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Measurement Resources

The measurement resources supported by Keysight B1500 series are shown below. For reading this manual, ignore the information about the unsupported resources.

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- HPSMU High power source/monitor unit (B1510A)
- MPSMU Medium power source/monitor unit (B1511A/B)
- MCSMU Medium current source/monitor unit (B1514A)
- MFCMU or CMU Multi frequency capacitance measurement unit (B1520A)
- HRSMU High resolution source/monitor unit (B1517A)
- HVSPGU or SPGU High voltage semiconductor pulse generator unit (B1525A)
- HVSMU High voltage source/monitor unit (B1513A/B/C)
- HVMCU High voltage medium current unit (N1266A with one B1513A/B/C and two B1514A/B1512A)
- HCSMU High current source/monitor unit (B1512A)
- UHCU Ultra high current unit (N1265A with two B1514A/B1512A)
- UHVU Ultra high voltage unit (N1268A with two B1514A/B1512A)
In This Manual

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

1. "Programming Basics"
   This chapter provides basic information to control the Keysight B1500.

2. "Remote Mode Functions"
   This chapter explains the functions of the Keysight B1500 in the remote mode.

3. "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.

4. "Command Reference"
   This chapter provides the complete reference of the GPIB commands of the Keysight B1500.

5. "Error Messages"
   This chapter lists the error codes, and explains them.
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<td>WSV</td>
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<td>WSX</td>
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</tr>
<tr>
<td>WT</td>
<td>4-246</td>
</tr>
<tr>
<td>WTACV</td>
<td>4-247</td>
</tr>
<tr>
<td>WTDCV</td>
<td>4-248</td>
</tr>
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<td>4-249</td>
</tr>
<tr>
<td>WV</td>
<td>4-250</td>
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</tr>
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</tr>
</tbody>
</table>

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1 Programming Basics
Programming Basics

This chapter describes basic information to control the Keysight 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 logical 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 Keysight FLEX command, perform following.

1. Terminate the Keysight 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 Keysight Connection Expert window by clicking Keysight IO Control icon on the Windows task bar and selecting Keysight 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 Required dialog box is opened, reboot the B1500.

**NOTE**

For the GPIB connection of this instrument, use an GPIB interface, Keysight 82350B (for PCI bus), Keysight 82357A/B (USB/GPIB), or National Instrument GPIB-USB-HS.

For using an USB/GPIB interface, it is recommended to set the GPIB address of this instrument to an even number. The USB/GPIB interface might cause serial poll error intermittently due to the intrinsic communication scheme differences. It is reported that using an even GPIB address sometimes significantly decreases the chance of the error.

**NOTE**

Start EasyEXPERT button

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 Keysight 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**

![FlexGUI Window](image)

**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 the *IDN? command response.
Example: Agilent Technologies,B1500A,0,A.03.10.2007.1021

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.
Programming Basics
Before Starting

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.

<table>
<thead>
<tr>
<th><strong>GPIB Capturing Mode</strong></th>
<th>Sets the display update mode to BYTE or BUFFER.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BYTE</strong></td>
<td>Updates the log display every byte data which is one character of ASCII format.</td>
</tr>
<tr>
<td><strong>BUFFER</strong></td>
<td>Updates the log display every buffer data which is data to a terminator.</td>
</tr>
</tbody>
</table>

| **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. |

<table>
<thead>
<tr>
<th><strong>Display Format</strong></th>
<th>Sets the following function ON or OFF. The function can be set to ON by checking the check box.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Show Hex Data</strong></td>
<td>Displays the values given in hexadecimal.</td>
</tr>
<tr>
<td><strong>Show Asci Data</strong></td>
<td>Displays the values given in ASCII format.</td>
</tr>
<tr>
<td><strong>Auto Clear</strong></td>
<td>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.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>OK</strong></th>
<th>Applies the setup changes and closes the dialog box.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cancel</strong></td>
<td>Cancels the setup changes and closes the dialog box.</td>
</tr>
</tbody>
</table>
Getting Started
This section explains the following basic operations. In this section, the HP BASIC language is used for the examples.

- “To Reset the Keysight 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 Keysight 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 2-87.

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 4-222.

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 4-58.
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 4-74.

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 4-151.
**Programming Basics**

**Getting Started**

### Table 1-1 Measurement Mode

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

**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**

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

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DV</td>
<td>Applies DC voltage from SMU immediately.</td>
</tr>
<tr>
<td>DI</td>
<td>Applies DC current from SMU immediately.</td>
</tr>
<tr>
<td>FC/ACV</td>
<td>Applies AC voltage from CMU immediately.</td>
</tr>
<tr>
<td>DCV</td>
<td>Applies DC bias from CMU immediately.</td>
</tr>
<tr>
<td>TDV</td>
<td>Applies DC voltage from SMU, and returns the time data.</td>
</tr>
<tr>
<td>TDI</td>
<td>Applies DC current from SMU, and returns the time data.</td>
</tr>
<tr>
<td>FC/TACV</td>
<td>Applies AC voltage from CMU, and returns the time data.</td>
</tr>
<tr>
<td>TDCV</td>
<td>Applies DC bias from CMU, and returns the time data.</td>
</tr>
</tbody>
</table>

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 Keysight 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.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-speed ADC</td>
<td>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.</td>
</tr>
<tr>
<td>High-resolution ADC</td>
<td>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.</td>
</tr>
<tr>
<td>Pulsed measurement ADC</td>
<td>Always used for the pulsed measurement. The number of averaging samples must be set by the AIT.</td>
</tr>
</tbody>
</table>

**Example**

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

```plaintext
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.

```plaintext
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:

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

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 4-187.
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 Keysight B1500A. ASU (atto sense and switch unit) has two inputs, SMU input for the B1511B/B1517A 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**

<table>
<thead>
<tr>
<th>Previous Connection</th>
<th>Command</th>
<th>Subsequent Connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMU side, Output on/off</td>
<td>SAP chnum, 1</td>
<td>AUX side</td>
</tr>
<tr>
<td>SMU side, Output off</td>
<td>CN chnum</td>
<td>SMU side, Output on</td>
</tr>
<tr>
<td></td>
<td>SAP chnum, 0</td>
<td></td>
</tr>
<tr>
<td>AUX side</td>
<td>CN chnum</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SAP chnum, 0</td>
<td></td>
</tr>
<tr>
<td>SMU side, Output on</td>
<td>CL [chnum]</td>
<td>SMU side, Output off</td>
</tr>
</tbody>
</table>

where, `chnum` must be the channel number of the SMU connected to the ASU. See “SAL”, “SAP”, and “SAR” on page 4-187 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 Keysight 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

<table>
<thead>
<tr>
<th>Command</th>
<th>SCUU output connection after the command</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CMUH/Force1/Sense1</td>
</tr>
<tr>
<td>SSP chnum, 1</td>
<td>Force1/Sense1</td>
</tr>
<tr>
<td>SSP chnum, 2</td>
<td>Open</td>
</tr>
<tr>
<td>SSP chnum, 3</td>
<td>Force1/Sense1</td>
</tr>
<tr>
<td>SSP chnum, 4</td>
<td>CMUH</td>
</tr>
</tbody>
</table>

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:

```vbnet
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:

```vbnet
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 \( (Time=0 \text{ s}) \) 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:

\[ \text{Block1} [, \text{Block2}] \ldots \ldots \text{<terminator>} \]

\[ \text{BlockN} (N: \text{integer}) = \text{Time1}, \text{Data1} [, \text{Time2}, \text{Data2}] \ldots [, \text{Source_data}] \]

\[ \text{TimeN} (N: \text{integer}) \text{ is the time from timer reset to the start of DataN measurement.} \]

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

- **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:**
  ```plaintext```
  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"
  ```plaintext```

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

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

<table>
<thead>
<tr>
<th>Line Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Assigns the I/O path to control the B1500.</td>
</tr>
<tr>
<td>20</td>
<td>Initializes the B1500.</td>
</tr>
<tr>
<td>30</td>
<td>Sets the data output format (ASCII with header and &lt;,&gt;).</td>
</tr>
<tr>
<td>40</td>
<td>Enables channels 1, 2, 3, and 4.</td>
</tr>
<tr>
<td>50 to 80</td>
<td>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.</td>
</tr>
<tr>
<td>90</td>
<td>Performs the high speed spot measurement using channel 4 with auto ranging.</td>
</tr>
<tr>
<td>100 to 110</td>
<td>Prints the header data and measurement data on the screen.</td>
</tr>
<tr>
<td>120</td>
<td>Forces 0 V. All channels force 0 V.</td>
</tr>
<tr>
<td>130</td>
<td>Disables all channels.</td>
</tr>
</tbody>
</table>
Command Input Format

Keysight FLEX commands (GPIB commands for the Keysight 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 Keysight 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**

*1: Here must be 2 digits or less.
Programming Basics
Command Input Format

**Terminator**

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

**Terminator Syntax Diagram**

![Terminator Syntax Diagram](image)

**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**

![Special Terminator Syntax Diagram](image)

**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

Keysight 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 Keysight 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 Keysight 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 4-118.

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

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 `<^EOI>` (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.

<table>
<thead>
<tr>
<th>Measurement Mode</th>
<th>Data Output Format</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High speed spot</strong></td>
<td><em>Data</em> &lt;terminator&gt; (by TI, TV, TMACV, or TMDCV command)</td>
</tr>
<tr>
<td></td>
<td><em>Time,Data</em> &lt;terminator&gt; (by TTI or TTV command)</td>
</tr>
<tr>
<td></td>
<td><em>Para1,Para2</em> &lt;terminator&gt; (by TIV or TC command)</td>
</tr>
<tr>
<td></td>
<td><em>Time,Para1,Para2</em> &lt;terminator&gt; (by TTIV or TTC command)</td>
</tr>
<tr>
<td></td>
<td>Data is the value measured by the channel you specify in the command. <em>Time</em> is the time from timer reset to the start of measurement. <em>Para1</em> and <em>Para2</em> 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 4-16 on page 4-29.</td>
</tr>
<tr>
<td><strong>TDI, TDV, TSQ, TACV, TDCV command</strong></td>
<td><em>Time</em> &lt;terminator&gt;</td>
</tr>
<tr>
<td></td>
<td><em>Time</em> is the time from timer reset to the start of output.</td>
</tr>
<tr>
<td><strong>Spot, Multi channel</strong></td>
<td><em>Data</em> &lt;terminator&gt;</td>
</tr>
<tr>
<td><strong>pulsed spot</strong></td>
<td><em>Data</em> is the value measured by the channel. The order of <em>Data</em> is defined by the MM command.</td>
</tr>
<tr>
<td><strong>Pulsed spot, Quasi-pulsed spot, Spot C, Pulsed spot C</strong></td>
<td><em>Data</em> &lt;terminator&gt;</td>
</tr>
<tr>
<td></td>
<td><em>Data</em> is the value measured by the channel you specify by using the MM command.</td>
</tr>
<tr>
<td></td>
<td>For the spot C measurement, <em>Data</em> will be <em>Para1,Para2 [ ,Osc_level, Dc_bias]</em>.</td>
</tr>
<tr>
<td></td>
<td>For the pulsed spot C measurement, <em>Data</em> will be <em>Para1,Para2</em>.</td>
</tr>
<tr>
<td></td>
<td><em>Para1</em> and <em>Para2</em> are the primary and secondary parameters (ex: Cp and G). They are selected by the IMP command. See Table 4-16 on page 4-29. And <em>Osc_level</em> and <em>Dc_bias</em> 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.</td>
</tr>
<tr>
<td><strong>Linear search, Binary search</strong></td>
<td><em>Data_search</em> &lt;terminator&gt;</td>
</tr>
<tr>
<td></td>
<td>This is the data at the measurement point closest to the search target. <em>Data_search</em> is the value forced by the search output channel. <em>Data_sense</em> 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.</td>
</tr>
</tbody>
</table>
Programming Basics
Data Output Format

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: C_p and G). They are selected by the IMP command. See Table 4-16 on page 4-29. 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: C_p and G). They are selected by the IMP command. See Table 4-16 on page 4-29. 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 4-16 on page 4-29.

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

<table>
<thead>
<tr>
<th>Data</th>
<th>FMT command</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABCDDDDDDDDDDDDDDDD</td>
<td>FMT1 or FMT5</td>
</tr>
<tr>
<td>ABCDDDDDDDDDDDDDDDD</td>
<td>FMT11 or FMT15</td>
</tr>
<tr>
<td>EEEFGDDDDDDDDDDDDDDDDDDDD</td>
<td>FMT21 or FMT25</td>
</tr>
<tr>
<td>DDDDDDDDDDDDDDDDDDD</td>
<td>FMT2</td>
</tr>
<tr>
<td>DDDDDDDDDDDDDDDDDDD</td>
<td>FMT12 or FMT22</td>
</tr>
</tbody>
</table>
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.nnnnnEsnn or sn.nnnnnnEsnn
   • snn.nnnnEsnn or snn.nnnn Esnn
   • ssnn.nnnEsnn or ssnn.nnnEsnn
   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).
Programming Basics
Data Output Format

**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**

<table>
<thead>
<tr>
<th>A or EEE</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>Data is for the first or intermediate sweep step.</td>
</tr>
<tr>
<td>E</td>
<td>Data is for the last sweep step.</td>
</tr>
</tbody>
</table>

**Table 1-8**
**SMU Status**

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

**Table 1-9**
**CMU Status**

<table>
<thead>
<tr>
<th>EEE</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A/D converter overflowed.</td>
</tr>
<tr>
<td>2</td>
<td>CMU is in the NULL loop unbalance condition.</td>
</tr>
<tr>
<td>4</td>
<td>CMU is in the IV amplifier saturation condition.</td>
</tr>
<tr>
<td>8</td>
<td>Not assigned.</td>
</tr>
<tr>
<td>16</td>
<td>Not assigned.</td>
</tr>
<tr>
<td>32</td>
<td>Not assigned.</td>
</tr>
<tr>
<td>64</td>
<td>Invalid data is returned. $D$ is not used.</td>
</tr>
<tr>
<td>128</td>
<td>EOD (End of Data).</td>
</tr>
</tbody>
</table>
### Table 1-10 Status for Measurement Data

<table>
<thead>
<tr>
<th>A</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>No status error occurred.</td>
</tr>
<tr>
<td>T</td>
<td>Another channel reached its compliance setting.</td>
</tr>
<tr>
<td>C</td>
<td>This channel reached its compliance setting.</td>
</tr>
<tr>
<td>V</td>
<td>Measurement data is over the measurement range. Or the sweep measurement</td>
</tr>
<tr>
<td></td>
<td>was aborted by the automatic stop function or power compliance. D will be</td>
</tr>
<tr>
<td></td>
<td>199.999E+99 (no meaning).</td>
</tr>
<tr>
<td>X</td>
<td>One or more channels are oscillating. Or source output did not settle before</td>
</tr>
<tr>
<td></td>
<td>measurement.</td>
</tr>
<tr>
<td></td>
<td>a. Make the wait time or delay time longer. Or make the current compliance</td>
</tr>
<tr>
<td></td>
<td>larger. For pulsed measurement, make the pulse width longer, or make the</td>
</tr>
<tr>
<td></td>
<td>pulse base value closer to the pulse peak value. For current output by</td>
</tr>
<tr>
<td></td>
<td>limited auto ranging, make the output range lower.</td>
</tr>
<tr>
<td>F</td>
<td>SMU is in the force saturation condition.</td>
</tr>
<tr>
<td>G</td>
<td>For linear or binary search measurement, the target value was not found</td>
</tr>
<tr>
<td></td>
<td>within the search range. Returns the source output value.</td>
</tr>
<tr>
<td></td>
<td>For quasi-pulsed spot measurement, the detection time was over the limit</td>
</tr>
<tr>
<td></td>
<td>(3 s for Short mode, 12 s for Long mode).</td>
</tr>
<tr>
<td>S</td>
<td>For linear or binary search measurement, the search measurement was stopped</td>
</tr>
<tr>
<td></td>
<td>Returns the source output value. See status of Data_sense.</td>
</tr>
<tr>
<td></td>
<td>For quasi-pulsed spot measurement, output slew rate was too slow to perform</td>
</tr>
<tr>
<td></td>
<td>the settling detection. Or quasi-pulsed source channel reached the current</td>
</tr>
<tr>
<td></td>
<td>compliance before the source output voltage changed 10 V from the start</td>
</tr>
<tr>
<td></td>
<td>voltage.</td>
</tr>
<tr>
<td>U</td>
<td>CMU is in the NULL loop unbalance condition.</td>
</tr>
<tr>
<td>D</td>
<td>CMU is in the IV amplifier saturation condition.</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>B or F</th>
<th>Explanationa</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Subchannel 1 of the module installed in the slot 1</td>
</tr>
<tr>
<td>B</td>
<td>Subchannel 1 of the module installed in the slot 2</td>
</tr>
<tr>
<td>C</td>
<td>Subchannel 1 of the module installed in the slot 3</td>
</tr>
<tr>
<td>D</td>
<td>Subchannel 1 of the module installed in the slot 4</td>
</tr>
<tr>
<td>E</td>
<td>Subchannel 1 of the module installed in the slot 5</td>
</tr>
<tr>
<td>F</td>
<td>Subchannel 1 of the module installed in the slot 6</td>
</tr>
<tr>
<td>G</td>
<td>Subchannel 1 of the module installed in the slot 7</td>
</tr>
<tr>
<td>H</td>
<td>Subchannel 1 of the module installed in the slot 8</td>
</tr>
<tr>
<td>I</td>
<td>Subchannel 1 of the module installed in the slot 9</td>
</tr>
<tr>
<td>J</td>
<td>Subchannel 1 of the module installed in the slot 10</td>
</tr>
<tr>
<td>a</td>
<td>Subchannel 2 of the module installed in the slot 1</td>
</tr>
<tr>
<td>b</td>
<td>Subchannel 2 of the module installed in the slot 2</td>
</tr>
<tr>
<td>c</td>
<td>Subchannel 2 of the module installed in the slot 3</td>
</tr>
<tr>
<td>d</td>
<td>Subchannel 2 of the module installed in the slot 4</td>
</tr>
<tr>
<td>e</td>
<td>Subchannel 2 of the module installed in the slot 5</td>
</tr>
<tr>
<td>f</td>
<td>Subchannel 2 of the module installed in the slot 6</td>
</tr>
<tr>
<td>g</td>
<td>Subchannel 2 of the module installed in the slot 7</td>
</tr>
<tr>
<td>h</td>
<td>Subchannel 2 of the module installed in the slot 8</td>
</tr>
<tr>
<td>i</td>
<td>Subchannel 2 of the module installed in the slot 9</td>
</tr>
<tr>
<td>j</td>
<td>Subchannel 2 of the module installed in the slot 10</td>
</tr>
<tr>
<td>F</td>
<td>Ground unit (GNDU)</td>
</tr>
<tr>
<td>V</td>
<td>Status code for extraneous data in the channel. TSQ command response or invalid data is returned.</td>
</tr>
</tbody>
</table>

a. SMU and CMU do not have the subchannel 2.
<table>
<thead>
<tr>
<th>C or G</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>Voltage (V)</td>
</tr>
<tr>
<td>I</td>
<td>Current (A)</td>
</tr>
<tr>
<td>F</td>
<td>Frequency (Hz)</td>
</tr>
<tr>
<td>Z</td>
<td>Impedance, resistance, or reactance (Ω)</td>
</tr>
<tr>
<td>Y</td>
<td>Admittance, conductance, or susceptance (S)</td>
</tr>
<tr>
<td>C</td>
<td>Capacitance (F)</td>
</tr>
<tr>
<td>L</td>
<td>Inductance (H)</td>
</tr>
<tr>
<td>R</td>
<td>Phase (radian)</td>
</tr>
<tr>
<td>P</td>
<td>Phase (degree)</td>
</tr>
<tr>
<td>D</td>
<td>Dissipation factor</td>
</tr>
<tr>
<td>Q</td>
<td>Quality factor</td>
</tr>
<tr>
<td>X</td>
<td>Sampling index</td>
</tr>
<tr>
<td>T</td>
<td>Time (second)</td>
</tr>
<tr>
<td>G</td>
<td>Voltage measurement value (V)</td>
</tr>
<tr>
<td>I</td>
<td>Current measurement value (A)</td>
</tr>
<tr>
<td>V</td>
<td>Voltage output value (V)</td>
</tr>
<tr>
<td>i</td>
<td>Current output value (A)</td>
</tr>
<tr>
<td>f</td>
<td>Frequency (Hz)</td>
</tr>
<tr>
<td>z</td>
<td>invalid data</td>
</tr>
</tbody>
</table>
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 \((\text{Time})\). 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.

\[
\text{Block1} \ [\text{Block2}] \ldots \ <\text{terminator}>
\]

where, \(\text{BlockN} (N: \text{integer}) = \text{Time1 Data1} [\text{Time2 Data2}] \ldots [\text{Source}\_\text{data}]\), then \(\text{TimeN} (N: \text{integer})\) is the time from timer reset to the start of \(\text{DataN}\) measurement.

The timer count is cleared/reset by the TSR command \((\text{Time}=0)\).

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): \(\text{Range} / 50000\)
- SMU output value (voltage or current): \(\text{Range} / 20000\)
- CMU measurement value (resistance or reactance): \(\text{Range} / 2^{12}\)
- CMU measurement value (conductance or susceptance): \(1 / (\text{Range} \times 2^{12})\)
- CMU oscillator level monitor value (Vac), DC bias monitor value (Vdc), frequency (Hz): \(\text{Range} / 50000\)
- 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): \(\text{Range} / 1000000\)
- CMU measurement value (resistance or reactance): \(\text{Range} / 2^{24}\)
- CMU measurement value (conductance or susceptance): \(1 / (\text{Range} \times 2^{24})\)
- CMU oscillator level monitor value (Vac), DC bias monitor value (Vdc), frequency (Hz): \(\text{Range} / 1000000\)
- 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.
Programming Basics

Data Output Format

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>
<thead>
<tr>
<th></th>
<th>Byte 1</th>
<th>Byte 2</th>
<th>Byte 3</th>
<th>Byte 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>E</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</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.

<table>
<thead>
<tr>
<th></th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Data other than measurement data.</td>
</tr>
<tr>
<td>1</td>
<td>Measurement data.</td>
</tr>
</tbody>
</table>

**B**

Parameter. One bit.

<table>
<thead>
<tr>
<th></th>
<th>for SMU data</th>
<th>for CMU data</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Voltage</td>
<td>Resistance or reactance</td>
</tr>
<tr>
<td>1</td>
<td>Current or Capacitance</td>
<td>Conductance or susceptance</td>
</tr>
</tbody>
</table>
**Programming Basics**

**Data Output Format**

C

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

<table>
<thead>
<tr>
<th>C</th>
<th>for SMU data</th>
<th>C</th>
<th>for CMU data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>01000 (8)</td>
<td>0.5 V</td>
<td>1 pA</td>
<td>1 pF</td>
</tr>
<tr>
<td>01001 (9)</td>
<td>5 V</td>
<td>10 pA</td>
<td>10 pF</td>
</tr>
<tr>
<td>01010 (10)</td>
<td>0.2 V</td>
<td>100 pA</td>
<td>100 pF</td>
</tr>
<tr>
<td>01011 (11)</td>
<td>2 V</td>
<td>1 nA</td>
<td>1 nF</td>
</tr>
<tr>
<td>01100 (12)</td>
<td>20 V</td>
<td>10 nA</td>
<td>10 nF</td>
</tr>
<tr>
<td>01101 (13)</td>
<td>40 V</td>
<td>100 nA</td>
<td>100 nF</td>
</tr>
<tr>
<td>01110 (14)</td>
<td>100 V</td>
<td>1 μA</td>
<td>1 μF</td>
</tr>
<tr>
<td>01111 (15)</td>
<td>200 V</td>
<td>10 μA</td>
<td>10 μF</td>
</tr>
<tr>
<td>10000 (16)</td>
<td>500 V</td>
<td>100 μA</td>
<td>100 μF</td>
</tr>
<tr>
<td>10001 (17)</td>
<td>1500 V</td>
<td>1 mA</td>
<td>1 mF</td>
</tr>
<tr>
<td>10010 (18)</td>
<td>3000 V</td>
<td>10 mA</td>
<td>10 mF</td>
</tr>
<tr>
<td>10011 (19)</td>
<td>10 kV</td>
<td>100 mA</td>
<td>100 mF</td>
</tr>
<tr>
<td>10100 (20)</td>
<td>1 A</td>
<td>1 F</td>
<td></td>
</tr>
<tr>
<td>10101 (21)</td>
<td>2 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10110 (22)</td>
<td>20 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10111 (23)</td>
<td>40 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11010 (26)</td>
<td>500 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11100 (28)</td>
<td>2000 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11111 (31)</td>
<td>Invalid data is returned.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**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 = \( \text{Count} \times \text{Range} / 50000 \)

Source data = \( \text{Count} \times \text{Range} / 20000 \)

where, \( \text{Count} \) is the \( D \) value, and \( \text{Range} \) is the measurement range or output range given by \( C \).

If the top bit of \( D \) is 0, \( \text{Count} \) is positive and equal to the value given by the following 16 bits. If the top bit of \( D \) is 1, \( \text{Count} \) is negative. Calculate \( \text{Count} \) 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)

\( \text{Range} \): 1 nA = \( 10^{-(11-20)} \) A (\( C=01011 \) in binary, \( C=11 \) in decimal)

\( \text{Count} \): 5000 (\( D=00001001110001000 \))

Status: Normal condition (\( E=000 \))

Channel: SMU1 (channel number 1) (\( F=00001 \))

\( \text{Measurement data} = 5000 \times 1\times 10^{-9} / 5\times 10^4 = 100 \text{ pA} \)

**NOTE**

For the current or capacitance data, \( \text{Range} \) value can be expressed by the following formula. This is effective for \( C \leq 20 \), not effective for \( 21 \leq C \).

\( \text{Range} = 10^{(C-20)} \)
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 = $\frac{\text{Count} \times \text{Range}}{2^{12}}$

Conductance or susceptance = $\frac{\text{Count}}{2^{12} \times \text{Range}}$

OSC level monitor value = $\frac{\text{Count} \times \text{Range}}{50000}$

DC bias monitor value = $\frac{\text{Count} \times \text{Range}}{50000}$

DC bias output value = $\frac{\text{Count}}{500}$

Output signal frequency = $\frac{\text{Count} \times \text{Range}}{50000}$

where, $\text{Count}$ is the $D$ value, and $\text{Range}$ is the measurement range or output range given by $C$.

If the top bit of $D$ is 0, $\text{Count}$ is positive and equal to the value given by the following 16 bits. If the top bit of $D$ is 1, $\text{Count}$ is negative. Calculate $\text{Count}$ by subtracting 65536 (10000000000000000 in binary) from the value given by the following 16 bits.

Example:

If the output binary data is:

1000100000001111101000000001000

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 ($D=00000111110100000$)
Status: Normal condition ($E=000$)
Channel: 8 ($F=01000$)

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

NOTE

For the resistance, reactance, conductance, or susceptance data, $\text{Range}$ value can be expressed by the following formula.

$\text{Range} = 10^C$
**E** Status. Three bits.

- Status for *Source data*:
  
  Severity of a status is 001<010.

<table>
<thead>
<tr>
<th></th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>001</td>
<td>Data is for the first or intermediate sweep step.</td>
</tr>
<tr>
<td>010</td>
<td>Data is for the last sweep step.</td>
</tr>
</tbody>
</table>

- 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

<table>
<thead>
<tr>
<th>E</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>000 (0)</td>
<td>No status error occurred.</td>
</tr>
<tr>
<td>001 (1)</td>
<td>For SMU: Another channel reached its compliance setting. For CMU: CMU is in the NULL loop unbalance condition.</td>
</tr>
<tr>
<td>010 (2)</td>
<td>For SMU: This channel reached its compliance setting. For CMU: CMU is in the IV amplifier saturation condition.</td>
</tr>
<tr>
<td>011 (3)</td>
<td>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.</td>
</tr>
<tr>
<td>100 (4)</td>
<td>One or more channels are oscillating. Or source output did not settle before measurement.</td>
</tr>
<tr>
<td>101 (5)</td>
<td>SMU is in the force saturation condition.</td>
</tr>
<tr>
<td>110 (6)</td>
<td>For linear or binary search measurement, the target value was not found within the search range. Returns the source output value.</td>
</tr>
<tr>
<td></td>
<td>For quasi-pulsed spot measurement, the detection time was over the limit (3 s for Short mode, 12 s for Long mode).</td>
</tr>
<tr>
<td>111 (7)</td>
<td>For linear or binary search measurement, the search measurement was stopped. Returns the source output value. See status of Data_sense.</td>
</tr>
<tr>
<td></td>
<td>For quasi-pulsed spot measurement, output slew rate was too slow to perform the settling detection. Or quasi-pulsed source channel reached the current compliance before the source output voltage changed 10 V from the start voltage.</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Channel Number</th>
<th>Explanation&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00001 (1)</td>
<td>Subchannel 1 of the module installed in the slot 1</td>
</tr>
<tr>
<td>00010 (2)</td>
<td>Subchannel 1 of the module installed in the slot 2</td>
</tr>
<tr>
<td>00011 (3)</td>
<td>Subchannel 1 of the module installed in the slot 3</td>
</tr>
<tr>
<td>00100 (4)</td>
<td>Subchannel 1 of the module installed in the slot 4</td>
</tr>
<tr>
<td>00101 (5)</td>
<td>Subchannel 1 of the module installed in the slot 5</td>
</tr>
<tr>
<td>00110 (6)</td>
<td>Subchannel 1 of the module installed in the slot 6</td>
</tr>
<tr>
<td>00111 (7)</td>
<td>Subchannel 1 of the module installed in the slot 7</td>
</tr>
<tr>
<td>01000 (8)</td>
<td>Subchannel 1 of the module installed in the slot 8</td>
</tr>
<tr>
<td>01001 (9)</td>
<td>Subchannel 1 of the module installed in the slot 9</td>
</tr>
<tr>
<td>01010 (10)</td>
<td>Subchannel 1 of the module installed in the slot 10</td>
</tr>
<tr>
<td>01011 (11)</td>
<td>Subchannel 2 of the module installed in the slot 1</td>
</tr>
<tr>
<td>01100 (12)</td>
<td>Subchannel 2 of the module installed in the slot 2</td>
</tr>
<tr>
<td>01101 (13)</td>
<td>Subchannel 2 of the module installed in the slot 3</td>
</tr>
<tr>
<td>01110 (14)</td>
<td>Subchannel 2 of the module installed in the slot 4</td>
</tr>
<tr>
<td>01111 (15)</td>
<td>Subchannel 2 of the module installed in the slot 5</td>
</tr>
<tr>
<td>10000 (16)</td>
<td>Subchannel 2 of the module installed in the slot 6</td>
</tr>
<tr>
<td>10001 (17)</td>
<td>Subchannel 2 of the module installed in the slot 7</td>
</tr>
<tr>
<td>10010 (18)</td>
<td>Subchannel 2 of the module installed in the slot 8</td>
</tr>
<tr>
<td>10011 (19)</td>
<td>Subchannel 2 of the module installed in the slot 9</td>
</tr>
<tr>
<td>10100 (20)</td>
<td>Subchannel 2 of the module installed in the slot 10</td>
</tr>
<tr>
<td>11010 (26)</td>
<td>Status code for extraneous data in the channel. TSQ command response or invalid data is returned.</td>
</tr>
<tr>
<td>11111 (31)</td>
<td>Invalid data is returned.</td>
</tr>
</tbody>
</table>

<sup>a</sup> 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>
<thead>
<tr>
<th>Byte 1</th>
<th>Byte 2</th>
<th>Byte 3</th>
<th>Byte 4</th>
<th>Byte 5</th>
<th>Byte 6</th>
<th>Byte 7</th>
<th>Byte 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td>G</td>
<td>H</td>
</tr>
</tbody>
</table>

For time data:

<table>
<thead>
<tr>
<th>Byte 1</th>
<th>Byte 2</th>
<th>Byte 3</th>
<th>Byte 4</th>
<th>Byte 5</th>
<th>Byte 6</th>
<th>Byte 7</th>
<th>Byte 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</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.

<table>
<thead>
<tr>
<th>A</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Data other than measurement data.</td>
</tr>
<tr>
<td>1</td>
<td>Measurement data.</td>
</tr>
</tbody>
</table>

### B

Parameter. Seven bits.

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

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

<table>
<thead>
<tr>
<th>C</th>
<th>for SMU data</th>
<th>for CMU data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V</td>
<td>I</td>
</tr>
<tr>
<td>00000000 (0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00000001 (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00000010 (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00000011 (3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00000100 (4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00000101 (5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00000110 (6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00000111 (7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00001000 (8)</td>
<td>0.5 V</td>
<td>1 pA</td>
</tr>
<tr>
<td>00001001 (9)</td>
<td>5 V</td>
<td>10 pA</td>
</tr>
<tr>
<td>00001010 (10)</td>
<td>0.2 V</td>
<td>100 pA</td>
</tr>
<tr>
<td>00001011 (11)</td>
<td>2 V</td>
<td>1 nA</td>
</tr>
<tr>
<td>00001100 (12)</td>
<td>20 V</td>
<td>10 nA</td>
</tr>
<tr>
<td>00001101 (13)</td>
<td>40 V</td>
<td>100 nA</td>
</tr>
<tr>
<td>00001110 (14)</td>
<td>100 V</td>
<td>1 μA</td>
</tr>
<tr>
<td>00001111 (15)</td>
<td>200 V</td>
<td>10 μA</td>
</tr>
<tr>
<td>00010000 (16)</td>
<td>500 V</td>
<td>100 μA</td>
</tr>
<tr>
<td>00010001 (17)</td>
<td>1500 V</td>
<td>1 mA</td>
</tr>
<tr>
<td>00010010 (18)</td>
<td>3000 V</td>
<td>10 mA</td>
</tr>
<tr>
<td>00010011 (19)</td>
<td>10 kV</td>
<td>100 mA</td>
</tr>
<tr>
<td>00010100 (20)</td>
<td>1 A</td>
<td>1 F</td>
</tr>
<tr>
<td>00010101 (21)</td>
<td>2 A</td>
<td></td>
</tr>
<tr>
<td>00010110 (22)</td>
<td>20 A</td>
<td></td>
</tr>
<tr>
<td>00010111 (23)</td>
<td>40 A</td>
<td></td>
</tr>
<tr>
<td>00011010 (26)</td>
<td>500 A</td>
<td></td>
</tr>
<tr>
<td>00011100 (28)</td>
<td>2000 A</td>
<td></td>
</tr>
<tr>
<td>00011111 (31)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 = \( \text{Count} \times \text{Range} \div 2^{24} \)

Conductance or susceptance = \( \frac{\text{Count}}{(2^{24} \times \text{Range})} \)

DC bias output value = \( \frac{\text{Count}}{1000} \)

Data other than the above parameters = \( \frac{\text{Count} \times \text{Range}}{1000000} \)

where, \( \text{Count} \) is the \( D \) value, and \( \text{Range} \) is the measurement range or output range given by \( C \).

If the top bit of \( D \) is 0, \( \text{Count} \) is positive and equal to the value given by the following 31 bits. If the top bit of \( D \) is 1, \( \text{Count} \) is negative. Calculate \( \text{Count} \) by subtracting 2,147,483,648 (10000000000000000000000000000000 in binary) from the value given by the following 31 bits.

Example:

If the output binary data is:

10000010000101100000000000000011000011010100000000000000000001

then,

**Type:** Measurement data (\( A=1 \))

**Parameter:** Current (\( B=0000001 \))

**Range:** 1 nA = \( 10^{\text{C} \times 10^{-20}} \) A (\( C=01011 \) in binary, \( C=11 \) in decimal)

**Count:** 100000 (\( D=00000000000000000000110000110101000000 \))

**Status:** Normal condition (\( E=00000000 \))

**ADC:** High speed ADC (\( G=000 \))

**Channel:** SMU1 (channel number 1) (\( F=00001 \))

**Measurement data** = \( 100000 \times 10^{-9} / 10^6 = 100 \text{ pA} \)

**NOTE**

For the current or capacitance data, \( \text{Range} \) value can be expressed by the following formula. This is effective for \( C \leq 20 \), not effective for \( 21 \leq C \).

\( \text{Range} = 10^{\text{C} \times 10^{-20}} \)

For the resistance, reactance, conductance, or susceptance data, \( \text{Range} \) value can be:

\( \text{Range} = 10^{\text{C}} \)
Programming Basics
Data Output Format

E

Status. One byte. Meaningless for the Time data.

- Status for Source_data:

  Severity of a status is 001<010.

<table>
<thead>
<tr>
<th>E</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>00000001</td>
<td>Data is for the first or intermediate sweep step.</td>
</tr>
<tr>
<td>00000010</td>
<td>Data is for the last sweep step.</td>
</tr>
</tbody>
</table>

- 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.

<table>
<thead>
<tr>
<th>G</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>000 (0)</td>
<td>SMU High Speed ADC</td>
</tr>
<tr>
<td>001 (1)</td>
<td>SMU High Resolution ADC</td>
</tr>
<tr>
<td>010 (2)</td>
<td>CMU ADC</td>
</tr>
</tbody>
</table>
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.

\[ \text{Time} = \frac{\text{Count}}{1000000} \]

where, \( \text{Count} \) is the decimal value of \( H \).

If the top bit of \( H \) is 0, \( \text{Count} \) is positive and equal to the value given by the following 47 bits.

If the top bit of \( H \) is 1, \( \text{Count} \) is negative. Calculate \( \text{Count} \) by subtracting 140737488355328 (100000000000000000000000000000000000000000 in binary) from the value given by the following 47 bits.

\( H=100000000000000000000000000000000000000000 \) means invalid data.

**Example:**

If the output binary data is:

0000001100000000000000000000000000000001100001101010000000000000

then,

**Type:** Data other than the measurement data \((A=0)\)

**Parameter:** Time \((B=000011)\)

**Count:**

100000 \((H=

000000000000000000000000000000000001100001101010000000000000)\)

**Channel:** SMU1 (channel number 1) \((F=00001)\)

\(\text{Time data} = \frac{1000000}{1000000} = 0.1 \text{ second}\)
<table>
<thead>
<tr>
<th>E</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>00000000 (0)</td>
<td>No status error occurred.</td>
</tr>
<tr>
<td>00000001 (1)</td>
<td>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 ).</td>
</tr>
</tbody>
</table>
| 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. |
| 00001000 (4) | For SMU: Another channel reached its compliance setting.  
For CMU: CMU is in the IV amplifier saturation condition. |
| 00001010 (5) | SMU is in the force saturation condition. |
| 00010000 (8) | This channel reached its compliance setting. |
| 00100000 (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 Keysight B1500. These functions provide the means for an instrument to receive, process, and transmit, commands, data, and status over the GPIB bus.

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

<table>
<thead>
<tr>
<th>Bit</th>
<th>Decimal Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>Data ready</td>
</tr>
<tr>
<td></td>
<td></td>
<td>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.</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>Wait</td>
</tr>
<tr>
<td></td>
<td></td>
<td>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.</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>Not applicable. This bit is always set to “0”.</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>Interlock open</td>
</tr>
<tr>
<td></td>
<td></td>
<td>If the interlock circuit is open, and a voltage output or voltage compliance setup value exceeds the allowable voltage for the interlock open condition, this bit is set to “1”. It is set to “0” when the B1500 receives a serial poll, *RST, or device clear command.</td>
</tr>
</tbody>
</table>
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.

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.

<table>
<thead>
<tr>
<th>Bit</th>
<th>Decimal Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>16</td>
<td>Set ready</td>
</tr>
<tr>
<td></td>
<td></td>
<td>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.</td>
</tr>
<tr>
<td>5</td>
<td>32</td>
<td>Error</td>
</tr>
<tr>
<td></td>
<td></td>
<td>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.</td>
</tr>
<tr>
<td>6</td>
<td>64</td>
<td>RQS (You cannot mask this bit.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>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.</td>
</tr>
<tr>
<td>7</td>
<td>128</td>
<td>Not applicable. This bit is always set to “0”.</td>
</tr>
</tbody>
</table>

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 Keysight 4142B”
- “To Use Programs for Keysight 4155/4156”
- “To Use Programs for Keysight 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 ",#;X,12D",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 Keysight 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:

\[
\text{wait time} = \text{initial wait time} \times A+B
\]

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

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AV</td>
<td>Changes the number of averaging samples during the measurement.</td>
</tr>
<tr>
<td>AIT</td>
<td>Changes the A/D converter setting of the SMU during the measurement.</td>
</tr>
<tr>
<td>ACT</td>
<td>Changes the A/D converter setting of the CMU during the measurement.</td>
</tr>
<tr>
<td>AB</td>
<td>Aborts the command execution.</td>
</tr>
<tr>
<td>*RST</td>
<td>Resets the B1500 during the command execution.</td>
</tr>
<tr>
<td>XE</td>
<td>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.”</td>
</tr>
</tbody>
</table>
To Use Programs for Keysight 4142B

Keysight B1500 supports most of the commands and the data output format supported by the Keysight 4142B Modular DC Source/Monitor. To reuse the programs created for the Keysight 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 Keysight 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>
<thead>
<tr>
<th>Table 1-17 Modules and Commands Unsupported</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plug-in Module</strong></td>
</tr>
<tr>
<td>Analog Feedback Unit</td>
</tr>
<tr>
<td>High Current Unit</td>
</tr>
<tr>
<td>High Voltage Unit</td>
</tr>
<tr>
<td>Voltage Source/Voltage Monitor Unit</td>
</tr>
</tbody>
</table>
To Use Programs for Keysight 4155/4156

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

- FL command

  The initial setting of the FL command is different. It is ON for the Keysight 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>
<thead>
<tr>
<th>Category</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control mode</td>
<td>:PAGE, US, US42</td>
</tr>
<tr>
<td>Measurement mode</td>
<td>VM, VMD</td>
</tr>
<tr>
<td>Staircase/pulsed sweep source setup</td>
<td>ESC</td>
</tr>
<tr>
<td>Sampling source setup</td>
<td>MP</td>
</tr>
<tr>
<td>Quasi-static CV measurement setup</td>
<td>QSZ?</td>
</tr>
<tr>
<td>PGU control</td>
<td>POR, SPG</td>
</tr>
<tr>
<td>Stress source setup</td>
<td>STC, STI, STM, STP, STT, STV</td>
</tr>
<tr>
<td>Integration time</td>
<td>SIT, SLI</td>
</tr>
<tr>
<td>Measurement execution</td>
<td>TI?, TTI?, TTV?, TV?</td>
</tr>
<tr>
<td>Time stamp</td>
<td>TSQ?</td>
</tr>
<tr>
<td>Output data</td>
<td>RMD?</td>
</tr>
<tr>
<td>Abort/pause/wait</td>
<td>*WAI</td>
</tr>
<tr>
<td>Zero offset cancel</td>
<td>GOC, SOC</td>
</tr>
<tr>
<td>SMU/PGU selector</td>
<td>SSP</td>
</tr>
<tr>
<td>R-box</td>
<td>RBC</td>
</tr>
<tr>
<td>External trigger</td>
<td>STG</td>
</tr>
<tr>
<td>Network operation</td>
<td>CLOSE, OPEN, PRN, RD?, SDSK, SPL, SPR, WR</td>
</tr>
<tr>
<td>Status byte</td>
<td>*CLS, *ESE(?), *ESR?</td>
</tr>
<tr>
<td>Query</td>
<td>CMD?, *OPT?, :SYST:ERR?</td>
</tr>
</tbody>
</table>
To Use Programs for Keysight E5260/E5270

Keysight B1500 supports most of the commands and the data output format supported by the Keysight E5260/E5270 Series of Parametric Measurement Solutions. To reuse the programs created for the Keysight 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>
<thead>
<tr>
<th>Category</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display Control</td>
<td>RED, DFM, SPA, MPA, SCH, MCH</td>
</tr>
<tr>
<td>Keyboard Control</td>
<td>KLC</td>
</tr>
</tbody>
</table>

Table 1-19 E5260/E5270 FLEX Commands Unsupported
Programming Basics
Programming Tips
2 Remote Mode Functions
Remote Mode Functions

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

- “Measurement Modes”
- “Synchronous Output”
- “Automatic Abort Function”
- “Parallel Measurement Function”
- “Program Memory”
- “Dual HCSMU”
- “SPGU Module”
- “Module Selector”
- “SMU/PG Selector”
- “Ultra High Current Expander/Fixture”
- “HVSMU Current Expander”
- “Ultra High Voltage Expander”
- “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 Keysight 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.

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**

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 trigger interval is longer than several 10 ms.

   • 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.

   If the hold time, pulse period, and trigger interval are very short, pulse settling time may be shown.

   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 trigger interval is longer than several 10 ms.

   • 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.

   If the hold time, pulse period, and trigger interval are very short, pulse settling time may be shown.

   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**

![Synchronous Sweep Diagram]

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**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](image)

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.

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.

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.
Remote Mode Functions  
Measurement Modes

**To Stop Sweep**

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.

![Quasi-Pulsed Spot Measurements](image)

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 4-46.

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**

![Synchronous Output Diagram]

**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.

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

\[ \text{time} = t + \text{Bias hold time} + (\text{index} - 1) \times \text{Sampling interval} \]

Where, \( t \) is the time of the sampling measurement time origin, and is the time when the output value is changed from \textit{base} to \textit{bias}.

\begin{center}
\textbf{NOTE}
\end{center}

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 SIM0 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.

\begin{center}
\textbf{To Stop Output}
\end{center}

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 \( Nth \) sweep voltage \(-\text{cvoltage}/2\) to \( Nth \) sweep voltage \(+\text{cvoltage}/2\), and capacitance is calculated by using the measured values. Where, \( \text{cvoltage} \) 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; \( \text{start} \), \( \text{stop} \), \( \text{cvoltage} \), and \( \text{step} \) are set by the QSV command. Time parameters; \( \text{hold time} \), \( \text{delay1} \), \( \text{delay2} \), \( \text{linteg} \), and \( \text{cinteg} \) are set by the QST command. \( \text{linteg} \) and \( \text{cinteg} \) are the integration time for the leakage current measurement and the capacitance measurement, respectively.

Figure 2-17 Setting Parameters and Operation of QSCV Measurement
Remote Mode Functions
Measurement Modes

The operation of the quasi-static CV measurements is explained below. This is the case of \textit{start} < \textit{stop}.

1. Measurement trigger enables the sweep source output. The sweep source forces \textit{1st step voltage} - \(V_q\), and waits for \textit{hold time}. where \(V_q = c\text{voltage}/2\).

2. Repeats 3 and 4 for the \(N\)th sweep step. where \(N\) is integer, 1 to \(\text{step}\).
\(\text{step}\) is the number of sweep steps given by \(\text{step} = \left|\text{start} - \text{stop}\right| / \left|\text{step voltage}\right| - 1\).

3. The sweep source forces \textit{Nth step voltage} - \(V_q\), and waits for delay time (\textit{delay1}).

4. The measurement unit measures the following items, and waits for delay time (\textit{delay2}).

\begin{itemize}
  \item \(I_{L0}\) Leakage current before the voltage transition
  \item \(V_0\) Voltage before the voltage transition
  \item \(I\) Charge current in the voltage transition to \textit{Nth step voltage} + \(V_q\)
  \item \(V_{avg}\) Averaging voltage in the voltage transition to \textit{Nth step voltage} + \(V_q\). Not measured for the 4155C/4156C compatible operation mode set by the \texttt{QSC1} command.
  \item \(I_L\) Leakage current after the voltage transition
  \item \(V\) Voltage after the voltage transition
\end{itemize}

5. After the sweep measurement, the sweep source forces the start or stop value, as specified by the QSM command, and keeps it.

\textbf{NOTE}

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

\begin{itemize}
  \item \(\text{delay2}\) is automatically set to 0.
  \item \(V_0\) and \(I_{L0}\) are not measured for the second step and later. The capacitance calculation uses the \(V\) and \(I_L\) values at the previous sweep step, instead.
\end{itemize}

\textbf{Condition:}

\[|\text{step voltage}| = \left|\text{start} - \text{stop}\right| / (\text{step} + 1) = cv\text{oltage}\]
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.
  
  \[ C = (I - \text{Leak}) \times \text{cinteg} / (V - V_0) \]

  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.
  
  \[ C = I \times \text{cinteg} / (V - V_0) \]

- 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.
  
  \[ \text{Leak} = IL_0 + (IL - IL_0) \times (V_{\text{avg}} - V_0) / (V - V_0) \]

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.
  
  \[ C = (I - \text{Leak}) \times \text{cinteg} / (V - V_0) \]

  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.
  
  \[ C = I \times \text{cinteg} / (V - V_0) \]

- 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.
  
  \[ \text{Leak} = IL + \tau \times (IL_0 - IL) / (2 \times \text{cinteg}) \], where \( \tau \) 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.

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 CMU and two MP/HRSMU modules 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.

![Diagram of Pulsed Spot C Measurements](image)

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 trigger interval is longer than several 10 ms.

- 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.
Remote Mode Functions
Measurement Modes

If the hold time, pulse period, and trigger interval are very short, pulse settling time may be shown.

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 CMU and two MP/HRSMU modules 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 CMU and two MP/HRSMU modules 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.

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 CMU and two MP/HRSMU modules 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.
Remote Mode Functions
Measurement Modes

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 CMU and two MP/HRSMU modules 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 CMU and two MP/HRSMU modules 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.

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 $Bias\ hold\ time + Sampling\ interval \times number$ 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
  \[ time = Bias\ hold\ time + index \times Sampling\ interval \]

- 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 CMU and two MP/HRSMU modules correctly, the source module is automatically selected by the DC bias setting. The CMU is selected if it is $\pm 25$ V or less (setting resolution: $0.001$ V), or the SMU is selected if it is greater than $\pm 25$ V (setting resolution: $0.005$ V).

**To Stop Output**

An automatic abort function is available. Refer to “Automatic Abort Function” on page 2-46.
Remote Mode Functions
Synchronous Output

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:

<table>
<thead>
<tr>
<th>Measurement Mode</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Staircase Sweep Measurements”</td>
<td>WSI or WSV</td>
</tr>
<tr>
<td>“Pulsed Sweep Measurements”</td>
<td>WSI or WSV</td>
</tr>
<tr>
<td>“Staircase Sweep with Pulsed Bias Measurements”</td>
<td>WSI or WSV</td>
</tr>
<tr>
<td>“Binary Search Measurements”</td>
<td>BSSI or BSSV</td>
</tr>
<tr>
<td>“Linear Search Measurements”</td>
<td>LSSI or LSSV</td>
</tr>
</tbody>
</table>

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:
  
  \[ \text{start} \quad \text{Synchronous sweep start value.} \]
  \[ \text{stop} \quad \text{Synchronous sweep stop value.} \]

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

- For the BSSI, BSSV, LSSI, and LSSV commands:
  
  \[ \text{offset} \quad \text{Offset value from the search source output.} \]
  \[ \text{polarity} \quad \text{Polarity (+ or –) of the synchronous source output.} \]

  Synchronous output is given by one of the following formulas:

  \[ \text{Synchronous output} = \text{primary source output} + \text{offset} \]
  \[ \text{Synchronous output} = -1 \times \text{primary source output} + \text{offset} \]

  All output values must be covered by the output range of the search source.
**Figure 2-27**  
**Synchronous Sweep Output Example for Staircase Sweep**

Voltage or current

Stop value

WT/WM/WV/WI

Trigger (e.g. XE)

Previous value

Start value

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

Voltage or current

Stop value

BSM, BST, and BSV/BSSV or BS/BSSI

Trigger (e.g. XE)

Previous value

Start value

Time
Remote Mode Functions
Automatic Abort Function

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 Keysight 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.
Remote Mode Functions
Program Memory

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

<table>
<thead>
<tr>
<th>Category</th>
<th>GPIB Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reset</td>
<td>*RST</td>
</tr>
<tr>
<td>Diagnostics</td>
<td>DIAG?</td>
</tr>
<tr>
<td>Self-test</td>
<td>*TST?</td>
</tr>
<tr>
<td>Self Calibration</td>
<td>CA, *CAL?, CM</td>
</tr>
<tr>
<td>Abort</td>
<td>AB</td>
</tr>
<tr>
<td>Channel Control</td>
<td>RCV, WZ?</td>
</tr>
<tr>
<td>Program Memory</td>
<td>ST, END, SCR, VAR?, LST?</td>
</tr>
<tr>
<td>SMU/PGU Selector Control</td>
<td>ERMOD?, ERSSP?</td>
</tr>
<tr>
<td>16 bit Control Port</td>
<td>ERS?</td>
</tr>
<tr>
<td>Query</td>
<td>ERRX?, ERR?, EMG?, *IDN?, LOP?, *LRN?, NUB?, *OPC?, UNT?, WNU?</td>
</tr>
<tr>
<td>Status Byte</td>
<td>*SRE?, *STB?</td>
</tr>
</tbody>
</table>
Dual HCSMU

This function is available when two HCSMU modules are installed in the B1505A and connected to the 16493S-020 Dual HCSMU Kelvin combination adapter or the 16493S-021 Dual HCSMU combination adapter. Two HCSMU modules can perform the dual HCSMU operation which supports ±40 A (pulse), ±2 A (DC).

The dual HCSMU operation is enabled by the following command.

PCH master,slave

where,

master : Channel number of HCSMU used as the dual HCSMU master channel
slave : Channel number of HCSMU used as the dual HCSMU slave channel

After the PCH command is executed, the HCSMU modules of channel numbers master and slave operate as the dual HCSMU (DHCSMU) of channel number master, and do not perform the single HCSMU operation.

The specified channels must have been disabled when the PCH command is executed. Do not execute the CN/CNX command for the specified channels before the PCH command.

NOTE

Available output and measurement ranges

The following output and measurement ranges are available for the dual HCSMU.

- Current ranges: 10 μA, 100 μA, 1 mA, 10 mA, 100 mA, 1 A, 2 A, and 40 A
- Voltage ranges: 0.2 V, 2 V, 20 V, and 40 V

The dual HCSMU does not support the 20 A range supported by the single HCSMU operation.
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 $50 \, \Omega$ 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: $> 1 \, \text{V}$

Minimum load impedance: $40 \, \Omega$

Maximum load impedance: $500 \, \Omega \, (1 \, \text{V})$, $2000 \, \Omega \, (2 \, \text{V})$, $5000 \, \Omega \, (10 \, \text{V})$
**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](image)

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

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIM 0</td>
<td>Sets the PG mode for all channels.</td>
</tr>
<tr>
<td>SPRM</td>
<td>Selects the output operation mode for all channels, free run (pulse output continues until SPP), pulse count, or duration.</td>
</tr>
<tr>
<td>SPPER</td>
<td>Sets the pulse period for all channels.</td>
</tr>
<tr>
<td>SPM</td>
<td>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.</td>
</tr>
<tr>
<td>SPT</td>
<td>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.</td>
</tr>
<tr>
<td>SPV</td>
<td>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.</td>
</tr>
<tr>
<td>SER/SER?</td>
<td>Specifies/returns the load impedance connected to the channel.</td>
</tr>
<tr>
<td>CORRSER?</td>
<td>Measures the terminal voltage and returns the voltage and the calculated impedance. Also sets the impedance as same as SER.</td>
</tr>
<tr>
<td>SPUPD</td>
<td>Applies the channel setup to the specified SPGUs. The channel outputs the base voltage.</td>
</tr>
<tr>
<td>SRP</td>
<td>Starts all SPGU channel outputs.</td>
</tr>
<tr>
<td>SPP</td>
<td>Stops all SPGU pulse outputs. The channel outputs the base voltage.</td>
</tr>
<tr>
<td>ODSW</td>
<td>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.</td>
</tr>
<tr>
<td>STGP</td>
<td>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.</td>
</tr>
<tr>
<td>SPST?</td>
<td>Returns the status of the SPGU, run or wait.</td>
</tr>
</tbody>
</table>
Figure 2-31  Pulse Setup Parameters

Figure 2-32  Trigger Output in PG Mode
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.

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

<table>
<thead>
<tr>
<th>STGP 901,1</th>
<th>Trigger Output</th>
<th>10 ns</th>
<th>&gt;= 1 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 V (chassis common)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STGP 901,2</th>
<th>Trigger Output</th>
<th>10 ns</th>
<th>&gt;= 1 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 V (chassis common)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STGP 901,3</th>
<th>Trigger Output</th>
<th>10 ns</th>
<th>&gt;= 1 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 V (chassis common)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SPGU 901</th>
<th>initial value</th>
<th>1 sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pattern2</td>
<td>Pattern2</td>
<td>Pattern1</td>
</tr>
<tr>
<td>Pattern1</td>
<td>Pattern1</td>
<td>Pattern1</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIM 1</td>
<td>Sets the ALWG mode for all channels.</td>
</tr>
<tr>
<td>SPRM</td>
<td>Selects the operation mode, free run (output continues until SPP), sequence count, or duration for all channels.</td>
</tr>
<tr>
<td>ALW</td>
<td>Sets the ALWG pattern data (binary format, big endian) for each channel. See Table 2-4.</td>
</tr>
<tr>
<td>ALS</td>
<td>Sets the ALWG sequence data (binary format, big endian) for the B1500A mainframe. See Table 2-5.</td>
</tr>
<tr>
<td>SER/SER?</td>
<td>Specifies/returns the load impedance connected to the channel.</td>
</tr>
<tr>
<td>CORRSER?</td>
<td>Measures the terminal voltage and returns the voltage and the calculated impedance. Also sets the impedance as same as SER.</td>
</tr>
<tr>
<td>SPUPD</td>
<td>Applies the channel setup to the specified SPGUs. The channel outputs the initial voltage.</td>
</tr>
<tr>
<td>SRP</td>
<td>Starts all SPGU channel outputs.</td>
</tr>
<tr>
<td>SPP</td>
<td>Stops all SPGU channel outputs. The channel outputs the initial voltage.</td>
</tr>
<tr>
<td>ODSW</td>
<td>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.</td>
</tr>
<tr>
<td>STGP</td>
<td>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.</td>
</tr>
<tr>
<td>SPST?</td>
<td>Returns the status of the SPGU, run or wait.</td>
</tr>
</tbody>
</table>
### Table 2-4  ALWG Pattern Data (binary format, big endian)

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Data length</th>
<th>Byte length</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Header</strong></td>
<td>Module type (ex: 0)</td>
<td>1 byte</td>
<td>20 bytes</td>
</tr>
<tr>
<td></td>
<td>Data format revision (ex: 0)</td>
<td>1 byte</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of patterns a (ex: x)</td>
<td>2 bytes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Others (0 for all bit. Do not change.)</td>
<td>16 bytes</td>
<td></td>
</tr>
<tr>
<td><strong>Pattern data</strong></td>
<td>Number of vector data in this pattern (ex: N_i)</td>
<td>2 bytes</td>
<td>6 bytes (\Sigma(6+8\times N_i)) bytes, (i=1) to (x)</td>
</tr>
<tr>
<td></td>
<td>Initial voltage (1 μV/count) b</td>
<td>4 bytes</td>
<td>(8 \times N_i) bytes</td>
</tr>
<tr>
<td><strong>Vector data</strong></td>
<td>Output level (1 μV/count) b</td>
<td>4 bytes</td>
<td>(8 \times N_i) bytes</td>
</tr>
<tr>
<td></td>
<td>Pulse switch status (1: close, 0: open)</td>
<td>1 bit</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incremental time from previous point (1 nsec/count) c</td>
<td>31 bits</td>
<td></td>
</tr>
</tbody>
</table>

: Vector data can be repeated until the \(N_i\)-th vector. (\(i: 1\) to \(x\), integer)

: Pattern data can be repeated until the \(x\)-th pattern. (\(x: \text{number of patterns, integer}\))

(Total number of vector data must be \(\leq 1024-x\).

a. Number of patterns must be 1 to 1000000000 (512).
b. Output level data must be 0 to 10011000100110101000000000 (40 V) or 111111111111111111110000011000 (−1 mV) to 1111111111111111111110000000000000 (−40 V) in 1111101000 (1 mV) resolution.
c. Incremental time data must be 1010 (10 nsec) to 1001111111111111111110110 (671.088630 msec, \(2^{26}−1\times10\) nsec) in 1010 (10 nsec) resolution.
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 $20+(6+8\times9)+(6+8\times9)=176$ 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 $20+(6+8\times9)+(6+8\times7)=160$ 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 $20+6\times2=32$ bytes.
Module Selector

The Keysight N1258A Module Selector is used to switch the measurement resources (HP/MPSMU, HC/DHCSMU, and HVSMU/HVMCU) connected to DUT (device under test). The Input ports must be connected to the HP/MPSMU, HC/DHCSMU, HVSMU/HVMCU, and GNDU. And the Output port must be connected to the DUT interface. For the packaged devices, use the Keysight 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 measurement resources connected to the input.

