Semiconductor Parameter Analyzer

User's Dictionary Reference

HP Part Number
04155-90020

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Product Warranty

This Hewlett-Packard product is warranted against defects in material and workmanship for a period of one year from date of shipment. During the warranty period, Hewlett-Packard will, at its option, either repair or replace products which prove to be defective.

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Certification

Hewlett-Packard Company certifies that this product met its published specifications at the time of shipment [from the factory]. Hewlett-Packard further certifies that its calibration measurements are traceable to the **National Institute of Standards and Technology** (NIST), to the extent allowed by the Institute's calibration facility, and to the calibration facilities of other International Standards Organization members.

Yokogawa-Hewlett-Packard, Ltd.
9-1, Takakura-Cho, Hachioji-Shi,
Tokyo, 192 Japan

Safety Summary

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual may impair the protection provided by the equipment. In addition it violates safety standards of design, manufacture, and intended use of the instrument. Hewlett-Packard Company assumes no liability for customer's failure to comply with these requirements.

NOTE
HP 4155A/4156A comply with INSTALLATION CATEGORY II and POLLUTION DEGREE 2 defined in IEC 1010-1.
HP 4155A/4156A are INDOOR USE products.

- *GROUND THE INSTRUMENT*

  To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. The power terminal and the power cable must meet International Electrotechnical Commission (IEC) safety standards.

- *DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE*

  Do not operate the instrument in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.

- *KEEP AWAY FROM LIVE CIRCUITS*

  Operation personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified maintenance personnel. Do not replace components with power cable connected. Under certain conditions, dangerous voltages may exist even with the power cable removed. To avoid injuries, always disconnect power and discharge circuits before touching them.

- *DO NOT SERVICE OR ADJUST ALONE*

  Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

- *DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT*

  Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to a Hewlett-Packard Sales and Service Office for services and repair to ensure that safety features are maintained.

- *DANGEROUS PROCEDURE WARNINGS*

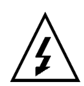
  Warnings, such as example below, precede potentially dangerous procedures throughout this manual. Instructions contained in the warnings must be followed.

WARNING
Dangerous voltages, capable of causing death, are present in this instrument. Use extreme caution when handling, testing, and adjusting.

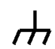
Safety Symbols

The general definitions of safety symbols used on equipment or in manuals are listed below.


Instruction manual symbol: the product will be marked with this symbol when it is necessary for the user to refer to the instruction manual in order to protect against damage to the instrument.


Indicates dangerous voltage (terminals fed from the interior by voltage exceeding 1000 volts must be so marked).


Indicates earth (ground) terminal.


Frame or chassis terminal. A connection to the frame (chassis) of the equipment which normally includes all exposed metal structures.


Alternating current.


Direct current.

| ON (Supply).

○ OFF (Supply).

WARNING The warning sign denotes a hazard. It calls attention to a procedure, practice, condition or the like, which, if not correctly performed or adhered to, could result in injury or death to personnel.

CAUTION The caution sign denotes a hazard. It calls attention to an operating procedure, practice, condition or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the product.

Herstellerbescheinigung

GEÄUSCHEMISSION

Lpa < 70 dB
am Arbeitsplatz
normaler Betrieb
nach DIN 45635 T. 19

Manufacturer's Declaration

ACOUSTIC NOISE EMISSION

Lpa < 70 dB
operator position
normal operation
per ISO 7779

Introduction

HP 4155A/4156A is an electronic instrument for measuring and analyzing the characteristics of semiconductor devices. This one instrument allows you to perform *both* measurement *and* analysis of measurement results.

highly accurate measurements.
HP 4155A/4156A has four highly accurate source/monitor units (SMUs), two voltage source units (VSUs), and two voltage measurement units (VMUs). The HP 4156A is designed for Kelvin connections and has high-resolution SMUs (HRSMUs), so HP 4156A is especially suited for low resistance and low current measurements. You can measure voltage values with a resolution of 0.2 μV by using the differential measurement mode of VMUs.

reliability testing.
HP 4155A/4156A can perform *stress* testing. That is, can force a specified dc voltage or current for the specified duration.

Also, you can force ac stress by using pulse generator units (PGUs), which are installed in HP 41501A SMU/Pulse Generator Expander. The HP 41501A is attached to HP 4155A or HP 4156A, and can be equipped with a ground unit (GNDU), high power SMU (HPSMU), two medium power SMUs (MPSMUs), or two PGUs.

data storing and printing.
HP 4155A/4156A can print and store, in addition to performing measurement and analysis. You can store measurement setup information, measurement data, and instrument setting information on a 3.5-inch diskette inserted into the disk drive of HP 4155A/4156A. And you can print the setting information and measurement results on a plotter or printer that is connected to HP 4155A/4156A.

remote control.
HP 4155A/4156A can be controlled by an external controller via HP-IB by using remote control commands. These commands are based on Standard Commands for Programmable Instruments (SCPI), so you can easily develop measurement programs.

HP 4155A/4156A has internal HP Instrument BASIC, so you can develop and execute measurement programs by using the HP 4155A/4156A only, without using an external controller.

In This Manual

This manual is a dictionary reference for all parts and functions of the HP 4155A/4156A, and consists of the following chapters:

- Measurement Units

  This chapter provides information about the measurement units.
- Measurement Mode

  This chapter provides information about sweep and sampling measurements.
- Measurement Functions

  This chapter provides information about the measurement functions.
- Page Organization

  This chapter provides information about each user interface page that is displayed on screen.
- Print/Plot Function

  This chapter provides information about the print/plot function.
- Data Variable and Analysis Function

  This chapter provides information about data variables and analysis functions.
- Softkey Maps and External Keyboard

  This chapter provides softkey maps and information about using an external keyboard.
- Specifications
- Accessories and Options
- Manual Changes Depending on ROM Version
- Index

Other Manuals.

The following HP 4155A/4156A manuals are also available:

- User's Task Guide

  This manual gives step-by-step instructions for performing common HP 4155A/4156A tasks, and consists of the following chapters:

  - Introducing the HP 4155A/4156A
  - Installation
  - Making a Measurement
  - Analyzing Measurement Results
  - Filer and Hardcopy
  - If You Have a Problem
  - Manual Changes Depending on ROM Version
  - Index

- Programmer's Guide

  This manual provides information about controlling the HP 4155A/4156A by remote command via HP-IB interface and HP Instrument BASIC, and consists of the following chapters:

  - Using HP Instrument BASIC
  - Reference: HP Instrument BASIC
  - Getting Started on Programming the HP 4155A/4156A
  - HP 4155A/4156A SCPI Programming
  - Running HP 4145A/B Program Directly on HP 4155A/4156A
  - Sample Application Programs
  - Manual Changes Depending on ROM Version

- HP-IB Command Reference

  This manual is a complete reference of HP-IB commands, and consists of the following chapters:

  - SCPI Commands
  - HP 4145B Syntax Commands
  - Manual Changes Depending on ROM Version
  - Index

- Quick Start Guide

  This manual is mainly for beginners and provides brief instructions about using HP 4155A/4156A.

Text Conventions.

The following text conventions are used in this manual:

Front-panel key	Represents a key physically located on HP 4155A/4156A or external keyboard.
Softkey	Represents a softkey that appears on screen of HP 4155A/4156A.
`Screen Text`	Represents text that appears on screen of HP 4155A/4156A.
Italic	Refers to a related document, or is used for emphasis.

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Measurement Units

Measurement Units

This chapter explains basic output and measurement functions of each measurement unit. For the following units, a simplified circuit diagram is shown, and where applicable, the output and measurement ranges are provided.

- ground unit (GNDU)
- source/monitor unit (SMU)
- voltage source unit (VSU)
- voltage monitor unit (VMU)
- pulse generator unit (PGU)

Ground Unit (GNDU)

The ground unit (GNDU) is in the HP 41501A (SMU and pulse generator expander). The GNDU is a 0 V constant source that provides a measurement ground reference, and can sink up to ±1.6 A. Figure 1-1 shows a simplified GNDU circuit diagram.

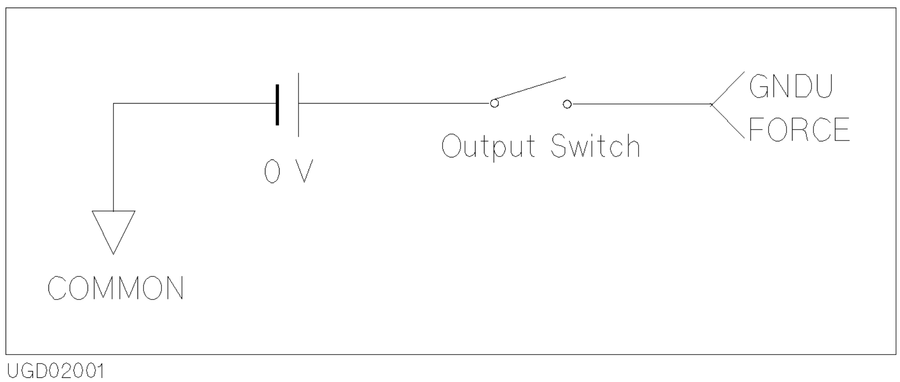

Figure 1-1. Simplified GNDU Circuit Diagram

Source/Monitor Unit (SMU)

The source/monitor unit (SMU) has the following three modes:

- voltage source and current monitor mode (V source and I monitor mode)
- current source and voltage monitor mode (I source and V monitor mode)
- source common mode

SMU can output constant or pulsed source. (Only one SMU can be set to pulsed source.)

Figure 1-2 shows a simplified SMU circuit diagram.

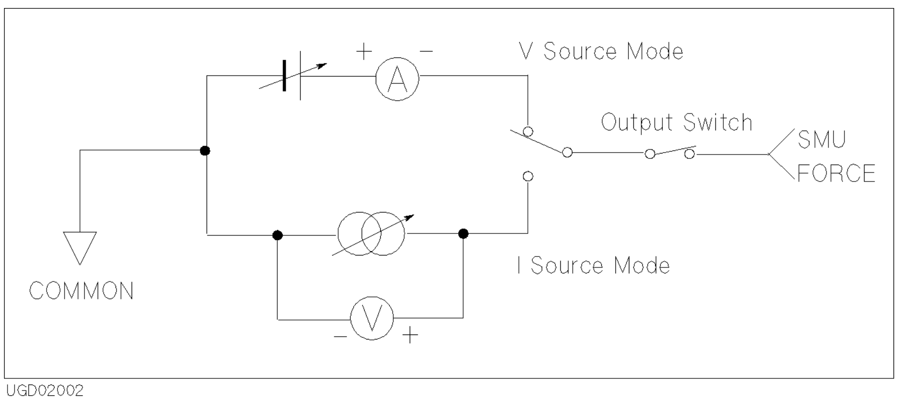

Figure 1-2. Simplified SMU Circuit Diagram

Three types of SMUs are available:

- HRSMU (high resolution SMU)
  - Force and measure: up to ±100 V or ±100 mA.
  - Maximum output power: 2 W.
  - Minimum current measurement range: 10 pA with 1 fA resolution.
  - Only HP 4156A has HRSMUs. HP 4156A has four HRSMUs.
- MPSMU (medium power SMU)
  - Force and measure: up to ±100 V or ±100 mA.
  - Maximum output power: 2 W.
  - HP 4155A has four MPSMUs, and HP 41501A can be equipped with either two MPSMUs or one HPSMU.
- HPSMU (high power SMU)
  - Force and measure: up to ±200 V or ±1 A.
  - Maximum output power: 20 W.
  - Only HP 41501A has HPSMU. HP 41501A can be equipped with either two MPSMUs or one HPSMU.

HPSMUs and HRSMUs can be connected to test devices by Kelvin connection.

Each SMU has a compliance feature that limits output voltage or current to prevent damage to your devices. When the SMU forces voltage, you can specify I compliance. When the SMU forces current, you can specify V compliance.

For details about the compliance setting range and resolution, see "Compliance" in Chapter 3.

The following figures and tables show the output and measurement ranges of each SMU type.

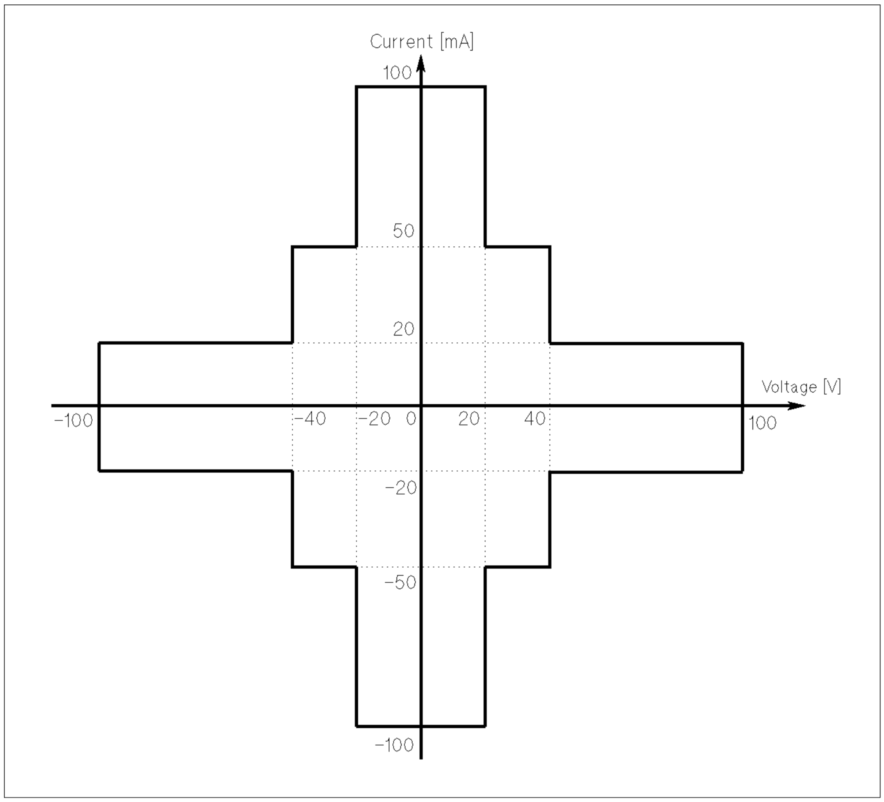

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Figure 1-3. HRSMU Output and Measurement Ranges

Table 1-1. HRSMU Output Voltage Ranges and Resolutions

Range	Output Value	Output Resolution	Current Compliance Range
2 V	$0 \leq \lvert V \rvert \leq 2$ V	100 μV	±100 mA
20 V	$0 \leq \lvert V \rvert \leq 20$ V	1 mV	±100 mA
40 V	$0 \leq \lvert V \rvert \leq 40$ V	2 mV	±50 mA
100 V	$0 \leq \lvert V \rvert \leq 100$ V	5 mV	±20 mA

Table 1-2. HRSMU Measurement Voltage Values and Resolutions

Range	Measurement Value[1]	Measurement Resolutions			
		Integration Time			Knob Sweep Measurement Sampling Measurement[2]
		1PLC or Longer	640 μs to 1.92 ms	80 μs to 560 μs	
2 V	$0 \leq \|V\| \leq 2.2$ V	2 μV	20 μV	200 μV	200 μV
20 V	$0 \leq \|V\| \leq 22$ V	20 μV	200 μV	2 mV	2 mV
40 V	$0 \leq \|V\| \leq 44$ V	40 μV	400 μV	4 mV	4 mV
100 V	$0 \leq \|V\| \leq 100$ V	100 μV	1 mV	10 mV	10 mV

1 Over range is used only when auto range or limited auto range is set. For fixed range, maximum measurement value is **Range** column value.

2 Only when *initial interval* is 480 μs or shorter.

Table 1-3. HRSMU Output Current Ranges and Resolutions

Range	Output Value	Output Resolution	Voltage Compliance Range
10 pA	$0 \leq \|I\| \leq 10$ pA	10 fA	±100 V
100 pA	$0 \leq \|I\| \leq 100$ pA	10 fA	±100 V
1 nA	$0 \leq \|I\| \leq 1$ nA	100 fA	±100 V
10 nA	$0 \leq \|I\| \leq 10$ nA	1 pA	±100 V
100 nA	$0 \leq \|I\| \leq 100$ nA	10 pA	±100 V
1 μA	$0 \leq \|I\| \leq 1$ μA	100 pA	±100 V
10 μA	$0 \leq \|I\| \leq 10$ μA	1 nA	±100 V
100 μA	$0 \leq \|I\| \leq 100$ μA	10 nA	±100 V
1 mA	$0 \leq \|I\| \leq 1$ mA	100 nA	±100 V
10 mA	$0 \leq \|I\| \leq 10$ mA	1 μA	±100 V
100 mA	$0 \leq \|I\| \leq 20$ mA	10 μA	±100 V
	20 mA $< \|I\| \leq 50$ mA	10 μA	±40 V
	50 mA $< \|I\| \leq 100$ mA	10 μA	±20 V

Table 1-4. HRSMU Measurement Current Values and Resolutions

Range	Measurement Value[1]	Measurement Resolutions			
		Integration Time			Knob Sweep Measurement Sampling Measurement[2]
		1PLC or Longer	640 μs to 1.92 ms	80 μs to 560 μs	
10 pA	$0 \leq \lvert I \rvert \leq$ 10.5 pA	1 fA	1 fA	1 fA	1 fA
100 pA	$0 \leq \lvert I \rvert \leq$ 115 pA	1 fA	1 fA	10 fA	10 fA
1 nA	$0 \leq \lvert I \rvert \leq$ 1.15 nA	10 fA	10 fA	100 fA	100 fA
10 nA	$0 \leq \lvert I \rvert \leq$ 11.5 nA	10 fA	100 fA	1 pA	1 pA
100 nA	$0 \leq \lvert I \rvert \leq$ 115 nA	100 fA	1 pA	10 pA	10 pA
1 μA	$0 \leq \lvert I \rvert \leq$ 1.15 μA	1 pA	10 pA	100 pA	100 pA
10 μA	$0 \leq \lvert I \rvert \leq$ 11.5 μA	10 pA	100 pA	1 nA	1 nA
100 μA	$0 \leq \lvert I \rvert \leq$ 115 μA	100 pA	1 nA	10 nA	10 nA
1 mA	$0 \leq \lvert I \rvert \leq$ 1.15 mA	1 nA	10 nA	100 nA	100 nA
10 mA	$0 \leq \lvert I \rvert \leq$ 11.5 mA	10 nA	100 nA	1 μA	1 μA
100 mA	$0 \leq \lvert I \rvert \leq$ 100 mA	100 nA	1 μA	10 μA	10 μA

1 Over range is used only when auto range or limited auto range is set. For fixed range, maximum measurement value is **Range** column value.

2 Only when *initial interval* is 480 μs or shorter.

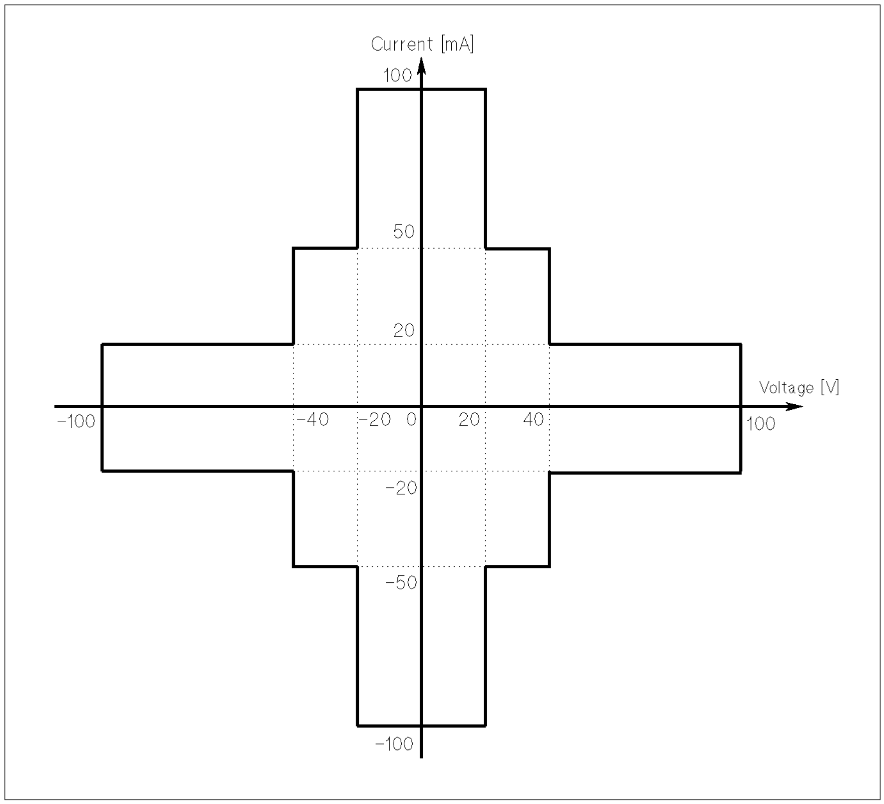

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Figure 1-4. MPSMU Output and Measurement Ranges

Table 1-5. MPSMU Output Voltage Ranges and Resolutions

Range	Output Value	Output Resolution	Current Compliance Range
2 V	$0 \leq \lvert V \rvert \leq 2$ V	100 μV	$\pm$100 mA
20 V	$0 \leq \lvert V \rvert \leq 20$ V	1 mV	$\pm$100 mA
40 V	$0 \leq \lvert V \rvert \leq 40$ V	2 mV	$\pm$50 mA
100 V	$0 \leq \lvert V \rvert \leq 100$ V	5 mV	$\pm$20 mA

Table 1-6. MPSMU Measurement Voltage Values and Resolutions

Range	Measurement Value[1]	Measurement Resolutions			
		Integration Time			Knob Sweep Measurement Sampling Measurement[2]
		1PLC or Longer	640 μs to 1.92 ms	80 μs to 560 μs	
2 V	$0 \leq \lvert V \rvert \leq 2.2$ V	2 μV	20 μV	200 μV	200 μV
20 V	$0 \leq \lvert V \rvert \leq 22$ V	20 μV	200 μV	2 mV	2 mV
40 V	$0 \leq \lvert V \rvert \leq 44$ V	40 μV	400 μV	4 mV	4 mV
100 V	$0 \leq \lvert V \rvert \leq 100$ V	100 μV	1 mV	10 mV	10 mV

1 Over range is used only when auto range or limited auto range is set. For fixed range, maximum measurement value is **Range** column value.

2 Only when *initial interval* is 480 μs or shorter.

Table 1-7. MPSMU Output Current Ranges and Resolutions

Range	Output Value	Output Resolution	Voltage Compliance Range
1 nA	$0 \leq \lvert I \rvert \leq 1$ nA	100 fA	$\pm$100 V
10 nA	$0 \leq \lvert I \rvert \leq 10$ nA	1 pA	$\pm$100 V
100 nA	$0 \leq \lvert I \rvert \leq 100$ nA	10 pA	$\pm$100 V
1 μA	$0 \leq \lvert I \rvert \leq 1$ μA	100 pA	$\pm$100 V
10 μA	$0 \leq \lvert I \rvert \leq 10$ μA	1 nA	$\pm$100 V
100 μA	$0 \leq \lvert I \rvert \leq 100$ μA	10 nA	$\pm$100 V
1 mA	$0 \leq \lvert I \rvert \leq 1$ mA	100 nA	$\pm$100 V
10 mA	$0 \leq \lvert I \rvert \leq 10$ mA	1 μA	$\pm$100 V
100 mA	$0 \leq \lvert I \rvert \leq 20$ mA	10 μA	$\pm$100 V
	20 mA $< \lvert I \rvert \leq 50$ mA	10 μA	$\pm$40 V
	50 mA $< \lvert I \rvert \leq 100$ mA	10 μA	$\pm$20 V

Table 1-8. MPSMU Measurement Current Values and Resolutions

Range	Measurement Value[1]	Measurement Resolutions			
		Integration Time			Knob Sweep Measurement Sampling Measurement[2]
		1PLC or Longer	640 μs to 1.92 ms	80 μs to 560 μs	
1 nA	$0 \leq \lvert I \rvert \leq 1.15$ nA	10 fA	10 fA	100 fA	100 fA
10 nA	$0 \leq \lvert I \rvert \leq 11.5$ nA	10 fA	100 fA	1 pA	1 pA
100 nA	$0 \leq \lvert I \rvert \leq 115$ nA	100 fA	1 pA	10 pA	10 pA
1 μA	$0 \leq \lvert I \rvert \leq 1.15$ μA	1 pA	10 pA	100 pA	100 pA
10 μA	$0 \leq \lvert I \rvert \leq 11.5$ μA	10 pA	100 pA	1 nA	1 nA
100 μA	$0 \leq \lvert I \rvert \leq 115$ μA	100 pA	1 nA	10 nA	10 nA
1 mA	$0 \leq \lvert I \rvert \leq 1.15$ mA	1 nA	10 nA	100 nA	100 nA
10 mA	$0 \leq \lvert I \rvert \leq 11.5$ mA	10 nA	100 nA	1 μA	1 μA
100 mA	$0 \leq \lvert I \rvert \leq 100$ mA	100 nA	1 μA	10 μA	10 μA

1 Over range is used only when auto range or limited auto range is set. For fixed range, maximum measurement value is **Range** column value.

2 Only when *initial interval* is 480 μs or shorter.

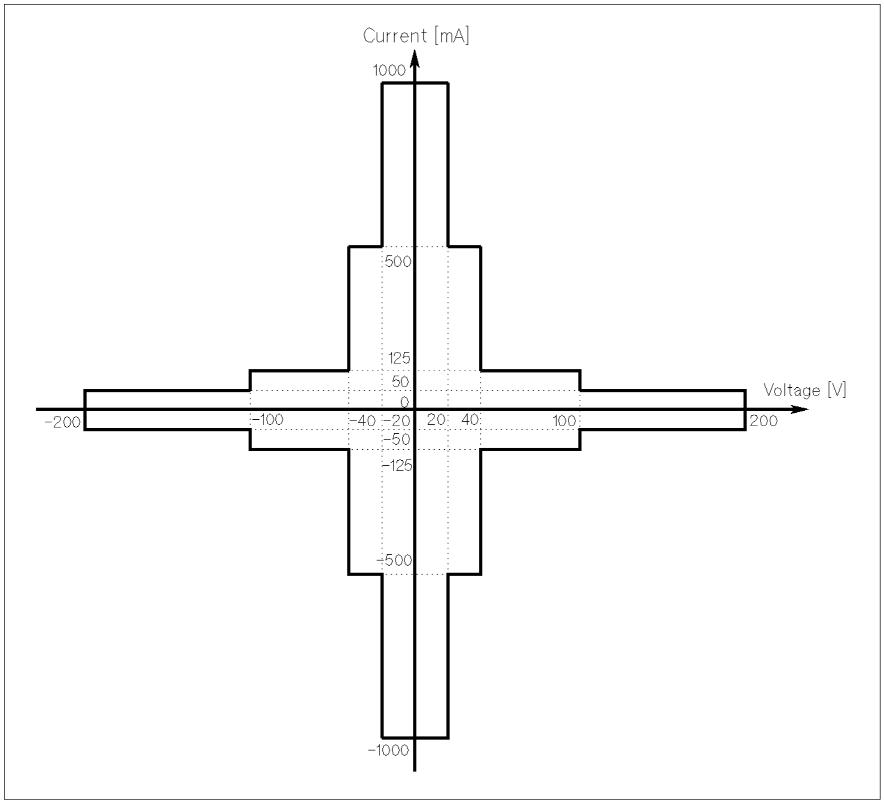

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Figure 1-5. HPSMU Output and Measurement Ranges

Table 1-9. HPSMU Output Voltage Ranges and Resolutions

Range	Output Value	Output Resolution	Current Compliance Range
2 V	$0 \le \|V\| \le 2$ V	100 μV	$\pm$1000 mA
20 V	$0 \le \|V\| \le 20$ V	1 mV	$\pm$1000 mA
40 V	$0 \le \|V\| \le 40$ V	2 mV	$\pm$500 mA
100 V	$0 \le \|V\| \le 100$ V	5 mV	$\pm$125 mA
200 V	$0 \le \|V\| \le 200$ V	10 mV	$\pm$50 mA

Table 1-10. HPSMU Measurement Voltage Values and Resolutions

Range	Measurement Value[1]	Measurement Resolutions			
		Integration Time			Knob Sweep Measurement Sampling Measurement[2]
		1PLC or Longer	640 μs to 1.92 ms	80 μs to 560 μs	
2 V	$0 \le \|V\| \le 2.2$ V	2 μV	20 μV	200 μV	200 μV
20 V	$0 \le \|V\| \le 22$ V	20 μV	200 μV	2 mV	2 mV
40 V	$0 \le \|V\| \le 44$ V	40 μV	400 μV	4 mV	4 mV
100 V	$0 \le \|V\| \le 110$ V	100 μV	1 mV	10 mV	10 mV
200 V	$0 \le \|V\| \le 200$ V	200 μV	2 mV	20 mV	20 mV

1 Over range is used only when auto range or limited auto range is set. For fixed range, maximum measurement value is **Range** column value.

2 Only when *initial interval* is 480 μs or shorter.

Table 1-11. HPSMU Output Current Ranges and Resolutions

Range	Output Value	Output Resolution	Voltage Compliance Range
1 nA	$0 \leq \|V\| \leq 1$ nA	100 fA	± 200 V
10 nA	$0 \leq \|I\| \leq 10$ nA	1 pA	± 200 V
100 nA	$0 \leq \|I\| \leq 100$ nA	10 pA	± 200 V
1 μA	$0 \leq \|I\| \leq 1$ μA	100 pA	± 200 V
10 μA	$0 \leq \|I\| \leq 10$ μA	1 nA	± 200 V
100 μA	$0 \leq \|I\| \leq 100$ μA	10 nA	± 200 V
1 mA	$0 \leq \|I\| \leq 1$ mA	100 nA	± 200 V
10 mA	$0 \leq \|I\| \leq 10$ mA	1 μA	± 200 V
100 mA	$0 \leq \|I\| \leq 50$ mA	10 μA	± 200 V
	50 mA $< \|I\| \leq 100$ mA	10 μA	± 100 V
1 A	$0 \leq \|I\| \leq 50$ mA	100 μA	± 200 V
	50 mA $< \|I\| \leq 125$ mA	100 μA	± 100 V
	125 mA $< \|I\| \leq 500$ mA	100 μA	± 40 V
	500 mA $< \|I\| \leq 1$ A	100 μA	± 20 V

Table 1-12. HPSMU Measurement Current Values and Resolutions

Range	Measurement Value[1]	Measurement Resolutions			
		Integration Time			Knob Sweep Measurement Sampling Measurement[2]
		1PLC or Longer	640 μs to 1.92 ms	80 μs to 560 μs	
1 nA	$0 \leq \lvert I \rvert \leq 1.15$ nA	10 fA	10 fA	100 fA	100 fA
10 nA	$0 \leq \lvert I \rvert \leq 11.5$ nA	10 fA	100 fA	1 pA	1 pA
100 nA	$0 \leq \lvert I \rvert \leq 115$ nA	100 fA	1 pA	10 pA	10 pA
1 μA	$0 \leq \lvert I \rvert \leq 1.15$ μA	1 pA	10 pA	100 pA	100 pA
10 μA	$0 \leq \lvert I \rvert \leq 11.5$ μA	10 pA	100 pA	1 nA	1 nA
100 μA	$0 \leq \lvert I \rvert \leq 115$ μA	100 pA	1 nA	10 nA	10 nA
1 mA	$0 \leq \lvert I \rvert \leq 1.15$ mA	1 nA	10 nA	100 nA	100 nA
10 mA	$0 \leq \lvert I \rvert \leq 11.5$ mA	10 nA	100 nA	1 μA	1 μA
100 mA	$0 \leq \lvert I \rvert \leq 50$ mA	100 nA	1 μA	10 μA	10 μA
	50 mA $< \lvert I \rvert \leq 115$ mA	100 nA	1 μA	10 μA	10 μA
1 A	$0 \leq \lvert I \rvert \leq 1$ A	1 μA	10 μA	100 μA	100 μA

1 Over range is used only when auto range or limited auto range is used. For fixed range, maximum measurement value is **Range** column value.

2 Only when *initial interval* is 480 μs or shorter.

When SMU is pulsed source, set pulse parameters in following ranges:

Pulse width	0.5 ms to 100 ms, 100 μs resolution
Pulse period	5 ms to 1 s, 100 μs resolution

where pulse period $\geq$ pulse width + 4 ms

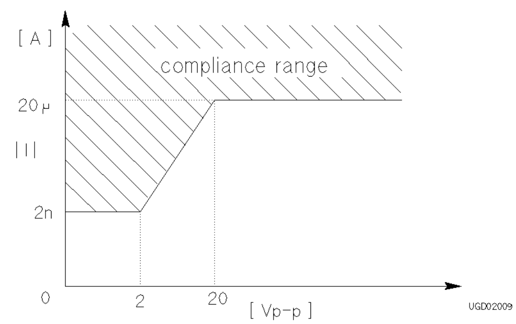
Be aware that if any of following are true, pulsed SMU channel may not output the pulse period and pulse width you specified:

- Measurement range differs from compliance range (lowest range that includes compliance).
- Ranging mode is set to auto range or limited auto range.
- Multi-channel measurement is set.

Compliance Range for Pulsed SMU

If you use an SMU as a pulsed source, the compliance setting range is as follows:

- current compliance
  For SMU used as pulsed voltage source, you can set current compliance as follows:



0 < | Vp-p | < 2 V	| I | > 2 nA
2 < | Vp-p | < 20 V	| I | > 1.111E-6 x | Vp-p | - 2.22E-6
20 < | Vp-p |	| I | > 20 μA

- voltage compliance
  If you use SMU as pulse current source, you can set voltage compliance as follows:

  - When $|I| \leq 10\ \mu$A, voltage compliance must be 2 V or less.
  - When $|I| > 10\ \mu$A, voltage compliance ranges are same as in tables on previous pages.

  If SMU is pulsed *constant* source, I is peak or base current, whichever has larger absolute value.
  If SMU is pulsed *sweep* source, I is start or stop value, whichever has larger absolute value.

Voltage Source Unit (VSU)

Figure 1-6 shows a simplified voltage source unit (VSU) circuit diagram.

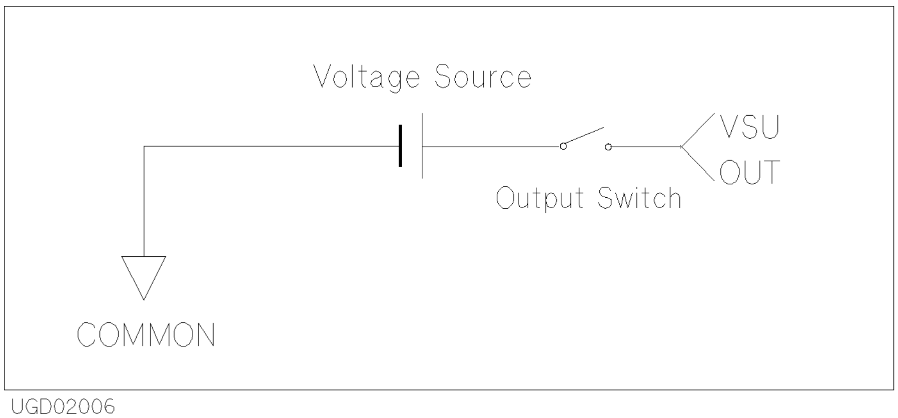


Figure 1-6. Simplified VSU Circuit Diagram

- VSU can force up to ±20 V.
- Only range available is 20 V range with 1 mV resolution, so output range is automatically set to 20 V.
- Current compliance is automatically set to ±100 mA.

Voltage Monitor Unit (VMU)

Voltage monitor unit (VMU) has two measurement modes: grounded or differential. Grounded mode uses one VMU. Differential mode uses two VMUs.

Figure 1-7 shows a simplified VMU circuit diagram.

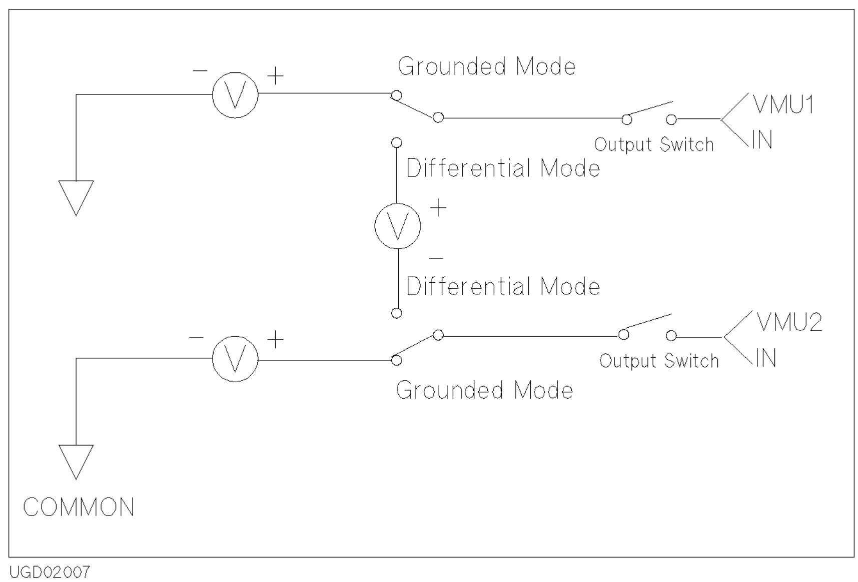


Figure 1-7. Simplified VMU Circuit Diagram

VMU can measure up to 20 V. Table 1-13 shows the voltage measurement range of VMU.

Table 1-13. VMU Voltage Ranges and Resolutions

Measurement Mode	Range	Measurement Resolutions			
		Integration Time			Sampling Measurement[1]
		1PLC or Longer	640 μs to 1.92 ms	80 μs to 560 μs	
Grounded Measurement	2 V	2 μV	20 μV	200 μV	1 mV
	20 V	20 μV	200 μV	1 mV	10 mV
Differential Measurement	0.2 V	1 μV	2 μV	20 μV	200 μV
	2 V	2 μV	20 μV	200 μV	2 mV

1 Only when *initial interval* is 480 μs or shorter.

When you perform knob sweep measurement,

- only 20 V range is available for grounded measurement mode
- only 2 V range is available for differential measurement mode

High Impedance DUT

Very high impedance DUT may cause measurement error due to the input leakage current from VMU.

To check the measurement error, perform voltage measurement as follows:

1. Connect SMU to the DUT.
2. Force very low current (under 1 pA) to the DUT from SMU.
3. Measure voltage by SMU.
4. Compare the voltage measured by SMU and VMU.

Pulse Generator Unit (PGU)

Two pulse generator units (PGUs) are available, which are in HP 41501A (SMU and pulse generator expander). Each PGU provides a pulsed output, and can also function as a dc source. For pulsed output of PGU, you can select 50 Ω or Low impedance. Figure 1-8 shows simplified PGU circuit diagram.

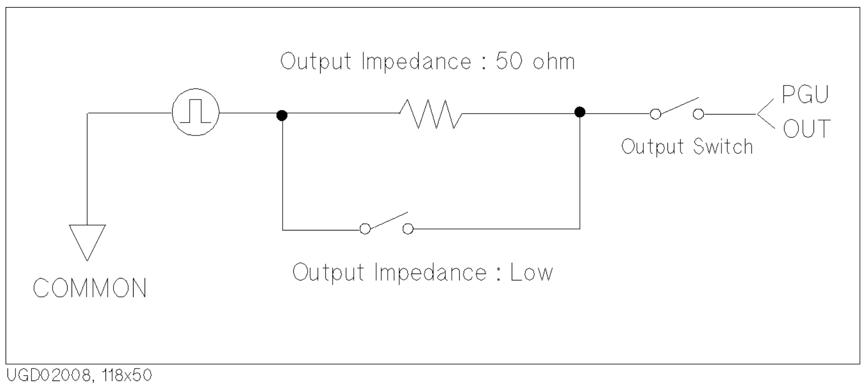


Figure 1-8. Simplified PGU Circuit Diagram

The PGU output value is defined to be the value that is output if the PGU output terminal is open. So, when a load is connected and PGU impedance is set to 50 Ω, the actual output value will be different. For example, if connected load is 50 Ω, specified PGU output impedance is 50 Ω, and specified output value is 2 V, the PGU outputs 1 V.

Table 1-14 shows the PGU setting ranges and resolutions.

Table 1-14. PGU Setting Ranges and Resolutions

Range	Peak Setting Value[1]	Base Setting Value[1]	Resolution	Maximum Current[2]
20 V	$0 \leq \lvert V \rvert \leq 20$ V	$0 \leq \lvert V \rvert \leq 20$ V	4 mV	±100 mA
40 V	$0 \leq \lvert V \rvert \leq 40$ V	$0 \leq \lvert V \rvert \leq 40$ V	8 mV	±100 mA

1 Maximum peak-to-peak voltage is 40 V.

2 If pulse width ≤ 1 ms, pulse duty is ≤ 50 %, and average current output is ≤ ±100 mA, the peak current output can be up to ±200 mA.

If the impedance of the load connected to the PGU differs from the specified impedance in the IMPEDANCE field on the MEASURE: PGU SETUP page or the STRESS: STRESS SETUP page, the average output current may exceed 100 mA. If so, a warning message is displayed.

When you use two PGUs, the outputs are *always* synchronized with each other. The PGUs cannot be synchronized with the other measurement units.

The following describe each pulse parameter. For more details, see "MEASURE: PGU SETUP page" in Chapter 4.

Pulse count.
Allowable range: 1 to 65535. If you use two PGUs, both PGUs are set to the same pulse count. You *cannot* set different values for each PGU.

Pulse period, pulse width, delay time.
Each parameter has six setting ranges as shown in Table 1-15.

Table 1-15. Ranges of Pulse Period, Pulse Width and Delay Time

Range	Pulse Period	Pulse Width	Delay Time[1]	Resolution
1	2.0 μs to 100.0 μs	1.0 μs to 99.9 μs	0 to 100.0 μs	0.1 μs
2	100 μs to 1000 μs	1 μs to 999 μs	0 to 1000 μs	1 μs
3	1.00 ms to 10.00 ms	0.01 ms to 9.99 ms	0 to 10.00 ms	10 μs
4	10.0 ms to 100.0 ms	0.1 ms to 99.9 ms	0 to 100.0 ms	100 μs
5	100 ms to 1000 ms	1 ms to 999 ms	0 to 1000 ms	1 ms
6	1.00 s to 10.00 s	0.01 s to 9.99 s	0 to 10.00 s	10 ms

1 The setting range of delay time is 0 ≤ *delay time* ≤ specified *pulse period*.

The pulse period, pulse width, and delay time must be set in the same range. Also, if you use two PGUs, both PGUs are set to the *same* pulse period value. So, these three parameters must be set in the same range for both PGUs.

Leading-edge and trailing-edge transition time.
The leading-edge and trailing-edge transition times have five setting ranges as shown in Table 1-16.

Table 1-16. Ranges and Resolutions of Leading and Trailing Transition Time

Range	Leading and Trailing Transition Time	Resolution
1	100 ns to 1000 ns	1 ns
2	0.50 μs to 10.00 μs	10 ns
3	5.0 μs to 100.0 μs	100 ns
4	50 μs to 1000 μs	1 μs
5	0.5 ms to 10.00 ms	10 μs

- restrictions

  leading-edge transition time $\leq$ *pulse width* $\times$ 0.8.

  trailing-edge transition time $\leq$ (*pulse period* $-$ *pulse width*) $\times$ 0.8.

  Leading and trailing-edge transition times for a PGU must be in the same range.

Output impedance.
You can select 50 Ω or Low impedance.

Trigger output.
PGUs output trigger signal to synchronize with external pulse generators. If an HP 41501A has PGUs, the HP 41501A has a trigger output terminal. For details of trigger functions, refer to “Trigger Function” in Chapter 3.

2

Measurement Mode

Measurement Mode

This chapter explains the HP 4155A/4156A measurement modes.
The HP 4155A/4156A has the following two measurement modes:

- Sweep measurement mode
- Sampling measurement mode

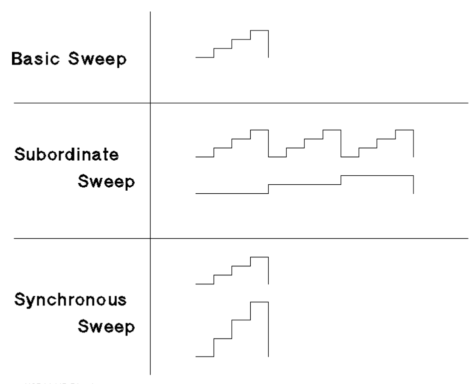
Sweep Measurement Mode

For sweep measurements, the sweep source channels perform staircase sweep output of voltage or current, while the monitor channels measure voltage or current for each sweep step.

Only SMUs and VSUs can be sweep sources (VAR1, VAR2, and VAR1').

HP 4155A/4156A provides three types of sweep measurement:

- Basic Sweep Measurement
  One sweep source (VAR1) is used.
- Subordinate Sweep Measurement
  A primary (VAR1) and secondary sweep source (VAR2) are used.
- Synchronous Sweep Measurement
  A primary (VAR1) and synchronous sweep source (VAR1') are used.



Also, you can set up a combined subordinate and synchronous sweep measurement.

In addition to the normal dc sweep, the sweep or constant source output can be pulsed to prevent thermal drift of the DUT.

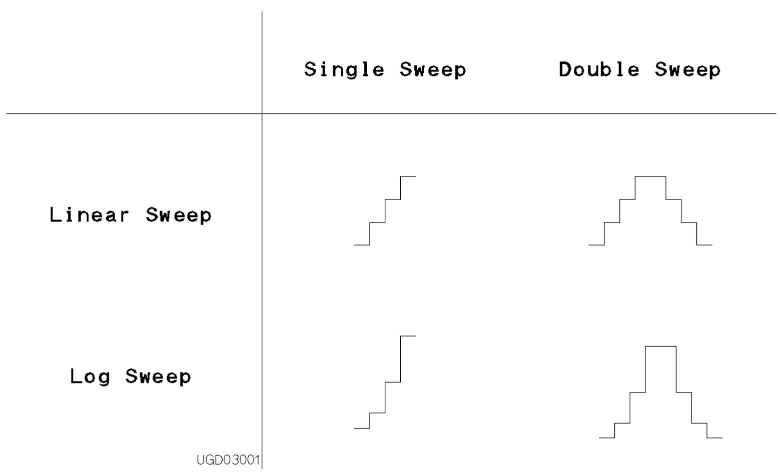
Basic Sweep Measurement

Basic sweep measurement uses one sweep source (VAR1).

The following sweep types are available:

- LIN/LOG
  - □ Linear staircase
  - □ Logarithmic staircase
- SWEEP MODE
  - □ Single
    Source channel sweeps the output from user specified *start* value to *stop* value.
  - □ Double
    Source channel sweeps the output from user specified *start* value to *stop* value, then from *stop* value to *start* value.

You can select any combination of LIN/LOG and SWEEP MODE as shown in the following table:



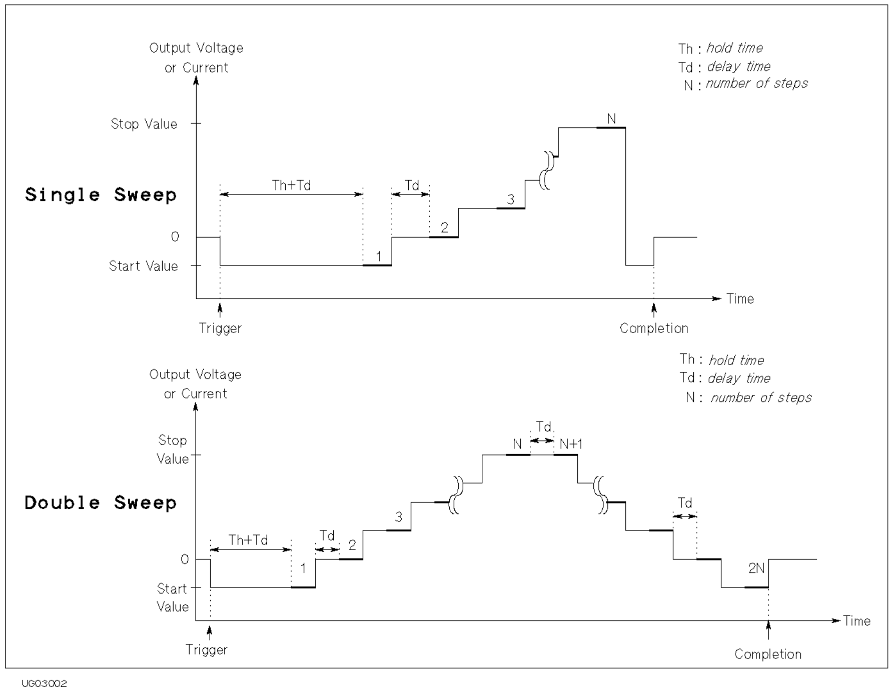


Figure 2-1. Basic Sweep Measurement

To set up basic sweep measurement, select VAR1 function for desired SMU or VSU on CHANNELS: CHANNEL DEFINITION page.

Parameters. Also, specify the following parameters for VAR1 on MEASURE: SWEEP SETUP page.

Parameter	Description
sweep mode	Single or double sweep.
linear/log	Linear or logarithmic sweep. For logarithmic sweep, select the number steps in one decade as follows:

LOG10	10 steps in one decade.
LOG25	25 steps in one decade.
LOG50	50 steps in one decade.

start	Start value of sweep. For logarithmic sweep, *start* must not be zero. Allowable range of *start* depends on output range of sweep source. For output range of each measurement channel, refer to Chapter 1.
stop	Stop value of single sweep or turning back value of double sweep. For logarithmic sweep, *stop* must have same polarity as *start*, and must not be zero. Allowable range of *stop* depends on output range of sweep source. For output range of each measurement channel, refer to Chapter 1.
step	• For linear sweep, *step* is step increment of sweep. Number of sweep steps is calculated from *start*, *stop*, and *step*. Calculated number of steps must be in range: 2 to 1001. • For logarithmic sweep, *step* is invalid. Number of sweep steps is calculated from *start*, *stop*, and number of steps in one decade, which is specified by *log* parameter. Calculated number of steps must be in range: 2 to 1001.
compliance	Compliance value of sweep source. This parameter applies to SMU only. Allowable range of *compliance* depends on the compliance range of sweep source. For the compliance range of each measurement channel, refer to Chapter 1.
power compliance	(Optional) Power compliance value of sweep source. This parameter applies to SMU only. Allowable range depends on power compliance range of sweep source. For details, refer to Chapter 3.
hold time	Time required for DUT to settle after forcing start value. Allowable range: • (for *initial interval* $<$ 2 ms) -30 ms to 655.35 s with 100 μs resolution. • (for *initial interval* $\geq$ 2 ms) 0 to 655.35 s with 100 μs resolution.
delay time	Time required for DUT to settle after stepping the output. Allowable range: 0 to 65.535 s. Resolution: 100 μs

Refer to “CHANNELS: CHANNEL DEFINITION page” in Chapter 4 and “MEASURE: MEASURE SETUP page” in Chapter 4 for setting up these parameters.

Subordinate Sweep Measurement

For subordinate sweep measurement, you set up a secondary sweep source (VAR2) in addition to a primary sweep source (VAR1). After primary sweep is completed, the output of secondary sweep source is incremented or decremented by the specified step value, then the primary sweep source is swept again.

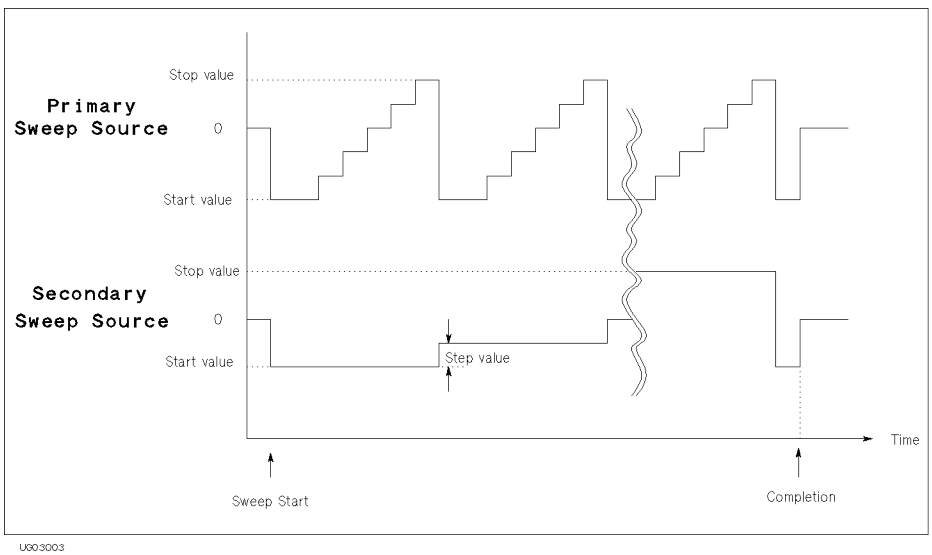


Figure 2-2. Subordinate Sweep Measurement

To set up the subordinate sweep measurement, select the following on CHANNELS: CHANNEL DEFINITION page:

- VAR1 function for desired primary sweep source (SMU or VSU).
- VAR2 function for desired secondary sweep source (SMU or VSU).

Subordinate sweep measurement has the following restriction:

- For the secondary sweep source, only *single* sweep mode and *linear* staircase mode are available.

Parameters. The parameters for primary sweep source (VAR1) are same as the parameters for sweep source of basic sweep measurement. For secondary sweep source (VAR2), specify the following parameters on MEASURE: SWEEP SETUP page.

Parameter	Description
start	Start value of secondary sweep. Allowable range of *start* depends on the output range of secondary sweep source. For the output range of each measurement channel, refer to Chapter 1.
step	Step increment of secondary sweep.
number of steps	Number of secondary sweep steps. Allowable range: 1 to 128.

Stop value

Stop value of secondary sweep is calculated from *start*, *step*, and *number of steps*. Allowable range of *stop* depends on the output range of secondary sweep source. For the output range of each measurement channel, refer to Chapter 1.

compliance	Compliance value of secondary sweep source. This parameter applies to SMU only. Allowable range of *compliance* depends on the compliance range of secondary sweep source. For the compliance range of each measurement channel, refer to Chapter 1.
power compliance	(Optional) Power compliance value of secondary sweep source. This parameter applies to SMU only. Allowable range of *power compliance* depends on the power compliance range of sweep source. For details, refer to Chapter 3.

Synchronous Sweep Measurement

For synchronous sweep measurement, you set up a synchronous sweep source (VAR1') in addition to a primary sweep source (VAR1). The output of the synchronous sweep source is swept synchronously with the output of the primary sweep source at a constant offset value and ratio.

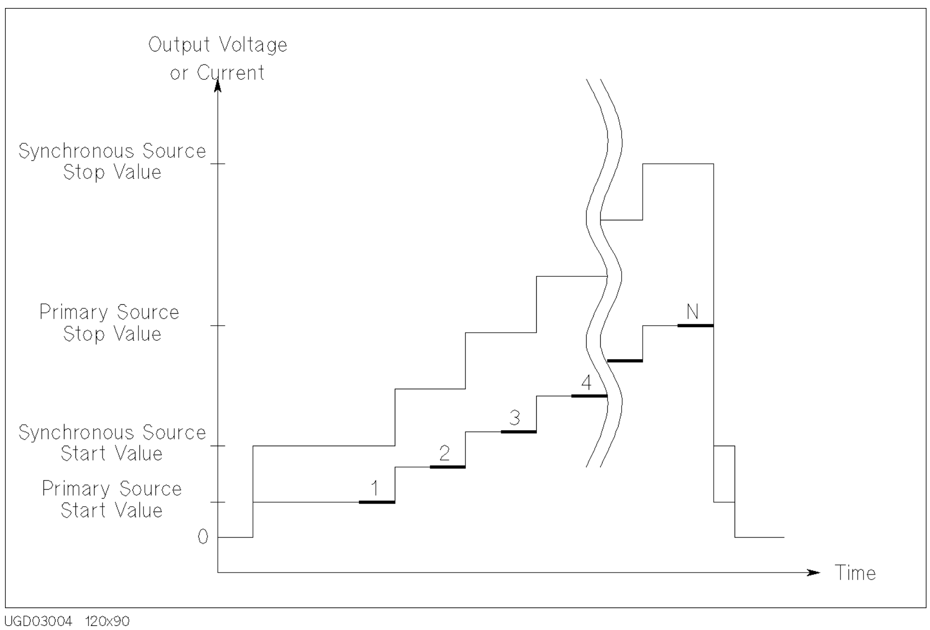


Figure 2-3. Synchronous Sweep Measurement

To set up synchronous sweep measurement, select the following on CHANNELS: CHANNEL DEFINITION page:

- VAR1 function for desired primary sweep source (SMU or VSU).
- VAR1' function for desired synchronous sweep source (SMU or VSU).

Synchronous sweep mode has the following restrictions:

- For the following, VAR1' is always set to the same mode as VAR1:
  - linear/log staircase
  - single/double sweep mode
- VAR1 and VAR1' must be same V/I output mode. For example, if VAR1 is set to `V` mode, then VAR1' must be set to `V` or `VPULSE` mode.

Parameters. The parameters for primary sweep source (VAR1) are same as the parameters for sweep source of basic sweep measurement. For synchronous sweep source (VAR1'), specify the following parameters on MEASURE: SWEEP SETUP page.

Parameter	Description
offset	Offset between outputs of primary and synchronous sweep sources.
ratio	Ratio between outputs of primary and synchronous sweep sources.
compliance	Compliance value of synchronous sweep source. This parameter applies to SMU only. Allowable range of *compliance* depends on the compliance range of synchronous sweep source. For the compliance range of each measurement channel, refer to Chapter 1.
power compliance	(Optional) Power compliance value of synchronous sweep source. This parameter applies to SMU only. Allowable range of *power compliance* depends on the power compliance range of synchronous sweep source. For details, refer to Chapter 3.

The relationship between the output of primary and synchronous sweep sources is determined by the following equation:

$$synchronous\ output = primary\ output \times ratio + offset$$

The synchronous output determined by above equation must not exceed the output range of synchronous sweep source.

Pulse Sweep Measurement

For a sweep measurement, a sweep or constant source SMU can be a pulse source. But *only one* SMU can be a pulse source. Figure 2-4 shows the relationship between pulse source and other sources.

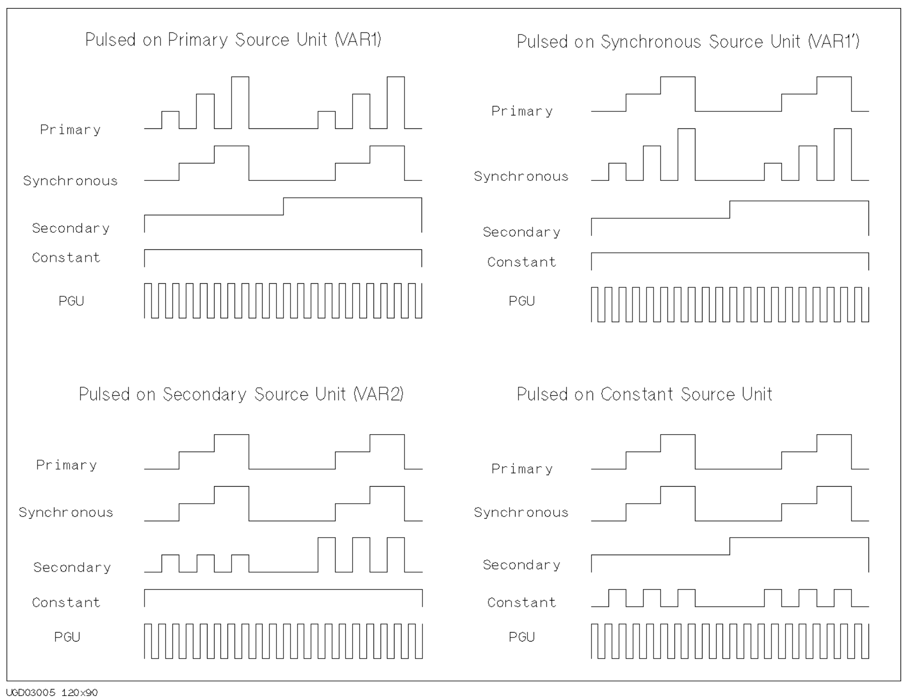


Figure 2-4. Pulse Source and Other Sources

For the pulse sweep measurement, the delay time of the primary sweep source is ignored, and each step of the primary sweep source is synchronized with output of the SMU pulse source. Measurements are made during the pulse output.

The pulse output of PGU is not synchronized with any other source.

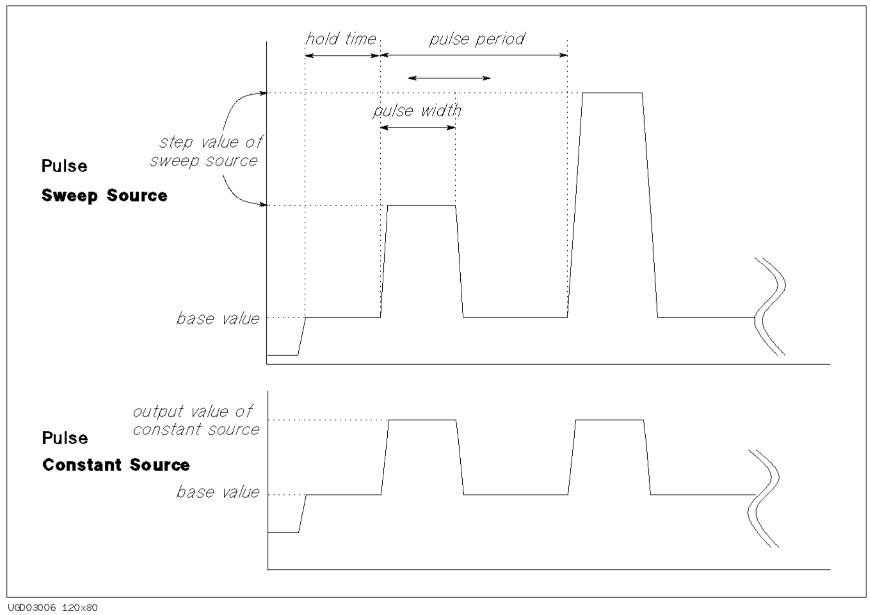


Figure 2-5. SMU Pulse

Parameters. Specify SMU pulse parameters (MEASURE: SWEEP SETUP):

Parameter	Description
pulse period	SMU forces the next pulse after specified *pulse period*. Allowable range: 5 ms to 1 s. Resolution: 100 μs.
pulse width	Time from when SMU output starts to change from *base value* to time when SMU starts to return from peak value. Measurements are made while the peak value is output. Allowable range: 0.5 ms to 100 ms. Resolution: 100 μs
base value	The base output value of the SMU pulse.

Be aware that if any of following are true, pulsed SMU channel may not output the pulse period and pulse width you specified:

- Measurement range differs from compliance range (lowest range that includes compliance).
- Ranging mode is set to auto range or limited auto range.
- Multi-channel measurement is set.

Pulse width

If the measurement settings do not meet the following conditions, *pulse width* setting of SMU may be insufficient to make measurement. If so, the pulse width is automatically changed to be appropriate.

Number of Meas. Channels:	1
Integration Time:	Short
Ranging Mode:	Fixed

Sampling Measurement Mode

For a sampling measurement, you can monitor current or voltage changes at a DUT while forcing constant current, constant voltage, or pulsed constant bias. The sampling measurement continues until the sampling completion condition is satisfied. Refer to "Sampling Completion".

You *cannot* execute a sampling measurement with a sweep measurement.

For sampling measurements, only the PGU output can be pulsed.

HP 4155A/4156A provides the following three types of sampling measurement according to the sampling interval:

- Linear Sampling Measurement
- Logarithmic Sampling Measurement
- Thinned-out Sampling Measurement

Table 2-1 shows available units and functions for sampling measurement.

Table 2-1. Available Units and Functions for Sampling Measurement

	Output Function					Output Mode			Pulse	Meas. Mode	
	VAR1	VAR1'	VAR2	CONST	STANDBY	V	I	COM		V	I
SMU	n.a.	n.a.	n.a.	•	•	•	•	•	n.a.	•	•
VSU	n.a.	n.a.	n.a.	•	•	•	–	–	–	–	–
VMU	–	–	–	–	–	–	–	–	–	•	–
GNDU	–	–	–	•	–	–	–	•	–	–	–
PGU	–	–	–	•	•	•	–	–	•	–	–

n.a. means "This is *not* available for sampling measurement".
• means "This is available for sampling measurement".
– means "This is *not* available for this unit".

The pulse output timing from PGU is not synchronized with the timing of sampling measurement.

Linear Sampling Measurement

For linear sampling measurement, initial sampling intervals are the specified *initial interval*.

However, if both the following two conditions occur, every other existing sample point is discarded:

- specified *number of samples* is reached and
- sampling completion condition is *not* satisfied

Then, the sampling interval is doubled and sampling continues. This discarding and doubling occurs every time *number of samples* is reached until the sampling completion condition is satisfied. Refer to "Sampling Completion".

