GPIB Command Reference

Agilent 4155C Semiconductor Parameter Analyzer
Agilent 4156C Precision Semiconductor Parameter Analyzer

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In This Manual

Agilent 4155C/4156C provides three command modes to control the 4155C/4156C via GPIB interface. You can control the 4155C/4156C using one of the following command modes.

- *4155/4156 SCPI command mode*

  SCPI means Standard Commands for Programmable Instruments. This mode is the default mode of the 4155C/4156C, and allows you to control the 4155C/4156C functions except for the timestamp, search, and the enhanced stop condition the FLEX mode supports.

- *4155/4156 FLEX command mode*

  FLEX means Fast Language for EXecution. This mode allows you to control *measurement* functions of the 4155C/4156C. Command execution is faster than the SCPI command mode.

- *4145 syntax command mode*

  This mode allows you to execute the 4145A/B programs on the 4155C/4156C directly with little or no modification. In this command mode, you *cannot* control all functions of the 4155C/4156C.

To confirm the present control mode, see the language mode indicator on the screen, or enter the CMD? command.

Language indicator: The indicator is located between the fourth primary softkey and the fifth primary softkey, and next to the screen lock indicator. The meaning of the indicator is as follows:

S: SCPI command mode

F: FLEX command mode

4: 4145 syntax command mode

CMD? command: This query command returns the present command mode. The response is as follows:

0: SCPI command mode

1: FLEX command mode

2: 4145 syntax command mode

This command is effective for all command mode.

This manual describes about the 4155C/4156C FLEX command set and the 4145 syntax command set, and consists of the following chapters:

- 4155C/4156C FLEX Commands

  Lists the 4155C/4156C FLEX commands, and provides description, command syntax, example statements, and so on. Also provides the command input format, data output format, status byte information and error messages.

- 4145B Syntax Commmand Set

  Lists the 4145 Syntax commands, and provides description, command syntax, example statements, and so on. Also provides the general conventions, differences from the 4145A/B commands and status byte information.

For information about the 4155C/4156C SCPI command set, refer to *SCPI Command Reference*.

See *User's Guide Measurement and Analysis* and *User's Guide General Information* for information about the 4155C/4156C itself.

Refer to *Programmer's Guide* to make a program and use built-in Instrument BASIC controller.

NOTE

4155C/4156C FLEX command set

The 4155C/4156C FLEX command set includes some commands which have the same name as the GPIB command of Agilent 4142B DC Source/Monitor. This is useful for you who create the 4155C/4156C measurement program by modifying the program created to control the 4142B.

However the 4155C/4156C commands are not fully compatible with the 4142B commands. So you need to do some modifications on the measurement program for the 4142B.

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1. 4155C/4156C FLEX Commands

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1 4155C/4156C FLEX Commands

This chapter provides the following information:

- “Control Mode”
- “Command Input Format”
- “Data Output Format”
- “Status Byte”
- “Command Reference”
- “Error Messages”

Control Mode

To use the 4155C/4156C FLEX commands, enter the *US* or *US42* command when the 4155C/4156C is in one of the following state. This command causes the 4155C/4156C control mode transition.

- Power on state
- Interactive operation mode (normal operation mode, which is not GPIB control mode)
- 4155C/4156C SCPI command control mode

The control mode transition resets the 4155C/4156C settings. For the initial settings in the FLEX command control mode, see the *RST command in the "Command Reference" section in this chapter.

In the FLEX command control mode, you can use the all commands described in this chapter, and the SCPI commands and the 4145A/B syntax commands are not available.

If you use the built-in IBASIC controller, use the full IBASIC screen. All front panel keys except for the following keys are available.

- MEASUREMENT key group
- **Plot/Print** key
- **Save** and **Get** keys
- IBASIC **Display** key

If you use an external controller, the screen and front panel keys on the 4155C/4156C front panel are not available. Only the LOCAL secondary softkey is available. This softkey is used to release the remote control state of the 4155C/4156C.

US/US42 Command

Syntax, command parameters, and example statements for the US and US42 command are shown below.

Difference between US command and US42 command is that the US42 command provides the 4142B DC Source/Monitor-like response for the following items:

- Output data format
- Query response
- Status code (status byte)

Syntax

Syntax of US command:

`US`

Syntax of US42 command:

`US42[level]`

Parameters

level Support level for the 4142B-like response. Must be an integer. Refer to the following table. If you do not specify this parameter, *level* is set to 255 (1+2+4+8+16+32+64+128). This means all *level*s are selected.

If you select multiple levels, enter a value that is the sum of the desired *level* values. For example, if you select levels 1, 2 and 4, enter 7 (1+2+4) as the *level* value.

Example Statements

```
OUTPUT @Hp4156;"US"
OUTPUT @Hp4156;"US42"
OUTPUT @Hp4156;"US42 15"
```

level	Description
1	Supports the 4142B-like data output format. (FMT command allows you to select data output format.)
2	Supports the 4142B-like status code (status byte).
4	Supports the 4142B-like query response.
8	Supports the 4142B-like GNDU, VMU output switch setting. (GNDU and VMU output switches are set to ON after executing the CL command without specifying channel number.)
16	Reads output data without RMD? command. [a]
32	Not defined.
64	Not defined.
128	Not defined.

a. Without *level*=16, you need to enter the RMD? command before entering the command (ex; ENTER (HP BASIC) command) to read the output data. If you select *level*=16, you do not need the RMD? command. But you cannot read the output data correctly if both output data and query response are in the 4155C/4156C output buffer.

To Quit FLEX Command Mode

To quit the FLEX command control mode, do one of the following:

- Enter the :PAGE command (ex: OUTPUT @Hp415x;":PAGE")
- Enter the LOCAL (HP BASIC) command
- If you use an external controller: Select the LOCAL secondary softkey displayed on the 4155C/4156C screen.
- If you use the built-in IBASIC controller: Press any key in the PAGE CONTROL key group.

The control mode transition resets the 4155C/4156C settings except for the auto calibration mode setting. Auto calibration is set to OFF forcibly.

To Use 4142B Measurement Program

If you want to use the measurement program created to control Agilent 4142B Modular DC Source/Monitor, remember the following precautions. You need to modify the measurement program.

- Command syntax:

  The 4155C/4156C FLEX commands need a space between the command and its command parameter. The 4142B commands do *not* need a space.

  Add a space between the command and the first command parameter as shown in the following example:

  - For 4142B:

    ```
    OUTPUT @Hp4142;"DV1,0,20"      !Applies 20V
    ```

  - For 4155C/4156C:

    ```
    OUTPUT @Hp4156;"DV 1,0,20"     !Applies 20V
    ```

- Reading output data:

  To read the 4155C/4156C output data after a measurement, use the RMD? command as shown in the following example:

  - For 4142B:

    ```
    OUTPUT @Hp4142;"XE"   !Executes measurements
    ENTER @Hp4142;A$      !Reads measurement data
    ```

  - For 4155C/4156C:

    ```
    OUTPUT @Hp4156;"XE"   !Executes measurements
    OUTPUT @Hp4156;"RMD?" !Puts data on the output buffer
    ENTER @Hp4156;A$      !Reads measurement data
    ```

  If you select *level*=16 for the US42 command parameter, you do not need the RMD? command before the ENTER command on this example. But you cannot read the output data correctly if both output data and query response are in the 4155C/4156C output buffer.

- Command parameters:

  For the 4155C/4156C FLEX commands which have the same name as the 4142B commands, such as DV and DI, the meaning and order of most parameters are the same as the 4142B commands. However, the values available for the command parameter will be different from the 4142B control command because of the difference in measurement performance. Also, some optional command parameters may be added.

  Confirm the command parameters and the available values.

- Measurement unit channel numbers:

  The channel numbers of the measurement units must be changed. To change the channel numbers, use the ACH command. The ACH command translates the channel numbers for the 4142B to the channel numbers for the 4155C/4156C.

  For details, see the ACH command in the “Command Reference” section in this chapter.

- Unsupported commands:

  The following 4142B commands are not supported by the 4155C/4156C.

  ```
  AIV, ASM, ASV, AVI, BDM, BDT, BDV, ERC,
  PDI, PDM, PDV, POL
  ```

- Multiple command strings

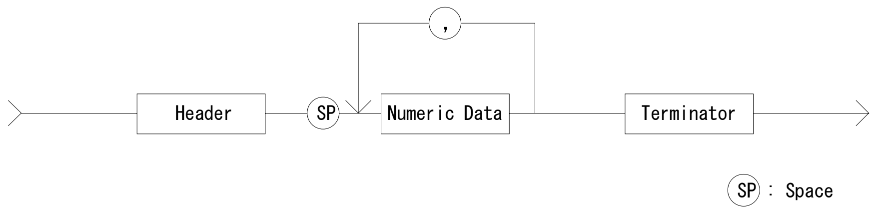
  The 4155C/4156C FLEX command mode does not support the multiple command strings such as the following example. Do not enter the multiple command strings.

  ```
  OUTPUT @Hp415x;"CN 1;DV 1,0,5;MM 1,1"
  ```

Command Input Format

The 4155C/4156C FLEX commands are composed of a header, numeric data, and terminator, as shown in the syntax diagram in the following figure.

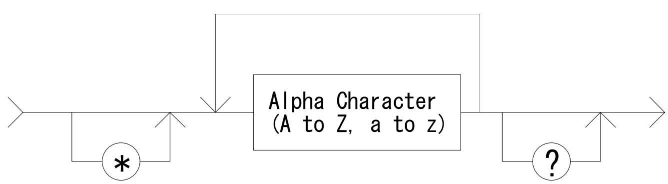
4155C/4156C Control Command Syntax Diagram



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.

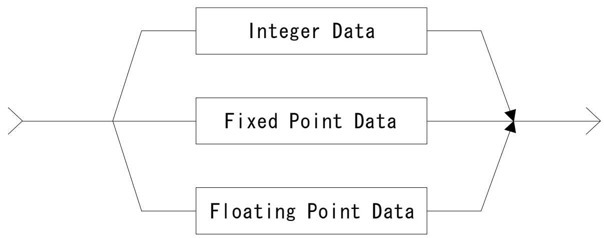
Header Syntax Diagram



Numeric Data

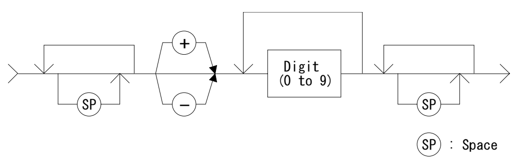
Numeric data is the command parameters. You need to insert a space between the header and the command parameters (numeric data). Some parameters require integer data. The following figure shows the syntax diagram for numeric data.

Numeric Data Syntax Diagram

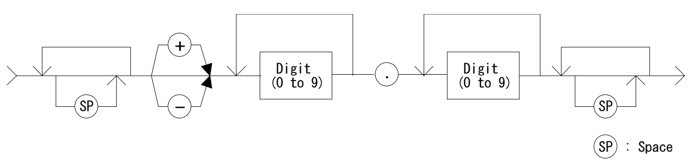


The following 3 figures show the syntax diagrams for integer, fixed point, and floating point data, respectively.

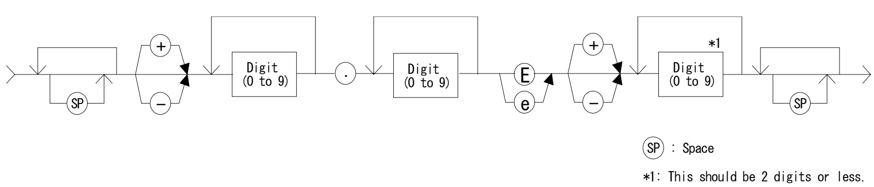
Integer Data Syntax Diagram



Fixed Point Data Syntax Diagram



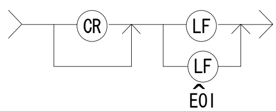
Floating Point Data Syntax Diagram



Terminator

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

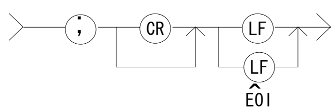
Terminator Syntax Diagram



Special Terminator

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

Special Terminator



Data Output Format

This section describes the data output formats of the 4155C/4156C. The 4155C/4156C provides the following four types of data output formats:

- "ASCII Format in US Mode"
- "Binary Format in US Mode"
- "ASCII Format in US42 Mode"
- "Binary Format in US42 Mode"

You can select the data output format using the FMT command. See the FMT command for more information.

Conventions

The following conventions are used in the data output format tables (Table 1-1 through Table 1-4).

Data	Output data that the 4155C/4156C sends after a measurement.
[*Data*]	Optional output data that is sent when there are multiple output data. See FMT command. For example, after the sampling measurements when the sampling point index output is specified by the FMT command.

Time Stamp Function

The time stamp function is used to record the start time of the measurement. When this function is enabled, the 4155C/4156C output data includes the time data (*Time*). For example, in the staircase sweep measurements, the output data will be as follows:

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

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

TimeN (*N*: integer) is the time from the point the count is cleared until the start of the *DataN* measurement.

The time stamp function is *not* available for the quasi-static CV measurements, linear search measurements, and binary search measurements in the US control mode. It is *not* available for any measurement in the US42 control mode.

ASCII Format in US Mode

Table 1-1 shows the ASCII data output format in control mode set by the US command. The format used depends on the measurement mode selected.

Table 1-1 **ASCII Data Output Format in US Control Mode**

Measurement Mode	Output Format
Stress Force	*Status* <terminator>[a] *Status* is the status information sent after a stress force.
High Speed Spot	*Data* <terminator>[a] *Data* is the data measured by the measurement unit specified for the high speed spot measurement using the MM command.
Spot	*Data1* [,*Data2*] . . . . <terminator>[a] *DataN* (*N*: integer) is the data measured by one unit. The order of *Data* is specified by the MM command.
1ch Pulsed Spot	*Data* <terminator>[a] *Data* is the data measured by the measurement unit specified for the pulsed spot measurement using the MM command.
Staircase Sweep, Pulsed Sweep, Staircase Sweep with Pulsed Bias	*Block1* [,*Block2*] . . . . <terminator>[a] *Block1* is the block of data measured at the first sweep step. *Block2* is the block of data measured at the second sweep step. where *Block* consists of the following data: *Data1* [,*Data2*] . . . . [,*Source_data*] *DataN* (*N*: integer) is the data measured by one unit. The order of *Data* is specified by the MM command. *Source_data* is the source data at the sweep step.

a. Terminator. <LF^EOI> or <,^EOI>, depending on the FMT command parameter. See FMT command.

Measurement Mode	**Output Format**
Sampling	*Block1* [,*Block2*] . . . . <terminator>[a] *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. 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 . . .). 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*. The measurement time depends on the settings of the AV, AZ, SIT and SLI commands. *DataN* (*N*: integer) is the data measured by one unit. The order of *Data* is specified by the MM command. The *Sampling_no* and *Data* values can be discarded when the range changes in the auto or limited auto ranging mode.

a. Terminator. <LF^EOI> or <,^EOI>, depending on the FMT command parameter. See FMT command.

Measurement Mode	Output Format
Quasi-static CV	*Block1* [,*Block2*] . . . . <terminator>[a] *Block1* is the data of the first measurement point. *Block2* is the data of the second 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 source output voltage. *DataL* is set by the QSL command.
Linear search, Binary search	[*D1*,*D2* . . . ,] *Search*,*Source_data*,*Data* <terminator>[a] *Search* is the search status. *Source_data* is the source output data of the search target. *Data* is the measurement data of the search target. *D1* is the data of the first measurement point. *D2* is the data of the second point. where *Dn* (*n*: integer) consists of the following data: *Source_data*,*Data* *Source_data* is the source output data. *Data* is the measurement data. *Dn* is set by the BSVM command for the binary search, or LSVM command for the linear search.

a. Terminator. <LF^EOI> or <,^EOI>, depending on the FMT command parameter. See FMT command.

Output Data

The 4155C/4156C sends the measurement data (*Data*), source output data (*Source_data*), sampling point index (*Sampling_no*), time data (*Time*) or status information (*Search* or *Status*) in the format specified by the FMT 1, FMT 2, or FMT 5 command.

- ASCII format with header (output by FMT 1 or FMT 5):

  AAABCDDDDDDDDDDDDDD

- ASCII format without header (output by FMT 2):

  DDDDDDDDDDDDD

where,

A: Status.

B: Channel number.

C: Data type.

D: Data.

NOTE

For *Sampling_no*, ignore *B*.

For *Time*, ignore *A*.

For *Search*, ignore *A* and *B*.

For *Status*, ignore *B* and *D*.

They are not valid for the output data.

The *A*, *B*, *C*, and *D* values are explained below.

***A* :** Status; 3 digits.

- Status for *Source_data*:

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

- Status for *Data*, *Sampling_no*, or *Status*:

AAA	Explanation
1	A/D converter overflowed.
2	One or more units are oscillating.
4	Another unit reached its compliance setting.
8	This unit reached its compliance setting.
	Integration time too short for capacitance measurement.
16	The PGU reached its compliance setting.
32	The sweep measurement was stopped by the ESC stop condition. Returned data is effective.
64	Invalid data is returned. *D* is not used.
128	EOD (End of Data).

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

***B* :** Channel number of the measurement/source unit; 1 digit.

B	Explanation
A	Channel number 1, SMU1.
B	Channel number 2, SMU2.
C	Channel number 3, SMU3.
D	Channel number 4, SMU4.
E	Channel number 5, SMU5 (in 41501A/B).
F	Channel number 6, SMU6 (in 41501A/B).
Q	Channel number 21, VSU1.
R	Channel number 22, VSU2.
S	Channel number 23, VMU1.
T	Channel number 24, VMU2.
V	Channel number 26, GNDU (in 41501A/B).
W	Channel number 27, PGU1 (in 41501A/B).
X	Channel number 28, PGU2 (in 41501A/B).
Z	Returned D value is not measurement data.

***C* :** Data type; 1 digit.

C	Explanation
V	Voltage measurement data (*Data*).
v	Voltage source setup data (*Setup_data*).
I	Current measurement data (*Data*).
i	Current source setup data (*Setup_data*).
C	Capacitance measurement data (*Data*).
p	Sampling point index (*Sampling_no*).
T	Time data (*Time*).
S	Status information (*Search* or *Status*).
Z	Invalid data is returned.
z	

***D* :** Data; 13 digits.

Value of *Data*, *Source_data*, *Sampling_no*, and *Time* may be one of the following:

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

where,

s: Sign, + or –.

n: Digit, 0 to 9.

E: Exponent symbol.

Value of *Search*:

D	Description
0	No error.
1	Measurement aborted, but cannot specify the reason. Ignore *Source_data* and *Data*.
10	No target found in the specified search range of the binary search. Data at the start or stop near the target value is set to *Source_data* and *Data*.
11	No target found in the limit mode binary search. The last search data is set to *Source_data* and *Data*.
12	Over-range at the synchronous output channel in the binary search. Ignore *Source_data* and *Data*.
20	No target found in the linear search. Ignore *Source_data* and *Data*.
21	Over-range at the synchronous output channel in the linear search. Ignore *Source_data* and *Data*.
22	Abort condition occurred in the linear search. Ignore *Source_data* and *Data*. The status of the *Data* is *AAA*=192. In all data output modes (LSVM 1), the status code is set to the status of the last measurement data. The abort condition is set by the WM command.

Binary Format in US Mode

Table 1-2 shows the binary data output format in control mode set by the US command. The format used depends on the measurement mode selected.

Table 1-2 **Binary Data Output Format in US Control Mode**

Measurement Mode	Output Format
Stress Force	*Status* <terminator>[a] *Status* is the status information sent after a stress force.
High Speed Spot	*Data* <terminator>[a] *Data* is the data measured by the measurement unit specified for the high speed spot measurement using the MM command.
Spot	*Data1* [*Data2*] . . . . <terminator>[a] *DataN* (*N*: integer) is the data measured by one unit. The order of *Data* is specified by the MM command.
1ch Pulsed Spot	*Data* <terminator>[a] *Data* is the data measured by the measurement unit specified for the pulsed spot measurement using the MM command.
Staircase Sweep, Pulsed Sweep, Staircase Sweep with Pulsed Bias	*Block1* [*Block2*] . . . . <terminator>[a] *Block1* is the block of data measured at the first sweep step. *Block2* is the block of data measured at the second sweep step. where *Block* consists of the following data: *Data1* [*Data2*] . . . . [*Source_data*] *DataN* (*N*: integer) is the data measured by one unit. The order of *Data* is specified by the MM command. *Source_data* is the source data at the sweep step.

a. Terminator. <LF^EOI> or <,^EOI>, depending on the FMT command parameter. See FMT command.

Measurement Mode	Output Format
Sampling	*Block1* [*Block2*] . . . . <terminator>[a] *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. 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 . . .). 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*. The measurement time depends on the settings of the AV, AZ, SIT and SLI commands. *DataN* (*N*: integer) is the data measured by one unit. The order of *Data* is specified by the MM command. The *Sampling_no* and *Data* values can be discarded when the range changes in the auto or limited auto ranging mode.

a. Terminator. <LF^EOI> or <,^EOI>, depending on the FMT command parameter. See FMT command.

Measurement Mode	Output Format
Quasi-static CV	*Block1* [*Block2*] . . . . <terminator>[a] *Block1* is the data of the first measurement point. *Block2* is the data of the second 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 source output voltage. *DataL* is set by the QSL command.
Linear search, Binary search	[*D1 D2* . . .] *Search Source_data Data* <terminator>[a] *Search* is the search status. *Source_data* is the source output data of the search target. *Data* is the measurement data of the search target. *D1* is the data of the first measurement point. *D2* is the data of the second point. where *Dn* (*n*: integer) consists of the following data: *Source_data Data* *Source_data* is the source output data. *Data* is the measurement data. *Dn* is set by the BSVM command for the binary search, or LSVM command for the linear search.

a. Terminator. <LF^EOI> or <,^EOI>, depending on the FMT command parameter. See FMT command.

Output Data

The 4155C/4156C sends the measurement data (*Data*), source output data (*Source_data*), sampling point index (*Sampling_no*), time data (*Time*), or status information (*Search* or *Status*) in the format specified by the FMT 3 or FMT 4 command.

The binary data is six (6) bytes long, and consists of some blocks as shown below:

For *Data*, *Source_data*, *Sampling_no*, *Search*, *Status*:

<table>
<tr><td colspan="8">Byte1</td><td colspan="8">Byte 2</td><td colspan="8">Byte 3</td><td colspan="8">Byte 4</td><td colspan="8">Byte 5</td><td colspan="8">Byte 6</td></tr>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>A</td><td colspan="3">B</td><td colspan="5">C</td><td colspan="26">D</td><td colspan="8">E</td><td colspan="5">F</td></tr>
</table>

For *Time*:

<table>
<tr><td colspan="8">Byte1</td><td colspan="8">Byte 2</td><td colspan="8">Byte 3</td><td colspan="8">Byte 4</td><td colspan="8">Byte 5</td><td colspan="8">Byte 6</td></tr>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>A</td><td colspan="3">B</td><td colspan="39">G</td><td colspan="5">F</td></tr>
</table>

where,

A: Measurement or source output data type.

B: Data type.

C: Measurement or output range.

D: Data.

E: Status.

F: Channel number.

G: Time data.

NOTE

For *Sampling_no*, ignore *A*, *C*, and *F*.

For *Search*, ignore *A*, *C*, *E* and *F*.

For *Status*, ignore *A*, *C*, *D*, and *F*.

For *Time*, ignore *A*.

They are not valid for the output data.

The *A*, *B*, *C*, *D*, *E*, *F*, and *G* values are explained below.

***A* :** Measurement or source output data type; one bit.

A	Explanation
0	Source output data.
1	Measurement data.

***B* :** Data type; three bits.

B	Explanation
000	Voltage data.
001	Current data.
010	Capacitance data.
011	Time data.
110	Sampling point index.
111	Status information.

***C* :** Measurement or output range; five bits.

C	Explanation
01001	10 pA or 10 pF
01010	0.2 V or 100 pA or 100 pF
01011	2 V or 1 nA or 1 nF
01100	20 V or 10 nA or 10 nF
01101	40 V or 100 nA or 100nF
01110	100 V or 1 μA or 1 μF
01111	200 V or 10 μA or 10 μF
10000	100 μA or 100 μF
10001	1 mA or 1 mF
10010	10 mA or 10 mF

C	Explanation
10011	100 mA or 100 mF
10100	1 A or 1 F
11111	Invalid data is returned.

***D* :** Value of *Data*, *Source_data*, or *Sampling_no*; 26 bits.

This value is expressed as 26-bit binary data. It is used to calculate the measurement data or source output data, using the equations shown below. For *Sampling_no*, this value is the binary expression of the value. You do not need the following equations.

Equations:

Measurement data = $Count \times Range$ /1000000

Source output data = $Count \times Range$ /20000

where, *Count* is the decimal value of D, and *Range* is the value indicated by C.

If the top bit of the 26-bit binary data is 0, the *Count* is positive and equal to the decimal value of the 25-bit binary data that follows the top bit.

If the top bit is 1, the measurement data is negative. Calculate the *Count* by subtracting 33554432 (10000000000000000000000000 in binary) from the decimal value of the 25-bit binary data.

Example:

If the output binary data is:

```
100101010000000000000000011000000100100000000000001
```

then,

Data type:	Current measurement data (A=1, B=001)
***Range*:**	100 pA (C=01010)
***Count*:**	1540 (D=00000000000000011000000100)
Status:	EOD (E=10000000)
Channel:	SMU1 (channel number 1) (F=00001)

Measurement data = 1540 × 100E–12/1E+6 = 154 fA

Value of *Search*; 26 bits. The following table shows lower 5 bits.

D	**Description**
00000	No error.
00001	Measurement aborted, but cannot specify the reason. Ignore *Source_data* and *Data*.
01010	No target found in the specified search range of the binary search. Data at the start or stop near the target value is set to *Source_data* and *Data*.
01011	No target found in the limit mode binary search. The last search data is set to *Source_data* and *Data*.
01100	Over-range at the synchronous output channel in the binary search. Ignore *Source_data* and *Data*.
10100	No target found in the linear search. Ignore *Source_data* and *Data*.
10101	Over-range at the synchronous output channel in the linear search. Ignore *Source_data* and *Data*.
10110	Abort condition occurred in the linear search. Ignore *Source_data* and *Data*. Status of *Data* is *E*=11000000. In all data output modes (LSVM 1), the status code is set to the status of the last measurement data. An abort condition is set by the WM command.

***E* :** Status; eight bits.

- Status for *Source_data*:

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

- Status for *Data*, *Sampling_no*, or *Status*:

E	**Explanation**
00000001	A/D converter overflowed.
00000010	One or more units are oscillating.
00000100	Another unit reached its compliance setting.
00001000	This unit reached its compliance setting.
	Integration time too short for capacitance measurement.
00010000	The PGU reached its compliance setting.
00100000	Sweep measurement was stopped by the ESC stop condition. The returned data is effective.
01000000	Invalid data is returned. D is not valid.
10000000	EOD (End of Data).

If multiple status conditions are found, the sum of the status values is returned. For example, if an A/D converter overflow occurred and an SMU was oscillating during the measurements, the returned value is 00000011 (00000001+00000010).

***F* :** Channel number of the measurement/source unit; five bits.

F	**Explanation**
00001	Channel number 1, SMU1.
00010	Channel number 2, SMU2.
00011	Channel number 3, SMU3.
00100	Channel number 4, SMU4.

F	**Explanation**
00101	Channel number 5, SMU5 (in 41501A/B).
00110	Channel number 6, SMU6 (in 41501A/B).
10101	Channel number 21, VSU1.
10110	Channel number 22, VSU2.
10111	Channel number 23, VMU1.
11000	Channel number 24, VMU2.
11010	Channel number 26, GNDU (in 41501A/B).
11011	Channel number 27, PGU1 (in 41501A/B).
11100	Channel number 28, PGU2 (in 41501A/B).
11111	Invalid data is returned.

G **:** Value of *Time*; 39 bits.

This value is expressed in 39-bit binary data. It is used to calculate the time data, using the equations shown below.

Equations:

`Time data =` *Count* × `100` μs

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

Example:

If the output binary data is:

`0011000000000000000000001001001001111100000000001`

then,

Data type: Time data (A=0, B=011)

***Count*:** 300000 (D=1001001001111100000)

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

Measurement data = 300000 × 100E–6 = 30 s

ASCII Format in US42 Mode

Table 1-3 shows the ASCII data output format in control mode set by the US42 command. The format used depends on the measurement mode selected.

Table 1-3 **ASCII Data Output Format in US42 Control Mode**

Measurement Mode	Output Format
Stress Force	*Status* <terminator>[a] *Status* is the status information sent after a stress force.
High Speed Spot	*Data* <terminator>[a] *Data* is the data measured by the measurement unit specified for the high speed spot measurement using the MM command.
Spot	*Data1* [,*Data2*] . . . . <terminator>[a] *DataN* (*N*: integer) is the data measured by one unit. The order of *Data* is specified by the MM command.
1ch Pulsed Spot	*Data* <terminator>[a] *Data* is the data measured by the measurement unit specified for the pulsed spot measurement using the MM command.
Staircase Sweep	*Block1* [,*Block2*] . . . . <terminator>[a] *Block1* is the block of data measured at the first sweep step. *Block2* is the block of data measured at the second sweep step. where *Block* consists of the following data: *Data1* [,*Data2*] . . . . [,*Source_data*] *DataN* (*N*: integer) is the data measured by one unit. The order of *Data* is specified by the MM command. *Source_data* is the source data at the sweep step.

a. Terminator. <CR/LF^EOI>, <^EOI> or , (comma), depending on the FMT command parameter. See FMT command.

Measurement Mode	**Output Format**
Pulsed Sweep, Staircase Sweep with Pulsed Bias	*Block1* [,*Block2*] . . . . <terminator>[a] *Block1* is the block of data measured at the first sweep step. *Block2* is the block of data measured at the second sweep step. where *Block* consists of the following data: *Data* [,*Source_data*] *Data* is the measurement data. *Source_data* is the source data at the sweep step.
Sampling	*Block1* [,*Block2*] . . . . <terminator>[a] *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. This value depends on the sampling interval setting and the measurement time. If the measurement time is shorter than the sampling interval, the *Sampling_no* will be *N* of *BlockN* (*N*: 1, 2, 3 . . .). If the measurement time is longer than the sampling interval, the *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*. The measurement time depends on the settings of the AV, AZ, SIT and SLI commands. *DataN* (*N*: integer) is the data measured by one unit. The order of *Data* is specified by the MM command. The *Sampling_no* and *Data* values can be discarded when the range changes in the auto or limited auto ranging mode.

a. Terminator. <CR/LF^EOI>, <^EOI> or , (comma), depending on the FMT command parameter. See FMT command.

Output Data

The 4155C/4156C sends the measurement data (*Data*), source output data (*Source_data*), sampling point index (*Sampling_no*), or stress status information (*Status*) in the format specified by the FMT 1, FMT 2, or FMT 5 command.

- ASCII format with header (output by FMT 1 or FMT 5):

  ABCDDDDDDDDDDDDD

  where no space is included between the parameters.

- ASCII format without header (output by FMT 2):

  DDDDDDDDDDDDD

where,

A: Status.

B: Channel number.

C: Data type.

D: Data.

NOTE

If the output data is *Sampling_no*, ignore *B*.

If the output data is *Status*, ignore *B* and *D*.

They are not valid for the output data.

The *A*, *B*, *C*, and *D* values are explained below.

***A* :** Status; 1 digit.

- Status for *Data*, *Sampling_no*, or *Status*:

A	Explanation
N	No status error occurred.
T	Another unit reached its compliance setting.
C	This unit reached its compliance setting.
V	Measurement data is over the measurement range.
X	One or more units are oscillating.

- Status for *Source_data*:

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

B **:** Channel number of the measurement/source unit; 1 digit.

B	**Explanation**
A	Channel number 1, SMU1.
B	Channel number 2, SMU2.
C	Channel number 3, SMU3.
D	Channel number 4, SMU4.
E	Channel number 5, SMU5 (in 41501A/B).
F	Channel number 6, SMU6 (in 41501A/B).
Q	Channel number 21, VSU1.
R	Channel number 22, VSU2.
S	Channel number 23, VMU1.
T	Channel number 24, VMU2.
V	Channel number 26, GNDU (in 41501A/B).
W	Channel number 27, PGU1 (in 41501A/B).
X	Channel number 28, PGU2 (in 41501A/B).
Z	Returned D value is not measurement data.

***C* :** Data type; 1 digit.

C	Explanation
V	Voltage measurement data.
v	Voltage source setup data.
I	Current measurement data.
i	Current source setup data.
p	Sampling point index.
S	Status information.
Z	Invalid data is returned.
z	

D Value of *Data*, *Source_data*, or *Sampling_no*; 12 digits, which may be one of the following:

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

where,

s: Sign, + or –.

n: Digit, 0 to 9.

E: Exponent symbol.

Binary Format in US42 Mode

Table 1-4 shows the binary data output format in control mode set by the US42 command. The format used depends on the measurement mode selected.

Table 1-4 **Binary Data Output Format in US42 Control Mode**

Measurement Mode	Output Format
Stress Force	*Status* <terminator>[a] *Status* is the status information sent after a stress force.
High Speed Spot	*Data* <terminator>[a] *Data* is the data measured by the measurement unit specified for the high speed spot measurement using the MM command.
Spot	*Data1* [*Data2*] . . . . <terminator>[a] *DataN* (*N*: integer) is the data measured by one unit. The order of *Data* is specified by the MM command.
1ch Pulsed Spot	*Data* <terminator>[a] *Data* is the data measured by the measurement unit specified for the pulsed spot measurement using the MM command.
Staircase Sweep	*Block1* [*Block2*] . . . . <terminator> [a] *Block1* is the block of data measured at the first sweep step. *Block2* is the block of data measured at the second sweep step. where *Block* consists of the following data: *Data1* [*Data2*] . . . . [*Source_data*] *DataN* (*N*: integer) is the data measured by one unit. The order of *Data* is specified by the MM command. *Source_data* is the source data at the sweep step.

a. Terminator. <CR/LF^EOI>, <^EOI> or , (comma), depending on the FMT command parameter. See FMT command.

Measurement Mode	Output Format
Pulse Sweep, Staircase Sweep with Pulsed Bias	*Block1* [*Block2*] . . . . <terminator>[a] *Block1* is the block of data measured at the first sweep step. *Block2* is the block of data measured at the second sweep step. where *Block* consists of the following data: *Data* [*Source_data*] *Data* is the measurement data. *Source_data* is the source data at the sweep step.
Sampling	*Block1* [*Block2*] . . . . <terminator>[a] *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. This value depends on the sampling interval setting and the measurement time. If the measurement time is shorter than the sampling interval, then the *Sampling_no* will be *N* of *BlockN* (*N*: 1, 2, 3 . . .). If the measurement time is longer than the sampling interval, then the *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, the *Sampling_no* is 2 for *Block1*, and 4 for *Block2*. The measurement time depends on the settings of the AV, AZ, SIT and SLI commands. *DataN* (*N*: integer) is the data measured by one unit. The order of *Data* is specified by the MM command. The *Sampling_no* and *Data* values can be discarded when the range changes in the auto or limited auto ranging mode.

a. Terminator. <CR/LF^EOI>, <^EOI> or , (comma), depending on the FMT command parameter. See FMT command.

Output Data

The 4155C/4156C sends the measurement data (*Data*), source output data (*Source_data*), sampling point index (*Sampling_no*), or status information (*Status*) in the format specified by the FMT 3 or FMT 4 command.

Binary data is four bytes long, and consists of six blocks (A, B, C, D, E and F) as shown below:

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

where,

A: Measurement or source output data type.

B: Data type.

C: Measurement or output range.

D: Data.

E: Status.

F: Channel number.

NOTE

If the output data is *Sampling_no*, ignore *A*, *B*, *C*, and *F*.

If the output data is *Status*, ignore *A*, *B*, *C*, *D*, and *F*.

They are not valid for the output data.

The *A*, *B*, *C*, and *D* values are explained below.

A **:** Measurement or source output data type; one bit.

A	**Explanation**
0	Source output data.
1	Measurement data.

B **:** Data type; one bit.

B	**Explanation**
0	Voltage data.
1	Current data.

***C* :** Measurement or output range; five bits.

C	Explanation
01010	0.2 V range.
01011	2 V or 1 nA range.
01100	20 V or 10 nA range.
01101	40 V or 100 nA range.
01110	100 V or 1 μA range.
01111	200 V or 10 μA range.
10000	100 μA range.
10001	1 mA range.
10010	10 mA range.
10011	100 mA range.
10100	1 A range.
11111	Invalid data is returned.

***D* :** Value of *Data*, *Source_data*, or *Sampling_no* parameter. This value is expressed in 17-bit binary data. It is used to calculate the measurement data or source output data using the following equations.

For *Sampling_no*, this value is the binary expression of the sampling measurement point index value. You do not need the following equations.

Equations:

$$\texttt{Measurement data} = \mathit{Count} \times \mathit{Range}\ /50000$$

$$\texttt{Source output data} = \mathit{Count} \times \mathit{Range}\ /20000$$

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

If the top bit of the 17-bit binary data is 0, the *Count* is positive and equal to the decimal value of the 16-bit binary data that follows the top bit.

If the top bit is 1, the measurement data is negative. Calculate the *Count* by subtracting 65536 (10000000000000000 in binary) from the decimal value of the 16-bit binary data.

Example:

If the output binary data is:

```
11010110000100111000100000000001
```

then,

Data type:	Current measurement data (A=1, B=1)
***Range*:**	1 nA (C=01011)
***Count*:**	5000 (D=00001001110001000)
Status:	Normal condition (E=000)
Channel:	SMU1 (channel number 1) (F=00001)

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

E **:** Status; three bits.

- Status for *Data*, *Sampling_no*, or *Status*:

E	**Explanation**
000	No status error occurred.
001	Another unit reached its compliance setting.
010	This unit reached its compliance setting.
011	Measurement data is over the measurement range.
100	One or more units are oscillating.

- Status for *Source_data*:

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

F **:** Channel number of the measurement/source unit; five bits.

F	**Explanation**
00001	Channel number 1, SMU1.
00010	Channel number 2, SMU2.
00011	Channel number 3, SMU3.
00100	Channel number 4, SMU4.
00101	Channel number 5, SMU5 (in 41501A/B).
00110	Channel number 6, SMU6 (in 41501A/B).
10101	Channel number 21, VSU1.
10110	Channel number 22, VSU2.
10111	Channel number 23, VMU1.
11000	Channel number 24, VMU2.
11010	Channel number 26, GNDU (in 41501A/B).
11011	Channel number 27, PGU1 (in 41501A/B).
11100	Channel number 28, PGU2 (in 41501A/B).
11111	Invalid data is returned.

Status Byte

This section provides the status byte information for the 4155C/4156C in the FLEX command control mode. The information depends on whether the control mode is set by US command or US42 command. See Table 1-5 and Table 1-6. The status byte bit assignment shown in Table 1-6 is identical to the 4142B definition.

Table 1-5 **In the US Command Mode**

Bit	Description
0	Emergency Status Indicates whether any emergency has occurred. If the instrument is in the emergency status, this bit is set to 1.
1	Measurement/Stress Status Indicates whether the measurement/stress force has been executed. If the instrument is in the measurement/stress status, this bit is set to 1.
2	not used
3	Questionable Status Indicates whether output buffer is empty. If an unread query response exists, this bit is set to 1.
4	MAV (Message Available summary-message) Indicates whether output buffer is empty. If an unread message exists, this bit is set to 1.
5	ESB (Event Status Bit) Shows the logical ORed value of the error summary register bits.
6	Request Service (RQS) Message Indicates whether an SRQ (Service Request) has occurred. You cannot mask this bit.
7	not used

Table 1-6 **In the US42 Command Mode**

Bit	Description
0	Data Ready Indicates whether the output buffer is empty. If unread data exists, this bit is set to 1.
1	Wait Indicates whether the instrument is in the wait status. If instrument is in the wait state, this bit is set to 1.
2	not used
3	Interlock Open If the interlock circuit is open, and an output voltage over ±40 V is applied, this bit is set to 1.
4	Set Ready Indicates whether an GPIB command or external trigger has been sent. If GPIB command execution or the operation by external trigger is completed, this bit is set to 1.
5	Error Indicates whether any error has occurred. If any error occurred, this bit is set to 1.
6	RQS (You cannot mask this bit.) Indicates whether an SRQ (Service Request) has occurred.
7	Shutdown If the instrument turned off by itself, to avoid damage, or instantaneous power down occurred on the site power line, this bit is set to 1.

The status byte register can be read with either a serial poll or the *STB? query command.

Serial poll is a low-level GPIB command that can be executed by the `SPOLL` command in HP BASIC, as follows:

```
Status=SPOLL(@Hp4156)
```

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.

Command Reference

This section contains detailed descriptions of each command. The commands are listed in alphabetical order. Each entry:

1. Defines one GPIB command
2. Describes the execution conditions, if any exist
3. Describes the syntax
4. Lists the parameters
5. Shows the query response after command execution, if there is a query command
6. Explains any additional information
7. Provides examples

The following conventions are used in this section.

parameter	Required command parameters, for which you must substitute a value or variable.
[*parameter*]	Optional command parameters, for which you may substitute a value or omit it.

Category	Command	Summary
Reset	*RST	Resets the 4155C/4156C to the initial settings, and clears the zero offset data.
Self-test	*TST?	Starts the self-test.
Control Mode	US	Enters the 4155C/4156C FLEX command control mode.
	US42	Enters the 4155C/4156C FLEX command control mode. This mode provides the 4142B-like response (data output, terminator, and so on).
	ACH	Used with the US42 command to assign the channel numbers used in the measurement programs for the 4142B to the channel numbers available for the 4155C/4156C.
	:PAGE	Returns to the 4155C/4156C SCPI command control mode.
Unit Control	CN	Enables the specified units by setting the output switches to ON.
	CL	Disables the specified units by setting the output switches to OFF.
	FL	Sets the filter of specified units to ON or OFF.
	IN	Sets the specified units to zero output.
	DZ	Stores the measurement setup of the units, and sets the units to Zero (0 V) Output.
	RZ	Returns the unit to the settings that are stored by the DZ command and clears the stored unit settings.
	RCV	Enables the units that fail self-test.
Measurement Mode	MM	Sets the measurement mode and measurement units.
	CMM	Sets the SMU measurement mode.
	VM	Sets the operation mode of the VMU.
	VMD	Controls the connection of the VMU input discharge resistors.
dc Source Setup	DI	Forces dc current from the specified unit.
	DV	Forces dc voltage from the specified unit.
	TDI	Forces dc current from the specified unit, and returns the time stamp.
	TDV	Forces dc voltage from the specified unit, and returns the time stamp.
SMU Pulse Setup	PT	Sets the timing parameters for a pulse source.
	PI	Specifies the pulse current source and its parameters, and clears the PV command setting.
	PV	Specifies the pulse voltage source and its parameters, and clears the PI command setting.

Category	Command	Summary
Staircase Sweep Source Setup	WT	Sets the hold time and delay time for staircase sweep measurements.
	WI	Specifies the current source for the staircase sweep and its parameters, and clears the WV, WSV, and WSI command settings.
	WV	Specifies the voltage source for the staircase sweep source and its parameters, and clears the WI, WSI, and WSV command settings.
	WM	Sets the automatic sweep abort function, and sets the post sweep condition.
	ESC	Enables or disables the enhanced sweep stop function, and sets the stop condition.
Pulsed Sweep Source Setup	PT	Sets the timing parameters for a pulse source.
	PWI	Specifies the pulsed sweep current source and its parameters, and clears the settings of the PWV, WSV, and WSI commands.
	PWV	Specifies the pulsed sweep voltage source and its parameters, and clears the settings of the PWI, WSV, and WSI commands.
	WM	Sets the automatic sweep abort function, and sets the post sweep condition.
	ESC	Enables or disables the sweep stop function, and sets the stop condition.
Synchronous Sweep Source Setup	WSI	Specifies the staircase sweep current source which is synchronized with the staircase sweep current source set by the WI command or the pulsed sweep current source set by the PWI command.
	WSV	Specifies the staircase sweep voltage source which is synchronized with the staircase sweep voltage source set by the WV command or the pulsed sweep voltage source set by the PWV command.
Source Setup for Sampling Measurements	MI	Specifies the current source (SMU) synchronized with the sampling measurements, and its parameters.
	MV	Specifies the voltage source (SMU or VSU) synchronized with the sampling measurement, and its parameters.
	MP	Specifies the PGU synchronized with the sampling measurements, and its parameters.
	MCC	Clears the settings of the specified sampling sources defined by MI, MV, or MP command.
	MSC	Sets the automatic abort condition (stop condition) for the sampling measurement.
Time stamp function	TSC	Enables or disables the time stamp function.
	TSR	Resets the time stamp to zero.
	TSQ?	Returns the time stamp.

Category	Command	Summary
Quasi-static CV Measurement Setup	QSM	Sets the automatic abort condition.
	QSL	Enables or disables the data output and compensation for the leakage current.
	QSZ/QSZ?	Enables or disables the capacitance offset cancel function, or executes the capacitance offset measurement. Query returns the offset data.
	QST	Sets the measurement timing parameters.
	QSR	Sets the current measurement range.
	QSV	Specifies the voltage output channel and its source parameters.
Binary Search Measurement Setup	BSM	Specifies the source output control mode; normal or cautious.
	BST	Sets the measurement timing parameters.
	BSVM	Selects the data output mode; normal or all data.
	BSI	Specifies the current output channel, and its source parameters.
	BSSI	Specifies the synchronous current output channel, and its source parameters.
	BGV	Specifies the voltage monitor channel, and its search parameters.
	BSV	Specifies the voltage output channel, and its source parameters.
	BSSV	Specifies the synchronous voltage output channel, and its source parameters.
	BGI	Specifies the current monitor channel, and its search parameters.
Linear Search Measurement Setup	LSTM	Sets the measurement timing parameters.
	LSVM	Selects the data output mode; normal or all data.
	LSI	Specifies the current output channel, and its source parameters.
	LSSI	Specifies the synchronous current output channel, and its source parameters.
	LGV	Specifies the voltage monitor channel, and its search parameters.
	LSV	Specifies the voltage output channel, and its source parameters.
	LSSV	Specifies the synchronous voltage output channel, and its source parameters.
	LGI	Specifies the current monitor channel, and its search parameters.
	WM	Sets the automatic abort function.
PGU Control	POR	Sets the output impedance of the PGU.
	SPG	Sets the PGU output mode, and its parameters.
	SRP	Starts the PGU output force.
	SPP	Stops the PGU output force.

Category	Command	Summary
Stress Source Setup	POR	Sets the output impedance of the PGU.
	STT	Sets the stress time and stress mode.
	STI	Specifies the dc stress current source (SMU) and its parameters.
	STV	Specifies the dc stress voltage source (SMU or VSU) and its parameters.
	STP	Sets the PGU for the dc voltage stress output or pulse stress output.
	STC	Clears the settings of the specified stress sources defined by STI, STV or STP command.
	STM	Sets the automatic abort condition (stop condition) for the stress force.
Measurement Setup	RI	Specifies the current measurement ranging mode for all types of measurements, except for the high speed spot measurements.
	RV	Specifies the voltage measurement ranging mode for all types of voltage measurements, except for the high speed spot measurements.
	MT	Only for Sampling measurements. Sets the timing parameters.
Integration Time	SIT	Changes the value of the integration time Short or Long.
	SLI	Selects the integration time setting, Short, Medium, or Long.
	AZ	Enables or disables the automatic zero offset function of the internal A/D converter.
Averaging	AV	Sets the number of samples that are taken and averaged for the measurement.
Measurement Execution	TM	Specifies the trigger mode which defines how events are effective for the measurement trigger, and for the trigger to release the wait status set by the PA command.
	XE	Triggers the 4155C/4156C to perform measurements, and returns the measurement data. Needs the RMD? command to read the measurement data.
	TI/TI?	Executes the high speed spot current measurement.
	TV/TV?	Executes the high speed spot voltage measurement.
	TTI/TTI?	Executes the high-speed spot current measurement, and returns the time stamp.
	TTV/TTV?	Executes the high-speed spot voltage measurement, and returns the time stamp.
Output Data	FMT	Specifies the measurement data output format and the data terminator.
	RMD?	Reads the output data and puts the data into the output buffer.
	BC	Clears the 4155C/4156C output data buffer that stores measurement data and/or query command response data.

Category	Command	Summary
Abort/Pause/ Wait	AB	Aborts the present operation and subsequent command execution.
	PA	Pauses command execution or internal memory program execution, until receiving a trigger specified by the TM command or until the specified wait time has elapsed.
	*WAI	Stops execution of any commands until the OPC bit is set to 1.
	WS	Goes into a wait state until the 4155C/4156C receives an external trigger signal via the `Ext Trig In` terminal.
Zero Offset Cancel	GOC	Measures the zero offset data and sets the zero offset cancel function to ON.
	SOC	Enables or disables the zero offset cancel function for the SMU low current measurements and the VMU differential voltage measurements.
Self Calibration	*CAL?	Performs a full calibration, and returns the calibration result.
	CA	Performs calibration of the measurement unit.
	CM	Sets Auto-Calibration ON or OFF.
Program Memory	ST	Used with END command to store a program in the internal program memory. ST command indicates the beginning of the program.
	END	Used with ST command to store a program in the internal program memory. END command indicates the end of the program.
	SCR	Scratches the specified program from the internal program memory.
	LST?	Requests a catalog of internal memory programs or a specific program listing.
	DO	Executes internal memory programs in the order specified.
	RU	Executes internal memory programs sequentially.
	PA	Pauses command execution or internal memory program execution, until receiving a trigger specified by the TM command or until the specified wait time has elapsed.
SMU/PGU Selector	SSP	Controls Agilent 16440A SMU/Pulse Generator Selector.
R-BOX	RBC	Controls Agilent 16441A R-BOX.
External Trigger	STG	Sets the trigger function using the `Ext Trig In/Out` terminals.
	OS	Causes the 4155C/4156C to send a trigger signal from the external trigger output terminal (`Ext Trig Out`).