The ERHPL command sets the condition of the status indicator.

The ERHPP command sets the module selector input-to-output connection status.

The ERHPS command controls the connection of the HVSMU series resistor.

Figure 2-36 Module Selector Block Diagram and Connections

CAUTION

For the measurement using dual HCSMU (DHCSMU), the maximum current must be ±30 A to prevent the module selector from performance degradation and failure.
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 logical state of the Relay control output pin.

**Figure 2-37 External Relay Control Output Connector**

- **Connector type**: D-sub 15 pin connector
- **Relay control signal output pins**: Relay control 1 to 6
- **Relay control signal level**: Normally 0 V (circuit common, in logical OFF state) or 12 V (in logical ON state)
- **Relay control input current**: Typical 100 mA/pin, maximum 500 mA/pin

**Figure 2-38 External Relay Control Output Internal Circuit**

- External Relay Control Output connector
- Digital I/O connector
- Control signal
- Part of module selector
- External relay
- 12 V
- Allowable input current:
  - 100 mA/pin (typical)
  - 500 mA/pin (maximum)
- Circuit common (0 V)
SMU/PG Selector

The Keysight 16440A SMU/PGU Selector (B1500A-A04) 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 ERMODE and ERSPP commands to control the 16440A selector. The ERMODE command sets the Digital IO control mode. The ERSPP command sets the selector channel CH 1 or CH 2 input-output path to the SMU connect, PGU connect, or open (no connection).

Figure 2-39  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.
Ultra High Current Expander/Fixture

The Keysight N1265A is a test fixture which contains the current expander to enable 500 A or 1500 A (option N1265A-015) output and measurement, and contains the selector to switch the measurement resource connected to the DUT.

The current expander is used to configure the ultra high current unit (UHCU).

The selector is used to switch the measurement resource connected to the DUT. The measurement resource will be the UHCU, HVSMU, HP/MPSMU, or GNDU. See Figure 2-41.

The selector output can be extended to your prober station by using the N1254A-524 ultra high current prober system cable. This cable supports current up to 500 A.

The N1265A also provides the connection paths for UHVU, MFCMU via bias-tee, and HP/MP/HC/DHCSMU.

Ultra High Current Unit

The ultra high current unit (UHCU) can be configured by using the N1265A and two MC/HCSMU modules as shown in Figure 2-40. The UHCU output can appear on the Selector Output by controlling the built-in selector.

To configure UHCU, use the following command.

- ERPFUHCA: Specifies the MC/HCSMU modules connected to the control terminals (V Control and I Control).

Figure 2-40 To Configure UHCU
To specify the selector input connections, use the following commands.

- **ERPFGA**: Specifies the MC/HCSMU module connected to the Gate input.
- **ERPFDA**: Specifies the measurement resources connected to the Selector Input.

To control the selector input-to-output path, use the following commands.

- **ERPFDLP**: Set the connection status of the selector input-to-output path.
- **ERPFDS**: Set the connection status of the series resistor on the HVSMU path.

To control the Gate path, use the following commands.

- **ERPFGP**: Set the connection status of the MC/HCSMU output connected to the Gate input.
- **ERPFGGR**: Set the connection status of the series resistor on the Gate path.
HVSMU Current Expander

The Keysight N1266A is a current expander for HVSMU. The N1266A is used to configure the high voltage medium current unit (HVMCU) with the HVSMU module and two MC/HCSMU modules as shown in Figure 2-42. Selector is initially installed for switching the HVSMU or the HVMCU connected to the DUT.

To configure HVMCU, use the following command.

- **ERHVCA**: Specifies the modules connected to the V Control, I Control, and HVSMU inputs.

To control the expander input-to-output path, use the following commands.

- **ERHVP**: Set the connection status of the expander input-to-output path.
- **ERHVS**: Set the connection status of the series resistor on the HVSMU path.

*Figure 2-42 To Configure HVMCU*

Ultra High Voltage Expander

The Keysight N1268A is a voltage expander to enable 10 kV output and measurement. The N1268A is used to configure the ultra high voltage unit (UHVU) with two MC/HCSMU modules as shown in Figure 2-43.

To configure UHVU, use the following command.

- ERUHV A: Specifies the MC/HCSMU modules connected to the control terminals (V Control and I Control).

![Figure 2-43 To Configure UHVU](image-url)
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

<table>
<thead>
<tr>
<th>Description</th>
<th>Pin Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GND</td>
<td>25</td>
<td>13</td>
</tr>
<tr>
<td>Do not use</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>Do not use</td>
<td>23</td>
<td>11</td>
</tr>
<tr>
<td>DIO 15 (bit 15)</td>
<td>22</td>
<td>10</td>
</tr>
<tr>
<td>DIO 13 (bit 13)</td>
<td>21</td>
<td>9</td>
</tr>
<tr>
<td>DIO 11 (bit 11)</td>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>DIO 9 (bit 9)</td>
<td>19</td>
<td>7</td>
</tr>
<tr>
<td>DIO 7 (bit 7)</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>DIO 5 (bit 5)</td>
<td>17</td>
<td>5</td>
</tr>
<tr>
<td>DIO 3 (bit 3)</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>DIO 1 (bit 1)</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>Do not use</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
Remote Mode Functions
Digital I/O Port

**Accessories**

The following accessories are available to connect the Digital I/O port.

- **Keysight 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

- **Keysight 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.

- **Keysight 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 2-44  Accessories for Digital I/O Port**

<table>
<thead>
<tr>
<th></th>
<th>D-Sub (m)</th>
<th>D-Sub (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16493G</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N1253A-100</td>
<td>D-Sub (m)</td>
<td>D-Sub (f)</td>
</tr>
<tr>
<td>N1253A-200</td>
<td>D-Sub (f)</td>
<td></td>
</tr>
</tbody>
</table>
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 2-45 Digital I/O Internal Circuit

- Vcc=5 V
- R1=1 kohm
- R2=100 ohm
- Q1: Vce(sat)=0.3 V
**Trigger Function**

The Keysight 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 2-46 shows a connection example of the B1500 and another device.

**Figure 2-46**

**Connecting Trigger Input/Output**

![Diagram showing connection example of B1500 and another device.]

**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 2-47. 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 2-47**  
**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**
  
  Available for the Start Step Measurement trigger (type 3). Delay time from a trigger input to starting a step measurement. You can set the delay time value by using the WT, WTDCV, WTACV, or WTFC command.
Remote Mode Functions

Trigger Function

**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**

<table>
<thead>
<tr>
<th>Type</th>
<th>B1500 Operation by Input Trigger</th>
<th>Commanda</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Starts the measurement specified by the MM command.</td>
<td>TGP $t_1,p_1,1$ TM3</td>
</tr>
<tr>
<td>2</td>
<td>Available for the staircase sweep, multi channel sweep, pulsed spot, pulsed sweep, staircase sweep with pulsed bias, multi channel pulsed spot, multi channel pulsed sweep, and CV(DC)/CV(AC)/C-f sweep measurements. The sweep source starts to set the sweep step output. The pulse source starts the pulse output at 110 $\mu$s after receiving the trigger.</td>
<td>TGP $t_1,p_2,1$ TGSI $m$</td>
</tr>
<tr>
<td>3</td>
<td>Available for the staircase sweep, multi channel sweep, and CV(DC)/CV(AC)/C-f sweep measurements. Waits for the measurement trigger delay, and starts the sweep step measurement.</td>
<td>TGP $t_1,p_3,1$</td>
</tr>
</tbody>
</table>

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 2-47).
**Trigger Output**

A trigger output operation example is shown in Figure 2-48. 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.

![Trigger Output Example, Staircase Sweep Measurement, Negative Logic](image)

**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 will be sent or a gate trigger level will be returned when an operation is completed (see Figure 2-49).

Initially, the negative edge trigger of approximately 10 μs width is sent.

For the measurements using SMU pulse, an edge trigger will be sent or a gate trigger level will be returned at 10 μs before starting the pulse output. Trigger width is approximately 100 μs for both edge trigger and gate trigger.
Remote Mode Functions

Trigger Function

Figure 2-49  Output Trigger for Staircase, Multi Channel, CV(DC)/CV(AC)/C-f Sweep

<table>
<thead>
<tr>
<th>Operation start or OS or OSX</th>
<th>Operation complete or OS or OSX</th>
</tr>
</thead>
</table>

Gate trigger

| High (Approx. 2.4 V) | Low (Approx. 0.8 V) |

Edge trigger

| High (Approx. 2.4 V) | Low (Approx. 0.8 V) |

Edge trigger

| Approx. 10us |

Negative logic

Positive logic

Source Trigger Delay

Available for the Step Output Setup Completion trigger (type 2) of the staircase sweep, multi channel sweep, and CV(DC)/CV(AC)/C-f sweep measurements.

Delay time from when the source output setup is completed until an edge trigger is sent or a gate trigger level is returned. You can set the delay time value by using the WT, WTDCV, WTACV, or WTFC command.

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.
### Table 2-8 Type of Trigger Output

<table>
<thead>
<tr>
<th>Type</th>
<th>Timing of Trigger Output by B1500</th>
<th>Command&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>When the measurement specified by the MM command is completed.</td>
<td>TGP t,2,p,1 TGXO m TM3</td>
</tr>
</tbody>
</table>
| 2    | Available for the staircase sweep, multi channel sweep, pulsed spot, pulsed sweep, staircase sweep with pulsed bias, multi channel pulsed spot, multi channel pulsed sweep, and CV(DC)/CV(AC)/C-f sweep measurements.  
For the staircase sweep, multi channel sweep, and CV(DC)/CV(AC)/C-f sweep measurements: when the source trigger delay time elapses after the sweep step output setup or pulse output setup is completed.  
For the pulsed spot, pulsed sweep, staircase sweep with pulsed bias, multi channel pulsed spot, multi channel pulsed sweep measurements: at 10 μs before starting the pulse output. | TGP t,2,p,2 TGSO m |
| 3    | Available for the staircase sweep, multi channel sweep, and CV(DC)/CV(AC)/C-f sweep measurements.  
When the measurement is completed at each sweep step. | TGP t,2,p,3 TGMO m |

---

<sup>a</sup> $t$ 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.
Remote Mode Functions
Trigger Function

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.

![Diagram](image-url)
Remote Mode Functions
Trigger Function

**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.

```
+-----------------+-------------------+
| Ext Trig In     | Start measurement |
+-----------------+-------------------+
| Ext Trig Out    | Measurement completion |
+-----------------+-------------------+
```

**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  
   OUTPUT @B1500;"TM3" ! Sets measurement condition  
   OUTPUT @B1500;"TGP -1,1,1,1" ! Uses external trigger  
   OUTPUT @B1500;"TGP -2,2,1,1" ! Sets trigger input  
   OUTPUT @B1500;"TGXO 2" ! Sets trigger output  
   ENTER @B1500 USING ",3X,12D,2X";M_data ! Enables gate trigger 

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.

   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.
Remote Mode Functions
Trigger Function

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:

<table>
<thead>
<tr>
<th>Trigger Name or Trigger Type</th>
<th>Terminal</th>
<th>TGP Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start Measurement</td>
<td>Ext Trig In</td>
<td>TGP -1,1,2,1</td>
</tr>
<tr>
<td>Start Step Measurement</td>
<td>DIO 2</td>
<td>TGP 2,1,2,3</td>
</tr>
<tr>
<td>Start Step Output Setup</td>
<td>DIO 1</td>
<td>TGP 1,1,2,2</td>
</tr>
<tr>
<td>Measurement Completion</td>
<td>Ext Trig Out</td>
<td>TGP -2,2,2,1</td>
</tr>
<tr>
<td>Step Measurement Completion</td>
<td>DIO 12</td>
<td>TGP 12,2,2,3</td>
</tr>
<tr>
<td>Step Output Setup Completion</td>
<td>DIO 11</td>
<td>TGP 11,2,2,2</td>
</tr>
</tbody>
</table>

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.

```plaintext
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
```

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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 2-51** Trigger Input Internal Circuit

![Trigger Input Internal Circuit Diagram]

**Figure 2-52** Trigger Output Internal Circuit

![Trigger Output Internal Circuit Diagram]
Initial Settings

Keysight 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>
<thead>
<tr>
<th>Setup Item</th>
<th>Initial Setting</th>
<th>Commands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto calibration</td>
<td>off</td>
<td>CM</td>
</tr>
<tr>
<td>Trigger mode</td>
<td>XE, TV, TI, or GET</td>
<td>TM</td>
</tr>
<tr>
<td>Trigger port</td>
<td>Ext Trig In, Start Measurement trigger input</td>
<td>TGP</td>
</tr>
<tr>
<td></td>
<td>Ext Trig Out, 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>0 s</td>
<td>WT, PT</td>
</tr>
<tr>
<td>Trigger condition of</td>
<td>with trigger for first sweep step</td>
<td>TGSI</td>
</tr>
<tr>
<td>Start Step Output Setup trigger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of output trigger</td>
<td>edge trigger</td>
<td>TGXO, TGSO, TGMO</td>
</tr>
<tr>
<td>Digital I/O port</td>
<td>output for all port</td>
<td>ERM</td>
</tr>
<tr>
<td>Program memory</td>
<td>cleared a</td>
<td>SCR</td>
</tr>
<tr>
<td>Value of internal variable (%In, %Rn)</td>
<td>0</td>
<td>VAR</td>
</tr>
<tr>
<td>Data output format</td>
<td>ASCII with header, CR/LF^EOI</td>
<td>FMT</td>
</tr>
<tr>
<td>Data output buffer</td>
<td>cleared</td>
<td>BC</td>
</tr>
<tr>
<td>Status byte</td>
<td>Only bit 6 is enabled.</td>
<td>*SRE</td>
</tr>
<tr>
<td>Error code register</td>
<td>cleared</td>
<td>ERRX?, ERR?</td>
</tr>
</tbody>
</table>

a. Program memory is not cleared by the *RST command or the device clear.
### Remote Mode Functions

#### Initial Settings

<table>
<thead>
<tr>
<th>Setup Item</th>
<th>Initial Setting</th>
<th>Commands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output switch</td>
<td>open</td>
<td>CN, CL</td>
</tr>
<tr>
<td>Filter</td>
<td>off</td>
<td>FL</td>
</tr>
<tr>
<td>Series resistor</td>
<td>off</td>
<td>SSR</td>
</tr>
<tr>
<td>ASU path/1 pA auto range/indicator</td>
<td>SMU side/disable/enable</td>
<td>SAP/SAR/SAL</td>
</tr>
<tr>
<td>Current measurement range</td>
<td>with pulse, compliance range</td>
<td>RI</td>
</tr>
<tr>
<td></td>
<td>without pulse, auto</td>
<td></td>
</tr>
<tr>
<td>Voltage measurement range</td>
<td>with pulse, compliance range</td>
<td>RV</td>
</tr>
<tr>
<td></td>
<td>without pulse, auto</td>
<td></td>
</tr>
<tr>
<td>A/D converter</td>
<td>high speed ADC</td>
<td>AAD</td>
</tr>
<tr>
<td>ADC integration time</td>
<td>high speed ADC: auto, non parallel</td>
<td>AIT, PAD</td>
</tr>
<tr>
<td></td>
<td>high resolution ADC: auto</td>
<td>AIT</td>
</tr>
<tr>
<td>ADC zero function</td>
<td>off</td>
<td>AZ</td>
</tr>
<tr>
<td>AV command parameter</td>
<td>number=1, mode=0</td>
<td>AV</td>
</tr>
<tr>
<td>Sweep source parameters</td>
<td>cleared</td>
<td>WV, WSV, WI, WSI</td>
</tr>
<tr>
<td>Pulse source parameters</td>
<td>cleared</td>
<td>PV, PI</td>
</tr>
<tr>
<td>Pulse sweep source parameters</td>
<td>cleared</td>
<td>PWV, PWI</td>
</tr>
<tr>
<td>Search source parameters</td>
<td>cleared</td>
<td>BSV, BSSV, BSI, BSSI, LSV, LSSV, LSI, LSSV</td>
</tr>
<tr>
<td>Search monitor parameters</td>
<td>cleared</td>
<td>BGV, BGI, LGV, LGI</td>
</tr>
<tr>
<td>Search measurement data</td>
<td>source output value only</td>
<td>BSVM, LSVM</td>
</tr>
<tr>
<td>Quasi-pulse source parameters</td>
<td>cleared</td>
<td>BDV</td>
</tr>
<tr>
<td>Quasi-pulsed spot measurement mode</td>
<td>voltage</td>
<td>BDM</td>
</tr>
</tbody>
</table>
### 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) | WT, PT, BDT, BST, LSTM
Hold time | 0 s | WT, PT, BDT, BST, LSTM
Delay time | 0 s | WT
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

<table>
<thead>
<tr>
<th>Setup Item</th>
<th>Initial Setting</th>
<th>Commands</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCUU path/indicator</td>
<td>open/enable</td>
<td>SSP/SSL</td>
</tr>
<tr>
<td>Measurement parameter</td>
<td>Cp-G</td>
<td>IMP</td>
</tr>
<tr>
<td>Measurement range</td>
<td>auto</td>
<td>RC</td>
</tr>
<tr>
<td>ADC integration time</td>
<td>auto</td>
<td>ACT</td>
</tr>
<tr>
<td>Open/short/load correction</td>
<td>off</td>
<td>OPEN/SHOR/LOAD</td>
</tr>
<tr>
<td>Phase compensation mode</td>
<td>auto</td>
<td>ADJ</td>
</tr>
<tr>
<td>AC signal</td>
<td>0 V, 1 kHz</td>
<td>ACV, FC</td>
</tr>
<tr>
<td>Sweep source parameters</td>
<td>cleared</td>
<td>WDCV</td>
</tr>
<tr>
<td>Automatic abort function</td>
<td>off</td>
<td>WMDCV</td>
</tr>
<tr>
<td>Output after measurement</td>
<td>start value</td>
<td>WMDCV</td>
</tr>
<tr>
<td>Hold time</td>
<td>0 s</td>
<td>WTDCV</td>
</tr>
<tr>
<td>Delay time</td>
<td>0 s</td>
<td>WTDCV</td>
</tr>
<tr>
<td>Step delay time</td>
<td>0 s</td>
<td>WTDCV</td>
</tr>
<tr>
<td>Trigger delay time</td>
<td>0 s</td>
<td>WTDCV</td>
</tr>
</tbody>
</table>
### Table 2-12  SPGU Settings

<table>
<thead>
<tr>
<th>Setup Item</th>
<th>Initial Setting</th>
<th>Commands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation mode</td>
<td>PG mode</td>
<td>SIM</td>
</tr>
<tr>
<td>Pulse period</td>
<td>1.0 μs</td>
<td>SPPER</td>
</tr>
<tr>
<td>Channel output operation mode</td>
<td>Free run</td>
<td>SPRM</td>
</tr>
<tr>
<td>Channel output mode</td>
<td>Pulse source 1, 2-level pulse output</td>
<td>SPM</td>
</tr>
<tr>
<td>DC source setup</td>
<td>0 V</td>
<td>SPV</td>
</tr>
<tr>
<td>Pulse source setup</td>
<td>Delay: 0 s, Width 100 ns, Leading: 20 ns, Trailing: 20 ns, Base: –0.5 V, Peak: 0.5 V</td>
<td>SPT, SPV</td>
</tr>
<tr>
<td>ALWG setup</td>
<td>Cleared</td>
<td>ALW, ALS</td>
</tr>
<tr>
<td>Pulse switch</td>
<td>Disable, Normally open, Delay: 0 s, Width: 100 ns</td>
<td>ODSW</td>
</tr>
<tr>
<td>DUT load impedance</td>
<td>50 Ω</td>
<td>SER</td>
</tr>
<tr>
<td>SPGU trigger output</td>
<td>Disable</td>
<td>STGP</td>
</tr>
<tr>
<td>SPGU setup in sampling measurement</td>
<td>Cleared</td>
<td>MSP</td>
</tr>
</tbody>
</table>
## Table 2-13  Initial Settings of Mainframe, SMU, and CMU

<table>
<thead>
<tr>
<th>Setup Item</th>
<th>Initial Setting</th>
<th>Commands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto calibration</td>
<td>off</td>
<td>CM</td>
</tr>
<tr>
<td>SMU output switch</td>
<td>open</td>
<td>CN, CL</td>
</tr>
<tr>
<td>SMU filter/series resistor</td>
<td>off/off</td>
<td>FL/SSR</td>
</tr>
<tr>
<td>ASU path/1 pA auto range/indicator</td>
<td>SMU side/disable</td>
<td>SAP/SAR/SAL</td>
</tr>
<tr>
<td>SCUU path/indicator</td>
<td>open/enable</td>
<td>SSP/SSL</td>
</tr>
<tr>
<td>SMU current measurement range</td>
<td>with pulse</td>
<td>auto</td>
</tr>
<tr>
<td>SMU voltage measurement range</td>
<td>with pulse</td>
<td>compliance range</td>
</tr>
<tr>
<td>SMU A/D converter</td>
<td>high speed ADC</td>
<td>AAD</td>
</tr>
<tr>
<td>SMU ADC Integration time</td>
<td>high speed ADC:</td>
<td>AIT, PAD</td>
</tr>
<tr>
<td>CMU measurement parameter</td>
<td>number=1, mode=0</td>
<td>AV</td>
</tr>
<tr>
<td>CMU measurement range</td>
<td>auto</td>
<td>IMP</td>
</tr>
<tr>
<td>CMU ADC integration time</td>
<td>auto</td>
<td>RC</td>
</tr>
<tr>
<td>CMU correction/compensation</td>
<td>Open/Short/Load:</td>
<td>OPEN/SHOR/LOAD, ADJ</td>
</tr>
<tr>
<td>CMU AC signal</td>
<td>0 V, 1 kHz</td>
<td>ACV</td>
</tr>
<tr>
<td>Sweep source parameters</td>
<td>cleared</td>
<td>WVS, WSV, WISI, WSDC, WDCV</td>
</tr>
<tr>
<td>Pulse source parameters</td>
<td>cleared</td>
<td>PV, PI</td>
</tr>
<tr>
<td>Pulse sweep source parameters</td>
<td>cleared</td>
<td>PWVs, PWI</td>
</tr>
<tr>
<td>Search source parameters</td>
<td>cleared</td>
<td>BSVs, BSSVs, BSi, BSSI, LSVs, LSSVs, LSI, LSSVs</td>
</tr>
<tr>
<td>Search monitor parameters</td>
<td>cleared</td>
<td>BGVs, BGI, LGVs, LGIs</td>
</tr>
<tr>
<td>Search measurement data</td>
<td>source output value only</td>
<td>BSVM, LSVM</td>
</tr>
<tr>
<td>Quasi-pulse source parameters</td>
<td>cleared</td>
<td>BDVs</td>
</tr>
<tr>
<td>Quasi-pulsed spot measurement mode</td>
<td>voltage</td>
<td>BDMs</td>
</tr>
<tr>
<td>Quasi-pulse settling detection interval</td>
<td>short</td>
<td>BDM</td>
</tr>
<tr>
<td>Sampling source</td>
<td>cleared</td>
<td>MLs, MVs</td>
</tr>
<tr>
<td>Sampling interval, sampling point</td>
<td>2 ms, 1000 points</td>
<td>MT</td>
</tr>
<tr>
<td>Automatic abort function</td>
<td>off</td>
<td>WM, BSM, LSM, WMDCVs, MSC</td>
</tr>
<tr>
<td>Output after measurement</td>
<td>start value (bias value for MSC)</td>
<td>WM, BSM, LSM, WMDCVs, MSC</td>
</tr>
<tr>
<td>Pulse width</td>
<td>0.001 s</td>
<td>PT</td>
</tr>
<tr>
<td>Pulse period</td>
<td>0.01 s</td>
<td>PT</td>
</tr>
<tr>
<td>Hold time</td>
<td>0 s</td>
<td>WT, PT, BDT, BST, LSTMs, WTDCVs, MT</td>
</tr>
<tr>
<td>Delay time</td>
<td>0 s</td>
<td>WT, PT, BDT, BST, LSTMs, WTDCVs</td>
</tr>
<tr>
<td>Step delay time</td>
<td>0 s</td>
<td>WT, WTDCVs</td>
</tr>
<tr>
<td>Trigger delay time</td>
<td>0 s</td>
<td>WT, PT, WTDCVs</td>
</tr>
<tr>
<td>Trigger mode</td>
<td>XE, TV, TI, or GET</td>
<td>TM</td>
</tr>
<tr>
<td>Trigger port</td>
<td>Ext Trig In</td>
<td>TGP</td>
</tr>
<tr>
<td>Trigger condition of Start Step Output Setup trigger</td>
<td>with trigger for first sweep step</td>
<td>TGSIs</td>
</tr>
<tr>
<td>Type of output trigger</td>
<td>edge trigger</td>
<td>TGXOs, TGSOs, TGMos</td>
</tr>
<tr>
<td>Digital I/O port</td>
<td>output for all port</td>
<td>ERM</td>
</tr>
<tr>
<td>Program memory</td>
<td>cleared. Not cleared by *RST command or device clear.</td>
<td>SCR</td>
</tr>
<tr>
<td>Value of internal variable (%In, %Kn)</td>
<td>0</td>
<td>VAR</td>
</tr>
<tr>
<td>Data output format</td>
<td>ASCII with header, CR/LF^EOI</td>
<td>FMT</td>
</tr>
<tr>
<td>Data output buffer</td>
<td>cleared</td>
<td>BC</td>
</tr>
<tr>
<td>Status byte</td>
<td>Only bit 6 is enabled.</td>
<td>*SRE</td>
</tr>
<tr>
<td>Error code register</td>
<td>cleared</td>
<td>ERRX?, ERR?</td>
</tr>
</tbody>
</table>
3  Programming Examples
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”
Programming Examples

- “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 Keysight B1500 FLEX commands.

The following command conventions are used in this chapter.

<table>
<thead>
<tr>
<th>command</th>
<th>Required command for measurement execution.</th>
</tr>
</thead>
<tbody>
<tr>
<td>[command]</td>
<td>Optional command for measurement execution.</td>
</tr>
<tr>
<td>parameter</td>
<td>Required command parameter. A value or variable must be specified.</td>
</tr>
<tr>
<td>[parameter]</td>
<td>Optional command parameter. A value may be specified.</td>
</tr>
</tbody>
</table>

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 Keysight 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 Keysight B1500, Keysight 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 Keysight GPIB interface, Keysight 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 Keysight 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**
  \( h_{FE} \), \( V_{th} \), 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`).
### Example Template Program Code for Visual Basic .NET

```vbnet
Imports Ivi.visa.interop

Module Module1

Sub Main()
    Dim B1500 As IResourceManager
    Dim session As IMessage
    B1500 = New ResourceManager
    session = B1500.Open("GPIB0::17::INSTR")
    session.WriteString("*RST" & vbCrLf)
    MsgBox("Click OK to start measurement.", vbOKOnly, ")
    Console.WriteLine("Measurement in progress..." & vbCrLf)

    Dim t() As Integer = {5, 4, 3, 1}
    Dim term As String = t(0) & "," & t(1) & "," & t(2) & "," & t(3)
    session.WriteString("CN " & term & vbCrLf)
    perform_meas(session, t)

    session.WriteString("CL" & vbCrLf)
    session.Close()
    MsgBox("Click OK to stop the program.", vbOKOnly, ")
    Console.WriteLine("Measurement completed." & vbCrLf)
End Sub
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>This line is required to use the VISA COM library.</td>
</tr>
<tr>
<td>5 to 23</td>
<td>Main subprogram establishes the connection with the Keysight 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.</td>
</tr>
<tr>
<td>9</td>
<td>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.</td>
</tr>
<tr>
<td>14 to 15</td>
<td>The above example uses the SMUs installed in the B1500 slots 1, 3, 4, and 5. Change the slot numbers for matching your configuration.</td>
</tr>
</tbody>
</table>
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" & vbCrLf) : err = session.ReadString(4 + 2)
If err <> 0 Then session.WriteString("DZ" & vbCrLf) : GoTo Check_err

session.WriteString("DZ" & vbCrLf)
save_data(fname, title, value, data, nop1, nop2, session, t) '40
Exit Sub

Check_err:
session.WriteString("EMG? " & err & vbCrLf) : msg = session.ReadString(256)
MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
End Sub '46

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>Beginning of the perform_meas subprogram.</td>
</tr>
<tr>
<td>26 to 32</td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td><em>i</em> and <em>j</em>: Variables used to specify the element of the <em>data</em> array.</td>
</tr>
<tr>
<td></td>
<td><em>nop1</em> and <em>nop2</em>: Number of measurement steps. Also used to declare the <em>data</em> array.</td>
</tr>
<tr>
<td></td>
<td><em>data</em>: String data array used to store the measurement result data.</td>
</tr>
<tr>
<td></td>
<td><em>value</em>: String data variable to store the header (first line) of the displayed data.</td>
</tr>
<tr>
<td></td>
<td><em>fname</em>: Full path name of the measurement result data file.</td>
</tr>
<tr>
<td></td>
<td><em>title</em>: Title of the message box used to display the measurement result data.</td>
</tr>
<tr>
<td></td>
<td><em>msg</em> and <em>err</em>: Variables used to store an error message and an error code.</td>
</tr>
<tr>
<td>34</td>
<td>The line is placed as dummy. Remove the line and insert your program code to control the instruments and perform measurement.</td>
</tr>
<tr>
<td>36 to 37</td>
<td>Checks if the instrument causes an error, and goes to Check_err if an error is detected.</td>
</tr>
<tr>
<td>39 to 40</td>
<td>Applies 0 V from all channels and calls the save_data subprogram (lines 48 to 70).</td>
</tr>
<tr>
<td>43 to 45</td>
<td>Opens a message box to display error message if an error is detected.</td>
</tr>
<tr>
<td>46</td>
<td>End of the perform_meas subprogram.</td>
</tr>
</tbody>
</table>
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) '70
End Sub

End Module

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>Beginning of the save_data subprogram.</td>
</tr>
<tr>
<td>49 to 50</td>
<td>Declares loop counters used to specify the element of the data array.</td>
</tr>
<tr>
<td>51 to 58</td>
<td>Saves measurement result data into a file specified by the fname variable.</td>
</tr>
<tr>
<td>60 to 68</td>
<td>Displays the data and a message on a message box.</td>
</tr>
<tr>
<td>69</td>
<td>If Yes is clicked on the message box, calls the perform_meas subprogram again. If No is clicked, returns to the perform_meas subprogram.</td>
</tr>
<tr>
<td>70</td>
<td>End of the save_data subprogram.</td>
</tr>
</tbody>
</table>
High-Speed Spot Measurements

To perform high-speed spot measurements, use the following commands.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td><code>[chnum ... [chnum] ... ]</code></td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td><code>[chnum ... [chnum] ... ]</code></td>
</tr>
<tr>
<td>Sets filter ON/OFF</td>
<td>[FL]</td>
<td><code>mode[,chnum ... [chnum] ... ]</code></td>
</tr>
<tr>
<td>Sets series resistor ON/OFF</td>
<td>[SSR]</td>
<td><code>chnum,mode</code></td>
</tr>
<tr>
<td>Sets integration time</td>
<td>[AV]</td>
<td><code>number[,mode]</code></td>
</tr>
<tr>
<td>(Keysight B1500 can use AAD/AIT instead of AV.)</td>
<td>[AAD]</td>
<td><code>chnum[,type]</code></td>
</tr>
<tr>
<td></td>
<td>[AIT]</td>
<td><code>type[,mode[,N]]</code></td>
</tr>
<tr>
<td>Forces constant voltage</td>
<td>DV, TDV</td>
<td><code>chnum,range,output</code></td>
</tr>
<tr>
<td></td>
<td></td>
<td><code>[comp[,polarity[,crange]]]</code></td>
</tr>
<tr>
<td>Forces constant current</td>
<td>DI, TDI</td>
<td><code>chnum[range]</code></td>
</tr>
<tr>
<td>Performs current measurement</td>
<td>TI</td>
<td><code>chnum[range]</code></td>
</tr>
<tr>
<td></td>
<td>TTI</td>
<td><code>chnum[range]</code></td>
</tr>
<tr>
<td>Performs voltage measurement</td>
<td>TV</td>
<td><code>chnum[range]</code></td>
</tr>
<tr>
<td></td>
<td>TTV</td>
<td><code>chnum[range]</code></td>
</tr>
<tr>
<td>Resets the time stamp</td>
<td>TSR</td>
<td></td>
</tr>
<tr>
<td>Returns the time stamp at this time</td>
<td>TSQ</td>
<td></td>
</tr>
</tbody>
</table>

You can use the above commands regardless of the measurement mode (MM command settings).
High-Speed Spot Measurements

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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 18</td>
<td>Declares variables and sets the value.</td>
</tr>
<tr>
<td>20 to 22</td>
<td>Sets the data output format and A/D converter. Also sets the SMU filter off.</td>
</tr>
<tr>
<td>23 to 28</td>
<td>Applies voltage to device and checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.</td>
</tr>
</tbody>
</table>
session.WriteString("TSR" & vbCrLf) '30
session.WriteString("TTI " & t(0) & "," & mrng & vbCrLf)
session.WriteString("TSQ" & vbCrLf)
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" & vbCrLf) '43
save_data(fname, title, value, data, nop1, nop2, session, t)
Exit Sub

Check_err:
  session.WriteString("EMG? " & err & vbCrLf) : msg = session.ReadString(256)
  MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
End Sub

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 to 41</td>
<td>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.</td>
</tr>
<tr>
<td>43 to 45</td>
<td>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.</td>
</tr>
<tr>
<td>48 to 49</td>
<td>Displays a message box to show an error message if the error is detected.</td>
</tr>
</tbody>
</table>

**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.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets filter ON/OFF</td>
<td>[FL]</td>
<td>mode[,chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets series resistor ON/OFF</td>
<td>[SSR]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Sets integration time</td>
<td>[AV]</td>
<td>number[,mode]</td>
</tr>
<tr>
<td>(Keysight B1500 can use AAD/AIT instead of AV.)</td>
<td></td>
<td>[AAD] chnum[,type]</td>
</tr>
<tr>
<td></td>
<td>[AIT]</td>
<td>type[,mode[,N]]</td>
</tr>
<tr>
<td>Forces constant voltage</td>
<td>DV, TDV</td>
<td>chnum,range,output [,comp[,polarity[,crange]]]</td>
</tr>
<tr>
<td>Forces constant current</td>
<td>DI, TDI</td>
<td></td>
</tr>
<tr>
<td>Sets voltage measurement range</td>
<td>[RV]</td>
<td>chnum,range</td>
</tr>
<tr>
<td>Sets current measurement range</td>
<td>[RI]</td>
<td>chnum,range</td>
</tr>
<tr>
<td></td>
<td>[RM]</td>
<td>chnum[,mode[,rate]]</td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td>1[,chnum[,chnum ... [,chnum] ... ]]</td>
</tr>
<tr>
<td>Sets SMU operation mode</td>
<td>[CMM]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>

**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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 18</td>
<td>Declares variables and sets the value.</td>
</tr>
<tr>
<td>19 to 22</td>
<td>Sets the data output format, time stamp data output mode, and A/D converter. Also sets the SMU filter off.</td>
</tr>
<tr>
<td>23 to 26</td>
<td>Applies voltage to device.</td>
</tr>
<tr>
<td>27 to 29</td>
<td>Sets the measurement mode, channel measurement mode, and measurement range.</td>
</tr>
<tr>
<td>30 to 31</td>
<td>Checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.</td>
</tr>
</tbody>
</table>
**Programming Examples**

**Spot Measurements**

```vbnet
session.WriteString("TSR" & vbCrLf)  '33
session.WriteString("XE" & vbCrLf)
session.WriteString("TSQ" & vbCrLf)
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" & vbCrLf)  '46
save_data(fname, title, value, data, nop1, nop2, session, t)
Exit Sub
Check_err:  '50
    session.WriteString("EMG? " & err & vbCrLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
End Sub
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>33 to 44</td>
<td>Resets time stamp and performs the spot measurement. And stores the returned data into the <code>mret</code> and <code>tret</code> string variables. Finally, stores the measured data into the <code>data</code> array.</td>
</tr>
<tr>
<td>46 to 48</td>
<td>Applies 0 V from all channels. And transfers the data stored in the <code>data</code> variable to the <code>save_data</code> subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the <code>fname</code> variable and displays the data on a message box.</td>
</tr>
<tr>
<td>51 to 52</td>
<td>Displays a message box to show an error message if the error is detected.</td>
</tr>
</tbody>
</table>

**Measurement Result Example**

<table>
<thead>
<tr>
<th>Id (µA), Status, Meas Time (msec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.495, NEI, 14.28</td>
</tr>
</tbody>
</table>

Data save completed.

Do you want to perform measurement again?
# Pulsed Spot Measurements

To perform pulsed spot measurements, use the following commands.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>[chnum ... [chnum] ... ]</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>[chnum ... [chnum] ... ]</td>
</tr>
<tr>
<td>Sets filter ON/OFF</td>
<td>[FL]</td>
<td>mode[chnum ... [chnum] ... ]</td>
</tr>
<tr>
<td>Sets series resistor ON/OFF</td>
<td>[SSR]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Measurement time</td>
<td>AIT</td>
<td>2,mode[N]</td>
</tr>
<tr>
<td>Forces constant voltage</td>
<td>DV, TDV</td>
<td>chnum,range, output</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[comp[polarity[range]]]</td>
</tr>
<tr>
<td>Forces constant current</td>
<td>DI, TDI</td>
<td></td>
</tr>
<tr>
<td>Sets pulse timing parameters</td>
<td>PT</td>
<td>hold,width[period [,tdelay]]</td>
</tr>
<tr>
<td>Sets pulse voltage</td>
<td>PV</td>
<td>chnum,range,base,pulse[comp]</td>
</tr>
<tr>
<td>Sets pulse current</td>
<td>PI</td>
<td>chnum,range,base,pulse [,comp]</td>
</tr>
<tr>
<td>Sets voltage measurement range</td>
<td>[RV]</td>
<td>chnum,range</td>
</tr>
<tr>
<td>Sets current measurement range</td>
<td>[RI]</td>
<td>chnum,range</td>
</tr>
<tr>
<td></td>
<td>[RM]</td>
<td>chnum,mode[,rate]</td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td>3,chnum</td>
</tr>
<tr>
<td>Sets SMU operation mode</td>
<td>[CMM]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>
A program example of a pulsed spot measurement is shown below. This example measures MOSFET drain current.

### Table 3-4 Pulsed Spot Measurement Example

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 18</td>
<td>Declares variables and sets the value.</td>
</tr>
<tr>
<td>19 to 22</td>
<td>Sets the data output format, time stamp data output mode, SMU filter, and averaging.</td>
</tr>
<tr>
<td>23 to 29</td>
<td>Applies DC voltage to device, and sets the voltage pulse source.</td>
</tr>
<tr>
<td>30 to 32</td>
<td>Sets the measurement mode, channel measurement mode, and measurement range.</td>
</tr>
<tr>
<td>33 to 34</td>
<td>Checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.</td>
</tr>
</tbody>
</table>
Programming Examples
Pulsed Spot Measurements

```vbnet
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
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 to 46</td>
<td>Resets time stamp and performs the pulsed spot measurement. And stores the returned data into the <code>mret</code> and <code>tret</code> string variables. Finally, stores the measured data into the <code>data</code> array.</td>
</tr>
<tr>
<td>48 to 50</td>
<td>Applies 0 V from all channels. And transfers the data stored in the <code>data</code> variable to the <code>save_data</code> subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the <code>fname</code> variable and displays the data on a message box.</td>
</tr>
<tr>
<td>53 to 54</td>
<td>Displays a message box to show an error message if the error is detected.</td>
</tr>
</tbody>
</table>

**Measurement Result Example**

<table>
<thead>
<tr>
<th>Id (uA), Status, Meas Time (msec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25, NEI, 17.58</td>
</tr>
</tbody>
</table>

Data save completed.

Do you want to perform measurement again?
Staircase Sweep Measurements

To perform staircase sweep measurements, use the following commands.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets filter ON/OFF</td>
<td>[FL]</td>
<td>mode[,chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets series resistor ON/OFF</td>
<td>[SSR]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Sets integration time</td>
<td>[AV]</td>
<td>number[,mode]</td>
</tr>
<tr>
<td>(Keysight B1500 can use AAD/AIT instead of AV.)</td>
<td>[AAD]</td>
<td>chnum[,type]</td>
</tr>
<tr>
<td></td>
<td>[AIT]</td>
<td>type[,mode[,N]]</td>
</tr>
<tr>
<td>Sets sweep source timing parameter</td>
<td>[WT]</td>
<td>hold,delay [,sdelay[,tdelay[,mdelay]]]</td>
</tr>
<tr>
<td>Sets auto abort function</td>
<td>[WM]</td>
<td>abort[,post]</td>
</tr>
<tr>
<td>Sets voltage sweep source</td>
<td>WV</td>
<td>chnum,mode,range,start,stop,step [,comp[,Pcomp]]</td>
</tr>
<tr>
<td>Sets current sweep source</td>
<td>WI</td>
<td></td>
</tr>
<tr>
<td>Sets synchronous sweep source a</td>
<td>[WSV]</td>
<td>chnum,range,start,stop [,comp[,Pcomp]]</td>
</tr>
<tr>
<td></td>
<td>[WSI]</td>
<td></td>
</tr>
<tr>
<td>Forces constant voltage</td>
<td>DV, TDV</td>
<td>chnum,range,output</td>
</tr>
<tr>
<td>Forces constant current</td>
<td>DI, TDI</td>
<td>[,comp[,polarity[,crange]]]</td>
</tr>
<tr>
<td>Sets voltage measurement range</td>
<td>[RV]</td>
<td>chnum,range</td>
</tr>
<tr>
<td>Sets current measurement range</td>
<td>[RI]</td>
<td>chnum,range</td>
</tr>
<tr>
<td></td>
<td>[RM]</td>
<td>chnum,mode[,rate]</td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td>2[,chnum[,chnum ... [,chnum] ... ]]</td>
</tr>
<tr>
<td>Sets SMU operation mode</td>
<td>[CMM]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 26</td>
<td>Declares variables used to set the source output, and sets the value.</td>
</tr>
<tr>
<td>27 to 31</td>
<td>Declares variables used to read the measurement data.</td>
</tr>
<tr>
<td>32 to 35</td>
<td>Sets the data output format, time stamp data output mode, SMU filter, and averaging.</td>
</tr>
<tr>
<td>36 to 37</td>
<td>Applies voltage to device.</td>
</tr>
</tbody>
</table>
**Programming Examples**

**Staircase Sweep Measurements**

```vbnet
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("NUP?" & 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)
    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
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>38 to 40</td>
<td>Sets the measurement mode, channel measurement mode, and measurement range.</td>
</tr>
<tr>
<td>41 to 44</td>
<td>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.</td>
</tr>
<tr>
<td>46 to 66</td>
<td>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.</td>
</tr>
<tr>
<td>54 to 55</td>
<td>Checks number of returned data. If it is not correct, forces 0 V and goes to Check_nop.</td>
</tr>
<tr>
<td>63</td>
<td>Stores the measured data into the data array.</td>
</tr>
<tr>
<td>67 to 69</td>
<td>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.</td>
</tr>
</tbody>
</table>
Programming Examples

Staircase Sweep Measurements

Measurement Result Example

<table>
<thead>
<tr>
<th>Vg (V), Vd (V), Id (mA), Time (sec), Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 0, 0.0001123, 0.05631, NEI</td>
</tr>
<tr>
<td>1, 0.3, 0.02327, 0.09489, NEI</td>
</tr>
<tr>
<td>1, 0.6, 0.0235, 0.12746, NEI</td>
</tr>
<tr>
<td>1, 0.9, 0.0235, 0.16004, NEI</td>
</tr>
<tr>
<td>1, 1.2, 0.0235, 0.19262, NEI</td>
</tr>
<tr>
<td>1, 1.5, 0.0235, 0.22518, NEI</td>
</tr>
<tr>
<td>1, 1.8, 0.02351, 0.25775, NEI</td>
</tr>
<tr>
<td>1, 2.1, 0.0235, 0.29032, NEI</td>
</tr>
<tr>
<td>1, 2.4, 0.02353, 0.32288, NEI</td>
</tr>
<tr>
<td>1, 2.7, 0.02351, 0.35545, NEI</td>
</tr>
<tr>
<td>1, 3, 0.02353, 0.38802, NEI</td>
</tr>
<tr>
<td>2, 0, 0.001794, 0.03458, NEI</td>
</tr>
<tr>
<td>2, 0.3, 2.085, 0.05779, NEI</td>
</tr>
<tr>
<td>2, 0.6, 3.5975, 0.07353, NEI</td>
</tr>
<tr>
<td>2, 0.9, 4.5655, 0.08926, NEI</td>
</tr>
<tr>
<td>2, 1.2, 5.0875, 0.10499, NEI</td>
</tr>
<tr>
<td>2, 1.5, 5.316, 0.12073, NEI</td>
</tr>
<tr>
<td>2, 1.8, 5.4045, 0.13646, NEI</td>
</tr>
<tr>
<td>2, 2.1, 5.4455, 0.15219, NEI</td>
</tr>
<tr>
<td>2, 2.4, 5.474, 0.16794, NEI</td>
</tr>
<tr>
<td>2, 2.7, 5.4935, 0.18367, NEI</td>
</tr>
<tr>
<td>2, 3, 5.513, 0.19941, NEI</td>
</tr>
<tr>
<td>3, 0, 0.0027225, 0.03542, NEI</td>
</tr>
<tr>
<td>3, 0.3, 3.4465, 0.05861, NEI</td>
</tr>
<tr>
<td>3, 0.6, 6.4185, 0.07436, NEI</td>
</tr>
<tr>
<td>3, 0.9, 8.904, 0.09011, NEI</td>
</tr>
<tr>
<td>3, 1.2, 10.9, 0.10008, NEI</td>
</tr>
<tr>
<td>3, 1.5, 12.425, 0.10527, NEI</td>
</tr>
<tr>
<td>3, 1.8, 13.51, 0.11046, NEI</td>
</tr>
<tr>
<td>3, 2.1, 14.215, 0.11566, NEI</td>
</tr>
<tr>
<td>3, 2.4, 14.63, 0.12085, NEI</td>
</tr>
<tr>
<td>3, 2.7, 14.875, 0.12605, NEI</td>
</tr>
<tr>
<td>3, 3, 15.04, 0.13124, NEI</td>
</tr>
</tbody>
</table>

Data save completed.
Do you want to perform measurement again?
Programming Examples
Staircase Sweep Measurements

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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 25</td>
<td>Declares variables and set the value. Almost same as the previous program. Only the fname value is different.</td>
</tr>
<tr>
<td>27</td>
<td>Sets the data output format. A comma will be sent as the data terminator.</td>
</tr>
<tr>
<td>28 to 39</td>
<td>Sets the measurement condition. Same as the lines 33 to 44 of the previous program.</td>
</tr>
</tbody>
</table>
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
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
        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
    Next i
    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
Next i
Next j

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>41 to 44</td>
<td>Declares the variables used to read and save the measurement data.</td>
</tr>
<tr>
<td>45 to 46</td>
<td>Declares that a comma is the data terminator needed to read data, and enables it.</td>
</tr>
<tr>
<td>49 to 52</td>
<td>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.</td>
</tr>
<tr>
<td>54 to 63</td>
<td>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.</td>
</tr>
<tr>
<td>64</td>
<td>Checks the status of the measurement channel. And applies 0 V and goes to Check_err if an error is detected.</td>
</tr>
<tr>
<td>65 to 71</td>
<td>Displays the data on the console window. And stores the data into the data array.</td>
</tr>
</tbody>
</table>
Programming Examples
Staircase Sweep Measurements

Measurement Result Example

<table>
<thead>
<tr>
<th>Vg (V)</th>
<th>Vd (V)</th>
<th>Id (mA)</th>
<th>Time (sec)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 0</td>
<td>0.00011485, 0.0595</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1, 0.3</td>
<td>0.02333, 0.09706</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1, 0.6</td>
<td>0.02351, 0.12941</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1, 0.9</td>
<td>0.023545, 0.16096</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1, 1.2</td>
<td>0.02356, 0.19251</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1, 1.5</td>
<td>0.02357, 0.22487</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1, 1.8</td>
<td>0.02356, 0.25643</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1, 2.1</td>
<td>0.02356, 0.28798</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1, 2.4</td>
<td>0.02356, 0.31978</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1, 2.7</td>
<td>0.02359, 0.35134</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1, 3</td>
<td>0.02357, 0.3829</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2, 0</td>
<td>0.001744, 0.0327</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2, 0.3</td>
<td>2.085, 0.05511</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2, 0.6</td>
<td>3.597, 0.07008</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2, 0.9</td>
<td>4.5645, 0.08505</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2, 1.2</td>
<td>5.0875, 0.10057</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2, 1.5</td>
<td>5.3175, 0.11609</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2, 1.8</td>
<td>5.4055, 0.131</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2, 2.1</td>
<td>5.4445, 0.14653</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2, 2.4</td>
<td>5.4725, 0.16147</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2, 2.7</td>
<td>5.4925, 0.17629</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2, 3</td>
<td>5.512, 0.19182</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3, 0</td>
<td>0.002838, 0.04035</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3, 0.3</td>
<td>3.445, 0.06253</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3, 0.6</td>
<td>6.416, 0.07754</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3, 0.9</td>
<td>8.8995, 0.09331</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3, 1.2</td>
<td>10.895, 0.10238</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3, 1.5</td>
<td>12.425, 0.10732</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3, 1.8</td>
<td>13.51, 0.11182</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3, 2.1</td>
<td>14.215, 0.11484</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3, 2.4</td>
<td>14.63, 0.11813</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3, 2.7</td>
<td>14.88, 0.12139</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3, 3</td>
<td>15.045, 0.12469</td>
<td>N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 24</td>
<td>Declares variables used to set the source output, and sets the value.</td>
</tr>
<tr>
<td>25 to 29</td>
<td>Declares variables used to read the measurement data.</td>
</tr>
<tr>
<td>30 to 33</td>
<td>Sets the data output format, time stamp data output mode, SMU filter, and averaging.</td>
</tr>
<tr>
<td>34 to 35</td>
<td>Applies voltage to device.</td>
</tr>
</tbody>
</table>
Programming Examples
Staircase Sweep Measurements

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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>37 to 39</td>
<td>Sets the measurement mode, channel measurement mode, and measurement range.</td>
</tr>
<tr>
<td>40 to 43</td>
<td>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.</td>
</tr>
<tr>
<td>45 to 62</td>
<td>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.</td>
</tr>
<tr>
<td>52 to 53</td>
<td>Checks number of returned data. If it is not correct, forces 0 V and goes to Check_nop.</td>
</tr>
<tr>
<td>61</td>
<td>Stores the measured data into the data array.</td>
</tr>
<tr>
<td>64 to 66</td>
<td>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.</td>
</tr>
</tbody>
</table>
Staircase Sweep Measurements

Measurement Result Example

<table>
<thead>
<tr>
<th>Vg (V), Id (mA), Time (sec), Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>0, -3.685E-10, 5.44653, NEI</td>
</tr>
<tr>
<td>0.2, 1.6695E-08, 5.67838, NEI</td>
</tr>
<tr>
<td>0.4, 5.2305E-07, 5.77096, NEI</td>
</tr>
<tr>
<td>0.6, 1.8995E-05, 5.84304, NEI</td>
</tr>
<tr>
<td>0.8, 0.00078485, 5.90087, NEI</td>
</tr>
<tr>
<td>1, 0.023885, 5.94082, NEI</td>
</tr>
<tr>
<td>1.2, 0.2708, 5.96907, NEI</td>
</tr>
<tr>
<td>1.4, 1.035, 5.98927, NEI</td>
</tr>
<tr>
<td>1.6, 2.261, 6.00637, NEI</td>
</tr>
<tr>
<td>1.8, 3.7695, 6.02346, NEI</td>
</tr>
<tr>
<td>2, 5.43, 6.04055, NEI</td>
</tr>
</tbody>
</table>

Data save completed.

Do you want to perform measurement again?

Check_err:
    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 * 3 & ")", vbOKOnly, "")
End Sub

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.
Pulsed Sweep Measurements

To perform pulsed sweep measurements, use the following commands.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets filter ON/OFF</td>
<td>[FL]</td>
<td>mode[,chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets series resistor ON/OFF</td>
<td>[SSR]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Measurement time</td>
<td>AIT</td>
<td>2,[mode[,]N]</td>
</tr>
<tr>
<td>Sets pulse timing parameters</td>
<td>PT</td>
<td>hold,width,period [,tdelay]</td>
</tr>
<tr>
<td>Sets auto abort function</td>
<td>[WM]</td>
<td>abort[,post]</td>
</tr>
<tr>
<td>Sets pulsed sweep source</td>
<td>PWV</td>
<td>chnum,mode,range,base,start, stop, step[,comp]</td>
</tr>
<tr>
<td></td>
<td>PWI</td>
<td></td>
</tr>
<tr>
<td>Sets synchronous sweep source a</td>
<td>[WSV]</td>
<td>chnum,range,start,stop [,comp[,Pcomp]]</td>
</tr>
<tr>
<td></td>
<td>[WSI]</td>
<td></td>
</tr>
<tr>
<td>Forces constant voltage</td>
<td>DV, TDV</td>
<td>chnum,range,output [,comp[,polarity[,crange]]]</td>
</tr>
<tr>
<td>Forces constant current</td>
<td>DI, TDI</td>
<td></td>
</tr>
<tr>
<td>Sets voltage measurement range</td>
<td>[RV]</td>
<td>chnum,range</td>
</tr>
<tr>
<td>Sets current measurement range</td>
<td>[RI]</td>
<td>chnum,range</td>
</tr>
<tr>
<td></td>
<td>[RM]</td>
<td>chnum,mode[,rate]</td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td>4,chnum</td>
</tr>
<tr>
<td>Sets SMU operation mode</td>
<td>[CMM]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>

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 \( I_c - V_c \) characteristics.

