User's Guide

Volume 2

Measurement and Analysis

Agilent 4155B Semiconductor Parameter Analyzer
Agilent 4156B Precision Semiconductor Parameter Analyzer

Agilent Technologies

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  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 protections provided by the equipment. In addition, it violates safety standards of design, manufacture, and intended use of the instrument. Agilent Technologies, Inc. assumes no liability for customer's failure to comply with these requirements.

NOTE

Agilent 4155B/4156B/41501B comply with INSTALLATION CATEGORY II for mains input and INSTALLATION CATEGORY I for measurement input terminals, and POLLUTION DEGREE 2 defined in IEC 1010-1.

Agilent 4155B/4156B/41501B are INDOOR USE products.

NOTE

LEDs in Agilent 4155B/4156B/41501B are Class 1 in accordance with IEC 825-1. CLASS 1 LED PRODUCT.

- *GROUND THE INSTRUMENT*

  This is Safety Class I 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 Agilent Technologies 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 Voltage, 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 and potential for electrical shock. Do not touch terminals that have this symbol when insrument is on.

Protective conductor terminal. For protection against electrical shock in case of a fault. Used with field wiring terminals to indicate the terminal which must be connected to ground before operating equipment.

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

Indicates earth (ground) terminal.

Alternating current.

Direct current.

ON (Supply).

OFF (Supply).

STANDBY (Supply).

CAT 1 Means INSTALLATION CATEGORY I. Measurement terminals on the rear panel comply with INSTALLATION CATEGORY I.

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 personal.

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 < 70dB

  operator position

  normal operation

  per ISO 7779

Printing History

Edition 1:	August 1997
Edition 2:	September 1997
Edition 3:	October 1998
Edition 4:	January 2000
Edition 5:	May 2000

In This Manual

This manual provides information for all parts and functions of Agilent 4155B/4156B, 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.

- Making a Measurement

  This chapter describes how to perform measurements.

- Analyzing Measurement Results

  This chapter describes how to analyze measurement results manually and automatically.

- Screen Organization

  This chapter provides information about each user interface that is displayed on the instrument screen.

- Data Variable and Analysis Function

  This chapter provides information about data variables and analysis functions.

- If You Have A Problem

  This chapter provides problem-solving information that you may encounter.

Text Conventions

The following text conventions are used in this manual:

`Screen Text`	Represents text that appears on screen of the 4155B/4156B.
Italic	Refers to a related document, or is used for emphasis.

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6. Screen Organization

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1 Measurement Units

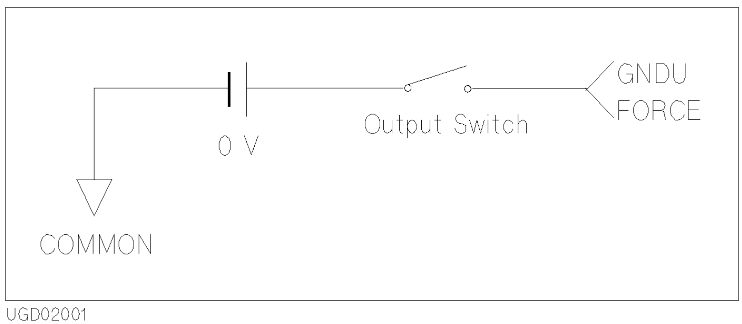
This chapter explains basic output and measurement functions of each measurement unit. For the following units, a simplified circuit diagram is shown, and where applicable, the output and measurement ranges are provided.

- "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 Agilent 41501A/B (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)

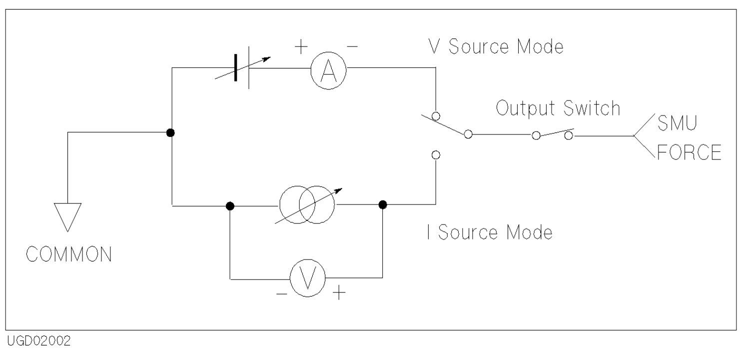
The source/monitor unit (SMU) has the following three modes:

- 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 the 4156B has HRSMUs. The 4156B has four HRSMUs.
- MPSMU (medium power SMU)
    - Force and measure: up to ±100 V or ±100 mA.
    - Maximum output power: 2 W.
    - The 4155B has four MPSMUs, and the 41501A/B 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 the 41501A/B has HPSMU. The 41501A/B 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.

Figure 1-3 **HRSMU Output and Measurement Ranges**

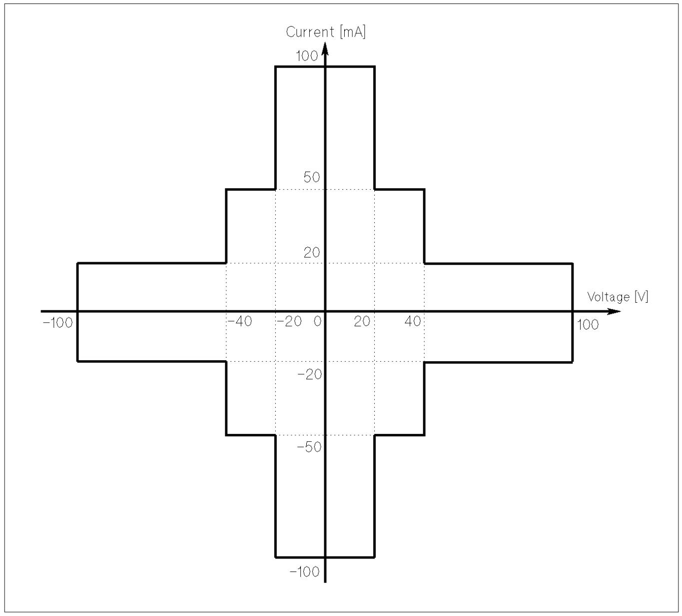


Table 1-1 **HRSMU Output Voltage Ranges and Resolutions**

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

Table 1-2 HRSMU Measurement Voltage Values and Resolutions

Range	Measurement Value [a]	Measurement Resolutions [b]			
		Integration Time			High Speed Sampling Measurement [c]
		1PLC or Longer	640 μs to 1.92 ms	80 μs to 560 μs	
2 V	0 ≤ |V| ≤ 2.2 V	2 μV	20 μV	200 μV	2 mV
20 V	0 ≤ |V| ≤ 22 V	20 μV	200 μV	2 mV	20 mV
40 V	0 ≤ |V| ≤ 44 V	40 μV	400 μV	4 mV	40 mV
100 V	0 ≤ |V| ≤ 100 V	100 μV	1 mV	10 mV	100 mV

a. This column is applied to the auto ranging or the limited auto ranging. For fixed ranging, maximum measurement value is **Range** column value.
b. Measurement resolution depends on the integration time setting. For Knob sweep measurement, see the column of Integration Time 80 μs to 560 μs.
c. This column is applied to the sampling measurement that *initial interval* is set to 480 μs or shorter.

Table 1-3 HRSMU Output Current Ranges and Resolutions

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

Table 1-4 **HRSMU Measurement Current Values and Resolutions**

Range	Measurement Value [a]	Measurement Resolutions [b]			
		Integration Time			High Speed Sampling Measurement [c]
		1PLC or Longer	640 μs to 1.92 ms	80 μs to 560 μs	
10 pA	$0 \le \lvert I \rvert \le$ 10.5 pA	1 fA	1 fA	1 fA	10 fA
100 pA	$0 \le \lvert I \rvert \le$ 115 pA	1 fA	1 fA	10 fA	100 fA
1 nA	$0 \le \lvert I \rvert \le$ 1.15 nA	10 fA	10 fA	100 fA	1 pA
10 nA	$0 \le \lvert I \rvert \le$ 11.5 nA	10 fA	100 fA	1 pA	10 pA
100 nA	$0 \le \lvert I \rvert \le$ 115 nA	100 fA	1 pA	10 pA	100 pA
1 μA	$0 \le \lvert I \rvert \le$ 1.15 μA	1 pA	10 pA	100 pA	1 nA
10 μA	$0 \le \lvert I \rvert \le$ 11.5 μA	10 pA	100 pA	1 nA	10 nA
100 μA	$0 \le \lvert I \rvert \le$ 115 μA	100 pA	1 nA	10 nA	100 nA
1 mA	$0 \le \lvert I \rvert \le$ 1.15 mA	1 nA	10 nA	100 nA	1 μA
10 mA	$0 \le \lvert I \rvert \le$ 11.5 mA	10 nA	100 nA	1 μA	10 μA
100 mA	$0 \le \lvert I \rvert \le$ 100 mA	100 nA	1 μA	10 μA	100 μA

a. This column is applied to the auto ranging or the limited auto ranging. For fixed ranging, maximum measurement value is **Range** column value.
b. Measurement resolution depends on the integration time setting. For Knob sweep measurement, see the column of Integration Time 80 μs to 560 μs.
c. This column is applied to the sampling measurement that *initial interval* is set to 480 μs or shorter.

Figure 1-4 **MPSMU Output and Measurement Ranges**

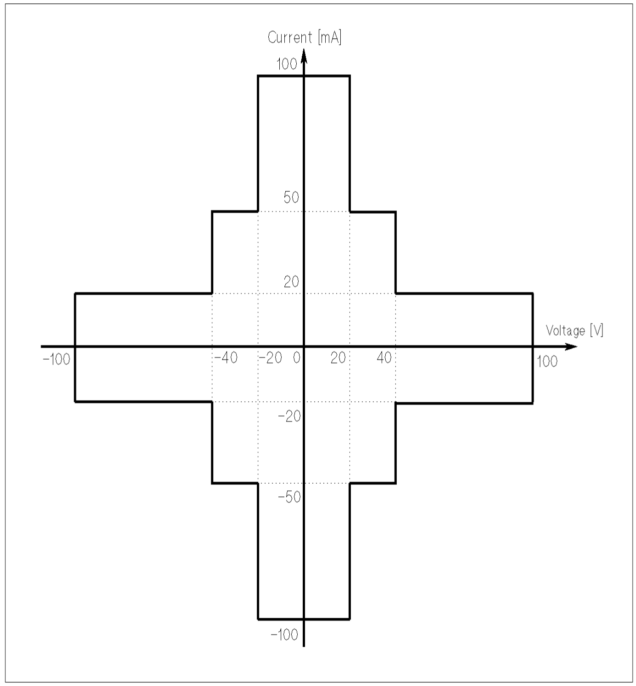


Table 1-5 **MPSMU Output Voltage Ranges and Resolutions**

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

Table 1-6 MPSMU Measurement Voltage Values and Resolutions

Range	Measurement Value [a]	Measurement Resolutions [b]			
		Integration Time			High Speed Sampling Measurement [c]
		1PLC or Longer	640 μs to 1.92 ms	80 μs to 560 μs	
2 V	0 ≤ |V| ≤ 2.2 V	2 μV	20 μV	200 μV	2 mV
20 V	0 ≤ |V| ≤ 22 V	20 μV	200 μV	2 mV	20 mV
40 V	0 ≤ |V| ≤ 44 V	40 μV	400 μV	4 mV	40 mV
100 V	0 ≤ |V| ≤ 100 V	100 μV	1 mV	10 mV	100 mV

a. This column is applied to the auto ranging or the limited auto ranging. For fixed ranging, maximum measurement value is **Range** column value.
b. Measurement resolution depends on the integration time setting. For Knob sweep measurement, see the column of Integration Time 80 μs to 560 μs.
c. This column is applied to the sampling measurement that *initial interval* is set to 480 μs or shorter.

Table 1-7 MPSMU Output Current Ranges and Resolutions

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

Table 1-8 MPSMU Measurement Current Values and Resolutions

Range	Measurement Value [a]	Measurement Resolutions [b]			
		Integration Time			High Speed Sampling Measurement [c]
		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	1 pA
10 nA	$0 \leq \lvert I \rvert \leq 11.5$ nA	10 fA	100 fA	1 pA	10 pA
100 nA	$0 \leq \lvert I \rvert \leq 115$ nA	100 fA	1 pA	10 pA	100 pA
1 μA	$0 \leq \lvert I \rvert \leq 1.15$ μA	1 pA	10 pA	100 pA	1 nA
10 μA	$0 \leq \lvert I \rvert \leq 11.5$ μA	10 pA	100 pA	1 nA	10 nA
100 μA	$0 \leq \lvert I \rvert \leq 115$ μA	100 pA	1 nA	10 nA	100 nA
1 mA	$0 \leq \lvert I \rvert \leq 1.15$ mA	1 nA	10 nA	100 nA	1 μA
10 mA	$0 \leq \lvert I \rvert \leq 11.5$ mA	10 nA	100 nA	1 μA	10 μA
100 mA	$0 \leq \lvert I \rvert \leq 100$ mA	100 nA	1 μA	10 μA	100 μA

a. This column is applied to the auto ranging or the limited auto ranging. For fixed ranging, maximum measurement value is **Range** column value.
b. Measurement resolution depends on the integration time setting. For Knob sweep measurement, see the column of Integration Time 80 μs to 560 μs.
c. This column is applied to the sampling measurement that *initial interval* is set to 480 μs or shorter.

Figure 1-5 **HPSMU Output and Measurement Ranges**

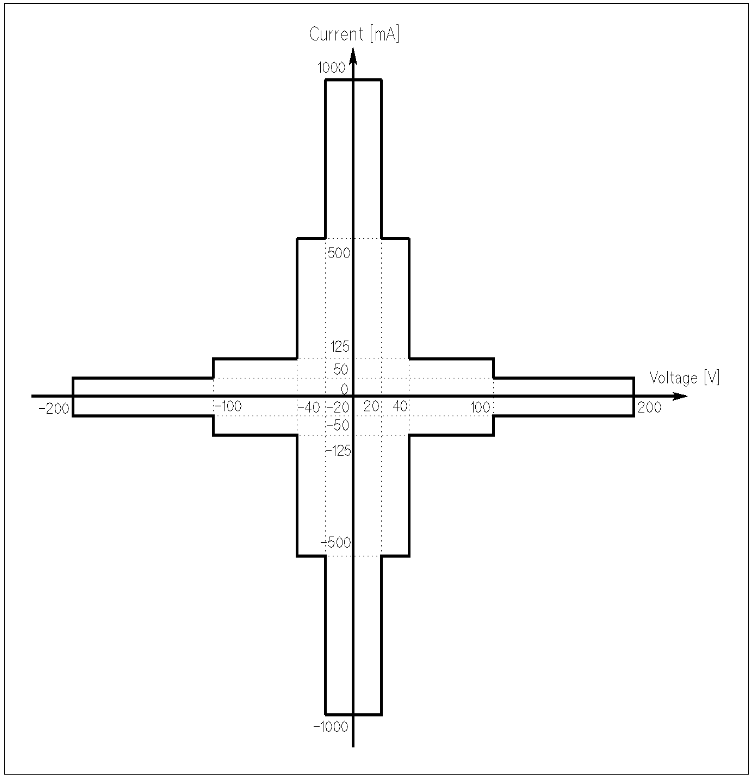


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Table 1-9 **HPSMU Output Voltage Ranges and Resolutions**

Range	Output Value	Output Resolution	Current Compliance Range
2 V	$0 \leq \lvert V \rvert \leq 2$ V	100 μV	±1000 mA
20 V	$0 \leq \lvert V \rvert \leq 20$ V	1 mV	±1000 mA
40 V	$0 \leq \lvert V \rvert \leq 40$ V	2 mV	±500 mA
100 V	$0 \leq \lvert V \rvert \leq 100$ V	5 mV	±125 mA
200 V	$0 \leq \lvert V \rvert \leq 200$ V	10 mV	±50 mA

Table 1-10 HPSMU Measurement Voltage Values and Resolutions

Range	Measurement Value [a]	Measurement Resolutions [b]			
		Integration Time			High Speed Sampling Measurement [c]
		1PLC or Longer	640 μs to 1.92 ms	80 μs to 560 μs	
2 V	0 ≤ |V| ≤ 2.2 V	2 μV	20 μV	200 μV	2 mV
20 V	0 ≤ |V| ≤ 22 V	20 μV	200 μV	2 mV	20 mV
40 V	0 ≤ |V| ≤ 44 V	40 μV	400 μV	4 mV	40 mV
100 V	0 ≤ |V| ≤ 110 V	100 μV	1 mV	10 mV	100 mV
200 V	0 ≤ |V| ≤ 200 V	200 μV	2 mV	20 mV	200 mV

a. This column is applied to the auto ranging or the limited auto ranging. For fixed ranging, maximum measurement value is **Range** column value.
b. Measurement resolution depends on the integration time setting. For Knob sweep measurement, see the column of Integration Time 80 μs to 560 μs.
c. This column is applied to the sampling measurement that *initial interval* is set to 480 μs or shorter.

Table 1-11 HPSMU Output Current Ranges and Resolutions

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

Table 1-12 **HPSMU Measurement Current Values and Resolutions**

Range	Measurement Value [a]	Measurement Resolutions [b]			
		Integration Time			High Speed Sampling Measurement [c]
		1PLC or Longer	640 µs to 1.92 ms	80 µs to 560 µs	
1 nA	0 ≤ |I| ≤ 1.15 nA	10 fA	10 fA	100 fA	1 pA
10 nA	0 ≤ |I| ≤ 11.5 nA	10 fA	100 fA	1 pA	10 pA
100 nA	0 ≤ |I| ≤ 115 nA	100 fA	1 pA	10 pA	100 pA
1 µA	0 ≤ |I| ≤ 1.15 µA	1 pA	10 pA	100 pA	1 nA
10 µA	0 ≤ |I| ≤ 11.5 µA	10 pA	100 pA	1 nA	10 nA
100 µA	0 ≤ |I| ≤ 115 µA	100 pA	1 nA	10 nA	100 nA
1 mA	0 ≤ |I| ≤ 1.15 mA	1 nA	10 nA	100 nA	1 µA
10 mA	0 ≤ |I| ≤ 11.5 mA	10 nA	100 nA	1 µA	10 µA
100 mA	0 ≤ |I| ≤ 50 mA	100 nA	1 µA	10 µA	100 µA
	50 mA < |I| ≤ 115 mA	100 nA	1 µA	10 µA	100 µA
1 A	0 ≤ |I| ≤ 1 A	1 µA	10 µA	100 µA	1 mA

a. This column is applied to the auto ranging or the limited auto ranging. For fixed ranging, maximum measurement value is **Range** column value.
b. Measurement resolution depends on the integration time setting. For Knob sweep measurement, see the column of Integration Time 80 µs to 560 µs.
c. This column is applied to the sampling measurement that *initial interval* is set to 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 ≥ 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.

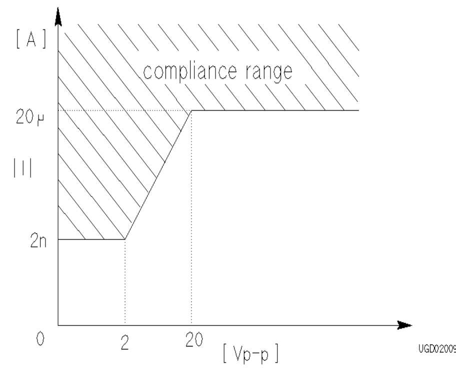
NOTE

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

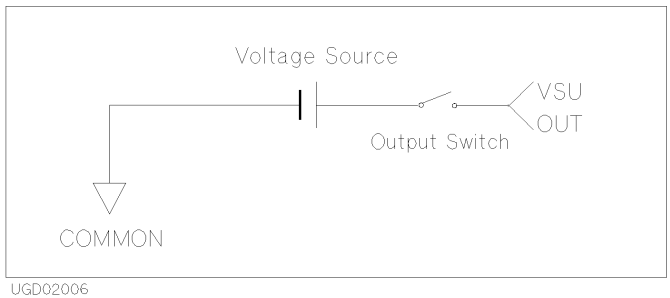
If SMU is pulsed *constant* source, I is peak or base current, whichever has larger absolute value.

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**



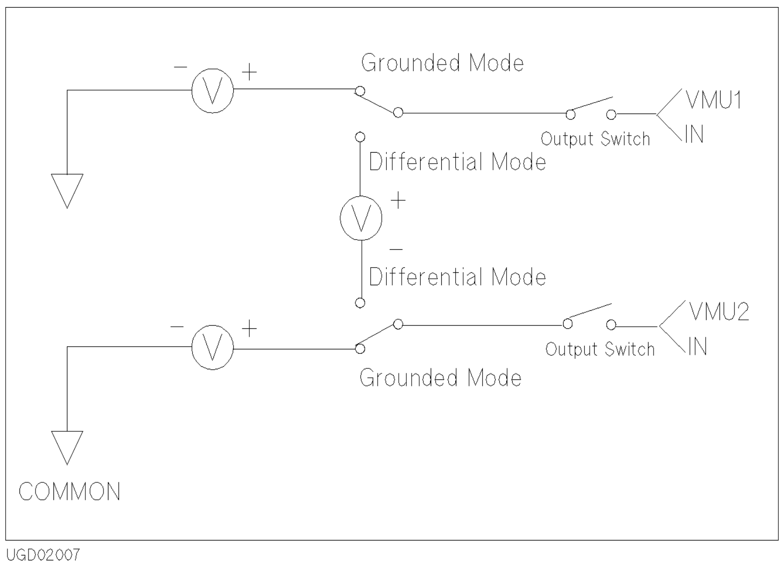
- VSU can force up to ±20 V.
- Only range available is 20 V range with 1 mV resolution, so output range is automatically set to 20 V.
- Current compliance is automatically set to ±100 mA.

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 [a]			
		Integration Time			High Speed Sampling Measurement [b]
		1PLC or Longer	640 µs to 1.92 ms	80 µs to 560 µs	
Grounded Measurement	2 V	2 µV	20 µV	200 µV	2 mV
	20 V	20 µV	200 µV	2 mV	20 mV
Differential Measurement	0.2 V	1 µV	2 µV	20 µV	200 µV
	2 V	2 µV	20 µV	200 µV	2 mV

a. Measurement resolution depends on the integration time setting. For Knob sweep measurement, see 20 V Range (for Grounded mode) and 2 V Range (for Differential mode) of Integration Time 80 µs to 560 µs.
b. This column is applied to the sampling measurement that *initial interval* is set to 480 µs or shorter.

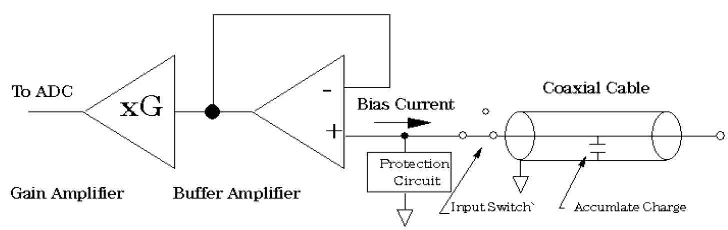
When you perform knob sweep measurement,

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

NOTE

Bias Current of Buffer Amplifier may Damage DUT

The following figure shows a circuit diagram of a VMU.



When a coaxial cable is connected to VMU and when the measurement terminal of VMU is open, the charge of the bias buffer amplifier current in the VMU increases the measurement terminal voltage.

After a long time charge, connecting DUT to the measurement terminal may damage the DUT by the discharging.

For the details of how to prevent this damage, refer to "If Measurement Damages the Device under Test" in Chapter 8.

NOTE

High Impedance DUT

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

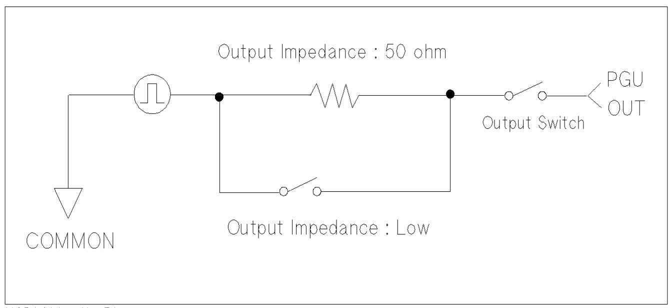
To check the measurement error, perform voltage measurement as follows:

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 the 41501A/B (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**



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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 [a]	Base Setting Value	Resolution	Maximum Current [b]
20 V	$0 \le \lvert V \rvert \le 20$ V	$0 \le \lvert V \rvert \le 20$ V	4 mV	±100 mA
40 V	$0 \le \lvert V \rvert \le 40$ V	$0 \le \lvert V \rvert \le 40$ V	8 mV	±100 mA

a. Maximum peak-to-peak voltage is 40 V.
b. 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 screen or the STRESS: STRESS SETUP screen, 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 screen" in Chapter 6.

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 [a]	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

a. 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* ≤ *pulse width* × 0.8.
  - *trailing-edge transition time* ≤ (*pulse period* – *pulse width*) × 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 41501A/B has PGUs, the 41501A/B has a trigger output terminal. For details of trigger functions, refer to “Trigger Function” in Chapter 3.