Category	Command	Summary
Network Operation	SDSK	Selects the mass storage device.
	OPEN	Opens the specified file on the mass storage device specified by the SDSK command.
	RD?	Reads the ASCII data in the file opened by the OPEN command.
	WR	Writes the specified characters or numeric data (ASCII) at the end of the file opened by the OPEN command.
	CLOSE	Closes the file opened by the OPEN command.
	SPR	Selects the remote printer.
	SPL	Specifies the ASCII data to print, and spools the data to the printer specified by the SPR command.
	PRN	Prints the data specified by the SPL command.
Status Byte	*CLS	Clears the status byte register, the standard event status register, and the error register.
	*ESE(?)	Sets or asks the bits of the standard event status enable register.
	*ESR?	Returns the present contents of the standard event status register.
	*SRE	Enables the specified bits of the status byte register.
	*SRE?	Requests which bits of the status byte register are enabled.
	*STB?	Requests the status byte.
Query	CMD?	Returns the 4155C/4156C control language mode.
	ERR?	Returns error codes.
	*IDN?	Requests the instrument model number and the ROM version number.
	LOP?	Requests the operation status of all source units (SMUs and VSUs).
	*LRN?	Requests unit settings or the 4155C/4156C command parameter settings.
	NUB?	Requests the number of measurement data in the output data buffer.
	*OPC(?)	Starts to monitor pending operations, or asks the OPC bit setting.
	*OPT?	Returns the reportable device options, which are the units in the 41501A/B Expander.
	:SYST:ERR?	Returns the error code and the error message.
	UNT?	Requests the model and revision numbers of all units.
	WNU?	Requests the number of sweep steps specified by the sweep command.

AB

The AB command aborts the present operation and subsequent command execution.

Syntax

```
AB
```

Remarks

The AB 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 4155C/4156C just keeps to force the dc bias, the AB command does not stop the dc bias output.

The AB command sets the 4155C/4156C as listed in the following table.

Present Operation	4155C/4156C Setting
Staircase Sweep Measurements	Sets specified start voltage or current.
1ch Pulsed Spot Measurements	Sets specified base voltage or current.
Pulsed Sweep Measurements	Sets specified base voltage or current.
Staircase Sweep with Pulsed Bias Measurements	Sets specified start voltage or current and base voltage or current.
Pulsed Sweep with Pulsed Bias Measurements	Sets specified base voltage or current.
Sampling Measurements	Sets specified base voltage or current.
Stress Force	Sets specified base voltage or current.
Self-Test [a]	Same as set by CL command.
Self-Calibration [a]	Same as set by CL command.
WAIT State (PA or WS command)	Settings do not change.
Program Execution (RU or DO command)	Settings do not change.

a. The AB command cannot abort this operation if the AB command is executed from the internal memory program. But the AB command from the memory program can abort the automatic calibration.

If you start an operation that you may want to abort, do not send any command after the command or command string that starts the operation. If you do, the AB command cannot enter the command input buffer until the intervening command execution starts, so the operation cannot be aborted. In this case, use the Device Clear (CLEAR command in HP BASIC) to end the operation.

Output Data

The 4155C/4156C returns the all measurement data until when the AB command is executed. The output format of the last data will be as shown below:

Measurement Mode	Data when abort occurs
1 channel sweep	*Dummy*[,*Source_data*]
Multi channel sweep	*Dummy*[,*Source_data*] [a]
1 channel sampling	[*Index_dummy*,]*Dummy*
Multi channel sampling	[*Index_dummy*,]*Dummy* [b]
QSCV	[*DummyL*,]*DummyC*[,*Source_data*]
Linear search	[raw data ... ,]*Search*,*Source_dummy*,*Dummy*
Binary search	

a. *Source_data* will be returned if the abort occurs during the measurement by the last measurement channel defined by the MM command.
b. *Index_dummy* will be returned even if the abort occurs during the measurement by the unit which is not the first measurement channel defined by the MM command.

where,

Dummy: Dummy of the measurement data.

Source_data: Source output data. Selected by the FMT command.

Index_dummy: Dummy of the data index. Selected by the FMT command.

DummyL: Leakage current dummy data. Selected by the QSL command.

DummyC: Capacitance dummy data.

Search: Status data of the search measurement.

Source_dummy: Dummy of the source output data.

raw data: Measurement data. Selected by the LSVM or BSVM command.

If *Source_data* output is disabled, the status of the last data will be 192 (128+64). where 128 means the EOD, and 64 means the invalid data.

Example Statements

```
OUTPUT @Hp4156;"AB"
```

ACH

The ACH command is effective when the instrument is in the US42 command mode. Otherwise, the ACH command is not required to control the 4155C/4156C.

The ACH command assigns the channel numbers used in the measurement programs for the 4142B to the channel numbers available for the 4155C/4156C.

Insert the US42 command and the ACH command to assign the channel numbers for the 4142B to the 4155C/4156C channel numbers at the beginning of the measurement program which was created to control the 4142B.

The ACH command translates the 4142B channel numbers to the 4155C/4156C channel numbers at the program execution. You do not need to change the 4142B channel numbers defined in the commands that follow the US42 and ACH commands in the program. Do not change the 4142B channel numbers in the program. Otherwise, the channel number will not be translated correctly.

Syntax

`ACH [chnum[,4142ch]]`

If you do not specify both *chnum* and *4142ch*, channel number assignment is canceled and all channel number assignments are cleared.

Parameter

chnum : Channel numbers available for the 4155C/4156C. Integer expression. See below.

chnum	Unit	*chnum*	Unit
1	SMU1	21	VSU1
2	SMU2	22	VSU2
3	SMU3	23	VMU1
4	SMU4	24	VMU2
5 [a]	SMU5	26	GNDU
6 [a]	SMU6		

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

4142ch **:** Channel number used in the measurement program for the 4142B. 1 to 28 channels are available. Integer expression.

If the measurement program includes the control routine for the 41425A AFU, you should not assign the channel numbers for AFU. The channel numbers should be for the 41420A HPSMU, 41421B MPSMU, 41422A HCU, 41423A HVU or 41424A VSU/VMU. If you specify the channel numbers for HCU or HVU, some commands and measurement ranges cannot be used for the 4155C/4156C. In this case, you must modify the command parameter settings.

If you do not specify *4142ch*, this channel number is not assigned. This is same as ACH *N*,*N* command.

Example Statements

```
OUTPUT @Hp4156;"US42"
OUTPUT @Hp4156;"ACH 1,2"
OUTPUT @Hp4156;"ACH 2,3"
OUTPUT @Hp4156;"ACH 3,4"
OUTPUT @Hp4156;"ACH 4,5"
```

AV

The AV command sets the number of samples that are taken and averaged for the measurement. This command setting is ignored by the following measurement mode.

1. 1ch pulsed spot measurements with "keep pulse width"
2. Pulsed sweep measurements with "keep pulse width"
3. Staircase sweep with pulsed bias measurements with "keep pulse width"
4. Sampling measurements with the sampling interval less than 2 msec (see the MT command)

where, "keep pulse width" means the measurement setup which the PT command *priority* parameter is set to 0 or default setting (see the PT command).

Syntax

`AV` *`averaging number`*`[,`*`averaging mode`*`]`

Parameters

averaging number **:** 1 to 1023 are available in US command mode. Numeric expression.

1 to 1023, and –1 to –1023 are available in US42 command mode. Initial setting is 1.

For *positive* number input, the number of samples is set to *averaging number*.

For *negative* number (–1 to –100) input, the `AV` command sets the 4155C/4156C integration time to `LONG`, and sets the `PLC` (Power Line Cycle) value to *averaging number*. If *averaging number* is –101 to –1023, the `PLC` value is automatically set to –100. To return the integration time to `SHORT`, use the SLI command.

averaging mode **:** 0 or 1. Integer expression. Initial setting is 0. Used as a placeholder only, the value is ignored. This parameter is just to keep the 4142B control command syntax.

Example Statements

```
OUTPUT @Hp4156;"AV 10"
OUTPUT @Hp4156;"AV -50"
OUTPUT @Hp4156;"AV 100,1"
```

AZ

The AZ command enables or disables the automatic zero offset function of the internal A/D converter (ADC). This command is effective for the measurement range more than 1 nA range.

The internal ADC automatic zero offset function must be set to ON to satisfy the measurement accuracy specifications. Set the function to OFF in cases that the measurement speed is more important than the measurement accuracy. This reduces the integration time to approximately half if the integration time is set to approx. 10 msec or more.

US, US42, *RST commands and the device clear enable the function.

Syntax

`AZ` *`mode`*

Parameters

mode Mode ON or OFF. 0 or 1 are available. Initial setting is 1.

0: OFF. Disables the function.

1: ON. Enables the function.

Example Statements

```
OUTPUT @Hp4156;"AZ 0"
```

BC

The BC command clears the output data buffer that stores measurement data and query command response data. This command does not change the measurement settings.

Syntax

```
BC
```

Example Statements

```
OUTPUT @Hp4156;"BC"
```

BGI

The BGI command specifies the current monitor channel and its search parameters in the binary search measurement. This command is only for the US control mode.

This command ignores the RI command setting.

This command setting is cleared by the BGV, LGV and LGI commands.

Execution Conditions

The MM 15 command must be sent *before* sending this command.

Syntax

`BGI chnum,mode,condition,Irange,Itarget`

Parameters

chnum: Channel number of the unit used to measure the current. Integer expression.

chnum	Unit	*chnum*	Unit
1	SMU1	4	SMU4
2	SMU2	5 [a]	SMU5
3	SMU3	6 [a]	SMU6

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

mode: Search mode. 0 (limit mode) or 1 (repeat mode). See *condition*.

condition: Search condition. The meaning of the *condition* parameter depends on the *mode* setting:

mode	*condition*
0	The *condition* parameter must be the limit value for the search target (*Itarget*). in A. The search stops when the measurement data reaches *Itarget* ± *condition*. The parameter must be either 0 or a positive value.
1	The *condition* parameter must be the times of current change of the source unit in the binary search. The parameter must be a value from 1 to 16.

Irange: Ranging type for current measurement. Integer expression.

range	**Ranging Type** [a]
9 (only for 4156C)	10 pA limited auto ranging
10 (only for 4156C)	100 pA limited auto ranging
11	1 nA limited auto ranging
12	10 nA limited auto ranging
13	100 nA limited auto ranging
14	1 μA limited auto ranging
15	10 μA limited auto ranging
16	100 μA limited auto ranging
17	1 mA limited auto ranging
18	10 mA limited auto ranging
19	100 mA limited auto ranging
20 (only for HPSMU)	1 A limited auto ranging

a. Limited auto ranging uses the lowest available measurement range that covers the measurement value, where the specified range is the minimum range. For example, 10 μA limited auto ranging uses the 10 μA range to measure 1 nA, and uses the 100 mA range to measure 50 mA.

Itarget: Search target current (in A). Numeric expression.

0 to ±100 mA for SMU, 0 to ±1 A for HPSMU.

NOTE

Itarget and Irange

If the *Itarget* value is greater than the minimum measurement range specified by the *Irange* parameter, the measurement unit does not use the measurement ranges below the *Itarget* value. It uses the lowest range that covers the *Itarget* value.

Example Statements

```
OUTPUT @Hp4156;"BGI 1,0,1E-8,0,1E-6"
```

See Also

BSM command

Remarks

In the limit search mode, if the search cannot find *Itarget* and the following two conditions are satisfied, the 4155C/4156C repeats the binary search between the last source value of the previous search and the source *stop* value.

- *Itarget* is between the first measurement data and the data at:
  source value = | *stop* – *start* | / 2.
- *Itarget* is between the last measurement data and the data at source *stop*.

If search cannot find *Itarget* and the following two conditions are satisfied, the 4155C/4156C repeats the binary search between the last source value of the previous search and the source *start* value.

- *Itarget* is between the measurement data at source *stop* and the data at:
  source value = | *stop* – *start* | / 2.
- *Itarget* is between the last measurement data and the data at source *start*.

BGV

The BGV command specifies the voltage monitor channel and its search parameters in the binary search measurement. This command is only for the US control mode.

This command ignores the RV command setting.

This command setting is cleared by the BGI, LGV and LGI commands.

Execution Conditions

The MM 15 command must be sent *before* sending this command.

Syntax

`BGV chnum,mode,condition,Vrange,Vtarget`

Parameters

chnum: Channel number of the unit used to measure voltage. Integer expression.

chnum	Unit	*chnum*	Unit
1	SMU1	5 [a]	SMU5
2	SMU2	6 [a]	SMU6
3	SMU3	23	VMU1
4	SMU4	24	VMU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

mode: Search mode. 0 (limit mode) or 1 (repeat mode). See *condition*.

condition: Search condition. The meaning of the *condition* parameter depends on the *mode* setting:

mode	*condition*
0	The *condition* parameter must be the limit value for the search target (*Vtarget*). in V. The search stops when the measurement data reaches *Vtarget* ± *condition*. The parameter must be either 0 or a positive value.
1	The *condition* parameter must be the times of voltage change of the source unit in the binary search. The parameter must be a value from 1 to 16.

Vrange: Ranging type for voltage measurement. Integer expression.

range	**Ranging Type [a]**
10 (only for VMU in differential mode)	0.2 V limited auto ranging
11	2 V limited auto ranging
12 (for SMU and VMU in grounded mode)	20 V limited auto ranging
13 (for SMU)	40 V limited auto ranging
14 (for SMU)	100 V limited auto ranging
15 (only for HPSMU)	200 V limited auto ranging

a. Limited auto ranging uses the lowest available measurement range that covers the measurement voltage, where the specified range is the minimum range. For example, 20 V limited auto ranging uses the 20 V range to measure 1 V, and uses the 100 V range to measure 50 V.

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

0 to ±100 for SMU, 0 to ±200 for HPSMU.

NOTE

Vtarget and Vrange

If the *Vtarget* value is greater than the minimum measurement range specified by the *Vrange* parameter, the measurement unit does not use the measurement ranges below the *Vtarget* value. It uses the lowest range that covers the *Vtarget* value.

Example Statements

```
OUTPUT @Hp4156;"BGV 1,0,0.1,0,5"
```

See Also

BSM command

Remarks

In the limited search mode, if the search cannot find *Vtarget* and the following two conditions are satisfied, the 4155C/4156C repeats the binary search between the last source value of the previous search and the source *stop* value.

- *Vtarget* is between the first measurement data and the data at:
  source value = | *stop* – *start* | / 2.
- *Vtarget* is between the last measurement data and the data at source *stop*.

If search cannot find *Vtarget* and the following two conditions are satisfied, the 4155C/4156C repeats the binary search between the last source value of the previous search and the source *start* value.

- *Vtarget* is between the measurement data at source *stop* and the data at:
  source value = | *stop* – *start* | / 2.
- *Vtarget* is between the last measurement data and the data at source *start*.

BSI

The BSI command specifies the current output channel, and its source parameters in the binary search measurement. This command is only for the US control mode.

This command setting is cleared by the BSV, LSV and LSI commands.

After search stops, source output goes to the source *start* value.

Execution Conditions

The MM 15 command must be sent *before* sending this command.

Syntax

`BSI chnum,range,start,stop[,Vcomp]`

If you send this command to the program memory (see the ST command), do not omit the *Vcomp* parameter. It is necessary when using the internal program memory.

Parameters

chnum: Channel number of the unit used to force current. Integer expression.

chnum	**Unit**
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5 (MPSMU)
6 [a]	SMU6 (MPSMU or HPSMU)

a. For SMUs in the 41501A/B Expander.

range: Ranging type for current output. Integer expression.

range	**Ranging Type [a]**
0	Auto ranging
9 (only for 4156C)	10 pA limited auto ranging
10 (only for 4156C)	100 pA limited auto ranging
11	1 nA limited auto ranging

range	**Ranging Type** [a]
12	10 nA limited auto ranging
13	100 nA limited auto ranging
14	1 μA limited auto ranging
15	10 μA limited auto ranging
16	100 μA limited auto ranging
17	1 mA limited auto ranging
18	10 mA limited auto ranging
19	100 mA limited auto ranging
20 (only for HPSMU)	1 A limited auto ranging

a. Auto ranging uses the lowest available output range that covers the *start* and *stop* values. Limited auto ranging is the same, but the specified range is the minimum range. For example, 10 μA limited auto ranging uses the 10 μA range to force 1 nA, and uses the 100 mA range to force 50 mA.

start: Source start current (in A). Numeric expression. See Table 1-7.

The *start* and *stop parameters* must have different values.

0 to ±100E–3 for SMU, 0 to ±1 for HPSMU

stop: Source stop current (in A). Numeric expression. See Table 1-7.

The *start* and *stop* parameters must have different values.

0 to ±100E–3 for SMU, 0 to ±1 for HPSMU

Vcomp: Voltage compliance value (in V). Numeric expression. See Table 1-7.

If you do not specify this parameter, *Vcomp* remains at its previous value.

Example Statements

```
OUTPUT @Hp4156;"BSI 1,0,1E-12,1E-6,10"
```

Table 1-7 **Available Parameter Values for BSI Command**

Output Range	Resolution in A	*start* and *stop* in A	Maximum *Vcomp* in V	Remarks
10 pA	10E–15	0 to ±10E–12	±100	For 4156C.
100 pA	10E–15	0 to ±100E–12	±100	
1 nA	100E–15	0 to ±1E–9	±100	
			±200	For HPSMU.
10 nA	1E–12	0 to ±10E–9	±100	
			±200	For HPSMU.
100 nA	10E–12	0 to ±100E–9	±100	
			±200	For HPSMU.
1 μA	100E–12	0 to ±1E–6	±100	
			±200	For HPSMU.
10 μA	1E–9	0 to ±10E–6	±100	
			±200	For HPSMU.
100 μA	10E–9	0 to ±100E–6	±100	
			±200	For HPSMU.
1 mA	100E–9	0 to ±1E–3	±100	
			±200	For HPSMU.
10 mA	1E–6	0 to ±10E–3	±100	
			±200	For HPSMU.
100 mA	10E–6	0 to ±20E–3	±100	
		to ±50E–3	±40	
		to ±100E–3	±20	
	100E–6	0 to ±50E–3	±200	For HPSMU.
		to ±100E–3	±100	
1 A	100E–6	0 to ±50E–3	±200	
		to ±125E–3	±100	
		to ±500E–3	±40	
		to ±1	±20	

BSM

The BSM command specifies the source output control mode in the binary search measurement. This command is only for the US control mode.

Execution Conditions

The MM 15 command must be sent *before* sending this command.

Syntax

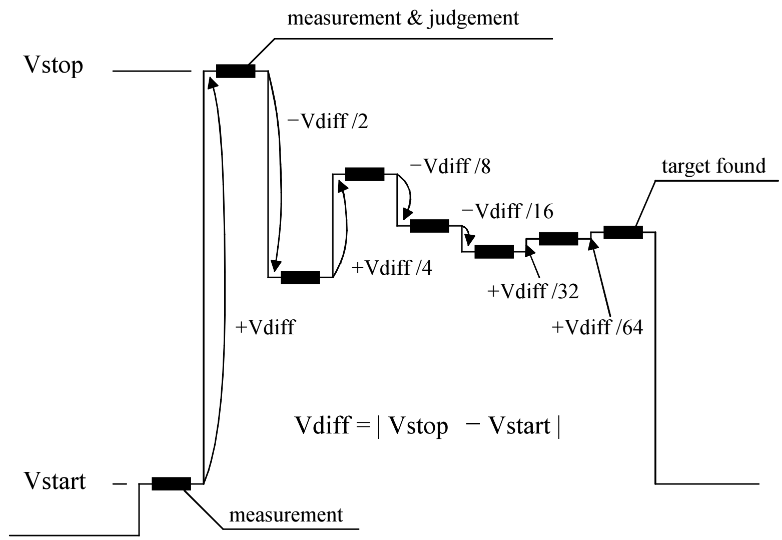
`BSM mode`

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.

Normal mode (BSM 0)

The operation of the normal mode is explained below. In this example the voltage output mode is described. The method is also effective for the current output mode.



1. The source unit forces Vstart, and the monitor unit makes a measurement.
2. The source unit forces Vstop, and the monitor unit makes a measurement.

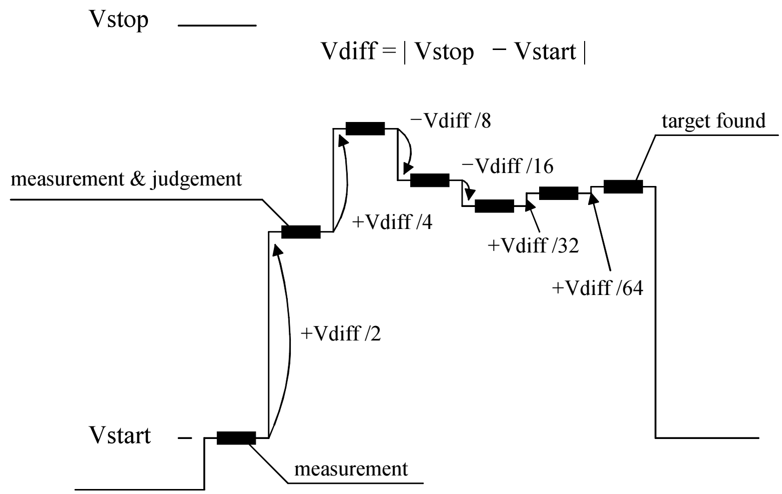
   If the target value is out of the range between the measured value at Vstart and the measured value at Vstop, the search stops.
3. The source unit forces Vdiff /2, and the monitor unit makes a measurement.

   If the result value is not the target value, the result value is used to decide the direction (+ or –) of the next voltage change. The value of the change is always half of the previous change.

4. Repeats this voltage change and measurement until the search condition is satisfied. For information on the search condition, see the BGV or BGI command. If the source change value is less than the setting resolution, the search stops.

Cautious mode (BSM 1)

The operation of the cautious mode is explained below. In this example the voltage output mode is described. This method is also effective for the current output mode.



1. The source unit forces Vstart, and the monitor unit makes a measurement.
2. The source unit forces Vdiff /2, and the monitor unit makes a measurement.

   If the result value is not the target value, the result value is used to decide the direction (+ or –) of the next voltage change. The value of the change is always half of the previous change.
3. Repeats this voltage change and measurement until the search condition is satisfied. For information on the search condition, see the BGV or BGI command. If the source output value is less than the setting resolution, the search stops.

Example Statements

```
OUTPUT @Hp4156;"BSM 1"
```

BSSI

The BSSI command specifies the synchronous current output channel and its source parameters in the binary search measurement. This command is only for the US control mode.

The synchronous source output will be:

Synchronous source output = BSI source output + offset current

where BSI source output means the output set by the BSI command. This command cannot be used with the BSV command (voltage force binary search).

This command setting is cleared by the BSSV, LSSV, or LSSI command.

Execution Conditions

The MM 15 command must be sent *before* sending this command.

The BSI command must be sent *before* sending this command.

Syntax

`BSSI chnum,polarity,offset[,Vcomp]`

If you enter this command into the program memory (see the ST command), do not omit the *Vcomp* parameter. It is necessary when using the internal program memory.

Parameters

chnum: Channel number of the unit used for synchronous current source. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5 (MPSMU)
6 [a]	SMU6 (MPSMU or HPSMU)

a. For SMUs in the 41501A/B Expander.

polarity: Polarity of the BSI source output. 0 (negative) or 1 (positive).

if you set *polarity*=0, synchronous output = –BSI output +*offset*.

if you set *polarity*=1, synchronous output = BSI output + *offset*.

***offset*:** Offset current (in A). Numeric expression.

Available values: 0 to ±0.1 for SMU, 0 to ±1 for HPSMU.

Synchronous output must *not* be over the output range specified by the BSI command.

***Vcomp*:** Voltage compliance value (in V). Numeric expression. If you do not specify this parameter, *Vcomp* remains at its previous value.

Example Statements

```
OUTPUT @Hp4156;"BSSI 1,0,1E-6,10"
```

See Also

Refer to the BSI command for the source output value, output range, and the available compliance values.

BSSV

The BSSV command specifies the synchronous voltage output channel, and its source parameters in the binary search measurement. This command is only for the US control mode.

The synchronous source output will be:

Synchronous source output = BSV source output + offset voltage

where BSV source output means the output set by the BSV command. This command cannot be used with the BSI command (current force binary search).

This command setting is cleared by the BSSI, LSSV, or LSSI command.

Execution Conditions

The MM 15 command must be sent *before* sending this command.

The BSV command must be sent *before* sending this command.

Syntax

`BSSV chnum,polarity,offset[,Icomp]`

If you enter this command into the program memory (see the ST command), do not omit the *Icomp* parameter. It is necessary when using the internal program memory.

Parameters

chnum: Channel number of the unit used for synchronous voltage source. Integer expression.

chnum	**Unit**
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5 (MPSMU)
6 [a]	SMU6 (MPSMU or HPSMU)
21	VSU1
22	VSU2

a. For SMUs in the 41501A/B Expander.

***polarity*:** Polarity of the BSV source output. 0 (negative) or 1 (positive).

if you set *polarity*=0, synchronous output = –BSV output +*offset*.

if you set *polarity*=1, synchronous output = BSV output + *offset*.

***offset*:** Offset voltage (in V). Numeric expression.

Available values: 0 to ±100 for SMU, 0 to ±200 for HPSMU.

Synchronous output must *not* be over the output range specified by the BSV command.

***Icomp*:** Current compliance value (in A). Numeric expression. If you do not specify this parameter, *Icomp* remains at its previous value. Zero amps (0 A) is not a valid value for the *Icomp* parameter.

Example Statements

```
OUTPUT @Hp4156;"BSSV 1,0,5,1E-6"
```

See Also

Refer to the BSV command for the source output value, output range, and the available compliance values.

BST

The BST command sets the timing parameters for the binary search measurement. This command is only for the US control mode.

Execution Conditions

The MM 15 command must be sent *before* sending this command.

Syntax

`BST hold,delay`

Parameters

hold : Hold time (in seconds). Numeric expression. This value is the time from measurement trigger to the beginning of delay time.

0 to 655.35 sec. 0.01 sec resolution. Initial setting = 0.

delay : Delay time (in seconds). Numeric expression. This is the time that has elapsed between the end of hold time, or the change of the source output value, and the start of the measurement.

0 to 65.535 sec. 0.0001 sec resolution. Initial setting = 0.

Example Statements

```
OUTPUT @Hp4155;"BST 5,0.1"
```

BSV

The BSV command specifies the voltage output channel, and its source parameters in the binary search measurement. This command is only for the US control mode.

This command setting is cleared by the BSI, LSV, or LSI command.

After search stops, source output goes to the source *start* value.

Execution Conditions

The MM 15 command must be sent *before* sending this command.

Syntax

`BSV chnum,range,start,stop[,Icomp]`

If you enter this command into the program memory (see the ST command), do not omit the *Icomp* parameter. It is necessary when using the internal program memory.

Parameters

chnum: Channel number of the unit used to force the voltage. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6
21	VSU1
22	VSU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

range: Ranging type for voltage output. Integer expression.

range	**Ranging Type** [a]
0	Auto ranging
11 (for SMU)	2 V limited auto ranging
12	20 V limited auto ranging
13 (for SMU)	40 V limited auto ranging
14 (for SMU)	100 V limited auto ranging
15 (only for HPSMU)	200 V limited auto ranging

a. Auto ranging uses the lowest output range that covers the *start* and *stop* values. Limited auto ranging is the same, but the specified range is the minimum range. For example, 20 V limited auto ranging uses the 20 V range to force 1 V start value to 10 V stop value.

start: Source start voltage (in V). Numeric expression. See Table 1-8.

The *start* and *stop* parameters must have different values.

0 to ±100 for SMU, 0 to ±200 for HPSMU.

stop: Source stop voltage (in V). Numeric expression. See Table 1-8.

The *start* and *stop* parameters must have different values.

0 to ±100 for SMU, 0 to ±200 for HPSMU.

Icomp: Current compliance value (in A). Numeric expression. See Table 1-8. If you do not specify this parameter, *Icomp* remains at its previous value. Zero amps (0 A) is not allowed for *Icomp*.

Example Statements

```
OUTPUT @Hp4156;"BSV 1,0,0,20,1E-6"
```

Table 1-8 Available Parameter Values for BSV Command

Output Range	Resolution in V	*start* and *stop* in V	Maximum *Icomp* in A	Remarks
2 V	100E–6	0 to ±2	±100E–3	For SMU.
			±1	For HPSMU.
20 V	1E–3	0 to ±20	±100E–3	For SMU.
			±1	For HPSMU.
			–	For VSU.
40 V	2E–3	0 to ±40	±50E–3	For SMU.
			±500E–3	For HPSMU.
100 V	5E–3	0 to ±100	±20E–3	For SMU.
			±125E–3	For HPSMU.
200 V	10E–3	0 to ±200	±50E–3	

BSVM

The BSVM command selects the data output mode for the binary search measurement. This command is only for the US control mode.

Execution Conditions

The MM 15 command must be sent *before* sending this command.

Syntax

```
BSVM mode
```

Parameters

mode : Data output mode. Integer expression. 0 (normal) or 1 (all data output).

0 : Outputs *Search*, *Source_data*, and *Data*.

1 : Outputs *D1*, *D2*, ..., *Search*, *Source_data*, and *Data*.

where,

Search is the search status.

Source_data is the source output data of the search target.

Data is the measurement data of the search target.

Dn (*n*: integer) is the data of the *n* th measurement point, and contains *Source_data* and *Measurement_data* of each measurement point.

For the data output format, refer to “Data Output Format” on page 1-11.

Example Statements

```
OUTPUT @Hp4155;"BSVM 1"
```

CA

The CA command performs calibration of the measurement unit. When you execute the CA command, the output switches of the specified units are set to OFF.

Syntax

```
CA [slotnum]
```

Parameters

slotnum: Slot number. Integer expression. See below.

slotnum	Unit calibrated
0	GNDU
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6
7	VSU1, VSU2, VMU1 and VMU2
8	PGU1 and PGU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

If you do not specify *slotnum*, all units are calibrated.

Example Statements

```
OUTPUT @Hp4156;"CA"
OUTPUT @Hp4156;"CA 1"
```

*CAL?

The CAL? query command performs a full calibration of the 4155C/4156C, then returns a <numeric_value> to indicate the calibration result.

Syntax

```
*CAL?
```

Query Response

In US command mode:

result<LF^EOI>

In US42 command mode:

result<CR/LF^EOI>

where, *result* returns one of the following values:

0: Pass.

1: Fail.

Example Statements

```
OUTPUT @Hp4156;"*CAL?"
ENTER @Hp4156;A
```

CL

The CL command disables the specified units by setting the output switches to OFF.

Execution Conditions

No unit may be in the HIGH VOLTAGE state (forcing more than ±40 V, or voltage compliance set to more than ±40 V). However, if you do not specify *chnum* for CL command, there are no restrictions on the execution conditions.

Syntax

```
CL [chnum[,chnum...[,chnum]...]]
```

Parameters

chnum: Channel number. Integer expression. See below.

chnum	Unit disabled	*chnum*	Unit disabled
1	SMU1	21	VSU1
2	SMU2	22	VSU2
3	SMU3	23 [a]	VMU1
4	SMU4	24 [a]	VMU2
5 [b]	SMU5	26	GNDU
6 [b]	SMU6	27	PGU1
		28	PGU2

a. VMU1 and VMU2 have the output switch in common.
b. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

If you do not specify *chnum* in the US command mode, the 4155C/4156C sets all units to 0 V in order, from higher voltage range (output range or measurement range) to lower voltage range, and all output switches are set to OFF.

If you do not specify *chnum* in the US42 command mode, the CL command does not open the output switch of GNDU and VMU. For SMU, VSU and PGU, the 4155C/4156C does the same operation as in the US command mode.

If you specify multiple *chnum*s, the 4155C/4156C sets the units to 0 V in the specified order, and the output switches are set to OFF.

For example, OUTPUT @Hp4156;"CL 1,2,3" disables SMU1, SMU2, and SMU3, in that order.

Remarks

The CL command sets the specified units to the following conditions:

Item	SMU	VSU	VMU	GNDU	PGU
Source Mode	V	V			V
Output Voltage	0 V	0 V		0 V	0 V
V Range	20 V	20 V	20 V [a]		20 V
I Compliance	100 μA	100 mA			
I limit		100 mA			100 mA
I Range	100 μA	100 mA			
Filter	ON				

a. In the differential voltage measurement mode, the voltage range is set to 2 V.

Example Statements

```
OUTPUT @Hp4156;"CL"
OUTPUT @Hp4156;"CL 1,2,3,5"
```

CLOSE

The CLOSE command closes the file opened by the OPEN command.

Syntax

```
CLOSE
```

Example Statements

```
OUTPUT @Hp4156;"CLOSE"
```

*CLS

The *CLS command clears the status byte register, standard event status register, and error register. This command does *not* clear the enable registers.

This command also stops the monitoring of pending operations by the *OPC command.

Syntax

```
*CLS
```

Example Statements

```
OUTPUT @Hp4156;"*CLS"
```

CM

The CM command sets the Auto-Calibration mode to ON or OFF. If Auto-Calibration is ON, and the following two conditions are satisfied, the 4155C/4156C automatically calibrates all units every 30 minutes.

- Output switches of all units have been OFF for 30 minutes
- The ST command is not entered at least 30 minutes after entering the last END command.

Syntax

`CM` *`mode`*

Parameters

mode: Auto-calibration mode ON/OFF. Integer expression. See below.

0: Auto-Calibration OFF

1: Auto-Calibration ON (initial setting)

Example Statements

```
OUTPUT @Hp4156;"CM 0"
OUTPUT @Hp4156;"CM 1"
```

CMD?

The CMD? command returns the current control language mode of the 4155C/4156C. This command has only the query form.

Syntax

`CMD?`

Query response

language_mode <terminator>

language_mode is NR1 response data type.

<terminator> depends on the language mode.

The values of *language_mode* and <terminator> are as follows:

Value	Control Language Mode	<terminator>
0	SCPI command control mode	<LF^EOI>
1	Agilent FLEX command control mode (US mode or US42 mode)	<LF^EOI>
2	4145 syntax command control mode	<CR/LF^EOI>

Example Statements

```
OUTPUT @Hp4155;"CMD?"
ENTER @Hp4155;A
```

CMM

The CMM command sets the SMU measurement mode.

The measurement mode set by this command is kept until the measurement mode is specified again by this command. If you want to return the setting to the normal mode (initial measurement mode), enter the CMM command with *mode*=0.

Syntax

`CMM chnum,mode`

Parameters

chnum **:** Channel number of SMU. Integer expression. See below.

chnum	Unit	*chnum*	Unit
1	SMU1	4	SMU4
2	SMU2	5 [a]	SMU5
3	SMU3	6 [a]	SMU6

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

mode **:** Measurement mode. 0 to 3 are available. Integer expression. See below.

mode	Description
0	Compliance side measurement (initial setting). If SMU is in the voltage source mode, SMU does current measurement. If SMU is in the current source mode, SMU does voltage measurement.
1	Current measurement. SMU does current measurement, regardless of the SMU output source mode.
2	Voltage measurement. SMU does voltage measurement, regardless of the SMU output source mode.
3	Force side measurement. If SMU is in the voltage source mode, SMU does voltage measurement. If SMU is in the current source mode, SMU does current measurement.

Example Statements

```
OUTPUT @Hp4156;"CMM 1,1"
```

CN

The CN command enables the specified units by setting the output switches to ON.

WARNING

SETTING THE OUTPUT SWITCH TO "ON" ENABLES THE UNIT TO FORCE DANGEROUS VOLTAGES.

WHEN THE UNIT IS NOT IN USE, SET THE OUTPUT SWITCH TO "OFF" WHENEVER POSSIBLE.

Execution Conditions

No unit may be in the HIGH VOLTAGE state (forcing more than ±40 V, or voltage compliance set to more than ±40 V).

Syntax

`CN [chnum[,chnum...[,chnum]...]]`

Parameters

chnum: Channel number. Integer expression. See below.

chnum	Slot No.	Unit enabled	*chnum*	Slot No.	Unit enabled
1	1	SMU1	21	7	VSU1
2	2	SMU2	22		VSU2
3	3	SMU3	23		VMU1 [a]
4	4	SMU4	24		VMU2 [a]
5 [b]	5	SMU5	26	0	GNDU
6 [b]	6	SMU6	27	8	PGU1
			28		PGU2

a. VMU1 and VMU2 have the output switch in common.
b. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

If you do not specify *chnum*, the 4155C/4156C sets all output switches to ON, in the order from lower to higher slot number.

If you specify multiple *chnum*s, the 4155C/4156C sets the output switches to ON, in the specified order.

For example, OUTPUT @Hp4156;"CN 1,2,3" enables the SMU1, SMU2, and SMU3, in that order.

Remarks

The CN command sets the specified units to the following conditions:

Item	SMU	VSU	VMU	GNDU	PGU
Output Switch	ON	ON	ON	ON	ON
Source Mode	V	V			V
Output Voltage	0 V	0 V		0 V	0 V
V Range	20 V	20 V	20 V [a]		20 V
I Compliance	100 μA	100 mA			
I limit		100 mA			100 mA
I Range	100 μA	100 mA			
Filter	no change				

a. In the differential voltage measurement mode, the voltage range is set to 2 V range.

If the output switch of the specified unit is already set to ON, the CN command is disabled.

Example Statements

```
OUTPUT @Hp4156;"CN"
OUTPUT @Hp4156;"CN 1,2,3,5"
```

DI

The DI command forces current from the specified unit.

Execution Conditions

The CN command has been executed for the specified unit. If the voltage compliance is greater than ±40 V, the interlock circuit must be shorted.

Syntax

`DI chnum,range,current[,Vcomp[,comp polarity]]`

If you enter the DI command into the program memory (see the ST command), do not omit the *Vcomp* parameter. *Vcomp* is necessary when using the internal program memory.

Parameters

chnum: Channel number of the unit used to force current. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

range: Range type for current output. Integer expression.

range	Ranging Type [a]
0	Auto ranging
9 (only for 4156C)	10 pA limited auto ranging
10 (only for 4156C)	100 pA limited auto ranging
11	1 nA limited auto ranging
12	10 nA limited auto ranging
13	100 nA limited auto ranging
14	1 μA limited auto ranging

range	**Ranging Type** [a]
15	10 μA limited auto ranging
16	100 μA limited auto ranging
17	1 mA limited auto ranging
18	10 mA limited auto ranging
19	100 mA limited auto ranging
20 (only for HPSMU)	1 A limited auto ranging

a. Auto ranging uses the lowest output range (available for the unit) that covers *current* value. Limited auto ranging uses the specified range or above. For example, 10 μA limited auto ranging uses the 10 μA range to force 1 nA.

current: Output current value (in A). Numeric expression. See Table 1-9.

0 to ±100E–3 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±1 (for HPSMU in 41501A/B)

Vcomp: Voltage compliance value (in V). Numeric expression. See Table 1-9.

If you do not specify this parameter, *Vcomp* is set to the previous setting.

comp polarity: Polarity of voltage compliance. Numeric expression.

0: Auto mode. Default.

The polarity of voltage compliance is automatically set to the same value as the polarity of the output current (*current*), regardless of the polarity of *Vcomp* value. If output current is 0 A, the polarity is positive.

1: Manual mode.

This parameter must be specified if you want to set the polarity of the voltage compliance to the same as the specified polarity of *Vcomp*.

Example Statements

```
OUTPUT @Hp4156;"DI 1,0,1E-6,100,1"
OUTPUT @Hp4156;"DI 3,14,5E-7,20,0"
```

Table 1-9 **Available Parameter Values for DI Command**

Output Range	Resolution in A [a]	*current* in A	Maximum *Vcomp* in V	Remarks
10 pA	10E–15	0 to ±10E–12	±100	For 4156C.
100 pA	10E–15	0 to ±100E–12	±100	
1 nA	100E–15	0 to ±1E–9	±100	For SMU.
			±200	For HPSMU.
10 nA	1E–12	0 to ±10E–9	±100	For SMU.
			±200	For HPSMU.
100 nA	10E–12	0 to ±100E–9	±100	For SMU.
			±200	For HPSMU.
1 μA	100E–12	0 to ±1E–6	±100	For SMU.
			±200	For HPSMU.
10 μA	1E–9	0 to ±10E–6	±100	For SMU.
			±200	For HPSMU.
100 μA	10E–9	0 to ±100E–6	±100	For SMU.
			±200	For HPSMU.
1 mA	100E–9	0 to ±1E–3	±100	For SMU.
			±200	For HPSMU.
10 mA	1E–6	0 to ±10E–3	±100	For SMU.
			±200	For HPSMU.
100 mA	10E–6	0 to ±20E–3	±100	For SMU.
		to ±50E–3	±40	
		to ±100E–3	±20	
	100E–6	0 to ±50E–3	±200	For HPSMU.
		to ±100E–3	±100	
1 A	100E–6	0 to ±50E–3	±200	
		to ±125E–3	±100	
		to ±500E–3	±40	
		to ±1	±20	

a. Minimum resolution is Range×5E–5. However the setting accuracy is not guaranteed for the resolution less than the value shown in the table.

DO

The DO command executes the 4155C/4156C internal memory programs (up to 8 programs) in the order specified.

Before executing the internal memory program, close the Interlock circuit. If you do not close the interlock circuit, an error occurred and the measurement is aborted.

Execution Conditions

The specified programs have been stored by using the ST and END commands.

Syntax

`DO` *`prog No.`*`[,`*`prog No.`*`[,`*`prog No.`*`....[,`*`prog No.`*`]...]]`

Parameters

***prog No.*:** Internal memory program number. 1 to 255. Integer expression.

Remarks

The 4155C/4156C cannot detect errors during the internal memory program execution.

Example Statements

```
OUTPUT @Hp4156;"DO 1,2,3,4,5,6,7,8"
OUTPUT @Hp4156;"DO 98,99"
```

DV

The DV command forces output voltage from the specified unit.

Execution Conditions

The CN command has been executed for the specified unit. If the output voltage is greater than ±40 V, the interlock circuit must be shorted.

Syntax

`DV chnum,range,voltage[,Icomp[,comp polarity]]`

If you enter the DV command into the program memory (see the ST command), do not omit the *Icomp* parameter. *Icomp* is necessary when using the internal program memory.

Parameters

chnum: Channel number of the unit used to force voltage. Integer expression.

chnum	Unit	*chnum*	Unit
1	SMU1	6 [a]	SMU6
2	SMU2	21	VSU1
3	SMU3	22	VSU2
4	SMU4	27 [b]	PGU1
5 [a]	SMU5	28 [b]	PGU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.
b. If you use the PGU, execute the SPG command before the DV command.

range: Ranging type for voltage output. Integer expression.

range	Ranging Type [a]
0	Auto ranging
11 (for SMU)	2 V limited auto ranging
12	20 V limited auto ranging

range	**Ranging Type** [a]
13 (for SMU and PGU)	40 V limited auto ranging
14 (for SMU)	100 V limited auto ranging
15 (only for HPSMU)	200 V limited auto ranging

a. Auto ranging uses the lowest output range (available for the unit) that covers the *voltage* value. Limited auto ranging uses the specified range or above. For example, 20 V limited auto ranging uses the 100 V range to force 50 V.

***voltage*:** Output voltage value (in V). Numeric expression. See Table 1-10.

0 to ±100 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±200 (for HPSMU in 41501A/B)

0 to ±20 (for VSU)

0 to ±40 (for PGU)

***Icomp*:** Current compliance value (in A). Numeric expression. See Table 1-10.

This parameter is not available for VSU and PGU. If you do not specify this parameter, *Icomp* is set to the previous setting. 0 A is not allowed for *Icomp*.

***comp polarity*:** Polarity of current compliance. Integer expression. This parameter is not available for VSU and PGU.

0: Auto mode. Default.

The polarity of the current compliance is automatically set to the same value as the polarity of the output voltage (*voltage*), regardless of the polarity of the *Icomp* value. If the output voltage is 0 V, the polarity is positive.

1: Manual mode.

This parameter must be specified if you want to set the polarity of the current compliance to the same value as the polarity of *Icomp* you specified.

Example Statements

```
OUTPUT @Hp4156;"DV 1,0,20,1E-6,0"
OUTPUT @Hp4156;"DV 21,12,10"
```

Table 1-10 Available Parameter Values for DV Command

Output Range	**Resolution in V**	***voltage* in V**	**Maximum *Icomp* in A**	**Remarks**
2 V	100E−6	0 to ±2	±100E−3	For SMU.
			±1	For HPSMU.
20 V	1E−3	0 to ±20	±100E−3	For SMU.
			±1	For HPSMU.
			–	For VSU.
	4E−3		–	For PGU.
40 V	2E−3	0 to ±40	±50E−3	For SMU.
			±500E−3	For HPSMU.
	8E−3		–	For PGU.
100 V	5E−3	0 to ±100	±20E−3	For SMU.
			±125E−3	For HPSMU.
200 V	10E−3	0 to ±200	±50E−3	

DZ

The DZ command stores the settings (V/I output values, V/I output ranges, and V/I compliance values) of the specified units, and sets the units to Zero (0 V) Output. The stored settings can be recovered by using the RZ command. The settings are cleared by using a Device Clear (HP BASIC CLEAR) command, *RST, RZ, CL, CA, or *TST?.

Execution Conditions

The CN command has been executed for the specified units.

Syntax

`DZ [chnum[,chnum...[,chnum]...]]`

Parameters

chnum: Channel number set to zero (0 V) output. Integer expression.

chnum	Unit	*chnum*	Unit
1	SMU1	21	VSU1
2	SMU2	22	VSU2
3	SMU3	23	VMU1
4	SMU4	24	VMU2
5 [a]	SMU5	26	GNDU
6 [a]	SMU6	27	PGU1
		28	PGU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

If you do not specify *chnum*, the DZ command applies the Zero Output to all units, where the output switch is set to ON, in order from higher (output or measurement range) to lower voltage range.

If you specify multiple *chnum*s, the 4155C/4156C sets the units to Zero Output in the specified order.

Remarks

The DZ command sets the specified units to the following conditions:

Item	SMU	VSU	VMU	GNDU	PGU
Output Switch	ON	ON	ON	ON	ON
Source Mode	V		Not changed	V	V
Output Voltage	0 V	0 V	Not changed	0 V	0 V
V Range	Not changed	20 V	Not changed		Not changed
I Compliance	See below	100 mA	Not changed		
I Range		100 mA	Not changed		100 mA
Filter	Not changed		Not changed		

Previous range [a]	I Compliance
10 pA to 10 nA	10 nA at 10 nA range
100 nA to 1 μA	1 μA at 1 μA range
over 10 μA	100 μA at 100 μA range

a. Previous range is the current output range, which was set before the DZ command.

Example Statements

```
OUTPUT @Hp4156;"DZ"
OUTPUT @Hp4156;"DZ 1,2,3"
```

END

The END command is used with the ST command to store a program in the internal program memory of the 4155C/4156C. See ST command.

Syntax

```
END
```

Example Statements

```
OUTPUT @Hp4156;"ST 1;CN 1;DV 1,0,5,1E-4;TI? 1,0;CL 1"
OUTPUT @Hp4156;"END"
```

ERR?

The ERR? query command returns error codes from the 4155C/4156C error register to the output data buffer (query buffer).

Output data is always stored in the query buffer in ASCII format, regardless of the FMT command.

This command clears the error register.

Syntax

```
ERR?
```

Query Response

In US command mode:

Error Code #1,....,*Error Code #7* <LF^EOI>

In US42 command mode:

Error Code #1,....,*Error Code #4* <CR/LF^EOI>

where, *Error Code #N* (*N*: integer) indicates 3 digits, 5 digits, or 10 digits error code. For the error codes, refer to “Error Messages” and *User's Guide*.

Example Statements

```
OUTPUT @Hp4156;"ERR?"
ENTER @Hp4156;A$
```

ESC

The ESC command enables or disables the sweep stop function and sets the stop conditions. This command is only for the US control mode, and is available in the following measurement modes:

- Staircase sweep measurement (MM 2)
- Pulsed sweep measurement (MM 4)
- Staircase sweep with pulsed bias measurement (MM 5)

Syntax

`ESC onoff[,chnum,condition1,value1,condition2,value2]`

This command stops the sweep measurement when the *condition1* or *condition2* parameter is satisfied. If you do not specify the *chnum* parameter, the stop function is disabled.

Parameters

onoff Sweep stop function on or off. 0 or 1. Integer expression.