### Table 3-8 Pulsed Sweep Measurement Example

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 26</td>
<td>Declares variables used to set the source output, and sets the value.</td>
</tr>
<tr>
<td>27 to 31</td>
<td>Declares variables used to read the measurement data.</td>
</tr>
<tr>
<td>32 to 35</td>
<td>Sets the data output format, time stamp data output mode, SMU filter, and averaging.</td>
</tr>
<tr>
<td>36</td>
<td>Disables SMU assigned to ( t(3) ) that is not needed.</td>
</tr>
</tbody>
</table>
Programming Examples  
Pulsed Sweep Measurements

```vbnet
session.WriteString("DV " & t(0) & ",0,0,0.1" & vbCrLf) '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 & vbCrLf)
session.WriteString("MM 4," & t(2) & vbCrLf) '4: pulsed sweep measurement
session.WriteString("CMM " & t(2) & ",1" & vbCrLf)
session.WriteString("RI " & t(2) & ",,0" & vbCrLf)
session.WriteString("WT " & hold & ",," & delay & ",," & s_delay & vbCrLf)
session.WriteString("WM 2,1" & vbCrLf) 'stops any abnormal
session.WriteString("ERR? 1" & vbCrLf) : err = session.ReadString(4 + 2) '46
If err <> 0 Then session.WriteString("DZ" & vbCrLf) : GoTo Check_err
For j = 0 To nop2 - 1 '49
    session.WriteString("PWV " & t(2) & ",1,0," & v0 & "," & vc1 & "," & vc2 & "," &
        nop1 & "," & iccomp & vbCrLf)
    session.WriteString("DI " & t(1) & ",0," & ib & "," & vbcomp & vbCrLf)
    session.WriteString("TSR" & vbCrLf)
    session.WriteString("XE" & vbCrLf)
    session.WriteString("*OPC?" & vbCrLf) : rep = session.ReadString(1 + 2)
    session.WriteString("ERR? 1" & vbCrLf) : err = session.ReadString(4 + 2)
    If err <> 0 Then session.WriteString("DZ" & vbCrLf) : GoTo Check_err
    session.WriteString("NUB?" & vbCrLf) : rep = session.ReadString(3 + 2) '57
    If rep <> nop1 * 3 Then session.WriteString("DZ" & vbCrLf) : 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
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>38 to 45</td>
<td>Applies voltage to device. And sets the pulse timing parameters, measurement mode, channel measurement mode, measurement range, and sweep mode.</td>
</tr>
<tr>
<td>46 to 47</td>
<td>Checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.</td>
</tr>
<tr>
<td>49 to 69</td>
<td>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.</td>
</tr>
<tr>
<td>57 to 58</td>
<td>Checks number of returned data. If it is not correct, forces 0 V and goes to Check_nop.</td>
</tr>
</tbody>
</table>
Programming Examples
Pulsed Sweep Measurements

Measurement Result Example

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>71 to 72</td>
<td>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.</td>
</tr>
<tr>
<td>75 to 77</td>
<td>Displays a message box to show an error message if the error is detected.</td>
</tr>
<tr>
<td>80 to 81</td>
<td>Displays a message box to show an error message if the number of returned data is not correct.</td>
</tr>
</tbody>
</table>

```
session.WriteString("DZ" & vbLf)  '71
save_data(fname, title, value, data, nop1, nop2, session, t)
Exit Sub

Check_err:
    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 * 3 & ")", vbOKOnly, ")
End Sub
```

```
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.
```
Programming Examples
Pulsed Sweep Measurements

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.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets filter ON/OFF</td>
<td>[FL]</td>
<td>mode[,chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets series resistor ON/OFF</td>
<td>[SSR]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Measurement time</td>
<td>AIT</td>
<td>2,mode[,N]</td>
</tr>
<tr>
<td>Sets auto abort function</td>
<td>[WM]</td>
<td>abort[,post]</td>
</tr>
<tr>
<td>Sets voltage sweep source</td>
<td>WV</td>
<td>chnum,mode,range,start,stop, step[,comp[,Pcomp]]</td>
</tr>
<tr>
<td>Sets current sweep source</td>
<td>WI</td>
<td></td>
</tr>
<tr>
<td>Sets synchronous sweep source a</td>
<td>[WSV]</td>
<td>chnum,range,start,stop[,comp[,Pcomp]]</td>
</tr>
<tr>
<td></td>
<td>[WSI]</td>
<td></td>
</tr>
<tr>
<td>Sets pulse timing parameters</td>
<td>PT</td>
<td>hold,width,period [,tdelay]</td>
</tr>
<tr>
<td>Forces pulse voltage</td>
<td>PV</td>
<td>chnum,range,base,pulse[,comp]</td>
</tr>
<tr>
<td>Forces pulse current</td>
<td>PI</td>
<td>chnum,range,base,pulse [,comp]</td>
</tr>
<tr>
<td>Forces constant voltage</td>
<td>DV, TDV</td>
<td>chnum,range,output[,comp[,polarity[,crange]]]</td>
</tr>
<tr>
<td>Forces constant current</td>
<td>DI, TDI</td>
<td></td>
</tr>
<tr>
<td>Sets voltage measurement range</td>
<td>[RV]</td>
<td>chnum,range</td>
</tr>
<tr>
<td>Sets current measurement range</td>
<td>[RI]</td>
<td>chnum,range</td>
</tr>
<tr>
<td></td>
<td>[RM]</td>
<td>chnum,mode[,rate]</td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td>5,chnum</td>
</tr>
<tr>
<td>Sets SMU operation mode</td>
<td>[CMM]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>

a. The WSV/WSI command must be entered after the WV/WI command.
Programming Examples
Staircase Sweep with Pulsed Bias Measurements

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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>12 to 26</td>
<td>Declares variables used to set the source output, and sets the value.</td>
</tr>
<tr>
<td>27 to 31</td>
<td>Declares variables used to read the measurement data.</td>
</tr>
<tr>
<td>32 to 35</td>
<td>Sets the data output format, time stamp data output mode, SMU filter, and averaging.</td>
</tr>
<tr>
<td>36</td>
<td>Disables SMU assigned to t(3) that is not needed.</td>
</tr>
</tbody>
</table>
Programming Examples

Staircase Sweep with Pulsed Bias Measurements

```
    session.WriteString("DV " & t(0) & ",0,0,0.1" & vbCrLf)                '37
    Dim b_pt As String = "0.1,0.01,0.02"                           'hold, width, period in sec
    session.WriteString("PT " & b_pt & vbCrLf)                     
    session.WriteString("MM 5," & t(2) & vbCrLf)              '5: staircase sweep w/pulsed bias
    session.WriteString("CMM " & t(2) & ",1" & vbCrLf)
    session.WriteString("RI " & t(2) & ",0" & vbCrLf)
    session.WriteString("WT " & hold & "," & delay & "," & s_delay & vbCrLf)
    session.WriteString("WM 2,1" & vbCrLf)
    session.WriteString("ERR? 1" & vbCrLf) : err = session.ReadString(4 + 2)               '45
    If err <> 0 Then session.WriteString("DZ" & vbCrLf) : GoTo Check_err

    For j = 0 To nop2 - 1                                          '48
        session.WriteString("WV " & t(2) & ",1,0," & vc1 & "," & vc2 & "," & nop1 & "," & iccomp & "," & pccomp & vbCrLf)
        session.WriteString("PI " & t(1) & ",0," & i0 & "," & ib & "," & vbcomp & vbCrLf)      
        session.WriteString("TSR" & vbCrLf)
        session.WriteString("XE" & vbCrLf)
        session.WriteString("*OPC?" & vbCrLf) : rep = session.ReadString(1 + 2)
        session.WriteString("ERR? 1" & vbCrLf) : err = session.ReadString(4 + 2)
        If err <> 0 Then session.WriteString("DZ" & vbCrLf) : GoTo Check_err
        session.WriteString("NUB?" & vbCrLf) : rep = session.ReadString(3 + 2)                '56
        If rep <> nop1 * 3 Then session.WriteString("DZ" & vbCrLf) : 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
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>37 to 44</td>
<td>Applies voltage to device. And sets the pulse timing parameters, measurement mode, channel measurement mode, measurement range, and sweep mode.</td>
</tr>
<tr>
<td>45 to 46</td>
<td>Checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.</td>
</tr>
<tr>
<td>48 to 68</td>
<td>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.</td>
</tr>
<tr>
<td>56 to 57</td>
<td>Checks number of returned data. If it is not correct, forces 0 V and goes to Check_nop.</td>
</tr>
</tbody>
</table>
Staircase Sweep with Pulsed Bias Measurements

Programming Examples

Measurement Result Example

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 to 72</td>
<td>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.</td>
</tr>
<tr>
<td>75 to 76</td>
<td>Displays a message box to show an error message if the error is detected.</td>
</tr>
<tr>
<td>80</td>
<td>Displays a message box to show an error message if the number of returned data is not correct.</td>
</tr>
</tbody>
</table>

Ib (mA), Vc (V), Ic (mA), Time (sec), Status

3, 0, -0.39, 0.14938, 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
5, 0, -0.98, 0.12291, NCI
5, 0.5, 9.685, 0.14291, NCI
5, 1, 9.85, 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, 14.55, 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.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets filter ON/OFF</td>
<td>[FL]</td>
<td>mode[,chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets series resistor ON/OFF</td>
<td>[SSR]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Sets integration time</td>
<td>[AV]</td>
<td>number[,mode]</td>
</tr>
<tr>
<td>(Keysight B1500 can use AAD/AIT instead of AV.)</td>
<td>[AAD]</td>
<td>chnum[,type]</td>
</tr>
<tr>
<td></td>
<td>[AIT]</td>
<td>type,mode[,N]</td>
</tr>
<tr>
<td>Sets detection interval</td>
<td>[BDM]</td>
<td>interval[,mode]</td>
</tr>
<tr>
<td>Sets timing parameters</td>
<td>[BDT]</td>
<td>hold,delay</td>
</tr>
<tr>
<td>Sets quasi-pulsed source</td>
<td>BDV</td>
<td>chnum,range,start,stop[,comp]</td>
</tr>
<tr>
<td>Forces constant voltage</td>
<td>DV, TDV</td>
<td>chnum,range,output [,[comp][,polarity][,range]]</td>
</tr>
<tr>
<td>Forces constant current</td>
<td>DI, TDI</td>
<td></td>
</tr>
<tr>
<td>Sets voltage measurement range</td>
<td>[RV]</td>
<td>chnum,range</td>
</tr>
<tr>
<td>Sets current measurement range</td>
<td>[RI]</td>
<td>chnum,range</td>
</tr>
<tr>
<td></td>
<td>[RM]</td>
<td>chnum,mode[,rate]</td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td>9[,chnum]</td>
</tr>
<tr>
<td>Sets SMU operation mode</td>
<td>[CMM]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 20</td>
<td>Declares variables, and sets the value.</td>
</tr>
<tr>
<td>22 to 23</td>
<td>Sets the data output format. And disables SMUs assigned to t(1) and t(3) that are not needed.</td>
</tr>
<tr>
<td>24 to 27</td>
<td>Sets the measurement mode, measurement timing parameters, measurement conditions, and source output conditions.</td>
</tr>
<tr>
<td>28 to 29</td>
<td>Checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.</td>
</tr>
<tr>
<td>30 to 31</td>
<td>Applies voltage to device, and performs the quasi pulsed spot measurement.</td>
</tr>
</tbody>
</table>
Programming Examples
Quasi Pulsed Spot Measurements

*Measurement Result Example*

**BVceo (V), Status**

7.759, CCV

Data save completed.

Do you want to perform measurement again?

```vba
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" & vbCrLf)  '39
save_data(fname, title, value, data, nop1, nop2, session, t)
Exit Sub

Check_err:  '43
    session.WriteString("EMG? " & err & vbCrLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
End Sub

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>33 to 37</td>
<td>Reads the returned data and stores it into the <em>data1</em> string variable. Finally, stores the measured data into the <em>data</em> array.</td>
</tr>
<tr>
<td>39 to 41</td>
<td>Applies 0 V from all channels. And transfers the data stored in the <em>data</em> variable to the <code>save_data</code> subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the <em>fname</em> variable and displays the data on a message box.</td>
</tr>
<tr>
<td>43 to 45</td>
<td>Displays a message box to show an error message if the error is detected.</td>
</tr>
</tbody>
</table>
Programming Examples
Linear Search Measurements

## Linear Search Measurements

To perform linear search measurements, use the following commands.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>([chnum \ldots [,chnum] \ldots ])</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>([chnum \ldots [,chnum] \ldots ])</td>
</tr>
<tr>
<td>Sets filter ON/OFF</td>
<td>[FL]</td>
<td>mode[,chnum \ldots [,chnum] \ldots ]</td>
</tr>
<tr>
<td>Sets series resistor ON/OFF</td>
<td>[SSR]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Sets integration time (Keysight B1500 can use AAD/AIT instead of AV.)</td>
<td>[AV]</td>
<td>number[,mode]</td>
</tr>
<tr>
<td></td>
<td>[AAD]</td>
<td>chnum,[type]</td>
</tr>
<tr>
<td></td>
<td>[AIT]</td>
<td>type,mode[,N]</td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td>14</td>
</tr>
<tr>
<td>Selects output data</td>
<td>[LSVM]</td>
<td>output_data</td>
</tr>
<tr>
<td>Sets timing parameters</td>
<td>[LSTM]</td>
<td>hold, delay</td>
</tr>
<tr>
<td>Sets auto abort function</td>
<td>[LSM]</td>
<td>abort[,post]</td>
</tr>
<tr>
<td>Sets current search or voltage search condition</td>
<td>LGI or LGV</td>
<td>chnum,mode,range,target</td>
</tr>
<tr>
<td>Sets voltage source or current source</td>
<td>LSV or LSI</td>
<td>chnum,range,start,stop,step [,comp]</td>
</tr>
<tr>
<td></td>
<td>[LSSV] or [LSSI]</td>
<td>chnum,polarity,offset[,comp]</td>
</tr>
<tr>
<td>Forces constant voltage</td>
<td>DV, TDV</td>
<td>chnum,range,output [,comp[,polarity[,crange]]]</td>
</tr>
<tr>
<td>Forces constant current</td>
<td>DI, TDI</td>
<td></td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 25</td>
<td>Declares variables, and sets the value.</td>
</tr>
<tr>
<td>27 to 28</td>
<td>Sets the data output format and the measurement mode.</td>
</tr>
<tr>
<td>29 to 32</td>
<td>Sets the linear search measurement conditions.</td>
</tr>
<tr>
<td>33 to 34</td>
<td>Sets the linear search sources, primary source and synchronous source.</td>
</tr>
</tbody>
</table>
Programming Examples
Linear Search Measurements

```
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
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>36 to 37</td>
<td>Checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.</td>
</tr>
<tr>
<td>38 to 40</td>
<td>Applies voltage to device, and performs the linear search measurement.</td>
</tr>
<tr>
<td>42 to 46</td>
<td>Reads the returned data and stores it into the mret string variable. Finally, stores the measured data into the data array.</td>
</tr>
<tr>
<td>48 to 50</td>
<td>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.</td>
</tr>
<tr>
<td>52 to 54</td>
<td>Displays a message box to show an error message if the error is detected.</td>
</tr>
</tbody>
</table>

**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.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>([\text{chnum} \ ... \ [,\text{chnum}] \ ... \ ])</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>([\text{chnum} \ ... \ [,\text{chnum}] \ ... \ ])</td>
</tr>
<tr>
<td>Sets filter ON/OFF</td>
<td>[FL]</td>
<td>(\text{mode},\text{chnum} \ ... \ [,\text{chnum}] \ ... \ ])</td>
</tr>
<tr>
<td>Sets series resistor ON/OFF</td>
<td>[SSR]</td>
<td>(\text{chnum},\text{mode})</td>
</tr>
<tr>
<td>Sets integration time</td>
<td>[AV]</td>
<td>(\text{number},[,\text{mode}])</td>
</tr>
<tr>
<td>(Keysight B1500 can use AAD/AIT instead of AV.)</td>
<td>[AAD]</td>
<td>(\text{chnum},[,\text{type}])</td>
</tr>
<tr>
<td></td>
<td>[AIT]</td>
<td>(\text{type},\text{mode},[,N])</td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td>15</td>
</tr>
<tr>
<td>Selects output data</td>
<td>[BSVM]</td>
<td>(\text{output}_\text{data})</td>
</tr>
<tr>
<td>Sets timing parameters</td>
<td>[BST]</td>
<td>(\text{hold},\text{delay})</td>
</tr>
<tr>
<td>Sets source control mode</td>
<td>BSM</td>
<td>(\text{mode},\text{abort},[,\text{post}])</td>
</tr>
<tr>
<td>Sets current search or voltage search condition</td>
<td>BGI or BGV</td>
<td>(\text{chnum},\text{mode},\text{condition},\text{range},\text{target})</td>
</tr>
<tr>
<td>Sets voltage source or current source</td>
<td>BSV or BSI</td>
<td>(\text{chnum},\text{range},\text{start},\text{stop}[,,,\text{comp}])</td>
</tr>
<tr>
<td>Sets synchronous voltage source or current source</td>
<td>[BSSV] or [BSSI]</td>
<td>(\text{chnum},\text{polarity},\text{offset}[,,,\text{comp}])</td>
</tr>
<tr>
<td>Forces constant voltage</td>
<td>DV, TDV</td>
<td>(\text{chnum},\text{range},\text{output}[,\text{comp},\text{polarity},[,\text{crange}]])</td>
</tr>
<tr>
<td>Forces constant current</td>
<td>DI, TDI</td>
<td></td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 25</td>
<td>Declares variables, and sets the value.</td>
</tr>
<tr>
<td>27 to 28</td>
<td>Sets the data output format and the measurement mode.</td>
</tr>
<tr>
<td>29 to 32</td>
<td>Sets the binary search measurement conditions.</td>
</tr>
<tr>
<td>33 to 34</td>
<td>Sets the binary search sources, primary source and synchronous source.</td>
</tr>
</tbody>
</table>
Programming Examples

Binary Search Measurements

Session.WriteString("ERR? 1" & vbCrLf) : err = session.ReadString(4 + 2) '36
If err <> 0 Then session.WriteString("DZ" & vbCrLf) : GoTo Check_err
session.WriteString("DV " & t(3) & ",0,0,0.1" & vbCrLf) 'out= 0 V, comp= 0.1 A
session.WriteString("DV " & t(2) & ",0,0,0.1" & vbCrLf) 'out= 0 V, comp= 0.1 A
session.WriteString("XE" & vbCrLf) '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)
data(j, i) = Chr(13) & Chr(10) & dsearch & "," & dsense * 1000 & "," & status

session.WriteString("DZ" & vbCrLf) '48
save_data(fname, title, value, data, nop1, nop2, session, t)
Exit Sub

Check_err:
    session.WriteString("EMG? " & err & vbCrLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, ")'52
End Sub

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>36 to 37</td>
<td>Checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.</td>
</tr>
<tr>
<td>38 to 40</td>
<td>Applies voltage to device, and performs the binary search measurement.</td>
</tr>
<tr>
<td>42 to 46</td>
<td>Reads the returned data and stores it into the mret string variable. Finally, stores the measured data into the data array.</td>
</tr>
<tr>
<td>48 to 50</td>
<td>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.</td>
</tr>
<tr>
<td>52 to 54</td>
<td>Displays a message box to show an error message if the error is detected.</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td><code>[chnum ... [chnum] ... ]</code></td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td><code>[chnum ... [chnum] ... ]</code></td>
</tr>
<tr>
<td>Sets filter ON/OFF</td>
<td>[FL]</td>
<td><code>mode,[chnum ... [chnum] ... ]</code></td>
</tr>
<tr>
<td>Sets series resistor ON/OFF</td>
<td>[SSR]</td>
<td><code>chnum,mode</code></td>
</tr>
<tr>
<td>Sets integration time</td>
<td>[AV]</td>
<td><code>number,[mode]</code></td>
</tr>
<tr>
<td></td>
<td>[AAD]</td>
<td><code>chnum,[type]</code></td>
</tr>
<tr>
<td></td>
<td>[AIT]</td>
<td><code>type,[N]</code></td>
</tr>
<tr>
<td>Sets sweep source timing parameter</td>
<td>[WT]</td>
<td><code>hold, delay, [sdelay,tdelay,mdelay]</code></td>
</tr>
<tr>
<td>Sets auto abort function</td>
<td>[WM]</td>
<td><code>abort,[post]</code></td>
</tr>
<tr>
<td>Sets voltage sweep source</td>
<td>WV</td>
<td><code>chnum,mode,range,start,stop,step [,.comp[.Pcomp]]</code></td>
</tr>
<tr>
<td>Sets current sweep source</td>
<td>WI</td>
<td></td>
</tr>
<tr>
<td>Sets synchronous sweep source</td>
<td>[WNX]</td>
<td><code>N,chnum,mode,range,start,stop [,.comp[.Pcomp]]</code></td>
</tr>
<tr>
<td>Forces constant voltage</td>
<td>DV, TDV</td>
<td><code>chnum,range,output [,.comp[.polarity[.crange]]]</code></td>
</tr>
<tr>
<td>Forces constant current</td>
<td>DI, TDI</td>
<td></td>
</tr>
<tr>
<td>Sets voltage measurement range</td>
<td>[RV]</td>
<td><code>chnum,range</code></td>
</tr>
<tr>
<td>Sets current measurement range</td>
<td>[RI]</td>
<td><code>chnum,range</code></td>
</tr>
<tr>
<td></td>
<td>[RM]</td>
<td><code>chnum,mode[,rate]</code></td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td><code>16,chnum,[chnum ... [chnum] ... ]</code></td>
</tr>
<tr>
<td>Sets SMU operation mode</td>
<td>[CMM]</td>
<td><code>chnum,mode</code></td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 21</td>
<td>Declares variables used to set the source output, and sets the value.</td>
</tr>
<tr>
<td>22 to 29</td>
<td>Declares variables used to read the measurement data.</td>
</tr>
</tbody>
</table>
Programming Examples
Multi Channel Sweep Measurements

```vbnet
session.WriteString("FMT 1,1" & vbLf) 'ASCII,<CRLF EOI>,w/sweep source data
session.WriteString("TSC 1" & vbLf) 'enables time stamp output
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) '100 mA fixed range
session.WriteString("RI" & t(2) & ",-19" & vbLf)
session.WriteString("WT " & hold & "," & delay & "," & s_delay & vbLf)
If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
If err <> 0 Then 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(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("*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)
If rep <> nop1 * 5 Then session.WriteString("DZ" & vbLf) : GoTo Check_nop
mret = session.ReadString(16 * 5 * nop1 + 1)
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 to 43</td>
<td>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.</td>
</tr>
<tr>
<td>45 to 49</td>
<td>Sets the sweep source, applies voltage to device, resets time stamp, and performs the multi channel sweep measurement.</td>
</tr>
<tr>
<td>50 to 54</td>
<td>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.</td>
</tr>
<tr>
<td>56</td>
<td>Stores the returned data into the mret string variable.</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>([chnum \ldots [chnum] \ldots ])</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>([chnum \ldots [chnum] \ldots ])</td>
</tr>
<tr>
<td>Sets filter ON/OFF</td>
<td>[FL]</td>
<td>(mode,[chnum \ldots [chnum] \ldots ])</td>
</tr>
<tr>
<td>Sets series resistor ON/OFF</td>
<td>[SSR]</td>
<td>(chnum, mode)</td>
</tr>
<tr>
<td>Measurement time</td>
<td>[AIT]</td>
<td>(2,mode,N)</td>
</tr>
<tr>
<td>Sets pulse common parameters</td>
<td>MCPT</td>
<td>(hold[,period[,Mdelay [,average]]]])</td>
</tr>
<tr>
<td>Sets pulse timing parameters</td>
<td>MCPNT</td>
<td>(chnum, delay, width)</td>
</tr>
<tr>
<td>Sets pulse output</td>
<td>MCPNX</td>
<td>(N,chnum, mode, range, base, pulse [,comp])</td>
</tr>
<tr>
<td>Forces constant voltage</td>
<td>DV, TDV</td>
<td>(chnum, range, output [,comp[,polarity[,crange]]]])</td>
</tr>
<tr>
<td>Forces constant current</td>
<td>DI, TDI</td>
<td></td>
</tr>
<tr>
<td>Sets voltage measurement range</td>
<td>[RV]</td>
<td>(chnum, range)</td>
</tr>
<tr>
<td>Sets current measurement range</td>
<td>[RI]</td>
<td>(chnum, range)</td>
</tr>
<tr>
<td></td>
<td>[RM]</td>
<td>(chnum, mode[,rate])</td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td>(27,chnum[,chnum \ldots [chnum] \ldots ])</td>
</tr>
<tr>
<td>Sets SMU operation mode</td>
<td>[CMM]</td>
<td>(chnum, mode)</td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 22</td>
<td>Declares variables and sets the value.</td>
</tr>
<tr>
<td>23 to 26</td>
<td>Sets the data output format, time data output mode, SMU filter, and measurement time.</td>
</tr>
<tr>
<td>27 to 33</td>
<td>Sets the voltage pulse sources, and applies DC voltage to device.</td>
</tr>
<tr>
<td>34 to 36</td>
<td>Sets the measurement mode, channel measurement mode, and measurement range.</td>
</tr>
</tbody>
</table>
Programming Examples
Multi Channel Pulsed Spot Measurements

```vbscript
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 * 100 & ", " & 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.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>[chnum ... [chnum] ... ]</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>[chnum ... [chnum] ... ]</td>
</tr>
<tr>
<td>Sets filter ON/OFF</td>
<td>[FL]</td>
<td>mode,[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets series resistor ON/OFF</td>
<td>[SSR]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Measurement time</td>
<td>[AIT]</td>
<td>2,mode[,]N</td>
</tr>
<tr>
<td>Sets auto abort function</td>
<td>[WM]</td>
<td>abort[,]post</td>
</tr>
<tr>
<td>Sets pulse common parameters</td>
<td>MCPT</td>
<td>hold[,period[,Mdelay [,average]]]]</td>
</tr>
<tr>
<td>Sets pulse timing parameters</td>
<td>MCPNT</td>
<td>chnum,delay,width</td>
</tr>
<tr>
<td>Sets sweep mode and steps</td>
<td>MCPWS</td>
<td>mode,numberOfSteps</td>
</tr>
<tr>
<td>Sets pulsed sweep output</td>
<td>MCPWNX</td>
<td>N,chnum,mode,range;base,start,stop[,comp[,Pcomp]]</td>
</tr>
<tr>
<td>Sets pulse output</td>
<td>[MCPNX]</td>
<td>N,chnum,mode,range;base,pulse [,comp]</td>
</tr>
<tr>
<td>Sets synchronous staircase sweep</td>
<td>[WNX]</td>
<td>N,chnum,mode,range,start,stop [,comp[,Pcomp]]</td>
</tr>
<tr>
<td>sweep source</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forces constant voltage</td>
<td>DV, TDV</td>
<td>chnum,range[,output [,comp[,polarity[,range]]]]</td>
</tr>
<tr>
<td>Forces constant current</td>
<td>DI, TDI</td>
<td></td>
</tr>
<tr>
<td>Sets voltage measurement range</td>
<td>[RV]</td>
<td>chnum,range</td>
</tr>
<tr>
<td>Sets current measurement range</td>
<td>[RI]</td>
<td>chnum,range</td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>[RM]</td>
<td>chnum,mode[,]rate</td>
</tr>
<tr>
<td>Sets SMU operation mode</td>
<td>[CMM]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>
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 \( I_b-V_b \) and \( I_c-V_b \) characteristics simultaneously.

Table 3-15  Multi Channel Pulsed Sweep Measurement Example

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 18</td>
<td>Declares variables used to set the source output, and sets the value.</td>
</tr>
<tr>
<td>19 to 26</td>
<td>Declares variables used to read the measurement data.</td>
</tr>
<tr>
<td>27 to 30</td>
<td>Declares variables used to set the pulse and measurement timing, and sets the value.</td>
</tr>
</tbody>
</table>
Programming Examples
Multi Channel Pulsed Sweep Measurements

```vbnet
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
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 to 45</td>
<td>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.</td>
</tr>
<tr>
<td>47 to 53</td>
<td>Sets the pulsed sweep source, sets the pulsed bias source, applies voltage to device, resets time stamp, and performs measurement.</td>
</tr>
<tr>
<td>54 to 57</td>
<td>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.</td>
</tr>
<tr>
<td>59</td>
<td>Stores the returned data into the mret string variable.</td>
</tr>
</tbody>
</table>
Programming Examples
Multi Channel Pulsed Sweep Measurements

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>61 to 70</td>
<td>Picks the measurement data out and stores it into the <code>data</code> array.</td>
</tr>
<tr>
<td>72 to 74</td>
<td>Applies 0 V from all channels and transfers the data stored in the <code>data</code> variable to the <code>save_data</code> subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the <code>fname</code> variable and displays the data on a message box.</td>
</tr>
<tr>
<td>76 to 82</td>
<td>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.</td>
</tr>
</tbody>
</table>

### Measurement Result Example

<table>
<thead>
<tr>
<th>Vb (V), Ib (mA), Tb (sec), Stat_b, Ic (mA), Tc (sec), Stat_c</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1, 0, 0.05717, NDI, -0.005, 0.05717, NCI</td>
</tr>
<tr>
<td>0.18, 0, 0.06927, NDI, -0.005, 0.06927, NCI</td>
</tr>
<tr>
<td>0.26, 0, 0.08134, NDI, -0.005, 0.08134, NCI</td>
</tr>
<tr>
<td>0.34, 0, 0.09343, NDI, -0.005, 0.09343, NCI</td>
</tr>
<tr>
<td>0.42, 0, 0.10551, NDI, -0.005, 0.10551, NCI</td>
</tr>
<tr>
<td>0.5, 0, 0.11759, NDI, 0.005, 0.11759, NCI</td>
</tr>
<tr>
<td>0.58, 0, 0.12966, NDI, 0.215, 0.12966, NCI</td>
</tr>
<tr>
<td>0.66, 0.045, 0.14173, NDI, 3.815, 0.14173, NCI</td>
</tr>
<tr>
<td>0.74, 0.385, 0.15382, NDI, 22.63, 0.15382, NCI</td>
</tr>
<tr>
<td>0.82, 2.225, 0.1659, NDI, 51.03, 0.1659, NCI</td>
</tr>
<tr>
<td>0.9, 7.86, 0.17795, NDI, 87.535, 0.17795, NCI</td>
</tr>
</tbody>
</table>

Data save completed.
Do you want to perform measurement again?
# Sampling Measurements

To make sampling measurements, use the following commands.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets filter ON/OFF</td>
<td>[FL]</td>
<td>mode[,chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets series resistor ON/OFF</td>
<td>[SSR]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Sets integration time (Keysight B1500 can use AAD/AIT instead of AV.)</td>
<td>[AV] number[,mode]</td>
<td>[AAD] chnum[,type]</td>
</tr>
<tr>
<td>Sets sampling mode</td>
<td>[ML]</td>
<td>mode</td>
</tr>
<tr>
<td>Sets timing parameters</td>
<td>MT</td>
<td>h_bias,interval,points[,h_base]</td>
</tr>
<tr>
<td>Sets constant voltage source</td>
<td>MV</td>
<td>chnum,range,base,bias[,comp]</td>
</tr>
<tr>
<td>Sets constant current source</td>
<td>MI</td>
<td></td>
</tr>
<tr>
<td>Sets pulse voltage source</td>
<td>MSP</td>
<td>chnum[,post[,base]]</td>
</tr>
<tr>
<td>Clears sampling source setup</td>
<td>[MCC]</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets automatic abort function</td>
<td>[MSC]</td>
<td>abort[,post]</td>
</tr>
<tr>
<td>Forces constant voltage</td>
<td>[DV, TDV]</td>
<td>chnum,range,output [,comp[,polarity[,crange]]]</td>
</tr>
<tr>
<td>Forces constant current</td>
<td>[DI, TDI]</td>
<td></td>
</tr>
<tr>
<td>Sets voltage measurement range</td>
<td>[RV]</td>
<td>chnum,range</td>
</tr>
<tr>
<td>Sets current measurement range</td>
<td>[RI]</td>
<td>chnum,range</td>
</tr>
<tr>
<td></td>
<td>[RM]</td>
<td>chnum,mode[,rate]</td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td>10,chnum[,chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets SMU measurement mode</td>
<td>[CMM]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>
Programming Examples
Sampling Measurements

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**

```vbscript
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:\Keysight\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
    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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 23</td>
<td>Declares variables used to set the source output, and sets the value.</td>
</tr>
<tr>
<td>24 to 31</td>
<td>Declares variables used to read the measurement data.</td>
</tr>
<tr>
<td>33</td>
<td>Sets the data output format. The source output data will be also returned.</td>
</tr>
<tr>
<td>34</td>
<td>Sets the SMU filter on.</td>
</tr>
</tbody>
</table>
Session.WriteString("AAD " & t(1) & ", 1" & vbCrLf)  'sets HR ADC for t(1)       '36
session.WriteString("AAD " & t(2) & ", 1" & vbCrLf)  'sets HR ADC for t(2)
session.WriteString("AIT 1,1,2" & vbCrLf)  'number of averaging samples for 1 data
session.WriteString("AZ 0" & vbCrLf)  'sets auto zero off                   '39
session.WriteString("MT " & bias_h & "," & interval & "," & nop1 & "," & base_h & vbCrLf)
session.WriteString("MV " & t(1) & ",0," & base & "," & bias & "," & icomp & vbCrLf)
session.WriteString("MV " & t(2) & ",0," & base & "," & bias & "," & icomp & vbCrLf)
session.WriteString("MM 10," & mch(0) & "," & mch(1) & vbCrLf)
session.WriteString("RI " & mch(0) & "," & range(0) & vbCrLf)
session.WriteString("RI " & mch(1) & "," & range(1) & vbCrLf)
session.WriteString("ERR? 1" & vbCrLf) : err = session.ReadString(4 + 2)
If err <> 0 Then session.WriteString("DZ" & vbCrLf) : GoTo Check_err             '47
session.WriteString("DV " & t(0) & ",0," & vlout & "," & ilcomp & ",0" & vbCrLf)
session.WriteString("DV " & t(3) & ",0," & vlout & "," & ilcomp & ",0" & vbCrLf)
session.WriteString("TSR" & vbCrLf)
session.WriteString("XE" & vbCrLf)

session.WriteString("*OPC?" & vbCrLf) : rep = session.ReadString(1 + 2)          '53
session.WriteString("ERR? 1" & vbCrLf) : err = session.ReadString(4 + 2)
If err <> 0 Then session.WriteString("DZ" & vbCrLf) : GoTo Check_err
session.WriteString("NUB?" & vbCrLf) : rep = session.ReadString(3 + 2)
If rep <> nop1 * 3 Then session.WriteString("DZ") : GoTo Check_nop

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>36 to 38</td>
<td>Sets the A/D converter.</td>
</tr>
<tr>
<td>39</td>
<td>Sets the SMU auto zero function off.</td>
</tr>
<tr>
<td>40 to 42</td>
<td>Sets the sampling timing parameters and the constant voltage sources.</td>
</tr>
<tr>
<td>43 to 47</td>
<td>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.</td>
</tr>
<tr>
<td>48 to 51</td>
<td>Applies 0 V to the device low terminal, resets the time stamp, and performs the sampling measurement.</td>
</tr>
<tr>
<td>53 to 57</td>
<td>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.</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>59 to 69</td>
<td>Reads the returned data and stores it into the mret string variable. Finally, stores the measured data into the data array.</td>
</tr>
<tr>
<td>71 to 73</td>
<td>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.</td>
</tr>
<tr>
<td>74 to 78</td>
<td>Displays a message box to show an error message if the error is detected.</td>
</tr>
<tr>
<td>80 to 81</td>
<td>Displays a message box to show an error message if the number of returned data is not correct (nop1).</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets filter ON/OFF</td>
<td>[FL]</td>
<td>mode[,chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets QSCV operation mode</td>
<td>[QSC]</td>
<td>mode</td>
</tr>
<tr>
<td>Sets offset cancel ON/OFF or performs capacitance offset measurement</td>
<td>[QSZ]</td>
<td>mode</td>
</tr>
<tr>
<td>Sets voltage sweep source</td>
<td>QSV</td>
<td>chnum,mode,vrange,start,stop ,cvoltage,step[,Icomp]</td>
</tr>
<tr>
<td>Sets time parameters</td>
<td>QST</td>
<td>cinteg,linteg,hold,delay1[,delay2]</td>
</tr>
<tr>
<td>Sets leak current data output and compensation ON/OFF</td>
<td>[QSL]</td>
<td>data,compen</td>
</tr>
<tr>
<td>Sets measurement range</td>
<td>[QSR]</td>
<td>range</td>
</tr>
<tr>
<td>Sets QSCV smart operation</td>
<td>[QSO]</td>
<td>mode[,chnum[,Vcomp]]</td>
</tr>
<tr>
<td>Sets automatic abort function</td>
<td>[QSM]</td>
<td>abort[,post]</td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td>13[,chnum]</td>
</tr>
<tr>
<td>Forces constant voltage</td>
<td>[DV, TDV]</td>
<td>chnum,range,output [,comp[,polarity,[crange]]]</td>
</tr>
<tr>
<td>Forces constant current</td>
<td>[DI, TDI]</td>
<td></td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 10</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>12 to 25</td>
<td>Declares variables used to set the source output, and sets the value.</td>
</tr>
<tr>
<td>26 to 34</td>
<td>Declares variables used to read the measurement data.</td>
</tr>
</tbody>
</table>
Progret:amming Examples
Quasi-static CV Measurements

```
session.Timeout = 60000 'timeout = 60 seconds
'
session.WriteString("FMT 1,1" & vbLf)
session.WriteString("TSC 1" & vbLf) 'enables time stamp output
'
session.WriteString("MM 13," & t(1) & vbLf) 'QSCV measurement
'session.WriteString("QSC 0" & vbLf)
session.WriteString("QSL 1,1" & vbLf) 'Normal QSCV operation
'session.WriteString("QSM 2,1" & vbLf)
'session.WriteString("QSR " & range & vbLf)
'session.WriteString("QST " & cinteg & "," & linteg & "," & hold & "," & delay1 & "," & delay2 & vbLf)
'session.WriteString("QSV " & t(1) & "," & swp & "," & vgl & "," & vlg2 & "," & 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)
'
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.", vbCrLf, ")
    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))
    MsgBox("Offset data = " & md1(0) * 1000000000000.0 & "pF" & Chr(10))
    session.WriteString("QSZ 1" & vbLf)
End If
'
<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>38 to 39</td>
<td>Sets the data output format and the time stamp data output mode.</td>
</tr>
<tr>
<td>41 to 49</td>
<td>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.</td>
</tr>
<tr>
<td>51</td>
<td>Sets the capacitance offset cancel to OFF.</td>
</tr>
<tr>
<td>53 to 67</td>
<td>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.</td>
</tr>
</tbody>
</table>
**Programming Examples**

**Quasi-static CV Measurements**

```vbnet
MsgBox("Connect DUT. Then click OK.", vbOKOnly, ")
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)
session.WriteString("ERR? 1" & vbLf) : err = session.ReadString(4 + 2)
If err <> 0 Then session.WriteString("DZ" & vbLf) : GoTo Check_err
session.WriteString("NUM?" & 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
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 + 16 * 3 + 4, 12))
    md1(i) = Val(Mid(mret, i * 16 * 4 + 16 * 4 + 1, 12))
    md2(i) = Val(Mid(mret, i * 16 * 4 + 16 * 5 + 4, 12))
    sc(i) = Val(Mid(mret, i * 16 * 4 + 16 * 6 + 1, 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
```

```vbnet
session.WriteString("DZ" & vbLf)
save_data(fname, title, value, data, nop1, nop2, session, t)
Exit Sub
```

**Check_err:**

```vbnet
session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, ")
Exit Sub
```

**Check_nop:**

```vbnet
MsgBox("No. of data: " & rep & " (not " & nop1 * 4 & ")", vbOKOnly, ")
End Sub
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>69 to 75</td>
<td>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.</td>
</tr>
<tr>
<td>77 to 81</td>
<td>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.</td>
</tr>
<tr>
<td>83 to 93</td>
<td>Stores the returned data into the <code>mret</code> string variable. Finally, stores the measured data into the <code>data</code> array.</td>
</tr>
<tr>
<td>95 to 105</td>
<td>Applies 0 V from all channels. And transfers the data stored in the <code>data</code> variable to the <code>save_data</code> subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the <code>fname</code> variable and displays the data on a message box.</td>
</tr>
</tbody>
</table>
**Measurement Result Example**

<table>
<thead>
<tr>
<th>Vg (V)</th>
<th>Cgb (pF)</th>
<th>C-status</th>
<th>Ileak (pA)</th>
<th>I-status</th>
<th>Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2</td>
<td>3.1277</td>
<td>NCC</td>
<td>0.298</td>
<td>NCI</td>
<td>5.41159</td>
</tr>
<tr>
<td>2.6</td>
<td>3.1034</td>
<td>NCC</td>
<td>0.241</td>
<td>NCI</td>
<td>5.71947</td>
</tr>
<tr>
<td>2.4</td>
<td>3.1334</td>
<td>NCC</td>
<td>0.278</td>
<td>NCI</td>
<td>6.02741</td>
</tr>
<tr>
<td>2.2</td>
<td>3.1314</td>
<td>NCC</td>
<td>0.255</td>
<td>NCI</td>
<td>6.33532</td>
</tr>
<tr>
<td>2.1</td>
<td>3.116</td>
<td>NCC</td>
<td>0.232</td>
<td>NCI</td>
<td>6.64316</td>
</tr>
<tr>
<td>1.8</td>
<td>3.1193</td>
<td>NCC</td>
<td>0.215</td>
<td>NCI</td>
<td>6.95102</td>
</tr>
<tr>
<td>1.6</td>
<td>3.1218</td>
<td>NCC</td>
<td>0.222</td>
<td>NCI</td>
<td>7.25891</td>
</tr>
<tr>
<td>1.4</td>
<td>3.106</td>
<td>NCC</td>
<td>0.18</td>
<td>NCI</td>
<td>7.56681</td>
</tr>
<tr>
<td>1.2</td>
<td>3.1303</td>
<td>NCC</td>
<td>0.171</td>
<td>NCI</td>
<td>7.87471</td>
</tr>
<tr>
<td>1.0</td>
<td>3.1317</td>
<td>NCC</td>
<td>0.184</td>
<td>NCI</td>
<td>8.18262</td>
</tr>
<tr>
<td>0.8</td>
<td>3.1096</td>
<td>NCC</td>
<td>0.168</td>
<td>NCI</td>
<td>8.49048</td>
</tr>
<tr>
<td>0.6</td>
<td>3.1235</td>
<td>NCC</td>
<td>0.185</td>
<td>NCI</td>
<td>8.79832</td>
</tr>
<tr>
<td>0.4</td>
<td>3.085</td>
<td>NCC</td>
<td>0.148</td>
<td>NCI</td>
<td>9.10628</td>
</tr>
<tr>
<td>0.2</td>
<td>3.1028</td>
<td>NCC</td>
<td>0.164</td>
<td>NCI</td>
<td>9.41414</td>
</tr>
<tr>
<td>0.0</td>
<td>3.1023</td>
<td>NCC</td>
<td>0.149</td>
<td>NCI</td>
<td>9.72198</td>
</tr>
<tr>
<td>-0.2</td>
<td>3.0651</td>
<td>NCC</td>
<td>0.117</td>
<td>NCI</td>
<td>10.0301</td>
</tr>
<tr>
<td>-0.4</td>
<td>3.0723</td>
<td>NCC</td>
<td>0.141</td>
<td>NCI</td>
<td>10.338</td>
</tr>
<tr>
<td>-0.6</td>
<td>3.0654</td>
<td>NCC</td>
<td>0.115</td>
<td>NCI</td>
<td>10.6459</td>
</tr>
<tr>
<td>-0.8</td>
<td>3.0375</td>
<td>NCC</td>
<td>0.141</td>
<td>NCI</td>
<td>10.9538</td>
</tr>
<tr>
<td>-1.2</td>
<td>2.9459</td>
<td>NCC</td>
<td>0.115</td>
<td>NCI</td>
<td>11.5696</td>
</tr>
<tr>
<td>-1.4</td>
<td>2.8877</td>
<td>NCC</td>
<td>0.079</td>
<td>NCI</td>
<td>11.8775</td>
</tr>
<tr>
<td>-1.6</td>
<td>2.7965</td>
<td>NCC</td>
<td>0.036</td>
<td>NCI</td>
<td>12.1854</td>
</tr>
<tr>
<td>-1.8</td>
<td>2.7727</td>
<td>NCC</td>
<td>0.056</td>
<td>NCI</td>
<td>12.4933</td>
</tr>
<tr>
<td>-2.2</td>
<td>2.7219</td>
<td>NCC</td>
<td>0.061</td>
<td>NCI</td>
<td>12.8011</td>
</tr>
<tr>
<td>-2.4</td>
<td>2.6781</td>
<td>NCC</td>
<td>0.044</td>
<td>NCI</td>
<td>13.109</td>
</tr>
<tr>
<td>-2.6</td>
<td>2.6496</td>
<td>NCC</td>
<td>0.032</td>
<td>NCI</td>
<td>13.4169</td>
</tr>
<tr>
<td>-2.8</td>
<td>2.6694</td>
<td>NCC</td>
<td>0.076</td>
<td>NCI</td>
<td>13.7248</td>
</tr>
<tr>
<td>-3.2</td>
<td>2.6174</td>
<td>NCC</td>
<td>0.053</td>
<td>NCI</td>
<td>14.0327</td>
</tr>
<tr>
<td>-3.4</td>
<td>2.5789</td>
<td>NCC</td>
<td>0.041</td>
<td>NCI</td>
<td>14.3406</td>
</tr>
<tr>
<td>-3.6</td>
<td>2.5974</td>
<td>NCC</td>
<td>0.046</td>
<td>NCI</td>
<td>14.6484</td>
</tr>
<tr>
<td>-3.8</td>
<td>2.6325</td>
<td>NCC</td>
<td>0.042</td>
<td>NCI</td>
<td>14.9564</td>
</tr>
<tr>
<td>-4.0</td>
<td>2.6338</td>
<td>NCC</td>
<td>0.002</td>
<td>NCI</td>
<td>15.2643</td>
</tr>
<tr>
<td>-4.2</td>
<td>2.706</td>
<td>NCC</td>
<td>0.031</td>
<td>NCI</td>
<td>15.5722</td>
</tr>
<tr>
<td>-4.4</td>
<td>2.7984</td>
<td>NCC</td>
<td>0.069</td>
<td>NCI</td>
<td>15.8801</td>
</tr>
<tr>
<td>-4.6</td>
<td>2.8384</td>
<td>NCC</td>
<td>0.036</td>
<td>NCI</td>
<td>16.188</td>
</tr>
<tr>
<td>-4.8</td>
<td>2.8908</td>
<td>NCC</td>
<td>0.044</td>
<td>NCI</td>
<td>16.4959</td>
</tr>
<tr>
<td>-5.0</td>
<td>2.9477</td>
<td>NCC</td>
<td>0.043</td>
<td>NCI</td>
<td>16.8038</td>
</tr>
<tr>
<td>-5.2</td>
<td>2.9606</td>
<td>NCC</td>
<td>0.034</td>
<td>NCI</td>
<td>17.1117</td>
</tr>
<tr>
<td>-5.4</td>
<td>2.9836</td>
<td>NCC</td>
<td>0.012</td>
<td>NCI</td>
<td>17.2396</td>
</tr>
<tr>
<td>-5.6</td>
<td>3.0091</td>
<td>NCC</td>
<td>0.017</td>
<td>NCI</td>
<td>17.7275</td>
</tr>
<tr>
<td>-5.8</td>
<td>3.0256</td>
<td>NCC</td>
<td>0.039</td>
<td>NCI</td>
<td>18.0353</td>
</tr>
<tr>
<td>-6.0</td>
<td>3.0433</td>
<td>NCC</td>
<td>0.035</td>
<td>NCI</td>
<td>18.3433</td>
</tr>
<tr>
<td>-6.2</td>
<td>3.0888</td>
<td>NCC</td>
<td>0.068</td>
<td>NCI</td>
<td>18.6512</td>
</tr>
<tr>
<td>-6.4</td>
<td>3.08</td>
<td>NCC</td>
<td>0.056</td>
<td>NCI</td>
<td>18.9591</td>
</tr>
<tr>
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<td>3.0803</td>
<td>NCC</td>
<td>0.041</td>
<td>NCI</td>
<td>19.267</td>
</tr>
<tr>
<td>-6.8</td>
<td>3.0658</td>
<td>NCC</td>
<td>0.024</td>
<td>NCI</td>
<td>19.5749</td>
</tr>
<tr>
<td>-7.0</td>
<td>3.0757</td>
<td>NCC</td>
<td>0.014</td>
<td>NCI</td>
<td>19.8828</td>
</tr>
<tr>
<td>-7.2</td>
<td>3.0961</td>
<td>NCC</td>
<td>0.028</td>
<td>NCI</td>
<td>20.1907</td>
</tr>
<tr>
<td>-7.4</td>
<td>3.0894</td>
<td>NCC</td>
<td>0.009</td>
<td>NCI</td>
<td>20.4986</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets SMU filter ON/OFF</td>
<td>[FL]</td>
<td>mode[,chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets SMU series resistor ON/OFF</td>
<td>[SSR]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Disables SCUU status indicator</td>
<td>[SSL]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Controls SCUU input-output path</td>
<td>[SSP]</td>
<td>chnum,path</td>
</tr>
<tr>
<td>Sets MFCMU A/D converter</td>
<td>[ACT]</td>
<td>mode[,N]</td>
</tr>
<tr>
<td>Sets MFCMU measurement mode</td>
<td>[IMP]</td>
<td>mode</td>
</tr>
<tr>
<td>Sets AC/DC voltage monitor ON/OFF</td>
<td>[LMN]</td>
<td>mode</td>
</tr>
<tr>
<td>Sets MFCMU output frequency</td>
<td>FC</td>
<td>chnum,freq</td>
</tr>
<tr>
<td>Forces AC voltage by using MFCMU</td>
<td>ACV</td>
<td>chnum,ac_level</td>
</tr>
<tr>
<td>Forces DC voltage by using MFCMU</td>
<td>DCV</td>
<td>chnum,voltage</td>
</tr>
<tr>
<td>Forces DC voltage by using SMU</td>
<td>[DV, TDV]</td>
<td>chnum,range,output [,comp[,polarity[,range]]]</td>
</tr>
<tr>
<td>Forces DC current by using SMU</td>
<td>[DI, TDI]</td>
<td></td>
</tr>
<tr>
<td>Performs capacitance measurement</td>
<td>TC</td>
<td>chnum,mode[,range]</td>
</tr>
<tr>
<td></td>
<td>TTC</td>
<td>chnum,mode[,range]</td>
</tr>
<tr>
<td>Resets the time stamp</td>
<td>TSR</td>
<td></td>
</tr>
<tr>
<td>Returns the time stamp at this time</td>
<td>TSQ</td>
<td></td>
</tr>
</tbody>
</table>

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 3-72.

### Table 3-18 High-Speed Spot C Measurement Example

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 23</td>
<td>Declares variables and sets the value.</td>
</tr>
<tr>
<td>25 to 27</td>
<td>Sets timeout and data output format. And enables time stamp output.</td>
</tr>
<tr>
<td>28 to 29</td>
<td>Applies 0 V to the drain and source terminals.</td>
</tr>
<tr>
<td>30 to 31</td>
<td>Makes the SCUU connection path, and sets the A/D converter of the MFCMU.</td>
</tr>
</tbody>
</table>
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
End If

MsgBox("Connect DUT. Then click OK.", vbOKOnly, ")                           ’59

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>33 to 41</td>
<td>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.</td>
</tr>
<tr>
<td>43 to 44</td>
<td>Sets the frequency and the oscillator level of the MFCMU output signal.</td>
</tr>
<tr>
<td>46 to 57</td>
<td>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.</td>
</tr>
<tr>
<td>59</td>
<td>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.</td>
</tr>
</tbody>
</table>
Programming Examples
High-Speed Spot C Measurements

```vbnet
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:
session.WriteString("EMG? " & err & vbLf) : msg = session.ReadString(256)
MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, ")
End Sub
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 to 67</td>
<td>Sets the measurement condition, resets the time stamp, and performs the high-speed spot C measurement.</td>
</tr>
<tr>
<td>69 to 83</td>
<td>Stores the returned data into the mret and tret string variables. Finally, stores the measured data into the data array.</td>
</tr>
<tr>
<td>85 to 87</td>
<td>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.</td>
</tr>
<tr>
<td>89 to 91</td>
<td>Displays a message box to show an error message if the error is detected.</td>
</tr>
</tbody>
</table>
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**

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sets the phase compensation mode, auto or manual</td>
<td>ADJ</td>
<td>slot, mode</td>
</tr>
<tr>
<td>Performs phase compensation data measurement</td>
<td>ADJ?</td>
<td>slot</td>
</tr>
<tr>
<td>Clears the frequency list for data correction</td>
<td>CLCORR</td>
<td>slot, mode</td>
</tr>
<tr>
<td>Adds the specified frequency to the frequency list</td>
<td>CORRL</td>
<td>slot, freq</td>
</tr>
<tr>
<td>Returns the frequency defined in the frequency list</td>
<td>CORRL?</td>
<td>slot[index]</td>
</tr>
<tr>
<td>Sets the reference value of open/short/load standard</td>
<td>DCORR</td>
<td>slot, corr, mode, primary, secondary</td>
</tr>
<tr>
<td>Returns the reference value of the specified standard</td>
<td>DCORR?</td>
<td>slot, corr</td>
</tr>
<tr>
<td>Performs the specified correction (open, short, or load) data measurement</td>
<td>CORR?</td>
<td>slot, corr</td>
</tr>
<tr>
<td>Sets the specified correction ON or OFF</td>
<td>CORRST</td>
<td>slot, corr, state</td>
</tr>
<tr>
<td>Returns the status ON or OFF of the specified correction</td>
<td>CORRST?</td>
<td>slot, corr</td>
</tr>
</tbody>
</table>
**Data Correction**

Table 3-19 lists the Keysight 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.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td><code>[chnum ... [,chnum] ... ]</code></td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td><code>[chnum ... [,chnum] ... ]</code></td>
</tr>
<tr>
<td>Sets SMU filter ON/OFF</td>
<td>[FL]</td>
<td><code>mode[,chnum ... [,chnum] ... ]</code></td>
</tr>
<tr>
<td>Sets SMU series resistor ON/OFF</td>
<td>[SSR]</td>
<td><code>chnum,mode</code></td>
</tr>
<tr>
<td>Disables SCUU status indicator</td>
<td>[SSL]</td>
<td><code>chnum,mode</code></td>
</tr>
<tr>
<td>Controls SCUU input-output path</td>
<td>[SSP]</td>
<td><code>chnum,path</code></td>
</tr>
<tr>
<td>Sets MFCMU A/D converter</td>
<td>[ACT]</td>
<td><code>mode[,] N</code></td>
</tr>
<tr>
<td>Sets MFCMU measurement mode</td>
<td>[IMP]</td>
<td><code>mode</code></td>
</tr>
<tr>
<td>Sets AC/DC voltage monitor ON/OFF</td>
<td>[LMN]</td>
<td><code>mode</code></td>
</tr>
<tr>
<td>Sets MFCMU output frequency</td>
<td>FC</td>
<td><code>chnum,freq</code></td>
</tr>
<tr>
<td>Forces AC voltage by using MFCMU</td>
<td>ACV</td>
<td><code>chnum,ac_level</code></td>
</tr>
<tr>
<td>Forces DC voltage by using MFCMU</td>
<td>DCV</td>
<td><code>chnum,voltage</code></td>
</tr>
<tr>
<td>Forces DC voltage by using SMU</td>
<td>[DV, TDV]</td>
<td><code>chnum,range,output</code> [,,comp[,polarity[,range]]]</td>
</tr>
<tr>
<td>Forces DC current by using SMU</td>
<td>[DI, TDI]</td>
<td></td>
</tr>
<tr>
<td>Sets MFCMU measurement range</td>
<td>[RC]</td>
<td><code>chnum,mode[,range]</code></td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td><code>17,chnum</code></td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>

**Measurement Result Example**

\[
\begin{align*}
C_p \ (\text{pF}), & \quad C_{st} \ (\text{uS}), \quad G \ (\text{uS}), \quad G_{st} \ (\text{mV}), \quad Osc_{st} \ (\text{V}), \quad \text{DC} \ (\text{V}), \quad Dc_{st}, \quad \text{Time} \ (\text{s}) \\
4.96981, & \quad \text{NJC}, \quad 26.1577, \quad \text{NJY}, \quad 28.7737, \quad \text{NJV}, \quad 4.72556, \quad \text{NJV}, \quad 0.0259
\end{align*}
\]

Data save completed.
Do you want to perform measurement again?
Programming Examples
Spot C Measurements

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 3-72.

Table 3-20 Spot C Measurement Example

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 24</td>
<td>Declares variables and sets the value.</td>
</tr>
<tr>
<td>25 to 27</td>
<td>Sets timeout and data output format. And enables the time stamp output.</td>
</tr>
<tr>
<td>28 to 29</td>
<td>Applies 0 V to the drain and source terminals.</td>
</tr>
<tr>
<td>30 to 31</td>
<td>Makes the SCUU connection path, and sets the A/D converter of the MFCMU.</td>
</tr>
</tbody>
</table>
Dim rbx As Integer
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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>33 to 41</td>
<td>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.</td>
</tr>
<tr>
<td>43 to 44</td>
<td>Sets the frequency and the oscillator level of the MFCMU output signal.</td>
</tr>
<tr>
<td>46 to 57</td>
<td>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.</td>
</tr>
<tr>
<td>59</td>
<td>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.</td>
</tr>
</tbody>
</table>
### Spot C Measurements

#### Programming Examples

```vba
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
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 to 67</td>
<td>Sets the measurement condition, resets the time stamp, and performs the measurement.</td>
</tr>
<tr>
<td>69 to 71</td>
<td>Waits until the measurement is completed. If an error is detected, applies 0 V and goes to Check_err.</td>
</tr>
<tr>
<td>73 to 84</td>
<td>Stores the returned data into the mret string variable. Finally, stores the measured data into the data array.</td>
</tr>
<tr>
<td>86 to 88</td>
<td>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.</td>
</tr>
<tr>
<td>90 to 92</td>
<td>Displays a message box to show an error message if the error is detected.</td>
</tr>
</tbody>
</table>
CV (DC Bias) Sweep Measurements

To perform capacitance-voltage (DC bias) sweep measurements, use the following commands.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>[chnum ... ,[chnum] ... ]</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>[chnum ... ,[chnum] ... ]</td>
</tr>
<tr>
<td>Sets SMU filter ON/OFF</td>
<td>[FL]</td>
<td>mode[,chnum ... ,[chnum] ... ]</td>
</tr>
<tr>
<td>Sets SMU series resistor ON/OFF</td>
<td>[SSR]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Disables SCUU status indicator</td>
<td>[SSL]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Controls SCUU input-output path</td>
<td>[SSP]</td>
<td>chnum,path</td>
</tr>
<tr>
<td>Sets MFCMU A/D converter</td>
<td>[ACT]</td>
<td>mode[,N]</td>
</tr>
<tr>
<td>Sets MFCMU measurement mode</td>
<td>[IMP]</td>
<td>mode</td>
</tr>
<tr>
<td>Sets AC/DC voltage monitor ON/OFF</td>
<td>[LMN]</td>
<td>mode</td>
</tr>
<tr>
<td>Sets MFCMU output frequency</td>
<td>FC</td>
<td>chnum,freq</td>
</tr>
<tr>
<td>Forces AC voltage by using MFCMU</td>
<td>ACV</td>
<td>chnum,level</td>
</tr>
<tr>
<td>Sets CV sweep timing parameter</td>
<td>WTDCV</td>
<td>hold,delay [,sdelay[,tdelay[,mdelay]]]</td>
</tr>
<tr>
<td>Sets auto abort function</td>
<td>[WMDCV]</td>
<td>abort[,post]</td>
</tr>
<tr>
<td>Sets DC bias sweep source</td>
<td>WDCV</td>
<td>chnum,mode,start,stop,step</td>
</tr>
<tr>
<td>Forces constant voltage</td>
<td>[DV, TDV]</td>
<td>chnum,range,output [,comp[,polarity[,crange]]]</td>
</tr>
<tr>
<td>Forces constant current</td>
<td>[DI, TDI]</td>
<td></td>
</tr>
<tr>
<td>Sets MFCMU measurement range</td>
<td>[RC]</td>
<td>chnum,mode[,range]</td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td>18,chnum</td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>
Programming Examples
CV (DC Bias) Sweep Measurements

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 3-72.