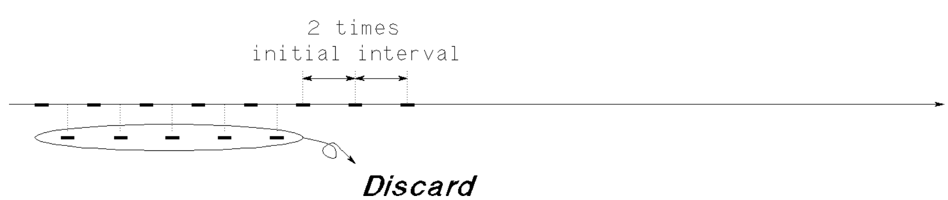
So, for long unknown measurement times, this function allows you to take a specified amount of equally spaced samples, thus reducing the amount of memory required as shown in the following example:

Example

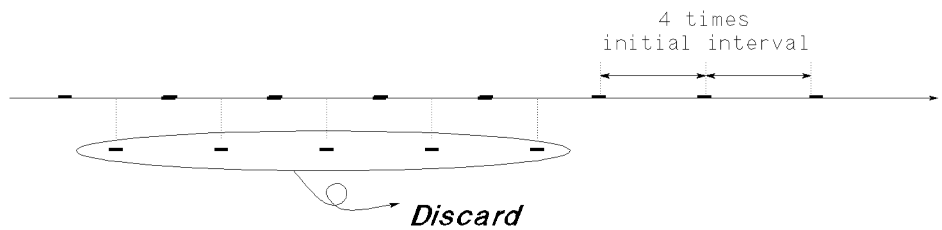
For the following example, the specified *number of samples* is 10:

1. Samples are taken at the specified *initial interval*:

2. If number of samples taken reaches 10, but sampling completion condition is not satisfied, every other existing sample is discarded, then five more samples are taken at two times the specified *initial interval*.



3. If sampling completion condition is still not satisfied, every other existing sample is discarded, then five more samples are taken at four times the specified *initial interval*.



4. This discarding and doubling of the sampling interval is repeated until the sampling completion condition is satisfied. By the end of the measurement, a maximum *number of samples* samples is stored.

Parameters. To set up the linear sampling measurement, specify the following parameters on MEASURE: SAMPLING SETUP page:

Parameter	Description
initial interval	The sampling interval for first *number of samples* samples. Allowable range: 60 μs to 65.535 s. If *total sampling time* $\geq$ *initial interval* $\times$ (*number of samples* $-$ 1), the sampling interval increases as described in previous example.
total sampling time	The maximum time for sampling. This is one of the sampling completion conditions, so sampling stops after this time elapses. Or you can set `NO LIMIT`, so sampling does not stop until another of the sampling completion conditions is reached. Restriction: 1×10^{11} s $\geq$ *total sampling time* $\geq$ *initial interval* $\times$ (*number of samples* $-$ 1).

number of samples	Number of samples to be stored by end of measurement. • If *total sampling time* $\geq$ *initial interval* $\times$ (*number of samples* $-$ 1), more samples are taken, but discarding occurs, so only *number of samples* samples are stored as described in previous example. • Restriction: *number of samples* $\leq$ 10001/(no. of sampling meas. channels).

Restrictions due to Initial Interval

- If *initial interval* $<$ 2 ms, the following must be true:

Number of meas. channels:	1 channel If you use R-Box for a channel, and the channel is V force mode, only the R-Box channel can be assigned to measurement channel.
Measurement ranging:	Fixed range only
Stop condition:	`DISABLE` For details about stop condition, see "Sampling Completion".

- If *initial interval* $\leq$ 480 μs, the following must be true:

  total sampling time = *initial interval* $\times$ (*number of samples* $-$ 1).

Logarithmic Sampling Measurement

For logarithmic sampling measurement, the sampling interval increases logarithmically.

You set the *initial interval*, *sample steps in one decade*, and *number of samples*, then the unit calculates sampling points that are equally spaced logarithmically.

Resolution of Sampling Timing

The specified *initial interval* is the resolution of sampling timing. So the first few samples may not be equally spaced logarithmically.

The specified *number of samples* is taken and stored, then measurement stops. So, *number of samples* is a sampling completion condition, not the *total sample time*, which has no meaning for log sampling.

Parameters. To set up a logarithmic sampling measurement, specify the following parameters on MEASURE: SAMPLING SETUP page:

Parameter	Description
initial interval	The first sampling interval. Also, this parameter is the resolution of sampling timing. Allowable range: 560 μs to 65.535 s.

sample steps in one decade — Number of sampling steps in one time decade. When you select logarithmic sampling measurement, select the number steps as follows:

LOG10	10 steps in one decade.
LOG25	25 steps in one decade.
LOG50	50 steps in one decade.

number of samples — Number of samples to take and store. Restriction: Sampling range must be 11 decades or less. So maximum *number of samples* is as follows:

LOG10	111
LOG25	276
LOG50	551

Restrictions due to Initial Interval

If *initial interval* $<$ 2 ms, the following must be true:

Number of meas. channels:	1 channel
Measurement ranging:	Fixed range only
Stop condition:	DISABLE

For details about stop condition, see "Sampling Completion".

If *initial interval* is 560 μs to 10 ms, the first 2 decades may not sample the specified number of measurement points. If so, the total measurement will be extended to add the number of measurement points that were not taken in the first 2 decades.

Thinned-out Sampling Measurement

Thinned-out sampling is similar to reverse log sampling. For thinned-out sampling measurement, sampling interval is always the specified *initial interval*, however thinning out is performed if both the following conditions occur:

- specified *number of samples* is reached and
- sampling completion condition is *not* satisfied

then every other existing sample point is discarded. Then sampling continues at *same* sampling interval. This occurs every time *number of samples* is reached until the sampling completion condition is satisfied. Refer to "Sampling Completion".

So, for long unknown measurement times, the sampling interval of the most recent sample points is the specified *initial interval*, and less recent sample points have increasingly longer intervals as shown in the following example.

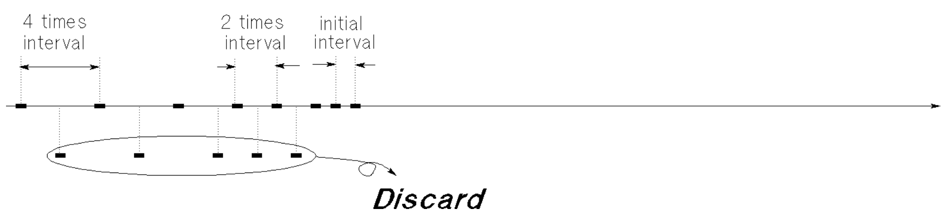
Example

For the following example, the specified *number of samples* is 10:

1. Samples are taken at the specified *initial interval*.

2. If number of samples taken reaches 10, but sampling completion condition is not satisfied, every other existing sample is discarded, then five more samples are taken at the specified *initial interval*.

3. If sampling completion condition is still not satisfied, every other existing sample is discarded, then five more samples are taken at the specified *initial interval*.



4. This discarding is repeated until the sampling completion condition is satisfied. By the end of the measurement, a maximum *number of samples* samples is stored.

Parameters. To set up thinned-out sampling measurement, specify the following parameters on MEASURE: SAMPLING SETUP page:

Parameter	Description
initial interval	The sampling interval. Allowable range: 720 μs to 65.535 s. If *total sampling time* $\geq$ *initial interval* $\times$ (*number of samples* $-$ 1), the sample points are thinned as described in previous example.
total sampling time	The maximum time for sampling. This is one of the sampling completion conditions, so sampling stops after this time elapses. Or you can set `NO LIMIT`, so sampling does not stop until another of the sampling completion conditions is reached.

Restriction: 1×10^{11} s $\geq$ *total sampling time* $\geq$ *initial interval* $\times$ (*number of samples* $-$ 1).

number of samples — The maximum number of sample points to be stored by end of measurement.

- If *total sampling time* $\geq$ *initial interval* $\times$ (*number of samples* $-$ 1), more samples are taken, but discarding occurs, so only *number of samples* samples are stored as described in previous example.
- Restriction: *number of samples* $\leq$ 10001/(no. of sampling meas. channels).

Restrictions due to Initial Interval

If *initial interval* $<$ 2 ms, the following must be true:

Number of meas. channels:	1 channel
Measurement ranging:	Fixed range only
Stop condition:	`DISABLE`

For details about stop condition, see "Sampling Completion".

Measurement Sequence

If the output sequence mode of sampling is set to *sequential*, the following occurs:

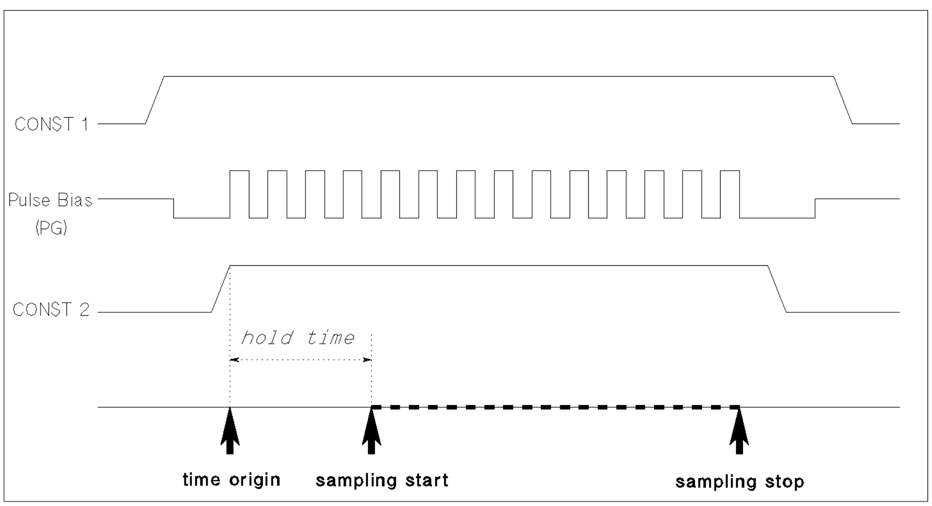
1. Constant sources force their output according to specified output sequence. Refer to "Output Sequence" in Chapter 3 about output sequence.
2. If there are pulse bias sources (PGUs), they start to force pulse bias.
3. After specified hold time, the sampling measurement starts. The hold time is relative to the time origin as described in the following.

If the output sequence mode of sampling is set to *simultaneous*, all sources start to force at same time.

Time Origin. The hold time before starting the sampling measurement is relative to the time origin, which is defined as follows:

- Output sequence mode: *sequential*.

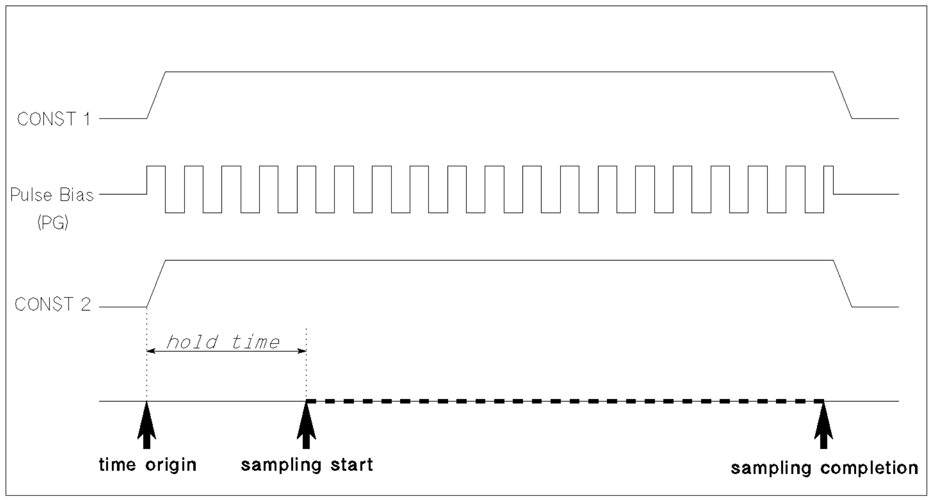
  Time origin: point at which last source reaches specified output value.



UGD03007 120x80

- Output sequence mode: *simultaneous*.

  Time origin: point at which all sources start to force.



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For information about output sequence mode, refer to "Output Sequence" in Chapter 3.

Sampling Completion

The sampling measurement completes when one of the following conditions is satisfied:

- Total sampling time

  The specified *total sampling time* has elapsed.

  For logarithmic sampling measurement, the *number of samples* is a sampling completion condition, not the *total sampling time*.

- Stop condition

  The stop condition is enabled, and specified *name* measurement value reaches the specified *threshold* value. See below.

- Stop

  Stop front-panel key in MEASUREMENT key group is pressed.

- HP-IB Command

  The HP 4155A/4156A receives HP-IB command to stop sampling.

- Emergency Condition

  An emergency condition occurs on HP 4155A/4156A.

- Interlock Open

  Interlock terminal opens due to high voltage.

Stop Condition. You can enable stop condition on MEASURE: SAMPLING SETUP page. If initial interval is less than 2 ms, you cannot enable stop condition.

To set up the stop condition, specify the following parameters on MEASURE: SAMPLING SETUP page.

Parameter	Description
name	The name of measurement data or user function to monitor for stop condition.
threshold	Threshold value at which to stop sampling measurement.

event	Sampling measurement stops when *name* value reaches the condition defined by *event*. One of the following four conditions can be selected for *event*. • *name* value > *threshold* value • *name* value < *threshold* value • |*name* value| > |*threshold* value| • |*name* value| < |*threshold* value|

Also, you may set the following parameters on MEASURE: SAMPLING SETUP page.

Parameter	Description
enable delay	Stop condition is disabled for *enable delay* seconds after measurement starts, then enabled. Allowable range: 0 to *initial interval*×32767 s. Resolution: *initial interval*.
event no	Sampling measurement stops when *event* occurs *event no* times. Allowable range: 1 to 200.

Sampling Measurement Mode

3

Measurement Functions

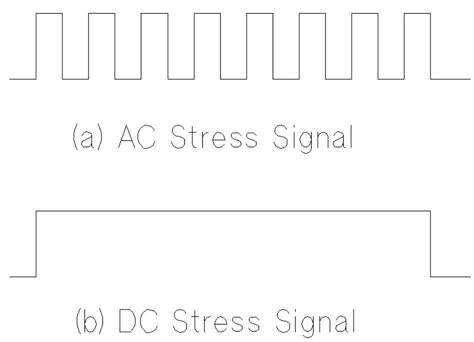
Measurement Functions

This chapter explains functions that can be used in measurements. HP 4155A/4156A has the following useful measurement functions.

- *Stress force function* allows you to force dc and ac stress for reliability tests.
- *Knob sweep function* allows you to perform measurements quickly without setting the setup pages.
- *Trigger function* allows you to synchronize measurements with other instruments.
- *Measurement range* allows you to set appropriate measurement range.
- *Compliance* allows you to prevent damage to the test device due to overcurrent or overvoltage.
- *Integration time* allows you to set appropriate measurement accuracy.
- *User-defined initial settings* allows you to set the setup pages automatically when you turn on the HP 4155A/4156A by using settings that are stored on a diskette.

Stress Force Function

When you press the (Stress) front-panel key in the MEASUREMENT key group, stress is forced to the DUTs for the specified period. The HP 4155A/4156A can force both dc stress and ac stress (pulsed stress) as shown in the following figure.



AC Stress and DC Stress Signals

setting the stress channels.
You can set up units for the stress force state on the STRESS: CHANNEL DEFINITION page independently from the measurement and standby states that you set on the CHANNELS: CHANNEL DEFINITION page.

For example, you can use the same SMU as a measurement channel in the measurement state, and as a stress force source in the stress force state.

switching channels when state changes.
The HP 4155A/4156A can control the 16440A SMU/Pulse Generator Selector (HP 16440A selector) to automatically switch the unit that is connected to a DUT pin depending on the state (stress force state or measurement state). You setup up this automatic control on the STRESS: CHANNEL DEFINITION page.

For example, the DUT pin is connected to a PGU for stress force when (Stress) front-panel key in the MEASUREMENT key group is pressed, then connected to an SMU for measurement when (Single) front-panel key is pressed.

For details about how to control the HP 16440A selector, refer to "To Control Selector for Switching SMU and PGU" in *HP 4155A/4156A User's Task Guide*, "To Install HP 16440A PGU/Pulse Generator Selector" in *HP 4155A/4156A User's Task Guide*, and "HP 16440A SMU/PG Selector Control" in this chapter.

displaying the stress force time.
The STRESS: STRESS FORCE page is displayed while stress is being forced. On this page, the time that stress has been forced is displayed and updated every second. For more details about the STRESS: STRESS FORCE page, refer to "STRESS: STRESS FORCE page" in Chapter 4.

Stress Output Channels

You can select up to four stress source channels among SMUs, VSUs, and PGUs.

To set a unit to be a stress source channel, set `SYNC` in the FCTN field on the STRESS: CHANNEL DEFINITION page. On this page, at least one channel must be set to `SYNC`. For details about the STRESS: CHANNEL DEFINITION page, refer to "STRESS: CHANNEL DEFINITION page" in Chapter 4.

The HP 4155A/4156A can force dc voltage stress, dc current stress, and ac voltage stress (by PGUs in HP 41501A), but cannot force ac current stress.

- available units and modes

  Table 3-1 shows available units and allowable modes for stress sources.

Table 3-1. Available Units and Modes for Stress Force

Units	DC Voltage Stress	DC Current Stress	AC Voltage Stress
SMU	•	•	
VSU	•		
PGU	•		•

Also, SMUs can be set to COMMON mode.

If you use two PGUs as *pulsed source* (`VPULSE`), you *cannot* set one PGU to `SYNC` (stress source channel) and the other PGU to `NSYNC` (non-stress source channel). That is, both PGUs must be `SYNC` or both must be `NSYNC`.

If a channel is set to STBY ON on the CHANNELS: CHANNEL DEFINITION page, the channel cannot be set to `SYNC`.

To Force Stress with more than Four Channels

The following trigger functions allow you to force stress from more than 4 channels by using external pulse generators, voltage sources, or current sources.

- gate trigger while stress is forced

  The HP 4155A/4156A can output a gate trigger while stress channels are forcing stress. For details about this gate trigger, refer to "Trigger Function".

- gate trigger of PGUs

  The output trigger terminal of PGUs (HP 41501A) can output a gate trigger to external pulse generators. So, use this function if you need more than two *ac* stress channels.

  For example, you can use HP 8110A to force ac stress by using this trigger.

  PGU outputs a gate trigger that is synchronized with pulse output. For details of the trigger signal, refer to "Triggering an External Instrument".

Stress Mode

You set stress mode to the pulse count mode or duration mode. The pulse count mode is used only when a PGU is used to force ac stress (that is, PGU is set to `MODE=VPULSE` and `FCTN=SYNC` on the STRESS:CHANNEL DEFINITION page).

Pulse count mode.
You specify the pulse count (1 to 65535). The total stress time is determined by the pulse count and pulse period.

Duration mode.
You specify the total stress time directly in seconds. Allowable range is 500 μs to 1 year (3.1536×10^7 s).

- setting resolution
  - □ When the specified time is 10 s or less:

    setting resolution is 100 μs.
  - □ When the specified time is more than 10 s:

    setting resolution is 10 ms.

Stress Force Sequence

- output sequence (idle state → stress force state)

  When the state changes from the idle state to the stress force state, the channels output the following values:

ac stress (`SYNC`) channel:	specified base value
dc stress (`SYNC`) channel:	0 V or 0 A
non-stress (`NSYNC`) channel:	specified source value or pulse output

  The output sequence of the channels depends on the order specified on the MEASURE: OUTPUT SEQUENCE page. For details, refer to "Sequential Mode".

- stress force sequence (in the stress force state)
  - □ stress output

    Stress force channels output stress at the same time when the stress start trigger is received. Stress start trigger is sent *hold time* after the last channel changes from idle state to stress force state.

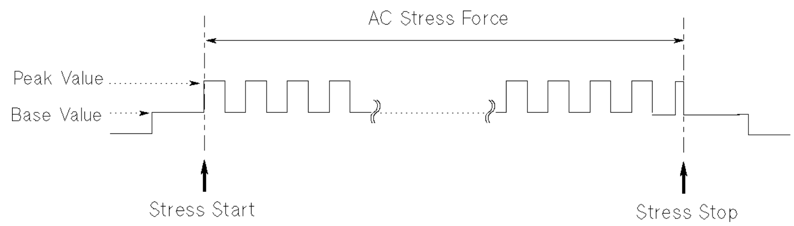
  - □ stress stop

    Stress force channels stop stress at the same time. When you set up both ac and dc stress on the STRESS: CHANNEL DEFINITION page, ac stress channels stop several microseconds before the dc stress channels.

    If you set delay time for pulse stress, finish of stress force time is after the period of the last pulse. (See Figure 3-1.)

Pulse Waveform when Stress Stops

When you set the duration mode or press the (Stop) front-panel key, be aware that stress force may stop during the pulse peak output as shown in the following figure:



- sequence for returning to 0 V (stress force state → idle state)

  When the state changes from the stress state to the idle state, the outputs of the channels are returned to 0 V in opposite order that forcing occurred.

- delay time of PGUs

  When PGUs are set to `VPULSE` (ac source), you can set a delay time as follows:

  - □ If PGU is set to `SYNC`, the PGU waits the delay time (after the *stress* start trigger is received), then starts to force ac stress.
  - □ If PGU is set to `NSYNC`, the PGU waits the delay time (after stress *force* state starts), then starts pulse output.

  For details about delay time, refer to “MEASURE: PGU SETUP page” in Chapter 4.

Example

Figure 3-1 shows an example of output sequence when forcing stress.

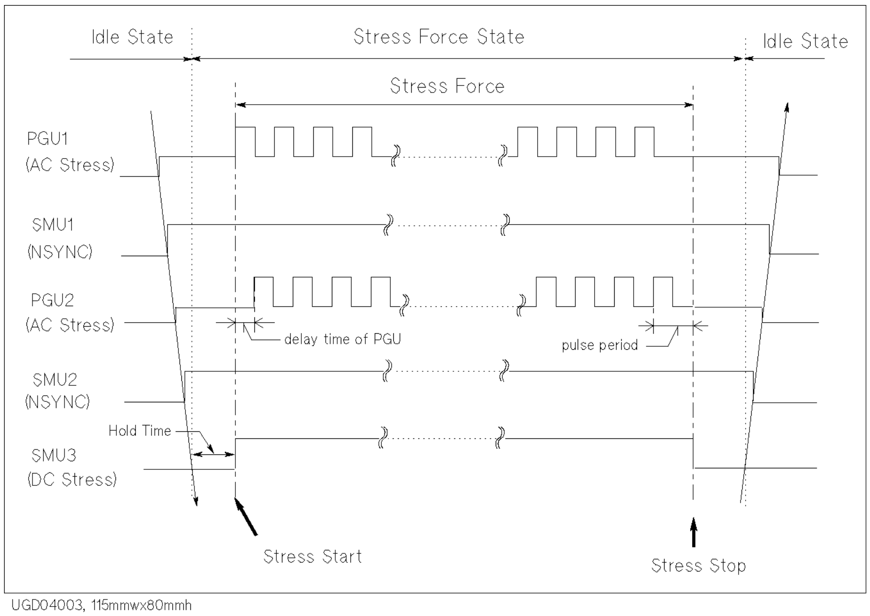


Figure 3-1. Example of the Stress Force Sequence

Figure 3-1 assumes the output sequence is set on the MEASURE: OUTPUT SEQUENCE page as follows.

1. PGU1
2. SMU1
3. PGU2
4. SMU2
5. SMU3

- output sequence (idle state → stress state)

  Specified output values are forced in the following order:

  1. PGU1
  2. SMU1
  3. PGU2
  4. SMU2
  5. SMU3

- stress force sequence (in the stress force state)

  The stress force channels (PGU1, PGU2, and SMU3) start stress and stop stress at the same time.

- sequence for returning to 0 V (stress force state → idle state)

  The order of returning to 0 V is:

  1. SMU3
  2. SMU2
  3. PGU2
  4. SMU1
  5. PGU1

Stress Stop Function at Abnormal Status

On the STRESS: STRESS SETUP page, you can select whether the stress stops or continues when an abnormal status occurs.

You can select one of the following in the `STRESS Status` field on the STRESS: STRESS SETUP page:

- Stress continues even if an abnormal status occurs.
- Stress stops if any abnormal status occurs.
- Stress stops only if SMU reaches its compliance setting.

Abnormal statuses are as follows:

- SMU reaches its compliance setting.
- Current of a VSU exceeds ±100 mA.
- SMU or a VSU oscillates.
- A/D converter overflow occurs.
- Average current of PGU exceeds ±100 mA.

When an HP 4155A/4156A is stopped by the stress stop function, a message is displayed in the message display area.

`STOP AT ANY ABNORM` and `STOP AT COMPLIANCE` secondary softkeys are displayed only when specified duration is more than 10 s. If you set pulse count mode, these secondary softkeys are displayed only when *pulse period* × *pulse count* is more than 10 s.

The stress stop function is not effective until the stress has been forced for 10 seconds. For example, if `STOP AT ANY ABNORM` or `STOP AT COMPLIANCE` is selected and abnormal status occurs after forcing stress for 5 seconds, the stop function does *not* stop stress until stress is forced for 10 seconds.

HP 16440A SMU/PG Selector Control

The HP 4155A/4156A can control the HP 16440A SMU/Pulse Generator Selector (HP 16440A selector) to automatically switch the unit that is connected to a DUT pin according to the state (stress force state or measurement state). You set up this automatic control on the STRESS: CHANNEL DEFINITION page.

For example, you can specify to connect the PGU to the DUT during stress, and connect the SMU to the DUT during measurement. So, when you press the (Stress) key in the MEASUREMENT key group, the PGU is automatically connected to the DUT. And when you press a measurement key, the SMU is automatically connected to the DUT.

You can use up to two HP 16440A selectors. For details about installation of HP 16440A selectors, refer to "Installation" in *HP 4155A/4156A User's Task Guide*.

When you use HP 16440A selector, SMUs *cannot* be connected to test devices by Kelvin connection.

- setup and restrictions

  If PGUs are not in the HP 41501A, the SMU/PG SELECTOR setup table is not displayed on the STRESS: CHANNEL DEFINITION page, so you cannot set HP 16440A selector on the display page.

- circuit diagram

  Figure 3-2 shows the simplified circuit diagram of an HP 16440A selector.

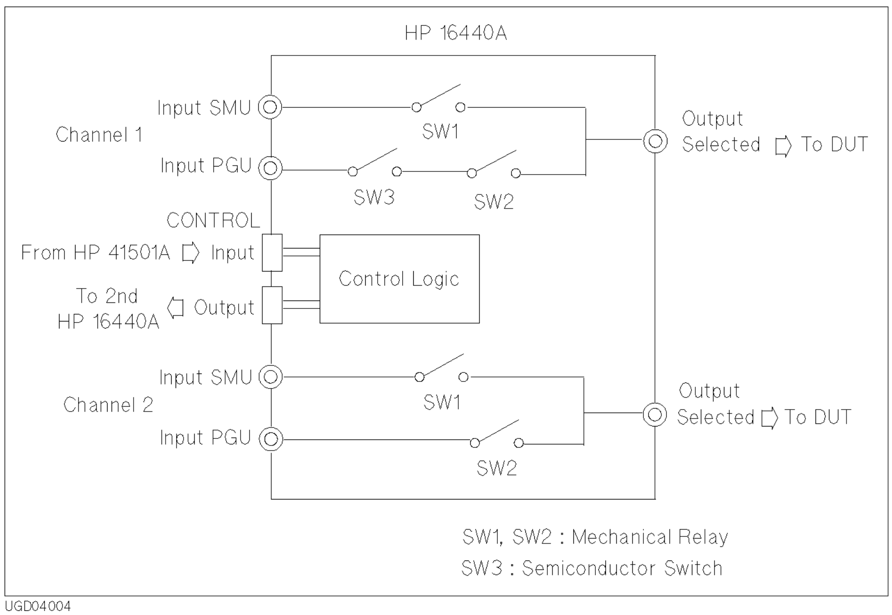


Figure 3-2. Simplified Circuit Diagram of an HP 16440A Selector

- switching conditions

  Channel 1 provides the following four switching conditions. Channel 2 also provides these switching conditions, except for `PGU OPEN`.

Switching Condition	SW1	SW2	SW3
SMU	ON	OFF	OFF
PGU	OFF	ON	ON
OPEN	OFF	OFF	OFF
PGU OPEN	OFF	ON	OFF

SMU means: SMU is connected. PGU is not connected.
PGU means: PGU is connected. SMU is not connected.
OPEN means: Both PGU and SMU are disconnected.
PGU OPEN means: Both PGU and SMU are disconnected. But PGU is disconnected by semiconductor relay. Mechanical relay stays connected.

Semiconductor Switch

In Figure 3-2, SW3 is a semiconductor switch. Leak current and stray capacitance of SW3 are greater than for the mechanical relays (SW1 and SW2). However, the switching speed of SW3 is faster and life is longer than SW1 and SW2. So, if you need to switch PGU many times, switch SW3 instead of SW2.

Knob Sweep Function

The knob sweep function allows you to easily perform real-time sweep measurements by rotating the rotary knob on the front panel after setting a few parameters.

The knob sweep function is useful in the following cases:

- when you want to determine a parameter value for normal sweep
- when you want to quickly make a rough measurement of a DUT characteristic

While the KNOB SWEEP page is displayed, the sweep measurements are repeated continuously with the specified sweep values. You can change the setting parameters by using the secondary softkeys on the KNOB SWEEP page, even while the measurements are being performed.

When knob sweep measurements are started, the VAR1 start value and VAR1 sweep range are 0 V or 0 A. You change the sweep range and watch the measurement results by rotating the knob.

For details about using the knob sweep function, refer to "Making a Measurement" in *HP 4155A/4156A User's Task Guide*.

comparison of normal sweep and knob sweep measurements. Table 3-2 compares the normal sweep measurement performed by measurement front-panel keys and knob sweep measurement by the front-panel knob.

Table 3-2.
Comparison of Sweep Measurement and Knob Sweep Measurement

Item	Sweep Measurement	Knob Sweep Measurement
Spacing of VAR1	Linear or Log	Linear
Sweep Mode of VAR1	Single or Double	Single or Double
Number of Steps for VAR1	1 to 1001	1 to 1001
Hold Time	0 to 655.35 s	0 to 655.35 s
Power Compliance	available	not available
Measurement Ranging Mode	Auto, Limited Auto, or Fixed	Compliance range[1]
Standby Function	available	available
Measurement Channel	1 to 8 ch	1 ch only
Output Sequence	can set	can set[2]
Trigger Function	available	not available
Integration Time	short, medium, or long	80 μs

1 Measurement range is automatically set according to specified compliance value.

2 Settings on the MEASURE: OUTPUT SEQUENCE page also apply to knob sweep measurement.

available units and functions.

Table 3-3 shows available units and functions for knob sweep measurement.

Table 3-3.
Available Units and Functions for Knob Sweep Measurement

Unit	Output Function					Output Mode			Pulse	Meas. Mode		
	VAR1	VAR1'	VAR2	CONST	STANDBY	V	I	COMMON		V	DVOLT	I
SMU	•	n.a.	•	•	•	•	•	•	n.a.	•	—	•
VSU	•	n.a.	•	•	•	•	—	—	—	—	—	—
VMU	—	—	—	—	—	—	—	—	—	•	•	—
GNDU	—	—	—	•	—	—	—	•	—	—	—	—
PGU	—	—	—	•	•	•	—	—	•	—	—	—

•	means "This is available for knob sweep measurement".
n.a.	means "This is not available for knob sweep measurement".
—	means "This is not available for this unit".

Features of Knob Sweep Function

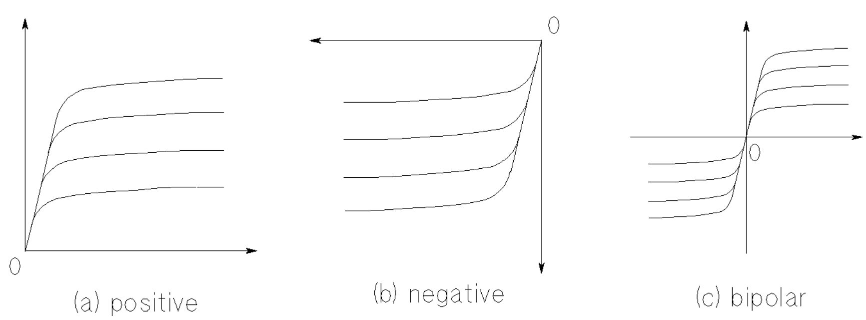
The following are parameters that are for knob sweep measurement only or that have a different a meaning or range from normal sweep measurement. Other parameters have the same meaning and range as normal sweep measurement. For details of these other parameters, refer to "KNOB SWEEP page" or Chapter 2.

LIN/LOG mode.
Only linear mode is available. Even if you set LOG in the LIN/LOG field on the MEASURE: SWEEP SETUP page, the knob sweep is a linear sweep measurement.

VAR1 Range.
To set the VAR1 range, refer to `VAR1 RANGE` softkey description in this section. If you do not set the VAR1 range, the default is the stop value specified for the VAR1 channel on the MEASURE: SWEEP SETUP page.

Polarity.
The following sweep polarities are available for the knob sweep function of the VAR1 source:

- positive
- negative
- bipolar



Polarity of Knob Sweep Measurement

To set sweep polarity, see `POLARITY` softkey description in this section.

positive Select *positive* to set VAR1 source for sweep in the positive X direction.

- To increase the source value toward the positive X direction:

  Rotate the rotary knob clockwise.

- To decrease the source value toward 0:

  Rotate the rotary knob counterclockwise. When measurement curves reach 0, the curves remain at 0 even if you continue to rotate the rotary knob counterclockwise.

negative Select *negative* to set VAR1 source for sweep in the negative X direction.

- To increase (greater absolute value) the source value toward the negative X direction:

  Rotate the rotary knob counterclockwise.

- To decrease the source value toward 0:

  Rotate the rotary knob clockwise. When measurement curves reach 0, the curves remain at 0 even if you continue to rotate the rotary knob clockwise.

bipolar Select *bipolar* to set the VAR1 source for sweep in both the positive and negative X directions.

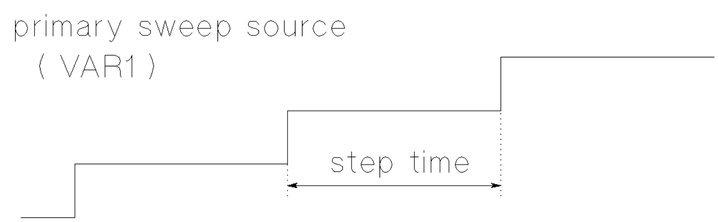
- To increase (greater absolute values) the source values in both directions:

  Rotate the rotary knob clockwise. This increases the measurement curves to the same absolute value in both directions.

- To decrease the source value toward 0:

  Rotate the rotary knob counterclockwise. This decreases the measurement curves toward 0 from both directions. When measurement curves reach 0, the curves remain at 0 even if you continue to rotate the rotary knob counterclockwise.

Step Time.
For knob sweep measurements, you cannot set the delay time. Instead, you set the step time, which you can only set on the KNOB SWEEP page. Step time is the time width of a sweep step as shown in the following figure.



Setup range is 0.5 ms to 100 ms, with 100 μs resolution.

For normal sweep measurement, the step time of each step depends on the measurement time. For knob sweep measurement, step time is *always* this specified value.

Measurement Channel.
You select the measurement channel by selecting the `Y-AXIS ASSIGN` softkey on the KNOB SWEEP page, then selecting the desired secondary softkey. You can select one measurement channel only, so the Y2 axis is not available on the KNOB SWEEP page.

- restrictions

  If you use series resistance for VAR1 channel and VAR1 channel is V force mode, only VAR1 measurement channel can be assigned to Y axis.

- default measurement channel

  When an SMU is set to VAR1

    Measurement channel is the VAR1 channel.

  When a VSU is set to VAR1

    Measurement channel is the first found channel that can measure. Searching order is:

    SMU1 $\rightarrow \cdots \rightarrow$ SMU6 $\rightarrow$ VMU1 $\rightarrow$ VMU2.

Measurement Resolution

When performing knob sweep measurement, measurement resolution of each measurement unit is worse than the measurement resolution of normal sweep measurements. For details of measurement resolution, refer to Chapter 1.

Step Value.
For the VAR1 channel, you do not set the step value. You can consider the step value to be the amount you rotate the knob. Then, the sweep is performed and displayed for the specified *number of steps*. Step value of VAR1 is 0 at the time when you initiate the knob sweep function. Step value range is 0 to *VAR1 range/number of steps*. For knob sweep measurements, the value in the STEP field on the MEASURE: SWEEP SETUP page has no meaning.

Number of Steps.
For the VAR1 channel, you set the number of steps on the KNOB SWEEP page. So, for the knob sweep function, the number of steps for VAR1 has no relation to the NO OF STEP setting on the MEASURE: SWEEP SETUP page.

Start Value.
The start value is always 0, and does not depend on the polarity. You cannot set the start value. So, the START setting on the MEASURE: SWEEP SETUP page has no meaning for the knob sweep function.

Stop Value.
Stop value is always *step value* × *number of steps*. You cannot set the stop value. The measurement is continuously repeated from 0 to the stop value until the (Stop) front-panel key is pressed or the KNOB SWEEP page is changed to another page.

Measurement Ranging Mode.
Measurement ranging mode depends on the unit as follows:

- SMUs

  Compliance range is used for SMUs. That is, the measurement range is set to the lowest range that includes the compliance value that is set on the MEASURE: SWEEP SETUP page. For details about compliance range, refer to "Compliance Range".

- VMUs

  VMUs measure in 20 V range for grounded measurement mode and the 2 V range for differential measurement mode.

Analysis of the Knob Sweep Measurement Results

- On the KNOB SWEEP page

  You cannot use analysis functions and user functions on the KNOB SWEEP page.

- On the GRAPH/LIST page group

  After performing knob sweep measurements, you can copy and display the knob sweep measurement results to the GRAPH/LIST: GRAPH page or GRAPH/LIST: LIST page by doing the following:

  1. Press the SETUP COPY primary softkey on the KNOB SWEEP page.
  2. Press the (Graph/List) front-panel key.

  The knob sweep results are displayed on the GRAPH/LIST page. You can use the analysis functions on the measurement results of knob sweep.

  Also, you can use user functions in GRAPH/LIST page group. Before performing knob sweep measurement, you must set up user functions as follows:

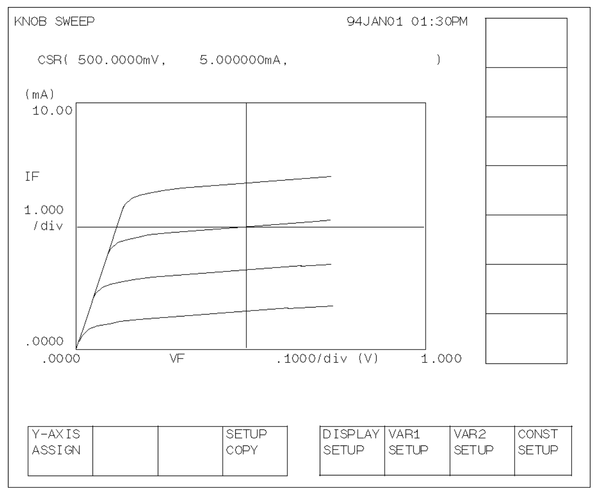
  1. Define user functions on CHANNELS: USER FUNCTION DEFINITION page.
  2. Enter user functions in DATA VARIABLES field of DISPLAY: DISPLAY SETUP page.
  3. On GRAPH/LIST: GRAPHICS page, select DISPLAY SETUP primary softkey, then set DATA VAR softkey to ON.

  When you press (Graph/List) front-panel key after knob sweep measurement, the user functions will be displayed.

  (Graph/List) front-panel key

  If you press the (Graph/List) front-panel key, the START and STOP values of VAR1 column on the MEASURE: SWEEP SETUP page are changed to the start and stop values that are determined by the KNOB SWEEP page.

KNOB SWEEP page



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To display the KNOB SWEEP page, press the green key, then press the (Single) front-panel key. On this page, you can set knob sweep parameters by using the secondary softkeys, and the knob sweep measurement results are shown on this page.

If you change from the KNOB SWEEP page to another page, then back to the KNOB SWEEP page, all knob sweep parameters are set to the default settings.

You can select softkeys on the KNOB SWEEP page even while the HP 4155A/4156A is performing knob sweep measurements.

cursor. On the KNOB SWEEP page, the long cursor is always displayed, and you cannot turn it off. In the `CURSOR` field, coordinate values of the cursor are displayed in X, Y order.

X axis setting. The variable to be displayed on X axis is automatically set to VAR1 source value, and you cannot change it. Maximum value of X axis scale is the value you set on the VAR1 RANGE secondary softkey of the VAR1 SETUP group.

Y axis setting. The measurement variable of the measurement channel is displayed on the Y axis. You can select the measurement channel by using the secondary softkeys of the Y-AXIS ASSIGN group. Maximum value of Y axis scale is the compliance value of the selected measurement channel.

The following explain softkeys on the KNOB SWEEP page.

Y-AXIS ASSIGN

Press Y-AXIS ASSIGN primary softkey to display the measurement data variable names of measurement channels. Variable names are displayed on secondary softkeys, which you select to set the variable to the Y axis. When you select the secondary softkey, the maximum absolute value(s) of the Y axis are changed to compliance value of the selected measurement channel. You cannot assign a user function to Y axis on the KNOB SWEEP page.

If you select this softkey during a measurement, an error occurs. So, press Stop front-panel key before selecting this softkey.

If you use series resistance for VAR1 channel and VAR1 channel is V force mode, Y-AXIS ASSIGN primary softkey is not displayed. VAR1 channel is automatically set to the Y axis.

SETUP COPY

Press SETUP COPY primary softkey to copy setups on the knob sweep page as follows:

- Axis variables, axis values, and GRID settings of KNOB SWEEP page are copied to the DISPLAY: DISPLAY SETUP page.
- For VAR1
  - □ Values are copied to START, STOP, STEP, and NO OF STEP fields of MEASURE: SWEEP SETUP page. Values are determined by VAR1 POLARITY setting and curve that is displayed on KNOB SWEEP page.
  - □ SWEEP MODE, HOLD TIME, and COMPLIANCE that you set for VAR1 on KNOB SWEEP page are copied to MEASURE: SWEEP SETUP page.
- For VAR2, all the settings that you set for VAR2 on the KNOB SWEEP page are copied to the MEASURE: SWEEP SETUP page.

- For CONST, all the settings that you set for CONST on the KNOB SWEEP page are copied to the MEASURE: SWEEP SETUP page.

`DISPLAY SETUP`

Press `DISPLAY SETUP` primary softkey to display secondary softkeys for setting the display format of graphics.

Setups on the DISPLAY: DISPLAY SETUP page are *not* used for the knob sweep measurement. But you can copy the settings of the `DISPLAY SETUP` key group to the DISPLAY: DISPLAY SETUP page by pressing `SETUP COPY` primary softkey.

`X-AXIS REGION +`

Polarity of X-axis region is displayed on this secondary softkey. This determines which part of the graph is displayed: negative X region, positive X region, or both.

- setting

  Pressing this softkey toggles polarity as follows:

  $+ \longrightarrow - \longrightarrow +/- \longrightarrow +$

- default

  If polarity of VAR1 stop and start value on MEASURE: SWEEP SETUP page are same, default value is same as polarity of stop and start value.

  If polarity of VAR1 stop and start value on MEASURE: SWEEP SETUP page are different, default value is `+/-`.

`Y-AXIS REGION +`

Polarity of Y-axis region is displayed on this secondary softkey. This determines which part of the graph is displayed: negative Y region, positive Y region, or both.

- setting

  Pressing this softkey toggles the polarity in the following order:

  $+ \longrightarrow - \longrightarrow +/- \longrightarrow +$

- default

  polarity of VAR1 compliance value on the MEASURE: SWEEP SETUP page

X-AXIS DISPLAY NORMAL

Direction of values on X-axis is displayed on this softkey.

- setting

  Selecting this softkey toggles NORMAL or REVERSE.

  - When NORMAL is selected:

    Minimum axis value is at *left* end of X-axis.
    Maximum axis value is at *right* end of X-axis.

  - When REVERSE is selected:

    Minimum axis value is at *right* end of X-axis.
    Maximum axis value is at *left* end of X-axis.

- default

  NORMAL

Y-AXIS DISPLAY NORMAL

Direction of values on Y-axis is displayed on this softkey.

- setting

  Selecting this softkey toggles NORMAL or REVERSE.

  - When NORMAL is selected:

    Minimum axis value is at *bottom* of Y-axis.
    Maximum axis value is at *top* of Y-axis.

  - When REVERSE is selected:

    Minimum axis value is at *top* of Y-axis.
    Maximum axis value is at *bottom* of Y-axis.

- default

  NORMAL

GRID ON

Present status of grid is displayed on GRID softkey.

- setting

  Pressing GRID secondary softkey toggles the grid on or off in the plotting area.

- default

  ON

VAR1 SETUP

Press VAR1 SETUP primary softkey to display secondary softkeys for setting the VAR1 parameters.

SWEEP MODE SINGLE

Sweep direction is displayed on this secondary softkey.

- setting

  Pressing this softkey toggles the sweep direction in the following order:

  SINGLE ⟶ DOUBLE ⟶ SINGLE

- default

  setting of the SWEEP MODE field on the MEASURE: SWEEP SETUP page

POLAR- ITY POS

Polarity of sweep is displayed on this secondary softkey.

- setting

  Pressing this softkey toggles the polarity of VAR1 channel in the following order:

  POS ⟶ NEG ⟶ BIPOLAR ⟶ POS

  Pressing this softkey resets the sweep step to 0, so the sweep measurement curve goes back to 0 on the graphics display.

- default

  If polarity of VAR1 stop and start value on MEASURE: SWEEP SETUP page are same, default value is same as polarity of stop and start value.

  If polarity of VAR1 stop and start value on MEASURE: SWEEP SETUP page are different, default value is BIPOLAR.

VAR1
RANGE
2V

Sweep range of VAR1 channel is displayed on this secondary softkey. This softkey setting defines the maximum sweep range and resolution of VAR1 channel.

- setting

  Select this softkey to display the VAR1 sweep range value in the data entry area, then you can change this range to allowed 1-2-5 values by using the rotary knob.

  When you rotate the rotary knob, the sweep ranges are displayed in order as shown in the following example (allowed values depend on the unit):

  0.1 V $\longrightarrow$ 0.2 V $\longrightarrow$ 0.5 V $\longrightarrow \cdots \longrightarrow$ 100 V $\longrightarrow$ 200 V $\longrightarrow$ 0.1 V.

- setting range

  The allowed sweep range (1-2-5) values depend on the output range of the measurement unit. See Chapter 1.

- default

  lowest 1-2-5 range that includes *VAR1 start and stop value* that is set on the MEASURE: SWEEP SETUP page

  For example, if stop value is set to 30 V on the MEASURE: SWEEP SETUP page, default VAR1 range is 50 V.

NUM OF STEPS 101

Number of steps for VAR1 channel is displayed on this secondary softkey. For knob sweep, NO OF STEP setting on MEASURE: SWEEP SETUP page has no meaning.

- setting

  Press this softkey to display the number of steps in the data entry area, then you can change the number of steps by using the rotary knob, or numeric keys and arrow keys in the Edit key group.

- setting range

  2 to 1001

- default

  101

COMPLI- ANCE 100.mA

Compliance value for VAR1 channel is displayed on this secondary softkey.

- setting

  Press this softkey to display the compliance value in the data entry area. Then, you can change the compliance value by using the rotary knob, or numeric keys and arrow keys in the Edit key group.

- setting range

  Compliance range depends on measurement unit. See Chapter 1.

- default

  VAR1 compliance value on the MEASURE: SWEEP SETUP page

HOLD TIME 0.00s

Hold time is displayed on this secondary softkey.

- setting

  Press this softkey to display the hold time in the data entry area. Then, you can change the hold time by using the rotary knob, or numeric keys and arrow keys in the Edit key group.

- setting range

  0 to 655.35 s with 10 ms resolution

- default

  hold time on the MEASURE: SWEEP SETUP page

STEP TIME 0.5ms

Step time is displayed on this secondary softkey. This is the time width of each step.

- setting

  Press this softkey to display the step time in the data entry area, then you can change the step time value by using the rotary knob, or numeric keys and arrow keys in the Edit key group.

- setting range

  0.5 ms to 100 ms with 100 μs resolution

- default

  0.5 ms

VAR2 SETUP

Press **VAR2 SETUP** primary softkey to display secondary softkeys for setting the VAR2 parameters.

If VAR2 is not set for any channel on the CHANNELS: CHANNEL DEFINITION page, the **VAR2 SETUP** primary softkey is not displayed.

VAR2 START 20.0μA

VAR2 start value is displayed on this secondary softkey.

- setting

  Press this softkey to display the VAR2 start value in the data entry area. Then, you can change the start value by using the rotary knob, or numeric keys and arrow keys in the Edit key group.

- setting range

  Depends on the measurement unit. See Chapter 1.

- default

  VAR2 start value on MEASURE: SWEEP SETUP page

VAR2 STEP 20.0μA

VAR2 step value is displayed on this secondary softkey.

- setting

  Press this softkey to display the VAR2 step value in the data entry area. Then, you can change the start value by using the rotary knob, or numeric keys and arrow keys in the Edit key group.

- setting range

  Depends on the measurement unit. See Chapter 1.

- default

  VAR2 step value on MEASURE: SWEEP SETUP page

`VAR2 POINTS 5`

Number of steps is displayed on this secondary softkey.

- setting

  Press this softkey to display the VAR2 number of steps in the data entry area. Then, you can change the number of steps by using the rotary knob, or numeric keys and arrow keys in the Edit key group.

- setting range

  1 to 128

- default

  VAR2 number of steps on MEASURE: SWEEP SETUP page

`COMPLI- ANCE 2V`

Compliance value is displayed on this secondary softkey.

- setting

  Press this softkey to display the VAR2 compliance value in the data entry area. Then, you can change the number of steps by using the rotary knob, or numeric keys and arrow keys in the Edit key group.

- setting range

  Setting range depends on the measurement unit. See Chapter 1.

- default

  VAR2 compliance value on MEASURE: SWEEP SETUP page

CONST SETUP

Select CONST SETUP primary softkey to display the secondary softkeys for setting the constant source parameters. Secondary softkeys for PGUs set to V mode (not VPULSE) are also displayed.

If CONST is not set for any channel on the CHANNELS: CHANNEL DEFINITION page, the CONST SETUP primary softkey is not displayed.

If more than six constant channels are defined, press the MORE softkey to display softkeys for the other constant channels.

Secondary softkeys for setting constant source parameters.
The first line of each secondary softkey displays the variable name of the constant source. The second line displays *force value*. For SMUs, the third line displays *compliance value*. For other units, the third line is blank.

- Example. If an SMU is set as follows, the following softkey appears:
  - Voltage source and current measurement mode.
  - Voltage source name (VNAME): "Vce".
  - Force value: 5.0 V.
  - Compliance value: 10 mA.

  ```
  Vce
    5.00V
   10.0mA
  ```

- setting
  - source value

    Pressing the source name secondary softkey displays the force value in the data entry area. You can change the source value by using the rotary knob, or numeric keys and arrow keys in the Edit key group.

  - compliance value (for SMUs only)

    Pressing the source name secondary softkey twice displays the compliance value in the data entry area. You can change the compliance value by using the rotary knob, or numeric keys and arrow keys in the Edit key group.

- setting range

  Each setting range depends on the measurement unit. See Chapter 1.

Operation States

HP 4155A/4156A has the following four operation states.

- idle state
- standby state
- measurement state
- stress state

Types of Operation State

Idle State.
In the idle state, the HP 4155A/4156A is not doing anything: no measurements, forcing current or voltage, forcing stress.

An HP 4155A/4156A is in the idle state after applying power. In this state, output switches of all the measurement units are on, and all of the units output 0 V. In this state, you can modify any setting items on the setting pages.

Conditions in the Idle State

The following are the conditions of each unit and accessories in idle state.

SMU	0 V output at 20 V range, and 100 μA compliance at 100 μA range
VSU	0 V output at 20 V range
PGU	0 V dc output at 20 V range (output impedance: `LOW`)
GNDU	0 V output
HP 16441A R-Box	0 Ω is connected.
HP 16440A selector	switching condition is `SMU`.

Standby State.
If the HP 4155A/4156A is in the standby state, the following occurs depending on the settings in the CHANNELS table of the CHANNELS: CHANNEL DEFINITION page:

- If STBY field of a unit is set `ON`, the units output the specified voltage or current. For the output voltage or current in the standby state, see Table 3-4. (VMUs and GNDU cannot be set to `ON` in the STBY field.)

  If both PGUs are set to VPULSE, the STBY settings of both PGUs must be same.

- If unit is enabled, but STBY field is blank, then the unit has following condition.
  - □ voltage range and value
    - V force channel

      outputs 0 V at same range as previous state.
    - V measure channel

      keeps same range as previous state.
  - □ current range and value
    - I force channel

      outputs the latest value of previous state. For example, if previous state was measurement state and latest value of VAR1 was stop value, the stop value is output for VAR1 during standby.
    - I measure channel

      keeps the latest range of previous state.
- Following settings keep the same conditions as the previous state:
  - □ output switch of each unit
  - □ output impedance of PGUs
  - □ switching condition of HP 16440A selector
  - □ resistance selection of HP 16441A R-Box

Unit Conditions in the Standby State

Table 3-4 shows the standby state conditions of the units that are set to ON in the STBY fields. The specified values are the values that are set on the MEASURE setup pages.

Table 3-4. Unit Conditions in the Standby State

FUNCTION	SMU	VSU	PGU
VAR1 VAR1' VAR2	Outputs specified start value. For pulsed mode, specified base value is output.		These functions are not available for PGU.
CONST	Outputs specified source value. For pulsed mode, specified base value is output.	Outputs specified source value.	For V mode, specified source value is output. For VPULSE mode, specified pulsed source is output.

To Keep Standby State after Getting Setups

To keep standby state after getting setups from a file or an internal memory, *all* of the following must be true. If not, state changes to idle after getting setups.

- STBY ON channel assignments do not change
- MODE and FCTN setups of STBY ON channels do not change
- Following setups of STBY ON channels do not change:

MODE	FCTN			
	CONST	**VAR1**	**VAR2**	**VAR1'**
V	SOURCE COMPLIANCE[2]	START STOP COMPLIANCE[2]	START STOP COMPLIANCE[2]	VAR1 START[1] VAR1 STOP[1] COMPLIANCE[2] OFFSET RATIO
I	SOURCE COMPLIANCE[2]	START COMPLIANCE[2]	START COMPLIANCE[2]	VAR1 START[1] COMPLIANCE[2] OFFSET RATIO
VPULSE	BASE PEAK COMPLIANCE[2] PGU setups[3]	BASE START STOP COMPLIANCE[2]	BASE START STOP COMPLIANCE[2]	BASE VAR1 START[1] VAR1 STOP[1] COMPLIANCE[2] OFFSET RATIO
IPULSE	BASE COMPLIANCE	BASE COMPLIANCE	BASE COMPLIANCE	BASE COMPLIANCE

1 This parameter is checked, even if VAR1 channel is not standby channel.

2 This parameter is checked for SMUs only

3 PGU setups on the MEASURE: PGU SETUP page.

For the following example, the STBY field is set to `ON` for SMU1, SMU2, PGU1, and PGU2. The STBY field is blank for SMU3 and SMU4.

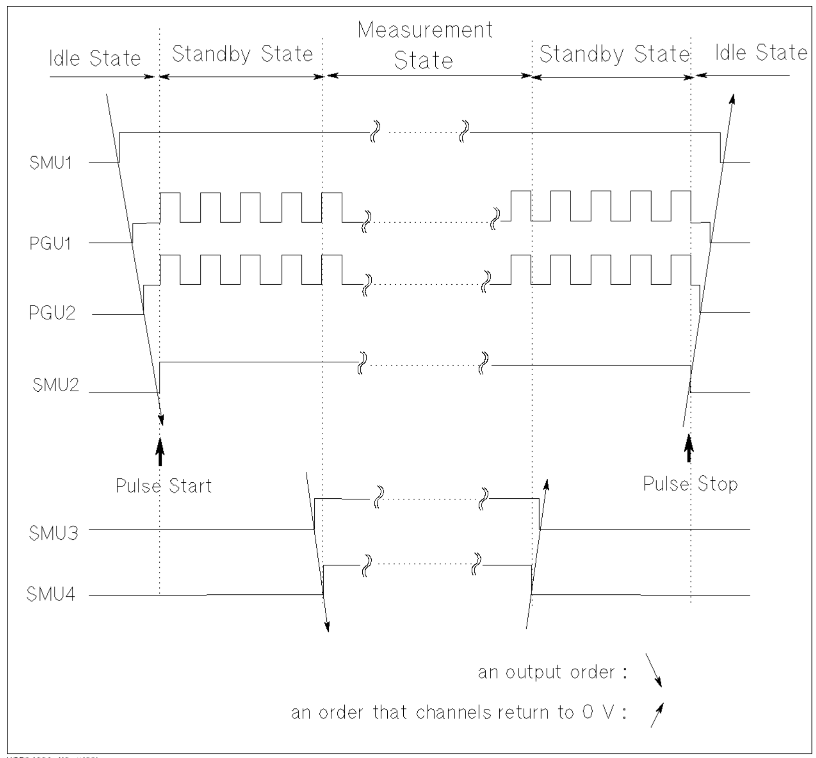


Figure 3-3. Example of the Output Sequence of the Standby Channels

The (Standby) front-panel key is used to toggle the HP 4155A/4156A between the standby and idle states. In the standby state, the Standby indicator is lit. In the idle state, the Standby indicator is off. If no units are set to `ON` in the STBY field, the HP 4155A/4156A cannot be in the standby state.

When the HP 4155A/4156A is in the standby state, you can modify setting parameters *only* for units that are *not* set to `ON` in the STBY fields. If you modify setting parameters of units that are set to `ON` in the STBY fields, the HP 4155A/4156A changes from the standby state to the idle state.

Measurement State.
In the measurement state, an HP 4155A/4156A performs sampling or sweep measurements. The output switches are off for units that do *not* have entries in the CHANNELS table of the CHANNELS: CHANNEL DEFINITION page.

Stress Force State.
In the stress force state, the HP 4155A/4156A outputs ac stress or dc stress according to the settings of the STRESS: STRESS SETUP page. The output switches are off for units that do *not* have entries in the CHANNELS table of the STRESS: CHANNEL DEFINITION page.

For channels that are set to `ON` in the STBY field, the standby values are forced during the stress state. For details of each value, see "Standby State" in this section. So, the STRESS: STRESS SETUP page settings have no meaning for STBY ON channels. And STBY ON channels cannot be set to `SYNC` on the STRESS: CHANNEL DEFINTION page. Must be set to `NSYNC`.

Changing among Operation States

Figure 3-4 shows how to change among the operation states.

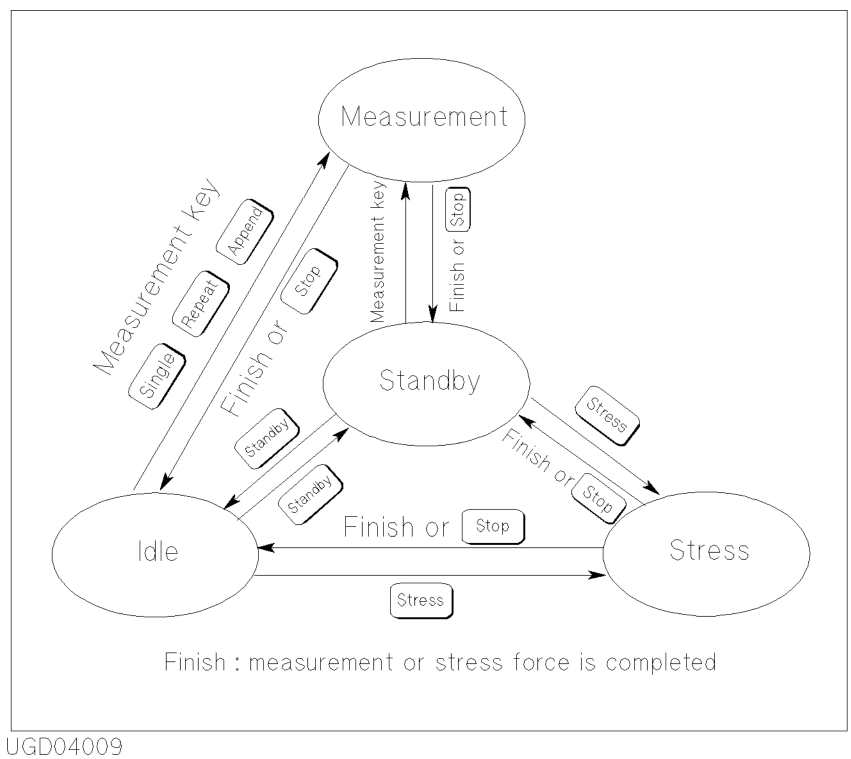


Figure 3-4. Changing among the Operation States

- changing between the idle and measurement/stress states

  If you perform measurements or force stress from the idle state, then the HP 4155A/4156A returns to the idle state after one of the following conditions occurs:

  - □ Measurement is finished.
  - □ Stress is finished.
  - □ Stop front-panel key in the MEASUREMENT key group is pressed.

- changing between the standby and measurement/stress states

  If you perform measurements or force stress from the standby state, then the HP 4155A/4156A returns to the standby state after one of the following conditions occurs:

  - Measurement is finished.
  - Stress if finished.
  - (Stop) front-panel key in the MEASUREMENT key group is pressed.

If the fixture lid is opened while an SMU is outputting more than ±40 V, the HP 4155A/4156A changes to the idle state. If the fixture lid is opened while an SMU is outputting ±40 V or less, the HP 4155A/4156A continues in its present state.

Output Sequence

When you perform measurements or force stress, or when you use the standby function, you can specify an output sequence for the source channels.

HP 4155A/4156A has two output sequence modes:

- sequential mode

  The source channels output in the order that you specify in the OUTPUT SEQUENCE table on the MEASURE: OUTPUT SEQUENCE page. The source outputs are stopped in the opposite order.

  You can set the output sequence to prevent damage to DUTs.

- simultaneous mode (for sampling measurements only)

  All the source channels output simultaneously. The source outputs are stopped in the opposite order that you specify in the OUTPUT SEQUENCE table on the MEASURE: OUTPUT SEQUENCE page.

For details of the OUTPUT SEQUENCE table, refer to "MEASURE: OUTPUT SEQUENCE page" in Chapter 4.

Sequential Mode

In the sequential mode, the channels start forcing the specified output value according to the order you specify in the OUTPUT SEQUENCE table on the MEASURE: OUTPUT SEQUENCE page. If you do not specify an order, the default is as follows:

- default output sequence

  1. SMU1
  2. SMU2
  3. SMU3
  4. SMU4
  5. VSU1
  6. VSU2
  7. PGU1
  8. PGU2

  In the idle state, output switches of *all* units are on, and the units output 0 V. For disabled units, the output switches are turned off before the source units output the specified source value. "Disabled" means that the entries for the unit are blank in the CHANNELS table of the CHANNEL DEFINITION page. There is no rule for the sequence of turning the output switches off.

  For example, if SMU4 and VSU2 are disabled, default output sequence is:

  1. Output switches of SMU4 and VSU2 are turned off
  2. SMU1
  3. SMU2
  4. SMU3
  5. VSU1
  6. PGU1
  7. PGU2

- sequence for returning to 0 V

  When returning to the idle state, the outputs of the enabled units are returned to 0 V in opposite order that forcing occurred. Then the output switches of the disabled units set are turned on.

Example

Figure 3-5 shows an example of using the default output sequence.

In Figure 3-5, assumptions are:

- Configuration of the units is 4 SMUs and 2 VSUs.
- SMU4 and VSU2 are disabled.
- Default output sequence is used.

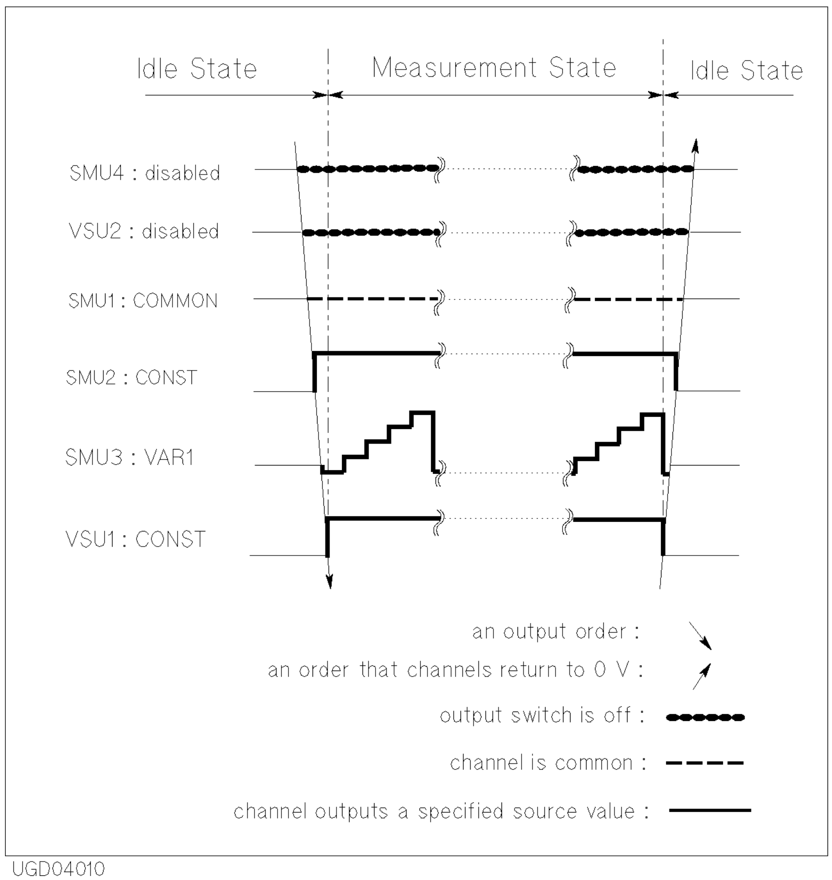


Figure 3-5. Default Output Sequence Example for the Sequential Mode

- output sequence (idle state → other state)

  "Other state" means the measurement, stress force, or standby state. In Figure 3-5, the HP 4155A/4156A first turns off output switches of SMU4 and VSU2, then outputs in the following order:

  1. SMU1
  2. SMU2
  3. SMU3
  4. VSU1

- sequence for returning to 0 V (other state → idle state)

  The order for returning to 0 V is:

  1. VSU1
  2. SMU3
  3. SMU2
  4. SMU1

  Then, the output switches of SMU4 and VSU2 are turned on, and the units output 0 V.