0: Disables the function

1: Enables the function

***chnum*:** Channel number of the unit used to monitor the stop conditions. The unit must be one of the measurement channels specified by the MM command. If the unit is not a measurement channel, the stop function is disabled. Integer expression.

chnum	**Unit**
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5 (MPSMU)
6 [a]	SMU6 (MPSMU or HPSMU)
23	VMU1
24	VMU2

a. For SMUs in the 41501A/B Expander.

condition1 Stop condition. 0, 1, 2, 3, or 4. Integer expression. If you do not specify this parameter, 0 is set.

condition1	**description**
0	Disables the stop condition.
1	Stops measurement if *Result1* ≤ *Value1*
2	Stops measurement if *Result1* ≥ *Value1*
3	Stops measurement if | *Result1* | ≤ | *Value1* |
4	Stops measurement if | *Result1* | ≥ | *Value1* |

where *Result1* is given by the following equation. *Value1* is the parameter value you specify (see the *value1* parameter).

Result1 = (Data[*n*]–Data[*n*–1]) / Data[*n*–1]

Data[*n*] (*n*: integer) is the *n*th data measured by the unit specified by the *chnum* parameter.

value1 Value compared with *Result1*. See *condition1* parameter.

Available values: –10000 to 10000. Numeric expression.

If you do not specify this parameter, 0 is set.

condition2 Stop condition. 0, 1, 2, 3, or 4. Integer expression. If you do not specify this parameter, 0 is set.

condition2	**description**
0	Disables the stop condition.
1	Stops measurement if Data[*n*] ≤ *Value2*
2	Stops measurement if Data[*n*] ≥ *Value2*
3	Stops measurement if | Data[*n*] | ≤ | *Value2* |
4	Stops measurement if | Data[*n*] | ≥ | *Value2* |

where Data[*n*] (*n*: integer) is the *n*th data measured by the unit specified by the *chnum* parameter. *Value2* is the parameter value you specify (see the *value2* parameter).

value2 Value compared with Data[*n*]. See the *condition2* parameter.

Available values: –200 to 200. Numeric expression.

If you do not specify this parameter, 0 is set.

Output Data

The 4155C/4156C returns the all measurement data until when the sweep stop condition is detected. The output format of the last data will be as shown below:

Measurement Mode	Data for the stopped sweep step
1 channel sweep	*Data*[,*Source_data*]
Multi channel sweep	*Data*, ... *Data*[,*Source_data*] [a]

a. *Source_data* will be returned if the *chnum* parameter of the ESC command specifies the last measurement channel defined by the MM command.

where,

Data: Measurement data.

Source_data: Source output data. Selected by the FMT command.

If the *Source_data* output is disabled, the status of the last *Data* will be 160 (128+32). where 128 means the EOD, and 32 means the ESC was detected.

For example, if there is 4 measurement channels, and if the ESC command specifies the 2nd measurement channel to monitor the stop condition, the 4155C/4156C returns only 2 data (*Data*,*Data*) for the stopped sweep step. And the status of the last *Data* is 160. The order of the measurement channel is defined by the MM command.

Example Statements

```
OUTPUT @Hp4155;"ESC 1,1,1,2,1,0.001"
```

*ESE(?)

The *ESE command sets the bits of the Standard Event Status "Enable" Register.

Syntax

`*ESE enable_number`

Parameters

enable_number: Decimal integer (the sum of the binary-weighted values for the desired bits), hexadecimal, octal, or binary value.

1: Enables.

0: Masks.

Query Response

In US command mode:

`enable_number<LF^EOI>`

In US42 command mode:

`enable_number<CR/LF^EOI>`

where, *enable_number* is a decimal integer value that is the sum of the binary-weighted values of the "Enable" register bits.

Semantics

The Standard Event Status "Enable" Register determines which bits of the Standard Event Status Register are enabled. Enabled bits are ORed together, and the result is reported to bit 5 of the Status Byte Register.

The Standard Event Status "Enable" Register consists of 16 bits, but only the lower 8 bits are used. These correspond to the bits of the Standard Event Status Register.

The following table shows the bits of the Standard Event Status Register and the binary-weighted decimal value.

bit	binary-weight	description
0	1	OPC (Operation Complete)
1	2	Not used. (always zero)
2	4	Not used. (always zero)
3	8	Set to 1 if error occurred.
4	16	Set to 1 if parameter error occurred.
5	32	Set to 1 if syntax error occurred.
6	64	Not used. (always zero)
7	128	Not used. (always zero)

Example Statements

The following four lines enable the same bit (bit 6):

```
OUTPUT @Hp4156;"*ESE 32"        using decimal numeric
OUTPUT @Hp4156;"*ESE #B100000"  using binary numeric
OUTPUT @Hp4156;"*ESE #Q40"      using octal numeric
OUTPUT @Hp4156;"*ESE #H20"      using hexadecimal numeric
```

The following is an example for a query:

```
OUTPUT @Hp4156;"*ESE?"
ENTER @Hp4156;A
```

*ESR?

The *ESR? query command returns the present contents of the Standard Event Status Register.

Syntax

`*ESR?`

Query Response

In US command mode:

register<LF^EOI>

In US42 command mode:

register<CR/LF^EOI>

Parameter	Type	Explanation
register	NR1	0 to 255 (decimal integer value that is the sum of the binary-weighted values for the set bits)

Semantics

The following table shows the bits of the Standard Event Status Register.

bit	binary-weight	description
0	1	OPC (Operation Complete)
1	2	Not used. (always zero)
2	4	Not used. (always zero)
3	8	Set to 1 if error occurred.
4	16	Set to 1 if parameter error occurred.
5	32	Set to 1 if syntax error occurred.
6	64	Not used. (always zero)
7	128	Not used. (always zero)

Example Statements

```
OUTPUT @Hp4156;"*ESR?"
ENTER @Hp4156;A
```

FL

The FL command sets the filter of specified units to ON or OFF. For pulsed source, set the filter to OFF (to enable pulsed output) before measurement trigger.

Syntax

`FL` *`mode`*`[,`*`chnum`*`[,`*`chnum`*`...[,`*`chnum`*`]...]]`

Parameters

mode: Status of the filter. Integer expression.

0: Filter OFF.

1: Filter ON.

chnum: Channel number. Integer expression. If you do not specify *chnum*, the FL command sets the filter of all channels to ON or OFF under the *mode* setting.

chnum	**Unit**
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

Example Statements

```
OUTPUT @Hp4156;"FL"
OUTPUT @Hp4156;"FL 1,1,3,5"
```

FMT

The FMT command specifies the measurement data output format and the data terminator. For details about output data format, see “Data Output Format” on page 1-11.

Query command output data is always stored in the query buffer in ASCII format, regardless of this command.

Syntax

`FMT format[,mode]`

Parameters

format : Output data format. Integer expression. If you do not specify this parameter, *format* is set to 1.

<table>
<tr><th rowspan="2">format</th><th rowspan="2">Description</th><th colspan="2">Terminator</th></tr>
<tr><th>US mode [a]</th><th>US42 mode [b]</th></tr>
<tr><td>1</td><td>ASCII data format with header.
Initial setting.</td><td rowspan="4"><LF^EOI></td><td rowspan="3"><CR/LF^EOI></td></tr>
<tr><td>2</td><td>ASCII data format without header</td></tr>
<tr><td>3</td><td>Binary data format</td></tr>
<tr><td>4</td><td>Binary data format</td><td><^EOI></td></tr>
<tr><td>5</td><td>ASCII data format with header</td><td><,^EOI></td><td>,</td></tr>
</table>

a. This column is effective for US command mode.
b. This column is effective for US42 command mode.

mode: Output data mode. Integer expression. If you do not specify this parameter, *mode* is set to 0.

mode	**Description**
0	For the sweep measurements, sweep source data is not output. For the sampling measurements, sampling point index is not output. For the QSCV measurements, source output data is not output.
1	For the sweep measurements, primary sweep source data is output with measurement data. For the sampling measurements, sampling point index is output with measurement data. For the QSCV measurements, source output data is output with measurement data.
2	For the sweep measurements, secondary sweep source data is output with measurement data. If WSI/WSV command was not entered properly, the invalid source data will be returned. Ignore the returned value. For the sampling data, sampling point index is output with measurement data.

Remarks

In the US command control mode, if you change the data output format, the FMT command clears the 4155C/4156C output data buffer and sets the new data output format. If the format specified by the FMT command is the same as the previous setting, the FMT command does not clear the output data buffer.

In the US42 command control mode, the FMT command clears the 4155C/4156C output data buffer and sets the data output format.

Example Statements

```
OUTPUT @Hp4156;"FMT 1"
OUTPUT @Hp4156;"FMT 2,1"
```

GOC

The GOC command measures the zero offset data and sets the zero offset cancel function to ON. The zero offset cancel function is available for the SMU in the low current measurement mode and the VMU in the differential voltage measurement mode. For details of the zero offset cancel function, refer to *User's Guide: Measurement and Analysis*.

The zero offset data is cleared by the US, US42, *RST command, or any emergency condition.

Execution Conditions

SMU must be set to the voltage force mode by the DV command.

Syntax

`GOC chnum,range`

Parameters

chnum : Channel number of the unit used to measure the zero offset data and to set the zero offset cancel function to ON. Integer expression.

chnum	**Unit**
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6
23 [b]	VMU1
24 [b]	VMU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.
b. Differential voltage measurements use both VMU1 and VMU2. Specify which VMU1 or VMU2.

range : Measurement range to measure the zero offset data. Integer expression.

range	Description
9 (for 4156C)	10 pA range
10 (for 4156C)	100 pA range
10 (for VMU)	0.2 V range
11 (for SMU)	1 nA range

Remarks

If the 4155C/4156C fails to measure the zero offset data in the GOC command execution, the GOC command keeps the previous zero offset data and sets the function to OFF.

Example Statements

```
OUTPUT @Hp4156;"GOC 1,9"
OUTPUT @Hp4156;"GOC 23,10"
```

*IDN?

The *IDN? query command requests the instrument model number and the ROM version number, then stores the results in the 4155C/4156C output data buffer (query buffer).

Output data is always stored in the query buffer in ASCII format, regardless of the FMT command.

Syntax

`*IDN?`

Query Response

`HEWLETT-PACKARD,`*`model`*`,0,`*`HOST rev`*`,`*`SMUC rev`*`,`*`AD rev`* <LF^EOI>

Response	Explanation
model	`4155C` or `4156C`
HOST rev	Revision number of HOST CPU.
SMUC rev	Revision number of SMU controller.
AD rev	Revision number of A/D converter.

Example Statements

```
OUTPUT @Hp4156;"*IDN?"
ENTER @Hp4156;A$
```

Example Response

```
HEWLETT-PACKARD,4156C,0,01.00,01.00,01.00
```

IN

The IN command sets the specified unit to Zero Output with an output range change.

Execution Conditions

The CN command has been executed for the specified unit.

Syntax

`IN [chnum[,chnum...[,chnum]...]]`

Parameters

chnum: Channel number. Integer expression. See below.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6
21	VSU1
22	VSU2
27	PGU1
28	PGU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

If you do not specify *chnum*, this command sets all units to Zero Output in order from higher voltage range (output or measurement range) to lower voltage range.

If you specify multiple *chnum*s, the 4155C/4156C sets the units to Zero Output in the specified order.

Remarks

The IN command sets the specified units to the following conditions, which are the same as the conditions after executing the CN command.

Item	SMU	VSU	VMU	GNDU	PGU
Output Switch	ON	ON	ON	ON	ON
Source Mode	V	V			V
Output Voltage	0 V	0 V		0 V	0 V
V Range	20 V	20 V	20 V [a]		20 V
I Compliance	100 μA	100 mA			
I Limit		100 mA			100 mA
I Range	100 μA	100 mA			
Filter	Not changed				

a. For differential voltage measurement mode, the voltage range is set to 2 V range.

Example Statements

```
OUTPUT @Hp4156;"IN"
OUTPUT @Hp4156;"IN 1,2,3,5,6"
```

LGI

The LGI command specifies the current monitor channel and its search parameters in the linear search measurement. This command is only for the US control mode.

This command ignores the RI command setting.

This command setting is cleared by the LGV, BGV or BGI command.

Execution Conditions

The MM 14 command must be entered before this command.

Syntax

`LGI` *`chnum`*`,`*`mode`*`,`*`Irange`*`,`*`Itarget`*

Parameters

chnum: The channel number of the unit used to measure the current. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5 (MPSMU)
6 [a]	SMU6 (MPSMU or HPSMU)

a. For SMUs in the 41501A/B Expander.

mode: Search mode. 0 or 1.

0 : If the value of the measurement data is less than or equal to the value of *Itarget*, it is the target data.

1 : If the value of the measurement data is greater than or equal to the value of *Itarget*, it is the target data.

Irange: Ranging type for current measurement. Integer expression.

range	Ranging Type [a]
9 (only for 4156C)	10 pA limited auto ranging
10 (only for 4156C)	100 pA limited auto ranging
11	1 nA limited auto ranging
12	10 nA limited auto ranging
13	100 nA limited auto ranging
14	1 μA limited auto ranging
15	10 μA limited auto ranging
16	100 μA limited auto ranging
17	1 mA limited auto ranging
18	10 mA limited auto ranging
19	100 mA limited auto ranging
20 (only for HPSMU)	1 A limited auto ranging

a. Limited auto ranging uses the lowest available measurement range that covers the measurement value, where the specified range is the minimum range. For example, 10 μA limited auto ranging uses the 10 μA range to measure 1 nA, and uses the 100 mA range to measure 50 mA.

Itarget: Search target current (in A). Numeric expression.

0 to ±100 mA for SMU, 0 to ±1 A for HPSMU.

NOTE

Itarget and Irange

If the *Itarget* value is greater than the minimum measurement range specified by the *Irange* parameter, the measurement unit does not use the measurement ranges below the *Itarget* value, but uses the lowest range that covers the *Itarget* value.

Example Statements

```
OUTPUT @Hp4156;"LGI 1,1,14,1E-6"
```

LGV

The LGV command specifies the voltage monitor channel and its search parameters in the linear search measurement. This command is only for the US control mode.

This command ignores the RV command setting.

This command setting is cleared by the LGI, BGV or BGI command.

Execution Conditions

The MM 14 command must be entered before this command.

Syntax

`LGV` *`chnum`*`,`*`mode`*`,`*`Vrange`*`,`*`Vtarget`*

Parameters

chnum: Channel number of the unit used to measure voltage. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5 (MPSMU)
6 [a]	SMU6 (MPSMU or HPSMU)
23	VMU1
24	VMU2

a. For SMUs in the 41501A/B Expander.

mode: Search mode. 0 or 1.

0 : If the value of the measurement data is less than or equal to the value of *Vtarget*, it is the target data.

1 : If the measurement data is greater than or equal to *Vtarget*, it is the target data.

Vrange: Ranging type for voltage measurement. Integer expression.

range	**Ranging Type** [a]
10 (only for VMU in differential mode)	0.2 V limited auto ranging
11	2 V limited auto ranging
12 (for SMU and VMU in grounded mode)	20 V limited auto ranging
13 (for SMU)	40 V limited auto ranging
14 (for SMU)	100 V limited auto ranging
15 (only for HPSMU)	200 V limited auto ranging

a. Limited auto ranging uses the lowest available measurement range that covers the measurement voltage, where the specified range is the minimum range. For example, 20 V limited auto ranging uses the 20 V range to measure 1 V, and uses the 100 V range to measure 50 V.

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

0 to ±100 for SMU, 0 to ±200 for HPSMU.

NOTE

Vtarget and Vrange

If the *Vtarget* value is greater than the minimum measurement range specified by the *Vrange* parameter, the measurement unit does not use the measurement ranges below the *Vtarget* value, but uses the lowest range that covers the *Vtarget* value.

Example Statements

```
OUTPUT @Hp4156;"LGV 1,1,12,3"
```

LOP?

The LOP? query command requests the operation status of all source units (SMUs and VSUs) and stores the results in the 4155C/4156C output data buffer (query buffer).

Output data is always stored in the query buffer in ASCII format, regardless of the FMT command.

Syntax

`LOP?`

Query Response

In US command mode:

`LOP slot0 status,slot1 status..,slot8 status <LF^EOI>`

In US42 command mode:

`LOP slot1 status,slot2 status..,slot8 status <CR/LF^EOI>`

where, *slotN status* (N: 0 to 8) means the following:

Parameter	Description
slot0 status	Status number indicates the operation status of GNDU.
slot1 status	Status number indicates the operation status of SMU1.
slot2 status	Status number indicates the operation status of SMU2.
slot3 status	Status number indicates the operation status of SMU3.
slot4 status	Status number indicates the operation status of SMU4.
slot5 status [a]	Status number indicates the operation status of SMU5.
slot6 status [a]	Status number indicates the operation status of SMU6.
slot7 status	Status number indicates the operation status of VSU1 and VSU2.
slot8 status	Status number indicates the operation status of PGU1 and PGU2.

a. For SMUs in the 41501A/B Expander. If the HPSMU is installed in the 41501A/B, *slot6 status* returns the HPSMU status, and *slot5 status* does not have meaning.

Status numbers indicate whether the units are operating normally or not, as follows:

in US mode:

Available status numbers are 0 to 255 (decimal number) which represents an 8-bit binary number. See the table below for a description of each bit of the binary number.

Bit	Unit	Value	Description
7 (MSB)[a]	for All	0	No unit is installed, or the output switch is OFF.
		1	Unit is installed, and the output switch is ON.
6	for VSU	0	No VSU2 is installed, or the output switch is OFF.
		1	VSU2 is installed, and the output switch is ON.
	for PGU	0	No PGU2 is installed, or the output switch is OFF.
		1	PGU2 is installed, and the output switch is ON.
5	for VMU	0	VMU1 is not installed, or the output switch is OFF.
		1	VMU1 is installed, and the output switch is ON.
4	for VMU	0	VMU2 is not installed, or the output switch is OFF.
		1	VMU2 is installed, and the output switch is ON.
3	for SMU	0	SMU is in the voltage source mode.
		1	SMU is in the current source mode.
1 and 2	for SMU	00	SMU reaches voltage compliance.
		01	SMU reaches negative current compliance.
		10	SMU reaches positive current compliance.
	for VSU	01	VSU2 reaches the current limit.
		10	VSU1 reaches the current limit.
		11	Both VSU1 and VSU2 reach the current limit.
	for PGU	01	PGU2 reaches the current limit.
		10	PGU1 reaches the current limit.
		11	Both PGU1 and PGU2 reach the current limit.
0	for SMU	0	SMU is not oscillating.
		1	SMU is oscillating.

a. Most Significant Bit. Top digit of the 8-digit binary number which indicates the operation status.

For example, if *Slot1 status* is 128 (*10000000*), SMU1 status is as follows:

1. SMU1 is installed in the slot and output switch is ON.
2. SMU1 is in the voltage force mode.
3. SMU1 reaches the voltage compliance.
4. SMU1 is not oscillating.

in US42 mode:

Status numbers are two-digit decimal numbers. Available numbers and meanings are as follows:

Status Number	Description
00	No unit is installed, or the output switch is OFF.
01	SMU does not reach current compliance.
02	SMU does not reach voltage compliance.
03	SMU does not reach voltage compliance. Both VSUs operate normally.
10	Both VSUs reach the current limit.
11	SMU reaches voltage compliance.
12	SMU reaches positive current compliance.
13	SMU reaches negative current compliance.
20	SMU is oscillating.
30	Not applicable.

The HPSMU, in the 41501A/B, occupies two slots (5 and 6). The status number is returned for slot number 6, and 00 is returned for slot number 5.

Example Statements

```
OUTPUT @Hp4156;"LOP?"
ENTER @Hp4156;A$
```

*LRN?

The *LRN? (learn) query command requests information about the unit settings or the 4155C/4156C command parameter settings, and stores the results in the 4155C/4156C output data buffer (query buffer).

Output data is always stored in the query buffer in ASCII format, regardless of the FMT command.

Syntax

`*LRN? type`

Parameters and Query Response

type **:** Available values are 0 to 48. Integer expression. See below.

The parameter selects the type of query response.

For all query responses, the terminator depends on the control mode (US or US42 command) as follows:

US command mode: <LF^EOI>

US42 command mode: <CR/LF^EOI>

A description and the query response of each *type* is described below.

0 : Returns the output switch ON/OFF status:

CN [*chnum*[,*chnum* . . . [,*chnum*] . . .]]<terminator>

where, *chnum* is the channel number for the unit whose output switch is set to ON.

If no output switches are ON, the query response is:

CL<terminator>

1 to 28 : Returns the SMU/VSU/PGU source status, or the VMU operation mode.

The *type* parameter corresponds to the channel number of the unit as shown in the following table. For example, enter 27 for the PGU1 source status.

For SMU (*type*: 1 to 6):

If the output switch is ON, the query response is:

DV *chnum*,*range*,*voltage*[,*Icomp*[,*comp polarity*]]<terminator>
or DI *chnum*,*range*,*current*[,*Vcomp*[,*comp polarity*]]<terminator>

where, *range* is the present setting of the output range.

If the output switch is OFF, the query response is:
CL *chnum* <terminator>

The returned value of the *comp polarity* parameter may be different from the value you set, but the force command works properly.

For VSU or VMU (*type*: 21 to 24):

DV *VSU1 chnum*,*range*,*voltage*; or CL *VSU1 chnum*;
DV *VSU2 chnum*,*range*,*voltage*; or CL *VSU2 chnum*;
VM *VMU1 chnum*,*operation mode*;
VM *VMU2 chnum*,*operation mode*<terminator>

where, *range* is the present setting of the output range.

For GNDU (*type*: 26):

CN<terminator> or CL<terminator>

For PGU (*type*: 27 or 28):

If the output switch is ON, the query response is:

DV *chnum*,*range*,*voltage*;
SPG *chnum*,*pulse mode*[,*base*[,*pulse*,*Td*,*Tw*,*Tl*,*Tt*,*Tp*,*count*]];
POR *chnum*,*Zout*<terminator>

If the output switch is OFF, the query response is:

CL *chnum*<terminator>

type **or Channel No.**	**Unit**	***type*** **or Channel No.**	**Unit**
1	SMU1	21	VSU1
2	SMU2	22	VSU2
3	SMU3	23	VMU1
4	SMU4	24	VMU2
5 [a]	SMU5	26	GNDU
6 [a]	SMU6	27	PGU1
		28	PGU2

a. For SMUs in the 41501A/B expander. For HPSMU, the channel number is 6.

29 : Not used.

30 : Returns the filter ON/OFF status:

FL 0 [*off ch*[,*off ch* . . . [,*off ch*] . . .];FL 1 [*on ch*[,*on ch* . . . [,*on ch*] . .] <terminator>

If all units are Filter OFF, the query response is:

FL 0<terminator>

If all units are Filter ON, the query response is:

FL 1<terminator>

31 : Returns the parameter values of the TM, AV, CM, FMT, and MM commands:

TM *trigger mode*;AV *number*[,*mode*];CM *auto calibration mode*;
FMT *output data format*,*output data mode*
[;MM *measurement mode*[,*chnum*[,*chnum*...[,*chnum*]...]]]<terminator>

If the present *averaging number* parameter setting of the AV command is a negative value, the *LRN? 31 command response of the *averaging number* will be –1.

32 : Returns the measurement ranging status (parameter values of the RI and RV commands):

RI *chnum*,*I measurement range*[,*ranging mode*]
or RV *chnum*,*V measurement range*[,*ranging mode*]
[;RI *chnum*,*I measurement range*[,*ranging mode*]]
or [;RV *chnum*,*V measurement range*[,*ranging mode*]]
:
:
[;RI *chnum*,*I measurement range*[,*ranging mode*]]
or [;RV *chnum*,*V measurement range*[,*ranging mode*]]<terminator>

In US42 command mode, if the 4142B-like query response is specified, the *ranging mode* is not returned. If the fixed ranging is specified, the returned value of the measurement range will be a negative value (–1× *range*).

33 : Returns the staircase sweep measurement settings (parameter values of the WM, WT, WV, WI, WSV and WSI commands):

WM *automatic sweep abort function*,*output after sweep*;
WT *hold time*,*delay time*[,*step delay time*]
[;WV *ch*,*mode*,*range*,*start*,*stop*,*nop*[,*Icomp* [,*pcomp*[,*rmode*]]]]
or [;WI *ch*,*mode*,*range*,*start*,*stop*,*nop*[,*Vcomp*[,*pcomp*[,*rmode*]]]]
[;WSV *ch*,*range*,*start*,*stop*[,*Icomp*[,*pcomp*[,*rmode*]]]]
or [;WSI *ch*,*range*,*start*,*stop*[,*Vcomp*[,*pcomp*[,*rmode*]]]]<terminator>

The returned value of the *ranging mode* parameter can be different than the value you set but the sweep command works properly.

When specifying the 4142B-like query response in the US42 command mode, the *step delay time* and *ranging mode* are not returned.

34 : Returns the pulsed source settings (parameter values of the PT, PV, PI, PWV and PWI commands):

PT *hold*,*width*[,*period*[,*trigger delay*[,*priority*]]]
[;PV *chnum*,*output range*,*base voltage*,*pulse voltage* [,*Icomp*]]
or [;PI *chnum*,*output range*,*base current*,*pulse current* [,*Vcomp*]]
[;PWV *ch*,*mode*,*range*,*base*,*start*,*stop*,*nop*[,*Icomp*[,*rmode*]]]
or [;PWI *ch*,*mode*,*range*,*baset*,*start*,*stop*,*nop*[,*Vcomp*[,*rmode*]]]
<terminator>

The returned value of the *ranging mode* parameter may be different from the value you set, but the sweep command works properly.

When specifying the 4142B-like query response in US42 command mode, the *trigger delay*, *priority* and *ranging mode* are not returned.

35 to 38 : Not used.

39 : Returns the trigger mode status:

STG 0 *state*,*polarity*;STG 1 *state*,*polarity*<terminator>

40 : Returns the channel assignment information:

ACH *4142ch*,*chnum*;ACH *4142ch*,*chnum* . . .
;ACH *4142ch*,*chnum*<terminator>

If no channel number is defined by the ACH command, the query response is:

ACH<terminator>

41 : Returns the settings of the US42 command:

US42 *mode*<terminator>

If the 4155C/4156C is not in the US42 command mode, the following response is returned.

US42 0<terminator>

42 : Returns the zero offset cancel ON/OFF status:

SOC 0,*chnum*[;SOC 0,*chnum* . . . [;SOC 0,*chnum*] . . .];
SOC 1,*chnum*[;SOC 1,*chnum* . . . [;SOC 1,*chnum*] . . .]<terminator>

If all units are set to Zero offset cancel OFF, the query response is:

SOC 0<terminator>

If all units are set to Zero offset cancel ON, the query response is:

SOC 1<terminator>

43 : Returns the integration time settings:

SLI *type*;SIT 1,*time*;SIT 3,*time*;
AZ 0 or AZ 1
<terminator>

where, if the present *number* parameter setting of the AV command is a negative value, the *LRN? 43 command response will be:

SLI 3;SIT 1,*time*;SIT 3, $plc \times |number|$

The value of *plc* is 20 msec for a line frequency of 50 Hz, and 16.7 msec for a line frequency of 60 Hz.

44 : Returns the Resistor Box settings:

RBC 1,*resistance*;RBC 2,*resistance*<terminator>

45 : Returns the SMU/PGU selector settings:

SSP 0,*mode*;SSP 1,*mode*;SSP 2,*mode*;SSP 3,*mode*<terminator>

46 : Returns the SMU measurement mode:

CMM *chnum*,*mode* . . . . ;CMM *chnum*,*mode*<terminator>

47 : Returns the sampling measurement settings (parameter values of the MT, MSC, MV, MI and MP commands):

MSC *stop mode*
;MT *hold time*,*init interval*,*sampling points*
[;MV *chnum*,*output range*,*base*,*bias*[,*Icomp*]
[;MV . . . . :
:
[;MV *chnum*,*output range*,*base*,*bias*[,*Icomp*]]...]]
[;MI *chnum*,*output range*,*base*,*bias*,[*Vcomp*]
[;MI . . . . :
:
[;MI *chnum*,*output range*,*base*,*bias*,[*Vcomp*]]...]]
[;MP *chnum*,*mode*,*base*,*bias*,*delay*,*width*,*lead*, *trail*,*period*,*count*
[;MP . . . . :
[;MP *chnum*,*mode*,*base*,*bias*,*delay*,*width*,*lead*, *trail*,*period*,*count*]...]]
<terminator>

48 : Returns the stress settings (parameter values of the STP, STT, STM, STI and STV commands):

STM *stop mode*;STT *hold_time*,*stress_mode*,*stress_time*[,*period*]
[;STI *source*,*chnum*,*range*,*base*,*stress*,*Vcomp*]
or [;STV *source*,*chnum*,*range*,*base*,*stress*,*Icomp*]
;STP *source*,*ch*,*mode*,*base*,*stress*[,*delay*[,*width*[,*leading*[,*trailing*]]]]
:
<terminator>

If you set the wrong values for the *period* parameter of the STT command and for the *delay* and *width* parameters of the STP command, the settings are automatically changed and you will see values different from the ones you set.

49 : Returns the quasi-static CV measurement settings (parameter values of the QSM, QSL, QST, QSR and QSV commands):

QSM *condition*,*output*
;QSL *data*,*compen*
;QST *integ*,*hold*,*delay1*[,*delay2*]
;QSR *range*
[;QSV *chnum*,*mode*,*range*,*start*,*stop*,*cvoltage*,*step*,[*Icomp*]]
<terminator>

50 : Returns the linear search measurement settings (parameter values of the LSTM, LSVM,WM, LGI, LGV, LSV, LSI, LSSV and LSSI commands):

LSTM *hold*,*delay*
;LSVM *mode*
;WM *automatic sweep abort function*,*output after sweep*
[;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*]]
<terminator>

51 : Returns the binary search measurement settings (parameter values of the BSM, BST, BSVM, BGI, BGV, BSV, BSI, BSSV and BSSI commands):

BSM *mode*
;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*]]
<terminator>

52 : Returns the sweep stop condition settings:

ESC *onoff* [,*chnum*,*condition1*,*value1*,*condition2*,*value2*]<terminator>

Example Statements

```
DIM A$[200]
OUTPUT @Hp4156;"*LRN? 1"
ENTER @Hp4156;A$
```

LSI

The LSI command specifies the current output channel and its source parameters in the linear search measurement. This command is only for the US control mode.

This command setting is cleared by the LSV, BSV or BSI command.

After the search stops, the source output goes to the source *start* value.

Execution Conditions

The MM 14 command must be entered before this command.

Syntax

`LSI chnum,range,start,stop,step[,Vcomp]`

If you enter this command into the program memory (see the ST command), do not omit the *Vcomp* parameter. It is necessary when using the internal program memory.

Parameters

chnum: Channel number of the unit used to force current. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5 (MPSMU)
6 [a]	SMU6 (MPSMU or HPSMU)

a. For SMUs in the 41501A/B Expander.

range: Ranging type for current output. Integer expression.

range	Ranging Type [a]
0	Auto ranging
9 (only for 4156C)	10 pA limited auto ranging
10 (only for 4156C)	100 pA limited auto ranging
11	1 nA limited auto ranging
12	10 nA limited auto ranging

range	Ranging Type [a]
13	100 nA limited auto ranging
14	1 μA limited auto ranging
15	10 μA limited auto ranging
16	100 μA limited auto ranging
17	1 mA limited auto ranging
18	10 mA limited auto ranging
19	100 mA limited auto ranging
20 (only for HPSMU)	1 A limited auto ranging

a. Auto ranging uses the lowest available output range that covers the *start* and *stop* values. Limited auto ranging uses the specified range or above. For example, 10 μA limited auto ranging uses the 10 μA range to force 1 nA start value to 1 μA stop value.

start: Source start current (in A). Numeric expression. See Table 1-11.

The *start* and *stop* parameters must have different values.

0 to ±100E–3 for SMU, 0 to ±1 for HPSMU

stop: Source stop current (in A). Numeric expression. See Table 1-11.

The *start* and *stop* parameters must have different values.

0 to ±100E–3 for an SMU, 0 to ±1 for an HPSMU

step: Source step current (in A). Numeric expression. See Table 1-11.

When the value of *start* < *stop*, the *step* must be positive, and when the value of *start* > *stop*, the *step* must be negative. The number of steps must be 1001 or less.

Vcomp: Voltage compliance value (in V). Numeric expression. See Table 1-11.

If you do not specify this parameter, *Vcomp* remains at its previous value.

Example Statements

```
OUTPUT @Hp4156;"LSI 1,0,0,1E-6,1E-8,10"
```

Table 1-11 Available Parameter Values for LSI Command

Output Range	Resolution in A	*start* and *stop* in A	Maximum *Vcomp* in V	Remarks
10 pA	10E–15	0 to ±10E–12	±100	For 4156C.
100 pA	10E–15	0 to ±100E–12	±100	
1 nA	100E–15	0 to ±1E–9	±100	
			±200	For HPSMU.
10 nA	1E–12	0 to ±10E–9	±100	
			±200	For HPSMU.
100 nA	10E–12	0 to ±100E–9	±100	
			±200	For HPSMU.
1 µA	100E–12	0 to ±1E–6	±100	
			±200	For HPSMU.
10 µA	1E–9	0 to ±10E–6	±100	
			±200	For HPSMU.
100 µA	10E–9	0 to ±100E–6	±100	
			±200	For HPSMU.
1 mA	100E–9	0 to ±1E–3	±100	
			±200	For HPSMU.
10 mA	1E–6	0 to ±10E–3	±100	
			±200	For HPSMU.
100 mA	10E–6	0 to ±20E–3	±100	
		to ±50E–3	±40	
		to ±100E–3	±20	
	100E–6	0 to ±50E–3	±200	For HPSMU.
		to ±100E–3	±100	
1 A	100E–6	0 to ±50E–3	±200	
		to ±125E–3	±100	
		to ±500E–3	±40	
		to ±1	±20	

LSSI

The LSSI command specifies the synchronous current output channel and its source parameters in the linear search measurement. This command is only for the US control mode.

The synchronous source output will be:

Synchronous source output = LSI source output + offset current

where the LSI source output is the output set by the LSI command. This command cannot be used with the LSV command (voltage force linear search).

This command setting is cleared by the LSSV, BSSV, or BSSI command.

Execution Conditions

The MM 14 command must be entered before this command.

The LSI command must be entered before this command.

Syntax

`LSSI chnum,polarity,offset[,Vcomp]`

If you enter this command into the program memory (see the ST command), do not omit the *Vcomp* parameter. It is necessary when using the internal program memory.

Parameters

chnum: Channel number of the unit used for synchronous current source. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5 (MPSMU)
6 [a]	SMU6 (MPSMU or HPSMU)

a. For SMUs in the 41501A/B Expander.

polarity: Polarity of the LSI source output. 0 (negative) or 1 (positive).

if you set *polarity*=0, synchronous output = –LSI output +*offset*.

if you set *polarity*=1, synchronous output = LSI output + *offset*.

offset: Offset current (in A). Numeric expression.

Available values: 0 to ±0.1 for SMU, 0 to ±1 for HPSMU.

The synchronous output level must *not* be greater than the output range specified by the LSI command.

Vcomp: Voltage compliance value (in V). Numeric expression. If you do not specify this parameter, *Vcomp* remains at its previous value.

Example Statements

```
OUTPUT @Hp4156;"LSSI 1,1,1E-6,5"
```

See Also

Refer to the LSI command for the source output value, output range, and the available compliance values.

LSSV

The LSSV command specifies the synchronous voltage output channel and its source parameters in the linear search measurement. This command is only for the US control mode.

The synchronous source output will be:

Synchronous source output = LSV source output + offset voltage

where the LSV source output is the value set by the LSV command. This command cannot be used with the LSI command (current force linear search).

This command setting is cleared by the LSSI, BSSV, or BSSI command.

Execution Conditions

The MM 14 command must be entered before this command.

The LSV command must be entered before this command.

Syntax

`LSSV` *`chnum`*`,`*`polarity`*`,`*`offset`*`[,`*`Icomp`*`]`

If you enter this command into the program memory (see the ST command), do not omit the *Icomp* parameter. It is necessary when using the internal program memory.

Parameters

chnum: Channel number of the unit used for synchronous voltage source. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5 (MPSMU)
6 [a]	SMU6 (MPSMU or HPSMU)
21	VSU1
22	VSU2

a. For SMUs in the 41501A/B Expander.

***polarity*:** Polarity of the LSV source output. 0 (negative) or 1 (positive).

if you set *polarity*=0, synchronous output = –LSV output +*offset*.

if you set *polarity*=1, synchronous output = LSV output + *offset*.

***offset*:** Offset voltage (in V). Numeric expression.

Available values: 0 to ±100 for an SMU, 0 to ±200 for an HPSMU.

Synchronous output must *not* be over the output range specified by the LSV command.

***Icomp*:** Current compliance value (in A). Numeric expression. If you do not specify this parameter, *Icomp* remains at its previous value. Zero amps (0 A) is not a valid value for the *Icomp* parameter.

Example Statements

```
OUTPUT @Hp4156;"LSSV 1,0,5,1E-6"
```

See Also

Refer to the LSV command for the source output value, output range, and the available compliance values.

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 4155C/4156C.

The output data is always stored in the query buffer in ASCII format, regardless of the FMT command.

Syntax

To get the catalog of internal memory programs:

`LST?`

To get the list of a specific internal memory program:

`LST? prog No.`

Parameters

prog No.: Internal memory program number. 1 to 255. Integer expression.

Query Response

Response by LST?:

```
Number of programs,[prog No.[,prog No.... [,prog No.]...]]
<terminator>
```

Response by LST? *program No.*:

```
ST prog No.<terminator>
[saved command #1]<terminator>
[saved command #2]<terminator>
          :
          :
[saved command #n]<terminator>
END<terminator>
```

To read this listing, set up a loop containing the ENTER command, and continue the loop until encountering the END command. The commands are read, one at a time, until the END command is encountered.

In the query response, <terminator> is as follows.

US command mode: <LF^EOI>

US42 command mode: <CR/LF^EOI>

Example Statements

Example of LST? :

```
OUTPUT @Hp4156;"LST?"
ENTER @Hp4156;A$
```

Example of LST? *prog No.* :

```
OUTPUT @Hp4156;"ST 3;CN;DV 1,0,20,1E-6;TI 1,0;CL"
OUTPUT @Hp4156;"END"
OUTPUT @Hp4156;"LST? 3"
LOOP
  ENTER @Hp4156;A$
  PRINT A$
EXIT IF A$="END"
END LOOP
```

LSTM

The LSTM command sets the timing parameters for the linear search measurement. This command is only for the US control mode.

Execution Conditions

The MM 14 command must be entered before this command.

Syntax

`LSTM hold,delay`

Parameters

hold : Hold time (in seconds). Numeric expression. This value is the time from the measurement trigger to the beginning of the delay time.

0 to 655.35 sec. 0.01 sec resolution. Initial setting = 0.

delay : Delay time (in seconds). Numeric expression. This value is the time from the end of hold time or the change of source output value to the start of the measurement.

0 to 65.535 sec. 0.0001 sec resolution. Initial setting = 0.

Example Statements

```
OUTPUT @Hp4155;"LSTM 5,0.1"
```

LSV

The LSV command specifies the voltage output channel and its source parameters in the linear search measurement. This command is only for the US control mode.

This command setting is cleared by the LSI, BSV, or BSI command.

After search stops, source output goes to the source *start* value.

Execution Conditions

The MM 14 command must be entered before this command.

Syntax

`LSV chnum,range,start,stop,step[,Icomp]`

If you enter this command into the program memory (see the ST command), do not omit the *Icomp* parameter. It is necessary when using the internal program memory.

Parameters

chnum: Channel number of the unit used to force voltage. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5 (MPSMU)
6 [a]	SMU6 (MPSMU or HPSMU)
21	VSU1
22	VSU2

a. For SMUs in the 41501A/B Expander.

range: Ranging type for voltage output. Integer expression.

range	**Ranging Type** [a]
0	Auto ranging
11 (for SMU)	2 V limited auto ranging
12	20 V limited auto ranging
13 (for SMU)	40 V limited auto ranging
14 (for SMU)	100 V limited auto ranging
15 (only for HPSMU)	200 V limited auto ranging

a. Auto ranging uses the lowest available output range that covers the *start* and *stop* values. Limited auto ranging uses the specified range or above. For example, 20 V limited auto ranging uses the 20 V range to force 1 V start value to 10 V stop value.

start: Source start voltage (in V). Numeric expression. See Table 1-12.

The *start* and *stop* parameters must have different values.

0 to ±100 for SMU, 0 to ±200 for HPSMU.

stop: Source stop voltage (in V). Numeric expression. See Table 1-12.

The *start* and *stop* parameters must have different values.

0 to ±100 for SMU, 0 to ±200 for HPSMU.

step: Source step voltage (in V). Numeric expression. See Table 1-12.

When the value of *start* < *stop*, the *step* must be positive, and when the value of *start* > *stop*, the *step* must be negative. The number of steps must be 1001 or less.

Icomp: Current compliance value (in A). Numeric expression. See Table 1-12. If you do not specify this parameter, *Icomp* remains at its previous value. Zero amps (0 A) is not allowed for *Icomp*.

Example Statements

```
OUTPUT @Hp4156;"LSV 1,0,0,20,.5,1E-6"
```

Table 1-12 **Available Parameter Values for LSV Command**

Output Range	Resolution in V	*start* and *stop* in V	Maximum *Icomp* in A	Remarks
2 V	100E–6	0 to ±2	±100E–3	For SMU.
			±1	For HPSMU.
20 V	1E–3	0 to ±20	±100E–3	For SMU.
			±1	For HPSMU.
			–	For VSU.
40 V	2E–3	0 to ±40	±50E–3	For SMU.
			±500E–3	For HPSMU.
100 V	5E–3	0 to ±100	±20E–3	For SMU.
			±125E–3	For HPSMU.
200 V	10E–3	0 to ±200	±50E–3	

LSVM

The LSVM command selects the data output mode for the linear search measurement. This command is only for the US control mode.

Execution Conditions

The MM 14 command must be entered before this command.

Syntax

`LSVM mode`

Parameters

mode : Data output mode. Integer expression. 0 (result only) or 1 (all data output).

0 : Outputs *Search*, *Source_data*, and *Data*.

1 : Outputs *D1*, *D2*, ..., *Search*, *Source_data*, and *Data*.

where,

Search is the search status.

Source_data is the source output data of the search target.

Data is the measurement data of the search target.

Dn (*n*: integer) is the data of the *n* th measurement point, and contains the *Source_data* and *Measurement_data* of each measurement point.

For the data output format, refer to “Data Output Format” on page 1-11.

Example Statements

```
OUTPUT @Hp4155;"LSVM 1"
```

MCC

The MCC command clears the settings of the specified sampling channels defined by the MV, MI or MP command.

Syntax

```
MCC [chnum[,chnum...[,chnum[,chnum]]...]]
```

Parameters

chnum : Channel number of the unit to clear the settings. Integer expression.

You can specify a maximum of 16 *chnum*s at once as the MCC command parameters.

If you do not specify *chnum*, the MCC command clears the settings of the all sampling channels.

chnum	**Unit**
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6
21	VSU1
22	VSU2
27	PGU1
28	PGU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

Example Statements

```
OUTPUT @Hp4156;"MCC"
OUTPUT @Hp4156;"MCC 1,2,3"
```

MI

The MI command specifies the dc current source (SMU) synchronized with the sampling measurements, and its parameters.

The output starts at the beginning of the sampling measurements (starts by the XE command). To stop the output, use the DI command. The output goes to the output value specified by the DI command.

Execution Conditions

If the voltage compliance is greater than ±40 V, the interlock circuit must be shorted.

Syntax

`MI` *`chnum`*`,`*`range`*`,`*`base`*`,`*`bias`*`[,`*`Vcomp`*`]`

If you enter the MI command into the program memory (see the ST command), do not omit the *Vcomp* parameter. *Vcomp* is necessary when using the internal program memory.

Parameters

chnum: Channel number of the unit used to force the current. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

range: Ranging type for current output. Integer expression.

range	Ranging Type [a]
0	Auto ranging
9 (only for 4156C)	10 pA limited auto ranging
10 (only for 4156C)	100 pA limited auto ranging

range	**Ranging Type** [a]
11	1 nA limited auto ranging
12	10 nA limited auto ranging
13	100 nA limited auto ranging
14	1 μA limited auto ranging
15	10 μA limited auto ranging
16	100 μA limited auto ranging
17	1 mA limited auto ranging
18	10 mA limited auto ranging
19	100 mA limited auto ranging
20 (only for HPSMU)	1 A limited auto ranging

a. Auto ranging uses the lowest output range (available for the unit) that covers both *bias* and *base* values. Limited auto ranging uses the specified range or above. For example, 10 μA limited auto ranging uses the 100 mA range to force 50 mA with 0 A base current.

base: Base current (in A). Numeric expression. Set the source unit output value which has been forced before the XE command. This minimizes the spike. See Table 1-13.

0 to ±100E–3 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±1 (for HPSMU in 41501A/B)

bias: Output bias current (in A). Numeric expression. See Table 1-13.

0 to ±100E–3 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±1 (for HPSMU in 41501A/B)

Vcomp: Voltage compliance value (in V). Numeric expression. See Table 1-13.

If this parameter is not specified, then *Vcomp* is set to the previous setting.

Example Statements

```
OUTPUT @Hp4156;"MI 1,18,0,5E-5,10"
```

Table 1-13 **Available Parameter Values for MI Command**

Output Range	Resolution in A [a]	*bias* and *base* in A	Maximum *Vcomp* in V	Remarks
10 pA	10E−15	0 to ±10E−12	±100	For 4156C.
100 pA	10E−15	0 to ±100E−12	±100	
1 nA	100E−15	0 to ±1E−9	±100	For SMU.
			±200	For HPSMU.
10 nA	1E−12	0 to ±10E−9	±100	For SMU.
			±200	For HPSMU.
100 nA	10E−12	0 to ±100E−9	±100	For SMU.
			±200	For HPSMU.
1 μA	100E−12	0 to ±1E−6	±100	For SMU.
			±200	For HPSMU.
10 μA	1E−9	0 to ±10E−6	±100	For SMU.
			±200	For HPSMU.
100 μA	10E−9	0 to ±100E−6	±100	For SMU.
			±200	For HPSMU.
1 mA	100E−9	0 to ±1E−3	±100	For SMU.
			±200	For HPSMU.
10 mA	1E−6	0 to ±10E−3	±100	For SMU.
			±200	For HPSMU.
100 mA	10E−6	0 to ±20E−3	±100	For SMU.
		to ±50E−3	±40	
		to ±100E−3	±20	
	100E−6	0 to ±50E−3	±200	For HPSMU.
		to ±100E−3	±100	
1 A	100E−6	0 to ±50E−3	±200	
		to ±125E−3	±100	
		to ±500E−3	±40	
		to ±1	±20	

a. Minimum resolution is Range×5E−5. However the setting accuracy is not guaranteed for the resolution less than the value shown in the table.

MM

The MM command sets the measurement mode and the measurement units.

This command is not required for the high speed spot measurements using the following commands.

TI, TI?, TV, TV?, TTI, TTI?, TTV, TTV?

Syntax

For spot, staircase sweep, sampling, 1ch pulsed spot, pulsed sweep, and staircase sweep with pulsed bias measurements:

`MM mode,chnum[,chnum...[,chnum]...]`

For quasi-static CV measurement:

`MM 13[,chnum]`

For stress force, binary search and linear search measurements:

`MM mode`

Parameters

mode : Measurement mode. Integer expression.

mode	Description	Related Source Setup Command
1	Spot measurement	DI, DV, TDI, TDV
2	Staircase sweep measurement	WI, WV, WT, WM, WSI, WSV
3	1ch pulsed spot measurement	PI, PV, PT
4	Pulsed sweep measurement	PWI, PWV, PT, WM, WSI, WSV
5	Staircase sweep with pulsed bias measurement	WI, WV, WT, WM, PI, PV, PT
6 to 9	Not defined.	
10	Sampling measurement	MI, MV, MP, MT, MSC, MCC
11	Stress force	POR, STI, STV, STP, STT, STM, STC
12	Not defined.	

mode	Description	Related Source Setup Command
13 [a]	Quasi-static CV measurement	QSV, QSI, QSR, QSM, QSL, QSZ
14 [a]	Linear search measurement	LSV, LSI, LGV, LGI, LSTM, LSSV, LSSI, LSVM, WM
15 [a]	Binary search measurement	BSV, BSI, BGV, BGI, BSM, BST, BSSV, BSSI, BSVM

a. This measurement is available only for the US control mode.

chnum **:** The channel number of the unit which executes the measurement. This parameter is not available for the linear search (MM 14) and binary search (MM 15) measurements.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6
23 [b]	VMU1
24 [b]	VMU2

a. For MPSMUs in the 41501A/B expander. For HPSMU, the channel number is 6, not 5.
b. Not available for the quasi-static CV (MM 13), linear search (MM 14), and binary search (MM 15) measurements.

A maximum of 8 units can be used for the measurements. But, for the following measurement mode, you can use only one measurement unit (only one *chnum* can be defined in the MM command).

1. Quasi-static CV measurement (MM 13)
2. 1ch pulsed spot measurements (MM 3) with "keep pulse width"
3. Pulsed sweep measurements (MM 4) with "keep pulse width"
4. Staircase sweep with pulsed bias measurements (MM 5) with "keep pulse width"
5. Sampling measurement (MM 10) with the sampling interval less than 2 msec (see the MT command)

where, "keep pulse width" means the measurement setup which the PT command *priority* parameter is set to 0 or default setting (see the PT command).

Remarks

For the SMU or HPSMU, the SMU measurement mode is defined by the CMM command. Refer to the CMM command.

The measurement range is defined by the RI or RV command. Refer to the RI and RV command.

To execute the measurement, use the XE command. Refer to the XE command. The measurement unit performs a measurement even if the source output value is 0.