Table 3-21 CV (DC bias) Sweep Measurement Example

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 29</td>
<td>Declares variables and sets the value.</td>
</tr>
<tr>
<td>31 to 33</td>
<td>Sets timeout and data output format. And enables the time stamp output.</td>
</tr>
<tr>
<td>34 to 35</td>
<td>Applies 0 V to the drain and source terminals.</td>
</tr>
</tbody>
</table>
### Programming Examples

#### CV (DC Bias) Sweep Measurements

```vbnet
session.WriteString("SSP " & t(1) & ", 4" & vbLf) 'CMU to SCUU output
session.WriteString("ACT 2, 4" & vbLf) 'CMU integration, 4 PLC

Dim rbx As Integer
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)
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
End If

MsgBox("Connect DUT. Then click OK.", vbOKOnly, ")
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>37 to 38</td>
<td>Makes the SCUU connection path, and sets the A/D converter of the MFCMU.</td>
</tr>
<tr>
<td>40 to 48</td>
<td>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.</td>
</tr>
<tr>
<td>50 to 51</td>
<td>Sets the frequency and the oscillator level of the MFCMU output signal.</td>
</tr>
<tr>
<td>53 to 64</td>
<td>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.</td>
</tr>
<tr>
<td>66</td>
<td>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.</td>
</tr>
</tbody>
</table>
Programming Examples
CV (DC Bias) Sweep Measurements

```vbnet
session.WriteString("WMDCV 2, 1" & vbCrLf) '68
session.WriteString("WTDCV " & hold & "," & delay & "," & s_delay & vbCrLf)
session.WriteString("WDCV " & t(1) & ",1," & vg1 & "," & vg2 & "," & nop1 & vbCrLf)
session.WriteString("MM 18," & t(1) & vbCrLf)
session.WriteString("IMP 100" & vbCrLf)
session.WriteString("LMN 1" & vbCrLf)
session.WriteString("RC " & t(1) & "," & range & vbCrLf)
session.WriteString("ERR? 1" & vbCrLf) : err = session.ReadString(4 + 2)
If err <> 0 Then session.WriteString("DZ" & vbCrLf) : GoTo Check_err
session.WriteString("TSR" & vbCrLf)
session.WriteString("*OPC?" & vbCrLf) : rep = session.ReadString(1 + 2) '79
session.WriteString("ERR? 1" & vbCrLf) : err = session.ReadString(4 + 2)
If err <> 0 Then session.WriteString("DZ" & vbCrLf) : GoTo Check_err
session.WriteString("NUB?" & vbCrLf) : rep = session.ReadString(3 + 2)
If rep <> nop1 * 6 Then session.WriteString("DZ" & vbCrLf) : 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) & vbCrLf
    data(j, i) = data(j, i) & "," & md(i * 2 + 1) * 1000000000000.0 & "," & st(i * 2 + 1) & vbCrLf
    data(j, i) = data(j, i) & "," & mon(i * 2) * 1000 & "," & st_mon(i * 2) & vbCrLf
    data(j, i) = data(j, i) & "," & mon(i * 2 + 1) & "," & st_mon(i * 2 + 1) & "," & tm(i) & vbCrLf
Next i '101
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>68 to 78</td>
<td>Sets the measurement condition, resets the time stamp, and performs the measurement.</td>
</tr>
<tr>
<td>68</td>
<td>Sets the automatic abort function to ON, and sets the post measurement output value to vg1.</td>
</tr>
<tr>
<td>69</td>
<td>Sets the MFCMU sweep output timing.</td>
</tr>
<tr>
<td>70</td>
<td>Sets the MFCMU DC bias sweep output.</td>
</tr>
<tr>
<td>79 to 83</td>
<td>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.</td>
</tr>
<tr>
<td>85 to 101</td>
<td>Stores the returned data into the mret string variable. Finally, stores the measured data into the data array.</td>
</tr>
</tbody>
</table>
### Programming Examples

**CV (DC Bias) Sweep Measurements**

**Measurement Result Example**

<table>
<thead>
<tr>
<th>Vg (V), Cp (pF), C_st, G (uS), G_st, OSC (mV), Osc_st, DC (V), Dc_st, Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5, 4.96677, NJC, 26.155, NJY, 28.7732, NJV, -4.72468, NJV, 0.0547</td>
</tr>
<tr>
<td>-4.5, 4.66524, NJC, 26.3993, NJY, 28.6384, NJV, -4.2384, NJV, 0.0884</td>
</tr>
<tr>
<td>-4, 4.2986, NJC, 26.2738, NJY, 28.4891, NJV, -3.75442, NJV, 0.1228</td>
</tr>
<tr>
<td>-3.5, 3.88182, NJC, 25.5785, NJY, 28.3222, NJV, -3.27358, NJV, 0.1535</td>
</tr>
<tr>
<td>-3, 3.43272, NJC, 24.1992, NJY, 28.1426, NJV, -2.79417, NJV, 0.1878</td>
</tr>
<tr>
<td>-2.5, 2.99286, NJC, 21.9946, NJY, 27.9503, NJV, -2.31792, NJV, 0.2294</td>
</tr>
<tr>
<td>-2, 2.57856, NJC, 18.7458, NJY, 27.7505, NJV, -1.84498, NJV, 0.2709</td>
</tr>
<tr>
<td>-1.5, 2.20793, NJC, 14.2867, NJY, 27.5502, NJV, -1.37609, NJV, 0.3125</td>
</tr>
<tr>
<td>-1, 1.92563, NJC, 7.57546, NJY, 27.3772, NJV, -0.91155, NJV, 0.3541</td>
</tr>
<tr>
<td>-0.5, 1.79915, NJC, -1.83967, NJY, 27.494, NJV, -0.45241, NJV, 0.3957</td>
</tr>
<tr>
<td>0, 1.77613, NJC, -2.50329, NJY, 27.4588, NJV, 0.0041, NJV, 0.4375</td>
</tr>
<tr>
<td>0.5, 1.78246, NJC, -2.73976, NJY, 27.488, NJV, 0.46025, NJV, 0.4789</td>
</tr>
<tr>
<td>1, 1.7831, NJC, -2.66401, NJY, 27.6511, NJV, 0.92066, NJV, 0.5205</td>
</tr>
<tr>
<td>1.5, 1.78149, NJC, -2.52984, NJY, 27.8257, NJV, 1.38437, NJV, 0.5621</td>
</tr>
<tr>
<td>2, 1.77384, NJC, -2.39091, NJY, 27.9928, NJV, 1.85152, NJV, 0.6037</td>
</tr>
<tr>
<td>2.5, 1.77054, NJC, -2.22722, NJY, 28.1473, NJV, 2.32111, NJV, 0.6453</td>
</tr>
<tr>
<td>3, 1.76359, NJC, -2.03388, NJY, 28.283, NJV, 2.79339, NJV, 0.6867</td>
</tr>
<tr>
<td>3.5, 1.75959, NJC, -1.58516, NJY, 28.3958, NJV, 3.26736, NJV, 0.7281</td>
</tr>
<tr>
<td>4, 1.75883, NJC, -0.542666, NJY, 28.481, NJV, 3.74189, NJV, 0.7697</td>
</tr>
<tr>
<td>4.5, 1.73431, NJC, 1.73765, NJY, 28.5416, NJV, 4.2182, NJV, 0.8113</td>
</tr>
<tr>
<td>5, 1.60909, NJC, 6.23405, NJY, 28.5737, NJV, 4.69593, NJV, 0.8529</td>
</tr>
</tbody>
</table>

Data save completed.

Do you want to perform measurement again?

---

```vba
session.WriteString("DZ" & vbCrLf) '103
save_data(fname, title, value, data, nop1, nop2, session, t)
Exit Sub

Check_err:
session.WriteString("EMG? " & err & vbCrLf) : msg = session.ReadString(256)
MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, ")
Exit Sub

Check_nop:
MsgBox("No. of data: " & rep & " (not " & nop1 * 6 & ")", vbOKOnly, ")
End Sub
```
# Pulsed Spot C Measurements

To perform capacitance pulsed spot measurement, use the following commands.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets SMU filter ON/OFF</td>
<td>[FL]</td>
<td>mode[,chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets SMU series resistor ON/OFF</td>
<td>[SSR]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Disables SCUU status indicator</td>
<td>[SSL]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Controls SCUU input-output path</td>
<td>[SSP]</td>
<td>chnum,path</td>
</tr>
<tr>
<td>Sets MFCMU A/D converter</td>
<td>[ACT]</td>
<td>mode[,N]</td>
</tr>
<tr>
<td>Sets MFCMU measurement mode</td>
<td>[IMP]</td>
<td>mode</td>
</tr>
<tr>
<td>Sets MFCMU output frequency</td>
<td>FC</td>
<td>chnum,freq</td>
</tr>
<tr>
<td>Forces AC voltage by using MFCMU</td>
<td>ACV</td>
<td>chnum,ac_level</td>
</tr>
<tr>
<td>Sets pulse timing parameters</td>
<td>PTDCV</td>
<td>hold,width[,period [,tdelay]]</td>
</tr>
<tr>
<td>Sets pulse voltage</td>
<td>PDCV</td>
<td>chnum,base,pulse</td>
</tr>
<tr>
<td>Forces DC voltage by using SMU</td>
<td>[DV, TDV]</td>
<td>chnum,range,output [,comp[,polarity[,[range]]]]</td>
</tr>
<tr>
<td>Forces DC current by using SMU</td>
<td>[DI, TDI]</td>
<td></td>
</tr>
<tr>
<td>Sets MFCMU measurement range</td>
<td>[RC]</td>
<td>chnum,mode[,range]</td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td>19,chnum</td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>

### 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 3-72.

Table 3-22  Pulsed Spot C Measurement Example

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 21</td>
<td>Declares variables and sets the value.</td>
</tr>
<tr>
<td>23 to 25</td>
<td>Sets timeout and data output format. And enables the time stamp output.</td>
</tr>
<tr>
<td>26 to 27</td>
<td>Applies 0 V to the drain and source terminals.</td>
</tr>
<tr>
<td>28 to 29</td>
<td>Makes the SCUU connection path, and sets the A/D converter of the MFCMU.</td>
</tr>
</tbody>
</table>
Dim rbx As Integer
    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" & vbCrLf)
    session.WriteString("ADJ? " & t(1) & vbCrLf) : err = session.ReadString(1 + 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbCrLf) : err =
    session.ReadString(4 + 2) : session.WriteString("DZ" & vbCrLf) : GoTo Check_err
End If

    session.WriteString("FC " & t(1) & "," & freq & vbCrLf)
    session.WriteString("ACV " & t(1) & "," & osc_level & vbCrLf)

    rbx = MsgBox("Do you want to perform Open correction?", vbYesNo, ")
If rbx = vbYes Then
    session.WriteString("CLCORR " & t(1) & ",2" & vbCrLf)
    MsgBox("Open measurement terminal.  Then click OK.", vbOKOnly, ")
    Console.WriteLine("Wait a minute . . ." & Chr(10) & vbCrLf)
    session.WriteString("DCORR " & t(1) & ",1,100," & ref_cp & "," & ref_g & vbCrLf)
    session.WriteString("CORR? " & t(1) & ",1" & vbCrLf) : err = session.ReadString(1 + 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbCrLf) : err =
    session.ReadString(4 + 2) : session.WriteString("DZ" & vbCrLf) : GoTo Check_err
End If

    MsgBox("Connect DUT.  Then click OK.", vbOKOnly, ")" )

Dim g_pt As String = "0.5, 0.1, 0.2" 'hold, width, period in sec
Dim v0 As Double = 0                  '0 V: pulse base voltage
session.WriteString("PTDCV " & g_pt & vbCrLf)
Dim v0 As Double = 0                  '0 V: pulse base voltage
session.WriteString("PDCV " & t(1) & "," & v0 & "," & dc_bias & vbCrLf)

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 to 39</td>
<td>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.</td>
</tr>
<tr>
<td>41 to 42</td>
<td>Sets the frequency and the oscillator level of the MFCMU output signal.</td>
</tr>
<tr>
<td>44 to 55</td>
<td>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.</td>
</tr>
<tr>
<td>57</td>
<td>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.</td>
</tr>
<tr>
<td>59 to 62</td>
<td>Sets the pulse timing parameters and the pulse voltage output of MFCMU.</td>
</tr>
</tbody>
</table>
```
session.WriteString("MM 19," & t(1) & vbCrLf)                                '63
session.WriteString("IMP 100" & vbCrLf)
session.WriteString("RC " & t(1) & "," & range & vbCrLf)
session.WriteString("ERR? 1" & vbCrLf) : err = session.ReadString(4 + 2)
If err <> 0 Then session.WriteString("DZ" & vbCrLf) : GoTo Check_err
session.WriteString("TSR" & vbCrLf)
session.WriteString("XE" & vbCrLf)
session.WriteString("*OPC?" & vbCrLf) : err = session.ReadString(1 + 2)        '70
session.WriteString("ERR? 1" & vbCrLf) : err = session.ReadString(4 + 2)
If err <> 0 Then session.WriteString("DZ" & vbCrLf) : 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" & vbCrLf)                                             '82
save_data(fname, title, value, data, nop1, nop2, session, t)
Exit Sub

Check_err:                                                                     '86
session.WriteString("EMG? " & err & vbCrLf) : msg = session.ReadString(256)
MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, ")
End Sub
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>63 to 69</td>
<td>Sets the measurement condition, resets the time stamp, and performs the measurement.</td>
</tr>
<tr>
<td>70 to 72</td>
<td>Waits until the measurement is completed. If an error is detected, applies 0 V and goes to Check_err.</td>
</tr>
<tr>
<td>74 to 80</td>
<td>Stores the returned data into the mret string variable. Finally, stores the measured data into the data array.</td>
</tr>
<tr>
<td>82 to 84</td>
<td>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.</td>
</tr>
<tr>
<td>86 to 88</td>
<td>Displays a message box to show an error message if the error is detected.</td>
</tr>
</tbody>
</table>
Pulsed Sweep CV Measurements

To perform capacitance-voltage pulsed sweep measurements, use the following commands.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>chnum ... [,chnum] ...</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>chnum ... [,chnum] ...</td>
</tr>
<tr>
<td>Sets SMU filter ON/OFF</td>
<td>[FL]</td>
<td>mode[,chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets SMU series resistor ON/OFF</td>
<td>[SSR]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Disables SCUU status indicator</td>
<td>[SSL]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Controls SCUU input-output path</td>
<td>[SSP]</td>
<td>chnum,path</td>
</tr>
<tr>
<td>Sets MFCMU A/D converter</td>
<td>[ACT]</td>
<td>model[,N]</td>
</tr>
<tr>
<td>Sets MFCMU measurement mode</td>
<td>[IMP]</td>
<td>mode</td>
</tr>
<tr>
<td>Sets MFCMU output frequency</td>
<td>FC</td>
<td>chnum,freq</td>
</tr>
<tr>
<td>Forces AC voltage by using MFCMU</td>
<td>ACV</td>
<td>chnum,level</td>
</tr>
<tr>
<td>Sets pulse timing parameters</td>
<td>PTDCV</td>
<td>hold,width,period [,tdelay]</td>
</tr>
<tr>
<td>Sets auto abort function</td>
<td>[WMDCV]</td>
<td>abort[,post]</td>
</tr>
<tr>
<td>Sets pulse voltage sweep source</td>
<td>PWDCV</td>
<td>chnum,mode,base,start,stop,step</td>
</tr>
<tr>
<td>Forces constant voltage</td>
<td>[DV, TDV]</td>
<td>chnum,rnage,output [,comp[,polarity[,crange]]]</td>
</tr>
<tr>
<td>Forces constant current</td>
<td>[DI, TDI]</td>
<td></td>
</tr>
<tr>
<td>Sets MFCMU measurement range</td>
<td>[RC]</td>
<td>chnum,mode[,range]</td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td>20,chnum</td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>
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 3-72.

**Table 3-23**

**Pulsed Sweep CV Measurement Example**

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 24</td>
<td>Declares variables and sets the value.</td>
</tr>
<tr>
<td>26 to 28</td>
<td>Sets timeout and data output format. And enables the time stamp output.</td>
</tr>
<tr>
<td>29 to 30</td>
<td>Applies 0 V to the drain and source terminals.</td>
</tr>
<tr>
<td>31 to 32</td>
<td>Makes the SCUU connection path, and sets the A/D converter of the MFCMU.</td>
</tr>
</tbody>
</table>
### Programming Examples
#### Pulsed Sweep CV Measurements

```vba
Dim rbx As Integer
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" & vbCrLf)
    session.WriteString("ADJ? " & t(1) & vbCrLf) : err = session.ReadString(1 + 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbCrLf) : err =
        session.ReadString(4 + 2) : session.WriteString("DZ" & vbCrLf) : GoTo Check_err
End If

session.WriteString("FC " & t(1) & "," & freq & vbCrLf)
session.WriteString("ACV " & t(1) & "," & osc_level & vbCrLf)
rbx = MsgBox("Do you want to perform Open correction?", vbYesNo, ")
If rbx = vbYes Then
    session.WriteString("CLCORR " & t(1) & ",2" & vbCrLf)
    MsgBox("Open measurement terminal. Then click OK.", vbOKOnly, ")
    Console.WriteLine("Wait a minute . . ." & Chr(10) & vbCrLf)
    session.WriteString("DCCORR " & t(1) & ",1,100," & ref_cp & "," & ref_g & vbCrLf)
    session.WriteString("CORR? " & t(1) & ",1" & vbCrLf) : err = session.ReadString(1 + 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbCrLf) : err =
        session.ReadString(4 + 2) : session.WriteString("DZ" & vbCrLf) : GoTo Check_err
 session.WriteString("CORRST " & t(1) & ",1,1" & vbCrLf)  'open correction ON
 session.WriteString("CORRST " & t(1) & ",2,0" & vbCrLf)  'short correction OFF
 session.WriteString("CORRST " & t(1) & ",3,0" & vbCrLf)  'load correction OFF
End If
MsgBox("Connect DUT. Then click OK.", vbOKOnly, ")
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>34 to 42</td>
<td>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.</td>
</tr>
<tr>
<td>44 to 45</td>
<td>Sets the frequency and the oscillator level of the MFCMU output signal.</td>
</tr>
<tr>
<td>47 to 58</td>
<td>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.</td>
</tr>
<tr>
<td>60</td>
<td>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.</td>
</tr>
</tbody>
</table>
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("MM 20," & t(1) & vbLf): err = session.ReadString(4 + 2)
If err <> 0 Then session.WriteString("ERR? 1" & 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 + 16 * 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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>61 to 73</td>
<td>Sets the measurement condition, resets the time stamp, and performs the measurement.</td>
</tr>
<tr>
<td>63</td>
<td>Sets the automatic abort function to ON, and sets the post measurement output value to vg1.</td>
</tr>
<tr>
<td>64</td>
<td>Sets the pulsed sweep timing parameters of MFCMU.</td>
</tr>
<tr>
<td>65</td>
<td>Sets the pulsed sweep output voltage of MFCMU.</td>
</tr>
<tr>
<td>74 to 78</td>
<td>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.</td>
</tr>
<tr>
<td>80 to 90</td>
<td>Stores the returned data into the mret string variable. Finally, stores the measured data into the data array.</td>
</tr>
</tbody>
</table>
Programming Examples
Pulsed Sweep CV Measurements

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>92 to 94</td>
<td>Applies 0 V from all channels. And transfers the data stored in the <code>data</code> variable to the <code>save_data</code> subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the <code>fname</code> variable and displays the data on a message box.</td>
</tr>
<tr>
<td>96 to 99</td>
<td>Displays a message box to show an error message if the error is detected.</td>
</tr>
<tr>
<td>101 to 102</td>
<td>Displays a message box to show an error message if the number of returned data is not correct.</td>
</tr>
</tbody>
</table>

Measurement Result Example

<table>
<thead>
<tr>
<th>Vg (V), Cp (pF), C_st, G (uS), G_st, Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5, 0.133441, NGC, -0.334621, NGY, 0.11755</td>
</tr>
<tr>
<td>-4.5, 0.11202, NGC, -0.301203, NGY, 0.13873</td>
</tr>
<tr>
<td>-4, 0.137815, NGC, -0.151185, NGY, 0.15973</td>
</tr>
<tr>
<td>-3.5, 0.103693, NGC, -0.0974783, NGY, 0.18053</td>
</tr>
<tr>
<td>-3, 0.0877819, NGC, -0.0884008, NGY, 0.20112</td>
</tr>
<tr>
<td>-2.5, 0.0523748, NGC, 0.697226, NGY, 0.22152</td>
</tr>
<tr>
<td>-2, 0.0487233, NGC, 0.0480156, NGY, 0.24172</td>
</tr>
<tr>
<td>-1.5, 0.118844, NGC, -0.322665, NGY, 0.26172</td>
</tr>
<tr>
<td>-1, 0.109541, NGC, -0.488218, NGY, 0.28155</td>
</tr>
<tr>
<td>-0.5, 0.0792613, NGC, -0.232565, NGY, 0.30135</td>
</tr>
<tr>
<td>0, 0.0580278, NGC, 0.240967, NGY, 0.32115</td>
</tr>
<tr>
<td>0.5, 0.110523, NGC, -0.0462759, NGY, 0.34094</td>
</tr>
<tr>
<td>1, 0.082289, NGC, 0.156317, NGY, 0.36075</td>
</tr>
<tr>
<td>1.5, 0.102956, NGC, -0.175315, NGY, 0.38055</td>
</tr>
<tr>
<td>2, 0.186602, NGC, -0.463437, NGY, 0.40045</td>
</tr>
<tr>
<td>2.5, 0.0818513, NGC, -0.620362, NGY, 0.42064</td>
</tr>
<tr>
<td>3, 0.0739288, NGC, -0.084286, NGY, 0.44104</td>
</tr>
<tr>
<td>3.5, 0.0476039, NGC, 0.287456, NGY, 0.46164</td>
</tr>
<tr>
<td>4, 0.0910013, NGC, 0.0407421, NGY, 0.48244</td>
</tr>
<tr>
<td>4.5, 0.0745168, NGC, 0.170635, NGY, 0.50344</td>
</tr>
<tr>
<td>5, 0.0627603, NGC, 0.144463, NGY, 0.52464</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets SMU filter ON/OFF</td>
<td>[FL]</td>
<td>mode[,chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets SMU series resistor ON/OFF</td>
<td>[SSR]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Disables SCUU status indicator</td>
<td>[SSL]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Controls SCUU input-output path</td>
<td>[SSP]</td>
<td>chnum,path</td>
</tr>
<tr>
<td>Sets MFCMU A/D converter</td>
<td>[ACT]</td>
<td>mode[,]</td>
</tr>
<tr>
<td>Sets MFCMU measurement mode</td>
<td>[IMP]</td>
<td>mode</td>
</tr>
<tr>
<td>Sets AC/DC voltage monitor ON/OFF</td>
<td>[LMN]</td>
<td>mode</td>
</tr>
<tr>
<td>Sets MFCMU output frequency</td>
<td>FC</td>
<td>chnum,freq</td>
</tr>
<tr>
<td>Forces AC voltage by using MFCMU</td>
<td>ACV</td>
<td>chnum,level</td>
</tr>
<tr>
<td>Sets CV sweep timing parameter</td>
<td>WTACV</td>
<td>hold,delay [,sdelay[,tdelay[,mdelay]]]</td>
</tr>
<tr>
<td>Sets auto abort function</td>
<td>[WMACV]</td>
<td>abort[,post]</td>
</tr>
<tr>
<td>Sets AC level sweep source</td>
<td>WACV</td>
<td>chnum,mode,start,stop,step</td>
</tr>
<tr>
<td>Forces DC voltage by using MFCMU</td>
<td>DCV</td>
<td>chnum,voltage</td>
</tr>
<tr>
<td>Forces constant voltage</td>
<td>[DV, TDV]</td>
<td>chnum,range,output [,comp[,polarity[,crange]]]</td>
</tr>
<tr>
<td>Forces constant current</td>
<td>[DI, TDI]</td>
<td></td>
</tr>
<tr>
<td>Sets MFCMU measurement range</td>
<td>[RC]</td>
<td>chnum,mode[,range]</td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td>23,chnum</td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>
Programming Examples
CV (AC Level) Sweep Measurements

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/C MU unify unit (SCUU).

Before performing the capacitance (impedance) measurement, you need to perform the phase compensation and data correction. See “Data Correction” on page 3-72.

Table 3-24
CV (AC level) Sweep Measurement Example

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 30</td>
<td>Declares variables and sets the value.</td>
</tr>
<tr>
<td>32 to 34</td>
<td>Sets the B1500A timeout and the data output format (data with source data). And enables the time stamp output.</td>
</tr>
</tbody>
</table>
### Session Code

```vbnet
Dim rbx As Integer
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" & vbCrLf)
    session.WriteString("ADJ? " & t(1) & vbCrLf) : err = session.ReadString(1 + 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbCrLf) : err = session.ReadString(4 + 2) : session.WriteString("DZ" & vbCrLf) : GoTo Check_err
End If

session.WriteString("FC " & t(1) & "," & freq & vbCrLf)
```

### Line Description

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 to 36</td>
<td>Applies 0 V to the drain and source terminals.</td>
</tr>
<tr>
<td>37 to 38</td>
<td>Makes the SCUU connection path, and sets the A/D converter of the MFCMU.</td>
</tr>
<tr>
<td>40 to 48</td>
<td>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.</td>
</tr>
<tr>
<td>50 to 51</td>
<td>Sets the frequency and the oscillator level of the MFCMU output signal.</td>
</tr>
<tr>
<td>53 to 64</td>
<td>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.</td>
</tr>
<tr>
<td>66</td>
<td>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.</td>
</tr>
</tbody>
</table>
session.WriteString("WMACV 2, 1" & vbCrLf)  '68
session.WriteString("WTACV " & hold & "," & delay & "," & s_delay & vbCrLf)
session.WriteString("WACV " & t(1) & ",1," & v1 & "," & v2 & "," & nop1 & vbCrLf)
session.WriteString("MM 23," & t(1) & vbCrLf)
session.WriteString("LMN 1" & vbCrLf)
session.WriteString("RC " & t(1) & "," & range & vbCrLf)
session.WriteString("ERR? 1" & vbCrLf) : err = session.ReadString(4 + 2)
If err <> 0 Then session.WriteString("DZ" & vbCrLf) : GoTo Check_err
session.WriteString("DCV " & t(1) & "," & dc_bias & vbCrLf)
session.WriteString("XE" & vbCrLf)
session.WriteString("*OPC?" & vbCrLf) : rep = session.ReadString(1 + 2)  '80
session.WriteString("ERR? 1" & vbCrLf) : err = session.ReadString(4 + 2)
If err <> 0 Then session.WriteString("DZ" & vbCrLf) : GoTo Check_err
session.WriteString("NUB?" & vbCrLf) : rep = session.ReadString(3 + 2)
If rep <> nop1 * 6 Then session.WriteString("DZ" & vbCrLf) : 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) * 1000000000000.0 & "," & 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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>68 to 79</td>
<td>Sets the measurement condition, resets the time stamp, and performs the measurement.</td>
</tr>
<tr>
<td>68</td>
<td>Sets the automatic abort function to ON, and sets the post measurement output value to v1.</td>
</tr>
<tr>
<td>69</td>
<td>Sets the MFCMU sweep output timing.</td>
</tr>
<tr>
<td>70</td>
<td>Sets the MFCMU AC level sweep output.</td>
</tr>
<tr>
<td>80 to 84</td>
<td>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.</td>
</tr>
<tr>
<td>86 to 102</td>
<td>Stores the returned data into the mret string variable. Finally, stores the measured data into the data array.</td>
</tr>
</tbody>
</table>
Programming Examples
CV (AC Level) Sweep Measurements

Data save completed.
Do you want to perform measurement again?

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>104 to 106</td>
<td>Applies 0 V from all channels. And transfers the data stored in the <code>data</code> variable to the <code>save_data</code> subprogram (see Table 3-1). And the subprogram will save the data into a CSV file specified by the <code>fname</code> variable and displays the data on a message box.</td>
</tr>
<tr>
<td>108 to 111</td>
<td>Displays a message box to show an error message if the error is detected.</td>
</tr>
<tr>
<td>113 to 114</td>
<td>Displays a message box to show an error message if the number of returned data is not correct.</td>
</tr>
</tbody>
</table>

**Measurement Result Example**

<table>
<thead>
<tr>
<th>Level (mV), Cp (pF), C_st, G (uS), G_st, OSC (mV), Osc_st, DC (V), Dc_st, Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10, 0.101413, NGC, 0.023601, NGY, 9.9799, NGV, 5.00485, NGV, 0.0714</td>
</tr>
<tr>
<td>20, 0.102654, NGC, 0.0450136, NGY, 19.963, NGV, 5.0049, NGV, 0.13921</td>
</tr>
<tr>
<td>30, 0.100627, NGC, 0.0522385, NGY, 29.946, NGV, 5.00488, NGV, 0.15706</td>
</tr>
<tr>
<td>40, 0.10053, NGC, 0.0529098, NGY, 39.926, NGV, 5.00491, NGV, 0.22501</td>
</tr>
<tr>
<td>50, 0.10008, NGC, 0.0562029, NGY, 49.8853, NGV, 5.00495, NGV, 0.24298</td>
</tr>
<tr>
<td>60, 0.0982925, NGC, 0.0492554, NGY, 59.8901, NGV, 5.00515, NGV, 0.26092</td>
</tr>
<tr>
<td>70, 0.0992213, NGC, 0.0548534, NGY, 69.899, NGV, 5.00502, NGV, 0.32885</td>
</tr>
<tr>
<td>80, 0.099067, NGC, 0.0501863, NGY, 79.915, NGV, 5.00514, NGV, 0.34679</td>
</tr>
<tr>
<td>90, 0.100248, NGC, 0.0512628, NGY, 89.892, NGV, 5.00487, NGV, 0.36446</td>
</tr>
<tr>
<td>100, 0.0996081, NGC, 0.0519715, NGY, 99.869, NGV, 5.00486, NGV, 0.38241</td>
</tr>
</tbody>
</table>

Data save completed.
Do you want to perform measurement again?

session.WriteString("DZ" & vbCrLf)                                             ’104
save_data(fname, title, value, data, nop1, nop2, session, t)
Exit Sub

Check_err:
    session.WriteString("EMG? " & err & vbCrLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, "")
Exit Sub

Check_nop:
    MsgBox("No. of data: " & rep & " (not " & nop1 * 6 & ")", vbOKOnly, "")
End Sub
C-f Sweep Measurements

To perform capacitance-frequency sweep measurements, use the following commands.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets SMU filter ON/OFF</td>
<td>[FL]</td>
<td>mode[,chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets SMU series resistor ON/OFF</td>
<td>[SSR]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Disables SCUU status indicator</td>
<td>[SSL]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Controls SCUU input-output path</td>
<td>[SSP]</td>
<td>chnum,path</td>
</tr>
<tr>
<td>Sets MFCMU A/D converter</td>
<td>[ACT]</td>
<td>mode[,N]</td>
</tr>
<tr>
<td>Sets MFCMU measurement mode</td>
<td>[IMP]</td>
<td>mode</td>
</tr>
<tr>
<td>Sets AC/DC voltage monitor ON/OFF</td>
<td>[LMN]</td>
<td>mode</td>
</tr>
<tr>
<td>Sets C-f sweep timing parameter</td>
<td>WTFC</td>
<td>hold,delay [,sdelay[,tdelay[,mdelay]]]</td>
</tr>
<tr>
<td>Sets auto abort function</td>
<td>[WMFC]</td>
<td>abort[,post]</td>
</tr>
<tr>
<td>Sets frequency sweep source</td>
<td>WFC</td>
<td>chnum,mode,start,stop,step</td>
</tr>
<tr>
<td>Forces AC voltage by using MFCMU</td>
<td>ACV</td>
<td>chnum,level</td>
</tr>
<tr>
<td>Forces DC voltage by using MFCMU</td>
<td>DCV</td>
<td>chnum,voltage</td>
</tr>
<tr>
<td>Forces constant voltage</td>
<td>[DV, TDV]</td>
<td>chnum,range,output [,comp[,polarity[,crange]]]</td>
</tr>
<tr>
<td>Forces constant current</td>
<td>[DI, TDI]</td>
<td></td>
</tr>
<tr>
<td>Sets MFCMU measurement range</td>
<td>[RC]</td>
<td>chnum,mode[,range]</td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td>22,chnum</td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>
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 3-72.

Table 3-25  C-f Sweep Measurement Example

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 30</td>
<td>Declares variables and sets the value.</td>
</tr>
<tr>
<td>32 to 34</td>
<td>Sets the B1500A timeout and the data output format (data with source data). And enables the time stamp output.</td>
</tr>
</tbody>
</table>
**Programming Examples**

**C-f Sweep Measurements**

```vbnet
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) & ",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" & vbLf) 'open correction ON
    session.WriteString("CORRST " & t(1) & ",2" & vbLf) 'short correction OFF
    session.WriteString("CORRST " & t(1) & ",3" & vbLf) 'load correction OFF
End If
```

### Line Description

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 to 36</td>
<td>Applies 0 V to the drain and source terminals.</td>
</tr>
<tr>
<td>37 to 38</td>
<td>Makes the SCUU connection path, and sets the A/D converter of the MFCMU.</td>
</tr>
<tr>
<td>40 to 48</td>
<td>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.</td>
</tr>
<tr>
<td>50</td>
<td>Sets the oscillator level of the MFCMU output signal.</td>
</tr>
<tr>
<td>52 to 69</td>
<td>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.</td>
</tr>
</tbody>
</table>
### Programming Examples

#### C-f Sweep Measurements

```vba
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) & "," & 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("*OPC?" & & 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) / 100000
   data(j, i) = data(j, i) & "," & md(i * 2) * 10000000000000 & "," & st(i * 2)
   data(j, i) = data(j, i) & "," & md(i * 2 + 1) * 10000000000 & "," & 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
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>71</td>
<td>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.</td>
</tr>
<tr>
<td>72 to 83</td>
<td>Sets the measurement condition, resets the time stamp, and performs the measurement.</td>
</tr>
<tr>
<td>84 to 88</td>
<td>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.</td>
</tr>
<tr>
<td>90 to 108</td>
<td>Stores the returned data into the mret string variable. Finally, stores the measured data into the data array.</td>
</tr>
</tbody>
</table>
Programming Examples
C-f Sweep Measurements

Measurement Result Example

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Capacitance (pF)</th>
<th>Series Resistance (μS)</th>
<th>Open Circuit (mV)</th>
<th>Stop Band (mV)</th>
<th>DC Voltage (V)</th>
<th>DC Stop Band (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.102504</td>
<td>-0.00489649</td>
<td>29.9602</td>
<td>5.00364</td>
<td>0.01205</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>0.103028</td>
<td>0.00752516</td>
<td>29.9472</td>
<td>5.00362</td>
<td>0.03098</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>0.0941827</td>
<td>0.0385718</td>
<td>29.914</td>
<td>5.00384</td>
<td>0.04993</td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>0.0925777</td>
<td>0.00978407</td>
<td>29.8359</td>
<td>5.00383</td>
<td>0.06891</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>0.0936848</td>
<td>0.0741706</td>
<td>29.7236</td>
<td>5.00383</td>
<td>0.08851</td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td>0.0926532</td>
<td>0.0838099</td>
<td>29.6289</td>
<td>5.00396</td>
<td>0.10756</td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>0.098542</td>
<td>0.0313031</td>
<td>29.4926</td>
<td>5.00391</td>
<td>0.12654</td>
<td></td>
</tr>
<tr>
<td>4.0</td>
<td>0.0985281</td>
<td>0.0103357</td>
<td>29.3519</td>
<td>5.00376</td>
<td>0.14551</td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td>0.101377</td>
<td>0.0136298</td>
<td>29.1433</td>
<td>5.004</td>
<td>0.1644</td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td>0.100967</td>
<td>0.10801</td>
<td>28.9145</td>
<td>5.0038</td>
<td>0.1833</td>
<td></td>
</tr>
</tbody>
</table>

Data save completed.

Do you want to perform measurement again?

```
session.WriteString("DZ" & vbCrLf)                                 '110
save_data(fname, title, value, data, nop1, nop2, session, t)
Exit Sub

Check_err:
session.WriteString("EMG? " & err & vbCrLf) : msg = session.ReadString(256)
MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, ")
Exit Sub

Check_nop:
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.
## C-t Sampling Measurements

To perform C-t sampling measurements, use the following commands.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables Measurement Units</td>
<td>CN</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Disables Measurement Units</td>
<td>CL</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets Filter ON/OFF</td>
<td>[FL]</td>
<td>mode[,chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets series resistor ON/OFF</td>
<td>[SSR]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Disables SCUU status indicator</td>
<td>[SSL]</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Controls SCUU input-output path</td>
<td>[SSP]</td>
<td>chnum,path</td>
</tr>
<tr>
<td>Sets MFCMU A/D converter</td>
<td>[ACT]</td>
<td>mode[,]N</td>
</tr>
<tr>
<td>Sets MFCMU measurement mode</td>
<td>[IMP]</td>
<td>mode</td>
</tr>
<tr>
<td>Sets timing parameters</td>
<td>MTDCV</td>
<td>h_bias,interval,points[,h_base]</td>
</tr>
<tr>
<td>Sets constant voltage source</td>
<td>MDCV</td>
<td>chnum,base,bias[,post]</td>
</tr>
<tr>
<td>Sets MFCMU output frequency</td>
<td>FC</td>
<td>chnum,freq</td>
</tr>
<tr>
<td>Forces AC voltage by using MFCMU</td>
<td>ACV</td>
<td>chnum,ac_level</td>
</tr>
<tr>
<td>Forces DC voltage by using SMU</td>
<td>[DV, TDV]</td>
<td>chnum,range,output [[,comp[,polarity[,crange]]]]</td>
</tr>
<tr>
<td>Forces DC current by using SMU</td>
<td>[DI, TDI]</td>
<td></td>
</tr>
<tr>
<td>Sets MFCMU measurement range</td>
<td>[RC]</td>
<td>chnum,mode[,range]</td>
</tr>
<tr>
<td>Sets measurement mode</td>
<td>MM</td>
<td>26,chnum</td>
</tr>
<tr>
<td>Executes measurement</td>
<td>XE</td>
<td></td>
</tr>
</tbody>
</table>
Programming Examples
C-t Sampling Measurements

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 3-72.

Table 3-26  C-t Sampling Measurement Example

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 27</td>
<td>Declares variables and sets the value.</td>
</tr>
<tr>
<td>29</td>
<td>Sets timeout for the B1500A.</td>
</tr>
<tr>
<td>30 to 31</td>
<td>Sets the data output format (data with source data). And enables the time stamp output.</td>
</tr>
</tbody>
</table>
```vbnet
session.WriteString("DV " & t(0) & ",0,0,0.1,0" & vbCrLf)  '32
session.WriteString("DV " & t(2) & ",0,0,0.1,0" & vbCrLf)
session.WriteString("SSP " & t(1) & ",4" & vbCrLf)   'CMU to SCUU output
session.WriteString("ACT 0, 2" & vbCrLf)             '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, "")
    session.WriteString("ADJ " & t(1) & ",1" & vbCrLf)
    session.WriteString("ADJ? " & t(1) & vbCrLf) : err = session.ReadString(1 + 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbCrLf) : err =
    session.ReadString(4 + 2) : session.WriteString("DZ" & vbCrLf) : GoTo Check_err
End If

session.WriteString("FC " & t(1) & "," & freq & vbCrLf)                          '47
session.WriteString("ACV " & t(1) & "," & osc_level & vbCrLf)

rbx = MsgBox("Do you want to perform Open correction?", vbYesNo, "")
If rbx = vbYes Then
    session.WriteString("CLCORR " & t(1) & ",2" & vbCrLf)
    MsgBox("Open measurement terminal. Then click OK.", vbOKOnly, "")
    Console.WriteLine("Wait a minute . . ." & Chr(10))
    session.WriteString("DCORR " & t(1) & ",1,100," & ref_cp & ",," & ref_g & vbCrLf)
    session.WriteString("CORR? " & t(1) & ",1" & vbCrLf) : err = session.ReadString(1 + 2)
    If err <> 0 Then session.WriteString("ERR? 1" & vbCrLf) : err =
    session.ReadString(4 + 2) : session.WriteString("DZ" & vbCrLf) : GoTo Check_err
    session.WriteString("CORRST " & t(1) & ",1,1" & vbCrLf)    'open correction ON
    session.WriteString("CORRST " & t(1) & ",2,0" & vbCrLf)    'short correction OFF
    session.WriteString("CORRST " & t(1) & ",3,0" & vbCrLf)    'load correction OFF
End If
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>32 to 33</td>
<td>Applies 0 V to the drain and source terminals.</td>
</tr>
<tr>
<td>34 to 35</td>
<td>Makes the SCUU connection path, and sets the A/D converter of the MFCMU.</td>
</tr>
<tr>
<td>37 to 45</td>
<td>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.</td>
</tr>
<tr>
<td>47 to 48</td>
<td>Sets the frequency and the oscillator level of the MFCMU output signal.</td>
</tr>
<tr>
<td>50 to 61</td>
<td>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.</td>
</tr>
</tbody>
</table>
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("*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) * 1000000000.0 & "," & 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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>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.</td>
</tr>
<tr>
<td>64 to 72</td>
<td>Sets the measurement condition, resets the time stamp, and performs the measurement.</td>
</tr>
<tr>
<td>73 to 77</td>
<td>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.</td>
</tr>
<tr>
<td>79 to 89</td>
<td>Stores the returned data into the mret string variable. Finally, stores the measured data into the data array.</td>
</tr>
<tr>
<td>90 to 92</td>
<td>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.</td>
</tr>
</tbody>
</table>
Programming Examples
C-t Sampling Measurements

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>94 to 97</td>
<td>Displays a message box to show an error message if the error is detected.</td>
</tr>
<tr>
<td>99 to 100</td>
<td>Displays a message box to show an error message if the number of returned data is not correct.</td>
</tr>
</tbody>
</table>

**Measurement Result Example**

<table>
<thead>
<tr>
<th>Index, Cp (pF), C_st, G (uS), G_st, Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 0.100051, NGC, 0.0579184, NGY, 0.10199</td>
</tr>
<tr>
<td>2, 0.0989954, NGC, 0.0510581, NGY, 0.152</td>
</tr>
<tr>
<td>3, 0.101344, NGC, 0.0603764, NGY, 0.20199</td>
</tr>
<tr>
<td>4, 0.0988522, NGC, 0.058593, NGY, 0.252</td>
</tr>
<tr>
<td>5, 0.0990403, NGC, 0.0514987, NGY, 0.30199</td>
</tr>
<tr>
<td>6, 0.10049, NGC, 0.0588621, NGY, 0.35199</td>
</tr>
<tr>
<td>7, 0.0997872, NGC, 0.0505812, NGY, 0.40199</td>
</tr>
<tr>
<td>8, 0.0990492, NGC, 0.0449747, NGY, 0.452</td>
</tr>
<tr>
<td>9, 0.0999805, NGC, 0.0460361, NGY, 0.50199</td>
</tr>
<tr>
<td>10, 0.0972752, NGC, 0.0518454, NGY, 0.552</td>
</tr>
<tr>
<td>11, 0.100533, NGC, 0.0604562, NGY, 0.60199</td>
</tr>
<tr>
<td>12, 0.0979196, NGC, 0.0573212, NGY, 0.65199</td>
</tr>
<tr>
<td>13, 0.0984623, NGC, 0.0589873, NGY, 0.70199</td>
</tr>
<tr>
<td>14, 0.0991157, NGC, 0.0501881, NGY, 0.752</td>
</tr>
<tr>
<td>15, 0.0985757, NGC, 0.0550837, NGY, 0.80199</td>
</tr>
<tr>
<td>16, 0.0972, NGC, 0.0564537, NGY, 0.852</td>
</tr>
<tr>
<td>17, 0.0993272, NGC, 0.0596557, NGY, 0.90199</td>
</tr>
<tr>
<td>18, 0.0986133, NGC, 0.0542398, NGY, 0.952</td>
</tr>
<tr>
<td>19, 0.0992744, NGC, 0.0634103, NGY, 1.00199</td>
</tr>
<tr>
<td>20, 0.0990222, NGC, 0.0627697, NGY, 1.052</td>
</tr>
<tr>
<td>21, 0.0985357, NGC, 0.0446665, NGY, 1.102</td>
</tr>
<tr>
<td>22, 0.0997336, NGC, 0.060945, NGY, 1.152</td>
</tr>
<tr>
<td>23, 0.0993864, NGC, 0.0538741, NGY, 1.202</td>
</tr>
<tr>
<td>24, 0.0986702, NGC, 0.04196, NGY, 1.25199</td>
</tr>
<tr>
<td>25, 0.099164, NGC, 0.0535988, NGY, 1.30199</td>
</tr>
<tr>
<td>26, 0.100364, NGC, 0.0378016, NGY, 1.352</td>
</tr>
<tr>
<td>27, 0.100047, NGC, 0.0534552, NGY, 1.402</td>
</tr>
<tr>
<td>28, 0.100995, NGC, 0.0550804, NGY, 1.452</td>
</tr>
<tr>
<td>29, 0.100044, NGC, 0.0452834, NGY, 1.50199</td>
</tr>
<tr>
<td>30, 0.101213, NGC, 0.0538826, NGY, 1.552</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables channels</td>
<td>CN</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Disables channels</td>
<td>CL</td>
<td>[chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Sets SPGU pulse output mode</td>
<td>SIM</td>
<td>0</td>
</tr>
<tr>
<td>Sets output operation mode</td>
<td>SPRM</td>
<td>mode[,condition]</td>
</tr>
<tr>
<td>Sets pulse period for all of SPGU channels</td>
<td>SPPER</td>
<td>period</td>
</tr>
<tr>
<td>Sets channel output mode</td>
<td>SPM</td>
<td>chnum,mode</td>
</tr>
<tr>
<td>Sets pulse timing parameters</td>
<td>SPT</td>
<td>chnum,src,delay,width,leading [,trailing]</td>
</tr>
<tr>
<td>Sets pulse level parameters</td>
<td>SPV</td>
<td>chnum,src,base[,peak]</td>
</tr>
<tr>
<td>Sets load impedance</td>
<td>SER</td>
<td>chnum,loadZ</td>
</tr>
<tr>
<td>Measures terminal voltage, calculates and sets load impedance</td>
<td>[CORRSER?]</td>
<td>chnum,mode,delay,interval, count</td>
</tr>
<tr>
<td>Sets pulse switch</td>
<td>[ODSW]</td>
<td>chnum,state[,normal[,delay, width]]</td>
</tr>
<tr>
<td>Sets SPGU trigger output</td>
<td>[STGP]</td>
<td>chnum,state</td>
</tr>
<tr>
<td>Applies SPGU channel setup</td>
<td>SPUPD</td>
<td>chnum[,chnum ... [,chnum] ... ]</td>
</tr>
<tr>
<td>Starts SPGU pulse output</td>
<td>SRP</td>
<td></td>
</tr>
<tr>
<td>Stops SPGU pulse output</td>
<td>[SPP]</td>
<td></td>
</tr>
<tr>
<td>Returns SPGU output status</td>
<td>[SPST?]</td>
<td></td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>This line is required to use the VISA COM library.</td>
</tr>
<tr>
<td>6 to 9</td>
<td>Establishes the connection with the Keysight B1500 of the GPIB address 17 on the interface GPIB0. “GPIB0” is the VISA name. Confirm your GPIB settings, and set them properly.</td>
</tr>
<tr>
<td>10</td>
<td>Resets the B1500.</td>
</tr>
<tr>
<td>14 to 32</td>
<td>Declares variables and sets the value. This program uses the SPGU installed in the slot 1 of the B1500.</td>
</tr>
</tbody>
</table>
Programming Examples
SPGU Pulse Output and Voltage Measurement

```vba
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("SPGU " & sp_ch(0) & ",1" & vbLf)  '2-level pulse setup '45
session.WriteString("SPGU " & sp_ch(1) & ",1" & vbLf)

session.WriteString("SPT " & sp_ch(0) & ",1," & p1_del & "," & p1_wid & "," & p_lead & "," & p_trail & vbLf)
session.WriteString("SPT " & sp_ch(1) & ",1," & p2_del1 & "," & p2_wid1 & "," & p2_lead1 & "," & p2_trail1 & vbLf)
session.WriteString("SPV " & sp_ch(0) & ",1," & p1_base & "," & p1_peak & 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.
```vbnet
session.WriteString("ERRX? 0" & vbLf) : msg = session.ReadString(256)  '55
err = Val(Left(msg, 2))
If err <> 0 Then session.WriteString("D2" & vbLf) : GoTo Check_err

session.WriteString("SRP" & vbLf)  'starts pulse output  '59
Console.Write("SPGU output in progress")

Spgu_stat:
    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:
    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
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>55 to 57</td>
<td>Reads error buffer. If an error is detected, changes the channel output to 0 V and goes to Check_err.</td>
</tr>
<tr>
<td>59</td>
<td>Starts the SPGU pulse output.</td>
</tr>
<tr>
<td>62 to 66</td>
<td>Checks the SPGU pulse output status. And waits for the end status.</td>
</tr>
<tr>
<td>68 to 69</td>
<td>Clears the error buffer. And displays a message box to show an error message.</td>
</tr>
<tr>
<td>71 to 76</td>
<td>Disables all channels, and closes the connection with the Keysight B1500.</td>
</tr>
</tbody>
</table>

**Measurement Result Example**

SPGU setup.

SPGU output in progress..........................................

SPGU output stopped.

SPGU output stopped.
Programming Examples
SPGU Pulse Output and Voltage Measurement

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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>This line is required to use the VISA COM library.</td>
</tr>
<tr>
<td>6 to 11</td>
<td>Establishes the connection with the Keysight 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.</td>
</tr>
<tr>
<td>13</td>
<td>Resets the B1500.</td>
</tr>
<tr>
<td>17 to 32</td>
<td>Declares variables and sets the value. This program uses the SPGU installed in the slot 1 of the B1500.</td>
</tr>
</tbody>
</table>
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."

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.

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>34 to 35</td>
<td>Declares variables used for error check.</td>
</tr>
<tr>
<td>37</td>
<td>Enables the SPGU channels specified by sp_ch(0).</td>
</tr>
<tr>
<td>38 to 45</td>
<td>Defines the channel setup and applies them to the channel specified by sp_ch(0). The channels start the pulse base output.</td>
</tr>
<tr>
<td>46 to 47</td>
<td>Reads error buffer. If an error is detected, changes the channel output to 0 V and goes to Check_err.</td>
</tr>
<tr>
<td>50 to 55</td>
<td>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.</td>
</tr>
<tr>
<td>56 to 62</td>
<td>Starts the SPGU pulse output and checks the SPGU pulse output status. And waits for the end status.</td>
</tr>
</tbody>
</table>
Dim i, n As Integer
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:
   MsgBox("Instrument error: " & Chr(10) & msg, vbOKOnly, ")

Close:
   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))
End Sub
End Module

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>64 to 74</td>
<td>Measures the terminal voltage, calculates the impedance, and displays the result.</td>
</tr>
<tr>
<td>76 to 77</td>
<td>Clears the error buffer. And displays a message box to show an error message.</td>
</tr>
<tr>
<td>79 to 84</td>
<td>Disables all channels, and closes the connection with the Keysight B1500.</td>
</tr>
</tbody>
</table>

**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.

<table>
<thead>
<tr>
<th>Command</th>
<th>Function and Syntax</th>
</tr>
</thead>
</table>
| ST and END | Stores the program in the memory.  

\[ \text{ST } pnum; \text{command[...[;command]...]}; \text{END} \]

or

\[ \text{ST } pnum 

[command] 

: 

[command] 

END \]

| [SCR] | Scratches the program.  

\[ \text{SCR } [pnum] \]

| [LST?] | Gets a catalog of program numbers or a specific program listing (up to 3000 commands).  

\[ \text{LST? } [pnum [, index [, size ]] ] \]

| DO | Executes specified programs.  

\[ \text{DO } pnum [, pnum ... [, pnum ] ... ] \]

| RU | Executes programs sequentially.  

\[ \text{RU } start, stop \]

| [PA] | Pauses command execution or internal memory program execution.  

\[ \text{PA } [wait] \]

| [VAR] | Defines an internal memory variable, and sets the value.  

\[ \text{VAR } Type, N, Value \]

| [VAR?] | Reads the value of the internal memory variable.  

\[ \text{VAR? } Type, N \]
Programming Examples
Using Program Memory

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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>This line is required to use the VISA COM library.</td>
</tr>
<tr>
<td>5 to 11</td>
<td>Establishes the connection with the Keysight B1500, resets the B1500, and sets the data output format. Also declares the SMUs used for measurement.</td>
</tr>
<tr>
<td>12 to 15</td>
<td>Declares variables used to set measurement conditions and sets the value.</td>
</tr>
<tr>
<td>17 to 25</td>
<td>Stores program in the internal memory 1, and displays it on the console window.</td>
</tr>
<tr>
<td>27 to 38</td>
<td>Stores program in the internal memory 2, and displays it on the console window.</td>
</tr>
</tbody>
</table>
Programming Examples
Using Program Memory

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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 to 52</td>
<td>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.</td>
</tr>
<tr>
<td>53 to 56</td>
<td>Applies 0 V from all channels, disables SMUs, and closes the connection with the Keysight B1500.</td>
</tr>
<tr>
<td>58 to 62</td>
<td>Displays a message box to show an error message if the error is detected.</td>
</tr>
<tr>
<td>64 to 69</td>
<td>Reads the program lists stored in the internal program memory, and displays it on the console window.</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 14</td>
<td>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.</td>
</tr>
<tr>
<td>16 to 24</td>
<td>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.</td>
</tr>
<tr>
<td>26 to 37</td>
<td>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.</td>
</tr>
</tbody>
</table>
Programming Examples
Using Program Memory

```
' changes vd and vg and performs measurement again
session.WriteString("VAR1,0,3" & vbCrLf)    ' R0=vd
For i = 1 To 2
    session.WriteString("DO" & i & vbCrLf)
    session.WriteString("*OPC?" & vbCrLf) : ret = session.ReadString(1 + 2)
    session.WriteString("ERR? 1" & vbCrLf) : ret = session.ReadString(4 + 2)
    If ret <> 0 Then session.WriteString("DZ" & vbCrLf) : 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
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>39 to 49</td>
<td>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.</td>
</tr>
</tbody>
</table>

**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 Keysight B1500 can be equipped with eight trigger ports that will be used for different purposes individually. The Keysight 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 2-74. The following commands are available for the trigger function.

<table>
<thead>
<tr>
<th>Command</th>
<th>Function and Syntax</th>
</tr>
</thead>
<tbody>
<tr>
<td>TGP</td>
<td>Sets the trigger port for the specified terminal.</td>
</tr>
<tr>
<td></td>
<td>TGP ( port, terminal, polarity[, type])</td>
</tr>
<tr>
<td>TGPC</td>
<td>Clears the trigger setting of the specified ports.</td>
</tr>
<tr>
<td></td>
<td>TGPC [port ... [,port] ... ]</td>
</tr>
<tr>
<td>TGSI</td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>TGSI ( mode)</td>
</tr>
<tr>
<td>TGSO</td>
<td>Selects the trigger type, edge or gate, for the Step Output Setup Completion trigger output set by the TGP ( port, 2, polarity, 2) command.</td>
</tr>
<tr>
<td></td>
<td>TGSO ( mode)</td>
</tr>
<tr>
<td>TGXO</td>
<td>Selects the trigger type, edge or gate, for the Measurement Completion trigger output set by the TGP ( port, 2, polarity, 1) command.</td>
</tr>
<tr>
<td></td>
<td>TGXO ( mode)</td>
</tr>
<tr>
<td>TGMO</td>
<td>Selects the trigger type, edge or gate, for the Step Measurement Completion trigger output set by the TGP ( port, 2, polarity, 3) command.</td>
</tr>
<tr>
<td></td>
<td>TGMO ( mode)</td>
</tr>
<tr>
<td>TM3</td>
<td>Enables the trigger set by the TGP ( port, terminal, polarity, 1) command.</td>
</tr>
</tbody>
</table>
The following commands are also available to send a trigger or wait for an external trigger input. Refer to “Using Trigger Function” on page 2-80.