For a stress sequence example, see Figure 3-1. For a standby sequence example, see Figure 3-3.

Simultaneous Mode

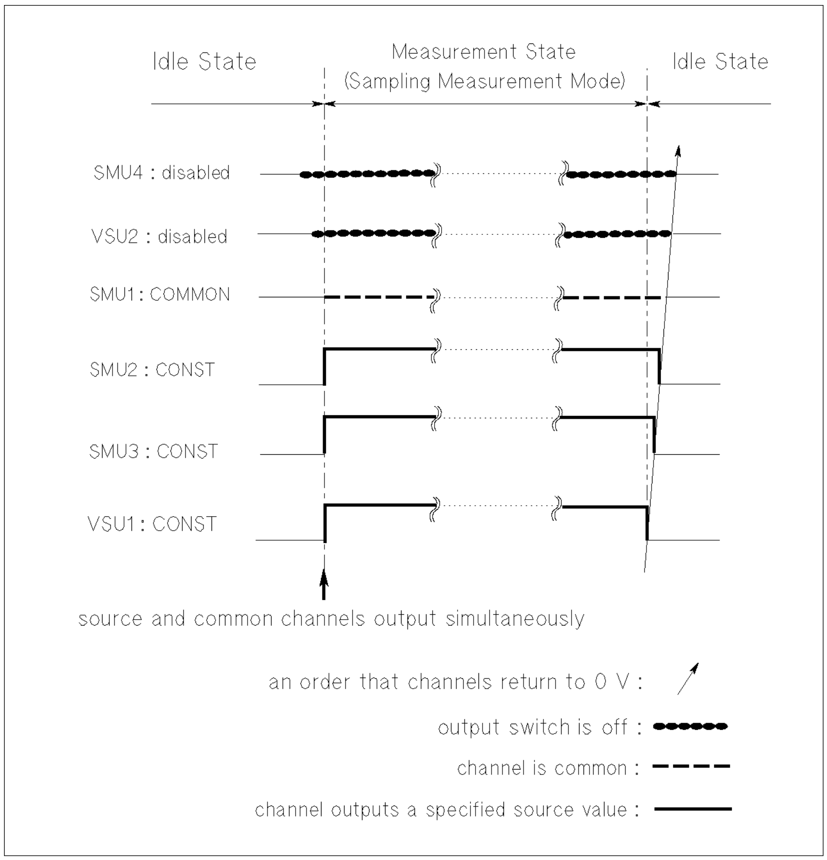
The simultaneous mode is allowed *only* when you select the sampling measurement mode in the MEASUREMENT MODE field on the CHANNELS: CHANNEL DEFINITION page.

In the simultaneous mode, all enabled units start the specified outputs at the same time. For disabled units, refer to description in “Sequential Mode”.

The order of returning the outputs to 0 V is *not* simultaneous, but is the opposite order of the OUTPUT SEQUENCE table on the MEASURE: OUTPUT SEQUENCE page. Refer to description in “Sequential Mode”.

Example

Figure 3-6 shows an example of the output sequence when you select the simultaneous mode.



UGD04011

Figure 3-6. Default Output Sequence Example for the Simultaneous Mode

In Figure 3-6, assumptions are:

- Configuration of the units is 4 SMUs and 2 VSUs.
- SMU4 and VSU2 are disabled.
- Default settings are used for OUTPUT SEQUENCE table, which determines the return to 0 V sequence.

- output sequence (idle state → measurement state)

  In Figure 3-6, when the state changes from the idle state to the measurement state, the output switches of SMU4 and VSU2 are turned off. Then, all of the source channels (SMU1, SMU2, SMU3, and VSU1) force the specified source value simultaneously.

- sequence for returning to 0 V (measurement state → idle state)

  The order for returning to 0 V is:

  1. VSU1
  2. SMU3
  3. SMU2
  4. SMU1

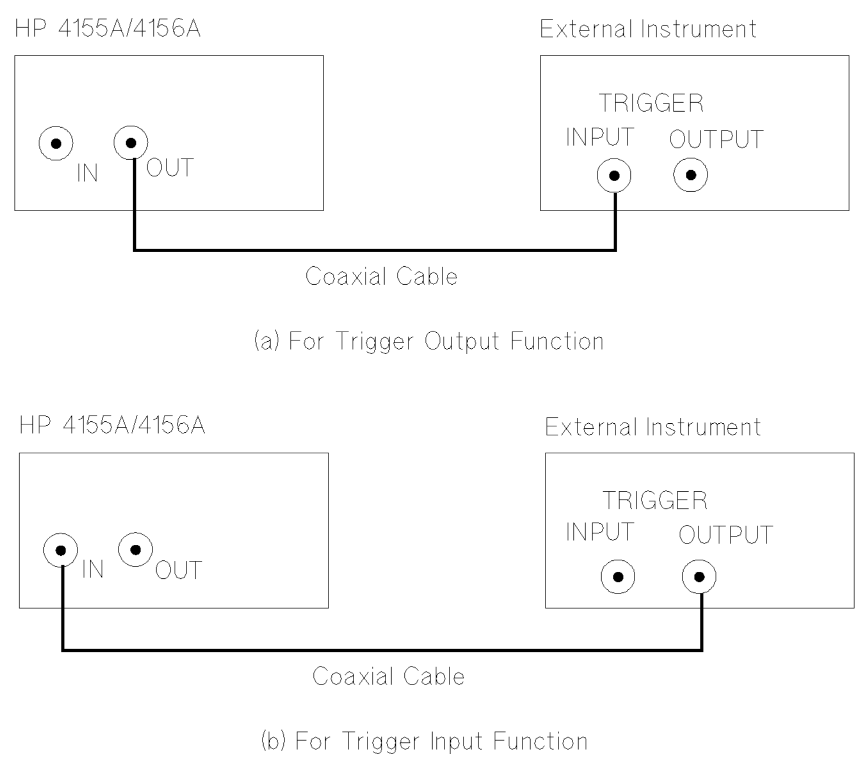
  Then the output switches of SMU4 and VSU2 are turned on, and the units output 0 V.

Trigger Function

HP 4155A/4156A can perform measurements synchronized with external instruments, such as external power supplies, capacitance meters, precision voltmeters/ammeters, probers, and handlers, via the trigger input and trigger output terminals.

- connection

  The following figure shows the connection between an HP 4155A/4156A and an external instrument.



Connection between HP 4155A/4156A and External Instrument

- setup and restrictions

  You *cannot* perform trigger outputs together with trigger inputs. You *must* select either trigger output or trigger input.

  To use a trigger function, you must enable the trigger function and select either TRIG OUT or TRIG IN in the TRIGGER SETUP table on the MEASURE: OUTPUT SEQUENCE page. Then the trigger inputs or outputs are performed automatically after you start a measurement by selecting a measurement front-panel key (Single, Repeat, or Append). For details of the MEASURE: OUTPUT SEQUENCE page, refer to "MEASURE: OUTPUT SEQUENCE page" in Chapter 4.

  The *trigger output* function is *not* available for sampling measurements.

  When you perform knob sweep measurements, the trigger function is not available.

  For the electrical specifications of trigger signals, refer to Chapter 9.

Externally Triggered Sampling or Sweep Measurement

HP 4155A/4156A can receive an edge trigger from external instruments via the trigger input terminal, and initiate a sweep or sampling measurement. Following figure shows examples of externally-triggered sampling and sweep measurements. For the trigger polarity, you can select positive or negative.

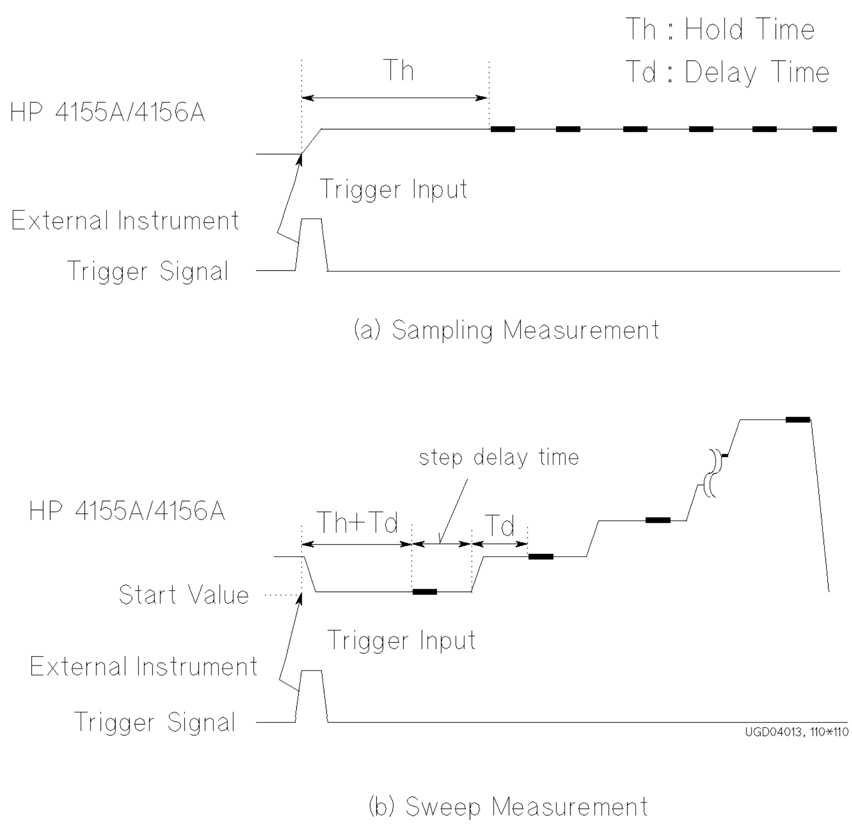


Figure 3-7. Examples of Externally Triggered Measurements

After you press a measurement front-panel key, HP 4155A/4156A receives the trigger signal *only once*. So, even if you select (Repeat) key, HP 4155A/4156A receives the trigger signal only once, then repeats measurements.

For *staircase* sweep measurements, you can specify the step delay time shown in Figure 3-7.

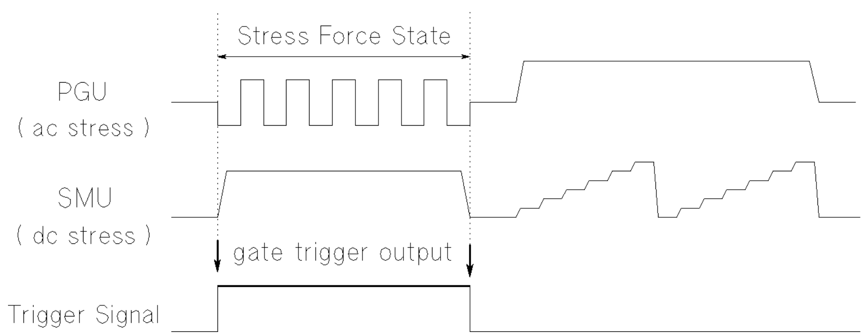
Triggering an External Instrument

HP 4155A/4156A triggers external instruments via the trigger output terminal. For the trigger polarity, you can select positive or negative. The trigger output function is *not* available for sampling measurements.

Gate Trigger Output for Stress Force.
In the stress force state, HP 4155A/4156A can output gate triggers. HP 4155A/4156A outputs a gate trigger while stress channels are forcing stress.

When stress forcing starts, the trigger signal changes to the active level. When stress forcing finishes, the trigger signal changes to the non-active level.

To use the gate trigger function, set the TRIGGER SETUP fields on the STRESS: CHANNEL DEFINITION page.



Gate Trigger Output in the Stress Force State

Edge Trigger Outputs for Sweep Measurement.
For sweep measurements, HP 4155A/4156A can output edge triggers, which are synchronized with each sweep step.

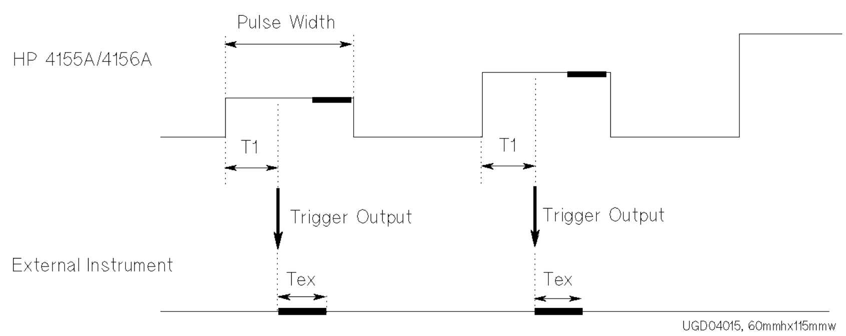
When you set pulse sweep measurement, the TRIG OUT DELAY field is displayed in the third column of the TRIGGER SETUP table on the MEASURE: OUTPUT SEQUENCE page .

When you set staircase sweep measurement, the STEP DELAY field is displayed in the third column of the TRIGGER SETUP table on the MEASURE: OUTPUT SEQUENCE page .

- trigger output delay time for pulse sweep measurements

  When using an SMU as a pulse source, the HP 4155A/4156A can output edge triggers at each pulse leading edge. Trigger output delay time specifies how much to delay the trigger after the leading edge. So, you set the trigger output delay time to wait until the HP 4155A/4156A outputs a stable pulse peak value. Trigger output delay time is shown as T1 in the following figure.

  The setting range of T1 is from 0 s to the specified pulse width or 32.7 ms, whichever is shorter. The setting resolution of T1 is 100 μs .



T1 : trigger output delay time
(set in TRIG OUT DELAY field on MEASURE: OUTPUT SEQUENCE page)
Tex : measurement time for external instrument

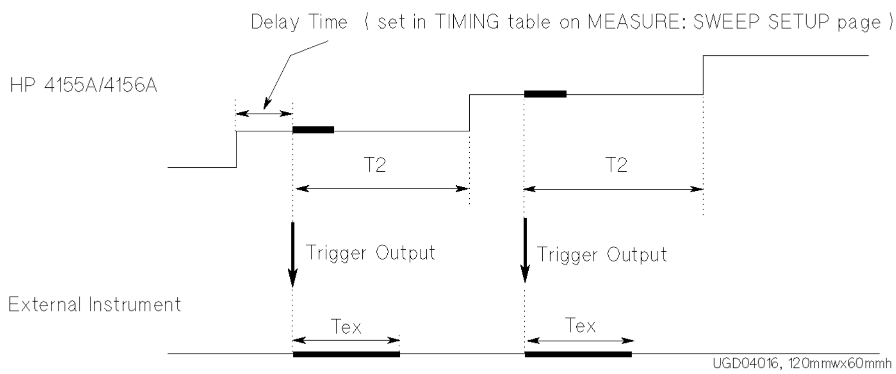
Trigger Output for Pulse Sweep Measurement

  If you want the external instruments to make a measurement while the pulse peak value is being forced, the specified T1 and pulse width must satisfy the following equation: *pulse width* > *T1* + Tex

- step delay time for staircase sweep measurements

  When performing sweep measurements without a pulsed SMU, the HP 4155A/4156A outputs an edge trigger at the time when HP 4155A/4156A starts performing measurement in each sweep step as shown in the following figure.

The step delay time you specify for trigger is the time from when the trigger is output to when the next step occurs. This is to make sure the external instrument has enough time to make the measurement. The step delay time is shown as T2 in the following figure. You can set T2 from 0 to 1 s with 100 μs resolution.



T2 : step delay time (set in STEP DELAY field on MEASURE: OUTPUT SEQUENCE page)

Tex : measurement time for external instument

Trigger Output for Non-Pulse Sweep Measurements

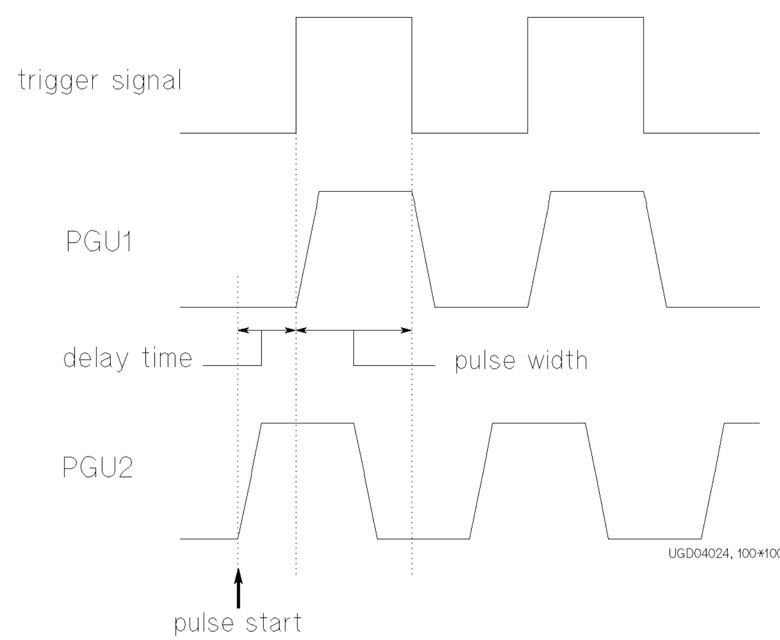
If the specified T2 is shorter than the measurement time of the HP 4155A/4156A, the HP 4155A/4156A waits until the measurement completes, then outputs the next step.

Trigger Output Function of PGU

If the HP 41501A contains PGUs, the PGUs can output a gate trigger through the HP 41501A trigger output terminal to external pulse generators. The trigger signal is output automatically when PGUs output pulses. You cannot control this function. This function allows you to perform measurements in which external pulse generators are synchronized with the HP 41501A PGUs.

You can use this function if you need more than two *ac* stress source channels.

The following figure shows the trigger signal.



Trigger Output of PGU

The leading-edge and tailing-edge of the trigger are synchronized with the leading-edge and tailing-edge of PGU1. The polarity of the trigger is positive and the output level is TTL.

HP 16441A R-BOX Control

HP 16441A R-Box adds series resistance between SMU output and DUT. This prevents excessive current from flowing and damaging the DUT when sudden voltage change occurs at the DUT.

SMUs cannot measure negative resistance. You need to connect resistance between SMU and DUT if you want to measure negative resistance characteristics.

So HP 16441A R-Box is useful for:

- breakdown characteristics measurement.
- negative resistance measurement.

You can connect a maximum of two SMU channels to the HP 16441A.

There are the limitations on measurement with HP 4155A/4156A and R-Box:

- If you measure device characteristics including negative resistance over 1 MΩ with HP 4155A/4156A and R-Box, there is a possibility that they cannot measure it.
- There is a possibility that HP 4155A/4156A cannot perform measurement circumstances.

HP 4155A/4156A automatically compensates for voltage drop of the series resistance value. So, the display pages of the GRAPH/LIST page group show the compensated data.

The LEDs on the HP 16441A R-Box indicate the currently connected resistance value.

For details of HP 16441A R-Box, refer to *HP 16441A R-Box User's Guide* or "If You Have a Problem" in *HP 4155A/4156A User's Task Guide*.

Resistance Value and Setups

Resistance Value.
The following resistance values are selectable for each channel.

- 1 MΩ
- 100 kΩ
- 10 kΩ
- 0 Ω

If you want to use Kelvin connections for HRSMUs or HPSMUs, you must select 0 Ω. You cannot use Kelvin connections for other resistances.

For the following SMUs, you can set 0 Ω *only*:

- SMU that is set to `ON` in the STBY field
- SMU that is set to `COMMON` in the MODE field

If HP 4155A/4156A is on and an emergency occurs, the resistance value changes to 1 MΩ.

Setups.
You set resistance values in the SERIES RESISTANCE column on the CHANNELS: CHANNEL DEFINITION page.

You can set resistance values for the following SMUs.

- If HP 41501A SMU/Pulse Generator Expander is not installed or does not have an HPSMU
  - SMU1
  - SMU2
- If HP 41501A has an HPSMU
  - SMU1
  - SMU5

If you connect the HP 16441A R-Box to the SMUs described above, HP 4155A/4156A automatically compensates for voltage drop of the resistance values. So, if the variables are used on graph/list page or in a user function, the values are the compensated values.

NOTE

If you connect HP 16441A R-Box to SMUs other than described above, resistance values are not compensated for automatically. You need to compensate for the resistance values manually, such as by using a user function or calculation in HP Instrument BASIC program.

NOTE

Be aware that an additional measurement channnel is automatically used if *both* the following are true:

- You *force voltage* from channel that is connected to R-Box, and
- You display this voltage variable on graph/list, or use voltage variable in user function.

Additional channel is used because the current is automatically measured. Current value is necessary to perform compensation calculation.

Circuit Diagram

Figure 3-8 shows a simplified circuit diagram of an HP 16441A R-Box.

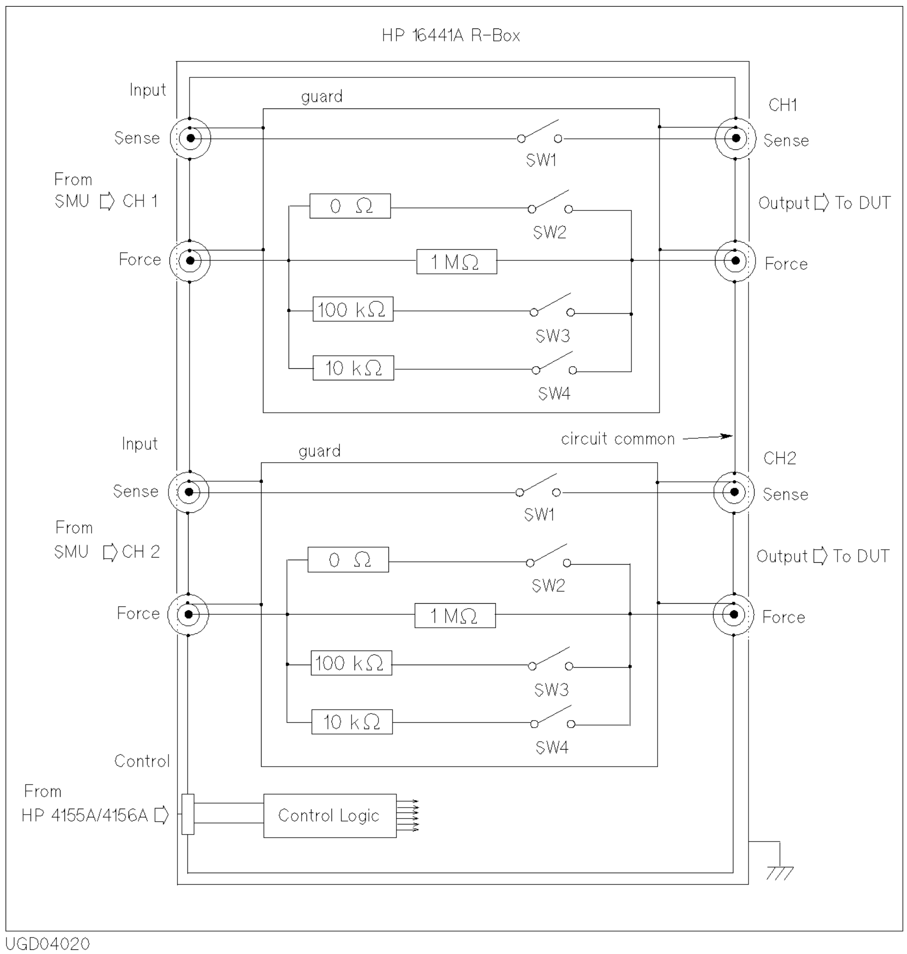


Figure 3-8. Simplified Circuit Diagram of an HP 16441A R-Box

Table 3-5 shows switching conditions for each setting.

Table 3-5. Switching Conditions of HP 16441A R-Box

Settings	Switches			
	SW1	SW2	SW3	SW4
0 Ω	ON	ON	OFF	OFF
10 kΩ	OFF	OFF	OFF	ON
100 kΩ	OFF	OFF	ON	OFF
1 MΩ	OFF	OFF	OFF	OFF

Resistance is switched before and after measurement state. In the standby state, the stress state, and the idle state, 0 Ω is connected.

Connections

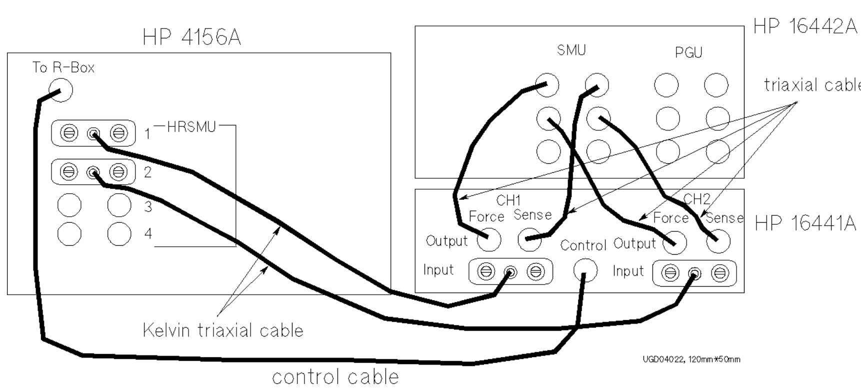
Table 3-6 is the parts list of cables for connecting HP 16441A R-Box.

Table 3-6. Parts List of Cables for Connecting HP 16441A

HP Model or Part Number	Description
04155-61610	Control Cable 1.5 m
04155-61609	Control Cable 3.0 m
04155-61605	Triaxial Cable 0.4 m
HP 16493K #001	Kelvin Triaxial Cable 1.5 m
HP 16493K #002	Kelvin Triaxial Cable 3.0 m

Kelvin Connections.
If you want to use Kelvin connections for HRSMUs and HPSMUs, you must set 0 Ω in the SERIES RESISTANCE column on the CHANNELS: CHANNEL DEFINITION page.

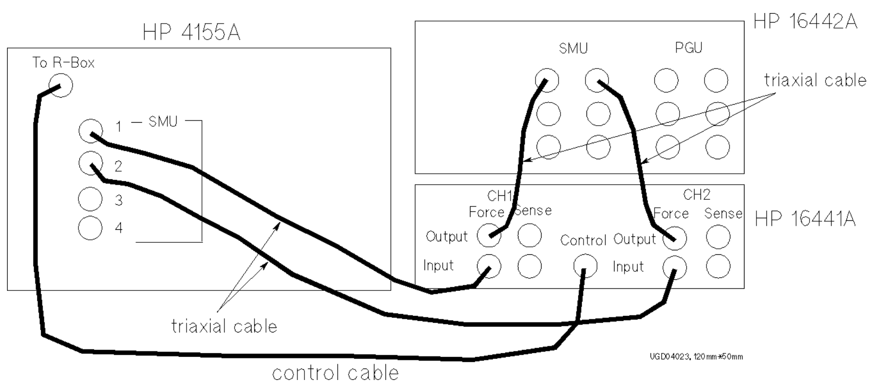
The following figure shows HP 16441A R-Box connections using Kelvin connections.



HP 16441A R-Box Connections Using Kelvin Connections

Non-Kelvin Connections.

The following figure shows HP 16441A R-Box connections using non-Kelvin connections.



HP 16441A R-Box Connections Using Non-Kelvin Connections

Measurement Ranging Mode

HP 4155A/4156A provides the following four measurement ranging modes:

- auto ranging
- limited auto ranging
- fixed range
- compliance range

You can choose the ranging modes for each measurement channel.

The following table lists the allowable measurement ranging modes for each measurement mode and measurement function.

Table 3-7. Allowable Measurement Ranging Modes

Measurement Mode/Function	Auto Ranging	Limited Auto Ranging	Compliance Range	Fixed Range
Sweep Measurement	•	•		•
Sampling Measurement (Initial Interval[1] $\geq$ 2 ms)	•	•		•
Sampling Measurement (Initial Interval $<$ 2 ms)				•
Knob Sweep			•	

1 You specify initial interval on the MEASURE: SAMPLING SETUP page.

If you choose sweep measurement or sampling measurement (initial interval $\geq$ 2 ms) and you do not set a ranging mode, auto ranging is set for V mode channel and limited auto (1nA) ranging is set for I mode channel automatically.

For sampling measurement (initial interval $<$ 2 ms), an error occurs if fixed range is not set.

Auto Ranging

The monitor unit searches for and measures at the range that provides the highest resolution as follows:

- V measurement

  The unit changes ranges (up or down one range at a time) until the measurement value is between 10% and 110% of the range, then the unit performs the measurement.

- I measurement
  - 1 A to 1 μA

    The unit changes ranges (up or down one range at a time) until the measurement value is between 10% and 114% of the range, then the unit performs the measurement.

    If the measurement value is less than 1 % of the present range and the present range is 100 μA or higher range, the range changes down two ranges instead of one range.

  - 100 nA to 100 pA

    The unit changes ranges (up or down one range at a time) until the measurement value is between 10% and 114% of the range, then the unit performs the measurement.

  - 10 pA

    The unit changes to the next higher range when the measurement value exceeds 104 % of the present range.

Limited Auto Ranging

You specify a range, which is the lowest possible range at which you want to measure. For V measurement, if the specified range is greater than the lowest range that contains V compliance, the measurement is performed at the compliance range. For I measurement, if specified range is greater than the lowest range that includes I compliance, an error occurs.

Measurement time for Limited Auto ranging is less than for Auto ranging because unit does not search below specified range, thus reducing number of range changes. So, specify highest range that gives you satisfactory results.

Monitor unit searches for and measures at measurement range that provides highest resolution (but is not below the specified range) as follows:

- V measurement

  The unit changes ranges (up or down one range at a time, but not below specified range) until the measurement value is between 10% and 110% of the range, then the unit performs the measurement.

- I measurement
  - □ 1 A to 1 μA

    The unit changes ranges (up or down one range at a time, but not below specified range) until the measurement value is between 10% and 114% of the range, then the unit performs the measurement.

    If the measurement value is less than 1 % of the present range, and if present range is 100 μA or higher range, and if the present range is two or more ranges above the specified range, the range changes down two ranges instead of one range.

  - □ 100 nA to 100 pA

    The unit changes ranges (up or down one range at a time, but not below specified range) until the measurement value is between 10% and 114% of the range, then the unit performs the measurement.

  - □ 10 pA

    The unit changes to the next higher range when the measurement value exceeds 104% of the present range.

Compliance Range

Compliance range is available for knob sweep measurement only.

- V measurement

  The monitor unit measures at the lowest range that includes V compliance.

  For VMUs, compliance range is automatically set as follows.

  - grounded mode

    20 V

  - differential mode

    2 V

- I measurement

  The monitor unit measures at the lowest range that includes I compliance.

For details about setting compliance, refer to "Compliance".

Fixed Range

The monitor unit measures at the specified range only.

For current measurement, if specified range is greater than the lowest range that includes I compliance, an error occurs.

Compliance

Allowable units:

HPSMU, MPSMU, HRSMU

To prevent damage to the test device due to overcurrent, overvoltage, or overpower, you can set current compliance, voltage compliance, or power compliance for the HPSMU, MPSMU, and HRSMU.

Voltage and Current Compliance

Voltage compliance (V compliance) and current compliance (I compliance) are limiters that can be set with the same resolution and accuracy as output current or output voltage. For V/I compliance setting range, refer to Table 3-8 and Table 3-9. For V/I compliance resolution, refer to Table 3-10 and Table 3-11.

When a unit reaches I compliance, the unit acts as a constant I source. When a unit reaches V compliance, the unit acts as a constant V source.

- setting and restrictions
  - □ V source mode channel

    When using a unit in the V source mode, specify I compliance.
  - □ I source mode channel

    When using a unit in the I source mode, specify V compliance.
  - □ VSU

    For VSU, current compliance is automatically set to approximately ±100 mA. You cannot change it.
  - □ common channel

    If you set COMMON measurement mode for the unit, then I compliance for the unit is automatically set as follows and you cannot change the setting.

GNDU	1.6 A
HRSMU	105 mA
MPSMU	105 mA
HPSMU	1 A

- polarity and output area
  - ☐ V compliance

    HP 4155A/4156A automatically sets V compliance polarity to the same polarity as the output current, regardless of the specified V compliance polarity. There is no compliance for the opposite polarity.

  - ☐ I compliance

    HP 4155A/4156A automatically sets I compliance for both the positive and negative polarity, regardless of the I compliance polarity.

    However, if the output voltage and output current are opposite polarity, the $|I\ compliance|$ value is increased by an amount that is 2.5% to 12% of the range value in the lowest range that includes *I compliance*. The following figure shows the relation of the compliance and output.

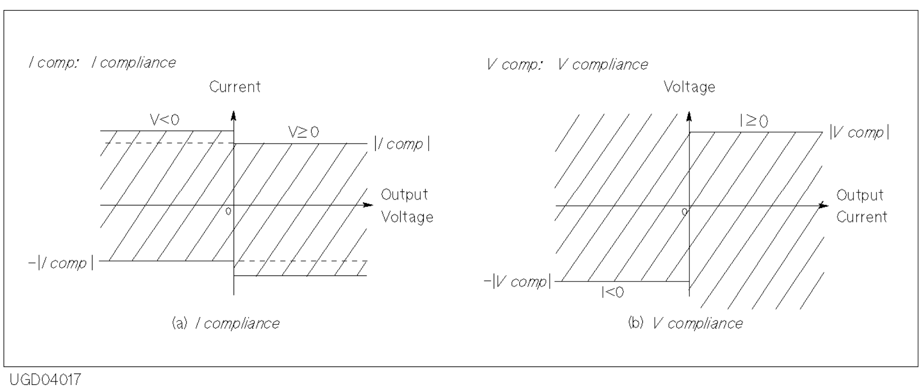


Figure 3-9. Relation of Compliance and Output

The following tables list the compliance setting range and compliance resolution.

Table 3-8. V Compliance Setting Range

Unit	Output Range	V Compliance Setting Range
HRSMU	10 pA $\sim$ 10 mA	0 to 100 V
	100 mA ($0 \le \lvert I \rvert \le 20$ mA)	0 to 100 V
	100 mA (20 mA $< \lvert I \rvert \le$ 50 mA)	0 to 40 V
	100 mA (50 mA $< \lvert I \rvert \le$ 100 mA)	0 to 20 V
MPSMU	1 nA $\sim$ 10 mA	0 to 100 V
	100 mA ($0 \le \lvert I \rvert \le 20$ mA)	0 to 100 V
	100 mA (20 mA $< \lvert I \rvert \le$ 50 mA)	0 to 40 V
	100 mA (50 mA $< \lvert I \rvert \le$ 100 mA)	0 to 20 V
HPSMU	1 nA $\sim$ 10 mA	0 to 200 V
	100 mA ($0 \le \lvert I \rvert \le 50$ mA)	0 to 200 V
	100 mA (50 mA $< \lvert I \rvert \le$ 115 mA)	0 to 100 V
	1 A ($0 \le \lvert I \rvert \le 50$ mA)	0 to 200 V
	1 A (50 mA $< \lvert I \rvert \le$ 125 mA)	0 to 100 V
	1 A (125 mA $< \lvert I \rvert \le$ 500 mA)	0 to 40 V
	1 A (500 mA $< \lvert I \rvert \le$ 1 A)	0 to 20 V

Table 3-9. I Compliance Setting Range

Unit	Output Range	I Compliance Setting Range
HRSMU	2 V	100 fA to 100 mA
	20 V	100 fA to 100 mA
	40 V	100 fA to 50 mA
	100 V	100 fA to 20 mA
MPSMU	2 V	1 pA to 100 mA
	20 V	1 pA to 100 mA
	40 V	1 pA to 50 mA
	100 V	1 pA to 20 mA
HPSMU	2 V	1 pA to 1000 mA
	20 V	1 pA to 1000 mA
	40 V	1 pA to 500 mA
	100 V	1 pA to 125 mA
	200 V	1 pA to 50 mA

Table 3-10. V Compliance Resolution

Unit	V Compliance	Resolution
HRSMU	$0 \text{ V} \le \lvert V \rvert \le 2 \text{ V}$	100 μV
MPSMU	$2 \text{ V} < \lvert V \rvert \le 20 \text{ V}$	1 mV
HPSMU	$20 \text{ V} < \lvert V \rvert \le 40 \text{ V}$	2 mV
	$40 \text{ V} < \lvert V \rvert \le 100 \text{ V}$	5 mV
	$100 \text{ V} < \lvert V \rvert \le 200 \text{ V}$	10 mV

Table 3-11. I Compliance Resolution

Unit	I Compliance	Resolution
HRSMU	100 fA $\leq$ |I| $\leq$ 100 pA	10 fA
	100 pA $<$ |I| $\leq$ 1 nA	100 fA
	1 nA $<$ |I| $\leq$ 10 nA	1 pA
	10 nA $<$ |I| $\leq$ 100 nA	10 pA
	100 nA $<$ |I| $\leq$ 1 μA	100 pA
	1 μA $<$ |I| $\leq$ 10 μA	1 nA
	10 μA $<$ |I| $\leq$ 100 μA	10 nA
	100 μA $<$ |I| $\leq$ 1 mA	100 nA
	1 mA $<$ |I| $\leq$ 10 mA	1 μA
	10 mA $<$ |I| $\leq$ 100 mA	10 μA
MPSMU	1 pA $\leq$ |I| $\leq$ 1 nA	100 fA
	1 nA $<$ |I| $\leq$ 10 nA	1 pA
	10 nA $<$ |I| $\leq$ 100 nA	10 pA
	100 nA $<$ |I| $\leq$ 1 μA	100 pA
	1 μA $<$ |I| $\leq$ 10 μA	1 nA
	10 μA $<$ |I| $\leq$ 100 μA	10 nA
	100 μA $<$ |I| $\leq$ 1 mA	100 nA
	1 mA $<$ |I| $\leq$ 10 mA	1 μA
	10 mA $<$ |I| $\leq$ 100 mA	10 μA
HPSMU	1 pA $\leq$ |I| $\leq$ 1 nA	100 fA
	1 nA $<$ |I| $\leq$ 10 nA	1 pA
	10 nA $<$ |I| $\leq$ 100 nA	10 pA
	100 nA $<$ |I| $\leq$ 1 μA	100 pA
	1 μA $<$ |I| $\leq$ 10 μA	1 nA
	10 μA $<$ |I| $\leq$ 100 μA	10 nA
	100 μA $<$ |I| $\leq$ 1 mA	100 nA
	1 mA $<$ |I| $\leq$ 10 mA	1 μA
	10 mA $<$ |I| $\leq$ 100 mA	10 μA
	100 mA $<$ |I| $\leq$ 1 A	100 μA

Power Compliance

In addition to V compliance or I compliance, you can set power compliance for the VAR1, VAR2, and VAR1' channels of sweep measurement. If the pulse output function is used for VAR1 or VAR1' channels, you *cannot* set power compliance for the VAR1 or VAR1' channel that is set to pulse output. You can set it for the other channels.

The power compliance setting range for each SMU is as follows:

HRSMU	1 to 2 W
MPSMU	1 to 2 W
HPSMU	1 to 20 W

If you specify I compliance and power compliance for a V sweep source, the HP 4155A/4156A changes the I compliance at every voltage step. The I compliance is set to the smaller value of *I compliance* and *power compliance/step voltage*, as shown in the following figure (a).

If you specify V compliance and power compliance for an I sweep source, the HP 4155A/4156A changes the V compliance at every current step. The V compliance is set to the smaller value of *V compliance* and *power compliance/step current* as shown in figure (b).

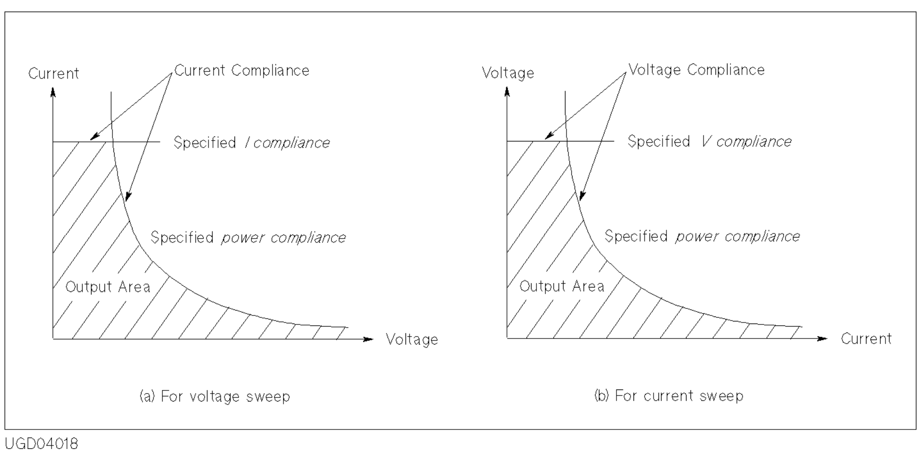
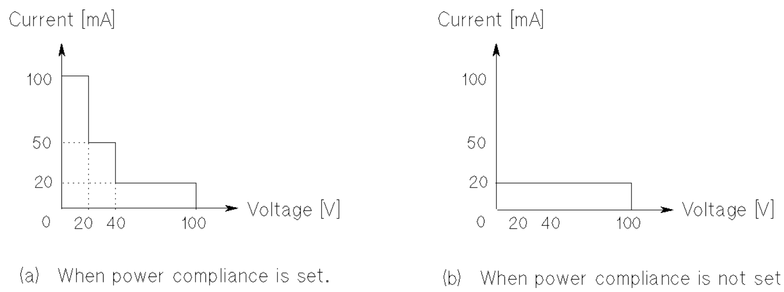


Figure 3-10. Power Compliance Output Area

If you specify power compliance, SMUs can be swept at their maximum output limits because the HP 4155A/4156A changes the V output range and I compliance range during a V sweep and changes the I output range and V compliance range during an I sweep. The following figure shows an example of the difference in SMU output when power compliance is set and when power compliance is not set.



Allowable I Output when the MPSMU Sweeps Voltage (0 V to 100 V)

If you specify power compliance, the measurement time increases slightly because of the range changing for every step.

When the ranges are changed during a sweep to accommodate power compliance, the SMU output is momentarily set to 0 V.

Integration Time

To reduce measurement errors caused by line frequency noise or any other environmental noise source, HP 4155A/4156A takes a number of measurement samples and averages them to obtain a measurement data. The number of measurement samples taken during each measurement depends on integration time. Setting a longer integration time increases the number of measurement samples, so you can get more accurate measurement data.
Integration time is divided into three categories:

- short
- medium
- long

To perform high-speed measurements, set integration time to short. To perform more accurate measurements, set integration time to long.

All measurement units are set to the same integration time that is specified in the INTEG TIME table on the MEASURE: MEASURE SETUP page. For details of the INTEG TIME table, see "MEASURE: MEASURE SETUP page" in Chapter 4.

Short

Short integration time is effective when you need high-speed measurements. But the measurement data have lower resolution.

You set the short integration time by pressing the (Short) front-panel key, then you can enter integration time from 80 μs to 1.92 ms with 80 μs resolution in the INTEG TIME table on the MEASURE: MEASURE SETUP page. The initial setting for short integration time is 640 μs.

If you set integration time in 80 μs to 560 μs range, the measurement units measure with specified integration time for all measurement ranges.

If you set integration time in 0.64 ms to 1.92 ms range and HP 4155A/4156A measures current in the 10 pA to 10 μA range, HP 4155A/4156A may set longer integration time than specified for better noise reduction.

Medium

Medium integration time is 1 PLC (power line cycle). You set the medium integration time by pressing the (Medium) front-panel key. The medium integration time depends on the power line cycle. (For example, if power line cycle is 50 Hz, medium integration time is 20 ms.) You cannot modify the medium integration time.

If you measure current in the 1 nA or lower ranges by using SMUs, integration time of SMUs is automatically changed as follows:

Table 3-12.
Actual Medium Integration Time of SMUs
($\leq$ 1 nA range)

Measurement Unit	Measurement Range	Integration Time
HRSMU	10 pA	50 PLC
	100 pA	10 PLC
	1 nA	5 PLC
MPSMU	1 nA	3 PLC
HPSMU	1 nA	3 PLC

Long

Long integration time is effective when you need high resolution and noise reduction measurement. But the measurement speed is slow. You set the integration time by pressing the (Long) front-panel key, then you can enter the integration time from 2 PLC to 100 PLC with 1 PLC resolution in INTEG TIME table on MEASURE: MEASURE SETUP page. Initial setting for long integration time is 16 PLC.

When an HP 4155A/4156A measures current in 1 nA or lower ranges by using HRSMU, integration time of HRSMU is automatically changed to longer integration time (maximum 100 PLC) than specified.

SMU Filter

You can set SMU filter to on or off for sampling measurements or stress forcing. If filter is *on*, noise and overshoot are decreased, but settling time takes longer.

- sampling measurement

  You set the FILTER field on the MEASURE: SAMPLING SETUP page.

  If you set initial interval to a short time, and if filter is set to `ON`, be aware that settling time takes several ms.

- stress force

  You set the FILTER field on the STRESS: STRESS SETUP page.

  If you set dc stress to short stress force time, set `OFF` in this field if you want the stress signal to be more pulsed shaped.

Filter Condition for Sweep Measurement

When you perform sweep measurements, the SMU filter conditions are automatically set as follows:

- For a pulsed SMU

  Filter is *off*.

- For non-pulsed SMUs

  Filters are *on*.

Zero Offset Cancel

HP 4155A/4156A has zero offset cancel function. This function measures the zero offset data when green key, then (Stop) key is pressed. Then, uses this data to compensate the measurement results when measurement is performed.

So, the offset cancel function allows you to minimize measurement error caused by undesired input current or voltage (for example leakage current of test leads or test fixture).

- measurement units

  You can use the zero offset cancel function for:

  - low current measurement (measurement range $\leq$ 10 nA) by SMUs.
  - differential mode V measurement by VMUs.

- offset data measurement range

  Offset data is measured in the following measurement ranges only:

  - for auto I range

HPSMU and MPSMU:	1 nA range
HRSMU:	10 pA range

  - for fixed I range or limited auto I range

HPSMU and MPSMU:	1 nA range (only when 1 nA limited auto range is set in right RANGE column).
HRSMU:	range set in right RANGE column (only when 1 nA, 100 pA, or 10 pA range is set).

    If 10 nA is set in right RANGE column, offset data measurement is not performed, so offset cancel will use the present data.

  - for differential V mode

    0.2 V range (VMU2 measures voltage in grounded mode to confirm that voltage does not exceed ±20 V.)

  The offset data is measured in the range that is displayed in brackets in the ZERO CANCEL table.

- offset cancel range

  Offset cancel is performed (using the measured offset data) for the following measurement ranges:

  - □ for auto range measurement

HPSMU and MPSMU:	1 nA and 10 nA range using offset data that was measured in 1 nA range.
HRSMU:	10 pA to 10 nA range using offset data that was measured in 10 pA range.
VMU:	0.2 V and 2 V range using offset data that was measured in 0.2 V range.

  - □ limited auto and fixed range measurement

HPSMU and MPSMU:	1 nA and 10 nA range using offset data that was measured in 1 nA range.
HRSMU:	10 pA to 10 nA (when the offset data was measured in 10 pA range.) 100 pA to 10 nA (when the offset data was measured in 100 pA range.) 1 nA and 10 nA (when the offset data was measured in 1 nA range.)
VMU:	0.2 V and 2 V range using offset that was measured in 0.2 V range.

  If measurement range setup is changed to a lower range than the range at which the offset data was measured, then offset cancel is not performed for the unit. (For example, if HRSMU measurement range is changed to auto range from 1 nA fixed range after measuring offset data in 1 nA range, `OFF` is displayed in the unit's ZERO CANCEL field. Because it is possible that auto range will use range lower than 1 nA.)

Setup and Restrictions.
To use zero offset cancel function, set ON in the ZERO CANCEL field on the MEASURE: MEASURE SETUP page by selecting ZERO CANCEL ON/OFF secondary softkey.

You cannot set zero cancel function to ON and OFF for each individual unit. If you select OFF in the ZERO CANCEL field, zero offset cancel is not performed for any units. If you select ON in ZERO CANCEL field, ON is displayed for the units that can perform zero offset cancel.

Measuring Offset Data.
To measure zero offset data, press green key, then press (Stop) front-panel key.

Even if OFF is set to the ZERO CANCEL field before offset data measurement, pressing green key and (Stop) front-panel key automatically sets ON in the ZERO CANCEL field, then performs the offset data measurement.

- integration time

  During offset data measurement, integration time is set to specified time or medium, whichever is longer. After offset data measurement, integration time returns to same setting as before the offset measurement was performed.

- operation state

  Offset data measurement and zero offset cancel can be performed from the *idle* or *standby* state.

Performing Offset Cancel.
To perform offset cancel, press a measurement key. The measurement data is automatically compensated (by using the offset data) while measurement is performed.

Offset Measurement Limit

If measured offset data is too large for the offset measurement range as shown below, an error occurs. In such cases, an * is displayed in the field of the failed unit, and HP 4155A/4156A keeps the previous offset data. The initial offset data is 0.

- HPSMU

  greater than or equal to ±1 % of 1 nA range.

- MPSMU

  greater than or equal to ±1 % of 1 nA range.

- HRSMU

offset meas. range:	measured offset data
1 nA:	greater than or equal to ±1 % of 1 nA range.
100 pA:	greater than or equal to ±1 % of 100 pA range.
10 pA:	greater than or equal to ±4 % of 10 pA range.

- VMU

  greater than or equal to ±1 % of 0.2 V range. (If VMU2 grounded mode measurement value is greater than or equal to ±20 V, error occurs.)

Initial Settings

This section explains the following:

- user-defined initial settings

  HP 4155A/4156A can automatically get files from a diskette after applying power, and set the HP 4155A/4156A according to the files. This function saves you the trouble of getting application files every time you turn on the HP 4155A/4156A.

- default initial settings

  If you turn on HP 4155A/4156A without a diskette, the HP 4155A/4156A is set to the default initial settings.

  In this condition, internal memories contain measurement setup data for the most common applications.

User-Defined Initial Settings

If you turn on an HP 4155A/4156A with a diskette in the flexible disk drive, HP 4155A/4156A automatically loads the following files from the diskette:

- files for setting setup and result pages

  The fields of the setup and result pages are automatically set according to the files on the diskette. Also, you can specify which page is displayed after turning on the HP 4155A/4156A.

- files for setting internal memories

  If the diskette has files that can be loaded into the internal memories of the HP 4155A/4156A, the files are automatically loaded after turning on the HP 4155A/4156A.

- IBASIC programming file

  If an IBASIC programming file with name "AUTOST" is on the diskette, this file is automatically loaded and started after loading the files for setting setup and result pages and internal memories. For details about "AUTOST" file, refer to HP 4155A/4156A *Programmer's Guide*.

Files for setting setup and result pages.
If the following files exist on diskette, the setup and result pages are automatically set up according to the files after you turn on the HP 4155A/4156A:

File Names for User-Defined Initial Settings

File Type	File Name
measurement setup file	INIT.MES
stress setup file	INIT.STR
measurement setup/result file	INIT.DAT
customize file	INIT.CST

HP 4155A/4156A can get multiple INIT files. So, if INIT.CST, INIT.MES, and INIT.STR files exist on the diskette, all of them are loaded. However, the INIT.MES and INIT.DAT file both contain measurement setup data. So, if both these files exist on the diskette, the HP 4155A/4156A gets INIT.DAT, not INIT.MES.

Which Page is Displayed after Getting Setup Files?

If the INIT.MES or INIT.DAT file exists on the diskette, the page that is displayed after getting the setup files is as follows.

- if file was created by `SAVE`

  When you create INIT.MES or INIT.DAT file by using SAVE function on the SYSTEM: FILER page, you can select one of the following files to be displayed after getting the files:

  - GRAPH/LIST: GRAPH page
  - GRAPH/LIST: LIST page
  - KNOB SWEEP page
  - CHANNELS: CHANNEL DEFINITION Page.

- if file was created by `RENAME` or `COPY`

  When you create INIT.MES or INIT.DAT file by using RENAME or COPY function on the SYSTEM: FILER page, you cannot select which page is displayed. The CHANNELS: CHANNEL DEFINITION page is always displayed after getting the files.

Files for setting internal memories.

If the following files exist on diskette, they are loaded automatically from diskette to internal memory after you turn on the HP 4155A/4156A:

- measurement setup files (MEM*.MES)
- stress setup files (MEM*.STR)
- measurement setup/result files (MEM*.DAT)

Where MEM* means MEM1, MEM2, MEM3, or MEM4, which correspond to the four internal memory areas. Only the above types of files can be loaded into internal memory.

If the same internal memory is specified by multiple files (for example, MEM1.MES, MEM1.DAT, and MEM1.STR), the priority is:

1. DAT
2. MES
3. STR

Default Initial Settings

When you turn on the HP 4155A/4156A without a diskette, the HP 4155A/4156A is set the default initial settings after finishing the power on test.

The default initial settings, except for system page group, are also set by selecting DEFAULT MEASURE SETUP secondary softkey in the MEASUREMENT MODE field on the CHANNELS: CHANNEL DEFINITION page. The default initial settings are as follows:

- measurement units

  Measurement units that are verified as operating normally are turned on and set to the idle state.

- setup items of setup and result pages

  These items are set to the default initial settings whenever power is applied or *RST command is sent, except for the following items, which keep the same value that they had before *RST or before power was turned off.

  - SYSTEM: MISCELLANEOUS page
    - HP 4155 (or HP 4156) is System Controller or not
    - HP-IB Address
    - Power Line Frequency
    - Serial Interface
  - SYSTEM: SELF-CALIBRATION/DIAGNOSTICS page
  - user comment field

    The default initial settings for USER COMMENT fields of the MEASURE page group and STRESS page group are blank.

- internal memories

  For the initial settings, internal memories contain the measurement setup data for the following basic applications.

  - measurement setup data for bipolar transistor Vce-Ic characteristics
  - measurement setup data for FET (field effect transistor) Vds-Id characteristics
  - measurement setup data for FET (field effect transistor) Vgs-Id characteristics
  - measurement setup data for diode Vf-If characteristics

  You can select the secondary softkeys for the above applications when the pointer is in the MEASUREMENT MODE field on the CHANNELS: CHANNEL DEFINITION page. The softkeys set the setup pages for the application, thus saving time.

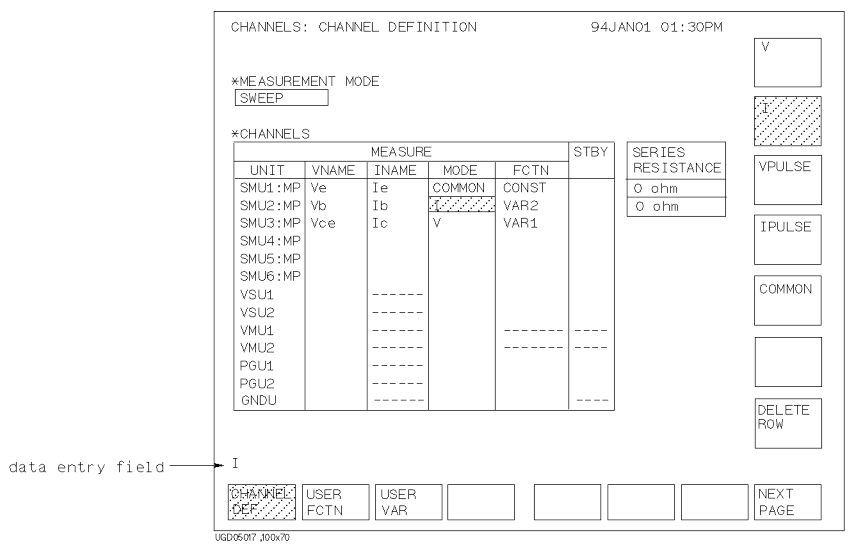
4

Page Organization

Page Organization

This chapter is a reference for operating the HP 4155A/4156A by using the front-panel controls. The HP 4155A/4156A is operated by *pages*: setup pages and results display pages. The following sections explain the page structure and give details about each page.

The pages have a **fill-in-the-blank** format for entering parameters. For example, to use SMU2 as a current source, you move the pointer to MODE field of SMU2, then select I secondary softkey as follows:



Data input or edit.
When you move pointer to a field of a page, you can fill in the field by entering characters or selecting a softkey. Softkeys related to the field appear when you move the pointer to the field. The HP 4155A/4156A has three types of fields. The following describes the methods for entering or editing input data of these field types:

- For option fields:

  When pointer is in an option field, selectable input items for field are displayed on secondary softkeys. You select desired softkey. The item appears in the field.

  For example, when pointer is in MEASUREMENT MODE field of CHANNELS: CHANNEL DEFINITION page, `SWEEP` and `SAMPLING` softkeys appear in secondary softkey area. Select `SWEEP` to select sweep measurement, or select `SAMPLING` to select sampling measurement.

  When pointer is located in a field that requires a variable name, all available variable names are displayed on secondary softkeys, so you can select desired variable name. Available variable names are names you already set up as measurement variables and user function variables. If more than six variable names are available, `MORE` secondary softkey appears, which you can select to display other available variable names.

- For comment and name fields

  When the pointer is located in a comment or name field, you input the desired characters by using the ENTRY front-panel key group. You press the desired characters. The characters appear in the **data entry area**.

  For name fields, you can enter alphanumeric characters. For comment fields, you can also enter non-alphanumeric characters. You can enter uppercase or lowercase alphabet characters by using *blue* and *green* front-panel keys. You can enter special (non-alphanumeric) characters by using the *green* front-panel key.

  If a comment or name is already entered in the field, it appears in the data entry area. You can edit it using Edit front-panel keys.

  After editing or entering the comment or name, press the (Enter) front-panel key to enter the name or comment into the field at the pointer location.

- For numeric data fields

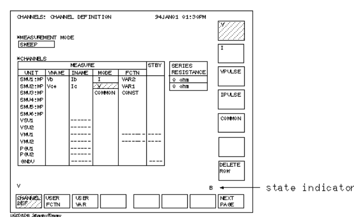
  When pointer is in a numeric data field, input numeric data as follows:

  - Type the numeric value by pressing numeric front-panel keys (value appears in the data entry area). Then, press (Enter) front-panel key (value is entered into the numeric data field at the pointer location).
  - Rotate the rotary knob to increase or decrease the value. Rotate clockwise to increase value. Rotate counterclockwise to decrease value.

Blue front-panel key usage

The blue front-panel key has three states:

- Non-shift state: B, b, or G is not displayed at lower-right corner of screen. You can enter numeric values.
- Uppercase shift state: B is displayed at lower-right corner of screen. G in not displayed. You can enter uppercase alphabet characters.
- Lowercase shift state: b is displayed at lower-right corner of screen. You can enter lowercase alphabet characters.



Basically, you change between these states as follows:

- To toggle between non-shift/shift state: press blue key.
- To toggle between uppercase/lowercase shift state: press green key, then blue key.

The following is a detailed description about changing between these states:

Non-shift ⟶ Uppercase blue-key shift	Press blue key.
Uppercase blue-key shift ⟶ Non-shift	Press blue key.
Non-shift ⟶ Lowercase blue-key shift	Press green key, then blue key.
Lowercase blue-key shift ⟶ Non-shift	Press blue key.
Uppercase blue-key shift ⟶ Lowercase blue-key shift	Press green key, then blue key.
Lowercase blue-key shift ⟶ Uppercase blue-key shift	Press green key, then blue key.

Green front-panel key usage

You can use the green front-panel key to enter special (non-alphanumeric), which are the characters printed in green above the keys.

The green key action is momentary. That is, after you press the green key, only the next keystroke is effective. For example, to enter "**#$**," you press:

1. green key
2. (0)# key
3. green key
4. (1)$ key

The green key mode has special functions when you enter data. The following table shows the special functions:

Keys	Label	Function
Green, (⇐)	|⇐	moves cursor to first character.
Green, (⇒)	⇒|	moves cursor to last character.
Green, (Recall↓)	Recall↑	recalls oldest input from the key buffer. Key buffer stores the 10 most recent entries of the data entry area.
Green, (Clear)	Clr→End	clears entered data from present cursor position to end.
Green, (Enter)	Calc	directly calculates the expression entered in data entry area.

Also, by using the green key, you can perform dump ((Plot/Print) key), knob sweep ((Single) key), and zero offset cancel ((Stop) key).

Edit front-panel keys

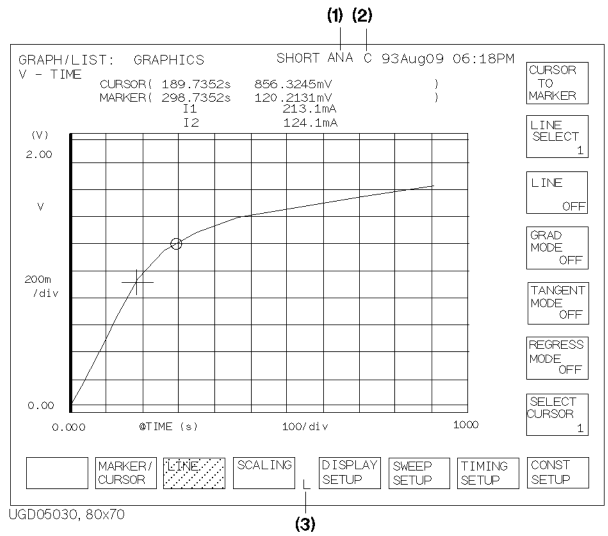
There are six keys in the Edit front-panel key group. Four of these keys also have other functions in the green-key shift mode. The following table shows the function of each keys:

Key	Functions
⇐	Moves the cursor to left by one column in the data entry area.
⇒	Moves the cursor to right by one column in the data entry area.
Delete	Deletes one character where the cursor is located.
Insert	Toggles the input mode in the data entry area between *insert* and *overtyping* modes.
Recall↓	Recalls the newest input from the key buffer.
Clear	Deletes all the characters in the data entry area.
Green + ⇐ = |⇐	Moves the cursor to first column in the data entry area.
Green + ⇒ = ⇒|	Moves the cursor to last column of the present entry in the data entry area.
Green + Recall↓ = Recall↑	Recalls the oldest input from the key buffer.
Green + Clear = Clr→End	Deletes the characters from present cursor position to end of entry.

The key buffer stores the 10 most recent entries of the data entry area. You can recall the stored entries by using the Recall↓ key as described above.

Status Indicators

HP 4155A/4156A displays the following status indicators.



(1) displays the following status:

`TRG`	HP 4155A/4156A is waiting for trigger input from an external instrument.
`DRW`	HP 4155A/4156A is drawing measurement curve.
`ANA`	HP 4155A/4156A is performing auto-analysis or regression calculation.

(2) displays the following status:

`C`	HP 4155A/4156A is performing auto-calibration.
`Z`	HP 4155A/4156A is performing offset measurement for zero offset cancel function.

(3) displays `L` when page is locked by HP-IB command.

Page Structure

The HP 4155A/4156A has seven page groups that have a total 22 pages as shown in Figure 4-1.

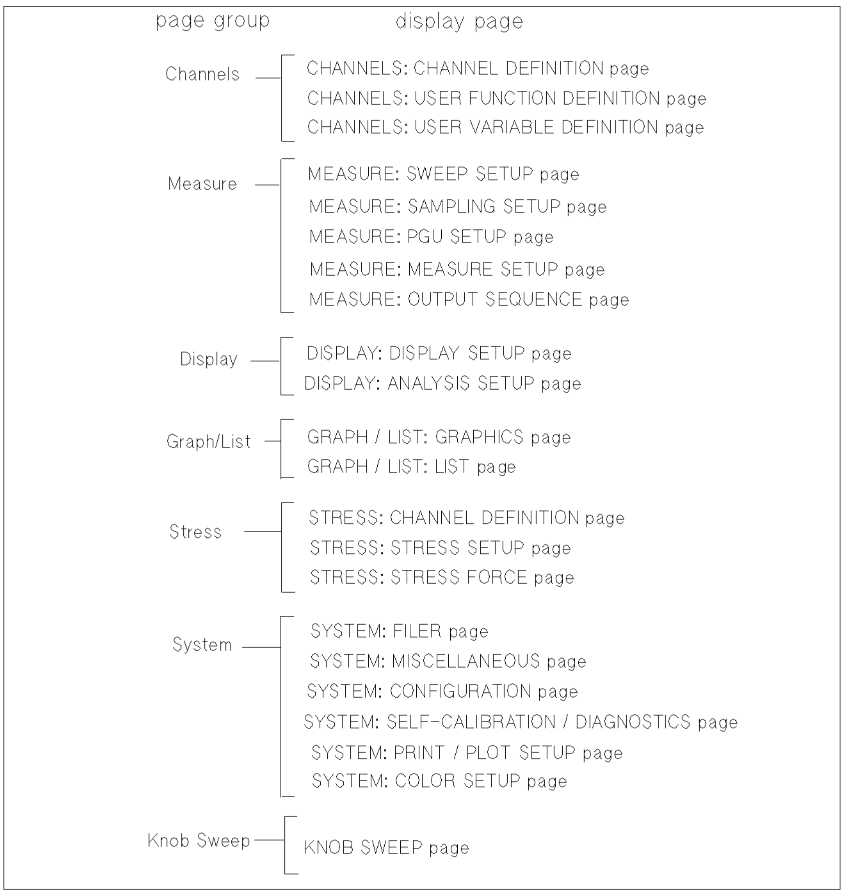


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Figure 4-1. Page Structure of HP 4155A/4156A

CHANNELS page group:	Pages for defining measurement mode, measurement channels, and user functions.
MEASURE page group:	Pages for setting measurement parameters.
DISPLAY page group:	Pages for setting up display of measurement results.
GRAPH/LIST page group:	Pages for displaying the measurement results.
STRESS page group:	Pages for setting and monitoring stress force.
SYSTEM page group:	Pages for controlling mass storage, for setting system parameters of the HP 4155A/4156A, for setting print/plot parameters, and so on.
KNOB SWEEP page group:	Pages for displaying measurement results when you use the knob sweep function.

