and they must be set to the same output mode (voltage or current).

274 Search sync source is overflow.

Set the search sources so that the same output range is set to both primary and synchronous search sources.

275 Search target must be compliance value or less.

The search target value must be less than or equal to the compliance value of the search monitor channel. Correct the search target value or the compliance value.

276 Start and stop must be different.

Set different values for the search start and stop values.

277 Step must be output resolution or more.

Set the search step value to the output resolution or more.

278 Search and sync channels must be different.

Set the search source and the synchronous source to different channels.

279 Search monitor mode must be compliance side.

Send the LGI/BGI command to set the voltage source search monitor channel, or send the LGV/BGV command to set the current source search monitor channel.

280 Send WDCV to set CV sweep source.

Before triggering the multi frequency CV measurement, send the WDCV command to set the DC voltage sweep source.

281 Send PDCV to set CV pulse source.

Before triggering the pulsed spot C measurement, send the PDCV command to set the pulsed voltage source.

282 Send PWDCV to set CV pulse sweep source.

Before triggering the pulsed CV measurement, send the PWDCV command to set the pulsed voltage sweep source.

283 Set linear sweep for MM20.

Only the linear sweep is available for the PWDCV command for the pulsed CV measurement (MM20).

284 Improper setting of CMU frequency and pulse width.

Pulse width value is out of the range for the CMU output frequency. Set both frequency value and pulse width value properly.

290 Send WFC to set Cf sweep source.

Before triggering the Cf sweep measurement, send the WFC command to set the frequency sweep source (oscillator).

301 Line power failure.

303 Excess voltage in MPSMU.

Voltage that exceeds maximum voltage at the present current range was detected by a MPSMU. All output switches were set to OFF.

304 Ground unit abuse is detected.

305 Excess current in HPSMU.

Current that exceeds maximum current at the present voltage range was detected by a HPSMU. All output switches were set to OFF.

307 Unsupported module.

This module is not supported by this firmware revision. Until you update the firmware, use Agilent B1500 with this module removed.

309 Unknown emergency occurred.

All modules stopped their output and opened their output relay.

310 Interlock open operation error. Initialized.

Initialization was automatically performed because the B1500 failed to set its output to 0 V when the interlock circuit was opened in the high voltage condition. Any module may be defective. Perform self-test.

311 ASU control cable was connected/disconnected.

The B1500 must be turned off when the Atto Sense and Switch Unit (ASU) is connected/disconnected.

312 SCUU control cable was connected/disconnected.

The B1500 must be turned off when the SMU CMU Unify Unit (SCUU) is connected/disconnected.

320 Excess current in CMU.

Current that exceeds maximum current at the present voltage range was detected by the CMU. The output switch was set to OFF.

321 This command is not available for CMU.

CMU was specified for the SMU dedicated command. Specify SMU.

322 This command is not available for SMU.

SMU was specified for the CMU dedicated command. Specify CMU.

323 Use SSP instead of CN for SCUU modules.

It is not necessary to specify the modules connected to the SMU CMU Unify Unit (SCUU) in the CN command. The output switches will be controlled by the SSP command.

330 Turn on again to detect source channel.

SCUU might be disconnected/connected on the power on condition. Restart the B1500 to detect and enable the channel.

331 Turn on again to detect synchronous channel.

SCUU might be disconnected/connected on the power on condition. Restart the B1500 to detect and enable the channel.

332 Turn on again to detect measurement channel.

SCUU might be disconnected/connected on the power on condition. Restart the B1500 to detect and enable the channel.

333 Turn on again to detect search source.

SCUU might be disconnected/connected on the power on condition. Restart the B1500 to detect and enable the channel.

334 Turn on again to detect search sync source.

SCUU might be disconnected/connected on the power on condition. Restart the B1500 to detect and enable the channel.

335 Turn on again to detect search monitor channel.

SCUU might be disconnected/connected on the power on condition. Restart the B1500 to detect and enable the channel.

603 Sweep and pulse channels must be different.

Set the sweep source and the pulse source to different channels for the staircase sweep with pulsed bias measurement (MM5).

610 Quasi-pulse source channel must be set.

Before triggering the quasi-pulsed spot measurement, send the BDV command to set the quasi-pulse source.

620 TGP specified incorrect I/O port.

Specify trigger input for the Ext Trig In port, or trigger output for the Ext Trig Out port by the TGP command. See the TGP command of Programming Guide.

621 Specify trigger input port for PAX/WSX.

No trigger input port was specified for the PAX or WSX command. Specify the trigger input port, or set the port as the trigger input port. See the TGP command of Programming Guide to set trigger port.