2 Measurement Mode

This chapter explains measurement modes of Agilent 4155B/4156B. The 4155B/4156B 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').

The 4155B/4156B provides three types of sweep measurement:

- "Basic Sweep Measurement"

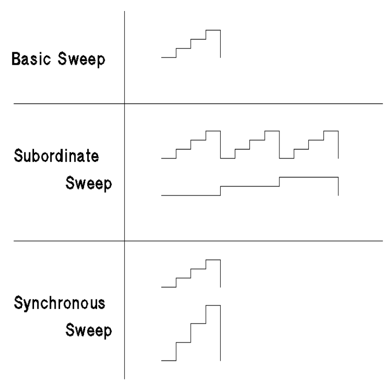
  One sweep source (VAR1) is used.

- "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:

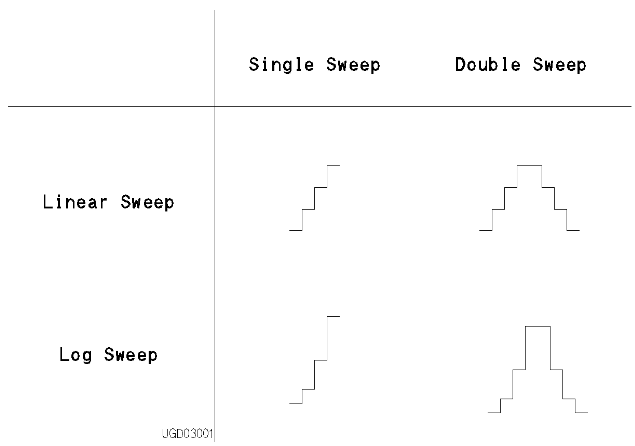
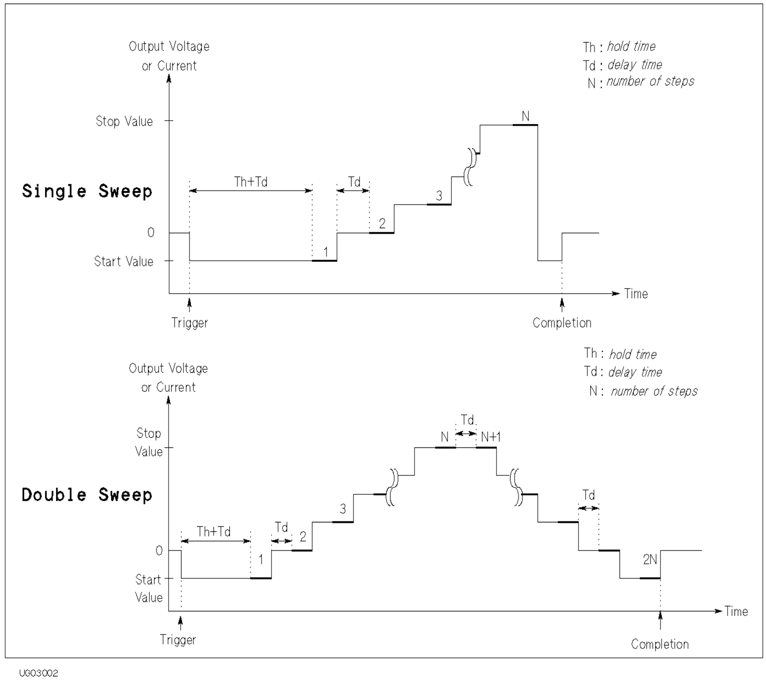


Figure 2-1 **Basic Sweep Measurement**



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.

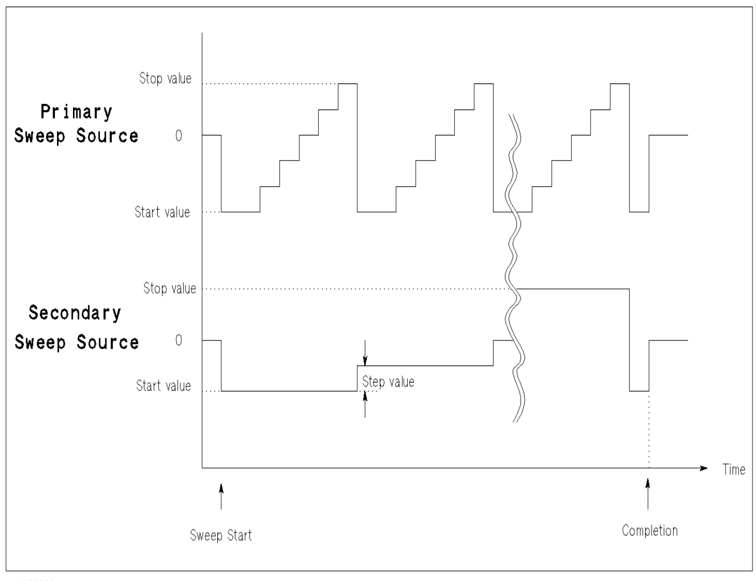
start	Start value of sweep. For logarithmic sweep, *start* must not be zero. Allowable range of *start* depends on output range of sweep source. For output range of each measurement channel, refer to Chapter 1.
stop	Stop value of single sweep or turning back value of double sweep. For logarithmic sweep, *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 is 0 to 655.35s. Resolution: 10 ms.
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 screen” and “MEASURE: MEASURE SETUP screen” in Chapter 6 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.

NOTE

Stop value

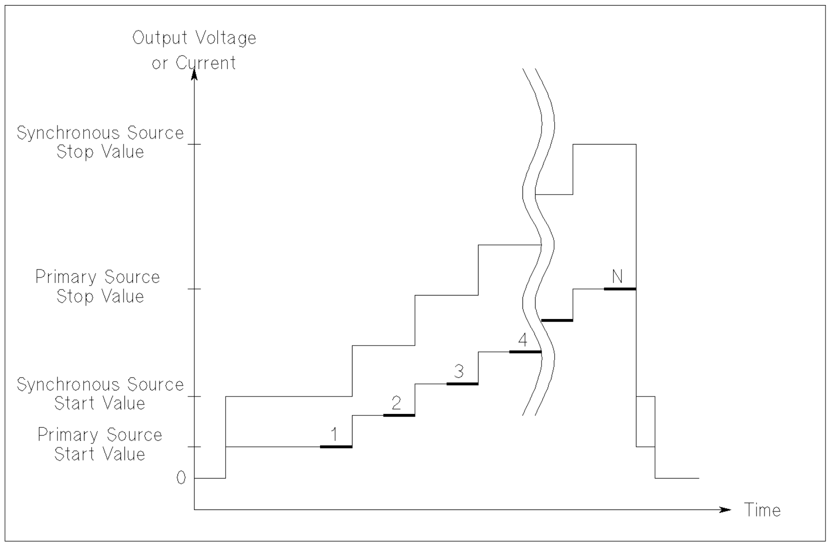
Stop value of secondary sweep is calculated from *start*, *step*, and *number of steps*. Allowable range of *stop* depends on the output range of secondary sweep source. For the output range of each measurement channel, refer to Chapter 1.

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**



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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:

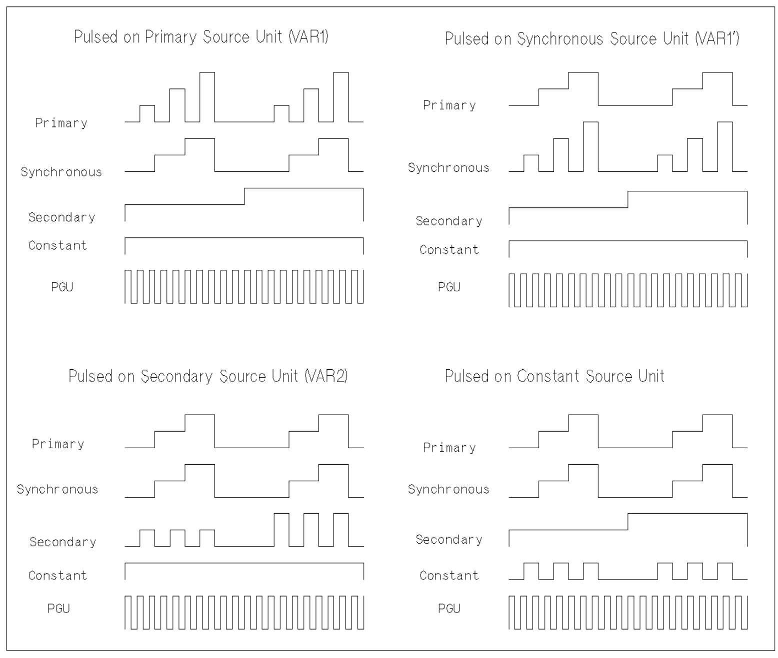
$$\textit{synchronous output} = \textit{primary output} \times \textit{ratio} + \textit{offset}$$

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.

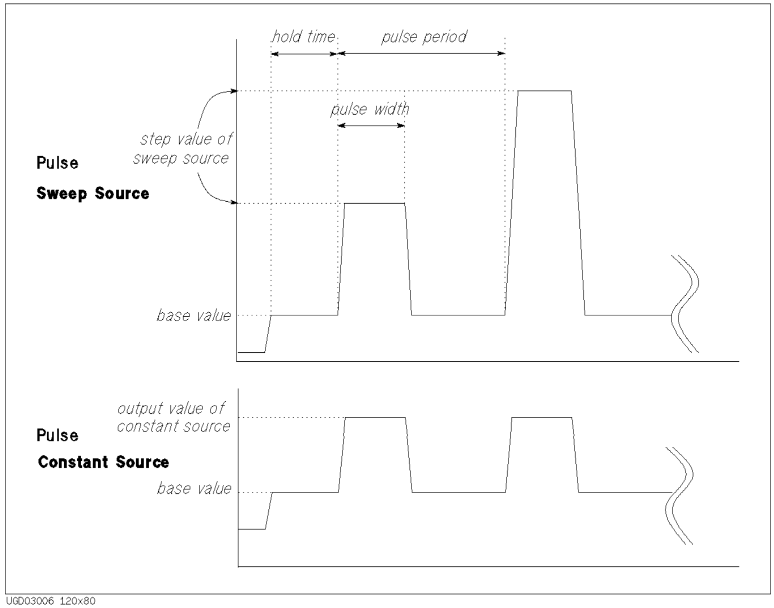
Figure 2-4 Pulse Source and Other Sources



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.

NOTE

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

- “Linear Sampling Measurement”
- “Thinned-out Sampling Measurement”
- “Logarithmic Sampling Measurement”

Available Units

Available units and functions for sampling measurement are shown below:

Unit	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".

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

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

Sampling Interval and Measurement Time

When the sampling interval enough longer than the actual measurement time, measurement unit repeats measurement every specified sampling interval. However, if the sampling interval is less than the measurement time, measurement unit cannot repeat measurements every specified interval. For example, if the measurement time is one and a half the specified sampling interval, the interval of measurement is two times the sampling interval. See Figure 2-6 which explains the operation of the sampling measurement.

Measurement time depends on the measurement condition: integration time, measurement range, and so on. So if you want to execute sampling measurement with the specified sampling interval, you need to know the actual measurement time upon your measurement setup, and set the sampling interval value enough longer than the actual measurement time. You can see typical measurement time by repeating the sampling measurements with several sampling interval settings. See “Sampling Measurement Data” on page 2-18.

Measurement time is given by the following fomula:

Tmeas = Tinteg + Toh

where,

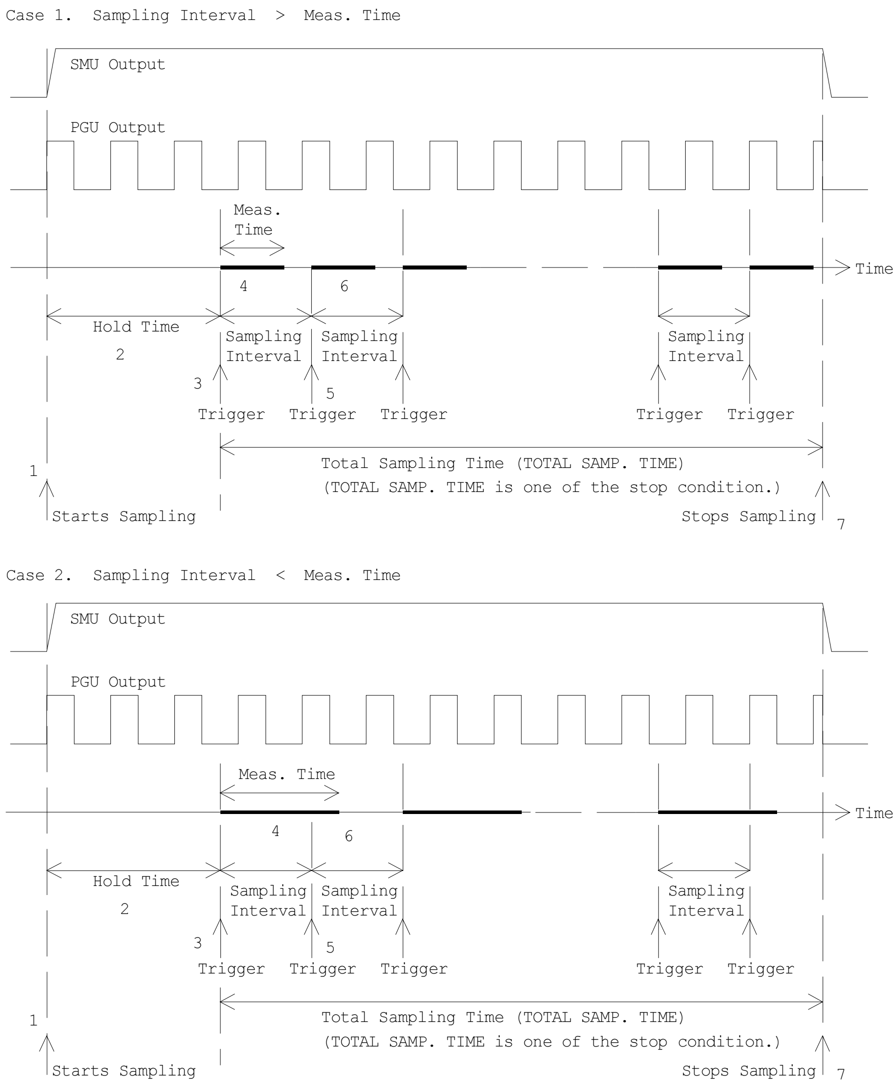
Tmeas : Measurement time.

Tinteg : Integration time.

Toh : Overhead time caused by the following elements:

- range changing time during measurement (when measurement ranging mode is set to auto or limited auto)
- range changing time at measurement start (when using measurement range less than the compliance value)
- time required for the compensation: getting compensation data and compensating measurement data (when the automatic compensation is set and executed)

Figure 2-6 **Sampling Measurement Operation Summary**



Sampling measurement is executed as explained below:

1. Forces constant current, constant voltage, or pulsed constant bias.
2. Waits hold time.
3. Triggers one point measurement.
4. Measurement unit executes measurement. Measurement result data is stored in memory.
5. Triggers one point measurement. Interval of trigger is same as *Sampling Interval*.
6. (Case 1) Measurement unit executes measurement if it is ready to measure. Measurement result data is stored in memory.

   (Case 2) Measurement unit waits next trigger if it is busy or in measurement.
7. Repeats steps 5 and 6 until that a sampling completion condition is satisfied.

   In Figure 2-6, sampling measurement stops when the completion condition *total sampling time* is satisfied.

Number of measurement data stored in memory depends on the sampling completion condition. Maximum number is specified by the NO. OF SAMPLES field of the MEASURE: SAMPLING SETUP screen. However the measurement will be immediately stopped if a sampling completion condition is satisfied before reaching the maximum number. For the sampling completion condition, see “Sampling Completion” on page 2-20.

Sampling Measurement Data

Measurement parameters of sampling measurement are set to the NAME column of the DISPLAY: DISPLAY SETUP screen. Available parameters and example parameters for the NAME field are listed in the table below:

Parameter Name	Meanings of Parameter
@TIME	Measurement start time. This is the time the measurement unit starts one point measurement. This is different from timing of the measurement trigger sent every sampling interval.
@INDEX	Data index. Integer. This is the index numbered to measurement data stored in memory.
V1	for example, SMU1 voltage output value or measured value.
I1	for example, SMU1 current output value or measured value.

Measurement start time can be expressed by the following fomula. This formula is available for the measurement points before starting the discarding operation for the linear sampling or thinned-out sampling. For logarithmic sampling, this is available for the measurement points in the first decade.

$$@TIME = Thold + Tinterval \times [(@INDEX - 1) + N]$$

where,

@TIME : Measurement start time.

Thold : Hold time.

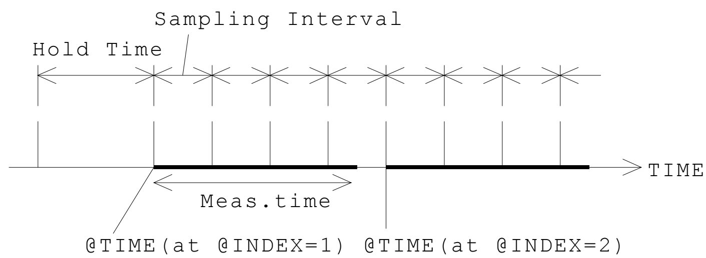
Tinterval : Sampling interval.

@INDEX : Data index.

N : Number of triggers between two nearest measurement points. This value is 0 if the sampling interval is enough longer than the measurement time.

For example, if Thold=10 ms, Tinterval=5 ms, and @TIME values are as shown below, estimated measurement time is 15 ms to 20 ms, and there are 3 triggers between @INDEX=1 and @INDEX=2.

- @TIME (for @INDEX=1) = 10 ms = 10 + 5 × [(1 – 1) + 0] ms
- @TIME (for @INDEX=2) = 30 ms = 10 + 5 × [(2 – 1) + 3] ms



To Use Multiple Measurement Units

If you define multiple measurement parameters in the NAME column of the DISPLAY: DISPLAY SETUP screen, sampling measurement is executed by using multiple measurement units. Differences between this measurement and the measurement using only one unit are shown below:

- Measurement Sequence

  Measurement units start measurement in the order below:

  Parameters for GRAPH: X → Y1 → Y2

  Parameters for LIST: Order of No. assigned for the parameters

- Value of @TIME

  @TIME stores the time the first measurement unit starts measurement. @TIME does not store the time another unit starts measurement.

- Measurement Time

  Measurement time is sum of the measurement time by all units. To execute sampling measurement with the specified sampling interval, the sampling interval must be enough longer than the measurement time.

Sampling Completion

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

- Stop condition

  The stop condition is satisfied. See below.

- Total sampling time

  The specified total sampling time has elapsed.

  Available for linear and thinned-out sampling. Setting `TOTAL SAMP.TIME` to auto or no limit disables this sampling completion condition.

- Number of sampling points

  The specified number of samples has elapsed.

  Available for logarithmic sampling. For linear sampling, setting `TOTAL SAMP.TIME` to auto enables this sampling completion condition.

- Stop front-panel key

  The Stop front-panel key is pressed.

- GPIB Command

  The 4155B/4156B receives GPIB command to stop sampling.

- Emergency Condition

  An emergency condition occurs on the 4155B/4156B.

- Interlock Open

  Interlock terminal opens due to high voltage.

Stop Condition

The stop condition is defined by using the STOP CONDITION table of MEASURE: SAMPLING SETUP screen. This function stops the measurement as shown below.

1. Compares the value of the parameter set to `NAME` field and the value defined in `THRESHOLD` field.
2. Counts how many times the selected `EVENT` occurs.
3. When the count reaches the value defined in `EVENT NO.` field, sampling is stopped immediately.

To use this function, the INITIAL INTERVAL value must be set to 2 ms or more. The INITIAL INTERVAL is the minimum resolution of the sampling interval. For details about the INITIAL INTERVAL, see “Linear Sampling Measurement” on page 2-24, “Thinned-out Sampling Measurement” on page 2-27, or “Logarithmic Sampling Measurement” on page 2-30.

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

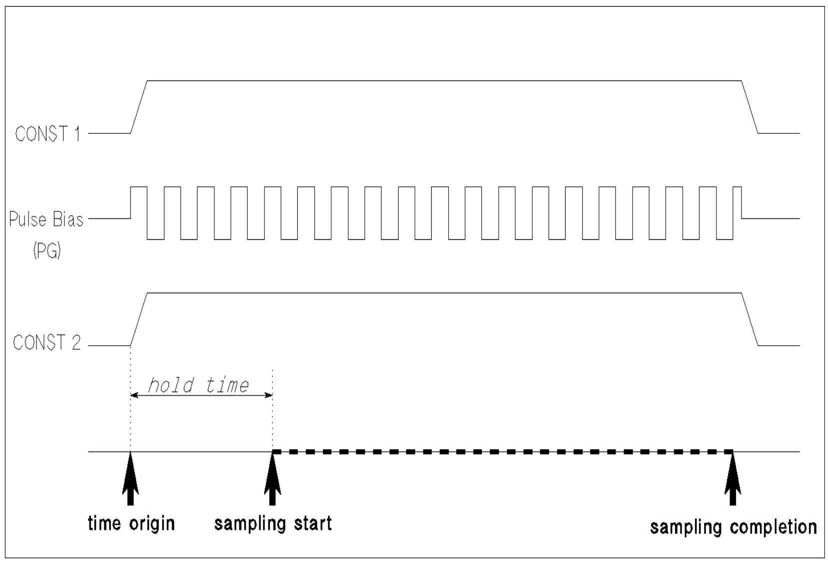
Parameter	Description	
ENABLE/ DISABLE	Enables or disables the stop condition.	
ENABLE DELAY	Delay time. in second. This is the time from starting sampling measurement to enabling this function. Allowable range: 0 to INITIAL INTERVAL × 32767 s. Resolution: INITIAL INTERVAL.	
NAME	Name of measurement data or user function to monitor for stop condition. `Val` of `EVENT`.	
THRESHOLD	Threshold value at which to stop sampling measurement. `Th` of `EVENT`.	
EVENT	Event for stop condition.	
	`Val > Th`	True if `NAME` parameter value is greater than `THRESHOLD` value.
	`Val < Th`	True if `NAME` parameter value is less than `THRESHOLD` value.
	`|Val| > |Th|`	True if absolute `NAME` parameter value is greater than absolute `THRESHOLD` value.
	`|Val| < |Th|`	True if absolute `NAME` parameter value is less than absolute `THRESHOLD` value.
EVENT NO.	Target value of the count the event occurs (*true*). When the count of *true* is this value, sampling is immediately stopped. Allowable range: 1 to 200.	

Source Output Sequence and Time Origin

Source unit output sequence and the time origin depends on the setup value of the OUTPUT SEQUENCE MODE OF SAMPLING field in the MEASURE: OUTPUT SEQUENCE screen. The following two modes are available for the field.

- SIMULTANEOUS mode

  All source unit starts output at same timing. This timing is defined as the Time Origin. See figure below.



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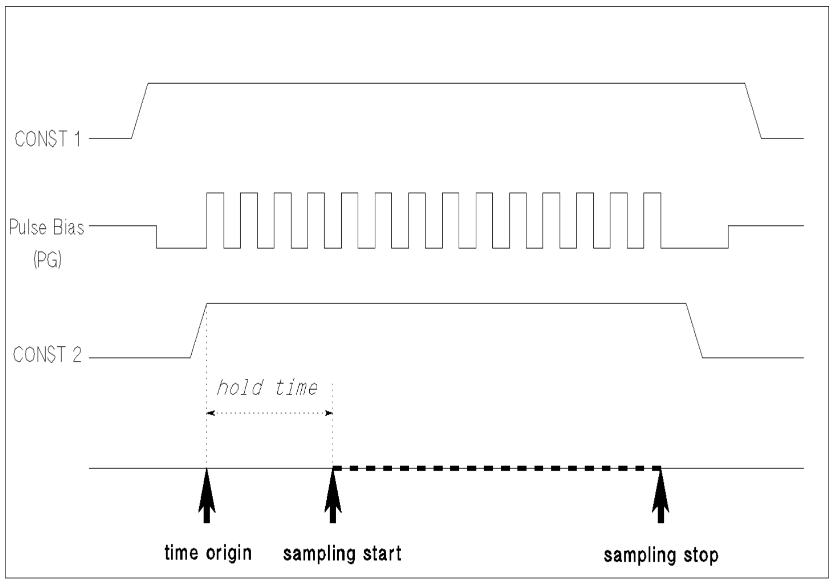
- SEQUENTIAL mode

  Source units starts output in the order defined in the OUTPUT SEQUENCE table of the MEASURE: OUTPUT SEQUENCE screen. Time Origin is when the last source reaches the specified output value. See figure below.

  If there is pulse bias sources (PGUs), they start to force pulse base value in the order shown above, and start to force pulse bias at the Time Origin.



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Linear Sampling Measurement

Linear sampling mode keeps a constant sampling interval that is the interval of measurement trigger. And if the measurement units are ready to measure, the units start measurement, and the result data is stored in memory. This is repeated until one of the sampling completion conditions is satisfied.