You can use front-panel keys in the PAGE CONTROL key group to display the desired page. The PAGE CONTROL key group has the following front-panel keys:

Chan	CHANNELS page group.
Meas	MEASURE page group.
Display	DISPLAY page group.
Graph/List	GRAPH/LIST page group.
Stress	STRESS page group.
System	SYSTEM page group.

To display the KNOB SWEEP page, you press the green front-panel key, then the Single front-panel key. For details about the KNOB SWEEP page, refer to "KNOB SWEEP page" in Chapter 3.

CHANNELS Page Group

CHANNELS page group has the following pages:

Channel Definition:	For defining the measurement mode and measurement channels of the HP 4155A/4156A.
User Function Definition:	For defining the user functions.
User Variable Definition:	For defining the user variables.

To move to the CHANNELS page group, do one of the following:

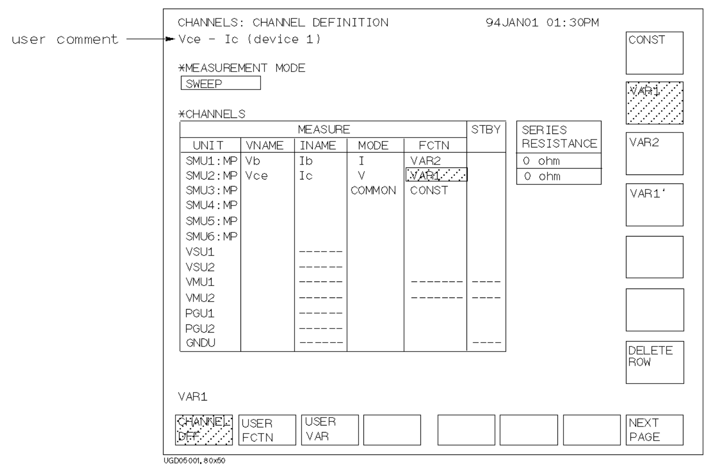
- Press Chan front-panel key in the PAGE CONTROL key group.
- Select PREV PAGE primary softkey in the MEASURE: SWEEP SETUP or MEASURE: SAMPLING SETUP page.

Then, the following primary softkeys appear:

CHANNEL DEF	USER FCTN	USER VAR				PREV PAGE	NEXT PAGE

- Select CHANNEL DEF softkey to move to CHANNELS: CHANNEL DEFINITION softkey.
- Select USER FCTN softkey to move to CHANNELS: USER FUNCTION DEFINITION page.
- Select USER VAR softkey to move to CHANNELS: USER VARIABLE DEFINITION page.

CHANNELS: CHANNEL DEFINITION page



On the "CHANNELS: CHANNEL DEFINITION" page, you define the measurement mode and how to use each channel.

User Comment

In this field, you can enter a desired comment. The comment you enter here is also displayed in the CHANNELS, MEASURE, DISPLAY, and GRAPH/LIST page groups.

MEASUREMENT MODE

MEASUREMENT MODE field sets measurement mode to sweep measurement mode or sampling measurement mode. In this field, select:

- `SWEEP` secondary softkey to set sweep measurement.
- `SAMPLING` secondary softkey to set sampling measurement.

To change settings (except for system page group) to default initial settings, select `DEFAULT MEASURE SETUP` secondary softkey.

Application setup data in internal memories

MEM* secondary softkeys indicate that setup or measurement result data is in the internal memory. When you turn on HP 4155A/4156A without a diskette, the following secondary softkeys are displayed:

MEM1 M B-Tr VCE-IC	measurement setup data for bipolar transistor Vce-Ic characteristics.
MEM2 M FET VDS-ID	measurement setup data for FET (field effect transistor) Vds-Id characteristics.
MEM3 M FET VGS-ID	measurement setup data for FET (field effect transistor) Vgs-Id characteristics.
MEM4 M DIODE VF-IF	measurement setup data for diode Vf-If characteristics.

M on the softkey means measurement setup data.

Select softkey to get the desired application measurement setup data. This eliminates the time required to set the setup pages.

See "User-Defined Initial Settings" in Chapter 3 for more information on the internal memory.

CHANNELS

- UNIT

  This column lists all the units that are installed in the HP 4155A/4156A.

- VNAME

  VNAME field assigns a variable name for voltage that will be forced or measured. You can use this name as a reference on the other pages. If channel does neither V force nor V measurement, you can omit VNAME.

  In this field, you can do the following:

  - Enter a name by using the keyboard or front panel keys
  - Select DELETE ROW to delete the VNAME, INAME, MODE, FCTN, and STBY entries for the unit. Unit is disabled.

  Restrictions:

  - VNAME must be 6 or less alphanumeric characters. First character must be alphabet character.
  - Name must be different from other names.

Switching units

To switch the VNAME, INAME, MODE, FCTN, and STBY assignment for units, do as follows:

1. Position pointer in top field of VNAME column. `CHANNEL ASSIGN` secondary softkey appears.
2. Select `CHANNEL ASSIGN` softkey. Pointer moves to the top field of UNIT column.
3. Use arrow keys in the MARKER/CURSOR key group to move pointer to desired row.
4. Select the secondary softkey of the desired unit. The selected unit appears at the pointer.

Perform steps 3 and 4 until you assign units as desired. Make sure that the same unit is not assigned to multiple rows. Then, select the `EXIT CHANNEL ASSIGN` softkey.

- INAME

  INAME field assigns a variable name for current that will be forced or measured. You can use this name as a reference on the other pages. If channel does neither I force nor I measurement, you can omit INAME.

  In this field, you can do the following:

  □ Enter a name by using the keyboard or front panel keys
  □ Select `DELETE ROW` to delete the VNAME, INAME, MODE, FCTN, and STBY entries for the unit. Unit is disabled.

  Restrictions:

  □ INAME must be 6 or less alphanumeric characters. First character must be alphabet character.
  □ Name must be different from other names.

- MODE

  You define an output mode for SMUs, VSUs, PGUs, and GNDU, and measurement mode for VMUs. When the pointer is located in this column, allowable modes appear in the secondary softkey area. You select a softkey to set a mode. The following table shows allowable modes for each unit:

	V	I	VPULSE	IPULSE	COMMON	DVOLT
SMU	•	•	•[1]	•[1]	•	
VSU	•					
PGU	•		•			
GNDU					•	
VMU	•					•

1 Only for sweep measurements, not for sampling.

To delete the VNAME, INAME, MODE, FCTN, and STBY entries for a unit, select the DELETE ROW secondary softkey. Unit is disabled.

Restrictions:

- Only one SMU can be set to VPULSE or IPULSE. That is, you cannot set multiple SMUs to VPULSE or IPULSE, or cannot set one SMU to VPULSE and another SMU to IPULSE.
- For sampling measurement, you cannot set VPULSE or IPULSE for SMUs. You can set VPULSE for PGUs.
- If both PGUs are set to VPULSE, the STBY settings of both PGUs must be same.

- FCTN

  This field defines an output function for SMUs, VSUs, PGUs, and GNDU. When the pointer is located in this column, allowable output functions appear in the secondary softkey area. You select a softkey to set an output function.

  - SMU or VSU: you can set VAR1, VAR1', VAR2, or CONST.
  - PGU or GNDU: you can set CONST.

  Restrictions:

  - In FCTN column, you *cannot* set multiple VAR1, VAR1', or VAR2. For example, you *cannot* set VAR1 for 2 units.
  - If VAR1' is set, you must set VAR1 also.
  - If VAR2 is set, you must set VAR1 also.
  - The output modes of VAR1 and VAR1' must be same. That is, the MODE setting for both must be set to a voltage mode, or both must be set to a current mode. For example, you can set VAR1 to V and VAR1' to VPULSE.
  - You *cannot* set VAR1, VAR1', or VAR2 for sampling measurement. You can set CONST only.

- STBY

  STBY field specifies which channels output source values in the standby state.

  - □ If STBY is set to ON, the unit forces a specified output value when in the standby state.
  - □ If STBY is blank, the unit outputs 0 V in the standby state (same as when in idle state).

  See "Types of Operation State" in Chapter 3 for more information on the standby state.

  Restrictions:

  - □ If both PGUs are set to VPULSE, the STBY setting of both PGUs must be the same.
  - □ For STBY=ON channel, SERIES RESISTANCE setting must be 0 ohm.

- SERIES RESISTANCE

  In the SERIES RESISTANCE fields, you select the value that you want to set in the HP 16441A R-Box. When the pointer is located in this field, allowable resistance values are shown in the secondary softkey area. You select the desired series resistance.

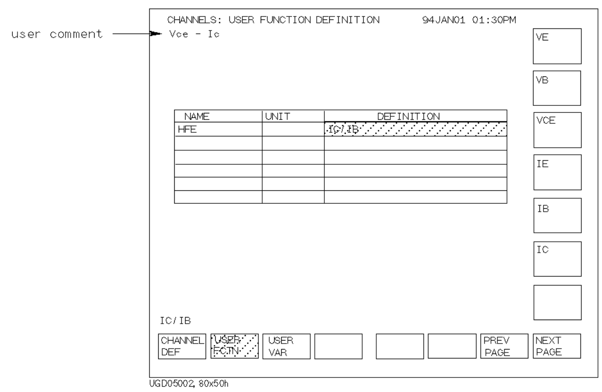
  Normally, SMU1 and SMU2 have SERIES RESISTANCE fields. However, if the SMU and Pulse Generator Expander is installed and if the expander has an HPSMU, then SMU1 and SMU5 have SERIES RESISTANCE fields.

  If HP 16441A R-box is *not* installed, you must set 0Ω in this field.

  Restrictions:

  - □ To use Kelvin connection for HRSMU or HPSMU, you must select 0 Ω.
  - □ For STBY channels, you can set 0 Ω only.
  - □ For COMMON channels, you can set 0 Ω only.

CHANNELS: USER FUNCTION DEFINITION page



On this page, you define user functions. For details about user functions, refer to "User Function" in Chapter 6.

User Comment

In this field, you can enter a desired comment, which is also displayed in the CHANNELS, MEASURE, DISPLAY, and GRAPH/LIST page groups.

- NAME

  NAME field defines the user function name. In this field, you can enter a name by using the keyboard or front panel keys. Or you can select variables that are shown on the secondary softkeys.

  To delete a user function, you can select `DELETE ROW` to delete the NAME, UNIT, and DEFINITION entries.

  After defining a user function, you can use this variable name for reference on other pages.

  Restrictions

  - NAME must be 6 or less alphanumeric characters. First character must be alphabet character.

- NAME must be different from other names. The alphabet characters are case sensitive. For example, HFE is different from Hfe.

- UNIT (optional)

  UNIT defines the unit of the user function. This unit is used on the graph and list result pages.

  Restriction: UNIT must be 6 or less alphanumeric characters.

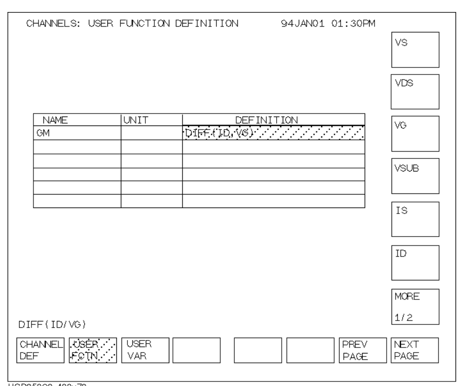
  To delete a user function, you can select `DELETE ROW` to delete the NAME, UNIT, and DEFINITION entries.

- DEFINITION

  You enter an expression that defines the user function. The expression can consist of numerical operators, constants, variables, built-in functions, and other user-defined functions.

  By selecting secondary softkeys, you can enter VNAMEs or INAMEs that are set on the CHANNELS: CHANNEL DEFINITION page.

  For syntax, see "Expression" in Chapter 6. For example, to define a user function for mutual conductance *gm* of an FET, define *gm* on this page as follows:



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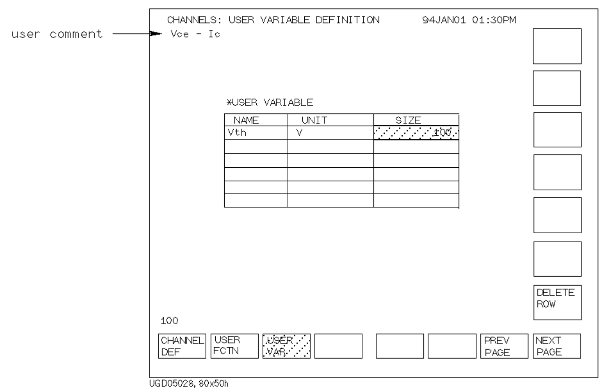
CHANNELS: USER VARIABLE DEFINITION page



On this page, you register user variables that were defined by HP-IB. To use a user variable, you must register it on this page. For details about user variables, refer to "User Variable" in Chapter 6.

User Comment

In this field, you can enter a desired comment, which is also displayed in the CHANNELS, MEASURE, DISPLAY, and GRAPH/LIST page groups.

- NAME

  NAME field defines the user variable name. You can enter a name by using the keyboard or front-panel keys.

  To delete a user variable, select DELETE ROW to delete the NAME, UNIT, and SIZE entries.

  After defining a user variable, you can use this variable name for reference on other pages.

  Restrictions

  - NAME must be 6 or less alphanumeric characters. First character must be alphabet character.

- NAME must be different from other names. The alphabet characters are case sensitive. For example, HFE is different from Hfe.

- UNIT (optional)

  UNIT defines the unit of the user variable. This unit is used on the graph and list result pages. You can enter the unit by using the keyboard or front-panel keys.

  To delete a user variable, select `DELETE ROW` to delete the NAME, UNIT, and SIZE entries.

  Restriction: UNIT must be 6 or less alphanumeric characters.

- SIZE

  SIZE field sets the number of data for the user variable. The number of data must be 10001 or less (total for all measurement data and user variables). You can enter the size by using the keyboard or front-panel keys.

  To delete a user variable, select `DELETE ROW` to delete the NAME, UNIT, and SIZE entries.

MEASURE Page Group

MEASURE page group has the following pages:

Sweep Setup or Sampling Setup:	For setting the parameters for sweep or sampling measurement, which was defined in the CHANNELS: CHANNEL DEFINITION page.
PGU Setup:	For setting the PGU parameters. This page is available when PGU is installed and the MODE and FCTN field of PGUs are set on the CHANNELS: CHANNEL DEFINITION page.
Measure Setup:	For setting the measurement range, integration time, zero cancel, and wait time.
Output Sequence:	For setting the output sequence and triggering.

To move into the MEASURE page group, do one of the following:

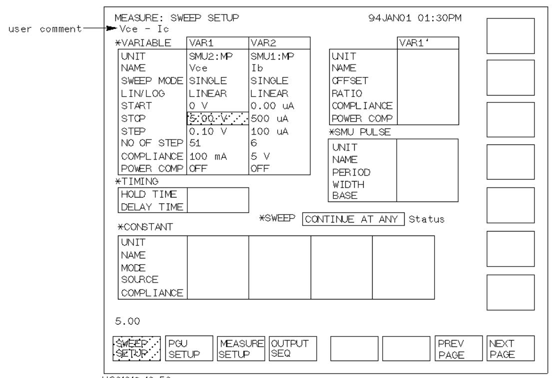
- Press (Meas) front-panel key in the PAGE CONTROL key group.
- Select NEXT PAGE primary softkey in the CHANNELS: USER FUNCTION DEFINITION page.
- Select PREV PAGE primary softkey in the DISPLAY: DISPLAY SETUP page.

Then, the following primary softkeys appear:

SWEEP SETUP	PGU SETUP	MEASURE SETUP	OUTPUT SEQ			PREV PAGE	NEXT PAGE

- Select SWEEP SETUP softkey to move to MEASURE: SWEEP SETUP page.
- Select SAMPLNG SETUP softkey to move to MEASURE: SAMPLING SETUP page.
- Select PGU SETUP softkey to move to MEASURE: PGU SETUP page.
- Select MEASURE SETUP softkey to move to MEASURE: MEASURE SETUP page.
- Select OUTPUT SEQ softkey to move to MEASURE: OUTPUT SEQUENCE page.

MEASURE: SWEEP SETUP page



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On this page, you set output parameters for each unit.

User Comment

In this field, you can enter a desired comment, which is also displayed in the CHANNELS, MEASURE, DISPLAY, and GRAPH/LIST page groups.

VAR1 parameters

In this column, you set up output parameters for primary sweep unit. UNIT and NAME are defined on CHANNELS: CHANNEL DEFINITION page.

- SWEEP MODE

  SWEEP MODE field sets **single** or **double sweep mode**. In this field, select:

  - `SINGLE` secondary softkey to specify the single sweep mode.
  - `DOUBLE` secondary softkey to specify the double sweep mode.

- LIN/LOG

  LIN/LOG field sets **linear** or **logarithmic sweep mode**. In this field, select:

  - `LINEAR` secondary softkey to set linear sweep mode.
  - `LOG10`, `LOG25`, or `LOG50` secondary softkey to set logarithmic sweep mode. The number specifies the sweep points per decade.

- START, STOP, and STEP

  In the START, STOP, and STEP fields, you specify the **start**, **stop**, and **step values**. The step value is used for the linear sweep mode *only*.

  The following applies to logarithmic sweep mode only:

  - □ STEP field has no meaning, so "`------`" is shown in the STEP field.
  - □ Start and stop values must be the same polarity.
  - □ If you specify `0` (zero) for the start or stop value, the minimum output value for the unit is used.
  - □ You specify the number of steps per decade in the LIN/LOG field.

- NO. OF STEP

  For the linear sweep mode, the number of steps is calculated from the start, stop, and step values, and appears in the NO. OF STEP field.

  For the logarithmic sweep mode, the number of steps is calculated from the start, stop, and LIN/LOG values, and appears in the NO. OF STEP field.

- COMPLIANCE

  In the COMPLIANCE field, you set the **compliance value**. If a VSU is used for the VAR1 unit, this field *cannot* be set: compliance value is fixed to 100 mA.

- POWER COMP

  In the POWER COMP field, you can set a **power compliance value** for SMUs. To disable the power compliance function, select the `OFF` secondary softkey. If *an* SMU is set to VPULSE or IPULSE mode and if the SMU is set to VAR1, you *cannot* set power compliance for the VAR1 SMU.

VAR2 parameters

In this column, you set up the output parameters for the secondary sweep unit. UNIT and NAME are defined on the CHANNELS: CHANNEL DEFINITION page.

SWEEP MODE and LIN/LOG fields are fixed to SINGLE and LINEAR.

- START, STEP, and NO. OF STEP

  In the START, STEP, and NO OF STEP fields, you specify the start value, step value, and number of steps. The stop value is calculated from these values, and is shown in the STOP field.

- COMPLIANCE

  In COMPLIANCE field, you set compliance value. If a VSU is used for VAR2 unit, this field *cannot* be set: compliance value is fixed to approximately 100 mA.

- POWER COMP

  In POWER COMP field, you can set power compliance value for SMUs. To disable power compliance function, select `OFF` secondary softkey.

VAR1' parameters

In this column, you set up the output parameters for the synchronous sweep unit. This VAR1' table is displayed only when VAR1' is set in the FCTN field on the CHANNELS: CHANNEL DEFINITION page.

UNIT and NAME are defined on CHANNELS: CHANNEL DEFINITION page.

- OFFSET and RATIO

  In the OFFSET and RATIO fields, you specify the *offset* and *ratio* values. The offset and ratio values determine the VAR1' value as follows:

  $$VAR1'\ output = VAR1\ output \times ratio + offset$$

- COMPLIANCE

  In COMPLIANCE field, you set compliance value. If a VSU is used for VAR1' unit, this field *cannot* be set: compliance value is fixed to 100 mA.

- POWER COMP

  In the POWER COMP field, you can set the power compliance value. To disable the power compliance function, select `OFF` secondary softkey. If *an* SMU is set to VPULSE or IPULSE mode and if the SMU is set to VAR1', you *cannot* set power compliance for the VAR1' SMU.

TIMING

- HOLD TIME

  In the HOLD TIME field, you set the **hold time**. The output unit waits this time after forcing the start value. Range: 0 to 655.35 s. Resolution: 10 ms.

- DELAY TIME
  In DELAY TIME field, you set the **delay time**. The output unit waits this time after each step, then starts measurement. If an SMU is set up to be a pulse source, DELAY TIME field is not displayed because each step is synchronized with pulse output. Range: 0 to 65.535s. Resolution: 100μs.

SWEEP Status

- Select CONT AT ANY secondary softkey (sweep will continue even if an abnormal status occurs). Abnormal status means the following:
  - □ SMU reaches its compliance setting.
  - □ Current of VSU exceeds approximately ±100 mA.
  - □ SMU or VSU oscillates.
  - □ A/D converter overflow occurs.
  - □ Average current of PGU exceeds ±100 mA.
- Select STOP AT ANY ABNORM secondary softkey (sweep will stop if any abnormal status occurs).
- Select STOP AT COMPLIANCE secondary softkey (sweep will stop only if SMU reaches its compliance setting).

STOP AT COMPLIANCE is automatically set when power compliance is set for SMUs, or when 10k ohm, 100k ohm, or 1M ohm is selected in the SERIES RESISTANCE field.
If power compliance is set for an SMU, the CONT AT ANY secondary softkey is not displayed.

SMU PULSE

These parameters set the SMU pulsed source (IPULSE or VPULSE). The SMU pulsed source is defined on the CHANNELS: CHANNEL DEFINITION page, so the UNIT and NAME fields are already set.

In the PERIOD, WIDTH, and BASE fields, you specify the pulse period, pulse width, and pulse base value. The pulse peak value is determined by the settings in the VAR1, VAR2, VAR1', or CONSTANT field.

Be aware that if any of following are true, pulsed SMU channel may not output the pulse period and pulse width you specified:

- Measurement range differs from compliance range (lowest range that includes compliance).
- Ranging mode is set to auto range or limited auto range.
- Multi-channel measurement is set.

CONSTANT

These parameters set the constant source units. UNIT, NAME, and MODE are defined on the CHANNELS: CHANNEL DEFINITION page.

- SOURCE

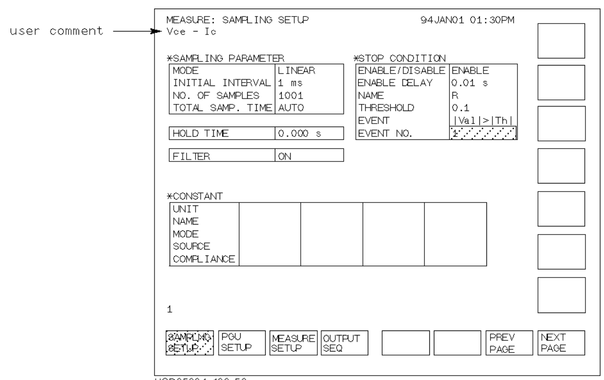
  In the SOURCE field, you specify the output value.

- COMPLIANCE

  In this field, you set compliance value. If VSU is used for constant output unit, this field cannot be set: compliance value is fixed to 100 mA.

If you define more than four constant output units, the first four units appear in the CONSTANT fields. To show other units, select `NEXT UNIT` secondary softkey. To scroll the units, put field pointer in most right or left column, then press (⇒) or (⇐) MARKER/CURSOR front-panel keys.

MEASURE: SAMPLING SETUP page



UGD05004, 100x50

On this page, you set sampling parameters for each unit.

User Comment

In this field, you can enter a desired comment, which is also displayed in the CHANNELS, MEASURE, DISPLAY, and GRAPH/LIST page groups.

SAMPLING PARAMETER

- MODE

  MODE field sets the **sampling mode**. For details about sampling mode, refer to "Sampling Measurement Mode" in Chapter 2. In this field, select:

  - LINEAR secondary softkey to specify the linear sampling mode.
  - LOG10, LOG25, or LOG50 secondary softkey to specify the logarithmic sampling mode. The number specifies how many samples to take per decade.
  - Select THINNED-OUT to specify the thinned-out sampling mode, which discards less recent samples.

- INITIAL INTERVAL

  In the INITIAL INTERVAL field, you set the **initial interval**.

- NO. OF SAMPLES
  This field sets the **number of samples**. The number of samples must be 10001 or less (total for all units that make measurements plus size of all registered user variables). The number of units that make measurements is determined by the DISPLAY: DISPLAY SETUP page.
- TOTAL SAMP. TIME

  TOTAL SAMP. TIME field sets the **total sampling time**. The total sampling time must satisfy the following condition:

  $total\ sampling\ time \geq initial\ interval \times number\ of\ samples$

  In this field, enter a value or select:

  □ `NO LIMIT` secondary softkey to continue the sampling until sampling completion condition is satisfied.
  □ (for linear sampling mode only) `AUTO` secondary softkey to set the total sampling time to *initial interval*×*number of samples*.
- HOLD TIME

  HOLD TIME field sets the **hold time**. The unit waits this time after forcing the specified constant value, then sampling starts.

  Range: (for *initial interval*<2 ms) −30ms to 655.35s with 100μs resolution.
  (for *initial interval*≥2ms) 0 to 655.35s with 100 μs resolution.
- FILTER
  This field specifies SMU filter to `ON` or `OFF`. If this field is set to `ON`, overshoot is decreased, but settling time takes several ms. Be aware of this if you set initial interval to a short time.

STOP CONDITION

- ENABLE/DISABLE
  This field defines whether the **stop conditions** are enabled. Cannot ENABLE if INITIAL INTERVAL < 2 ms. In this field, select:

  □ `ENABLE` secondary softkey to enable the stop conditions.

  □ `DISABLE` secondary softkey to disable the stop conditions.
- ENABLE DELAY
  This field sets the **enable delay** time. The stop condition is ignored for the enable delay time after the sampling starts. The resolution of enable delay time is the initial interval time.

- NAME

  NAME field sets the variable name or user function name that you want to monitor for the stop conditions. Allowable variable names and user function names are shown in the secondary softkey area.

- THRESHOLD

  In the THRESHOLD field, you set the **threshold value**.

- EVENT

  In the EVENT field, you set the event type as follows:

  - `Val>Th` : event occurs when NAME value is greater than THRESHOLD.
  - `Val<Th` : event occurs when NAME value is less than THRESHOLD.
  - `|Val|>|Th|` : event occurs when absolute NAME value is greater than absolute THRESHOLD value.
  - `|Val|<|Th|` : event occurs when absolute NAME value is less than absolute THRESHOLD value.

- EVENT NO.

  EVENT NO. specifies sampling to stop if event occurs EVENT NO. times. EVENT NO. can be an integer from 1 to 200.

CONSTANT

This is for setting the output parameters of the constant source units. UNIT, NAME, and MODE are defined on the CHANNELS: CHANNEL DEFINITION page.

- SOURCE

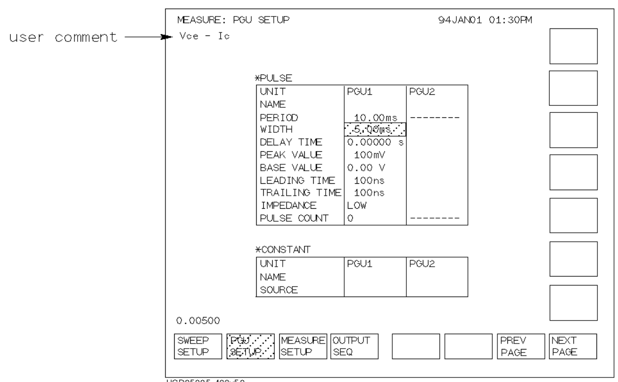
  In the SOURCE field, you specify the output value.

- COMPLIANCE

  In the COMPLIANCE field, you specify the compliance value. If a VSU is used for the constant output unit, this field cannot be set: compliance value is fixed to 100 mA.

If you define more than four constant output units, first four units appear in CONSTANT fields. To show other units, select `NEXT UNIT` secondary softkey. To scroll units, put field pointer in most right or left column, then press [⇒] or [⇐] MARKER/CURSOR front-panel keys.

MEASURE: PGU SETUP page



UGD05005, 100x50

On the "MEASURE: PGU SETUP" page, you set output parameters for each PGU. For more information about PGUs, see "Pulse Generator Unit (PGU)" in Chapter 1.

User Comment

In this field, you can enter a desired comment. The comment you enter here is also displayed in the CHANNELS, MEASURE, DISPLAY, and GRAPH/LIST page groups.

PULSE

You set the pulse output parameters in the PULSE area.

UNIT and NAME are defined on the CHANNELS: CHANNEL DEFINITION page.

- PERIOD

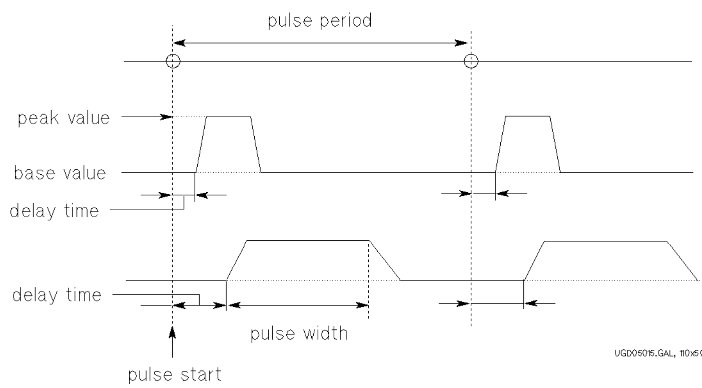
  PERIOD field specifies the pulse period of the PGU. Note that the pulse period of PGUs is independent from that of the SMUs.

- WIDTH

  WIDTH field specifies the pulse width. The pulse width must be less than the pulse period.

- DELAY TIME

  DELAY TIME field specifies the delay time from the pulse period start time. The delay time must be less than or equal to the pulse period.



PGU Parameters

- PEAK VALUE and BASE VALUE

  PEAK VALUE and BASE VALUE fields specify the pulse peak and pulse base values.

- LEADING TIME and TRAILING TIME

  LEADING TIME and TRAILING TIME fields specify the transition time of leading and trailing edges, which is time for pulse to change from 10% to 90% of pulse amplitude.

- IMPEDANCE

  IMPEDANCE field specifies the PGU output impedance. In this field, select:

  - □ `LOW` secondary softkey to set output impedance to about 0Ω.
  - □ `50 ohm` secondary softkey to set output impedance to 50Ω.

- PULSE COUNT

  PULSE COUNT field specifies the number of pulses for the sampling measurement (for sweep measurements, only FREE RUN is available).

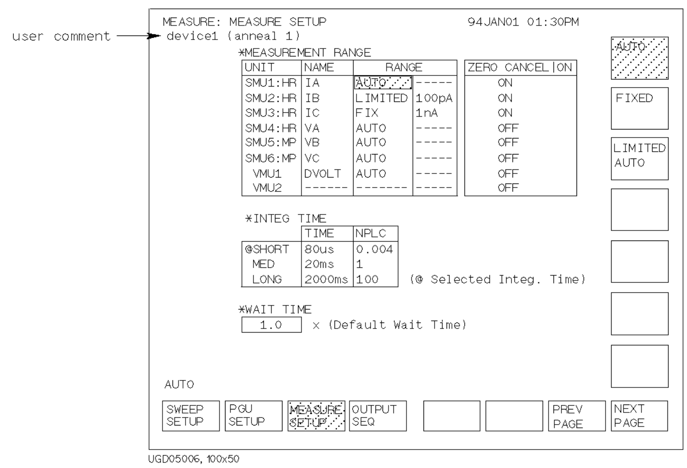
  - ☐ Enter a pulse count value (only for sampling measurements).
  - ☐ Select FREE RUN or enter 0 (zero) to set continuous pulse output. If either PGU1, PGU2, or both are set to standby ON on the CHANNELS: CHANNEL DEFINITION page, this field is automatically set to *free run* mode.

CONSTANT

UNIT and NAME are defined on CHANNELS: CHANNEL DEFINITION page.

In the SOURCE field, you specify the output value.

MEASURE: MEASURE SETUP page



On the “MEASURE: MEASURE SETUP” page, you set measurement range, zero cancel, integration time, and wait time.

User Comment

In this field, you can enter a desired comment. The comment you enter here is also displayed in the CHANNELS, MEASURE, DISPLAY, and GRAPH/LIST page groups.

MEASUREMENT RANGE

You can set the measurement range for each unit.

- UNIT

  The UNIT field shows all the installed measurement units. Only measurement units are shown, so VSU, PGU, and GNDU are not shown.

- NAME

  The NAME field shows all names for the measurement units, which you defined on the CHANNELS: CHANNEL DEFINITION page. For example, when the SMU1 is set to V mode, current value is measured. So the current name (INAME) is shown in the NAME field.

- RANGE

  The left field of RANGE specifies the **ranging mode**. In this field, select:

  - □ `AUTO` secondary softkey to set **auto-ranging** mode.
  - □ `FIXED` secondary softkey to set **fixed-ranging** mode.
  - □ `LIMITED AUTO` secondary softkey to set **limited auto-ranging** mode.

  The right field of RANGE specifies the **range value**. For auto-ranging mode, "`------`" appears. For the fixed-ranging and limited auto-ranging modes, allowable range values are shown in the secondary softkey area. You select a softkey to set the range value.

  For details, see "Measurement Ranging Mode" in Chapter 3.

- ZERO CANCEL

  ZERO CANCEL field specifies **zero offset cancel mode**. Select `ZERO CANCEL ON/OFF` to toggle the zero offset cancel mode between on and off.

  If the zero offset cancel mode is set to OFF, then `OFF` appears in all the ZERO CANCEL fields. If zero offset cancel mode is set to ON, then `ON` or `OFF` appear automatically in each field depending on the measurement range.

  For details, see "Zero Offset Cancel" in Chapter 3.

INTEG TIME

INTEG TIME area shows integration time and corresponding number of power line cycles (NPLC) for short, medium, and long modes. You can change integration time for short and long modes, but not for medium mode.

The selected integration time is indicated by @, and is used for all measurement units. You select the integration time by using the [Short], [Medium], or [Long] front panel keys from any page.

- SHORT

  The TIME field for SHORT shows the integration time of the short mode. You can change this integration time. NPLC value is calculated from the integration time and power line frequency.

- MED

  The TIME field for MED shows the integration time of the medium mode, which is calculated from the power line frequency and NPLC value. NPLC value is always 1. You cannot change it.

- LONG

  The TIME field for LONG shows the integration time of the long mode, which is calculated from the NPLC and power line frequency. You can change the NPLC value.

For details, see “Integration Time” in Chapter 3.

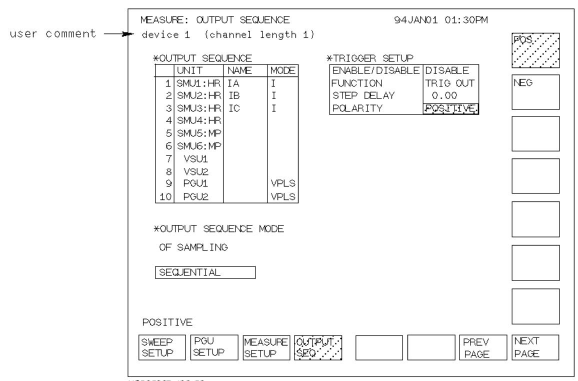
WAIT TIME

For each unit, the HP 4155A/4156A automatically uses a wait time that depends on the range value. This is the default wait time. In the WAIT TIME field, the value you specify is multiplied times the default wait time. Allowed values are 0.0 to 10.0 with 0.1 step.

The wait time is the time that a unit waits after forcing a value. During the wait time, the unit cannot start the measurement.

The default wait time is recommended. It is not easy to determine the best wait time. If you specify a wait time that is too short, the measurement may start before the output is stable. If too long, time will be wasted.

MEASURE: OUTPUT SEQUENCE page



UGD05007,100x50

On this page, you set the output sequence and triggering parameters for measurement state.

The output sequence set on this page is also used when the state changes from idle state to stress force state.

For trigger setup for stress force state, see “Stress Output Channels” in Chapter 3.

User Comment

In this field, you can enter a desired comment, which is also displayed in the CHANNELS, MEASURE, DISPLAY, and GRAPH/LIST page groups.

OUTPUT SEQUENCE

In the UNIT column, allowable units are shown in output sequence order. Only output units are shown, so VMU and GNDU are not shown. In the NAME and MODE fields, the output names and mode that you set up on the CHANNELS: CHANNEL DEFINITION page are shown.

To change the output order of the units, enter unit names in desired order by selecting secondary softkeys.

For details about default sequence, see “Sequential Mode” in Chapter 3.

OUTPUT SEQUENCE MODE OF SAMPLING

For a sampling measurement, you can set the output sequence to **sequential mode** or **simultaneous mode**. This field is displayed only when sampling mode is selected on the CHANNELS: CHANNEL DEFINITION page. If you select sequential mode, OUTPUT SEQUENCE table determines the output order. If you select simultaneous mode, all the units force at the same time.

TRIGGER SETUP

- ENABLE/DISABLE

  ENABLE/DISABLE field defines whether the triggering function is used or not. In this field, select:

  - `ENABLE` secondary softkey to enable the triggering function.
  - `DISABLE` secondary softkey to disable the triggering function.

- FUNCTION

  FUNCTION field sets the triggering mode.

  - Select `TRIG OUT` secondary softkey to enable the following functions:
    - For a normal (non-pulse) sweep measurement, HP 4155A/4156A outputs an edge-trigger signal when a measurement starts for each step.
    - For a pulsed sweep measurement, HP 4155A/4156A outputs an edge-trigger signal synchronized with the pulse leading edge.
  - Select `TRIG IN` to enable the following function:
    - Sweep measurement or sampling measurement starts when the HP 4155A/4156A receives a trigger signal from an external instrument.

- STEP DELAY

  STEP DELAY field is displayed when you set staircase sweep measurement. The step delay time is the time from when the trigger is output to when the next step occurs. For details about setup delay time, refer to "Triggering an External Instrument" in Chapter 3. When you set `TRIG IN` in the FUNCTION field, this field has no meaning , so "`-----`" is displayed.

- TRIG OUT DELAY

  TRIG OUT DELAY field is displayed when you set pulse sweep measurement. The trigger output delay time specifies how much to delay the trigger after the leading edge. For details about trigger output delay time, refer to "Triggering an External Instrument" in Chapter 3. When you set `TRIG IN` in the FUNCTION field, this field has no meaning, so "`-----`" is displayed.

- POLARITY

  In the POLARITY field, select secondary softkeys to select trigger polarity as follows: `POSITIVE` or `NEGATIVE`.

DISPLAY Page Group

DISPLAY page group has the following pages:

Display Setup:	For setting the graphics/list display mode, the parameters for graphics/list page, and measurement channels.
Analysis Setup:	For defining where to automatically display lines and marker after a measurement.

To move into the DISPLAY page group, do one of the following:

- Press (Display) front-panel key in the PAGE CONTROL key group.
- Select NEXT PAGE primary softkey in the MEASURE: OUTPUT SEQUENCE page.

Then, the following primary softkeys appear:

DISPLAY SETUP	ANLYSIS SETUP					PREV PAGE	NEXT PAGE

- Select DISPLAY SETUP softkey to move to the DISPLAY: DISPLAY SETUP page.
- Select ANLYSIS SETUP softkey to move to DISPLAY: ANALYSIS SETUP page.

Execution Timing of the Automatic Analysis Function

You set up automatic analysis on the DISPLAY: ANALYSIS SETUP page.

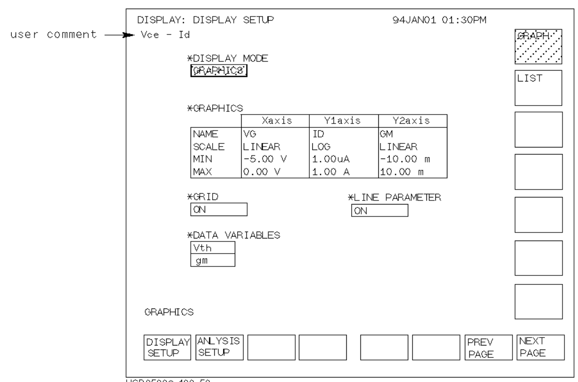
Automatic analysis function is executed:

- after a measurement is executed by (Single) or (Append) front-panel key.
- when the (Stop) front-panel key is pressed to stop the measurement.
- after each measurement execution (before the next measurement execution).
- when you select the AUTO ANALYSIS secondary softkey after selecting the MARKER/CURSOR primary softkey on the GRAPH/LIST: GRAPH or GRAPH/LIST: LIST page.
- when you return to the GRAPH/LIST: GRAPH or GRAPH/LIST: LIST page after changing the condition of the automatic analysis function on the DISPLAY: ANALYSIS SETUP page.

If you define both the automatic marker positioning and automatic line drawing functions, the functions are executed in the following order:

1. Automatic line drawing for LINE1.
2. Automatic line drawing for LINE2.
3. Automatic marker positioning.

DISPLAY: DISPLAY SETUP page for graphic results



UGD05008, 100x50

On the "DISPLAY: DISPLAY SETUP" page for graphics results, you set axes, grid, and data variable names for the "GRAPHICS" page. The channels that actually perform measurements are determined by the axis names and data variables that you set on this page.

User Comment

In this field, you can enter a desired comment. The comment you enter here is also displayed in the CHANNELS, MEASURE, DISPLAY, and GRAPH/LIST page groups.

DISPLAY MODE

In the DISPLAY MODE field, you specify the display mode. If present display mode is list mode, then select the GRAPHICS secondary softkey to change to graphics mode.

GRAPHICS

In the GRAPHICS area, you set up the X, Y1, and Y2 axes. You must set up the X and Y1 axes. Y2 axis is optional.

- NAME

  NAME fields specify the variable names that you want to assign to the axes, which will be plotted on the GRAPHICS page. In this field, you can select the desired variable names in the secondary softkey area.

  The entries in these fields and the data variable fields determine which channels will actually make measurements.

- SCALE

  The SCALE fields specify linear or logarithmic scale for the axis by selecting `LINEAR` or `LOG` secondary softkey.

- MIN and MAX

  MIN and MAX fields specify the minimum and maximum values for the axis. The minimum and maximum values are automatically set according to the NAME and SCALE settings. You can modify these values if desired.

GRID

In the GRID field, you can specify whether to display the grid on the plotting area by selecting `ON` or `OFF` secondary softkey.

LINE PARAMETER

In the LINE PARAMETER field, you can specify whether to display X and Y intercepts and gradients of lines on the plotting area by selecting `ON` or `OFF` secondary softkey.

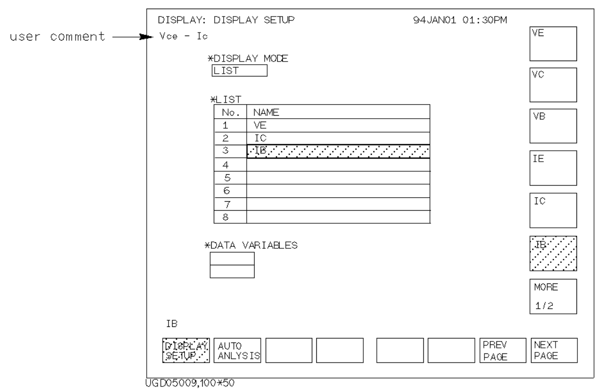
OFF	The line parameters are not displayed.
ON	The line parameters are displayed when lines are displayed on the graph.

DATA VARIABLES

In the DATA VARIABLES fields, you can enter two variable names. The numerical values of these variables will be shown on the GRAPHICS page according to the marker position. In this field, you can select the desired variable names in the secondary softkey area.

Even if the setup data variables are defined using variables that are not set in the NAME field of the GRAPHICS table, the variables are automatically measured after pressing a measurement front-panel key.

DISPLAY: DISPLAY SETUP page for list results



On the "DISPLAY: DISPLAY SETUP" page for list results, you enter variable names for which you want results to be displayed numerically. The measurement channels are determined by the variable names that you set on this page.

User Comment

In this field, you can enter a desired comment, which is also displayed in the CHANNELS, MEASURE, DISPLAY, and GRAPH/LIST page groups.

DISPLAY MODE

This field specifies display mode. If present mode is graphics mode, select `LIST` softkey to change to list mode. LIST table is displayed.

LIST

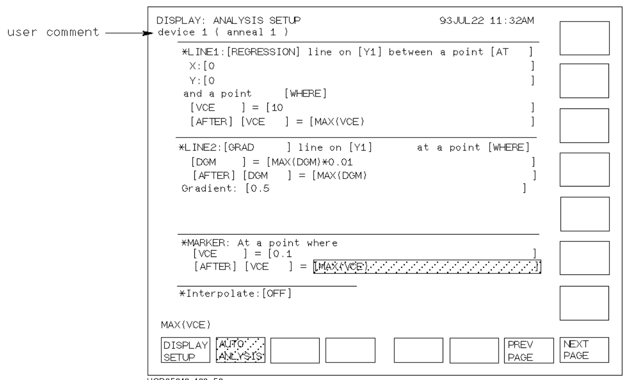
NAME fields of LIST area specify variables that you want to display on LIST page. You can enter the desired variable names. Entries in this area and data variable area determine which channels will actually make measurements. You can enter up to eight variable names. When the pointer is located in NAME field, you can select desired variable names in secondary softkey area.

DATA VARIABLES

DATA VARIABLES fields specify the variable names that you want to display on the GRAPH/LIST: LIST page. The numerical values of these variables will be shown on the LIST page according to the marker position. In this field, you can select the desired variable names in the secondary softkey area.

Even if the setup data variables are defined using variables that are not set in the NAME field of the LIST table, the variables are automatically measured after pressing a measurement front-panel key.

DISPLAY: ANALYSIS SETUP page



UGD05010, 100x50

On the “DISPLAY: ANALYSIS SETUP” page, you set up the automatic analysis function. When a measurement finishes, the function automatically draws lines, a marker, or both as specified on this page.

You can set up two lines and one marker for the automatic analysis function. In the LINE1 and LINE2 fields, you can set up the lines to be drawn. In the MARKER field, you set up the marker.

For the automatic analysis function and the manual analysis function, four line modes can be used:

- Normal mode: drawing a line between *any two* points.
- Grad mode: drawing a line through *any point* with a specified gradient.
- Tangent mode: drawing a tangent to a *measurement* point.
- Regression mode: drawing a regression line for the area specified by *any two* points.

The following explains how to set up the lines and marker. For details about line modes, refer to “Line Drawing” in Chapter 6.

User Comment

In this field, you can enter a desired comment. This comment is also displayed in the CHANNELS, MEASURE, DISPLAY, and GRAPH/LIST page groups.

Normal mode line

In the first bracketed field after `LINE1` or `LINE2`, you select the line mode. Select the `NORMAL` secondary softkey to set the normal line mode. The pointer moves to the second bracketed field as shown:

```
LINE1: [NORMAL   ] line on [Y1] between a point [AT   ]
```

In the second bracketed field, you specify which measurement curve you want to analyze by selecting the related axis: `Y1` or `Y2` secondary softkey.

In the third bracketed field, you specify how to select a point:

- Select `BY X-Y COORDINATE`. "`AT`" is displayed. Then, you enter the desired X-Y coordinate values or expressions in the `X:` and `Y:` fields.
- Select `BY DATA CONDITION`. "`WHERE`" is displayed. Then, you enter a variable name and condition expression to specify a measurement point.

```
LINE1: [NORMAL   ] line on [Y1] between a point [AT   ]
 X: [0                                                 ]
 Y: [0                                                 ]
and a point [WHERE]
 [DGM   ] = [MAX(DGM)*0.01                             ]
 [     ]
```

In addition, you can specify another condition if you position the pointer in the last bracketed field shown above. Select the `AFTER` secondary softkey. `AFTER` is displayed, and you can enter a second variable and condition expression. This sets up a search start condition for finding specified point. (This setup is optional.)

For example, you can specify the following expressions to search for a measurement point that satisfies the first condition after the second condition is satisfied.

```
LINE1: [NORMAL   ] line on [Y1] between a point [AT   ]
 X: [0                                                 ]
 Y: [0                                                 ]
and a point [WHERE]
 [DGM   ] = [MAX(DGM)*0.01                             ]
 [AFTER] [DGM   ] = [MAX(DGM)                          ]
```

On GRAPH/LIST: GRAPHICS page, `LINE` *secondary* softkey must be `ON`.

Gradient mode line

In the first bracketed field after LINE1 or LINE2, you select the line mode. Select the GRAD secondary softkey to set the gradient line mode. The pointer moves to the second bracketed field as shown:

```
LINE1: [GRAD     ] line on [Y1] at a point [     ]


Gradient: [                                        ]
```

In the second bracketed field, you specify which measurement curve you want to analyze by selecting the related axis: Y1 or Y2 secondary softkey.

In the third bracketed field, you specify how to select a point:

- Select BY X-Y COORDINATE. "AT" is displayed. Then, you enter the desired X-Y coordinate values or expressions in the X: and Y: fields.
- Select BY DATA CONDITION. "WHERE" is displayed. Then, you enter a variable name and condition expression to specify a measurement point.

```
LINE1: [GRAD     ] line on [Y1] at a point [WHERE]
 [DGM   ] = [MAX(DGM)*0.01                         ]
 [     ]
Gradient: [                                        ]
```

In addition, you can specify another condition if you position the pointer in the bracketed field above Gradient. Select the AFTER secondary softkey. AFTER is displayed, and you can enter a second variable and condition expression. This sets up a search start condition for finding specified point. (This setup is optional.)

For example, you can specify the following expressions to search for a measurement point that satisfies the first condition after the second condition is satisfied.

```
LINE1: [GRAD     ] line on [Y1] at a point [WHERE]
 [DGM   ] = [MAX(DGM)*0.01                         ]
 [AFTER] [DGM   ] = [MAX(DGM)                      ]
Gradient: [                                        ]
```

In a field after Gradient:, you enter a gradient value or expression.

On GRAPH/LIST: GRAPHICS page, LINE *secondary* softkey must be ON.

Tangent mode line

In the first bracketed field after `LINE1` or `LINE2`, you select the line mode. Select the `TANGENT` secondary softkey to set the tangent line mode. The pointer moves to the second bracketed field as shown:

```
LINE1: [TANGENT   ] line on [Y1] at a point where
  [      ] = [                                                  ]
  [     ]
```

In the second bracketed field, you specify which measurement curve you want to analyze by selecting the related axis: `Y1` or `Y2` secondary softkey.

Enter a variable name and condition expression to specify the measurement point for which you want to draw a tangent line.

```
LINE1: [TANGENT   ] line on [Y1] at a point where
  [DGM   ] = [MAX(DGM)*0.01                                     ]
  [     ]
```

In addition, you can specify another condition if you position the pointer in the last bracketed field shown above. Select the `AFTER` secondary softkey. `AFTER` is displayed, and you can enter a second variable and condition expression. This sets up a search start condition for finding specified point. (This setup is optional.)

For example, you can specify the following expressions to search for a measurement point that satisfies the first condition after the second condition is satisfied.

```
LINE1: [TANGENT   ] line on [Y1] at a point where
  [DGM   ] = [MAX(DGM)*0.01                                     ]
  [AFTER] [DGM   ] = [MAX(DGM)                                  ]
```

On GRAPH/LIST: GRAPHICS page, `LINE` *secondary* softkey must be `ON`.

Regression mode line

In the first bracketed field after `LINE1` or `LINE2`, you select the line mode. Select the `REGRESSION` secondary softkey to set the regression line mode. For details about regression calculation range, see "Line Drawing" in Chapter 6.

The pointer moves to second bracketed field as shown:

```
LINE1: [REGRESSION] line on [Y1] between a point [AT   ]
 X: [                                                  ]
 Y: [                                                  ]
and a point [AT   ]
 X: [                                                  ]
 Y: [                                                  ]
```

In the second bracketed field, you specify which measurement curve you want to analyze by selecting the related axis: `Y1` or `Y2` secondary softkey.

In the third bracketed field, you specify how to select a point:

- Select `BY X-Y COORDINATE`. "`AT`" is displayed. Then, you enter the desired X-Y coordinate values or expressions in the `X:` and `Y:` fields.
- Select `BY DATA CONDITION`. "`WHERE`" is displayed. Then, you enter a variable name and condition expression to specify a measurement point.

```
LINE1: [REGRESSION] line on [Y1] between a point [AT   ]
 X: [0                                                 ]
 Y: [0                                                 ]
and a point [WHERE]
 [DGM   ] = [MAX(DGM)*0.01                             ]
 [     ]
```

In addition, you can specify another condition if you position the pointer in the last bracketed field shown above. Select the `AFTER` secondary softkey. `AFTER` is displayed, and you can enter a second variable and condition expression. This sets up a search start condition for finding specified point. (This setup is optional.)

For example, you can specify the following expressions to search for a measurement point that satisfies the first condition after the second condition is satisfied.

```
LINE1: [REGRESSION] line on [Y1] between a point [AT   ]
 X: [0                                                  ]
 Y: [0                                                  ]
and a point [WHERE]
 [DGM   ] = [MAX(DGM)*0.01                              ]
 [AFTER] [DGM   ] = [MAX(DGM)                           ]
```

On GRAPH/LIST: GRAPHICS page, `LINE` *secondary* softkey must be `ON`.

Marker

In the next line after `MARKER: At a point where`, you enter a variable name and a condition expression to specify where you want the marker to appear as shown in the following example:

```
MARKER: At a point where
 [DGM   ] = [MAX(DGM)*0.01                              ]
 [     ]
```

In addition, you can specify another condition if you position the pointer in the last bracketed field shown above. Select the `AFTER` secondary softkey. `AFTER` is displayed, and you can enter a second variable and condition expression. This sets up a search start condition for finding specified point. (This setup is optional.)

For example, you can specify the following expressions to search for a measurement point that satisfies the first condition after the second condition is satisfied.

```
MARKER: At a point where
 [DGM   ] = [MAX(DGM)*0.01                              ]
 [AFTER] [DGM   ] = [MAX(DGM)                           ]
```

Disabling entries

In the field after `LINE1`, `LINE2`, or `MARKER`, you can select the `DISABLE` secondary softkey to clear the entries, which disables the item for the automatic analysis function.

Interpolation mode

You can also use the interpolation mode for the automatic analysis function by selecting the `ON` secondary softkey in the `Interpolate` field. When interpolation mode is on, you can position marker between measurement points. Select `OFF` to turn interpolation mode to off.

GRAPH/LIST Page Group

GRAPH/LIST page group has the following pages:

Graphic Results:	For displaying the measurement results graphically. You can use lines or a marker on the graphics page to analyze the measurement results graphically.
List Results:	For listing the measurement results.

To move into the GRAPH/LIST page group, do one of the following:

- Press (Graph/List) front-panel key in the PAGE CONTROL key group (if present page is not GRAPHICS or LIST page).
- Press (Single), (Repeat), or (Append) front-panel key (if present page is not GRAPHICS or LIST page). Measurement is performed.

If the present page is the GRAPHICS or LIST page, you can toggle between these pages by pressing the (Graph/List) front-panel key.

On the GRAPHICS results page.
In the primary softkey area of the GRAPHICS page, the following softkeys are available for performing the manual analysis functions:

For sweep measurements:

AXIS Y2	MARKER/ CURSOR	LINE	SCALING	DISPLAY SETUP	SWEEP SETUP	TIMING SETUP	CONST SETUP

For sampling measurements:

AXIS Y2	MARKER/ CURSOR	LINE	SCALING	DISPLAY SETUP	SAMPLNG SETUP	STOP COND	CONST SETUP

On the LIST results page.
In the primary softkey area of the LIST page, the following softkeys are available for performing the manual analysis functions:

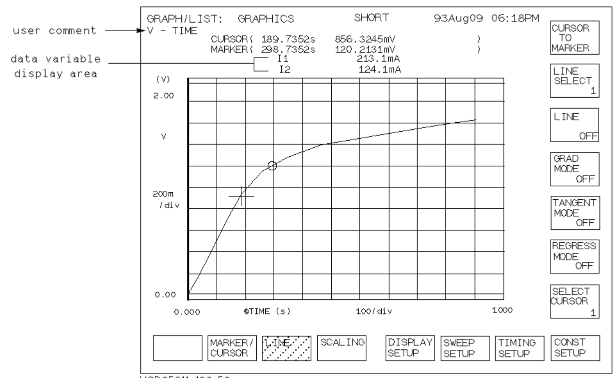
For sweep measurements:

AXIS Y2	MARKER		SPREAD SHEET	RE- SETUP	SWEEP SETUP	TIMING SETUP	CONST SETUP

For sampling measurements:

AXIS Y2	MARKER		SPREAD SHEET	RE- SETUP	SAMPLNG SETUP	STOP COND	CONST SETUP

GRAPH/LIST: GRAPHICS page



UGD05011, 100x50

On the "GRAPH/LIST: GRAPHICS" page, measurement results are displayed, and you can analyze the measurement results graphically.

User Comment

In this field, you can enter a desired comment. This comment is also displayed in the CHANNELS, MEASURE, DISPLAY, and GRAPH/LIST page groups.

Cursor/marker indicator

In these fields, the coordinate values of the cursor and marker locations are displayed. If cursor or marker is not displayed, these fields are blank. The three fields are for X, Y1, and Y2 coordinate values, respectively.

Data variable display

This area displays the numerical value of up to two variables that you set up on DISPLAY: DISPLAY SETUP page. These are values at the marker position.

Plotting area

In this area, measurement curves are drawn according to measurement results.

You can analyze measurement results by using lines or marker in this area. If you use lines, the X and Y intercept points and gradient are displayed.

AXIS
Y1

Select AXIS primary softkey to toggle active axis between the Y1 and Y2 axes (this softkey is displayed only if Y2 axis is used). The active axis name is displayed on the AXIS primary softkey.

For tangent or regression lines, the active line selected by LINE SELECT softkey is independent for each axis.

MARKER/
CURSOR

Select MARKER/CURSOR primary softkey to display secondary softkeys for performing analysis with marker and cursor.

- MARKER

  Select MARKER secondary softkey to toggle the marker on and off. Marker status is displayed on MARKER secondary softkey. If on, marker is displayed in the plotting area. If off, marker is not displayed.

  For Y1 axis, marker is a circle (∘). For Y2 axis, marker is an asterisk (∗). Active marker is highlighted for the axis that is selected by AXIS softkey.

  The HP 4155A/4156A remembers the location of marker. That is, when marker is turned off, then redisplayed, it appears at its previous location.

- MARKER MIN/MAX

  Select MARKER MIN/MAX secondary softkey to move the marker to the maximum or minimum measurement point value. The search direction is from present to last measurement point, then from first to present measurement point.

  After the search, the marker moves to the first minimum or maximum value that was found. If you press this softkey *again*, the marker moves to the next minimum or maximum value. If consecutive measurement points have the same minimum or same maximum value, the marker skips the values when you press the softkey again.

- INTERPOLATE

  Select INTERPOLATE secondary softkey to toggle the interpolation mode. If interpolation mode is on, marker can move on line between adjacent measurement points. If interpolation mode is off, marker can be positioned on measurement points only (not between measurement points).

- `DIRECT MARKER/CURSOR`

  Select `DIRECT MARKER/CURSOR` secondary softkey to display secondary softkeys for positioning the marker and cursor. A pointer appears in the `CURSOR` and `MARKER` coordinate fields. These fields are displayed only if cursor and marker are displayed in the plotting area.

  You can move the pointer to the desired field by using ⇐, ⇑, ⇒, and ⇓ of the MARKER/CURSOR key group. To move marker and cursors to desired position, enter coordinate values into corresponding fields as follows:

  - Enter the value by using numeric keys.
  - Change the value by rotating rotary knob.

  Select `CANCEL` primary softkey to move marker and cursor back to original position, and exit the direct marker and cursor function. Select `EXIT` primary softkey to exit the direct marker and cursor function.

  The marker can move on the measurement curve *only*, so changing the X value automatically changes the Y value, and vice versa. If the interpolation mode is off, the marker moves to the measurement point that is closest to the specified coordinate.

  If the pointer is in a `MARKER` coordinate field, the following softkeys appear:

  - Select `MIN/MAX` secondary softkey to move marker to minimum measurement value. If marker is at minimum value, marker moves to maximum value.
  - Select `INTERPOLATE` secondary softkey to toggle the interpolation mode on or off. The present mode is displayed on the `INTERPOLATE` softkey.
  - Select `SEARCH MORE` secondary softkey to move marker to the next candidate (when more than one measurement point satisfies the specified value).
  - Select `MARKER SKIP` secondary softkey to move the marker to the next measurement curve that was added by VAR2 variable or append measurement.

  If the pointer is in a `CURSOR` coordinate field, the following softkey appears:

  - Select `MIN/MAX` secondary softkey to move cursor to minimum axis point. If cursor is at minimum point, cursor moves to maximum point.

When a Specified Value is Inappropriate

When a specified value is inappropriate, marker or cursor is located as follows:

- marker
  If the specified value for marker is greater or less than the maximum or minimum measurement value, the marker moves to the maximum or minimum *measurement point*.
- cursor
  If a specified value for cursor is greater or less than maximum or minimum scale value, cursor moves to the maximum or minimum *axis point*.

- `MARKER SKIP`

  Select `MARKER SKIP` secondary softkey to move the marker to the next measurement curve that was added by VAR2 variable or append measurement.

- `CURSOR`

  Select `CURSOR` secondary softkey to toggle the cursor display. The cursor status changes between `OFF`, `SHORT`, and `LONG`, which is shown on the `CURSOR` softkey.

- `AUTO ANALYSIS`

  Select `AUTO ANALYSIS` secondary softkey to redisplay the auto-analysis that was originally displayed after the measurement was finished.

LINE

Select LINE primary softkey to display the secondary softkeys for performing manual analysis that uses lines.

- CURSOR TO MARKER

  Select CURSOR TO MARKER secondary softkey to move the cursor to the marker position. Both marker and cursor must be displayed.

- LINE SELECT

  Selecting this secondary toggles as follows:

  □ 1: line 1 is selected, and can be operated on.
  □ 2: line 2 is selected, and can be operated on.
  □ NONE: no lines are selected. The line secondary softkeys disappear.

  You use the following softkeys to operate on each line. LINE SELECT setting is not changed by auto-analysis function.

- LINE

  Select LINE secondary softkey to toggle the line mode between OFF and ON. You can set up two lines for each axis.

  OFF Line selected by LINE SELECT softkey disappears.

  ON Line selected by LINE SELECT softkey is displayed.

  If ON is displayed on this softkey, and OFF is displayed on GRAD MODE, TANGENT MODE, and REGRESS MODE softkeys, the line mode is normal.

  If you display lines by auto-analysis functions, you need to set LINE softkey to ON in advance.

- GRAD MODE

  Select GRAD MODE secondary softkey to change the line mode to gradient mode. If present mode is gradient mode, ON is displayed on the GRAD MODE softkey.

  For gradient line mode, GRAD VALUE secondary softkey is displayed.

  If line mode is gradient mode, selecting GRAD MODE softkey changes to normal mode.

- TANGENT MODE

  Select TANGENT MODE secondary softkey to change the line mode to tangent mode. If present mode is tangent mode, ON is displayed on the TANGENT MODE softkey.

  For tangent line mode, MARKER SKIP secondary softkey is displayed.

  When line mode is tangent mode, selecting TANGENT MODE softkey changes to normal mode.

- REGRESS MODE

  Select REGRESS MODE secondary softkey to change the line mode to regression mode. If present mode is regression mode, ON is displayed on the REGRESS MODE softkey.

  For regression line mode, SELECT CURSOR secondary softkey is displayed.

  When line mode is regression mode, selecting REGRESS MODE softkey changes to normal mode.

- SELECT CURSOR

  Select SELECT CURSOR secondary softkey to exchange the active and non-active cursors. Active cursor is highlighted. This softkey is displayed only when line mode is normal or regression.

- GRAD VALUE

  Select GRAD VALUE secondary softkey to change the gradient value. The present gradient value is shown on this softkey and in the data entry area. This softkey is displayed only when line mode is gradient. You can change the value as follows:

  - Enter number by using numeric keys.
  - Change number by rotating rotary knob.

- MARKER SKIP

  Select MARKER SKIP secondary softkey to move the marker to the next measurement curve that was added by VAR2 variable or append measurement. This softkey is displayed only when line mode is tangent.

SCALING

Select SCALING primary softkey to display secondary softkeys for enlarging or reducing the plotting area.

- AUTO SCALING

  Select AUTO SCALING secondary softkey to change the X and Y scaling to fit the measurement curve in the plotting area. If Y2 axis is used, the measurement curve selected by AXIS primary softkey is auto scaled.

- ZOOM IN

  Select ZOOM IN secondary softkey to display the area around the cursor with double resolution. If the cursor is not displayed, long cursor appears at the center, then presently displayed area becomes double resolution around the cursor.

- ZOOM OUT

  Select ZOOM OUT secondary softkey to display the area around the cursor with half resolution. If the cursor is not displayed, long cursor appears at the center, then presently displayed area becomes half resolution around the cursor.

- CENTER AT CURSOR

  Select CENTER AT CURSOR secondary softkey to center the display around the cursor at the same resolution. If a cursor is not displayed, a long cursor appears at the center.

- CURSOR TO MARKER

  Select CURSOR TO MARKER secondary softkey to move the cursor to the marker position. Both marker and cursor must be displayed.

- CANCEL SCALING

  Select CANCEL SCALING secondary softkey to redraw the plotting area with the original settings (most recent DISPLAY: DISPLAY SETUP page settings or RE-SETUP GRAPH settings).

DISPLAY SETUP

Select DISPLAY SETUP primary softkey to display secondary softkeys for setting or changing the display.

- RE-SETUP GRAPH

  Select RE-SETUP GRAPH secondary softkey to change the user comments, variable name for each axis, minimum and maximum values for each axis, scale mode of each axis, and displayed data variables.

  After you select this softkey, a pointer (highlight) appears on a setup parameter of the graph. You can move the pointer to the desired parameter by using ⇐, ⇑, ⇒, and ⇓ of the MARKER/CURSOR key group.

  When the pointer is located in the user comment field, the present user comment is displayed in the data entry area, which you can edit by using the front panel keys.

  When the pointer is located in the variable name field for X, Y1, or Y2 axis, allowable variable names are shown in the secondary softkey area. You can select secondary softkey to change the variable name for each axis. Measurement units change automatically according to variable you select.