622 Specify trigger output port for OSX.

No trigger output port was specified for the OSX command. Specify the trigger output port, or set the port as the trigger output port. See the TGP command of Programming Guide to set trigger port.

626 DIO control mode must be HV/HC/HP SMU selector control mode (ERMOD 2).

Set the digital IO control mode to the N1258A/N1259A control mode by using the ERMOD 2 command.

627 Mismatch HV/HC/HP SMU selector ID

Module selector is not connected to the Digital IO connector. Connect the N1258A or the module selector of the N1259A.

628 HV/HC/HP SMU selector control cable was disconnected.

Connection cable was removed. Turn the instrument off and connect the cable. And then turn the instrument on again.

629 HV/HC/HP SMU selector is not active.

Module selector does not respond. The power code may be removed.

630 Incorrect polarity of search step value.

For the linear search measurement. The step value must be positive if start<stop, or negative if start>stop.

631 Number of search steps must be 1001 or less.

For the linear search measurement. The number of search steps between start and stop must be 1001 or less. This means the |step| value must be |stop - start|/1001 or more.

632 Search measurement was aborted.

Search measurement was aborted by the automatic abort function.

640 Search limits must be range/20000 or more.

For the binary search measurement. The limit value for the search target must be *range*/20000 or more. where *range* means the measurement range actually used for the measurement.

650 Data format must be ASCII to get time data.

The time stamp function is not available for the binary data output format. To use the time stamp function, set the data output format to ASCII.

655 Cannot connect/disconnect series resistor.

The series resistor status cannot be changed in the high voltage state. Set the output voltage or the voltage compliance to ±42 V or less to connect or disconnect the series resistor.

656 Series resistor must be OFF for 1 A range.

The series resistor cannot be set to ON for the measurement channels or the output channels that use 1 A range.

657 Series resistor cannot be used with ASU.

The series resistor is not available for the channel connected to the Atto Sense and Switch Unit (ASU).

660 Sampling measurement was aborted.

Sampling measurement was aborted by the automatic abort function.

661 Negative hold time is only valid for I/V-t linear sampling with interval < 2 ms.

662 Sampling interval for I/V-t log sampling must be 2 ms or longer.

663 Number of samples does not have to exceed 100001.

664 Base and bias must be same polarity for I mode.

The *base* and *bias* values of the MI command must be the same polarity.

670 Specified channel does not have ASU.

Specify the module that can be used with the ASU.

671 SSP is not available for this channel.

SSP command is available only for the CMU. Specify the slot number that the CMU has been installed.

680 CMU correction mode must be manual.

To perform the CMU correction by using the ADJ? command, set the CMU correction mode to manual by using the ADJ command.

681 CMU correction mode must be off.

682 Invalid standard is specified as CMU correction.

683 Frequency index is not available for CMU correction.

684 AC Voltage is 0 mV.

685 CMU correction is not complete.

1000 The specified module doesn't support power compliance.

The power compliance is not available for the specified module.

1001 Illegal pulse duty

Set the pulse period and the pulse width so that the pulse duty ratio is within the acceptable range.

1002 Illegal pulse width

Check the pulse width and set the correct value.

1003 Illegal pulse base/peak limit

Check the pulse base and peak values, and set the correct values.

1004 Illegal pulse base/peak polarity

Check the pulse base and peak values, and set the polarity properly.

1005 Illegal sweep polarity

Check the sweep start and stop values, and set the polarity properly.

1006 Application measurement setup is not sufficient.

Check the setup required for the specified measurement and set it properly.

1007 Source channel must be set.

Set the source output channel properly.

1008 Pulse output channel is required.

Specify the pulse output channel. Or set the pulse output channel properly.

2000 SPGU module does not exist.

The SPGU channel number must be specified correctly.

2001 SPGU channel does not exist.

The SPGU channel number must be specified correctly.

2002 SPGU signal source does not exist.

	The SPGU signal source number must be specified correctly.
2003	SPGU operation mode must be PG. (SIM 0).
2004	SPGU operation mode must be ALWG (SIM 1).
2051	Over voltage emergency occurred.
	All modules stopped their output and opened their output relay.
2052	Over current emergency occurred.
	All modules stopped their output and opened their output relay.
2053	High temperature emergency occurred.
	All modules stopped their output and opened their output relay.
2054	Over voltage H/W SRQ detected.
	Specified module stopped the output and opened the output relay.
2055	Over current H/W SRQ detected.
	Specified module stopped the output and opened the output relay.
2056	High temperature H/W SRQ detected.
	Specified module stopped the output and opened the output relay.
2101	Specified load impedance is out of absolute limits.
	Set the appropriate impedance value to SER.
2103	Specified period is out of absolute limits.
	Set the appropriate pulse period value to SPPER.
2104	Specified trigger count is out of absolute limits.
	Set the appropriate count value to SPRM.
2105	Specified load voltage is out of range.
	Set the appropriate voltage to SPV or ALW.
2106	Specified load voltage of added amplitude is out of range.
	Set the appropriate voltage to SPV for setting the 3-level pulse output.
2107	Specified voltage is out of absolute limits (can't achieve amplitude).
	Set the appropriate voltage to SPV. It must be the voltage which can be applied under the present load impedance condition.
2108	Specified transition time is out of absolute limits.