If you specify multiple measurement units in the MM command, the measurement is performed by the units in the order defined in the MM command.

For the 1ch pulsed spot, pulsed sweep or staircase sweep with pulsed bias measurements, the WT command is ignored.

For the 1ch pulsed spot, pulsed sweep or staircase sweep with pulsed bias measurements with "keep pulse width" (PT command *priority* parameter setting), the AV and SLI commands are ignored. The integration time is automatically set to 80 μsec.

For the sampling measurement with a sampling interval of less than 2 msec, the AV and SLI commands are ignored.

Example Statements

```
OUTPUT @Hp4156;"MM 1,1"
OUTPUT @Hp4156;"MM 2,1,3"
```

MP

The MP command specifies the PGU synchronized with the sampling measurements, and its parameters.

The output starts at the beginning of the sampling measurements (starts by the XE command). To stop the output, use the DV command. Or to stop the pulse output, use the SPP command. The output goes to the output value specified by the DV command or the base value specified by the MP command.

If you specify the pulse output mode and pulse count (not free run), the pulse output starts at the beginning of the sampling measurements, and the PGU forces the pulses specified by *count*.

Execution Conditions

If the output voltage is greater than ±40 V, the interlock circuit must be shorted.

Syntax

`MP chnum,mode,base,bias[,Td,Tw,Tl,Tt,Tp,count]`

Parameters

chnum : Channel number of PGU 27 or 28. Integer expression.

27: PGU1

28: PGU2

mode : Output mode. 0 or 1. Integer expression.

0: dc voltage output. Set *base* and *bias*.

1: Pulse voltage output. Set all parameters.

base : Base voltage (in V). Numeric expression.

0 to ±40 V.

in 4 mV resolution (0 to ±20 V), in 8 mV resolution (±20 to ±40 V).

bias : Bias voltage (in V). Numeric expression.

0 to ±40 V.

in 4 mV resolution (0 to ±20 V), in 8 mV resolution (±20 to ±40 V).

Td : Delay time (in seconds). Only for pulse output.

0 to 10 sec. Numeric expression. See Table 1-14.

Tw : Pulse width (in seconds). Only for pulse output.

1 μsec to 9.99 sec. Numeric expression. See Table 1-14.

Tl **:** Leading edge transition time (in seconds). Only for pulse output.

100 nsec to 10 msec. Numeric expression. See Table 1-15.
Restrictions: $Tl \leq Tw \times 0.8$

Tt **:** Trailing edge transition time (in seconds). Only for pulse output.

100 nsec to 10 msec. Numeric expression. See Table 1-15.
Restrictions: $Tt \leq (Tp - Tw) \times 0.8$

Tp **:** Pulse period (in seconds). Only for pulse output.

2 μsec to 10 sec. Numeric expression. See Table 1-14.

Tp parameter setting is effective for both PGU1 and PGU2. If you use both PGUs, the pulse period setting must be the same. Check the pulse period setting value of the MP command and the SPG command in your program.

count **:** Pulse count. Only for pulse output.

0 to 65535. Numeric expression.

count=0 specifies free run pulse force.

count parameter setting is effective for both PGU1 and PGU2. If you use both PGUs, the pulse count setting must be the same. Check the pulse count setting value of the MP command and the SPG command in your program.

If you enter the MP command into the internal program memory, do not set *count*=0. Free run pulse output is not available.

Example Statements

```
OUTPUT @Hp4156;"MP 28,0,0,5"
OUTPUT @Hp4156;"MP 28,1,0,5,5E-6,1E-5,1E-6,1E-6,5E-5,0"
```

Table 1-14 Ranges of Pulse Period, Pulse Width and Delay Time for MP Command

Range[a]	*Tp* in sec	*Td* in sec	*Tw* in sec	Resolution in sec
1	2E–6 to 100E–6	0 to 100E–6	1E–6 to 99.9E–6	0.1E–6
2	100E–6 to 1E–3	0 to 1E–3	1E–6 to 999E–6	1E–6
3	1E–3 to 10E–3	0 to 10E–3	10E–6 to 9.99E–3	10E–6
4	10E–3 to 100E–3	0 to 100E–3	100E–6 to 99.9E–3	100E–6
5	100E–3 to 1	0 to 1	1E–3 to 999E–3	1E–3
6	1 to 10	0 to 10	10E–3 to 9.99	10E–3

a. Settings of *Tp*, *Td* and *Tw* for a PGU must be in the same range. If you use two PGUs, these three parameters must be set in the same range for both PGUs.

Table 1-15 Leading and Trailing Edge Transition Time for MP Command

Range[a]	*Tl* or *Tt* in sec	Resolution in sec
1	100E–9 to 1E–6	1E–9
2	500E–9 to 10E–6	10E–9
3	5E–6 to 100E–6	100E–9
4	50E–6 to 1E–3	1E–6
5	500E–6 to 10E–3	10E–6

a. Leading time and trailing time for a PGU must be in the same range.

MSC

The MSC command sets the automatic abort condition (stop condition) for the sampling measurement.

Syntax

`MSC abort`

Parameters

abort **:** Automatic abort condition (stop condition). Integer expression. The following values are available:

abort	**Abort condition**
1	Disables the automatic abort function.
2	One of following occurs. - Compliance on the measurement unit. - Compliance on the non-measurement unit. - Overflow on the AD converter. - Oscillation on any unit.
4	Compliance on the non-measurement unit.
8	Compliance on the measurement unit.
16	Overflow on the AD converter.
32	Oscillation on any unit.

If you want to set multiple abort conditions, specify the sum of the *abort* values for the abort conditions shown above. This is allowed for *abort*=4 to 32.

For example, if you want to enable the abort function when compliance on the measurement unit (*abort*=8) or oscillation (*abort*=32) are detected, set *abort* to 40 (8 + 32).

Output Data

The 4155C/4156C returns the all measurement data until when any abort condition is detected. The output format of the last data will be as shown below:

Measurement Mode	Data for the index when abort occurs	
	if aborted in the index n	**if aborted in the last index**
1 channel sampling	[*Index_dummy*,]*Dummy* The data is returned after the nth *Data*.	[*Index*,]*Data*
Multi channel sampling	[*Index_dummy*,]*Dummy* The data is returned after the m×n th *Data*.	[*Index*,]*Data*, ... *Data*

The status of the last data will be greater than 128 (EOD).

where,

Data: Measurement data.

Dummy: Dummy of the measurement data.

Index: Data index. Selected by the FMT command.

Index_dummy: Dummy of the data index. Selected by the FMT command.

m: Number of the measurement channels.

Example Statements

```
OUTPUT @Hp4156;"MSC 32"
```

MT

The MT command sets the sampling measurement conditions.

Syntax

```
MT hold,interval,points
```

Parameters

hold : Hold time (in seconds).

–0.03 to 655.35 sec. Numeric expression.

interval : Initial interval time (in seconds). This value is the initial value of the sampling interval.

0.00006 to 65.535 sec. Numeric expression.

points : Sampling points.

1 to 10001. Numeric expression.

Remarks

Sampling points depend on the sampling interval setting (*interval*). And the measurement points depend on the measurement time (settings of the AV, AZ, SIT and SLI commands).

If the sampling interval is longer than the measurement time, the number of measurement points will be same as the number of sampling points. But if the sampling interval is shorter than the measurement time, the number of measurement points is less than the number of sampling points.

For example, if the measurement time is longer than the sampling interval and shorter than twice the sampling interval, the number of measurement points will be half the number of sampling points.

Example Statements

```
OUTPUT @Hp4156;"MT 5,0.1,1001"
```

MV

The MV command specifies the voltage source (SMU or VSU) synchronized with the sampling measurement, and its parameters.

The output starts at the beginning of the sampling measurements (starts by the XE command). To stop the output, use the DV command. The output goes to the output value specified by the DV command.

Execution Conditions

If the output voltage is greater than ±40 V, the interlock circuit must be shorted.

Syntax

`MV chnum,range,base,bias[,Icomp]`

If you enter the MV command into the program memory (see the ST command), do not omit the *Icomp* parameter. *Icomp* is necessary when using the internal program memory.

Parameters

***chnum*:** Channel number of the unit used to force voltage. Integer expression.

chnum	Unit	*chnum*	Unit
1	SMU1	5 [a]	SMU5
2	SMU2	6 [a]	SMU6
3	SMU3	21	VSU1
4	SMU4	22	VSU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

***range*:** Range type for voltage output. Integer expression.

range	Ranging Type [a]
0	Auto ranging
11 (for SMU)	2 V limited auto ranging
12	20 V limited auto ranging

range	**Ranging Type** [a]
13 (for SMU)	40 V limited auto ranging
14 (for SMU)	100 V limited auto ranging
15 (only for HPSMU)	200 V limited auto ranging

a. Auto ranging uses the lowest output range (available for the unit) that covers both the *bias* value and the *base* value. Limited auto ranging uses the specified range or above. For example, 20 V limited auto ranging uses the 100 V range to force 50 V with 0 V base voltage.

base: Base voltage (in V). Numeric expression. Set the source unit output value which has been forced before the XE command. This minimizes the spike. See Table 1-16.

0 to ±100 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±200 (for HPSMU in 41501A/B)

0 to ±20 (for VSU)

bias: Output bias voltage (in V). Numeric expression. See Table 1-16.

0 to ±100 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±200 (for HPSMU in 41501A/B)

0 to ±20 (for VSU)

Icomp: Current compliance value (in A). Numeric expression. See Table 1-16.

This parameter is not available for VSU.

If you do not specify this parameter, *Icomp* is set to the previous setting.

0 A is not allowed for *Icomp*.

Example Statements

```
OUTPUT @Hp4156;"MV 1,12,0,5,1E-3"
```

Table 1-16 Available Parameter Values for MV Command

Output Range	Resolution in V	*bias* and *base* in V	Maximum *Icomp* in A	Remarks
2 V	100E−6	0 to ±2	±100E−3	For SMU.
			±1	For HPSMU.
20 V	1E−3	0 to ±20	±100E−3	For SMU.
			±1	For HPSMU.
			−	For VSU.
40 V	2E−3	0 to ±40	±50E−3	For SMU.
			±500E−3	For HPSMU.
100 V	5E−3	0 to ±100	±20E−3	For SMU.
			±125E−3	For HPSMU.
200 V	10E−3	0 to ±200	±50E−3	

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).

The output data is always stored in the query buffer in ASCII format, regardless of the FMT command.

The NUB? command cannot check and return the number of the measurement data measured by the TI? command and TV? command.

Syntax

`NUB?`

Query Response

In US command mode:

Number of measurement data<LF^EOI>

In US42 command mode:

Number of measurement data<CR/LF^EOI>

Example Statements

```
OUTPUT @Hp4156;"NUB?"
ENTER @Hp4156;A
```

*OPC(?)

The *OPC command monitors the pending operations, and 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.

The *OPC command is required to enable the OPC bit. To stop monitoring pending operations (disable the OPC bit), execute the *CLS command.

Syntax

```
*OPC
```

Query Response

In US command mode:

```
1<LF^EOI>
```

In US42 command mode:

```
1<CR/LF^EOI>
```

`*OPC?` places ASCII character `1` into the Output Queue when all pending operations are completed.

Example Statements

```
OUTPUT @Hp4156;"*OPC"
```

The following example is for query:

```
OUTPUT @Hp4156;"*OPC?"
ENTER @Hp4156;A
```

OPEN

The OPEN command opens the specified file on the mass storage device specified by the SDSK command. If the file does not exist on the device, this command creates a new file with the specified file name.

To read data in the file, use the RD? command. To write data into the file, use the WR command. After the file operation, enter the CLOSE command to close the file.

Execution Conditions

Mass storage device is specified by the SDSK command.

Syntax

`OPEN` *`file`*`[,`*`mode`*`]`

Parameters

file **:** File name to be opened.

mode **:** Open mode. 0, 1 or 2. Integer expression. See below.

If you do not specify this parameter, *mode* is set to 0.

0: Reads data from the file.

1: Writes data to the file. The data is written over the file. The previous data will be deleted.

2: Writes data to the file. The data is appended to the file. Not available for the flexible disk drive (SDSK 0 command).

Remarks

If you open a new file on a LIF formatted diskette into the built-in flexible disk drive, the OPEN command creates a 8 KB file.

Example Statements

```
OUTPUT @Hp4156;"OPEN 'MDATA'"
OUTPUT @Hp4156;"OPEN 'MDATA',2"
```

*OPT?

The *OPT? query command returns the reportable device options, which are the units in the 41501A/B Expander.

The output data is always stored in the query buffer in ASCII format, regardless of the FMT format.

Syntax

```
*OPT?
```

Query Response

In US command mode:

```
0|GNDU,0|SMU5,0|SMU6,0|PGU<LF^EOI>
```

In US42 command mode:

```
0|GNDU,0|SMU5,0|SMU6,0|PGU<CR/LF^EOI>
```

Example Statements

```
OUTPUT @Hp4156;"*OPT?"
ENTER @Hp4156;A$
```

OS

The OS command causes the 4155C/4156C to send a trigger signal from the external trigger output terminal (`Ext Trig Out`) on the rear panel.

Execution Conditions

Trigger mode must be set to the trigger output mode, and it must be enabled. See STG command.

Syntax

```
OS
```

Example Statements

```
OUTPUT @Hp4156;"OS"
```

PA

The PA command pauses the command execution or internal memory program execution, until receiving a trigger specified by the TM command or until the specified wait time has elapsed. The trigger only releases the wait status. It does not start the measurement.

Syntax

`PA [wait time]`

Parameters

wait time **:** 0 to 99.9999 seconds, with 100 μsec resolution. Numeric expression.

If this parameter is not specified, the wait state is kept until receiving the trigger specified by the TM command.

Remarks

If you send the PA command after the DV or DI command, actual wait time includes the wait time of the DV or DI command for the output setting.

Example Statements

```
OUTPUT @Hp4156;"PA"
OUTPUT @Hp4156;"PA 10"
```

PI

The PI command specifies the pulse current source and its parameters. This command also clears, and is cleared by, the PV command setting.

In the staircase sweep with pulsed bias measurement mode (set by the MM 5 command), the output forced by the PI command synchronized with the staircase sweep outputs forced by the WI or WV command.

Execution Conditions

The filter must be set to OFF using the FL command before the measurement trigger.

Syntax

`PI chnum,range,base,pulse[,Vcomp]`

If you enter the PI command into the program memory (see the ST command), do not omit the *Vcomp* parameter. The all parameters are necessary when using the internal program memory.

Parameters

chnum **:** Channel number of the unit used to force pulse current. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

range: Ranging type for pulse current output. Integer expression.

range	**Ranging Type** [a]
0	Auto ranging
13	100 nA limited auto ranging
14	1 μA limited auto ranging
15	10 μA limited auto ranging
16	100 μA limited auto ranging
17	1 mA limited auto ranging
18	10 mA limited auto ranging
19	100 mA limited auto ranging
20 (only for HPSMU)	1 A limited auto ranging

a. Auto ranging uses the lowest output range (available for the unit) that covers both the *base* and *pulse* values. Limited auto ranging uses the specified range or above. For example, 10 μA limited auto ranging uses the 100 mA range to force *pulse*=50 mA with *base*=0.

base **:** Pulse base current (in A). Numeric expression. See Table 1-17.

0 to ±100E–3 (for 4155C/4156C and MPSMU in 41501A/B) 0 to ±1 (for HPSMU in 41501A/B)

base and *pulse* must have the same polarity.

pulse **:** Pulse current (in A). Numeric expression. See Table 1-17.

0 to ±100E–3 (for 4155C/4156C and MPSMU in 41501A/B) 0 to ±1 (for HPSMU in 41501A/B)

base and *pulse* must have the same polarity.

***Vcomp*:** Voltage compliance value (in V). Numeric expression. See Table 1-17. If this parameter is not specified, *Vcomp* is set to the previous setting.

The voltage compliance polarity is automatically set to the same polarity as the *pulse* and *base* values, regardless of the specified *Vcomp*. If *pulse*=0 and *base*=0, the polarity of the voltage compliance is positive.

Table 1-17 **Available Parameter Values for PI Command**

Output Range	Resolution in A [a]	*base* and *pulse* in A	Maximum *Vcomp* in V [b]	Remarks
100 nA	10E−12	0 to ±100E−9	±2	
1 µA	100E−12	0 to ±1E−6	±2	
10 µA	1E−9	0 to ±10E−6	±2	
100 µA	10E−9	0 to ±100E−6	±100	For SMU.
			±200	For HPSMU.
1 mA	100E−9	0 to ±1E−3	±100	For SMU.
			±200	For HPSMU.
10 mA	1E−6	0 to ±10E−3	±100	For SMU.
			±200	For HPSMU.
100 mA	10E−6	0 to ±20E−3	±100	For SMU.
		to ±50E−3	±40	
		to ±100E−3	±20	
	100E−6	0 to ±50E−3	±200	For HPSMU.
		to ±100E−3	±100	
1 A	100E−6	0 to ±50E−3	±200	
		to ±125E−3	±100	
		to ±500E−3	±40	
		to ±1	±20	

a. Minimum resolution is Range×5E−5. However the setting accuracy is not guaranteed for the resolution less than the value shown in the table.
b. If *base* or *pulse* value is within 10 µA and not 0, the maximum *Vcomp* value must be 2 V even though the output range is 100 µA or large.

Example Statements

```
OUTPUT @Hp4156;"PI 1,16,0,5E-5,20"
OUTPUT @Hp4156;"PI 3,15,0,5E-6,2"
```

POR

The POR command sets the output impedance of the PGU.

Syntax

`POR` *`chnum`*`,`*`impedance`*

Parameters

chnum **:** Channel number of PGU 27 or 28. Integer expression.

27: PGU1

28: PGU2

impedance **:** Output impedance. 0 or 1. Integer expression.

0: Low impedance. Almost 0 Ω.

1: 50 Ω.

Example Statements

```
OUTPUT @Hp4156;"POR 28,0"
```

PRN

The PRN command prints the data that the SPL command spools in the temporary file on the network file system. This command deletes the temporary file.

Execution Conditions

The SDSK command specifies the network file system. The SPR command specifies the remote printer. The SPL command specifies the data to be printed.

Syntax

```
PRN
```

Example Statements

```
OUTPUT @Hp4156;"TI? 1,0"
ENTER @Hp4156 USING "#,5X,13D,X";Mdata
Mdata$="'Id(A)="&VAL$(Mdata)&CHR$(13)&CHR$(10)&"'"
Title$="'Test Results"&CHR$(13)&CHR$(10)&"'"
OUTPUT @Hp4156;"SDSK 1"
OUTPUT @Hp4156;"SPR 1"
OUTPUT @Hp4156;"SPL ";Title$
OUTPUT @Hp4156;"SPL ";Mdata$
OUTPUT @Hp4156;"PRN"
```

This example makes the following example output.

```
TestResults
Id(A)=4.156E-12
```

PT

The PT command sets timing parameters (hold time, pulse width, and pulse period) for a pulse source set by the PI, PV, PWI or PWV command.

Syntax

For 1ch pulsed spot measurements:

```
PT hold time,width[,period[,trigger delay[,priority]]]
```

For pulsed sweep or staircase sweep with pulsed bias measurements:

```
PT hold time,width,period[,trigger delay[,priority]]
```

Parameters

hold time : Hold time (in seconds). Numeric expression.

0 to 655.35 sec. 0.01 sec resolution. Initial setting = 0.

width : Pulse width (in seconds). Numeric expression.

0.5E–3 to 0.1 sec. 0.1E–3 sec resolution. Initial setting = 1E–3 sec.

period : Pulse period (in seconds). Numeric expression.

5E–3 to 1 sec. 0.1E–3 sec resolution. Initial setting = 10E–3 sec.

Restrictions: *period* ≥ *width* + 4 ms

If you do not specify *period* for the pulse spot measurements, *period* is automatically set to 10 msec.

trigger delay : Trigger output delay time (in seconds). Numeric expression.

0 to 32.7E–3 sec. 0.1E–3 sec resolution. Initial setting = 0.

Restrictions: *trigger delay* < *width*

This parameter is the time from pulse leading edge to timing of trigger output from the Ext Trig Out connector.

If you do not use the external trigger, set *trigger delay* to 0.

If you do not specify this parameter, the value is set to the previous setting.

priority **:** Priority to force the pulse output. 0 or 1.

0: Keep pulse width (default)

In this mode,

- If the measurement time is greater than the specified pulse width, the pulse does not wait the measurement completion, and goes to the base level. Then measurement result data will be meaningless.
- Only 1 measurement unit (either a pulse measurement unit or a dc measurement unit) is available.
- Measurement range set by the RI or RV command must be the fixed range or compliance range.
- The AV, SLI and WT command settings are ignored.
- Integration time is always set to 80 μsec.

1: Wait for measurement completion

In this mode,

- If the measurement time is greater than the specified pulse width, the pulse keeps the peak level until the measurement completion.
- Multi channel measurement is available. This allows to use a pulse measurement unit and dc measurement units.
- The WT command settings are ignored.

Example Statements

```
OUTPUT @Hp4156;"PT 1,0.01"
OUTPUT @Hp4156;"PT 1,0.005,0.01,0.001,1"
```

PV

The PV command specifies the pulse voltage source and its parameters. This command also clears, and is cleared by, the PI command setting.

In the staircase sweep with pulsed bias measurement mode (MM 5 command), the output forced by the PV command synchronized with the staircase sweep outputs forced by the WI or WV command.

Execution Conditions

Filter must be set to OFF using the FL command before the measurement trigger.

Syntax

For SMU:

```
PV chnum,range,base,pulse[,Icomp]
```

If you enter the PV command into the program memory (see the ST command), do not omit the *Icomp* parameter. The all parameters are necessary when using the internal program memory.

For VSU:

```
PV chnum,range,base,pulse
```

Parameters

chnum **:** Channel number of the unit used to force pulse voltage. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6
21	VSU1
22	VSU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

range: Ranging type for pulse voltage output. Integer expression.

range	**Ranging Type** [a]
0	Auto ranging
11 (for SMU)	2 V limited auto ranging
12	20 V limited auto ranging
13 (for SMU)	40 V limited auto ranging
14 (for SMU)	100 V limited auto ranging
15 (only for HPSMU)	200 V limited auto ranging

a. Auto ranging uses the lowest output range (available for the unit) that covers both the *base* and *pulse* values. Limited auto ranging uses the specified range or above. For example, 20 V limited auto ranging uses the 100 V range to force *pulse*=50 V with *base*=0.

base : Pulse base voltage (in V). Numeric expression. See Table 1-18.

0 to ±100 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±200 (for HPSMU in 41501A/B)

0 to ±20 (for VSU)

pulse : Pulse voltage (in V). Numeric expression. See Table 1-18.

0 to ±100 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±200 (for HPSMU in 41501A/B)

0 to ±20 (for VSU)

***Icomp*:** Current compliance value (in A). Numeric expression. See Table 1-18. If you do not specify this parameter, *Icomp* is set to the previous setting.

The minimum value (lower limit) of |*Icomp*| must be as shown in the following table.

V pulse [a]	*Icomp*
0 < |Vp-p| < 2 V	|*Icomp*| > 2 nA
2 V < |Vp-p| < 20 V	|*Icomp*| > |Vp-p|×1.111×10E−6 −2.22×10E−6
20 V < |Vp-p|	|*Icomp*| > 20 μA

a. |Vp-p| is the voltage from the *base* value to the *pulse* value.

The current compliance polarity is automatically set to the same polarity of as *pulse* and *base*, regardless of the specified *Icomp*. If *pulse*=0, the polarity of the current compliance is positive.

Table 1-18 Available Parameter Values for PV Command

Output Range	Resolution in V	*base* and *pulse* in V	Maximum *Icomp* in A	Remarks
2 V	100E−6	0 to ±2	±100E−3	For SMU.
			±1	For HPSMU.
20 V	1E−3	0 to ±20	±100E−3	For SMU.
			±1	For HPSMU.
			−	For VSU.
40 V	2E−3	0 to ±40	±50E−3	For SMU.
			±500E−3	For HPSMU.
100 V	5E−3	0 to ±100	±20E−3	For SMU.
			±125E−3	For HPSMU.
200 V	10E−3	0 to ±200	±50E−3	

Example Statements

```
OUTPUT @Hp4156;"PV 1,12,0,5,1E-3"
OUTPUT @Hp4156;"PV 21,12,-3,5"
```

PWI

The PWI command specifies the pulsed sweep current 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.

Execution Conditions

Filter must be set to OFF using the FL command before the measurement trigger.

If you do not specify the *Rmode* value, the 4155C/4156C uses the lowest output range that covers all *base*, *start* and *stop* values. Then the setting resolution must be the same for the *base*, *start*, and *stop* values. See *Rmode* on page 1-173.

Syntax

```
PWI chnum,mode,range,base,start,stop,step[,Vcomp
[,Rmode]]
```

If you enter the PWI command into the program memory (see the ST command), do not omit the *Vcomp* parameter. *Vcomp* is necessary when using the internal program memory.

Parameters

chnum **:** Channel number of the unit for the pulsed sweep current source. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

mode **:** Sweep mode. 1 to 4 are available. Integer expression.

1: Linear sweep (single stair)

2: Log sweep (single stair)

3: Linear sweep (double stair)

4: Log sweep (double stair)

range : Ranging type for pulsed current sweep. Integer expression.

Operation of ranging depends on the *Rmode* (ranging mode) setting. See *Rmode* on page 1-173.

range	**Ranging Type** [a]
0	Auto ranging
9 (only for 4156C)	10 pA limited auto ranging
10 (only for 4156C)	100 pA limited auto ranging
11	1 nA limited auto ranging
12	10 nA limited auto ranging
13	100 nA limited auto ranging
14	1 μA limited auto ranging
15	10 μA limited auto ranging
16	100 μA limited auto ranging
17	1 mA limited auto ranging
18	10 mA limited auto ranging
19	100 mA limited auto ranging
20 (only for HPSMU)	1 A limited auto ranging

a. Auto ranging uses the lowest output range (available for the unit) that covers all *base*, *start* and *stop* values. Limited auto ranging uses the specified range or above.

base : Base current (in A). Numeric expression. See Table 1-19.

0 to ±100E–3 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±1 (for HPSMU in 41501A/B)

base, *start* and *stop* must have the same polarity.

start **:** Start pulse current (in A). Numeric expression. See Table 1-19.

0 to ±100E–3 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±1 (for HPSMU in 41501A/B)

base, *start* and *stop* must have the same polarity.

stop **:** Stop pulse current (in A). Numeric expression. See Table 1-19.

0 to ±100E–3 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±1 (for HPSMU in 41501A/B)

base, *start* and *stop* must have the same polarity.

step **:** Number of steps for staircase sweep. 1 to 1001 are available. Numeric expression.

Vcomp **:** Voltage compliance (in V). Numeric expression. See Table 1-19.

If you do not specify this parameter, *Vcomp* is set to the previous setting.

The voltage compliance polarity is automatically set to the same polarity as *base*, *start* and *stop*, regardless of the specified *Vcomp*. If *base*=0, *start*=0 and *stop*=0, the polarity of the voltage compliance is positive.

Rmode **:** Ranging mode. 0 or 1. Integer expression. If you do not specify *Rmode*, ranging mode is set to 0 (fixed mode).

0: Fixed

Uses the output range, which covers all *base*, *start* and *stop* values, during the pulsed sweep.

For example, if you enter the following command, the 4155C/4156C uses the 100 mA range to force both 1 mA pulse and 100 mA pulse.

```
PWI 1,1,17,0,0.001,0.1,2,10,0
```

1: Auto

Uses the optimum output range for the output pulse.

For example, if you enter the following command, the 4155C/4156C uses 1 mA range to force 1 mA, and uses 100 mA range to force 100 mA.

```
PWI 1,1,17,0,0.001,0.1,2,10,1
```

Range changing may cause 0 A output in a moment.

Table 1-19 **Available Parameter Values for PWI Command**

Output Range	Resolution in A [a]	*base*, *start* or *stop* in A	Maximum *Vcomp* in V [b]	Remarks
10 pA	10E−15	0 to ±10E−12	±2	For 4156C.
100 pA	10E−15	0 to ±100E−12	±2	
1 nA	100E−15	0 to ±1E−9	±2	
10 nA	1E−12	0 to ±10E−9	±2	
100 nA	10E−12	0 to ±100E−9	±2	
1 μA	100E−12	0 to ±1E−6	±2	
10 μA	1E−9	0 to ±10E−6	±2	
100 μA	10E−9	0 to ±100E−6	±100	For SMU.
			±200	For HPSMU.
1 mA	100E−9	0 to ±1E−3	±100	For SMU.
			±200	For HPSMU.
10 mA	1E−6	0 to ±10E−3	±100	For SMU.
			±200	For HPSMU.
100 mA	10E−6	0 to ±20E−3	±100	For SMU.
		to ±50E−3	±40	
		to ±100E−3	±20	
	100E−6	0 to ±50E−3	±200	For HPSMU.
		to ±100E−3	±100	
1 A	100E−6	0 to ±50E−3	±200	
		to ±125E−3	±100	
		to ±500E−3	±40	
		to ±1	±20	

a. Minimum resolution is Range×5E−5. However the setting accuracy is not guaranteed for the resolution less than the value shown in the table.
b. If *base* or *pulse* value is within 10 μA and not 0, the maximum *Vcomp* value must be 2 V even though the output range is 100 μA or large.

Example Statements

```
OUTPUT @Hp4156;"PWI 1,1,17,0,0,0.1"
OUTPUT @Hp4156;"PWI 3,2,13,0,1E-7,1E-2,100,10,1"
```

PWV

The PWV command specifies the pulsed sweep voltage 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.

Execution Conditions

Filter must be set to OFF using the FL command before the measurement trigger.

If you do not specify the *Rmode* value, the 4155C/4156C uses the lowest output range that covers all *base*, *start* and *stop* values. Then the setting resolution must be the same for the *base*, *start*, and *stop* values. See *Rmode* on page 1-177.

Syntax

```
PWV chnum,mode,range,base,start,stop,step[,Icomp
[,Rmode]]
```

If you enter the PWV command into the program memory (see the ST command), do not omit the *Icomp* parameter. *Icomp* is necessary when using the internal program memory.

Parameters

chnum **:** Channel number of the unit for the pulsed sweep voltage source. Integer expression.

chnum	Unit	*chnum*	Unit
1	SMU1	5 [a]	SMU5
2	SMU2	6 [a]	SMU6
3	SMU3	21	VSU1
4	SMU4	22	VSU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

mode **:** Sweep mode. 1 to 4 are available. Integer expression.

1: Linear sweep (single stair)

2: Log sweep (single stair)

3: Linear sweep (double stair)

4: Log sweep (double stair)

range: Ranging type for pulsed voltage sweep. Integer expression.

Operation of ranging depends on the *Rmode* (ranging mode) setting. See *Rmode* on page 1-177.

range	**Ranging Type** [a]
0	Auto ranging
11 (for SMU)	2 V limited auto ranging
12	20 V limited auto ranging
13 (for SMU)	40 V limited auto ranging
14 (for SMU)	100 V limited auto ranging
15 (only for HPSMU)	200 V limited auto ranging

a. Auto ranging uses the lowest output range (available for the unit) that covers all *base*, *start* and *stop* values. Limited auto ranging uses the specified range or above.

base : Base voltage (in V). Numeric expression. See Table 1-20.

0 to ±100 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±200 (for HPSMU in 41501A/B)

0 to ±20 (for VSU)

base, *start* and *stop* must have the same polarity for *log* sweep.

start : Start pulse voltage (in V). Numeric expression. See Table 1-20.

0 to ±100 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±200 (for HPSMU in 41501A/B)

0 to ±20 (for VSU)

base, *start* and *stop* must have the same polarity for *log* sweep.

stop : Stop pulse voltage (in V). Numeric expression. See Table 1-20.

0 to ±100 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±200 (for HPSMU in 41501A/B)

0 to ±20 (for VSU)

base, *start* and *stop* must have the same polarity for *log* sweep.

step **:** Number of steps for staircase sweep. Numeric expression. 1 to 1001 are available.

Icomp **:** Current compliance (in A). Numeric expression. See Table 1-20.

If you do not specify this parameter, *Icomp* is set to the previous setting.

The minimum value (lower limit) of |*Icomp*| must be as shown in the following table.

V pulse [a]	***Icomp***
0 < |Vp-p| < 2 V	|*Icomp*| > 2 nA
2 V < |Vp-p| < 20 V	|*Icomp*| > |Vp-p|×1.111×10E−6 −2.22×10E−6
20 V < |Vp-p|	|*Icomp*| > 20 μA

a. |Vp-p| is the voltage from the base value to the pulse value.

The current compliance polarity is automatically set to the same as the polarity of *base*, *start* and *stop*, regardless of the specified *Icomp*. If *start*=0, the polarity of current compliance is positive.

Rmode **:** Ranging mode. 0 or 1. Integer expression. If you do not specify *Rmode*, ranging mode is set to 0 (fixed mode).

0: Fixed

Uses the output range, which covers all *base*, *start* and *stop* values, during the pulsed sweep.

For example, if you enter the following command, the 4155C/4156C uses the 20 V range to force both 1 V pulse and 10 V pulse.

```
PWV 1,1,12,0,1,10,2,1E-3,0
```

1: Auto

Uses the optimum output range for the output pulse.

For example, if you enter the following command, the 4155C/4156C uses the 2 V range to force 1 V, and uses the 20 V range to force 10 V.

```
PWV 1,1,12,0,1,10,2,1E-3,1
```

Range changing may cause 0 V output in a moment.

Table 1-20 Available Parameter Values for PWV Command

Output Range	Resolution in V	*base*, *start* or *stop* in V	Maximum *Icomp* in A	Remarks
2 V	100E–6	0 to ±2	±100E–3	For SMU.
			±1	For HPSMU.
20 V	1E–3	0 to ±20	±100E–3	For SMU.
			±1	For HPSMU.
			–	For VSU.
40 V	2E–3	0 to ±40	±50E–3	For SMU.
			±500E–3	For HPSMU.
100 V	5E–3	0 to ±100	±20E–3	For SMU.
			±125E–3	For HPSMU.
200 V	10E–3	0 to ±200	±50E–3	

Example Statements

```
OUTPUT @Hp4156;"PWV 1,1,12,0,1,10,2"
OUTPUT @Hp4156;"PWV 3,3,14,0,1,10,100,0.1,1"
```

QSL

The QSL command enables or disables the leakage current data output, and enables or disables the leakage current compensation for the quasi-static CV measurements. This command is only for the US control mode.

Execution Conditions

The MM 13 command must be sent *before* sending this command.

Syntax

`QSL data,compen`

Parameters

data : Leakage current data output. Integer expression.

data	Description
0	Disables data output. Default setting.
1	Enables data output.

compen : Leakage current compensation. Integer expression.

compen	Description
0	Disables compensation. Default setting.
1	Enables compensation.

Example Statements

```
OUTPUT @Hp4156;"QSL 0,0"
```

If you send the above command, the leakage current is not measured during the quasi-static CV measurements.

See Also

For details on the quasi-static CV measurements, refer to the QSV command.

QSM

The QSM command sets the automatic abort condition for the quasi-static CV measurements. This command is only for the US control mode.

Execution Conditions

The MM 13 command must be sent *before* sending this command.

Syntax

`QSM condition[,output]`

If you send this command to the program memory (see the ST command), do not omit the *output* parameter. It is necessary when using the internal program memory.

Parameters

condition **:** Automatic abort condition. Integer expression. The following values are available:

condition	Abort condition
1	Disables the automatic abort function. Default setting.
2	One of following occurs. - Compliance on the non-measurement unit. - Compliance on the leakage current measurement unit. - Integration time too short at the capacitance measurement. - Overflow on ADC. - Oscillation on any unit.
4	Compliance on the non-measurement unit.
8	One of following occurs. - Compliance on the leakage current measurement unit. - Integration time too short at the capacitance measurement.
16	Overflow on ADC.
32	Oscillation on any unit.

To set multiple conditions, specify the sum of the *condition* values for the abort conditions shown above. This is allowed for *condition*=4 to 32. For example, if you want to enable the abort function for when integration time is too short (*abort*=8) or oscillation (*abort*=32) are detected, set *abort* to 40 (8 + 32).

output **:** Source output value after abort condition occurred. Integer expression.

output	Description
1	Returns to the start value. Default setting.
2	Keeps the stop value.

Output Data

The 4155C/4156C returns the all measurement data until when any abort condition is detected. The output format of the last data will be as shown below:

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

where,

DataL: Leakage current measurement data. Selected by the QSL command.

DataC: Capacitance measurement data.

Source_data: Source output data. Selected by the FMT command.

If the *Source_data* output is disabled, the status of the last *DataC* will be greater than 128 (EOD).

Example Statements

```
OUTPUT @Hp4156;"QSM 24"
```

QSR

The QSR command sets the current measurement range used for the quasi-static CV measurements. This command is only for the US control mode.

Execution Conditions

The MM 13 command must be sent *before* sending this command.

Syntax

`QSV range`

Parameters

range: The available range values are shown below. Integer expression.

range	Ranging type
–9 (only for 4156C)	10 pA range fixed
–10 (only for 4156C)	100 pA range fixed
–11	1 nA range fixed (default setting)
–12	10 nA range fixed

Remarks

The range set by this command is used for both the leakage current measurement and the capacitance measurement.

Use the QST command to set the integration time of the capacitance measurement and the leakage current measurement.

Example Statements

```
OUTPUT @Hp4155;"QSR -11"
```

See Also

For details on the quasi-static CV measurements, refer to the QSV command.

QST

The QST command sets the timing parameters of the quasi-static CV measurements. This command is only for the US control mode.

Execution Conditions

The MM 13 command must be sent *before* sending this command.

Syntax

`QST cinteg,linteg,hold,delay1[,delay2]`

If you send this command to the program memory (see the ST command), do not omit the *delay2* parameter. It is necessary when using the internal program memory.

Parameters

cinteg : Integration time for the capacitance measurement, in seconds. Numeric expression. The available values are 0.04 to 400 s for a 50 Hz line frequency, and 0.033333 to 333.33 s for 60 Hz. But the value is rounded as follows:

cinteg = *n* / *selected line frequency* (*n* : integer. 2 to 20000.)

The initial setting is 5/ *selected line frequency*. So this value is 0.1 s for a 50 Hz line frequency, and approximately 0.083 s for 60 Hz.

linteg : Integration time for the leakage current measurement, in seconds. Numeric expression. The available values are 0.02 to 2 s for a 50 Hz line frequency, and 0.016667 to 1.6667 s for 60 Hz. But the value is rounded as follows:

linteg = *n* / *selected line frequency* (*n* : integer. 1 to 100.)

The initial setting is 5/ *selected line frequency*. So this value is 0.1 s for a 50 Hz line frequency, and approx. 0.083 s for 60 Hz.

hold : Hold time (in seconds). Numeric expression. This is the time from the start of the first sweep step to the beginning of the delay time (*delay1*).

0 to 655.35 sec. 0.01 sec resolution. Initial setting = 0.

delay1 : Delay time (in seconds). Numeric expression. This is the time from the start of each sweep step to the start of the measurement.

0 to 65.535 sec. 0.0001 sec resolution. Initial setting = 0.

delay2 : Delay time (in seconds). Numeric expression. This is the time from the end of the measurement to the start of the next sweep step or the end of the sweep. *delay2* is not effective for the spot measurement.

0 to 65.535 sec. 0.0001 sec resolution. Initial setting = 0.

Example Statements

```
OUTPUT @Hp4155;"QST 0.35,0.1,5,0.2"
```

This example sets a hold time of 5 s and a delay time of 0.2 s for *delay1*. 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.

See Also

For details on the quasi-static CV measurements, refer to the QSV command.

QSV

The QSV command specifies the voltage sweep source and its parameters for the quasi-static CV measurements. This command is only for the US control mode.

For the operation of the sweep source, see "Remarks" on page 1-188

Execution Conditions

The MM 13 command must be sent *before* sending this command. 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,range,start,stop,cvoltage,step[,Icomp]`

If you send this command to the program memory (see the ST command), do not omit the *Icomp* parameter. *Icomp* is necessary when using the internal program memory.

Parameters

chnum: Channel number of the voltage source. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5 (MPSMU)
6 [a]	SMU6 (MPSMU or HPSMU)

a. For SMUs in the 41501A/B Expander.

mode : Sweep mode. Integer expression.

mode	Description
1	Single sweep mode (start to stop).
2	Double sweep mode (start to stop to start).

range: Ranging type for voltage output. Integer expression.

range	**Ranging Type**
0	Auto ranging
11	2 V limited auto ranging
12	20 V limited auto ranging
13	40 V limited auto ranging
14	100 V limited auto ranging
15 (only for HPSMU)	200 V limited auto ranging

Auto ranging uses the lowest output range that covers both the *start* and the *stop* value. Limited auto ranging uses the specified range or above. For example, 20 V limited auto ranging uses the 20 V range even if both the *start* and *stop* values are less than 2 V.

start **:** Start voltage (in V). Numeric expression. See Table 1-21.

0 to ±100 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±200 (for HPSMU in 41501A/B)

This value is the upper or lower limit of the sweep output voltage.

stop **:** Stop voltage (in V). Numeric expression. See Table 1-21.

0 to ±100 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±200 (for HPSMU in 41501A/B)

This value is the upper or lower limit of the sweep output voltage.

NOTE

In the QSCV measurement, the 4155C/4156C executes the capacitance measurement at the sweep steps except for the sweep start voltage and stop voltage. At each sweep step, the capacitance measurement is executed over the voltage range: output voltage ± *cvoltage*/2 (V).

cvoltage : Capacitance measurement voltage (in V).

The minimum value is double the resolution of the output range, and the maximum value is 10 V. The value must be ≤ |sweep step voltage| you desire. If you set the value greater than |sweep step voltage|, the *cvoltage* is automatically set to the same value as |sweep step voltage|. See *step*.

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*| ≤ 10, the 4155C/4156C 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 Table 1-21.

If this parameter is not specified, *Icomp* is set to the previous setting.

The current compliance polarity is automatically set to the same polarity value as *start* and *stop*, regardless of polarity of the specified *Icomp*.

Table 1-21 **Available Parameter Values for QSV Command**

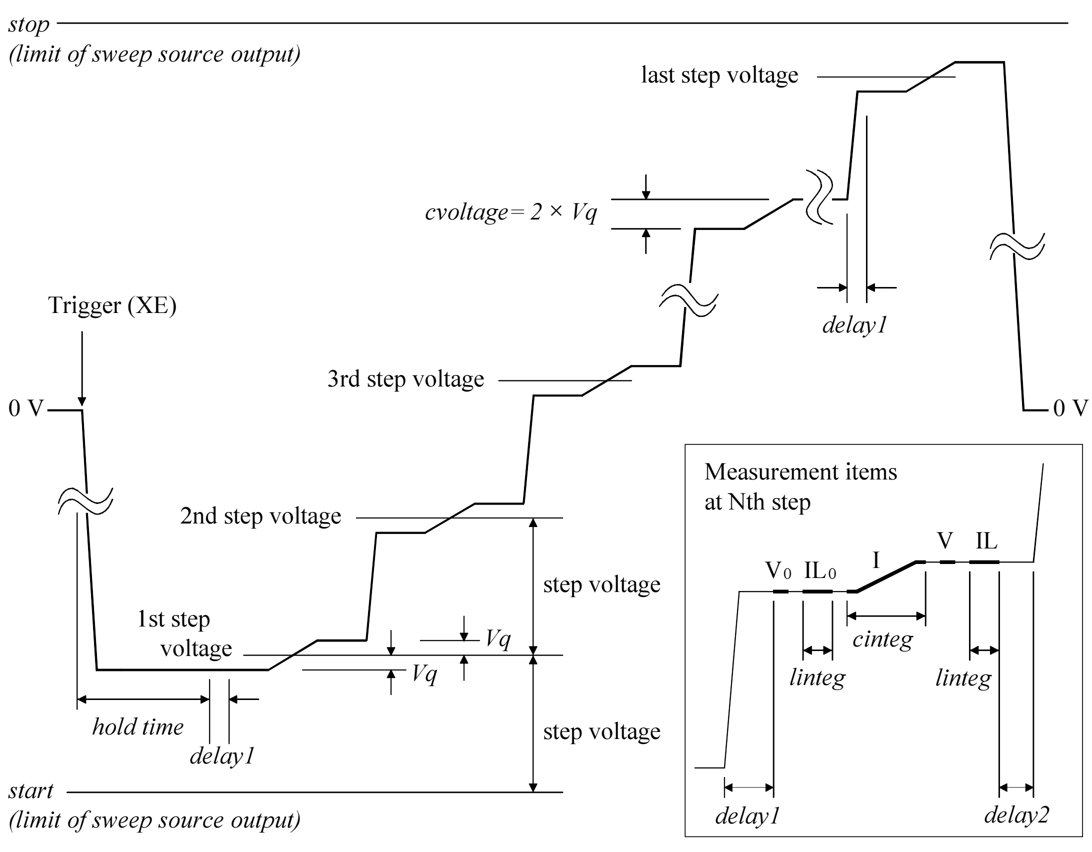
Output Range	Resolution in V	***start*** and ***stop*** in V	Maximum ***Icomp*** in A	Remarks
2 V	100E–6	0 to ±2	±100E–3	For SMU.
			±1	For HPSMU.
20 V	1E–3	0 to ±20	±100E–3	For SMU.
			±1	For HPSMU.
40 V	2E–3	0 to ±40	±50E–3	For SMU.
			±500E–3	For HPSMU.
100 V	5E–3	0 to ±100	±20E–3	For SMU.
			±125E–3	For HPSMU.
200 V	10E–3	0 to ±200	±50E–3	

Remarks

In the QSCV measurement, the 4155C/4156C executes the capacitance measurement at the sweep steps except for the sweep start voltage and stop voltage. At each sweep step, the capacitance measurement is executed over the voltage range: output voltage ± *cvoltage*/2 (V). where *cvoltage* is the capacitance measurement voltage. See Figure 1-1.

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

Figure 1-1 Setting Parameters and Operation of QSCV Measurement



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

a. Measurement trigger enables the sweep source output. The sweep source forces the first step output voltage−*Vq* V, and waits for *hold time*.
where *Vq*=*cvoltage*/2 V.

b. Repeats *c.* and *d.* for the Nth sweep step. where N is integer, 1 to *step* (number of sweep steps. *step* = |*start*-*stop*| / |step voltage| - 1).

c. The sweep source changes the output voltage to the Nth step output voltage−*Vq* V, and waits for delay time (*delay1*).

d. The measurement unit measures the following items, and waits for delay time (*delay2*).

$\mathbf{V_0}$	Voltage at the Nth step voltage−*Vq* V
$\mathbf{IL_0}$	Leakage current at the Nth step voltage−*Vq* V
I	Current at the voltage transition to the Nth step voltage+*Vq* V
V	Voltage at the Nth step voltage+*Vq* V
IL	Leakage current at the Nth step voltage+*Vq* V

e. After the sweep measurement, the sweep source changes output voltage to 0 V.

NOTE

when step voltage = capacitance measurement voltage (*cvoltage*):

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

Capacitance Data

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

$$C = \frac{I \times cinteg - \frac{1}{2}(IL_0 + IL) \times linteg}{V - V_0}$$

NOTE

If the QSL command turns the leakage current compensation OFF and the leakage current data output OFF, ignore measurement items IL_0 and IL shown above. That is, if the `QSL 0,0` command is executed, ignore measurement items IL_0 and IL shown above. The leakage current measurement is not executed. And the capacitance data is calculated as shown below:

$$C = \frac{I \times cinteg}{V - V_0}$$

Leakage Current Data

At each sweep step, the leakage current data is calculated using the following formula:

$$Leak = \frac{IL_0 + IL}{2}$$

Example Statements

```
OUTPUT @Hp4155;"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 @Hp4155;"QSV 1,1,0,Start,Stop,Cvolt,Nop,0.1"
```

QSZ/QSZ?

The QSZ command executes the capacitance offset measurement and returns the offset data, or it enables/disables the offset capacitance cancel function for the quasi-static CV measurements. This command is only for the US control mode.

Execution Conditions

The MM 13 command must be sent *before* sending this command.

The QSCV measurement setup must be completed *before* executing the offset measurement.

Syntax

```
QSZ mode
QSZ?
```

Parameters

mode **:** Offset cancel mode. Integer expression.

mode	Description
0	Disables offset cancel. Default setting.
1	Enables offset cancel.
2	Executes an offset data measurement, and returns the offset data. Does not enable the offset cancel function.

Query Response

QSZ? and QSZ 2 returns the capacitance offset data.

offset data <terminator>

<terminator> depends on the FMT command setting.

Example Statements

```
OUTPUT @Hp4156;"QSZ 2"
OUTPUT @Hp4156;"RMD? 1"
ENTER @Hp4156 USING "#,5X,13D,X";Offset

OUTPUT @Hp4156;"QSZ 1"

OUTPUT @Hp4156;"QSZ?"
ENTER @Hp4156 USING "#,5X,13D,X";Offset
```

RBC

The RBC command controls the 16441A R-BOX.

Syntax

`RBC` *`chnum`*`,`*`resistance`*

Parameters

chnum : Channel number of the R-BOX. 1 or 2. Integer expression. See below.

1: Channel 1.

2: Channel 2.

resistance : Resistance for the specified channel. Integer expression. 0, 1, 2 or 3. See below.

0: 0 Ω.

1: 10 kΩ.

2: 100 kΩ.

3: 1 MΩ.