  When the pointer is located in the maximum or minimum value field for an axis, the present maximum or minimum value is displayed in the data entry area, which you can change by using rotary knob, arrow keys, or numeric keys of the front panel.

  When the pointer is located in the scale value field for an axis, LINEAR and LOG secondary softkeys are displayed. So, you can select linear or logarithmic axis mode.

  When the pointer is located in the variable name field of the data variable display area, allowable variable names are shown in the secondary softkey area. Measurement units change automatically according to variable you select.

- GRID

  Select GRID secondary softkey to toggle the grid on or off in the plotting area. The present status of the grid is shown on the GRID softkey.

- `DATA VAR`

  Select `DATA VAR` secondary softkey to toggle on or off the display of data variable values. The present status of the display of the data variable display is shown on the `DATA VAR` softkey.

- `LINE PRMTRS`

  Select `LINE PRMTRS` secondary softkey to toggle on or off the display of line parameters (X and Y intercepts and gradients). Line parameters are displayed when *both* of the following are true:

  □ `ON` is set on this softkey

  □ line is displayed in the plotting area.

- `OVERLAY PLANE`

  Select `OVERLAY PLANE` to control which internal memory measurement curve is overlaid. This softkey toggles the internal memory number as follows:

  OFF → 1 → 2 → 3 → 4 → OFF.

- `SHOW OVERLAY INFO`

  Select `SHOW OVERLAY INFO` secondary softkey to display the following for the overlay plane: axes, cursor, marker, and data variables. Select `DONE` primary softkey to remove information.

- `SCALE TO OVERLAY`

  Select `SCALE TO OVERLAY` secondary softkey to force the present scaling values to that of overlaid plane even if unit of axis is different.

SWEEP SETUP

Select SWEEP SETUP primary softkey to display secondary softkeys for changing the sweep source parameters. This softkey is displayed only when SWEEP is selected in the MEASUREMENT MODE field on the CHANNELS: CHANNEL DEFINITION page.

To change the values on the secondary softkeys: enter number by *using numeric keys* or change number by *rotating rotary knob*.

- VAR1 START

  Select VAR1 START secondary softkey to change the start value of the primary sweep VAR1. The present start value is shown on this softkey and in the data entry area. Then you can change the value.

- VAR1 STOP

  Select VAR1 STOP secondary softkey to change the stop value of the primary sweep VAR1. The present stop value is shown on this softkey and in the data entry area. Then you can change the value.

- VAR1 STEP

  Select VAR1 STEP secondary softkey to change the step value of the primary sweep VAR1. The present step value is shown on this softkey and in the data entry area. Then you can change the value.

- COMP

  Select COMP secondary softkey to change the compliance and power compliance values of the primary sweep VAR1. The present V or I compliance value is shown on the middle line of this softkey, and the present power compliance value is shown on the last line of this softkey.

  Selecting COMP softkey highlights this softkey, and the present I or V compliance value appears in the data entry area. Then you can change the value.

  Then selecting COMP softkey *again* displays the present power compliance value in data entry area. Then you can change the value. To disable power compliance, you enter 0 (zero) or OFF.

- VAR2 START (displayed only if VAR2 is defined)

  Select VAR2 START secondary softkey to change the start value of the secondary sweep VAR2. The present start value is shown on this softkey and in the data entry area. Then you can change the value.

- VAR2 STEP (displayed only if VAR2 is defined)

  Select VAR2 STEP secondary softkey to change the step value of the secondary sweep VAR2. The present step value is shown on this softkey and in the data entry area. Then you can change the value.

- COMP (displayed only if VAR2 is defined)

  Select COMP secondary softkey to change the compliance and power compliance values of the secondary sweep VAR2. The present V or I compliance value is shown on the middle line of this softkey, and the present power compliance value is shown on the last line of this softkey.

  Selecting COMP softkey highlights this softkey, and the present I or V compliance value appears in the data entry area. Then you can change the value.

  Then selecting COMP softkey *again* displays the power compliance value in the data entry area. You can change the value. To disable the power compliance, enter 0 (zero) or OFF.

TIMING SETUP

Select `TIMING SETUP` primary softkey to display secondary softkeys for changing the hold time, delay time, and SMU pulse parameters. This softkey is displayed only when SWEEP is selected in the MEASUREMENT MODE field on the CHANNELS: CHANNEL DEFINITION page.

To change the values on the secondary softkeys: enter number by *using numeric keys* or change number by *rotating rotary knob*.

- `HOLD TIME`

  Select `HOLD TIME` secondary softkey to change the hold time for the sweep measurement. The present hold time is shown on this softkey and in the data entry area. Then you can change the value. You can change the hold time while measurement is being performed.

- `DELAY TIME`

  Select `DELAY TIME` secondary softkey to change the delay time for the sweep measurement. The present delay time is shown on this softkey and in the data entry area. Then you can change the value. You can change the delay time while measurement is being performed. This softkey is not displayed when an SMU is set to VPULSE or IPULSE in the MODE field on the CHANNELS: CHANNEL DEFINITION page.

- `PULSE BASE` (displayed only if SMU pulse source is defined)

  Select `PULSE BASE` secondary softkey to change the base value of SMU pulse. The present base value is shown on this softkey and in the data entry area. Then you can change the value.

- `PULSE PERIOD` (displayed only if SMU pulse source is defined)

  Select `PULSE PERIOD` secondary softkey to change the period of SMU pulse. The present period is shown on this softkey and in the data entry area. Then you can change the value.

- `PULSE WIDTH` (displayed only if SMU pulse source is defined)

  Select `PULSE WIDTH` secondary softkey to change the pulse width of SMU pulse. The present pulse width is shown on this softkey and in the data entry area. Then you can change the value.

SAMPLNG SETUP

Select SAMPLNG SETUP primary softkey to display secondary softkeys for changing the sampling parameters. This softkey is displayed only when SAMPLING is selected in the MEASUREMENT MODE field on the CHANNELS: CHANNEL DEFINITION page.

To change the values on the secondary softkeys: enter number by *using numeric keys* or change number by *rotating rotary knob*.

- SAMPLNG MODE

  Select SAMPLNG MODE secondary softkey to change the sampling mode. Selecting this softkey changes the sampling mode in the following order:

  LINEAR ⟶ LOG10 ⟶ LOG25 ⟶ LOG50 ⟶ THINNED ⟶ LINEAR

- INITIAL INTRVAL

  Select INITIAL INTRVAL secondary softkey to change the initial interval time for sampling measurements. The present initial interval time is shown on this softkey and in the data entry area. You can change the value.

- NO. OF SAMPLES

  Select NO. OF SAMPLES secondary softkey to change number of samples. Present number of samples is shown on this softkey and in data entry area. Then you can change the value.

- TOT SAM TIME

  Select TOT SAM TIME secondary softkey to change the total sampling time for the sampling measurements. The present total sampling time is shown on this softkey and in the data entry area. Then you can change the value.

- HOLD TIME

  Select HOLD TIME secondary softkey to change the hold time for sampling measurements. The present hold time is shown on this softkey and in the data entry area. Then you can change the value. You can change the hold time while measurement is being performed.

STOP COND

Select `STOP COND` primary softkey to display secondary softkeys for changing the sampling parameters. This softkey is displayed only when SAMPLING is selected in the MEASUREMENT MODE field on the CHANNELS: CHANNEL DEFINITION page.

To change the values on the secondary softkeys: enter number by *using numeric keys* or change number by *rotating rotary knob*.

- `STOP COND`

  Select `STOP COND` secondary softkey to enable or disable the stop condition. Selecting this softkey toggles between `ENABLE` and `DISABLE`.

- `ENABLE DELAY`

  Select `ENABLE DELAY` secondary softkey to change the enable delay time for the stop condition. The present enable delay time is shown on this softkey and in the data entry area. Then you can change the value.

- `THRESHOLD`

  Select `THRESHOLD` secondary softkey to change threshold value of the stop condition. The present threshold value is shown on this softkey and in the data entry area. Then you can change the value.

  You can change the threshold value while measurement is being performed.

- `EVENT TYPE`

  Select `EVENT TYPE` secondary softkey to change the event type. Selecting this softkey changes the event type in the following order:

  `Val>Th` ⟶ `Val<Th` ⟶ `|Val|>|Th|` ⟶ `|Val|<|Th|` ⟶ `Val>Th`

- `EVENT NUMBER`

  Select `EVENT NUMBER` secondary softkey to change the event number of stop condition. The present event number is shown on this softkey and in the data entry area. Then you can change the value.

CONST SETUP

Select CONST SETUP primary softkey to display secondary softkeys for changing the constant source parameters. This softkey is displayed only when CONST is set in the FCTN field on CHANNELS: CHANNEL DEFINITION page.

Output source names appear on the secondary softkeys, and the present output value and compliance also appears. For example, when a output source named "Vce" is defined "5.0 V output with 100 mA compliance," the following softkey appears:

```
Vce
 5.00 V
 100.mA
```

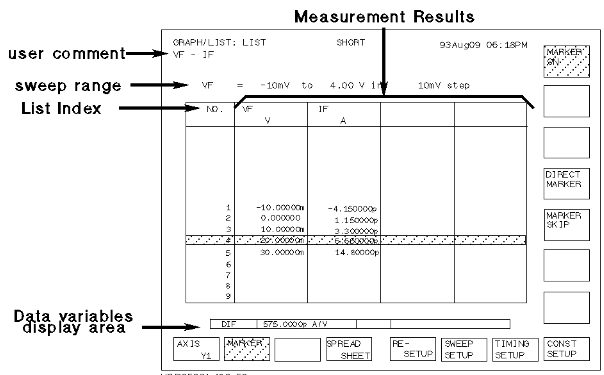
Select the secondary softkey that you want to change. The selected softkey is highlighted, and the present output value appears in the data entry area. You can change the value.

Then selecting the same softkey *again* displays the present compliance in the data entry area. You can change the compliance.

Use the following methods to change the value:

- Enter number by using numeric keys.
- Change number by rotating rotary knob.

GRAPH/LIST: LIST page



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On the “GRAPH/LIST: LIST” page, measurement results are displayed.

User Comment

In this field, you can enter a desired comment. This comment is also displayed in the CHANNELS, MEASURE, DISPLAY, and GRAPH/LIST page groups.

Sweep Range

This field displays sweep start, stop, and step values of VAR1 primary sweep and VAR2 secondary sweep (if VAR2 sweep is selected).

List Index Number

This column displays index number of each measurement point. Index number is assigned from 1 in increasing order.

For a VAR2 secondary sweep, the index continues to increase for each VAR2 step, that is, each VAR2 measurement does *not* start at index 1. For example, if VAR1 has 5 steps, then the first VAR2 step is index 1 to 5, second VAR2 step is index 6 to 10, and so on.

If you have appended measurements, index number for each append measurement starts at 1.

In this column head, you can confirm how many append measurements you have executed and which append you are currently viewing. Refer to the following example:

`2/4`

If the above appears in the column head, it means you have appended three measurements to the original measurement (total four measurements), and you are currently viewing the second measurement (first append measurement).

Measurement Results

These columns display measurement result data for the variables that you set up in the LIST area on the DISPLAY: DISPLAY SETUP page.

Data Variable Display

This area displays the numerical value for the variables that you set up in the DATA VARIABLES area on DISPLAY: DISPLAY SETUP page. This is the value of the variable at the marker position.

`AXIS Y1`

For GRAPH/LIST: GRAPHICS page, this softkey is used to toggle active axis to analyze between the Y1 and Y2 axis.

This softkey is displayed only if Y2 axis is set up.

For GRAPH/LIST: LIST page, this softkey only has meaning for the data variable fields, which are just above the primary softkeys. If you set up a data variable that uses a line or marker read-out function, selecting this softkey changes displayed data variable value according to read-out function.

MARKER

Select MARKER primary softkey to display secondary softkeys for operation with marker.

- MARKER

  Select MARKER secondary softkey to toggle marker display between ON and OFF. When ON is displayed on this softkey, the row at marker location is highlighted. When OFF is displayed on this softkey, no row is highlighted.

  The marker on the GRAPH/LIST: LIST page is linked to marker on the GRAPH/LIST: GRAPHICS page. So, if marker is moved on the GRAPH/LIST: GRAPHICS page, the marker also moves on the GRAPH/LIST: LIST page.

  The HP 4155A/4156A remembers the location of marker. So, if you turn marker display OFF, then the marker appears at the same location when you turn marker ON again.

- DIRECT MARKER

  Select DIRECT MARKER secondary softkey to move the marker to the specified value directly. When you select this softkey, a cell marker is displayed in the row of the marker, and the primary and secondary softkeys change as follows:

  Primary softkeys:

EXIT							CANCEL

  Secondary softkeys:

	MARKER MIN/MAX		SEARCH MORE	MARKER SKIP		

  In this mode, you can move the marker to a specified value. You enter the value in the data entry area, then the marker moves to the value in list that is closest to the specified value. If you have executed append measurement, the marker moves within the append measurement you refer to.

  You use the cell marker to specify the target variable (column). You can move this marker by using ⇐, ⇑, ⇒, and ⇓ keys in the MARKER/CURSOR key group.

Selecting EXIT primary softkey exits the DIRECT MARKER function.

Selecting CANCEL primary softkey returns the marker to the same position as before selecting the DIRECT MARKER secondary softkey.

- □ MARKER MIN/MAX

  Select MARKER MIN/MAX secondary softkey to move the marker to where the measured value is maximum or minimum value. If the marker is on the minimum value, selecting this softkey moves to the maximum value. Otherwise, selecting this softkey moves to the minimum value.

- □ SEARCH MORE

  Select SEARCH MORE secondary softkey to move marker to next candidate that satisfies specified value. If consecutive values also satisfy specified value, the next search starts after the consecutive values.

- □ MARKER SKIP

  Select MARKER SKIP secondary softkey to move the marker to the next VAR2 value or to the next appended measurement data.

- MARKER SKIP

  Select MARKER SKIP secondary softkey to move the marker to the next VAR2 value or to the next appended measurement data.

- NEXT APPEND

  Select NEXT APPEND secondary softkey to move the marker to the next appended measurement data.

SPREAD SHEET

Select SPREAD SHEET primary softkey to display ASCII SAVE window. The following entry fields appear:

```
FUNCTION: ASCII SAVE
NAME                           UNIT          OFF
OUTPUT DATA (INDEX NO)         DELIMITER     SPACE
          1 <-->    MAX        STRING MARK   NONE
```

Also, the following softkeys appear:

- Select EXECUTE softkey to store result data to diskette file.
- Select EXIT softkey to exit the ASCII SAVE window.
- Select FILE CATALOG secondary softkey to list the names of all files that are on diskette. You can select a file name from the list.

ASCII SAVE function automatically adds TXT extension to specified file name.

- NAME

  Enter the name of file (without extension) to which you want to save the result data.

- OUTPUT DATA

  Enter numbers to specify range of data you want to save.
  These numbers correspond to NO. column of LIST page.

  - left field: upper limit
  - right field: lower limit

  Select ALL secondary softkey to specify all result data.

- UNIT

  Specify whether to include units (for example, V or ms).

  - ON secondary softkey to include units.
  - OFF secondary softkey to not include units.

  For ON, result data is saved as string data, not numeric data. So result data is saved with specified string marker. For string marker, see description of STRING MARK field. Ineffective value (----) is treated as string, even if you set this field to OFF.

- DELIMITER

  Specify the data delimiter:

  - SPACE secondary softkey to specify space.
  - TAB secondary softkey to specify tab.
  - COMMA secondary softkey to specify comma.

- STRING MARK

  Specify the string marker:

  - NONE secondary softkey to specify no string marker.
  - " " secondary softkey to specify double quotes string marker.
  - ' ' secondary softkey to specify single quotes string marker.

Output Format for ASCII SAVE Function.
The following describes the output format for each item of LIST page. In this description, the following notation is used to indicate string or numeric type:

- [S]: string
- [S/N]: If UNIT field is `ON`, the value is output as *string* with string marker. If UNIT field is `OFF`, the value is output as *numeric value*.
- [N]: numeric value

1. user comment

   User comment is output as string with specified string marker.

   - Example

     ```
     "Bipolar Tr. Vce-Ic"
     ```

     (Setups: STRING MARK = " ")

2. VAR1 output range

   - for sweep measurement

     Format: <VAR1 name>=<start>to<stop>in<step>step
     Type: [S] [S/N] [S] [S/N] [S] [S/N] [S]

     For log sweep measurement, `LOG` is output for step value.

     - □ Example

       `"VCE=",0.0001,"to",1,"in","LOG","step"`

       (setups: UNIT=`OFF`, STRING MARK = " ", DELIMITER=`COMMA`)

   - for sampling measurement

     Format: @TIME = <start time> to <stop time>
     Type: [S] [S/N] [S] [S/N]

     - □ Example

       `"@TIME="," 0.00 s","to"," 1.516 s"`

       (Setups: UNIT=`ON`, STRING MARK = " ", DELIMITER=`COMMA`)

3. VAR2 output range

   Format: <VAR2 name>=<start value>to<stop value>in<step value>step
   Type: [S] [S/N] [S] [S/N] [S] [S/N] [S]

   - Example

     `"IB=",1E-05,"to",5E-05,"in",1E-05,"step"`

     (Setups: UNIT=`OFF`, STRING MARK = " ", DELIMITER=`COMMA`)

4. variable names

   Format: `NO.` <variable name> <variable name> ...
   Type: [S] [S] [S]

   - Example

     `"NO.","VCE","IC"`

     (Setups: STRING MARK = " " and DELIMITER=`COMMA`)

5. unit

   Format: <blank><1st variable unit><2nd variable unit> . . .
   Type: [S] [S] [S]

   - Example

     ```
     "","V","A"
     ```

     (Setups: STRING MARK = " " and DELIMITER = `COMMA`)

6. measurement data

   Format: <index><1st variable data><2nd variable data> . . .
   Type: [N] [S/N] [S/N]

   - Example

     ```
     1,0.001,-9.265E-10,...,...
     ```

     (Setups: UNIT = `OFF` and DELIMITER = `COMMA`)

Example

Output examples are as follows.

Example 1: for Lotus® 1-2-3®

- Setups
  - □ UNIT = `OFF`
  - □ DELIMITER = `COMMA`
  - □ STRING MARK = " "
- Output

```
"Bipolar Tr. Vce-Ic"
"VCE=",0.0001,"to",1,"in","LOG","step"
"IB=",1E-05,"to",5E-05,"in",1E-05,"step"
"NO.","VCE","IC"
"","V","A"
1,0.0001,-9.265E-10
2,0.00013,1.0416E-09
3,0.00016,1.527E-09
4,0.0002,-8.975E-10
5,0.00025,-1.7453E-09
```

Example 2: for Microsoft® Excel®

- Setups
  - □ UNIT = `OFF`
  - □ DELIMITER = `TAB`
  - □ STRING MARK = `NONE`
- Output

```
V3-I3 characteristics
V3=   0  to 1 in 0.1 step
I3=   2E-05 to 0.0001 in 2E-05 step
NO.   V3 I3
      V  A
1     0  1.665E-09
2     0.1 1.9072E-09
3     0.2 1.4471E-08
4     0.3 1.8823E-07
5     0.4 2.1995E-06
```

Example 3 : Append Measurement

- Setups
  - □ UNIT = `OFF`
  - □ DELIMITER = `TAB`
  - □ STRING MARK = `NONE`
- Output

```
V3= 0 to 1 in 0.5 step
I2= 2E-05 to 0.0001 in 2E-05 step
/* Append 1 */
V3= 0 to 1 in 0.5 step
I2= 2E-05 to 0.0001 in 2E-05 step
NO. V3 I3
 V A
1 0 4.3E-13
2 0.5 5.7E-13
3 1 3.1E-13
.
.
.
15 1 3.2E-13
```

```
/* Append 1 */
NO. V3 I3
 V A
1 0 1.7E-13
2 0.5 8E-13
3 1 2.8E-13
.
.
.
15 1 4.5E-13
```

RE-SETUP

Select RE-SETUP primary softkey to change the user comments, variable name for each column, and displayed data variables.

After you select this softkey, a pointer (highlight) appears on the variable name of the first column. You can move the pointer to the desired parameter by using (⇐), (⇑), (⇒), and (⇓) of the MARKER/CURSOR key group.

When the pointer is located in the user comment field, the present user comment appears in the data entry area, and you can edit it using edit keys.

When the pointer is located in the variable name field, allowable variable names are shown in the secondary softkey area. Measurement units change automatically according to variable you select.

When the pointer is located in the data variable display area, allowable variable names are shown in the secondary softkey area. Measurement units change automatically according to variable you select.

SWEEP SETUP

Select SWEEP SETUP primary softkey to display secondary softkeys for changing the sweep source parameters. This softkey is displayed only when SWEEP is selected in the MEASUREMENT MODE field on the CHANNELS: CHANNEL DEFINITION page.

To change the values on the secondary softkeys: enter number by *using numeric keys* or change number by *rotating rotary knob*.

- VAR1 START

  Select VAR1 START secondary softkey to change the start value of the primary sweep VAR1. The present start value is shown on this softkey and in the data entry area. Then you can change the value.

- VAR1 STOP

  Select VAR1 STOP secondary softkey to change the stop value of the primary sweep VAR1. The present stop value is shown on this softkey and in the data entry area. Then you can change the value.

- VAR1 STEP

  Select VAR1 STEP secondary softkey to change the step value of the primary sweep VAR1. The present step value is shown on this softkey and in the data entry area. Then you can change the value.

- COMP

  Select COMP secondary softkey to change the compliance and power compliance values of the primary sweep VAR1. The present V or I compliance value is shown on the middle line of this softkey, and the present power compliance value is shown on the last line of this softkey.

  Selecting COMP softkey highlights this softkey, and the present I or V compliance value appears in the data entry area. You can change the value.

  Then selecting COMP softkey *again* displays the present power compliance value in the data entry area. You can change the value. To disable the power compliance, enter 0 (zero) or OFF.

- VAR2 START (displayed only if VAR2 is defined)

  Select VAR2 START secondary softkey to change the start value of the secondary sweep VAR2. The present start value is shown on this softkey and in the data entry area. Then you can change the value.

- VAR2 STEP (displayed only if VAR2 is defined)

  Select VAR2 STEP secondary softkey to change the step value of the secondary sweep VAR2. The present step value is shown on this softkey and in the data entry area. Then you can change the value.

- COMP (displayed only if VAR2 is defined)

  Select COMP secondary softkey to change the compliance and power compliance values of the secondary sweep VAR2. The present V or I compliance value is shown on the middle line of this softkey, and the present power compliance value is shown on the last line of this softkey.

  Selecting COMP softkey highlights this softkey, and the present I or V compliance value appears in the data entry area. You can change the value.

  Then selecting COMP softkey *again* displays the power compliance value in the data entry area. You can change the value. To disable the power compliance, enter 0 (zero) or OFF.

TIMING SETUP

Select `TIMING SETUP` primary softkey to display secondary softkeys for changing the hold and delay time and SMU pulse parameters. This softkey is displayed only when SWEEP is selected in the MEASUREMENT MODE field on the CHANNELS: CHANNEL DEFINITION page.

To change the values on the secondary softkeys: enter number by *using numeric keys* or change number by *rotating rotary knob*.

- `HOLD TIME`

  Select `HOLD TIME` secondary softkey to change the hold time for the sweep measurement. The present hold time is shown on this softkey and in the data entry area. Then you can change the value. You can change the hold time while measurement is being performed.

- `DELAY TIME`

  Select `DELAY TIME` secondary softkey to change the delay time for the sweep measurement. The present delay time is shown on this softkey and in the data entry area. Then you can change the value. You can change the delay time while measurement is being performed. This softkey is not displayed when an SMU is set to VPULSE or IPULSE in the FCTN field on the CHANNELS: CHANNEL DEFINITION page.

- `PULSE BASE` (displayed only if SMU pulse source is defined)

  Select `PULSE BASE` secondary softkey to change the base value of SMU pulse. The present base value is shown on this softkey and in the data entry area. Then you can change the value.

- `PULSE PERIOD` (displayed only if SMU pulse source is defined)

  Select `PULSE PERIOD` secondary softkey to change the period of SMU pulse. The present period is shown on this softkey and in the data entry area. Then you can change the value.

- `PULSE WIDTH` (displayed only if SMU pulse source is defined)

  Select `PULSE WIDTH` secondary softkey to change the pulse width of SMU pulse. The present pulse width is shown on this softkey and in the data entry area. Then you can change the value.

SAMPLNG SETUP

Select SAMPLNG SETUP primary softkey to display secondary softkeys for changing the sampling parameters. This softkey is displayed only when SAMPLING is selected in the MEASUREMENT MODE field on the CHANNELS: CHANNEL DEFINITION page.

- SAMPLNG MODE

  Select SAMPLNG MODE secondary softkey to change the sampling mode. Selecting this softkey changes the sampling mode in the following order:

  LINEAR ⟶ LOG10 ⟶ LOG25 ⟶ LOG50 ⟶ THINNED ⟶ LINEAR

- INITIAL INTRVAL

  Select INITIAL INTRVAL secondary softkey to change the initial interval time for sampling measurements. The present initial interval time is shown on this softkey and in the data entry area. Then you can change the value.

- NO. OF SAMPLES

  Select NO. OF SAMPLES secondary softkey to change the number of samples. The present number of samples is shown on this softkey and in the data entry area. Then you can change the value.

- TOT SAM TIME

  Select TOT SAM TIME secondary softkey to change the total sampling time for the sampling measurements. The present total sampling time is shown on this softkey and in the data entry area. Then you can change the value.

- HOLD TIME

  Select HOLD TIME secondary softkey to change the hold time for sampling measurements. The present hold time is shown on this softkey and in the data entry area. Then you can change the value.

  You can change the hold time while measurement is being performed.

STOP COND

Select STOP COND primary softkey to display secondary softkeys for changing the sampling parameters. This softkey is displayed only when SAMPLING is selected in the MEASUREMENT MODE field on the CHANNELS: CHANNEL DEFINITION page.

- STOP COND

  Select STOP COND secondary softkey to enable or disable the stop condition. Selecting this softkey toggles between ENABLE and DISABLE.

- ENABLE DELAY

  Select ENABLE DELAY secondary softkey to change the enable delay time for the stop condition. The present enable delay time is shown on this softkey and in the data entry area. Then you can change the value.

- THRESHOLD

  Select THRESHOLD secondary softkey to change threshold value of the stop condition. The present threshold value is shown on this softkey and in the data entry area. Then you can change the value.

  You can change the threshold value while measurement is being performed.

- EVENT TYPE

  Select EVENT TYPE secondary softkey to change the event type. Selecting this softkey changes the event type in the following order:

  Val>Th ⟶ Val<Th ⟶ |Val|>|Th| ⟶ |Val|<|Th| ⟶ Val>Th

- EVENT NUMBER

  Select EVENT NUMBER secondary softkey to change the event number of stop condition. The present event number is shown on this softkey and in the data entry area. Then you can change the value.

CONST SETUP

Select CONST SETUP primary softkey to display secondary softkeys for changing the constant source parameters. This softkey is displayed only when CONST is set in the FCTN field on CHANNELS: CHANNEL DEFINITION page.

Output source names appear on the secondary softkeys, and the present output value and compliance also appears. For example, when a output source named "Vce" is defined "5.0 V output with 100 mA compliance," the following softkey appears:

```
Vce
 5.00 V
 100.mA
```

Select the secondary softkey that you want to change. The selected softkey and is highlighted, and the present output value appears in the data entry area. You can change the value.

Then selecting the same softkey *again* displays the compliance value in the data entry area. You can change the compliance.

Use the following methods to change the value:

- Enter number by using numeric keys.
- Change number by rotating rotary knob.

STRESS Page Group

STRESS page group has the following pages:

Stress channel definition:	For defining the stress channels of the HP 4155A/4156A, setting up SMU/PG selector, and setting up the trigger.
Stress setup:	For setting the stress parameters.
Stress force:	For monitoring the progress of stress forcing.

To move into the STRESS page group, do the following:

- Press (Stress) front-panel key in the PAGE CONTROL key group.

Then the following softkeys appear in the primary softkey area:

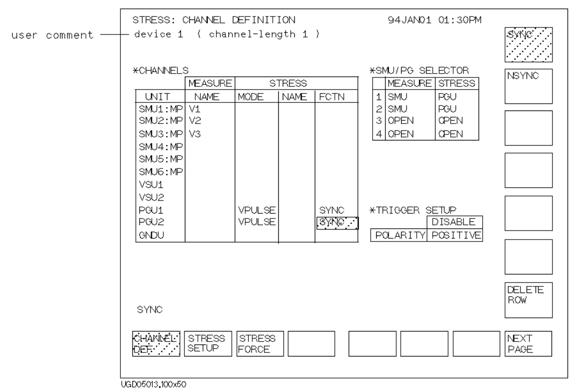
CHANNEL DEF	STRESS SETUP	STRESS FORCE			PREV PAGE	NEXT PAGE

Note that the PREV PAGE softkey does not appear when the STRESS: CHANNEL DEFINITION page is displayed. The NEXT PAGE softkey does not appear when the STRESS: STRESS FORCE page is displayed.

- Select CHANNEL DEF softkey to move to the STRESS: CHANNEL DEFINITION page.
- Select STRESS SETUP softkey to move to the STRESS: STRESS SETUP page.
- Select STRESS FORCE softkey to move to the STRESS: STRESS FORCE page.

When you press the (Stress) front-panel key in the MEASUREMENT key group, the STRESS: STRESS FORCE page appears and stress forcing starts.

STRESS: CHANNEL DEFINITION page



On the “STRESS: CHANNEL DEFINITION” page, you define how to use the channels for stress force, how to control the SMU/PG selector, and trigger usage in the stress force state.

User Comment

In this field, you can enter a desired comment. The comment you enter here is also displayed on the other STRESS pages.

CHANNELS

CHANNELS table defines the mode, name, and function for the stress state.

- UNIT

  This column lists all the source units that are installed in the HP 4155A/4156A.

- NAME of MEASURE

  Source name that was defined for the measurement state (on CHANNELS: CHANNEL DEFINITION page). For example, if the unit is set to V source mode, the specified VNAME is shown here.

- MODE of STRESS

  Output mode for each unit that will be used during stress force state. In the MODE column, allowable modes are shown in the secondary softkey area as follows, and you select a softkey to set an output mode.

V	dc voltage source
I	dc current source
VPULSE	ac voltage source
COMMON	circuit common
DELETE ROW	Deletes all entries in row of unit, so unit is not used during stress force. Output switch of unit is open.

  Allowable modes for each unit are shown in the following table:

	V	I	VPULSE	COMMON	DELETE ROW
SMU	•	•		•	•
VSU	•				•
PGU	•		•		•
GNDU				•	•

  When pointer is at *top of this column*, CHANNEL ASSIGN softkey appears:

Switching units

To switch the STRESS MODE, NAME, and FCTN assignments for two units, do as follows:

1. Position pointer in top field of STRESS MODE column. CHANNEL ASSIGN softkey appears.
2. Select CHANNEL ASSIGN. Pointer moves to the top field of UNIT column.
3. Use arrow keys in the MARKER/CURSOR key group to move pointer to desired row.
4. Select the secondary softkey of the desired unit. The selected unit appears at the pointer.

Perform steps 3 and 4 until you assign units as desired. Make sure that the same unit is not assigned to multiple rows. Then select EXIT CHANNEL ASSIGN softkey.

- NAME of STRESS (optional)

  Defines stress name that is used as a reference on STRESS: STRESS SETUP page. In this column, enter a desired name by using alphanumeric keys.

  When pointer is in field of this column, `DELETE ROW` softkey is shown in secondary softkey area: clears all the entries for a unit where the pointer is located, and disables that unit.

  Restriction:

  - NAME must be 6 or less alphanumeric characters. First character must be alphabet character.

- FCTN of STRESS

  This field defines channels to be stress force channels or non-stress force channels. In this field, select:

  - `SYNC` secondary softkey to set channel to stress force channel.
  - `NSYNC` secondary softkey to set channel to non-stress force channel.

  The output timing is different for stress force channels and non-stress force channels:

  - Non-stress force channels output the source values in the order specified on the MEASURE: OUTPUT SEQUENCE page *when state changes from idle to stress*.
  - Stress force channels output the stress source values simultaneously *when the stress start trigger is received*.

  For details about output sequence, refer to "Stress Force Sequence" in Chapter 3.

  Restrictions:

  - At least *one* channel must be set to `SYNC`.
  - Up to four channels can be set to `SYNC`.
  - If both PGUs are set to pulsed source (`VPULSE`), you cannot set one PGU to `SYNC` and other PGU to `NSYNC`. Both must be set to `SYNC` or both to `NSYNC`.

SMU/PG SELECTOR

HP 16440A SMU/PG selector's operation is defined in the SMU/PG SELECTOR table. Switches in the SMU/PG selector are controlled as defined in these fields. MEASURE column sets the switch connections for measurement state. STRESS column sets the switch connections for stress force state.

When the pointer is located in this table, the following softkeys appear:

SMU Will connect DUT to SMU.

PGU Will connect DUT to PGU.

OPEN Will disconnect DUT from both SMU and PGU.

PGU OPEN Will disconnect DUT from both PGU and SMU. But PGU is disconnected by using semiconductor switch. The normal relay switch for PGU stays closed. This is used to prevent the normal relay switch from being damaged. Semiconductor switch has longer life than normal relay switch. Note that CH2 and CH4 do not have this function.

For details about the SMU/PG selector, refer to "HP 16440A SMU/PG Selector Control" in Chapter 3 or *HP 16440A SMU/Pulse Generator Selector User's Guide*.

TRIGGER SETUP

In the TRIGGER SETUP table, you can set how to use the trigger function during the stress force state.

- ENABLE/DISABLE

  In the ENABLE or DISABLE field, select:

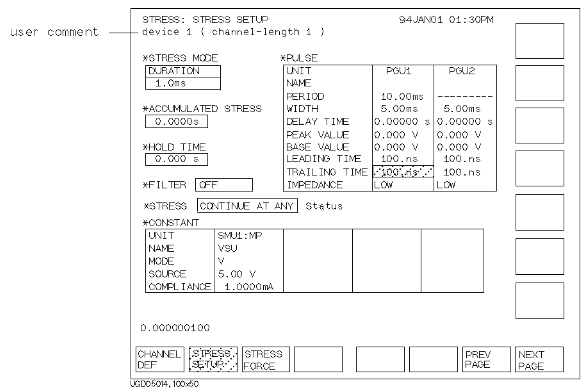
  - ENABLE secondary softkey to enable the trigger function.
  - DISABLE secondary softkey to disable the trigger function.

- POLARITY

  In this field, select:

  - POSITIVE secondary softkey to set positive logic for the output trigger.
  - NEGATIVE secondary softkey to set negative logic for the output trigger.

STRESS: STRESS SETUP page



On the “STRESS: STRESS SETUP” page, you set the stress parameters.

User Comment

In this field, you can enter a desired comment. The comment you enter here is also displayed on the other STRESS pages.

STRESS MODE

STRESS MODE table specifies the stress mode. When the stress mode is pulse count mode, you specify the number of pulse counts, and when the stress mode is duration mode, you specify the stress duration in seconds. For details of stress mode, refer to “Stress Mode” in Chapter 3.
In the first field, select:

- `DURATION` secondary softkey to set the duration mode. Then, enter the pulse stress duration in the next field by using numeric keys.
- `PULSE COUNT` secondary softkey to set the pulse count mode. Then, enter the pulse count in the next field by using numeric keys. This softkey appears only for ac stress: PGU set to `VPULSE` and `SYNC`.

In the next field, `FREE RUN` secondary softkey appears. Select the `FREE RUN` softkey to force stress *continuously*. Entering 0 (zero) also sets to free run mode.

ACCUMULATED STRESS

The ACCUMULATED STRESS field on this page and on STRESS: STRESS FORCE page are linked. So, if value is changed on this page, value is changed to same value on STRESS: STRESS FORCE page and vice versa.

To change the displayed accumulated stress time, enter the time in this field. Selecting `RESET ACCUM STRESS` secondary softkey resets the displayed accumulated stress time to 0 (zero).

HOLD TIME

In the HOLD TIME, you can set the hold time. After the stress force state starts, the stress force channels wait the specified hold time, then start forcing stress at the same time.

For details about hold time, see example figure in "Stress Force Sequence" in Chapter 3.

FILTER

FILTER field specifies SMU filter to `ON` or `OFF`. If this field is set to `ON`, overshoot decreases, but settling time takes several ms. If you set dc stress to short stress force time, set `OFF` in this field if you want the stress signal to be more pulse shaped.

STRESS Status

- Select `CONT AT ANY` secondary softkey (stress will continue even if an abnormal status occurs). Abnormal status means the following:
  - SMU reaches its compliance setting.
  - Current of VSU exceeds ±100 mA.
  - SMU or VSU oscillates.
  - A/D converter overflow occurs.
  - Average current of PGU exceeds ±100 mA.
- Select `STOP AT ANY ABNORM` secondary softkey (stress will stop if any abnormal status occurs).
- Select `STOP AT COMPLIANCE` secondary softkey (stress will stop only if SMU reaches its compliance setting).

`STOP AT ANY ABNORM` and `STOP AT COMPLIANCE` secondary softkeys are displayed only when specified duration is more than 10 s. If you set pulse count mode, these secondary softkeys are displayed only when *pulse period* × *pulse count* is more than 10 s.

Stress stop function is not effective until stress has been forced for 10 s.

PULSE

UNIT and NAME are defined on STRESS: CHANNEL DEFINITION page.

On the STRESS: CHANNEL DEFINITION page you set the PGUs as follows:

- ac stress: `MODE=VPULSE`, `FCTN=SYNC`
- ac non-stress: `MODE=VPULSE`, `FCTN=NSYNC`
- dc stress: `MODE=V`, `FCTN=SYNC`
- dc non-stress: `MODE=V`, `FCTN=NSYNC`

PULSE table is for setting the pulse output parameters of PGUs:

- PERIOD

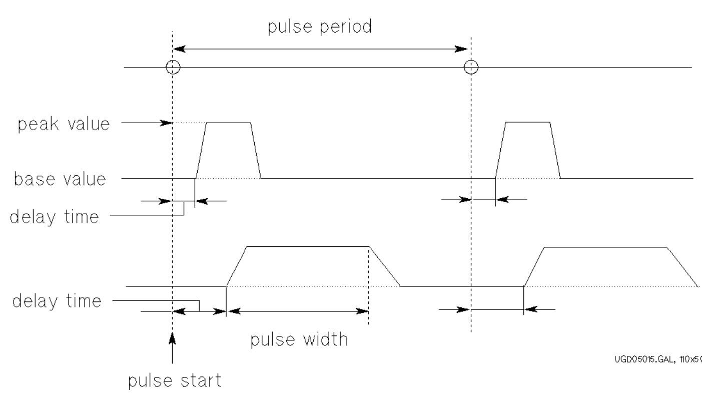
  This field specifies the pulse period of the PGU. Both PGUs are set to same value.

- WIDTH

  This field specifies pulse width, which must be less than pulse period.

- DELAY TIME

  This field specifies the delay time from the pulse start time. The delay time must be less than or equal to the pulse period.



PGU Parameters

- PEAK VALUE and BASE VALUE

  These fields specify pulse peak and base values.

- LEADING TIME and TRAILING TIME

  These specify transition time (10 to 90%) of leading and trailing edges.

- IMPEDANCE

  This field specifies the PGU output impedance. In this field, select:

  - `LOW` secondary softkey to set output impedance to about 0Ω.
  - `50 ohm` secondary softkey to set output impedance to 50Ω.

CONSTANT

The UNIT, NAME, and MODE are defined on STRESS: CHANNEL DEFINITION page.

On the STRESS: CHANNEL DEFINITION page you set the SMUs and VSUs as follows:

- dc stress: `MODE= I` (SMUs only) or `V`, `FCTN=SYNC`
- dc non-stress: `MODE=I` (SMUs only) or `V`, `FCTN=NSYNC`

CONSTANT table is for setting the output parameters of SMUs, VSUs, and PGUs (V mode):

- SOURCE

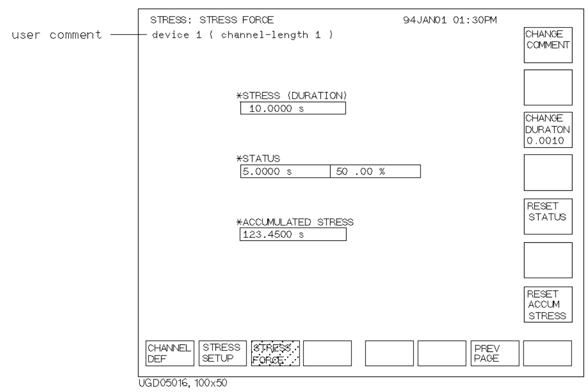
  In the SOURCE field, you specify the output value.

- COMPLIANCE

  In the COMPLIANCE field, you specify the compliance value. For a VSU, this field cannot be set: compliance value is fixed to 100 mA.

If you define more than four VSUs, SMUs, and PGUs to be constant stress or non-stress units on the CHANNELS: CHANNEL DEFINITION page, first four units appear in this table. To show other units, select `NEXT UNIT` secondary softkey. To scroll units, put field pointer in most right or left column, then press ⇒ or ⇐ MARKER/CURSOR front-panel keys.

STRESS: STRESS FORCE page



On the "STRESS: STRESS FORCE" page, you can monitor the stress status.

User Comment

In this field, you can enter a desired comment. The comment you enter here is also displayed on the other STRESS pages.

Select CHANGE COMMENT secondary softkey to enter or edit the comment in this field. When you select this softkey, you can enter or edit the comment in the data entry area.

STRESS (DURATION)

STRESS (DURATION) field shows duration setting specified on the STRESS: STRESS SETUP page. If the STRESS MODE is set to pulse count mode in the STRESS: STRESS SETUP page, the duration is calculated by multiplying the pulse count by the pulse period.

Depending on the stress mode, select one of the following:

- CHANGE DURATON secondary softkey to change the stress duration.
- CHANGE PLS CNT secondary softkey to change the pulse count.

The stress mode and duration or pulse count were originally set on the STRESS: STRESS SETUP page. The present stress duration or pulse count is shown on the softkey. When you select the softkey, the present value appears in the data entry area. You change the value as follows:

- Enter number by using numeric and edit keys.
- Change number by rotating rotary knob.

STATUS

In the STATUS field, the time that stress has been forced is displayed in seconds. And the percent completion is also displayed.

To reset stress status to 0, select RESET STATUS secondary softkey. Then, when you press the (Stress) front-panel key in the MEASUREMENT key group, the stress is forced for the specified duration.

If you press the (Stress) key after aborting the stress (pressing the (Stop) front-panel key), the stress is forced starting at the present status, that is, stress status is not reset to 0.

ACCUMULATED STRESS

As the time in the STATUS field increases, the time in the ACCUMULATED STRESS field on this page and also on STRESS: STRESS SETUP page increases by the same amount.

To reset accumulated stress on both pages to 0, select RESET ACCUM STRESS secondary softkey. To change to non-zero value, change accumulated stress on STRESS: STRESS SETUP page.

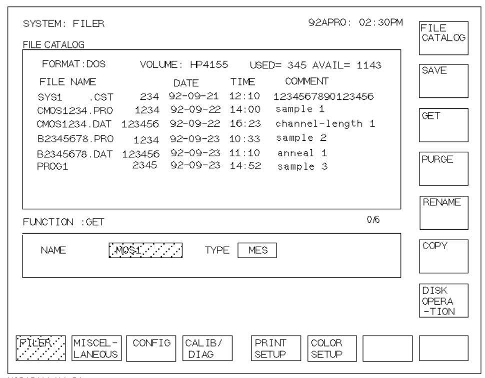
SYSTEM Page Group

SYSTEM page group has the following pages:

Filer:	For executing file operations, such as saving and getting files, on diskette or internal memory.
Miscellaneous:	For miscellaneous system settings, such as HP-IB addresses and built-in clock.
Configuration:	For displaying software revision and units configuration.
Self-Calibration/Diagnostics:	For executing calibration and diagnostics.
Print/Plot setup:	For setting the print/plot parameters.
Color setup:	For setting the screen colors.

To move into the SYSTEM page group, you press (System) front-panel key. Also, you can start the *save* and *get* functions of the filer (SYSTEM: FILER) page by pressing (Save) and (Get) front-panel keys.

SYSTEM: FILER page



UGD05021, 100x50

On the “SYSTEM: FILER” page, you can execute operations on diskette files, and on measurement or setup data that is in internal memory.

HP 4155A/4156A filer cannot operate on files that are created by another system. However, if the files satisfy the file name restrictions of HP 4155A/4156A file system, you can use the following functions:

- purge
- rename
- copy from a diskette to a diskette

FILE CATALOG

Select FILE CATALOG secondary softkey to display the following diskette file information in the FILE CATALOG area:

- Format type: DOS or HP LIF format of the diskette.
- Volume name: volume name of the diskette.
- Used space: disk space occupied by the files in the diskette.
- Available space: free disk space for data storage in the diskette.
- File name: file name used to identify the data in the diskette.
- Size: file size in bytes for DOS or in blocks for HP LIF.
- Date and time: date and time when file was created or modified last.
- Comment: file comment. Up to 16 characters.

The following is an example of the FILE CATALOG area:

```
FORMAT:DOS  VOLUME:4155A     USED= 178k   AVAIL=1268k
 FILE NAME    SIZE[byte]   DATE    TIME COMMENT
 SYS1    .CST       144   93-10-10 13:45 System Config 1
 CMOS123 .PRO       387   93-10-10 14:39 CMOS#123 Program
 CMOS123 .DAT   174228   93-10-10 14:40 CMOS#123 Data
 PROG1             3389   93-09-21 15:12 BASIC Program
```

A maximum of 12 files can be displayed in the FILE CATALOG area. The number at the bottom right (for example, 5/16) of the FILE CATALOG area is: *file indicated by pointer/total files on disk*. If disk has more than 12 files, you can scroll by rotating the rotary knob or by using ⇧ or ⇩.

You can search for a desired file name by pressing an alphanumeric key. Field pointer moves to the first file name that starts with the entered character.

When using the save, get, purge, rename, or copy function, you can specify a file name from the FILE CATALOG area. Move the pointer to the desired filename using the rotary knob, then select SELECT secondary softkey.

The FILE CATALOG softkey does not display the file comments. If you want to display the file comments, select the READ COMMENT softkey.

File Type

The following are file types (file suffixes) used by HP 4155A/4156A:

MES	measurement setup data file
STR	stress setup data file
DAT	measurement setup and result data file
CST	customized file (consists of some settings of SYSTEM and STRESS page groups and ASCII SAVE window)
PRO	HP 4145B setup data file
PCL	hardcopy file for PCL language
PGL	hardcopy file for HP-GL language
TXT	measurement result data file for Spreadsheet

SAVE

You can start the *save* function by:

- Selecting SAVE secondary softkey.
- Pressing (Save) front-panel key in the User File key group (you can perform this on any page).

When you start the save function, the following entry fields appear:

```
FUNCTION: SAVE

NAME:          TYPE:      COMMENT
```

Also, EXECUTE and EXIT primary softkeys appear:

- Select the EXECUTE softkey to save the data to diskette or to internal memory.
- Select the EXIT softkey to exit the save function.

If you want to save data to an existing file on diskette, select FILE CATALOG secondary softkey, use rotary knob to move to desired file, then select the SELECT softkey to fill in the NAME, TYPE, and COMMENT fields.

If you want to save data to a new file on diskette, type in the new NAME, TYPE, and COMMENT.

If you want to save data to internal memory MEM*, select the desired MEM* in the NAME field, and fill in the TYPE and COMMENT.

- NAME

  When the pointer is in the NAME field, you enter name of file that you want to save. In this field, the following secondary softkeys appear:

  - maximum characters for HP LIF file: 6 (You cannot set "_" for the last character.)
  - maximum characters for DOS file: 8

  FILE CATALOG — Use if you want to save data to an existing file on diskette. You can move to the desired file name, then select SELECT to set the NAME, TYPE, and COMMENT fields.

  MEM* — Use if you want to save data to internal memory MEM1, MEM2, MEM3, or MEM4.

- TYPE

  TYPE field specifies the data type. In this field, select:

  - MES secondary softkey to save measurement setup data.
  - STR secondary softkey to save stress setup data.
  - DAT secondary softkey to save measurement setup and result data.
  - CST secondary softkey to save customized system data.

  If you save data to internal memory, the following appears on the secondary softkey: M (for measurement setup data), S (for stress setup data), D (for measurement setup and result data), or C (for customized system data).

- COMMENT

  In this field, you can add a file comment of up to 16 characters. (Only 14 characters can be displayed on MEM* softkey.)

Setup items that are saved to customize (CST) file.
The following setup items (mainly some of the STRESS and SYSTEM page settings) are stored when you set CST in the TYPE field.

- SYSTEM: CONFIGURATION page
  - CONFIGURATION setup table
- SYSTEM: PRINT/PLOT SETUP page
  - DESTINATION
  - LANGUAGE
  - FORM FEED
  - COLOR/ B/W
  - LINE
  - COLUMN
  - RESOLUTION
  - PAPER
  - OUTPUT ITEM
  - INIT STRING
  - TRAILER STRING
- SYSTEM: COLOR SETUP page
  - HUE
  - SATURATION
  - LUMINOSITY
  - PLOTTER PEN NO.

- SYSTEM: MISCELLANEOUS page
  - □ REMOTE CONTROL
  - □ BEEP
- STRESS: STRESS SETUP page
  - □ pulse count (only when pulse count mode is set)
  - □ HOLD TIME
  - □ STRESS Status
  - □ FILTER
- STRESS: STRESS FORCE page
  - □ STRESS
  - □ STATUS
- ASCII SAVE WINDOW
  - □ UNIT
  - □ DELIMITER
  - □ STRING MARK
- start page setting that was entered in window when saving INIT file
- hardcopy setup window
  - □ DESTINATION
  - □ FILE NAME
  - □ OUTPUT REGION
  - □ PRINT/PLOT COMMENT
  - □ OUTPUT PAGE
  - □ GRAPH TRACE ONLY
  - □ OUTPUT DATA
  - □ PRINT SETUP DATA

GET

You can start the *get* function by:

- Selecting GET secondary softkey
- Pressing (Get) front-panel key (you can perform this on any page).

When you start the get function, the following entry fields appear:

```
FUNCTION: GET
NAME:          TYPE:
```

Also, EXECUTE and EXIT primary softkeys appear:

Select EXECUTE softkey to get (retrieve) the specified data from the diskette or from the internal memory.

Select EXIT softkey to exit the get function.

- NAME

In the NAME field, you enter the file name that you want to get. And the following secondary softkeys appear:

FILE CATALOG	Use if you want to get data from a diskette file. You can move to the desired file name, then select SELECT to set the NAME and TYPE fields.
MEM*	Use if you want to get data from internal memory MEM1, MEM2, MEM3, or MEM4.

- TYPE

  TYPE field specifies the data type. In this field, select:

  - MES secondary softkey to get measurement setup data.
  - STR secondary softkey to get stress setup data.
  - DAT secondary softkey to get measurement setup and result data.
  - CST secondary softkey to get customized system data.
  - PRO secondary softkey to get HP 4145B setup data.

Number of Sweep Steps

The DAT or PRO types can be used for data from HP 4145B. If the number of primary sweep steps in HP 4145B setup data is more than 1001, the number of sweep steps is set to 1001, and the corresponding measurement results are discarded.

On secondary softkeys for internal memory, notations have following meaning: M (measurement setup or HP 4145B setup data), S (stress setup data), D (measurement setup and result data), or C (customized system data).

PURGE

You can start the *purge* function by selecting PURGE secondary softkey. The following entry fields appear:

```
FUNCTION: PURGE

NAME:          TYPE:
```

Also, EXECUTE and EXIT primary softkeys appear:

Select the EXECUTE softkey to purge (remove) the specified data from the diskette or from the internal memory.
Select the EXIT softkey to exit the purge function.

- NAME

  In the NAME field, you enter the file name that you want to purge. And the following secondary softkeys appear:

FILE CATALOG	Use if you want to delete a diskette file. You can move to the desired file name, then select SELECT to set the NAME and TYPE fields.
MEM*	Use if you want to delete data from MEM1, MEM2, MEM3, or MEM4. After delete, default data is stored in the selected memory.

- TYPE

  TYPE field specifies the data type. In this field, select:

  - ☐ * secondary softkey to delete all types of data.
  - ☐ MES secondary softkey to delete measurement setup data.
  - ☐ STR secondary softkey to delete stress setup data.
  - ☐ DAT secondary softkey to delete measurement setup and result data.
  - ☐ CST secondary softkey to delete customized system data.
  - ☐ PRO secondary softkey to delete HP 4145B setup data.

  On secondary softkeys for internal memory, the notations have following meaning: M (measurement setup or HP 4145B setup data), S (stress setup data), D (measurement setup and result data), or C (customized system data).

RENAME

You can start the *rename* function by selecting RENAME secondary softkey. The following entry fields appear:

```
FUNCTION: RENAME
NAME    :          TYPE:
NEW NAME:
```

Also, EXECUTE and EXIT primary softkeys appear:

Select the EXECUTE softkey to rename the file name on the diskette.

Select the EXIT softkey to exit rename function.

- NAME
  In the NAME field, you enter the file name that you want to rename. And the following secondary softkey appears:

FILE CATALOG	Lists the names of all files that are on the diskette. You can move to desired file name, then select SELECT SOURCE to set the NAME and TYPE fields.

- TYPE
  The TYPE field specifies the data type. In this field, select:

  - MES secondary softkey to rename measurement setup data.
  - STR secondary softkey to rename stress setup data.
  - DAT secondary softkey to rename measurement setup and result data.
  - CST secondary softkey to rename customized system data.
  - PRO secondary softkey to rename HP 4145B setup data.

  On secondary softkeys for internal memory, notations have following meaning: M (measurement setup or HP 4145B setup data), S (stress setup data), D (measurement setup and result data), or C (customized system data).

- NEW NAME
  In the NEW NAME field, you enter the new file name of the file. And the following secondary softkey appears:

FILE CATALOG	Lists the names of all files that are on the diskette. You can move to desired file name, then select SELECT TARGET to set the NEW NAME field.

COPY

You can start the *copy* function by selecting COPY secondary softkey. The following entry fields appear:

```
FUNCTION: COPY

SOURCE NAME:            TYPE:
TARGET NAME:
```

Also, EXECUTE and EXIT primary softkeys appear:

Select EXECUTE softkey to copy the data in diskette and internal memory.

Select the EXIT softkey to exit the copy function.

- SOURCE NAME

  Enter the source file name that you want to copy. Also, the following secondary softkey appears:

FILE CATALOG	Lists the names of all files that are on the diskette. You can move to the desired file name, then select SELECT SOURCE to set SOURCE NAME and TYPE fields.
MEM*	Specifies data that is in internal memory MEM1, MEM2, MEM3, or MEM4.

- TYPE

  TYPE field specifies the data type. In this field, select:

  - * secondary softkey to copy all types of data.
  - MES secondary softkey to copy measurement setup data.
  - STR secondary softkey to copy stress setup data.
  - DAT secondary softkey to copy measurement setup and result data.
  - CST secondary softkey to copy customized system data.
  - PRO secondary softkey to copy HP 4145B setup data.

  On secondary softkeys for internal memory, notations have following meaning: M (measurement setup or HP 4145B setup data), S (stress setup data), D (measurement setup and result data), or C (customized system data).

- TARGET NAME

  Enter the target file name to which you want to copy. Also, the following secondary softkeys appear:

FILE CATALOG	Lists the names of all files that are on the diskette. You can move to the desired file name, then select SELECT TARGET to set TARGET NAME field.
MEM*	Specifies internal memory MEM1, MEM2, MEM3, or MEM4.

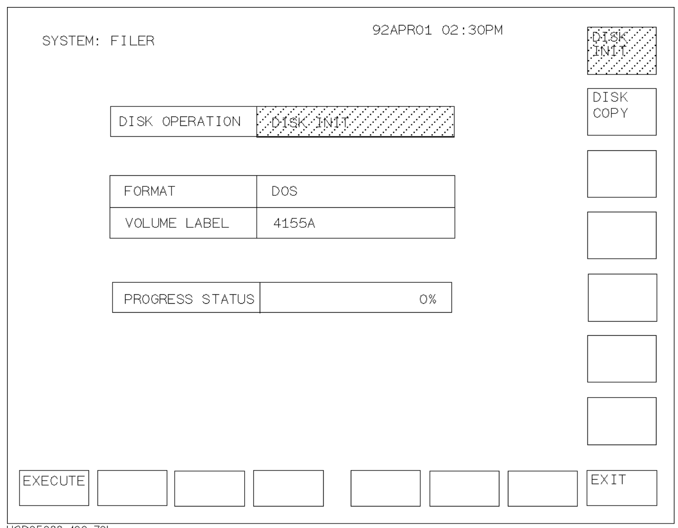
- TARGET DISK

  Enter whether the source and target files are on the same disk or different disks. The following secondary softkeys appear:

SAME	Target file is on same disk as source file.
OTHER	Target file is on different disk from source file.

DISK OPERA -TION

You can initialize or copy a disk by selecting DISK OPERATION secondary softkey. The following figure shows an example setup of disk operation function.



UGD05022, 100x70h

Also, EXECUTE and EXIT primary softkeys appear:

Select the EXECUTE softkey to execute the specified operation for the diskette inserted in the HP 4155A/4156A.
Select the EXIT softkey to exit the disk operation function.

- DISK OPERATION

  You select the desired operation in the DISK OPERATION field. In this field, the following secondary softkeys appear:

DISK INIT	Initializes the diskette that is inserted in the HP 4155A/4156A. Initialization prepares the diskette so that the HP 4155A/4156A can use it for storing and retrieving data.
DISK COPY	Copies entire contents of one diskette to another diskette. Typically, to make a backup copy.

Note that diskettes must have same format and capacities.

- FORMAT (appears only when DISK INIT is selected)

  You select a disk format for the diskette. In this field, DOS and HP LIF secondary softkeys appear.

- VOLUME LABEL (appears only when DISK INIT is selected)

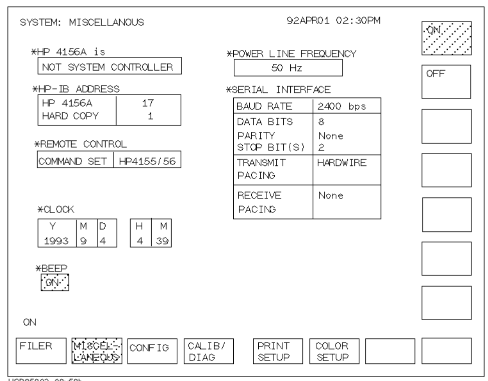
  You can specify a volume label for the diskette. The default volume name is "HP4155" or "HP4156". You cannot specify blank.

  In this field, you can enter a volume name that consists of up to 8 characters for DOS format or up to 6 characters for HP LIF format.

- PROGRESS STATUS

  This field shows the progress of diskette initialization or copy.

SYSTEM: MISCELLANEOUS page



On this page, you set miscellaneous settings of the HP 4155A/4156A.

HP 4156A is

This field specifies the operation mode of the HP 4155A/4156A for the HP-IB. In this field, the following secondary softkeys appear:

CONTROLLER — Sets the HP 4155A/4156A to be system controller. If you use IBASIC of HP 4155A/4156A, you set CONTROLLER.

NOT CONTROLLER — Sets the HP 4155A/4156A to not be system controller. If you control the HP 4155A/4156A from another controller via HP-IB, you set to NOT CONTROLLER.

HP-IB ADDRESS

Specifies addresses of your HP 4155A/56A and hard copy device.

- HP 4155A/4156A

  Enter HP-IB address of your HP 4155A/4156A in this field.

- HARD COPY

  Enter HP-IB address of printer or plotter connected to HP 4155A/56A.

REMOTE CONTROL

The REMOTE CONTROL table specifies the remote control command set as follows:

COMMAND SET	You can select HP4155/56 or HP4145 command set.
DELIMITER	(Only appears for HP4145 COMMAND SET) You can select delimiter to be comma, or carriage return and line feed (CR/LF).
EOI	(Only appears for HP4145 COMMAND SET) You set EOI function to on or off for the HP-IB.

NOTE

If you change the COMMAND SET field, the HP 4155A/56A is reset, so setup data is lost.

CLOCK

The CLOCK table sets the present date and time. In this table, enter the correct time and date. You can increment or decrement the number by using UP and DOWN secondary softkeys.

BEEP

BEEP field sets the usage of beep sound. In this field, select:

- ON secondary softkey if you want to use beep sound.
- OFF secondary softkey if you do not want to use beep sound.

POWER LINE FREQUENCY

The POWER LINE FREQUENCY field selects your power line frequency. Selectable frequency is 50 and 60 Hz.

SERIAL INTERFACE

The SERIAL INTERFACE table sets the data transfer parameters for the serial interface as follows:

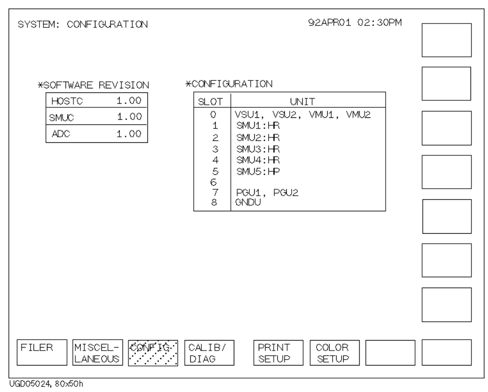
BAUD RATE — Transfer speed. You can select one of following:

- 600 bps
- 1200 bps

- 2400 bps
- 4800 bps
- 9600 bps
- 19200 bps
- 38400 bps

DATA BITS, PARITY, STOP BIT(S)	Data bits, parity setting, and stop bits. You can select one of the following: • 8 data bits, no parity, 2 stop bits. • 8 data bits, no parity, 1 stop bit. • 8 data bits, odd parity, 1 stop bit. • 8 data bits, even parity, 1 stop bit.
TRANSMIT PACING	Handshake method for transmitting line. You can select one of the following: • HARDWIRE HANDSHAKE: handshaking with CS (clear to send) line. • Xon/Xoff HANDSHAKE: handshaking with Xon and Xoff control code. Note that only HARDWIRE handshake is available for 38400 bps. Xon/Xoff is not available.
RECEIVE PACING	Handshake method for receiving line. You can select one of the following: • HARDWIRE HANDSHAKE: handshaking with CS (clear to send) line. • Xon/Xoff HANDSHAKE: handshaking with Xon and Xoff control code. • None Note that this field is blank when BAUD RATE is set to 38400 bps because 38400 baud rate is used for transmitting data only.

SYSTEM: CONFIGURATION page



On the “SYSTEM: CONFIGURATION” page, you see the system firmware revision, and hardware configuration of your HP 4155A/4156A.

SOFTWARE REVISION

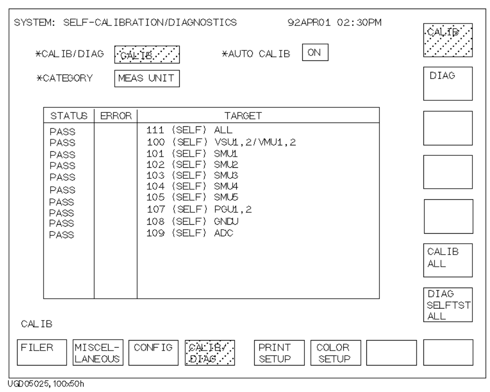
SOFTWARE REVISION table shows the following software revisions of the firmware:

- host controller
- SMU controller
- A/D converter controller

CONFIGURATION

CONFIGURATION table shows the hardware configuration of your HP 4155A/4156A.

SYSTEM: SELF-CALIBRATION/DIAGNOSTICS page



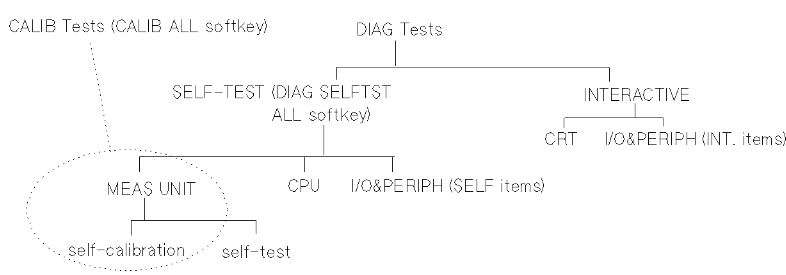
On the "SYSTEM: SELF-CALIBRATION/DIAGNOSTICS" page, you execute the self-calibration and diagnostics.

While executing self-calibration or diagnostics, you cannot perform measurements.

CALIB/DIAG

The CALIB/DIAG field specifies whether to execute self-calibration or diagnostics by selecting `CALIB` or `DIAG` secondary softkey.

The self-calibration tests are a part of the **MEAS UNIT** diagnostics tests as shown in the following figure.



AUTO CALIB

The AUTO CALIB field sets whether to execute self-calibration automatically or not by selecting `ON` or `OFF` secondary softkey.

If this field is set to `ON`, self-calibration is performed automatically every 30 minutes. When the state is not idle, self-calibration is performed after state changes to idle. Be aware of this when you perform long-time stress forcing or measurements, or when you use standby state.

CATEGORY

When `CALIB` is set in the CALIB/DIAG field, the CATEGORY field is automatically set to `MEAS UNIT`. You can set the CATEGORY field *only when* `DIAG` is set in the CALIB/DIAG field. In this field, select:

- `MEAS UNIT` secondary softkey to display test items for measurement units.
- `CRT` secondary softkey to display test items for CRT.
- `CPU` secondary softkey to display test items for CPU.
- `I/O & PERIPH` secondary softkey to display test items for I/O and peripherals.

The columns in the table mean the following:

- STATUS

  STATUS column displays test results as follows:

  - For the test items that HP 4155A/4156A *can* detect whether the test passes or fails:

`FAIL`	Executed test failed.
`PASS`	Executed test passed.
blank	Test result is not performed.