Set the appropriate value of leading time or trailing time to SPT.

2111 Leading/0.8 must be within Width value.

Set the appropriate value to SPT. The pulse width value must be more than *leading time*/0.8 value.

2112 Delay + Width + Trail/0.8 must be within Period value.

Set the appropriate value to SPT. The pulse period value must be more than *delay time*+*pulse width*+*trailing time*/0.8 value.

2113 Specified pulse delay is out of absolute limits.

Set the appropriate delay time value to SPT.

2114 Specified pulse width is out of absolute limits.

Set the appropriate pulse width value to SPT.

2115 Specified duration is out of absolute limits.

Set the appropriate duration value to SPRM.

2121 Delay + Width must be within Period value (ODSW Timing).

Set the appropriate value to ODSW. The period value must be more than *delay*+*width* value.

2122 Specified ODSW delay timing parameter out of absolute limits.

Set the appropriate *delay* value to ODSW.

2123 Specified ODSW width timing parameter out of absolute limits.

Set the appropriate *width* value to ODSW.

2131 Delay + Interval * N must be within Period value (ADC Timing).

Set the appropriate value to CORRSER?. The period value must be more than *delay*+*interval*×*count* value.

2132 Specified delay for DUT impedance measurement out of absolute limits.

Set the appropriate *delay* time value to CORRSER?.

2133 Specified interval for DUT impedance measurement out of absolute limits.

Set the appropriate *interval* value to CORRSER?.

2134 Specified count for DUT impedance measurement out of absolute limits.

Set the appropriate *count* value to CORRSER?.

2151 ALWG Sequence Data is not ready.

Sequence data must be set by using ALS before starting the output.

2152 Specified ALWG Sequence Data size is out of absolute limits.

Set the appropriate sequence data to ALS. Too large data was specified.

2153 Specified pattern index of ALWG Sequence Data is out of absolute limits.

Set the appropriate sequence data to ALS. The pattern index in the sequence data must be the index of a pattern defined in the pattern data.

2154 Specified repeat count of ALWG Sequence Data is out of absolute limits.

Set the appropriate sequence data to ALS. The repeat count in the sequence data must be 1 to 1048576.

2155 ALWG Pattern Data is not ready.

Pattern data must be set by using ALW before starting the output.

2156 Specified ALWG Pattern Data size is out of absolute limits.

Set the appropriate pattern data to ALW. Too large data was specified.

2157 Specified interval time of ALWG Pattern is out of absolute limits.

Set the appropriate pattern data to ALW. The incremental time value in the pattern data must be 10 ns to 671.088630 ms in 10 ns resolution.

2158 Specified output voltage of ALWG Pattern Data is out of absolute limits.

Set the appropriate pattern data to ALW. The output level value in the pattern data must be 0 to ± 40 V in 1 mV resolution.

2204 Load voltage is too small for DUT impedance measurement.

Failed to perform the terminal voltage measurement and the load impedance calculation by the CORRSER? command. Set the SPGU output voltage more than 1 V. Set high voltage for high impedance.

2206 Auto correction of load impedance failed.

Cannot perform the SPGU automatic level adjustment. Load impedance exceeds the acceptable range. Change the SPGU output voltage or the DUT.

3000 WGFMU module does not exist.

Check the channel number of the WGFMU module and set the correct value.

3001 RSU is not connected.

Check the channel number of the WGFMU module connected to the RSU and set the correct value.

3015 Measurement data corrupted.

Cannot get the measurement data. Correct measurement result is not stored in the memory.

3050 Measurement data memory overflow error.

ALWG sequencer run time error. WGFMU module memory overflow occurred. Data exceeds memory size could not be stored.

3051 Measurement data FIFO overflow error.

ALWG sequencer run time error. WGFMU module FIFO overflow occurred because the averaging count was frequently changed.

3052 Measurement range change request error.

ALWG sequencer run time error. Measurement range cannot be changed because the range change interval is too short.