However, if both the following two conditions occur, linear sampling mode changes the sampling interval to two times the previous sampling interval, and continues sampling measurement.

- number of sampling points reaches specified `NO.OF SAMPLES`
- sampling completion condition is not satisfied

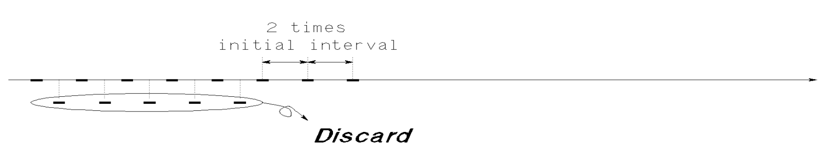
Example Operation

This example assumes the following sampling setup:

- `INITIAL INTERVAL` value is longer than the measurement time
- `NO.OF SAMPLES` value is set to 10
- `TOTAL SAMP.TIME` is long (for example, 50 × `INITIAL INTERVAL`). Do not set to `AUTO` which enables the *number of sampling points* sampling completion condition.

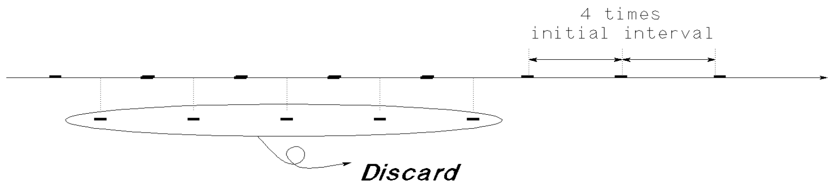
1. Executes one point measurement, and stores data in memory. Repeats this 10 times every sampling interval (INITIAL INTERVAL setting value) because of the sampling interval enough longer than the measurement time.

2. If the sampling completion condition is not satisfied after 10 points measurement, linear sampling mode changes the sampling interval to two times the INITIAL INTERVAL, and continues sampling measurement.



To store new measurement data, linear sampling mode discards a data every couple of nearest data as shown above. Data is updated every measurement.

3. If the sampling completion condition is not satisfied after additional 5 points measurement, linear sampling mode changes the sampling interval to two times the previous interval, and continues sampling measurement. Measurement data is updated as described in step 2.



4. This discarding and doubling of the sampling interval is repeated until the sampling completion condition is satisfied. By the end of the measurement, 10 measurement result data is stored in memory.

Parameters

To set up the linear sampling measurement, specify the following parameters on MEASURE: SAMPLING SETUP page. See Table 2-1.

Parameter	Description
MODE	Sampling mode. LINEAR.
INITIAL INTERVAL	The sampling interval for first NO.OF SAMPLES samples. Allowable range: 60 μs to 65.535 s.
NO.OF SAMPLES	Number of data to be stored by end of measurement. Maximum: 10001. If there are multiple measurement units, this value must be 10001/(number of units) or less.
TOTAL SAMP.TIME	Total sampling time. Does not include HOLD TIME. This is the time from the 1st trigger to the sampling completion. One of the sampling completion conditions, so sampling stops after this time elapses. • Allowable range when INITIAL INTERVAL ≤ 480 μs: AUTO • Allowable range when INITIAL INTERVAL > 480 μs: INITIAL INTERVAL × (NO.OF SAMPLES − 1) sec to 1×10^{11} sec, AUTO, or NO LIMIT.
AUTO	Enables the *number of sampling points* sampling completion condition.
NO LIMIT	Disables the *total sampling time* sampling completion condition

HOLD TIME — Hold time. This is the time from starting source output to first trigger. If this value is 0, first @TIME value is 0.

- Allowable range when INITIAL INTERVAL ≥2 ms: 0 to 655.35 s with 100 μs resolution.
- Allowable range when INITIAL INTERVAL <2 ms: – 30 ms to 655.35 s with 100 μs resolution.

Table 2-1 Effective Parameter Values

INITIAL INTERVAL	60 μs to 480 μs	560 μs to 1.92 ms	2 ms to 65.535 s
NO.OF SAMPLES	Max. 10001/(number of measurement units)		
TOTAL SAMP.TIME	AUTO	AUTO/NO LIMIT/ INITIAL INTERVAL × (NO.OF SAMPLES – 1) s to 1×10^{11} s	
HOLD TIME	– 30 ms to 655.35 s, 100 μs resolution		0 to 655.35 s, 100 μs resolution
Stop Condition	DISABLE		DISABLE/ENABLE
Measurement Units [a]	1 [b]		Max. 8 [c]
Measurement Range [d]	FIX		FIX/AUTO/LIMITED
Integration Time [e]	Short		Short/Medium/Long

[a] Number of units (SMUs or VMUs) used for measurements.

[b] If voltage source SMU is connected to R-BOX, only this SMU can be used for the measurement.

[c] Maximum 8 units if the 41501 is used (6 SMUs and 2 VMUs). If multiple measurement units are used, total measurement time will be more than the sum of the measurement time by all units.

[d] If compliance value is more than the measurement range, range change when starting measurement makes long measurement time. Also if ranging mode is set to AUTO or LIMITED, range changing makes long measurement time.

[e] Integration time is an element of the measurement time. If automatic measurement data compensation is executed, the measurement time will be more than two times the integration time.

Thinned-out Sampling Measurement

Thinned-out sampling mode operates like the linear sampling mode. Difference is that the sampling interval is not changed in the thinned-out sampling measurement. So even if both the following two conditions occur, thinned-out sampling mode does not change the sampling interval, and continues sampling measurement.

- number of sampling points reaches specified NO.OF SAMPLES
- sampling completion condition is not satisfied

Example Operation

This example assumes the following sampling setup:

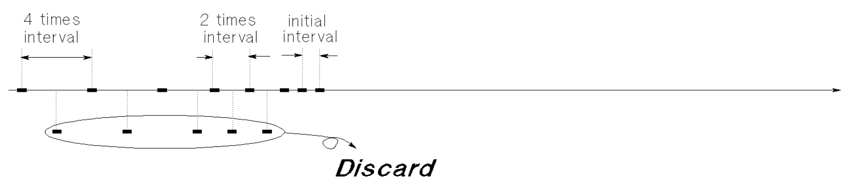
- INITIAL INTERVAL value is longer than the measurement time
- NO.OF SAMPLES value is set to 10

1. Executes one point measurement, and stores data in memory. Repeats this 10 times every sampling interval (INITIAL INTERVAL setting value) because of the sampling interval enough longer than the measurement time.

2. If the sampling completion condition is not satisfied after 10 points measurement, thinned-out sampling mode keeps the sampling interval, and continues sampling measurement.

To store new measurement data, thinned-out sampling mode discards a data every couple of nearest data as shown above. Data is updated every measurement.

3. If the sampling completion condition is not satisfied after additional 5 points measurement, thinned-out sampling mode keeps the sampling interval, and continues sampling measurement. Data is updated as described in step 2.



4. This discarding is repeated until the sampling completion condition is satisfied. By the end of the measurement, 10 measurement result data is stored in memory.

Parameters

To set up the thinned-out sampling measurement, specify the following parameters on MEASURE: SAMPLING SETUP page. See Table 2-2.

Parameter	Description
MODE	Sampling mode. THINNED OUT.
INITIAL INTERVAL	The sampling interval during thinned-out sampling. Allowable range: 720 μs to 65.535 s.
NO.OF SAMPLES	Number of data to be stored by end of measurement. Maximum: 10001. If there are multiple measurement units, this value must be 10001/(number of units) or less.
TOTAL SAMP.TIME	Total sampling time. Does not include HOLD TIME. This is the time from the 1st trigger to the sampling completion. One of the sampling completion conditions, so sampling stops after this time elapses. Allowable range: NO LIMIT, or INITIAL INTERVAL × (NO.OF SAMPLES – 1) sec to 1×10^{11} sec
NO LIMIT	Disables the *total sampling time* sampling completion condition
HOLD TIME	Hold time. This is the time from starting source output to first trigger. If this value is 0, first @TIME value is 0. • Allowable range when INITIAL INTERVAL ≥2 ms: 0 to 655.35 s with 100 μs resolution. • Allowable range when INITIAL INTERVAL <2 ms: – 30 ms to 655.35 s with 100 μs resolution.

Table 2-2 Effective Parameter Values

INITIAL INTERVAL	720 μs to 1.92 ms	2 ms to 65.535 s
NO.OF SAMPLES	Max. 10001/(number of measurement units)	
TOTAL SAMP.TIME	NO LIMIT/ INITIAL INTERVAL × (NO.OF SAMPLES − 1) s to 1×10^{11} s	
HOLD TIME	– 30 ms to 655.35 s, 100 μs resolution	0 to 655.35 s, 100 μs resolution
Stop Condition	DISABLE	DISABLE/ENABLE
Measurement Units [a]	1 [b]	Max. 8 [c]
Measurement Range [d]	FIX	FIX/AUTO/LIMITED
Integration Time [e]	Short	Short/Medium/Long

[a] Number of units (SMUs or VMUs) used for measurements.

[b] If voltage source SMU is connected to R-BOX, only this SMU can be used for the measurement.

[c] Maximum 8 units if the 41501 is used (6 SMUs and 2 VMUs). If multiple measurement units are used, total measurement time will be more than the sum of the measurement time by all units.

[d] If compliance value is more than the measurement range, range change when starting measurement makes long measurement time. Also if ranging mode is set to AUTO or LIMITED, range changing makes long measurement time.

[e] Integration time is an element of the measurement time. If automatic measurement data compensation is executed, the measurement time will be more than two times the integration time.

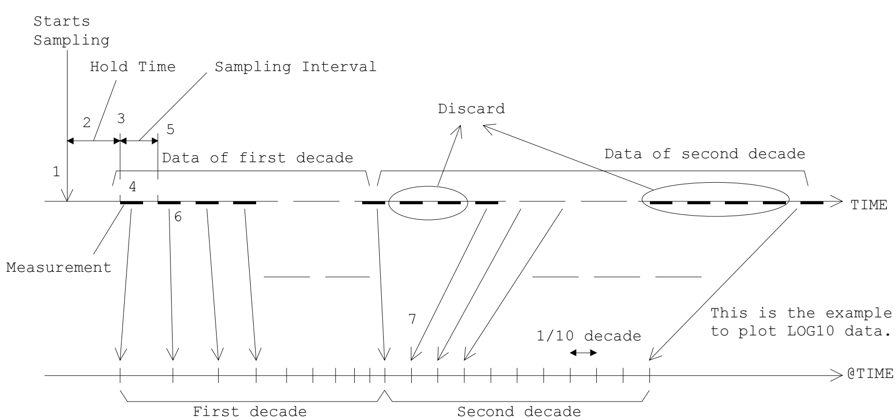
Logarithmic Sampling Measurement

Logarithmic sampling mode plots the measurement data on the X-axis (@TIME) set to the logarithmic scale by doing the following operation. See Figure 2-7.

1. Forces constant current, constant voltage, or pulsed constant bias.
2. Waits hold time.
3. Triggers one point measurement.
4. Measurement unit executes measurement. Measurement result data is stored in memory.
5. Triggers one point measurement. Interval of trigger is constant (setting value of INITIAL INTERVAL).
6. Measurement unit executes measurement if it is ready to measure. Measurement result data is stored in memory.

   Measurement unit waits next trigger if it is busy or in measurement.
7. Repeats steps 5 and 6 until that a sampling completion condition is satisfied. Logarithmic sampling mode retains only the measurement data that can plot the data on the logarithmic X-axis in almost the same interval.

Figure 2-7 **Example Operation of Logarithmic Sampling**



@TIME Value

@TIME value of measurement data is determined by MODE, INITIAL INTERVAL, NO. OF SAMPLES, and HOLD TIME parameters. Where MODE decides number of measurement points in 1 decades. For example, LOG10 mode obtains 10 data per 1 decade.

An example to get measurement data in logarithmic sampling measurement is explained below. This example assumes the following settings. See also Figure 2-7.

- MODE = LOG10 (10 data / 1 decade)
- `INITIAL INTERVAL` = 10 ms
- `NO.OF SAMPLES` = 20
- `HOLD TIME` = 10 ms
- `STOP CONDITION` = DISABLE

If sampling interval is enough longer than measurement time:

INITIAL INTERVAL value decides the range of a decade.

10 ms to 100 ms (1st decade) Sampling is executed at the following @TIME value: 10 ms, 20 ms, 30 ms, 40 ms, 50 ms, 60 ms, 70 ms, 80 ms, 90 ms, 100 ms. LOG10 mode allows to have 10 data in 1 decade. Therefore all measurement data is stored in memory.

100 ms to 1 s There are 90 sampling points in this range. Number of data can remain is only 10. They can plot the data on the X-axis in almost the same interval.

@TIME values are as follows:
140 ms, 170 ms, 210 ms, 270 ms, 330 ms, 410 ms, 520 ms, 650 ms, 810 ms, 1.02 s.

If sampling interval is less than measurement time:

Measurement time decides the range of a decade. If the measurement time is 18 ms, interval of measurement is 20 ms, and the following data are stored in memory:

20 ms to 200 ms (1st decade) Sampling is executed at the following @TIME value: 20 ms, 40 ms, 60 ms, 80 ms, 100 ms, 120 ms, 140 ms, 160 ms, 180 ms, 200 ms. LOG10 mode allows to have 10 data in 1 decade. Therefore all data is stored in memory.

200 ms to 2 s There are 90 sampling points in this range. Number of data can remain is only 10. They can plot the data on the X-axis in almost the same interval.

Rule to determine @TIME:

@TIME value is determined by the following rule. Data measured at @TIME=*Tlog* are stored in memory.

$$Tlog \geq Ttarget$$

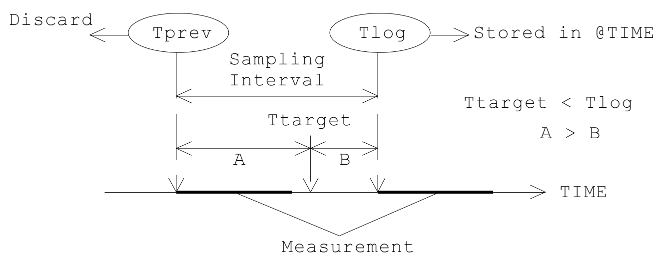
$$| Tlog - Ttarget | < | Ttarget - Tprev |$$

where,

Tlog Data stored in @TIME. Actual measurement point.

Ttarget Target value of @TIME. The values can plot data on the logarithmic X-axis in the same interval completely.

Tprev *Tlog – sampling interval*. Actual measurement point.



A= | *Ttarget – Tprev* |
B = | *Tlog – Ttarget* |

Parameters

To set up the logarithmic sampling measurement, specify the following parameters on MEASURE: SAMPLING SETUP page. See Table 2-3.

Parameter | **Description**

`MODE` Sampling mode. LOG10, LOG25, or LOG50.

MODE	Number of data in 1 decade
LOG10	10
LOG25	25
LOG50	50

`INITIAL INTERVAL` The sampling interval during logarithmic sampling. Allowable range: 560 µs to 65.535 s.

If this value is 560 µs to 10 ms, number of measurement data may be less than the specified number of data for top 2 decades. Then sampling continues to get all samples.

`NO.OF SAMPLES` Number of data to be stored by end of measurement. One of the sampling completion conditions, so sampling stops after this point elapses. Maximum 11 decades.

MODE	Maximum value
LOG10	111
LOG25	276
LOG50	551

`HOLD TIME` Hold time. This is the time from starting source output to first trigger. If this value is 0, first @TIME value is 0.

- Allowable range when `INITIAL INTERVAL` ≥2 ms: 0 to 655.35 s with 100 µs resolution.
- Allowable range when `INITIAL INTERVAL` <2 ms: – 30 ms to 655.35 s with 100 µs resolution.

Example:

`HOLD TIME`=1.003 s, and measurement interval is 3 ms, decade and its range are as shown below:

decade	Range (in sec)
1st decade	1.003 to 1.030 (3 m +1 to 30 m +1)
2nd decade	1.030 to 1.300 (30 m +1 to 300 m +1)
3rd decade	1.300 to 4.00 (300 m +1 to 3+1)
4th decade	4 to 31 (3+1 to 30+1)
5th decade	31 to 301 (30+1 to 300+1)

Table 2-3 Effective Parameter Values

INITIAL INTERVAL	560 µs to 1.92 ms	2 ms to 65.535 s
NO.OF SAMPLES	Maximum 111 (LOG10), 276 (LOG25), 551 (LOG50)	
HOLD TIME	– 30 ms to 655.35 s, 100 µs resolution	0 to 655.35 s, 100 µs resolution
Stop Condition	DISABLE	DISABLE/ENABLE
Measurement Units [a]	1 [b]	Max. 8 [c]
Measurement Range [d]	FIX	FIX/AUTO/LIMITED
Integration Time [e]	Short	Short/Medium/Long

[a] Number of units (SMUs or VMUs) used for measurements.

[b] If voltage source SMU is connected to R-BOX, only this SMU can be used for the measurement.

[c] Maximum 8 units if the 41501 is used (6 SMUs and 2 VMUs). If multiple measurement units are used, total measurement time will be more than the sum of the measurement time by all units.

[d] If compliance value is more than the measurement range, range change when starting measurement makes long measurement time. Also if ranging mode is set to AUTO or LIMITED, range changing makes long measurement time.

[e] Integration time is an element of the measurement time. If automatic measurement data compensation is executed, the measurement time will be more than two times the integration time.

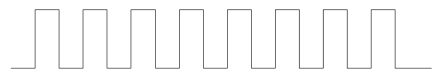
3 Measurement Functions

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

- “Stress Force Function”
- “Knob Sweep Function”
- “Operation States”
- “Standby Function”
- “Output Sequence”
- “Trigger Function”
- “SMU/PG Selector Control”
- “R-BOX Control”
- “Measurement Ranging Mode”
- “Compliance”
- “Integration Time”
- “SMU Filter”
- “Zero Offset Cancel”

Stress Force Function

The 4155B/4156B can force both dc stress and ac stress (pulsed stress) as shown in the following figure. Stress is defined as the bias that the 4155B/4156B can monitor the bias output time correctly. To start stress force, press Stress front-panel key.



(a) AC Stress Signal

(b) DC Stress Signal

displaying the stress force time

The STRESS: STRESS FORCE screen is displayed while stress is being forced. On this screen, the time that stress has been forced is displayed and updated every second.

Stress Output Channels

Stress output channel is defined as the unit used to force stress.

Available Units

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

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 (Pulsed Source)
SMU	yes	yes	
VSU	yes		
PGU	yes		yes

Also, SMUs can be set to COMMON mode.

Setting the Stress Channels

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

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.

To set a unit to the stress channel, select SYNC in the FCTN field for the unit. If you select NSYNC, the 4155B/4156B does not monitor the bias output time for the unit. The unit is called as non-stress channel or bias channel in this manual.

To use the stress force function, at least one unit must be set to the stress channel which the FCTN field is set to SYNC. You can select up to four stress source channels among SMUs, VSUs, and PGUs.

If a unit is set to STBY ON on the CHANNELS: CHANNEL DEFINITION screen, the unit cannot be set to the stress channel.

If you use two PGUs as ac pulse source, both PGUs must be the stress channel or the non-stress channel. This means that if PGU1 is a stress channel, PGU2 must be a stress channel, *not* non-stress channel.

Switching Channels Connected to DUT

The 4155B/4156B can control Agilent 16440A SMU/Pulse Generator Selector to automatically switch units that are connected to a DUT pin. You set up this automatic control on the STRESS: CHANNEL DEFINITION screen.

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 16440A selector, refer to “SMU/PG Selector Control” on page 3-46.

External Stress Source

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 4155B/4156B can output a gate trigger while stress channels are forcing stress. For details about this gate trigger, refer to “Trigger Function” on page 3-39.

- gate trigger of PGUs

  The output trigger terminal of PGUs (41501A/B) 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 Agilent 8110A pulse generator 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 “Trigger Output” on page 3-42.

Stress Mode

You set stress mode to the pulse count mode or duration mode.

Pulse count mode

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

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 screen).

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: 100 μs
- When the specified time is more than 10 s: 10 ms

Stress Force Sequence

This section explains the source output sequence when starting the stress force, and when finishing the stress force.

- Output sequence from idle state to the stress state
- Output sequence in the stress state
- Output sequence from stress state to the idle state

Output sequence (idle state to the 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 screen. For details, refer to “Sequential Mode” on page 3-35.

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

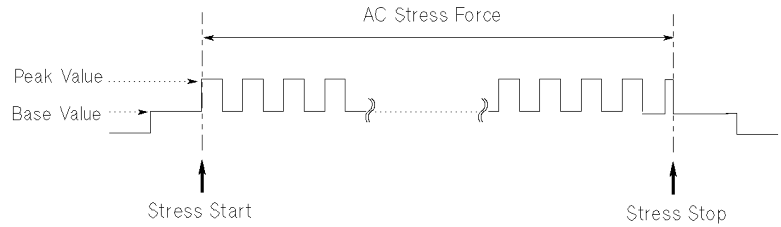
  Stress force channels stop stress at the same time. When you set up both ac and dc stress on the STRESS: CHANNEL DEFINITION screen, ac stress channels stop several microseconds before the dc stress channels.

  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 on page 3-9.)

NOTE

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 to the 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.

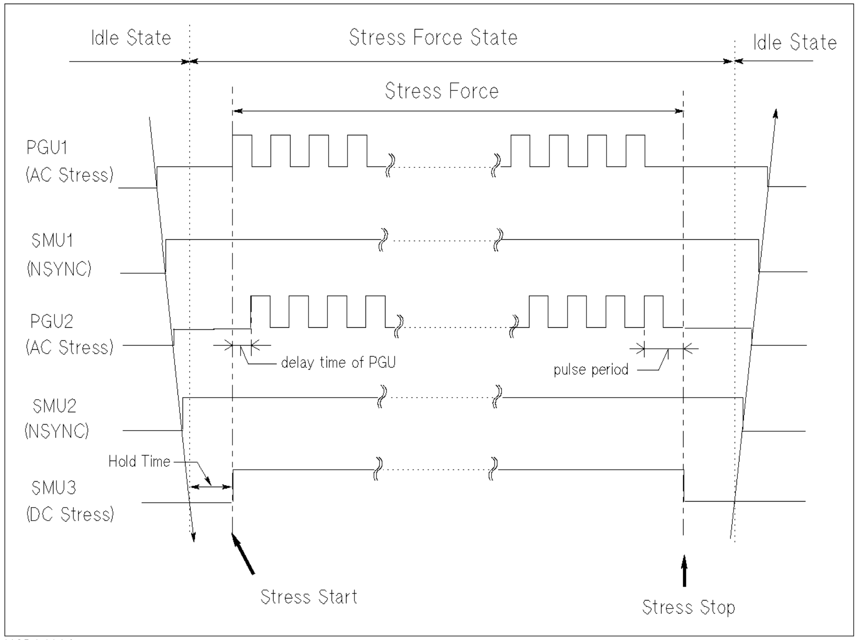
Example

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

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

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

Figure 3-1 **Example of the Stress Force Sequence**



UGD04003

- output sequence from idle state to the stress state:

  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.

- output sequence from stress state to the idle state:

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

Stress Stop Function at Abnormal Status

On the STRESS: STRESS SETUP screen, you can select whether the stress stops or continues when an abnormal status occurs. When an 4155B/4156B is stopped by the stress stop function, a message is displayed in the message display area.

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.

Setting the Stress Stop Function

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

- STRESS Status = CONT AT ANY

  Stress continues even if an abnormal status occurs.

- STRESS Status = STOP AT ANY ABNORM

  Stress stops if any abnormal status occurs.

- STRESS Status = STOP AT COMPLIANCE

  Stress stops only if SMU reaches its compliance setting.

STOP AT ANY ABNORM and STOP AT COMPLIANCE are available at the following conditions:

- in PULSE COUNT mode: when *pulse period* × *pulse count* is more than 10 s.
- in DURATION mode: when specified duration is more than 10 s.

Abnormal Status

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.

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. This function is useful when you want to quickly make a rough measurement of a DUT characteristic, or when you want to easily define a measurement setup for normal sweep.

To start the knob sweep measurement, press the green key and then the Single front-panel key. The 4155B/4156B starts knob sweep measurement, and repeats measurements continuously until this function is stopped. You can change the measurement setups 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 from 0 to the stop value by rotating the knob.

To stop the knob sweep measurements, press Stop front-panel key, or a PAGE CONTROL group key. To restart the measurement, press the following key(s):

If you pressed the Stop key: Single key

If you pressed a PAGE CONTROL key: green key and Single key

Available units and functions

Table 3-2 shows available units and functions for knob sweep measurement.

Table 3-2 **Available Units and Functions for Knob Sweep Measurement**

Unit	Output Function					Output Mode			Pulse	Meas. Mode		
	VAR1	VAR1'	VAR2	CONST	STAND BY	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".

Normal Sweep and Knob Sweep Measurements

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

Table 3-3 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 [a]
Standby Function	available	available
Measurement Channel	1 to 8 ch	1 ch only
Output Sequence	can set	can set [b]
Trigger Function	available	not available
Integration Time	short, medium, or long	80 μs

[a] Measurement range is automatically set according to specified compliance value.