  - For the test items that HP 4155A/4156A *cannot* detect whether the test passes or fails:

`DONE`	Executed test is finished.
blank	Executed test is *not* finished.

- ERROR

  ERROR column displays an error code if the executed test failed. Only the first error code is displayed in this field. To see if more errors occurred, move the pointer to the test line. Up to 7 error codes are displayed in the data entry field. For details of error codes, see "If You Have a Problem" in *HP 4155A/4156A User's Task Guide*.

- TARGET

  TARGET column displays the following:

  □ test item number

    Using this number, you can execute the test item by remote command. For details, refer to *HP 4155A/4156A Programmer's Guide*.

  □ `(SELF)` or `(INT.)`

    `(SELF)` is displayed if the test can be executed automatically. All `(SELF)` items are executed if you select `DIAG SELFTST ALL` softkey.

    `(INT.)` is displayed if the test must be executed interactively, that is, you must make cable connections or judgements.

  □ test items

    You can execute each displayed test item by moving a pointer to the desired test item field, then selecting `EXECUTE` secondary softkey.

    If pointer is at a `(SELF)` test item, you can repeat the test continuously by selecting `REPEAT TEST` secondary softkey. You can stop executing the test by selecting `STOP` secondary softkey. `REPEAT TEST` secondary softkey is not displayed if `CALIB` is set in the CALIB/DIAG field.

    To perform serial interface test (test item number:401), I/F connecter (HP part number 04155-61001) is needed. To order this I/F connector, contact the nearest Hewlett-Packard Sales and Service office.

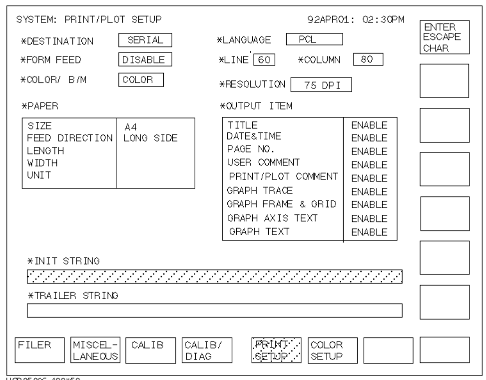
To Execute All Tests Automatically

In every field, CALIB ALL and DIAG SELFTST ALL secondary softkeys are displayed. Select:

- CALIB ALL secondary softkey to execute all self-calibration test items.
- DIAG SELFTST ALL secondary softkey to execute all test items in which (SELF) is displayed in the TARGET field.

To stop the executing tests, select STOP secondary softkey.

SYSTEM: PRINT/PLOT SETUP page



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On the "SYSTEM: PRINT/PLOT SETUP" page, you set the parameters of printer or plotter. For details about print/plot function, refer to Chapter 5 or "Hardcopy" in *HP 4155A/4156A User's Task Guide*.

DESTINATION

DESTINATION field sets the interface used to connect your printer or plotter. The available interfaces are HP-IB and serial:

- `HP-IB` softkey if your printer or plotter is connected to HP-IB interface of HP 4155A/4156A.
- `SERIAL` softkey if your printer or plotter is connected to serial interface of HP 4155A/4156A.

The HP-IB addresses and serial parameters are set on the SYSTEM: MISCELLANEOUS page.

FORM FEED

FORM FEED field sets whether the printer or plotter feeds a paper after print or plot out. In this field, select:

- `ENABLE` secondary softkey to enable the form feed function.
- `DISABLE` secondary softkey to disable the form feed function.

COLOR/ B/W

COLOR/ B/W field sets color, fixed color, or monochrome (black/white) mode. In this field, select:

- COLOR secondary softkey to set the color mode. This mode is available only for HP-GL or PCL printers that have sixteen color capability, for example, HP DeskJet 1200C and HP PaintJet. You can make a color print that has exactly same colors as display.
- FIX CLR secondary softkey to set the fixed color mode. This mode is for HP-GL pen plotters and for PCL color printers that have only eight color capability, for example, HP DeskJet 500C, 550C, and 560C. You can change the pen assignment or color for each screen item of the color plot/print by using the SYSTEM: COLOR SETUP page. For details, refer to "SYSTEM: COLOR SETUP page".
- B/W secondary softkey to set the monochrome (black/white) mode.

LANGUAGE

LANGUAGE field sets the printer or plotter control language. Available languages are HP PCL and HP-GL. In this field, select:

- PCL secondary softkey to set the control language to PCL. If you save hardcopy to a file, file type (file suffix) will be `PCL`.
- HP-GL secondary softkey to set the control language to HP-GL. If you save hardcopy to a file, file type (file suffix) will be `PGL`.

LINE and COLUMN

LINE field sets the number of lines on a page, and COLUMN field sets the number of characters in a line.

RESOLUTION

RESOLUTION field sets the resolution for the hardcopy (that is, changes actual resolution of printer). The available resolutions are 75, 90, 100, 150, 180, 300, and 600 dpi (dots per inch). These numbers have meaning only when the LANGUAGE is set to PCL.

PAPER

PAPER table sets the paper information such as paper size, orientation, and so on. The paper information consists of:

SIZE	Paper size. Available sizes are CUSTOM, A3 (297 × 420 mm), A4 (210 × 297 mm), B4 (257 × 364 mm), B5 (182 × 257 mm), A (letter: 8.5 × 11 inch), and B (11 × 17 inch).

FEED DIRECTION	Feed direction of paper. Specify if short or long side is inserted. This is *not* available for CUSTOM paper size.
LENGTH	Vertical length of the paper. This is available for CUSTOM paper size only.
WIDTH	Horizontal width of the paper. This is available for CUSTOM paper size only.
UNIT	Units for the paper size. You set inch or millimeter.

OUTPUT ITEM

OUTPUT ITEM table sets the output items to be output. For HP-GL, you can enable/disable all items. For PCL, GRAPH items are always enabled.

TITLE	Title of the print or plot out. This is the title that is determined automatically according to the type of output information.
	`*** HP 4155A SETUP DATA ***`
	`*** HP 4155A DATA LIST ***`
	`*** HP 4155A GRAPH PLOT ***`

DATE&TIME	Present date and time of the built-in clock.
PAGE NO.	Page number of the print or plot out.
USER COMMENT	User defined comment, which you defined on MEASURE pages or STRESS pages.
PRINT/PLOT COMMENT	User defined comment, which you defined in the PRINT/PLOT SETUP DATA, PRINT/PLOT DATA LIST, or GRAPH PLOT window.
GRAPH TRACE	(HP-GL only) Graphics plot curve of the GRAPH/LIST: GRAPH page.
GRAPH FRAME & GRID	(HP-GL only) Frame and grid of the GRAPH/LIST: GRAPH page.
GRAPH AXIS TEXT	(HP-GL only) Names, units, and scale of graph axis.
GRAPH TEXT	(HP-GL only) Marker and cursor coordinate fields, data variables, and line parameters (gradient and intercept).

In the above fields, the `ENABLE` and `DISABLE` secondary softkeys appear:

- Select the `ENABLE` softkey to enable the item.
- Select the `DISABLE` softkey to disable the item.

INIT STRING

In this field, you can set any initialization command of printer or plotter. Enter commands by using keyboard or ENTRY keys on front panel.

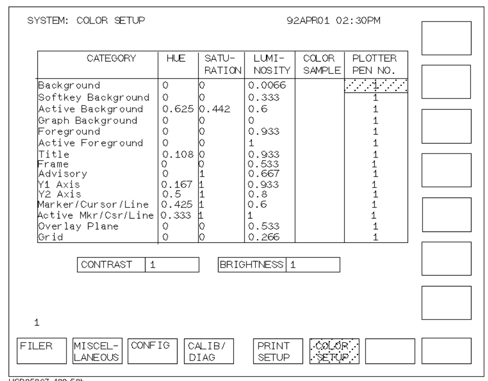
- Select the ENTER ESCAPE CHAR softkey to enter an escape character.

TRAILER STRING

In this field, you can set any commands that you want to execute after printing or plotting is finished. Enter commands by using keyboard or ENTRY group keys on front panel.

- Select the ENTER ESCAPE CHAR softkey to enter an escape character.

SYSTEM: COLOR SETUP page



UGD05027, 100x50h

On the "SYSTEM: COLOR SETUP" page, you set colors for various items of the screen. And you set the related plotter pens for plotting or colors for printing by the fixed color mode. Refer to "SYSTEM: PRINT/PLOT SETUP page" about the fixed color mode.

CATEGORY

CATEGORY fields lists the various screen items for which you can specify the colors.

Background	Background color of the screen. Note that if you set Background and Graph Background to different colors, graphic drawing speed becomes slow to paint out Background.
Softkey Background	Softkey background color.
Active Background	Background color of selected softkey or field.
Graph Background	Background color of graph. Note that if you set Graph Background and Background to different colors, graphic drawing speed becomes slow to paint out Background.

Foreground	Color of text (except for titles and text related to Y1 and Y2 axes).
Active Foreground	Color of text in selected field.
Title	Color of page/table titles and selected Y axis.
Frame	Color of frames (table and graph plotting area).
Advisory	Background color of boxes that pop up (for example, if you make an incorrect setting).
Y1 Axis	Color of Y1 axis text and curve.
Y2 Axis	Color of Y2 axis text and curve.
Marker/Cursor/Line	Color of inactive marker, cursor, and line.
Active Mkr/Csr/Lne	Color of active marker, cursor, and line.
Overlay Plane	Color of overlay plane.
Grid	Color of grid.

HUE, SATURATION, LUMINOSITY

HUE, SATURATION, and LUMINOSITY set the color. You can specify a value from 0 to 1 in each field.

HUE	Pure color. As you change this value from 0 to 1, the color changes red, orange, yellow, green, cyan (greenish blue), blue, magenta (purplish red), then red again. So, 0 and 1 are both red.
SATURATION	Ratio of pure color to white. 0 is no pure color (all white), and 1 is 100% pure color (no white). If this field is set to 0, the color is always white.
LUMINOSITY	Brightness. 0 is no brightness, 1 is 100% brightness. If this field is set to 0, the color is always black.

You can set *a row* to give desired color by selecting desired secondary softkey:

- `DEFAULT COLOR` sets *all rows* table to the default colors.
- `BLACK`
- `GREY`
- `WHITE`
- `RED`

- ORANGE
- YELLOW
- GREEN
- CYAN (greenish blue)
- BLUE
- MAGENTA (purplish red)

COLOR SAMPLE

This shows what color the item will be according to the HUE, SATURATION, and LUMINOSITY that you set.

PLOTTER PEN NO.

This is effective only for fixed color mode hardcopy. See COLOR/ B/W field on "SYSTEM: PRINT/PLOT SETUP page".

- For HP-GL Pen Plotter:

  This specifies which pen the plotter uses to draw each screen item. So, you need to load the appropriate pens in the pen carousel.

- For Color Printer:

  This specifies which color the printer uses to print each screen item. The following shows the values and corresponding colors:

1	Black
2	Red
3	Green
4	Yellow
5	Blue
6	Magenta
7	Cyan
8	White

CONTRAST

The difference in tone between the lightest and darkest areas on the screen. You can specify a value from 0 to 1.

BRIGHTNESS

The brightness of the whole screen. You can specify a value from 0.15 to 1.

5

Print/Plot Function

Print/Plot Function

This chapter explains the print/plot function.

HP 4155A/4156A can print, plot, or save to a diskette file the following in PCL or HP-GL format:

- Screen image of the displayed page

  Dumps the image of the displayed page to printer, plotter, or diskette file.
- Setup data

  Prints or plots a list of the setup data, or saves data to a file.
- List of the measurement results

  Prints or plots a list of the measurement results, or saves list to a file.
- Graph of the measurement results

  Prints or plots a graph of the measurement results, or saves graph to a file.

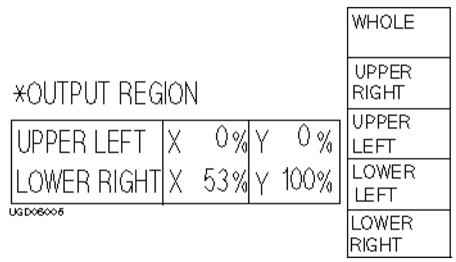
The following table shows the display pages for which the print/plot function is executable:

Information	Executable display pages
screen image	all pages
setup data	all setup pages (that is, all pages except GRAPH/LIST, STRESS: STRESS FORCE, and KNOB SWEEP pages)
list of measurement results	GRAPH/LIST: LIST page
graph of measurement results	GRAPH/LIST: GRAPH page

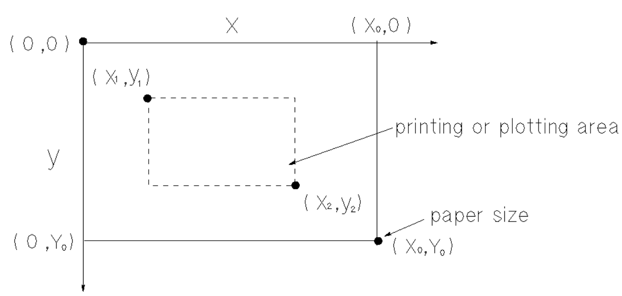
You can specify PCL or HP-GL format. Before executing the print/plot function, you may need to setup the SYSTEM: PRINT/PLOT SETUP page. Refer to "SYSTEM: PRINT/PLOT SETUP page" in Chapter 4.

Output Region

For the print/plot function, you need to set up the OUTPUT REGION table, which appears in the setup screen when you start a print/plot function. The fields of OUTPUT REGION table specify the print/plot area of the paper.



Output Region



UPPER LEFT	$\frac{X_1}{X_0} \times 100$ (%)	$\frac{y_1}{Y_0} \times 100$ (%)
LOWER RIGHT	$\frac{X_2}{X_0} \times 100$ (%)	$\frac{y_2}{Y_0} \times 100$ (%)

Defining Print/Plot Area of Paper

Output Region for PCL

For PCL format, fixed fonts are used, so the actual print plot area may not match the specified print/plot area. Also, the output will always have the same aspect ratio as the original.

For setup data or LIST measurement data, only the UPPER LEFT fields appear. And the settings in these fields may be ignored depending on the capabilities of the printer. If the DESTINATION field is set to FILE, the OUTPUT REGION table disappears.

For dump data, the screen is 548 by 400 dots. So, if the printer resolution is 300 DPI, the minimum print size is 548/300 by 400/300 inches. You can print out in integer multiples of this minimum size.

For graph data, the top five lines are for text. The graph area is 484 by 326 dots.

So, when you use the `WHOLE`, `UPPER RIGHT`, `UPPER LEFT`, `LOWER LEFT`, or `LOWER RIGHT` secondary softkeys to set the OUTPUT REGION fields, these field settings might not be exactly as you would expect: Because the SIZE, ORIENTATION, and RESOLUTION settings on the SYSTEM: PRINT/PLOT SETUP page determine the percentages that appear in OUTPUT REGION fields when you use these secondary softkeys.

To Store the Output Region Settings into Internal Memory.
You can memorize or recall the Output Region Settings as follows:

- `STORE REGION` secondary softkey to store the output region settings into internal memory.
- `RECALL REGION` secondary softkey to recall the output region settings from internal memory.

Output Region for HP-GL

For HP-GL, the fonts are scalable and the aspect ratio does not have to be maintained. So if you enter percentages directly into the OUTPUT REGION table, the actual print/plot area will match the specified area.

But when you use the WHOLE, UPPER RIGHT, UPPER LEFT, LOWER LEFT, or LOWER RIGHT secondary softkeys to set the OUTPUT REGION fields, calculations are made to keep the original aspect ratio. So the settings might not be exactly as you would expect: because the SIZE, ORIENTATION, LINE, and COLUMN settings on the SYSTEM: PRINT/PLOT SETUP page determine the numbers that appear in OUTPUT REGION fields.

To set entire paper area as output region.
Select WHOLE secondary softkey in the OUTPUT REGION table. This sets 0%, 0% in the UPPER LEFT fields, and sets the LOWER RIGHT fields depending on SYSTEM: PRINT/PLOT SETUP settings as described above. Aspect ratio is not changed.

To set desired quarter of paper area as output region.
Select UPPER RIGHT, UPPER LEFT, LOWER LEFT, or LOWER RIGHT secondary softkey to specify the desired quarter of the paper. This sets the OUTPUT REGION fields depending on SYSTEM: PRINT/PLOT SETUP settings as described above. Aspect ratio is not changed.

To Store the Output Region Settings into Internal Memory.
You can memorize or recall the Output Region Settings as follows:

- STORE REGION secondary softkey to store the output region settings into internal memory.
- RECALL REGION secondary softkey to recall the output region settings from internal memory.

Print/Plot Function for Screen Image

This function dumps a screen image of the displayed page to printer, plotter, or diskette file. You can specify HP-GL or PCL format on the SYSTEM: PRINT/PLOT SETUP page.

To start this function, display the page you want to dump. Press the green key, then press the (Plot/Print) front-panel key. The SCREEN DUMP area appears.

Print/Plot Setup Area for Screen Image

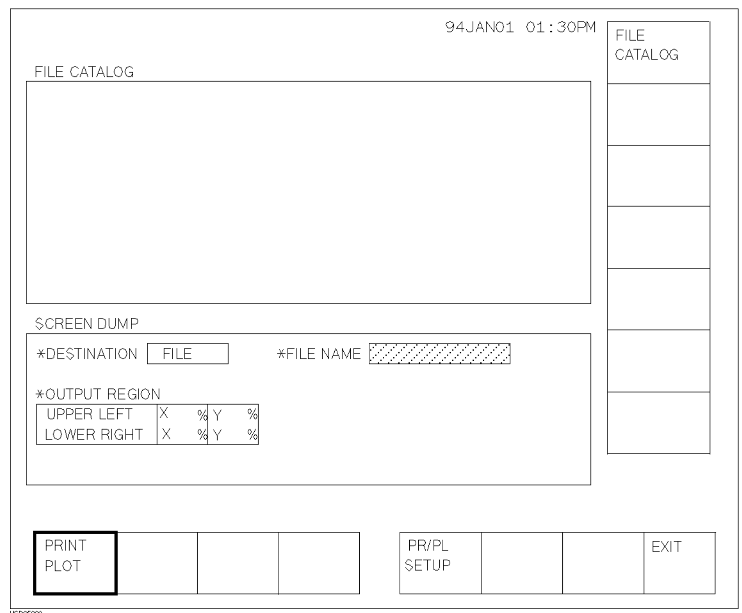


Figure 5-1. Print/Plot Setup Area for Screen Image

PRINT PLOT

PRINT/PLOT primary softkey dumps the screen image to the destination specified in the DESTINATION field.

PR/PL SETUP

PR/PL SETUP primary softkey displays the SYSTEM: PRINT/PLOT SETUP page, which you can use to set up the print/plot function. Refer to “SYSTEM: PRINT/PLOT SETUP page” in Chapter 4

EXIT

EXIT primary softkey returns to the page that was displayed before the SCREEN DUMP area was displayed.

FILE CATALOG Area

When `FILE` is selected in DESTINATION field, you can display the diskette file names in this area. Refer to "FILE NAME field" below.

SCREEN DUMP Area

- DESTINATION field

  DESTINATION specifies to dump the image to printer, plotter, or diskette file. When the pointer is located in this field, select one of the following secondary softkeys:

  - `PRINTER/PLOTTER`

    `PRINTER/PLOTTER` secondary softkey specifies to dump the image to printer or plotter.

  - `FILE`

    `FILE` secondary softkey specifies to dump the image to a diskette file. You specify the file name in the FILE NAME field.

- FILE NAME field

  FILE NAME field is displayed only when `FILE` is selected in DESTINATION field. This field specifies the file name in which to dump the image.

  When the pointer is located in this field, the following secondary softkey is displayed:

  - `FILE CATALOG`

    `FILE CATALOG` secondary softkey lists the file names that are stored on the diskette. You can enter a FILE CATALOG area file name into FILE NAME field by moving pointer to desired file name, then selecting `SELECT` softkey.

- OUTPUT REGION table

  OUTPUT REGION defines where to dump the image on the paper.

  For a description of this area, see "Output Region" at the beginning of this chapter.

Print/Plot Function for Setup Data

This function prints or plots a list of the setup data, or saves the setup data to a file. You can specify HP-GL or PCL format on the SYSTEM: PRINT/PLOT SETUP page.

You can output the setup data of one of the following:

- presently displayed page
- entire page group of presently displayed page
- all setup data.

To start this function, display the setup page you want to print, then press (Plot/Print) front-panel key to display the PRINT/PLOT SETUP DATA area.

Print/Plot Setup Area for Setup Data

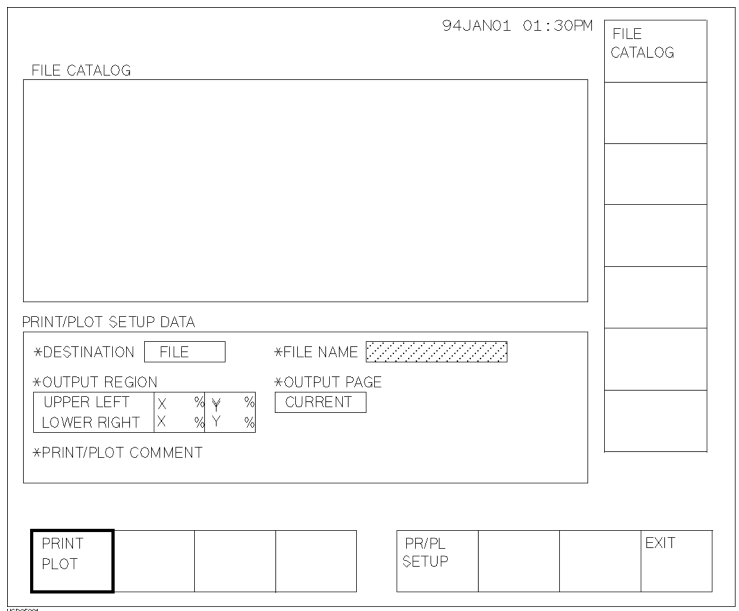


Figure 5-2. Print/Plot Setup Area for Setup Data

PRINT PLOT

PRINT/PLOT primary softkey outputs the setup data to the destination specified in the DESTINATION field.

PR/PL SETUP

PR/PL SETUP primary softkey displays the SYSTEM: PRINT/PLOT SETUP page, which you can use to set up the print/plot function. Refer to “SYSTEM: PRINT/PLOT SETUP page” in Chapter 4

EXIT

EXIT primary softkey returns to the page that was displayed before the PRINT/PLOT SETUP DATA area was displayed.

FILE CATALOG Area

When `FILE` is selected in DESTINATION field, you can display the diskette file names in this area. Refer to "FILE NAME field" below.

PRINT/PLOT SETUP DATA Area

- DESTINATION field

  DESTINATION specifies to output the setup data to printer or plotter, or to save the data to a file. When the pointer is located in this field, select one of the following secondary softkeys:

  - `PRINTER/PLOTTER`
    This softkey specifies to output the setup data to printer or plotter.
  - `FILE`
    This softkey specifies to save the setup data to a diskette file. You specify the file name in the FILE NAME field.
    A file suffix is added automatically depending on setting in LANGUAGE field on SYSTEM: PRINT/PLOT SETUP page. If `PCL`, suffix is `PCL`. If `HP-GL`, suffix is `PGL`.

- FILE NAME field

  FILE NAME field is displayed only when `FILE` is selected in DESTINATION field. This field specifies the file name in which to save the setup data.

  When the pointer is located in this field, the following secondary softkey is displayed:

  - `FILE CATALOG`
    This softkey lists the file names that are stored on the diskette. You can enter a FILE CATALOG area file name into FILE NAME field by moving pointer to desired file name, then selecting `SELECT` softkey.

- OUTPUT REGION table

  OUTPUT REGION defines where to print the measurement result list on the paper. You specify the UPPER LEFT and LOWER RIGHT fields, which determine the print/plot area of the paper. For a description of this area, see "Output Region" at the beginning of this chapter.

  If PCL is set on the SYSTEM: PRINT/PLOT SETUP page, only the UPPER LEFT field appears. If the DESTINATION field is set to FILE, the OUTPUT REGION table disappears.

- OUTPUT PAGE field

  OUTPUT PAGE field specifies the range of setup data to output. When pointer is located in this field, following secondary softkeys are displayed:

  - `CURRENT`

    `CURRENT` secondary softkey specifies the setup data of *only the page* where the print/plot function is invoked.

  - `GROUP`

    `GROUP` secondary softkey specifies the setup data of the *page group* where the print/plot function is invoked.

  - `ALL`

    `All` secondary softkey specifies *all* the setup data.

- PRINT/PLOT COMMENT field

  In PRINT/PLOT COMMENT field, you can enter a comment to be printed with the output. This comment is output *only* when the PRINT/PLOT COMMENT field on the SYSTEM: PRINT/PLOT SETUP page is enabled.

Print/Plot Function for List of Measurement Results

This function prints or plots a list of the measurement results, or saves results to a diskette file. You can specify HP-GL or PCL format on the SYSTEM: PRINT/PLOT SETUP page.

To start this function, press (Plot/Print) front-panel key when the GRAPH/LIST: LIST page is displayed. The PRINT/PLOT DATA LIST area is displayed.

Print/Plot Setup Area for List of Measurement Results

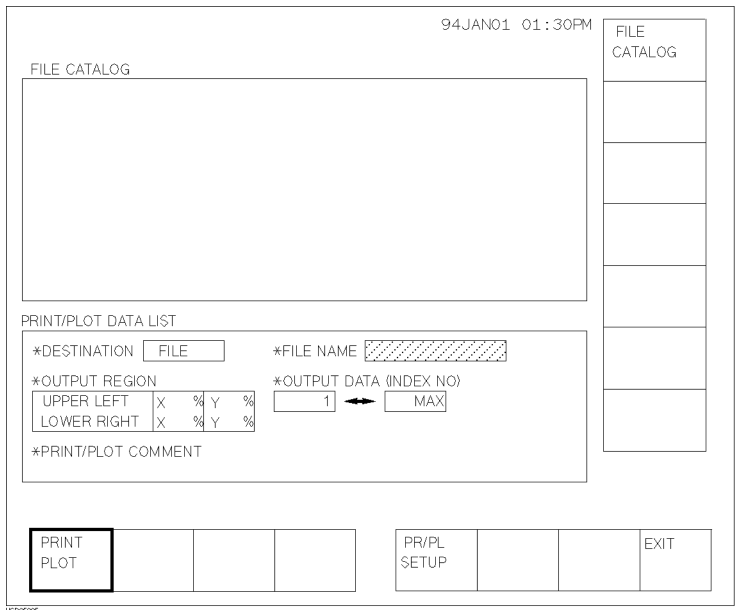


Figure 5-3. Print/Plot Setup Area for List of Measurement Results

PRINT PLOT

PRINT/PLOT primary softkey outputs a list of the measurement results to the destination specified in the DESTINATION field.

PR/PL SETUP

PR/PL SETUP primary softkey displays the SYSTEM: PRINT/PLOT SETUP page, which you can use to set up the print/plot function. Refer to “SYSTEM: PRINT/PLOT SETUP page” in Chapter 4

EXIT

EXIT primary softkey returns to the GRAPH/LIST: LIST page.

FILE CATALOG Area

When `FILE` is selected in DESTINATION field, you can display the diskette file names in this area. Refer to "FILE NAME field" below.

PRINT/PLOT DATA LIST Area

- DESTINATION field

  DESTINATION specifies to output the measurement result list to printer or plotter, or to save the list to a file. When the pointer is located in this field, select one of the following secondary softkeys:

  □ `PRINTER/PLOTTER`
  This softkey specifies to output the measurement result list to printer or plotter.

  □ `FILE`
  This softkey specifies to save the measurement result list to a diskette file. You specify the file name in FILE NAME field.
  A file suffix is added automatically depending on setting in LANGUAGE field on SYSTEM: PRINT/PLOT SETUP page. If `PCL`, suffix is `PCL`. If `HP-GL`, suffix is `PGL`.

- FILE NAME field

  FILE NAME field is displayed only when `FILE` is selected in the DESTINATION field. This field defines the file name in which to save the measurement result list.

  When the pointer is located in this field, the following secondary softkey is displayed:

  □ `FILE CATALOG`
  This softkey lists the file names that are stored on the diskette. You can enter a FILE CATALOG area file name into FILE NAME field by moving pointer to desired file name, then selecting `SELECT` softkey.

- OUTPUT REGION table

  OUTPUT REGION defines where to print the measurement result list on the paper. You specify the UPPER LEFT and LOWER RIGHT fields, which determine the print/plot area of the paper. For a description of this area, see "Output Region" at the beginning of this chapter.

  If PCL is set on the SYSTEM: PRINT/PLOT SETUP page, only the UPPER LEFT field appears. If the DESTINATION field is set to FILE, the OUTPUT REGION table disappears.

- OUTPUT DATA fields

  OUTPUT DATA fields specify the range of measurement results to output. You specify the range by using index numbers that correspond to the `NO.` column of GRAPH/LIST: LIST page. You can use `MAX` to define the maximum index number of data. `ALL` secondary softkey specifies the range from `1` to `MAX`, so all measurement results are output.

- PRINT/PLOT COMMENT field

  In PRINT/PLOT COMMENT field, you can enter a comment to be printed with the output. This comment is output *only* when the PRINT/PLOT COMMENT field on the SYSTEM: PRINT/PLOT SETUP page is enabled.

Print/Plot Function for Graph of Measurement Results

This function prints or plots a graph of the measurement results, or saves graph to a diskette file. You can specify HP-GL or PCL format on the SYSTEM: PRINT/PLOT SETUP page.

To start this function, press (Plot/Print) front-panel key when the GRAPH/LIST: GRAPH page is displayed. The GRAPH PLOT area is displayed.

Print/Plot Setup Area for Graph of Measurement Results

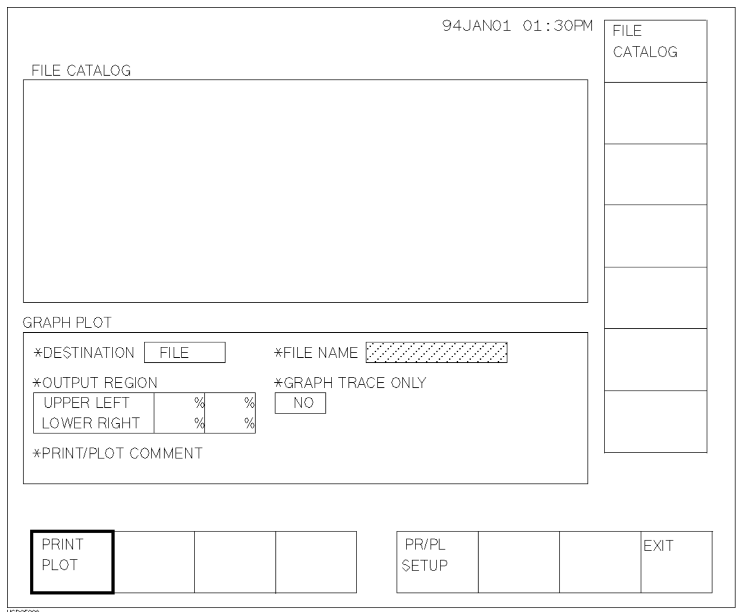


Figure 5-4. Print/Plot Setup Area for Graph of Measurement Results

PRINT PLOT

PRINT/PLOT primary softkey outputs a graph of the measurement results to the destination specified in the DESTINATION field.

PR/PL SETUP

PR/PL SETUP primary softkey displays the SYSTEM: PRINT/PLOT SETUP page, which you can use to set up the print/plot function. Refer to "SYSTEM: PRINT/PLOT SETUP page" in Chapter 4

EXIT

EXIT primary softkey returns to the GRAPH/LIST: GRAPH page.

FILE CATALOG Area

When FILE is selected in DESTINATION field, you can display the diskette file names in this area. Refer to "FILE NAME field" below.

GRAPH PLOT Area

- DESTINATION field

  DESTINATION specifies to output the measurement result graph to printer or plotter, or to save the graph to a file. When the pointer is located in this field, select one of the following secondary softkeys:

  - PRINTER/PLOTTER
    This softkey specifies to output the measurement result graph to printer or plotter.
  - FILE
    This softkey specifies to save the measurement result graph to a diskette file. You specify the file name in the FILE NAME field.
    A file suffix is added automatically depending on setting in LANGUAGE field on SYSTEM: PRINT/PLOT SETUP page. If PCL, suffix is PCL. If HP-GL, suffix is PGL.

- FILE NAME field

  FILE NAME field is displayed only when FILE is selected in the DESTINATION field. This field defines the file name in which to save the measurement result graph.

  When the pointer is located in this field, the following secondary softkey is displayed:

  - FILE CATALOG
    This softkey lists the file names that are stored on the diskette. You can enter a FILE CATALOG area file name into FILE NAME field by moving pointer to desired file name, then selecting SELECT softkey.

- OUTPUT REGION table

  OUTPUT REGION defines where to print the measurement result graph on the paper.

  For a description of this area, see "Output Region" at the beginning of this chapter.

- GRAPH TRACE ONLY field

  In this field, you can specify to output the graph trace *only*, and to ignore the other output items that are enabled on the SYSTEM: PRINT/PLOT SETUP page.

  - YES secondary softkey
    Output the graph trace only.
  - NO secondary softkey
    Output the items that are enabled on SYSTEM: PRINT/PLOT SETUP page.

  If LANGUAGE=PCL on the SYSTEM: PRINT/PLOT SETUP page, the GRAPH TRACE ONLY field is not displayed. For PCL, graph trace output is always enabled, and cannot be disabled.

- PRINT SETUP DATA field

  In PRINT SETUP DATA field, you can specify to output the measurement setup data with graph.

  - YES secondary softkey
    Output the measurement setup data.
  - NO secondary softkey
    Output graph only.

- PRINT/PLOT COMMENT field

  In PRINT/PLOT COMMENT field, you can enter a comment to be printed with the output. This comment is output *only* when the PRINT/PLOT COMMENT field on the SYSTEM: PRINT/PLOT SETUP page is enabled.

6

Data Variable and Analysis Function

Data Variable and Analysis Function

This chapter explains the display and analysis functions of the HP 4155A/4156A:

- data variable
- expression
- built-in functions
- read-out functions
- analysis function

Data Variable

Data variables are used for displaying and analyzing measurement results. You use data variables to assign output or measurement data to an axis for display.

Each data variable has a name. You refer to a data variable by its name.

The following are the three types of data variable:

- Output or measurement data
- User function
- User variable

Data Variable for Output or Measurement Data

Data variables are available for the following measurement result data:

- Output data that you set for SMU or VSU.
- Measurement data of SMU or VMU.
- Output data that you set for PGU.
- Time data of sampling measurement.
- Index of measurement result data.

Output data of SMU or VSU.
The data variable names are the output names that you set in the VNAME or INAME columns of CHANNELS: CHANNEL DEFINITION page. For a voltage MODE, the output name is specified in the VNAME column. For a current MODE, output name is specified in INAME column.

Measurement data of SMU or VMU.
The data variable names are the measurement result names that you set in the VNAME or INAME columns of CHANNELS: CHANNEL DEFINITION page. For a voltage MODE, the measurement result name is specified in the INAME column. For a current MODE, measurement result name is specified in VNAME column.

You can get the measurement results by using the measurement result names. If the corresponding SMU or VMU does not perform a measurement, invalid data is returned.

Output data of PGU.

The data variables for PGU output are as follows:

Set data	Data variable name
pulse peak	VNAME for PGU that you defined on CHANNELS: CHANNEL DEFINITION page is the data variable name for pulse peak voltage.
pulse period	@PGT is the data variable for pulse period.
pulse duration	@PGD is the data variable for duration time of pulse stress force. Duration time is the pulse count multiplied by pulse period.
pulse delay time	@PG1DL is the data variable for pulse delay time of PGU1. @PG2DL is the data variable for pulse delay time of PGU2.
pulse width	@PG1W is the data variable for pulse width of PGU1. @PG2W is the data variable for pulse width of PGU2.
pulse base	@PG1B is the data variable for pulse base voltage or current of PGU1. @PG2B is the data variable for pulse base voltage or current of PGU2
pulse leading	@PG1LD is the data variable for leading-edge transition time of PGU1. @PG2LD is the data variable for leading-edge transition time of PGU2.
pulse trailing	@PG1TR is the data variable for trailing-edge transition time of PGU1. @PG2TR is the data variable for trailing-edge transition time of PGU2.

Time data of sampling measurement.

`@TIME` is the data variable for time data of sampling measurement.

Index of the measurement result data.

`@INDEX` is the data variable for index number of measurement data.

The index number of the first data is 1. For a subordinate sweep measurement, the index number continues to increment by 1 between secondary sweep steps, that is,

- last data of a primary sweep: *index*
- first data of next primary sweep: *index*+1

User Function

A user function consists of one or more data variables used in an expression. You define the user function name, expression, and unit on the CHANNELS: USER FUNCTION DEFINITION page.

You can use a user function inside another user function. And you can set up the user function on the DISPLAY: DISPLAY SETUP pages to plot the user function values or display the numeric value.

To define a user function, you define a name and an expression on the CHANNELS: USER FUNCTION DEFINITION page. If desired, you can define a unit, such as ms.

- User function name must start with alphabet character and can consist of maximum six alphanumeric characters. Name must be unique. Name is case sensitive. For example, Gm is different from gm.
- Syntax of an expression is described in "Expression".
- Unit name is optional. Length: 1 to 6 characters. Valid characters: any characters.

For example.
To define a user function for mutual conductance *gm* of an FET, define *gm* on the CHANNELS: USER FUNCTION DEFINITION page as follows:

NAME	UNIT	DEFINITION
gm	S	DELTA(Id)/DELTA(Vg)

User Variable

A user variable is a data variable that is a numeric list, which is passed via HP-IB commands of PAGE:CHANNels:UVARiable and TRACe|DATA subsystems from an external computer or HP Internal BASIC. For information about the PAGE:CHANNels:UVARiable and TRACe|DATA subsystems, refer to *HP 4155A/4156A HP-IB Command Reference*.

You can perform calculations between measurement results and the numeric list, or plot the numeric list on the GRAPH/LIST: GRAPHICS page.

You can define up to six user variables. A user variable consists of the following:

user variable name must start with alphabet character and can consist of maximum six alphanumeric characters. Name must be unique. Name is case sensitive. For example, VTH is different from Vth.

data numeric list.

unit Optional. Length: 1 to 6 characters. Valid characters: any characters.

Calculation between variables of different length.

If you perform calculation between user variables, or between a user variable and a measurement data variable, and the number of data are different, the extra data in the longer variable are invalid.

Example.

Following IBASIC program defines a user variable that has 5 data elements:

```
10  ASSIGN @Hp4155 TO 800
20  OUTPUT @Hp4155;":FORM:DATA ASC"
30  OUTPUT @Hp4155;":TRAC:DEF 'UVAR1',5"
40  OUTPUT @Hp4155;":TRAC:DATA 'UVAR1',1.1, 1.2, 1.3, 1.4, 1.5"
50  END
```

20 Format of data to be transferred is ASCII format.
30 Defines the name of user variable and number of data.
40 Transfers the data.

Syntax of Data Variable Name

A data variable name must start with alphabet character and can consist of maximum six alphanumeric characters. Refer to Figure 6-1.

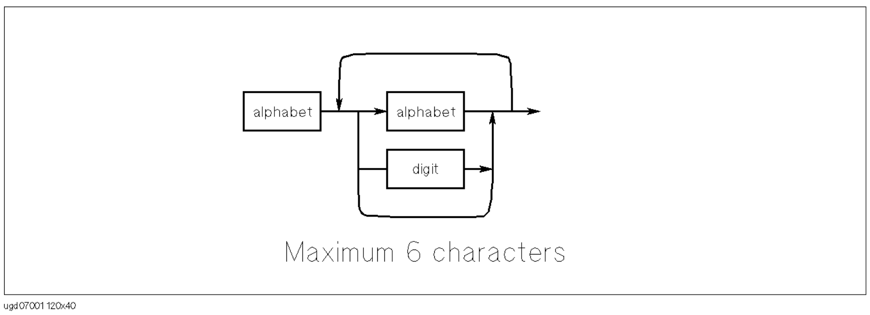


Figure 6-1. Syntax of Data Variable Name

The name must be unique. Name is case sensitive. For example, Gm is different from GM.

Using Built-in Function Name as Data Variable Name

You can give a data variable name the same name as a built-in function. But if you use the name in an expression, the system considers the name to be a data variable name, not a built-in function name. So, in this case, you cannot use the built-in function in an expression.

Expression

An expression can be used for following:

- In a user function definition
- As a condition for an automatic analysis function
- For direct keyboard calculation

Direct Keyboard Calculation

You can directly calculate the value of an expression as follows:

- Enter the expression by using the front-panel keys, press the green key, then press (Enter). The value of the expression is displayed.

If the expression contains data variables that are related to measurement points, the calculated value corresponds to the marker position.

Figure 6-2 shows the syntax of an expression. Notice that an expression can be used within an expression.

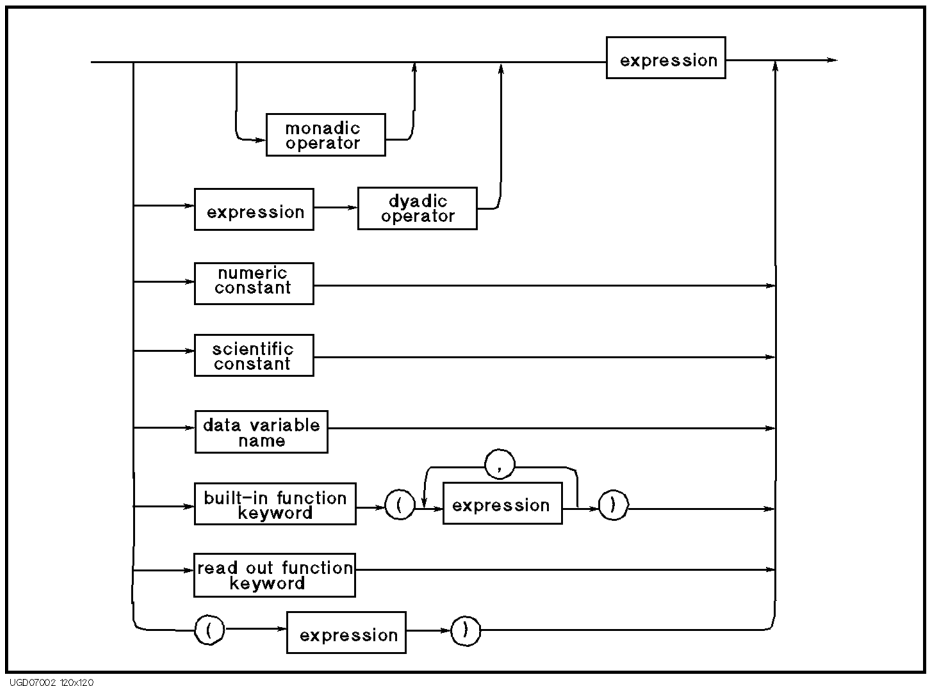


Figure 6-2. Expression Syntax

monadic operator.

Monadic operator performs operation on expression immediately to its right:

```
+  positive     –  negative
```

dyadic operator.

Dyadic operator performs operation between two expressions:

```
+  addition       *  multiplication     ^  exponentiation
-  subtraction    /  division
```

> **Operation between data variables**
>
> Operation between data variables is performed between data at the same measurement points.

numeric constant.
Numeric constant can consist of digits, decimal point, and optional exponent notation. Refer to Figure 6-3

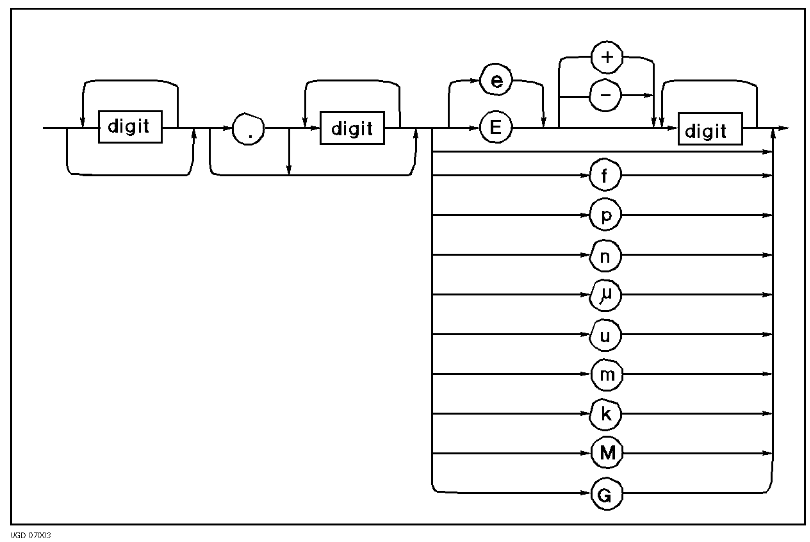


Figure 6-3. Numeric Constant

- Mantissa (decimal part) of greater than seven digits is truncated to seven digits.
- The following predefined notations are available:

f	10^{-15}
p	10^{-12}
n	10^{-9}
μ	10^{-6}
u	10^{-6}
m	10^{-3}
k	10^{3}
M	10^{6}
G	10^{9}

scientific constant.
The following scientific constants are available:

q	electric charge. 1.602177×10^{-19}
k	Boltzmann's constant. 1.380658×10^{-23}
e	space permittivity. 8.854188×10^{-12}

data variable name.
Any data variable name.

read out function keyword.
A keyword that invokes a built-in HP 4155A/HP4156B read out function. Refer to "Read Out Function".

built-in function keyword.
A keyword that invokes a built-in HP 4155A/4156A function. Refer to "Reference: Built-in Function".

Arithmetic operator precedence

When an expression contains more than one operation, the order of operation is determined by operator precedence. Operations with the highest precedence are performed first. Multiple operations with the same precedence are performed left to right. The following table shows the arithmetic operator precedence.

Arithmetic Operations

Precedence	Operator
Highest	Parentheses: (may be used to force any order of operations)
	Functions: built-in function and data variable
	Exponentiation: ^
	Multiplication and division: * /
Lowest	Addition, subtraction, monadic operators: + -

Reference: Built-in Function

You can use built-in functions for the following:

- In the expression that is used to define a user function on the CHANNELS: USER FUNCTION DEFINITION page.
- As the condition for an automatic analysis function on the DISPLAY: ANALYSIS SETUP page.
- For direct keyboard calculations.

The following functions are available:

- ABS
- AT
- AVG
- COND
- DELTA
- DIFF
- EXP
- INTEG
- LGT
- LOG
- MAVG
- MAX
- MIN
- SQRT

ABS

Returns the absolute value of the *expression*.

Syntax

`ABS(`*expression*`)`

Example

To return the absolute value of `ID`:

```
ABS(ID)
```

AT

Returns the value of *1st expression* at the index number specified by the *2nd expression*.

Syntax

`AT(`*1st expression*`,`*2nd expression*`)`

If *2nd expression* is not integer, linear interpolated value of *1st expression* will be returned.

Example

To return difference of `Id` from its first value:

```
Id - AT(Id, 1)
```

AVG

Returns the average value of sweep data or sampling data.

Syntax

`AVG(`*expression*`)`

For subordinate sweep measurement, this function returns the average value of the primary sweep for the secondary sweep step.

Example

To return the average value of `ID`:

```
AVG(ID)
```

COND

This function does the following:

- If *1st expression* < *2nd expression*, returns *3rd expression*.
  or
- If *1st expression* ≥ *2nd expression*, returns *4th expression*.

Syntax

`COND(`*1st expression*`,` *2nd expression*`,` *3rd expression*`,` *4th expression*`)`

If value of *1st expression* or a *2nd expression* is invalid, the value for the previous measurement index number is used for the comparison.

Example

To return:

- `VD` if `ID-VG` < `SQRT(ID)-VG`.
- `VGS-VTH` if `ID-VG` ≥ `SQRT(ID)-VG`.

```
COND(ID-VG, SQRT(ID)-VG, VD, VGS-VTH)
```

DELTA

Returns the difference of the *expression*.

Syntax

`DELTA(`*expression*`)`

The difference is defined as follows:

- Basic or synchronous sweep measurement or sampling measurement

$$\delta_n = \begin{cases} (a_2 - a_1) & \text{when } n = 1 \\ \frac{1}{2}(a_{n+1} - a_{n-1}) & \text{when } 1 < n < N \\ (a_N - a_{N-1}) & \text{when } n = N \end{cases}$$

  Where,

δ_n:	difference for measurement index number n.
a_n:	value of an *expression* for measurement index number n.
N:	number of sweep steps or number of samples.

- Subordinate sweep measurement

  For each primary sweep, use same definition as for basic sweep measurement and assume measurement index number 1 for the first step of each primary sweep.

  If *expression* is a data variable for a secondary sweep source, this function returns the sweep step value of the secondary sweep.

Example

To return the difference of `ID`:

```
DELTA(ID)
```

DIFF

Returns differential coefficient of *1st expression* by *2nd expression*.

Syntax

`DIFF(`*1st expression*`,`*2nd expression*`)`

The differential coefficient is defined as follows:

- Basic or synchronous sweep measurement or sampling measurement

$$y'_n = \begin{cases} \frac{y_2 - y_1}{x_2 - x_1} & \text{when n = 1} \\ \frac{y_{n+1} - y_{n-1}}{x_{n+1} - x_{n-1}} & \text{when } 1 < n < N \\ \frac{y_N - y_{N-1}}{x_N - x_{N-1}} & \text{when n = N} \end{cases}$$

  Where,

y'_n:	differential coefficient for measurement index number n.
y_n:	value of *1st expression* for measurement index number n.
x_n:	value of *2nd expression* for measurement index number n.
N:	number of sweep steps or number of samples.

- Subordinate sweep measurement

  For each primary sweep, use same definition as for basic sweep measurement and assume measurement index number 1 for the first step of each primary sweep.

Example

To return the 2nd order differential coefficient of `ID` by `VG`:

```
DIFF(DIFF(ID,VG),VG)
```

EXP

Raises e to the power of *expression*.

Syntax

```
EXP(expression)
```

Example

To raise e to the power of the `ID`:

```
EXP(ID)
```

INTEG

Performs numerical integration of the *1st expression* by the *2nd expression*.

Syntax

`INTEG(`*1st expression*`,` *2nd expression*`)`

This operation is defined as follows:

- Basic or synchronous sweep measurement or sampling measurement

$$\sigma_n = \begin{cases} 0 & \text{when } n = 1 \\ \frac{1}{2}\sum_{i=2}^{n}(y_i + y_{i-1})(x_i - x_{i-1}) & \text{when } n > 1 \end{cases}$$

  Where,

σ_n:	integral of *1st expression* for measurement index number n.
y_i:	value of *1st expression* for measurement index number i.
x_i:	value of *2nd expression* for measurement index number i.
N:	number of sweep steps or number of samples.

  If there are some invalid values in the *expression*s, the invalid values are ignored for the calculation.

- Subordinate sweep measurement

  For each primary sweep, use same definition as for basic sweep measurement and assume measurement index number 1 for the first step of each primary sweep.

Example

To integrate `ID` by `VD`:

```
INTEG(ID,VD)
```

LGT

Returns the logarithm (base 10) of *expression*.

Syntax

`LGT(`*expression*`)`

If the *expression* is:

0	`XXXXXX` is returned with status of “Arithmetic error”.
negative value	logarithm of absolute value is returned with status of “Arithmetic error”.

Example

To return the logarithm of `ID`:

```
LGT(ID)
```

LOG

Returns the logarithm (base e) of *expression*.

Syntax

`LOG(`*expression*`)`

If the *expression* is:

0	`XXXXXX` is returned with status of “Arithmetic error”.
negative value	logarithm of absolute value is returned with status of “Arithmetic error”.

Example

To return the logarithm of `ID`:

```
LOG(ID)
```

MAVG

Returns the moving average value of *1st expression*. The *2nd expression* specifies how many measurement points to use for average.

Syntax

`MAVG(`*1st expression*`,`*2nd expression*`)`

This operation is defined as follows:

- Basic or synchronous sweep measurement or sampling measurement

  The moving average at measurement index number n is defined as follows:

$$\overline{x}_n = \begin{cases} \frac{1}{r+n} \sum_{i=1}^{n+r} x_i & \text{when } n \le r \\ \frac{1}{2r+1} \sum_{i=n-r}^{n+r} x_i & \text{when } r < n \le N - r \\ \frac{1}{r+N-n+1} \sum_{i=n-r}^{N} x_i & \text{when } N - r < n \end{cases}$$

  Where,

  $\overline{x}_n$: moving average of the *1st expression* for measurement index number n.
  x_i: value of the *1st expression* for measurement index number i.
  r: value of the *2nd expression*.

  If there are some invalid values in the *1st expression*, the invalid values are ignored for the calculation.

- Subordinate sweep measurement

  For each primary sweep, use same definition as for basic sweep measurement and assume measurement index number 1 for the first step of each primary sweep.

Example

To return the moving average value of ''ID'' by using five measurement values:

```
MAVG(ID,5)
```

MAX

Returns the maximum sweep or sampling value.

Syntax

`MAX(`*expression*`)`

For subordinate sweep measurement, this function returns the maximum value of the primary sweep for the secondary sweep step.

If there are invalid values in *expression*, invalid values are ignored.

Example

To return the maximum value of `ID`:

```
MAX(ID)
```

MIN

Returns the minimum sweep or sampling value.

Syntax

`MIN(`*expression*`)`

For subordinate sweep measurement, this function returns the minimum value of the primary sweep for the secondary sweep step.

If there are invalid values in *expression*, invalid values are ignored.

Example

To return the minimum value of `ID`:

```
MIN(ID)
```

SQRT

Returns the square root of the *expression*.

Syntax

`SQRT(`*expression*`)`

Example

To return the square root of `ID`:

```
SQRT(ID)
```

Read Out Function

The read out functions are built-in functions for reading various values related to the maker, cursor, or line. You can use these functions to perform complex analysis of the measurement results.

You can use read out functions for the following:

- In the expression that is used to define a user function on the CHANNELS: USER FUNCTION DEFINITION page.
- As a condition for an automatic analysis function on the DISPLAY: ANALYSIS SETUP page.
- For direct keyboard calculations.

The following functions are available:

Function	Read Out Function
Marker	@MI, @MX, @MY, @MY1, @MY2
Cursor	@CX, @CY, @CY1, @CY2
Line	@IX, @IY, @IY1, @IY2, @L1CO, @L1G, @L1G1, @L1G2, @L1X, @L1Y, @L1Y1, @L1Y2, @L2CO, @L2G, @L2G1, @L2G2, @L2X, @L2Y, @L2Y1, @L2Y2

The following are restrictions for using read out functions:

- `GRAPHICS` must be selected in the DISPLAY MODE field on the DISPLAY: DISPLAY SETUP page when you use the read out function. If not, invalid data is returned. (`@MI` is an exception. `@MI` can be used in GRAPHICS or LIST mode.)
- If the marker, cursor, or line that are referred to by the read out function are not displayed, the read out function uses the position at which it was most recently displayed. If the marker, cursor, and line have not been displayed, the read out function returns invalid data.
- You cannot assign a data variable that includes a read out function to an axis of graphics plot.

@CX

Returns the value of X coordinate at the active cursor position.

Syntax

```
@CX
```

@CY

Returns the value of Y coordinate at the active cursor position.

Syntax

```
@CY
```

If there are Y1 and Y2 axes, this function returns the value for selected axis.

@CY1

Returns the value of Y1 coordinate at the active cursor position.

Syntax

```
@CY1
```

@CY2

Returns the value of Y2 coordinate at the active cursor position.

Syntax

```
@CY2
```

@IX

Returns the value of X coordinate at the cross point of LINE1 and LINE2.

Syntax

```
@IX
```

This function calculates the cross point by using the following formula:

$$x = \frac{y_2 - y_1}{\alpha_2 - \alpha_1}$$

Where,

x: Value of X coordinate at the cross point. If the X axis is logarithmic scale, this function returns 10^x.

y_n: Y-intercept value of LINEn. If the Y axis is logarithmic scale, y_n is the log value of the y intercept of LINEn.

α_n: Slope of LINEn.

If LINE1 is parallel to LINE2, this function returns invalid data with the status "Arithmetic error".

@IY

Returns the value of Y coordinate at the cross point of LINE1 and LINE2.

Syntax

`@IY`

If there are Y1 and Y2 axes, this function returns the value for selected axis.

This function calculates the cross point by using the following formula:

$$y = \frac{\alpha_1}{\alpha_1 - \alpha_2}(y_2 - y_1) + y_1$$

Where,

y: Value of Y coordinate at the cross point. If the Y axis is logarithmic scale, this function returns 10^y.

y_n: Y-intercept of LINEn. If the Y axis is logarithmic scale, y_n is the log value of the y intercept of LINEn.

α_n: Slope of LINEn.

If LINE1 is parallel to LINE2, this function returns invalid data with the status "Arithmetic error".

@IY1

Returns the value of Y1 coordinate at the cross point of LINE1 and LINE2.

Syntax

```
@IY1
```

This function calculates the cross point by using the following formula:

$$y1 = \frac{\alpha_1}{\alpha_1 - \alpha_2}(y_2 - y_1) + y_1$$

Where,

$y1$:	Value of Y1 coordinate at the cross point. If the Y1 axis is logarithmic scale, this function returns 10^{y1}.
y_n:	Y1-intercept of LINEn. If the Y1 axis is logarithmic scale, y_n is the log value of the Y1 intercept of LINEn.
α_n:	Slope of LINEn.

If LINE1 is parallel to LINE2, this function returns invalid data with the status "Arithmetic error".

@IY2

Returns the value of Y2 coordinate at the cross point of LINE1 and LINE2.

Syntax

```
@IY2
```

This function calculates the cross point by using the following formula:

$$y2 = \frac{\alpha_1}{\alpha_1 - \alpha_2}(y_2 - y_1) + y_1$$

Where,

$y2$:	Value of Y2 coordinate at the cross point. If the Y2 axis is logarithmic scale, this function returns 10^{y2}.
y_n:	Y2-intercept of LINEn. If the Y2 axis is logarithmic scale, y_n is the log value of the Y2 intercept of LINEn.
α_n:	Slope of LINEn.

If LINE1 is parallel to LINE2, this function returns invalid data with the status "Arithmetic error".

@L1CO

Returns the correlation coefficient of the regression for LINE1.

Syntax

```
@L1CO
```

LINE1 must be in regression mode. If not, this function returns invalid data.

@L1G

Returns the slope of LINE1.

Syntax

```
@L1G
```

If there are Y1 and Y2 axes, this function returns the value for selected axis.

This function calculates the slope by using the following formula:

- If X and Y axes are both linear scaling:

$$\alpha = \frac{y_1 - y_0}{x_1 - x_0}$$

- If X axis is logarithmic scaling, and Y axis is linear scaling:

$$\alpha = \frac{y_1 - y_0}{log x_1 - log x_0}$$

- If X axis is linear scaling, and Y axis is logarithmic scaling:

$$\alpha = \frac{log y_1 - log y_0}{x_1 - x_0}$$

- If X and Y axes are both logarithmic scaling:

$$\alpha = \frac{log y_1 - log y_0}{log x_1 - log x_0}$$

Where,

α:	Slope of LINE1.
x_0, y_0, x_1, y_1:	X and Y coordinate values at the two points where LINE1 intercepts the perimeter of the plotting area.

@L1G1

Returns the slope of LINE1 for Y1 axis.

Syntax

```
@L1G1
```

This function calculates the slope by using the following formula:

- If X and Y1 axis are both linear scaling:

$$\alpha = \frac{y_1 - y_0}{x_1 - x_0}$$

- If X axis is logarithmic scaling, and Y1 axis is linear scaling:

$$\alpha = \frac{y_1 - y_0}{log x_1 - log x_0}$$

- If X axis is linear scaling, and Y1 axis is logarithmic scaling:

$$\alpha = \frac{log y_1 - log y_0}{x_1 - x_0}$$

- If X and Y1 axes are both logarithmic scaling:

$$\alpha = \frac{log y_1 - log y_0}{log x_1 - log x_0}$$

Where,

α:	Slope of LINE1.
x_0,y_0,x_1,y_1:	X and Y1 coordinate values at the two points where LINE1 intercepts the perimeter of the plotting area.

@L1G2

Returns the slope of LINE1 for Y2 axis.

Syntax

`@L1G2`

This function calculates the slope by using the following formula:

- If X and Y2 axes are both linear scaling:

$$\alpha = \frac{y_1 - y_0}{x_1 - x_0}$$

- If X axis is logarithmic scaling, and Y2 axis is linear scaling:

$$\alpha = \frac{y_1 - y_0}{log x_1 - log x_0}$$

- If X axis is linear scaling, and Y2 axis is logarithmic scaling:

$$\alpha = \frac{log y_1 - log y_0}{x_1 - x_0}$$

- If X and Y2 axes are both logarithmic scaling:

$$\alpha = \frac{log y_1 - log y_0}{log x_1 - log x_0}$$

Where,

α:	Slope of LINE1.
x_0, y_0, x_1, y_1:	X and Y2 coordinate values at the two points where LINE1 intercepts the perimeter of the plotting area.

@L1X

Returns the X intercept value (Y=0) of LINE1.

Syntax

```
@L1X
```

If LINE1 is horizontal, this function returns invalid data.

@L1Y

Returns the Y intercept value (X=0) of LINE1.

Syntax

```
@L1Y
```

If there are Y1 and Y2 axes, this function returns the value for selected axis.

If LINE1 is vertical, this function returns invalid data.

@L1Y1

Returns the Y1 intercept value (X=0) of LINE1.

Syntax

```
@L1Y1
```

If LINE1 is vertical, this function returns invalid data.

@L1Y2

Returns the Y2 intercept value (X=0) of LINE1.

Syntax

```
@L1Y2
```

If LINE1 is vertical, this function returns invalid data.

@L2CO

Returns the correlation coefficient of the regression for LINE2.

Syntax

```
@L2CO
```

LINE2 must be in regression mode. If not, this function returns invalid data.

@L2G

Returns the slope of LINE2.

Syntax

```
@L2G
```

If there are Y1 and Y2 axes, this function returns the value for selected axis.

This function calculates the slope by using the following formula:

- If X and Y axes are both linear scaling:

$$\alpha = \frac{y_1 - y_0}{x_1 - x_0}$$

- If X axis is logarithmic scaling, and Y axis is linear scaling:

$$\alpha = \frac{y_1 - y_0}{log x_1 - log x_0}$$

- If X axis is linear scaling, and Y axis is logarithmic scaling:

$$\alpha = \frac{log y_1 - log y_0}{x_1 - x_0}$$

- If X and Y axes are both logarithmic scaling:

$$\alpha = \frac{log y_1 - log y_0}{log x_1 - log x_0}$$

Where,

α:	Slope of LINE2.
x_0, y_0, x_1, y_1:	X and Y coordinate values at the two points where LINE2 intercepts the perimeter of the plotting area.

@L2G1

Returns the slope of LINE2 for Y1 axis.

Syntax

```
@L2G1
```

This function calculates the slope by using the following formula:

- If X and Y1 axis are both linear scaling:

$$\alpha = \frac{y_1 - y_0}{x_1 - x_0}$$

- If X axis is logarithmic scaling, and Y1 axis is linear scaling:

$$\alpha = \frac{y_1 - y_0}{log x_1 - log x_0}$$

- If X axis is linear scaling, and Y1 axis is logarithmic scaling:

$$\alpha = \frac{log y_1 - log y_0}{x_1 - x_0}$$

- If X and Y1 axes are both logarithmic scaling:

$$\alpha = \frac{log y_1 - log y_0}{log x_1 - log x_0}$$

Where,

α:	Slope of LINE2.
x_0,y_0,x_1,y_1:	X and Y1 coordinate values at the two points where LINE2 intercepts the perimeter of the plotting area.

@L2G2

Returns the slope of LINE2 for Y2 axis.

Syntax

```
@L2G2
```

This function calculates the slope by using the following formula:

- If X and Y2 axes are both linear scaling:

$$\alpha = \frac{y_1 - y_0}{x_1 - x_0}$$

- If X axis is logarithmic scaling, and Y2 axis is linear scaling:

$$\alpha = \frac{y_1 - y_0}{log x_1 - log x_0}$$

- If X axis is linear scaling, and Y2 axis is logarithmic scaling:

$$\alpha = \frac{log y_1 - log y_0}{x_1 - x_0}$$

- If X and Y2 axes are both logarithmic scaling:

$$\alpha = \frac{log y_1 - log y_0}{log x_1 - log x_0}$$

Where,

α:	Slope of LINE2.
x_0,y_0,x_1,y_1:	X and Y2 coordinate values at the two points where LINE2 intercepts the perimeter of the plotting area.

@L2X

Returns the X intercept value (Y=0) of LINE2.

Syntax

```
@L2X
```

If LINE2 is horizontal, this function returns invalid data.

@L2Y

Returns the Y intercept value (X=0) of LINE2.

Syntax

```
@L2Y
```

If there are Y1 and Y2 axes, this function returns the value for selected axis.

If LINE2 is vertical, this function returns invalid data.

@L2Y1

Returns the Y1 intercept value (X=0) of LINE2.

Syntax

```
@L2Y1
```

If LINE2 is vertical, this function returns invalid data.

@L2Y2

Returns the Y2 intercept value (X=0) of LINE2.

Syntax

```
@L2Y2
```

If LINE2 is vertical, this function returns invalid data.

@MI

Returns the index number of measurement data at the marker location.

Syntax

```
@MI
```

This function can be used in both GRAPHICS and LIST display modes.

If the interpolation mode is enabled in GRAPHICS display and the marker is located between the measurement data, this function returns a non-integer value.

@MX

Returns the value of the X coordinate at the marker location.

Syntax

```
@MX
```

@MY

Returns the value of the Y coordinate at the marker location.

Syntax

```
@MY
```

If there are Y1 and Y2 axes, this function returns the value for selected axis.

@MY1

Returns the value of the Y1 coordinate at the marker location.

Syntax

```
@MY1
```

@MY2

Returns the value of the Y2 coordinate at the marker location.