3201 ALWG Sequence Data is not ready.

Sequence data must be set to the specified WGFMU channel.

3202 ALWG Waveform Data is not ready.

Waveform data must be set to the specified WGFMU channel.

3301 Specified output voltage is out of absolute limits.

Check the output voltage and set the correct value. The value must be -3 V to +3 V for the 3 V range, -5 V to +5 V for the 5 V range, -10 V to 0 V for the -10 V range, or 0 V to +10 V for the + 10 V range.

3302 Specified voltage output range is invalid.

Check the voltage output range and set the correct value.

3303 Invalid measurement mode for current operation mode.

Operation mode must be Fast IV or DC to perform current measurement.

3304 Specified ALWG Vector Data size is out of absolute limits.

ALWG data cannot be read because of too large data size.

3305 Specified ALWG Sequence Data size is out of absolute limits.

ALWG data cannot be read because of too large sequence data size.

3306 ALWG Waveform Data is empty.

ALWG data must not be empty.

3307 Specified ALWG Waveform Data size is out of absolute limits.

ALWG data cannot be read because of too large waveform data size.

3308 Specified waveform index of ALWG Sequence Data is out of absolute limits.

Check the index value of the sequence data and set the correct value.

3309 Specified loop number of ALWG Sequence Data is out of absolute limits.

Check the loop value of the sequence data and set the correct value.

3310 Specified output voltage of ALWG Waveform Data is out of absolute limits.

Check the output voltage and set the correct value. The value must be -3 V to +3 V for the 3 V range, -5 V to +5 V for the 5 V range, -10 V to 0 V for the -10 V range, or 0 V to +10 V for the + 10 V range.

3311 Specified interval time of ALWG Waveform is out of absolute limits.

Check the incremental time (interval time) and set the correct value. The value must be 10 ns to 10995.11627775 s, in 10 ns resolution.

3312 Specified ALWG measurement interval time is out of absolute limits.

Check the measurement interval time and set the correct value. The value must be 10 ns to 1.34217728 s, in 10 ns resolution.

3313 Specified ALWG measurement instruction code is invalid.

Check the measurement event setting and set the correct values.

3314 Specified ALWG range change instruction code is invalid.

Check the range event setting and set the correct values.

3315 Specified ALWG measurement count is out of absolute limits.

Check the measurement averaging time and set the correct value. The value must be 0, or 10 ns to 0.020971512 s, in 10 ns resolution.

3316 Specified ALWG measurement count is greater than measurement interval.

Check the measurement averaging time and set the correct value. The value must less than or equal to the measurement interval time.

3317 Specified slot is invalid.

Check the slot number and set the correct value. The slot number must be 1 to 10.

3318 Specified module channel is invalid.

Check the channel number and set the correct value.

3319 Output delay is out of absolute limits.

Check the output delay and set the correct value. The value must be -50 ns to 50 ns, in 625 ps resolution.

3320 Measurement delay is out of absolute limits.

Check the measurement delay and set the correct value. The value must be -50 ns to 50 ns, in 625 ps resolution.

3321 VM/IM measurement mode is invalid.

Check the measurement mode and set the correct value.

3322 Voltage measurement range is invalid.

Check the voltage measurement range and set the correct value.

3323 Current measurement range is invalid.

Check the current measurement range and set the correct value.

3324 WGMA?,WGMB? command query size is out of absolute limits.

Check the data size for WGMA? or WGMB? and set the correct value.

3325 Specified count for spot measurement is out of absolute limits.

Check the count value for WGMS? and set the correct value.

3326 Specified interval for spot measurement is out of absolute limits.

Check the interval value for WGMS? and set the correct value.

3327 Specified operation mode is invalid for spot measurement.

Operation mode must be DC to perform spot measurement.

4304 HV/HC/HP SMU selector must be open state.

Set the module selector input-output path to the open status to execute the specified command.

4305 External relay control is not active.

Enable the external relay control function by using the ERHPE command to enter the specified command. Also, check the cable connection and the relay operation.

NOTE If one of the errors 4401 to 4408 occurs, the all module output is changed to 0 V and the all output switch is disconnected.

4401 HVSMU over voltage emergency occurred.

4402 HVSMU over current or guard abuse emergency occurred.

4403 HVSMU guard abuse emergency occurred.

4404 HVSMU HVPS cannot power-off emergency occurred.

4405 HVSMU V ADC lost emergency occurred.

4406 HVSMU I ADC lost emergency occurred.

4407 HVSMU Float lost emergency occurred.

4408 HVSMU HVPS cannot power-on emergency occurred.

NOTE If one of the errors 5401 to 5413 occurs, the all module output is changed to 0 V and the all output switch is disconnected.