Example Statements

```
OUTPUT @Hp4156;"RBC 1,3"
```

RCV

The RCV command enables the units that fail self-test.

If a unit fails self-test, the unit is disabled and does not respond to any command except the RCV and TST? commands. The RCV command enables the unit so that it can receive commands again. This command should only be used for servicing the 4155C/4156C. DO NOT use this command during normal operation.

If the 4155C/4156C fails self-test, contact the nearest Agilent Technologies Sales and Service Office.

Syntax

`RCV slotnum`

Parameters

slotnum : Slot number where the unit is installed. 0 to 8 are available. Integer expression.

slotnum	Unit
0	GNDU
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6
7 [b]	VSU1, VSU2, VMU1 and VMU2
8 [c]	PGU1 and PGU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, slot number is 6, not 5.
b. All VSU1, VSU2, VMU1, and VMU2 are enabled by specifying this value.
c. Both PGU1 and PGU2 are enabled by specifying this value.

Example Statements

```
OUTPUT @Hp4156;"RCV 1"
OUTPUT @Hp4156;"RCV 3"
```

RD?

The RD? command reads an ASCII data in the file opened by the OPEN command. The ASCII data is read sequentially, and is put in the output buffer of the 4155C/4156C. The data may be read by using the ENTER (HP BASIC) command.

Execution Conditions

The OPEN command mode parameter is set to 0 (reading the data).

Output Response

In the control mode by US command:

`[Data]<LF^EOI>`

In the control mode by US42 command:

`[Data]<CR/LF^EOI>`

where, *Data* is the contents of the file now opened by the OPEN command. The RD? command reads the maximum 8 KB data at once. If the data is less than 8 KB, the RD? command reads the data from the head until receiving EOF. If the data is more than 8 KB, the RD? command reads the data from the head to the 8 KB.

For the HP LIF file, the RD? command reads the data written in a file by one write operation. So if the data was written by two write operations, you need to enter the RD? command twice to read whole data in the file, even if the file is less than 8 KB.

Example Statements

This example reads data from the “MDATA” file, and print the data.

```
OUTPUT @Hp4156;"SDSK 1"
OUTPUT @Hp4156;"OPEN 'MDATA',0"
OUTPUT @Hp4156;"RD?"
OUTPUT @Hp4156;"CLOSE"
ENTER @Hp4156;A$
PRINT A$
```

RI

The RI command specifies the current measurement ranging mode for all types of measurements, except for the high-speed spot measurements. The RI command only specifies the measurement range or ranging type, and the ranging mode. Range changing occurs immediately after the trigger (that is, during the measurements).

For high-speed spot measurements, the current measurement range is set by the TI/TI? command.

Syntax

`RI chnum,range[,Rmode]`

Parameters

chnum : Channel number of the unit used to measure current. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

range* and *Rmode: Ranging type or the measurement range for the current measurements.

The *range* value is used to specify the ranging type or the measurement range by itself. If you specify the *Rmode* parameter, the ranging type or the measurement range is specified by a combination of the *range* and *Rmode* values.

For example, both an "RI 1,14" command and an "RI 1,14,1" command can be used for the same operation (to measure current by the 1 μA limited auto ranging, using SMU1). However, an "RI 1,14,0" command is for a different operation.

If you omit *Rmode* value.

Available range value is shown below. Integer expression.

range	**Ranging type** [a]
0	Auto ranging
9 (only for 4156C)	10 pA limited auto ranging
10 (only for 4156C)	100 pA limited auto ranging
11	1 nA limited auto ranging
12	10 nA limited auto ranging
13	100 nA limited auto ranging
14	1 μA limited auto ranging
15	10 μA limited auto ranging
16	100 μA limited auto ranging
17	1 mA limited auto ranging
18	10 mA limited auto ranging
19	100 mA limited auto ranging
20 (only for HPSMU)	1 A limited auto ranging
–9 (only for 4156C)	10 pA range fixed
–10 (only for 4156C)	100 pA range fixed
–11	1 nA range fixed
–12	10 nA range fixed
–13	100 nA range fixed
–14	1 μA range fixed
–15	10 μA range fixed
–16	100 μA range fixed
–17	1 mA range fixed
–18	10 mA range fixed
–19	100 mA range fixed
–20 (only for HPSMU)	1 A range fixed

a. Auto ranging uses the lowest measurement range (available for the unit) that covers the measurement value. Limited auto ranging uses the specified range or above. For example, 10 μA limited auto ranging uses the 10 μA range to measure 1 nA, and uses the 100 mA range to measure 50 mA.

NOTE

For the following measurement mode, use the following table instead of the table above.

- 1ch pulsed spot measurements with "keep pulse width"
- Pulsed sweep measurements with "keep pulse width"
- Staircase sweep with pulsed bias measurements with "keep pulse width"
- Sampling measurement with the sampling interval less than 2 msec (see the MT command)

where, "keep pulse width" means the measurement setup which the PT command *priority* parameter is set to 0 or default setting (see the PT command).

range	**Ranging type**
0 (for SMU)	100mA range fixed
0 (for HPSMU)	1 A range fixed
9, –9 (only for 4156C)	10 pA range fixed
10, –10 (only for 4156C)	100 pA range fixed
11, –11	1 nA range fixed
12, –12	10 nA range fixed
13, –13	100 nA range fixed
14, –14	1 μA range fixed
15, –15	10 μA range fixed
16, –16	100 μA range fixed
17, –17	1 mA range fixed
18, –18	10 mA range fixed
19, –19	100 mA range fixed
20, –20 (only for HPSMU)	1 A range fixed

If you specify *Rmode* value.

The following ranging mode is available:

- Auto ranging mode (*Rmode*=0)
- Limited auto ranging mode (*Rmode*=1)
- Fixed range mode (*Rmode*=2)
- Compliance range mode (*Rmode*=3)

NOTE

For the following measurement mode, only the fixed range mode (*Rmode*=2) and the compliance range mode (*Rmode*=3) are available. If you set *Rmode*=0 or 1, the RI command works as same as when *Rmode*=3.

- 1ch pulsed spot measurements with "keep pulse width"
- Pulsed sweep measurements with "keep pulse width"
- Staircase sweep with pulsed bias measurements with "keep pulse width"
- Sampling measurement with the sampling interval less than 2 msec (see the MT command)

where, "keep pulse width" means the measurement setup which the PT command *priority* parameter is set to 0 or default setting (see the PT command).

- **To use auto ranging (*Rmode*=0):**

  Measurement unit uses the lowest measurement range that covers the measurement value. The minimum range depends on the unit you use.

  Set the parameters as follows:

  range **:** One of 9 to 20. Used as a placeholder only, the value is ignored.

  Rmode **:** 0

- **To use compliance range (*Rmode*=3):**

  Measurement unit uses the lowest measurement range that covers the current compliance value or the current output value set by the source output command you use, such as DV, DI, WV, WI and so on.

  Set the parameters as follows:

  range **:** One of 9 to 20. Used as a placeholder only, the value is ignored.

  Rmode **:** 3

- **To use limited auto ranging (*Rmode*=1):**

  Measurement unit uses the lowest measurement range that covers the measurement value. The minimum allowed range is the range specified by the *range* value.

  Set the parameters as follows:

  ***range* :** One of 9 to 20. See below.

  ***Rmode* :** 1

range	**Ranging type**
9 (only for 4156C)	10 pA limited auto ranging
10 (only for 4156C)	100 pA limited auto ranging
11	1 nA limited auto ranging
12	10 nA limited auto ranging
13	100 nA limited auto ranging
14	1 μA limited auto ranging
15	10 μA limited auto ranging
16	100 μA limited auto ranging
17	1 mA limited auto ranging
18	10 mA limited auto ranging
19	100 mA limited auto ranging
20 (only for HPSMU)	1 A limited auto ranging

- **To use fixed range (*Rmode*=2):**

  Measurement unit uses the range specified by the *range* value.

  Set the parameters as follows:

  ***range* :** One of 9 to 20. See below.

  ***Rmode* :** 2

range	Measurement range
9 (only for 4156C)	10 pA range fixed
10 (only for 4156C)	100 pA range fixed
11	1 nA range fixed
12	10 nA range fixed
13	100 nA range fixed
14	1 μA range fixed
15	10 μA range fixed
16	100 μA range fixed
17	1 mA range fixed
18	10 mA range fixed
19	100 mA range fixed
20 (only for HPSMU)	1 A range fixed

Example Statements

```
OUTPUT @Hp4156;"RI 1,0"
OUTPUT @Hp4156;"RI 3,14,1"
```

RMD?

The RMD? command puts the measurement data into the 4155C/4156C output data buffer.

Read the data before the 4155C/4156C output buffer becomes full up. The output buffer can store approximately 1500 measurement data.

For the high-speed spot measurements by the TI? or TV? command, and for the US42 command mode with *level*=16, the RMD? command is not required after the measurement execution command.

For the data output format, refer to “Data Output Format” on page 1-11.

Syntax

`RMD? [count]`

Parameters

count : Number of data to read. Integer expression. Available number is 0 to 20002. *count* must be the number of measurement data or less.

If *count* is more than the number of measurement data, the 4155C/4156C goes to the wait state after putting all data into the output buffer. To release this wait state, send the device clear (ex: CLEAR command of HP BASIC) to the 4155C/4156C. Then the data will be cleared. If you do not specify *count* or if you specify *count*=0, the RMD? command reads the data until EOD (end of data). If you set *count*=1500 or more, read the measurement data immediately. The output data buffer will become full up.

Example Statements

```
OUTPUT @Hp4156;"XE"
OUTPUT @Hp4156;"RMD? 1"
ENTER @Hp4156;A
```

If the output data is:

`1.1111,2.2222,3.3333<terminator>`

A is:

`1.1111,`

*RST

The *RST command resets the 4155C/4156C to the initial settings, and clears the zero offset data. This command does not clear the self calibration data.
Initial settings by the *RST command is shown below:

Item	with US command	with US42 command
Output Switch	ON for all units	GNDU, VMU: ON SMU, VSU, PGU: OFF
Filter (SMUs)	ON	
SMU Measurement Mode	Compliance side measurement mode (see CMM)	
SMU Measurement Range	Auto for spot and staircase sweep. Compliance range for others.	
VMU Operation Mode	Grounded measurement mode	
VMU Measurement Range	Auto for spot and staircase sweep. 20 V range for others.	
Source Parameters	Cleared for both sweep source and pulse source	
Hold Time, Delay Time	0 sec, 0 sec	
Pulse Width, Period	0.001 sec, 0.01 sec	
Averaging Mode, Number	Auto, 1	
Auto Calibration	ON	
Auto Abort Function	OFF	
Program Memory	Not cleared. Cleared by power on.	
Trigger	XE, TV, TI, and GET (Group Execute Trigger)	
Output Data Format	ASCII with Header data	
Terminator for Output Data	<LF^EOI>	<CR/LF^EOI>
Output Data Buffer	Cleared	
Error Register	Cleared	
Status Byte	Only bit 6 is enabled.	

Syntax

```
*RST
```

Remarks

If you want to reset units while a sweep measurement is being performed, you must first send the AB command, then the *RST command.

Device Clear (CLEAR statement for HP BASIC) resets the 4155C/4156C more directly than this command, bypassing the input buffer.

Example Statement

```
OUTPUT @Hp4156;"*RST"
```

RU

The RU command sequentially executes the 4155C/4156C internal memory programs.

Before executing the internal memory program, close the Interlock circuit. If you do not close the interlock circuit, an error occurred and the measurement is aborted.

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. 1 to 255 are available. Integer expression.

stop : Stop program number. 1 to 255 are available. Integer expression.

where, *stop* value must be greater than or equal to the *start* value.

Remarks

The 4155C/4156C does not detect errors during the internal memory program execution.

Example Statements

```
OUTPUT @Hp4156;"RU 1,10"
OUTPUT @Hp4156;"RU 3,6"
```

RV

The RV command specifies the voltage measurement ranging mode for all types of voltage measurements, except for high-speed spot measurements. The RV command only specifies the measurement range or ranging type, and the ranging mode. Range changing occurs immediately after the trigger (that is, during the measurements).

For high-speed spot measurements, the voltage measurement range is set by the TV/TV? command.

Syntax

```
RV chnum,range[,Rmode]
```

Parameters

chnum **:** Channel number of the unit used to measure voltage. Integer expression.

chnum	Unit	*chnum*	Unit
1	SMU1	5 [a]	SMU5
2	SMU2	6 [a]	SMU6
3	SMU3	23	VMU1
4	SMU4	24	VMU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

range **and *Rmode*:** Ranging type or the measurement range for the voltage measurements.

The *range* value is used to specify the ranging type or the measurement range by itself. If you specify the *Rmode* parameter, the ranging type or the measurement range is specified by the combination of the *range* and *Rmode* values. In this case, the meaning of *range* is changed as described in the next table.

For example, both an "RV 1,14" command and an "RV 1,14,1" command can be used for the same operation (to measure voltage by the 100 V limited auto ranging using SMU1). The "RI 1,14,0" command is for different operations.

If you omit *Rmode* value.

Available range value is shown below: Integer expression.

range	Ranging type [a]
0	Auto ranging
10, −10 (only for VMU in differential mode)	0.2 V limited auto ranging
11, −11	2 V limited auto ranging
12, −12 (for SMU and VMU in grounded mode)	20 V limited auto ranging
13, −13 (for SMU)	40 V limited auto ranging
14, −14 (for SMU)	100 V limited auto ranging
15, −15 (only for HPSMU)	200 V limited auto ranging

a. Auto ranging uses the lowest measurement range (available for the unit) that covers the measurement value. Limited auto ranging uses the specified range or above. For example, 20 V limited auto ranging uses the 20 V range to measure 1 V, and uses the 40 V range to measure 30 V.

NOTE

For the following measurement mode, see the following table instead of the table above.

1. 1ch pulsed spot measurements with "keep pulse width"
2. Pulsed sweep measurements with "keep pulse width"
3. Staircase sweep with pulsed bias measurements with "keep pulse width"
4. Sampling measurement with the sampling interval less than 2 msec (see the MT command)

where, "keep pulse width" means the measurement setup which the PT command *priority* parameter is set to 0 or default setting (see the PT command).

range	Ranging type
0 (for SMU)	100 V range fixed
0 (for HPSMU)	200 V range fixed
10, −10 (only for VMU in differential mode)	0.2 V range fixed
11, −11	2 V range fixed
12, −12 (for SMU and VMU in grounded mode)	20 V range fixed
13, −13 (for SMU)	40 V range fixed
14, −14 (for SMU)	100 V range fixed
15, −15 (only for HPSMU)	200 V range fixed

If you specify *Rmode* value.

The following ranging mode is available:

- Auto ranging mode (*Rmode*=0)
- Limited auto ranging mode (*Rmode*=1)
- Fixed range mode (*Rmode*=2)
- Compliance range mode (*Rmode*=3)

NOTE

For the following measurement mode, only the fixed range mode and the compliance range mode (*Rmode*=2 or 3) are available. If you enter *Rmode*=0 or 1, the RI command works as same as when *Rmode*=3.

1. 1ch pulsed spot measurements with "keep pulse width"
2. Pulsed sweep measurements with "keep pulse width"
3. Staircase sweep with pulsed bias measurements with "keep pulse width"
4. Sampling measurement with the sampling interval less than 2 msec (see the MT command)

where, "keep pulse width" means the measurement setup which the PT command *priority* parameter is set to 0 or default setting (see the PT command).

- **To use auto ranging (*Rmode*=0):**

  The measurement unit uses the lowest measurement range that covers the measurement value. The minimum range depends on the unit you use.

  Set the parameters as follows:

  range **:** One of 10 to 15. Used as a placeholder only, the value is ignored.

  Rmode **:** 0

- **To use limited auto ranging (*Rmode*=1):**

  The measurement unit uses the lowest measurement range that covers the measurement value. The minimum allowed range is the range specified by the *range* value.

  Set the parameters as follows:

  range **:** One of 10 to 15. See below.

  Rmode **:** 1

range	**Ranging type**
10 (only for VMU in differential mode)	0.2 V limited auto ranging
11	2 V limited auto ranging
12 (for SMU and VMU in grounded mode)	20 V limited auto ranging
13 (for SMU)	40 V limited auto ranging
14 (for SMU)	100 V limited auto ranging
15 (only for HPSMU)	200 V limited auto ranging

- **To use fixed range (*Rmode*=2):**

  The measurement unit uses the range specified by the *range* value.

  Set the parameters as follows:

  range **:** One of 10 to 15. See below.

  Rmode **:** 2

range	**Measurement range**
10 (only for VMU in differential mode)	0.2 V range fixed
11	2 V range fixed
12 (for SMU and VMU in grounded mode)	20 V range fixed
13 (for SMU)	40 V range fixed
14 (for SMU)	100 V range fixed
15 (only for HPSMU)	200 V range fixed

- **To use compliance range (*Rmode*=3):**

  The measurement unit uses the lowest measurement range that covers the voltage compliance value or the voltage output value set by the source output command you use, such as DI, DV, WI, WV and so on.

  Set the parameters as follows:

  range **:** One of 10 to 15. Used as a placeholder only, the value is ignored.

  Rmode **:** 3

  For VMU, the measurement range is fixed to 20 V in the grounded mode, and fixed to 2 V in the differential mode.

Example Statements

```
OUTPUT @Hp4156;"RV 23,10"
OUTPUT @Hp4156;"RV 1,12,1"
```

RZ

The RZ command returns the unit to the settings that are stored by the DZ command and clears the stored unit settings.

The DZ command stores the unit settings (V/I output values, V/I output ranges, and V/I compliance values), then sets the unit to Zero Output.

Execution Conditions

The DZ command has been executed for the specified unit. The US, US42, RZ, CL, CA, *TST?, *RST or Device Clear command is not executed for the specified unit.

Syntax

```
RZ [chnum[,chnum...[,chnum]...]]
```

Parameters

chnum : Channel number. Integer expression.

1: SMU1

2: SMU2

3: SMU3

4: SMU4

5: SMU5. For HPSMU, *chnum* 5 is not used.

6: SMU6. For HPSMU, *chnum* is 6.

21: VSU1

22: VSU2

27: PGU1

28: PGU2

If you do not specify this parameter, this command returns the settings for all units that satisfy the conditions described in "Execution Conditions" above, in the order that the DZ command stored them.

You can specify up to 10 channels at once using the RZ command. The 4155C/4156C returns the stored unit settings in the order specified.

Example Statements

```
OUTPUT @Hp4156;"RZ"
OUTPUT @Hp4156;"RZ 1,2,3,21,22"
```

SCR

The SCR command scratches the specified program from the internal program memory of the 4155C/4156C.

Syntax

`SCR [prog No.]`

Parameters

prog No. : Program number. 1 to 255 are available. Integer expression. If you do not specify this parameter, this command scratches all programs stored in the program memory.

Example Statements

```
OUTPUT @Hp4156;"SCR"
OUTPUT @Hp4156;"SCR 5,10"
```

SDSK

The SDSK command selects the mass storage device used to get or save data, such as the measurement data or setup data.

Execution Conditions

Network file system is registered on the NETWORK DISK SETUP table of the SYSTEM: MISCELLANEOUS screen.

Syntax

`SDSK disk`

Parameters

disk **:** Identification to specify the mass storage device. 0, 1, 2, 3 or 4. Integer expression.

disk value is relative to the position of softkeys available for the DISK field of the SYSTEM: FILER screen.

Softkeys for DISK		Description	*disk*
Position	Label		
top	FLOPPY	Internal flexible disk drive.	0
second from top	–	Network file system.	1
third from top	–	Network file system.	2
4th from top	–	Network file system.	3
5th from top	–	Network file system.	4

Softkey label of the network file system can be defined by using the NETWORK DISK SETUP table of the SYSTEM: MISCELLANEOUS screen.

Example Statements

```
OUTPUT @Hp4156;"SDSK 2"
```

SIT

The SIT command changes the value of the integration time, Short or Long.

Syntax

`SIT type,time`

Parameters

type : 1 (Short) or 3 (Long). Integer expression.

time : Integration time. Numeric expression. For the available values, see table below.

type		*time*
Value	**Description**	
1	Short	80E–6 to 10.16E–3 seconds
3	Long	16.7E–3 to 2 seconds

For the integration time `Long`, SIT command translates the input *time* value to the PLC (Power Line Cycles) value. If you enter "SIT 3,2" command to the 4155C/4156C at 50 Hz line frequency site (1 PLC is 0.02 sec), the 4155C/4156C sets the PLC value to 100 (= 2 sec / 0.02 sec) automatically.

Example Statements

```
OUTPUT @Hp4156;"SIT 1,80E-6"
OUTPUT @Hp4156;"SIT 3,1"
```

SLI

The SLI command selects the integration time setting, Short, Medium, or Long.

This command setting is ignored by the following measurement mode.

1. 1ch pulsed spot measurements with "keep pulse width"
2. Pulsed sweep measurements with "keep pulse width"
3. Staircase sweep with pulsed bias measurements with "keep pulse width"
4. Sampling measurements with the sampling interval less than 2 msec (see the MT command)

where, "keep pulse width" means the measurement setup which the PT command *priority* parameter is set to 0 or default setting (see the PT command).

Syntax

`SLI type`

Parameters

type **:** 1, 2 or 3. Integer expression. See below.

1: Selects the Short integration time

2: Selects the Medium integration time

3: Selects the Long integration time

Example Statements

```
OUTPUT @Hp4156;"SLI 1"
```

SOC

The SOC command enables or disables the zero offset cancel function for the SMU low current measurements and the VMU differential voltage measurements.

Execution Conditions

Zero offset data is already measured by the GOC command. If you do not measure the zero offset data before executing the SOC command, the previous zero offset data or 0 (zero) is used.

For SMU, the measurement mode must be set to the current measurement mode.

For VMU, the measurement mode must be set to the differential voltage measurement mode.

Syntax

`SOC` *`chnum`*`,`*`status`*

Parameters

chnum : Channel number of the unit to set the zero offset cancel function. Integer expression.

chnum	Unit	*chnum*	Unit
1	SMU1	5 [a]	SMU5
2	SMU2	6 [a]	SMU6
3	SMU3	23 [b]	VMU1
4	SMU4	24 [b]	VMU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.
b. Differential voltage measurements use both VMU1 and VMU2. Specify 23 or 24.

status : ON/OFF status of the zero offset cancel function. 0 or 1. Integer expression. Zero offset cancel function is initially set to OFF.

0: Zero offset function OFF.

1: Zero offset function ON.

Example Statements

```
OUTPUT @Hp4156;"SOC 1,1"
```

SPG

The SPG command specifies the PGU and its parameters.

To force the output, use the SRP command. To stop the output, use the SPP command or the DV command. If you use two PGUs, the SRP, SPP and DV commands are effective for both PGUs.

Syntax

`SPG chnum,mode[,base[,pulse,Td,Tw,Tl,Tt,Tp,Pc]]`

Parameters

chnum : Channel number of PGU 27 or 28. Integer expression.

27: PGU1

28: PGU2

mode : Output mode. 0, 1 or 2. Integer expression.

0: Clears the settings of the PGU specified by *chnum*.

1: dc voltage output. Set *base*.

2: Pulse voltage output. Set all parameters.

base : Base voltage (in V). For *mode* = 1 or 2.

When *mode*=1, this value is set to the output value.

0 to ±40 V. Numeric expression.

Resolution: 4 mV (for 0 to ±20 V), 8 mV (for ±20 to ±40 V).

pulse : Pulse voltage (in V). Only for pulse output.

0 to ±40 V. Numeric expression.

Resolution: 4 mV (for 0 to ±20 V), 8 mV (for ±20 to ±40 V).

Td **:** Delay time (in seconds). Only for pulse output.

0 to 10 sec. Numeric expression. See Table 1-22.

Restrictions: $Td < Tp$

Tw **:** Pulse width (in seconds). Only for pulse output.

1 μsec to 9.99 sec. Numeric expression. See Table 1-22.

Restrictions: $Tw < Tp$

Tl **:** Leading edge transition time (in seconds). Only for pulse output.

100 nsec to 10 msec. Numeric expression. See Table 1-23.

Restrictions: $Tl < Tw \times 0.8$

Tt **:** Trailing edge transition time (in seconds). Only for pulse output.

100 nsec to 10 msec. Numeric expression. See Table 1-23.

Restrictions: $Tt < (Tp - Tw) \times 0.8$

Tp **:** Pulse period (in seconds). Only for pulse output.

2 μsec to 10 sec. Numeric expression. See Table 1-22.

Tp parameter setting is effective for both PGU1 and PGU2. If you use both PGUs, the pulse period setting must be the same. Check the pulse period setting value of the SPG, MP and STT commands in your program.

Pc **:** Number of pulses. Only for pulse output.

1 to 65535, or 0. Numeric expression.

If you set *Pc* to 0, the 4155C/4156C forces pulse voltage in free run mode (continues pulse output).

count parameter setting is effective for both PGU1 and PGU2. If you use both PGUs, the pulse count setting must be the same. Check the pulse count setting value of the SPG, MP and STT commands in your program.

If you enter the SPG command into the internal program memory, do not set *Pc*=0. Free run pulse output is not available.

Table 1-22 Ranges of Pulse Period, Pulse Width and Delay Time for SPG Command

Range [a]	*Tp* in sec	*Tw* in sec	*Td* in sec	Resolution in sec
1	2E–6 to 100E–6	1E–6 to 99.9E–6	0 to 100E–6	0.1E–6
2	100E–6 to 1E–3	1E–6 to 999E–6	0 to 1E–3	1E–6
3	1E–3 to 10E–3	10E–6 to 9.99E–3	0 to 10E–3	10E–6
4	10E–3 to 100E–3	100E–6 to 99.9E–3	0 to 100E–3	100E–6
5	100E–3 to 1	1E–3 to 999E–3	0 to 1	1E–3
6	1 to 10	10E–3 to 9.99	0 to 10	10E–3

a. Settings of *Tp*, *Tw* and *Td* for a PGU must be in the same range. If you use two PGUs, these three parameters must be set in the same range for both PGUs.

Table 1-23 Leading and Trailing Edge Transition Time for SPG Command

Range [a]	*Tl* or *Tt* in sec	Resolution in sec
1	100E–9 to 1E–6	1E–9
2	500E–9 to 10E–6	10E–9
3	5E–6 to 100E–6	100E–9
4	50E–6 to 1E–3	1E–6
5	500E–6 to 10E–3	10E–6

a. Leading time and trailing time for a PGU must be in the same range.

Example Statements

```
OUTPUT @Hp4156;"SPG 28,0"
OUTPUT @Hp4156;"SPG 28,1,5"
OUTPUT @Hp4156;"SPG 28,2,0,5,0,5E-6,1E-6,1E-6,1E-5,1000"
```

SPL

The SPL command specifies the data to print, and spools the data.

This command requires a temporary file on the network file system specified by the SDSK command to spool the data. If a temporary file is not opened, this command creates a temporary file and names it with the IP address of the 4155C/4156C. The temporary file is deleted by the PRN command which executes print-out.

Execution Conditions

The SDSK command specifies the network file system.

The SPR command specifies the remote printer.

Syntax

`SPL` *`data`*

Parameters

data : Data to print. Characters or numeric data (ASCII).

Example Statements

```
OUTPUT @Hp4156;"SPL 'TestResults'"
OUTPUT @Hp4156;"SPL";A$
```

SPP

The SPP command stops the PGU pulse output started by the SRP command. The PGU output goes to the *base* value set by the SPG command. If you use two PGUs, this command stops both PGU outputs.

Syntax

```
SPP
```

Example Statements

```
OUTPUT @Hp4156;"SPP"
```

SPR

The SPR command selects the remote printer used to print the data.

Execution Conditions

Remote printer is registered on the NETWORK PRINTER SETUP table of the SYSTEM: MISCELLANEOUS screen.

Syntax

`SPR printer`

Parameters

printer : Identification for the printer. 1, 2, 3 or 4. Integer expression.

printer value is relative to the position of softkeys available for the DESTINATION field of the SYSTEM: PRINT/PLOT SETUP screen.

Softkeys for DESTINATION		Description	*printer*
Position	Label		
top	GPIB	Printer connected to GP-IB	–
second from top	PARAL-LEL	Printer connected to parallel interface	–
third from top	–	Remote printer	1
4th from top	–	Remote printer	2
5th from top	–	Remote printer	3
6th from top	–	Remote printer	4

Softkey label of the remote printer can be defined by using the NETWORK PRINTER SETUP table of the SYSTEM: MISCELLANEOUS screen.

Example Statements

```
OUTPUT @Hp4156;"SPR 1"
```

*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* :** 0 to 255 are available. Integer expression. To specify *bit*, use the decimal value of the bits as shown in the following tables.

For example, to enable Bit 0, 4, and 7 for the SRQ, the *bit* value must be 145 (1 + 16 + 128). If *bit*=0, or if you do not specify a *bit* value, all bits, except for Bit 6, will be masked (disabled for the SRQ).

In US command mode: You cannot mask bit 6.

Decimal Value	Bit Number	Description
1	Bit 0	Emergency Status
2	Bit 1	Measurement/Stress Status
4	Bit 2	not used
8	Bit 3	Questionable Status
16	Bit 4	MAV (Message Available summary-message)
32	Bit 5	ESB (Event Status Bit)
64	Bit 6	Request Service (RQS) Message
128	Bit 7	not used

In US42 command mode: You cannot mask bit 6.

Decimal Value	Bit Number	Description
1	Bit 0	Data Ready
2	Bit 1	Wait
4	Bit 2	not used
8	Bit 3	Interlock Open
16	Bit 4	Set Ready
32	Bit 5	Error
64	Bit 6	RQS
128	Bit 7	Shut Down

Example Statements

```
OUTPUT @Hp4156;"*SRE 6"
OUTPUT @Hp4156;"*SRE 128"
```

*SRE?

The *SRE? query command requests 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).

The output data is always stored in the query buffer in ASCII format, regardless of the FMT command.

Syntax

`*SRE?`

Query Response

In US command mode: `enabled bits<LF^EOI>`

enabled bits are represented by the corresponding decimal values shown below.

Decimal Value	Bit Number	Description
1	Bit 0	Emergency Status
2	Bit 1	Measurement/Stress Status
4	Bit 2	not used
8	Bit 3	Questionable Status
16	Bit 4	MAV (Message Available summary-message)
32	Bit 5	ESB (Event Status Bit)
64	Bit 6	Request Service (RQS) Message
128	Bit 7	not used

In US42 command mode: `enabled bits<CR/LF^EOI>`

enabled bits are represented by the corresponding decimal values shown below.

Decimal Value	Bit Number	Description
1	Bit 0	Data Ready
2	Bit 1	Wait
4	Bit 2	not used
8	Bit 3	Interlock Open
16	Bit 4	Set Ready
32	Bit 5	Error
64	Bit 6	RQS
128	Bit 7	Shut Down

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 @Hp4156;"*SRE?"
ENTER @Hp4156;A
```

SRP

SRP command forces the PGU output (dc voltage or pulse voltage) set by the SPG command, immediately. If you use two PGUs, this command starts to force both PGU outputs.

To stop the PGU pulse output, use the SPP command or the DV command. The SPP command sets the PGU output to the *base* value set by the SPG command. And the DV command sets the PGU output to the output value specified by the DV command. For example, the following HP BASIC command sets the PGU output to 0 V.

```
OUTPUT @Hp4156;"DV 27,0,0"
```

To stop the PGU dc voltage output, use the DV command.

Execution Conditions

The SPG command specifies the settings of the PGU.

Syntax

```
SRP
```

Example Statements

```
OUTPUT @Hp4156;"SRP"
```

SSP

The SSP command controls the 16440A SMU/Pulse Generator Selector.

Syntax

```
SSP port,status
```

Parameters

port **:** Output port number. 0, 1, 2 or 3. Integer expression.

port	Description
0	Output channel 1 of the primary 16440A.
1	Output channel 2 of the primary 16440A.
2	Output channel 1 of the secondary 16440A.
3	Output channel 2 of the secondary 16440A.

status **:** Connection status of the specified port. 0, 1, 2 or 3. Integer expression.

status	Description
0	No input is connected to output.
1	Connects SMU input to output.
2	Connects PGU input to output.
3	Disconnects PGU input using the semiconductor relay. No input is connected to output.

Example Statements

```
OUTPUT @Hp4156;"SSP 0,0"
OUTPUT @Hp4156;"SSP 1,3"
```

ST

The ST command is used with the END command to store a program in the internal program memory of the 4155C/4156C. Maximum 255 programs can be stored (total 100 KB). The ST command indicates the start of the program, and assigns the program number. If the assigned program number already exists, the 4155C/4156C 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 4155C/4156C stores the commands until the program memory is full.

Use the DO or RU command to execute stored programs. Before executing the internal memory program, close the Interlock circuit. If you do not close the interlock circuit, an error occurred and the measurement is aborted.

Internal program memory is available when the 4155C/4156C is in the FLEX command control mode. The internal memory programs are deleted by the US or US42 command execution.

Syntax

```
ST prog No.;command[;command...[;command]...]
END
```

or

```
ST prog No.
[command]
[command]
     :
     :
[command]
END
```

Parameters

prog No. : Program number. 1 to 255. Integer expression.

command : Command stored in the internal program memory. Specify commands according to normal syntax – no special syntax is necessary.

Note that the following commands cannot be stored in program memory:

```
AB        ACH
CA        CLOSE     CM        *CAL?     *CLS?
DO        END       ERR?      *ESE?
*IDN?     LOP?      LST?      *LRN?
NUB?      OPEN      *OPC(?)   *OPT?     PRN
RCV       RD?       RMD?      RU        *RST
SCR       SDSK      SPL       SPR       ST
*SRE?     *STB?     :SYST:ERR?
*TST?     UNT?      US        US42
WNU?      WR        *WAI
```

Remarks

The internal memory program should be the complete program which makes the measurement setup completely, or executes the measurements with no error.

If you use the internal program memory to make a few changes in the present measurement setup, grasp the present setup, decide the next setup carefully, and enter the FLEX commands into the program memory. If there is mismatch in the changes with the present setup, you cannot execute the measurement in the desirable setup because of no error check for the commands in the program memory.

Create a complete program at first. And confirm that the program does not cause any error during the program execution. Then enter the FLEX commands into the program memory. The commands must make the complete measurement setup, or execute the measurements with no error, or make changes consistently with the present setup.

Example Statements

Example 1:

```
OUTPUT @Hp4156;"ST 1;CN 1;DV 1,0,5,1E-4;TI? 1,0;CL 1"
OUTPUT @Hp4156;"END"
```

Example 2:

```
OUTPUT @Hp4156;"ST 1"
OUTPUT @Hp4156;"CN 1"
OUTPUT @Hp4156;"DV 1,0,5,1E-4"
OUTPUT @Hp4156;"TI? 1,0"
OUTPUT @Hp4156;"CL 1"
OUTPUT @Hp4156;"END"
```

*STB?

The *STB? query command stores the decimal representation of the status byte in the output data buffer (query buffer).

The output data is always stored in the query buffer in ASCII format, regardless of the FMT command.

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?
```

Query Response

In US command mode: `status byte<LF^EOI>`

Decimal Value	Bit Number	Description
1	Bit 0	Emergency Status
2	Bit 1	Measurement/Stress Status
4	Bit 2	not used
8	Bit 3	Questionable Status
16	Bit 4	MAV (Message Available summary-message)
32	Bit 5	ESB (Event Status Bit)
64	Bit 6	Request Service (RQS) Message
128	Bit 7	not used

In US42 command mode: `status byte<CR/LF^EOI>`

Decimal Value	Bit Number	Description
1	Bit 0	Data Ready
2	Bit 1	Wait
4	Bit 2	not used
8	Bit 3	Interlock Open
16	Bit 4	Set Ready
32	Bit 5	Error
64	Bit 6	RQS
128	Bit 7	Shut Down

where, the *status byte* value is a decimal number that indicates which bits of the status byte are ON ("1"). Bits of the status byte indicate conditions that may require attention. For example, if *status byte* is 40 (8 + 32), then Bit 3 and 5 are set to 1.

Example Statements

```
OUTPUT @Hp4156;"*STB?"
ENTER @Hp4156;A
```

STC

The STC command clears the settings of the specified stress source.

Syntax

`STC [`*source*`[,`*source*`[,`*source*`[,`*source*`]]]]`

Parameters

source : Reference number of the stress source.

0 to 3 are available. Integer expression.

source value is the value (0, 1, 2 or 3) you assigned for the stress source using the STI, STV or STP command. Enter the *source* value for the stress source you want to clear the settings.

If you do not specify *source* parameter, STC command clears the settings for the all stress sources (4 sources).

Example Statements

```
OUTPUT @Hp4156;"STC"
OUTPUT @Hp4156;"STC 0"
```

STG

The STG command sets the trigger function using the Ext Trig In/Out terminals on the rear panel of the 4155C/4156C.

Syntax

STG *mode*,*state*,*polarity*

Parameter

mode : Trigger mode. 0 or 1. Integer expression.

0: Trigger input.

1: Trigger output.

In the trigger input mode, the 4155C/4156C waits for the edge trigger from the external instrument, and cannot output the trigger.

When the trigger mode is set to the output mode, the 4155C/4156C outputs gate triggers in the stress force state, and outputs edge triggers in other measurement states. In this case, the 4155C/4156C cannot receive the external trigger signal.

state : Trigger function status. 0 or 1. Integer expression.

0: Disables trigger function. (initial setting)

1: Enables trigger function.

polarity : Polarity of the trigger. 0 or 1. Integer expression.

0: Positive trigger. (initial setting)

1: Negative trigger.

Example Statements

```
OUTPUT @Hp4156;"STG 0,1,0"
OUTPUT @Hp4156;"STG 1,1,0"
```

STI

The STI command specifies the dc stress current source (SMU) and its parameters. The XE command triggers the stress force. To stop the stress force, use the AB command.

The 4155C/4156C allows to use maximum four stress sources (specified by the STI, STV and/or STP command) for a measurement.

Syntax

```
STI source,chnum,range,base,stress[,Vcomp]
```

If you enter the STI command into the program memory (see the ST command), do not omit the *Vcomp* parameter. *Vcomp* is necessary when using the internal program memory.

Parameters

source : Reference number for the stress source. 0 to 3 are available. Integer expression.

Enter 0, 1, 2, or 3 to assign the reference number to the stress source.

If you specify multiple stress sources for a measurement, independent *source* value should be defined for the stress setup command (STI, STV or STP). If a *source* value is defined for multiple stress setup commands, the last command is effective when executing the measurement.

chnum : Channel number of the unit that will force the stress current. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

range : Stress output range. Integer expression.

range	**Ranging Type** [a]
0	Auto ranging
9 (only for 4156C)	10 pA limited auto ranging
10 (only for 4156C)	100 pA limited auto ranging
11	1 nA limited auto ranging
12	10 nA limited auto ranging
13	100 nA limited auto ranging
14	1 μA limited auto ranging
15	10 μA limited auto ranging
16	100 μA limited auto ranging
17	1 mA limited auto ranging
18	10 mA limited auto ranging
19	100 mA limited auto ranging
20 (only for HPSMU)	1 A limited auto ranging

a. Auto ranging uses the lowest output range (available for the unit) that covers both *base* and *stress* value. Limited auto ranging uses the specified range or above. For example, 10 μA limited auto ranging uses the 100 mA range to force *stress*=50 mA with *base*=1 mA.

base : Base current (in A). Numeric expression. See Table 1-24.

0 to ±100E–3 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±1 (for HPSMU in 41501A/B)

Set the source unit output values which has been forced before the XE command. This minimizes the spike.

stress **:** Stress current (in A). Numeric expression. See Table 1-24.

0 to ±100E−3 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±1 (for HPSMU in 41501A/B)

Vcomp **:** Voltage compliance (in V). Numeric expression. See Table 1-24.

If you do not specify this parameter, *Vcomp* is set to the previous setting.

The voltage compliance polarity is automatically set to the same value as the polarity of *stress* and *base*, regardless of the specified *Vcomp*. If *stress*=0 and *base*=0, the polarity of the voltage compliance is positive.

Table 1-24 **Available Parameter Values for STI Command**

Output Range	Resolution in A [a]	***base*** and ***stress*** in A	Maximum ***Vcomp*** in V	Remarks
10 pA	10E−15	0 to ±10E−12	±100	For 4156C.
100 pA	10E−15	0 to ±100E−12	±100	
1 nA	100E−15	0 to ±1E−9	±100	For SMU.
			±200	For HPSMU.
10 nA	1E−12	0 to ±10E−9	±100	For SMU.
			±200	For HPSMU.
100 nA	10E−12	0 to ±100E−9	±100	For SMU.
			±200	For HPSMU.
1 µA	100E−12	0 to ±1E−6	±100	For SMU.
			±200	For HPSMU.
10 µA	1E−9	0 to ±10E−6	±100	For SMU.
			±200	For HPSMU.
100 µA	10E−9	0 to ±100E−6	±100	For SMU.
			±200	For HPSMU.

Output Range	**Resolution in A** [a]	***base* and *stress* in A**	**Maximum *Vcomp* in V**	**Remarks**
1 mA	100E–9	0 to ±1E–3	±100	For SMU.
			±200	For HPSMU.
10 mA	1E–6	0 to ±10E–3	±100	For SMU.
			±200	For HPSMU.
100 mA	10E–6	0 to ±20E–3	±100	For SMU.
		to ±50E–3	±40	
		to ±100E–3	±20	
	100E–6	0 to ±50E–3	±200	For HPSMU
		to ±100E–3	±100	
1 A	100E–6	0 to ±50E–3	±200	
		to ±125E–3	±100	
		to ±500E–3	±40	
		to ±1	±20	

a. Minimum resolution is Range×5E–5. However the setting accuracy is not guaranteed for the resolution less than the value shown in the table.

Example Statements

```
OUTPUT @Hp4156;"STI 0,1,14,0,5E-7,10"
```

STM

The STM command sets the automatic abort condition (stop condition) for the stress force.

The automatic abort function of the stress force is available for the free run stress mode and for the pulse count stress mode (more than 10 sec). Refer to the STT command.

Syntax

```
STM abort
```

Parameters

abort **:** Automatic abort condition (stop condition). Integer expression. The following values are available:

abort	Abort condition
1	Disables the automatic abort function.
2	One of following occurs. - Compliance on the non-measurement unit. - Oscillation on any unit.
4	Compliance on the non-measurement unit.
32	Oscillation on any unit.

Example Statements

```
OUTPUT @Hp4156;"STM 32"
```

STP

The STP command sets the PGU for the dc voltage stress output or pulse stress output. The XE command triggers the stress force. To stop the stress force, use the AB command.

The 4155C/4156C allows to use maximum four stress sources (specified by the STI, STV and/or STP command) for a measurement.

Syntax

`STP source,chnum,mode,base,stress[,Td[,Tw[,Tl[,Tt]]]]`

Parameters

source : Reference number for the stress source. 0 to 3 are available. Integer expression.

Enter 0, 1, 2, or 3 to assign the reference number to the stress source.

If you specify multiple stress sources for a measurement, independent *source* value should be defined for the stress setup command (STI, STV or STP). If a *source* value is defined for multiple stress setup commands, the last command is effective when executing the measurement.

chnum : Channel number of PGU 27 or 28. Integer expression.

27: PGU1

28: PGU2

mode : Output mode. 0 or 1. Integer expression.

0: dc voltage output

1: pulse voltage output

base : Base voltage (in V).

0 to ±40 V. Numeric expression.

Resolution: 4 mV (for 0 to ±20 V), 8 mV (for ±20 to ±40 V).

stress : Stress voltage (in V).

0 to ±40V. Numeric expression.

Resolution: 4 mV (for 0 to ±20 V), 8 mV (for ±20 to ±40 V).

***Td* :** Delay time (in seconds). Only for pulse stress.

0 to 10 sec. Numeric expression. See Table 1-25.

Restrictions: $Td < period$ of STT command

***Tw* :** Pulse width (in seconds). Only for pulse stress.

1 μsec to 9.99 sec. Numeric expression. See Table 1-25.

Restrictions: $Tw < period$ of STT command

***Tl* :** Leading edge transition time (in seconds). Only for pulse stress.

100 nsec to 10 msec. Numeric expression. See Table 1-26.

Restrictions: $Tl < Tw \times 0.8$

***Tt* :** Trailing edge transition time (in seconds). Only for pulse stress.

100 nsec to 10 msec. Numeric expression. See Table 1-26.

Restrictions: $Tt < (period - Tw) \times 0.8$

where *period* is a parameter of STT command.

Table 1-25 Ranges of Delay Time and Pulse Width

Range [a]	*period* [b] in sec	*Tw* in sec	*Td* in sec	Resolution in sec
1	2E–6 to 100E–6	1E–6 to 99.9E–6	0 to 100E–6	0.1E–6
2	100E–6 to 1E–3	1E–6 to 999E–6	0 to 1E–3	1E–6
3	1E–3 to 10E–3	10E–6 to 9.99E–3	0 to 10E–3	10E–6
4	10E–3 to 100E–3	100E–6 to 99.9E–3	0 to 100E–3	100E–6
5	100E–3 to 1	1E–3 to 999E–3	0 to 1	1E–3
6	1 to 10	10E–3 to 9.99	0 to 10	10E–3

a. Settings of *period*, *Tw* and *Td* for a PGU must be in the same range. If you use two PGUs, these three parameters must be set in the same range for both PGUs.

b. This parameter is a STT command parameter.

Table 1-26 **Leading and Trailing Edge Transition Time**

Range [a]	*Tl* or *Tt* in sec	Resolution in sec
1	100E–9 to 1E–6	1E–9
2	500E–9 to 10E–6	10E–9
3	5E–6 to 100E–6	100E–9
4	50E–6 to 1E–3	1E–6
5	500E–6 to 10E–3	10E–6

a. Leading time and trailing time for a PGU must be in the same range.

Example Statements

```
OUTPUT @Hp4156;"STP 0,28,0,0,5"
OUTPUT @Hp4156;"STP 0,28,1,0,5,1E-3,1E-3,1E-4,1E-4"
```

STT

The STT command sets the stress time and stress mode.

Syntax

`STT hold,mode[,count[,period]]`

Parameters

hold **:** Hold time (in seconds).

0 to 655.35 sec. Numeric expression.

mode **:** Stress mode.

0, 1 or 2. Integer expression. See Table 1-27.

If you use *only* the dc stress source, set *mode* to 0 or 2. *mode*=1 is not available for the dc stress. Do not set *count* and *period*.

If you enter the STT command into the internal program memory, do not set *mode*=0. Free run pulse output is not available.

count **:** Stress time or pulse count. Numeric expression. See Table 1-27.

period **:** Pulse period (in seconds). Only for pulse stress.

2E–6 to 10 sec. Numeric expression.

This value must match the STP command *Td* and *Tw* parameters. See Table 1-25 of the STP command. Initial setting: 10 msec

If this parameter is not specified, *period* is set to the previous value or the initial setting value.

If you use the automatic abort function in the pulse count mode, pulse output must be more than 10 seconds. ($count \times period > 10$ sec)

Table 1-27 **Available *mode* and *count* value**

mode	Description	*count*
0	Free run mode. Continues stress output. Not available for the program memory.	The value is ignored, but a number must be entered for pulse stress setup.
1	Pulse count mode. Forces pulse stress until the number of pulses reaches the total pulse count specified by *count*. Available for the stress by the STP command.	Specifies the total pulse count. 1 to 65535.
2	Duration mode. Forces stress until the stress force time reaches the total stress time specified by *count*. Automatic abort function is not available in this mode.	Specifies the total stress time. 500E–6 to 655 sec.

NOTE

Pulse Count and Pulse Period

Pulse count and pulse period settings are effective for both PGU1 and PGU2. If you use a PGU as a stress source, and another PGU as a pulse source (controlled by the SPG/SRP/SPP commands), check the settings of the SPG command in your program. The settings of each commands must be the same value.

Example Statements

```
OUTPUT @Hp4156;"STT 1,0,100"
OUTPUT @Hp4156;"STT 1,1,100"
OUTPUT @Hp4156;"STT 1,2,100,0.1"
```

STV

The STV command specifies the dc stress voltage source (SMU or VSU) and its parameters. The XE command triggers the stress force. To stop the stress force, use the AB command.

The 4155C/4156C allows to use maximum four stress sources (specified by the STI, STV and/or STP command) for a measurement.

Syntax

`STV source,chnum,range,base,stress[,Icomp]`

If you enter the STV command into the program memory (see the ST command), do not omit the *Icomp* parameter. *Icomp* is necessary when using the internal program memory.

Parameters

source : Reference number for the stress source. 0 to 3 are available. Integer expression.

Enter 0, 1, 2, or 3 to assign the reference number to the stress source.

If you specify multiple stress sources for a measurement, independent *source* value should be defined for the stress setup command (STI, STV or STP). If a *source* value is defined for multiple stress setup commands, the last command is effective when executing the measurement.

chnum : Channel number of the unit that will force the stress voltage. Integer expression.

chnum	Unit	*chnum*	Unit
1	SMU1	5 [a]	SMU5
2	SMU2	6 [a]	SMU6
3	SMU3	21	VSU1
4	SMU4	22	VSU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

range : Stress output range. Integer expression.

range	Ranging Type [a]
0	Auto ranging
11 (for SMU)	2 V limited auto ranging
12	20 V limited auto ranging
13 (for SMU)	40 V limited auto ranging
14 (for SMU)	100 V limited auto ranging
15 (only for HPSMU)	200 V limited auto ranging

a. Auto ranging uses the lowest output range (available for the unit) that covers both *base* and *stress* value. Limited auto ranging uses the specified range or above. For example, 20 V limited auto ranging uses the 100 V range to force *stress*=50 V with *base*=0 V.

base : Base voltage (in V). Numeric expression. See Table 1-28.