[b] Settings on the MEASURE: OUTPUT SEQUENCE screen also apply to knob sweep measurement.

Features of Knob Sweep Function

The following are parameters that are for knob sweep measurement only or that have a different meaning or range from normal sweep measurement.

LIN/LOG mode

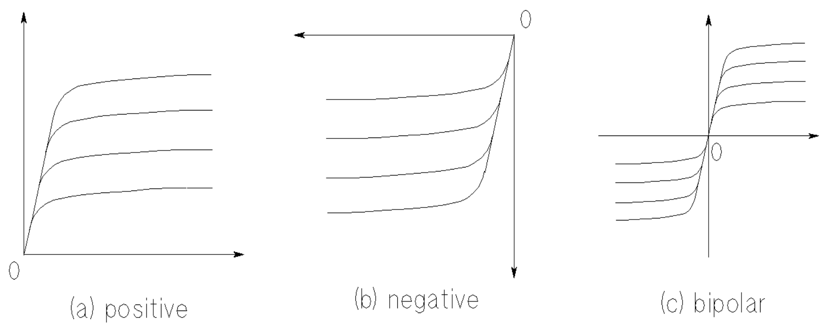
Only linear mode is available. Even if you set LOG on the MEASURE: SWEEP SETUP screen, the knob sweep is a linear sweep measurement.

VAR1 Range

To set the VAR1 range, refer to VAR1 RANGE softkey description in "VAR1 SETUP Softkey" on page 3-20. If you do not set the VAR1 RANGE, the default is the stop value specified for the VAR1 channel on the MEASURE: SWEEP SETUP screen.

Polarity

The following sweep polarities are available for the knob sweep function of the VAR1 source. To set the polarity, select VAR1 SETUP and POLARITY softkeys.



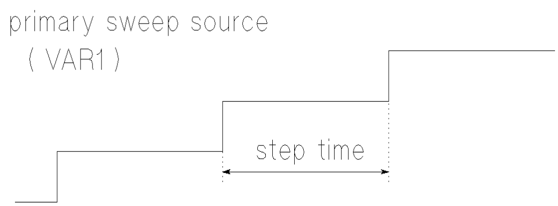
+ (positive)	Used to set the sweep output in the positive X direction.
– (negative)	Used to set the sweep output in the negative X direction.
+/– (bipolar)	Used to set the sweep output in both the positive and negative X directions.

To increase the source absolute value, rotate the rotary knob in clockwise.

To decrease the source value toward 0, rotate the rotary knob in counterclockwise. When measurement curves reach 0, the curves remain at 0 even if you continue to rotate the rotary knob counterclockwise.

Step Time

Step time is the time width of a sweep step as shown in the following figure. 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 screen.



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

For normal sweep measurement, the step time 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 screen, then selecting the desired secondary softkey. You can select one measurement channel only, so the Y2 axis is not available on the KNOB SWEEP screen.

- 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 → . . . . . → SMU6 → VMU1 → VMU2.
- 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.

NOTE

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.

Sweep 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 for the specified *number of steps*. The STEP field on the MEASURE: SWEEP SETUP screen has no meaning.

Initial value: 0, Step value automatically set: 0 to VAR1 range/number of steps.

Number of Steps

For the VAR1 channel, you set the number of steps on the KNOB SWEEP screen. 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 screen.

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 screen 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 screen is changed to another screen.

Measurement Range

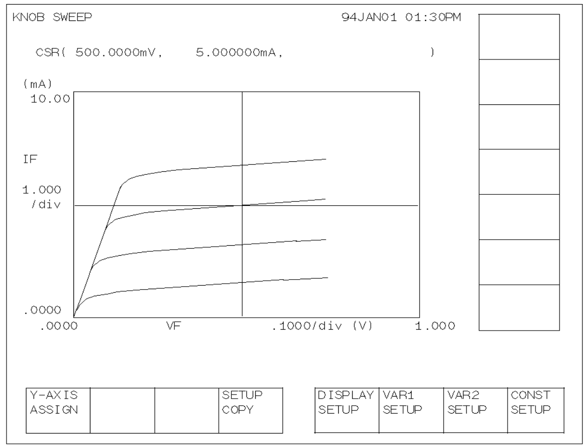
If SMU is the measurement channel:

Compliance range is used. That is, the measurement range is set to the lowest range that includes the compliance value that is set on the MEASURE: SWEEP SETUP screen. For details about compliance range, refer to “Compliance Range” on page 3-56.

If VMU is the measurement channel:

20 V range is used for the grounded measurement mode, and the 2 V range is used for the differential measurement mode.

KNOB SWEEP screen



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To start the knob sweep measurement, press the green key and then the Single front-panel key. The 4155B/4156B displays KNOB SWEEP screen, and starts measurements. To stop the knob sweep measurement, press the Stop front-panel key or a PAGE CONTROL group key.

Cursor

On the KNOB SWEEP screen, 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

X axis always plots the VAR1 source value. Maximum value of X axis is the setting value of the VAR1 RANGE secondary softkey of VAR1 SETUP softkey group.

Y axis setting

Y axis always plots the measurement data of the measurement channel. You can select the measurement channel by using the secondary softkeys of the Y-AXIS ASSIGN softkey group. Maximum value of Y axis scale is the compliance value of the measurement channel.

Y-AXIS ASSIGN Softkey

This softkey is used to change the measurement channel. Before selecting this softkey, the knob sweep measurement must be stopped. So press the Stop front-panel key to change the measurement channel. To restart measurement, press the Single front-panel key.

If you connect R-box to the VAR1 channel, and set the VAR1 to V force mode, the measurement channel is automatically decided to the VAR1 channel. In this setup, this softkey is not be displayed.

Y-AXIS ASSIGN primary softkey displays secondary softkeys used to select the measurement channel. The measurement variable names of measurement channels are labeled on the softkeys. User function is not available for the knob sweep function. So there is no user function variable in the softkey label.

When you select a secondary softkey, the maximum absolute value(s) of the Y axis are changed to compliance value of the selected measurement channel.

SETUP COPY Softkey

This softkey is used to memorize measurement setups used in the knob sweep measurement mode. This function allows you to copy and use the setups in the normal-sweep measurement mode.

1. Select this softkey to memorize the measurement setups.
2. Quit the knob sweep measurement mode using a PAGE CONTROL group key. Then the measurement setups are copied to the normal-sweep setup screens.

The information memorized and copied is as following:

- Axis variables, axis values, and GRID settings:

  copied to the DISPLAY: DISPLAY SETUP screen.

- Settings of VAR1, VAR2, CONST:

  copied to the MEASURE: SWEEP SETUP screen.

Knob sweep measurement setup cannot be directly stored into a file. This function allows you to save the setup as a normal-sweep measurement setup file. But the setup data cannot be retrieved to the knob sweep mode.

DISPLAY SETUP Softkey

This softkey displays secondary softkeys for setting the display format of graphics.

X-AXIS REGION

\+ Selects polarity of X-axis region displayed on the screen. This softkey displays present setting.

- setting

  Pressing this softkey toggles polarity as follows:

  \+ → − → +/− → +

- default

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

Y-AXIS REGION

\+ Selects polarity of Y-axis region displayed on the screen. This softkey displays present setting.

- setting

  Pressing this softkey toggles the polarity in the following order:

  \+ → − → +/− → +

- default

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

X-AXIS DISPLAY NORMAL Selects direction of the X-axis. This softkey displays present setting.

- 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 Selects direction of the Y-axis. This softkey displays present setting.

- 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 Selects grit on or off. This softkey displays present setting.

- setting

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

- default : ON

VAR1 SETUP Softkey

This softkey displays secondary softkeys for setting the primary sweep source (VAR1) parameters.

SWEEP MODE SINGLE

Selects sweep mode. This softkey displays present setting.

- setting

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

  SINGLE → DOUBLE → SINGLE

- default

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

POLAR-ITY POS

Selects polarity of sweep source. Changing the setting resets the sweep step to 0, so the sweep measurement curve goes back to 0 on the screen. For details, see “Sweep Step Value” on page 3-15. This softkey displays present setting.

- setting

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

  POS → NEG → BIPOLAR → POS

- default

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

VAR1 RANGE 2V

Sets sweep range of VAR1 channel. This setting defines the maximum sweep range and resolution of VAR1 channel. This softkey displays present setting.

- setting

  Select this softkey to display the VAR1 sweep range value in the data entry area, then rotate the knob to change the value. Setting value will be changed by 1-2-5 steps as shown below:

  0.1 V → 0.2 V → 0.5 V → ... → 100 V → 200 V → 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

  Minimum value that includes *VAR1 start and stop value* that is set on the MEASURE: SWEEP SETUP screen. However the value must be 1-2-5 steps. For example, if start value is 0 V and stop value is 30 V on the MEASURE: SWEEP SETUP screen, default VAR1 range is 50 V.

NUM OF STEPS 101

Sets number of steps for VAR1 channel. For knob sweep, NO OF STEP setting on MEASURE: SWEEP SETUP screen has no meaning. This softkey displays present setting.

- setting

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

- setting range : 2 to 1001
- default : 101

COMPLI-ANCE 100.mA Sets compliance value for VAR1 channel. This softkey displays present setting.

- setting

  Press this softkey to display the compliance value in the data entry area. Then, you can change the setting value by using the rotary knob, numeric keys, or 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 screen

HOLD TIME 0.00s Sets hold time. This softkey displays present setting.

- setting

  Press this softkey to display the hold time in the data entry area. Then, you can change the setting value by using the rotary knob, numeric keys, or 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 screen

STEP TIME 500us Sets step time which is the time width of each sweep step. This softkey displays present setting.

- setting

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

- setting range : 500 μs to 100 ms with 100 μs resolution
- default : 500 μs

VAR2 SETUP Softkey

This softkey displays secondary softkeys for setting the secondary sweep source (VAR2) parameters.

If VAR2 is not set for any channel on the CHANNELS: CHANNEL DEFINITION screen, this softkey is not displayed.

VAR2 START 20.0uA Sets VAR2 start value. This softkey displays present setting.

- setting

  Press this softkey to display the VAR2 start value in the data entry area. Then, you can change the setting value by using the rotary knob, numeric keys, or 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 screen

VAR2 STEP 20.0uA Sets VAR2 step value. This softkey displays present setting.

- setting

  Press this softkey to display the VAR2 step value in the data entry area. Then, you can change the setting value by using the rotary knob, numeric keys, or 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 screen

VAR2 POINTS 5

Sets Number of steps for VAR2 channel. This softkey displays present setting.

- setting

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

- setting range : 1 to 128
- default

  VAR2 number of steps on MEASURE: SWEEP SETUP screen

COMPLI-ANCE 2.00 V

Sets compliance value for VAR2 channel. This softkey displays present setting.

- setting

  Press this softkey to display the VAR2 compliance value in the data entry area. Then, you can change the setting value by using the rotary knob, numeric keys, or 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 screen

CONST SETUP Softkey

This softkey displays the secondary softkeys for setting the constant voltage source parameter or the constant current source parameters. Secondary softkeys for PGUs set to `V` mode are also displayed.

If CONST is not set for any channel on the CHANNELS: CHANNEL DEFINITION screen, this 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

The first line of each secondary softkey displays the variable name of the constant source. The second line displays *source output 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:

  ```
  Vce
    5.00V
   10.0mA
  ```

  - Voltage source mode.
  - Variable name (VNAME): "Vce".
  - Output voltage value: 5.0 V.
  - Compliance value: 10 mA.

- source output value

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

- compliance value (only for SMU)

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

- setting range

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

Analysis of the Knob Sweep Measurement Results

On the KNOB SWEEP screen, you cannot use analysis functions and user functions. But you can analyze the knob sweep measurement result by quitting knob sweep mode as shown below:

1. Select the SETUP COPY primary softkey on the KNOB SWEEP screen.
2. Press the Graph/List front-panel key.

The knob sweep results are displayed on the GRAPH/LIST screen. Then you can use analysis functions.

To Use User Function

If you want to use user functions in GRAPH/LIST screen group, do following before entering to the knob sweep mode:

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

After getting the measurement data on the knob sweep mode, and quitting the knob sweep mode as described above, the results of user function will be displayed on the GRAPH/LIST screen.

Standby Function

The 4155B/4156B can force standby outputs before starting or after stopping a measurement or stress. You can select dc or pulse bias for the standby output.

Standby Channels

Standby channels are the measurement units which force the standby output. SMUs, VSUs, and PGUs can be used for the standby channel. VMUs and GNDU are not available.

To define a measurement unit as a standby channnel, move the field pointer to the STBY field on the CHANNELS: CHANNEL DEFINITION screen, and select the STANDBY ON softkey.

You cannot use the standby channel as the stress channel. The standby channels keep the standby output when the 4155B/4156B is in the stress force state.

Standby State

Before starting or after stopping a measurement or stress, if only the standby channels perform dc or pulse outputs, the 4155B/4156B is in the standby operation state.

To start the standby output, press Standby front-panel key. Then the indicator is lit. However, if no units are defined as the standby channel, the 4155B/4156B cannot be in the standby state.

To stop the standby output, press Standby front-panel key. The indicator is off.

When the 4155B/4156B is in the standby state, you can change setting parameters for non-standby channels without changing the state. But if you modify the settings for the standby channels, the 4155B/4156B changes from the standby state to the idle state.

Available Units and Output Values

Following table shows the output value of the standby channels in the standby state. The specified values are the values that are set on the MEASURE setup screens.

FCTN	MODE	Unit [a]		
		SMU	VSU	PGU
VAR1 VAR2 VAR1'	V	START	START	-
	I	START	-	-
	VPULSE	BASE	-	-
	IPULSE	BASE	-	-
CONST	V	SOURCE	SOURCE	SOURCE
	I	SOURCE	-	-
	VPULSE	BASE	-	Specified pulses. [b]
	IPULSE	BASE	-	-

a. VMUs and GNDU cannot be set to the standby channel.
b. Pulses as defined in MEASURE: PGU SETUP screen. If both PGUs are set to VPULSE, the STBY settings of both PGUs must be same.

Output Values of non-Standby Channels

Following table shows the output value of non-standby channels in the standby state.

Function of Unit	Output Value	Range
Voltage Output	0 V	Output Range used in the previous state.
Current Output	Output value in the previous state. [a]	
Voltage Measurement	-	Output Range used in the previous state.
Current Measurement	-	

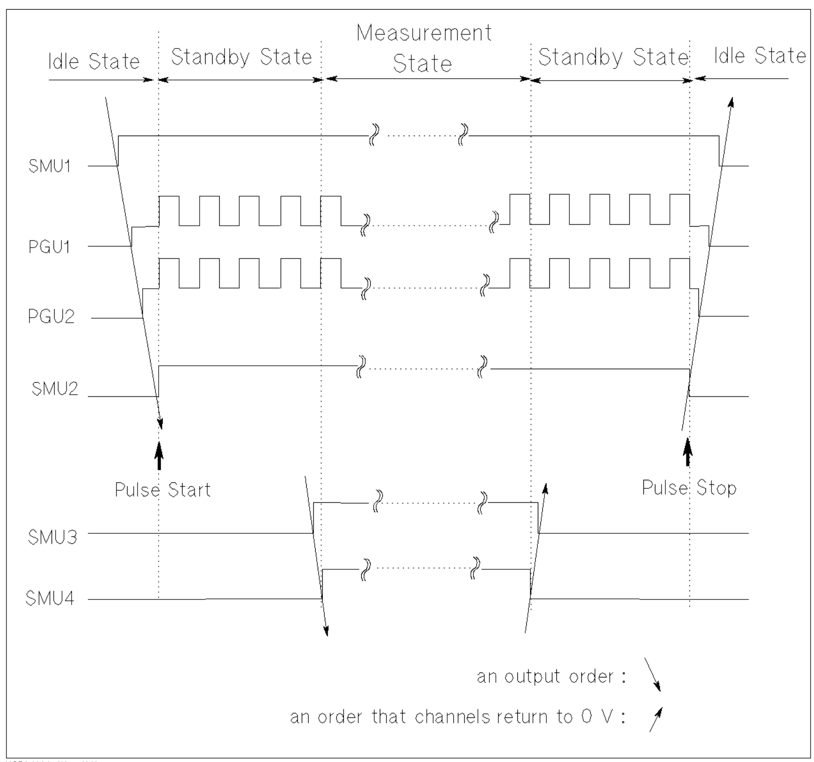
a. outputs the latest value of previous state. For example, if previous state was measurement state and latest value of VAR1 was stop value, the stop value is output for VAR1 during standby.

Output Sequence of Standby Channels

Output sequence of measurement units is defined on the MEASURE: OUTPUT SEQUENCE screen. Example output sequence setup is shown in the following table, and Figure 3-2 shows timing diagram of this example:

Unit	Output Sequence	STBY
SMU1	1	ON
SMU3	2	OFF
SMU4	3	OFF
PGU1	4	ON
PGU2	5	ON
SMU2	6	ON

Figure 3-2 **Example of the Output Sequence of the Standby Channels**



When Getting Setup File

Usually, the 4155B/4156B is in the idle state after getting setups from a file or an internal memory. But if *all* of the following must be true, the 4155B/4156B keeps the standby state:

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

FCTN	MODE	Parameters
VAR1 VAR2	V	START, STOP, COMPLIANCE [a]
	I	START, COMPLIANCE
	VPULSE	BASE, START, STOP, COMPLIANCE [a]
	IPULSE	BASE, COMPLIANCE
VAR1'	V	START [b], STOP [b], COMPLIANCE [a], OFFSET, RATIO
	I	START [b], COMPLIANCE, OFFSET, RATIO
	VPULSE	BASE, START [b], STOP [b], COMPLIANCE [a], OFFSET, RATIO
	IPULSE	BASE, COMPLIANCE
CONST	V	SOURCE, COMPLIANCE [a]
	I	SOURCE, COMPLIANCE, Pulse setup [c]
	VPULSE	BASE, PEAK, COMPLIANCE [a]
	IPULSE	BASE, COMPLIANCE

a. This parameter is checked for SMUs only.
b. This parameter is checked, even if VAR1 channel is not standby channel.
c. PGU setups on the MEASURE: PGU SETUP screen.

Operation States

The 4155B/4156B has the following four operation states.

- "Idle State"
- "Measurement State"
- "Stress Force State"
- "Standby State"

Idle State

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

An 4155B/4156B 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 setup screens.

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
16441A R-Box	0 Ω is connected.
16440A selector	switching condition is `SMU`.

Measurement State

In the measurement state, an 4155B/4156B 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 screen.

Stress Force State

In the stress force state, the 4155B/4156B outputs stress. The output switches are off for units that do *not* have entries in the CHANNELS table of the STRESS: CHANNEL DEFINITION screen.

Standby State

In the standby state, the 4155B/4156B does not perform measurements or stress force, but it outputs dc bias and/or pulses using the measurement units defined as the standby channel. Following settings keep the same conditions as the previous state:

- output switch of each unit
- output impedance of PGUs
- switching condition of the 16440A selector
- resistance selection of the 16441A R-Box

Changing among Operation States

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

- From measurement/stress states to idle state:

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

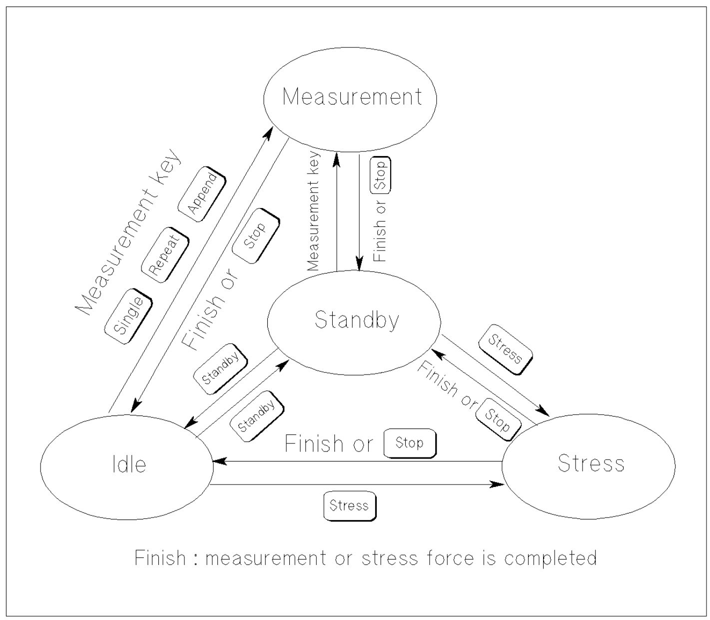
  - Measurement is finished.
  - Fixture lid is opened while an SMU is outputting more than ±40 V.
  - Stress is finished.
  - Stop front-panel key is pressed.

- From measurement/stress states to standby state:

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

  - Measurement is finished.
  - Stress is finished.
  - Stop front-panel key is pressed.

Figure 3-3 **Changing among the Operation States**



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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.

The 4155B/4156B 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 screen. 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 screen.

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

For a standby sequence example, see Figure 3-2.

Sequential Mode

Default output sequence in the sequential mode is shown below. In the default settings, output channels start the output in this order, and stop the output in the opposite order.

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

Starting Outputs

In the idle state, output switches of *all* units are on, and the units output 0 V. When moving to the measurement, stress force, or standby state, the units operate as shown below:

1. Disabled units keep 0 V output, and turn the output switch off.

   where disabled unit means the unit you select the DELETE ROW softkey in the CHANNELS table on the CHANNELS: CHANNEL DEFINITION screen.

2. Output channels start the output in the order specified in the OUTPUT SEQUENCE table.

Stopping Outputs

When returning to the idle state, the units operate as shown below:

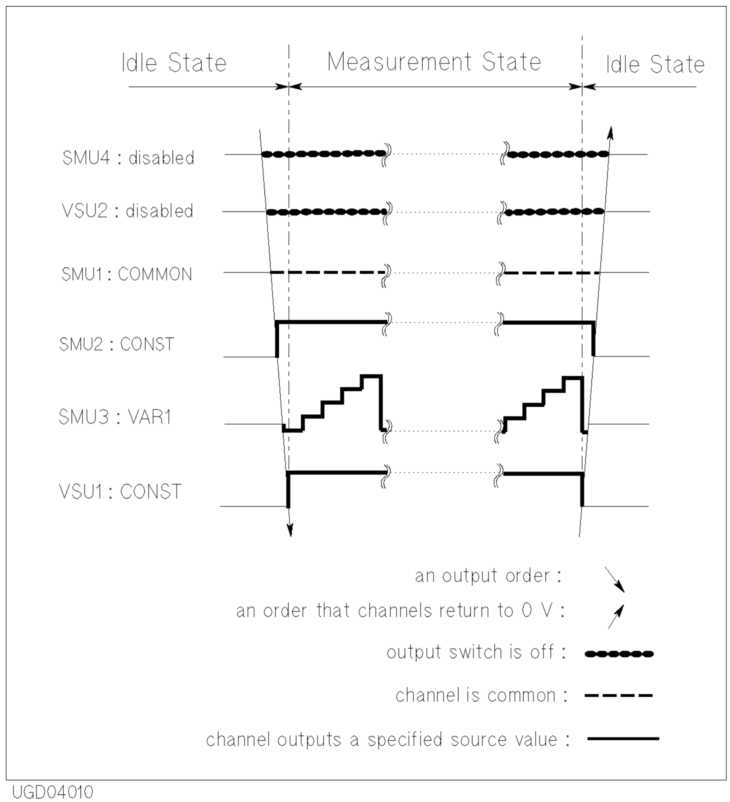
1. Output channels stop the output in the opposite order of the OUTPUT SEQUENCE table.
2. Disabled units keep 0 V output, and turn the output switch on.

Example

Output sequence in the following conditions is shown in Figure 3-4.

- Units available: SMU1 to SMU 4, VSU1 to VSU2.
- Units disabled: SMU4 and VSU2.
- Output sequence: No change from the default setting.

Figure 3-4 **Output Sequence Example for the Sequential Mode**



Simultaneous Mode

The simultaneous mode is available only for the sampling measurements.

In this mode, all enabled units start the specified outputs at the same time, and stop the outputs in the opposite order of the OUTPUT SEQUENCE table.

Default output sequence defined in the OUTPUT SEQUENCE table of the MEASURE: OUTPUT SEQUENCE screen is shown below. In the default settings, output channels stop the output in the opposite order of the following:

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

Starting Outputs

In the idle state, output switches of *all* units are on, and the units output 0 V. When moving to the measurement state, the units operate as shown below:

1. Disabled units keep 0 V output, and turn the output switch off.

   where disabled unit means the unit you select the DELETE ROW softkey in the CHANNELS table on the CHANNELS: CHANNEL DEFINITION screen.