5401 HCSMU high force over voltage emergency occurred.

5402 HCSMU high sense over voltage emergency occurred.

5403 HCSMU low force over voltage emergency occurred.

5404 HCSMU low sense over voltage emergency occurred.

5405 HCSMU low sense chassis over voltage emergency occurred.

5406 HCSMU power supply shortage voltage emergency occurred.

5407 HCSMU sense open error detected.

5408 HCSMU pulse peak over current emergency occurred.

5409 HCSMU DC over current emergency occurred.

5410 HCSMU pulse width over current emergency occurred.

5411 HCSMU float lost emergency occurred.

5413 HCSMU should not apply low current to high impedance device.

Self-test/Calibration Error

When the Agilent B1500 fails the self-test or self-calibration, the Agilent B1500 returns the following error code and error message.

In the error code, N indicates the slot number. If the module is installed in slot 1, and it fails the function test, the error code will be 1760.

700	CPU failed NVRAM read/write test.
701	CPU failed FPGA read/write test.
702	CPU failed H-RESOLN ADC end signal test.
703	CPU failed H-RESOLN ADC start signal test.
704	CPU failed emergency status signal test.
705	CPU failed SRQ status signal test.
706	CPU failed high voltage status signal test.
707	CPU failed low voltage status signal test.
708	CPU failed DAC settling status signal test.
709	CPU failed measure ready status signal test.
710	CPU failed set ready status signal test.
711	CPU failed measure end status signal test.
712	CPU failed measure trigger signal test.
713	CPU failed pulse trigger signal test.
714	CPU failed abort trigger signal test.
715	CPU failed DAC set trigger signal test.
720	H-RESOLN ADC is not installed.
721	H-RESOLN ADC failed ROM/RAM test.
722	H-RESOLN ADC failed B-COM offset DAC test.
723	H-RESOLN ADC failed sampling ADC test.
724	H-RESOLN ADC failed integrating ADC test.
725	H-RESOLN ADC failed bus function test.

740	GNDU failed calibration.
935	CMU FPGA version mismatch.
2400	SPGU module is in TEST FAIL state.
2401	Digital H/W function test failed.
2402	CPLD access function test failed.
2403	CPLD version check test failed.
2404	CPLD revision check test failed.
2405	FPGA configuration test failed.
2406	FPGA access function test failed.
2407	FPGA version check test failed.
2408	FPGA revision check test failed.
2409	DCM function test failed.
2410	CONVEND interrupt function test failed.
2411	EMG interrupt function test failed.
2412	10 MHz clock test failed.
2413	FPGA SYNC SEL pin control function test failed.
2414	FPGA SYNC FB pin control function test failed.
2415	FPGA SYNC IN pin control function test failed.
2416	IDELAY function test failed.
2417	NVRAM access function test failed.
2418	ADC function test failed.
2419	SDRAM access function test failed.
2430	Module EEPROM CRC data is invalid.
2431	Module EEPROM CRC data of module data ID is invalid.
2432	Module EEPROM CRC data of format revision data is invalid.
2433	Module EEPROM CRC data of analog reference data is invalid.
2434	Module EEPROM CRC data of timing calibration data is invalid.
2435	Module EEPROM CRC data is skew calibration data invalid.

2450	Internal ADC function test failed.
2451	0.5 Vref Internal ADC function test failed.
2452	4.5 Vref Internal ADC function test failed.
2453	Power Amp initial test failed.
2454	Filter & Amp test failed.
2455	Internal temperature test failed.
2456	Internal output resistance test failed.
2481	Invalid frame configuration.
2482	Frame has no modules.
2483	PLL not locked in slave module.
2484	Reference line is not connected.
2485	Sync line is not connected.
2486	Interrupt line is not available.
2487	Module service request assertion test failed.
2488	Module service request detection test failed.
2489	Emergency interrupt is not available.
2500	SPGU calibration failed.
2501	Power Amp idling calibration failed.
2502	DAC output level calibration failed.
3002	WGFMU initialization failure.
3003	WGFMU FPGA is not configured.
3004	EEPROM CRC data of system timing data is invalid.
3005	EEPROM CRC data of DAC DCM PS data is invalid.
3006	EEPROM CRC data of ADC DCM PS data is invalid.
3007	EEPROM CRC data of DAC clock edge data is invalid.
3008	EEPROM CRC data of ADC clock edge data is invalid.
3009	EEPROM CRC data of DAC level calibration data is invalid.
3010	EEPROM CRC data of ADC level calibration data is invalid.