<table>
<thead>
<tr>
<th>Command</th>
<th>Function and Syntax</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS</td>
<td>Causes the Keysight B1500 to send a trigger signal from the Ext Trig Out terminal. OS</td>
</tr>
<tr>
<td>OSX a</td>
<td>Causes the Keysight B1500 to send a trigger signal from the specified port. OSX port [, level]</td>
</tr>
<tr>
<td>WS</td>
<td>Enters a wait state until the Keysight B1500 receives an external trigger via the Ext Trig In terminal. WS [mode]</td>
</tr>
<tr>
<td>WSX a</td>
<td>Enters a wait state until the Keysight B1500 receives an external trigger via the specified port. WSX port [, mode]</td>
</tr>
<tr>
<td>PA</td>
<td>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]</td>
</tr>
<tr>
<td>PAX a</td>
<td>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]</td>
</tr>
<tr>
<td>TGP</td>
<td>Sets trigger port to the specified terminal. TGP port, terminal, polarity [, type]</td>
</tr>
<tr>
<td>TM3</td>
<td>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.</td>
</tr>
</tbody>
</table>

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 Keysight B1500A and the Keysight 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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>This line is required to use the VISA COM library.</td>
</tr>
<tr>
<td>5 to 20</td>
<td>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.</td>
</tr>
</tbody>
</table>
unit1.WriteString("CL" & vbCrLf)  '22
unit2.WriteString("CL" & vbCrLf)
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:\Keysight\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
    unit1.WriteString("FMT 1" & vbCrLf)
    unit1.WriteString("TM 1" & vbCrLf)
    unit1.WriteString("AV -1" & vbCrLf)
    unit1.WriteString("MM 1," & t(0) & vbCrLf)
    unit2.WriteString("DV" & t(3) & ",0," & vs & "," & icomp & vbCrLf)
    unit2.WriteString("DV" & t(2) & ",0," & vs & "," & icomp & vbCrLf)
    unit1.WriteString("DV" & t(0) & ",0," & vd & "," & icomp & vbCrLf)
    unit1.WriteString("DV" & t(1) & ",0," & vg & "," & igcomp & vbCrLf)              '53

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 to 28</td>
<td>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.</td>
</tr>
<tr>
<td>31 to 40</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>42 to 44</td>
<td>Declares variables used to perform measurement, and sets the value.</td>
</tr>
<tr>
<td>46 to 49</td>
<td>Sets the data output format, trigger mode, A/D converter, and measurement mode.</td>
</tr>
<tr>
<td>50 to 51</td>
<td>Unit2 applies voltage to the source and substrate terminals of a device.</td>
</tr>
<tr>
<td>52 to 53</td>
<td>Unit1 applies voltage to the gate and drain terminals of a device.</td>
</tr>
</tbody>
</table>
Programming Examples
Using Trigger Function

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>55 to 57</td>
<td>Unit1 waits for a trigger sent to the Ext Trig In terminal, and starts measurement by receiving a trigger sent by Unit2.</td>
</tr>
<tr>
<td>59 to 61</td>
<td>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.</td>
</tr>
<tr>
<td>62 to 64</td>
<td>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.</td>
</tr>
<tr>
<td>66 to 71</td>
<td>Waits for the operation complete and checks if an error occurred. If an error is detected, forces 0 V and goes to Check_err.</td>
</tr>
<tr>
<td>73 to 77</td>
<td>Reads measurement data and stores it into the data array.</td>
</tr>
<tr>
<td>79 to 81</td>
<td>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.</td>
</tr>
</tbody>
</table>
Programming Examples
Using Trigger Function

Check_err:

unit1.WriteString("EMG? " & err & vbCrLf) : msg = unit1.ReadString(256)
MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, ")
Exit Sub

End Sub

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)

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)
    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
    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

End Module

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>83 to 86</td>
<td>Displays a message box to show an error message if the error is detected.</td>
</tr>
<tr>
<td>90 to 114</td>
<td>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.</td>
</tr>
</tbody>
</table>

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:\Keysight\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

    unit1.WriteString("FMT 1" & vbCrLf)
    unit1.WriteString("AV -1" & vbCrLf)
    unit1.WriteString("WT 0, 0.01" & vbCrLf)
    unit1.WriteString("TM 3" & vbCrLf)
    unit1.WriteString("TGMO 1" & vbCrLf) '21
```

**Line Description**

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 11</td>
<td>Declares variables used in the Main of Table 3-31. And sets the proper values.</td>
</tr>
<tr>
<td>12 to 14</td>
<td>Declares variables used to perform measurement, and sets the value.</td>
</tr>
<tr>
<td>15 to 17</td>
<td>Unit1 sets the data output format, A/D converter, and sweep delay time.</td>
</tr>
<tr>
<td>18 to 19</td>
<td>Unit1 sets the Start Measurement trigger input for the Ext Trig In terminal.</td>
</tr>
<tr>
<td>20 to 21</td>
<td>Unit1 sets the Step Measurement Completion trigger output for the Ext Trig Out terminal.</td>
</tr>
</tbody>
</table>
Programming Examples
Using Trigger Function

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, 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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 to 25</td>
<td>Unit1 applies voltage to device, and sets the sweep source, the measurement mode, and the time stamp data output.</td>
</tr>
<tr>
<td>27 to 29</td>
<td>Unit2 sets the data output format, A/D converter, and sweep delay time.</td>
</tr>
<tr>
<td>30 to 32</td>
<td>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.</td>
</tr>
<tr>
<td>33 to 34</td>
<td>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.</td>
</tr>
<tr>
<td>35 to 38</td>
<td>Unit2 applies voltage to device, and sets the sweep source, the measurement mode, and the time stamp data output.</td>
</tr>
<tr>
<td>39</td>
<td>Resets the time stamp.</td>
</tr>
<tr>
<td>40</td>
<td>Unit2 starts measurement, and sends a gate trigger to the Ext Trig Out terminal. Then Unit1 starts measurement.</td>
</tr>
<tr>
<td>42 to 46</td>
<td>Waits for the operation complete. Goes to Check_err if an error is detected.</td>
</tr>
</tbody>
</table>
Using Trigger Function

Measurement Result Example

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>48 to 62</td>
<td>Reads measurement data and stores it into the data array.</td>
</tr>
<tr>
<td>64 to 65</td>
<td>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.</td>
</tr>
<tr>
<td>68 to 73</td>
<td>Applies 0 V from all channels and displays a message box to show an error message.</td>
</tr>
</tbody>
</table>
Programming Examples
Using Trigger Function

This is a program written in the HP BASIC language, and performs the following.

1. Sets the Keysight 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 Keysight B1500 channel output

This is a part of the program used to synchronize the Keysight 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     !
```

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Assigns the I/O path to control the B1500.</td>
</tr>
<tr>
<td>50 to 130</td>
<td>Sets the value of the variables for source setup and so on.</td>
</tr>
<tr>
<td>140 to 160</td>
<td>Add program lines to perform initialization and measurement setup of the other instrument.</td>
</tr>
</tbody>
</table>
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 Keysight B1500 operation with the operation of the other instrument, add program lines to set it to the measurement ready and trigger wait condition.
Programming Examples
Using Trigger Function

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>320</td>
<td>OUTPUT @B1500;&quot;XE&quot;</td>
</tr>
<tr>
<td>330</td>
<td>!</td>
</tr>
<tr>
<td>340</td>
<td>!B1500 starts measurement. Then B1500 sends negative gate trigger to the other instrument.</td>
</tr>
<tr>
<td>350</td>
<td>!Then the instrument should start measurement.</td>
</tr>
<tr>
<td>360</td>
<td>!</td>
</tr>
<tr>
<td>370</td>
<td>FOR I=1 TO Ib_num</td>
</tr>
<tr>
<td>380</td>
<td>ENTER @B1500 USING &quot;;#,3X,12D,X&quot;;Ic</td>
</tr>
<tr>
<td>390</td>
<td>PRINT &quot;Ic= &quot;;Ic*1000;&quot;[mA]&quot;</td>
</tr>
<tr>
<td>400</td>
<td>!</td>
</tr>
<tr>
<td>410</td>
<td>!Measurement data of the other instrument should be read.</td>
</tr>
<tr>
<td>420</td>
<td>!And the data should be displayed.</td>
</tr>
<tr>
<td>430</td>
<td>!</td>
</tr>
<tr>
<td>440</td>
<td>!The instrument must be set to the measurement ready and trigger wait condition.</td>
</tr>
<tr>
<td>450</td>
<td>!</td>
</tr>
<tr>
<td>460</td>
<td>!The instrument must send trigger to B1500. B1500 will start a step source output by the trigger, and perform a step measurement.</td>
</tr>
<tr>
<td>470</td>
<td>!</td>
</tr>
<tr>
<td>480</td>
<td>NEXT I</td>
</tr>
<tr>
<td>490</td>
<td>!</td>
</tr>
<tr>
<td>500</td>
<td>OUTPUT @B1500;&quot;CL&quot;</td>
</tr>
</tbody>
</table>

**Line No.**

- 320 Starts sweep measurement, and performs a step measurement. When the Keysight 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 Keysight 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 Keysight 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.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sets the time stamp function</td>
<td>TSC</td>
<td>onoff</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forces DC voltage from SMU</td>
<td>TDV</td>
<td>chnum,range,output[,Icomp]</td>
</tr>
<tr>
<td>Forces DC current from SMU</td>
<td>TDI</td>
<td>chnum,range,output[,Vcomp]</td>
</tr>
<tr>
<td>Forces DC bias from CMU</td>
<td>TDCV</td>
<td>chnum,output</td>
</tr>
<tr>
<td>Forces AC signal from CMU</td>
<td>TACV</td>
<td>chnum,output</td>
</tr>
<tr>
<td>Performs high speed spot current measurement</td>
<td>TTI</td>
<td>chnum,output</td>
</tr>
<tr>
<td>Performs high speed spot voltage measurement</td>
<td>TTV</td>
<td>chnum,range</td>
</tr>
<tr>
<td>Performs high speed spot C measurement</td>
<td>TTC</td>
<td>chnum,mode[,range]</td>
</tr>
<tr>
<td>Just returns the time data</td>
<td>TSQ</td>
<td></td>
</tr>
</tbody>
</table>
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**

<table>
<thead>
<tr>
<th>Id (uA), Status</th>
<th>status = 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>type = 1</td>
<td></td>
</tr>
<tr>
<td>mode = 1</td>
<td></td>
</tr>
<tr>
<td>channel = 5</td>
<td></td>
</tr>
<tr>
<td>sign = 0</td>
<td></td>
</tr>
<tr>
<td>range = 0.0001</td>
<td></td>
</tr>
<tr>
<td>count = 12010</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 11</td>
<td>Declares variables used through the project. And sets the proper values.</td>
</tr>
<tr>
<td>13 to 18</td>
<td>Declares variables and sets the value.</td>
</tr>
<tr>
<td>20 to 22</td>
<td>Sets the data output format and A/D converter. Also sets the SMU filter off.</td>
</tr>
<tr>
<td>23 to 26</td>
<td>Applies voltage to device.</td>
</tr>
<tr>
<td>28 to 29</td>
<td>Checks if an error occurred. If an error is detected, forces 0 V and goes to Check.err.</td>
</tr>
<tr>
<td>30 to 31</td>
<td>Performs the high-speed spot measurement. And stores the returned binary data (four bytes) into the dat array variable.</td>
</tr>
<tr>
<td>33 to 41</td>
<td>Picks up the elements, status, type, mode, sign, rng, count, and chan, included in the returned binary data.</td>
</tr>
</tbody>
</table>
Dim range As Double
If mode = 1 Then ' current range
    If rng < 21 Then range = 10 ^ (rng - 20)
    If rng = 21 Then range = 2
    If rng = 22 Then range = 20
    If rng = 23 Then range = 40
Else ' voltage range
    If rng = 8 Then range = 0.5
    If rng = 9 Then range = 5
    If rng = 10 Then range = 0.2
    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
    If rng = 16 Then range = 500
    If rng = 17 Then range = 1500
    If rng = 18 Then range = 3000
End If

'value = value & Chr(13) & Chr(10) & "status = " & status
'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
If type = 0 Then meas = count * range / 20000 'source data
If type = 1 Then meas = count * range / 50000 'measurement data

Dim meas As Double
If type = 0 Then meas = count * range / 20000 'source data
If type = 1 Then meas = count * range / 50000 'measurement data

Dim meas As Double
If type = 0 Then meas = count * range / 20000 'source data
If type = 1 Then meas = count * range / 50000 'measurement data

Check_err:
    session.WriteString("EMG? " & err & vbCrLf) : msg = session.ReadString(256)
    MsgBox("Instrument error: " & err & Chr(10) & msg, vbOKOnly, ")
End Sub

Line Description

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>43 to 61</td>
<td>Checks the measurement range or output range setting.</td>
</tr>
<tr>
<td>63 to 69</td>
<td>If you want to display and save the binary data elements, delete ‘ at the top of the lines.</td>
</tr>
<tr>
<td>71 to 75</td>
<td>Calculates the measurement data or source output data. And, stores the data into the data array.</td>
</tr>
<tr>
<td>77 to 79</td>
<td>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.</td>
</tr>
<tr>
<td>81 to 84</td>
<td>Displays a message box to show an error message if the error is detected.</td>
</tr>
</tbody>
</table>
Using Programs for 4142B

This section describes the program modification example to use a program created for the Keysight 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 Keysight 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 "#;12D;X";Mdata
160    PRINT "Id(A)=";Mdata
170    OUTPUT @Hp4142;"CL"
180    END
```

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Assigns the I/O path to control the 4142B.</td>
</tr>
</tbody>
</table>
Programming Examples
Using Programs for 4142B

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>Specifies the data output format.</td>
</tr>
<tr>
<td>100 to 130</td>
<td>Enables the source/measurement channels, and forces voltage.</td>
</tr>
<tr>
<td>140 to 180</td>
<td>Executes the measurement, reads and displays the measurement data, and disables channels.</td>
</tr>
</tbody>
</table>

The program modified to control the B1500:

```plaintext
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
```

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Change GPIB address, if necessary.</td>
</tr>
<tr>
<td>21, 81</td>
<td>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.</td>
</tr>
<tr>
<td>82 to 84</td>
<td>Add program line to set the channel map. This example transfers the Sub value to the variable S_ch used in the original program.</td>
</tr>
</tbody>
</table>
Using Programs for 4155B/4156B/4155C/4156C

This section describes the program modification example to use a FLEX command program created for the Keysight 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 Keysight 4155/4156” on page 1-65.

The following program examples show a modified measurement program, which performs a high-speed spot measurement.
Programming Examples
Using Programs for 4155B/4156B/4155C/4156C

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

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Assigns the I/O path to control the 4155/4156.</td>
</tr>
<tr>
<td>90</td>
<td>Enters the FLEX command mode.</td>
</tr>
<tr>
<td>100</td>
<td>Specifies the data output format.</td>
</tr>
<tr>
<td>110 to 150</td>
<td>Enables the source/measurement channels, and forces voltage.</td>
</tr>
<tr>
<td>160 to 210</td>
<td>Executes the measurement, reads and displays the measurement data, and disables channels.</td>
</tr>
</tbody>
</table>
The program modified to control the B1500:

```plaintext
10 ASSIGN @Hp415x TO 717                 !<<<<
20 INTEGER G_ch,D_ch,S_ch,B_ch         !<<<<
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
```

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Change GPIB address, if necessary.</td>
</tr>
<tr>
<td>21, 81</td>
<td>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.</td>
</tr>
<tr>
<td>82</td>
<td>Add program line to set the channel map. This example transfers the Sub value to the variable B_ch used in the original program.</td>
</tr>
<tr>
<td>90</td>
<td>Remove the US command. This command is not required.</td>
</tr>
<tr>
<td>100</td>
<td>Change the FMT command parameter value.</td>
</tr>
<tr>
<td>40, 110, 120</td>
<td>This example uses the GNDU instead of the SMU1. So remove the program lines that include the variable S_ch (SMU1).</td>
</tr>
<tr>
<td>170</td>
<td>Remove the RMD? command. This command is not required.</td>
</tr>
</tbody>
</table>
Programming Examples
Using Programs for 4155B/4156B/4155C/4156C
4 Command Reference
Command Reference

This chapter is the complete reference of the GPIB commands of the Keysight B1500:

- “Command Summary”
- “Command Parameters”
- “Command Reference”

Abbreviations in this chapter

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASU</td>
<td>Atto Sense and Switch Unit (E5288A)</td>
</tr>
<tr>
<td>CMU, MFCMU</td>
<td>Multi Frequency Capacitance Measurement Unit (B1520A)</td>
</tr>
<tr>
<td>DHC, DHCSMU</td>
<td>Dual HCSMU</td>
</tr>
<tr>
<td>HC, HCSMU</td>
<td>High Current SMU (B1512A)</td>
</tr>
<tr>
<td>HP, HPSMU</td>
<td>High Power SMU (B1510A)</td>
</tr>
<tr>
<td>HR, HRSMU</td>
<td>High Resolution SMU (B1517A)</td>
</tr>
<tr>
<td>HV, HVSMU</td>
<td>High Voltage SMU (B1513A, B1513B or B1513C)</td>
</tr>
<tr>
<td>HVMC, HVMCU</td>
<td>High Voltage Medium Current Unit (resource using N1266A)</td>
</tr>
<tr>
<td>MC, MCSMU</td>
<td>Medium Current SMU (B1514A)</td>
</tr>
<tr>
<td>MP, MPSMU</td>
<td>Medium Power SMU (B1511A or B1511B)</td>
</tr>
<tr>
<td>N1265A</td>
<td>Ultra high current expander/fixture</td>
</tr>
<tr>
<td>N1266A</td>
<td>HVSMU current expander</td>
</tr>
<tr>
<td>N1268A</td>
<td>Ultra high voltage expander</td>
</tr>
<tr>
<td>SCUU</td>
<td>SMU CMU Unify Unit (N1301A)</td>
</tr>
<tr>
<td>SMU</td>
<td>Source and Monitor Unit</td>
</tr>
<tr>
<td>SPGU, HVSPGU</td>
<td>High Voltage Semiconductor Pulse Generator Unit (B1525A)</td>
</tr>
<tr>
<td>UHC, UHCU</td>
<td>Ultra High Current Unit (resource using N1265A)</td>
</tr>
<tr>
<td>UHV, UHVU</td>
<td>Ultra High Voltage Unit (resource using N1268A)</td>
</tr>
</tbody>
</table>
## Command Summary

The following table summarizes the Keysight B1500 GPIB commands.

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<tr>
<th>Category</th>
<th>Command</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reset</td>
<td>*RST</td>
<td>Resets the B1500 to the initial settings.</td>
</tr>
<tr>
<td>Diagnostics</td>
<td>DIAG?</td>
<td>Performs diagnostics, and returns the result.</td>
</tr>
<tr>
<td>Self-test</td>
<td>*TST?</td>
<td>Performs the self-test, and returns the result.</td>
</tr>
<tr>
<td></td>
<td>RCV</td>
<td>Enables the channels that fail self-test.</td>
</tr>
<tr>
<td>Self Calibration</td>
<td>CA</td>
<td>Performs self-calibration.</td>
</tr>
<tr>
<td></td>
<td>*CAL?</td>
<td>Performs self-calibration, and returns the result.</td>
</tr>
<tr>
<td></td>
<td>CM</td>
<td>Sets SMU auto-calibration ON or OFF.</td>
</tr>
<tr>
<td>Interlock</td>
<td>INTLKVTH/ INTLKVTH?</td>
<td>Sets or returns the allowable voltage for the interlock open condition.</td>
</tr>
<tr>
<td>MFCMU Data Correction</td>
<td>ADJ/ADJ?</td>
<td>Sets the phase compensation data.</td>
</tr>
<tr>
<td></td>
<td>CLCORR</td>
<td>Clears the frequency list for the correction data measurement.</td>
</tr>
<tr>
<td></td>
<td>CORRL/CORRL?</td>
<td>Adds or returns the frequency for the correction data measurement.</td>
</tr>
<tr>
<td></td>
<td>DCORR/DCORR?</td>
<td>Sets or returns the calibration/reference value of the standard.</td>
</tr>
<tr>
<td></td>
<td>CORR?</td>
<td>Performs the open/short/load correction data measurement.</td>
</tr>
<tr>
<td></td>
<td>CORRST/CORRST?</td>
<td>Sets or returns the open/short/load correction function ON/OFF.</td>
</tr>
<tr>
<td></td>
<td>CORRDT/CORRDT?</td>
<td>Sets or returns the open/short/load correction data.</td>
</tr>
<tr>
<td>Abort</td>
<td>AB</td>
<td>Aborts the present operation and subsequent command execution.</td>
</tr>
<tr>
<td>Pause/Continue</td>
<td>PA/PAX</td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>TM</td>
<td>Sets the event to start measurement or to release the B1500 from the paused status set by the PA or PAX command.</td>
</tr>
<tr>
<td>Data Output</td>
<td>FMT</td>
<td>Specifies the measurement data output format and the data terminator.</td>
</tr>
<tr>
<td></td>
<td>BC</td>
<td>Clears the B1500 output data buffer that stores measurement data and/or query command response data.</td>
</tr>
<tr>
<td>Category</td>
<td>Command</td>
<td>Summary</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Timer Clear</td>
<td>TSR</td>
<td>Clears the timer count.</td>
</tr>
<tr>
<td>Time Stamp</td>
<td>TSC</td>
<td>Enables the time stamp function. This function is <em>not</em> 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.</td>
</tr>
<tr>
<td></td>
<td>TSQ</td>
<td>Returns the time data from timer reset (TSR) to this command.</td>
</tr>
<tr>
<td>ASU Control</td>
<td>SAL</td>
<td>Disables the connection status indicator of the ASU.</td>
</tr>
<tr>
<td></td>
<td>SAP</td>
<td>Sets the input-output path of the ASU.</td>
</tr>
<tr>
<td></td>
<td>SAR</td>
<td>Enables 1 pA range for the auto ranging operation.</td>
</tr>
<tr>
<td>SCUU Control</td>
<td>SSL</td>
<td>Disables the connection status indicator of the SCUU.</td>
</tr>
<tr>
<td></td>
<td>SSP</td>
<td>Sets the input-output path of the SCUU.</td>
</tr>
<tr>
<td>SMU Series Resistor</td>
<td>SSR</td>
<td>Sets the internal series resistor of the specified SMU to ON or OFF.</td>
</tr>
<tr>
<td>SMU Filter</td>
<td>FL</td>
<td>Sets the internal filter of the specified SMUs to ON or OFF.</td>
</tr>
<tr>
<td>SMU Max. Output</td>
<td>LIM/LIM?</td>
<td>Sets/returns the maximum output limit value effective for all SMUs.</td>
</tr>
<tr>
<td>Channel Control</td>
<td>ACH</td>
<td>Translates a channel number to another channel number.</td>
</tr>
<tr>
<td></td>
<td>CN/CNX</td>
<td>Enables the specified channels by setting the output switches to ON.</td>
</tr>
<tr>
<td></td>
<td>CL</td>
<td>Disables the specified channels by setting the output switches to OFF.</td>
</tr>
<tr>
<td></td>
<td>IN</td>
<td>Sets the specified channels to 0 V.</td>
</tr>
<tr>
<td></td>
<td>DZ</td>
<td>Stores the setup of the channels, and sets the output to 0 V.</td>
</tr>
<tr>
<td></td>
<td>PCH/PCH?</td>
<td>Sets/returns the dual HCSMU (DHCSMU) operating conditions.</td>
</tr>
<tr>
<td></td>
<td>RZ</td>
<td>Returns the channel to the settings that are stored by the DZ command and clears the stored channel settings.</td>
</tr>
<tr>
<td></td>
<td>WAT</td>
<td>Sets the source wait time and the measurement wait time.</td>
</tr>
<tr>
<td>Category</td>
<td>Command</td>
<td>Summary</td>
</tr>
<tr>
<td>-------------------------</td>
<td>---------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SMU Integration Time and Averaging</td>
<td>AV</td>
<td>Sets the number of samples for averaging of the high-speed ADC (A/D converter). Not effective for the high-resolution ADC.</td>
</tr>
<tr>
<td></td>
<td>AAD</td>
<td>Selects the type of A/D converter.</td>
</tr>
<tr>
<td></td>
<td>AIT</td>
<td>Sets the operation mode and the setup parameter of the ADC.</td>
</tr>
<tr>
<td></td>
<td>AITM/AITM?</td>
<td>Only for the current measurement by using HRSMU. Sets/returns the PLC operation type of the high-resolution ADC.</td>
</tr>
<tr>
<td></td>
<td>AZ</td>
<td>Enables or disables the ADC zero function.</td>
</tr>
<tr>
<td>High Speed Spot Measurement</td>
<td>TC</td>
<td>Measures impedance (TC), current (TI), current and voltage (TIV), voltage (TV), AC level (TMACV), or DC bias (TMDCV), and returns the measured data.</td>
</tr>
<tr>
<td></td>
<td>TI</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TIV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TMACV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TMDCV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TTC</td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>TTI</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TTIV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TTV</td>
<td></td>
</tr>
<tr>
<td>Source Output</td>
<td>DI</td>
<td>Applies DC current from the specified SMU.</td>
</tr>
<tr>
<td></td>
<td>DV</td>
<td>Applies DC voltage from the specified SMU.</td>
</tr>
<tr>
<td></td>
<td>TDI</td>
<td>Applies DC current (TDI) or voltage (TDV) from the specified SMU, and returns the time data from timer reset to the start of output.</td>
</tr>
<tr>
<td></td>
<td>TDV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FC</td>
<td>Sets the output signal frequency of the MFCMU.</td>
</tr>
<tr>
<td></td>
<td>ACV</td>
<td>Sets the output signal level of the MFCMU, and starts AC voltage output.</td>
</tr>
<tr>
<td></td>
<td>DCV</td>
<td>Applies DC voltage from the MFCMU.</td>
</tr>
<tr>
<td></td>
<td>TACV</td>
<td>Applies AC (TACV) or DC (TDCV) voltage from the MFCMU, and returns the time data from timer reset to the start of output.</td>
</tr>
<tr>
<td></td>
<td>TDCV</td>
<td></td>
</tr>
</tbody>
</table>
### Command Summary

<table>
<thead>
<tr>
<th>Category</th>
<th>Command</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>MFCMU Setup</td>
<td>FC</td>
<td>Sets the output signal frequency of the MFCMU.</td>
</tr>
<tr>
<td></td>
<td>ACV</td>
<td>Sets the output signal level of the MFCMU, and starts AC voltage output.</td>
</tr>
<tr>
<td></td>
<td>ACT</td>
<td>Sets the A/D converter of the MFCMU.</td>
</tr>
<tr>
<td></td>
<td>IMP</td>
<td>Specifies the impedance measurement parameters. For the ASCII data output. Not available for FMT 3/4/13/14.</td>
</tr>
<tr>
<td></td>
<td>LMN</td>
<td>Enables or disables data output of the OSC level/DC bias monitor values.</td>
</tr>
<tr>
<td>Measurement Mode</td>
<td>MM</td>
<td>Sets the measurement mode and measurement channels.</td>
</tr>
<tr>
<td>Measurement Execution</td>
<td>XE</td>
<td>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.</td>
</tr>
<tr>
<td>Measurement Setup</td>
<td>CMM</td>
<td>Sets the SMU measurement operation mode.</td>
</tr>
<tr>
<td></td>
<td>PAD</td>
<td>Enables or disables the SMU parallel measurements. This is effective for the spot (MM1), sweep (MM2), and sampling (MM10) measurements.</td>
</tr>
<tr>
<td></td>
<td>RC</td>
<td>Specifies the impedance (RC), current (RI), or voltage (RV) measurement ranging mode for the measurement other than the high speed spot measurement.</td>
</tr>
<tr>
<td></td>
<td>RI</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RM</td>
<td>Sets the range selection rule for the auto ranging current measurement.</td>
</tr>
<tr>
<td>Staircase Sweep Source Setup</td>
<td>WT</td>
<td>Sets the hold time, delay time, step delay time, and trigger delay time.</td>
</tr>
<tr>
<td></td>
<td>WI</td>
<td>Sets the staircase current sweep source.</td>
</tr>
<tr>
<td></td>
<td>WV</td>
<td>Sets the staircase voltage sweep source.</td>
</tr>
<tr>
<td>Automatic Sweep Stop</td>
<td>WM</td>
<td>Sets the automatic abort function.</td>
</tr>
<tr>
<td>Category</td>
<td>Command</td>
<td>Summary</td>
</tr>
<tr>
<td>----------------------------</td>
<td>---------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Output Comparison</td>
<td>SOPC/SOPC?</td>
<td>Enables the output power comparison function, and returns the comparison reference value set by the SOPC command.</td>
</tr>
<tr>
<td></td>
<td>SOVC/SOVC?</td>
<td>Enables the output voltage comparison function, and returns the comparison reference value set by the SOVC command.</td>
</tr>
<tr>
<td>Synchronous Sweep Source Setup</td>
<td>WSI</td>
<td>Sets the synchronous current sweep source used with the WI or PWI command.</td>
</tr>
<tr>
<td></td>
<td>WSV</td>
<td>Sets the synchronous voltage sweep source used with the WV or PWV command.</td>
</tr>
<tr>
<td>Multi channel Sweep Source Setup</td>
<td>WNX</td>
<td>Sets the synchronous current sweep source or synchronous voltage sweep source used with the WI or WV command.</td>
</tr>
<tr>
<td>Pulsed Source Setup</td>
<td>PT</td>
<td>Sets the hold time, pulse width, pulse period, and trigger output delay time.</td>
</tr>
<tr>
<td></td>
<td>PI</td>
<td>Sets the pulsed current source.</td>
</tr>
<tr>
<td></td>
<td>PV</td>
<td>Sets the pulsed voltage source.</td>
</tr>
<tr>
<td>Pulsed Sweep Source Setup</td>
<td>PT</td>
<td>Sets the hold time, pulse width, pulse period, and trigger output delay time.</td>
</tr>
<tr>
<td></td>
<td>PWI</td>
<td>Sets the pulsed current sweep source.</td>
</tr>
<tr>
<td></td>
<td>PWV</td>
<td>Sets the pulsed voltage sweep source.</td>
</tr>
<tr>
<td>Multi channel Setup Clear</td>
<td>WNCC</td>
<td>Clears setup of all channels defined for the multi channel measurement.</td>
</tr>
<tr>
<td>Multi channel Pulsed Source and Multi channel Pulsed Sweep Source Setup</td>
<td>MCPT</td>
<td>Sets the hold time, pulse width, measurement timing, etc.</td>
</tr>
<tr>
<td></td>
<td>MCPNT</td>
<td>Sets the pulse width and the delay time.</td>
</tr>
<tr>
<td></td>
<td>MCPNX</td>
<td>Sets the pulsed bias source.</td>
</tr>
<tr>
<td></td>
<td>MCPWS</td>
<td>Sets the sweep mode and the number of sweep steps.</td>
</tr>
<tr>
<td></td>
<td>MCPWNX</td>
<td>Sets the pulsed sweep source.</td>
</tr>
<tr>
<td>Quasi-pulsed Spot Measurement/Source Setup</td>
<td>BDM</td>
<td>Specifies the detection interval, and either voltage or current measurement.</td>
</tr>
<tr>
<td></td>
<td>BDT</td>
<td>Specifies the hold time and delay time.</td>
</tr>
<tr>
<td></td>
<td>BDV</td>
<td>Sets the quasi-pulsed voltage source.</td>
</tr>
</tbody>
</table>
### Command Summary

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<tr>
<th>Category</th>
<th>Command</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sampling Measurement/Source Setup</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MCC</td>
<td>Clears the settings of the constant sources defined by MI, MV, or MSP.</td>
</tr>
<tr>
<td></td>
<td>MI</td>
<td>Sets the current source synchronized with the sampling measurement.</td>
</tr>
<tr>
<td></td>
<td>MSC</td>
<td>Sets the automatic abort function.</td>
</tr>
<tr>
<td></td>
<td>ML</td>
<td>Sets the sampling mode, linear or logarithm.</td>
</tr>
<tr>
<td></td>
<td>MT</td>
<td>Sets the timing parameters.</td>
</tr>
<tr>
<td></td>
<td>MV</td>
<td>Sets the voltage source synchronized with the sampling measurement.</td>
</tr>
<tr>
<td></td>
<td>MSP</td>
<td>Sets the SPGU channel synchronized with the sampling measurement, and its output after the measurement.</td>
</tr>
<tr>
<td><strong>Binary Search Measurement/Source Setup</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BSM</td>
<td>Sets the source output control mode and the automatic abort function.</td>
</tr>
<tr>
<td></td>
<td>BST</td>
<td>Specifies the hold time and delay time.</td>
</tr>
<tr>
<td></td>
<td>BSVM</td>
<td>Selects the data output mode.</td>
</tr>
<tr>
<td></td>
<td>BSI</td>
<td>Sets the current source channel.</td>
</tr>
<tr>
<td></td>
<td>BSSI</td>
<td>Sets the synchronous current source channel.</td>
</tr>
<tr>
<td></td>
<td>BGV</td>
<td>Sets the voltage monitor channel.</td>
</tr>
<tr>
<td></td>
<td>BSV</td>
<td>Sets the voltage source channel.</td>
</tr>
<tr>
<td></td>
<td>BSSV</td>
<td>Sets the synchronous voltage source channel.</td>
</tr>
<tr>
<td></td>
<td>BGI</td>
<td>Sets the current monitor channel.</td>
</tr>
<tr>
<td><strong>Linear Search Measurement/Source Setup</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LSTM</td>
<td>Specifies the hold time and delay time.</td>
</tr>
<tr>
<td></td>
<td>LSVM</td>
<td>Selects the data output mode.</td>
</tr>
<tr>
<td></td>
<td>LSI</td>
<td>Sets the current source channel.</td>
</tr>
<tr>
<td></td>
<td>LSSI</td>
<td>Sets the synchronous current source channel.</td>
</tr>
<tr>
<td></td>
<td>LGV</td>
<td>Sets the voltage monitor channel.</td>
</tr>
<tr>
<td></td>
<td>LSV</td>
<td>Sets the voltage source channel.</td>
</tr>
<tr>
<td></td>
<td>LSSV</td>
<td>Sets the synchronous voltage source channel.</td>
</tr>
<tr>
<td></td>
<td>LGI</td>
<td>Sets the current monitor channel.</td>
</tr>
<tr>
<td></td>
<td>LSM</td>
<td>Sets the automatic abort function.</td>
</tr>
<tr>
<td>Category</td>
<td>Command</td>
<td>Summary</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Quasi-static CV Measurement/</td>
<td>QSC</td>
<td>Sets the QSCV measurement operation.</td>
</tr>
<tr>
<td>Source Setup</td>
<td>QSO</td>
<td>Enables or disables the QSCV smart operation.</td>
</tr>
<tr>
<td></td>
<td>QSM</td>
<td>Sets the automatic abort function and the post measurement condition.</td>
</tr>
<tr>
<td></td>
<td>QSL</td>
<td>Enables or disables the data output and compensation for the leakage current.</td>
</tr>
<tr>
<td></td>
<td>QSZ</td>
<td>Enables or disables the capacitance offset cancel function. Or executes the capacitance offset measurement.</td>
</tr>
<tr>
<td></td>
<td>QST</td>
<td>Sets the integration time, hold time, and delay time.</td>
</tr>
<tr>
<td></td>
<td>QSR</td>
<td>Sets the current measurement range.</td>
</tr>
<tr>
<td></td>
<td>QSV</td>
<td>Specifies the voltage output channel and its source parameters.</td>
</tr>
<tr>
<td>MFCMU DC Bias Sweep Source</td>
<td>WDCV</td>
<td>Sets the DC bias sweep source by the MFCMU or SMU.</td>
</tr>
<tr>
<td>Setup</td>
<td>WMDCV</td>
<td>Sets the automatic abort function, also sets the post sweep condition.</td>
</tr>
<tr>
<td>MFCMU Frequency Sweep Source</td>
<td>WFC</td>
<td>Sets the frequency sweep source of the MFCMU.</td>
</tr>
<tr>
<td>Setup</td>
<td>WMFC</td>
<td>Sets the automatic abort function, also sets the post sweep condition.</td>
</tr>
<tr>
<td>MFCMU Sweep Source Setup</td>
<td>WACV</td>
<td>Sets the AC level sweep source of the MFCMU.</td>
</tr>
<tr>
<td></td>
<td>WMACV</td>
<td>Sets the automatic abort function, also sets the post sweep condition.</td>
</tr>
<tr>
<td></td>
<td>WTACV</td>
<td>Sets the hold time, delay time, step delay time, and trigger delay time.</td>
</tr>
<tr>
<td>MFCMU Pulsed Source Setup</td>
<td>PDCV</td>
<td>Sets the pulsed voltage source of the MFCMU.</td>
</tr>
<tr>
<td></td>
<td>PTDCV</td>
<td>Sets the hold time, pulse width, pulse period, and trigger output delay time.</td>
</tr>
<tr>
<td>MFCMU Pulsed Sweep Source</td>
<td>PWDCV</td>
<td>Sets the pulsed voltage sweep source of the MFCMU.</td>
</tr>
<tr>
<td>Setup</td>
<td>PTDCV</td>
<td>Sets the hold time, pulse width, pulse period, and trigger output delay time.</td>
</tr>
<tr>
<td>Category</td>
<td>Command</td>
<td>Summary</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-----------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>MFCMU Sampling Measurement/</td>
<td>MSC</td>
<td>Sets the automatic abort function.</td>
</tr>
<tr>
<td>Source Setup</td>
<td>MTDCV</td>
<td>Sets the timing parameters.</td>
</tr>
<tr>
<td></td>
<td>MDCV</td>
<td>Sets the voltage source synchronized with the sampling measurement.</td>
</tr>
<tr>
<td>SPGU Control</td>
<td>SIM/SIM?</td>
<td>Sets/returns the SPGU operation mode, PG or ALWG.</td>
</tr>
<tr>
<td></td>
<td>SPRM/SPRM?</td>
<td>Sets/returns the output operating mode (free run, duration, count).</td>
</tr>
<tr>
<td></td>
<td>SRP</td>
<td>Starts the SPGU output.</td>
</tr>
<tr>
<td></td>
<td>SPP</td>
<td>Stops all channel outputs and all trigger outputs of the SPGU.</td>
</tr>
<tr>
<td></td>
<td>SPUPD</td>
<td>Applies the setup of the specified SPGU channels.</td>
</tr>
<tr>
<td></td>
<td>SPST?</td>
<td>Returns the waveform output state of the SPGU.</td>
</tr>
<tr>
<td></td>
<td>ODSW/ODSW?</td>
<td>Sets/returns the pulse switch condition of the specified channel.</td>
</tr>
<tr>
<td></td>
<td>SER/SER?</td>
<td>Specifies/returns the load impedance connected to the channel.</td>
</tr>
<tr>
<td></td>
<td>CORRSER?</td>
<td>Measures the terminal voltage and returns the voltage and the calculated impedance. Also sets the impedance as same as SER.</td>
</tr>
<tr>
<td></td>
<td>STGP/STGP?</td>
<td>Sets/returns the trigger output condition of the specified channel.</td>
</tr>
<tr>
<td>SPGU Pulse Setup</td>
<td>SPPER/SPPER?</td>
<td>Sets/returns the pulse period for all SPGU channels.</td>
</tr>
<tr>
<td></td>
<td>SPM/SPM?</td>
<td>Sets/returns the output mode (2-level pulse, 3-level pulse, or DC bias) of the specified channel.</td>
</tr>
<tr>
<td></td>
<td>SPT/SPT?</td>
<td>Sets/returns the pulse timing parameter of the specified channel.</td>
</tr>
<tr>
<td></td>
<td>SPV/SPV?</td>
<td>Sets/returns the voltage parameter for the DC bias source or pulse signal source of the specified channel.</td>
</tr>
<tr>
<td>SPGU ALWG Setup</td>
<td>ALW/ALW?</td>
<td>Sets/returns the ALWG pattern data.</td>
</tr>
<tr>
<td></td>
<td>ALS/ALS?</td>
<td>Sets/returns the ALWG sequence data.</td>
</tr>
<tr>
<td>Signal monitor function</td>
<td>DSMPLSETUP</td>
<td>Sets the signal monitor function for the specified channel.</td>
</tr>
<tr>
<td></td>
<td>DSMPLARM</td>
<td>Sets the timing to start the signal monitor operation.</td>
</tr>
<tr>
<td></td>
<td>DSMPLFLUSH</td>
<td>Sends the signal monitor data to the data output buffer.</td>
</tr>
</tbody>
</table>

For the multi channel pulsed spot measurement (MM27) and the multi channel pulsed sweep measurement (MM28) using HVSMU, HCSMU, MCSMU, DHCSMU, UHCU, HVMCU, or UHVU.
### Command Reference

<table>
<thead>
<tr>
<th>Category</th>
<th>Command</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>External Trigger</strong></td>
<td>TGP</td>
<td>Enables the trigger function for a terminal.</td>
</tr>
<tr>
<td></td>
<td>TGPC</td>
<td>Clears the trigger setting of the specified ports.</td>
</tr>
<tr>
<td></td>
<td>TGSI</td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>TGSO</td>
<td>Selects the trigger type, edge or gate, for the Step Output Setup Completion trigger output set by the ( TGP ) ( port,2,polarity,2 ) command.</td>
</tr>
<tr>
<td></td>
<td>TGXO</td>
<td>Selects the trigger type, edge or gate, for the Measurement Completion trigger output set by the ( TGP ) ( port,2,polarity,1 ) command.</td>
</tr>
<tr>
<td></td>
<td>TGMO</td>
<td>Selects the trigger type, edge or gate, for the Step Measurement Completion trigger output set by the ( TGP ) ( port,2,polarity,3 ) command.</td>
</tr>
<tr>
<td></td>
<td>OS/OSX</td>
<td>Causes the B1500 to send a trigger signal from a trigger output terminal.</td>
</tr>
<tr>
<td></td>
<td>WS/WSX</td>
<td>Enters a wait state until the B1500 receives an external trigger via a trigger input terminal.</td>
</tr>
<tr>
<td></td>
<td>TM3</td>
<td>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 ).</td>
</tr>
<tr>
<td><strong>Digital I/O port</strong></td>
<td>ERM</td>
<td>Changes the digital I/O port assignments.</td>
</tr>
<tr>
<td></td>
<td>ERS?</td>
<td>Returns the digital I/O port status.</td>
</tr>
<tr>
<td></td>
<td>ERC</td>
<td>Changes the output status of the digital I/O port.</td>
</tr>
<tr>
<td></td>
<td>ERMOD/ERMOD?</td>
<td>Sets/returns the digital I/O control mode, direct control (normal), SMU/PGU selector control, or N1258A/N1259A control.</td>
</tr>
<tr>
<td><strong>SMU/PGU Selector Control</strong></td>
<td>ERSSP/ERSSP?</td>
<td>Sets/returns the input output connection path of the selector.</td>
</tr>
</tbody>
</table>

---

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### N1258A/N1259A Module Selector Control

<table>
<thead>
<tr>
<th>Command</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERHPA/ERHPA?</td>
<td>Specifies/returns the module connected to the module selector input.</td>
</tr>
<tr>
<td>ERHPL/ERHPL?</td>
<td>Sets/returns the LED status indicator operation status.</td>
</tr>
<tr>
<td>ERHPS/ERHPS?</td>
<td>Sets/returns the connection status of the series resistor on the HVSMU path.</td>
</tr>
<tr>
<td>ERHPP/ERHPP?</td>
<td>Sets/returns the connection status of the input-to-output path.</td>
</tr>
<tr>
<td>ERHPE/ERHPE?</td>
<td>Sets/returns the External Relay Control status.</td>
</tr>
<tr>
<td>ERHPR/ERHPR?</td>
<td>Sets/returns the signal level applied to the External Relay Control connector pin.</td>
</tr>
</tbody>
</table>

### N1265A Ultra High Current Expander/Fixture Control

<table>
<thead>
<tr>
<th>Command</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERPFUHCA/ERPFUHCA?</td>
<td>Specifies/returns the MC/HCSMU modules connected to the V Control and I Control inputs of the N1265A.</td>
</tr>
<tr>
<td>ERPFUHCTST?</td>
<td>Executes the self-test of the N1265A and returns the result.</td>
</tr>
<tr>
<td>ERPFUHCCAL?</td>
<td>Executes the self-calibration of the N1265A and returns the result.</td>
</tr>
<tr>
<td>ERPFUHCMAX?</td>
<td>Returns the maximum current supported by the currently-connected N1265A.</td>
</tr>
<tr>
<td>ERPFGA/ERPFGA?</td>
<td>Specifies/returns the MC/HCSMU module connected to the Gate input.</td>
</tr>
<tr>
<td>ERPFDA/ERPFDA?</td>
<td>Specifies/returns the measurement resources connected to the Selector Input.</td>
</tr>
<tr>
<td>ERPFDP/ERPFDP?</td>
<td>Sets/returns the connection status of the selector input-to-output path.</td>
</tr>
<tr>
<td>ERPFDS/ERPFD?</td>
<td>Sets/returns the connection status of the series resistor on the HVSMU path.</td>
</tr>
<tr>
<td>ERPFGP/ERPFGP?</td>
<td>Sets/returns the connection status of the MC/HCSMU output connected to the Gate input.</td>
</tr>
<tr>
<td>ERPFGR/ERPFGR?</td>
<td>Sets/returns the connection status of the series resistor on the Gate path.</td>
</tr>
<tr>
<td>ERPFTTEMP?</td>
<td>Returns the temperature measured by using the thermocouple (N1265A-041) connected to the K Thermocouple 1 or 2 terminal.</td>
</tr>
<tr>
<td>Category</td>
<td>Command</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>N1266A HVSMU Current Expander Control</td>
<td>ERHVCA/ERHVCA?</td>
</tr>
<tr>
<td></td>
<td>ERHVCTST?</td>
</tr>
<tr>
<td></td>
<td>ERHVP/ERHVP?</td>
</tr>
<tr>
<td></td>
<td>ERHVS/ERHVS?</td>
</tr>
<tr>
<td></td>
<td>ERHVPV</td>
</tr>
<tr>
<td>N1268A Ultra High Voltage Expander Control</td>
<td>ERUHVA/ERUHVA?</td>
</tr>
<tr>
<td>N1272A/B1506A/B1507A Selector Control</td>
<td>ERCMAA/ERCMAA?</td>
</tr>
<tr>
<td></td>
<td>ERCMAGRD/ERCMAI O?</td>
</tr>
<tr>
<td></td>
<td>ERCMAIO/ERCMAIO?</td>
</tr>
<tr>
<td>B1506A Control</td>
<td>ERCMAPFGD</td>
</tr>
<tr>
<td></td>
<td>ERPFQG/ERPFQG?</td>
</tr>
<tr>
<td>B1274A Adapter Control</td>
<td>ERHPQG/ERHPQG?</td>
</tr>
<tr>
<td>HVSMU Control</td>
<td>HVSMUOP/HVSMUOP?</td>
</tr>
<tr>
<td>Internal Variable</td>
<td>VAR/VAR?</td>
</tr>
<tr>
<td>Category</td>
<td>Command</td>
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</tr>
<tr>
<td>Program Memory</td>
<td>ST</td>
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<td>END</td>
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<td></td>
<td>SCR</td>
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<tr>
<td></td>
<td>LST?</td>
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<td>DO</td>
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<td></td>
<td>RU</td>
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<tr>
<td>Error Management</td>
<td>ERRX?</td>
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<td>ERR?</td>
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<td>EMG?</td>
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<tr>
<td>Query</td>
<td>*IDN?</td>
</tr>
<tr>
<td></td>
<td>LOP?</td>
</tr>
<tr>
<td></td>
<td>*LRN?</td>
</tr>
<tr>
<td></td>
<td>NUB?</td>
</tr>
<tr>
<td></td>
<td>*OPC?</td>
</tr>
<tr>
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<td>UNT?</td>
</tr>
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<td>WNU?</td>
</tr>
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<td>WZ?</td>
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<td>Status Byte</td>
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<td>*SRE?</td>
</tr>
<tr>
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<td>*STB?</td>
</tr>
</tbody>
</table>
Command Parameters

The parameters used by several commands are explained in this section.

• Channel Number
• Measurement Ranging Type
• Output Ranging Type
• HR/MP/HPSMU Source Setup Parameters
• MC/HC/DHCSMU Source Setup Parameters
• HVMCU Source Setup Parameters
• HVSMU Source Setup Parameters
• UHCU Source Setup Parameters
• UHVU 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

Keysight 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

Keysight 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

<table>
<thead>
<tr>
<th>chnum&lt;sup&gt;a,b&lt;/sup&gt;</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>101 or 1</td>
<td>Subchannel 1 of the module installed in slot 1</td>
</tr>
<tr>
<td>201 or 2</td>
<td>Subchannel 1 of the module installed in slot 2</td>
</tr>
<tr>
<td>301 or 3</td>
<td>Subchannel 1 of the module installed in slot 3</td>
</tr>
<tr>
<td>401 or 4</td>
<td>Subchannel 1 of the module installed in slot 4</td>
</tr>
<tr>
<td>501 or 5</td>
<td>Subchannel 1 of the module installed in slot 5</td>
</tr>
<tr>
<td>601 or 6</td>
<td>Subchannel 1 of the module installed in slot 6</td>
</tr>
<tr>
<td>701 or 7</td>
<td>Subchannel 1 of the module installed in slot 7</td>
</tr>
<tr>
<td>801 or 8</td>
<td>Subchannel 1 of the module installed in slot 8</td>
</tr>
<tr>
<td>901 or 9</td>
<td>Subchannel 1 of the module installed in slot 9</td>
</tr>
<tr>
<td>1001 or 10</td>
<td>Subchannel 1 of the module installed in slot 10</td>
</tr>
<tr>
<td>102</td>
<td>Subchannel 2 of the module installed in slot 1</td>
</tr>
<tr>
<td>202</td>
<td>Subchannel 2 of the module installed in slot 2</td>
</tr>
<tr>
<td>302</td>
<td>Subchannel 2 of the module installed in slot 3</td>
</tr>
<tr>
<td>402</td>
<td>Subchannel 2 of the module installed in slot 4</td>
</tr>
<tr>
<td>502</td>
<td>Subchannel 2 of the module installed in slot 5</td>
</tr>
<tr>
<td>602</td>
<td>Subchannel 2 of the module installed in slot 6</td>
</tr>
<tr>
<td>702</td>
<td>Subchannel 2 of the module installed in slot 7</td>
</tr>
<tr>
<td>802</td>
<td>Subchannel 2 of the module installed in slot 8</td>
</tr>
<tr>
<td>902</td>
<td>Subchannel 2 of the module installed in slot 9</td>
</tr>
<tr>
<td>1002</td>
<td>Subchannel 2 of the module installed in slot 10</td>
</tr>
</tbody>
</table>

<sup>a</sup> 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.

<sup>b</sup> To specify the UHCU, HVMCU, and UHVU, use the channel number of MCSMU or HCSMU connected to the V Control input on the N1265A, N1266A, and N1268A expander respectively.
Table 4-2 Voltage Measurement Ranging Type

<table>
<thead>
<tr>
<th>range (^a)</th>
<th>Measurement resource type</th>
<th>Ranging type(^b)</th>
<th>without pulse</th>
<th>using pulse</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR</td>
<td>MP</td>
<td>HP</td>
<td>MC</td>
</tr>
<tr>
<td>0</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>20 or 11</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>50</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>200 or 12</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>400 or 13</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>1000 or 14</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2000 or 15</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>5000</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
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<td>15000</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>30000</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>–2</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>–5</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>–20 or –11</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>–50</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>–200 or –12</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>–400 or –13</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>–1000 or –14</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>–2000 or –15</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>–5000</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>–15000</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>–30000</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

---

a. Regardless of the range value, the voltage output channel uses the voltage output range for the voltage measurement.

b. If the fixed range greater than the compliance value is specified, the channel uses the compliance range (except for MP/HR/HPSMU).
<table>
<thead>
<tr>
<th>range</th>
<th>Measurement resource type</th>
<th>Ranging type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UHCU</td>
<td>HVMCU</td>
</tr>
<tr>
<td>0</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>1000, –1000, 14, or –14</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>30000 or –30000</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>103 or –103</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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 Keysight 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.
### Table 4-3: Current Measurement Ranging Type

<table>
<thead>
<tr>
<th>range a</th>
<th>Measurement resource type</th>
<th>Ranging typeb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR</td>
<td>MP</td>
</tr>
<tr>
<td>0</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>8, for ASU</td>
<td>Yes</td>
<td><strong>Yes</strong>&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>9</td>
<td>Yes</td>
<td><strong>Yes</strong>&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>10</td>
<td>Yes</td>
<td><strong>Yes</strong>&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>11</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>12</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>13</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>14</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>15</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>16</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>17</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>18</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>19</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>20</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>21</td>
<td>Yes</td>
<td></td>
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<tr>
<td>22</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>−8, for ASU</td>
<td>Yes</td>
<td><strong>Yes</strong>&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>−9</td>
<td>Yes</td>
<td><strong>Yes</strong>&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>−10</td>
<td>Yes</td>
<td><strong>Yes</strong>&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>−11</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>−12</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>−13</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>−14</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>−15</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>−16</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>−17</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>−18</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>−19</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>−20</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>−21</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>−22</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>−23</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

a. Regardless of the range value, the current output channel uses the current output range for the current measurement.

b. If the fixed range greater than the compliance value is specified, the channel uses the compliance range.

c. For B1511B MPSMU. Available when the ASU is used.
**Command Parameters**

<table>
<thead>
<tr>
<th>range</th>
<th>Resource type</th>
<th>Ranging type&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UHCU&lt;sup&gt;b&lt;/sup&gt;</td>
<td>HVMCU</td>
</tr>
<tr>
<td>0</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>21</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>26</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>−19</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>−21</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>−26</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>−28</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> If the fixed range greater than the compliance value is specified, the channel uses the compliance range.

<sup>b</sup> Regardless of the range value, the current output channel uses the current output range for the current measurement.

<table>
<thead>
<tr>
<th>range</th>
<th>Resource type</th>
<th>DC voltage output</th>
<th>Pulse voltage output</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UHVU</td>
<td>Auto ranging</td>
<td>Compliance range</td>
</tr>
<tr>
<td>0</td>
<td>Yes</td>
<td>10 μA limited auto</td>
<td>Measurement channel uses the minimum range that covers the compliance value.</td>
</tr>
<tr>
<td>15</td>
<td>Yes</td>
<td>100 μA limited auto</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Yes</td>
<td>1 mA limited auto</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Yes</td>
<td>10 mA limited auto</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Yes</td>
<td>100 mA limited auto</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Yes</td>
<td>100 mA limited auto</td>
<td></td>
</tr>
<tr>
<td>−15</td>
<td>Yes</td>
<td>10 μA range fixed</td>
<td></td>
</tr>
<tr>
<td>−16</td>
<td>Yes</td>
<td>100 μA range fixed</td>
<td></td>
</tr>
<tr>
<td>−17</td>
<td>Yes</td>
<td>1 mA range fixed</td>
<td></td>
</tr>
<tr>
<td>−18</td>
<td>Yes</td>
<td>10 mA range fixed</td>
<td></td>
</tr>
<tr>
<td>−19</td>
<td>Yes</td>
<td>100 mA range fixed</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> If the fixed range greater than the compliance value is specified, the channel uses the compliance range.
### Table 4-4 Voltage Output Ranging Type

<table>
<thead>
<tr>
<th>range or vrange</th>
<th>Measurement resource type</th>
<th>Ranging type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR</td>
<td>MP</td>
</tr>
<tr>
<td>0</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>20 or 11</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>50</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>200 or 12</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>400 or 13</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>1000 or 14</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2000 or 15</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>5000</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>15000</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>30000</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>range or vrange</th>
<th>Measurement resource type</th>
<th>Ranging type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UHCU</td>
<td>HVMCU</td>
</tr>
<tr>
<td>0</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>1000 or 14</td>
<td>Yes</td>
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</tr>
<tr>
<td>15000</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>30000</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>103</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 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 4-5  Current Output Ranging Type

<table>
<thead>
<tr>
<th>range or</th>
<th>Measurement resource type</th>
<th>Ranging type</th>
</tr>
</thead>
<tbody>
<tr>
<td>irange</td>
<td>HR</td>
<td>MP</td>
</tr>
<tr>
<td>0</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>8, for  ASU</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>9</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>10</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>11</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>12</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>13</td>
<td>Yes</td>
<td>Yes</td>
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<td>14</td>
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<td>Yes</td>
</tr>
<tr>
<td>23</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

a. For B1511B MPSSMU. Available when the ASU is used.

### Table 4-5  Current Output Ranging Type

<table>
<thead>
<tr>
<th>range or</th>
<th>Measurement resource type</th>
<th>Ranging type</th>
</tr>
</thead>
<tbody>
<tr>
<td>irange</td>
<td>UHCU</td>
<td>HVMCU</td>
</tr>
<tr>
<td>0</td>
<td>Yes</td>
<td>NA</td>
</tr>
<tr>
<td>26</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

---

**Module selector maximum current**

When using dual HCSMU (DHCSMU) connected to the N1258A or N1259A-300 module selector, the maximum current must be ± 30 A to prevent the module selector from performance degradation and failure.
Table 4-6  HR/MP/HP/SMU Current Source Setup Parameters

<table>
<thead>
<tr>
<th>Output range (actually used)</th>
<th>Setting resolution in A</th>
<th>current, start, stop, base, bias, or pulse in A</th>
<th>Maximum V&lt;sub&gt;comp&lt;/sub&gt; value in V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>HRSMU</td>
</tr>
<tr>
<td>1 pA</td>
<td>1E-15</td>
<td>0 to ± 1.15E-12</td>
<td>±100</td>
</tr>
<tr>
<td>10 pA</td>
<td>5E-15</td>
<td>0 to ± 11.5E-12</td>
<td>±100</td>
</tr>
<tr>
<td>100 pA</td>
<td>5E-15</td>
<td>0 to ± 115E-12</td>
<td>±100</td>
</tr>
<tr>
<td>1 nA</td>
<td>50E-15</td>
<td>0 to ± 1.15E-9</td>
<td>±100</td>
</tr>
<tr>
<td>10 nA</td>
<td>500E-15</td>
<td>0 to ± 11.5E-9</td>
<td>±100</td>
</tr>
<tr>
<td>100 nA</td>
<td>5E-12</td>
<td>0 to ± 115E-9</td>
<td>±100</td>
</tr>
<tr>
<td>1 μA</td>
<td>50E-12</td>
<td>0 to ± 1.15E-6</td>
<td>±100</td>
</tr>
<tr>
<td>10 μA</td>
<td>500E-12</td>
<td>0 to ± 11.5E-6</td>
<td>±100</td>
</tr>
<tr>
<td>100 μA</td>
<td>5E-9</td>
<td>0 to ± 115E-6</td>
<td>±100</td>
</tr>
<tr>
<td>1 mA</td>
<td>50E-9</td>
<td>0 to ± 1.15E-3</td>
<td>±100</td>
</tr>
<tr>
<td>10 mA</td>
<td>500E-9</td>
<td>0 to ± 11.5E-3</td>
<td>±100</td>
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<tr>
<td>100 mA</td>
<td>5E-6</td>
<td>0 to ± 20E-3</td>
<td>±100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>to ± 50E-3</td>
<td>±40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>to ± 100E-3</td>
<td>±20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>to ± 115E-3</td>
<td>NA</td>
</tr>
<tr>
<td>1 A</td>
<td>50E-6</td>
<td>0 to ± 50E-3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>to ± 125E-3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>to ± 500E-3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>to ± 1</td>
<td></td>
</tr>
</tbody>
</table>

a. Output ranges 1 pA to 1 nA are available only for DC output, not for pulse output.

1. The following commands are used for setting the MP/HR/HP/SMU to the current source.
   DI, TDI, WI, WSI, WNX, PI, PWI, LSI, LSSI, BSI, BSSI, MI, MCPNX, MCPWNX
### Table 4-7 HR/MP/HPSMU Voltage Source Setup Parameters

<table>
<thead>
<tr>
<th>Output range (actually used)</th>
<th>Setting resolution in V</th>
<th>voltage, start, stop, base, bias, or pulse in V</th>
<th>Maximum $I_{comp}$ value in A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>HRSMU</td>
</tr>
<tr>
<td>0.5 V</td>
<td>25E-6</td>
<td>0 to ± 0.5</td>
<td>±100E-3</td>
</tr>
<tr>
<td>2 V</td>
<td>100E-6</td>
<td>0 to ± 2</td>
<td>±100E-3</td>
</tr>
<tr>
<td>5 V</td>
<td>250E-6</td>
<td>0 to ± 5</td>
<td>±100E-3</td>
</tr>
<tr>
<td>20 V</td>
<td>1E-3</td>
<td>0 to ± 20</td>
<td>±100E-3</td>
</tr>
<tr>
<td>40 V</td>
<td>2E-3</td>
<td>0 to ± 20, 0 to ± 40</td>
<td>±100E-3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>±50E-3</td>
</tr>
<tr>
<td>100 V</td>
<td>5E-3</td>
<td>0 to ± 20, 0 to ± 40</td>
<td>±100E-3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>±50E-3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>±20E-3</td>
</tr>
<tr>
<td>200 V</td>
<td>10E-3</td>
<td>0 to ± 200</td>
<td>NA</td>
</tr>
</tbody>
</table>

1. 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, BS, BSSV, MV, MCPNX, MCPWNS, MDCV, PDCV, WDCV, PWDCV
### Table 4-8 MC/HC/DHCSMU Current Source Setup Parameters

<table>
<thead>
<tr>
<th>Output range (actually used)</th>
<th>Setting resolution in A</th>
<th>current, start, stop, base, bias, or pulse in A</th>
<th>Maximum ( V_{comp} ) value in V</th>
<th>Maximum pulse base value</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 ( \mu )A</td>
<td>1E-11</td>
<td>0 to ± 11.5E-6</td>
<td>± 30</td>
<td>± 10 ( \mu )A</td>
</tr>
<tr>
<td>100 ( \mu )A</td>
<td>1E-10</td>
<td>0 to ± 115E-6</td>
<td>± 40</td>
<td>± 100 ( \mu )A</td>
</tr>
<tr>
<td>1 mA</td>
<td>1E-9</td>
<td>0 to ± 1.15E-3</td>
<td>± 1 mA</td>
<td>± 10 mA</td>
</tr>
<tr>
<td>10 mA</td>
<td>1E-8</td>
<td>0 to ± 11.5E-3</td>
<td>± 10 mA</td>
<td>± 100 mA</td>
</tr>
<tr>
<td>100 mA</td>
<td>1E-7</td>
<td>0 to ± 115E-3 ( ^{b} )</td>
<td>± 100 mA</td>
<td>± 1 A ( ^{e} )</td>
</tr>
<tr>
<td>1 A ( ^{c} )</td>
<td>1E-6</td>
<td>0 to ± 1.15 ( ^{d} )</td>
<td>NA</td>
<td>± 2 A</td>
</tr>
<tr>
<td>2 A</td>
<td>2E-6</td>
<td>0 to ± 2.02 ( ^{f} )</td>
<td>NA</td>
<td>± 2 A</td>
</tr>
<tr>
<td>20 A</td>
<td>2E-5</td>
<td>0 to ± 20</td>
<td>± 20</td>
<td>NA</td>
</tr>
<tr>
<td>40 A</td>
<td>4E-5</td>
<td>0 to ± 40</td>
<td>NA</td>
<td>± 200 mA</td>
</tr>
</tbody>
</table>

| \( ^{a} \) Output ranges 20 A and 40 A are available only for pulse output, not for DC output. | \( ^{b} \) Maximum 100 mA for the DC output of MCSMU. | \( ^{c} \) For the MCSMU, the 1 A range is available only for the pulse output within the maximum pulse width 100 ms and maximum duty ratio 5%. | \( ^{d} \) Maximum 1 A for the MCSMU and for the DC output of HCSMU. | \( ^{e} \) Maximum 50 mA for the MCSMU. | \( ^{f} \) Maximum 2 A for the DC output. |

---

1. The following commands are used for setting the HCSMU, DHCSMU, and MCSMU to the current source.

- DI, TDI, WI, WSI, WNX, PI, PWI, LSI, LSSI, BSI, BSSI, MI, MCPNX, MCPWNX
## Command Parameters

### Table 4-9 MC/HC/DHCSMU Voltage Source Setup Parameters

<table>
<thead>
<tr>
<th>Output range (actually used)</th>
<th>Setting resolution in V</th>
<th>voltage, start, stop, base, bias, or pulse in V</th>
<th>Maximum $I_{comp}$ value in A&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Maximum pulse base value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>MC SMU</td>
<td>HC SMU</td>
</tr>
<tr>
<td>0.2 V</td>
<td>2E-7</td>
<td>0 to ± 0.2</td>
<td>± 0.1 for DC, ± 1 for pulse</td>
<td>± 1 for DC, ± 20 for pulse</td>
</tr>
<tr>
<td>2 V</td>
<td>2E-6</td>
<td>0 to ± 2</td>
<td>± 1 for pulse</td>
<td>± 2 for DC, ± 40 for pulse</td>
</tr>
<tr>
<td>20 V</td>
<td>2E-5</td>
<td>0 to ± 20</td>
<td>± 1 for pulse</td>
<td>± 2 for DC, ± 40 for pulse</td>
</tr>
<tr>
<td>40 V</td>
<td>4E-5</td>
<td>0 to ± 40&lt;sup&gt;b&lt;/sup&gt;</td>
<td>± 1 for pulse</td>
<td>± 2 for DC, ± 40 for pulse</td>
</tr>
</tbody>
</table>

<sup><sup>a</sup> When the compliance value is set to > 1 A or < −1 A, the current measurement range is fixed to the compliance range.</sup>

<sup><sup>b</sup> Maximum ±30 V for the MCSMU.</sup>

### Table 4-10 HVMCU Pulsed Voltage Source Setup Parameters

<table>
<thead>
<tr>
<th>Output range (actually used)</th>
<th>Setting resolution in V</th>
<th>start, stop, or pulse in V&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Compliance range</th>
<th>Maximum $I_{comp}$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1500 V</td>
<td>1.5E-3</td>
<td>0 to ± 1500</td>
<td>2 A</td>
<td>±2.5 A</td>
</tr>
<tr>
<td>3000 V</td>
<td>3E-3</td>
<td>0 to ± 2200</td>
<td>1 A</td>
<td>±1.1 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>100 mA</td>
<td>±110 mA</td>
</tr>
</tbody>
</table>

<sup><sup>a</sup> Pulse base value must be 0 A.</sup>

---

1. The following commands are used for setting the HCSMU, DHCSMU, and MCSMU to the voltage source.
   - DV, TDV, WV, WSV, WNX, PV, PWV, LSV, LSSV, BSV, BSSV, MV, MCPNX, MCPWNX, WDCV

2. The following commands are used for setting the HVMCU to the voltage pulse source.
   - PV, PWV, MCPNX, MCPWNX
Table 4-11  
HVSMU Current Source Setup Parameters$^1$

<table>
<thead>
<tr>
<th>Output range (actually used) $^a$</th>
<th>Setting resolution in A</th>
<th>current, start, stop, base, bias, or pulse in A</th>
<th>Maximum $V_{\text{comp}}$ value in V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Negative output</td>
</tr>
<tr>
<td>1 nA</td>
<td>1E-14</td>
<td>0 to ± 1.15E-9</td>
<td>-3000 to 0</td>
</tr>
<tr>
<td>10 nA</td>
<td>1E-13</td>
<td>0 to ± 11.5E-9</td>
<td></td>
</tr>
<tr>
<td>100 nA</td>
<td>1E-13</td>
<td>0 to ± 115E-9</td>
<td></td>
</tr>
<tr>
<td>1 μA</td>
<td>1E-12</td>
<td>0 to ± 1.15E-6</td>
<td></td>
</tr>
<tr>
<td>10 μA</td>
<td>1E-11</td>
<td>0 to ± 11.5E-6</td>
<td></td>
</tr>
<tr>
<td>100 μA</td>
<td>1E-10</td>
<td>0 to ± 115E-6</td>
<td></td>
</tr>
<tr>
<td>1 mA</td>
<td>1E-9</td>
<td>0 to ± 1.15E-3</td>
<td></td>
</tr>
<tr>
<td>10 mA</td>
<td>1E-8</td>
<td>0 to ± 4E-3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>to ± 8E-3</td>
<td>-1500 to 0</td>
</tr>
</tbody>
</table>

$^a$. The 1 nA output range is available only for DC output, not for pulse output.

Table 4-12  
HVSMU Voltage Source Setup Parameters$^2$

<table>
<thead>
<tr>
<th>Output range (actually used)</th>
<th>Setting resolution in V</th>
<th>voltage, start, stop, base, bias, or pulse in V</th>
<th>Maximum $I_{\text{comp}}$ value in A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Negative output</td>
</tr>
<tr>
<td>200 V</td>
<td>0.2E-3</td>
<td>0 to ± 200</td>
<td>-8E-3 to 0</td>
</tr>
<tr>
<td>500 V</td>
<td>0.5E-3</td>
<td>0 to ± 500</td>
<td></td>
</tr>
<tr>
<td>1500 V</td>
<td>1.5E-3</td>
<td>0 to ± 1500</td>
<td></td>
</tr>
<tr>
<td>3000 V</td>
<td>3E-3</td>
<td>0 to ± 3000</td>
<td>-4E-3 to 0</td>
</tr>
</tbody>
</table>

1. 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
2. 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, WDCV
### Table 4-13 UHCU Pulsed Current Source Setup Parameters

<table>
<thead>
<tr>
<th>Output range (actually used)</th>
<th>Setting resolution in A</th>
<th>current, start, stop, base, bias, or pulse in A</th>
<th>Maximum Vcomp value in V</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 A</td>
<td>1E-3</td>
<td>0 to ± 500</td>
<td>± 63</td>
</tr>
<tr>
<td>2000 A&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4E-3</td>
<td>0 to ± 1500</td>
<td></td>
</tr>
</tbody>
</table>

- a. Pulse base value must be 0 A.
- b. Only for the N1265A-015.

### Table 4-14 UHCU Pulsed Voltage Source Setup Parameters

<table>
<thead>
<tr>
<th>Output range (actually used)</th>
<th>Setting resolution in V</th>
<th>voltage, start, stop, base, bias, or pulse in V</th>
<th>Maximum Icomp value in A</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 V</td>
<td>200E-6</td>
<td>0 to ± 60</td>
<td>± 500 or ± 150&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

- a. Pulse base value must be 0 A.
- b. Only for the N1265A-015.

### Table 4-15 UHVU Voltage Source Setup Parameters

<table>
<thead>
<tr>
<th>Output range (actually used)</th>
<th>Setting resolution in V</th>
<th>voltage, start, stop, base, bias, or pulse in V</th>
<th>Maximum Icomp value in A</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 kV</td>
<td>10E-3</td>
<td>0 to ± 10000&lt;sup&gt;a&lt;/sup&gt;</td>
<td>± 20E-3&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>±10E-3</td>
</tr>
</tbody>
</table>

- a. Pulse base and peak values must be the same polarity.
- b. Only for the pulse output within maximum 1 ms pulse width.

---

1. The following commands are used for setting the UHCU to the current pulse source:
   - PI, PWI, MCPNX, MCPWNX
2. The following commands are used for setting the UHCU to the voltage pulse source:
   - PV, PWV, MCPNX, MCPWNX
3. The following commands are used for setting the UHVU to the voltage source:
   - DV, TDV, WV, WSV, WNX, PV, PWV, LSV, LSSV, BSV, BSSV, MV, MCPNX, MCPWNX
### Table 4-16 MFCMU Measurement Parameters

<table>
<thead>
<tr>
<th>mode</th>
<th>Primary Parameter</th>
<th>Secondary Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R (resistance, Ω)</td>
<td>X (reactance, Ω)</td>
</tr>
<tr>
<td>2</td>
<td>G (conductance, S)</td>
<td>B (susceptance, S)</td>
</tr>
<tr>
<td>10</td>
<td>Z (impedance, Ω)</td>
<td>θ (phase, radian)</td>
</tr>
<tr>
<td>11</td>
<td>Z (impedance, Ω)</td>
<td>θ (phase, degree)</td>
</tr>
<tr>
<td>20</td>
<td>Y (admittance, S)</td>
<td>θ (phase, radian)</td>
</tr>
<tr>
<td>21</td>
<td>Y (admittance, S)</td>
<td>θ (phase, degree)</td>
</tr>
<tr>
<td>100</td>
<td>Cp (parallel capacitance, F)</td>
<td>G (conductance, S)</td>
</tr>
<tr>
<td>101</td>
<td>Cp (parallel capacitance, F)</td>
<td>D (dissipation factor)</td>
</tr>
<tr>
<td>102</td>
<td>Cp (parallel capacitance, F)</td>
<td>Q (quality factor)</td>
</tr>
<tr>
<td>103</td>
<td>Cp (parallel capacitance, F)</td>
<td>Rp (parallel resistance, Ω)</td>
</tr>
<tr>
<td>200</td>
<td>Cs (series capacitance, F)</td>
<td>Rs (series resistance, Ω)</td>
</tr>
<tr>
<td>201</td>
<td>Cs (series capacitance, F)</td>
<td>D (dissipation factor)</td>
</tr>
<tr>
<td>202</td>
<td>Cs (series capacitance, F)</td>
<td>Q (quality factor)</td>
</tr>
<tr>
<td>300</td>
<td>Lp (parallel inductance, H)</td>
<td>G (conductance, S)</td>
</tr>
<tr>
<td>301</td>
<td>Lp (parallel inductance, H)</td>
<td>D (dissipation factor)</td>
</tr>
<tr>
<td>302</td>
<td>Lp (parallel inductance, H)</td>
<td>Q (quality factor)</td>
</tr>
<tr>
<td>303</td>
<td>Lp (parallel inductance, H)</td>
<td>Rp (parallel resistance, Ω)</td>
</tr>
<tr>
<td>400</td>
<td>Ls (series inductance, H)</td>
<td>Rs (series resistance, Ω)</td>
</tr>
<tr>
<td>401</td>
<td>Ls (series inductance, H)</td>
<td>D (dissipation factor)</td>
</tr>
<tr>
<td>402</td>
<td>Ls (series inductance, H)</td>
<td>Q (quality factor)</td>
</tr>
</tbody>
</table>
Table 4-17  MFCMU Measurement Range for Fixed Ranging Mode

<table>
<thead>
<tr>
<th>range</th>
<th>Measurement range (impedance range) a</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 kHz ≤ f ≤ 200 kHz</td>
</tr>
<tr>
<td>0 ≤ range &lt; 100</td>
<td>50 Ω</td>
</tr>
<tr>
<td>100 ≤ range &lt; 300</td>
<td>100 Ω</td>
</tr>
<tr>
<td>300 ≤ range &lt; 1000</td>
<td>300 Ω</td>
</tr>
<tr>
<td>1000 ≤ range &lt; 3000</td>
<td>1 kΩ</td>
</tr>
<tr>
<td>3000 ≤ range &lt; 10000</td>
<td>3 kΩ</td>
</tr>
<tr>
<td>10000 ≤ range &lt; 30000</td>
<td>10 kΩ</td>
</tr>
<tr>
<td>30000 ≤ range &lt; 100000</td>
<td>30 kΩ</td>
</tr>
<tr>
<td>100000 ≤ range &lt; 300000</td>
<td>100 kΩ</td>
</tr>
<tr>
<td>300000 ≤ range</td>
<td>300 kΩ</td>
</tr>
</tbody>
</table>

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 $C = \frac{1}{2\pi f Z}$ where $f$ is frequency (Hz) and $Z$ is impedance (Ω). To decide the measurement range, also see Figure 4-1.

Table 4-18  MFCMU Output Signal Frequency

<table>
<thead>
<tr>
<th>freq</th>
<th>Setting resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 ≤ freq &lt; 10000</td>
<td>0.001 Hz</td>
</tr>
<tr>
<td>10000 ≤ freq &lt; 100000</td>
<td>0.01 Hz</td>
</tr>
<tr>
<td>1000000 ≤ freq &lt; 1000000</td>
<td>0.1 Hz</td>
</tr>
<tr>
<td>100000000 ≤ freq ≤ 500000000</td>
<td>1 Hz</td>
</tr>
</tbody>
</table>

Table 4-19  MFCMU AC Level Measurement Range

<table>
<thead>
<tr>
<th>range</th>
<th>Maximum measurement value, absolute value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.016</td>
<td>0.016 V</td>
</tr>
<tr>
<td>0.032</td>
<td>0.032 V</td>
</tr>
<tr>
<td>0.064</td>
<td>0.064 V</td>
</tr>
<tr>
<td>0.125</td>
<td>0.125 V</td>
</tr>
<tr>
<td>0.250</td>
<td>0.250 V</td>
</tr>
</tbody>
</table>
Table 4-20  MFCMU DC Bias Measurement Range

<table>
<thead>
<tr>
<th>range a</th>
<th>Maximum measurement value, absolute value</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>100 V (SMU)</td>
</tr>
<tr>
<td></td>
<td>8 V (MFCMU)</td>
</tr>
<tr>
<td>12</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>12 V (MFCMU)</td>
</tr>
<tr>
<td>100</td>
<td>25 V (MFCMU)</td>
</tr>
</tbody>
</table>

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 25 V 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.

<table>
<thead>
<tr>
<th>parameter</th>
<th>Required command parameters, for which you must substitute a value or variable.</th>
</tr>
</thead>
<tbody>
<tr>
<td>[parameter]</td>
<td>Optional command parameters, for which you may substitute a value or omit it.</td>
</tr>
</tbody>
</table>
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 16.
- **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, HVSMU, and MCSMU.
  - 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 a device clear 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.

<table>
<thead>
<tr>
<th>Operation before AB</th>
<th>Setting after AB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staircase sweep output</td>
<td>Sets specified start value.</td>
</tr>
<tr>
<td>Pulse output</td>
<td>Sets specified base value.</td>
</tr>
<tr>
<td>Quasi-pulsed spot measurement</td>
<td>Sets specified start value.</td>
</tr>
<tr>
<td>Sampling measurement</td>
<td>Sets specified base value.</td>
</tr>
<tr>
<td>Quasi-static CV measurement</td>
<td>Sets specified start value.</td>
</tr>
<tr>
<td>Linear search measurement</td>
<td>Sets specified start value.</td>
</tr>
<tr>
<td>Binary search measurement</td>
<td>Sets specified start value.</td>
</tr>
<tr>
<td>Multi channel sweep measurement</td>
<td>Sets specified start value.</td>
</tr>
<tr>
<td>MFCMU DC/AC/frequency sweep measurement</td>
<td>Sets specified start value.</td>
</tr>
<tr>
<td>Self-test</td>
<td>Same as set by CL command.</td>
</tr>
<tr>
<td>Self-calibration</td>
<td>Same as set by CL command.</td>
</tr>
<tr>
<td>Wait state (PA/PAX/WS/WSX command)</td>
<td>Settings do not change.</td>
</tr>
<tr>
<td>Program execution (RU or DO command)</td>
<td>Settings do not change.</td>
</tr>
</tbody>
</table>
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 16.

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.