0 to ±100 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±200 (for HPSMU in 41501A/B)

0 to ±20 (for VSU)

stress : Stress current (in V). Numeric expression. See Table 1-28.

0 to ±100 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±200 (for HPSMU in 41501A/B)

0 to ±20 (for VSU)

Icomp : Current compliance (in A). Numeric expression. See Table 1-28.

If this parameter is not specified, *Icomp* is set to the previous setting. 0 A is not allowed for *Icomp*.

The current compliance polarity is automatically set to the same polarity as the *stress* and *base* values, regardless of the specified *Icomp*. If *stress*=0 and *base*=0, the polarity of the current compliance is positive.

Table 1-28 Available Parameter Values for STV Command

Output Range	Resolution in V	*base* and *stress* in V	Maximum *Icomp* in A	Remarks
2 V	100E–6	0 to ±2	±100E–3	For SMU.
			±1	For HPSMU.
20 V	1E–3	0 to ±20	±100E–3	For SMU.
			±1	For HPSMU.
			–	For VSU.
40 V	2E–3	0 to ±40	±50E–3	For SMU.
			±500E–3	For HPSMU.
100 V	5E–3	0 to ±100	±20E–3	For SMU.
			±125E–3	For HPSMU.
200 V	10E–3	0 to ±200	±50E–3	

Example Statements

```
OUTPUT @Hp4156;"STV 0,1,12,0,5,1E-2"
```

:SYST:ERR?

This query command returns an error code from the 4155C/4156C error register, and the error message. An error code and error message pair is returned, and the error code is deleted from the error register.

The output data is always stored in the query buffer in ASCII format, regardless of the FMT command.

Syntax

`:SYST:ERR?`

Query Response

In US command mode:

error_code,*message*<LF^EOI>

In US42 command mode:

error_code,*message*<CR/LF^EOI>

Example Statements

```
OUTPUT @Hp4156;":SYST:ERR?"
ENTER @Hp4156;A,A$
```

TDI

The TDI command forces the current using the specified unit, and returns the time stamp, which is the time that has elapsed between the execution of the TSR command and the execution of this command. This command is only for the US control mode.

Execution Conditions

The CN command has been executed for the specified unit. If the voltage compliance is greater than ±40 V, the interlock circuit must be shorted.

Syntax

`TDI chnum,range,current[,Vcomp[,comp polarity]]`

If you send the TDI command to the program memory (see the ST command), do not omit the *Vcomp* parameter. *Vcomp* is necessary when using the internal program memory.

Parameters

chnum: Channel number of the unit used to force the current. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5 (MPSMU)
6 [a]	SMU6 (MPSMU or HPSMU)

a. For SMUs in the 41501A/B Expander.

range: Ranging type for the current output. Integer expression.

range	Ranging Type [a]
0	Auto ranging
9 (only for 4156C)	10 pA limited auto ranging
10 (only for 4156C)	100 pA limited auto ranging

range	**Ranging Type** [a]
11	1 nA limited auto ranging
12	10 nA limited auto ranging
13	100 nA limited auto ranging
14	1 μA limited auto ranging
15	10 μA limited auto ranging
16	100 μA limited auto ranging
17	1 mA limited auto ranging
18	10 mA limited auto ranging
19	100 mA limited auto ranging
20 (only for HPSMU)	1 A limited auto ranging

a. Auto ranging uses the lowest output range that covers the *current* value. Limited auto ranging uses the specified range or above. For example, 10 μA limited auto ranging uses the 10 μA range to force 1 nA.

***current*:** Output current value (in A). Numeric expression.

0 to ±100E–3 (for the 4155C/4156C and MPSMU in the 41501A/B)

0 to ±1 (for HPSMU in the 41501A/B)

For the relation between the *current* value and the output range, and for the resolution of the *current* value, see Table 1-29.

***Vcomp*:** Voltage compliance value (in V). Numeric expression. If you do not specify this parameter, *Vcomp* remains at its previous value.

For available values, see Table 1-29.

***comp polarity*:** Polarity of voltage compliance. Numeric expression.

0: Auto mode. Default.

The polarity of the voltage compliance is automatically set to the same value as the polarity of the output current (*current*), regardless of the polarity of the *Vcomp* value. If the output current is 0 A, the polarity is positive.

1: Manual mode.

This parameter must be specified if you want the polarity of the voltage compliance to be set the same as the specified polarity of *Vcomp*.

Response

time <terminator>

Where *time* is the time that has elapsed between the execution of the TSR command and the execution of this command.

<terminator> depends on the FMT command setting.

Example Statements

```
OUTPUT @Hp4156;"TDI 1,0,1E-6,100,1"
ENTER @Hp4156;Time
```

Table 1-29 Available Parameter Values for TDI Command

Output Range	Resolution in A [a]	*current* in A	Maximum *Vcomp* in V	Remarks
10 pA	10E–15	0 to ±10E–12	±100	For 4156C.
100 pA	10E–15	0 to ±100E–12	±100	
1 nA	100E–15	0 to ±1E–9	±100	For SMU.
			±200	For HPSMU.
10 nA	1E–12	0 to ±10E–9	±100	For SMU.
			±200	For HPSMU.
100 nA	10E–12	0 to ±100E–9	±100	For SMU.
			±200	For HPSMU.
1 μA	100E–12	0 to ±1E–6	±100	For SMU.
			±200	For HPSMU.
10 μA	1E–9	0 to ±10E–6	±100	For SMU.
			±200	For HPSMU.
100 μA	10E–9	0 to ±100E–6	±100	For SMU.
			±200	For HPSMU.
1 mA	100E–9	0 to ±1E–3	±100	For SMU.
			±200	For HPSMU.
10 mA	1E–6	0 to ±10E–3	±100	For SMU.
			±200	For HPSMU.
100 mA	10E–6	0 to ±20E–3	±100	For SMU.
		to ±50E–3	±40	
		to ±100E–3	±20	
	100E–6	0 to ±50E–3	±200	For HPSMU.
		to ±100E–3	±100	
1 A	100E–6	0 to ±50E–3	±200	
		to ±125E–3	±100	
		to ±500E–3	±40	
		to ±1	±20	

a. Minimum resolution is Range×5E–5. However the setting accuracy is not guaranteed for the resolution less than the value shown in the table.

TDV

The TDV command forces the output voltage using the specified unit, and returns the time stamp, which is the time that has elapsed between the execution of the TSR command and the execution of this command. This command is only for the US control mode.

Execution Conditions

The CN command has been executed for the specified unit. If the output voltage is greater than ±40 V, the interlock circuit must be shorted.

Syntax

`TDV chnum,range,voltage[,Icomp[,comp polarity]]`

If you send the TDV command to the program memory (see the ST command), do not omit the *Icomp* parameter. *Icomp* is necessary when using the internal program memory.

Parameters

chnum: Channel number of the unit used to force voltage. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5 (MPSMU)
6 [a]	SMU6 (MPSMU or HPSMU)
21	VSU1
22	VSU2
27	PGU1 [b]
28	PGU2 [b]

a. For SMUs in the 41501A/B Expander.
b. If you use the PGU, execute the SPG command *before* the TDV command.

range: Ranging type for voltage output. Integer expression.

range	**Ranging Type** [a]
0	Auto ranging
11 (for SMU)	2 V limited auto ranging
12	20 V limited auto ranging
13 (for SMU and PGU)	40 V limited auto ranging
14 (for SMU)	100 V limited auto ranging
15 (only for HPSMU)	200 V limited auto ranging

a. Auto ranging uses the lowest output range that covers the *voltage* value. Limited auto ranging uses the specified range or above. For example, 20 V limited auto ranging uses the 20 V range to force 1 V.

voltage: Output voltage value (in V). Numeric expression.

0 to ±100 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±200 (for HPSMU in 41501A/B)

0 to ±20 (for VSU)

0 to ±40 (for PGU)

For the relation between the *voltage* and the output range and for the resolution of the *voltage* value, see Table 1-30.

Icomp: Current compliance value (in A). Numeric expression. If you do not specify this parameter, *Icomp* remains at its previous value. Zero amps (0 A) is not allowed for *Icomp*. This parameter is not available for the VSU and PGU.

For available values, see Table 1-30.

comp polarity: Polarity of the current compliance. Integer expression. This parameter is not available for the VSU and PGU.

0 (auto mode) or 1 (manual mode).

0: Auto mode. Default.

The polarity of the current compliance is automatically set to the same value as the polarity of the output voltage (*voltage*), regardless of the polarity of the *Icomp* value. If the output voltage is 0 V, the polarity is positive.

1: Manual mode.

This parameter must be specified if you want the polarity of the current compliance to be set to the same value as the polarity of the specified *Icomp*.

Table 1-30 **Available Parameter Values for TDV Command**

Output Range	**Resolution in V**	***voltage* in V**	**Maximum *Icomp* in A**	**Remarks**
2 V	100E–6	0 to ±2	±100E–3	For SMU.
			±1	For HPSMU.
20 V	1E–3	0 to ±20	±100E–3	For SMU.
			±1	For HPSMU.
			–	For VSU.
	4E–3		–	For PGU.
40 V	2E–3	0 to ±40	±50E–3	For SMU.
			±500E–3	For HPSMU.
	8E–3		–	For PGU.
100 V	5E–3	0 to ±100	±20E–3	For SMU.
			±125E–3	For HPSMU.
200 V	10E–3	0 to ±200	±50E–3	

Response

time <terminator>

Where *time* is the time that has elapsed between the execution of the TSR command and the execution of this command.

<terminator> depends on the FMT command setting.

Example Statements

```
OUTPUT @Hp4156;"TDV 1,0,20,1E-6,0"
ENTER @Hp4156;Time
```

TI/TI?

The TI and TI? commands are the trigger command for high-speed spot current measurement. The commands perform a high-speed spot current measurement, independent of the SMU source mode, trigger mode (TM command), and measurement mode (MM command).

Difference between the TI command and the TI? command is the way to read the measurement data as shown in the Example Statements. If you use the TI? command, you do not need to enter the RMD? command.

For the output data format, refer to “Data Output Format” on page 1-11.

The TI command cannot be used with the TI?, TV?, TTI?, or TTV? command in a same measurement program. Also the TI? command cannot be used with the TI, TV, TTI, or TTV command in a same measurement program.

Execution Conditions

CN command has been executed for the specified unit.

Syntax

`TI` *`chnum`*`[,`*`range`*`]`

`TI?` *`chnum`*`[,`*`range`*`]`

If you enter the TI/TI? command into the program memory (see the ST command), do not omit the *range* parameter. *range* is necessary when using the internal program memory.

Parameters

chnum : Channel number of the unit used to measure current. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

range **:** Ranging type for current measurement. 0, 9 to 20, and −9 to −20 are available. Integer expression. See table below.

For SMU set to the current source, the input *range* value is ignored, and the SMU measures the current using the current output range.

If you do not specify *range*, measurement range is automatically set to the compliance range for voltage force SMU, and set to the current output range for current force SMU.

range	**Ranging type** [a]	***range***	**Ranging type** [a]
0	Auto ranging		
9 [b]	10 pA limited auto ranging	−9 [b]	10 pA range fixed
10 [b]	100 pA limited auto ranging	−10 [b]	100 pA range fixed
11	1 nA limited auto ranging	−11	1 nA range fixed
12	10 nA limited auto ranging	−12	10 nA range fixed
13	100 nA limited auto ranging	−13	100 nA range fixed
14	1 μA limited auto ranging	−14	1 μA range fixed
15	10 μA limited auto ranging	−15	10 μA range fixed
16	100 μA limited auto ranging	−16	100 μA range fixed
17	1 mA limited auto ranging	−17	1 mA range fixed
18	10 mA limited auto ranging	−18	10 mA range fixed
19	100 mA limited auto ranging	−19	100 mA range fixed
20 [b]	1 A limited auto ranging	−20 [b]	1 A range fixed

a. Auto ranging uses the lowest measurement range (available for the unit) that covers the measurement value. Limited auto ranging uses the specified range or above. For example, 10 μA limited auto ranging uses the 10 μA range to measure 1 nA, and uses the 100 mA range to measure 50 mA.

b. 9, 10, −9, and −10 are only for 4156C. 20 and −20 are only for HPSMU.

Example Statements

For TI command:

```
OUTPUT @Hp4156;"TI 1,0"
OUTPUT @Hp4156;"RMD?"
ENTER @Hp4156;A
```

For TI? command:

```
OUTPUT @Hp4156;"TI? 1,0"
ENTER @Hp4156;A
```

TM

The TM command specifies the trigger mode which defines how events are effected for the measurement trigger, and releases the wait status set by the PA command. The TM command is effective for all types of measurements, except for high-speed spot measurements.

Syntax

```
TM mode
```

Parameters

***mode* :** Trigger mode. 1 to 4 are available. Integer expression. See below. The *mode* value is initially set to 1.

mode	**Events effective for trigger**
1	XE command and GPIB GET (Group Execute Trigger, trigger command in HP BASIC)
2	XE command
3	XE command and external trigger (signal via the Ext Trig In terminal)
4	XE command and MM command (automatic trigger after the MM command execution)

If the *mode* value is set to 3, and the measurement is performed by an external trigger signal via the Ext Trig In terminal, the 4155C/4156C outputs a pulse signal via the Ext Trig Out terminal on the rear panel.

Example Statements

```
OUTPUT @Hp4156;"TM 1"
OUTPUT @Hp4156;"TM 3"
```

TSC

The TSC command enables or disables the time stamp function. This command is only for the US control mode.

Execution Conditions

The TSC command is effective in the following measurement modes:

- Spot measurement (MM 1)
- Staircase sweep measurement (MM 2)
- 1-channel pulsed spot measurement (MM 3)
- Pulsed sweep measurement (MM 4)
- Staircase sweep with pulsed bias measurement (MM 5)
- Sampling measurement (MM 10)

  The initial interval must be 2 msec or more.

Syntax

`TSC` *`mode`*

Parameters

mode : Time stamp function mode. Integer expression.

mode	Description
0	Disables the time stamp function. Default setting.
1	Enables the time stamp function.

When the function is enabled, the 4155C/4156C returns the time stamp with the measurement data. The time stamp is the time that has elapsed between the execution of the TSR command and the start of the measurement. Refer to “Data Output Format” on page 1-11.

Example Statements

```
OUTPUT @Hp4156;"TSC 1"
```

TSQ?

The TSQ? command returns the time stamp which is the time that has elapsed between the execution of the TSR command and the execution of this command. This command is only for the US control mode.

This command is effective for all measurement modes, regardless of the TSC setting.

Syntax

```
TSQ?
```

Query Response

time <terminator>

The *time* is the time that has elapsed between the execution of the TSR command and the execution of this command.

<terminator> depends on the FMT command setting.

Example Statements

```
OUTPUT @Hp4156;"TSQ?"
ENTER @Hp4156 USING "#,5X,13D,X";Dtime
```

TSR

The TSR command resets the time stamp to zero. This command is only for the US control mode.

This command is effective for all measurement modes, regardless of the TSC setting.

Syntax

```
TSR
```

Example Statements

```
OUTPUT @Hp4156;"TSR"
```

*TST?

The *TST? query command starts the 4155C/4156C self-test, and stores the results in the output data buffer (query buffer).

The output data is always stored in the query buffer in ASCII format, regardless of the FMT command.

When you execute the TST? command, the output switches of the specified units are set to OFF (the same conditions as after the CL command execution). The *TST? command also performs self-calibration.

If the 4155C/4156C fails self-test, contact the nearest Agilent Technologies Sales and Service Office. Units that fail self-test are disabled, except for the *TST? command, and can only be enabled by the RCV command.

Syntax

```
*TST? [test slot]
```

Parameters

test slot : Slot number. 0 to 9 are available. Integer expression. If you do not specify this parameter, the *test slot* value is set to 0.

test slot	Unit tested
0	All units and mainframe
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6
7 [b]	VSU1, VSU2, VMU1 and VMU2
8 [c]	PGU1 and PGU2
9	GNDU

a. For SMUs in the 41501A/B Expander. If HPSMU is installed in the 41501A/B, set *test slot* of HPSMU to 6, do not set to 5.
b. All VSU1, VSU2, VMU1, and VMU2 are tested.
c. Both PGU1 and PGU2 are tested.

Query Response

In US command mode:

results<LF^EOI>

In US42 command mode:

results<CR/LF^EOI>

results *results* has the meanings shown in the table below. If multiple failures are detected, the returned *results* value is equal to the sum of the *results* values corresponding to the failures.

results	**Description / Failures**
0	Passed. No failure detected.
1	SMU1 failed.
2	SMU2 failed.
4	SMU3 failed.
8	SMU4 failed.
16	SMU5 failed.
32	SMU6 failed.
64	VSU/VMU failed.
128	PGU failed.
256	Mainframe failed.
512	GNDU failed.
1024	Not applicable.

Remarks

If the self-test execution is aborted, fatal error occurred, or 41501A/B expander is not turned on, the *TST? command returns 256 (Mainframe failed).

If *test slot* specifies the slot number that does not have a measurement unit, the *TST? command returns 0 (Passed. No error.).

Example Statements

```
OUTPUT @Hp4156;"*TST?"
ENTER @Hp4156;A
```

TTI/TTI?

The TTI and TTI? commands are the trigger commands for high-speed spot current measurements. The commands perform a high-speed spot current measurement, independent of the SMU source mode, trigger mode (TM command), and measurement mode (MM command). This command also returns the time stamp which is the time that has elapsed between the execution of the TSR command and the execution of this command.

The TTI command and the TTI? command display the measurement data differently, as shown in the example statements. If you use the TTI? command, you do not need to enter the RMD? command.

For the output data format, refer to “Data Output Format” on page 1-11.

The TTI command cannot be used in a measurement program with the TI?, TV?, TTI?, or TTV? commands. The TTI? command cannot be used in a measurement program with the TI, TV, TTI, or TTV commands.

This command is only for the US control mode.

Execution Conditions

The CN command has been executed for the specified unit.

Syntax

`TTI` *`chnum`*`[,`*`range`*`]`

`TTI?` *`chnum`*`[,`*`range`*`]`

If you send the TTI/TTI? command to the program memory (see the ST command), do not omit the *range* parameter. The *range* parameter is necessary when using the internal program memory.

Parameters

chnum **:** Channel number of the unit used to measure current. Integer expression.

chnum	**Unit**
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5 (MPSMU)
6 [a]	SMU6 (MPSMU or HPSMU)

a. For SMUs in the 41501A/B Expander.

range : Ranging type for the current measurement. Ranges from 0, 9 to 20, and –9 to –20 are available. Integer expression. See the table below.

If the unit specified by the *chnum* parameter is set to the current source, this parameter value is ignored, and the unit uses the current output range to measure current.

If you do not specify a *range*, it is automatically set to the compliance range for the voltage force SMU, and set to the current output range for current force SMU.

range	**Ranging type** [a]	***range***	**Ranging type** [a]
0	Auto ranging		
9 [b]	10 pA limited auto ranging	–9 [b]	10 pA range fixed
10 [b]	100 pA limited auto ranging	–10 [b]	100 pA range fixed
11	1 nA limited auto ranging	–11	1 nA range fixed
12	10 nA limited auto ranging	–12	10 nA range fixed
13	100 nA limited auto ranging	–13	100 nA range fixed
14	1 μA limited auto ranging	–14	1 μA range fixed
15	10 μA limited auto ranging	–15	10 μA range fixed
16	100 μA limited auto ranging	–16	100 μA range fixed
17	1 mA limited auto ranging	–17	1 mA range fixed
18	10 mA limited auto ranging	–18	10 mA range fixed
19	100 mA limited auto ranging	–19	100 mA range fixed
20 [b]	1 A limited auto ranging	–20 [b]	1 A range fixed

a. Auto ranging uses the lowest available measurement range that covers the measurement value. Limited auto ranging uses the specified range or above. For example, 10 μA limited auto ranging uses the 10 μA range to measure 1 nA, and uses the 100 mA range to measure 50 mA.
b. 9, 10, –9, and –10 are only for 4156C. 20 and –20 are only for HPSMU.

Response

time, *data* <terminator>

time: the time that has elapsed between the execution of the TSR command and the start of the measurement.

data: current measurement data

<terminator> depends on the FMT command setting.

Example Statements

For TTI command:

```
OUTPUT @Hp4156;"TTI 1,0"
OUTPUT @Hp4156;"RMD? 2"
ENTER @Hp4156;Time,A
```

For TTI? command:

```
OUTPUT @Hp4156;"TTI? 1,0"
ENTER @Hp4156;Time,A
```

TTV/TTV?

The TTV and TTV? commands are the trigger commands for the high-speed spot voltage measurements. The commands perform a voltage measurement, independent of the SMU source mode, trigger mode (TM command), and measurement mode (MM command). This command also returns the time stamp which is the time that has elapsed between the execution of the TSR command and the execution of this command.

The TTV command and the TTV? command display the measurement data differently, as shown in the example statements. If you use the TTV? command, you do not need to enter the RMD? command.

For the data output format, refer to “Data Output Format” on page 1-11.

The TTV command cannot be used in a measurement program with the TI?, TV?, TTI?, or TTV? command. The TTV? command cannot be used in a measurement program with the TI, TV, TTI, or TTV command.

This command is only for the US control mode.

Execution Conditions

CN command has been executed for the specified unit.

Syntax

`TTV` *chnum*`[,`*range*`]`

`TTV?` *chnum*`[,`*range*`]`

If you send the TTV/TTV? command to the program memory (see the ST command), do not omit the *range* parameter. The *range* parameter is necessary when using the internal program memory.

Parameters

chnum : Channel number of the unit used to measure voltage. Integer expression.

chnum	Unit	*chnum*	Unit
1	SMU1	5 [a]	SMU5
2	SMU2	6 [a]	SMU6
3	SMU3	21	VSU1
4	SMU4	22	VSU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

range : Ranging type for voltage measurement. The ranges 0, 10 to 15, and –10 to –15 are available. Integer expression.

If you do not specify this parameter, the *range* is set to 0.

range	**Ranging type [a]**	***range***	**Ranging type [a]**
0	Auto ranging		
10 [b]	0.2 V limited auto ranging	–10 [b]	0.2 V range fixed
11	2 V limited auto ranging	–11	2 V range fixed
12 [c]	20 V limited auto ranging	–12 [c]	20 V range fixed
13 [d]	40 V limited auto ranging	–13 [d]	40 V range fixed
14 [d]	100 V limited auto ranging	–14 [d]	100 V range fixed
15 [e]	200 V limited auto ranging	–15 [e]	200 V range fixed

a. Auto ranging uses the lowest available measurement range that covers the measurement value. Limited auto ranging uses the specified range or above. For example, 2 V limited auto ranging uses the 2 V range to measure 0.1 V, and uses the 20 V range to measure 10 V.
b. 10 and –10 are available only for VMU in the differential mode.
c. 12 and –12 are available for VMU in the grounded mode, and SMU
d. 13, 14, –13, and –14 are available for SMU.
e. 15 and –15 are available only for HPSMU.

Response

time, *data* <terminator>

time: the time that has elapsed between the execution of the TSR command and the start of the measurement.

data: voltage measurement data

<terminator> depends on the FMT command setting.

Example Statements

For TTV command:

```
OUTPUT @Hp4156;"TTV 1,0"
OUTPUT @Hp4156;"RMD? 2"
ENTER @Hp4156;Time,A
```

For TTV? command:

```
OUTPUT @Hp4156;"TTV? 1,0"
ENTER @Hp4156;Time,A
```

TV/TV?

The TV and TV? commands are the trigger command for high-speed spot voltage measurements. The commands perform a voltage measurement, independent of the SMU source mode, trigger mode (TM command), and measurement mode (MM command).

Difference between the TV command and the TV? command is the way to read the measurement data as shown in the Example Statements. If you use the TV? command, you do not need to enter the RMD? command.

For the data output format, refer to “Data Output Format” on page 1-11.

The TV command cannot be used with the TI?, TV?, TTI?, or TTV? command in a same measurement program. Also the TV? command cannot be used with the TI, TV, TTI, or TTV command in a same measurement program.

Execution Conditions

CN command has been executed for the specified unit.

In the US42 command control mode, if you specify the VMU for *chnum*, there are no execution conditions.

Syntax

`TV` *`chnum`*`[,`*`range`*`]`

`TV?` *`chnum`*`[,`*`range`*`]`

If you enter the TV/TV? command into the program memory (see the ST command), do not omit the *range* parameter. *range* is necessary when using the internal program memory.

Parameters

chnum : Channel number of the unit used to measure voltage. Integer expression.

chnum	Unit	*chnum*	Unit
1	SMU1	5 [a]	SMU5
2	SMU2	6 [a]	SMU6
3	SMU3	21	VSU1
4	SMU4	22	VSU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

range : Ranging type for voltage measurement. 0, 10 to 15, and –10 to –15 are available. Integer expression.

If you do not specify this parameter, *range* is set to 0.

range	**Ranging type** [a]	***range***	**Ranging type** [a]
0	Auto ranging		
10 [b]	0.2 V limited auto ranging	–10 [b]	0.2 V range fixed
11	2 V limited auto ranging	–11	2 V range fixed
12 [c]	20 V limited auto ranging	–12 [c]	20 V range fixed
13 [d]	40 V limited auto ranging	–13 [d]	40 V range fixed
14 [d]	100 V limited auto ranging	–14 [d]	100 V range fixed
15 [e]	200 V limited auto ranging	–15 [e]	200 V range fixed

a. Auto ranging uses the lowest measurement range (available for the unit) that covers the measurement value. Limited auto ranging uses the specified range or above. For example, 2 V limited auto ranging uses the 2 V range to measure 0.1 V, and uses the 20 V range to measure 10 V.
b. 10 and –10 are available only for VMU in the differential mode.
c. 12 and –12 are available for VMU in the grounded mode, and SMU
d. 13, 14, –13, and –14 are available for SMU.
e. 15 and –15 are available only for HPSMU.

Example Statements

For TV command:

```
OUTPUT @Hp4156;"TV 1,0"
OUTPUT @Hp4156;"RMD? 1"
ENTER @Hp4156;A
```

For TV? command:

```
OUTPUT @Hp4156;"TV? 1,0"
ENTER @Hp4156;A
```

UNT?

The UNT? query command requests the model and revision numbers of all units in the 4155C/4156C, and stores the results in the 4155C/4156C output data buffer (query buffer).

The output data is always stored in the query buffer in ASCII format, regardless of the FMT command.

Syntax

```
UNT? [mode]
```

Parameters

mode **:** Integer expression. 0 or 1.

There is no difference between a "UNT? 0" command and a "UNT? 1" command. If you do not specify this parameter, the *mode* is set to 0.

Query Response

```
model number at slot 0,revision number at slot 0;
model number at slot 1,revision number at slot 1;
       ......                 ......
model number at slot 8,revision number at slot 8<terminator>
```

where, the terminator depends on the control mode (US or US42) as follows:

US command mode: <LF^EOI>

US42 command mode: <CR/LF^EOI>

Example Statements

```
DIM A$[50]
OUTPUT @Hp4156;"UNT?"
ENTER @Hp4156;A$
```

VM

The VM command sets the operation mode of the VMU.

Syntax

`VM chnum,mode`

Parameters

chnum **:** Channel number of VMU 23 or 24. Integer expression.

23: VMU1

24: VMU2

mode **:** Operation mode. 1 or 2. Integer expression.

1: Grounded measurement mode

2: Differential measurement mode

Remarks

To use the grounded measurement mode, enter the VM 23,1 and/or VM 24,1 commands. And you should define the measurement units in the MM command. You can set the measurement range of VMU1 and VMU2 independently by the RV commands.

To use the differential measurement mode, enter the VM 23,2 or VM 24,2 command. And you should define either VMU1 or VMU2 in the MM command. The 4155C/4156C uses the unit defined in the MM command for a measurement, and uses the measurement range specified for the unit by using the RV command.

Example Statements

```
OUTPUT @Hp4156;"VM 23,1"
```

VMD

The VMD command controls the connection of the VMU input discharge resistor which prevents the VMU inputs from building up a charge when the inputs are opened. This command is only for the US control mode.

Syntax

`VMD` *discharge*

Parameters

discharge Connection of the VMU discharge resistor. 0, 1, or 2. Integer expression. If you do not enter this command, 1 is set.

discharge	**description**
0	Connects the discharge resistors to the VMU1 and VMU2 inputs immediately.
1	Depends on the status of the VMU input relays: a. If the input relays are open, the discharge resistors are connected immediately. b. If the input relays are closed, the discharge resistors are disconnected immediately.
2	Disconnects the discharge resistors from the VMU1 and VMU2 inputs immediately.

When the auto-calibration is executed, this setting is not changed.

Remarks

The discharge resistors must be disconnected before starting the measurement.

To synchronize with the status of the VMU input relays, use `VMD 1`. The discharge resistors are disconnected from the inputs only when the input relays are closed. The connection of the input relays is controlled by the `CN` and `CL` commands.

Example Statements

```
OUTPUT @Hp4155;"VMD 1"
    :        :
OUTPUT @Hp4155;"CN"
    :        :
OUTPUT @Hp4155;"CL"
```

In the above example, the CN command closes the VMU input relays and disconnects the discharge resistors. And the CL command opens the VMU input relays and connects the discharge resistors.

*WAI

The *WAI command stops execution of all commands until the Operation Complete (OPC) bit is set to 1, which means there are no pending operations. See the *OPC command.

Syntax

```
*WAI
```

Example Statements

```
OUTPUT @Hp4156;"*WAI"
```

WI

The WI command specifies the current source for the staircase sweep and its parameters. This command also clears the WV, WSV, and WSI command settings.

This command setting is cleared by the WV command.

Remarks

If you do not specify the *Rmode* value, the 4155C/4156C uses the lowest output range that covers both *start* and *stop* values. Then the setting resolution must be the same for the *start* and *stop* values. See *Rmode* on page 1-273.

Syntax

For Staircase Sweep Measurement:

`WI ch,mode,range,start,stop,step[,Vcomp[,Pcomp[,Rmode]]]`

For Staircase Sweep with Pulsed Bias Measurement:

`WI ch,mode,range,start,stop,step[,Vcomp]`

If you enter the WI command into the program memory (see the ST command), do not omit the *Vcomp* parameter. *Vcomp* is necessary when using the internal program memory.

Parameters

***ch* :** Channel number of the unit for the staircase sweep current source. 1 to 6 are available. Integer expression.

ch	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

***mode* :** Sweep mode. 1 to 4 are available. Integer expression.

1: Linear sweep (single stair)

2: Log sweep (single stair)

3: Linear sweep (double stair)

4: Log sweep (double stair)

range : Ranging type for staircase sweep current output. Integer expression.

range	Ranging Type
0	Auto ranging
9 (only for 4156C)	10 pA limited auto ranging
10 (only for 4156C)	100 pA limited auto ranging
11	1 nA limited auto ranging
12	10 nA limited auto ranging
13	100 nA limited auto ranging
14	1 μA limited auto ranging
15	10 μA limited auto ranging
16	100 μA limited auto ranging
17	1 mA limited auto ranging
18	10 mA limited auto ranging
19	100 mA limited auto ranging
20 (only for HPSMU)	1 A limited auto ranging

where, auto ranging uses the optimum range available for the SMU, and limited auto ranging uses the specified range or above. Actual ranging operation depends on the ranging mode setting. See *Rmode* on page 1-273.

start : Start current (in A). Numeric expression. See Table 1-31.

0 to ±100E–3 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±1 (for HPSMU in 41501A/B)

start and *stop* must have the same polarity for *log* sweep.

stop : Stop current (in A). Numeric expression. See Table 1-31.

0 to ±100E–3 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±1 (for HPSMU in 41501A/B)

start and *stop* must have the same polarity for *log* sweep.

step : Number of steps for staircase sweep. Numeric expression. 1 to 1001 are available.

Vcomp : Voltage compliance (in V). Numeric expression. See Table 1-31.

If this parameter is not specified, *Vcomp* is set to the previous setting.

The voltage compliance polarity is automatically set to the same value as the polarity of *start* and *stop*, regardless of the specified *Vcomp*.

Pcomp : Power compliance (in W). Numeric expression.

1E−3 to 2 (for 4155C/4156C and MPSMU in 41501A/B)

1E−3 to 14 (for HPSMU in 41501A/B)

Setting resolution: 1E−3 W.

If you do not specify the *Pcomp* value, the power compliance is not set.

Rmode : Ranging mode.

Used to specify the operation of range change during the current sweep.

0 or 1. Integer expression.

If you do not specify the *Rmode* value, ranging mode is set to 0 (fixed mode).

0: Fixed

Uses the output range, which covers both *start* and *stop* values, during the current sweep.

For example, if you enter the following command, the 4155C/4156C uses 100 mA range to force both 100 µA and 100 mA.

```
WI 1,1,17,1E-4,100E-3,2,10,5E-2,0
```

1: Auto

Uses the optimum output range for the output current.

For example, if you enter the following command, the 4155C/4156C uses 1 mA range to force 100 µA, and uses 100 mA range to force 100 mA.

```
WI 1,1,17,1E-4,100E-3,2,10,5E-2,1
```

Range changing may cause 0 A output in a moment.

Table 1-31 **Available Parameter Values for WI Command**

Output Range	Resolution in A [a]	*start* or *stop* in A	Maximum *Vcomp* in V	Remarks
10 pA	10E−15	0 to ±10E−12	±100	For 4156C.
100 pA	10E−15	0 to ±100E−12	±100	
1 nA	100E−15	0 to ±1E−9	±100	For SMU.
			±200	For HPSMU.
10 nA	1E−12	0 to ±10E−9	±100	For SMU.
			±200	For HPSMU.
100 nA	10E−12	0 to ±100E−9	±100	For SMU.
			±200	For HPSMU.
1 μA	100E−12	0 to ±1E−6	±100	For SMU.
			±200	For HPSMU
10 μA	1E−9	0 to ±10E−6	±100	For SMU.
			±200	For HPSMU.
100 μA	10E−9	0 to ±100E−6	±100	For SMU.
			±200	For HPSMU.
1 mA	100E−9	0 to ±1E−3	±100	For SMU.
			±200	For HPSMU.
10 mA	1E−6	0 to ±10E−3	±100	For SMU.
			±200	For HPSMU
100 mA	10E−6	0 to ±20E−3	±100	For SMU.
		to ±50E−3	±40	
		to ±100E−3	±20	
	100E−6	0 to ±50E−3	±200	For HPSMU.
		to ±100E−3	±100	
1 A	100E−6	0 to ±50E−3	±200	
		to ±125E−3	±100	
		to ±500E−3	±40	
		to ±1	±20	

a. Minimum resolution is Range×5E−5. However the setting accuracy is not guaranteed for the resolution less than the value shown in the table.

Example Statements

```
OUTPUT @Hp4156;"WI 1,1,11,0,0.1,100,10,1,1"
OUTPUT @Hp4156;"WI 1,2,15,1E-6,0.1,100"
```

WM

The WM command sets the automatic sweep abort function for the staircase sweep sources, the pulsed sweep source, and the linear search source. It also sets the post sweep condition of the sweep sources.

Syntax

`WM abort[,post]`

The automatic sweep abort function stops the source output when the abort condition specified by the *abort* parameter is detected. The source output is set to the condition specified by the *post* parameter. For the linear search measurement, ignore the *post* parameter.

Parameters

abort **:** Abort condition. Integer expression.

abort	Abort condition
1	Disables the automatic sweep abort function.
2	One of following occurs. - Compliance on the measurement unit. - Compliance on the non-measurement unit. - Overflow on the AD converter. - Oscillation on any unit.
4	Compliance on the non-measurement unit.
8	Compliance on the measurement unit.
16	Overflow on the AD converter.
32	Oscillation on any unit.

To set multiple abort conditions, specify the sum of the *abort* values for the abort conditions shown above. This is allowed for *abort*=4 to 32. For example, if you want to enable the abort function when compliance on the measurement unit (*abort*=8) or oscillation (*abort*=32) is detected, set the *abort* parameter to 40 (8 + 32).

post **:** Post sweep condition of the sources. 1 or 2. Integer expression.

1: Sets the source output to the start value.

2: Sets the source output to the stop value.

If this parameter is not specified, *post* is set to 1.

Output Data

The 4155C/4156C returns the all measurement data until when any abort condition is detected. The output format of the last data will be as shown below:

Measurement Mode	Data for the sweep step when abort occurs	
	if aborted in the nth step	**if aborted in the last step**
1 channel sweep	*Dummy*[,*Source_data*] The data is returned after the nth data	*Data*[,*Source_data*]
Multi channel sweep	*Dummy*[,*Source_data*] The data is returned after the m×n th *Data*.	*Data*, ... *Data*[,*Source_data*]
Linear search	[raw data ... ,]*Search*,*Source_dummy*,*Dummy*	

The status of the last data will be greater than 128 (EOD).

where,

Data: Measurement data.

Source_data: Source output data. Selected by the FMT command.

Dummy: Dummy of the measurement data.

m: Number of the measurement channels.

Search: Status data in the linear search measurement.

Source_dummy: Dummy of the source output data.

raw data: Measurement data in the linear search. Selected by the LSVM command.

Example Statements

```
OUTPUT @Hp4156;"WM 1"
OUTPUT @Hp4156;"WM 2,2"
```

WNU?

The WNU? query command requests the number of sweep steps specified by the sweep command (WI, WV, PWI or PWV), and stores the results in the 4155C/4156C output data buffer (query buffer).

The output data is always stored in the query buffer in ASCII format, regardless of the FMT command.

Syntax

`WNU?`

Query Response

In US command mode:

number of sweep steps<LF^EOI>

In US42 command mode:

number of sweep steps<CR/LF^EOI>

After executing this command, the 4155C/4156C reports the number of steps specified by the sweep command (PWI, PWV, WI, or WV).

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.

Example Statement

```
OUTPUT @Hp4156;"WNU?"
ENTER @Hp4156;A
```

WR

The WR command writes the specified characters or numeric data (ASCII) at the end of the file opened by the OPEN command.

Syntax

`WR` *`data`*

Parameters

data : ASCII characters or numeric data to be written into the file. Maximum 254 bytes.

Example Statements

This example writes the TI? measurement data to the "MDATA" file.

```
OUTPUT @Hp4156;"TI? 1,0"
ENTER @Hp4156 USING "#,5X,13D,X";Mdata
A$="'Id(A)="&VAL$(Mdata)&",'"
OUTPUT @Hp4156;"SDSK 1"
OUTPUT @Hp4156;"OPEN 'MDATA',2"
OUTPUT @Hp4156;"WR 'Test Results,'"
OUTPUT @Hp4156;"WR ";A$
OUTPUT @Hp4156;"CLOSE"
```

WS

The WS command causes the 4155C/4156C to go into a wait state until the 4155C/4156C receives an external trigger signal via the `Ext Trig In` terminal on the rear panel.

Syntax

`WS [mode]`

Parameters

mode : Waiting mode. 1 or 2. Integer expression.

If this parameter is not specified, *mode* is set to 1.

mode	Description
1	Continues the operation if an external trigger was already received. Otherwise, the 4155C/4156C immediately goes into a wait state for an external trigger.
2	In any condition, the 4155C/4156C immediately goes into a wait state for an external trigger.

Remarks

To end a wait state, execute the AB or *RST command.

Example Statements

```
OUTPUT @Hp4156;"STG 0,1,0"
OUTPUT @Hp4156;"WS 2"
```

WSI

The WSI command specifies the staircase sweep current source that will be synchronized with the staircase sweep current source set by the WI command, or the pulsed sweep current source set by the PWI command.

Then the current source set by the WI command or PWI command will be called as the primary sweep source, and the current source set by the WSI command will be called as the synchronous sweep source.

This command setting is cleared by the WI, WV, PWI or PWV command.

Execution Conditions

Available for the staircase sweep measurement mode (set by the MM 2 command) or the pulsed sweep measurement mode (set by the MM 4 command).

The parameters of the WI command or the PWI command are set.

If you do not specify the *Rmode* value, the 4155C/4156C uses the lowest output range that covers both *start* and *stop* values. Then the setting resolution must be the same for the *start* and *stop* values. See *Rmode* on page 1-282.

Syntax

`WSI chnum,range,start,stop[,Vcomp[,Pcomp[,Rmode]]]`

If you enter the WSI command into the program memory (see the ST command), do not omit the *Vcomp* parameter. *Vcomp* is necessary when using the internal program memory.

Parameters

chnum : Channel number of the unit for the synchronous sweep current source. 1 to 6 are available. Integer expression.

chnum	Unit
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

range : Ranging type for synchronous sweep current output. Integer expression.

range	Description
0	Auto ranging
9 (only for 4156C)	10 pA limited auto ranging
10 (only for 4156C)	100 pA limited auto ranging
11	1 nA limited auto ranging
12	10 nA limited auto ranging
13	100 nA limited auto ranging
14	1 μA limited auto ranging
15	10 μA limited auto ranging
16	100 μA limited auto ranging
17	1 mA limited auto ranging
18	10 mA limited auto ranging
19	100 mA limited auto ranging
20 (only for HPSMU)	1 A limited auto ranging

where, auto ranging uses one of the ranges available for the SMU, and the limited auto ranging uses the specified range or above. Actual ranging operation depends on the ranging mode setting. See *Rmode* on page 1-282.

start : Start current (in A). Numeric expression. See Table 1-31 on page 1-274.

0 to ±100E–3 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±1 (for HPSMU in 41501A/B)

start and *stop* must have the same polarity for *log* sweep.

stop : Stop current (in A). Numeric expression. See Table 1-31 on page 1-274.

0 to ±100E–3 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±1 (for HPSMU in 41501A/B)

start and *stop* must have the same polarity for *log* sweep.

The number of sweep steps is the same as the setting for the WI command.

Vcomp **:** Voltage compliance (in V). Numeric expression. See Table 1-31 on page 1-274.

If this parameter is not specified, *Vcomp* is set to the previous setting.

The voltage compliance polarity is automatically set to the same polarity value of *start* and *stop*, regardless of the specified *Vcomp*.

Pcomp **:** Power compliance (in W). Numeric expression.

1E–3 to 2 (for 4155C/4156C and MPSMU in 41501A/B)

1E–3 to 14 (for HPSMU in 41501A/B)

Setting resolution: 1E–3 W.

If the *Pcomp* value is not specified, the power compliance is not set.

Rmode **:** Ranging mode.

Used to specify the operation of range change during the current sweep. 0 or 1. Integer expression.

If the *Rmode* value is not specified, ranging mode is set to 0 (fixed mode).

0: Fixed

Uses the output range which covers both *start* and *stop* values, during the current sweep.

For example, if you enter the following command, SMU1 and SMU2 force both 100 µA and 100 mA, by using the 100 mA range.

```
WI 1,1,17,1E-4,100E-3,2,10,5E-2,0
WSI 2,17,1E-4,100E-3,10,5E-2,0
```

1: Auto

Uses the optimum output range for the output current.

For example, if you enter the following command, SMU1 and SMU2 force 100 µA by using the 1 mA range, and force 100 mA by using the 100 mA range.

```
WI 1,1,17,1E-4,100E-3,2,10,5E-2,1
WSI 2,17,1E-4,100E-3,10,5E-2,1
```

Range changing may cause 0 A output in a moment.

Example Statements

```
OUTPUT @Hp4156;"WSI 1,16,0,4E-5"
OUTPUT @Hp4156;"WSI 2,0,1E-3,1E-2,5,5E-2,1"
```

WSV

The WSV command specifies the staircase sweep voltage source that will be synchronized with the staircase sweep voltage source set by the WV command, or the pulsed sweep voltage source set by the PWV command.

The voltage source set by the WV command or PWV command will be called as the primary sweep source, and the voltage source set by the WSV command will be called as the synchronous sweep source.

This command setting is cleared by the WI, WV, PWI or PWV command.

Execution Conditions

Available for the staircase sweep measurement mode (set by the MM 2 command) or the pulsed sweep measurement mode (set by the MM 4 command).

The parameters of the WV command or the PWV command are set.

If you do not specify the *Rmode* value, the 4155C/4156C uses the lowest output range that covers both *start* and *stop* values. Then the setting resolution must be the same for the *start* and *stop* values. See *Rmode* on page 1-285.

Syntax

For SMU:

`WSV chnum,range,start,stop[,Icomp[,Pcomp[,Rmode]]]`

For VSU:

`WSV chnum,range,start,stop`

If you enter the WSV command into the program memory (see the ST command), do not omit the *Icomp* parameter. *Icomp* is necessary when using the internal program memory.

Parameters

chnum : Channel number of the unit for the synchronous sweep voltage source. 1 to 6, 21 and 22 are available. Integer expression.

chnum	Unit	*chnum*	Unit
1	SMU1	5 [a]	SMU5
2	SMU2	6 [a]	SMU6
3	SMU3	21	VSU1
4	SMU4	22	VSU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

range : Ranging type for synchronous sweep voltage output. Integer expression.

range	**Ranging type**
0	Auto ranging
11 (for SMU)	2 V limited auto ranging
12	20 V limited auto ranging
13 (for SMU)	40 V limited auto ranging
14 (for SMU)	100 V limited auto ranging
15 (only for HPSMU)	200 V limited auto ranging

where, auto ranging uses one of the ranges available for the unit used, and limited auto ranging uses the specified range or above. Actual ranging operation depends on the ranging mode setting. See *Rmode* on page 1-285.

start : Start voltage (in V). Numeric expression. See Table 1-32 on page 1-290.

0 to ±100 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±200 (for HPSMU in 41501A/B)

0 to ±20 (for VSU)

start and *stop* must have the same polarity for *log* sweep.

stop : Stop voltage (in V). Numeric expression. See Table 1-32 on page 1-290.

0 to ±100 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±200 (for HPSMU in 41501A/B)

0 to ±20 (for VSU)

start and *stop* must have the same polarity for *log* sweep.

The number of sweep steps is the same as the setting for the WV command.

Icomp : Current compliance (in A). Numeric expression. See Table 1-32 on page 1-290.

If this parameter is not specified, *Icomp* is set to the previous setting.

The current compliance polarity is automatically set to the same polarity value of *start* and *stop*, regardless of the specified *Icomp*.

Pcomp : Power compliance (in W). Numeric expression.

1E−3 to 2 (for 4155C/4156C and MPSMU in 41501A/B)

1E−3 to 14 (for HPSMU in 41501A/B)

Setting resolution: 1E−3 W.

If the *Pcomp* value is not specified, the power compliance is not set.

Rmode : Ranging mode. Used to specify the operation of range change during the voltage sweep. 0 or 1. Integer expression. If the *Rmode* value is not specified, ranging mode is set to 0 (fixed mode).

0: Fixed

Uses the output range which covers both *start* and *stop* values, during the voltage sweep.

For example, if you enter the following command, SMU1 and SMU2 force both 1 V and 50 V by using the 100 V range.

```
WV 1,1,11,1,50,2,0.01,0.5,0
WSV 2,11,1,50,0.01,0.5,0
```

1: Auto

Uses the optimum output range for the output voltage.

For example, if you enter the following command, SMU1 and SMU2 force 1 V by using the 2 V range, and force 50 V by using the 100 V range.

```
WV 1,1,11,1,50,2,0.01,0.5,1
WSV 2,11,1,50,0.01,0.5,1
```

Range changing may cause 0 V output in a moment.

Example Statements

```
OUTPUT @Hp4156;"WSV 1,0,1,100,0.01,1,1"
OUTPUT @Hp4156;"WSV 21,12,0,10"
```

WT

The WT command sets the hold time and delay time for staircase sweep measurements.

This command setting is ignored by the following measurement mode.

- 1ch pulsed spot measurements
- Pulsed sweep measurements
- Staircase sweep with pulsed bias measurements

Syntax

`WT hold,delay[,step delay]`

Parameters

hold : Hold time. The wait time from the trigger of sweep measurement to the beginning of the delay time for the first step value (in seconds).

0 to 655.35, with 0.01 sec resolution. Numeric expression.

delay : Delay time. The wait time from the end of the hold time or the beginning of the step value to the beginning of the measurement (in seconds).

0 to 65.535, with 0.0001 sec resolution. Numeric expression.

step delay : Step delay time. The wait time from the beginning of the measurement to the next step value (in seconds).

0 to 1, with 0.0001 sec resolution. Numeric expression.

If this parameter is not specified, *step delay* is set to 0.

If the specified *step delay* is shorter than the measurement time, the 4155C/4156C waits until the measurement completes, then outputs the next step.

Example Statements

```
OUTPUT @Hp4156;"WT 10,0.01,0.001"
OUTPUT @Hp4156;"WT 5,0.2"
```

WV

The WV command specifies the voltage source for the staircase sweep source and its parameters. This command also clears the WI, WSI and WSV command settings.

This command setting is cleared by the WI command.

Remarks

If you do not specify the *Rmode* value, the 4155C/4156C uses the lowest output range that covers both *start* and *stop* values. Then the setting resolution must be the same for the *start* and *stop* values. See *Rmode* on page 1-289.

Syntax

For SMU, Staircase Sweep Measurement:

```
WV chnum,mode,range,start,stop,step[,Icomp[,Pcomp[,Rmode
]]]
```

For SMU, Staircase Sweep with Pulsed Bias Measurement:

```
WV chnum,mode,range,start,stop,step[,Icomp]
```

For VSU:

```
WV chnum,mode,range,start,stop,step
```

If you enter the WV command into the program memory (see the ST command), do not omit the *Icomp* parameter. *Icomp* is necessary when using the internal program memory.