3011	EEPROM CRC data of DAC skew calibration data is invalid.
3012	EEPROM CRC data of ADC skew calibration data is invalid.
3013	EEPROM CRC data of RSU calibration data is invalid.
3014	Invalid EEPROM type.
3400	WGFMU module is in TEST FAIL state.
3401	Digital H/W function test failed.
3402	CPLD access function test failed.
3403	FPGA configuration test failed.
3404	FPGA1 access function test failed.
3405	FPGA2 access function test failed.
3406	FPGA1 System Clock DCM function test failed.
3407	FPGA1 DAC Clock DCM function test failed.
3408	FPGA1 ADC Clock DCM function test failed.
3409	FPGA1 Memory Clock DCM function test failed.
3410	FPGA2 System Clock DCM function test failed.
3411	FPGA2 DAC Clock DCM function test failed.
3412	FPGA2 ADC Clock DCM function test failed.
3413	FPGA2 Memory Clock DCM function test failed.
3414	FPGA1, 2 communication I/F test failed.
3415	CONVEND interrupt function test failed.
3416	10 MHz clock test failed.
3417	FPGA SYNC SEL pin control function test failed.
3418	FPGA SYNC FB pin control function test failed.
3419	FPGA SYNC IN pin control function test failed.
3420	IDELAY function test failed.
3421	Channel 1 SDRAM access function test failed.
3422	Channel 2 SDRAM access function test failed.
3423	WGFMU EEPROM access function test failed.

3424	Channel 1 RSU EEPROM access function test failed.
3425	Channel 2 RSU EEPROM access function test failed.
3426	WGFMU EEPROM CRC data is invalid.
3427	WGFMU EEPROM CRC data of format revision data is invalid.
3428	WGFMU EEPROM CRC data of serial number data is invalid.
3429	WGFMU EEPROM CRC data of system timing data is invalid.
3430	WGFMU EEPROM CRC data of DAC DCM PS data is invalid.
3431	WGFMU EEPROM CRC data of ADC DCM PS data is invalid.
3432	WGFMU EEPROM CRC data of DAC clock edge data is invalid.
3433	WGFMU EEPROM CRC data of ADC clock edge data is invalid.
3434	WGFMU EEPROM CRC data of DAC level calibration data is invalid.
3435	WGFMU EEPROM CRC data of ADC level calibration data is invalid.
3436	WGFMU EEPROM CRC data of DAC skew calibration data is invalid.
3437	WGFMU EEPROM CRC data of ADC skew calibration data is invalid.
3438	RSU EEPROM CRC data of format revision data is invalid.
3439	RSU EEPROM CRC data of serial number data is invalid.
3440	RSU EEPROM CRC data of type id data is invalid.
3441	RSU EEPROM CRC data of calibration data is invalid.
3450	WGFMU EEPROM data is invalid.
3451	WGFMU EEPROM data of RSU type is invalid.
3452	WGFMU EEPROM data of RSU cable type is invalid.
3460	Main DAC, Main ADC test failed.
3461	Bias DAC, Main ADC test failed.
3462	Main DAC, Reference ADC test failed.
3463	VM function test failed.
3464	IM offset test failed.
3465	IM short test failed.
3480	Invalid frame configuration.

3481	Invalid frame configuration.
3482	Frame has no modules.
3483	PLL not locked in slave module.
3484	Reference line is not connected.
3485	Sync line is not connected.
3486	Sync Reserve line is not connected.
3487	Interrupt line is not available.
3488	Module service request assertion test failed.
3489	Module service request detection test failed.
3490	Emergency interrupt is not available.
3500	WGFMU calibration failed.
3501	ADC gain calibration failed.
3502	CMR calibration failed.
3503	IM offset calibration failed.
3504	VM offset calibration failed.
3505	VF gain calibration failed.
3506	VF offset calibration failed.
3507	Reference ADC does not exist. Cannot perform WGFMU calibration.
3508	WGFMU, RSU cable length calibration failed.

NOTE Error codes 4501 to 4701 are for HVSMU.

4501	Digital H/W function test failed.
4502	CPLC access function test failed.
4503	FPGA access function test failed.
4504	SERDES access function test failed.
4505	Bus FPGA JTAG function test failed.
4506	Float FPGA JTAG function test failed.
4507	OPT I/F access function test failed.
4508	Internal temperature test failed.