```plaintext
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"    !
```

ACT

This command sets the number of averaging samples or the averaging time set to the A/D converter of the MFCMU.

**Syntax**

\[ \text{ACT } mode[,N] \]

**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.
    \[
    \text{Number of averaging samples} = N \times \text{initial averaging}
    \]
  - 2: Power line cycle (PLC) mode.
    - Defines the averaging time given by the following formula.
    \[
    \text{Averaging time} = \frac{N}{\text{power line frequency}}
    \]
- **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**

\[ \text{ACV } chnum,voltage \]

**Parameters**

- **chnum**: MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.
- **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

```plaintext
ADJ chnum, mode
```

Parameters

- `chnum`: MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.
- `mode`: Phase compensation mode. Integer expression. 0 or 1.
  - 0: Auto mode. Initial setting.
  - 1: Manual mode.
  - 2: Load adaptive 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.

For `mode`=2, the B1500 performs the phase compensation before every measurement. It is useful when there are wide load fluctuations by changing the bias and so on.

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

```plaintext
ADJ? chnum[,mode]
```
Parameters

*chnum*: MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.

*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.

<table>
<thead>
<tr>
<th><em>results</em></th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Phase compensation measurement was normally completed.</td>
</tr>
<tr>
<td>1</td>
<td>Phase compensation measurement failed.</td>
</tr>
<tr>
<td>2</td>
<td>Phase compensation measurement was aborted.</td>
</tr>
<tr>
<td>3</td>
<td>Phase compensation measurement has not been performed.</td>
</tr>
</tbody>
</table>

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, HVSMU and MCSMU.
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 4-21.

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>
<thead>
<tr>
<th>type</th>
<th>mode</th>
<th>( N )</th>
</tr>
</thead>
</table>
| 0    | 0    | Value that defines the number of averaging samples given by the following formula. \( N=1 \) to 1023. Default setting is 1.  

\[
Number of averaging samples = N \times initial averaging
\]

where \( initial averaging \) is the number of averaging samples automatically set by Keysight 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.  

\[
Number of averaging samples = N \times 128
\]

The Keysight 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. \( N=2 \) \( \mu \)s to 20 ms, 2 \( \mu \)s resolution. Default setting is 2 \( \mu \)s.  

For HR/MP/HPSMU, it performs the operation of \( mode=1 \). Then the number of averaging samples is automatically set to the following value.  

\[
Number of averaging samples = \frac{N}{Tm}
\]

\( Tm \): Required time for one sample measurement  
If \( N / Tm < 1 \), \( Number of averaging samples =1. \) |
<table>
<thead>
<tr>
<th>type</th>
<th>mode</th>
<th>Value that defines the integration time given by the following formula. ( N=1 ) to 127. Default setting is 6.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>( \text{Integration time} = N \times \text{initial integration time} ) where ( \text{initial integration time} ) is the integration time automatically set by Keysight B1500 and you cannot change.</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Value that defines the integration time given by the following formula. ( N=1 ) to 127. Default setting is 3.</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>( \text{Integration time} = N \times 80 \mu \text{sec} )</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>Not applicable.</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Not applicable.</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Value that defines the number of averaging samples given by the following formula. ( N=1 ) to 100. Default setting is 1.</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>Not applicable.</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>Actual measurement time, in seconds. ( N=2 ) ( \mu \text{s} ) to 20 ms, 2 ( \mu \text{s} ) resolution. Default setting is 2 ( \mu \text{s} ).</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>For HR/MP/HPSMU, it performs the operation of ( \text{type}=0 ) and ( \text{mode}=1 ). Then the number of averaging samples is automatically set to the following value.</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>( \text{Number of averaging samples} = N / Tm )</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>( Tm ): Required time for one sample measurement</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>If ( N / Tm &lt; 1 ), ( \text{Number of averaging samples} = 1 ).</td>
</tr>
</tbody>
</table>
Example Statements

OUTPUT @B1500;"AIT 2,3,.001"

**AITM**

Only for the current measurement by using HRSMU. This command sets the operation type of the high-resolution ADC that is set to the power line cycle (PLC) mode by the AIT 1, 2, N command.

This setting is cleared by the *RST or a device clear.

**Syntax**

AITM type

**Parameters**

*type*: Operation type. Integer expression. 0 or 1.

0: B1500 standard operation. Initial setting.

1: Classic operation. Performs the operation similar to the PLC mode of Keysight 4156.

**AITM?**

This command returns the operation type of the high-resolution ADC that is set by the AITM command.

**Syntax**

AITM?

**Query Response**

*type*<^EOI>

Operation type of the high-resolution ADC. 0 (standard) or 1 (classic).

**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 2-53 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 2-53 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 Keysight 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 = \( number \times initial\ number \)
  - 1: Manual mode.
  - Number of samples = \( number \)
where initial number means the number of samples the Keysight B1500 automatically sets and you cannot change. For voltage measurement, initial number=1. For current measurement, see Table 4-22.

If you select the manual mode, number must be initial number or more to satisfy the specifications.

Table 4-22

<table>
<thead>
<tr>
<th>Current Measurement Range</th>
<th>Voltage Output Range$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>to 40 V</td>
</tr>
<tr>
<td>to 10 μA</td>
<td>4</td>
</tr>
<tr>
<td>100 μA to 1 A</td>
<td>1</td>
</tr>
</tbody>
</table>

$^a$ 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.
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 : Setting 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**

```plaintext
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**

```plaintext
OUTPUT @B1500; "BDT 0.1, 1E-3"
```

**BDV**

The BDV command specifies the quasi-pulsed voltage source and its parameters.

**Execution Conditions**

If the output voltage is greater than the allowable voltage for the interlock open condition, the interlock circuit must be shorted.

**Syntax**

```plaintext
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 16.
- **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 21.
- **start, stop**: Start or stop voltage (in V). Numeric expression. See Table 4-7 on page 24.
  
  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 4-7 on page 4-24.
  
  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 \textit{stop} value will be approximately 1.5 ms to 1.8 ms with the following settings:

- BDM, BDT command parameters: \textit{interval}=0, \textit{mode}=0, \textit{delay}=0
- AV or AAD/AIT command parameters: initial setting

Example Statements

\texttt{OUTPUT @B1500;"BDV 1,0,0,100,0.01"}

\section*{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.

\section*{Syntax}

\texttt{BGI chnum, mode, condition, range, target}

\section*{Parameters}

\texttt{chnum} : SMU search monitor channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.

\texttt{mode, condition} : Search mode (0: limit mode or 1: repeat mode) and search stop condition. The meaning of \textit{condition} depends on the \textit{mode} setting.

<table>
<thead>
<tr>
<th>\textit{mode}</th>
<th>\textit{condition}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Limit value for the search target (\textit{target}). The search stops when the monitor data reaches \textit{target} \pm \textit{condition}. Numeric expression. Positive value. in A. Setting resolution: \textit{range}/20000. where \textit{range} means the measurement range actually used for the measurement.</td>
</tr>
<tr>
<td>1</td>
<td>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.</td>
</tr>
</tbody>
</table>

\texttt{range} : Measurement ranging type. Integer expression. The measurement range will be set to the minimum range that covers the \textit{target} value. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-3 on page 19.

\texttt{target} : Search target current (in A). Numeric expression.
0 to ±0.1 A (MPSMU/HRSMU/MCSMU)
0 to ±1 A (HPSMU/HCSMU)
0 to ±2 A (DHCSMU)
0 to ±0.008 A (HVSMU)

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 16.
**mode, condition**: Search mode (0: limit mode or 1: repeat mode) and search stop condition. The meaning of *condition* depends on the *mode* setting.

<table>
<thead>
<tr>
<th>mode</th>
<th>condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Limit value for the search target (<em>target</em>). The search stops when the monitor data reaches <em>target</em> ± <em>condition</em>. Numeric expression. Positive value in V. Setting resolution: <em>range</em>/20000, where <em>range</em> means the measurement range actually used for the measurement.</td>
</tr>
<tr>
<td>1</td>
<td>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.</td>
</tr>
</tbody>
</table>

**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 17.

**target**: Search target voltage (in V). Numeric expression.

- 0 to ±100 V (MPSMU/HRSMU)
- 0 to ±200 V (HPSMU)
- 0 to ±30 V (MCSMU)
- 0 to ±40 V (HCSMU/DHCSMU)
- 0 to ±3000 V (HVSMU)

**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.
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.

Execution Conditions

If $V_{\text{comp}}$ value is greater than the allowable voltage for the interlock open condition, 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 16.
- **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 22.
- **start, stop**: Search start or stop current (in A). Numeric expression. See Table 4-6 on page 23, Table 4-8 on page 25, or Table 4-11 on page 27 for each measurement resource type. The start and stop must have different values.
- **Vcomp**: Voltage compliance value (in V). Numeric expression. See Table 4-6 on page 23, Table 4-8 on page 25, or Table 4-11 on page 27 for each measurement resource type. If you do not specify $V_{\text{comp}}$, the previous value is set.

Example Statements

```
OUTPUT @B1500;"BSI 1,0,1E-12,1E-6,10"
```

See Also

“BSM”

Example Statements

```
OUTPUT @B1500;"BGV 1,0,0.1,12,5"
```
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**

![Diagram showing binary search source output control mode]

- **Voltage or current**
- **Stop**
- **Start**
- **Delay time**
- **Hold time**
- **Trigger**
- **Search stopped**
- **BSM, BST, and BSV or BSI**
- **Time**
- **D = | Stop - Start |**
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 = \( polarity \times BSI \) 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 16.
- **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 4-6 on page 23, Table 4-8 on page 25, or Table 4-11 on page 27 for each measurement resource 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.

\[ V_{comp} : \] Voltage compliance value (in V). Numeric expression. If you do not specify \( V_{comp} \), 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 4-6 on page 23, Table 4-8 on page 25, or Table 4-11 on page 27 for each measurement resource type.

**BSSV**

The BSSV command sets the synchronous voltage source for the binary search measurement (MM15). The synchronous source output will be:

\[
\text{Synchronous source output} = \text{polarity} \times \text{BSV source output} + \text{offset}
\]

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**

\[
\text{BSSV chnum,polarity,offset[,Icomp]}
\]

**Parameters**

- \( \text{chnum} : \) SMU synchronous source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.

- \( \text{polarity} : \) Polarity of the BSSV output for the BSV output.
  - 0: Negative. BSSV output = \(-\)BSV output + \( \text{offset} \)
  - 1: Positive. BSSV output = BSV output + \( \text{offset} \)

- \( \text{offset} : \) Offset voltage (in V). Numeric expression. See Table 4-7 on page 24, Table 4-9 on page 26, Table 4-12 on page 27, or Table 4-15 on page 28 for each measurement resource 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 4-7 on page 24, Table 4-9 on page 26, Table 4-12 on page 27, or Table 4-15 on page 28 for each measurement resource 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.

Execution Conditions

If the output voltage is greater than the allowable voltage for the interlock open condition, 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 16.

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 21.

start, stop : Search start or stop voltage (in V). Numeric expression. See Table 4-7 on page 24, Table 4-9 on page 26, Table 4-12 on page 27, or Table 4-15 on page 28 for each measurement resource type. The start and stop parameters must have different values.

Icomp : Current compliance value (in A). Numeric expression. See Table 4-7 on page 24, Table 4-9 on page 26, Table 4-12 on page 27, or Table 4-15 on page 28 for each measurement resource 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 channel must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it).

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 Keysight 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 channel must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it).

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.

<table>
<thead>
<tr>
<th>results</th>
<th>Description</th>
<th>results</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Passed. No failure detected.</td>
<td>32</td>
<td>Slot 6 module failed.</td>
</tr>
<tr>
<td>1</td>
<td>Slot 1 module failed.</td>
<td>64</td>
<td>Slot 7 module failed.</td>
</tr>
<tr>
<td>2</td>
<td>Slot 2 module failed.</td>
<td>128</td>
<td>Slot 8 module failed.</td>
</tr>
<tr>
<td>4</td>
<td>Slot 3 module failed.</td>
<td>256</td>
<td>Slot 9 module failed.</td>
</tr>
<tr>
<td>8</td>
<td>Slot 4 module failed.</td>
<td>512</td>
<td>Slot 10 module failed.</td>
</tr>
<tr>
<td>16</td>
<td>Slot 5 module failed.</td>
<td>1024</td>
<td>Mainframe failed.</td>
</tr>
</tbody>
</table>

Example Statements

OUTPUT @B1500;"*CAL?"
ENTER @B1500;Å

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 must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it). 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 16.

If you specify multiple `chnums`, 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:

<table>
<thead>
<tr>
<th>SMU setup parameter</th>
<th>Value</th>
<th>MFCMU setup parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output switch</td>
<td>OFF</td>
<td>DC bias</td>
<td>0 V</td>
</tr>
<tr>
<td>Source mode</td>
<td>Voltage</td>
<td>AC level</td>
<td>0 V</td>
</tr>
<tr>
<td>Output voltage</td>
<td>0 V</td>
<td>Output signal frequency</td>
<td>1 kHz</td>
</tr>
<tr>
<td>V range</td>
<td>20 V</td>
<td>Measurement range</td>
<td>50 Ω</td>
</tr>
<tr>
<td>I compliance</td>
<td>100 μA</td>
<td>SPGU setup parameter</td>
<td>Value</td>
</tr>
<tr>
<td>I range</td>
<td>100 μA</td>
<td>Output switch</td>
<td>OFF</td>
</tr>
<tr>
<td>Filter</td>
<td>OFF</td>
<td>Output mode</td>
<td>DC</td>
</tr>
<tr>
<td>Series resistor</td>
<td>Not changed</td>
<td>Output voltage</td>
<td>0 V</td>
</tr>
</tbody>
</table>

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 16.
- `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 16.
- **mode**: SMU measurement operation mode. Integer expression. 0 to 4. *mode*=4 is not available for HPSMU, MPSMU, and HRSMU.

  0: Compliance side measurement. Initial setting. Measures current in the voltage source operation or voltage in the current source operation.
  1: Current measurement
  2: Voltage measurement
  3: Force side measurement. Measures current in the current source operation or voltage in the voltage source operation.
  4: Current and voltage synchronous measurement. Measurement result contains the compliance side data and the force side data in this order.

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 4-23 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 must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it).

**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 16.

If the output switch of the specified SMU is already set to ON, no action is performed by this command.

If you specify multiple *chnums*, 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 16.

If you specify the channel connected to the ASU, this command enables the channel 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.

### Table 4-23 Differences between CN and CNX

<table>
<thead>
<tr>
<th>Module status</th>
<th>Output switch</th>
<th>CN</th>
<th>CNX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Open/Close</td>
<td>Close with no error</td>
<td></td>
</tr>
<tr>
<td>High voltage</td>
<td>Open</td>
<td>Open with an error</td>
<td>Close with no error</td>
</tr>
<tr>
<td></td>
<td>Close</td>
<td></td>
<td>Close with no error</td>
</tr>
</tbody>
</table>

### Example Statements

```
OUTPUT @B1500;"CN"
OUTPUT @B1500;"CN 1,2,3,5"
OUTPUT @B1500;"CNX"
OUTPUT @B1500;"CNX 1,2,3,5"
```
The CN/CNX command sets the specified module to the following conditions:

<table>
<thead>
<tr>
<th>SMU setup parameter</th>
<th>Value</th>
<th>MFCMU setup parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output switch</td>
<td>ON</td>
<td>DC bias</td>
<td>0 V</td>
</tr>
<tr>
<td>Source mode</td>
<td>Voltage</td>
<td>AC level</td>
<td>0 V</td>
</tr>
<tr>
<td>Output voltage</td>
<td>0 V</td>
<td>Output signal frequency</td>
<td>1 kHz</td>
</tr>
<tr>
<td>V range</td>
<td>20 V</td>
<td>Measurement range</td>
<td>50 Ω</td>
</tr>
<tr>
<td>I compliance</td>
<td>100 μA</td>
<td>SPGU setup parameter</td>
<td>Value</td>
</tr>
<tr>
<td>I range</td>
<td>100 μA</td>
<td>Output switch</td>
<td>ON</td>
</tr>
<tr>
<td>Filter</td>
<td>Not changed</td>
<td>Output mode</td>
<td>DC</td>
</tr>
<tr>
<td>Series resistor</td>
<td>Not changed</td>
<td>Output voltage</td>
<td>0 V</td>
</tr>
</tbody>
</table>

After this command, there is no additional power consumption for the idle state.

**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**  

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>chnum :</td>
<td>MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.</td>
</tr>
<tr>
<td>corr :</td>
<td>Correction data to measure. Integer expression. 1, 2, or 3.</td>
</tr>
<tr>
<td></td>
<td>1: Open correction data</td>
</tr>
<tr>
<td></td>
<td>2: Short correction data</td>
</tr>
<tr>
<td></td>
<td>3: Load correction data</td>
</tr>
</tbody>
</table>

**Query Response**  

result<CR/LF^EOI>  

0: Correction data measurement completed successfully.  
1: Correction data measurement failed.  
2: Correction data measurement aborted.  

**Example Statements**  

```plaintext```
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  

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>chnum :</td>
<td>MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.</td>
</tr>
<tr>
<td>freq :</td>
<td>Frequency to be added. Numeric expression in Hz. See Table 4-18 on page 30.</td>
</tr>
<tr>
<td>open_r :</td>
<td>Open correction data (G). Numeric expression in S.</td>
</tr>
<tr>
<td>open_i :</td>
<td>Open correction data (B). Numeric expression in S.</td>
</tr>
<tr>
<td>short_r :</td>
<td>Short correction data (R). Numeric expression in Ω.</td>
</tr>
<tr>
<td>short_i :</td>
<td>Short correction data (X). Numeric expression in Ω.</td>
</tr>
<tr>
<td>load_r :</td>
<td>Load correction data (R). Numeric expression in Ω.</td>
</tr>
<tr>
<td>load_i :</td>
<td>Load correction data (X). Numeric expression in Ω.</td>
</tr>
</tbody>
</table>
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**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>chnum</td>
<td>MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.</td>
</tr>
<tr>
<td>index</td>
<td>Index number of the list. Integer expression.</td>
</tr>
</tbody>
</table>

**Query Response**

freq,open_r,open_i,short_r,short_i,load_r,load_i<CR/LF^E OI>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>freq</td>
<td>Frequency of the correction data. Numeric expression in Hz.</td>
</tr>
<tr>
<td>open_r</td>
<td>Open correction data (G). Numeric expression in S.</td>
</tr>
<tr>
<td>open_i</td>
<td>Open correction data (B). Numeric expression in S.</td>
</tr>
<tr>
<td>short_r</td>
<td>Short correction data (R). Numeric expression in Ω.</td>
</tr>
<tr>
<td>short_i</td>
<td>Short correction data (X). Numeric expression in Ω.</td>
</tr>
<tr>
<td>load_r</td>
<td>Load correction data (R). Numeric expression in Ω.</td>
</tr>
<tr>
<td>load_i</td>
<td>Load correction data (X). Numeric expression in Ω.</td>
</tr>
</tbody>
</table>

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**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>chnum</td>
<td>MFCMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.</td>
</tr>
<tr>
<td>freq</td>
<td>Frequency to be added. Numeric expression. in Hz. See Table 4-18 on page 30.</td>
</tr>
</tbody>
</table>
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 16.

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 \( \text{delay} + \text{interval} \times \text{count} \) 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**

\[
\text{CORRSER}\? \text{ chnum}, \text{mode}, \text{delay}, \text{interval}, \text{count}
\]

**Parameters**

- **chnum**: SPGU channel number. Integer expression. 1 to 10 or 101 to 1002. See Table 4-1 on page 16.
- **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.

**Query Response**

\[
\text{loadZ}, \text{voltage}<\text{CR}/\text{LF}^\text{EOI}>
\]

- **loadZ**: Returns the impedance calculation data (\(\Omega\)).
- **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)

Figure 4-3 Voltage Monitor and CORRSER? Setup Parameters

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 16.

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 16.

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 16.

- **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.

  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 16.
Command Reference

Command Reference

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.

    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, Primary=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 the allowable voltage for the interlock open condition, the interlock circuit must be shorted.
DCV chnum,voltage

Parameters

chnum: MFCMU source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.

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 the allowable voltage for the interlock open condition, 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 16.

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 22.

current: Output current value (in A). Numeric expression. See Table 4-6 on page 23, Table 4-8 on page 25, or Table 4-11 on page 27 for each measurement resource type.

Vcomp: Voltage compliance value (in V). Numeric expression. See Table 4-6 on page 23, Table 4-8 on page 25, or Table 4-11 on page 27 for each measurement resource 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 21.

**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.

<table>
<thead>
<tr>
<th>item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Trigger In/Out diagnostics.</td>
</tr>
<tr>
<td>3</td>
<td>High voltage LED diagnostics.</td>
</tr>
<tr>
<td>4</td>
<td>Digital I/O diagnostics.</td>
</tr>
<tr>
<td>6</td>
<td>Interlock open diagnostics.</td>
</tr>
<tr>
<td>7</td>
<td>Interlock close diagnostics.</td>
</tr>
</tbody>
</table>

- **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"
```

**DSMPLARM**

Available for the multi channel pulsed spot measurement (MM27) and the multi channel pulsed sweep measurement (MM28) using HVSMU, HCSMU, MCSMU, DHCSMU, UHCU, HVMCU, or UHVU.

The DSMPLARM command sets the timing to start the signal monitor operation set by the DSMPLSETUP command. The signal monitor is started when the specified event is repeated the specified count.
**Command Reference**

**Command Reference**

**Execution Conditions**

The DSMPLSETUP command must be executed before this command.

**Syntax**

DSMPLARM chnum, type, count

**Parameters**

**chnum**: SMU channel number. Integer expression. 1 to 10. See Table 4-1 on page 16.

**type**: Event type. Integer expression.

1: Start of pulse output

**count**: Number of events. Integer expression. 0 disables the signal monitor.

**Example Statements**

If the following command is executed, the channel 5 starts the signal monitor when the 10th pulse output starts.

OUTPUT @B1500; "DSMPLARM 5, 1, 10"

**Remarks**

The signal monitor operation is performed as a part of the MM27/MM28 measurement.

The MM27/MM28 measurement data is directly sent to the data output buffer regardless of the signal monitor operation ON or OFF. The data is a dummy data if the signal monitor operation does not overlap the MM27/MM28 measurement operation, or the averaging result of the signal monitor data obtained in the overlap period.

The channel can store all data obtained by one execution of the signal monitor. And the data is sent to the data output buffer by the DSMPLFLUSH command.

**DSMPLFLUSH**

Available for the multi channel pulsed spot measurement (MM27) and the multi channel pulsed sweep measurement (MM28) using HVSMU, HCSMU, MCSMU, DHCSMU, UHCU, HVMCU, or UHVU.

The DSMPLFLUSH command sends the signal monitor data to the data output buffer.

**Execution Conditions**

The DSMPLARM command must be executed before this command.

**Syntax**

DSMPLFLUSH chnum
Parameters

\texttt{chnum} : SMU channel number. Integer expression. 1 to 10. See Table 4-1 on page 16.

Response

All data obtained by one execution of the signal monitor is returned. One data contains the compliance side data and the force side data in this order. Time stamp data is not included. The data output format depends on the FMT command setting.

If there is no signal monitor data, a dummy data is returned.

Example Statements

\texttt{OUTPUT @B1500;"DSMPLFLUSH 5"}

\section*{DSMPLSETUP}

Available for the multi channel pulsed spot measurement (MM27) and the multi channel pulsed sweep measurement (MM28) using HVSMU, HCSMU, MCSMU, DHCSMU, UHCU, HVMCU, or UHVU.

The DSMPLSETUP command sets the signal monitor function for the specified channel. This function is used to monitor the channel input/output during the measurement specified by the MM command. The channel measures its voltage and current, and repeats it the specified count in the specified interval. Then the voltage and current measurements are performed at the same time. Use the DSMPLARM command to set the timing to start the signal monitor operation.

Syntax

\texttt{DSMPLSETUP \texttt{chnum, count, interval[, delay]}}

Parameters

\texttt{chnum} : SMU channel number. Integer expression. 1 to 10. See Table 4-1 on page 16.

\texttt{count} : Number of sampling. Integer expression. 1 to 4000 for HVSMU. 1 to 2000 for HCSMU, MCSMU, DHCSMU, UHCU, HVMCU, and UHVU.

\texttt{interval} : Sampling interval. Numeric expression. 6 $\mu$s to 12 $\mu$s in 2 $\mu$s resolution for HVSMU. 2 $\mu$s to 12 $\mu$s in 2 $\mu$s resolution for HCSMU, MCSMU, DHCSMU, UHCU, HVMCU, and UHVU.

\texttt{delay} : Delay time. Numeric expression. $-\text{maximum count value} \times \text{interval}$ to $+\text{maximum count value} \times \text{interval}$, in 2 $\mu$s resolution. Default setting is 0.

Set 110 $\mu$s to start the signal monitor at the timing to start the transition from the pulse base value to the pulse peak value.
Example Statements

OUTPUT @B1500;"DSMPLSETUP 5,100,6E-6,1E-4"

**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 the allowable voltage for the interlock open condition, 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 16.

- **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 21.

- **voltage**: Output voltage value (in V). Numeric expression. See Table 4-7 on page 24, Table 4-9 on page 26, Table 4-12 on page 27, or Table 4-15 on page 28 for each measurement resource type.

- **Icomp**: Current compliance value (in A). Numeric expression. See Table 4-7 on page 24, Table 4-9 on page 26, Table 4-12 on page 27, or Table 4-15 on page 28 for each measurement resource 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 22.

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 the *RST, RZ, CL, CA, *TST?, or a device clear.

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 16.

If you specify multiple chnums, 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:

<table>
<thead>
<tr>
<th>SMU setup parameter</th>
<th>Value</th>
<th>MFCMU setup parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source mode</td>
<td>Voltage</td>
<td>DC bias</td>
<td>0 V</td>
</tr>
<tr>
<td>Output voltage</td>
<td>0 V</td>
<td>AC level</td>
<td>0 V</td>
</tr>
<tr>
<td>V range</td>
<td>Not changed</td>
<td>Output signal frequency</td>
<td>Not changed</td>
</tr>
<tr>
<td>I compliance</td>
<td>See next table</td>
<td>Measurement range</td>
<td>50 Ω</td>
</tr>
<tr>
<td>I range</td>
<td>See next table</td>
<td>SPGU setup parameter</td>
<td>Value</td>
</tr>
<tr>
<td>Filter</td>
<td>Not changed</td>
<td>Output mode</td>
<td>Not changed</td>
</tr>
<tr>
<td>Series resistor</td>
<td>Not changed</td>
<td>Output voltage</td>
<td>0 V</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Previous range a</th>
<th>I Range</th>
<th>I Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 nA to 100 μA</td>
<td>same as previous range</td>
<td>range value</td>
</tr>
<tr>
<td>over 100 μA</td>
<td>100 μA</td>
<td>100 μA</td>
</tr>
</tbody>
</table>

a. Range value that was set before the DZ command.
Command Reference
Command Reference

**Example Statements**

**OUTPUT** @B1500;"DZ 1,2,3"

**EMG?**

The EMG? query command returns error message corresponding to the specified error code. This command supports the error code 0 to 999.

If unsupported error is detected, 999 is returned by the ERR? command. The EMG? 999 command returns the message associated with the last error.

**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.

**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 4-203.

**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 a 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 Keysight 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 Keysight 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?”

### ERCMAA

The ERCMAA command specifies the measurement resources connected to the input ports of Keysight N1272A/B1506A/B1507A’s device capacitance selector.

### Execution Conditions

- Digital I/O port must be set to the N1272A control mode using the ERMOD 32 command.
- No channel must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it).
- The CN/CNX command has not been executed for the specified channels.

### Syntax

```
ERCMAA mfcmu, hvsmu, mpsmu
```

### Parameters

- **mfcmu**: Slot number of MFCMU connected to the MFCMU port
- **hvsmu**: Slot number of HVSMU connected to the HVSMU port
- **mpsmu**: Slot number of MPSMU connected to the MPSMU port
Effective slot numbers are 1 to 10. Integer expression. Use the smaller slot number for the module which occupies two slots, such as HVSMU.

Enter 0 to cancel the assignment.

**Example Statements**

```
OUTPUT @B1500; "ERCMAA 2,7,1"
```

**ERCMAA?**

The ERCMAA? command returns the slot numbers of the measurement resources connected to the input ports of Keysight N1272A/B1506A/B1507A’s device capacitance selector.

**Syntax**

```
ERCMAA?
```

**Query Response**

```
mfcmu, hvsmu, mpsmu<CR/LF^EOI>
```

- **mfcmu**: Slot number of MFCMU connected to the MFCMU port
- **hvsmu**: Slot number of HVSMU connected to the HVSMU port
- **mpsmu**: Slot number of MPSMU connected to the MPSMU port

Channel number will be 1 to 10. Integer expression. Or 0 is returned if the associated module has not been specified.

**Example Statements**

```
OUTPUT @B1500; "ERCMAA?"
ENTER @B1500; A, B, C
```

**ERCMAGRD**

The ERCMAGRD command specifies the type of the output from the guard output port of Keysight N1272A/B1506A/B1507A’s device capacitance selector.

**Execution Conditions**

Digital I/O port must be set to the N1272A control mode using the ERMOD 32 command.

The output terminal must be set to Open using the ERCMAIO 000,000,000 command.

**Syntax**

```
ERCMAGRD [guard]
```

**Parameters**

- **guard**: Output type
  - 1: Common AC guard (default setting)
  - 2: Floating AC guard
When $guard = 1$, if the capacitance measurement path is connected by the ERCMAIO command, the guard terminal outputs the common AC guard.

When $guard = 2$, if the capacitance measurement path is connected by the ERCMAIO command, the guard terminal outputs the floating AC guard.

When $guard = 1$, if the I/V measurement path is connected by the ERCMAIO command, the guard terminal outputs the common level.

When $guard = 2$, if the I/V measurement path using the HVSMU is connected by the ERCMAIO command, the guard terminal outputs the guard output of the HVSMU. If HVSMU is not used in the I/V measurement path, the guard terminal is opened.

**Example Statements**

```
OUTPUT @B1500; "ERCMAGRD 2"
```

**ERCMAGRD?**

The ERCMAGRD? command returns the type of the output from the guard output port of Keysight N1272A/B1506A/B1507A's device capacitance selector.

**Syntax**

```
ERCMAGRD?
```

**Query Response**

```
guard<CR/LF^EOI>

guard : Output
   1: Common AC guard
   2: Floating AC guard
```

**Example Statements**

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

**ERCMAIO**

The ERCMAIO command sets the input-to-output connection paths of Keysight N1272A/B1506A/B1507A's device capacitance selector.

**Execution Conditions**

Digital I/O port must be set to the N1272A control mode using the ERMOD 32 command.

No channel must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it).

**Syntax**

```
ERCMAIO [cmh1[,acgs[,bias[,corr]]]]
```
Parameters

**cmhl**: MFCMU connection paths to the DUT terminals represented by three digit number \((DGS)\). Integer expression. Where;

- **D**: DUT Collector/Drain output terminal
- **G**: DUT Base/Gate output terminal
- **S**: DUT Emitter/Source output terminal

Specify the following numbers to \(DGS\) respectively.

- 0: No connection (NC)
- 1: MFCMU Low terminal (CML)
- 2: MFCMU High terminal (CMH)

The following combinations are available.

- 000: NC, NC, NC (default setting)
- 021: NC, CMH, CML
- 121: CML, CMH, CML
- 201: CMH, NC, CML
- 210: CMH, CML, NC
- 211: CMH, CML, CML
- 212: CMH, CML, CMH

**acgs**: Guard connection paths to the DUT terminals represented by three digit number \((DGS)\). Integer expression. Where;

- **D**: DUT Collector/Drain output terminal
- **G**: DUT Base/Gate output terminal
- **S**: DUT Emitter/Source output terminal

Specify the following numbers to \(DGS\) respectively.

- 0: No connection (NC)
- 1: Common AC guard (Common)
- 2: Floating AC guard (Floating)
- 9: AC short (Short)

The following combinations are available.

- 000: NC, NC, NC (default setting)
- 001: NC, NC, Common
- 010: NC, Common, NC
- 020: NC, Floating, NC
100: Common, NC, NC
200: Floating, NC, NC
909: Short, NC, Short (AC Short between the Collector/Drain and Emitter/Source terminals)

**bias**: Bias connection paths to the DUT terminals represented by three digit number (DGS). Integer expression. Where;

\[D: \text{DUT Collector/Drain output terminal}\]
\[G: \text{DUT Base/Gate output terminal}\]
\[S: \text{DUT Emitter/Source output terminal}\]

Specify the following numbers to DGS respectively.

0: No connection or open (Open)
1: Common DC bias (Common)
2: CMU DC bias (CMH)
3: SMU DC bias (SMU)

As the SMU DC bias, the HVSMU is connected to the Collector/Drain output terminal, and the MPSMU is connected to the Base/Gate output terminal.

The following combinations are available.

000: Open, Open, Open (default setting)
021: Open, CMH, Common
031: Open, SMU, Common
121: Common, CMH, Common
131: Common, SMU, Common
201: CMH, Open, Common
210: CMH, Common, Open
211: CMH, Common, Common
212: CMH, Common, CMH
231: CMH, SMU, Common
311: SMU, Common, Common
321: SMU, CMH, Common
331: SMU, SMU, Common
**corr**: Open/Short/Load paths to measure the correction data

0: Normal measurement path (default setting)

1: Open path

2: Short path

3: Load path

The following combinations of the `cmhl`, `acgs`, and `bias` parameters are available.

- Capacitance measurement paths

  021,909,321
  021,909,331
  021,200,321
  021,200,331
  021,200,021
  021,200,031
  021,100,121
  021,100,131
  021,000,021
  021,000,031
  121,000,121
  121,000,131
  211,000,211
  211,000,231
  211,000,311
  211,000,331
  210,001,211
  210,001,231
  210,001,311
  210,001,331
  210,000,210
• Open the output terminal (If the N1272A is used, the HVSMU is connected directly)
  000,000,000
• I/V measurement paths
  000,000,031
  000,000,331

Example Statements

OUTPUT @B1500; "ERCMAIO 021,909,331"

ERCMAIO?

The ERCMAA? command returns the input-to-output connection paths of Keysight N1272A/B1506A/B1507A's device capacitance selector.

Syntax

ERCMAIO?

Query Response

\[cmhl, acgs, bias[, corr]\]<CR/LF^EOI>

The status of the connection paths is returned. Integer expression. If corr=0, it is not included in the response.

\[cmhl\] : MFCMU connection paths to the DUT terminals represented by three digit number (DGS). Integer expression. Where;

\[D\] : DUT Collector/Drain output terminal
\[G\] : DUT Base/Gate output terminal
\[S\] : DUT Emitter/Source output terminal

The following numbers mean the resources connected to DGS terminals respectively.
0: No connection (NC)
1: MFCMU Low terminal (CML)
2: MFCMU High terminal (CMH)

One of the following combinations is returned.
000: NC, NC, NC (default setting)
021: NC, CMH, CML
121: CML, CMH, CML
201: CMH, NC, CML
210: CMH, CML, NC
211: CMH, CML, CML
212: CMH, CML, CMH

`acgs`: Guard connection paths to the DUT terminals represented by three digit number (`DGS`). Integer expression. Where;

D: DUT Collector/Drain output terminal
G: DUT Base/Gate output terminal
S: DUT Emitter/Source output terminal

The following numbers means the resources connected to `DGS` terminals respectively.
0: No connection (NC)
1: Common AC guard (Common)
2: Floating AC guard (Floating)
9: AC short (Short)

One of the following combinations is returned.
000: NC, NC, NC (default setting)
001: NC, NC, Common
010: NC, Common, NC
020: NC, Floating, NC
100: Common, NC, NC
200: Floating, NC, NC
909: Short, NC, Short (AC Short between the Collector/Drain and Emitter/Source terminals)
**bias:** Bias connection paths to the DUT terminals represented by three digit number (DGS). Integer expression. Where;

- **D:** DUT Collector/Drain output terminal
- **G:** DUT Base/Gate output terminal
- **S:** DUT Emitter/Source output terminal

The following numbers means the resources connected to DGS terminals respectively.

- 0: No connection or open (Open)
- 1: Common DC bias (Common)
- 2: CMU DC bias (CMH)
- 3: SMU DC bias (SMU)

As the SMU DC bias, the HVSMU is connected to the Collector/Drain output terminal, and the MPSMU is connected to the Base/Gate output terminal.

One of the following combinations is returned.

- 000: Open, Open, Open (default setting)
- 021: Open, CMH, Common
- 031: Open, SMU, Common
- 121: Common, CMH, Common
- 131: Common, SMU, Common
- 201: CMH, Open, Common
- 210: CMH, Common, Open
- 211: CMH, Common, Common
- 212: CMH, Common, CMH
- 231: CMH, SMU, Common
- 311: SMU, Common, Common
- 321: SMU, CMH, Common
- 331: SMU, SMU, Common

**corr:** Open/Short/Load paths to measure the correction data

- 1: Open path
- 2: Short path
3: Load path

Example Statements

```
OUTPUT @B1500;"ERCMAIO?"
ENTER @B1500;A,B,C
```

**ERCMAFGD**

Only for the Keysight B1506A users. The ERCMAFGD command sets the paths from the MPSMU to the Base/Gate and the Collector/Drain terminals and from the GNDU to the Emitter/Source terminal.

The paths are used when the threshold voltage is measured on VGS=VDS condition for MOSFET devices or VGE=VCE condition for IGBT devices.

The path setting by this command is canceled by ERPFD or ERCMAIO command.

**Execution Conditions**

Digital I/O port must be set to the N1272A control mode using the ERMOD 32 command.

No channel must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it).

**Syntax**

```
ERCMAFGD
```

**Example Statements**

```
OUTPUT @B1500;"ERCMAFGD"
```

**ERHPA**

The ERHPA command specifies the measurement resources connected to the input ports of Keysight N1258A/N1259A module selector.

**Execution Conditions**

Digital I/O port must be set to the N1258A/N1259A control mode using the ERMOD 2 command.

**Syntax**

```
ERHPA crumbling, hcsmu, hpsmu
```

**Parameters**

- **hsvmu** : Channel number of HVSMU connected to the HVSMU port, even if it is HVMCU/HVSMU through the Keysight N1266A expander
- **hcsmu** : Channel number of HCSMU or DHCSMU connected to the HCSMU port
- **smu** : Channel number of MPSMU or HPSMU connected to the HPSMU port

Effective channel numbers are 1 to 10, or 101 to 1001. Integer expression. See Table 4-1 on page 16.
Enter 0 if the associated module is not installed.

**Example Statements**

```output
OUTPUT @B1500;"ERHPA 7,5,3"
```

### ERHPA?

The ERHPA? command returns the channel numbers of the measurement resources connected to the input ports of Keysight N1258A/N1259A module selector.

**Syntax**

```plaintext
ERHPA?
```

**Query Response**

```
hvsmu, hcsmu, hpsmu<CR/LF^EOI>
```

- **hvsmu**: Channel number of HVSMU connected to the HVSMU port, even if it is HVMCU/HVSMU through the Keysight N1266A expander.
- **hcsmu**: Channel number of HCSMU or DHCSMU connected to the HCSMU port.
- **smu**: Channel number of MPSMU or HPSMU connected to the HPSMU port.

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**

```enter
OUTPUT @B1500;"ERHPA?"
ENTER @B1500;A,B,C
```

### ERHPE

Only for the N1258A module selector users. This command enables or disables the external relay control function. See “External Relay Control Output” on page 2-65.

**Execution Conditions**

Digital I/O port must be set to the N1258A/N1259A control mode using the ERMOD 2 command.

**Syntax**

```plaintext
ERHPE onoff
```

**Parameters**

- **onoff**: 1 (enable) or 0 (disable, initial setting). Integer expression.

**Example Statements**

```output
OUTPUT @B1500;"ERHPE 1"
```

### ERHPE?

Only for the N1258A module selector users. This command returns the condition of the external relay control function.
ERHPE?

Syntax

Query Response

Example Statements

ERHPL

The ERHPL command enables or disables the LED status indicator of Keysight N1258A/N1259A module selector.

Syntax

Parameters

Example Statements

ERHPL?

The ERHPL? command returns the condition of the LED status indicator of Keysight N1258A/N1259A module selector.

Syntax

Query Response

Example Statements

ERHPP

The ERHPP command sets the input-to-output connection path of Keysight N1258A/N1259A module selector.

Execution Conditions

Digital I/O port must be set to the N1258A/N1259A control mode using the ERMOD 2 command.

Syntax

Parameters

Example Statements
ERHPP  path

Parameters  path :  Input-to-output connection path. Integer expression. 0, 1, 2, 3, or 4.

0: Open, no module is connected, initial setting
1: Connects to HVSMU port
2: Connects to HCSMU port
3: Connects to HPSMU port
4: Connects to HVSMU port, also connects the series resistor

Example Statements

OUTPUT @B1500;"ERHPP 3"

ERHPP?

The ERHPP? command returns the input-to-output connection path of Keysight N1258A/N1259A module selector.

Syntax  ERHPP?

Query Response  path<CR/LF^EOI>

Input-to-output connection path. Integer expression. 0, 1, 2, 3, or 4.

0: Open, no module is connected
1: Connects to HVSMU port
2: Connects to HCSMU port
3: Connects to HPSMU port
4: Connects to HVSMU port, also connects the series resistor

Example Statements

OUTPUT @B1500;"ERHPP?"
ENTER @B1500;A

ERHPQG

The ERHPQG command specifies the measurement input/output mode of the Keysight N1274A on-wafer gate charge measurement adapter.

According to the measurement input/output mode, the measurement path is switched by the relay control function of Keysight N1258A module selector.
**Execution Conditions**

Digital I/O port must be set to the N1258A/N1259A control mode using the ERMOD 2 command.

External relay control function must be enabled using the ERHPE 1 command.

No channel must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it).

**Syntax**

ERHPQG  *state*

**Parameters**

*state* : Measurement input/output mode. Integer expression.

- 0: Open (default setting)
- 1: Gate charge measurement mode
- 2: I/V measurement mode

When *state*=0, the output of Keysight N1274A is opened.

When *state*=1, the input/output paths of Keysight N1274A are switched to the following path according to the input/output switching of Keysight N1258A.

- If the output terminal of N1258A is opened, the output terminal of N1274A is opened.
- If the output terminal of N1258A is not opened, the input/output of N1274A make the gate charge measurement path that the output terminals of N1258A are connected to the High and Low output terminals of N1274A.
  
  If the output terminal of N1258A is connected to HVSMU, the output terminal of HVSMU is connected to the High Sense output terminal of N1274A.

When *state*=2, the input/output paths of Keysight N1274A are switched to the following path according to the input/output switching of Keysight N1258A.

- If the output terminal of N1258A is opened, the output terminal of N1274A is opened.
- If the output terminal of N1258A is not opened, the input/output of N1274A make the I/V measurement path that the output terminals of N1258A are connected to the High and Low output terminals of N1274A.
  
  If the output terminal of N1258A is connected to HVSMU, the output terminal of HVSMU is connected to the High Sense output terminal of N1274A.

**Example Statements**

```
OUTPUT @B1500; "ERHPQG 1"
```
ERHPQG?

The ERHPQG? command returns the measurement input/output mode of the Keysight N1274A on-wafer gate charge measurement adapter.

**Syntax**

ERHPQG?

**Query Response**

`state<CR/LF^EOI>`

`state` : Measurement input/output mode. Integer expression.

- 0: Open
- 1: Gate charge measurement mode
- 2: I/V measurement mode

**Example Statements**

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

ERHPR

Only for the N1258A module selector users. This command sets the logical state ON or OFF to the specified relay control output pin. See “External Relay Control Output” on page 2-65 for the external relay control function.

**Execution Conditions**

- Digital I/O port must be set to the N1258A/N1259A control mode using the ERMOD 2 command.
- External relay control function must be enabled using the ERHPE 1 command.

**Syntax**

ERHPR `pin,state`

**Parameters**

- `pin` : Relay control output pin number. Integer expression. 1 to 6.
- `state` : Logical state. Integer expression. 0 or 1.
  - 0: OFF (0 V, circuit common), initial setting
  - 1: ON (12 V)

**Example Statements**

```
OUTPUT @B1500;"ERHPR 1,1"
OUTPUT @B1500;"ERHPR 2,1"
```
**ERHPR?**

Only for the N1258A module selector users. This command returns the logical state set to the specified relay control output pin.

**Syntax**

ERHPR? *pin*

**Parameters**

*pin*: Relay control output pin number. Integer expression. 1 to 6.

**Query Response**

`state<CR/LF^EOI>`

0 (logical state OFF, 0 V) or 1 (logical state ON, 12 V). Integer expression.

**Example Statements**

```
OUTPUT @B1500;"ERHPR? 1"
ENTER @B1500;A
```

**ERHPS**

The ERHPS command sets the connection status of the series resistor on the HVSMU path of Keysight N1258A/N1259A module selector.

**Execution Conditions**

Digital I/O port must be set to the 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 connection status of the series resistor on the HVSMU path of Keysight N1258A/N1259A module selector.

**Syntax**

ERHPS?

**Query Response**

`onoff<CR/LF^EOI>`

Connection status of the series resistor on the HVSMU path. 1 (connect) or 0 (disconnect). Integer expression.
Example Statements
OUTPUT @B1500;"ERHPS?"
ENTER @B1500;A

**ERHVCA**

This command specifies the modules connected to the V Control, I Control, and HVSMU inputs of Keysight N1266A HVSMU current expander.

**Execution Conditions**

No channel must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it).

The CL command has been already executed for the channels specified in this command.

Digital I/O port must be set to the N1266A control mode using the ERMOD 8 command.

**Syntax**

`ERHVCA vsmu, ismu, hvsmu`

**Parameters**

- **vsmu**: Slot number for the MC/HCSMU connected to the V Control input.
- **ismu**: Slot number for the MC/HCSMU connected to the I Control input.
- **hvsmu**: Slot number for the HVSMU connected to the HVSMU input.

Effective slot numbers are 1 to 10. Integer expression. Use the smaller slot number for the module which occupies two slots, such as HVSMU and HCSMU.

Enter 0 to cancel the assignment.

Example Statements

OUTPUT @B1500;"ERHVCA 3,4,9"

**ERHVCA?**

This query command returns the slot numbers for the modules connected to the V Control, I Control, and HVSMU inputs of Keysight N1266A HVSMU current expander.

**Syntax**

`ERHVCA?`

**Query Response**

`vsmu, ismu, hvsmu<CR/LF^EOI>`

- **vsmu**: Slot number for the MC/HCSMU connected to the V Control input.
- **ismu**: Slot number for the MC/HCSMU connected to the I Control input.
- **hvsmu**: Slot number for the HVSMU connected to the HVSMU input.
Example Statements

```
OUTPUT @B1500;"ERHVCA?"
ENTER @B1500;vsmu,ismu,hvsmu
```

**ERHVCTST?**

This query command performs the self-test of Keysight N1266A HVSMU current expander, and returns the execution results. After this command, read the result soon.

**Execution Conditions**

The ERHVCA command has been executed before this command.

**Syntax**

```
ERHVCTST?
```

**Query Response**

```
result<CR/LF^EOI>
0: Pass
1: Fail
```

Example Statements

```
OUTPUT @B1500;"ERHVCTST?"
ENTER @B1500;result
```

**ERHVP**

This command sets the input-to-output connection path of Keysight N1266A HVSMU current expander.

**Execution Conditions**

No channel must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it). Digital I/O port must be set to the N1266A control mode using the ERMOD 8 command.

**Syntax**

```
ERHVP state
```

**Parameters**

```
state : Connection status of the input-to-output path. Integer expression. 0, 1, or 2.
```

```
0: Open, initial setting.
1: Connects to HVSMU
2: Connects to HVMCU
```
Example Statements

```plaintext
OUTPUT @B1500;"ERHVP 2"
```

**ERHVP?**

This query command returns the connection status of the input-to-output path of Keysight N1266A HVSMU current expander.

**Syntax**

```plaintext
ERHVP?
```

**Query Response**

`state<CR/LEOI>

Connection status of the input-to-output path. 0, 1, or 2 (see ERHVP).

Example Statements

```plaintext
OUTPUT @B1500;"ERHVP?"
ENTER @B1500;pathHVMC
```

**ERHVPV**

This command sets the operation mode of Keysight N1266A HVSMU current expander for the performance verification.

**Execution Conditions**

Digital I/O port must be set to the N1266A control mode using the ERMOD 8 command.

The ERHVP 0 command has been already executed.

The CL command has been already executed for the channels specified in the ERHVCA command.

**Syntax**

```plaintext
ERHVPV state
```

**Parameters**

`state`: Operation mode. Integer expression. 0, 1, or 2.

0: Normal mode, initial setting

1: HVMCU DC output mode

2: Capacitance charge mode

Example Statements

```plaintext
OUTPUT @B1500;"ERHVPV 2"
```

**ERHVS**

This command sets the connection status of the series resistor on the HVSMU path of Keysight N1266A HVSMU current expander.
Digital I/O port must be set to the N1266A control mode using the ERMOD 8 command.

The ERHVP 0 command has been already executed.

The CL command has been already executed for the channels specified in the ERHVCA command.

**Syntax**

``` ERHVS state ``

**Parameters**

- `state`: Connection status of the series resistor on the HVSMU path. Integer expression. 0 or 1.
  - 0: Disable the series resistor connection, initial setting
  - 1: Enable the series resistor connection.