2. Output channels start the output at the same time.

Stopping Outputs

When returning to the idle state, the units operate as shown below:

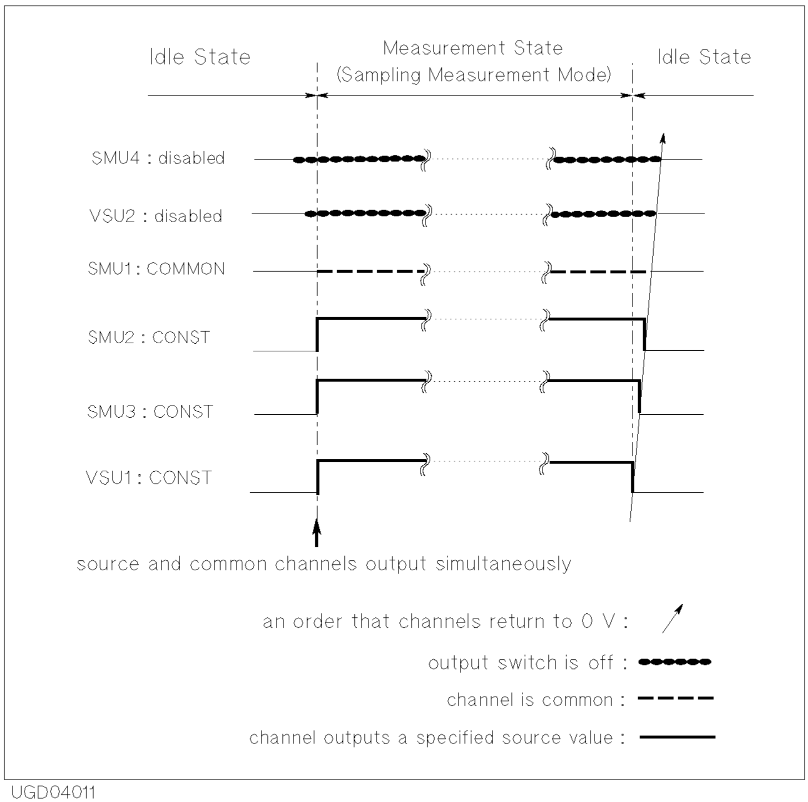
1. Output channels stop the output in the opposite order of the OUTPUT SEQUENCE table.
2. Disabled units keep 0 V output, and turn the output switch on.

Example

Output sequence in the following conditions is shown in Figure 3-5.

- Units available: SMU1 to SMU 4, VSU1 to VSU2.
- Units disabled: SMU4 and VSU2.
- Output sequence: No change from the default setting.

Figure 3-5 **Default Output Sequence Example for the Simultaneous Mode**

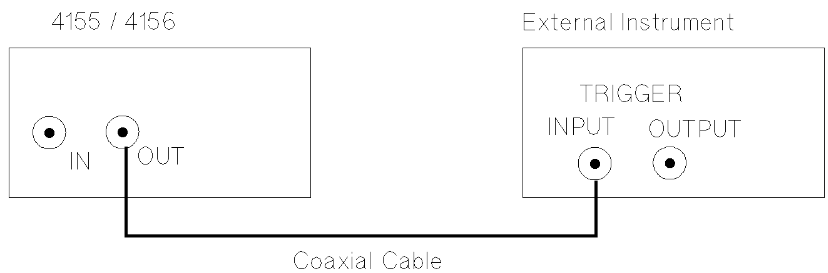


Trigger Function

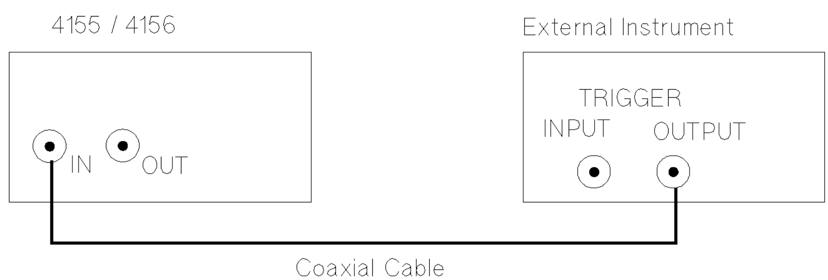
Trigger function is used to perform measurements synchronized with the measurements or source outputs by external instruments..

Connection

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



(a) For Trigger Output Function



(b) For Trigger Input Function

Setup and restrictions

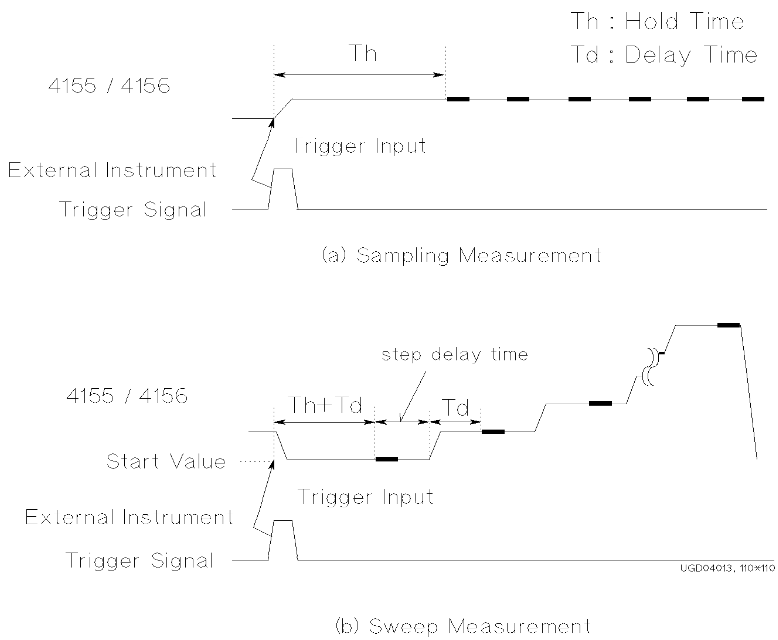
- You *cannot* perform trigger outputs together with trigger inputs. You *must* select either trigger output or trigger input.
- To use a trigger function, you must enable the trigger function and select either TRIG OUT or TRIG IN in the TRIGGER SETUP table on the MEASURE: OUTPUT SEQUENCE screen. Then the trigger inputs or outputs are performed automatically after you start a measurement by selecting a measurement front-panel key (Single, Repeat, or Append).
- 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 *User's Guide General Information*.

Trigger Input

The 4155B/4156B 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 3-6 **Examples of Externally Triggered Measurements**



After you press the Single, Repeat, or Append front-panel key, the 4155B/4156B waits for the trigger signal *only once*. When the 4155B/4156B receives the trigger signal, the 4155B/4156B starts measurements.

For *staircase* sweep measurements, you can specify the step delay time shown in Figure 3-6.

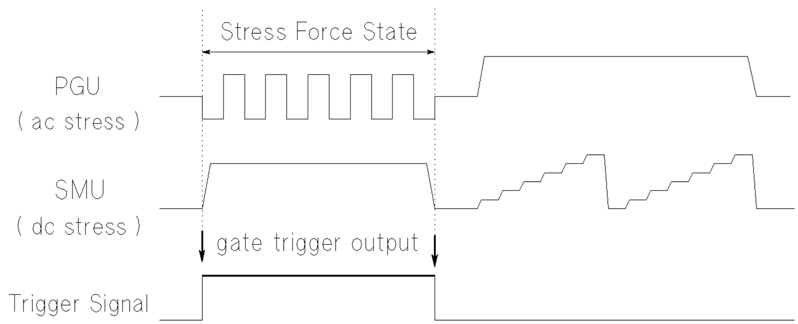
Trigger Output

The 4155B/4156B 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

The 4155B/4156B can output gate triggers when 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 screen.



Edge Trigger Output

For sweep measurements, the 4155B/4156B can output edge triggers, which are synchronized with each sweep step.

To set the trigger output timing, use the following field on the MEASURE: OUTPUT SEQUENCE screen. Name of entry field depends on the measurement mode.

Measurement Mode	Entry Field
Pulse sweep measurement	TRIG OUT DELAY
Sweep measurement	STEP DELAY

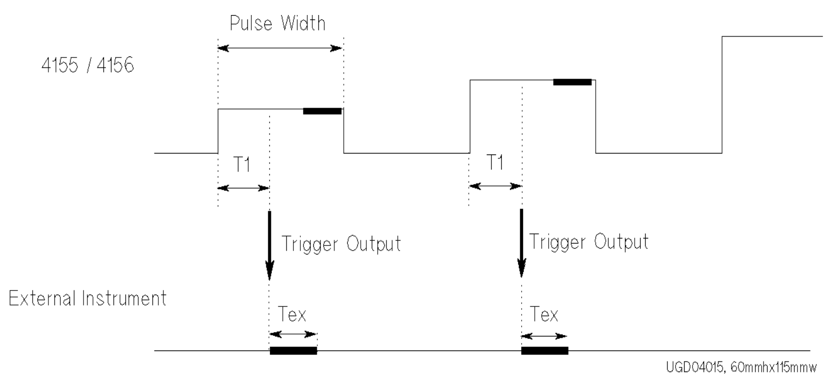
Trigger output delay time for pulsed sweep measurements.

When using an SMU as a pulse source, the 4155B/4156B can output edge triggers at each pulse leading edge. Trigger output delay time (TRIG OUT DELAY) specifies how much to delay the trigger after the leading edge. So, you set the trigger output delay time to wait until the 4155B/4156B outputs a stable pulse peak value. Available setting range for the trigger output delay time is:

Range: 0 to specified pulse width, maximum 32.7 ms

Resolution: 100 µs

Trigger output delay time is shown as T1 in the following figure.



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

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

where, Tex means the measurement time.

Step delay time for staircase sweep measurements.

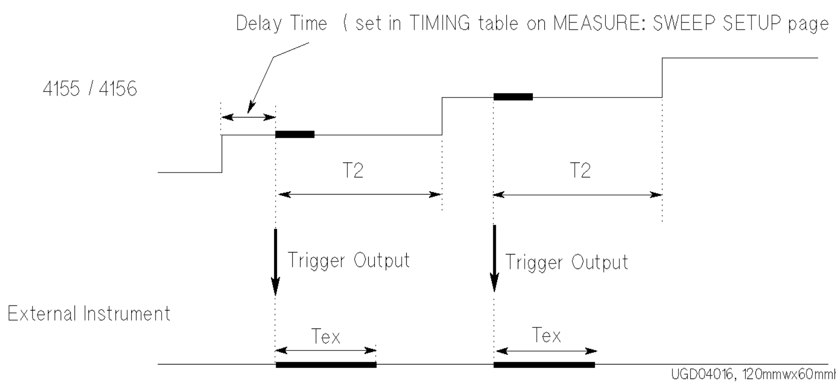
When performing sweep measurements without a pulsed SMU, the 4155B/4156B outputs an edge trigger at the time when the 4155B/4156B starts performing measurement in each sweep step as shown in the following figure.

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. Available setting range for the step delay time is:

Range: 0 to 1 s

Resolution: 100 μs

Trigger output delay time is shown as T2 in the following figure.



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

Tex : measurement time for external instument

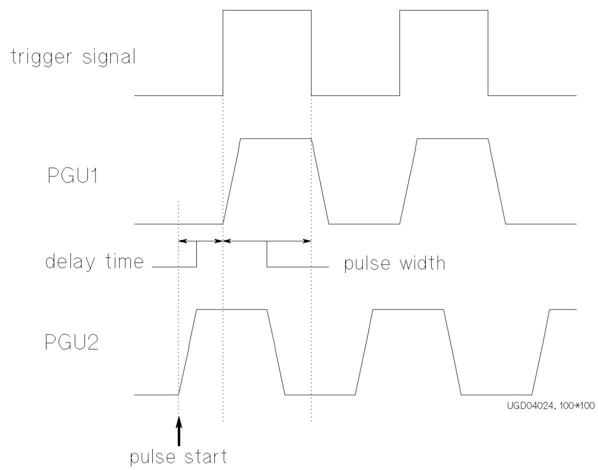
If the specified T2 is shorter than the measurement time of the 4155B/4156B, the 4155B/4156B waits until the measurement completes, then outputs the next step.

Trigger output function of PGU

Using the Agilent 41501A/B contains PGUs, the 4155B/4156B can output a gate trigger through the 41501A/B Ext Pulse Generator Trig Out terminal. The trigger signal is synchronized with the PGU output pulses, and you cannot control trigger timing.

The polarity of the trigger is positive and the output level is TTL.

The following figure shows the trigger signal. The leading-edge and tailing-edge of the trigger are synchronized with the leading-edge and tailing-edge of PGU1.



This function allows you to perform multiple pulse outputs using external pulse generators synchronized with the PGUs.

SMU/PG Selector Control

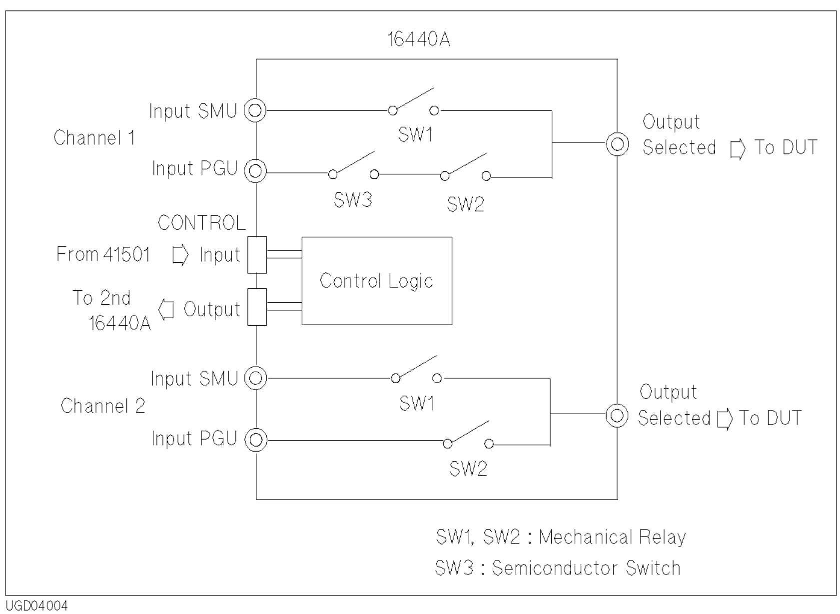
The 4155B/4156B can control the 16440A SMU/Pulse Generator Selector to automatically switch units that are connected to a DUT pin. You set up this automatic control using the SMU/PG SELECTOR field on the STRESS: CHANNEL DEFINITION screen.

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 selectors. For details about installation of the selectors, refer to *User's Guide General Information*.

Figure 3-7 shows the simplified circuit diagram of an 16440A selector.

Figure 3-7 **Simplified Circuit Diagram of the 16440A Selector**



Setup and Switching Conditions

Setup of the SMU/PG SELECTOR field and switching conditions are explained below:

CH1 (or CH3 for second selector):

Setup	SW1	SW2	SW3	Description
SMU	ON	OFF	OFF	Connects SMU.
PGU	OFF	ON	ON	Connects PGU.
PGU OPEN	OFF	ON	OFF	Open. Disconnected.
OPEN	OFF	OFF	OFF	Open. Disconnected.

CH2 (or CH4 for second selector):

Setup	SW1	SW2	Description
SMU	ON	OFF	Connects SMU.
PGU	OFF	ON	Connects PGU.
OPEN	OFF	OFF	Open. Disconnected.

NOTE

SW1 and SW2 are mechanical relays, and SW3 is a semiconductor switch. Leakage current and stray capacitance of SW1 and SW2 are less than for SW3. However, the switching speed of SW3 is faster and life is longer than SW1 and SW2.

If you need to switch PGU many times, use PGU OPEN, not OPEN to disconnect PGU.

Restrictions using Selector

- 41501A/B Expander equipped with PGU must be connected to 4155B/4156B.
- Kelvin connection is not available.

R-BOX Control

Agilent 16441A R-Box must be used for applications which need to connect a series resistor between SMU and DUT. For example, the R-Box is effective for the DUT protection. If sudden voltage change occurs at DUT, excessive current flows to the DUT, and it may damage the DUT without the R-Box. In other case, you may want to measure negative resistance characteristics. This application needs series resistor because SMUs cannot measure negative resistance.

The 4155B/4156B automatically compensates for voltage drop of the series resistance value. So, the GRAPH/LIST screen group show the compensated data.

For details of the 16441A R-Box, refer to *Agilent 16441A R-Box User's Guide*.

Resistance Value

The 16441A R-Box provides two sets of the series resistors. So you can connect two SMU channels to the R-Box. Resistance values of resistors are listed below:

- 1 MΩ
- 100 kΩ
- 10 kΩ
- 0 Ω

You can select the resistance values on the 4155B/4156B setup screen. The LEDs on the 16441A R-Box indicate the present resistance value.

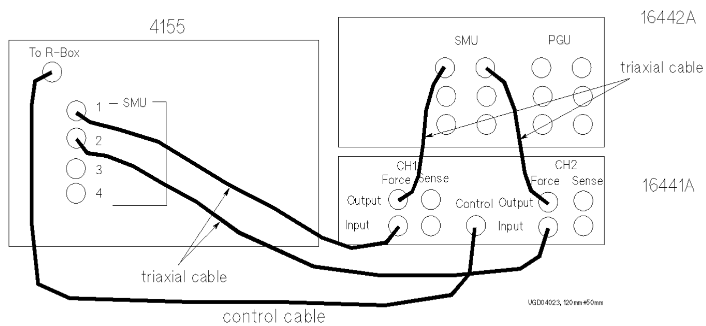
Connections

Following table is the parts list of cables for connecting the 16441A R-Box.

Agilent 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
16493K #001	Kelvin Triaxial Cable 1.5 m
16493K #002	Kelvin Triaxial Cable 3.0 m

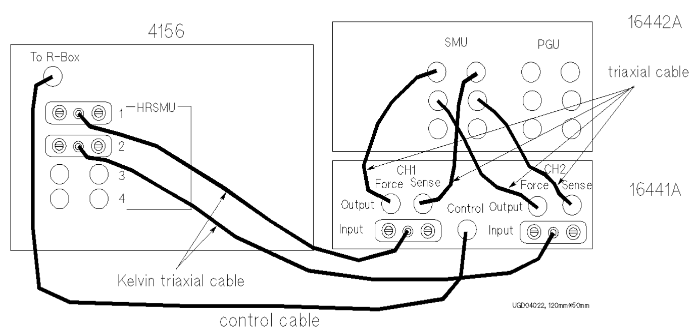
Non-Kelvin Connections

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



Kelvin Connections

The following figure shows the 16441A R-Box connections using Kelvin connections. Only 0 ohm is available for the Kelvin connection.



Setups

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

You can set resistance values for the following SMUs:

- SMU1 (to CH1 terminal of R-Box)
- SMU2 (to CH2 terminal of R-Box) if the 41501A/B SMU/Pulse Generator Expander is not installed or does not have an HPSMU
- SMU5 (to CH2 terminal of R-Box) if the 41501A/B is installed and has an HPSMU

If you connect the 16441A R-Box to the SMUs described above, the 4155B/4156B automatically compensates for voltage drop of the resistance values. So, the measured data displayed on the screen and the results of user function are the compensated data.

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

- SMU that is set to standby channel
- SMU that is set to `COMMON` output mode

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

There is a possibility that the 4155B/4156B cannot perform measurement circumstances. If you measure device characteristics including negative resistance over 1 MΩ, there is a possibility that they cannot measure it.

NOTE

If you connect the 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 the IBASIC program.

NOTE

To perform automatic compensation of R-Box, the 4155B/4156B automatically uses 1 SMU to measure current through the R-Box.

So if the SMU forces voltage, and monitors voltage value or use the monitored value for user function calculation, the 4155B/4156B need additional 1 measurement channel other than the measurement channels defined in the CHANNELS: CHANNEL DEFINITION screen.

Circuit Diagram

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

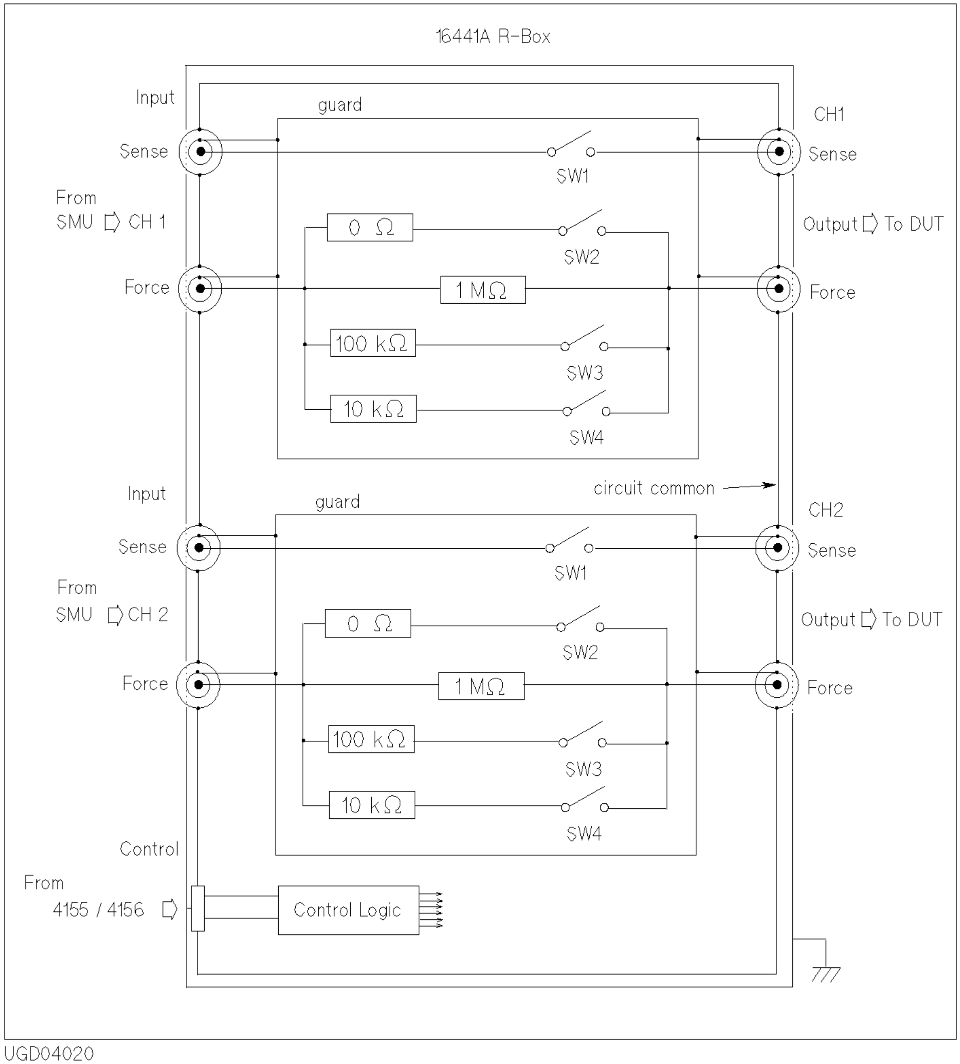
Table 3-4 shows switching conditions for each setting.

Table 3-4 **Switching Conditions of the 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.

Figure 3-8 Simplified Circuit Diagram of the 16441A R-Box



Measurement Ranging Mode

Before executing measurements, you select a ranging mode from the following four modes. You can set the ranging mode for each measurement unit.

- "Auto Ranging"
- "Limited Auto Ranging"
- "Compliance Range"
- "Fixed Range"

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

Table 3-5 Allowable Measurement Ranging Modes

Measurement Mode	Ranging Mode
Sweep Measurement	Auto, Limited Auto, Fixed
Sampling Measurement (Initial Interval [a] $\geq$ 2 ms)	Auto, Limited Auto, Fixed
Sampling Measurement (Initial Interval [a] < 2 ms)	Fixed
Knob Sweep	Compliance

a. You specify initial interval on the MEASURE: SAMPLING SETUP screen.

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 voltage measurement mode channel and limited auto (1nA) ranging is set for current measurement mode channel automatically.

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

Auto Ranging

The monitor unit automatically 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

Limited auto ranging is similar to the auto ranging. But the limited auto ranging does not use the range(s) less than the range you specified. For example, if you select the 10 nA limited auto ranging, measurement unit does not use the 1 nA range or less. So the measurement time for limited auto ranging is less than for auto ranging.

Monitor unit automatically 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.

If the specified range is greater than the lowest range that contains V compliance, the measurement is performed at the lowest range that contains V compliance.

I measurement

If specified range is greater than the lowest range that includes I compliance, an error occurs.

- 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.

For details about setting compliance, refer to “Compliance” on page 3-57.

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.

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

Compliance is available for SMU (HPSMU, MPSMU, HRSMU) and VSU.

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

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

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. Voltage compliance is for the SMU in current output mode, current compliance is for the SMU in voltage output mode.

When a unit reaches compliance, the unit acts as a constant voltage source or a constant current source. The unit keeps the output value when reaching compliance.

For compliance setting range and resolution, refer to Table 3-6 to Table 3-9.