Syntax

```
@MY2
```

Analysis Function

The HP 4155A/4156A provides the following functions for analyzing measurement results:

- Marker on the GRAPH/LIST: GRAPHICS page
- Marker on the GRAPH/LIST: LIST page
- Cursor
- Line Drawing
- Scaling
- Display Overlay
- Automatic Analysis

Marker on the GRAPH/LIST: GRAPHICS page

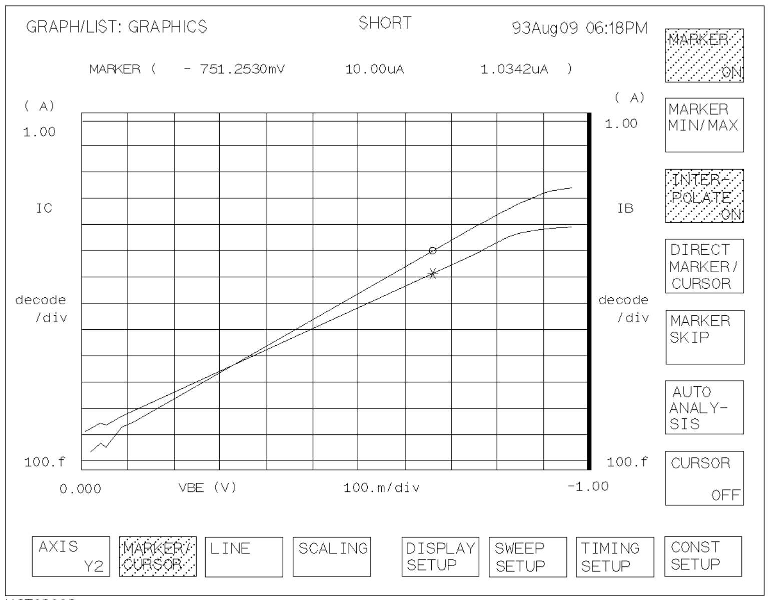


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Figure 6-4. Markers on the GRAPH/LIST: GRAPHICS page

You can display the markers on the plotted measurement curves on the GRAPH/LIST: GRAPHICS page by selecting `MARKER/CURSOR` primary softkey, then selecting `MARKER` secondary softkey. The marker for Y1 axis is a circle (∘), and the marker for Y2 axis is an asterisk (∗). The active marker depends on the selected axis.

Markers have the following functions on the GRAPH/LIST: GRAPHICS page:

- displaying values of measurement curve.

  The X, Y1, or Y2 coordinate values at the marker location are displayed.

- specifying a point at which to draw a tangent line

  For tangent line mode, the marker is used to specify the position at which to draw a tangent to the measurement curve. Refer to "Line Drawing".

- displaying values of data variables

  The data variable values at the marker location are displayed.

- specifying the position for direct keyboard calculation

  If you enter an expression that has data variables related to measurement points, the value of the expression at the marker position is displayed.

- indicating measurement point determined by auto analysis expression

  If you set up an expression for the marker on DISPLAY: ANALYSIS SETUP page, the marker moves to the point determined by the expression after auto analysis is performed.

Moving the marker.
Basically, you can move the markers on measurement points of the measurement curve by using the knob on the front panel. In addition to the basic movement, the following functions allow you to quickly move the marker to the desired position.

- Interpolation Mode

  Enables you to move the marker on lines between adjacent measurement points.

- Marker to Min/Max

  Moves the marker to the maximum or minimum measurement point value.

- Direct Movement

  Moves the marker directly to specified coordinates on measurement curve.

- Marker Skip

  Moves the marker to the next measurement curve. This function only has meaning for subordinate sweep measurements and append measurements.

Marker on the GRAPH/LIST: LIST page

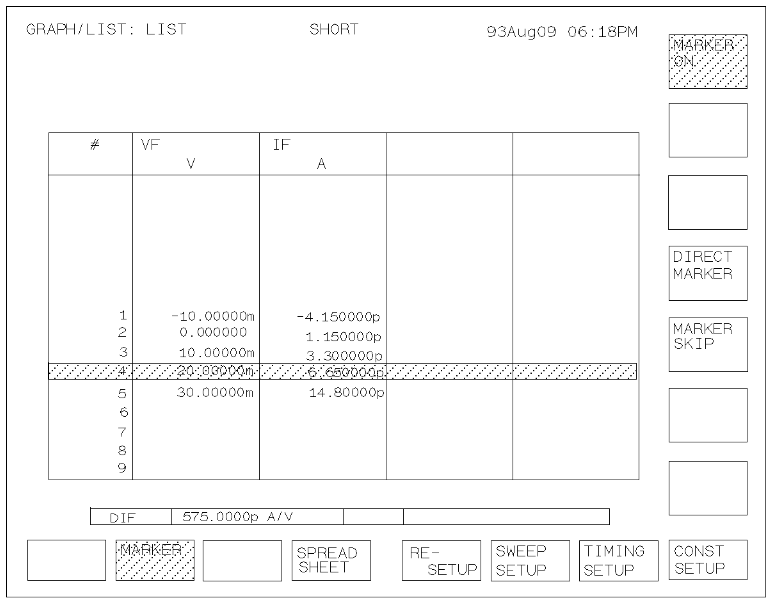


Figure 6-5. Marker on the GRAPH/LIST: LIST page

When marker function is enabled on GRAPH/LIST: LIST page, a marker (highlighted row) is displayed.

Marker has following functions on this page:

- displaying values of data variables

  The data variable values are displayed for the highlighted row.

- specifying the position for direct keyboard calculation

  If you enter an expression that has data variables related to measurement points, the value of the expression for the highlighted row is displayed.

- indicating measurement point determined by auto analysis expression

  If you set up an expression for the marker on DISPLAY: ANALYSIS SETUP page, the marker moves to the row determined by the expression after auto analysis is performed.

Moving the marker.
Basically, you can move the marker up or down by using the rotary knob on the front panel or by using the ⇑ and ⇓ front-panel keys. If you have defined more than four variable values, you can scroll right or left by using the ⇒ or ⇐ front-panel keys.

In addition to the basic movement, the following functions allow you to quickly move the marker to the desired position. For these functions, the row marker becomes a one cell pointer, so these functions are for the column that contains the pointer, not the entire row.

- Marker to Min/Max

  Moves the pointer to the maximum or minimum measurement point value.

- Direct Movement

  Moves the pointer directly to the value that is closest to the specified value.

- Marker Skip

  Moves the pointer to data for the next measurement curve. This function only has meaning for subordinate sweep measurements and append measurements.

Cursor

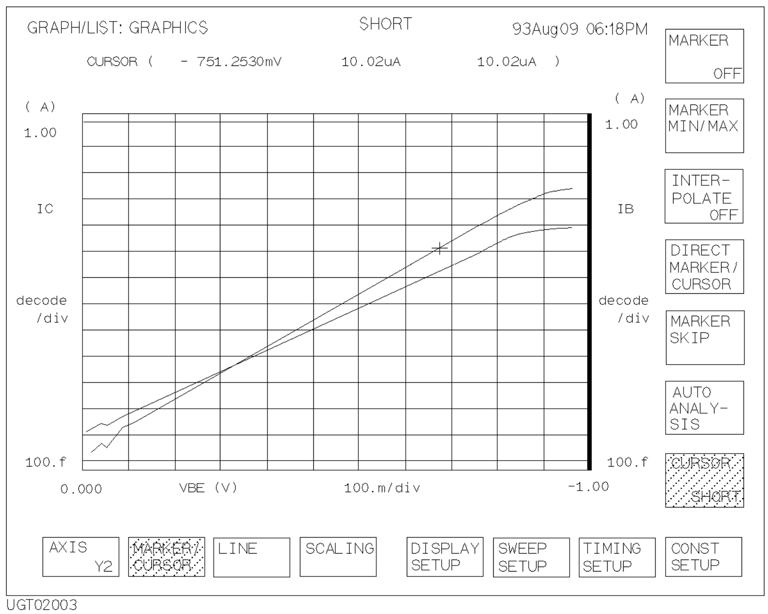


Figure 6-6. Cursors on the GRAPH/LIST: GRAPHICS page

Cursors are used to specify the position for line drawing or scaling functions on the GRAPH/LIST: GRAPHICS page. Refer to "Line Drawing" and "Scaling Functions".

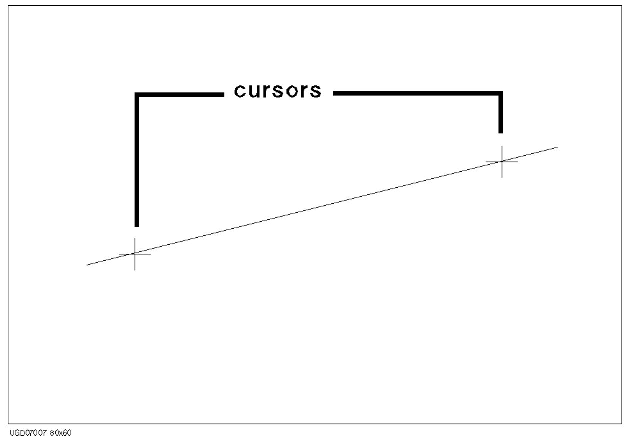
You can select a short cursor, which is a cross "'+'", or a long cursor, which is a cross with long lines.

You can move the cursor *anywhere* in the plotting area by using arrow keys of the Marker/Cursor key group.

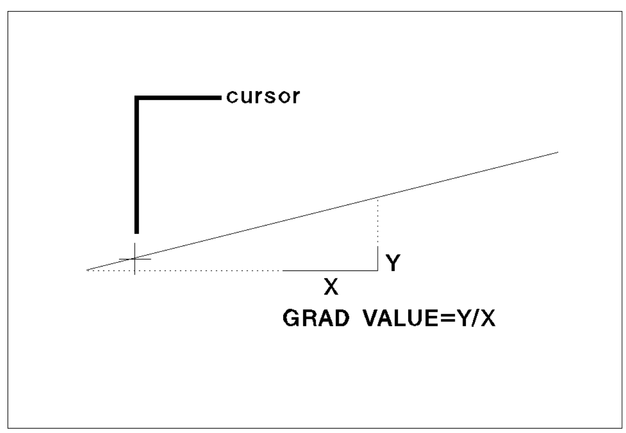
Line Drawing

You can draw up to two lines in plotting area on GRAPH/LIST: GRAPHICS page. To draw lines, you can select one of following four line modes:

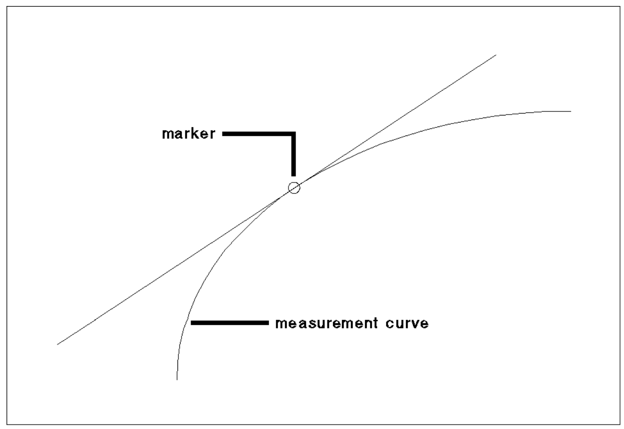
- Normal line mode: can draw a line through two cursors.



- Grad line mode: can draw a line through a cursor with specified gradient.

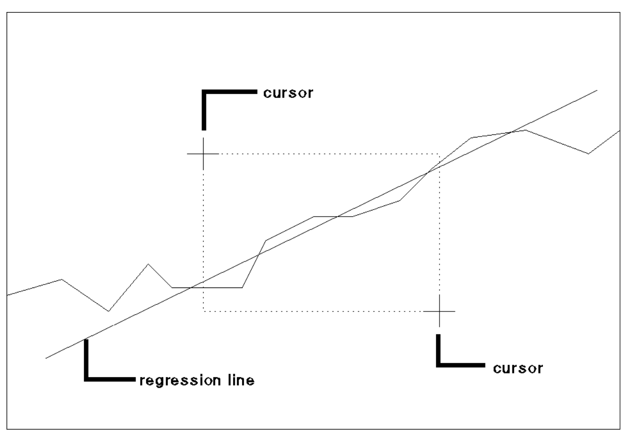


- Tangent line mode: can draw tangent line to marker, which is on measurement curve.



UGD07009 80x60

- Regression line mode: can draw regression line within area specified by two cursors.



UGD07010 80x60

Scaling Functions

You can change the axis scales after plotting the measurement results on the GRAPH/LIST: GRAPHICS page. The following scaling functions are provided:

- Autoscaling

  Changes X and Y-axis scaling to fit the measurement curve.

- Zooming in

  Displays the area around the cursor with double resolution.

- Zooming out

  Displays the area around the cursor with half resolution.

- Centering at cursor

  Centers the display around the cursor at the same resolution.

Overlay Display Function

You can overlay a measurement curve (that was previously saved into one of the four internal memories) onto the curve that is presently displayed on the GRAPH/LIST: GRAPHICS page. This is useful for comparing measurement results.

Overlay Display Information.
You can use following information of overlaid curve instead of present information:

- Axis information
- Cursor and marker position
- List of the data variables

Adjusting axes.
You can use the axis scaling of overlaid plane instead of present scaling.

Automatic Analysis Function

This function can automatically draw up to two lines and position a marker on the plotting area of the GRAPH/LIST: GRAPHICS page. You set up this function on the DISPLAY: ANALYSIS SETUP page. This function is performed automatically when:

- measurement finishes.
- `AUTO ANALYSIS` secondary softkey on the GRAPH/LIST: GRAPHICS page is pressed.

The same four line modes as for manual analysis are available: normal, grad, tangent, and regression. For details about these line modes, refer to "Line Drawing".

Specifying Points for Drawing Lines and Positioning Marker. Two modes are available: X-Y mode and on plot mode. Following table shows which of these modes are available for drawing lines and positioning marker.

Positioning Mode	Line Mode				Marker Positioning
	Normal	Grad	Tangent	Regression	
X-Y	○	○	n.a.	○	n.a.
On plot	○	○	○	○	○

- X-Y mode

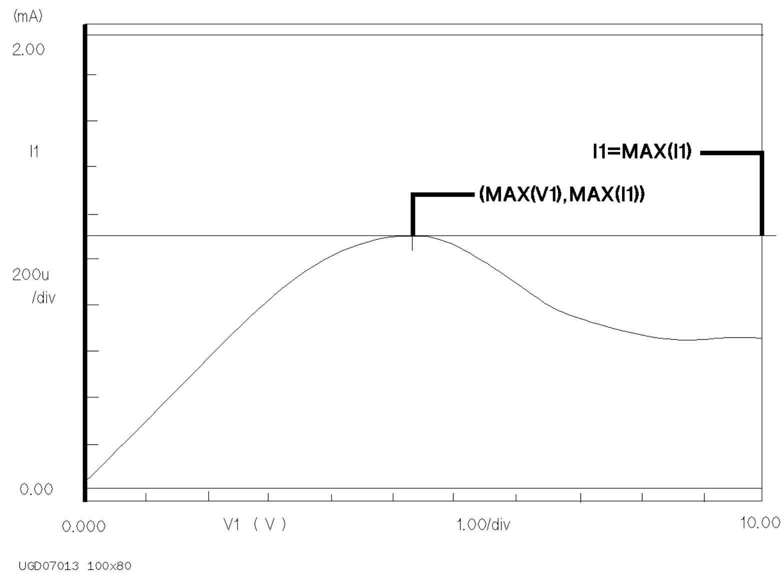
  You can specify *any* point in plotting area by using X and Y coordinate values. Can directly specify coordinate values or specify an expression.

- On plot mode

  You can specify a point on the measurement curve by using a data variable and an expression. The measurement point is determined by the point where the data variable is equal to the expression.

  You can also specify a second expression that is the starting point of the search. That is, the search for the measurement point that satisfies the first expression does not start until the finding the measurement point that satisfies the second expression.

Example:



If you want to automatically draw a normal mode line between the following two points:

- point where X value is same as maximum V1, and Y value is same as maximum I1
- maximum I1 point on measurement curve

then specify the following on the DISPLAY: ANALYSIS SETUP page:

```
LINE1:  [NORMAL  ] line on [Y1] between a point [AT]
 X:[MAX(V1)]
 Y:[MAX(I1)]
and a point [WHERE]
 [ I1   ]=[ MAX(I1)       ]
```

7

Softkey Maps and External Keyboard

Softkey Maps and External Keyboard

This chapter is organized into the following two sections:

- softkey maps

  HP 4155A/4156A has many primary and secondary softkeys for each page. This chapter shows softkey maps for these softkeys.

- external keyboard

  You can use an external keyboard (HP C1405B) with the HP 4155A/4156A. The front-panel keys and softkeys on HP 4155A/4156A can be operated from the external keyboard. This is useful when you use HP Instrument BASIC, or when conditions make it difficult for you to use the front-panel keys and softkeys.

Softkey Maps

This section shows softkey maps of the primary and secondary softkeys for each page.

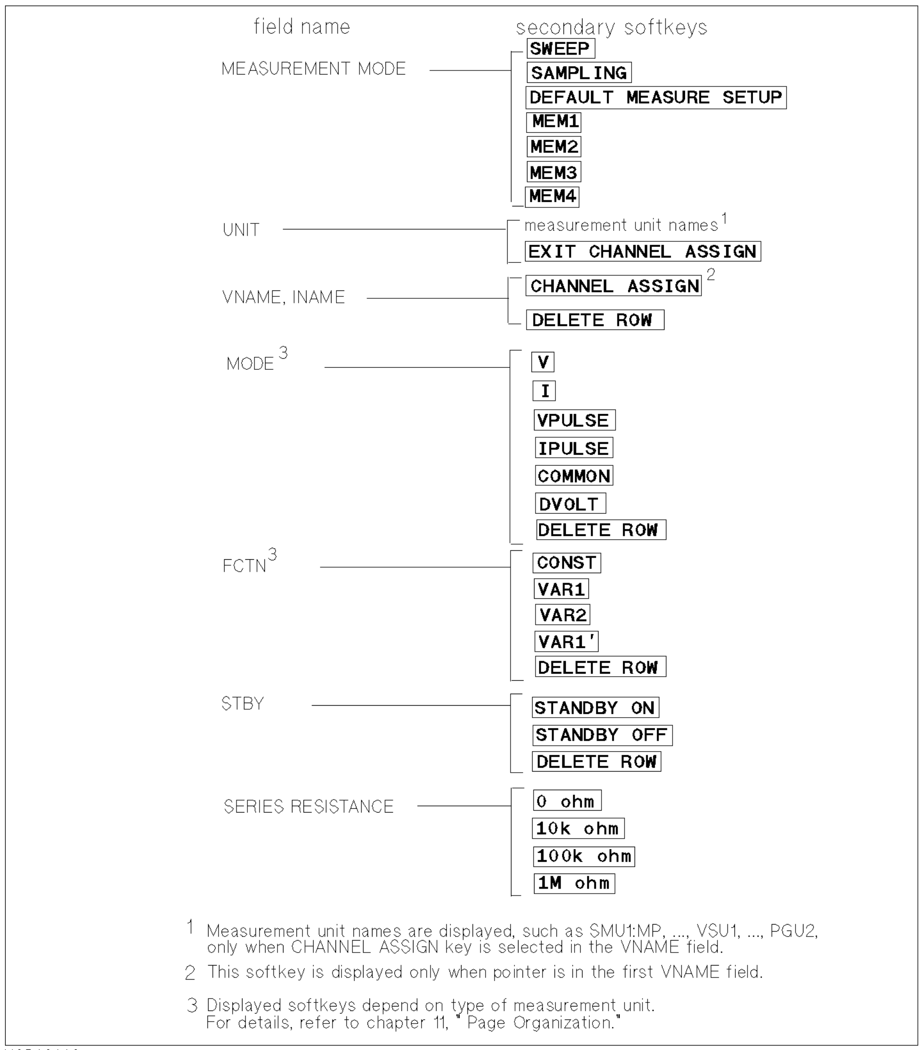
The first map shows the front-panel keys of the PAGE CONTROL key group and their associated primary softkeys, which are used to select each page. The second and following maps are softkey maps for each page.

Softkey Maps

page group	primary softkeys	
Channels	CHANNEL DEF	go to CHANNELS: CHANNEL DEFINITION page
	USER FCTN	go to CHANNELS: USER FUNCTION DEFINITION page
	USER VAR	go to CHANNELS: USER VARIABLE DEFINITION page
	NEXT PAGE	
Measure	SWEEP SETUP or SAMPLNG SETUP	go to MEASURE: SWEEP SETUP page or MEASURE: SAMPLING SETUP page
	PGU SETUP	go to MEASURE: PGU SETUP page
	MEASURE SETUP	go to MEASURE: MEASURE SETUP page
	OUTPUT SEQ	go to MEASURE: OUTPUT SEQUENCE page
	PREV PAGE	
	NEXT PAGE	
Display	DISPLAY SETUP	go to DISPLAY: DISPLAY SETUP page
	ANLYSIS SETUP	go to DISPLAY: ANALYSIS SETUP page
	PREV PAGE	
	NEXT PAGE	
Graph/List	*GRAPHICS page*	
	AXIS	go to GRAPH / LIST: GRAPHICS page
	MARKER/CURSOR	
	LINE	
	SCALING	
	DISPLAY SETUP	
	SWEEP SETUP or SAMPLNG SETUP	
	TIMING SETUP or STOP COND	
	CONST SETUP	
	LIST page	
	AXIS	go to GRAPH / LIST: LIST page
	MARKER	
	SPREAD SHEET	
	RE-SETUP	
	SWEEP SETUP or SAMPLNG SETUP	
	TIMING SETUP or STOP COND	
	CONST SETUP	
Stress	CHANNEL DEF	go to STRESS: CHANNEL DEFINITION page
	STRESS SETUP	go to STRESS: STRESS SETUP page
	STRESS FORCE	go to STRESS: STRESS FORCE page
	NEXT PAGE	
System	FILER	go to SYSTEM: FILER page
	CONFIG	go to SYSTEM: CONFIGURATION page
	MAINTENANCE	go to SYSTEM: MAINTENANCE page
	CALIB/DIAG	go to SYSTEM: SELF-CALIBRATION/DIAGNOSTICS page
	PRINT SETUP	go to SYSTEM: PRINT/PLOT SETUP page
	COLOR SETUP	go to SYSTEM: COLOR SETUP page

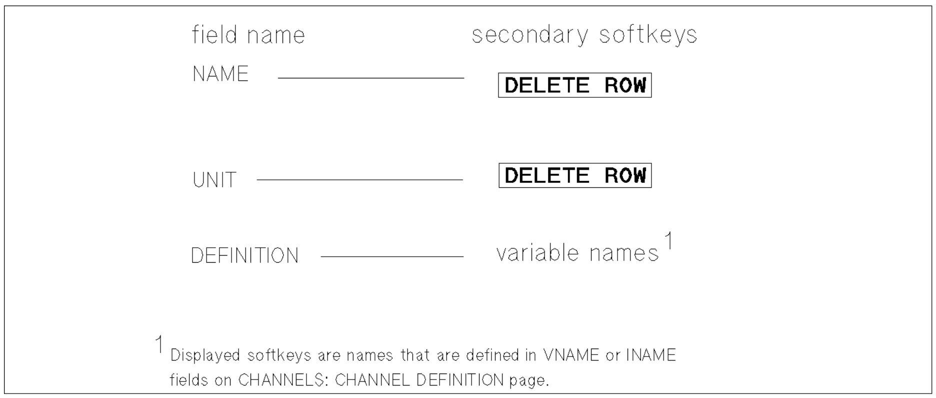
UGD08001

CHANNELS: CHANNEL DEFINITION page



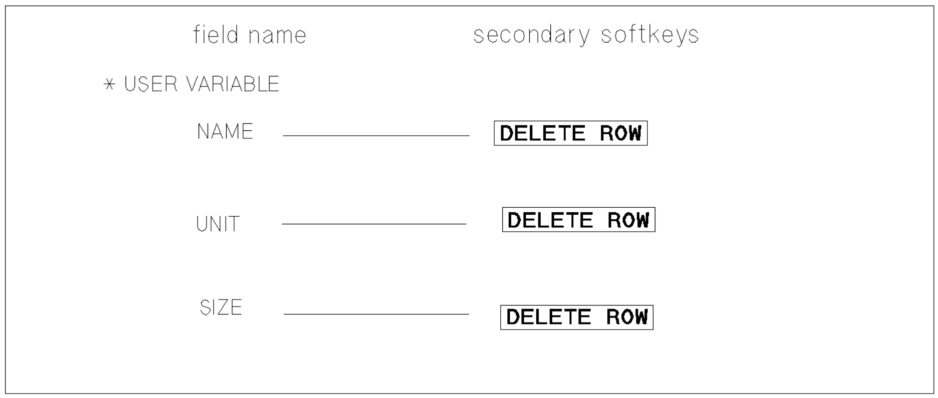
UGD08002

CHANNELS: USER FUNCTION DEFINITION page



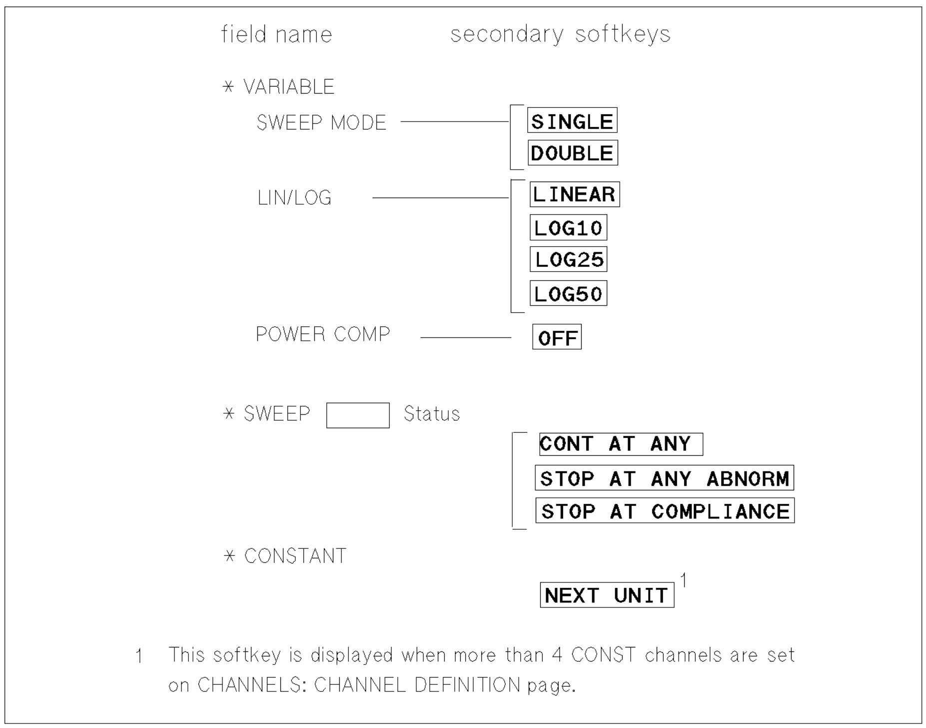
UGD08003

CHANNELS: USER VARIABLE DEFINITION page



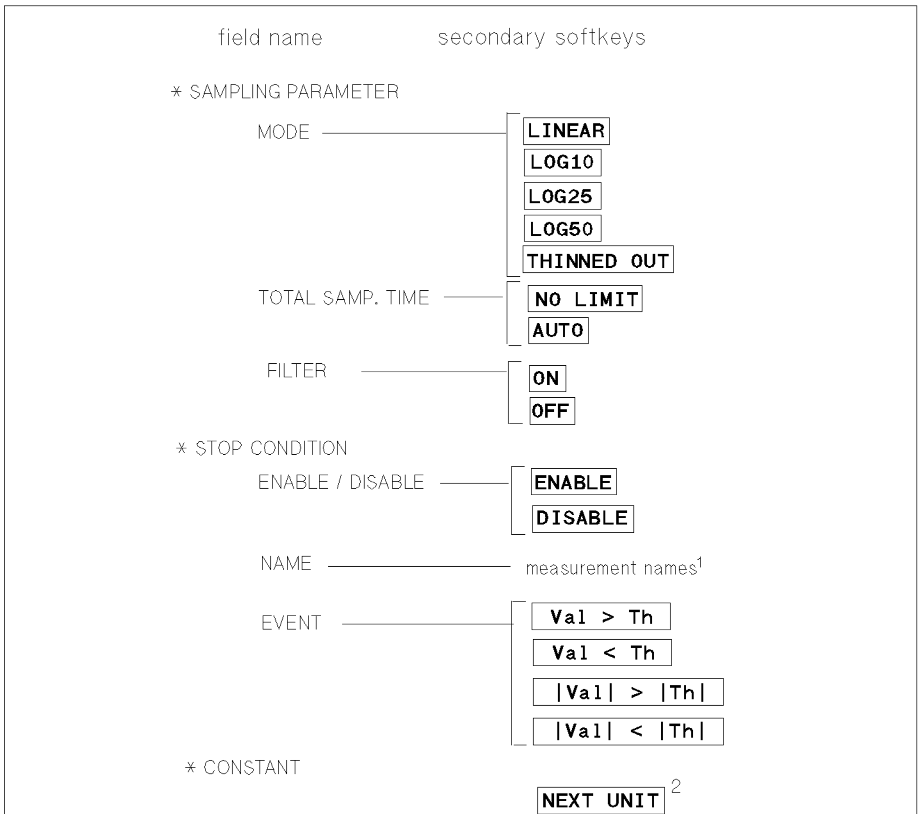
UGD08032

MEASURE: SWEEP SETUP page



UGD08004

MEASURE: SAMPLING SETUP page

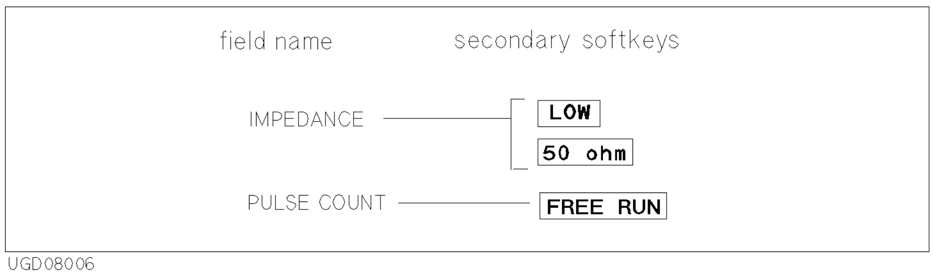


1 Displayed softkeys are measurement names set in VNAME or INAME fields on CHANNELS: CHANNEL DEFINITION page and NAME fields on CHANNELS: USER FUNCTION DEFINITION page.

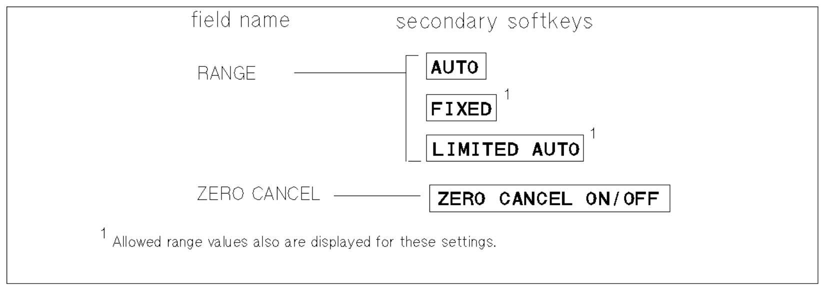
2 This softkey is displayed when more than 4 CONST channels are set on CHANNELS : CHANNEL DEFINITION page.

UGD08005

MEASURE: PGU SETUP page

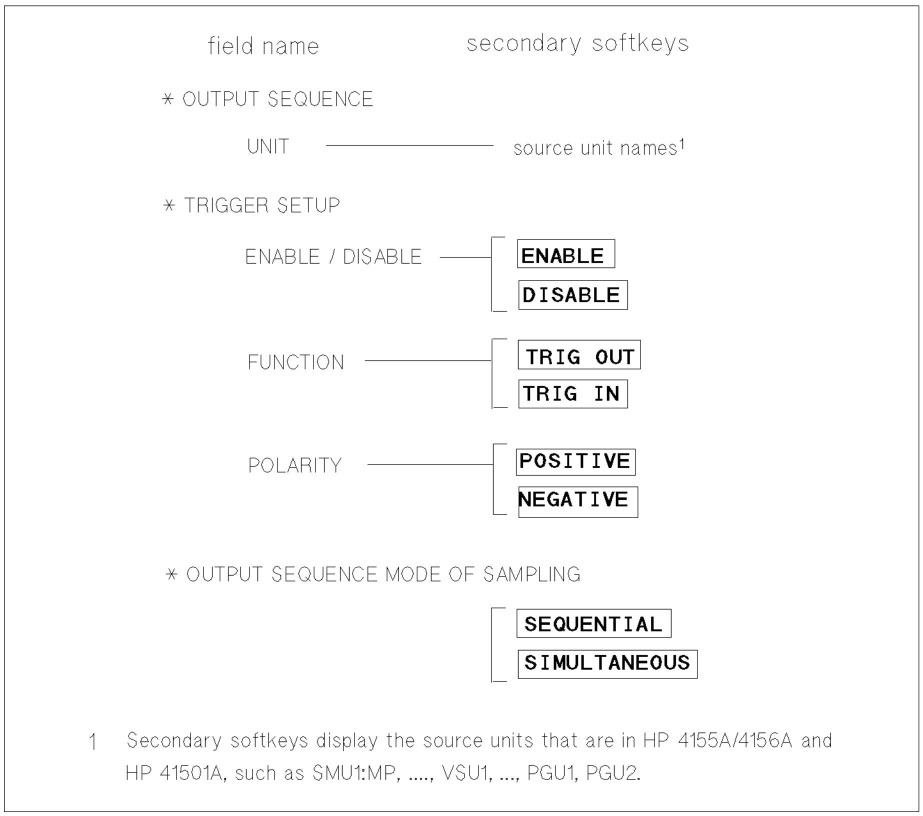


MEASURE: MEASURE SETUP page



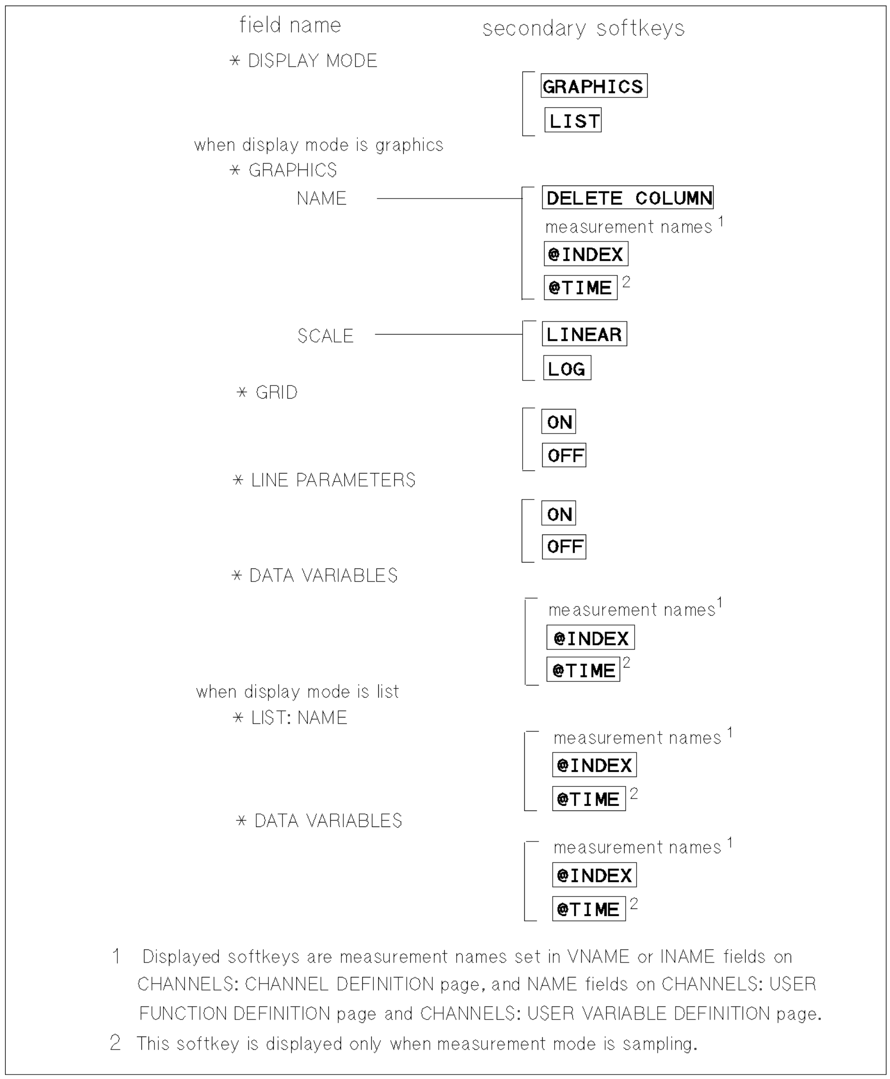
UGD08007

MEASURE: OUTPUT SEQUENCE page



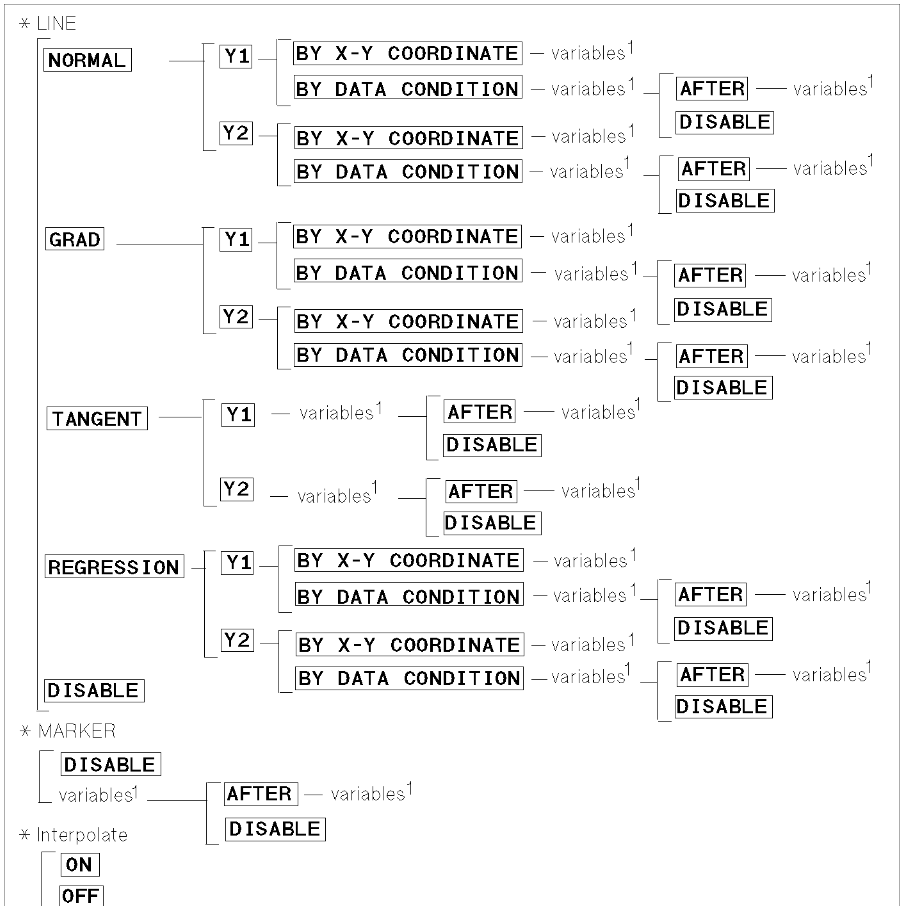
UGD08008

DISPLAY: DISPLAY SETUP page



UGD08009

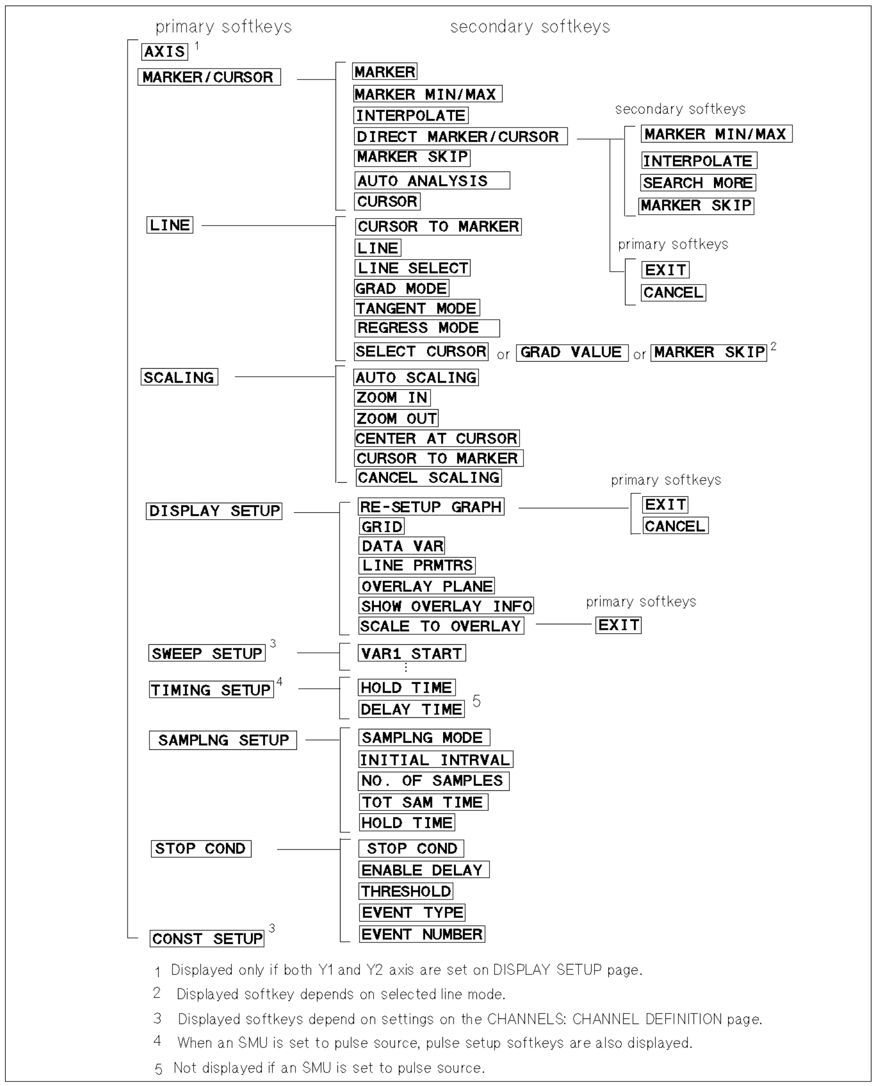
DISPLAY: ANALYSIS SETUP page



[1] All VNAME and INAME names, user functions, and user variables are displayed on secondary softkeys. Depending on the field, readout variables for PGUs, INDEX, and TIME are also displayed.

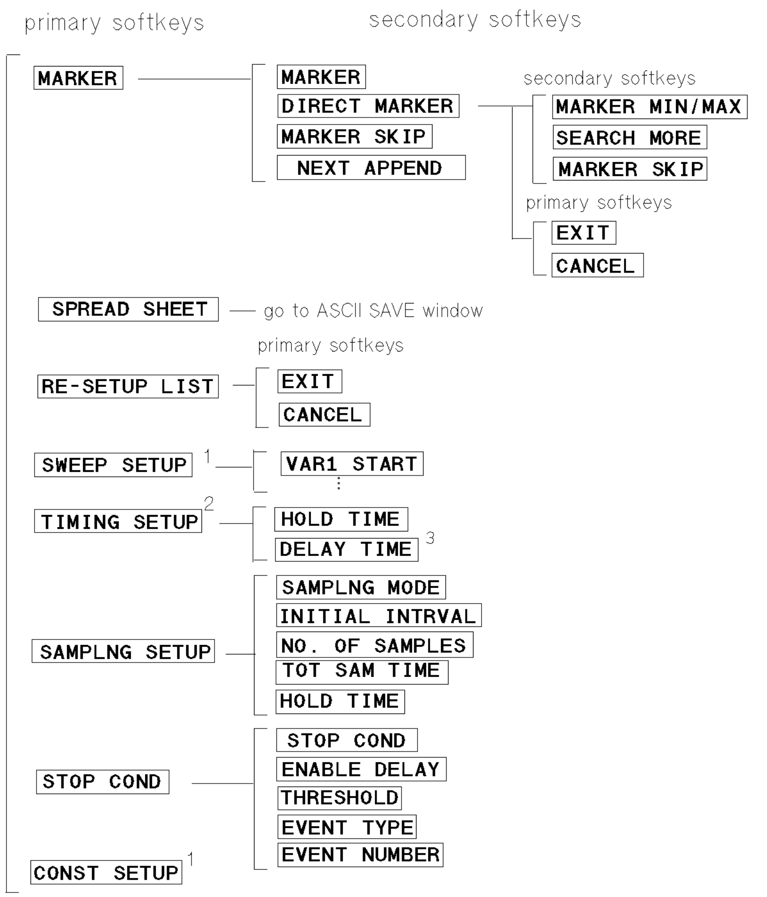
UGD08010

GRAPH/LIST: GRAPHICS page



UGD08011

GRAPH/LIST: LIST page



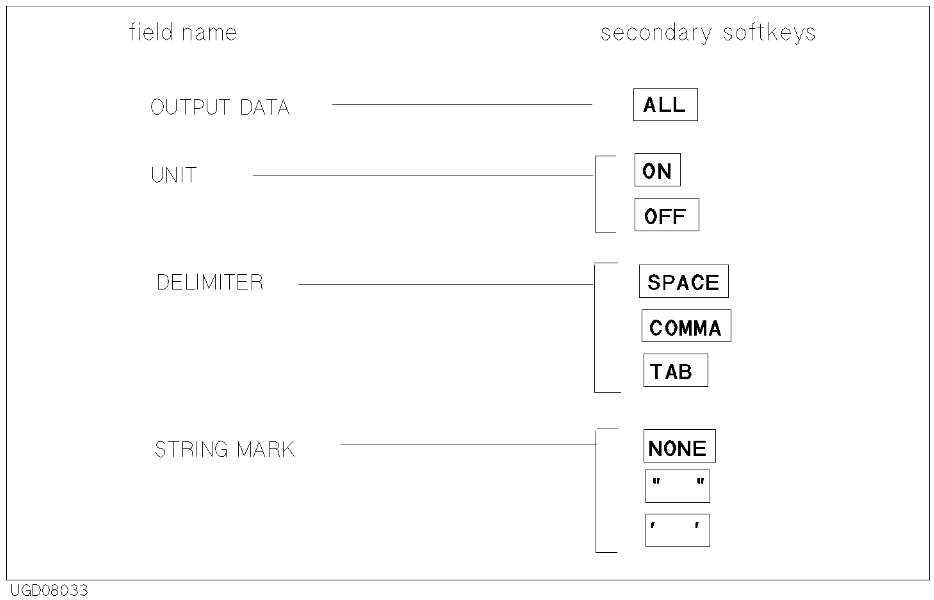
1 Displayed softkeys depend on settings on the CHANNELS: CHANNEL DEFINITION page.

2 When an SMU is set to pulse source, pulse setup softkeys are also displayed.

3 Not displayed if an SMU is set to pulse source.

UGD08034, 120X140

- ASCII SAVE window



STRESS: CHANNEL DEFINITION page

field name	secondary softkeys
* CHANNELS	
STRESS : MODE [1]	V I CHANNEL ASSIGN [2] VPULSE COMMON DELETE ROW
STRESS : NAME	DELETE ROW
STRESS : FUNC	SYNC NSYNC
* SMU / PG SELECTOR	
MEASURE, STRESS	SMU PGU OPEN PGU OPEN [3]
* TRIGGER SETUP	ENABLE DISABLE
POLARITY	POSITIVE NEGATIVE

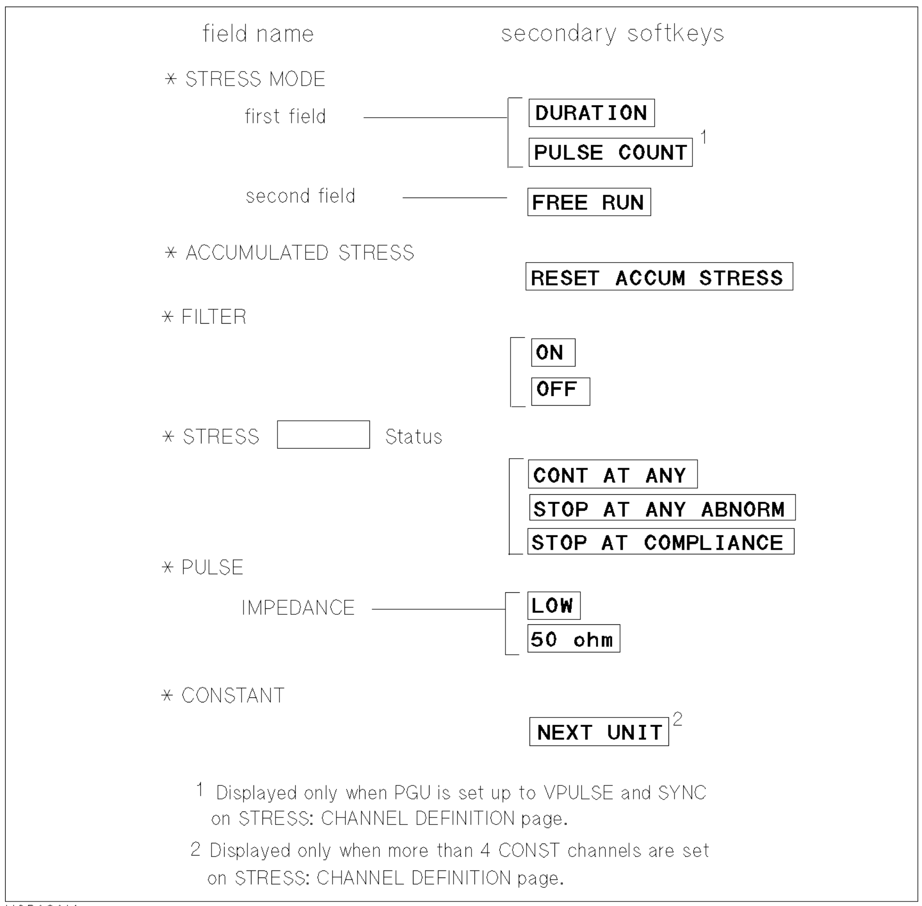
1 Displayed softkeys depend on measurement units.

2 This softkey is displayed only when pointer is in the first STRESS: NAME field.

3 This softkey is not displayed in channel 2 and channel 4 fields.

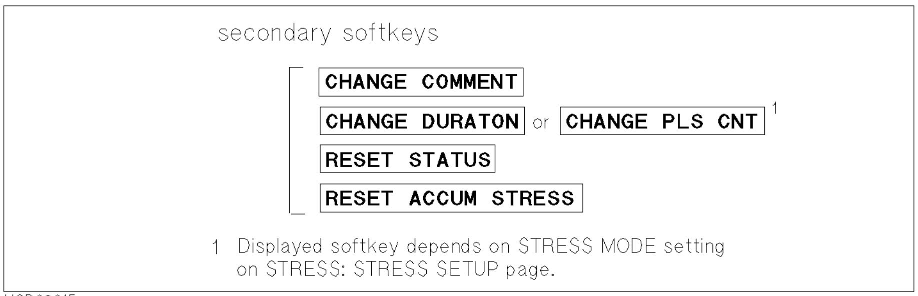
UGD08013

STRESS: STRESS SETUP page



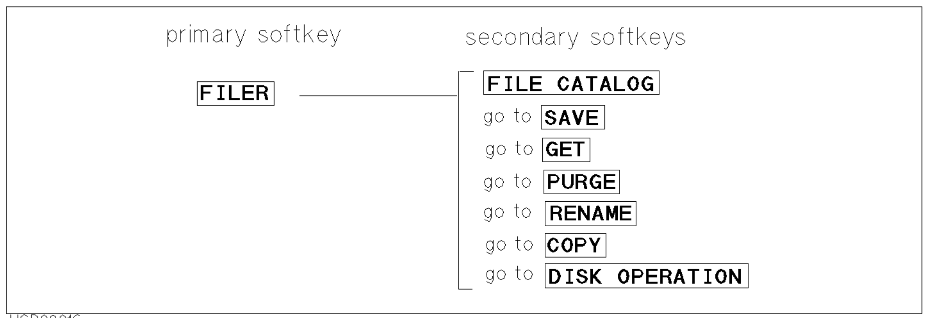
UGD08014

STRESS: STRESS FORCE page

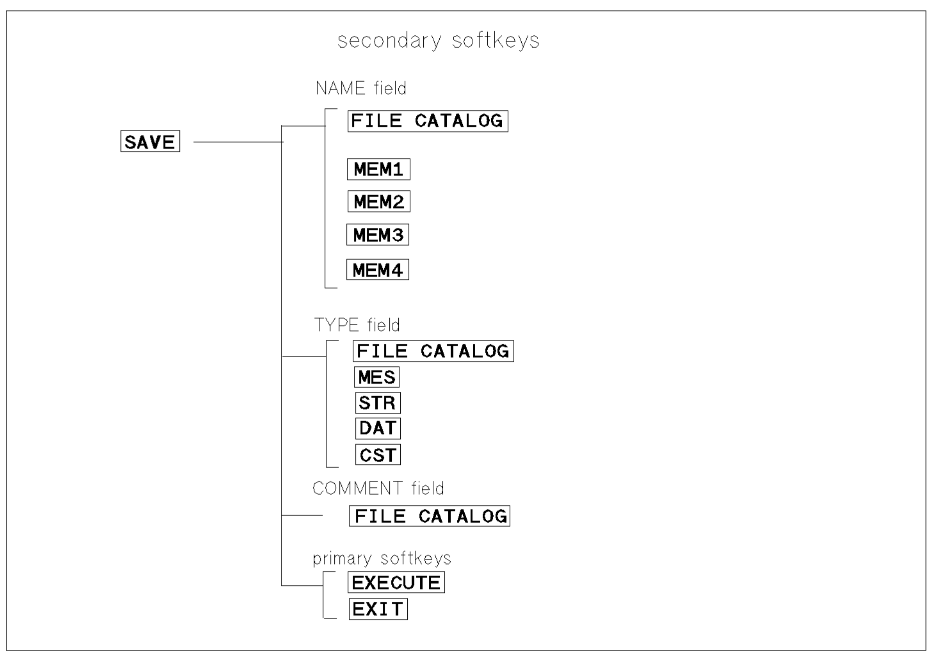


UGD08015

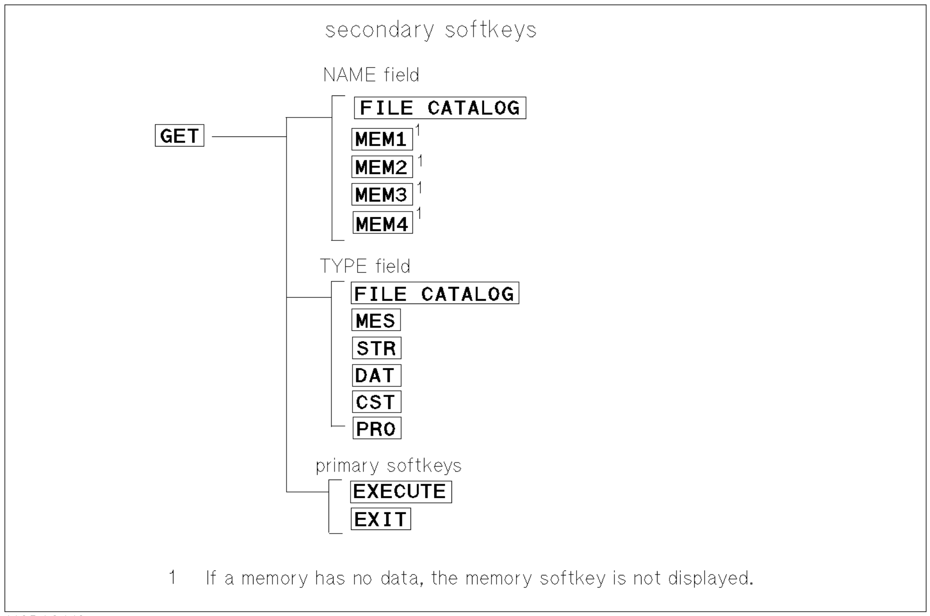
SYSTEM: FILER page



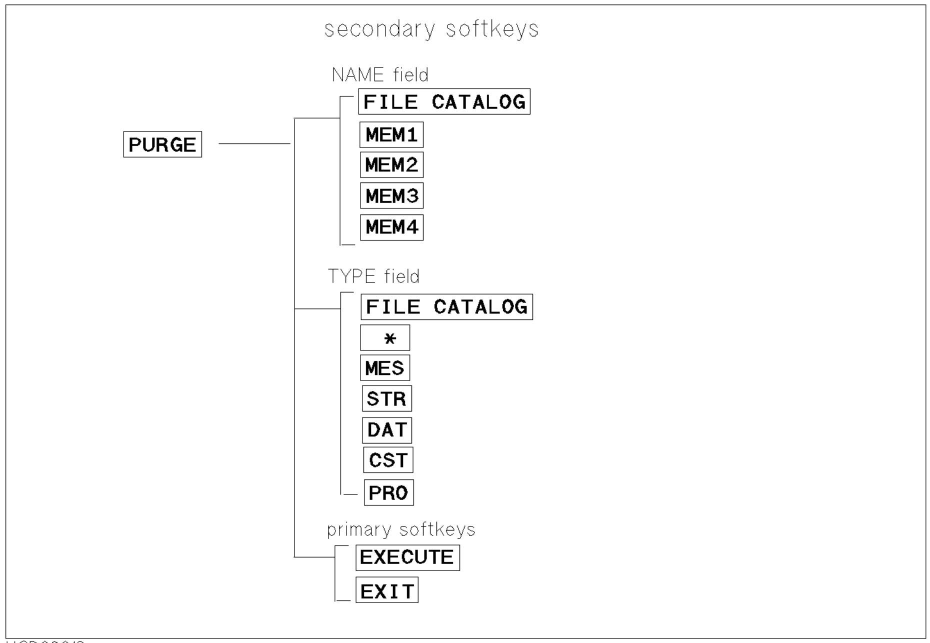
UGD08016

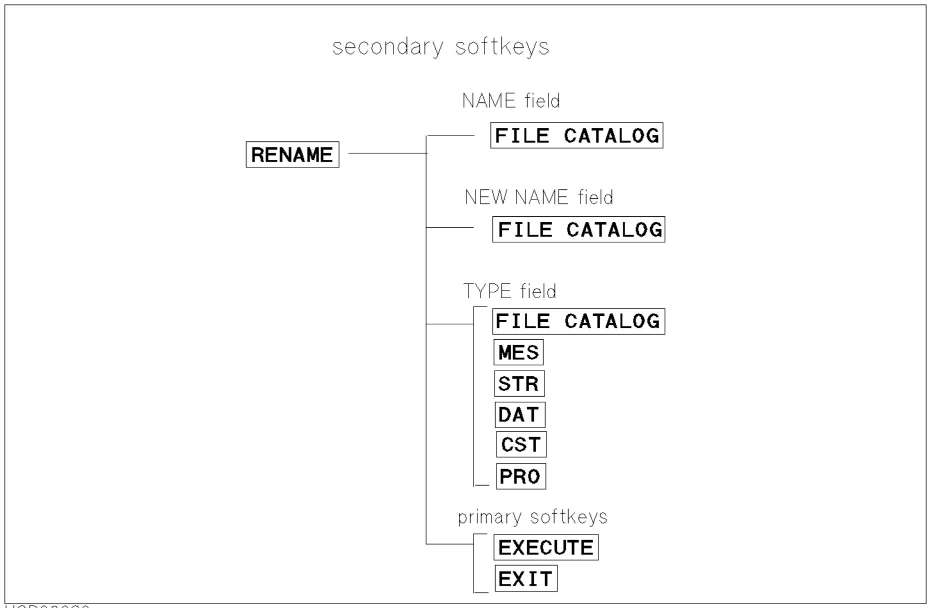


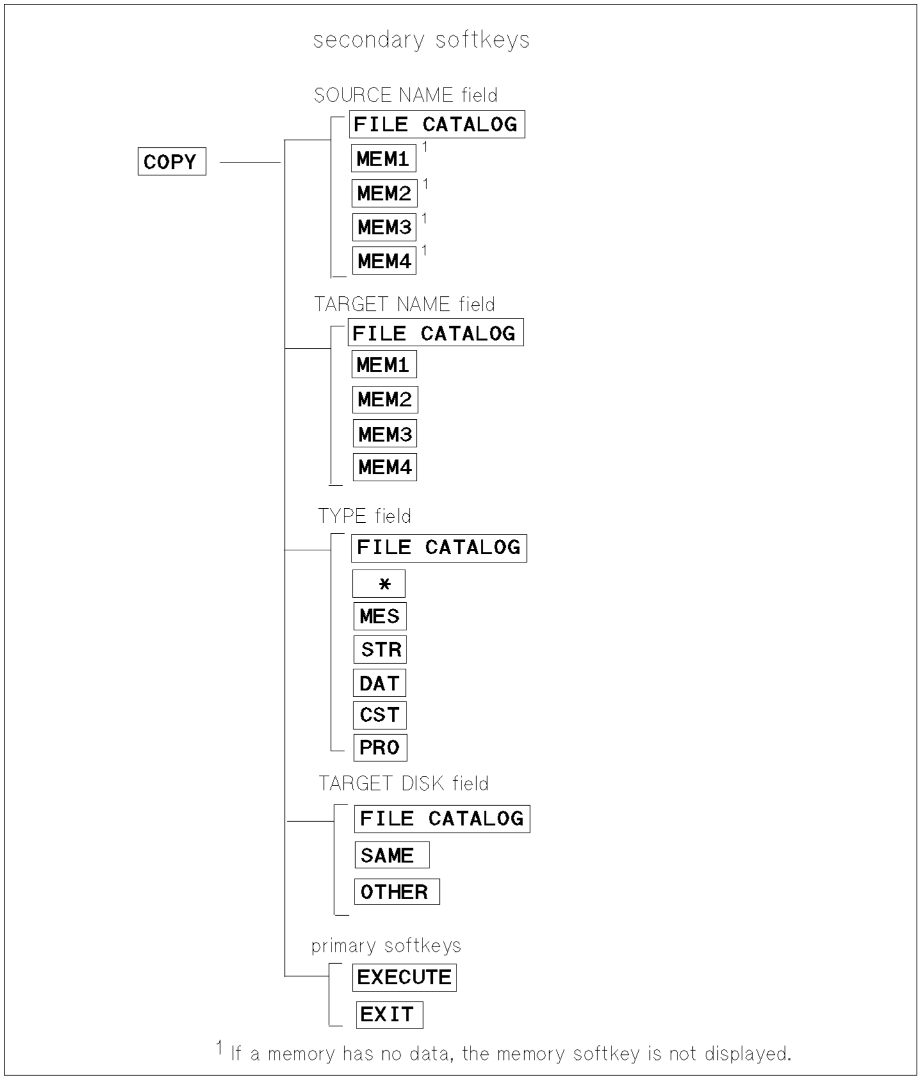
UGD08017


secondary softkeys
NAME field
GET
FILE CATALOG
MEM1 1
MEM2 1
MEM3 1
MEM4 1
TYPE field
FILE CATALOG
MES
STR
DAT
CST
PRO
primary softkeys
EXECUTE
EXIT
1 If a memory has no data, the memory softkey is not displayed.