**Example Statements**

``` OUTPUT @B1500;"ERHVS 1" ```

**ERHVS?**

This query command returns the connection status of the series resistor on the HVSMU path of Keysight N1266A HVSMU current expander.

**Syntax**

``` ERHVS? ```

**Query Response**

```
state<CR/LF^EOI>
```

Connection status of the series resistor on the HVSMU path. 0 (disconnect) or 1 (connect).

**Example Statements**

``` OUTPUT @B1500;"ERHVS?"
ENTER @B1500;hvRHVMC ```

**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 a 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[,option]
```

**Parameters**

`mode` : Control mode. Integer expression. 0, 1, 2, 4, 8, or 16.

0: General purpose control mode, initial setting.
1: 16440A SMU/PGU selector (B1500A-A04) control mode
2: N1258A/N1259A control mode
4: N1265A control mode
8: N1266A control mode
16: N1268A control mode
32: N1272A control mode

`option` : Disable/enable of the specified mode. Integer expression. 0 or 1.

0: Disables the specified mode.
1: Enables the specified mode, initial setting.

The 16440A control mode offers easy control over the 16440A selector (B1500A-A04) connected to the digital I/O port via the Keysight 16445A selector adapter. Use ERSSP and ERSSP?.

The N1258A/N1259A control mode offers easy control over the Keysight N1258A module selector or the module selector installed in the Keysight N1259A test fixture. Use ERHPA, ERHP, and ERHP?.

The N1265A control mode offers easy control over the Keysight N1265A ultra high current expander/fixture. Use ERPFDA, ERPFDA?, ERPFD, ERPFD?, ERPFD?, ERPFDA, ERPFDA?, ERPFGA, ERPFGA?, ERPFGP, ERPFGP?, ERPFGR, ERPFGR?, ERPFTEMP, ERPFUHCA, ERPFUHCA?, and ERPFUHCMAX?.

The N1266A control mode offers easy control over the Keysight N1266A HVSMU current expander. Use ERHVCA, ERHVCA?, ERHVP, ERHVP?, ERHVPV, ERHVS, and ERHVS?.

The N1268A control mode offers easy control over the Keysight N1268A ultra high voltage expander. Use ERUHVA and ERUHVA?.

The N1272A control mode offers easy control over the Keysight N1272A device capacitance selector.

B1506A is equipped with the ultra high current expander and device capacitance selector sections. Controlling these sections requires the N1265A control mode and N1272A control mode.

B1507A is equipped with the device capacitance selector section. Controlling this section requires the N1272A control mode.

The general purpose control mode is for controlling the other equipments. Use ERM, ERS?, ERC, and TGP.

**Remarks**

If much equipment is used, execute the ERMOD command for all equipment. For example, execute the ERMOD 4, ERMOD 8, and ERMOD 16 commands for using the N1265A, N1266A, and N1268A. There is no requirement for the execution order of these commands.

**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 SMU/PGU selector (B1500A-A04) control mode
2: N1258A/N1259A control mode
4: N1265A control mode
8: N1266A control mode
16: N1268A control mode
32: N1272A control mode

Remarks
If some control modes are enabled, the ERMOD? command returns sum of mode values. For example, after the ERMOD 4, ERMOD 8, and ERMOD 16 commands are executed, the ERMOD? command returns 28 (=4+8+16).

Example Statements
OUTPUT @B1500;"ERMOD?"
ENTER @B1500;

ERPFDA
This command specifies the measurement resources connected to the Selector Input of Keysight N1265A ultra high current expanderfixture.

Execution Conditions
No channel must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it).

Digital I/O port must be set to the N1265A control mode using the ERMOD 4 command.

Syntax
ERPFDA hvsmu, smu

Parameters
hvsmu: Slot number for the HVSMU connected to the Selector Input HVSMU port, even if it is HVMCU/HVSMU through Keysight N1266A expander

smu: Slot number for the MP/HPSMU connected to the Selector Input SMU port.

Effective slot numbers are 1 to 10. Integer expression. Use the smaller slot number for the module which occupies two slots, such as HVSMU and HPSMU.
Command Reference
Command Reference

Enter 0 to cancel the assignment.

Example Statements

OUTPUT @B1500;"ERPFDA 6,0"

**ERPFDA?**

This query command returns the slot numbers for the measurement resources connected to the Selector Input of Keysight N1265A ultra high current expander/fixture.

**Syntax**

ERPFDA?

**Query Response**

`hvsmu,smu<CR/LF^EOI>`

- `hvsmu`: Slot number for the HVSMU connected to the Selector Input HVSMU port, even if it is HVMCU/HVSMU through Keysight N1266A expander.
- `smu`: Slot number for the MP/HPSMU connected to the Selector Input SMU port.

Example Statements

OUTPUT @B1500;"ERPFDA?"

ENTER @B1500;hvSelUHC,smuSelUHC

**ERPFD**

This command sets the selector input-to-output connection path of Keysight N1265A ultra high current expander/fixture.

**Execution Conditions**

No channel must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it).

Digital I/O port must be set to the N1265A control mode using the ERMOD 4 command.

**Syntax**

ERPFDP *state*

**Parameters**

- `state`: Selector input-to-output connection path. Integer expression. 0, 1, 2, 3, or 4.

  - 0: Open, no resource is connected, initial setting.
  - 1: Connects the Low terminal to UHCU Low, and the High terminal to the UHCU High.
2: Connects the Low terminal to the GNDU, and the High terminal to the HVSMU/HVMCU.

3: Connects the Low terminal to the GNDU, and the High terminal to the MP/HPSMU.

4: Connects the Low terminal to the GNDU, and opens the High terminal.

Example Statements

```
OUTPUT @B1500;"ERPFDP 1"
```

**ERPFDP?**

This query command returns the selector input-to-output connection status of Keysight N1265A ultra high current expander/fixture.

**Syntax**

```
ERPFDP?
```

**Query Response**

```
state<CR/LF^EOI>
```

Selector input-to-output connection status. 0, 1, 2, 3, or 4 (see ERPFDP).

Example Statements

```
OUTPUT @B1500;"ERPFDP?"
ENTER @B1500;pathSelUHC
```

**ERPFDS**

This command sets the connection status of the series resistor on the HVSMU path of Keysight N1265A ultra high current expander/fixture.

**Execution Conditions**

- Digital I/O port must be set to the N1265A control mode using the ERMOD 4 command.
- The ERPFDP 0 command has been already executed.
- The CL command has been already executed for the channels specified in the ERPFDA command.

**Syntax**

```
ERPFDS state
```

**Parameters**

```
state : Connection status of the series resistor on the HVSMU path. Integer expression. 0 or 1.

0: Disables the series resistor connection, initial setting.

1: Enables the series resistor connection.
```
**ERPFDS?**

This query command returns the connection status of the series resistor on the HVSMU path of Keysight N1265A ultra high current expander/fixture.

**Syntax**

```
ERPFDS?
```

**Query Response**

```
state<CR/LF^EOI>
```

Connection status of the series resistor on the HVSMU path. 0 (disconnect) or 1 (connect).

**Example Statements**

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

**ERPFGA**

This command specifies the MC/HCSMU module connected to the Gate input of Keysight N1265A ultra high current expander/fixture.

**Execution Conditions**

No channel must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it).

Digital I/O port must be set to the N1265A control mode using the ERMOD 4 command.

**Syntax**

```
ERPFGA gsmu
```

**Parameters**

`gsmu` : Slot number for the MC/HCSMU connected to the Gate input.

Effective slot numbers are 1 to 10. Integer expression. Use the smaller slot number for the HCSMU which occupies two slots.

Enter 0 to cancel the assignment.

**Remarks**

If the HCSMU is connected to the Gate input, the maximum current of the HCSMU for gate controlling is as follows:

- DC: 100 mA
- Pulse: 1 A, maximum duty ratio is 5%.

**Example Statements**

```
OUTPUT @B1500;"ERPFGA 5"
```
**ERPFGA?**

This query command returns the slot number for the MC/HCSMU module connected to the Gate input of Keysight N1265A ultra high current expander(fixture).

**Syntax**

```
ERPFGA?
```

**Query Response**

```
gsmu<CR/LF^EOI>
```

**gsmu** : Slot number for the MC/HCSMU connected to the Gate input.

**Example Statements**

```
OUTPUT @B1500;"ERPFGA?"
ENTER @B1500;gsmuUHC
```

**ERPFGP**

This command sets the connection status of the MC/HCSMU output connected to the Gate input of Keysight N1265A ultra high current expander(fixture).

**Execution Conditions**

No channel must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it).

Digital I/O port must be set to the N1265A control mode using the ERMOD 4 command.

**Syntax**

```
ERPFGP state
```

**Parameters**

```
state : Connection status. Integer expression. 0 or 1.
```

- 0: Open, initial setting.
- 1: Connected.

**Example Statements**

```
OUTPUT @B1500;"ERPFGP 1"
```

**ERPFGP?**

This query command returns the connection status of the MC/HCSMU module connected to the Gate input of Keysight N1265A ultra high current expander(fixture).

**Syntax**

```
ERPFGP?
```

**Query Response**

```
state<CR/LF^EOI>
```
Command Reference

Connection status. 0 (open) or 1 (connect).

Example Statements

```plaintext
OUTPUT @B1500;"ERPFGP?"
ENTER @B1500;gpathUHC
```

**ERPFGR**

This command sets the connection status of the series resistor on the Gate path of Keysight N1265A ultra high current expander/fixture.

Execution Conditions

Digital I/O port must be set to the N1265A control mode using the ERMOD 4 command.

The ERPFGP 0 command has been already executed.

Syntax

```
ERPFGR state
```

Parameters

`state` : Connection status of the series resistor on the Gate path. Integer expression. 0, 10, 100, or 1000.

- 0: 0 Ω
- 10: 10 Ω
- 100: 100 Ω
- 1000: 1000 Ω

Example Statements

```plaintext
OUTPUT @B1500;"ERPFGR 100"
```

**ERPFGR?**

This query command returns the connection status of the series resistor on the Gate path of Keysight N1265A ultra high current expander/fixture.

Syntax

```
ERPFGR?
```

Query Response

```
state<CR/LF^EOI>
```

Connection status of the series resistor on the Gate path. 0, 10, 100, or 1000 (see ERPFGR).

Example Statements

```plaintext
OUTPUT @B1500;"ERPFGR?"
ENTER @B1500;gateR
```
**ERPFQG**

This command enables or disables the gate charge measurement control mode on Keysight B1506A.

**Execution Conditions**

Digital I/O port must be set to the N1265A control mode using the ERMOD 4 command.

No channel must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it).

**Syntax**

```
ERPFQG state
```

**Parameters**

`state`: Gate charge measurement mode. Integer expression.

0: Disable (default setting)
1: Enable

When `state`=0, the MCSMU output from the AUX output terminal has Kelvin connection.

When `state`=1, the MCSMU output from the AUX output terminal has non-Kelvin connection.

**Example Statements**

```
OUTPUT @B1500;"ERPFQG 1"
```

**ERPFQG?**

This query command returns the enable/disable state of the gate charge measurement control mode on Keysight B1506A.

**Syntax**

```
ERPFQG?
```

**Query Response**

```
state<CR/LF^EOI>
```

`state`: Gate charge measurement mode. Integer expression.

0: Disable
1: Enable

**Example Statements**

```
OUTPUT @B1500;"ERPFQG?"
ENTER @B1500;A
```
ERPFTEMP?

This query command returns the temperature measured by using the thermocouple (N1265A-041) connected to the K Thermocouple 1 or 2 terminal of Keysight N1265A ultra high current expander/fixture.

**Execution Conditions**

Digital I/O port must be set to the N1265A control mode using the ERMOD 4 command.

**Syntax**

ERPFTEMP? chnum

**Parameters**

chnum: Terminal number of the K thermocouple; 1 or 2.

**Query Response**

value<CR/LF^EOI>

Measured temperature in degrees C. Numeric expression.

**Example Statements**

OUTPUT @B1500;"ERPFTEMP? 1"
ENTER @B1500;Temp1

ERPFUHCA

This command specifies the MC/HCSMU modules connected to the V Control and I Control inputs of Keysight N1265A ultra high current expander/fixture.

**Execution Conditions**

No channel must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it).

The CL command has been already executed for the channels specified in this command.

Digital I/O port must be set to the N1265A control mode using the ERMOD 4 command.

**Syntax**

ERPFUHCA vsmu,ismu

**Parameters**

vsmu: Slot number for the MC/HCSMU connected to the V Control input.

ismu: Slot number for the MC/HCSMU connected to the I Control input.

Effective slot numbers are 1 to 10. Integer expression. Use the smaller slot number for the HCSMU which occupies two slots.

Enter 0 to cancel the assignment.
ERPFUHCA?

This query command returns the slot numbers for the MC/HCSMU modules connected to the V Control and I Control inputs of Keysight N1265A ultra high current expander(fixture).

Syntax

ERPFUHCA?

Query Response

vsmu, ismu<CR/LF^EOI>

vsmu : Slot number for the MC/HCSMU connected to the V Control input.

ismu : Slot number for the MC/HCSMU connected to the I Control input.

Example Statements

OUTPUT @B1500;"ERPFUHCA 3,4"

ERPFUHCCAL?

This query command performs the self-calibration of Keysight N1265A ultra high current expander(fixture), and returns the execution results. After this command, read the result soon.

Execution Conditions

The ERPFUHCA command has been executed before this command.

Syntax

ERPFUHCCAL?

Query Response

result<CR/LF^EOI>

0: Pass

1: Fail

Example Statements

OUTPUT @B1500;"ERPFUHCCAL?"

ENTER @B1500;result

ERPFUHCMAX?

This query command returns the maximum current supported by the currently-connected Keysight N1265A ultra high current expander(fixture).
**Execution Conditions**

Digital I/O port must be set to the N1265A control mode using the ERMOD 4 command.

**Syntax**

ERPFUHCMAX?

**Query Response**

$ima<CR/LF^EOI$

If the N1265A has the 1500 A option (N1265A-015), 1500 is returned. If not, 500 is returned.

**Example Statements**

```
OUTPUT @B1500;"ERPFUHCMAX?"
ENTER @B1500;maxUHC
```

**ERPFUHCTST?**

This query command performs the self-test of Keysight N1265A ultra high current expander/fixture, and returns the execution results. After this command, read the result soon.

**Execution Conditions**

The ERPFUHCA command has been executed before this command.

**Syntax**

ERPFUHCTST?

**Query Response**

$result<CR/LF^EOI$

0: Pass
1: Fail

**Example Statements**

```
OUTPUT @B1500;"ERPFUHCTST?"
ENTER @B1500;result
```

**ERR?**

The ERR? query command returns error code. This command supports the error code 0 to 999. Use the ERRX? command to support all errors.

**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>
```

Response of the ERR? 1 command is one of the followings.

- 0: No error. Normal condition.
- `XYZ`: Error `XYZ` (100 to 999) occurs.
- `aXYZ`: Error `XYZ` (100 to 999) occurs on the slot `a` (1 to 9).
- `10XYZ`: Error `XYZ` (100 to 999) occurs on the slot 10.

If the error 305 occurs on the slot 1, ERR? 1 returns 1305, and EMG? 305 returns "Excess current in HPSMU."

If unsupported error is detected, 999 is returned. The EMG? 999 command returns the message associated with the last error. If the error code 999 is returned, execute the “ERRX?” command to read the error code and the error message.

See Chapter 5, ?Error Messages? for the error codes and error messages.

Remarks

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, B, C, D

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. Supports all errors.

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.
I: 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 slot number. They are separated by a semicolon (;). For example, if the error 305 occurs on the slot 1, this command returns the following response.

305, "Excess current in HPSMU.; SLOT1"

If no error occurred, this command returns 0, "No Error."

See Chapter 5, "Error Messages" for the error codes and error messages.

**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 Keysight 16440A SMU/PGU selector (B1500A-A04). Set it for each output port on the selector.

Execution Conditions

Digital I/O port must be set to the 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 the first selector
  - 1: Output 2 on the first selector
  - 2: Output 1 on the second selector
  - 3: Output 2 on the second selector

- **status:** Connection status of I/O path. Integer expression.
  - 0: All open. Breaks connection. Initial setting.
  - 1: SMU on. Makes connection to the SMU input.
  - 2: PGU on. Makes connection to the PGU input.
  - 3: PGU open. Open status made by opening the semiconductor relay installed on the PGU on 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 Keysight 16440A SMU/PGU selector (B1500A-A04).

**Syntax**

```
ERSSP? port
```

**Parameters**

- `port`:
  - Output port of SMU/PG selector. Integer expression.
    - 0: Output 1 on the first selector
    - 1: Output 2 on the first selector
    - 2: Output 1 on the second selector
    - 3: Output 2 on the second selector

**Query Response**

```
status<CR/LF^EOI>
```

- 0: All open
- 1: SMU on
- 2: PGU on
- 3: PGU open

**Example Statements**

```
OUTPUT @B1500;"ERSSP? 1"
ENTER @B1500;A
```

**See Also**

“ERMOD”

**ERUHVA**

This command specifies the MC/HCSMU modules connected to the V Control and I Control inputs of Keysight N1268A ultra high voltage expander.

**Execution Conditions**

- No channel must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it).
- The CL command has been already executed for the channels specified in this command.
- Digital I/O port must be set to the N1268A control mode using the ERMOD 16 command.

**Syntax**

```
ERUHVA vsmu,ismu
```
Parameters

Parameters

- **vsmu**: Slot number for the MC/HCSMU connected to the V Control input.
- **ismu**: Slot number for the MCSMU connected to the I Control input.

Effective slot numbers are 1 to 10. Integer expression. Use the smaller slot number for the HCSMU which occupies two slots.

Enter 0 to cancel the assignment.

Example Statements

```
OUTPUT @B1500;"ERUHVA 3,4"
```

ERUHVA?

This query command returns the slot numbers for the MC/HCSMU modules connected to the V Control and I Control inputs of Keysight N1268A ultra high voltage expander.

Syntax

```
ERUHVA?
```

Query Response

```
vsmu,ismu<CR/LF^EOI>
```

- **vsmu**: Slot number for the MC/HCSMU connected to the V Control input.
- **ismu**: Slot number for the MCSMU connected to the I Control input.

Example Statements

```
OUTPUT @B1500;"ERUHVA?"
ENTER @B1500;vsmuUHV,ismuUHV
```

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 16.
- **freq**: Frequency (in Hz). Numeric expression. in Hz. See Table 4-18 on page 30.

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 16.

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 4-24.

- **mode**: Data output mode. Integer expression. 0 to 10. See Table 4-25. 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 4-24 FMT format parameter

<table>
<thead>
<tr>
<th>format</th>
<th>Data format</th>
<th>Terminator</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 a</td>
<td>ASCII (12 digits data with header)</td>
<td>&lt;CR/LF^EOI&gt;</td>
</tr>
<tr>
<td>2 a</td>
<td>ASCII (12 digits data without header)</td>
<td>&lt;CR/LF^EOI&gt;</td>
</tr>
<tr>
<td>3 a</td>
<td>4 byte binary</td>
<td>&lt;CR/LF^EOI&gt;</td>
</tr>
<tr>
<td>4 a</td>
<td>4 byte binary</td>
<td>&lt;^EOI&gt;</td>
</tr>
<tr>
<td>5 a</td>
<td>ASCII (12 digits data with header)</td>
<td>,</td>
</tr>
<tr>
<td>11</td>
<td>ASCII (13 digits data with header)</td>
<td>&lt;CR/LF^EOI&gt;</td>
</tr>
<tr>
<td>12</td>
<td>ASCII (13 digits data without header) b</td>
<td>&lt;CR/LF^EOI&gt;</td>
</tr>
<tr>
<td>13</td>
<td>8 byte binary</td>
<td>&lt;CR/LF^EOI&gt;</td>
</tr>
<tr>
<td>14</td>
<td>8 byte binary</td>
<td>&lt;^EOI&gt;</td>
</tr>
<tr>
<td>15</td>
<td>ASCII (13 digits data with header)</td>
<td>,</td>
</tr>
<tr>
<td>21</td>
<td>ASCII (13 digits data with header) b</td>
<td>&lt;CR/LF^EOI&gt;</td>
</tr>
<tr>
<td>22</td>
<td>ASCII (13 digits data without header) b</td>
<td>&lt;CR/LF^EOI&gt;</td>
</tr>
<tr>
<td>25</td>
<td>ASCII (13 digits data with header) b</td>
<td>,</td>
</tr>
</tbody>
</table>

a. Compatible with the Keysight 4142B data output format.
b. Compatible with the Keysight 4155/4156 FLEX mode ASCII data.

12 digits data will be sn.nnnnEsnn, snn.nnnnEsnn, or snnn.nnnnEsnn.
13 digits data will be sn.nnnnnnEsnn, snn.nnnnnnEsnn, or snnn.nnnnnnEsnn.

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 4-25  FMT mode parameter

<table>
<thead>
<tr>
<th>mode</th>
<th>Source data returned with measurement data</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None (default setting). Only the measurement data is returned.</td>
</tr>
<tr>
<td>1</td>
<td>Source output data of the primary sweep source.</td>
</tr>
</tbody>
</table>
| 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. |

---

**HVSMUOP**

This command specifies the output range of HVSMU.

When multiple HVSMUs are configured, use this command to set the same output range to all HVSMUs.

**Execution Conditions**

All HVSMU channels are set to 0 V or disabled.

No channel must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it).

**Syntax**

```
HVSMUOP  mode
```

**Parameters**

- **mode**:  
  Output range of HVSMU. Integer expression.  
  1: Single channel mode (default setting)  
  2: ±1500V mode  
  3: +3000V mode  
  4: −3000V mode

When mode=1, an HVSMU channel is available, but other channels can be set to 0 V or −4 mA to +4 mA. The setting range of the available channel is same as the range of the single HVSMU configuration.
When `mode`=2, the output range of all HVSMU channels is from −1500 V to 0 V or from −8 mA to 0 mA, and from 0 V to +1500 V or from 0 mA to +8 mA.

When `mode`=3, the output range of all HVSMU channels is from 0 V to +3000 V or from 0 mA to +4 mA.

When `mode`=4, the output range of all HVSMU channels is from −3000 V to 0 V or from −4 mA to 0 mA.

After performing this command, the conditions of the enabled HVSMU channels are same as the conditions set by the IN command.

Example Statements

```
OUTPUT @B1500;"HVSMUOP 2"
```

**HVSMUOP?**

This query command returns the output range of HVSMU.

**Syntax**

```
HVSMUOP?
```

**Query Response**

```
mode<CR/LF^EOI>
```

- `mode`: Output range of HVSMU. Integer expression.
  - 1: Single channel mode
  - 2: ±1500V mode
  - 3: +3000V mode
  - 4: −3000V mode

Example Statements

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

**IDN?**

The *IDN? query command returns the instrument model number and the firmware revision number.

**Syntax**

```
*IDN?
```
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 4-16 on page 29.

Initial setting: \textit{mode}=100 (Cp-G measurement)

Example Statements

\texttt{OUTPUT @B1500;"IMP 10"}

\textbf{IN}

The IN command sets the specified channel to 0 V with an output range change.

Syntax

\texttt{IN [chnum[, chnum...[, chnum]...]]}

A maximum of 15 channels can be set.

Parameters  

**chnum**: Channel number. Integer expression. See Table 4-1 on page 16.

If you specify multiple \textit{chnums}, the channel outputs will be set to 0 V in the specified order.

If you do not specify \textit{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.

Remarks

The IN command sets the specified module to the following conditions:

<table>
<thead>
<tr>
<th>SMU setup parameter</th>
<th>Value</th>
<th>MFCMU setup parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source mode</td>
<td>Voltage</td>
<td>DC bias</td>
<td>0 V</td>
</tr>
<tr>
<td>Output voltage</td>
<td>0 V</td>
<td>AC level</td>
<td>0 V</td>
</tr>
<tr>
<td>V range</td>
<td>20 V</td>
<td>Output signal frequency</td>
<td>1 kHz</td>
</tr>
<tr>
<td>I compliance</td>
<td>100 μA</td>
<td>Measurement range</td>
<td>50 Ω</td>
</tr>
<tr>
<td>I range</td>
<td>100 μA</td>
<td>SPGU setup parameter</td>
<td></td>
</tr>
<tr>
<td>Filter</td>
<td>Not changed</td>
<td>Output mode</td>
<td>DC</td>
</tr>
<tr>
<td>Series resistor</td>
<td>Not changed</td>
<td>Output voltage</td>
<td>0 V</td>
</tr>
</tbody>
</table>

After this command, there is no additional power consumption for the idle state.

Example Statements

\texttt{OUTPUT @B1500;"IN"}

\texttt{OUTPUT @B1500;"IN 1,2,3,5,6"}
INTLKVT

The INTLKVT command sets the allowable voltage for the interlock open condition. The B1500 output voltage and compliance voltage cannot exceed the setting value when the interlock circuit is opening. This setting is stored in the non-volatile memory and is not changed until this command is sent again.

Syntax
INTLKVT voltage

Parameters
voltage: Allowable voltage for the interlock open condition. 0 or 42. Numeric expression.

0: Maximum 0 V
42: Maximum ±42 V (factory-shipped non-volatile setting)

Example Statements
OUTPUT @B1500; "INTLKVT 0"

INTLKVT?

The INTLKVT? query command returns the present setting of the allowable voltage for the interlock open condition.

Syntax
INTLKVT?

Query Response
voltage<CR/LF^EOI>
This value returns 0 (maximum 0 V) or 42 (maximum ±42 V).

Example Statements
OUTPUT @B1500; "INTLKVT?"
ENTER @B1500; Vintlk

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 16.

mode: Search mode. Integer expression.
0: If the measured value \( \leq \) target, it is the search result data.

1: If the measured value \( \geq \) 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 19.

**target**: Search target current (in A). Numeric expression.

0 to \( \pm 0.1 \) A (MPSMU/HRSMU/MCSMU)
0 to \( \pm 1 \) A (HPSMU/HCSMU)
0 to \( \pm 2 \) A (DHCSMU)
0 to \( \pm 0.008 \) A (HVSMU)

**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 16.

**mode**: Search mode. Integer expression.

0: If the measured value \( \leq \) target, it is the search result data.

1: If the measured value \( \geq \) 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 17.

**target**: Search target voltage (in V). Numeric expression.
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 10000 V (initial value), 100 V resolution.

For current limit: 1 A to 1500 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 4-26.

Table 4-26 LOP? Response

<table>
<thead>
<tr>
<th>Status code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>No module is installed, or the output switch is OFF.</td>
</tr>
<tr>
<td>01</td>
<td>SMU forces voltage, and does not reach current compliance.</td>
</tr>
<tr>
<td>02</td>
<td>SMU forces positive current, and does not reach voltage compliance.</td>
</tr>
<tr>
<td>03</td>
<td>SMU forces negative current, and does not reach voltage compliance.</td>
</tr>
</tbody>
</table>
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, \texttt{LOP00,11,00,00,00,00,00,00,00,00,00} will be returned when only the HPSMU installed in the slot 1-2 is used and is in the voltage compliance condition.

**Example Statements**

\begin{verbatim}
OUTPUT @B1500;"LOP?"
ENTER @B1500;A$
\end{verbatim}

*\texttt{LRN}?*

The *\texttt{LRN}?* (learn) query command returns the B1500 command parameter settings.

**Syntax**

\begin{verbatim}
*\texttt{LRN}? type
\end{verbatim}

**Example Statements**

\begin{verbatim}
DIM A$[200]
OUTPUT @B1500;"*LRN? 1"
ENTER @B1500;A$
\end{verbatim}

**Parameters and Query Response**

\begin{verbatim}
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 \texttt{type} is described below.

\begin{verbatim}
0 : Returns the output switch ON/OFF status:
\texttt{CN[chnum[,chnum . . . [,chnum] . . . ]]<CR/LF^EOI>}
\end{verbatim}
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:

\[ \text{FL1}<\text{CR}/\text{LF}^\text{EOI}> \]

**31 :** Returns the parameter values of the TM, AV, CM, FMT, and MM commands:

- TM trigger mode
- AV number
- CM auto calibration mode
- FMT output data format
- Output data mode
- MM measurement mode

\[ [:\text{MM measurement mode}[\text{chnum}, \text{chnum}...[\text{chnum}...]]]<\text{CR}/\text{LF}^\text{EOI}> \]

**32 :** Returns the measurement ranging status:

- RI chnum, lrange
- RV chnum, Vrange

\[ [:\text{RI chnum}, \text{lrange}; \text{RV chnum}, \text{Vrange}] ... <\text{CR}/\text{LF}^\text{EOI}> \]

**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

\[ [:\text{WV chnum}, \text{mode}, \text{range}, \text{start}, \text{stop}, \text{nop}[, \text{Icomp}[, \text{pcomp}]]] \text{ or } [:\text{WI chnum}, \text{mode}, \text{range}, \text{start}, \text{stop}, \text{nop}[, \text{Vcomp}[, \text{pcomp}]]] \]

\[ [:\text{WSV chnum}, \text{range}, \text{start}, \text{stop}[, \text{Icomp}[, \text{pcomp}]]] \text{ or } [:\text{WSI chnum}, \text{range}, \text{start}, \text{stop}[, \text{Vcomp}[, \text{pcomp}]]]<\text{CR}/\text{LF}^\text{EOI}> \]

**34 :** Returns the pulsed source settings:

- PT hold time, pulse width
- Pulse period
- Trig delay

\[ [:\text{PV chnum}, \text{output range}, \text{base voltage}, \text{pulse voltage}[, \text{Icomp}]] \text{ or } [:\text{PI chnum}, \text{output range}, \text{base current}, \text{pulse current}[, \text{Vcomp}]] \]

\[ [:\text{PWV chnum}, \text{mode}, \text{range}, \text{base}, \text{start}, \text{stop}, \text{nop}[, \text{Icomp}]] \text{ or } [:\text{PWI chnum}, \text{mode}, \text{range}, \text{base}, \text{start}, \text{stop}, \text{nop}[, \text{Vcomp}]]<\text{CR}/\text{LF}^\text{EOI}> \]

**37 :** Returns the quasi-pulsed source settings:

- BDM detection interval
- BDT hold time

\[ [:\text{BDV chnum}, \text{range}, \text{start}, \text{stop}[, \text{Icomp}]]<\text{CR}/\text{LF}^\text{EOI}> \]

**38 :** Returns the digital I/O port information:

- ERM input pin
- ERC2, value

\[ <\text{CR}/\text{LF}^\text{EOI}> \]

**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,delay[,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,[;SSR chnum,mode] . . .
[;SSR chnum,mode]<CR/LF^EOI>

54 : Returns the auto ranging mode status:
RM chnum,[;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 $V_{comp}$ value is greater than the allowable voltage for the interlock open condition, the interlock circuit must be shorted.

Syntax

```plaintext
LSI chnum, range, start, stop, step[, $V_{comp}$]
```

Parameters

- **chnum**: SMU search source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.
- **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 22.
- **start, stop**: Search start or stop current (in A). Numeric expression. See Table 4-6 on page 23, Table 4-8 on page 25, or Table 4-11 on page 27 for each measurement resource 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.
- **$V_{comp}$**: Voltage compliance value (in V). Numeric expression. See Table 4-6 on page 23, Table 4-8 on page 25, or Table 4-11 on page 27 for each measurement resource type. If you do not specify $V_{comp}$, the previous value is set.

Example Statements

```plaintext
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 \textit{post} parameter.

If the search operation is stopped by the automatic abort function, the linear search sources force the start value after search.

\textbf{Syntax}

\begin{verbatim}
LSM \text{abort[,post]}
\end{verbatim}

\textbf{Parameters}

\texttt{abort} : Automatic abort function. Integer expression.

1: Disables the function. Initial setting.

2: Enables the function.

\texttt{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 after search.

\textbf{Example Statements}

\begin{verbatim}
OUTPUT @B1500;"LSM 2"
OUTPUT @B1500;"LSM 2,3"
\end{verbatim}

\textbf{LSSI}

The LSSI command sets the synchronous current source for the linear search measurement (MM14). The synchronous source output will be:

\[
\text{Synchronous source output} = \text{polarity} \times \text{LSI source output} + \text{offset}
\]

where the LSI source output is the output set by the LSI command.

This command setting is cleared by the LSV/LSI command.

\textbf{Execution Conditions}

The LSI command must be entered before this command.

If $V_{\text{comp}}$ value is greater than the allowable voltage for the interlock open condition, the interlock circuit must be shorted.
Command Reference

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 16.
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 4-6 on page 23, Table 4-8 on page 25, or Table 4-11 on page 27 for each measurement resource 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 4-6 on page 23, Table 4-8 on page 25, or Table 4-11 on page 27 for each measurement resource 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 x 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 the allowable voltage for the interlock open condition, 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 16.

**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 4-7 on page 24, Table 4-9 on page 26, Table 4-12 on page 27, or Table 4-15 on page 28 for each measurement resource 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 4-7 on page 24, Table 4-9 on page 26, Table 4-12 on page 27, or Table 4-15 on page 28 for each measurement resource 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:

\[
\text{number_of_programs}[, pnum[, pnum ... [, pnum]...]]<\text{CR/LF}^EOL^I>
\]

Response by LST? pnum[, index[, size]]:

\[
\text{ST } pnum<\text{CR/LF}>
[\text{saved_command}<\text{CR/LF}>]
[\text{saved_command}<\text{CR/LF}>]
[\text{saved_command}<\text{CR/LF}>]
\text{END}<\text{CR/LF}^EOL^I>
\]

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 the allowable voltage for the interlock open condition, 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 16.
- **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 21.
- **start, stop**: Search start or stop voltage (in V). Numeric expression. See Table 4-7 on page 24, Table 4-9 on page 26, Table 4-12 on page 27, or Table 4-15 on page 28 for each measurement resource 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 4-7 on page 24, Table 4-9 on page 26, Table 4-12 on page 27, or Table 4-15 on page 28 for each measurement resource 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

\[ \text{LSVM } \text{mode} \]

Parameters

\text{\textbf{mode}} : Data output mode. Integer expression. 0 (initial setting) or 1.

- 0 : Returns \textit{Data_search} only.
- 1 : Returns \textit{Data_search} and \textit{Data_sense}.

\textit{Data_search} is the value forced by the search output channel set by LSI or LSV.

\textit{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"
```

\textbf{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

\[ \text{MCC } \{ \text{chnum}[,\text{chnum}...[,\text{chnum}[,\text{chnum}]]]... \} \]

A maximum of 15 channels can be set.

Parameters

\text{\textbf{chnum}} : Channel number of the unit to clear the settings. Integer expression. See Table 4-1 on page 16.

If you do not specify \textit{chnum}, the MCC command clears the settings of all sampling channels.

Example Statements

```
OUTPUT @B1500;"MCC"
OUTPUT @B1500;"MCC 1,2,3"
```

\textbf{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

\[ \text{MCPNT } \text{chnum},\text{delay},\text{width} \]

Parameters

\text{\textbf{chnum}} : SMU pulsed source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.
**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 measurement resource type. See Table 4-27 on page 143.

**width** : Pulse width (in seconds). Numeric expression. Effective value depends on the measurement resource type. See Table 4-27 on page 143.

<table>
<thead>
<tr>
<th>Table 4-27</th>
<th>Effective value for delay and width</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>delay</strong></td>
<td>HR/MP/HP SMU</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>width</td>
<td>500 μs to 2 s</td>
</tr>
<tr>
<td></td>
<td>10 μs to 100 ms, duty ratio maximum 5 %, for 1 A range</td>
</tr>
<tr>
<td></td>
<td>10 μs to 2 s for other range</td>
</tr>
<tr>
<td></td>
<td>Resolution: 2 μs</td>
</tr>
<tr>
<td></td>
<td>Initial setting: 1 ms</td>
</tr>
<tr>
<td></td>
<td>10 μs to 1 ms, duty ratio maximum 0.4 %, for 500 A range</td>
</tr>
<tr>
<td></td>
<td>10 μs to 500 μs, duty ratio maximum 0.1 %, for 2000 A range</td>
</tr>
<tr>
<td></td>
<td>500 μs to 2 s</td>
</tr>
<tr>
<td></td>
<td>Resolution: 2 μs</td>
</tr>
<tr>
<td></td>
<td>Initial setting: 1 ms</td>
</tr>
<tr>
<td></td>
<td>10 μs to 1 ms for 100 mA range</td>
</tr>
<tr>
<td></td>
<td>10 μs to 2 s for other range</td>
</tr>
<tr>
<td></td>
<td>Resolution: 2 μs</td>
</tr>
<tr>
<td></td>
<td>Initial setting: 1 ms</td>
</tr>
<tr>
<td></td>
<td>10 μs to 1 ms for 100 mA range</td>
</tr>
<tr>
<td></td>
<td>10 μs to 2 s for other range</td>
</tr>
<tr>
<td></td>
<td>Resolution: 2 μs</td>
</tr>
<tr>
<td></td>
<td>Initial setting: 100 μs</td>
</tr>
</tbody>
</table>

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.

**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 16.

$mode:$ 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 21.
- For current source ($mode=2$): See Table 4-5 on page 22.

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 4-7 on page 24, Table 4-9 on page 26, Table 4-10 on page 26, Table 4-12 on page 27, Table 4-14 on page 28, or Table 4-15 on page 28 for each measurement resource type. For using 3000 V range of HVSMU, $base$ and $peak$ must have the same polarity. For using UHVU, $base$ and $peak$ must have the same polarity.

- For current source ($mode=2$): See Table 4-6 on page 23, Table 4-8 on page 25, Table 4-11 on page 27, or Table 4-13 on page 28 for each measurement resource 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 4-7 on page 24, Table 4-9 on page 26, Table 4-10 on page 26, Table 4-12 on page 27, Table 4-14 on page 28, or Table 4-15 on page 28 for each measurement resource type.

- For current source ($mode=2$): See Table 4-6 on page 23, Table 4-8 on page 25, Table 4-11 on page 27, or Table 4-13 on page 28 for each measurement resource 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. For using UHVU, minimum pulse period is 10 ms. Initial setting = 10 ms. Default setting = 0. $t_0 = delay + width$, where `delay` and `width` are the parameters set by the MCPNT command.

- $period \geq t_0 + 2$ ms (for $t_0 \leq 100$ ms)
- $period \geq t_0 + 10$ ms (for 100 ms < $t_0$)
- `period` = -1: Automatically set to the effective minimum period.
- `period` = 0: Automatically set to the longest one of the followings.
  - Minimum period given by the pulse width and the duty ratio
• Pulse period = 5 ms (for \(t_0 \leq 3\) ms)
• Pulse period = \(t_0 + 2\) ms (for \(3\) ms < \(t_0 \leq 100\) ms)
• Pulse period = \(t_0 + 10\) ms (for \(100\) ms < \(t_0\))

**Mdelay**: Measurement timing (in seconds) from the beginning of the pulse period to the beginning of the measurement. Numeric expression. 2 \(\mu\)s to \(period-\text{N} \) 2 ms. 2 \(\mu\)s 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 10001.

**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 16.

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 21.
- For current source (mode=2): See Table 4-5 on page 22.

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 4-7 on page 24, Table 4-9 on page 26, Table 4-10 on page 26, Table 4-12 on page 27, Table 4-14 on page 28, or Table 4-15 on page 28 for each measurement resource type. For the log sweep or using 3000 V range of HVSMU, base, start, and stop must have the same polarity. For using UHVU, base and peak must have the same polarity.

- For current source (mode=2): See Table 4-6 on page 23, Table 4-8 on page 25, Table 4-11 on page 27, or Table 4-13 on page 28 for each measurement resource 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 4-7 on page 24, Table 4-9 on page 26, Table 4-10 on page 26, Table 4-12 on page 27, Table 4-14 on page 28, or Table 4-15 on page 28 for each measurement resource type.
For current source (mode=2): See Table 4-6 on page 23, Table 4-8 on page 25, Table 4-11 on page 27, or Table 4-13 on page 28 for each measurement resource 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 measurement resource 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, 0.001 to 800 for dual HCSMU, 0.001 to 30 for MCSMU, 0.001 to 22500 for UHCU, 0.001 to 200 for UHVU, 0.001 to 600 for HVMCU

**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 2,4,1,0,0,5,1E-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 the allowable voltage for the interlock open condition, 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 16.

**base, bias**: Base or bias voltage (in V). Numeric expression. See NOTE below.

- 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 16.

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 the allowable voltage for the interlock open condition, 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 16.
- **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 22.
- **base, bias**: Base current and bias current (in A). Numeric expression. See Table 4-6 on page 23, Table 4-8 on page 25, or Table 4-11 on page 27 for each measurement resource type. *base* and *bias* must have the same polarity.
- **Vcomp**: Voltage compliance value (in V). Numeric expression. See Table 4-6 on page 23, Table 4-8 on page 25, or Table 4-11 on page 27 for each measurement resource 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]
  ```
• \( \text{mode} = 14 \) or \( 15 \):

\[
\text{MM} \ \text{mode}
\]

**Parameters**

- \( \text{mode} \): Measurement mode. Integer expression. 1 to 28. See Table 4-28.
- \( \text{chnum} \): Measurement channel number. Integer expression. See Table 4-1 on page 16.

**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 \( \text{mode} = 1, 2, \text{or} 10 \), if you use multiple measurement channels, the channels start measurement in the order defined in the MM command.

For \( \text{mode} = 16 \), 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 \( \text{mode} = 9 \) or 13, if you do not specify \( \text{chnum} \), the B1500 uses the channel specified by the BDV or QSV command to execute measurement.

For \( \text{mode} = 9, 14, \text{or} 15 \), the time stamp function is not available. See “Data Output Format” on page 1-25.

For \( \text{mode} = 18 \), MFCMU must be specified for the first \( \text{chnum} \). 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 \( \text{chnum} \) parameter must not specify the SMU connected to the SCUU.

**Example Statements**

\[
\text{OUTPUT } @B1500; "\text{MM 1,1}" \\
\text{OUTPUT } @B1500; "\text{MM 2,1,3}"
\]
Table 4-28  Measurement Mode

<table>
<thead>
<tr>
<th>mode</th>
<th>Measurement mode</th>
<th>Related source setup command</th>
<th>SMU</th>
<th>MF</th>
<th>UHCU</th>
<th>HV</th>
<th>UHVU</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>HP/MP/HR</td>
<td>MC/HC/HV</td>
<td>CMU</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Spot</td>
<td>DI, DV</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Staircase sweep</td>
<td>WI, WV, WT, WM, WSI, WSV</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Pulsed spot</td>
<td>PI, PV, PT</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>Pulsed sweep</td>
<td>PWI, PWV, PT, WM, WSI, WSV</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>Staircase sweep with pulsed bias</td>
<td>WI, WV, WM, WSI, WSV, PI, PV, PT</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>9</td>
<td>Quasi-pulsed spot</td>
<td>BDV, BDT, BDM</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Sampling</td>
<td>MCC, MSC, ML, MT, MI, MV</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>13</td>
<td>Quasi-static CV</td>
<td>QSV, QST, QSM</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Linear search</td>
<td>LSV, LSI, LGV, LGI, LSM, LSTM, LSSV, LSSI, LSVM</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>15</td>
<td>Binary search</td>
<td>BSV, BSI, BGV, BGI, BSMB, BST, BSSV, BSSI, BSV</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>16</td>
<td>Multi channel sweep</td>
<td>WI, WV, WT, WM, WNX</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>17</td>
<td>Spot C</td>
<td>FC, ACV, DCV</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>CV (DC bias) sweep</td>
<td>FC, ACV, WDCV, WMDCV, WTDCV</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Pulsed spot C</td>
<td>PDCV, PTDCV</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Pulsed sweep CV</td>
<td>PWDCV, PTDCV</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>C-f sweep</td>
<td>WFC, ACV, DCV, WMFC, WTFC</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>CV (AC level) sweep</td>
<td>FC, WACV, DCV, WMACV, WTACV</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>C-t sampling</td>
<td>MSC, MDCV, MTDCV</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Multi channel pulsed spot</td>
<td>MCPT, MCPNT, MCPNX</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Multi channel pulsed sweep</td>
<td>MCPT, MCPNT, MCPNX, MCPWS, MCPWNX, WNX</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
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**

  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 \( \geq 2 \) 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 16.
- **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 \( \pm 40 \) 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 \( \pm 40 \) 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.
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. $h_{\text{base}}$ 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 $h_{\text{bias}}$ 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 $\text{interval} < 2 \text{ ms}$, if the total measurement time runs over the specified time $\text{interval} \times \text{number}$, 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.

$$\text{time data} = t + h_{\text{bias}} + (\text{index data} - 1) \times \text{interval}$$

For the linear sampling: $100001 / (\text{number of measurement channels})$

For the log sampling: $1 + (\text{number of data for 11 decades})$
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 16.

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 the allowable voltage for the interlock open condition, 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 16.

- **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 21.

- **base, bias**: Base voltage and bias voltage (in V). Numeric expression. See Table 4-7 on page 24, Table 4-9 on page 26, Table 4-12 on page 27, or Table 4-15 on page 28 for each measurement resource 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 4-7 on page 24, Table 4-9 on page 26, Table 4-12 on page 27, or Table 4-15 on page 28 for each measurement resource 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 2-53 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 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 \textit{wait time} independent of the source wait time and the measurement wait time set by the WAT command. So the \textit{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 \textit{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:

```plaintext
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”

PCH

This command specifies two HCSMU modules and enables the dual HCSMU operation. The HCSMU modules of channel numbers master and slave operate as the dual HCSMU (DHCSMU) of channel number master, and do not perform the single HCSMU operation.

This setting is cleared by the PCH 0,0, PCH master,0, *RST, or a device clear.
Two HCSMU modules are installed in the B1505A and connected to the 16493S-020 Dual HCSMU Kelvin combination adapter or the 16493S-021 Dual HCSMU combination adapter.

The CN/CNX command has not been executed for the specified channels.

**Syntax**

```
PCH master, slave
```

**Parameters**

- `master`: Channel number of HCSMU used as the dual HCSMU master channel
- `slave`: Channel number of HCSMU used as the dual HCSMU slave channel

Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.

**Example Statements**

```
OUTPUT @B1500;"PCH 6,8"
OUTPUT @B1500;"PCH 6"
ENTER @B1500;Master,Slave
```

**PCH?**

PCH?, PCH? 0, and PCH? `master` commands return the master HCSMU channel number and the slave HCSMU channel number used for the dual HCSMU.

This command returns 0 if the dual HCSMU (DHCSMU) is not specified by `master`.

**Syntax**

```
PCH? [master]
```

**Parameters**

- `master`: Master HCSMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.

**Query Response**

```
master, slave<CR/LF^EOI>
master: Master HCSMU channel number
slave: Slave HCSMU channel number
```

**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 the allowable voltage for the interlock open condition, 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 16.
- **base**, **pulse**: Pulse base voltage or pulse peak voltage (in V). Numeric expression. 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 the allowable voltage for the interlock open condition, 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 16.

**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 22.

**base, pulse**: Pulse base current or peak current (in A). Numeric expression. See Table 4-6 on page 23, Table 4-8 on page 25, Table 4-11 on page 27, or Table 4-13 on page 28 for each measurement resource type. base and pulse must have the same polarity.

**Vcomp**: Voltage compliance value (in V). Numeric expression. See Table 4-6 on page 23, Table 4-8 on page 25, Table 4-11 on page 27, or Table 4-13 on page 28 for each measurement resource 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 output 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/MPSMU: 500 μs to 2 s, 100 μs resolution
HVSMU: 500 μs to 2 s, 2 μs resolution
HCSMU / dual HCSMU: 50 μs to 2 s, 2 μs resolution. Maximum 1 ms and duty ratio ≤ 1 % for using 20 A range or 40 A range.
MCSMU: 10 μs to 100 ms and duty ratio maximum 5 % for 1 A range, 10 μs to 2 s for other range, 2 μs resolution
UHCU: 10 μs to 1 ms and duty ratio maximum 0.4 % for 500 A range, 10 μs to 500 μs and duty ratio maximum 0.1 % for 2000 A range, 2 μs resolution.
UHVU: 100 μs to 1 ms for 100 mA range, 100 μs to 2 s for other range, 2 μs resolution.
HVMCU: 10 μs to 1 ms for 100 mA range, 10 μs to 100 μs for 1 A/2 A range, 2 μs resolution.

**period**: Pulse period (in seconds). Numeric expression. 0, -1, or 5 ms to 5.0 s. 0.1 ms resolution. For using UHVU, minimum pulse period is 10 ms. Initial setting = 10 ms. Default setting = 0.

- \( period \geq width + 2 \text{ ms} \) (for \( width \leq 100 \text{ ms} \))
- \( period \geq width + 10 \text{ ms} \) (for 100 ms < \( width \))
- \( period = -1 \): Automatically set to the effective minimum period.
- \( period = 0 \): Automatically set to the longest one of the followings.
  - Minimum period given by the pulse width and the duty ratio
  - Pulse period = 5 ms (for \( width \leq 3 \text{ ms} \))
  - Pulse period = \( width + 2 \text{ ms} \) (for 3 ms < \( width \leq 100 \text{ ms} \))
  - Pulse period = \( width + 10 \text{ ms} \) (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.
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.
  - \( width \geq 50 \text{ ms} \) (for \( 1 \text{ kHz} \leq \text{MFCMU frequency} \leq 10 \text{ kHz} \))
  - \( width \geq 10 \text{ ms} \) (for \( 10 \text{ kHz} < \text{MFCMU frequency} \leq 200 \text{ kHz} \))
  - \( width \geq 8 \text{ ms} \) (for \( 200 \text{ kHz} < \text{MFCMU frequency} \leq 5 \text{ MHz} \))
- **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.
  - \( period \geq width + 2 \text{ ms} \) (for \( width \leq 100 \text{ ms} \))
  - \( period \geq width + 10 \text{ ms} \) (for \( 100 \text{ ms} < width \))
  - \( period = 0 \): Pulse period is automatically set as follows.
    - Pulse period = \( width + 2 \text{ ms} \) (for \( width \leq 100 \text{ ms} \))
    - Pulse period = \( width + 10 \text{ ms} \) (for \( 100 \text{ ms} < width \))
- **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 the allowable voltage for the interlock open condition, 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 16.

- **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 21.

- **base, pulse**: Pulse base voltage or pulse peak voltage (in V). Numeric expression. See Table 4-7 on page 24, Table 4-9 on page 26, Table 4-10 on page 26, Table 4-12 on page 27, Table 4-14 on page 28, or Table 4-15 on page 28 for each measurement resource type. For using 3000 V range of HVSMU, `base` and `pulse` must have the same polarity. For using UHVU, `base` and `peak` must have the same polarity.

- **Icomp**: Current compliance value (in A). Numeric expression. See Table 4-7 on page 24, Table 4-9 on page 26, Table 4-10 on page 26, Table 4-12 on page 27, Table 4-14 on page 28, or Table 4-15 on page 28 for each measurement resource 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 the allowable voltage for the interlock open condition, 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 16.

`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.

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"
```
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 16.
- **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 22.
- **base, start, stop**: Pulse base, start, or stop current (in A). Numeric expression. See Table 4-6 on page 23, Table 4-8 on page 25, Table 4-11 on page 27, or Table 4-13 on page 28 for each measurement resource type. `base`, `start` and `stop` must have the same polarity.
- **step**: Number of steps for pulsed sweep. Numeric expression. 1 to 10001.
- **Vcomp**: Voltage compliance (in V). Numeric expression. See Table 4-6 on page 23, Table 4-8 on page 25, Table 4-11 on page 27, or Table 4-13 on page 28 for each measurement resource type. If you do not specify `Vcomp`, the previous value is set. If `Vcomp` value is greater than the allowable voltage for the interlock open condition, 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.
$P_{comp}$: Power compliance (in W). Numeric expression. Resolution: 0.001 W. If the $P_{comp}$ 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, 0.001 to 800 for dual HCSMU, 0.001 to 30 for MCSMU, 0.001 to 22500 for UHCU, 0.001 to 200 for UHVU, 0.001 to 600 for HVMCU

**Example Statements**

```
OUTPUT @B1500;"PT 1,0.01"
OUTPUT @B1500;"PWV 1,1,0,0,0.1,101"
OUTPUT @B1500;"PT 1,0.01"
OUTPUT @B1500;"PWV 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 16.

*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 21.
**base, start, stop:** Pulse base, start, or stop voltage (in V). Numeric expression. See Table 4-7 on page 24, Table 4-9 on page 26, Table 4-10 on page 26, Table 4-12 on page 27, Table 4-14 on page 28, or Table 4-15 on page 28 for each measurement resource type. If the output voltage is greater than the allowable voltage for the interlock open condition, 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. For using UHVU, base, start, and stop must have the same polarity.

**step:** Number of steps for pulsed sweep. Numeric expression. 1 to 10001.

**Icomp:** Current compliance (in A). Numeric expression. See Table 4-7 on page 24, Table 4-9 on page 26, Table 4-10 on page 26, Table 4-12 on page 27, Table 4-14 on page 28, or Table 4-15 on page 28 for each measurement resource 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, 0.001 to 800 for dual HCSMU, 0.001 to 30 for MCSMU, 0.001 to 22500 for UHCU, 0.001 to 200 for UHVU, 0.001 to 600 for HVMCU

**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 \textit{chnum}.

Do not specify the following parameters when \textit{mode}=0.

\textbf{chnum} : SMU source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.

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.

\textbf{Vcomp} : Voltage compliance (in V). Numeric expression. See Table 4-6 on page 23. If you do not specify \textit{Vcomp}, the previous value is set.

This value is set to the SMU specified by \textit{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**

\textbf{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 \(\mu\)A 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.
Command Reference

**Example Statements**

```plaintext
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:

  \[
  \text{cinteg} = \frac{n}{\text{selected line frequency}} \quad (n : \text{integer. 1 to 20000.})
  \]

  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:

  \[
  \text{linteg} = \frac{n}{\text{selected line frequency}} \quad (n : \text{integer. 1 to 100.})
  \]

  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 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**

```plaintext
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 16.
- **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 21.
- **start, stop**: Start or stop voltage (in V). Numeric expression. See Table 4-7 on page 24.
  - 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 $\leq |\text{sweep step voltage}|$ you desire. If you set the value greater than $|\text{sweep step voltage}|$, the $cvoltage$ is automatically set to the same value as $|\text{sweep step voltage}|$. 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 $\pm cvoltage/2$ (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.

$$step = |start-stop| / |\text{sweep step voltage}| - 1$$

If you set $step=1$ and $|stop-start| \leq 10$, 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**

```plaintext
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.