Parameters

chnum : Channel number of the unit for the staircase sweep voltage source. 1 to 6, 21 and 22 are available. Integer expression.

chnum	**Unit**
1	SMU1
2	SMU2
3	SMU3
4	SMU4
5 [a]	SMU5
6 [a]	SMU6
21	VSU1
22	VSU2

a. For MPSMUs in the 41501A/B Expander. For HPSMU, channel number is 6, not 5.

***mode* :** Sweep mode. 1 to 4 are available. Integer expression.

1: Linear sweep (single stair)

2: Log sweep (single stair)

3: Linear sweep (double stair)

4: Log sweep (double stair)

***range* :** Ranging type for staircase sweep voltage output. Integer expression.

range	**Ranging type**
0	Auto ranging
11 (for SMU)	2 V limited auto ranging
12	20 V limited auto ranging
13 (for SMU)	40 V limited auto ranging
14 (for SMU)	100 V limited auto ranging
15 (only for HPSMU)	200 V limited auto ranging

where, auto ranging uses one of the ranges available for the unit used, and limited auto ranging uses the specified range or above. Actual ranging operation depends on the ranging mode setting. See *Rmode* on page 1-289.

***start* :** Start voltage (in V). Numeric expression. See Table 1-32.

0 to ±100 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±200 (for HPSMU in 41501A/B)

0 to ±20 (for VSU)

start and *stop* must have the same polarity for *log* sweep.

***stop* :** Stop voltage (in V). Numeric expression. See Table 1-32.

0 to ±100 (for 4155C/4156C and MPSMU in 41501A/B)

0 to ±200 (for HPSMU in 41501A/B)

0 to ±20 (for VSU)

start and *stop* must have the same polarity for *log* sweep.

step : Number of steps for staircase sweep. 1 to 1001 are available. Numeric expression.

Icomp : Current compliance (in A). Numeric expression. See Table 1-32.

If this parameter is not specified, *Icomp* is set to the previous setting.

The current compliance polarity is automatically set to the same polarity value of *start* and *stop*, regardless of the specified *Icomp*.

Pcomp : Power compliance (in W). Numeric expression.

1E−3 to 2 (for 4155C/4156C and MPSMU in 41501A/B)

1E−3 to 14 (for HPSMU in 41501A/B)

Setting resolution: 1E−3 W.

If the *Pcomp* value is not specified, the power compliance is not set.

Rmode : Ranging mode. Used to specify the operation of range change during the voltage sweep. 0 or 1. Integer expression.

If the *Rmode* value is not specified, ranging mode is set to 0 (fixed mode).

0: Fixed

Uses the output range which covers both *start* and *stop* values, during the voltage sweep.

For example, if you enter the following command, the 4155C/4156C uses 100 V range to force both 1 V and 50 V.

```
WV 1,1,11,1,50,2,0.01,0.5,0
```

1: Auto

Uses the optimum output range for the output voltage.

For example, if you enter the following command, the 4155C/4156C uses 2 V range to force 1 V, and uses 100 V range to force 50 V.

```
WV 1,1,11,1,50,2,0.01,0.5,1
```

Range changing may cause 0 V output in a moment.

Table 1-32 Available Parameter Values for WV Command

Output Range	Resolution in V	*start* or *stop* in V	Maximum *Icomp* in A	Remarks
2 V	100E–6	0 to ±2	±100E–3	For SMU.
			±1	For HPSMU.
20 V	1E–3	0 to ±20	±100E–3	For SMU.
			±1	For HPSMU.
			–	For VSU.
40 V	2E–3	0 to ±40	±50E–3	For SMU.
			±500E–3	For HPSMU.
100 V	5E–3	0 to ±100	±20E–3	For SMU.
			±125E–3	For HPSMU.
200 V	10E–3	0 to ±200	±50E–3	

Example Statements

```
OUTPUT @Hp4156;"WV 1,2,12,1E-6,10,100,0.1,1,1"
OUTPUT @Hp4156;"WV 21,1,0,0,20,101"
```

XE

XE command triggers the 4155C/4156C to perform measurements. To put the measurement data into the 4155C/4156C output data buffer, enter the RMD? command.

The XE command cannot be used to trigger the high-speed spot measurement which is triggered by the TI/TI? or TV/TV? command.

For the data output format, refer to “Data Output Format” on page 1-11.

In the US42 command mode with *level*=16, the XE command triggers the measurement and puts the data into the output buffer without using the RMD? command. Read the measurement data before the 4155C/4156C output buffer becomes full up. The output buffer can store approximately 1500 measurement data.

Execution Conditions

If any unit is set to the HIGH VOLTAGE state (forcing more than ±40 V, or voltage compliance set to more than ±40 V) after the trigger (XE), the interlock terminal must be shorted.

The following commands must be executed before executing the XE command. The necessary commands depend on the measurement mode.

Measurement Mode	Commands [a]
Spot	CN, MM, DV or DI
Staircase sweep	CN, MM, WV or WI
1ch pulsed spot	CN, MM, PV or PI, FL
Pulsed sweep	CN, MM, PWV or PWI, FL
Staircase sweep with pulsed bias	CN, MM, WV or WI, PV or PI, FL
Sampling	CN, MM, MT, MI or MV or MP
Stress force by SMU	CN, MM, STT, STI or STV
Stress force by PGU [b]	CN, MM, STT, STP

a. FL command is required only when the SMU output is a pulse voltage or current.
b. PGU outputs can be controlled by the SPG, SRP and SPP commands. Then MM and XE commands are not required.

Syntax

```
XE
```

Example Statement

```
OUTPUT @Hp4156;"XE"
OUTPUT @Hp4156;"RMD? 1"
ENTER @Hp4156;A$
```

Error Messages

This section lists the error codes and the messages that can occur when you operate the 4155C/4156C using the 4155C/4156C FLEX commands.

500 `Improper parameter value. Check setup range.`

The parameter value specified is out of range. Check the parameter setup range.

501 `Improper channel number or slot number.`

The channel number or slot number in the command is incorrect. The channel number must be 1 to 8, 11 to 18, or 21 to 28. The slot number must be 0 to 8.

502 `A unit is not installed on specified channel.`

This error is displayed when a command is sent for a device that isn't installed. For example, when PGU channels are specified in the command line but the 41501A/B is not installed.

503 `Specified unit cannot execute this command.`

The specified unit cannot execute this command.

504 `Specified unit failed self-test/self-calib.`

Unable to use the unit specified in the command line. The unit failed self-test or self-calibration. Contact the nearest Agilent Technologies sales and service office.

505 `Filter can be set to SMUs only.`

Filter can be set to SMUs only by using the `FL` command.

506 `Unsupported unit detected in some slot.`

The measurement unit in some slot must be changed. Contact the nearest Agilent Technologies sales and service office.

507*xxxyyyy* `Program memory is full. Reduce commands.`

Program memory is full. When using the `ST` command, too many program commands were sent to the program memory. Reduce the number of program commands being sent. *xxx* is for the program number. *yyyy* is for where the overflow occurred from the first command execution.

508 `Program creation aborted.`

While making a program, an abort occurred.

509 `ST must be executed before END command.`

The `END` command cannot be executed prior to the execution of the `ST` command.

510 `Unable to use this command between ST and END.`

This command cannot be executed between the execution of the `ST` and `END` commands.

511 `Comp/range cannot be omit to use prog memory.`

Compliance and range parameters' setups cannot be omit when using the internal program memory. Range setup cannot be omit in the `TV` and `TI` command.

512 `Output data buffer full. Too many points.`

The output data buffer overflowed because too many data points were received.

513 `Improper output range or output value.`

The output range or output value in the command line is incorrect for the specified measurement unit. Check the setup range for the measurement unit.

514 `Improper measurement range setup.`

Measurement range setup is wrong in `RI`,`RV`,`TI`, or `TV` command. For example, the specified range is out of range for the measurement unit. Or, another example is that in the `RI` or `RV` command, the measurement range is set to fixed or limited auto range, though the range mode is set to 0 (auto range).

515 `Specified output values are out of range.`

The specified output values are out of range. Check the correct output range for the unit.

516 `Cannot omit compliance setup.`

The compliance value cannot be omitted when the force mode is changed from the previous force mode using the `DV`, `DI`, `PWI`, `PWV`, `PI`, `PV`, `WI`, or `WV` command.

517 `The compliance setup is out of range.`

The compliance setup is incorrect for the measurement unit. Check the correct compliance range.

518 `Power compliance setting is out of range.`

The power compliance setting is incorrect for the unit. Verify the correct power compliance setting range for the specified unit.

519 `Current output range must be >= 100 nA in PI.`

Output range for pulse current must be set 100 nA or more in `PT` command.

520 `Measurement range must be less than compliance.`

The measurement range set by RI or TI command must be less than the compliance set by the `DI`, `WI`, `WSI`, `PWI`, `PI`, and `STI` commands.

521 `Range setup is wrong for the specified VMU.`

For VMUs, when grounded measurement mode is set, the measurement range must be 2 V or 20 V. When differential measurement mode is set, the measurement range must be 0.2 V or 2 V.

522 `Unable to set compliance for VSU or PGU.`

The `VSU` and `PGU` commands do not have a compliance function. Delete the compliance setup from the `VSU` or `PGU` setup commands.

523 `Cannot open the relay driving more than 40 V.`

When the unit output more than 40 V, the output relay of the unit cannot be open.

524 `Unable to output over 40 V. Interlock open.`

An output voltage greater than 40 V cannot be forced when an interlock terminal is open. The output is aborted if the fixture lid is opened when applying greater than 40 V.

525 `Unit sw must be ON before command execution.`

The output relay of the specified unit must be turned on before executing a command.

526 `Filter must be set to OFF for pulse SMU.`

The SMU filter must be set to *off* when you perform pulsed SMU measurements.

527 `SMU/VSU hold time must be <= 655.35 s in the PT.`

Hold time must be 0 to 655.35 s with 0.01 s resolution for pulsed SMUs or VSUs.

528 `SMU/VSU pulse width must be 0.5 ms to 100 ms.`

The pulse width for pulsed SMUs or VSUs must be 0.5 ms to 100 ms with 1 ms resolution in the `PT` command.

529 `SMU/VSU pulse period must be 5 ms to 1 s.`

The pulse period for pulsed SMUs and VSUs must be 5 ms to 1 s with 100 μs resolution in the `PT` command.

530 `SMU/VSU pulse trigger must be 0 ms to 32.7 ms.`

The trigger out delay for pulsed SMUs and VSUs must be 0 to 32.7 ms in the `PT` command,

531 `Improper measurement mode in MM command.`

The `MM` command mode parameter value must be 1 to 5, or 10 to 11.

532 `Only one meas unit when priority is 0 in PT.`

When you set the priority parameter to 0 ("keep pulse width") in the `PT` command, only one measurement channel can be set for pulsed measurement in `MM` command.

533 `Only one meas channel when init int < 2 us.`

Only one measurement channel can be set when the initial interval is less than 2 μs.

534 `Measurement mode must be set by MM command.`

The `MM` command must be used to set up a measurement mode *before* you can perform the measurement.

535 `At least one meas. unit must be set in MM.`

At least one measurement unit must be specified in the `MM` command.

536 `Command order must be MT, MM, then XE.`

The command order must be `MT`, `MM`, and then `XE` for sampling measurements.

537 `Chan no cannot be set for stress force in MM.`

The channel number cannot be set for stress force in the `MM` command.

538 `Set PV/PI for meas. using pulse source.`

Use the `PV` or `PI` command to set the pulse source for pulse spot measurement or sweep measurement with pulse bias.

539 `At least one SYNC channel must be specified.`

For stress force, SYNC channel (stress channel) must be assigned to at least one measurement unit *before* executing the `XE` command.

540 `WV or WI must be set for sweep measurement.`

Specify the sweep source using the `WV` or `WI` command *before* executing the `XE` command for a basic sweep or for a sweep measurement with pulse bias.

541 `PWV/PWI must be set for pulse sweep meas.`

The `PWV` or `PWI` command must be used to specify the pulsed SMU sweep source *before* executing the `XE` command for pulsed sweep measurement,.

542 `Cal/Diag may not be performed on some units.`

A calibration or a diagnostics may not be performed on some measurement units.

543 `Cal/Diag failed. Cannot use the units.`

Calibration or diagnostics failed. The units may be in need of service. Contact the nearest Agilent Technologies sales and service office.

544 `41501A/B is not turned on.`

Unable to execute calibration or diagnostics. Turn the 41501A/B on and then cycle the mainframe power.

545 `Unable to execute RZ before DZ.`

The `RZ` command cannot be executed before the `DZ` command.

546 `Start and stop value must be same when step=1.`

The start and stop values must be the same when the number of steps is set to 1.

547 `Set WV/WI/PWV/PWI before WSV/WSI.`

The sweep channel must be set using a `WV`, `WI`, `PWV`, or `PWI` command *before* the synchronous channel can be set using the `WSV` or `WSI` command.

548 `CH num for pulse must differ from other sources.`

For pulsed sweep measurement, the channel number for the pulsed SMU cannot be set to the same channel number for any other sources.

549 `Ranging mode must be 0 to 3 (0 to 2 for VMU) in RV/RI.`

For SMUs, the ranging mode parameter must be set to 0, 1, 2, or 3 in `RV` and `RI` command. For VMUs, the ranging mode parameter must be set to 0, 1, or 2 in the `RV` commands.

550 `Ranging mode must be 0 or 1 in WI/WV/WSV/WSI/PWI/PWV.`

The ranging mode parameter must be set to 0 or 1 in the `WI`, `WV`, `WSV`, `WSI`, `PWI`, and `PWV` commands.

551 `Improper comp. polarity for manual polarity.`

If you set the compliance polarity mode of the `DI` or `DV` command to manual, set the compliance as follows:

- If the specified source value is positive or zero, set the compliance value more positive than the source value.
- If the specified source value is negative, set the compliance value less positive than the source value.

552 `Sweep mode must be 1 to 4 in WI/WV/PWI/PWV.`

The sweep mode parameter must be set to 1, 2, 3, or 4 in the `WI`, `WV`, `PWI`, and `PW` commands.

553 `Num of steps in WI/WV/PWI/PWV must be 1 to 1001.`

The number of sweep steps specified in the `WI`, `WV`, `PWI`, and `PWV` commands must be 1 to 1001.

554 `Start/stop must be same pol and not 0 for log.`

The start and stop value must be the same polarity and cannot be 0 (zero) for logarithmic measurements.

555 `Base and pulse current must be same polarity.`

When forcing pulsed current, SMU base current and pulse current must be set to the same polarity.

556 `Unable to assign primary/sync. sweep to same CH.`

The primary sweep source and the synchronous sweep source must be set to different units.

557 `Improper WSI/WSV entry. Ignore returned value.`

`WSI` or `WSV` command is missing. Or, `WSI` or `WSV` must be entered after `WI`, `WV`, `PWI`, or `PWV` command. The invalid source data will be returned.

558 `Pulse mode must be 0 or 1 in PT command.`

The pulse mode parameter must be set to 0 or 1 in the `PT` command.

559 `Trigger output delay must be <= pulse width.`

The trigger output delay time must be ≤ the pulse width.

560 `Mode must be set to 0 or 1 in FL command.`

The mode parameter must be set to 0 or 1 in the `FL` command.

561 `Mode must be set to 1 or 2 in VM.`

The mode parameter must be set to 1 or 2 in the `VM` command.

562 `Incorrect trigger mode. Check TM syntax.`

Incorrect trigger mode specified in the `TM` command. Check the syntax for the `TM` command, set the correct trigger mode number.

563 `PGU pulse delay time must be 0 s to 10 s.`

The PGU pulse delay time must be 0 to 10 s.

564 `PGU pulse width must be 1 us to 10 s.`

The PGU pulse width must be 1 μs to 10 s.

565 `PGU pulse period must be 1 us to 10 s.`

The PGU pulse period must be 1 μs to 10 s.

566 `PGU leading time must be 100 ns to 10.0 ms.`

The PGU leading-edge transition time must be 100 ns to 10.0 ms. The leading-edge transition time and trailing-edge transition time values must be in the same range. For details about setting the range, refer to Chapter 1 of *User's Guide: Measurement and Analysis*.

567 `PGU trailing time must be 100 ns to 10.0 ms.`

The PGU trailing-edge transition time must be 100 ns to 10.0 ms. The leading-edge transition time and trailing-edge transition time values must be in the same range. For details about setting range, refer to Chapter 1 of *User's Guide: Measurement and Analysis*.

568 `PG pulse width/period/delay must be same range.`

The PGU pulse width, pulse period, and pulse delay time must be in the same range. For details about the ranges, see Chapter 1 of *User's Guide: Measurement and Analysis*.

569 `SMU pulse period must be >= pulse width + 4 ms.`

The `SMU` pulse period must be ≥ pulse width + 4ms.

570 `Offset mode must be set 0 or 1 in SOC command.`

The offset mode parameter must be 0 or 1 in the `SOC` command.

571 `Zero offset meas failed for the unit.`

The offset value is too large, so the zero offset measurement aborted.

572 `Too big offset for 10 pA range of the unit.`

The offset value is too large, so the output offset cannot be canceled.

573 `Range setup is wrong in GOC command.`

The measurement range setup is incorrect in the `GOC` command. Check the command syntax.

574 `Category must be 1 or 3 in SIT.`

The category parameter must be 1 (short) or 3 (long) in the `SIT` command.

575 `Integration time must be more than 0 s.`

The integration time setup must be greater than 0 s.

576 `System error. Unable to communicate with SMUC.`

The 4155C/4156C may be in need of service. Contact the nearest Agilent Technologies sales and service office.

577 `Mode must be set 0, 1, or 2 in SPG command.`

The mode parameter must be set to 0, 1, or 2 in the `SPG` command.

578 `PGU pulse and base value must be <= +/- 40 V.`

The PGU pulse and base value must be ≤ ±40 V in the `SPG` command.

579 `Pulse count must be 0 to 65535 s in SPG.`

The number of pulse count must be set to 0 to 65535 in the `SPG` command.

580 `Pulse unit must be set by SPG before SRP.`

Set the pulse parameters using the `SPG` command *before* using the `SPR` command to trigger the pulse output.

581 `Set 0 or 1 to output impedance parameter in POR.`

The output impedance parameter must be set to 0 or 1 in the `POR` command.

582 `PGUs are not installed.`

The `SSP` command failed because the PGUs are not installed.

583 `Port number must be set to 0, 1, 2, or 3 in SSP.`

The port number must be set to 0, 1, 2, or 3 in the `SSP` command.

584 `Status must be set to 0, 1, 2, or 3 in SSP.`

The 16440A selector status must be set to 0, 1, 2, or 3 in the `SSP` command.

585 `Channel number must be set to 1 or 2 in RBC.`

The 16441A R-Box channel number must be set to 1 or 2 in the `RBC` command.

586 `Resistance must be set to 0, 1, 2, or 3 in RBC.`

The 16441A R-Box resistance parameter must be set to 0, 1, 2, or 3 in the `RBC` command.

587 `Reference number must be 0 to 3 in STI/STV/STP.`

The reference number must be set to 0, 1, 2, or 3 in the `STI`, `STV`, and `STP` commands.

588 `Output mode must be set to 0 or 1 in STP.`

The output mode parameter for the PGU pulse stress channel must be set to 0 or 1 in the `STP` command.

589 `Stress mode must be set to 0, 1, or 2 in STT.`

The stress mode parameter must be set to 0, 1, or 2 in the `STT` command.

590 `Set 500 us to 655 s for time, or 1 to 65535 for count.`

In the `STT` command, the stress duration time must be set from 500 μs to 655 s for time mode. The duration pulse count must be 1 to 65535 for pulse count mode.

591 `Pulse period must be 1 us to 10 s in STT.`

Pulse period must be 1 μs to 10 s in `STT` command.

592 `Output mode must be set to 0 or 1 in MP.`

The output mode parameter must be set to 0 or 1 in the `MP` command.

593 `The specified programs are not stored.`

Measurements were not performed. The specified programs by the program number are not stored in the internal program memory.

594 `Start prog num must be <= stop prog num in RU.`

In the `RU` command, the start program number must be ≤ the stop program number.

595 `Program # must be 1 to 255 in DO/RU/SCR/LST?.`

The program number must be 1 to 255 in the `DO`, `RU`, `SCR`, and `LST?` commands.

596 `DO or RU command execution was aborted.`

Execution of the `DO` or `RU` command was aborted by the `AB` command.

597 `Measurement aborted. Interlock open while > 40 V.`

The measurement execution was aborted because the interlock circuit is opened while forcing more than ±40 V.

598 `Network disabled. Improper network setup.`

Unable to access the network. The network setup for the 4155C/4156C is not set or the setup is incorrect.

599 `Disk must be set to 0, 1, 2, 3, or 4 in SDSK.`

The identification to specify the disk drive must be set to 0, 1, 2, 3, or 4 in the `SDSK` command.

600 `Open mode must be set to 0, 1, or 2 in OPEN.`

The open mode must be set to 0, 1, or 2 in the `OPEN` command.

601 `Printer must be 1, 2, 3, or 4 in SPR.`

Identification for the printer must be set to 1, 2, 3, or 4 in SPR.

602 `Data cannot be appended to a file on a diskette.`

Unable to set 2 (appending data to a file) to the open mode in the `OPEN` command for a file on a diskette.

603 `Incomplete network setup. Unable to mount disk.`

The network setup for the disk connection must be complete before executing the `SDSK` command.

604 `Cannot open two files. Close the opened file.`

Cannot open two files at the same time. Use the `CLOSE` command to close the currently open file *before* opening another file.

605 `Unable to open file.`

Unable to open file specified by the `OPEN` command. Permission was denied or the file was not found.

606 `Seek operation to the network disk failed.`

Seek operation failed for opening the file. when appending the data. Verify the network is working properly.

607 `Unable to create the file specified in OPEN.`

Unable to create the file specified in the `OPEN` command, because the file name is wrong or upper directory permission has been denied. When using a diskette, an HP LIF file name can be a maximum of 6 characters. A DOS file name can be a maximum of 8 characters. When using a network disk, a maximum of 36 characters are allowed in a file name.

608 `Unable to close the file specified in CLOSE.`

Unable to close the specified file using the `CLOSE` command. The file may not be open.

609 `Unable to write or read. File is not opened.`

Unable to write or read a specified file using the `WR` or `RD?` command because the file is not opened.

610 `Read error occurred. Data or media corrupt.`

The `RD?` command cannot be executed because the data or media is corrupted. This can be caused by a bad disk, the wrong format, a new reading started but not completed, or a network error occurred.

611 `Write error occurred. Media corrupt or full.`

The `WR` command cannot be executed because the media is corrupted or full. This can be caused by a bad disk, the wrong format, a full disk, or a network error.

612 `PA command gets no return from SMUC.`

Unable to communicate with the SMUC, or the SMUC lost data. The 4155C/4156C may be in need of service. Contact the nearest Agilent Technologies sales and service office.

613 `Select printer registered in the MISC page.`

Unable to select the printer using the `SPR` command, because the printer is not set in the `NETWORK PRINTER SETUP` table of the `SYSTEM: MISCELLANEOUS` screen.

614 `Must select disk before executing SPL or PRN.`

The `SDSK` command must be correctly executed *before* using the `SPL` command to spool or the `PRN` command to print.

615 `Must select network printer before PRN.`

Select a network printer using the `SPR` command *before* sending a `PRN` command to print.

616 `Unable to connect server. Network problem.`

Unable to connect to the print server. A cable may be disconnected, the network printer setup in the 4155C/4156C may be incorrect, or the network may not be functioning properly.

617 `Unable to print out. LPD went down.`

Unable to print out because no response was received when executing the `PRN` command. The LPD print server did not respond.

618 `Unable to print out. Data transfer failed.`

Data transfer failed while printing. A cable may be disconnected or the network may not be functioning properly. Abort the printing job, and try again.

619 `Unable to delete spool file.`

After printing the temporary spool file cannot be deleted. The network is not functioning properly.

620 `Measurement aborted by AB command.`

The measurement was aborted by the `AB` command.

621 `Measurement aborted. Timeout occurred.`

The measurement was aborted because a timeout occurred.

622 `Meas./stress completed. Stop condition satisfied.`

The measurement or forcing stress has been completed because measurement or stress completion condition was satisfied.

623 `Measurement aborted. Data buffer full.`

The measurement was aborted because the SMUC data buffer overflowed. Too many data points.

624 `Measurement aborted. Reason unknown.`

The measurement was aborted but the reason is unknown.

625 `Measurement mode must be 0, 1, 2 or 3 in CMM.`

The measurement mode parameter must be set to 0, 1, 2 or 3 in the `CMM` command.

626 `Unsupported file, or file name is wrong.`

Requested file is of an unsupported file type, or the file name is wrong. When using a diskette, an HP LIF file name can be a maximum of 6 characters. A DOS file name can be a maximum of 8 characters. When using a network disk, a maximum of 36 characters are allowed in a file name.

627 `PGU pulse period must be > pulse width.`

The PGU pulse period must be > the pulse width.

628 `PGU pulse period must be >= pulse delay.`

The PGU pulse period must be ≥ the pulse delay.

629 `PGU leading time must be <= 0.8 x pulse width.`

The leading-edge transition time must satisfy the following equation.
$\textit{rise time} \leq \textit{pulse width} \times 0.8$

630 `PGU trailing time must be <= 0.8 x(Period - Width).`

The trailing-edge transition time must satisfy the following equation.
$\textit{fall time} \leq (\textit{pulse period} - \textit{pulse width}) \times 0.8$

631 `Emergency. Reason unknown.`

An emergency occurred on an empty slot. Or an emergency occurred on an existing slot, but the reason is unspecified.

632 `At least one PG must be set for pulse count mode.`

When setting up the pulse count mode, at least one PGU must be set to stress source channel.

633 `Auto calib must be 0 or 1 in CM.`

The auto calibration parameter must be set to 0 or 1 in the `CM` command.

634 `Level must be 1, 2, 4, 8, or 16 in US42.`

The level parameter must be set to 1, 2, 4, 8, or 16 in the `US42` command.

635 `Type parameter setup is wrong in *LRN? command.`

The type parameter must be set to 0 to 28, 30 to 34, or 39 to 48 in the `*LRN?` command.

636 `Format must be 1 to 5 in FMT.`

The format parameter must be set to 1 to 5 in the `FMT` command.

637 `Mode must be 0, 1, or 2 in FMT.`

The mode parameter must be set to 0, 1, or 2 in the `FMT` command.

638 `Wait time must be 0 to 99.9999 s in PA.`

The wait time must be set to 0 to 99.9999 sec in the `PA` command.

639 `Mode must be 1 or 2 in WS.`

The mode parameter must be set to 1 or 2 in the `WS` command.

640 `Mode must be 0 or 1 in STG.`

The mode parameter must be set to 0 or 1 in the `STG` command.

641 `State must be 0 or 1 in STG.`

The state parameter must be set to 0 or 1 in the `STG` command.

642 `Polarity must be 0 or 1 in STG.`

The polarity parameter must be set to 0 or 1 in the `STG` command.

643 `Mode must be 0 or 1 in UNT?.`

The mode parameter must be set to 0 or 1 in the `UNT?` command.

644 `4142ch must be 1 to 28 in ACH.`

The 4142ch parameter must be set to 1 to 28 in the `ACH` command.

645 `chnum must be 1 to 6, or 21 to 28 in ACH.`

The channel number parameter must be set to 1 to 6, or 21 to 28 in the `ACH` command.

646 `Averaging num must be -1023 to 1023 (not 0) in AV.`

When using the US syntax for the `AV` command, the averaging number must be 1 to 1023. When using the US42 syntax of the `AV` command, the averaging number must be –1 to –1023. So 0 (zero) cannot be set for the averaging number.

647 `Averaging mode must be 0 or 1 in AV.`

The averaging mode parameter must be set to 0 or 1 in the `AV` command.

648 `Post sweep condition must be 1 or 2 in WM.`

The post sweep condition for the staircase sweep source must be set to 1 or 2 in the `WM` command.

649 `Abort condition setup is wrong in WM/MSC/STM.`

The abort parameter must be set to 1, 2, 4, 8, 16, or 32 in the `WM`, `MSC`, and `STM` commands. When setting multiple abort conditions (allowed only for 4 to 32), specify sum of the abort values.

650 `Hold time must be 0 to 655.35 s in WT.`

The hold time must be set to 0 to 655.35 sec with 0.01 sec resolution in the `WT` command.

651 `Delay time must be 0 to 65.535 s in WT.`

The delay time must be set to 0 to 65.535 sec with 0.001 sec resolution in the `WT` command.

652 `Step delay time must be 0 to 1 s in WT.`

The step delay time must be set to 0 to 1 sec with 0.001 sec resolution in the `WT` command.

653 `Number of data must be 0 to 20002 in RMD?.`

The number of data parameters must be set to 0 to 20002 in the `RMD?` command.

654 `Category must be 1, 2, or 3 in SLI command.`

The category parameter must be set to 1, 2, or 3 in the `SLI` command.

655 `Mode must be 0 (off) or 1 (on) in AZ.`

Mode parameter must be set to 0 (0ff) or 1 (on) in `AZ` command.

656 `For pulse mode, pulse para must be set in STP.`

When pulse mode is set, the delay time, pulse width, leading-edge transition time, and trailing-edge transition time must be set in the `STP` command.

657 `Time or num of pulse must be set in STT.`

The duration time or pulse count must be set in the `STT` command.

658 `Base must be set when mode = 1 or 2 in SPG.`

If the mode has been set to 1 or 2 (constant or pulse voltage output) in the `SPG` command., the PGU base value must be set.

659 `Pulse para must be set when mode = 2 in SPG.`

If the mode is set to pulse voltage output in the `SPG` command, the pulse parameter must be set.

660 `Unable to use Free run to use program memory.`

When using internal program memory, free run mode (continuous stress) cannot be used for stress force.

661 `Improper stress time to use program memory.`

Unable to perform free run mode (continuous stress) for stress when using the internal program memory. Or, setups for PGUs may be wrong in the `STP` or `STP` command.

662 `Hold time must be -0.03 to 655.35 s in MT.`

The hold time must be set to –0.03 to +655.35 sec in the `MT` command.

663 `Interval must be 0.00006 to 65.534 s in MT.`

The initial time interval must be set to 0.00006 to 65.534 sec in the `MT` command.

664 `Sampling points must be 1 to 10001 in MT.`

The number of sampling points must be 1 to 10001 in the `MT` command.

665 `Hold time must be >= 0 when init int >= 2 ms.`

The hold time must be ≥ 0 s, when the initial interval is set to ≥ 2 ms.

666 `Pulse para must be set for pulse mode in MP.`

The pulse parameters must be set when pulse output mode is set in the `MP` command.

667 `Pulse count must be 0 to 65535 in MP.`

The pulse count must be set to 0 to 65535 in the `MP` command.

668 `Unable to use TV/TI&TV?/TI? in same program.`

Unable to use the `TV` or `TI` and `TV?` or `TI?` commands in the same program. If a program contains a `TV` or `TI` commands, the `TV?` or `TI?` commands cannot be used.

669 `V force must be set for the chan set in GOC.`

To execute a zero offset cancel, the voltage force mode must first have been set for the specified channels using the `GOC` command.

670 `10 (0.2 V range) must be set for VMU in GOC.`

The measurement range must be 10 (0.2 V range) for the VMU in the `GOC` command.

671 `Offset data was out of range or GOC failed.`

The offset data measured was out of range, the `GOC` command execution failed.

672 `VMU must be diff. mode when SOC is executed.`

VMU must be set to differential mode when offset cancel is set to ON in the `SOC` command.

673 `Primary and secondary sweep must be same force mode.`

Primary and secondary sweep sources must be set to the same force mode.

674 `Slot number must be 0 to 9 in *TST? command.`

The slot number parameter must be set from 0 to 9 in the `*TST?` command.

675 `Slot number must be 0 to 8 in CA command.`

The slot number parameter must be set from 0 to 8 in the `CA` command.

676 `This mode is only for the system with PGU.`

The pulse count mode in the `STT` command cannot be used in an 4155C/4156C that does not have a PGU in the 41501A/B.

677 `WV/WI/QSV: Sweep step value too small.`

The minimum value of the sweep step is the resolution of the specified output range for the WV/WI commands, and double the resolution for the QSV. Set the start, stop, and number_of_steps values correctly. The sweep step value is defined as: *ABS(stop–start)/number_of_steps*.

678 `QSV: Use SMU for VAR1 channel.`

Only the SMU can be used as the voltage sweep source (VAR1) for the quasi-static CV measurement. Specify the correct channel number of the SMU in the QSV command.

679 `QSV: Sweep mode must be 1(single) or 2(double).`

In the QSV command, the sweep mode value must be 1 (single sweep), or 2 (double sweep). Set the correct value.

680 `QSV: Number of steps must be 1 to 1001.`

In the QSV command, the number of steps value must be 1 to 1001. Set the correct value.

681 `QSL: Data mode must be 0(off) or 1(on).`

In the QSL command, the first parameter value must be 0 (disables leakage current data output) or 1 (enables data output). Set the correct value.

682 `QSL: Compensation mode must be 0(off) or 1(on).`

In the QSL command, the second parameter value must be 0 (disables leakage current compensation) or 1 (enables compensation). Set the correct value.

683 `QSM: Improper stop condition was specified.`

In the QSM command, the first parameter value must be 1, 2, 4, 8, 16, 32, or sum of the numbers 4, 8, 16, or 32 you desire. Set the correct value.

684 `QSM: Abort voltage must be 1(start) or 2(stop).`

In the QSM command, the second parameter value must be 1 (forces start value after stop condition) or 2 (forces stop value after stop condition). Set the correct value.

685 `QST: Hold time must be 0 to 655.35s in 0.01s.`

In the QST command, available hold time values are 0 to 655.35 sec, in 0.01 sec steps. Set the correct value.

686 `QST: Delay1 must be 0 to 65.535s in 0.0001s.`

In the QST command, available delay time values are 0 to 65.535 sec, in 0.0001 sec steps. Set the correct value.

687 `QST: Delay2 must be 0 to 65.535s in 0.0001s.`

In the QST command, available delay time values are 0 to 65.535 sec, in 0.0001 sec steps. Set the correct value.

689 `QSR: Range must be -9,-10,-11, or -12.`

In the QSR command, available range values are –9 (10 pA fixed), –10 (100 pA fixed), –11 (1 nA fixed), and –12 (10 nA fixed). Set the correct value.

690 `Enter MM 13 and QSV before XE command.`

The MM 13 and QSV commands must be sent *before* the XE command. Do not send the WV, WI, PWV, or PWI command after the QSV command because they clear the QSV command setting.

691 `MM 13 allows only one measurement channel.`

Only one measurement channel is available for the quasi-static CV measurement (MM 13). Set a channel number for the MM command.

692 `TSC: Time stamp mode must be 0(off) or 1(on).`

In the TSC command, the parameter value must be 0 (disables time stamp function) or 1 (enables time stamp function). Set the correct value.

693 `LSV/LSI: Improper start, stop, or step value.`

In the LSV or LSI command, the start value must be different from the stop value. The step value must be positive if the start value is less than the stop value, or it must be negative if the start value is greater than the stop value. And *ABS(stop–start)/step* value must be an integer from 1 to 1001. Set the correct values.

694 `LSV/LSI: Step value must be + or - value, not 0.`

In the LSV or LSI command, the step value must be positive if the start value is less than the stop value, or negative if the start value is greater than the stop value. Zero (0) is not available for the step value. Set the correct value.

695 `LSTM: Hold time must be 0 to 655.35s in 0.01s.`

In the LSTM command, available hold time values are 0 to 655.35 sec, in 0.01 sec steps. Set the correct value.

696 `LSTM: Delay must be 0 to 65.535s in 0.0001s.`

In the LSTM command, available delay time values are 0 to 65.535 sec, in 0.0001 sec steps. Set the correct value.

697 `LSVM: Data mode must be 0(result) or 1(all).`

In the LSVM command, the parameter value must be 0 (outputs search results only) or 1 (outputs search results with raw data). Set the correct value.

698 `LGV/LGI: Search mode must be 0(drop) or 1(rise).`

In the LGV or LGI command, the search mode parameter value must be 0 (search stops when the measured data drops below the target value) or 1 (search stops when the measured data exceeds the target value). Set the correct value.

699 `LGV/LGI: Improper range or target value.`

In the LGV command, available range values are 11 (2 V limited auto) to 15 (200 V limited auto). In the LGI command, available range values are 9 (10 pA limited auto) to 20 (1 A limited auto), where the available values depend on the measurement unit specified.The target value specified must *not* be greater than the maximum measurement value of the unit. Set the correct values.

700 `LSSV/LSSI: Polarity must be 0(-) or 1(+).`

In the LSSV or LSSI command, the polarity parameter value must be 0 (negative) or 1 (positive). Set the correct value.

701 `Enter MM 14 and LSV/LSI before XE command.`

The MM14 and LSV/LSI commands must be sent *before* the XE command. Do not send the BSV, BSI, or LSI command after the LSV command. Do not send the BSV, BSI, or LSV command after the LSI command. In both cases they clear the command setting.

702 `Enter MM 14 and LGV/LGI before XE command.`

The MM14 and LGV/LGI commands must be sent *before* the XE command. Do not send the BGV, BGI, or LGI command after the LGV command. Do not send the BGV, BGI, or LGV command after the LGI command. In both cases they clear the command setting.

703 `LSSV/LSSI: Offset value too large.`

The synchronous source channel uses the same output range as the linear search source channel.The output value of the synchronous source must be covered by the minimum range that covers the start and stop values set to the LSV or LSI command. Set the smaller offset value to the LSSV or LSSI command.

704 `Search target must be =< compliance setting.`

The target value set to the BGV/BGI/LGV/LGI command was too large. The search target value must be less than or equal to the compliance setting of the search channel. Confirm the present compliance setting and then set smaller target value, or set a compliance value which covers the target value.

705 `Set search source before synchronous source.`

The search source channel must be set *before* the synchronous source channel is set. To do this, send the LSV command and then the LSSV command, send the LSI command and then the LSSI command, send the BSV command and then the BSSV command, or send the BSI command and then the BSSI command.

706 `V(or I)search unit must be I(or V)source mode.`

The BGV/LGV command must be used for the I source unit, and the BGI/LGI command must be used for the V source unit. Confirm the present source mode setting of the unit, and then either use the correct command or set the source mode properly.

707 `Sync source channel must be set to another unit.`

The channel number set to the BSV/BSI/LSV/LSI command cannot be set to the BSSV/BSSI/LSSV/LSSI command. Set a channel number other than the search source channel to the BSSV/BSSI/LSSV/LSSI command.

708 `Synchronous source output setting too large.`

The synchronous source channel uses the same output range as the search source channel. The output value of the synchronous source must be covered by the minimum range that covers both the start and stop values set to the BSV/BSI/LSV/LSI command. Change the search source settings or the synchronous source settings.

709 `Do not specify channel number for MM 14 and 15.`

For the search measurement, the MM command needs only the mode parameter. The channel number parameter is not required for the search measurement mode. Enter MM 14 for linear search, or enter MM 15 for binary search.

710 `BSV/BSI: Start and stop must be different.`

The same value was set for both the start and stop values in the BSV or BSI command. They must be different. Set the correct values.

711 `BST: Hold time must be 0 to 655.35s in 0.01s.`

In the BST command, available hold time values are 0 to 655.35 sec, in 0.01 sec steps. Set the correct value.

712 `BST: Delay must be 0 to 65.535s in 0.0001s.`

In the BST command, available delay time values are 0 to 65.535 sec, in 0.0001 sec steps. Set the correct value.

713 `BGV/BGI: Mode must be 0(limit) or 1(repeat).`

In the BGV or BGI command, the search mode parameter value must be 0 (search stops when data is within the limit specified) or 1 (repeats search the times specified). Set the correct value.

714 `BGV/BGI: Improper search stop condition.`

In the BGV/BGI command, the condition parameter value must be a positive numeric value for the limit mode (mode=0), or 1 to 16 for the repeat mode (mode=1). Set the correct value.

715 `BGV/BGI: Improper range, target, or limit value.`

In the BGV command, available range values are 11 (2 V limited auto) to 15 (200 V limited auto). In the BGI command, available range values are 9 (10 pA limited auto) to 20 (1 A limited auto). where the available values depend on the measurement unit specified. The target value must *not* be greater than the maximum measurement value for the repeat mode (mode=1), and the target value +/– limit values must *not* be greater than the maximum measurement value for the limit mode (mode=0). Set the correct values.

716 `BSSV/BSSI: Polarity must be 0(-) or 1(+).`

The polarity parameter value set to the BSSV or BSSI command, must be 0 (negative) or 1 (positive). Set the correct value.

717 `BSSV/BSSI: Offset value too large.`

The synchronous source channel uses the same output range as the binary search source channel, so the output value of the synchronous source must be covered by the minimum range that covers the start and stop values set to the BSV or BSI command. Set a smaller offset value to the BSSV or BSSI command.

718 `BSM: Mode must be 0(normal) or 1(cautious).`

In the BSM command, the mode parameter value must be 0 (normal) or 1 (cautious). Set the correct value.

719 `BSVM: Data mode must be 0(result) or 1(all).`

In the BSVM command, the parameter value must be 0 (outputs search results only) or 1 (outputs search results with raw data). Set the correct value.

720 `Enter MM 15 and BSV/BSI before XE command.`

The MM15 and BSV/BSI commands must be sent *before* the XE command. Do not send the LSV, LSI, or BSI command after the BSV command. Do not send the LSV, LSI, or BSV command after the BSI command. In both cases they clear the command setting.

721 `Enter MM 15 and BGV/BGI before XE command.`

The MM15 and BGV/BGI commands must be sent *before* the XE command. Do not send the LGV, LGI, or BGI command after the BGV command. Do not send the LGV, LGI, or BGV command after the BGI command. In both cases they clear the command setting.

722 `Invalid command for the US42 control mode.`

The US42 control mode does not support the commands for the quasi-static CV measurement, search measurement, time stamp, and the ESC command. They are available for the US control mode.

723 `VMD: Parameter value must be 0, 1, or 2.`

VMD 0 connects the discharge resistor to the VMU inputs, and VMD 2 disconnects the resistor. VMD 1 connects the resistor if the input relay is off and disconnects the resistor if the relay is on.

724 `ESC: Mode must be 0(off) or 1(on).`

In the ESC command, the first parameter must be 0 (disables the sweep stop function) or 1 (enables the sweep stop function). Set the correct value.

725 `ESC: Condition1 must be 0,1,2,3, or 4.`

In the ESC command, the condition1 parameter must be 0 (disables the stop function), 1 (stops measurement if result=<value1), 2 (stops if result>=value1), 3 (stops if |result|=<|value1|), or 4 (stops if |result|>=|value1|), where the result is the rate of measurement data change, and value1 is a parameter of ESC. Set the correct value.

726 `ESC: Value1 must be -10000 to 10000.`

In the ESC command, the value1 parameter must be –10000 to 10000. The value1 is effective for the condition1. Set the correct value.

727 `ESC: Condition2 must be 0,1,2,3, or 4.`

In the ESC command, the condition2 parameter must be 0 (disables the stop function), 1 (stops measurement if data=<value2), 2 (stops if data>=value2), 3 (stops if |data|=<|value2|), or 4 (stops if |data|>=|value2|), where data is the measured data, and value2 is a parameter of ESC. Set the correct value.

728 `ESC: Value2 must be -200 to 200.`

In the ESC command, the value2 parameter must be –200 to 200. The value2 is effective for the condition2. Set the correct value.

729 `QSZ: Integration time too short for zero cancel.`

The integration time specified is too short to execute the zero offset cancel in the quasi-static CV measurement. To set a longer value, use the QST command.

730 `QSZ: Offset value too large for zero cancel.`

The measurement unit measured a leakage current greater than 70% of the measurement range of the QSCV zero offset measurement. Use the next greater measurement range. To change the range, enter the QSR command.

731 `Enter MM 13 before QSZ.`

The MM 13 command must be sent *before* the QSZ command. The offset measurement was not executed.

732 `Enter QSV before QSZ command.`

The QSV command must be sent *before* the QSZ command. The offset measurement was not executed. Do not send the WV, WI, PWV, or PWI command after the QSV command. They clear the QSV command setting.

734 `QSZ: Mode must be 0(off), 1(on) or 2(execution).`

Mode parameter value of the QSZ command must be 0 (disables offset cancel), 1 (enables offset cancel), or 2 (measures the offset data, and returns the data). Set the correct value.

735 `MM: Specify channel number of the V mode SMU.`

Only the V mode SMU can be defined as the measurement channel in the quasi-static CV measurement. Specify the channel number of the V mode SMU to the MM 13 command.

2 4145B Syntax Command Set

The 4145B Syntax command set has same syntax as the 4145A/B Semiconductor Parameter Analyzer command set.

So, you can execute the 4145A/B programs on the 4155C/4156C with minimum modification.

The differences between the 4145B Syntax commands and the 4145A/B commands are summarized in “Differences from 4145A/B Commands”.

This chapter describes the following:

- General Conventions
- Differences from the 4145A/B Commands
- Running the 4145A/B Program directly on the 4155C/4156C
- Reference: System Mode Commands
- Reference: User Mode Commands
- Reference: Common Mode Commands

To Enter into 4145B Syntax Commands Mode

When the 4155C/4156C is turned on, the 4155C/4156C is always in the 4155C/4156C commands mode.

To enter into the 4145B syntax commands mode:

Front panel:	on the SYSTEM: MISCELLANEOUS screen, set `COMMAND SET` field to `4145`.
Remote command:	send ":SYSTem:LANGuage COMPatibility" command to the 4155C/4156C.

To Exit from 4145B Syntax Commands Mode

The command `*RST` exits the 4145B Syntax Commands Mode and returns to the 4155C/4156C command set.

General Conventions

Command Modes

There are three types of the 4145B Syntax commands:

System Mode commands:	Only work in System Mode.
User Mode commands:	Only work in User Mode.
Common commands:	Work in both System and User Mode.

The default setting is System Mode. Therefore, the first command of a program must be a System or Common Mode command. A command issued in the wrong mode generates an error.

Changing the Command Mode

To change the command mode, use the appropriate command shown below:

- To change to User Mode, use the US command. Example:

  ```
  OUTPUT @Hp415x;"US"
  ```

- To change to System Mode, use DE, SS, SM, or MD command. Example:

  ```
  OUTPUT @Hp415x;"DE"
  ```

Command and Screens for System Mode

System Mode commands are related to a certain screen(s). A System Mode command must be executed on its related screen.

To change to the related screen, use a display changing command:

DE	Channel Definition screen
SS	Sweep Setup screen or Sampling Setup screen
SM	Display Setup screen. This corresponds to Display Setup, Measurement Setup, or Sampling Setup screen of the 4155C/4156C.
MD	Graph or List Display screen (depends on DM command)

Parameter Separator

Parameters must be separated by single commas (,).

String Parameter

All string parameters, for example, channel names and file names, must be enclosed in single quotes ('*NAME*').

The first character of a string parameter must be an uppercase alphabetical character or <whitespace>. The remaining characters must be uppercase alphabetical, numeric, or <whitespace>.

Real Parameter

Real numeric values can be entered in fixed or floating point format.

Example:

Fixed: 12.34 or −12.34

Floating: 1.23E+4 or 1.23E−4 or −1.23E+4 or −1.23E−4

Voltage (V), current (A), or time (S) units are not required after numeric values.

Semicolons and <whitespace>

A command can begin and end with multiple semicolons (;).

For example, `;;;;CH1;;;;CH2` is a legal command.

<whitespace> is allowed at the beginning or end of commands, and before and after parameters.

For example, ` CH1 ,'VNAME', 'INAME' , 1, 1 ` is allowed.

<whitespace> is allowed between the command and the first parameter. For example, `CH1` above can be `CH 1`.

Invalid Input

When invalid input generates a parsing error, the rest of the command is discarded until the next terminator (; or <CR> or <LF>). Then, the commands following this terminator are processed.

4145B Syntax Mode Status Byte

In general, the bit assignment of the status byte in the 4145B syntax command mode is identical to the 4145 definition.

Bit No.	Description
Bit 1	Data Ready
Bit 2	Syntax Error
Bit 3	END Status
Bit 4	Illegal Program
Bit 5	Busy
Bit 6	Self-test Fail
Bit 7	RQS
Bit 8	Emergency

Differences from 4145A/B Commands

This section summarizes the differences between the 4145B syntax commands and the 4145A/B commands:

Non-supported Commands

The following 4145A/B commands are not supported in the 4145B syntax command mode:

`GL0`	Disables HP-GL
`GL1`	Enables HP-GL overlay graphics
`GL2`	Enables HP-GL stand-alone graphics
`MX`	Matrix
`SH`	Schmoo
`SV S`	Save ASP file
`GT S`	Get ASP file
`DM3`	Display mode Matrix
`DM4`	Display mode Schmoo
`AS1`	Auto Sequence Program Start
`AS2`	Auto Sequence Program Continue
`AS3`	Auto Sequence Program Stop

If you have the 4145A/B programs that include any of the above commands, they will not work with the 4155C/4156C.

Differences on Commands

CH

SMU channel number

4145A/B	4145 syntax
1 to 4	1 to 6

VR, IR

- START setting range is expanded to the 4155C/4156C's range.
- STOP setting range is expanded to the 4155C/4156C's range.
- STEP setting range is expanded to the 4155C/4156C's range.
- COMPLIANCE setting range is expanded to the 4155C/4156C's range.
- Setting resolution is same as the 4155C/4156C.