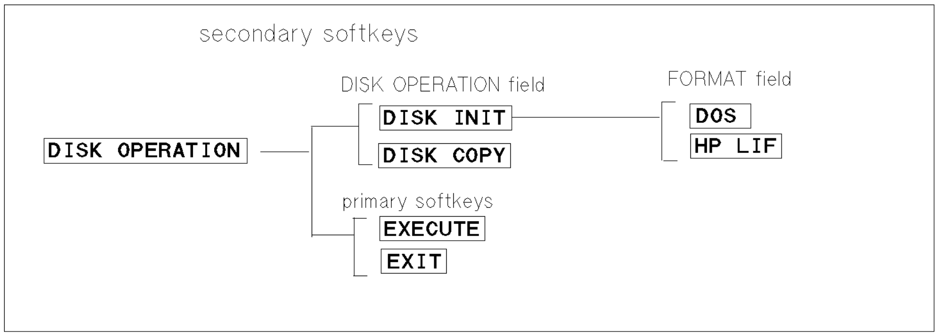
UGD08018


secondary softkeys
NAME field
PURGE
FILE CATALOG
MEM1
MEM2
MEM3
MEM4
TYPE field
FILE CATALOG
*
MES
STR
DAT
CST
PRO
primary softkeys
EXECUTE
EXIT
UGD08019


secondary softkeys
NAME field
FILE CATALOG
RENAME
NEW NAME field
FILE CATALOG
TYPE field
FILE CATALOG
MES
STR
DAT
CST
PRO
primary softkeys
EXECUTE
EXIT
UGD08020

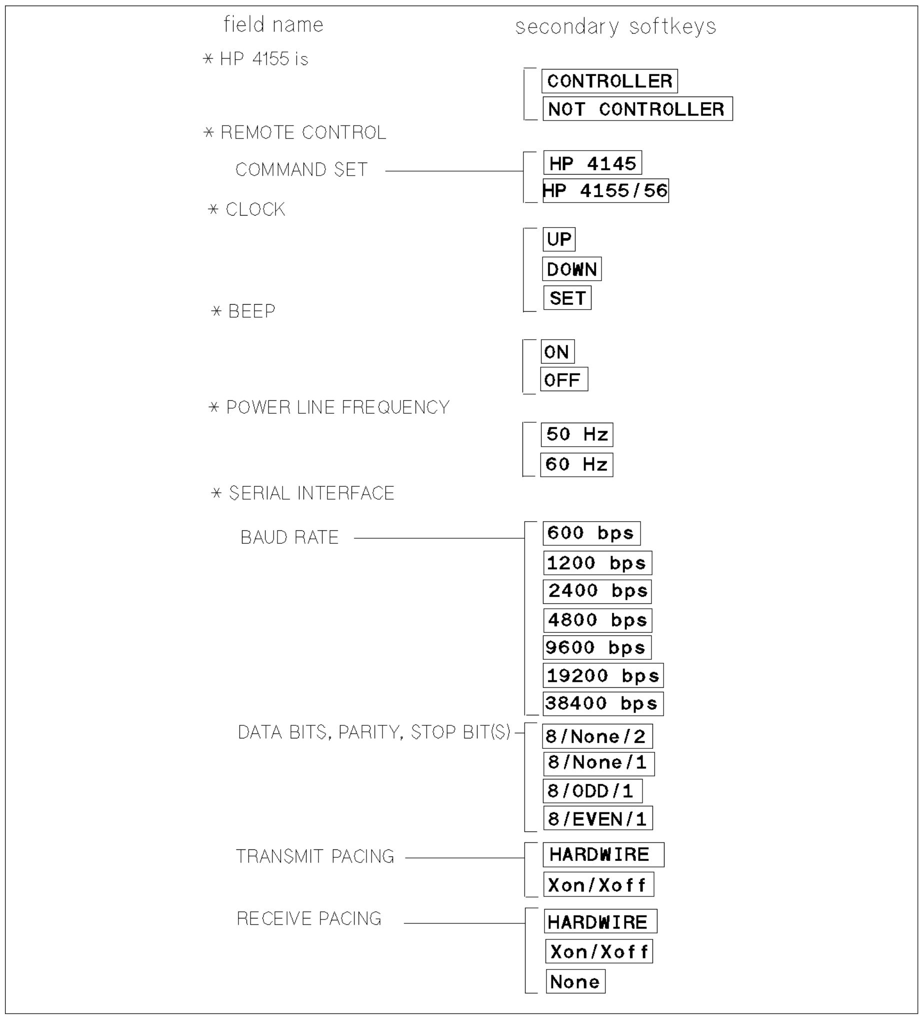

secondary softkeys
SOURCE NAME field
COPY
FILE CATALOG
MEM1 1
MEM2 1
MEM3 1
MEM4 1
TARGET NAME field
FILE CATALOG
MEM1
MEM2
MEM3
MEM4
TYPE field
FILE CATALOG
*
MES
STR
DAT
CST
PRO
TARGET DISK field
FILE CATALOG
SAME
OTHER
primary softkeys
EXECUTE
EXIT
1 If a memory has no data, the memory softkey is not displayed.

UGD08021


secondary softkeys
DISK OPERATION field
FORMAT field
DISK INIT
DISK COPY
DOS
HP LIF
DISK OPERATION
primary softkeys
EXECUTE
EXIT

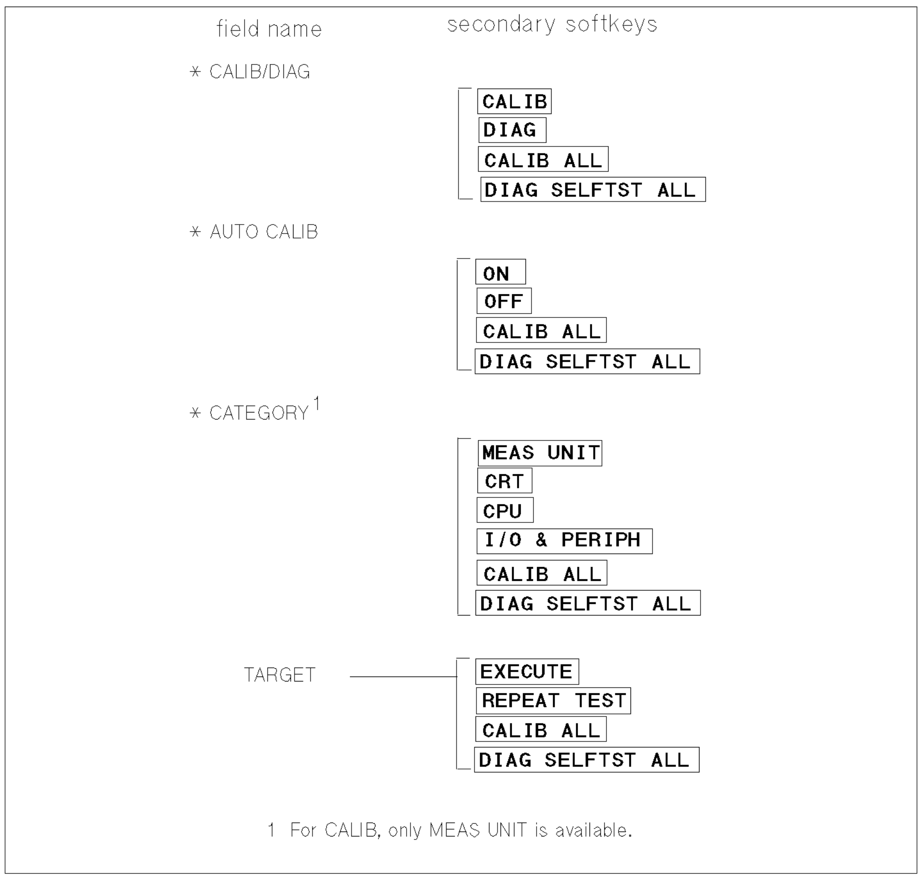
UGD08022

SYSTEM: MISCELLANEOUS page



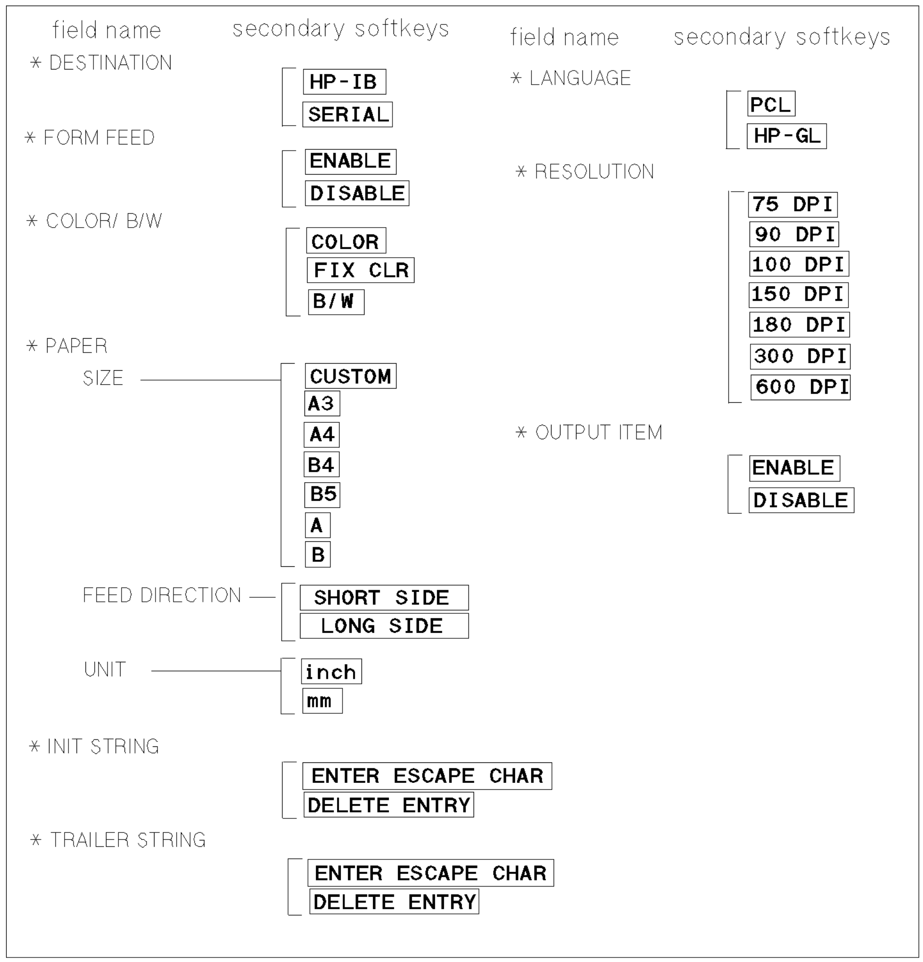
UGD08023

SYSTEM: SELF-CALIBRATION/DIAGNOSTICS page



UGD08024

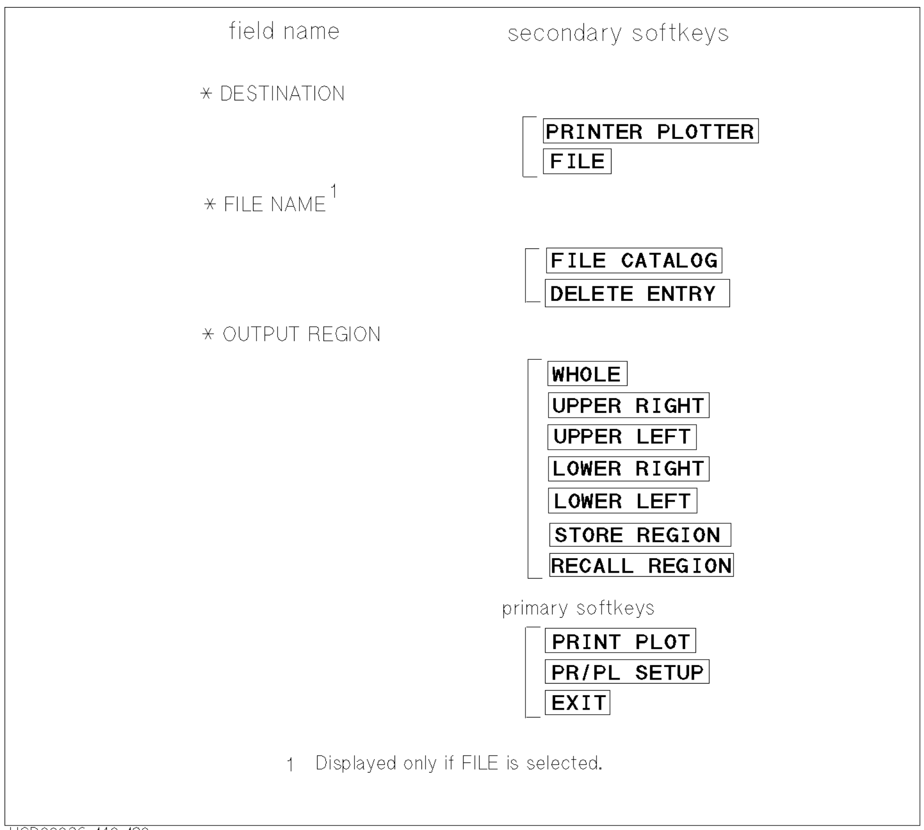
SYSTEM: PRINT/PLOT SETUP page



UGD08035, 140x120

- SCREEN DUMP WINDOW

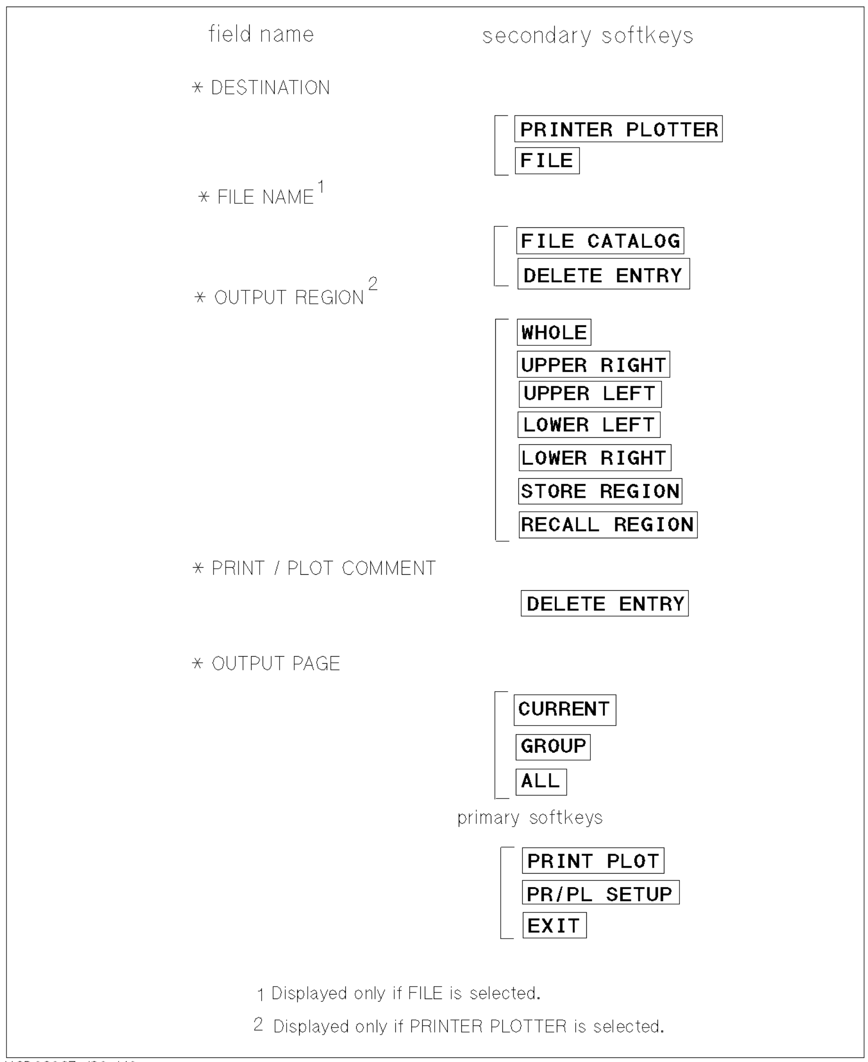
  You can open this window from any page. Press green front-panel key, then (Print/Plot) front-panel key.



UGD08036, 140x120

- PRINT/PLOT SETUP DATA WINDOW

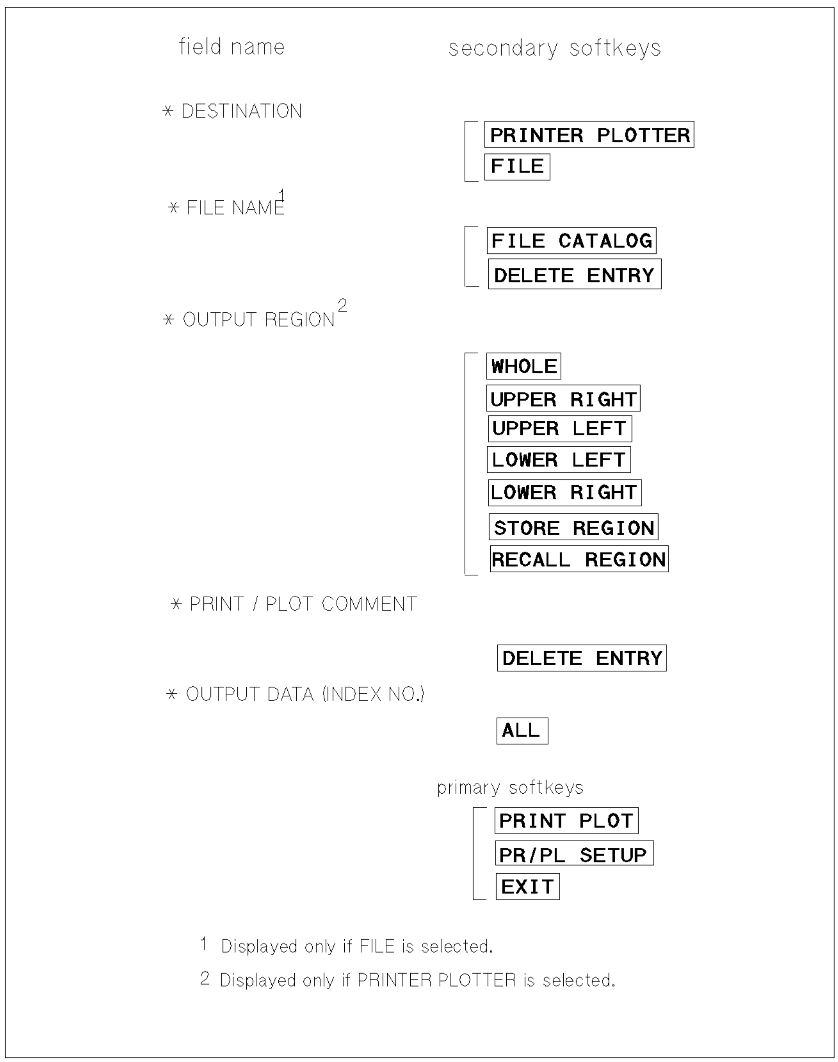
  You can open this window from any setup page. Press (Print/Plot) front-panel key.



UGD08037, 120x140

- PRINT/PLOT DATA LIST WINDOW

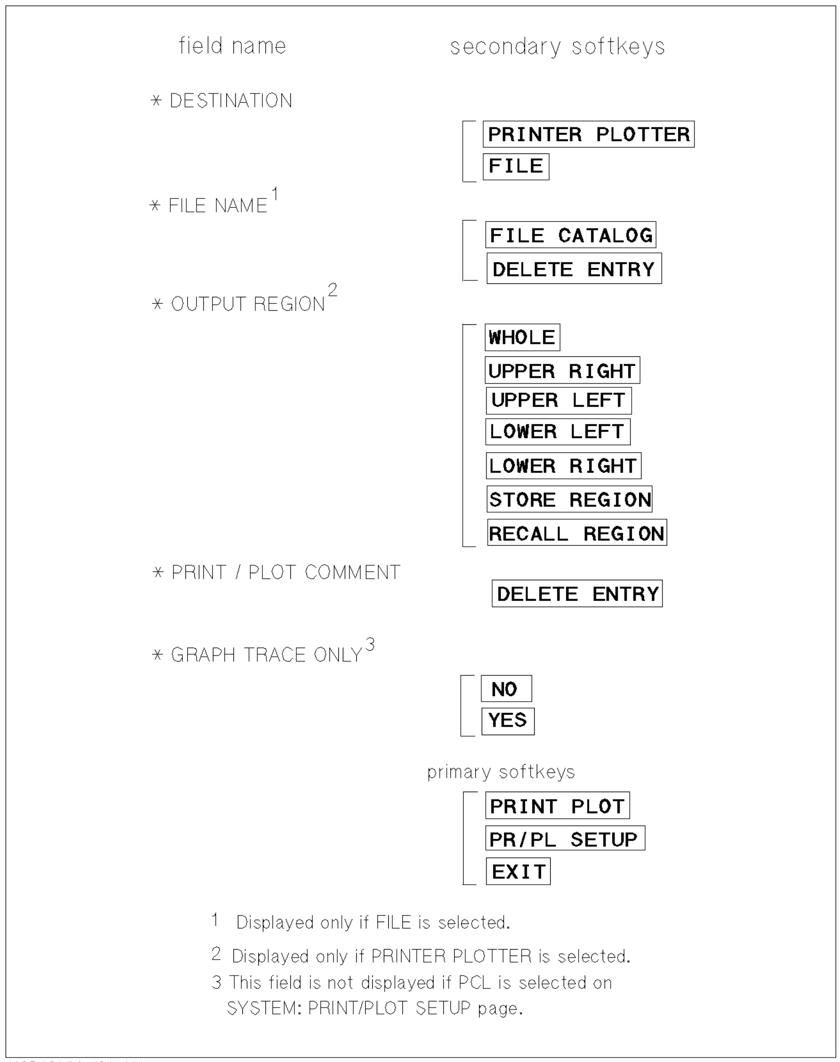
  You can open this window from GRAPH/LIST: LIST page only. Press (Print/Plot) front-panel key.



UGD08038, 120x140

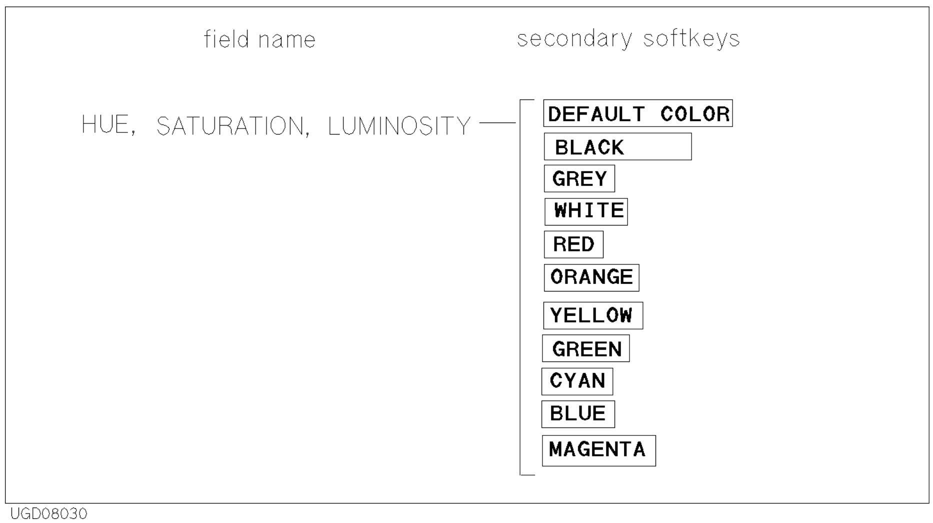
- GRAPH PLOT WINDOW

  You can open this window from GRAPH/LIST: GRAPHICS page only. Press (Print/Plot) front-panel key.

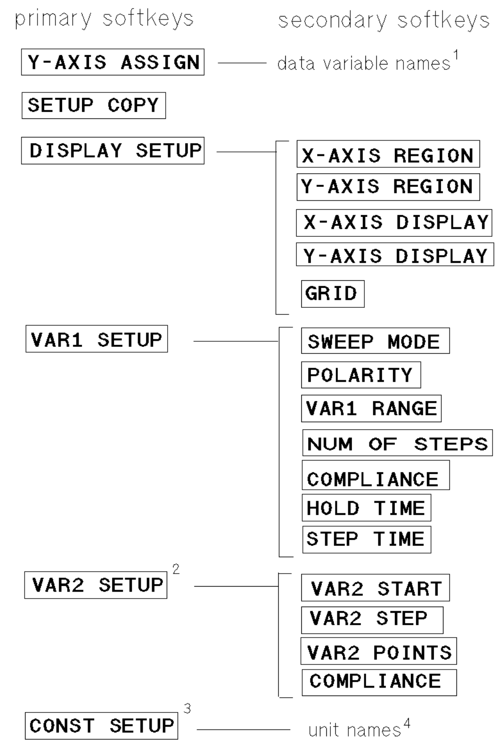


UGD08039, 120x140

SYSTEM: COLOR SETUP page



KNOB SWEEP page



1 Secondary softkeys display data variable names that can be assigned to y axis.

2 This softkey is displayed only when VAR2 is set on the CHANNELS: CHANNEL DEFINITION page.

3 This softkey is displayed only when CONST is set on the CHANNELS: CHANNEL DEFINITION page.

4 Displayed softkeys depend on settings on the MEASURE: SWEEP SETUP page.

UGD08031

External Keyboard

You can operate the HP 4155A/4156A from an external keyboard (HP C1405B) instead of by pressing front-panel keys and softkeys.

Table 7-1 shows the correspondence between front-panel keys/softkeys and the external keyboard. For correspondence when using HP Instrument BASIC, refer to *HP 4155A/4156A Programmer's Guide*.

When using an external keyboard, connect the external keyboard to HP 4155A/4156A before applying power. If you connect the keyboard to HP 4155A/4156A after applying power, the keyboard does not work.

For functions of each key, refer to "Overview of HP 4155A/4156A" in *HP 4155A/4156A User's Task Guide*.

Unavailable Keys

You cannot operate the following from external keyboard:

- PAGE CONTROL key group

  Chan, Meas, Display, Graph/List, Stress, System
- Ω and °(deg)

Table 7-1. Correspondence of Front-Panel Keys and External Keyboard

Front-Panel Keys		External Keyboard
softkeys	(from the left side)	
	primary softkey 1 to 8	F1 to F8
	(from the top)	
	secondary softkey 1 to 7	Shift+F1 to Shift+F7
MEASUREMENT key group	Single	Ctrl+S
	Repeat	Ctrl+R
	Append	Ctrl+A
	Stop	Ctrl+C
	Standby	Ctrl+Y
	Stress	Ctrl+T
	green key+Single	Ctrl+N
	green key+Stop	Ctrl+Z
Integ Time key group	Short	Ctrl+I
	Medium	Ctrl+J
	Long	Ctrl+K
IBASIC	Run	Ctrl+U or enter "RUN" in the data entry field on the IBASIC page
	Pause	Ctrl+P or Pause
	Display	Ctrl+G or F9

Correspondence of Front-Panel Keys and External Keyboard, continued

Front-Panel Key		External Keyboard
arrow keys in the	(⇐)	(◀)
MARKER/CURSOR key group	(⇒)	(▶)
	(⇑)	(▲)
	(⇓)	(▼)
	(Fast)+(⇐)	(Shift)+(◀)
	(Fast)+(⇒)	(Shift)+(▶)
	(Fast)+(⇑)	(Shift)+(▲)
	(Fast)+(⇓)	(Shift)+(▼)
rotary knob	clockwise	(Alt)+(▶)
	counterclockwise	(Alt)+(◀)
	(Fast)+clockwise	(Alt)+(Shift)+(▶)
	(Fast)+counterclockwise	(Alt)+(Shift)+(◀)
	(Plot/Print)	(Ctrl)+D or (Print Screen)
	green key+(Plot/Print)	(Shift)+(Print Screen)
	(Help)	(Ctrl)+(Shift)+H
User File	(Save)	(Ctrl)+(Shift)+S
	(Get)	(Ctrl)+(Shift)+R

Correspondence of Front-Panel Keys and External Keyboard, continued

Front-Panel Key		External Keyboard
Edit key group	(⇐)	(Ctrl)+B, (Shift)+(Tab), or (Backspace)
	green key+(⇐)	(Ctrl)+(Shift)+B, (Ctrl)+(Shift)+(Tab), or (Ctrl)+(Backspace)
	(⇒)	(Ctrl)+F or (Tab)
	green key+(⇒)	(Ctrl)+(Shift)+F or (Ctrl)+(Tab)
	(Delete)	(Delete) or (Alt)+D
	(Insert)	(Insert) or (Alt)+I
	(Recall↓)	(Ctrl)+L
	green key+(Recall↓)	(Ctrl)+(Shift)+L
	(Clear)	(Shift)+(F11) or (Ctrl)+(Delete)
	green key+(Clear)	(F11)
ENTRY key group	(μ)	u
	(Exp)	E
	(Enter)	(Enter)
	green key+(Enter)	(Shift)+(Enter)
	(Space)	space key
	Other front-panel keys (except for Ω, °(deg), blue key, and green key) correspond to same keys on the external keyboard.	

8

Accessories and Options

Accessories and Options

The following table lists accessories and options for the HP 4155A/4156A.

Table 8-1. Accessories and Options

Product Number	Option Number	Description
4155A		Semiconductor Parameter Analyzer
	050	50 Hz line frequency
	060	60 Hz line frequency
	ABA	English- English localization
	ABJ	Japan - Japanese localization
	200	Substitute 1.5 m length HP 4155A cables
	201	Substitute 1.5 m length HP 41501A cables
	280	SMU/Pulse Generator Selector (1.5 m cable)
	281	SMU/Pulse Generator Selector (3.0 m cable)
	282	2nd SMU/Pulse Generator Selector
	298	R-Box (1.5 m Cable)
	299	R-Box (3.0 m Cable)
	402	Add HP 41501A with 2 PGUs
	410	Add HP 41501A with HPSMU
	412	Add HP 41501A with HPSMU and 2 PGUs
	420	Add HP 41501A with 2 MPSMUs
	422	Add HP 41501A with 2 MPSMUs and 2 PGUs
	1BN	Mil Std 45662A Calibration Certification
	1BP	Mil Std 45662A Calibration w/ Test data
	0B1	Add Manual Set

Accessories and Options, continued

Product Number	Option Number	Description
4156A		Precision Semiconductor Parameter Analyzer
	050	50 Hz line frequency
	060	60 Hz line frequency
	ABA	English - English localization
	ABJ	Japan - Japanese localization
	200	Substitute 1.5 m length HP 4156A cables
	201	Substitute 1.5 m length HP 41501A cables
	280	SMU/Pulse Generator Selector (1.5 m cable)
	281	SMU/Pulse Generator Selector (3.0 m cable)
	282	2nd SMU/Pulse Generator Selector
	283	2nd SMU/Pulse Generator Selector
	298	R-BOX (1.5 m Cable)
	299	R-BOX (3.0 m Cable)
	402	Add HP 41501A with 2 PGUs
	410	Add HP 41501A with HPSMU
	412	Add HP 41501A with HPSMU and 2 PGUs
	420	Add HP 41501A with 2 MPSMUs
	422	Add HP 41501A with 2 MPSMUs and 2 PGUs
	1BN	Mil Std 45662A Calibration Certification
	1BP	Mil Std 45662A Calibration w/ Test data
	0B1	Add Manual Set
41501A		SMU and Pulse Generator Expander
	201	Substitute 1.5 m length HP 41501A cables
	402	Add HP 41501A with 2 PGUs
	410	Add HP 41501A with HPSMU
	412	Add HP 41501A with HPSMU and 2 PGUs
	420	Add HP 41501A with 2 MPSMUs
	422	Add HP 41501A with 2 MPSMUs and 2 PGUs

Accessories and Options, continued

Product Number	Option Number	Description
16442A		Test Fixture
	010	Add 1.5 m triax cables for 4156A
	011	Add 3.0 m triax cables for 4156A
	800	Extra blank Teflon Board
	801	0.1 inch pitch universal socket module
	802	0.075 inch pitch universal socket module
	803	0.05 inch pitch universal socket module
	810	Extra connection pin set
	811	Extra wire set
	812	Extra wire set
	813	Extra wire set
	814	Extra wire set
	821	Socket module(transistor)
	822	Socket module(18-pin DIP)
	823	Extra socket module (28-pin DIP socket)
	824	Socket module (8 pin TO package)
	825	Socket module (10 pin TO package)
	826	Extra socket module (12 pin TO package)
	830	Socket module (TO3 & TO66 package)
	831	Socket module (In-line package)
	832	Extra socket module (Axial lead package)
	890	Extra accessory case
16440A		SMU/Pulse generator selector
	001	Control cable (1.5 m)
	002	Control cable (3.0 m)
	003	Control cable (0.4 m) for 2nd selector

Accessories and Options, continued

Product Number	Option Number	Description
16441A		R-Box
	001	Control cable (1.5 m)
	002	Control cable (3.0 m)
16353A		Standard resistor set
16434A		Kelvin triaxial cable
	001	Kelvin triaxial cable(1.5 m)
	002	Kelvin triaxial cable(3.0 m)
16435A		Interlock cable adapter
16493J		Interlock cable for 4155A/4156A
	001	Interlock cable (1.5 m) for 4155A/4156A
	002	Interlock cable (3.0 m) for 4155A/4156A
16493K		Kelvin triaxial cable
	001	Kelvin triaxial cable (1.5 m)
	002	Kelvin triaxial cable (3.0 m)
16431A		HPSMU board install kit
	001	One 1.5 m Kelvin triaxial cable
	002	One 3.0 m Kelvin triaxial cable
16432A		2ch-PGU board install kit
	001	Two 1.5 m coaxial cables
	002	Two 3.0 m coaxial cables
16433A		2ch-MPSMU board install kit
	001	Two 1.5 m triaxial cables
	002	Two 3.0 m triaxial cables

9

Specifications

Specifications

This chapter lists complete HP 4155A/4156A and HP 41501A specifications and supplemental information. The specifications are the performance standards or limits against which the HP 4155A/4156A and HP 41501A are tested. When the HP 4155A/4156A and HP 41501A is shipped from the factory, it meets the specifications. The supplemental information are not specifications but are typical characteristics included as additional information for the operator.

The HP 4155A and HP 4156A functions:

- Set measurement and/or stress conditions
- Control measurement and/or stress execution
- Perform arithmetic calculations
- Display measured and calculated results on the CRT display
- Perform graphical analysis
- Store and recall measurement setups, and measurement and graphical display data
- Dump to printers or plotters for hardcopy output
- Perform measurement and analysis with internal HP Instrument BASIC
- Self-test, Auto-calibration

Configuration

- HP 4155A configuration:
  - four medium power source monitor units (MPSMUs: 10 fA/2 μV to 100 mA/100 V).
  - two voltage source units (VSUs).
  - two voltage monitor units (VMUs).
- HP 4156A configuration:
  - four high resolution source monitor units (HRSMUs: 1 fA/2 μV to 100 mA/100 V).
  - two voltage source units (VSUs).

  - □ two voltage monitor units (VMUs).
- HP 41501A (Option) configuration:
  - □ two pulse generator units (PGUs) (Option).
  - □ one high power source monitor unit (HPSMU: 10 fA/2 μV to 1 A/200 V) (Option) or two MPSMUs (Option).
  - □ one ground unit (GNDU).

Specification Conditions

The "supplemental information" and "typical" entries, in the following specifications are not warranted, but provide useful information about the functions and performance of the instruments.

The measurement and output accuracies are specified at the rear panel connector terminals when referenced to the Zero Check terminal under the following conditions:

1. 23 °C ±5 °C (double between 5 °C to 18 °C, and 28 °C to 40 °C if not noted otherwise).
2. After 40 minutes warm-up.
3. Ambient temperature changes less than ±1 °C after auto calibration execution.
4. Integration time: medium or long
5. Filter: ON (for SMUs)
6. Kelvin connection (for HRSMU, HPSMU, and GNDU)
7. Calibration period: 1 year

- HP 4156A Precision Semiconductor Parameter Analyzer
  - HRSMU (High resolution SMU) Specifications

Table 9-1. Voltage Range, Resolution, and Accuracy (HRSMU)

Voltage Range	Set Reso.	Set Accuracy	Meas. Reso.	Meas. Accuracy	Max. Current
±2V	100μV	±(0.02% + 400μV)	2μV	±(0.01% + 200μV)	100mA
±20V	1mV	±(0.02% + 3mV)	20μV	±(0.01% + 1mV)	100mA
±40V	2mV	±(0.025% + 6mV)	40μV	±(0.015% + 2mV)	100mA (Vout ≤ 20V) 50mA (20V < Vout ≤ 40V)
±100V	5mV	±(0.03% + 15mV)	100μV	±(0.02% + 5mV)	100mA (Vout ≤ 20V) 50mA (20V < Vout ≤ 40V) 20mA (40V < Vout ≤ 100V)

Table 9-2. Current Range, Resolution, and Accuracy (HRSMU)

Current Range	Set Reso.	Set Accuracy	Meas. Reso.	Measurement Accuracy	Max. Voltage
±10pA	10fA	±(4% + 400fA) *1, *2	1fA	±(4% + 20fA + 1fA ×Vout/100) *1, *2	100V
±100pA	10fA	±(4% + 400fA) *1, *2	1fA	±(4% + 40fA + 10fA ×Vout/100) *1, *2	100V
±1nA	100fA	±(0.5% + 0.7pA + 1fA ×Vout) *2	10fA	±(0.5% + 0.4pA + 1fA ×Vout) *2	100V
±10nA	1pA	±(0.5% + 4pA + 10fA ×Vout)	10fA	±(0.5% + 2pA + 10fA ×Vout)	100V
±100nA	10pA	±(0.12% + 40pA + 100fA ×Vout)	100fA	±(0.1% + 20pA + 100fA ×Vout)	100V
±1μA	100pA	±(0.12% + 400pA + 1pA ×Vout)	1pA	±(0.1% + 200pA + 1pA ×Vout)	100V
±10μA	1nA	±(0.07% + 4nA + 10pA ×Vout)	10pA	±(0.05% + 2nA + 10pA ×Vout)	100V
±100μA	10nA	±(0.07% + 40nA + 100pA ×Vout)	100pA	±(0.05% + 20nA + 100pA ×Vout)	100V
±1mA	100nA	±(0.06% + 400nA + 1nA ×Vout)	1nA	±(0.04% + 200nA + 1nA) ×Vout)	100V
±10mA	1μA	±(0.06% + 4μA + 10nA ×Vout)	10nA	±(0.04% + 2μA + 10nA ×Vout)	100V
±100mA	10μA	±(0.12% + 40μA + 100nA ×Vout)	100nA	±(0.1% + 20μA + 100nA ×Vout)	100V (Iout ≤ 20mA) 40V (20mA < Iout ≤ 50mA) 20V (50mA < Iout ≤ 100mA)

*1 The accuracy is applicable when offset cancellation has been performed.

*2 The offset current specification is multiplied by one of the following factors depending upon the ambient temperature and humidity

Temperature/Humidity % RH	5 to 60	60 to 80
5 to 18 °C	× 2	× 2
18 to 28 °C	× 1	× 2
28 to 40 °C	× 2	× 5

*3 Vout is the output voltage in volts. Iout is the output current in amps.

For example, accuracy specifications are given as ±% of set/measured value (0.04 %) plus offset value (200 nA + 1 nA × Vout) for the 1 mA range. The offset value consists of a fixed part determined by the set/measurement range and a proportional part that is multiplied by Vout or Vout/100.

Output terminal/connection

dual triaxial connectors, Kelvin (remote sensing)

Voltage/Current Compliance (Limiting)

The SMU can limit output voltage or current to prevent damaging the device under test.

Voltage	:	0 V to ±100 V
Current	:	±100 fA to ±100 mA
Compliance accuracy	:	same as current (voltage) set accuracy

HRSMU Supplemental Information

Maximum allowable cable resistance when using Kelvin connection (Force, Sense)	: 10 Ω
Typical voltage source output resistance (Force line/non-Kelvin connection)	: 0.2 Ω
Voltage measurement input resistance/current source output resistance	: $\geq 10^{15}$ Ω (10 pA range)
Current compliance setting accuracy for opposite polarity	: 10 pA to 10 nA range: V/I setting accuracy ±12 % of range
	: 100 nA to 100 mA range: V/I setting accuracy ±2.5 % of range

HRSMU, MPSMU, and HPSMU Supplemental Information

Maximum capacitive load	: 1000 pF
Maximum guard capacitance	: 900 pF
Maximum shield capacitance	: 5000 pF
Maximum guard offset voltage	: ±1 mV
Noise characteristics (typical, Filter: ON)	: Voltage source noise: 0.01 % of V range (rms)
	: Current source noise: 0.1 % of I range (rms)
	: Voltage monitor noise: 0.02 % of V range (p-p)
	: Current monitor noise: 0.2 % of I range (p-p)
Output overshoot (typical, Filter: ON)	: Voltage source: 0.03 % of V range
	: Current source: 1 % of I range
Range switching transient noise (typical, Filter: ON)	: Voltage ranging: 250 mV
	: Current ranging: 10 mV

Maximum slew rate : 0.2 V/μs

- VSU (Voltage Source Unit) Specifications

Table 9-3. VSU Output Range

Voltage Range	Resolution	Accuracy	Max.Output Current
±20 V	1 mV	±(0.05 % of setting + 10 mV)[1]	100 mA

1 Specification is applicable under no load current.

VSU Supplemental Information

Output resistance : 0.2 Ω (typical)

Maximum capacitive load : 10 μF

Maximum slew rate : 0.2 V/μs

Current limit : 120 mA (typical)

Output Noise : 1 mV rms (typical)

- VMU (Voltage Monitor Unit) Specifications

Table 9-4.
VMU Measurement Range, Resolution, and Accuracy

Voltage Range	Meas. Reso.	Meas. Accuracy
±2 V	2 μV	±(0.02 % + 200 μV)
±20 V	20 μV	±(0.02 % + 1 mV)

Table 9-5. VMU Differential Mode Range, Resolution, and Accuracy

Differential Voltage Range	Meas. Reso.	Meas. Accuracy	Max. Common Mode Voltage
±0.2 V	1 μV	±(0.03 % + 100 μV + 1.3 μV × Vi[1])	±20 V
±2 V	2 μV	±(0.02 % + 200 μV + 13 μV × Vi[1])	±20 V

1 Vi is the input voltage of VMU2 in volts.

For example, accuracy specifications are given as ±% of measured value (0.02 %) plus offset value (1 mV + 13 μV × Vi) for the 2 V range. The differential mode offset value consists of a fixed part determined by the measurement range and proportional part that is multiplied by Vi.

VMU Supplemental Information

Input impedance	:	$\geq$ 1 GΩ
Input leakage current (@ 0 V)	:	10 nA (typical)
Measurement noise	:	0.01 % of range (p-p) (Typical)
Differential mode measurement noise	:	0.005 % of range (p-p) (Typical)

- HP 4155A Semiconductor Parameter Analyzer
  - □ MPSMU (Medium Power SMU) Specifications

Table 9-6. Voltage Range, Resolution, and Accuracy (MPSMU)

Voltage Range	Set Reso.	Set Accuracy	Meas. Reso.	Meas. Accuracy	Max. Current
±2V	100μV	±(0.03% + 900μV + 0.3× Iout)	2μV	±(0.02% + 700μV + 0.3 × Iout)	100mA
±20V	1mV	±(0.03% + 4mV + 0.3× Iout)	20μV	±(0.02% + 2mV + 0.3 × Iout)	100mA
±40V	2mV	±(0.03% + 7mV + 0.3× Iout)	40μV	±(0.02% + 3mV + 0.3 × Iout)	100mA (Vout ≤ 20V)
					50mA (20V < Vout ≤ 40V)
±100V	5mV	±(0.04% + 15mV + 0.3× Iout)	100μV	±(0.03% + 5mV + 0.3 × Iout)	100mA (Vout ≤ 20V)
					50mA (20V < Vout ≤ 40V)
					20mA (40V < Vout ≤ 100V)

Table 9-7. Current Range, Resolution, and Accuracy (MPSMU)

Current Range	Set Reso.	Set Accuracy	Meas. Reso.	Measurement Accuracy	Max. Voltage
±1nA	100fA	±(0.5% + 3pA + 2fA × Vout)	10fA	±(0.5% + 3pA + 2fA × Vout *1)	100V
±10nA	1pA	±(0.5% + 7pA + 20fA × Vout)	10fA	±(0.5% + 5pA + 20fA × Vout *1)	100V
±100nA	10pA	±(0.12% + 50pA + 200fA × Vout)	100fA	±(0.1% + 30pA + 200fA × Vout *1)	100V
±1μA	100pA	±(0.12% + 400pA + 2pA × Vout)	1pA	±(0.1% + 200pA + 2pA × Vout *1)	100V
±10μA	1nA	±(0.12% + 5nA + 20pA × Vout)	10pA	±(0.1% + 3nA + 20pA × Vout *1)	100V
±100μA	10nA	±(0.12% + 40nA + 200pA × Vout)	100pA	±(0.1% + 20nA + 200pA × Vout *1)	100V
±1mA	100nA	±(0.12% + 500nA + 2nA × Vout)	1nA	±(0.1% + 300nA + 2nA × Vout *1)	100V
±10mA	1μA	±(0.12% + 4μA + 20nA × Vout)	10nA	±(0.1% + 2μA + 20nA × Vout *1)	100V
±100mA	10μA	±(0.12% + 50μA + 200nA × Vout)	100nA	±(0.1% + 30μA + 200nA × Vout *1)	100V (Iout*2 ≤ 20mA) 40V (20mA < Iout*2 ≤ 50mA) 20V (50mA < Iout*2 ≤ 100mA)

*1 Vout is the output voltage in volts.

*2 Iout is the output current in amps.

For example, accuracy specifications are given as ±% of set/measured value (0.1 %) plus offset value (30 pA + 200 fA × Vout) for the 100 nA range. The offset value consists of a fixed part determined by the set/measurement range and a proportional part that is multiplied by Vout.

Output terminal/connection

single triaxial connector, non-Kelvin (no remote sensing)

Voltage/Current compliance (Limiting)

Voltage : 0 V to ±100 V

Current : ±1 pA to ±100 mA

Compliance accuracy : same as current (voltage) set accuracy

MPSMU Supplemental Information

Voltage source output resistance (typical) : 0.3 Ω

Voltage measurement input resistance/current source output resistance : $\geq 10^{13}$ Ω (1 nA range)

Current compliance setting accuracy for opposite polarity : 1 nA to 10 nA range: V/I setting accuracy ±12 % of range

: 100 nA to 100 mA range: V/I setting accuracy ±2.5 % of range

- VSU Specifications

  Same as HP 4156A VSU.

- VMU Specifications

  Same as HP 4156A VMU.

- HP 41501A SMU and Pulse Generator Expander
  - HPSMU (High Power SMU) Specifications

Table 9-8. Voltage Range, Resolution, and Accuracy (HPSMU)

Voltage Range	Set Reso.	Set Accuracy	Meas. Reso.	Meas. Accuracy	Max. Current
±2 V	100 μV	±(0.03 % + 900 μV)	2 μV	±(0.02 % + 700 μV)	1 A
±20 V	1 mV	±(0.03 % + 4 mV)	20 μV	±(0.02 % + 2 mV)	1 A
±40 V	2 mV	±(0.03 % + 7mV)	40 μV	±(0.02 % + 3 mV)	500 mA
±100 V	5 mV	±(0.04 % + 15 mV)	100 μV	±(0.03 % + 5 mV)	125 mA
±200 V	10 mV	±(0.045 % + 30 mV)	200 μV	±(0.035 % + 10 mV)	50 mA

Table 9-9. Current Range, Resolution and Accuracy (HPSMU)

Current Range	Set Reso.	Set Accuracy	Meas. Reso.	Measurement Accuracy	Max. Voltage
±1nA	100fA	±(0.5% + 3pA + 2fA × Vout)	10fA	±(0.5% + 3pA + 2fA × Vout *1)	200V
±10nA	1pA	±(0.5% + 7pA + 20fA × Vout)	10fA	±(0.5% + 5pA + 20fA × Vout *1)	200V
±100nA	10pA	±(0.12% + 50pA + 200fA × Vout)	100fA	±(0.1% + 30pA + 200fA × Vout *1)	200V
±1μA	100pA	±(0.12% + 400pA + 2pA × Vout)	1pA	±(0.1% + 200pA + 2pA × Vout *1)	200V
±10μA	1nA	±(0.12% + 5nA + 20pA × Vout)	10pA	±(0.1% + 3nA + 20pA × Vout *1)	200V
±100μA	10nA	±(0.12% + 40nA + 200pA × Vout)	100pA	±(0.1% + 20nA + 200pA × Vout *1)	200V
±1mA	100nA	±(0.12% + 500nA + 2nA × Vout)	1nA	±(0.1% + 300nA + 2nA × Vout *1)	200V
±10mA	1μA	±(0.12% + 4μA + 20nA × Vout)	10nA	±(0.1% + 2μA + 20nA × Vout *1)	200V
±100mA	10μA	±(0.12% + 50μA + 200nA × Vout)	100nA	±(0.1% + 30μA + 200nA × Vout *1)	200V (Iout*2 ≤ 50mA) 100V (50mA < Iout*2 < 100mA)
±1A	100μA	±(0.5% + 500μA + 2μA × Vout)	1μA	±(0.5% + 300μA + 2μA × Vout *1)	200V (Iout*2 ≤ 50mA) 100V (50mA < Iout*2 < 125mA) 40V (125mA < Iout*2 < 500mA) 20V (500mA < Iout*2 < 1A)

*1 Vout is the output voltage in volts.

*2 Iout is the output current in amps.

For example, accuracy specifications are given as ±% of set/measured value (0.1 %) plus offset value (30 pA + 200 fA × Vout) for the 100 nA range. The offset value consists of a fixed part determined by the set/measurement range and a proportional part that is multiplied by Vout.

Output terminal/connection

dual triaxial connectors, Kelvin (remote sensing)

Voltage/Current Compliance (Limiting)

The SMU can limit output voltage or current to prevent damaging the device under test.

Voltage	: 0 V to ±200 V
Current	: ±1 pA to ±1 A
Compliance accuracy	: same as current (voltage) set accuracy

HPSMU Supplemental Information

Maximum allowable cable resistance when using Kelvin connection	: Force: 0.7 Ω (100 mA to 1 A)
	: Force: 10 Ω (≤ 100 mA)
	: Sense: 10 Ω
Typical voltage source output resistance (force line/non Kelvin connection)	: 0.2 Ω
Voltage measurement input resistance/current source output resistance	: ≥ 10^{13} Ω (1 nA range)
Current compliance setting accuracy for opposite polarity	: 1 nA to 10 nA range: V/I setting accuracy ±12 % of range
	: 100 nA to 1 A range: V/I setting accuracy ±2.5 % of range

- PGU (Pulse Generator Unit) Specifications

Modes	: pulse or constant
Amplitude	: 0 Vpp to 40 Vpp
Window	: -40.0 V to +40.0 V

Maximum current : ±200 mA (pulse width: ≤ 1 ms, Average current ≤ 100 mA)

: ±100 mA

Table 9-10. Pulse/DC Output voltage and accuracy

Set Parameter	Voltage Range	Resolution	Accuracy[1]
Base	±20V	4mV	±(1% of Base + 50mV + 1% of Pulse)
	±40V	8mV	±(1% of Base + 50mV + 1% of Pulse)
Pulse	±20V	4mV	±(3% of Base + 50mV)
	±40V	8mV	±(3% of Base + 50mV)

1 Accuracy is specified at leading = trailing time = 1 μs.

DC output is performed by the Base parameter.

Table 9-11. Pulse Range and Pulse Parameter

Range	Period	Width	Delay	Set resolution
1	2 μs - 100 μs	1 μs - 99.9 μs	0 - 100 μs	0.1 μs
2	100 μs - 1000 μs	1 μs - 999 μs	0 - 1000 μs	1 μs
3	1 ms - 10 ms	0.01 ms - 9.99 ms	0 - 10 ms	10 μs
4	10 ms - 100 ms	0.1 ms - 99.9 ms	0 - 100 ms	100 μs
5	100 ms - 1000 ms	1 ms - 999 ms	0 - 1000 ms	1 ms
6	1 s - 10 s	0.01 s - 9.99 s	0 - 10 s	10 ms

Pulse width is defined when leading time is equal to trailing time. PGU2 must be set in the same range as PGU1.

Pulse parameter accuracy:

Period : ±(2 % + 2 ns)

Width : ±(3 % + 2 ns)

Delay : ±(2 % + 40 ns)

Table 9-12. Leading/Trailing Time

Range	Set Resolution	Accuracy
100 ns - 1000 ns	1 ns	±(5 % + 10 ns)
0.5 μs - 10.0 μs	10 ns	±(5 % + 10 ns)
5.0 μs - 100.0 μs	100 ns	±(5 % + 10 ns)
50 μs - 1000 μs	1 μs	±(5 % + 10 ns)
0.5 ms - 10.0 ms	10 μs	±(5 % + 10 ns)

restrictions:

Pulse width < Pulse period

Delay time < Pulse period

Leading time < Pulse width × 0.8

Trailing time < (Pulse period - Pulse width) × 0.8

Period, width, and delay of PGU1 and PGU2 must be in the same range. Leading time and trailing time for a PGU must be in the same range.

Output impedance : 50 Ω and low impedance (≤1 Ω)

Burst count range : 1 - 65535

Trigger output : Level: TTL

: Timing: same timing and width as PGU1 pulse output

PGU supplemental information

Overshoot(Undershoot, ringing)	: $\leq \pm 5$ % of amplitude ± 10 mV (50 Ω output impedance to 50 Ω load)
Pulse width jitter	: 0.2 % + 100 ps
Pulse period jitter	: 0.2 % + 100 ps
Maximum slew rate	: 100 V/μs (50 Ω output impedance to 50 Ω load)
Noise	: 0.2 % of range (@ DC output)

- □ MPSMU Specifications

  Same as HP 4155A MPSMU.

- □ GNDU (Ground Unit) Specifications

Output voltage	: 0 V ± 100 μV
Maximum sink current	: 1.6 A
Output terminal/connection	: single triaxial connector, Kelvin (remote sensing)

GNDU Supplemental Information

Load capacitance	: $\leq 1\ \mu$F
Cable resistance	: force ≤ 1 Ω
	: sense ≤ 10 Ω

Functions

- Measurement Set-up

  Setting:

  - □ Fill-in-the-blanks using front-panel or full-size external keyboard
  - □ Load settings from floppy disk
  - □ Program using internal HP Instrument BASIC or via HP-IB
  - □ HELP function
  - □ Library: Default Measure Setup, Vce-Ic, Vds-Id, Vgs-Id, and Vf-If are pre-defined softkeys
  - □ User-defined measurement setup library
  - □ Auto file load function on power-up

- Measurement

  The HP 4155A and HP 4156A can perform dc or pulsed force/measure, and stress force. For dc, voltage/current sweep and sampling (time domain) measurements are available.

  - □ Voltage/Current Sweep Measurement Characteristics

    Each SMU can be swept using VAR1 (primary sweep), VAR2 (subordinate sweep), or VAR1' (synchronous sweep).

    VAR1 : Primary sweep, controls the staircase (dc or pulsed) voltage or current sweep.

    Max. number of steps: 1001 for one VAR1 sweep.

    Sweep type: Linear or logarithmic

    Sweep direction: Single or double sweep

    Hold time: Initial wait time or wait time after VAR2 is set, 0 to 655.35 s with 10 ms resolution

    Delay time: Wait time from VAR1 step to the start of the measurement, 0 to 65.535 s with 100 μs resolution

VAR2 : Subordinate linear staircase or linear pulsed sweep. After primary sweep is completed, the VAR2 unit output is incremented.

Max. number of steps: 128

VAR1' : Staircase or pulsed sweep synchronized with the VAR1 sweep. Sweep is made with a user specified ratio and offset value. VAR1' output is calculated as VAR1' = a × VAR1 + b, where "a" is the user-specified ratio and "b" is the user-specified offset value.

CONSTANT : A source unit can be set as a constant voltage or current source depending on the unit.

PULSE : One of SMUs can be set as a pulse source.

Pulse width: 0.5 ms to 100 ms, 100 μs resolutions.

Pulse period: 5 ms to 1 s ($\geq$ pulse width + 4 ms), 100 μs resolutions.

SMU pulse setting accuracy (supplemental information): (conditions: fixed range measurement except multi channel measurement)

Width: 0.5 % + 50 μs

Period: 0.5 % + 100 μs

Trigger out delay for pulsed measurement: 0 - 32.7 ms with 100 μs resolution (< pulse width)

- Sampling (Time Domain) Measurement Characteristics

Displays the time sampled voltage/current data versus time. The source unit is SMU, VSU, or PGU.

Maximum sampling points : 10,001 (Linear)

Sampling mode : linear, log, and thinned-out

Sampling interval range and resolution : Linear scale (auto mode):

60 μs to 480 μs range, 20 μs resolution

480 μs to 1 s range, 80 μs resolution

1 s to 65.535 s range, 2 ms resolution

	: Linear scale (no limit mode), log scale, and thinned-out modes:
	560 μs (720 μs at thinned-out mode) to 1 s range, 80 μs resolution
	1 s to 65.535 s range, 2 ms resolution
Hold time	: initial wait time, 0.03 to 655.35 s, 100 μs resolution.
Sampling measurement stop condition	: a condition to stop the sampling can be defined.
Sampling interval setting accuracy (supplemental data)	: 0.5 % + 10 μs (sampling interval $\leq$ 480 μs)
	: 0.5 % + 10 μs (560 μs $\leq$ sampling interval < 2 ms)
	: 0.5 % + 100 μs (2 ms $\leq$ sampling interval)

The thinned-out mode is similar to reverse-log sampling. Sampling measurement continues by thinning out older data until the sampling completion condition is satisfied.

There are the following restrictions if initial interval < 2 ms

Number of measurement channels = 1 channel

Measurement ranging = Fixed range

Stop condition = Disable

□ Stress Force Characteristics

SMU, VSU, and PGU output can be forced for the user specified period.

Stress time set range	: 500 μs to 31,536,000 s (365 days)
Resolution	: 100 μs (500 μs $\leq$ stress time $\leq$ 10 s)
	: 10 ms (10 s < stress time $\leq$ 31,536,000 s)
Burst pulse count	: 1 - 65,535 (PGU only)
Trigger	: HP 4155A/4156A outputs a gate trigger while stress channels are forcing stress.

- Knob Sweep

  In the knob sweep mode, sweep range is controlled instantaneously with the front-panel rotary knob. Only the CHANNELS: CHANNEL DEFINITION page needs to be defined.

  Typical measurement time (Supplemental data, including a CRT write time): 0.65 ms/one point measurement

- Standby Mode

  SMUs in “Standby” remain programmed to their specified output value even as other SMUs are reset for the next measurement.

- Other Characteristics

  Measurement control:

V/I sweep and sampling measurement	: single, append, repeat, and stop
Stress force	: stress, and stop
SMU settings capabilities	: limited auto-ranging, voltage/current compliance, power compliance, automatic sweep abort functions, self-test, and self calibration.

- Arithmetic and Analysis Functions

  - Arithmetic Functions

User functions	: up to six USER FUNCTIONs can be defined using arithmetic expressions. Measured data and analyzed variables from graphics analysis (marker, cursor and line data) can be used in the computation. The results can be displayed on the CRT.
Arithmetic operators	: +, -,*, /, ^, LGT(logarithm, base 10), LOG(logarithm, base e), EXP(Napierian constant), DELTA, DIFF(differential), INTEG(integration), MAVG(moving average), SQRT, ABS(absolute), MAX, MIN, AVG(averaging), COND(conditional evaluation).
Physical constants	: Keyboard constants are stored in memory as follows.

q : Electron Charge, 1.602177 E-19 C

k : Boltzmann's Constant, 1.380658 E-23

e : Dielectric Constant of vacuum, 8.854188 E-12

Engineering units : The following unit symbols are also available on the keyboard. m (10^{-3}), μ (10^{-6}), u (10^{-6}), n (10^{-9}), p (10^{-12}), f (10^{-15}), k (10^{3}), M (10^{6}), G (10^{9})

- Analysis Capabilities

Overlay graph comparison : a graphic plot can be stored and later recalled as an overlay plane. Four overlay planes can be stored. One plane can be overlaid onto the current data.

Marker : marker to min/max, interpolation, direct marker, and marker skip

Cursor : long and short, direct cursor

Line : two lines, normal mode, grad mode, tangent mode, and regression mode

Scaling : auto scale and zoom

Data variable display : Up to two user defined parameters can be displayed on graphics screen.

Read Out Function : The read out functions are built-in functions for reading various values related to the marker, cursor, or line.

Automatic Analysis Function : On a graphics plot, the markers and lines can be automatically located using the auto analysis setup. Parameters can be automatically determined using automatic analysis, user function, and read out functions.

User Variable : Display the data on the CRT via HP-IB or Instrument BASIC.

- Output
  - Display

    Display modes : graphics and list

    Graphics display : two-axes (X-Y) or three-axes (X-Y1,Y2) plot of source current/voltage, measured current/voltage, time, or calculated USER FUNCTION data.

    List display : measurement data and calculated USER FUNCTION data are listed in conjunction with VAR1 step number or time domain sampling step number. Up to eight data sets can be displayed.

    Display : 7.5 inch diagonal color raster scanned CRT, 512 dot (H) by 400 dot (V)

  - Hard Copy Functions

    Graphics hard copy : measured data and all data appearing on the CRT can be output via HP-IB or serial interface to a supported HP plotter or printer. PCL and HP-GL formats are supported (selectable).

    Text hard copy : print out setup information or measured data list as an ASCII text via HP-IB or serial interface to a supported HP plotter or printer. PCL and HP-GL formats are supported (selectable).

    Hard copy file : hard copy output can be stored to a floppy disk file instead of sending it to a printer or plotter. The data can be stored in PCL or HP-GL.

- Data Storage

  Mass storage device : built-in 3.5 inch flexible disk drive

  Media : 3.5 inch 2HD or 2DD diskette

  Format type : HP LIF and DOS

  User area : 1.44 Mbyte (2HD)or 720 Kbyte (2DD)

  File types : auto start program file, initial setup file, measurement setup file, measurement setup/result file, stress setup file, customize file, hard copy data file, and HP Instrument BASIC program and data file.

Format of data made by HP BASIC program : data made by HP BASIC program and data made by HP Instrument BASIC program are compatible.

Data storage (Supplemental data):

2HD DOS format : available bytes = 1457K (byte)

File size : Measurement setup: 3833 (byte)

: Stress setup: 601 (byte)

: Measurement setup/result (typical data): 15377 (byte) (VAR1: 101, VAR2: 5)

: Hardcopy data: 21760 (byte) (monochrome PCL file)

For LIF format, the total number of files is limited to 199.

- Repeating and Automating Test
  - □ Instrument Control

    HP 4155A and 4156A function control : internal or external computer control HP 4155A and HP 4156A functions via HP-IB interface.

    External instrument remote control : control external equipment via HP-IB or serial interface.

  - □ HP Instrument BASIC

    HP Instrument BASIC is a subset of HP BASIC.

    Functions : arithmetic operation, binary operation, string manipulation, logical operation, array operation, program flow control, event-initiated branching, program editing and debugging support, mass storage operation, instrument control, real-time clock, softkey operation, and graphics.

    HP 4145B automatic sequence program (ASP) like typing aid : HP 4145B ASP like syntax softkeys are available in HP Instrument BASIC. An

HP 4145B ASP file cannot be read by the HP 4155A and 4156A.

Remote control : HP Instrument BASIC is remote controllable from an external computer via the HP-IB interface.

IBASIC memory area (Supplemental data):

Program (text) area : 16K (byte)

Variable/stack area : 500K (byte)

Common variable area : 560K (byte) The memory size for common variable is decreased when hard copy or disk operation is performed.

- □ Trigger

  Input : external trigger input starts a sweep or sampling measurement or can be used as a trigger input for continuing HP Instrument BASIC program.

  Input level : TTL level, negative or positive edge trigger

  Output : external trigger can be generated by the following events: start of each sweep measurement step, start of each pulse (SMU) output, while the stress source is forcing, and Instrument BASIC trigger out command execution.

  Output level : TTL level, negative or positive logic

- HP 4145B Data Compatibility and HP 4145B Syntax Commands

  Setup and data file : load measurement setup and data of HP 4145B

  HP-IB program : HP-IB programs for HP 4145B can be used when HP 4145B command set is selected.

  There is a possibility that HP-IB programs for HP 4145B need to be modified before using.

- Interfaces

  - □ HP-IB interface : SH1, AH1, T6, L4, SR1, RL1, PP0, DC1, DT1, C1, C2, C3, C4, C11, E2

- Serial interface
- External keyboard : compatible PC-style 101-key keyboard (mini DIN connector)
- Interlock and LED connector
- R-BOX control connector
- Trigger in/out
- SMU/PGU Selector control connector (HP 41501A)

- Sample Application Programs
  - Hot carrier injection
  - Flash EEPROM test
  - V-Ramp test
  - TDDB
  - Constant I (Electromigration)

General Specifications

- Temperature range

  Operating : +10 °C to +40 °C

  Storage : -40 °C to +60 °C

- Humidity range

  Operating : 15% to 80% RH at 40 °C (non-condensing)

  Storage : 5% to 90% RH at 60 °C (non-condensing)

- Altitude

  Operating: 0 to 4,500 m (15,000 ft)

  Storage: 0 to 15,240 m (50,000 ft)

- Power requirement

  100/120/220/240 V ± 10 %, 47 to 63 Hz

- Maximum VA

  HP 4155A or 4156A : 600 VA

  HP 41501A : 450 VA

- Regulatory Compliance

  EMC: EN55011 Group1, ClassA

  EN50082-1

  Safety: CSA C22.2 NO.1010, IEC 1010-1

- Dimensions

  HP 4155A and 4156A : 426 mmW by 235 mmH by 600 mmD

  HP 41501A : 426 mmW by 190 mmH by 600 mmD

- Weight(approx.)

  HP 4155A and 4156A : 25 kg

  HP 41501A : 15 kg (option 412). . . . (HPSMU + 2 × PGU)

HP 4155A and HP 4156A Furnished Accessories

The following are the furnished accessories for the HP 4155A/4156A.

- Triaxial Cable, 4 ea. (HP 4155A)
- Kelvin Triaxial Cable, 4 ea. (HP 4156A)
- Coaxial Cable, 4 ea.
- Interlock Cable, 1 ea.
- Connection Plate, 1 ea.
- Keyboard, 1 ea.
- User's Guide, 1 set
- Programmer's Guide, 1 ea.
- Sample application program disk, 1 ea.

10

Manual Changes Depending on ROM Version

Manual Changes Depending on ROM Version

HP 4155A/4156A may vary slightly, depending on the version of the ROM based firmware. The information in this manual applies to an HP 4155A/4156A with the following ROM version.

Manual Applies to this ROM Version

ROM	ROM Version
HOSTC	01.02

ROM version

To confirm your ROM version, check the `SOFTWARE REVISION` field on the SYSTEM: CONFIGURATION page.

This chapter contains information for customizing this manual so that it is correct for the HP 4155A/4156A that you are using.

To customize this manual for your HP 4155A/4156A, refer to the following table, and make the manual changes depending on the ROM version of your HP 4155A/56A.

Manual Changes by ROM version

ROM version (HOSTC)	Make Manual Changes
01.00	1
01.01	1

Change 1

- GRAPH/LIST: LIST page
  - List Index Number field (Page 4-66)

    Append measurement number is not displayed.
  - NEXT APPEND secondary softkey (Page 4-69)

    is not available, use MARKER SKIP secondary softkey to move to the next append measurement data.
- Setup items that are saved to customize (CST) file (Page 4-100)

  The setup items on hardcopy setup window are not saved into customize (CST) file.
- SYSTEM: PRINT/PLOT SETUP page
  - COLOR/ B/W field (Page 4-118)

    FIX CLR secondary softkey and fixed color mode are not available.
  - RESOLUTION field (Page 4-118)

    HP 4155A/4156A does not change the actual resolution setting of the printer.

Change 1