**Syntax**

```plaintext
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 16.
- **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 4-17 on page 30. 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**

```plaintext
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.
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.

**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 16.

range : Measurement range or ranging type. Integer expression. See Table 4-3 on page 19.

**Example Statements**

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 16.

mode : Range changing operation mode. Integer expression. 1, 2 or 3.

<table>
<thead>
<tr>
<th>mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Initial setting. If you set mode=1, do not set rate.</td>
</tr>
<tr>
<td>2</td>
<td>If measured data ( \geq ) current1, the range changes up after measurement.</td>
</tr>
<tr>
<td>3</td>
<td>If measured data ( \leq ) current2, the range changes down immediately, and if measured data ( \geq ) current1, the range changes up after measurement.</td>
</tr>
</tbody>
</table>

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:

\[
\begin{align*}
\text{current1} & = 9 \text{ mA} \\
\text{current2} & = 0.9 \text{ mA}
\end{align*}
\]

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.

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 16.

range: Measurement range or ranging type. Integer expression. See Table 4-2 on page 17.

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 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 16.

If you specify multiple *chnums*, 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 Keysight B1500 installed with 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 SMU connected to the ASU. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.

*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 Keysight B1500 installed with the atto sense and switch unit (ASU). This command is not effective when the High Voltage indicator of the Keysight B1500 has been lighted.

Sets the connection path of the ASU. Switches the ASU input resource (B1511B/B1517A 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 Keysight B1500 is turned on or the CL command is entered, the ASU output will be connected to the SMU connector side, but the SMU will not be enabled yet. After this command is entered with path=1, the SMU specified by chnum cannot be used. After this command is entered with path=0 or the CN command is entered, the SMU output will appear on the ASU output. Then the SMU output will be 0 V.

NOTE
To use ASU
To use the ASU, connect it to the correct SMU properly before turning the Keysight 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 SMU. Use the SAR command to enable/disable the 1 pA range for the auto ranging operation.

Remember that the series resistor in the SMU connected to the ASU cannot be used.

Syntax
SAP chnum, path

Parameters
chnum : Channel number of the SMU connected to the ASU. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.

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 Keysight B1500 installed with 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.
SAR  

Syntax  
SAR  chnum, mode

Parameters  
chnum : Channel number of the SMU connected to the ASU. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.

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  
        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
```

SOPC
This command is effective for the HVMCU, UHCU, and UHVU. This command enables the output power comparison function.

This function automatically calculates the power by multiplying the current by the voltage applied to the device under test and compares the calculation result with the `power` value specified in this command. Then if it is not less than the `power` value, the measurement status is set to “compliance”.

This function is disabled by setting 0 to `power`.

If the automatic abort function for sweep source is enabled by the WM command, the sweep measurement is automatically stopped by detecting “compliance”.

**Syntax**

`SOPC chnum, power`

**Parameters**

`chnum`: Channel number assigned to the measurement resource. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1.

`power`: Comparison reference value (in W). Numeric expression. Resolution: 0.001 W.

0.001 to 22500 for UHCU, 0.001 to 100 for UHVU (DC), 0.001 to 200 for UHVU (pulse), 0.001 to 600 for HVMCU

**Example Statements**

```
OUTPUT @B1500;"SOPC 3,100"
```

SOPC?
This query command is effective for the HVMCU, UHCU, and UHVU. This query command returns the comparison reference value set by the SOPC command.
Syntax

```
SOPC? chnum
```

Parameters

- **chnum**: Channel number assigned to the measurement resource. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1.

Query Response

```
power<CR/LF^EOI>
```

Comparison reference value (in W).

Example Statements

```
OUTPUT @B1500;"SOPC? 3"
ENTER @B1500;A
```

**SOVC**

This command is effective for the HVMCU, UHCU, and UHVU. This command enables the output voltage comparison function.

This function automatically measures the voltage applied to the device under test and compares the measurement result with the `voltage` value specified in this command. Then if it is not less than the `voltage` value, the measurement status is set to “compliance”.

This function is disabled by setting 0 to `voltage`.

If the automatic abort function for sweep source is enabled by the WM command, the sweep measurement is automatically stopped by detecting “compliance”.

Syntax

```
SOVC chnum, voltage
```

Parameters

- **chnum**: Channel number assigned to the measurement resource. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1.

- **voltage**: Comparison reference value (in V). Numeric expression. The effective values and resolution depend on the measurement resource. See Table 4-10, Table 4-14, and Table 4-15.

Example Statements

```
OUTPUT @B1500;"SOVC 3,300"
```

**SOVC?**

This query command is effective for the HVMCU, UHCU, and UHVU. This query command returns the comparison reference value set by the SOVC command.

Syntax

```
SOVC? chnum
```
Parameters

chnum : Channel number assigned to the measurement resource. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1.

Query Response

voltage<CR/LF^EOI>

Comparison reference value (in V).

Example Statements

OUTPUT @B1500;"SOVC? 3"
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**

```plaintext
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**

```plaintext
SPP
```

**Example Statements**

```plaintext
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 2-53.

**Syntax**

```plaintext
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**

```plaintext
OUTPUT @B1500;"SPPER 20E-6"
```

**SPPER?**

This query command returns the pulse period for the SPGU channel.

**Syntax**

```plaintext
SPPER?
```

**Query Response**

```plaintext
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`, 1E−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;"SPRMR"
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 2-57.

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]...

A maximum of ten channels can be set.

Parameters

chnum: SPGU channel number. Integer expression. 1 to 10 or 101 to 1002.

If multiple chnums 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 16.

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 2-57.

Execution Conditions

The SPGU operating mode must be set to PG with the SIM 0 command.
Command Reference

Command Reference

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)
**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 4-29.

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 4-29**

<table>
<thead>
<tr>
<th>Decimal Value</th>
<th>Bit Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bit 0</td>
<td>data ready</td>
</tr>
<tr>
<td>2</td>
<td>Bit 1</td>
<td>wait</td>
</tr>
<tr>
<td>4</td>
<td>Bit 2</td>
<td>not used</td>
</tr>
<tr>
<td>8</td>
<td>Bit 3</td>
<td>interlock open</td>
</tr>
<tr>
<td>16</td>
<td>Bit 4</td>
<td>set ready</td>
</tr>
<tr>
<td>32</td>
<td>Bit 5</td>
<td>error</td>
</tr>
<tr>
<td>64</td>
<td>Bit 6</td>
<td>RQS</td>
</tr>
<tr>
<td>128</td>
<td>Bit 7</td>
<td>not used</td>
</tr>
</tbody>
</table>
**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 4-29. 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 Keysight 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. 3 to 10 or 301 to 1001. See Table 4-1 on page 16.
- `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 Keysight 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 Keysight 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.

Sets 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. 3 to 10 or 301 to 1001. See Table 4-1 on page 16.
- **path**: Path connected to the SCUU output. 1 to 4. See Table 4-30.

**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 4-30** SCUU Input Output Connection Control

<table>
<thead>
<tr>
<th>Command</th>
<th>SCUU output connection after the command</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CMUH/Force1/Sense1</td>
</tr>
<tr>
<td>SSP chnum, 1</td>
<td>Force1/Sense1</td>
</tr>
<tr>
<td>SSP chnum, 2</td>
<td>Open</td>
</tr>
<tr>
<td>SSP chnum, 3</td>
<td>Force1/Sense1</td>
</tr>
<tr>
<td>SSP chnum, 4</td>
<td>CMUH</td>
</tr>
</tbody>
</table>

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 Keysight B1500 on, connect the SCUU to the MFCMU and two MPSMU/HRSUs 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 MCSMU, the SMU 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 the allowable voltage for the interlock open condition, or voltage compliance set to more than it).

**Syntax**

```
SSR chnum, mode
```

**Parameters**

- **chnum**: SMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.
- **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**

```
ST pnum [command[;command...[;command]...]];END
```

or

```
ST pnum
[command]
[command]
```
Command Reference

Command Reference

: [command]
END

Parameters

\[ \text{pnum} : \text{ Program number. Integer expression. 1 to 2000.} \]
\[ \text{command} : \text{ Command stored in the internal program memory. Specify commands according to normal syntax – no special syntax is necessary.} \]

For the commands that cannot be stored in the program memory, refer to Table 2-1 on page 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

\[ \text{status_byte<CR/LF^EOI>} \]

\[ \text{status_byte value is a decimal number that indicates which bits of the status byte are ON (“1”). See Table 4-29.} \]

For example, if \text{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 2-53 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 16.
- **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 4-122.

**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 16.
- **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 4-17 on page 30. Available measurement ranges depend on the output signal frequency set by the FC command.

Example Statements

```plaintext
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 16.
- **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 the allowable voltage for the interlock open condition, 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 the allowable voltage for the interlock open condition, 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 16.
- **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 22.
- **current**: Output current (in A). Numeric expression. See Table 4-6 on page 23, Table 4-8 on page 25, or Table 4-11 on page 27 for each measurement resource type.
- **Vcomp**: Voltage compliance value (in V). Numeric expression. See Table 4-6 on page 23, Table 4-8 on page 25, or Table 4-11 on page 27 for each measurement resource 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 $V_{comp}$ you specified.

$vrange$: Voltage compliance ranging type. Integer expression. The compliance range will be set to the minimum range that covers $V_{comp}$ value. For the limited auto ranging, the instrument never uses the range less than the specified range. See Table 4-4 on page 21.

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 the allowable voltage for the interlock open condition, 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 16.

$vrange$: 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 21.

$voltage$: Output voltage (V). Numeric expression. See Table 4-7 on page 24, Table 4-9 on page 26, Table 4-12 on page 27, or Table 4-15 on page 28 for each measurement resource type.

$Icomp$: Current compliance value (in A). Numeric expression. See Table 4-7 on page 24, Table 4-9 on page 26, Table 4-12 on page 27, or Table 4-15 on page 28 for each measurement resource 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.
Command Reference

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 22.

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 \texttt{TGP \textit{port}, \textit{2}, \textit{polarity}, \textit{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](image)

**Syntax**

\texttt{TGMO \textit{mode}}

**Parameters**

\textit{mode} : Edge trigger or gate trigger. Integer expression. 1 or 2.

1: Edge trigger (initial setting).

2: Gate trigger.

**Example Statements**

\texttt{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 2-74.

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.


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 4-31.

If this parameter is not specified, type is set to 0.

Example Statements

OUTPUT @B1500; "TGP 1,1,1,2"

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 4-31 Trigger Type

<table>
<thead>
<tr>
<th>type</th>
<th>terminal</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>When a trigger is received, the B1500 recovers from the wait state set by the PA, PAX, WS, or WSX command.</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>The B1500 sends a trigger by the OS or OSX command.</td>
</tr>
</tbody>
</table>
| 1 a  | 1        | Start measurement trigger  
When a trigger is received, the B1500 starts the measurement. |
| 1    | 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, multi channel pulsed spot, multi channel pulsed sweep, and CV(DC)/CV(AC)/C-f sweep measurements. |
| 2    | 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, multi channel pulsed spot, multi channel pulsed sweep, and CV(DC)/CV(AC)/C-f 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 CV(DC)/CV(AC)/C-f sweep measurements. |
| 3    | 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 CV(DC)/CV(AC)/C-f sweep measurements. |

---

- **See Also**

See Figure 4-4 on page 4-211 for a trigger output example and Figure 4-5 on page 4-215 for a trigger input example.

---

a. TM3 command must be entered to use this trigger type.
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, multi channel pulsed spot, multi channel pulsed sweep, 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 4-211

This command is available for the staircase sweep, multi channel sweep, pulsed spot, pulsed sweep, staircase sweep with pulsed bias, multi channel pulsed spot, multi channel pulsed sweep, 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 4-211

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**

```plaintext
TI chnum[,range]
```

**Parameters**

- **chnum**: SMU measurement channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.
- **range**: Measurement range or ranging type. Integer expression. See Table 4-3 on page 19.

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**

```plaintext
OUTPUT @B1500;"TI 1"
ENTER @B1500 USING "#,3X,13D,X";Idata
```

**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**

```plaintext
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 16.
Command Reference
Command Reference

**irange**: Current measurement range or ranging type. Integer expression. See Table 4-3 on page 19.

**vrange**: Voltage measurement range or ranging type. Integer expression. See Table 4-2 on page 17.

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"
```

**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.

<table>
<thead>
<tr>
<th>mode</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>XE command and GPIB GET (Group Execute Trigger, TRIGGER command in HP BASIC). Initial setting.</td>
</tr>
<tr>
<td>2</td>
<td>XE command</td>
</tr>
<tr>
<td>3</td>
<td>XE command and external trigger</td>
</tr>
<tr>
<td>4</td>
<td>XE command and MM command (automatic trigger after the MM command execution)</td>
</tr>
</tbody>
</table>

To enable the trigger function set by the TGP *port,terminal,polarity*,1 command, the *mode* value must be 3.
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 16.
- **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 4-19 on page 30.

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.
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 the allowable voltage for the interlock open condition, 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 16.
- **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 4-20 on page 31.

**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.

<table>
<thead>
<tr>
<th>mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Disables the time stamp function. Initial setting.</td>
</tr>
<tr>
<td>1</td>
<td>Enables the time stamp function.</td>
</tr>
</tbody>
</table>

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  

\textit{chnum} :  
SMU or MFCMU channel number. Integer expression. 1 to 10. See Table 4-1 on page 16.

If \textit{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 this command is entered many times before timer count is cleared, only the last command is effective.

If \textit{chnum} is not specified, this command clears the timer count immediately.

Example Statements

\begin{verbatim}
OUTPUT @B1500;"TSR"
OUTPUT @B1500;"TSR 1"
\end{verbatim}

Remarks  
To read the time data with the best resolution (100 \(\mu s\)), 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 channel must be in the high voltage state (forcing more than the allowable voltage for the interlock open condition, or voltage compliance set to more than it).

Before this command, open the measurement terminals.

Syntax  

\*TST? [\textit{slot},\textit{option}] 

Parameters

\textit{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.

\textit{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 4-32. `results` returns the sum of the values corresponding to the failures.

**Example Statements**

```
OUTPUT @B1500;"*TST?"
ENTER @B1500;A
```

**Table 4-32**

<table>
<thead>
<tr>
<th>results</th>
<th>Description</th>
<th>results</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Passed. No failure detected.</td>
<td>32</td>
<td>Slot 6 module failed.</td>
</tr>
<tr>
<td>1</td>
<td>Slot 1 module failed.</td>
<td>64</td>
<td>Slot 7 module failed.</td>
</tr>
<tr>
<td>2</td>
<td>Slot 2 module failed.</td>
<td>128</td>
<td>Slot 8 module failed.</td>
</tr>
<tr>
<td>4</td>
<td>Slot 3 module failed.</td>
<td>256</td>
<td>Slot 9 module failed.</td>
</tr>
<tr>
<td>8</td>
<td>Slot 4 module failed.</td>
<td>512</td>
<td>Slot 10 module failed.</td>
</tr>
<tr>
<td>16</td>
<td>Slot 5 module failed.</td>
<td>1024</td>
<td>Mainframe failed.</td>
</tr>
</tbody>
</table>

**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, \(C_p\) and \(G\)). Use the IMP command to select the measurement parameters. See “IMP” on page 4-122.

**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 16.
- **mode**: Ranging mode. 0 (auto ranging. initial setting) or 2 (fixed range).
- **range**: Measurement range. Needs to set when \(\text{mode}=2\). Integer (0 or more). 50 \(\Omega\), 100 \(\Omega\), 300 \(\Omega\), 1 k\(\Omega\), 3 k\(\Omega\), 10 k\(\Omega\), 30 k\(\Omega\), 100 k\(\Omega\), and 300 k\(\Omega\) are selectable. See Table 4-17 on page 30. 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 \(\mu\)s), 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 16.

range: Measurement range or ranging type. Integer expression. See Table 4-3 on page 19.

Remarks

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;"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, HVSMU, and MCSMU 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 16.

irange: Current measurement range or ranging type. Integer expression. See Table 4-3 on page 19.
**Command Reference**

**Command Reference**

**vrange**: Voltage measurement range or ranging type. Integer expression. See Table 4-2 on page 17.

If you do not specify the `i range` and `vrange` parameters, the channel uses the minimum range that covers the compliance value and the minimum range that covers the output 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;"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 16.
- `range`: Measurement range or ranging type. Integer expression. See Table 4-2 on page 17.

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 ";Time
ENTER @B1500 USING ";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 16.
range : Measurement range or ranging type. Integer expression. See Table 4-2 on page 17.

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 ";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 Keysight 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 %In.
- 1: Real variable. Variable name will be %Rn.

**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 %In.
- 1: Real variable. For the variable %Rn.

**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 16.
- `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:

\[
\text{wait time} = N \times \text{initial wait time} + \text{offset}
\]

where `initial wait time` is the time the Keysight 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.
**Syntax**

```plaintext
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 SCUU, 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 the allowable voltage for the interlock open condition, the interlock circuit must be shorted.

**Syntax**

\[ \text{WDCV } \text{chnum}, \text{mode, start, stop, step[, comp]} \]

**Parameters**

- **chnum**: MFCMU or SMU channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.

- **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.

  See Table 4-7 on page 24, Table 4-9 on page 26, or Table 4-12 on page 27 for each measurement resource 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.
Command Reference
Command Reference

**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 4-7 on page 24, Table 4-9 on page 26, or Table 4-12 on page 27 for each measurement resource 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 16.

- **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 4-18 on page 30.
  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 16.

- **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 22.

  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 4-6 on page 23, Table 4-8 on page 25, or Table 4-11 on page 27 for each measurement resource type. *start* and *stop* must have the same polarity for *log* sweep.

- **step**: Number of steps for staircase sweep. Numeric expression. 1 to 10001.
Command Reference

Command Reference

**Vcomp**: Voltage compliance (in V). Numeric expression. See Table 4-6 on page 23, Table 4-8 on page 25, or Table 4-11 on page 27 for each measurement resource type.

If you do not set $V_{comp}$, the previous value is used. If $V_{comp}$ value is greater than the allowable voltage for the interlock open condition, the interlock circuit must be shorted.

Compliance polarity is automatically set to the same polarity as the output value, regardless of the specified $V_{comp}$. If the output value is 0, the polarity is set to positive.

If you set $P_{comp}$, the maximum $V_{comp}$ value for the measurement resource is allowed, regardless of the output range setting.

For the log sweep and without $P_{comp}$, 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 $P_{comp}$ 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, 0.001 to 80 for dual HCSMU, 0.001 to 3 for MCSMU, 0.001 to 100 for UHVU

**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.

\textbf{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.

\textbf{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.

\textbf{Example Statements}

\begin{verbatim}
OUTPUT @B1500;"WMDCV 2"
OUTPUT @B1500;"WMDCV 2,2"
\end{verbatim}

\textbf{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 \textit{post} parameter.

If the measurement is stopped by the automatic abort function, the MFCMU forces the start value.

\textbf{Syntax}

\texttt{WMFC \textit{abort}[,\textit{post}]} 

\textbf{Parameters}

\textit{abort}: Automatic abort function. Integer expression. 1 or 2.

1: Disables the function. Initial setting.
2: Enables the function.

\textit{post}: Signal frequency value after the measurement is normally completed. 
Integer expression. 1 or 2.

1: Start value. Initial setting.
Command Reference
Command Reference

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**

```plaintext
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**

```plaintext
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**

```plaintext
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 the allowable voltage for the interlock open condition, the interlock circuit must be shorted.

**Syntax**

\[ \text{WNX } N, \text{chnum}, \text{mode}, \text{range}, \text{start}, \text{stop}[, \text{comp}[,.P\text{comp}]] \]

**Parameters**

- **\( N \)**: Source number. Integer expression. 2 to 10 for MM16. 1 to 10 for MM28. See Remarks below.
- **\( \text{chnum} \)**: SMU sweep source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.
- **\( \text{mode} \)**: Sweep source type. Integer expression. 1 or 2.
  - 1: Voltage sweep source
  - 2: Current sweep source
- **\( \text{range} \)**: Ranging type for synchronous sweep output. Integer expression.
  - For voltage source (\( \text{mode}=1 \)): See Table 4-4 on page 21.
    - The B1500 usually uses the minimum range that covers both \( \text{start} \) and \( \text{stop} \) values to force the staircase sweep voltage. However, if you set \( P\text{comp} \) 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.
      - \( \text{comp} > \text{maximum current for the output range} \)
      - \( P\text{comp}/\text{output value} > \text{maximum current for the output range} \)
      - For current source (\( \text{mode}=2 \)): See Table 4-5 on page 22.
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 4-7 on page 24, Table 4-9 on page 26, Table 4-10 on page 26, Table 4-12 on page 27, Table 4-14 on page 28, or Table 4-15 on page 28 for each measurement resource type.

- For current source (`mode=2`): See Table 4-6 on page 23, Table 4-8 on page 25, Table 4-11 on page 27, or Table 4-13 on page 28 for each measurement resource 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 4-7 on page 24, Table 4-9 on page 26, Table 4-10 on page 26, Table 4-12 on page 27, Table 4-14 on page 28, or Table 4-15 on page 28 for each measurement resource type.

- For current source (`mode=2`): See Table 4-6 on page 23, Table 4-8 on page 25, Table 4-11 on page 27, or Table 4-13 on page 28 for each measurement resource 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, 0.001 to 80 for dual HCSMU, 0.001 to 3 for MCSMU, 0.001 to 100 for UHVU

**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 command or a device clear.
- 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

\[ \text{WSI \ chnum, range, start, stop[, Vcomp[, Pcomp]]} \]

Parameters

- **chnum**: SMU synchronous sweep source channel number. Integer expression. 1 to 10 or 101 to 1001. See Table 4-1 on page 16.

- **range**: Ranging type for synchronous sweep current output. Integer expression. See Table 4-5 on page 22.

  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 4-6 on page 23, Table 4-8 on page 25, or Table 4-11 on page 27 for each measurement resource 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 4-6 on page 23, Table 4-8 on page 25, or Table 4-11 on page 27 for each measurement resource type. If you do not set *Vcomp*, the previous value is used. If *Vcomp* value is greater than the allowable voltage for the interlock open condition, 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 measurement resource 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, 0.001 to 80 for dual HCSMU, 0.001 to 3 for MCSMU, 0.001 to 100 for UHVU

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 16.

range : Ranging type for synchronous sweep voltage output. Integer expression. See Table 4-4 on page 21.

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 4-7 on page 24, Table 4-9 on page 26, Table 4-12 on page 27, or Table 4-15 on page 28 for each measurement resource 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 the allowable voltage for the interlock open condition, the interlock circuit must be shorted.

Icomp : Current compliance (in A). Numeric expression. See Table 4-7 on page 24, Table 4-9 on page 26, Table 4-12 on page 27, or Table 4-15 on page 28 for each measurement resource 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 measurement resource 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, 0.001 to 80 for dual HCSMU, 0.001 to 3 for MCMU, 0.001 to 100 for UHUV

---

**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 command or a device clear.
- 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 2-74.

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.
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 2-74. 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.
**Command Reference**

**Command Reference**

**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 2-74. 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 2-74. If you do not enter this command, all parameters are set to 0.

**Syntax**

```plaintext
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 the allowable voltage for the interlock open condition, 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 16.

- **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 21.

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 4-7 on page 24, Table 4-9 on page 26, Table 4-12 on page 27, or Table 4-15 on page 28 for each measurement resource type. *start* and *stop* must have the same polarity for log sweep.

**step**: Number of steps for staircase sweep. Numeric expression. 1 to 10001.

**Icomp**: Current compliance (in A). Numeric expression. See Table 4-7 on page 24, Table 4-9 on page 26, Table 4-12 on page 27, or Table 4-15 on page 28 for each measurement resource 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 measurement resource 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, 0.001 to 80 for dual HCSMU, 0.001 to 3 for MCSMU, 0.001 to 100 for UHVU
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.
**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 the allowable voltage for the interlock open condition, or voltage compliance set to more than it) after the trigger (XE), the interlock terminal must be shorted.

- The commands shown in Table 4-33 must be entered before the XE command.

### Table 4-33

**Required Commands before XE, by Measurement Mode**

<table>
<thead>
<tr>
<th>Measurement Mode</th>
<th>Commands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot</td>
<td>CN, MM, DV or DI</td>
</tr>
<tr>
<td>Staircase sweep</td>
<td>CN, MM, WV or WI</td>
</tr>
<tr>
<td>Pulsed spot</td>
<td>CN, MM, PT, PV or PI</td>
</tr>
<tr>
<td>Pulsed sweep</td>
<td>CN, MM, PT, PWV or PWI</td>
</tr>
<tr>
<td>Staircase sweep with pulsed bias</td>
<td>CN, MM, PT, WV or WI, PV or PI</td>
</tr>
<tr>
<td>Quasi-pulsed spot</td>
<td>CN, MM, BDV</td>
</tr>
<tr>
<td>Sampling</td>
<td>CN, MM, MCC, ML, MT, MSC, MI, MV, MSP</td>
</tr>
<tr>
<td>Quasi-static CV</td>
<td>CN, MM, QST, QSV</td>
</tr>
<tr>
<td>Liner search</td>
<td>CN, MM, LSV or LSI, LGV or LGI</td>
</tr>
<tr>
<td>Binary search</td>
<td>CN, MM, BSV or BSI, BGV or BGI</td>
</tr>
<tr>
<td>Multi channel sweep</td>
<td>CN, MM, WI or WV, WNX</td>
</tr>
<tr>
<td>Spot C</td>
<td>CN, MM, IMP, FC, ACV, DCV</td>
</tr>
<tr>
<td>CV (DC bias) sweep</td>
<td>CN, MM, IMP, FC, ACV, WDCV</td>
</tr>
<tr>
<td>CV (AC level) sweep</td>
<td>CN, MM, IMP, FC, DCV, WACV</td>
</tr>
<tr>
<td>C-f sweep</td>
<td>CN, MM, IMP, DCV, ACV, WFC</td>
</tr>
<tr>
<td>Pulsed spot C</td>
<td>CN, MM, IMP, FC, ACV, PTDCV, PDCV</td>
</tr>
<tr>
<td>Pulsed sweep CV</td>
<td>CN, MM, IMP, FC, ACV, PTDCV, PWDCV</td>
</tr>
<tr>
<td>Measurement Mode</td>
<td>Commands</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>C-t sampling</td>
<td>CN, MM, IMP, FC, ACV, MDCV, MTDCV</td>
</tr>
<tr>
<td>Multi channel pulsed spot</td>
<td>CN, MM, MCPT, MCPNT, MCPNX</td>
</tr>
<tr>
<td>Multi channel pulsed sweep</td>
<td>CN, MM, MCPT, MCPNT, MCPWS, MCPWNX</td>
</tr>
</tbody>
</table>
5 Error Messages
Error Messages

This chapter lists the error code of the Keysight B1500.

If error occurs, find solutions in this section and solve problems. However, if problems still remain, perform self-test.

If the Keysight B1500 fails self-test, contact your nearest Keysight 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?” command. The output of the error codes is in the order that they occurred.

Example response by “ERRX?”: 305,”Excess current in HPSMU.; SLOT1”

This response indicates that the error 305 occurs on the slot 1.

NOTE “ERR?” command and “EMG?” command

These commands can be used to read the error code 0 to 999 and the corresponding error message. If the error code 999 is returned, execute the “ERRX?” command to read the error code and the error message.

Response of the ERR? 1 command is one of the followings.

• 0: No error. Normal condition.
• XYZ: Error XYZ (100 to 999) occurs.
• aXYZ: Error XYZ (100 to 999) occurs on the slot a (1 to 9).
• 10XYZ: Error XYZ (100 to 999) occurs on the slot 10.

If the error 305 occurs on the slot 1, ERR? 1 returns 1305, and EMG? 305 returns ”Excess current in HPSMU.”
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 Keysight 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  Force and compliance must be set correctly.
    Incorrect force and compliance values were set. Set them 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.
    Keysight 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 “Program Memory” on page 2-49.

170 Incorrect usage of internal variable.
The internal variable must be %In for integer data, or %Rn for real data. where n is an integer, 0 to 99. Use %In for the integer type command parameters; and use %Rn for the real type command parameters. For the internal variables, see “VAR” on page 4-228.

171 Internal variable is not allowed.
The internal variables %In and %Rn 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 the allowable voltage for the interlock open condition (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 the allowable voltage for the interlock open condition 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 the allowable voltage for the interlock open condition 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.
Error Messages
Operation Error

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 the allowable voltage for the interlock open condition 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 “FMT” on page 4-118.

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.
Error Messages
Operation Error

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 “PT” on page 4-167.

239  Pulse width must be 0.01 ms or more.
Set the pulse width to 0.01 ms or more. See “PT” on page 4-167.

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 “ST” on page 4-203.

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.
Error Messages
Operation Error

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 Keysight 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.
Error Messages
Operation Error

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 “TGP” on page 4-212.

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 “TGP” on page 4-212 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 “TGP” on page 4-212 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 cord 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.
Error Messages
Operation Error

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 the allowable voltage for the interlock open condition 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.

690  DIO control mode must be Ultra High Current Expander / Fixture control mode (ERMOD 4).

Set the digital IO control mode to N1265A control mode by using the ERMOD 4 command.

691  Mismatch Ultra High Current Expander / Fixture ID.

Ultra high current expander/fixture is not connected to the Digital IO connector. Connect the N1265A.

692  Ultra High Current Expander / Fixture control cable was disconnected.

Connection cable was removed. Turn the instrument off and connect the cable. And then turn the instrument on again.

693  Ultra High Current Expander / Fixture is not active.

Ultra high current expander/fixture does not respond. The power switch may be off or the power cord may be removed.

694  DIO control mode must be HVSMU Current Expander control mode (ERMOD 8).

Set the digital IO control mode to N1266A control mode by using the ERMOD 8 command.

695  Mismatch HVSMU Current Expander ID.

HVSMU current expander is not connected to the Digital IO connector. Connect the N1266A.
Error Messages
Operation Error

696  HVSMU Current Expander control cable was disconnected.
Connection cable was removed. Turn the instrument off and connect
the cable. And then turn the instrument on again.

697  HVSMU Current Expander is not active.
HVSMU current expander does not respond. The power switch may be
off or the power cord may be removed.

940  DIO control mode must be Ultra High Voltage Expander control mode
(ERMOD 16).
Set the digital IO control mode to N1268A control mode by using the
ERMOD 16 command.

941  Mismatch Ultra High Voltage Expander ID.
Ultra high voltage expander is not connected to the Digital IO
connector. Connect the N1268A.

942  Ultra High Voltage Expander control cable was disconnected.
Connection cable was removed. Turn the instrument off and connect
the cable. And then turn the instrument on again.

943  Ultra High Voltage Expander is not active.
Ultra high voltage expander does not respond. The power cord may be
removed.

950  DIO control mode must be Device Capacitance Selector control mode
(ERMOD 32).
Set the digital IO control mode to N1272A control mode by using the
ERMOD 32 command.

951  Mismatch Device Capacitance Selector ID.
N1272A/B1506A/B1507A is not connected to the Digital IO connector.
Connect the N1272A, B1506A, or B1507A.

952  Device Capacitance Selector control cable was disconnected.
Connection cable was removed. Turn the instrument off and connect
the cable. And then turn the instrument on again.

953  Device Capacitance Selector is not active.
N1272A/B1506A/B1507A does not respond. The power cord may be
removed.
<table>
<thead>
<tr>
<th>Error Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>999</td>
<td>Error not supported by the “ERR?” command occurs. Execute the “ERRX?” command to read the error code and the error message.</td>
</tr>
<tr>
<td>1000</td>
<td>The specified module doesn’t support power compliance. The power compliance is not available for the specified module.</td>
</tr>
<tr>
<td>1001</td>
<td>Illegal pulse duty</td>
</tr>
<tr>
<td></td>
<td>Set the pulse period and the pulse width so that the pulse duty ratio is within the acceptable range.</td>
</tr>
<tr>
<td>1002</td>
<td>Illegal pulse width</td>
</tr>
<tr>
<td></td>
<td>Check the pulse width and set the correct value.</td>
</tr>
<tr>
<td>1003</td>
<td>Illegal pulse base/peak limit</td>
</tr>
<tr>
<td></td>
<td>Check the pulse base and peak values, and set the correct values.</td>
</tr>
<tr>
<td>1004</td>
<td>Illegal pulse base/peak polarity</td>
</tr>
<tr>
<td></td>
<td>Check the pulse base and peak values, and set the polarity properly.</td>
</tr>
<tr>
<td>1005</td>
<td>Illegal sweep polarity</td>
</tr>
<tr>
<td></td>
<td>Check the sweep start and stop values, and set the polarity properly.</td>
</tr>
<tr>
<td>1006</td>
<td>Application measurement setup is not sufficient.</td>
</tr>
<tr>
<td></td>
<td>Check the setup required for the specified measurement and set it properly.</td>
</tr>
<tr>
<td>1007</td>
<td>Source channel must be set.</td>
</tr>
<tr>
<td></td>
<td>Set the source output channel properly.</td>
</tr>
<tr>
<td>1008</td>
<td>Pulse output channel is required.</td>
</tr>
<tr>
<td></td>
<td>Specify the pulse output channel. Or set the pulse output channel properly.</td>
</tr>
<tr>
<td>1010</td>
<td>This B1500A does not support PCH. PCH is not supported by this B1500A. The B1500A must be upgraded to use the dual HCSMU operation.</td>
</tr>
<tr>
<td>1011</td>
<td>SMU is not installed in the slot set to PCH. Empty slot or non SMU module was specified by PCH. The HCSMU modules must be specified.</td>
</tr>
</tbody>
</table>
Error Messages
Operation Error

1012
Execute CL to the modules set to PCH.

Output switch of the modules set to PCH must be OFF previously.

1013
Execute ERHPA 0,0,0 before PCH.

Modules set to ERHPA cannot be specified in PCH.
Execute ERHPA 0,0,0, then execute PCH. After that execute ERHPA to set the module selector input connection.

1014
Modules set to PCH must be HCSMU.

Only the HCSMU module can be specified in PCH.

1015
Modules set to PCH must be different.

Same module was specified by PCH for both master and slave HCSMU modules. They must be the different modules.

1016
Do not execute CN/CNX to the slave module set to PCH.

Specify the master module in CN/CNX to enable the dual HCSMU channel.

1017
Specified module is already used for dual HCSMU.

Specify a free HCSMU.

1018
Total setting current exceeds the capacity of main frame power supply. Reduce setting current.
Set the current lower than the specified value.

1019
A voltage setting other than 0 V or a current setting above +4 mA or below −4 mA can be applied to only one HVSMU channel in case of single channel HVSMU operation. Change HVSMU operation mode by HVSMUOP command.

1020
Cannot change HVSMU operation mode in high voltage status.

Execute HVSMUOP command after solving the high voltage status.

1021
Cannot change N1274A path in high voltage status.

Execute ERHPQG command after solving the high voltage status.

1022
Execute ERHPE 1 before ERHPQG.

Enable the external relay control function of the N1258A module selector using ERHPE command, and then execute ERHPQG command.
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.
Error Messages
Operation Error

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.
### Error Messages

#### Operation Error

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3312</td>
<td>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.</td>
</tr>
<tr>
<td>3313</td>
<td>Specified ALWG measurement instruction code is invalid. Check the measurement event setting and set the correct values.</td>
</tr>
<tr>
<td>3314</td>
<td>Specified ALWG range change instruction code is invalid. Check the range event setting and set the correct values.</td>
</tr>
<tr>
<td>3315</td>
<td>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.</td>
</tr>
<tr>
<td>3316</td>
<td>Specified ALWG measurement count is greater than measurement interval. Check the measurement averaging time and set the correct value. The value must be less than or equal to the measurement interval time.</td>
</tr>
<tr>
<td>3317</td>
<td>Specified slot is invalid. Check the slot number and set the correct value. The slot number must be 1 to 10.</td>
</tr>
<tr>
<td>3318</td>
<td>Specified module channel is invalid. Check the channel number and set the correct value.</td>
</tr>
<tr>
<td>3319</td>
<td>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.</td>
</tr>
<tr>
<td>3320</td>
<td>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.</td>
</tr>
<tr>
<td>3321</td>
<td>VM/IM measurement mode is invalid. Check the measurement mode and set the correct value.</td>
</tr>
<tr>
<td>3322</td>
<td>Voltage measurement range is invalid. Check the voltage measurement range and set the correct value.</td>
</tr>
<tr>
<td>3323</td>
<td>Current measurement range is invalid. Check the current measurement range and set the correct value.</td>
</tr>
</tbody>
</table>
Error Messages

Operation Error

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.

5301  Specified module is already assigned to voltage control, current control or gate control.
Specify a free MCSMU/HCSMU.
5302 Voltage control module and current control module must be different. Specify a free MCSMU/HCSMU.

5303 Do not execute CN/CNX to the current control module set to ERPFUHCA. Execute the CN/CNX command to the module that is set to voltage control by the ERPFUHCA command.

5304 Ultra High Current Expander / Fixture drain path must be open state. Open the selector connection path before switch the HVSMU series resistor.

5305 Execute CL to the module set to ERPFUHCA. Execute the CL command to the modules that will be specified by the ERPFUHCA command.

5306 Ultra High Current Expander / Fixture gate path must be open state. Open the gate connection path before switching the series resistor for the path.

5307 CRC for N1265A/B1506A EEPROM Vs correction segment failed. N1265A/B1506A might be defective. Contact your nearest Keysight Technologies service center.

5308 CRC for N1265A/B1506A EEPROM Is correction segment failed. N1265A/B1506A might be defective. Contact your nearest Keysight Technologies service center.

5309 CRC for N1265A/B1506A EEPROM Vm correction segment failed. N1265A/B1506A might be defective. Contact your nearest Keysight Technologies service center.

5310 CRC for N1265A/B1506A EEPROM Im correction segment failed. N1265A/B1506A might be defective. Contact your nearest Keysight Technologies service center.

5311 Specified module is already assigned to voltage control or current control of HVMCU. Specify a free MCSMU/HCSMU.
Error Messages
Operation Error

5312 Different module must be assigned to voltage control and current control of HVMCU.
Specify a free MCSMU/HCSMU.

5313 Do not execute CN/CNX to the current control module set to ERHVCA.
Execute the CN/CNX command to the module that is set to voltage control by the ERHVCA command.

5314 HVSMU Current Expander output must be open state.
Open the input-output path before switching the HVSMU series resistor.

5315 Execute CL to the module set to ERHVCA.
Execute the CL command to the modules that will be specified by the ERHVCA command.

5316 CRC for N1266A EEPROM Vm correction segment failed.
N1266A might be defective. Contact your nearest Keysight Technologies service center.

5317 CRC for N1266A EEPROM Im correction segment failed.
N1266A might be defective. Contact your nearest Keysight Technologies service center.

5318 Over voltage is detected in Selector Output High Force, Low Force, or Low Sense terminal of N1265A/B1506A.
Remove the causes of overvoltage.

5319 Over voltage is detected in Selector Output High Sense terminal of N1265A/B1506A.
Remove the causes of overvoltage.

5320 Pulse width overrun is detected in N1265A/B1506A.
Check the assignment of control modules.

5321 Specified module is already assigned to voltage control or current control of UHVU.
Specify a free MCSMU/HCSMU.
Error Messages
Operation Error

5322 Different module must be assigned to voltage control and current control of UHVU.
Specify a free MCSMU/HCSMU.

5323 Do not execute CN/CNX to the current control module set to ERUHVA.
Execute the CN/CNX command to the module that is set to voltage control by the ERUHVA command.

5324 Execute CL to the module set to ERUHVA.
Execute the CL command to the modules that will be specified by the ERUHVA command.

5325 Specified module is already used for UHCU, Selector, or Gate of N1265A/B1506A.
Specify a free module.

5326 Specified module is already used for HVMCU.
Specify a free module.

5327 Specified module is already used for UHVU.
Specify a free module.

5330 N1265A/B1506A: Cooling fan is not operating.
Check the operation of cooling fan and the condition around the fan.

5331 Execute CL to the module set to ERCMAA.

5332 Execute ERCMAIO to clear measurement path of Device Capacitance Selector before executing ERCMAGRD.

5333 Invalid parameters for ERCMAIO.

5334 N1272A/B1506A/B1507A: Input modules are not assigned. Execute ERCMAAA to assign input modules.

5340 N1265A/B1506A: Control modules are not assigned. Execute ERPFUHCA to assign control modules.

5341 N1265A/B1506A: Status test failed.

5342 N1265A/B1506A: Voltage pulse test failed.

5343 N1265A/B1506A: Current pulse test failed.

5344 N1265A/B1506A: Current measurement CMR test failed.
Error Messages

Operation Error

5345 N1265A/B1506A: Offset voltage test failed.
5346 N1265A/B1506A: Voltage measurement offset test failed.
5347 N1265A/B1506A: Current measurement offset test failed.
5350 N1266A/B1506A: Control modules are not assigned. Execute ERHVCA to assign control modules.
5351 N1265A/B1506A: Voltage measurement offset calibration failed.
5352 N1265A/B1506A: Current measurement offset calibration failed.
5355 N1266A: Cannot use N1258A’s series resistor for HVSMU.
5356 N1266A: Cannot use N1265A’s series resistor for HVSMU.
5360 N1268A: Control modules are not assigned. Execute EROHVA to assign control modules.
5361 N1266A: Voltage pulse test failed.
5371 Specified module cannot be used in the present measurement mode.
5381 N1265A/B1506A diagnosis failed.
5385 N1268A diagnosis failed.
5395 N1272A/B1506A/B1507A diagnosis failed.

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.
Error Messages
Operation Error

5413  HCSMU should not apply low current to high impedance device.

NOTE
If one of the errors 6401 to 6413 occurs, the all module output is changed to 0 V and the all output switch is disconnected.

6401  MCSMU high force over voltage emergency occurred.
6402  MCSMU high sense over voltage emergency occurred.
6403  MCSMU low force over voltage emergency occurred.
6404  MCSMU low sense over voltage emergency occurred.
6410  MCSMU pulse width over current emergency occurred.
6411  MCSMU float lost emergency occurred.
6412  MCSMU calculation overflow emergency occurred.
6413  MCSMU should not apply low current to high impedance device.
**Self-test/Calibration Error**

When the Keysight B1500 fails the self-test or self-calibration, the Keysight 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.

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>700</td>
<td>CPU failed NVRAM read/write test.</td>
</tr>
<tr>
<td>701</td>
<td>CPU failed FPGA read/write test.</td>
</tr>
<tr>
<td>702</td>
<td>CPU failed H-RESOLN ADC end signal test.</td>
</tr>
<tr>
<td>703</td>
<td>CPU failed H-RESOLN ADC start signal test.</td>
</tr>
<tr>
<td>704</td>
<td>CPU failed emergency status signal test.</td>
</tr>
<tr>
<td>705</td>
<td>CPU failed SRQ status signal test.</td>
</tr>
<tr>
<td>706</td>
<td>CPU failed high voltage status signal test.</td>
</tr>
<tr>
<td>707</td>
<td>CPU failed low voltage status signal test.</td>
</tr>
<tr>
<td>708</td>
<td>CPU failed DAC settling status signal test.</td>
</tr>
<tr>
<td>709</td>
<td>CPU failed measure ready status signal test.</td>
</tr>
<tr>
<td>710</td>
<td>CPU failed set ready status signal test.</td>
</tr>
<tr>
<td>711</td>
<td>CPU failed measure end status signal test.</td>
</tr>
<tr>
<td>712</td>
<td>CPU failed measure trigger signal test.</td>
</tr>
<tr>
<td>713</td>
<td>CPU failed pulse trigger signal test.</td>
</tr>
<tr>
<td>714</td>
<td>CPU failed abort trigger signal test.</td>
</tr>
<tr>
<td>715</td>
<td>CPU failed DAC set trigger signal test.</td>
</tr>
<tr>
<td>720</td>
<td>H-RESOLN ADC is not installed.</td>
</tr>
<tr>
<td>721</td>
<td>H-RESOLN ADC failed ROM/RAM test.</td>
</tr>
<tr>
<td>722</td>
<td>H-RESOLN ADC failed B-COM offset DAC test.</td>
</tr>
<tr>
<td>723</td>
<td>H-RESOLN ADC failed sampling ADC test.</td>
</tr>
<tr>
<td>724</td>
<td>H-RESOLN ADC failed integrating ADC test.</td>
</tr>
<tr>
<td>725</td>
<td>H-RESOLN ADC failed bus function test.</td>
</tr>
</tbody>
</table>
## Error Messages

### Self-test/Calibration Error

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>740</td>
<td>GNDU failed calibration.</td>
</tr>
<tr>
<td>935</td>
<td>CMU FPGA version mismatch.</td>
</tr>
<tr>
<td>2400</td>
<td>SPGU module is in TEST FAIL state.</td>
</tr>
<tr>
<td>2401</td>
<td>Digital H/W function test failed.</td>
</tr>
<tr>
<td>2402</td>
<td>CPLD access function test failed.</td>
</tr>
<tr>
<td>2403</td>
<td>CPLD version check test failed.</td>
</tr>
<tr>
<td>2404</td>
<td>CPLD revision check test failed.</td>
</tr>
<tr>
<td>2405</td>
<td>FPGA configuration test failed.</td>
</tr>
<tr>
<td>2406</td>
<td>FPGA access function test failed.</td>
</tr>
<tr>
<td>2407</td>
<td>FPGA version check test failed.</td>
</tr>
<tr>
<td>2408</td>
<td>FPGA revision check test failed.</td>
</tr>
<tr>
<td>2409</td>
<td>DCM function test failed.</td>
</tr>
<tr>
<td>2410</td>
<td>CONVEND interrupt function test failed.</td>
</tr>
<tr>
<td>2411</td>
<td>EMG interrupt function test failed.</td>
</tr>
<tr>
<td>2412</td>
<td>10 MHz clock test failed.</td>
</tr>
<tr>
<td>2413</td>
<td>FPGA SYNC SEL pin control function test failed.</td>
</tr>
<tr>
<td>2414</td>
<td>FPGA SYNC FB pin control function test failed.</td>
</tr>
<tr>
<td>2415</td>
<td>FPGA SYNC IN pin control function test failed.</td>
</tr>
<tr>
<td>2416</td>
<td>IDELAY function test failed.</td>
</tr>
<tr>
<td>2417</td>
<td>NVRAM access function test failed.</td>
</tr>
<tr>
<td>2418</td>
<td>ADC function test failed.</td>
</tr>
<tr>
<td>2419</td>
<td>SDRAM access function test failed.</td>
</tr>
<tr>
<td>2430</td>
<td>Module EEPROM CRC data is invalid.</td>
</tr>
<tr>
<td>2431</td>
<td>Module EEPROM CRC data of module data ID is invalid.</td>
</tr>
<tr>
<td>2432</td>
<td>Module EEPROM CRC data of format revision data is invalid.</td>
</tr>
<tr>
<td>2433</td>
<td>Module EEPROM CRC data of analog reference data is invalid.</td>
</tr>
<tr>
<td>2434</td>
<td>Module EEPROM CRC data of timing calibration data is invalid.</td>
</tr>
<tr>
<td>2435</td>
<td>Module EEPROM CRC data is skew calibration data invalid.</td>
</tr>
<tr>
<td>Code</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>2450</td>
<td>Internal ADC function test failed.</td>
</tr>
<tr>
<td>2451</td>
<td>0.5 Vref Internal ADC function test failed.</td>
</tr>
<tr>
<td>2452</td>
<td>4.5 Vref Internal ADC function test failed.</td>
</tr>
<tr>
<td>2453</td>
<td>Power Amp initial test failed.</td>
</tr>
<tr>
<td>2454</td>
<td>Filter &amp; Amp test failed.</td>
</tr>
<tr>
<td>2455</td>
<td>Internal temperature test failed.</td>
</tr>
<tr>
<td>2456</td>
<td>Internal output resistance test failed.</td>
</tr>
<tr>
<td>2481</td>
<td>Invalid frame configuration.</td>
</tr>
<tr>
<td>2482</td>
<td>Frame has no modules.</td>
</tr>
<tr>
<td>2483</td>
<td>PLL not locked in slave module.</td>
</tr>
<tr>
<td>2484</td>
<td>Reference line is not connected.</td>
</tr>
<tr>
<td>2485</td>
<td>Sync line is not connected.</td>
</tr>
<tr>
<td>2486</td>
<td>Interrupt line is not available.</td>
</tr>
<tr>
<td>2487</td>
<td>Module service request assertion test failed.</td>
</tr>
<tr>
<td>2488</td>
<td>Module service request detection test failed.</td>
</tr>
<tr>
<td>2489</td>
<td>Emergency interrupt is not available.</td>
</tr>
<tr>
<td>2500</td>
<td>SPGU calibration failed.</td>
</tr>
<tr>
<td>2501</td>
<td>Power Amp idling calibration failed.</td>
</tr>
<tr>
<td>2502</td>
<td>DAC output level calibration failed.</td>
</tr>
<tr>
<td>3002</td>
<td>WGFMU initialization failure.</td>
</tr>
<tr>
<td>3003</td>
<td>WGFMU FPGA is not configured.</td>
</tr>
<tr>
<td>3004</td>
<td>EEPROM CRC data of system timing data is invalid.</td>
</tr>
<tr>
<td>3005</td>
<td>EEPROM CRC data of DAC DCM PS data is invalid.</td>
</tr>
<tr>
<td>3006</td>
<td>EEPROM CRC data of ADC DCM PS data is invalid.</td>
</tr>
<tr>
<td>3007</td>
<td>EEPROM CRC data of DAC clock edge data is invalid.</td>
</tr>
<tr>
<td>3008</td>
<td>EEPROM CRC data of ADC clock edge data is invalid.</td>
</tr>
<tr>
<td>3009</td>
<td>EEPROM CRC data of DAC level calibration data is invalid.</td>
</tr>
<tr>
<td>3010</td>
<td>EEPROM CRC data of ADC level calibration data is invalid.</td>
</tr>
</tbody>
</table>

Error Messages
Self-test/Calibration Error
Error Messages
Self-test/Calibration Error

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.
<table>
<thead>
<tr>
<th>Error Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3424</td>
<td>Channel 1 RSU EEPROM access function test failed.</td>
</tr>
<tr>
<td>3425</td>
<td>Channel 2 RSU EEPROM access function test failed.</td>
</tr>
<tr>
<td>3426</td>
<td>WGFMU EEPROM CRC data is invalid.</td>
</tr>
<tr>
<td>3427</td>
<td>WGFMU EEPROM CRC data of format revision data is invalid.</td>
</tr>
<tr>
<td>3428</td>
<td>WGFMU EEPROM CRC data of serial number data is invalid.</td>
</tr>
<tr>
<td>3429</td>
<td>WGFMU EEPROM CRC data of system timing data is invalid.</td>
</tr>
<tr>
<td>3430</td>
<td>WGFMU EEPROM CRC data of DAC DCM PS data is invalid.</td>
</tr>
<tr>
<td>3431</td>
<td>WGFMU EEPROM CRC data of ADC DCM PS data is invalid.</td>
</tr>
<tr>
<td>3432</td>
<td>WGFMU EEPROM CRC data of DAC clock edge data is invalid.</td>
</tr>
<tr>
<td>3433</td>
<td>WGFMU EEPROM CRC data of ADC clock edge data is invalid.</td>
</tr>
<tr>
<td>3434</td>
<td>WGFMU EEPROM CRC data of DAC level calibration data is invalid.</td>
</tr>
<tr>
<td>3435</td>
<td>WGFMU EEPROM CRC data of ADC level calibration data is invalid.</td>
</tr>
<tr>
<td>3436</td>
<td>WGFMU EEPROM CRC data of DAC skew calibration data is invalid.</td>
</tr>
<tr>
<td>3437</td>
<td>WGFMU EEPROM CRC data of ADC skew calibration data is invalid.</td>
</tr>
<tr>
<td>3438</td>
<td>RSU EEPROM CRC data of format revision data is invalid.</td>
</tr>
<tr>
<td>3439</td>
<td>RSU EEPROM CRC data of serial number data is invalid.</td>
</tr>
<tr>
<td>3440</td>
<td>RSU EEPROM CRC data of type id data is invalid.</td>
</tr>
<tr>
<td>3441</td>
<td>RSU EEPROM CRC data of calibration data is invalid.</td>
</tr>
<tr>
<td>3450</td>
<td>WGFMU EEPROM data is invalid.</td>
</tr>
<tr>
<td>3451</td>
<td>WGFMU EEPROM data of RSU type is invalid.</td>
</tr>
<tr>
<td>3452</td>
<td>WGFMU EEPROM data of RSU cable type is invalid.</td>
</tr>
<tr>
<td>3460</td>
<td>Main DAC, Main ADC test failed.</td>
</tr>
<tr>
<td>3461</td>
<td>Bias DAC, Main ADC test failed.</td>
</tr>
<tr>
<td>3462</td>
<td>Main DAC, Reference ADC test failed.</td>
</tr>
<tr>
<td>3463</td>
<td>VM function test failed.</td>
</tr>
<tr>
<td>3464</td>
<td>IM offset test failed.</td>
</tr>
<tr>
<td>3465</td>
<td>IM short test failed.</td>
</tr>
<tr>
<td>3480</td>
<td>Invalid frame configuration.</td>
</tr>
</tbody>
</table>
Error Messages
Self-test/Calibration Error

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.
Error Messages
Self-test/Calibration Error

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.
## Error Messages

### Self-test/Calibration Error

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4615</td>
<td>IFIM gain measurement by I ADC failed.</td>
</tr>
<tr>
<td>4616</td>
<td>Calculation of IM correction data failed.</td>
</tr>
<tr>
<td>4617</td>
<td>Calculation of IF correction data failed.</td>
</tr>
<tr>
<td>4701</td>
<td>Non-feedback offset adjustment failed.</td>
</tr>
</tbody>
</table>

### NOTE

Error codes 5501 to 5701 are for HCSMU.

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5501</td>
<td>Digital H/W function test failed.</td>
</tr>
<tr>
<td>5502</td>
<td>CPLC access function test failed.</td>
</tr>
<tr>
<td>5503</td>
<td>FPGA access function test failed.</td>
</tr>
<tr>
<td>5505</td>
<td>Bus FPGA JTAG function test failed.</td>
</tr>
<tr>
<td>5506</td>
<td>Float FPGA JTAG function test failed.</td>
</tr>
<tr>
<td>5507</td>
<td>OPT I/F access function test failed.</td>
</tr>
<tr>
<td>5509</td>
<td>ADC access test failed.</td>
</tr>
<tr>
<td>5510</td>
<td>EEPROM access function test failed.</td>
</tr>
<tr>
<td>5513</td>
<td>Power AMP bias test failed.</td>
</tr>
<tr>
<td>5551</td>
<td>V offset self-test failed.</td>
</tr>
<tr>
<td>5552</td>
<td>V sense self-test failed.</td>
</tr>
<tr>
<td>5553</td>
<td>HS VADC self-test failed.</td>
</tr>
<tr>
<td>5554</td>
<td>V CMR DAC self-test failed.</td>
</tr>
<tr>
<td>5555</td>
<td>I offset self-test failed.</td>
</tr>
<tr>
<td>5556</td>
<td>V loop self-test failed.</td>
</tr>
<tr>
<td>5557</td>
<td>I sense low self-test failed.</td>
</tr>
<tr>
<td>5558</td>
<td>HS IADC self-test failed.</td>
</tr>
<tr>
<td>5559</td>
<td>I CMR DAC self-test failed.</td>
</tr>
<tr>
<td>5560</td>
<td>I sense high self-test failed.</td>
</tr>
<tr>
<td>5561</td>
<td>Power supply test failed.</td>
</tr>
<tr>
<td>5562</td>
<td>V switch test failed.</td>
</tr>
<tr>
<td>5563</td>
<td>High force output relay test failed.</td>
</tr>
<tr>
<td>5564</td>
<td>High sense output relay test failed.</td>
</tr>
</tbody>
</table>
Error Messages
Self-test/Calibration Error

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.

NOTE
Error codes 6501 to 6606 are for MCSMU.

6501 Digital H/W function test failed.
6502 CPLC access function test failed.
6503 FPGA access function test failed.
6505 Bus FPGA JTAG function test failed.
6506 Float FPGA JTAG function test failed.
6507 OPT I/F access function test failed.
6509 ADC access test failed.
6510 EEPROM access function test failed.
6551 V offset self-test is failed.
6552 V sense self-test is failed.
6553 HS VADC self-test is failed.
6554 V CMR DAC self-test is failed.
6555 I offset self-test is failed.
6556 V loop self-test is failed.
6557 I sense low self-test is failed.
6558 HS IADC self-test is failed.
6559 I CMR DAC self-test is failed.
6560 I sense high self-test is failed.
6562 V switch test is failed.
6563 High force output relay test is failed.
Error Messages
Self-test/Calibration Error

6564  High sense output relay test is failed.
6601  VM offset calibration is failed.
6602  V CMR DAC calibration is failed.
6603  VM gain calibration is failed.
6604  IM offset calibration is failed.
6605  I CMR DAC calibration is failed.
6606  Iad gain calibration is 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.
Error Messages
Self-test/Calibration Error

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.
Error Messages
Self-test/Calibration Error

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.
Error Messages
Self-test/Calibration Error

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.
Error Messages
Self-test/Calibration Error