Polarity and Output Area

- Polarity of Voltage compliance

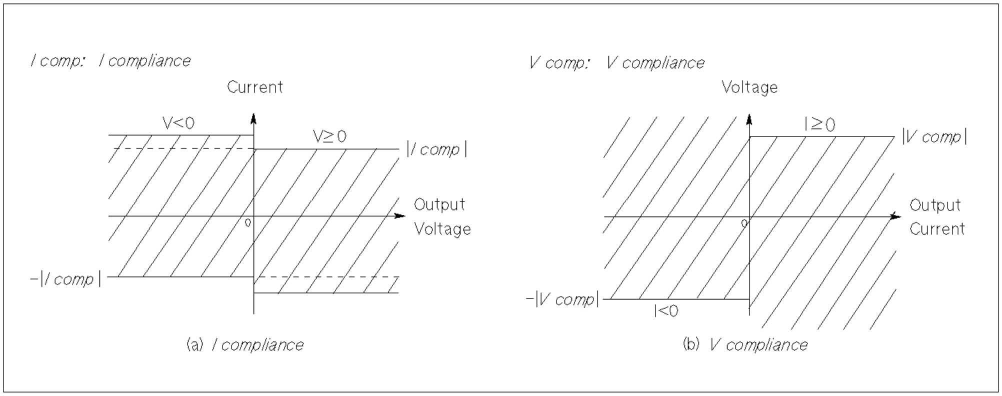
  The 4155B/4156B automatically sets V compliance polarity to the same polarity as the output current, regardless of the specified V compliance polarity. There is no compliance for the opposite polarity.

- Polarity of Current compliance

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

  However, if the output voltage and the current compliance 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*. Figure 3-9 shows the relation of the compliance and output.

Figure 3-9 **Relation of Compliance and Output**



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Current Complinace for COMMON Unit

If you set COMMON output mode for the unit, current 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

Table 3-6 **V Compliance Setting Range**

Unit	Output Range	V Compliance Setting Range
HRSMU	10 pA to 10 mA	0 to 100 V
	100 mA (0 ≤ | I | ≤ 20 mA)	0 to 100 V
	100 mA (20 mA < | I | ≤ 50 mA)	0 to 40 V
	100 mA (50 mA < | I | ≤ 100 mA)	0 to 20 V
MPSMU	1 nA to 10 mA	0 to 100 V
	100 mA (0 ≤ | I | ≤ 20 mA)	0 to 100 V
	100 mA (20 mA < | I | ≤ 50 mA)	0 to 40 V
	100 mA (50 mA < | I | ≤ 100 mA)	0 to 20 V

Unit	Output Range	V Compliance Setting Range
HPSMU	1 nA to 10 mA	0 to 200 V
	100 mA (0 ≤ | I | ≤ 50 mA)	0 to 200 V
	100 mA (50 mA < | I | ≤ 115 mA)	0 to 100 V
	1 A (0 ≤ | I | ≤ 50 mA)	0 to 200 V
	1 A (50 mA < | I | ≤ 125 mA)	0 to 100 V
	1 A (125 mA < | I | ≤ 500 mA)	0 to 40 V
	1 A (500 mA < | I | ≤ 1 A)	0 to 20 V

Table 3-7 V Compliance Resolution

Unit	V Compliance	Resolution
HRSMU	0 V ≤ | V | ≤ 2 V	100 μV
MPSMU	2 V < | V | ≤ 20 V	1 mV
HPSMU	20 V < | V | ≤ 40 V	2 mV
	40 V < | V | ≤ 100 V	5 mV
	100 V < | V | ≤ 200 V	10 mV

Table 3-8 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

Unit	Output Range	I Compliance Setting Range
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 3-9 **I Compliance Resolution**

Unit	I Compliance	Resolution
HRSMU	100 fA ≤ | I | ≤ 100 pA	10 fA
	100 pA < | I | ≤ 1 nA	100 fA
	1 nA < | I | ≤ 10 nA	1 pA
	10 nA < | I | ≤ 100 nA	10 pA
	100 nA < | I | ≤ 1 µA	100 pA
	1 µA < | I | ≤ 10 µA	1 nA
	10 µA < | I | ≤ 100 µA	10 nA
	100 µA < | I | ≤ 1 mA	100 nA
	1 mA < | I | ≤ 10 mA	1 µA
	10 mA < | I | ≤ 100 mA	10 µA
MPSMU	1 pA ≤ | I | ≤ 1 nA	100 fA
	1 nA < | I | ≤ 10 nA	1 pA
	10 nA < | I | ≤ 100 nA	10 pA
	100 nA < | I | ≤ 1 µA	100 pA
	1 µA < | I | ≤ 10 µA	1 nA
	10 µA < | I | ≤ 100 µA	10 nA
	100 µA < | I | ≤ 1 mA	100 nA
	1 mA < | I | ≤ 10 mA	1 µA
	10 mA < | I | ≤ 100 mA	10 µA

Unit	I Compliance	Resolution
HPSMU	1 pA ≤ | I | ≤ 1 nA	100 fA
	1 nA < | I | ≤ 10 nA	1 pA
	10 nA < | I | ≤ 100 nA	10 pA
	100 nA < | I | ≤ 1 μA	100 pA
	1 μA < | I | ≤ 10 μA	1 nA
	10 μA < | I | ≤ 100 μA	10 nA
	100 μA < | I | ≤ 1 mA	100 nA
	1 mA < | I | ≤ 10 mA	1 μA
	10 mA < | I | ≤ 100 mA	10 μA
	100 mA < | I | ≤ 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. However, 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.

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

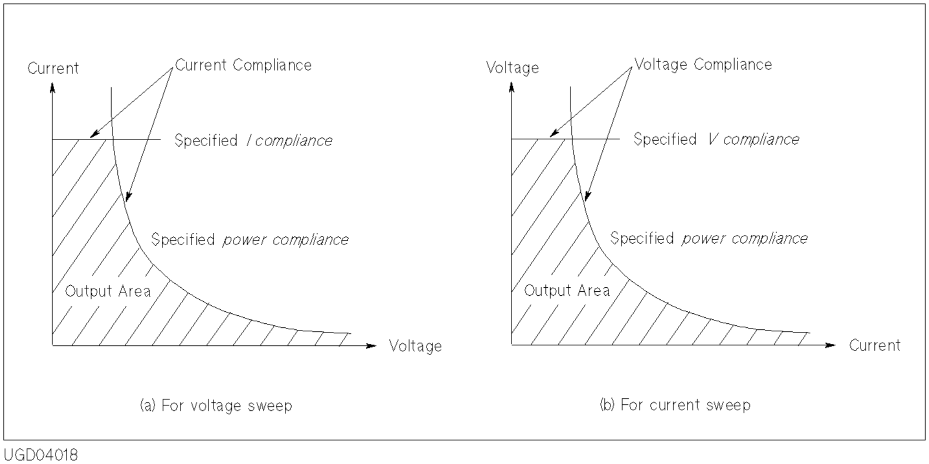
If you specify I compliance and power compliance for a V sweep source, the 4155B/4156B changes the I compliance at every voltage step. The I compliance is set to the smaller value of *I compliance* and *Icomp* value below. See Figure 3-10 (a).

Icomp = power compliance / step voltage

If you specify V compliance and power compliance for an I sweep source, the 4155B/4156B changes the V compliance at every current step. The V compliance is set to the smaller value of *V compliance* and *Vcomp* value below. See Figure 3-10 (b).

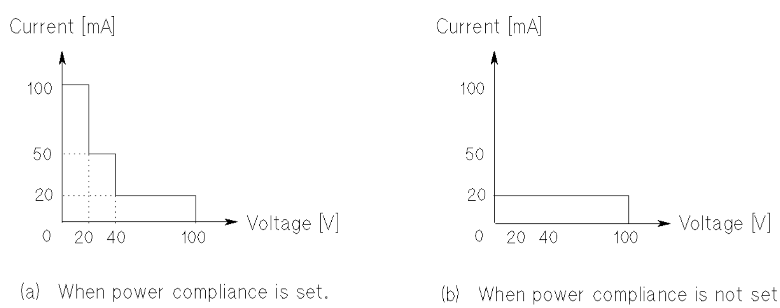
Vcomp = power compliance / step current

Figure 3-10 Power Compliance Output Area



If you specify power compliance, SMUs can be swept at their maximum output limits because the 4155B/4156B changes the V (or I) output range and I (or V) compliance range during a V (or I) sweep. Figure 3-11 shows an example of the difference in SMU output when power compliance is set and when power compliance is not set.

Figure 3-11 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, the 4155B/4156B 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

All measurement units use the same integration time setting. To perform high-speed measurements, set integration time to short. To perform more accurate measurements, set integration time to long.

Integration time is specified in the INTEG TIME table on the MEASURE: MEASURE SETUP screen.

Short

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

Setting	Press Short front-panel key.
Integration time	80 μs to 1.92 ms with 80 μs resolution
Initial setting	640 μs

Basically, the measurement units measure with specified integration time. But if both of the following conditions are satisfied, the units may measure with longer integration time than specified:

- Settings of integration time: 0.64 ms to 1.92 ms
- Measurement range: 10 pA to 10 μA range

Medium

Medium integration time is 1 PLC (power line cycle).

Setting Press Medium front-panel key.

Integration time depends on the power line cycle. cannot change this value. (for example, 20 ms for 50 Hz)

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

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.

Setting Press Long front-panel key.

Integration time 2 PLC to 100 PLC with 1 PLC resolution

Initial setting 16 PLC

When an 4155B/4156B 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 screen.

  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 screen.

  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.

- 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

The 4155B/4156B has zero offset cancel function. This function allows you to minimize measurement error (offset) caused by resistance and leakage current of cables, prober, and so on.

You can use the zero offset cancel function for:

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

To Measure Offset Data

To measure the offset data, do following:

1. Select the measurement range in the MEASUREMENT RANGE table on the MEASURE: MEASURE SETUP screen. See Table 3-10 for the ranging mode available.
2. Open the measurement terminals at the cable end of the device side.
3. Press green key and Stop front-panel key in this order. The ZERO CANCEL field is automatically set to ON, and offset data is measured. This data is used for the offset cancel.

   Allowable offset value is shown in Table 3-11. If offset data is too large, offset measurement for this measurement path is not performed. For this path, an * is marked in the ZERO CANCEL table. Then the previous data is used for the offset cancel. The initial offset data is 0.

NOTE During offset measurement, integration time is automatically 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.

NOTE After you perform the offset measurement, if you change the ranging mode to 10 nA limited auto or 10 nA fixed and you try to perform the offset measurement again, the offset data is not measured for this unit. But the previous offset data is effective. So the offset cancel can be performed for this unit using the old offset data.

Table 3-10 Ranging Mode Available for Offset Measurement

<table>
<tr><th>Measurement Mode</th><th>Unit</th><th>Available Ranging Mode</th><th>Measurement Range [a]</th></tr>
<tr><td rowspan="6">Current Measurement</td><td rowspan="2">HPSMU, MPSMU</td><td>auto</td><td>1 nA</td></tr>
<tr><td>1 nA limited or fixed</td><td>1 nA</td></tr>
<tr><td rowspan="4">HRSMU</td><td>auto</td><td>10 pA</td></tr>
<tr><td>10 pA limited or fixed</td><td>10 pA</td></tr>
<tr><td>100 pA limited or fixed</td><td>100 pA</td></tr>
<tr><td>1 nA limited or fixed</td><td>1 nA</td></tr>
<tr><td>Differential Voltage Measurement</td><td>VMU</td><td>auto, limited auto, fixed</td><td>0.2 V [b]</td></tr>
</table>

a. Offset data is measured in the measurement range shown above.
b. VMU2 measures voltage in grounded mode to confirm that voltage does not exceed ±20 V.

Table 3-11 Allowable Offset Value

<table>
<tr><th>Measurement Mode</th><th>Unit</th><th>Measurement Range</th><th>Allowable Offset Value</th></tr>
<tr><td rowspan="5">Current Measurement</td><td>HPSMU</td><td>1 nA</td><td>less than ±1 % of range</td></tr>
<tr><td>MPSMU</td><td>1 nA</td><td>less than ±1 % of range</td></tr>
<tr><td rowspan="3">HRSMU</td><td>1 nA</td><td>less than ±1 % of range</td></tr>
<tr><td>100 pA</td><td>less than ±1 % of range</td></tr>
<tr><td>10 pA</td><td>less than ±4 % of range</td></tr>
<tr><td>Differential Voltage Measurement</td><td>VMU</td><td>0.2 V</td><td>less than ±1 % of range [a]</td></tr>
</table>

a. If VMU2 grounded mode measurement value is greater than or equal to ±20 V, error occurs.

To Perform Offset Cancel

Offset cancel is automatically performed during measurement. The measurement execution and the offset cancel are explained below:

1. Select the measurement range in the MEASUREMENT RANGE table on the MEASURE: MEASURE SETUP screen. See Table 3-10 for the ranging mode available. 10 nA limited auto and 10 nA fixed are also available.

   When you set 10 nA range, offset cancel function uses the 1 nA range offset data for the data measured in both 1 nA range and 10 nA range.

   For the 100 nA range or more, offset cancel function is not available.

2. Set the ZERO CANCEL field to ON.

   Offset cancel is not performed for the measurement paths set to OFF in the ZERO CANCEL table.

3. Press Single, Repeat, or Append front-panel key to execute measurement.

   The offset cancel is automatically performed while measurement is performed. The measurement data is automatically compensated by using the offset data. And the compensated data is displayed on the GRAPH/LIST screen.

To disable the offset cancel function, select the ZERO CANCEL ON/OFF softkey on the ZERO CANCEL field. It toggles ON and OFF.

If you select OFF, all paths in the ZERO CANCEL table are set to OFF. If you select ON, only the available paths are set to ON.

NOTE

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.

4 Making a Measurement

This chapter describes how to perform sweep measurements, sampling measurements, and stress force, and consists of the following sections:

- “Connecting DUT”
- “Sweep Measurements”
- “Knob Sweep Measurements”
- “Sampling Measurements”
- “Stress Force”

For details about entry fields on the 4155B/4156B setup screen, refer to Chapter 6.

To satisfy the specifications of the 4155B/4156B and the 41501A/B, you need minimum 40 minutes warm-up before performing measurements.

Connecting DUT

This section describes how to connect device under test (DUT) to the 16442A test fixture, and how to connect cables to the connector plate.

For connecting the test fixture or the connector plate to the 4155B/4156B, see *User's Guide General Information*. If you use a wafer prober, see wafer prober manuals.

Note that you must set the 4155B/4156B to the idle state when connecting or disconnecting DUTs. If not, the DUTs may be damaged.

To set to idle state, press **Stop** key and make sure Standby indicator is off.

This section has the following descriptions:

- "Using Test Fixture"
- "Using Connector Plate"

Using Test Fixture

1. Press the Stop front-panel key to set your 4155B/4156B to idle state. If the standby indicator is lit, press the Standby front-panel key.
2. Select a proper socket module for your DUT, then set the module on the test fixture.
3. Mount your DUT on the socket module.
4. Connect between the socket module and the test fixture by using the proper test leads.
5. Close the lid of the test fixture.

   To force more than ±40 V, close the lid of the test fixture. Otherwise, the interlock function will stop the 4155B/4156B output.

To connect between the socket module and the test fixture, you can use test leads that have the following terminals:

- Miniature banana — miniature banana
- Miniature banana — pin plug
- Miniature banana — miniature clip

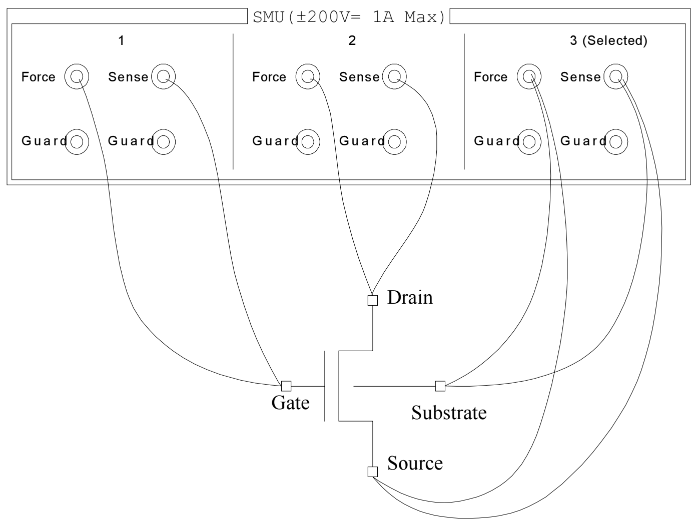
CAUTION Do not connect or disconnect your DUT while the 4155B/4156B is forcing voltage or current. Otherwise, your DUT may be damaged.

CAUTION Do not touch the terminals of the test leads. Oil, perspiration, and dirt prevent good electrical contact, deteriorate insulation, and degrade measurement accuracy.

Connections for High Current Measurements

When you force or measure a large current, you may want to use a **Kelvin (4-wire) connection** to eliminate the residual resistance effects of test leads and contacts. For example, you can use the following connections as Kelvin connections on the test fixture. The Kelvin connection is available for the 4156B's HRSMU and 41501A/B's HPSMU.

Examples: Kelvin Connection



To cancel the effects of the residual resistance, test leads must be connected as close as possible to the DUT.

Using Connector Plate

This section provides the information useful for connecting cables and probing needles to a connector plate.

- "To Reduce Leakage Current"
- "To Measure Low Resistance"

To Reduce Leakage Current

To reduce the leakage current caused by connection cables, the guard technique is effective. Connect the probing needles to the terminals of the connector plate by using coaxial cables as shown below:

1. At end of cable, connect coaxial center conductor to force terminal of connector plate, and connect coaxial outer conductor to guard terminal of connector plate.
2. At another end, connect coaxial center conductor to tail of the probing needle. Never connect the outer conductor at this cable end.

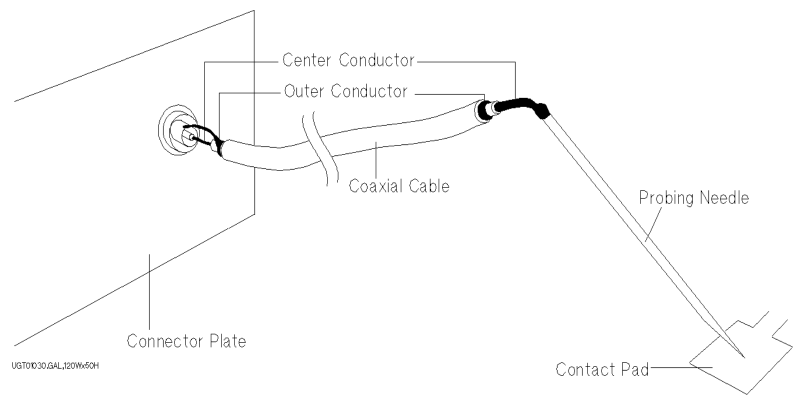
   Extend the outer conductor as close as possible to the probing needle.

WARNING **Do not touch the guard terminal with bare hands because you may be shocked by high voltage. The potential of the guard terminal is equal to the output voltage.**

CAUTION Never connect the guard terminal to any other output, including circuit common, frame ground, or the terminals of any other unit. Doing so may damage the unit.

Example

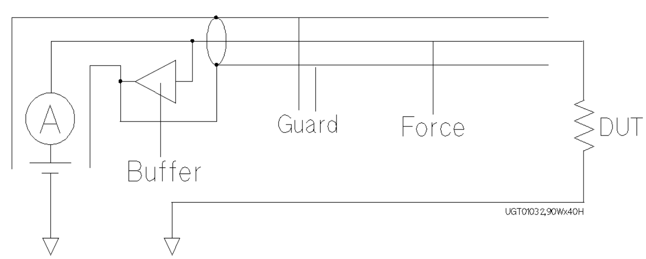
The following example connection can be used to reduce the leakage current. Extend the outer conductor as close as possible to the probing needle. This also reduces the induced noise.



Guarding

Guarding reduces the leakage current between the measurement points and instrument. This is important when you measure low current.

The following figure shows the theory of guarding. The buffer amplifier (×1) keeps the potential of the guard conductor at the same potential as the force conductor, so current does not flow between the force and guard conductors. Therefore, the current measured by SMU is same as current at measurement point because no current is leaked.



To Measure Low Resistance

When you measure a low resistance, high current flows through the DUT. This high current increases the measurement error caused by the residual resistance of cables. To cancel the effect of this resistance, you can use *Kelvin connections* (4-wire), which means the force and sense lines are extended separately to the DUT. The Kelvin connection is available for the 4156B's HRSMU and the 41501A/B's HPSMU.

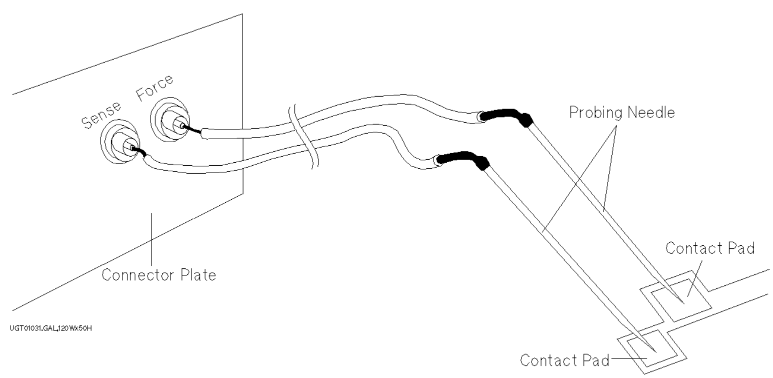
Connect the probing needles to the terminals of the connector plate by using test leads or coaxial cables. Following instruction uses the coaxial cables:

1. At end of cable, connect coaxial center conductor to force terminal of connector plate, and connect coaxial outer conductor to guard terminal of connector plate.
2. At another end, connect coaxial center conductor to tail of the probing needle. Never connect the outer conductor at this cable end.

   Extend the outer conductor as close as possible to the probing needle.
3. Repeat 1 and 2 for the sense terminal of connector plate.
4. Contact the probing needles from force and sense terminals as close as possible to the DUT.

Example

The following example connection can be used to measure low resistance. The sense line is extended to the probing pad, and contacts the force line through the pad, so the voltage drop due to the residual resistance caused by cables and test leads is canceled.

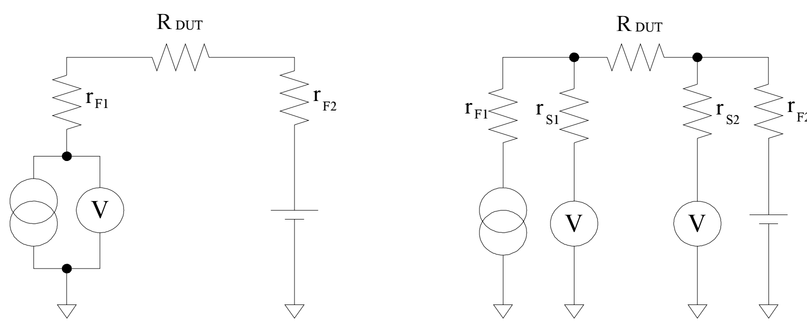


This example uses test leads. To reduce the leakage current, use coaxial cables.

Kelvin Connection

Kelvin connections give good measurement results when you force high-current. The following figure shows the equivalent circuits for Kelvin and non-Kelvin connections.

- For the non-Kelvin connection, the voltmeter measures the voltage drop of resistances r_{F1}, R_{DUT}, and r_{F2}.
- For the Kelvin connection, the voltmeter measures the voltage drop of resistance R_{DUT} only. The impedance of the voltmeter is very high, so the voltage drop of resistances r_{S1} and r_{S2} can be ignored.



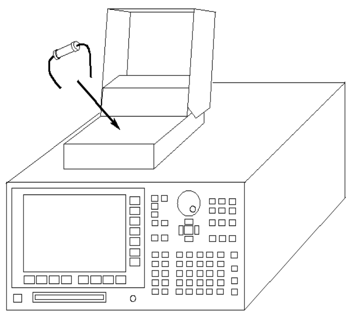
(a) non-Kelvin connection (b) Kelvin connection

The Kelvin connection is effective even when forcing voltage. The voltage drop due to the residual resistance of the force line wiring is fed back to the voltage source via a comparator in the sense line. The input impedance of comparator is high, and current flow into the sense line is very low. So output error is not significant if the sense line wiring has a residual resistance of 10 Ω or less. Therefore, the specified voltage appears at the sense point (point where sense line contacts force line)

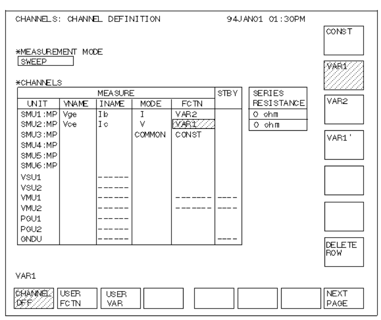
Sweep Measurements

This section describes the sweep measurement tasks.