4509	ADC access test failed.
4510	EEPROM access function test failed.
4511	Float lost detection test failed.
4512	ADC lost detection test failed.
4513	HVPS control test failed.
4514	ADC control test failed.
4515	DAC switch test failed.
4516	DAC control test failed.
4517	CALBUS control test failed.
4520	V divider gain test failed.
4521	V loop control test failed.
4522	Voltage detector test failed.
4523	Oscillation detector test failed.
4524	I ADC gain test failed.
4525	I loop control test failed.
4526	I range change test failed.
4527	HVPS force test failed.
4528	Over current detector test failed.
4529	Guard abuse detector test failed.
4601	VFVM calibration failed.
4602	EEPROM CRC data of VFVM adjust is invalid.
4603	Non-feedback mode offset calibration failed.
4604	Calculation of VM correction data failed.
4605	Calculation of VF correction data failed.
4611	IFIM calibration failed.
4612	EEPROM CRC data of IFIM adjust is invalid.
4613	IFIM offset measurement failed.
4614	IFIM gain measurement by Ref ADC failed.

4615	IFIM gain measurement by I ADC failed.
4616	Calculation of IM correction data failed.
4617	Calculation of IF correction data failed.
4701	Non-feedback offset adjustment failed.

NOTE Error codes 5501 to 5701 are for HCSMU.

5501	Digital H/W function test failed.
5502	CPLC access function test failed.
5503	FPGA access function test failed.
5505	Bus FPGA JTAG function test failed.
5506	Float FPGA JTAG function test failed.
5507	OPT I/F access function test failed.
5509	ADC access test failed.
5510	EEPROM access function test failed.
5513	Power AMP bias test failed.
5551	V offset self-test failed.
5552	V sense self-test failed.
5553	HS VADC self-test failed.
5554	V CMR DAC self-test failed.
5555	I offset self-test failed.
5556	V loop self-test failed.
5557	I sense low self-test failed.
5558	HS IADC self-test failed.
5559	I CMR DAC self-test failed.
5560	I sense high self-test failed.
5561	Power supply test failed.
5562	V switch test failed.
5563	High force output relay test failed.
5564	High sense output relay test failed.

5601	VM offset calibration failed.
5602	V CMR DAC calibration failed.
5603	VM gain calibration failed.
5604	IM offset calibration failed.
5605	I CMR DAC calibration failed.
5606	Iad gain calibration failed.
5701	Power AMP bias adjustment failed.
N760	SMU failed function test.
N761	SMU failed VF/VM function test.
N762	SMU failed IF/IM function test.
N763	SMU failed loop status test.
N764	SMU failed temperature sensor test.
N765	SMU failed CMR amplifier calibration.
N766	SMU failed CMR amplifier adjustment.
N767	SMU failed CMR 100 V range full output test.
N768	SMU failed VF/VM calibration.
N769	SMU failed VM offset calibration.
N770	SMU failed VM gain calibration.
N771	SMU failed VF offset calibration.
N772	SMU failed VF gain calibration.
N773	SMU failed VF gain calibration at 20 V range.
N774	SMU failed VF filter offset calibration.
N775	SMU failed H-SPEED ADC self-calibration.
N776	SMU failed H-SPEED ADC VM offset calibration.
N777	SMU failed H-SPEED ADC VM gain calibration.
N778	SMU failed IF/IM calibration.
N779	SMU failed calibration bus test.
N780	SMU failed IM offset calibration.

N781	SMU failed IM gain calibration.
N782	SMU failed IF offset calibration.
N783	SMU failed IF gain calibration.
N784	SMU failed IDAC filter offset calibration.
N785	SMU failed oscillation detector test.
N786	SMU failed I bias test.
N787	SMU failed common mode rejection test.
N789	SMU failed high voltage detector test.
N790	SMU failed zero voltage detector test.
N791	SMU failed V hold test.
N792	SMU failed V switch test.
N800	CMU failed NULL DC offset adjustment.
N801	CMU failed NULL DC offset measurement.
N802	CMU failed VRD DC offset adjustment.
N803	CMU failed VRD heterodyne offset adjustment.
N804	CMU failed NULL gain/phase adjustment.
N805	CMU failed MODEM offset adjustment.
N806	CMU failed relative Z adjustment.
N807	CMU failed Vch full scale measurement.
N808	CMU failed nominal gain measurement
N809	CMU failed extent range X3 adjustment.
N810	CMU failed range resistor 50ohm adjustment.
N811	CMU failed range resistor 1kohm adjustment.
N812	CMU failed range resistor 10kohm adjustment.
N813	CMU failed range resistor 100kohm adjustment.
N814	CMU failed relative Z calculation.
N820	CMU failed correction.
N830	CMU failed configuration test.