VP, IP

- START setting range is expanded to the 4155C/4156C's range.
- STEP setting range is expanded to the 4155C/4156C's range.
- Number of steps setting range is expanded to the 4155C/4156C's range.
- COMPLIANCE setting range is expanded to the 4155C/4156C's range.
- Setting resolution is same as the 4155C/4156C.

VC, IC

- SMU channel number

4145A/B	4145 syntax
1 to 4	1 to 6

- Output setting range is expanded to the 4155C/4156C's range
- Setting resolution is same as the 4155C/4156C

RT, FS

- VAR1' value

4145A/B	4145 syntax
VAR1' = VAR1 + offset or VAR1' = VAR1 * ratio	VAR1' = VAR1 * ratio + offset

- VAR1' ratio specification

4145A/B	4145 syntax
Applicable in LOG sweep only	Both ratio and offset work for LOG

WT, IN

- Wait/Interval time setting range is expanded to the 4155C/4156C's range.
- Availability

4145A/B	4145 syntax
Must be on DISPLAY SETUP screen	Can be on Display Setup, Measurement Setup, or Sampling Setup screen.

- Setting resolution is same as the 4155C/4156C.

NR

- No. of Readings (that is, number of samples) setting range is expanded to the 4155C/4156C's range
- Availability

4145A/B	4145 syntax
Must be in DISPLAY SETUP	Must be in Display Setup, Measurement Setup or Sampling Setup screen.

- Setting resolution is same as the 4155C/4156C.

DM3, DM4

- Equivalent to DM1.
- Availability

4145A/B	4145 syntax
Must be in DISPLAY SETUP	Must be on Display Setup, Measurement Setup or Sampling Setup screen.

LI

Num. of Monitor Channels

4145A/B	4145 syntax
1 to 6	1 to 8

AS1,AS2,AS3

Controls IBASIC program instead of ASP.

SV

- File type S (ASP file) is *not* supported; generates an error.
- File name follows the 4155C/4156C file naming convention, but without the file extension.
- Comment is ignored.
- Supports both LIF and DOS media format.
- Creates the 4155C/4156C compatible file. Not 4145 compatible.

GT

- File type S (ASP file) is *not* supported; generates an error.
- File name follows the 4155C/4156C file naming convention, but without the file extension.
- Supports both LIF and DOS media format.
- Recognizes the 4155C/4156C and the 4145 compatible files.

DO

Channel name

4145A/B	4145 syntax
Measurement channel name only	Source, measure, user function, user variable names.

PR

- Changes screen to LIST Display prior to start printing.
- Printing format is the 4155C/4156C's data list format.

DV

- Channel number: 1 to 4, 7 to 8 for SMUs, 5 to 6 for VSUs, 9 to 10 for PGUs.
- 2 V and 200 V ranges are available.
- Output setting range is expanded to the 4155C/4156C's range.
- Compliance setting range is expanded to the 4155C/4156C's range.
- Setting resolution is same as the 4155C/4156C.

DI

- Channel number

4145A/B	4145 syntax
1 to 4	1 to 6

- 10 pA, 100 pA and 1 A output ranges are available.
- Output setting range is expanded to the 4155C/4156C's range.
- Compliance setting range is expanded to the 4155C/4156C's range.
- Setting resolution is same as the 4155C/4156C.

TV

Channel number

4145A/B	4145 syntax
1 to 4	1 to 6

IT

Integration time is same as the 4155C/4156C.

CA

Calibration time is different.

4145A/B	4145 syntax
about 4 sec	about 15 s to 50 s (depends on its configuration)

PL

Printing format is the 4155C/4156C's hard copy format.

ID

Response text is same as defined for IEEE488.2 *IDN response.

All HP-GL Commands

All HP-GL Commands are not supported.

Running 4145A/B Program Directly on 4155C/4156C

This section describes how to directly run an 4145A/B control program (non-ASP program) on the 4155C/4156C with little or no modification. To run these programs directly, you need to use the *4145 syntax command mode* of the 4155C/4156C.

Usually, you can run these programs with no modification. But sometimes small modifications are required due to the differences from the 4145A/B on the following points:

- Spot Measurement
- Sweep Steps in Logarithmic Step Mode
- Terminator

For differences on commands, see "Differences from 4145A/B Commands" on page 2-6.

Spot Measurement

The 4145A/B can execute a spot measurement by setting both start and stop of the sweep to the same value, but the 4155C/4156C executes the measurement twice even if you set both start and stop of the sweep to the same value.

Sweep Steps in Logarithmic Step Mode

Calculation algorithm for primary sweep steps in logarithmic step mode is slightly different between the 4155C/4156C and the 4145A/B, so step values and number of steps may be different between the 4155C/4156C and the 4145A/B.

Terminator

If you run your program on an external controller, use <CR> + <LF> as the command terminator if you execute serial polling to read a status of the 4155C/4156C in your program.

If you use only <CR> or <LF> as command terminator, the 4155C/4156C may respond with incorrect status.

This is due to the differences of reading and parsing commands between the 4145A/B and the 4155C/4156C.

The following example and explanation gives a better understanding of this.

```
10 OUTPUT @Hp415x;"ME1"
20 REPEAT
30 Status=SPOLL(@Hp415x)
40 UNTIL BIT(Status,0)
```

10 triggers measurement and clears the data ready bit (bit1) of status register.

20 to 40 waits until the data ready bit of status register is set to 1.

- When the Terminator is only <CR>

  If the program controls the 4145A/B, at line 10:

  1. The 4145A/B starts reading data with RFD line set to false (data bus is halted) after each byte.

     In this example:

     `M → bus halted → E → bus halted → 1 → bus halted`

  2. After receiving `1`, the 4145A/B recognizes valid command `ME1`, then executes `ME1`.

     At this time, the program is paused because the controller is trying to send <CR>, which is a terminator, but the 4145A/B has halted data bus and does not receive <CR>.

  3. After the 4145A/B triggers measurement and clears status bit1, the 4145A/B reads <CR>, then the program proceeds to next step (line 20).

  The program reads the correct status at line 30.

If the program controls the 4155C/4156C, at line 10:

1. The 4155C/4156C starts and continues reading data until reading a terminator.

   In this example, the 4155C/4156C reads `ME1<CR>`, then halts data bus.

2. The 4155C/4156C starts executing "ME1". At the same time, the external controller can proceed to the next line, because all data of this line has transferred, then program continues.

At line 30, controller can read status of the 4155C/4156C even if RFD line is false. RFD holdoff is not effective for serial polling.

However, the clearing of the status register bit by line 10 may not have been completed yet, so line 30 may get the incorrect status.

- When the Terminator is <CR> + <LF>

The example program for the 4155C/4156C performs as follows:

1. The 4155C/4156C starts and continues reading data until reading a terminator.

   In this example, the 4155C/4156C reads `ME1<CR>`, then halts data bus.

2. The 4155C/4156C executes "ME1".

   At this time, the program is paused because the controller is trying to send <LF>, which is part of the terminator, but the 4155C/4156C has halted data bus and does not receive <LF>.

3. After the 4155C/4156C triggers measurement and clears the status bit1, the 4155C/4156C reads <LF>, then the program proceeds to next step (line 20).

The program reads the correct status at line 30.

System Mode Commands

Table 2-1 **System Mode Commands (1 of 2)**

Category	Command	Description
Channel Definition	DE	Displays Channel Definition screen
	CH	Defines SMU operation mode and settings
	VM	Defines VMU settings
	VS	Defines VSU settings
Source Setup	SS	Displays Sweep Setup screen or Sampling Setup screen
	IC	Defines SMU constant current source setup
	IR	Defines SMU VAR1 current output source setup
	IP	Defines SMU VAR2 current output source setup
	VC	Defines SMU constant voltage source setup
	VR	Defines SMU VAR1 voltage output source setup
	VP	Defines SMU VAR2 voltage output source setup
	SC	Defines VSU constant voltage source setup
	RT	Defines VAR1’ ratio
	FS	Defines VAR1’ offset
	DT	Sets delay time
	HT	Sets hold time

Table 2-2 System Mode Commands (2 of 2)

Category	Command	Description
Sampling Setup	WT	Sets wait time
	IN	Sets sampling interval
	NR	Sets number of sampling points
	XT	Sets X-axis for sampling measurement
Display Setup	SM	Displays Display Setup screen
	DM	Selects display mode; GRAPH or LIST
	XN	Sets X-axis
	YA	Sets Y1-axis
	YB	Sets Y2-axis
	LI	Selects channels displayed on LIST screen
Measurement Display	MD	Displays GRAPH screen or LIST screen
	MX	No action
	SH	No action
Measurement Control	ME	Selects measurement mode, and executes measurement
Data Output	DO	Outputs measurement data
Program Execution Control	AS	Controls IBASIC program execution
File Operation	SV	Saves file
	GT	Gets file
Print Function	PR	Prints data list
	GL	No action

AS

The command controls the IBASIC program execution, instead of ASP execution.

Syntax

`AS` *`auto_seq_code`*

Parameter

Parameter	Explanation
auto_seq_code	1: Start 2: Continue 3: Stop

Description

AS3 pauses the IBASIC program; does not stop it.

Valid on any System Mode screen.

Example

```
OUTPUT @Hp4155;"AS1"
```

Corresponding Command

```
:PROG:STAT RUN | CONT | PAUS
```

CH

Defines the SMU name, mode, and function.

Syntax

`CH SMU_number,'VNAME','INAME',mode,function`

Parameters

Parameter	Explanation
SMU_number	1 to 6
VNAME	up to 6 alphanumeric characters
INAME	up to 6 alphanumeric characters
(source) mode	1: V (voltage source) 2: I (current source) 3: common
(source) function	1: VAR1, 2: VAR2, 3: CONSTANT, 4: VAR1'

Description

Most recently executed display changing command must have been DE. The 4155C/4156C has up to 6 SMUs (depending on the configuration). If no parameters are specified after *SMU_number*, the channel is disabled. If *mode* is set to 3 (common), *function* must be set to 3 (CONSTANT).

Example

```
OUTPUT @Hp4155;"CH1,'VNAME','INAME',1,2"
OUTPUT @Hp4155;"CH2"
```
for disable

Corresponding Commands

```
:PAGE:CHAN:SMU<smu num>:VNAM 'VNAME'
:PAGE:CHAN:SMU<smu num>:INAM 'INAME'
:PAGE:CHAN:SMU<smu num>:MODE V | I | COMM
:PAGE:CHAN:SMU<smu num>:FUNC VAR1 | VAR2 | CONS | VARD
:PAGE:CHAN:SMU<smu num>:DIS
```
for disable

DE

Changes mode to System Mode, then changes display to Channel Definition screen.

Syntax

```
DE
```

Example

```
OUTPUT @Hp4155;"DE"
```

Corresponding Command

```
:PAGE:CHAN
```

DM

Selects the display mode.

Syntax `DM display_mode`

Parameter

Parameter	Explanation
display_mode	1: Graphics 2: List 3: Graphics 4: Graphics

Description

Most recently executed display changing command must have been `SM`.

`DM` determines whether the GRAPHICS or LIST screen is displayed when `MD` command is executed.

The 4145A/B Matrix (MX command) and Schmoo (SH command) are not supported.

- If DM is sent with parameter `3` or `4` (to select Matrix or Schmoo), it is equivalent to selecting parameter `1` (Graphics). And the display is changed to the Display Setup screen.
- If the MX or SH commands themselves are sent, no error is generated. The commands are simply ignored.

Example

```
OUTPUT @Hp4155;"DM1"
```

Corresponding Command

```
:PAGE:DISP:MODE GRAP | LIST
```

DO

Outputs measurement data of the specified channel (name) to the controller.

Syntax

`DO 'name'`

Parameter

Parameter	Explanation
(data) name	must be a name previously defined on the Channel Definition screen, User Function screen, or User Variable screen.

Response

status value <delimiter> [*status value* <delimiter>] <terminator>

Response	Explanation
(data) status	N | T | C | P | X | V | D | A | S N: Normal T: Other channel compliance error C: This channel compliance error P: PG exceeding current limit error X: Oscillation V: ADC overflow D: Insufficient data A: Arithmetic error S: Calculation stack overflow
value	4145 compatible format or IEEE488.2 <NR3 NUMERIC RESPONSE DATA> format. Selected by DP command.
<delimiter>	, or <CR> + <LF>. Selected by DL command.
<terminator>	<CR> + <LF> with or without EOI. Selected by EI command.

Description

Measurement value name, source value name, user function name, or user variable name can be specified.

Valid on any System Mode screen.

Status D, A, and S reported only for user function value.

Example

Example 1: Response data is the 4145 compatible format

```
DIM A(1:3)
OUTPUT @Hp4155;"DO 'NAME'"
ENTER @Hp4155;A(*)
```

Response is in the 4145 compatible format:

`N 0.0000E+00,N 100.00E-03,N 200.00E-03`<CR><LF>^<END>

Example 2: Response data is NR3 format

```
DIM A(1:3)
OUTPUT @Hp4155;"DP1"
OUTPUT @Hp4155;"DO 'NAME'"
ENTER @Hp4155;A(*)
```

Response is in NR3 format:

`N+0.000000E+000,N+1.000000E-001,N+2.000000E-001`<CR><LF>^<END>

Corresponding Command

`:TRAC?` '*channel_name*' for query

DT

Sets the delay time for sweep.

Syntax

`DT delay_time`

Parameter

Parameter	Explanation
delay_time	0.000 s to 65.535 s

Description

Most recently executed display changing command must have been `SS`.

Example

```
OUTPUT @Hp4155;"DT 1.5"
```

Corresponding Command

`:PAGE:MEAS:DEL delay_time`

FS

Sets the offset value of VAR1'.

Syntax

`FS offset`

Parameter

Parameter	Explanation
offset	real numeric value

Description

Most recently executed display changing command must have been `SS`.

The VAR1' output value is determined by the following equation:

VAR1' value = VAR1 value × ratio + offset

Before executing this command, a unit must be defined to be VAR1' (the CH or VS command).

Example

`OUTPUT @Hp4155;"FS 0.5"`

Corresponding Command

`:PAGE:MEAS:VARD:OFFS offset`

GL

This command is ignored on the 4155C/4156C.

Syntax `GL`

Description The Graphics Language Mode (GL1) is not supported. If the GL command is sent, no error is generated; the next command is parsed.

GT

Gets measurement setup and/or measurement results from file.

Syntax `GT '`*`filetype`*`<space>`*`filename`*`'`

Parameters

Parameter	Explanation
filetype	P or D P: Program File (measurement setup) D: Program/Data File (measurement setup and results)
filename	File name

The string parameter of GT must be enclosed in single quotes:
Example: `GT 'P MYFILE'`

Description

The 4145A/B *filetype* `S` (ASP File) is not supported and generates an error.

The file name should comply with the 4155C/4156C file naming conventions. Do not specify an extension (suffix) in the *filename*.

Handles both LIF and DOS format disk. Recognizes the 4155C/4156C and the 4145B compatible files.

Valid on any System Mode screen.

Example

```
OUTPUT @Hp4155;"GT 'P MYFILE'"
```

Corresponding Commands

`:MMEM:LOAD:STAT 0,` *filename* for P type files

`:MMEM:LOAD:TRAC DEF` *filename* for D type files

HT

Sets the hold time for sweep.

Syntax

`HT hold_time`

Parameter

Parameter	Explanation
hold_time	0.00 s to 655.35 s

Description

Most recently executed display changing command must have been `SS`.

Example

`OUTPUT @Hp4155;"HT 1.5"`

Corresponding Command

`:PAGE:MEAS:HTIM hold_time`

IC

Sets the source parameters for an SMU that was defined to be a constant current source.

Syntax

```
IC SMU_number,output_value,compliance
```

Parameters

Parameter	Explanation
SMU_number	1 to 6
output_value	-0.1 to 0.1 A for SMU. -1 to 1 A for HPSMU.
compliance	-100 to 100 V for SMU. -200 to 200 V for HPSMU.

Description

Most recently executed display changing command must have been `SS`.

The specified SMU must be in the current (I) source mode.

The 4155C/4156C has up to 6 SMUs (depending on the configuration).

The source function of the specified SMU channel must be CONSTANT.

The *output_value* and *compliance* parameters must comply with the maximum voltage/current limitation of the corresponding module. And the range and resolution for these parameters is same as for the 4155C/4156C.

Example

```
OUTPUT @Hp4155;"IC1,1,200"
```

Corresponding Commands

```
:PAGE:MEAS:CONS:SMU<smu num> output_value
:PAGE:MEAS:CONS:SMU<smu num>:COMP compliance
```

IN

Sets the initial sampling interval (Interval time of time domain measurement).

Syntax

`IN` *`interval_time`*

Parameter

Parameter	Explanation
interval_time	60 µs to 65.532 s

Description

Most recently executed display changing command must have been `SM`.

For sampling measurement (time domain measurements), VAR1 cannot be selected on the Channel Definition screen.

The mode must be Sampling mode (that is, all functions must be CONSTANT). `IN` is not allowed in Sweep mode.

The *interval_time* range and resolution are the same as range and resolution of the 4155C/4156C initial sampling interval.

Example

```
OUTPUT @Hp4155;"IN 0.5"
```

Corresponding Command

`:PAGE:MEAS:SAMP:IINT` *`interval_time`*

IP

Sets the sweep parameters for unit that was defined to be the VAR2 current sweep source.

Syntax

`IP` *`start,step,num_of_steps,compliance`*

Parameters

Parameter	Explanation
start	-0.1 to 0.1 A for SMU. -1 to 1 A for HPSMU.
step	-0.2 to 0.2 A for SMU. -2 to 2 A for HPSMU.
num_of_steps	1 to 128
compliance	-100 to 100 V for SMU. -200 to 200 V for HPSMU.

Description

Most recently executed display changing command must have been `SS`.

Before executing this command, a unit must be defined to be VAR2 (the CH command).

The VAR2 unit must be in the current (I) source mode. (So, VAR2 unit cannot be VSU).

The *start*, *step* and *compliance* parameters must comply with the maximum voltage/current limitation of the corresponding module. And the range and resolution for these parameters is same as for the 4155C/4156C.

Example

```
OUTPUT @Hp4155;"IP0,0.2,5,200"
```

Corresponding Commands

`:PAGE:MEAS:VAR2:STAR` *`start`*

`:PAGE:MEAS:VAR2:STEP` *`step`*

`:PAGE:MEAS:VAR2:POIN` *`num_of_steps`*

`:PAGE:MEAS:VAR2:COMP` *`compliance`*

IR

Sets the sweep parameters for unit that was defined to be the VAR1 current sweep source.

Syntax

`IR` *`sweep_mode,start,stop,step,compliance`*

Parameters

Parameter	Explanation
sweep_mode	1: Linear 2: Log 10 3: Log 25 4: Log 50
start	-0.1 to 0.1 A for SMU. -1 to 1 A for HPSMU.
stop	-0.1 to 0.1 A for SMU. -1 to 1 A for HPSMU.
step	0 to 0.2 A for SMU. 0 to 2 A for HPSMU.
compliance	-100 to 100 V for SMU. -200 to 200 V for HPSMU.

Description

Most recently executed display changing command must have been `SS`.

VAR1 unit must be in current (I) source mode. (VAR1 unit cannot be VSU).

If *sweep_mode* is not `1` (Linear), the *step* value should be omitted. If *step* value is included, it will be ignored; no error is generated.

The *start*, *stop*, *step* and *compliance* parameters must comply with the maximum voltage/current limitation of the corresponding module. And the range and resolution for these parameters is same as for the 4155C/4156C.

Example

```
OUTPUT @Hp4155;"IR1,0,1,0.01,200"     for Linear
OUTPUT @Hp4155;"IR2,0,1,200"          for Log
```

Corresponding Commands

```
:PAGE:MEAS:VAR1:SPAC LIN | L10 | L25 | L50
:PAGE:MEAS:VAR1:STAR start
:PAGE:MEAS:VAR1:STOP stop
:PAGE:MEAS:VAR1:STEP step
:PAGE:MEAS:VAR1:COMP compliance
```

LI

Assigns channel names for List display.

Syntax

`LI 'name'{,'name'}`

Parameters

Parameter	Explanation
(data) name	from 1 to 8 names can be selected. The channel names must be names previously defined on the Channel Definition screen, User function screen, or User Variable screen.

Description

Most recently executed display changing command must have been `SM`. And `DM2` must be executed.

The allowed number of channel names (eight) differs from the number allowed for the 4145A/B (six).

Example

```
OUTPUT @Hp4155;"LI 'NAME'"
OUTPUT @Hp4155;"LI 'NAME1','NAME2','NAME3','NAME4'"
```

Corresponding Command

`:PAGE:DISP:LIST 'name',{'name'}`

MD

Changes mode to System Mode, then changes screen to the LIST or GRAPH screen, depending on DM command.

Syntax

```
MD
```

Example

```
OUTPUT @Hp4155;"MD"
```

Corresponding Commands

`:PAGE:GLIS`	to graph display screen
`:PAGE:GLIS:LIST`	to list display screen

ME

Triggers measurement with the specified measurement execution mode.

Syntax

`ME meas_code`

Parameter

Parameter	Explanation
meas_code	1: Single 2: Repeat 3: Append 4: Stop

Description

Valid on any System Mode screen.

Example

```
OUTPUT @Hp4155;"ME1"
```

Corresponding Command

```
:PAGE:SCON:SING | REP | APP | STOP
```

MX

This command is ignored on the 4155C/4156C.

Syntax `MX`

Description The Matrix Display Mode is not supported. If the MX command is sent, it is ignored; no error is generated.

Sending `DM3` (set Display Mode to Matrix), however, changes the screen to the Display Setup screen, and uses the default values there.

NR

Sets number of readings (that is, number of samples) for sampling measurement (time domain measurement).

Syntax

`NR` *`num_readings`*

Parameter

Parameter	Explanation
num_readings	1 to 10001

Description

Most recently executed display changing command must have been `SM`.

For sampling measurement (time domain measurements), VAR1 cannot be selected on the Channel Definition screen.

The mode must be Sampling mode (that is, all functions must be CONSTANT).

`NR` is not allowed in Sweep mode.

Example

```
OUTPUT @Hp4155;"NR 5"
```

Corresponding Command

`:PAGE:MEAS:SAMP:POIN` *`num_readings`*

PR

Changes screen to LIST Display screen, switches the hard copy language to PCL, then starts printing the data list.

Syntax

`PR`

Description

This command does not affect any print/plot parameters except the hard copy language.

Print out format is compatible with the 4155C/4156C.

Valid on any System Mode screen.

Corresponding Commands

`:PAGE:GLIS:LIST`

`:HCOP:DEV:LANG PCL`

`:HCOP:ITEM:ALL`

RT

Sets the ratio value for the unit that was defined to be VAR1'.

Syntax

`RT` *`ratio`*

Parameter

Parameter	Explanation
ratio	real numeric value

Description

Most recently executed display changing command must have been `SS`.

The VAR1' output value is determined by the following equation:

VAR1' value = VAR1 value × ratio + offset

Before executing this command, a unit must be defined to be VAR1' (the CH or VS command).

Example

```
OUTPUT @Hp4155;"RT 0.1"
```

Corresponding Command

`:PAGE:MEAS:VARD:RAT` *`ratio`*

SC

Sets the source parameters for a VSU that was defined to be a constant source.

Syntax

`SC Vsu_number,output_value`

Parameters

Parameter	Explanation
Vsu_number	1 to 2
output_value	-20 V to 20 V

Description

Most recently executed display changing command must have been `SS`.

The specified VSU must have been defined to be a CONSTANT source (VS command).

The range and resolution for the *output_value* parameter are same as for the 4155C/4156C.

Example

`OUTPUT @Hp4155;"SC1,10"`

Corresponding Command

`:PAGE:MEAS:CONS:VSU<vsu num> output_value`

SH

This command is ignored on the 4155C/4156C.

Syntax

`SH`

Description

The Schmoo Display Mode is not supported. If the SH command is sent, it is ignored; no error is generated.

Sending `DM4` (set Display Mode to Schmoo), however, changes the screen to the Display Setup screen, and uses the default values there.

SM

Changes mode to System Mode, then changes screen to Display Setup screen ("Meas Disp Mode Setup" on the 4145A/B).

Syntax

`SM`

Description

On the 4145A/B, the `SM` command changes to the "Measurement and Display Mode Setup" screen. On the 4155C/4156C, there are 3 corresponding screens: Display Setup, Sampling Setup, and Measurement Setup. `SM` changes the screen to Display Setup screen.

Example

`OUTPUT @Hp4155;"SM"`

Corresponding Commands

`:PAGE:DISP`	for Display Setup screen
`:PAGE:MEAS:SAMP`	for Sampling Setup screen
`:PAGE:MEAS:MSET`	for Measurement Setup screen

SS

Changes mode to System Mode, then changes screen to Sweep Setup screen ("Source Setup" on the 4145A/B) if the previous measurement mode is the sweep measurements, or Sampling Setup screen if the previous measurement mode is the sampling measurements.

Syntax

```
SS
```

Example

```
OUTPUT @Hp4155;"SS"
```

Corresponding Command

```
:PAGE:MEAS
```

SV

Saves measurement setup and/or measurement results into file.

Syntax

`SV '`*`filetype`*`<spage>`*`filname`*`<space>`*`comment`*`'`

Parameters

Parameter	Explanation
filetype	P or D P: Program File (measurement setup) D: Program/Data File (measurement setup and results)
filename	File name
comment	(ignored) User's comment

The string parameter of SV must be enclosed in single quotes:
Example: SV ‘P MYFILE’

Description

The 4145A/B *filetype* `S` (ASP File) is not supported and generates an error.

The file name should comply with the 4155C/4156C file naming conventions. The extension is added automatically, so do not specify an extension (suffix) in the *filename*.

The second <space> and the *comment* are optional. Ignored if specified.

Handles both LIF and MS-DOS format disk. Creates the 4155C/4156C compatible file; not 4145B compatible file. Valid on any System Mode screen.

Example

```
OUTPUT @Hp4155;"SV'P MYFILE COMMENT'"
```

Corresponding Commands

`:MMEM:STOR:STAT 0,` *filename*	for P type files
`:MMEM:STOR:TRAC DEF` *filename*	for D type files

VC

Sets the source parameters for an SMU that was defined to be a constant voltage source.

Syntax

`VC` *`SMU_number`*`,`*`output_value`*`,`*`compliance`*

Parameters

Parameter	Explanation
SMU_number	1 to 6
output_value	-100 to 100 V for SMU. -200 to 200 V for HPSMU.
compliance	-0.1 to 0.1 A for SMU. -1 to 1 A for HPSMU.

Description

Most recently executed display changing command must have been `SS`.

The 4155C/4156C has up to 6 SMUs (depending on the configuration).

The CONSTANT SMU must be in the voltage (V) source mode.

The source function of the specified SMU channel must be CONSTANT.

The *output_value* and *compliance* parameters must comply with the maximum voltage/current limitation of the corresponding module. And the range and resolution for these parameters is same as for the 4155C/4156C.

Example

```
OUTPUT @Hp4155;"VC1,10,0.1"
```

Corresponding Commands

`:PAGE:MEAS:CONS:SMU`<*`smu_num`*> *`output_value`*

`:PAGE:MEAS:CONS:SMU`<*`smu_num`*>`:COMP` *`compliance`*

VM

Defines the VM name.

Syntax `VM Vm_number,'VNAME'`

Parameters

Parameter	Explanation
Vm_number	1 to 2
VNAME	up to 6 alphanumeric characters

Description Most recently executed display changing command must have been `DE`.

If no parameters are specified after *Vm_number*, the channel is disabled.

Example `OUTPUT @Hp4155;"VM1,'VNAME'"`

Corresponding Commands Define Channel:

`:PAGE:CHAN:VMU<vm num>:VNAM 'VNAME'`

Disable:

`:PAGE:CHAN:VMU<vm num>:DIS`

VP

Sets the sweep parameters for the unit that was defined to be the VAR2 voltage sweep source.

Syntax

`VP start,step,num_of_steps,compliance`

Parameters

Parameter	Explanation
start	-100 to 100 V for SMU. -200 to 200 V for HPSMU. -20 to 20 V for VSU.
step	-200 to 200 V for SMU. -400 to 400 V for HPSMU. -40 to 40 V for VSU.
num_of_steps	1 to 128
compliance	-0.1 to 0.1 A for SMU. -1 to 1 A for HPSMU.

Description

Most recently executed display changing command must have been `SS`.

Before executing this command, a unit must be defined to be VAR2 (the CH or VS command).

The VAR2 unit must be in the voltage (V) source mode.

If the VAR2 unit is a VSU, the *compliance* parameter is ignored.

The *start*, *step* and *compliance* parameters must comply with the maximum voltage/current limitation of the corresponding module. And the range and resolution for these parameters is same as for the 4155C/4156C.

Example

```
OUTPUT @Hp4155;"VP0,20E-6,5,1"
```

Corresponding Commands

```
:PAGE:MEAS:VAR2:STAR start
:PAGE:MEAS:VAR2:STEP step
:PAGE:MEAS:VAR2:POIN num_of_steps
:PAGE:MEAS:VAR2:COMP compliance
```

VR

Sets the sweep parameters for unit that was defined to be the VAR1 voltage sweep source.

Syntax

```
VR sweep_mode,start,stop,step,compliance
```

Parameters

Parameter	Explanation
sweep_mode	1: Linear 2: Log 10 3: Log 25 4: Log 50
start	-100 to 100 V for SMU. -200 to 200 V for HPSMU. -20 to 20 V for VSU.
stop	-100 to 100 V for SMU. -200 to 200 V for HPSMU. -20 to 20 V for VSU.
step	0 to 200 V for SMU. 0 to 400 V for HPSMU. 0 to 40 V for VSU.
compliance	-0.1 to 0.1 A for SMU. -1 to 1 A for HPSMU.

Description

Most recently executed display changing command must have been `SS`.

The VAR1 module must be in the voltage (V) source mode.

If *sweep_mode* is not 1 (Linear), the *step* value should be omitted. If *step* value is included, it will be ignored; no error is generated.

If the VAR1 module is VSU, the *compliance* parameter is ignored.

The *start*, *stop*, *step* and *compliance* parameters must comply with the maximum voltage/current limitation of the corresponding module. And the range and resolution for these parameters is same as for the 4155C/4156C.

Example

```
OUTPUT @Hp4155;"VR1,0,1,0.01,100E-3"     for Linear
OUTPUT @Hp4155;"VR2,0,1,100E-3"          for Log
```

Corresponding Commands

```
:PAGE:MEAS:VAR1:SPAC LIN | L10 | L25 | L50
:PAGE:MEAS:VAR1:STAR start
:PAGE:MEAS:VAR1:STOP stop
:PAGE:MEAS:VAR1:STEP step
:PAGE:MEAS:VAR1:COMP compliance
```

VS

Defines the VSU name and function.

Syntax

```
VS Vsu_number,'VNAME',function
```

Parameters

Parameter	Explanation
Vsu_number	1 to 2
VNAME	up to 6 alphanumeric characters
(source) function	1: VAR1 2: VAR2 3: CONSTANT 4: VAR1’

Description

Most recently executed display changing command must have been DE.

If no parameters are specified after *Vsu_number*, the channel is disabled.

Example

```
OUTPUT @Hp4155;"VS1,'VNAME',1"
OUTPUT @Hp4155;"VS2"
                              for Disable
```

Corresponding Commands

Define Channel:

```
:PAGE:CHAN:VSU<vsu num>:VNAM 'VNAME'
:PAGE:CHAN:VSU<vsu num>:FUNC VAR1 | VAR2 | CONS | VARD
```

Disable:

```
:PAGE:CHAN:VSU<vsu num>:DIS
```

WT

Sets the hold time for sampling.

Syntax

`WT` *`wait_time`*

Parameter

Parameter	Explanation
wait_time	-30.0 ms to 838.8607 s

Description

Most recently executed display changing command must have been `SM`.

For time domain measurements (sampling measurement), VAR1 cannot be selected on the Channel Definition screen.

The mode must be Sampling mode (that is, all functions must be CONSTANT). `WT" is not allowed in Sweep mode.

The *wait_time* range and resolution are the same as the range and resolution of the 4155C/4156C sampling hold time.

Example

```
OUTPUT @Hp4155;"WT 1.5"
```

Corresponding Command

`:PAGE:MEAS:SAMP:HTIM` *`hold_time`*

XN, YA, YB

These commands set the graphics axis parameters.

Syntax

`XN | YA | YB 'data_name',scale,min,max`

- XN = X axis (for sweep only; for sampling, use `XT`)
- YA = Y1 axis
- YB = Y2 axis

Parameters

Parameter	Explanation
data_name	must be a name previously defined on the Channel Definition screen, User Function screen, or User Variable screen.
scale	1: Linear 2: Logarithmic
min (value)	real numeric value
max (value)	real numeric value

Description

Most recently executed display changing command must have been `SM`. And `DM1` must be executed.

For Sweep, VAR1 must be set up. And you can use `XN`, `YA`, and `YB`.

For Sampling, do not use VAR1 (that is, all functions must be CONSTANT). And you can use `YA` and `YB`. For X axis, do not use `XN`. Use `XT`.

The Y2 axis (YB) is optional; the YB command can be omitted.

Example

```
OUTPUT @Hp4155;"XN 'NAME',1,0,10"
```

Corresponding Commands

```
:PAGE:DISP:GRAP:X|Y1|Y2:NAME var_name
:PAGE:DISP:GRAP:X|Y1|Y2:SCAL LIN|LOG
:PAGE:DISP:GRAP:X|Y1|Y2:MIN min_value
:PAGE:DISP:GRAP:X|Y1|Y2:MAX max_value
```

XT

Sets the graphics parameters (X axis only) for sampling measurement (time domain measurement).

Syntax

`XT` *`min,max`*

Parameters

Parameter	Explanation
min (value)	real numeric value
max (value)	real numeric value

Description

Most recently executed display changing command must have been `SM`. And `DM1` must be executed.

For sampling measurement (time domain measurements), VAR1 cannot be selected. Mode must be Sampling (that is, all functions must be CONSTANT). `XT` is not allowed in Sweep mode.

Scale is Linear for sampling measurement (time domain measurement.)

For setting Y1 and Y2 axis, use the `YA` and `YB` commands.

Example

```
OUTPUT @Hp4155;"XT 0,10"
```

Corresponding Commands

`:PAGE:DISP:GRAP:X:MIN` *`min_value`*

`:PAGE:DISP:GRAP:X:MAX` *`max_value`*

User Mode Commands

Table 2-3 User Mode Commands

Command	Description
DI	SMU Output (Current Source)
DS	VSU Output
DV	SMU Output (Voltage Source)
GL	Graphics Language (GL2) Mode
TI	Triggering Measurement (Current Monitor)
TV	Triggering Measurement (Voltage Monitor)

HP-GL commands are not supported. For details, refer to “HP-GL Commands” on page 2-60.

DI

Triggers current output from specified SMU.

Syntax

`DI SMU_number,output_range,output_value,compliance`

Parameters

Parameter	Explanation
SMU_number	1 to 6
output_range	-2: 10 pA (only for 4156C) -1: 100 pA (only for 4156C) 0: AUTO 1: 1 nA 2: 10 nA 3: 100 nA 4: 1 μA 5: 10 μA 6: 100 μA 7: 1 mA 8: 10 mA 9: 100 mA 10: 1 A (only for HPSMU)
output_value	-0.1 to 0.1 A for SMU. -1 to 1 A for HPSMU.
compliance	-100 to 100 V for SMU. -200 to 200 V for HPSMU.

Description

The 4155/4156C can have up to 6 SMUs. *output_range*, *output_value*, and *compliance* must comply with maximum voltage/current of corresponding module. If not, error is generated same as for the 4155C/4156C. Range and resolution for these parameters is same as for the 4155C/4156C. If no parameters after *SMU_number*, SMU is disabled.

Example

`OUTPUT @Hp4155;"DI1,0,9.876E-3,10"`

`OUTPUT @Hp4155;"DI4"` for disable

DS

Triggers voltage output from specified VSU.

Syntax

`DS` *`Vsu_number,output_value`*

Parameters

Parameter	Explanation
Vsu_number	1 to 2
output_value	-20 V to 20 V

Description

If no parameters are specified after *Vsu_number*, the channel is disabled.

Example

`OUTPUT @Hp4155;"DS2,10.0"`

`OUTPUT @Hp4155;"DS1"` for disable

DV

Triggers voltage output from specified SMU, VSU, or PGU.

Syntax

```
DV channel_number,output_range,output_value,compliance
```

Parameters

Parameter	Explanation
channel_number	1: SMU1, 2: SMU2, 3: SMU3, 4: SMU4, 5: VSU1, 6: VSU2, 7: SMU5, 8: SMU6, 9: PGU1, 10: PGU2.
output_range	-1: 2 V (for SMU and HPSMU) 0: AUTO 1: 20 V 2: 40 V (for SMU, HPSMU and PGU) 3: 100 V (for SMU and HPSMU) 4: 200 V (only for HPSMU)
output_value	-100 to 100 V for SMU. -200 to 200 V for HPSMU. -20 to 20 V for VSU. -40 to 40 V for PGU.
compliance	-0.1 to 0.1 A for SMU. -1 to 1 A for HPSMU.

Description

The 4155C/4156C can have up to 6 SMUs. DV can trigger a VSU, PGU, or SMU. For non-SMUs, *compliance* is ignored.

If no parameters are specified after *channel_number*, channel is disabled. The *output_range*, *output_value* and *compliance* parameters must comply with the maximum voltage/current limitation of the corresponding module. Otherwise, an error is generated the same as for the 4155C/4156C. And the range and resolution for these parameters is same as for the 4155C/4156C.

Example

```
OUTPUT @Hp4155;"DV1,0,12.34,0.001"
OUTPUT @Hp4155;"DV2"                  for disable
```

GL

This command is ignored on the 4155C/4156C.

Syntax `GL`

Description The Graphics Language Mode (GL2) is not supported. If the GL command is sent, no error is generated; the next command is parsed.

TI

Triggers current measurement by specified unit, then outputs measurement result data to controller.

Syntax `TI` *`channel_number`*

Parameter

Parameter	Explanation
channel_number	1: SMU1, 2: SMU2, 3: SMU3, 4: SMU4, 7: SMU5, 8: SMU6

Response *`status channel`* `I` *`value`* *<terminator>*

Response	Explanation
(data) status	N | T | C | P | X | V N: Normal T: Other channel compliance error C: This channel compliance error P: PG exceeding current limit error X: Oscillation V: ADC overflow
channel	A | B | C | D | G | H A: SMU1 B: SMU2 C: SMU3 D: SMU4 G: SMU5 H: SMU6
value	4145 compatible format or IEEE488.2 <NR3 NUMERIC RESPONSE DATA> format. Selected by DP command.
<terminator>	<CR> + <LF> with or without EOI. Selected by EI command.

Description

The 4155C/4156C has up to 6 SMUs (depending on the configuration).

The command applies the range and resolution specifications of the 4155C/4156C for the measurement.

Example

```
OUTPUT @Hp4155;"TI7"
ENTER @Hp4155 USING "A,A,A,K";S$,C$,M$,V
```

Response in the 4145 compatible format:

```
NGI 7.6543E-03<CR><LF>^<END>
```

Response in NR3 format:

```
NGI+7.654321E-003<CR><LF>^<END>
```

TV

Triggers voltage measurement by specified unit, then outputs measurement result data to controller.

Syntax `TV` *`channel_number`*

Parameter

Parameter	Explanation
channel_number	1: SMU1, 2: SMU2, 3: SMU3, 4: SMU4, 5: VMU1, 6: VMU2, 7: SMU5, 8: SMU6

Response *`status channel`* `V` *`value`* *<terminator>*

Response	Explanation
(data) status	N | T | C | P | X | V N: Normal T: Other channel compliance error C: This channel compliance error P: PG exceeding current limit error X: Oscillation V: ADC overflow
channel	A | B | C | D | G | H A: SMU1 B: SMU2 C: SMU3 D: SMU4 E: VMU1 F: VMU2 G: SMU5 H: SMU6
value	4145 compatible format or IEEE488.2 <NR3 NUMERIC RESPONSE DATA> format. Selected by DP command.
<terminator>	<CR> + <LF> with or without EOI. Selected by EI command.

Description

The 4155C/4156C has up to 6 SMUs (depending on the configuration).

The command applies the range and resolution specifications of the 4155C/4156C for the measurement.

Example

```
OUTPUT @Hp4155;"TV2"
ENTER @Hp4155 USING "A,A,A,K";S$,C$,M$,V
```

Response in the 4145 compatible format:

```
NBV1.2345E+00<CR><LF>^<END>
```

Response in NR3 format:

```
NBV+1.234567E+000<CR><LF>^<END>
```

HP-GL Commands

The following User Mode HP-GL Commands (VECTOR, CHARACTER, LINE TYPE, AXES, SETUP, and CONFIGURATION & STATUS Groups) are not supported. However, inputting these commands does not generate an error. Input until the next terminator (';' or CR or LF) is ignored. For example, if the line "PU;DE" were sent, only DE would be executed.

VECTOR Group

- PU (Pen Up)
- PD (Pen Down)
- PA (Plot Absolute)
- PR (Plot Relative)

CHARACTER Group

- CS (Designates Standard Character Set)
- LB (Label)
- DR (Relative Direction)
- SR (Relative Character Size)
- CP (Character Plot)

LINE TYPE Group

- LT (Line Type)
- SP (Pen Select)
- VS (Velocity Select)

AXES Group

- XT (X Tick)
- YT (Y Tick)

SETUP Group

- IP (Input P1 and P2)
- OP (Output P1 and P2)
- IW (Input Window)

CONFIGURATION and STATUS Group

- DF (Default)
- IN (Initialize)
- IM (Input Mask)
- OE (Output Error)
- OS (Output Status)

Common Mode Commands

Table 2-4 **Common Mode Commands**

Command	Description
BC	GPIB Data Output Buffer Clear
CA	Auto-Calibration
CMD?	Command Mode
DC	Calibration on Device Clear
DL	Delimiter
DP	Double Precision
DR	Data Ready Service Request
EI	Terminator
ID	Identification Output
IT	Integration Time
PF	Print/Plot Function Abort
PL	Plotting Function
SF	Self-Test

BC

This command clears the GPIB data output buffer and bit 1 (Data Ready) of the 4145B syntax mode status byte.

Syntax

```
BC
```

Description

A Buffer Clear must be performed before data output.

Corresponding Command

No 4155C/4156C command exactly corresponds to the BC command.

On the 4155C/4156C, Device Clear performs this operation.

CA

Auto-Calibration

Syntax

`CA auto-calibration`

Parameters

Parameter	Explanation
auto-calibration	0: off 1: on

Description

For System Mode, `CA1` enables auto-calibration.

For User Mode, `CA1` performs calibration immediately, but does not enable auto-calibration.

If the mode changes (SYSTEM to USER or USER to SYSTEM), auto-calibration is turned off.

Example

```
OUTPUT @Hp4155;"CA1"
```

Corresponding Commands

`:CAL:AUTO ON | OFF`

This command enables/disables auto-calibration only; does not actually perform calibration.

No 4155C/4156C command exactly corresponds to CA command.

The *CAL? query performs calibration, and returns result response. The `CA` command does not return the result response.

CMD?

This command returns the 4155C/4156C's control language mode set now. This command has query form only.

Syntax

CMD?

Response

language_mode <terminator>

language_mode is NR1 response data type.

<terminator> depends on the language mode.

The values of *language_mode* and <terminator> are as follows:

Value	Control Language Mode	<terminator>
0	SCPI command control mode	<LF^EOI>
1	Agilent FLEX command control mode (US mode or US42 mode)	<LF^EOI>
2	4145 syntax command control mode	<CR/LF^EOI>

Example

```
OUTPUT @Hp4155;"CMD?"
ENTER @Hp4155;A
```

DC

This command selects whether the calibration is performed or not on sending Device Clear.

Syntax

`DC` *`calibration`*

Parameters

Parameter	Explanation
calibration	1: does not perform calibration 2: performs calibration

Description

Default setting is 1.

Example

```
OUTPUT @Hp4155;"DC2"
```

DL

This command selects delimiter of output data.

Syntax

`DL delimiter`

Parameter

Parameter	Explanation
delimiter	1: comma 2: <CR><LF>

Description

This command selects data delimiter of output data specified by DO command in System mode.

Default setting is comma (DL1).

Example

```
OUTPUT @Hp4155;"DL2"
OUTPUT @Hp4155;"DO 'NAME'"
ENTER @Hp4155;A(*)
```

Response:

```
N 0.0000E+00<CR><LF>N 100.00E-03<CR><LF>N 200.00E-03<CR>
<LF>^<END>
```

DP

This command selects precision of output data.

Device Clear does not affect the setting of this command.

Syntax `DP` *`double_precision`*

Parameter

Parameter	Explanation
double_precision	0: 4145 compatible format 1: double precision (NR3 format)

Description

In the *4145 syntax command mode*, default data length of response data corresponding to DO, TI, and TV commands is same as the 4145. `DP` command can change the data length of response data to double precision, which is standard data precision of the 4155C/4156C.

Double precision format of response data for each command is as follows:

- DO (System mode)

  `X±N.NNNNNNE±NNN`<delimiter> `...` `X±N.NNNNNNE±NNN`<CR><LF>^<END>

  where,

  X: Data Status

  N: Measurement Data

- TV or TI (User mode)

  `XXX±N.NNNNNNE±NNN`<CR><LF>^<END>

  where,

  X: Data Status

  N: Measurement Data

DR

Enables the Data Ready Service Request.

Syntax

`DR service_request`

Parameters

Parameter	Explanation
service_request	0: off 1: on

Description

If Data Ready Service Request is on, bit 1 (Data Ready) and bit 7 (RQS) of the 4145B syntax mode status byte are set to 1 when measurement data is valid.

If Data Ready Service Request is off, only bit 1 (Data Ready) of the 4145B syntax mode status byte is set to 1 when measurement data is valid.

Corresponding Command

No 4155C/4156C command exactly corresponds to the DR command.

:STAT:OPER:ENAB causes the 4155C/4156C to perform a similar operation, but on a different status register.

EI

This command selects data terminator of output data.

Syntax

`EI terminator`

Parameters

Parameter	Explanation
terminator	0: <CR><LF> 1: <CR><LF> with EOI, where EOI means ^<END>

Description

Default setting is 1.

Example

```
OUTPUT @Hp4155;"EI0"
```

ID

Returns the identification string, which contains the 4155C/4156C model and revision numbers.

Syntax `ID`

Response `HEWLETT-PACKARD,`*`model#`*`,0,`*`HOSTC_rev`*`:`*`SMUC_rev`*`:`*`ADC_rev`*<term>

Response	Explanation
Model#	4155C | 4156C
HOSTC_rev	nn.nn
SMUC_rev	nn.nn
ADC_rev	nn.nn
<term>	<CR> + <LF> with or without EOI. Selected by EI command.

Example

```
DIM A$[101]
OUTPUT @Hp4155;"ID"
ENTER @Hp4155;A$
```

Response:

`HEWLETT-PACKARD,4155C,0,01.00:01.00:01.00`<CR><LF>^<END>

NOTE For the 4145A/B, ID returns 16 characters. For the 4155C/4156C, ID returns 41 characters. So, you need to make sure the data string variable is large enough to contain the returned characters.

Corresponding Command `*IDN?` for query

IT

This command sets the integration time to SHORT, MEDIUM or LONG, according to the 4155C/4156C integration time definition; does not comply with the 4145A/B integration time definition.

Syntax

`IT integ_time`

Parameter

Parameter	Explanation
integ_time	1: SHORT 2: MEDIUM 3: LONG

Description

The 4155C/4156C setting for SHORT and LONG integration time is effective for the 4145B syntax mode. There is no way to change these values from the 4145B syntax command set. However, these values are reset to default when the 4155C/4156C switches to the 4145B syntax mode. So, these values are default values until operator changes the values at front panel after 4155C/4156C has switched into the 4145B syntax mode.

Example

`OUTPUT @Hp4155;"IT1"`

Corresponding Command

`:PAGE:MEAS:MSET:ITIM SHOR | MED | LONG`

PF

This command aborts the printing or plotting that is currently being performed.

Syntax

`PF`

Corresponding Command

`:HCOP:ABOR`

PL

This command calculates and sets up the 4155C/4156C Output Region according to the specified parameters and the paper size.

Syntax

PL *x_min*,*y_min*,*x_max*,*y_max*

Parameters

Parameter	Explanation
x_min (value)	0 to 65535
y_min (value)	0 to 65535
x_max (value)	0 to 65535
y_max (value)	0 to 65535

Description

If the calculation result exceeds 100%, it will be rounded down to 100%.

After setting the Output Region, the command switches the hard copy language to HP-GL, then starts plotting the present screen.

This command does not affect any print/plot parameters except the hard copy language.

Plot format is compatible with the 4155C/4156C.

Corresponding Commands

:HCOP:PAGE:DIM:LLEF *x*,*y*

:HCOP:PAGE:DIM:URIG *x*,*y*

:HCOP:DEV:LANG HPGL

:HCOP:ITEM:ALL

SF

Executes the built-in self-test of the 4155C/4156C.

Syntax

```
SF
```

Description

Bit 3 of the 4145B syntax mode status byte is set when self-test is completed.

Example

```
OUTPUT @Hp4155;"SF"
```

Corresponding Command

```
:DIAG:TEST 111
```