The basic procedure to test your DUT is as follows:

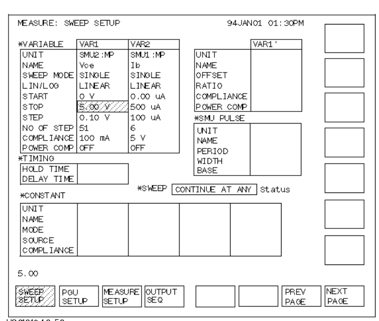


1. Connecting your DUT to the 4155B/4156B. See “Connecting DUT” on page 4-3 for procedures.



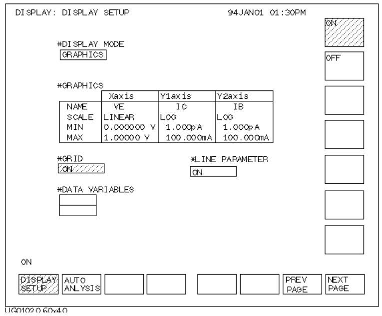
2. Defining measurement mode and measurement units that you use to make measurement.
The following tasks are described:

- “To Define Measurement Units”
- “To Define a User Function”
- “To Use R-Box”

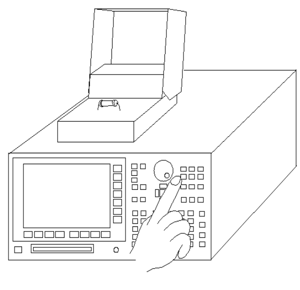


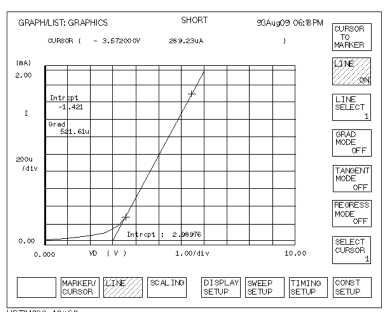
3. Setting the source parameters of the units. The following tasks are described:

- “To Set up Primary Sweep”
- “To Set up Secondary Sweep”
- “To Set up Synchronous Sweep”
- “To Set up Constant Output”
- “To Set up SMU Pulsed Output”
- “To Set up PGU Output”

<table>
<tr>
<td>


</td>
<td>4. Setting the display mode to show measurement results.
The following tasks are described:

• “To Display Graphics Results”
• “To Display List Results”</td>
</tr>
<tr>
<td>

</td>
<td>5. Executing the measurement.
The following tasks are described:

• “To Use Standby Function”
• “To Execute Calibration”
• “To Use Offset Cancel Function”
• “To Execute or Stop Measurement”</td>
</tr>
<tr>
<td>


</td>
<td>Results.
For example, displayed graphically.</td>
</tr>
</table>

To Define Measurement Units

Press Chan front-panel key to define the measurement units. CHANNELS: CHANNEL DEFINITION screen is displayed.

1. MEASUREMENT MODE:

   Select SWEEP secondary softkey for sweep measurement.

2. VNAME:

   Enter a unique name for voltage variable. For example, enter `Vce` for collector-emitter voltage. If channel does neither V force nor V measurement, you can omit VNAME.

3. INAME:

   Enter a unique name for current variable. For example, enter `Ic` for collector current. If channel does neither I force nor I measurement, you can omit INAME.

4. MODE:

   Select one of the following softkeys to set the output mode:

   - V : Voltage output (for SMU, VSU, and PGU, and grounded mode of VMU).
   - I : Current output (for SMU).
   - VPULSE : Pulsed voltage output (for SMU and PGU).
   - IPULSE : Pulsed current output (for SMU).
   - COMMON : Circuit common (for SMU and GNDU).
   - DVOLT : Differential voltage measurement (for VMU).

5. FCTN:

   Select one of the following softkeys to set the output function:

   - CONST : Constant output function (for SMU, VSU, and PGU).
   - VAR1 : Primary sweep output function (for SMU and VSU).
   - VAR2 : Secondary sweep output function (for SMU and VSU).
   - VAR1' : Synchronous sweep output function (for SMU and VSU).

VNAME and INAME

You can use VNAME and INAME names in user function definitions or for analysis on the GRAPHICS/LIST screens. These names must be 6 or less alphanumeric characters. First character must be alphabet character.

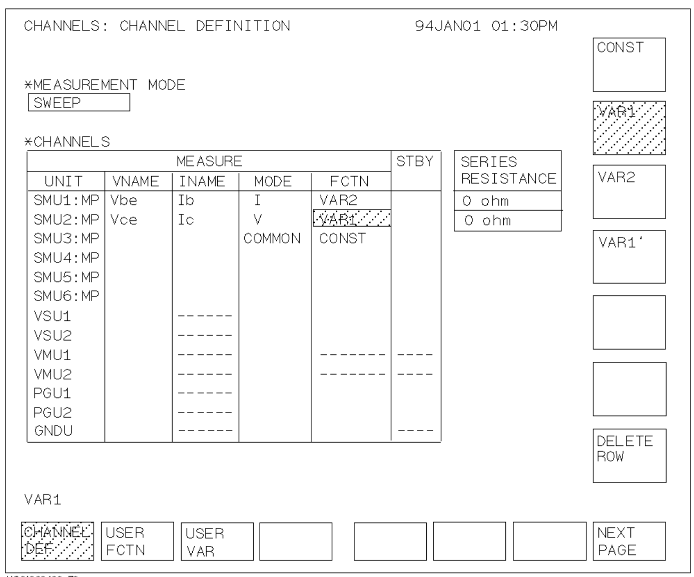
To disable a unit

Select DELETE ROW softkey. The settings for the unit are deleted.

Example

The following settings show an example for measuring an n-p-n transistor's I-V characteristics. SMU1 is connected to base, SMU2 is connected to collector, and SMU3 is connected to emitter. SMU1 is set to current source (I mode) and secondary sweep (VAR2) function. SMU2 is set to voltage source (V mode) and primary sweep (VAR1) function. SMU3 is set to COMMON.

Example: Channel Definition: Sweep Measurement



UG01002,100x70

To Set up Primary Sweep

Primary sweep source is the measurement unit defined as VAR1 in the CHANNELS: CHANNEL DEFINITION screen. To set up the primary sweep source, press Meas front-panel key. The MEASURE: SWEEP SETUP screen is displayed.

1. VAR1 : SWEEP MODE

   Select one of the following softkeys to set the sweep mode:

   - SINGLE : single sweep mode.
   - DOUBLE : double sweep mode.

2. VAR1 : LIN/LOG

   Select one of the following softkeys to set the sweep step mode:

   - LINEAR : linear step mode.
   - LOG XX : logarithmic step mode. XX specifies the number of steps per decade. XX is 10, 25, or 50.

3. VAR1 : START

   Enter the sweep start value.

4. VAR1 : STOP

   Enter the sweep stop value.

   If you select LOG sweep step mode, the polarity of stop value must be same as the polarity of start value.

5. VAR1 : STEP

   If you select LINEAR sweep step mode, enter the sweep step value. This field is not available for the LOG mode.

6. VAR1 : COMPLIANCE, POWER COMPLIANCE

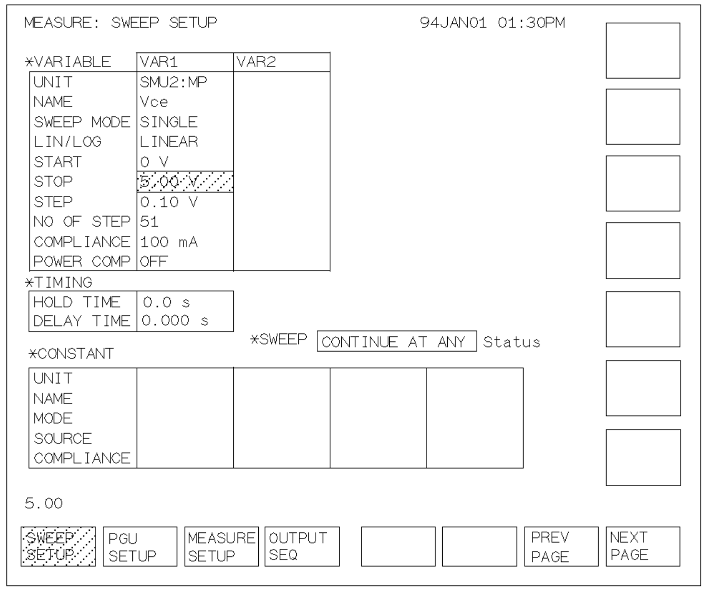
   Only for SMU. Enter the compliance value, and power compliance (ON or OFF) for the primary sweep source.

NO OF STEP is automatically calculated from START, STOP, and STEP values.

You cannot change UNIT and NAME in this screen. To change the values, go to the CHANNELS: CHANNEL DEFINITION screen.

Example

The following example shows the primary sweep conditions (VAR1 parameters):



UG01003,90x70

To Set up Secondary Sweep

Secondary sweep source is the measurement unit defined as VAR2 in the CHANNELS: CHANNEL DEFINITION screen. On the MEASURE: SWEEP SETUP screen, set up the primary sweep source (VAR1), then do following:

1. VAR2: START

   Enter the secondary sweep start value.

2. VAR2: STEP

   Enter the secondary sweep step value.

3. VAR2: NO OF STEP

   Enter the number of steps for the secondary sweep.

4. VAR2 : COMPLIANCE, POWER COMPLIANCE

   Only for SMU. Enter the compliance value, and power compliance (ON or OFF) for the secondary sweep source.

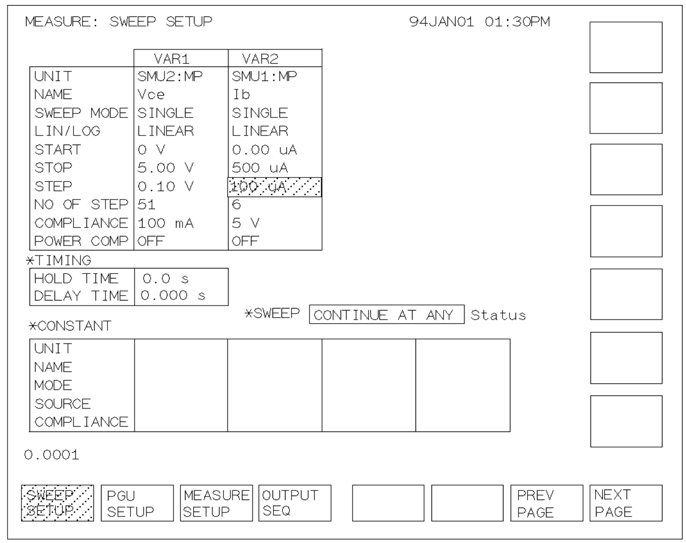
SWEEP MODE and LIN/LOG are automatically set to SINGLE and LINEAR, respectively. You cannot change the settings.

The STOP value is automatically calculated from START, STEP, and NO OF STEP values.

You cannot change UNIT and NAME in this screen. To change the values, go to the CHANNELS: CHANNEL DEFINITION screen.

Example

The following example shows the secondary sweep conditions (VAR2 parameters):



UG01004,90x70

To Set up Synchronous Sweep

Synchronous sweep source is the measurement unit defined as VAR1’ in the CHANNELS: CHANNEL DEFINITION screen. VAR1’ is available for the measurement units set to the output mode same as the VAR1 output mode. The output value of VAR1' is calculated by the following equation:

VAR1' = VAR1 × RATIO + OFFSET

On the MEASURE: SWEEP SETUP screen, set up the primary sweep source (VAR1), then do following:

1. VAR1’ : OFFSET

   Enter the offset value of the VAR1’ output against the VAR1 output.

2. VAR1’ : RATIO

   Enter the ratio value of the VAR1’ output against the VAR1 output.

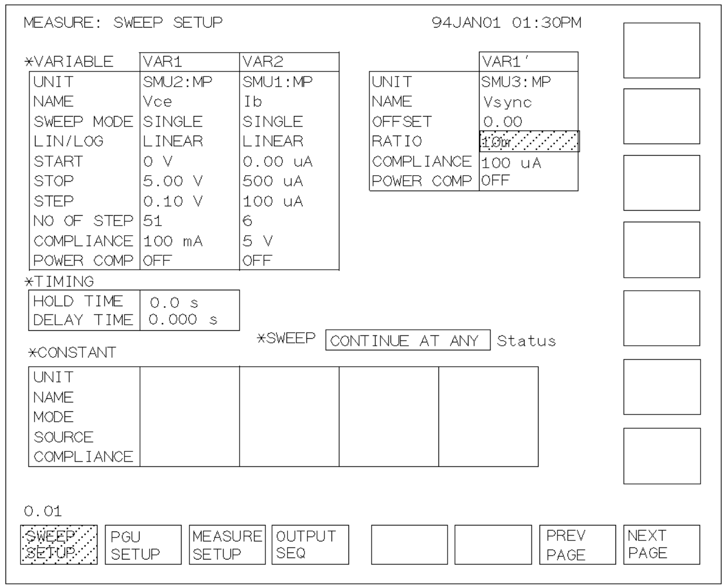
3. VAR1’ : COMPLIANCE, POWER COMPLIANCE

   Only for SMU. Enter the compliance value, and power compliance (ON or OFF) for the synchronous sweep source.

You cannot change UNIT and NAME in this screen. To change the values, go to the CHANNELS: CHANNEL DEFINITION screen.

Example

The following example shows the synchronous sweep conditions (VAR1' parameters):



UG01005,90x70

To Set up Constant Output

Constant voltage/current source is the measurement unit defined as CONST in the CHANNELS: CHANNEL DEFINITION screen. To set up the constant output source, press Meas front-panel key. The MEASURE: SWEEP SETUP screen is displayed.

1. CONSTANT : SOURCE

   Enter the desired output value of the constant source.

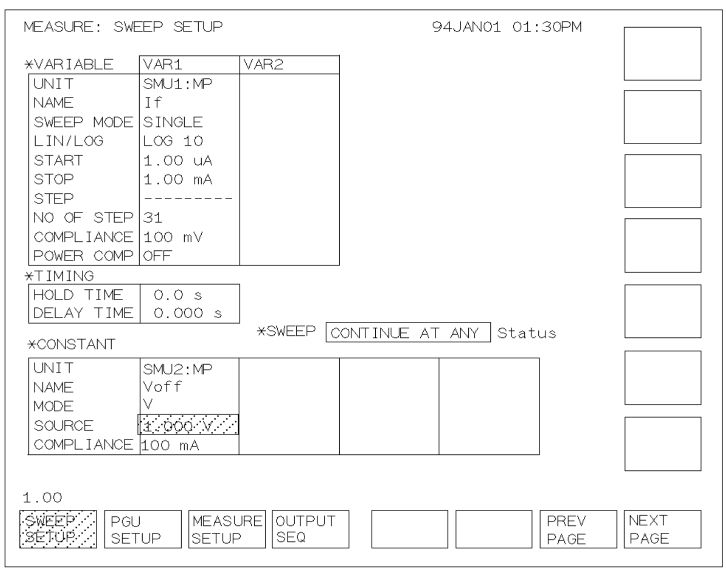
2. CONSTANT : COMPLIANCE

   Only for SMU. Enter the compliance value for the constant source.

You cannot change UNIT, NAME, and MODE in this screen. To change the values, go to the CHANNELS: CHANNEL DEFINITION screen.

Example

The following example shows the constant output conditions (CONSTANT parameters):



UG01006,90x70

To Set up SMU Pulsed Output

SMU pulse output source is the measurement unit defined as VPULSE or IPULSE in the CHANNELS: CHANNEL DEFINITION screen. For pulsed sweep source, set the function (FCTN) to VAR1, VAR2, or VAR1'. For pulsed constant source, set the function to CONST. To set up the SMU pulse output source, press Meas front-panel key. The MEASURE: SWEEP SETUP screen is displayed.

1. Set the source output parameters:
   - For VAR1, refer to "To Set up Primary Sweep" on page 4-14.
   - For VAR2, refer to "To Set up Secondary Sweep" on page 4-16.
   - For VAR1', refer to "To Set up Synchronous Sweep" on page 4-18.
   - For CONST, refer to "To Set up Constant Output" on page 4-20.
2. SMU PULSE: PERIOD

   Enter the pulse period value.
3. SMU PULSE: WIDTH

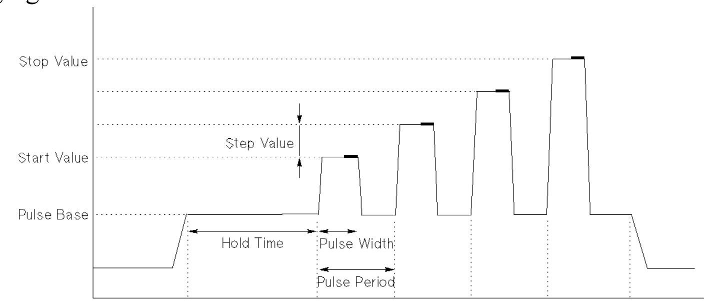
   Enter the pulse width value.
4. SMU PULSE: BASE

   Enter the pulse base value.

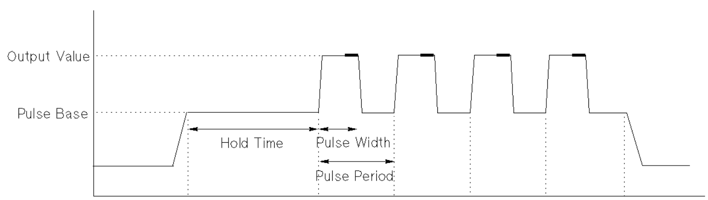
You cannot change UNIT and NAME in this screen. To change the values, go to the CHANNELS: CHANNEL DEFINITION screen.

Pulse Parameters

The relation between the PERIOD, WIDTH, and BASE values are as shown in the following figures.



(a) For Pulsed Sweep Source



(b) For Pulsed Constant Source

SMU outputs the pulses as shown in figure (a) or figure (b).

- Figure (a)

  When the function (FCTN) is set to VAR1, VAR2, or VAR1'.

  The pulse peak values are the sweep output values calculated from the sweep start, stop, step values, and so on.

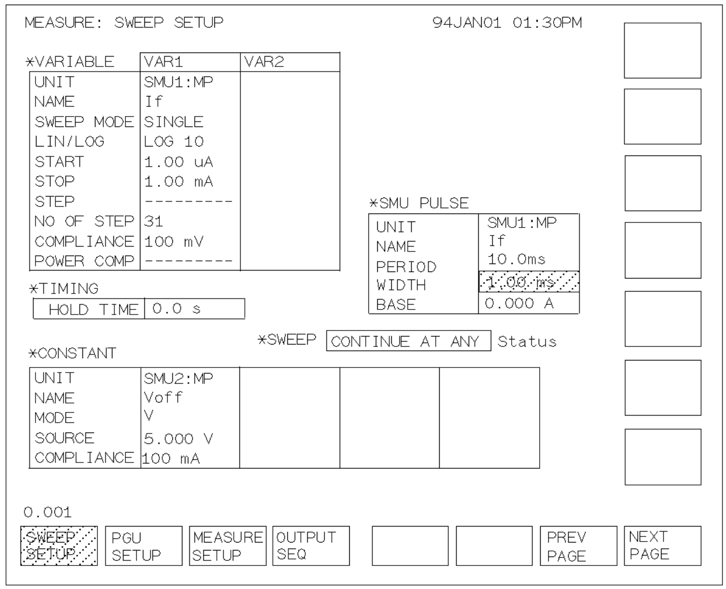
- Figure (b)

  When the function (FCTN) is set to CONST.

  The pulse peak value is the output value of the constant output source.

Example

The following shows an example setup of SMU pulsed output on the MEASURE: SWEEP SETUP screen.

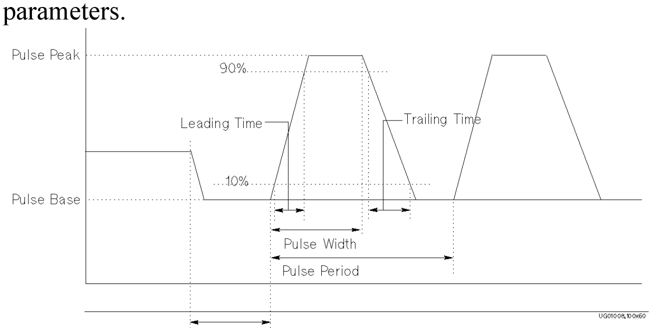


UG01039,90x70

To Set up PGU Output

1. Define PGU to be VPULSE and CONST as described in "To Define Measurement Units" on page 4-12.
2. Press Meas key in the PAGE CONTROL key group.
3. Select PGU SETUP primary softkey.
4. In the PERIOD field of PGU1, enter the pulse period value.
5. In the WIDTH field of desired PGU column, enter the pulse width value.
6. In the DELAY TIME field of desired PGU column, enter delay time value.
7. In the PEAK VALUE field of desired PGU column, enter pulse peak value.
8. In the BASE VALUE field of desired PGU column, enter pulse base value.
9. In the LEADING TIME field of desired PGU column, enter the leading-edge transition time.
10. In the TRAILING TIME field of desired PGU column, enter the trailing-edge transition time.
11. In the IMPEDANCE field of desired PGU column, select:
    - LOW secondary softkey for approximately zero ohm output impedance.
    - 50 ohm secondary softkey for 50 ohm output impedance.
12. In the PULSE COUNT field, do one of the following:
    - Select FREE RUN secondary softkey to force the pulse continuously.
    - Or enter the number of pulses to output (for sampling measurement only).

For the pulse period and pulse count values, the values you set for PGU1 are also used for PGU2. The following figure shows the relation between pulse waveform and setup parameters.



To modify the UNIT and NAME fields

Modify the UNIT and NAME fields on the CHANNELS: CHANNEL DEFINITION screen.

Using PGUs as constant voltage source

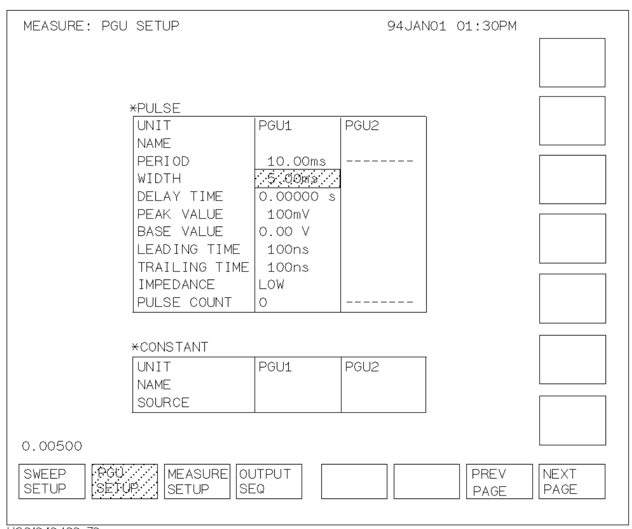
To use a PGU as a constant voltage source, set the desired PGU as follows:

- V in MODE column on the CHANNEL DEFINITION screen
- Desired output voltage value in SOURCE field on MEASURE: PGU SETUP screen.

Example

The following example shows setup of PGU pulsed output on the MEASURE: PGU SETUP screen.

You cannot set compliance for a PGU, which has a 100 mA current limit.



UG01040,100x70

To Use Standby Function

1. Press Chan key in the PAGE CONTROL key group.
2. Select CHANNEL DEF primary softkey.
3. In the STBY column of the desired unit, select STANDBY ON secondary softkey.
4. Press Standby key in the MEASUREMENT key group.

The indicator above the Standby key shows whether the Standby function is enabled. If this indicator is ON, then for the units that you selected STANDBY ON, the units have the following output value during the Standby state (that is, before and after measurements or stress):

Function of a Unit	Output during Standby State
VAR1	VAR1 Start value
VAR1'	Ratio × Start + Offset
VAR2	VAR2 Start value
CONSTANT	Output value

For sampling measurements, only the CONSTANT function is available.

From Standby state, you can execute measurements or force stress by pressing Single, Repeat, Append, or Stress key. After measurement or stress, the STANDBY ON units are returned to same output value as before measurement or stress.

If Standby indicator is ON, then pressing the Standby key disables the Standby function, and Standby output stops. Pressing the Stop key has no affect on the Standby state.

To Define a User Function

1. Press Chan key in the PAGE CONTROL key group.
2. Select USER FCTN primary softkey.
3. In the NAME column, enter the user function name.
4. In the UNIT column, enter the units.
5. In the DEFINITION column, enter the user function definition.

The user function name must be 6 or less alphanumeric characters. First character must be alphabet character. Name must be unique. Name is case sensitive. For example, HFE is different from Hfe.

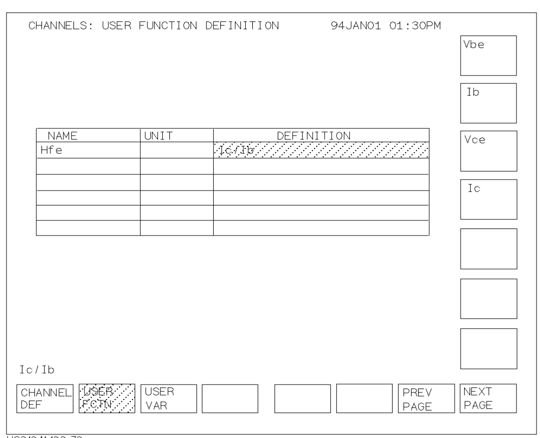
In the user function definition, you can enter an expression that consists of any of the following:

- VNAME and INAME names that you entered on the CHANNELS: CHANNEL DEFINITION screen.
- Other user functions.
- Numerical operators.
- Built-in functions such as `DELTA` and `SQRT`.