N831	SCUU failed SCUU configuration test.
N832	SCUU failed SMU configuration test.
N833	SCUU failed CMU configuration test.
N834	CMU failed digital function test.
N835	CMU failed CPLD test.
N836	CMU failed FPGA test.
N837	CMU failed EEPROM test.
N838	CMU failed PLL1/PLL2 test.
N839	CMU failed PLL DET low state test.
N840	CMU failed PLL DET high state test.
N841	CMU failed PLL1 lock test
N842	CMU failed PLL2 lock test.
N843	CMU failed PLL2 lock test.
N844	CMU failed Hcur DC and VRD ADC test.
N845	CMU failed DC offset test.
N846	CMU failed DC bias 0V test.
N847	CMU failed DC bias -25V test.
N848	CMU failed DC bias +25V test.
N849	CMU failed PLL0 test.
N850	CMU failed PLL0 lock test.
N851	CMU failed PLL0 lock test.
N852	CMU failed DDS test.
N853	CMU failed DDS1 test.
N854	CMU failed DDS2 test.
N855	CMU failed VRD normalizer test.
N856	CMU failed RA1 test.
N857	CMU failed RA2 test.
N858	CMU failed ExR test.

N859	CMU failed R_LPF2 f1 test.
N860	CMU failed MODEM DAC test.
N861	CMU failed N_II_DAC test.
N862	CMU failed N_QI_DAC test.
N863	CMU failed N_IQ_DAC test.
N864	CMU failed N_QQ_DAC test.
N865	CMU failed TRD normalizer test.
N866	CMU failed NA1 test.
N867	CMU failed NA2 test.
N868	CMU failed NA3 test.
N869	CMU failed N_LPF1 f2 test.
N870	CMU failed N_LPF1 f3 test.
N871	CMU failed N_LPF1 f4 test.
N872	CMU failed N_LPF1 f5 test.
N873	SCUU failed EEPROM test.
N874	SCUU failed output relay test.
N875	SCUU failed control test.
N876	SCUU failed CG2 test.
N877	SCUU failed LRL test.
N880	CMU failed Hcur AC and VRD Fm test.
N881	CMU failed SA/RA 32mV test.
N882	CMU failed SA/RA 64mV test.
N883	CMU failed SA/RA 125mV test.
N884	CMU failed SA/RA 250mV test.
N885	CMU failed ExR test.
N886	CMU failed Bias_chg test.
N887	CMU failed R_LPF2/R_HPF_vs test.
N888	CMU failed VRD IF test.

N889	CMU failed IRM local 0deg test.
N890	CMU failed IRM local 90deg test.
N891	CMU failed S_LPF1 f1 120kHz test.
N892	CMU failed S_LPF1 f2 500kHz test.
N893	CMU failed S_LPF1 f3 2MHz test.
N894	CMU failed S_LPF1 f4 5MHz test.
N895	CMU failed TRD MODEM test.
N896	CMU failed VG local 90deg test.
N897	CMU failed VG local 0deg test.
N898	CMU failed NA4 test.
N899	CMU failed NA5 X1/4 test.
N900	CMU failed NA5 X1/8 test.
N901	CMU failed N_LPF2 f2 500kHz test.
N902	CMU failed N_LPF2 f3 5MHz test.
N903	CMU failed MODEM PSD test.
N904	CMU failed PSD 0deg test.
N905	CMU failed PSD 90deg test.
N906	CMU failed Rr/Rf 100ohm test.
N907	CMU failed Rr/Rf 1kohm test.
N908	CMU failed Rr/Rf 10kohm test.
N909	CMU failed Rr/Rf 100kohm test.
N910	CMU failed TRD IVAmp test.
N911	CMU failed N_HPF1/N_LPF1 10kHz test.
N912	CMU failed N_HPF1/N_LPF1 200kHz test.
N913	CMU failed N_HPF1/N_LPF1 1MHz test.
N914	CMU failed N_HPF1/N_LPF1 2MHz test.
N915	CMU failed N_HPF1/N_LPF1 5MHz test.
N916	CMU failed NA1 test.

N917	CMU failed NA2 test.
N918	CMU failed NA3 test.
N919	CMU failed IV saturation detector test.
N920	CMU failed normal status test.
N921	CMU failed normal status test.
N922	CMU failed IV saturation status test.
N923	CMU failed IV saturation status test.
N924	CMU failed unbalance detector test.
N925	CMU failed normal status test.
N926	CMU failed normal status test.
N927	CMU failed unbalance status test.
N928	CMU failed unbalance status test.
N929	CMU failed over current detector test.
N930	CMU failed normal status test.
N931	CMU failed normal status test.
N932	CMU failed over current status test.
N933	CMU failed over current status test.