For details about expressions, numerical operators, and built-in functions, refer to Chapter 7.

Example

The following figure shows an example setup to define `Hfe`.



To Display Graphics Results

1. Press Display key in the PAGE CONTROL key group.
2. Select DISPLAY SETUP primary softkey.
3. In the DISPLAY MODE field, select GRAPHICS secondary softkey.
4. In the X axis column, enter variable name, select axis scale, and enter minimum and maximum values.
5. In the Y1 axis column, enter variable name, select axis scale, and enter minimum and maximum values.
6. If you use Y2 axis, enter variable name, select axis scale, and enter minimum and maximum values in Y2 axis column.

When the pointer is in the NAME row, the allowable variable names appear in the secondary softkey area. To set a variable name, select the desired secondary softkey. The allowable names are names that you already set up on the CHANNEL DEFINITION, USER FUNCTION, and USER VARIABLE screens.

To display a grid on the plotting area

In GRID field, select ON secondary softkey.

To remove the grid

In GRID field, select OFF secondary softkey.

To control display of line parameters on GRAPHICS screen

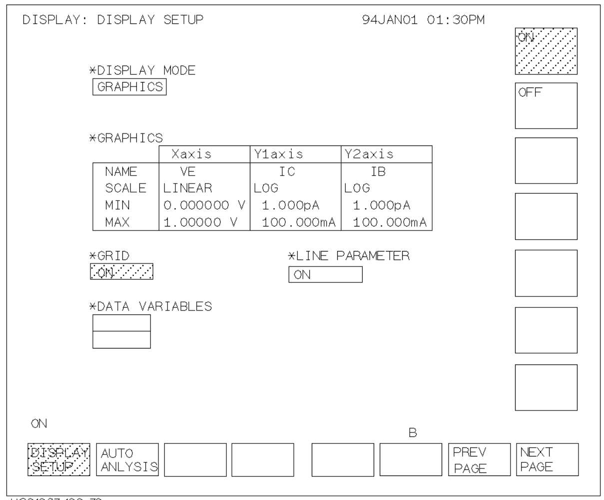
In LINE PARAMETER field, select ON to display or OFF to not display. Line parameters are the X and Y intercepts and gradient of the analysis lines.

To set up variable to be displayed on the GRAPHICS screen

In DATA VARIABLES fields, select secondary softkey for desired variable.

Example

The following figure shows an example to set up both Y1 and Y2 axes, and to set grid to ON.



UG01037,100x70

To Display List Results

1. Press Display key in the PAGE CONTROL key group.
2. Select DISPLAY SETUP primary softkey.
3. In the DISPLAY MODE field, select LIST secondary softkey.
4. In the LIST area, select the secondary softkey of the variables for which you want to list the measurement results.

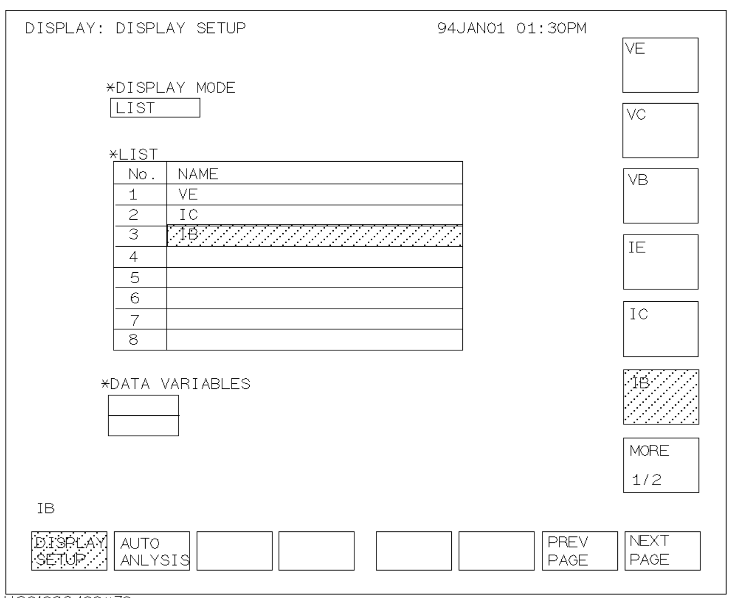
When the pointer is in the NAME row, the allowable variable names appear in the secondary softkey area. To set a variable name, select the desired secondary softkey. The allowable names are names that you already set up on CHANNEL DEFINITION, USER FUNCTION, and USER VARIABLE screens.

To set up variable to be displayed on the LIST page

In DATA VARIABLES fields, select secondary softkey for desired variable.

Example

Following figure is an example setup to display VE, IC, and IB on LIST screen.



UG01038,100*70

To Execute Calibration

To execute all self-calibration test items, perform the following:

1. Press System key in the PAGE CONTROL key group.
2. Select CALIB/DIAG primary softkey.
3. In the SYSTEM: SELF-CALIBRATION/DIAGNOSTICS screen, select CALIB ALL secondary softkey. After the calibration execution, each test result is displayed in each `STATUS` field.

To set auto-calibration

Move the pointer to the `AUTO CALIB` field, then select the ON secondary softkey. Self-calibration is performed automatically every 30 minutes.

Be aware that measurement cannot be performed while calibration is executed.

To Use Offset Cancel Function

1. Press Meas key in the PAGE CONTROL key group.
2. Select MEASURE SETUP primary softkey.
3. In the `ZERO CANCEL` field, select ZERO CANCEL ON/OFF secondary softkey to toggle the zero offset cancel mode between on and off. Then `ON` or `OFF` appear automatically in each unit field depending on the measurement range.
4. Press green key, then Stop key to measure the zero offset data. Then this measured data is used to compensate the measurement results when measurement is performed.

For more details about the zero offset cancel function, refer to “Zero Offset Cancel” in Chapter 3.

To Execute or Stop Measurement

- To execute a measurement, press:
  - Single key in the MEASUREMENT key group for single measurement.
  - Repeat key in the MEASUREMENT key group for repeat measurement.
  - Append key in the MEASUREMENT key group for append measurement.
- To stop a measurement, press Stop key in the MEASUREMENT key group.

Single, Repeat, and Append Measurement

There are three measurement execution modes as follows:

Single measurement Clears GRAPHICS or LIST screen, then executes measurement one time. Measurement results are displayed on GRAPHICS or LIST screen.

Repeat measurement Executes measurements continuously. Before each measurement is executed, the GRAPHICS or LIST screen is cleared. Most recent measurement results are displayed on GRAPHICS or LIST screen.

Append measurement Executes measurement one time. Does *not* clear GRAPHICS or LIST screen. That is, measurement results are added to the existing results.

To Use R-Box

1. Connect the 16441A R-Box to the 4155B/4156B and to the 16442A Test Fixture or connector plate on your shield box. For details about connections, refer to “R-BOX Control” in Chapter 3.
2. Press Chan front-panel key of the PAGE CONTROL key group.
3. Select CHANNEL DEF primary softkey to display the CHANNELS: CHANNEL DEFINITION screen.
4. In the SERIES RESISTANCE fields, select:
   - 0 ohm secondary softkey to connect 0 Ω resistance.
   - 10k ohm secondary softkey to connect 10 kΩ resistance.
   - 100k ohm secondary softkey to connect 100 kΩ resistance.
   - 1M ohm secondary softkey to connect 1 MΩ resistance.

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

The 4155B/4156B automatically compensates for the resistance values.

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.

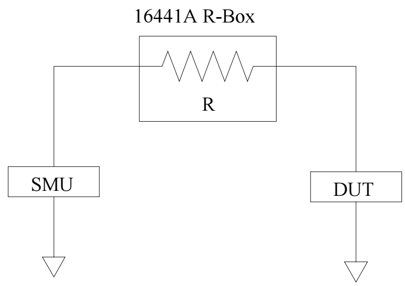
You can set resistance values for the following SMUs.

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

To measure negative resistance characteristics

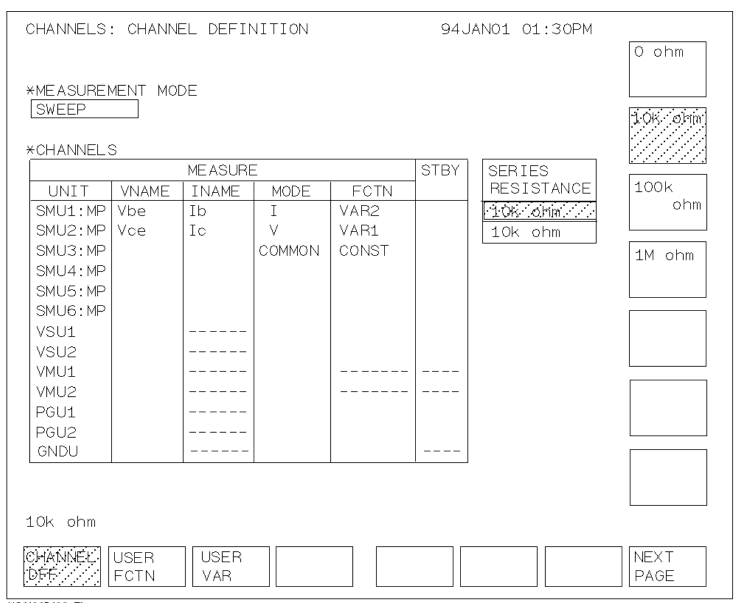
The 16441A R-Box allows SMUs to measure current-controlled negative resistance (1 MΩ) characteristics.

Connect the resistance of the 16441A as shown in following figure.



Example

The following figure shows an example setup to connect 10 kΩ resistance to SMU1 and SMU2.

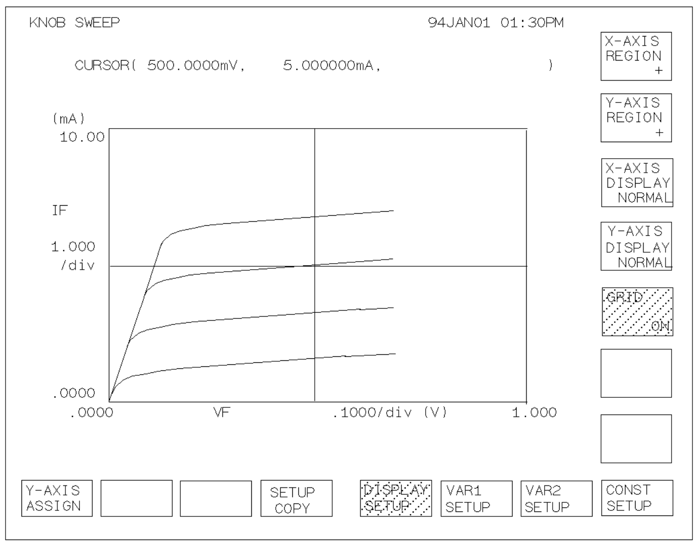


Knob Sweep Measurements

This section covers the following tasks about knob sweep measurements. The knob sweep function is useful in the following cases:

- to determine a parameter value for normal sweep
- to quickly make a rough measurement of a DUT characteristics

The following figure shows the KNOB SWEEP screen.



UGT01034, 100*70

To Execute Knob Sweep Measurement

1. Define the measurement units. See “To Define Measurement Units” on page 4-12. For the knob sweep measurement, note the following:

   - Select SWEEP for the MEASUREMENT MODE field.
   - Do not select VPULSE and IPULSE for the MODE column.
   - Do not select VAR1’ for the FCTN column.

   INAME or VNAME can be set to X or Y axis of knob sweep measurement. User function and the user variables are not available for the knob sweep.

   If you use PGUs, set PGU outputs. See “To Set up PGU Output” on page 4-24.

2. Press the green key, then Single front-panel key. The KNOB SWEEP screen is displayed, and knob sweep measurement starts.

   During measurements, self-test, or forcing stress, this operation is ignored.

   If you want to change the Y-axis parameter, press Stop front-panel key and Y-AXIS ASSIGN primary softkey. Then select a secondary softkey for the Y-axis parameter you want.

   To start knob sweep measurement again, press Single front-panel key only.

3. Rotate the rotary knob to stretch or shrink the sweep range. Knob sweep measurement is executed, and measurement curve appears on the graph.

   To change the measurement conditions, use the following primary softkeys:

Softkey	Description
DISPLAY SETUP	Used to change graph display. The following secondary softkeys are available: **X-AXIS REGION** Selects the X-axis display range from +, –, or +/-. **Y-AXIS REGION** Selects the Y-axis display range from +, –, or +/-. **X-AXIS DISPLAY** Selects the X-axis direction from NORMAL or REVERSE. **Y-AXIS DISPLAY** Selects the Y-axis direction from NORMAL or REVERSE. **GRID** Sets grid on or off.

Softkey	Description	
VAR1 SETUP	Used to change VAR1 sweep source setup. The following secondary softkeys are available:	
	SWEEP MODE	Sets sweep mode to SINGLE or DOUBLE.
	POLARITY	Sets polarity of VAR1 output to POS, NEG, or BIPOLAR.
	VAR1 RANGE	Sets VAR1 sweep range. This sets X-axis scale.
	NO OF STEPS	Sets number of sweep steps.
	COMPLIANCE	Sets VAR1 compliance value. This sets Y-axis scale.
	HOLD TIME	Sets hold time.
	STEP TIME	Sets step time.
VAR2 SETUP	Used to change VAR2 sweep source setup. The following secondary softkeys are available:	
	VAR2 START	Sets VAR2 sweep start value.
	VAR2 STEP	Sets VAR2 sweep steps.
	VAR2 POINTS	Sets number of sweep steps.
	COMPLIANCE	Sets VAR2 compliance value.
CONST SETUP	Used to change CONST source setup. Secondary softkeys are available for selecting CONST source. Select a secondary softkey to change the CONST source output value.	

To copy knob sweep setups

Select SETUP COPY primary softkey. This copies knob sweep setups to the MEASURE: SWEEP SETUP and DISPLAY: DISPLAY SETUP screens. Then you can see the setups on the screens, and use the setups for the *normal* sweep measurement.

Note that the power compliance function is not available for the knob sweep measurement. So the POWER COMP column is set to OFF.

Warning messages

If the CHANNELS or MEASURE screen group have incorrect settings for knob sweep measurements when starting the knob sweep, a warning message is displayed, then the STOP and CONT primary softkeys are available.

Select STOP softkey to know the incorrect setting. The setting is highlighted on the screen.

Select CONT softkey to perform knob sweep measurement with the following settings:

- If VAR1’ function (FCTN) has been set:

  The unit works as CONST channel. The output value is VAR1’ start value.

- If VPULSE or IPULSE mode (MODE) has been set:

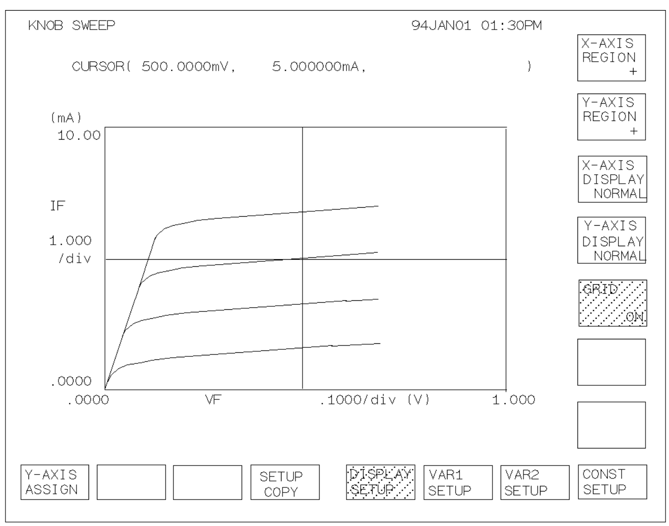
  The unit works as V or I channel.

- If the power compliance function (POWER COMP) has been set:

  The function does not work. Same as POWER COMP = OFF.

Example

The following figure shows an example to set both X axis and Y axis display regions to positive.



UGT01034, 100*70

To Stop Knob Sweep Measurement

To stop the knob sweep measurement, press Stop front-panel key.

This returns the 4155B/4156B operation state to the previous state. For example, if the knob sweep measurement starts from the idle state, the operation state returns to the idle state.

Starting knob sweep again

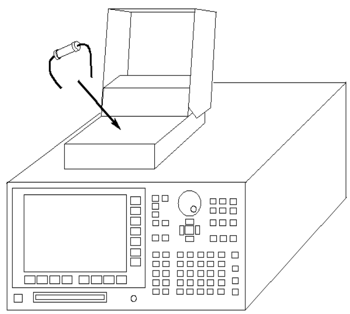
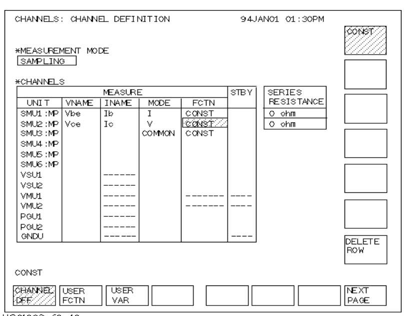
To start the knob sweep measurement again, press the following front-panel key:

Single	The knob sweep measurement will start from the point where it was stopped.
Green, Single	The knob sweep measurement will start from 0 V or 0 A.

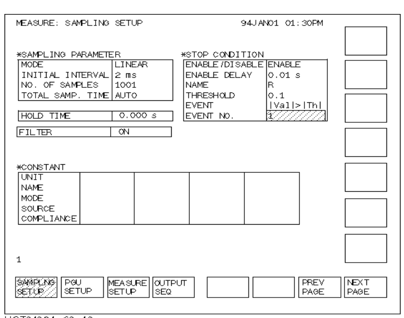
Sampling Measurements

This section covers the tasks for sampling measurements.

The basic procedure to test your DUT is as follows:

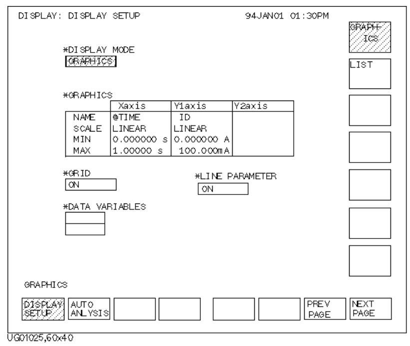
<table>
<tr>
<td></td>
<td>1. Connecting your DUT to the 4155B/4156B. See “Connecting DUT” on page 4-3 for procedures.</td>
</tr>
<tr>
<td>

UG01023, 60x40</td>
<td>2. Defining measurement mode and measurement units that you use to make measurement. The following tasks are described:

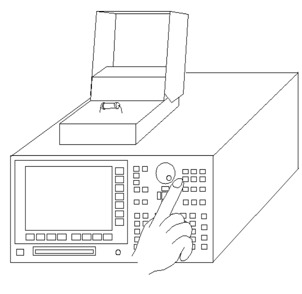
• To Define Sampling Measurement Units.
• To Define a User Function (see previous section)
• To Control R-Box (see previous section)</td>
</tr>
<tr>
<td>

UGT01024, 60x40</td>
<td>3. Setting the source parameters of the units. The following tasks are described:

• To Set up Sampling Parameters
• To Set up Constant Output
• To Define Measurement Stop Conditions
• To Set up PGU Pulsed Output (see previous section)</td>
</tr>
</table>

<table>
<tr>
<td>
</td>
<td>4. Setting the display mode to show measurement results. The following tasks are described:

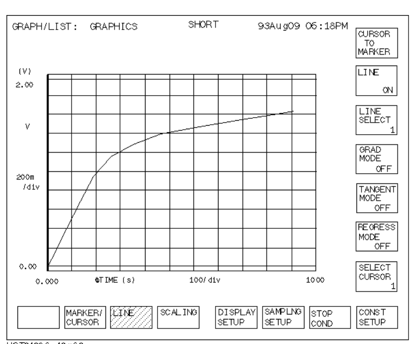
• To Set up Graphical Display of Measurement Results (see previous section)

• To Set up List Display of Measurement Results (see previous section)</td>
</tr>
<tr>
<td></td>
<td>5. Executing the measurement. The following tasks are described:

• To Output Same Value Before and After Measurements (see previous section)

• To Execute Calibration (see previous section)

• To Cancel Zero Offset (see previous section)

• To Execute or Stop Measurement (see previous section)</td>
</tr>
<tr>
<td>
</td>
<td>Results. For example, displayed graphically.</td>
</tr>
</table>

To Define Measurement Units

1. Press Chan key in the PAGE CONTROL key group.
2. Select CHANNEL DEF primary softkey.
3. In the MEASUREMENT MODE area, select SAMPLING secondary softkey.
4. In the VNAME column, enter a unique name for voltage variable. For example, enter `Vce` for collector-emitter voltage. If channel does neither V force nor V measurement, you can omit VNAME.
5. In the INAME column, enter a unique name for current variable. For example, enter "`Ic`" for collector current. If channel does neither I force nor I measurement, you can omit INAME.
6. In the MODE column, select:
   - V secondary softkey for voltage output mode (SMU, VSU, and PGU, and grounded voltage measurement mode of VMU).
   - I secondary softkey for current output mode (SMU).
   - VPULSE secondary softkey for pulsed voltage output mode (PGU).
   - COMMON secondary softkey for circuit common mode (SMU and GNDU).
   - DVOLT secondary softkey for differential voltage measurement mode (VMU).
7. In the FCTN column, select CONST secondary softkey for all source units.

VNAME and INAME

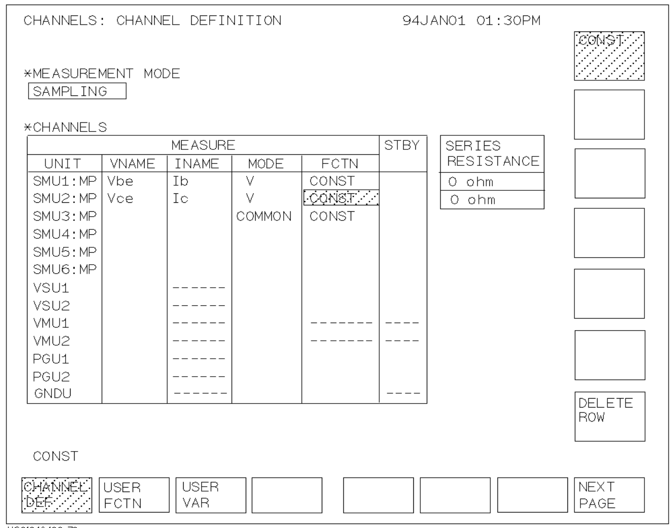
You can use VNAME and INAME in user function definitions or for analysis on the GRAPHICS/LIST screens. These names must be 6 or less alphanumeric characters. First character must be alphabet character.

To disable a unit

Move the pointer to the row of the unit, then select the DELETE ROW secondary softkey. The settings in the row are deleted.

Example

The following figure shows an example setup to define sampling measurement units.



UG01046,100x70

To Set up Sampling Parameters

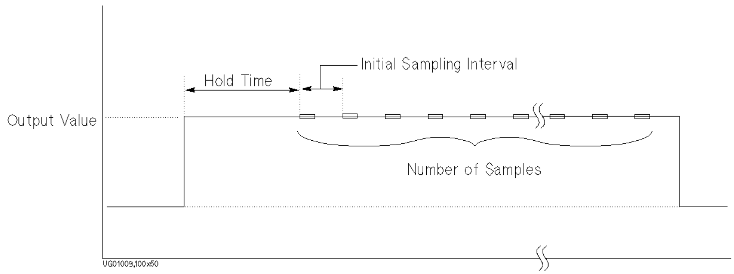
1. Confirm that `SAMPLING` is set in the MEASUREMENT MODE field on the CHANNELS: CHANNEL DEFINITION screen. If `SAMPLING` is not set, select SAMPLING secondary softkey in the MEASUREMENT MODE field.
2. Press Meas key in the PAGE CONTROL key group.
3. Select SAMPLING SETUP primary softkey.
4. In the MODE field of SAMPLING PARAMETER, select:
   - LINEAR secondary softkey for equally spaced sampling intervals.
   - LOG XX secondary softkey for logarithmically spaced sampling intervals. `XX` is 10, 25, or 50 sampling points per decade.
   - THINNED-OUT secondary softkey for reduced sampling interval of more recent samples (by thinning less recent samples).

   For details about sampling mode, see "Sampling Measurement Mode" in Chapter 2.
5. In the INITIAL INTERVAL field, enter a value for the first sampling interval.
6. In the NO. OF SAMPLES field, enter the number of points at which to sample.
7. If you select LINEAR or THINNED-OUT in MODE field, set the TOTAL SAMP. TIME (total sampling time) which specifies the time from the start of sampling to the end. This field is not available for the logarithmic sampling.

   In the TOTAL SAMP. TIME field, enter a value or select:
   - NO LIMIT secondary softkey for excluding the total sampling time from the sampling completion conditions.
   - AUTO secondary softkey for excluding the total sampling time from the sampling completion conditions, and including the number of samples to the completion conditions. This softkey is available only for the linear sampling.

   For details about sampling completion conditions, see "To Define Stop Conditions" on page 4-47.

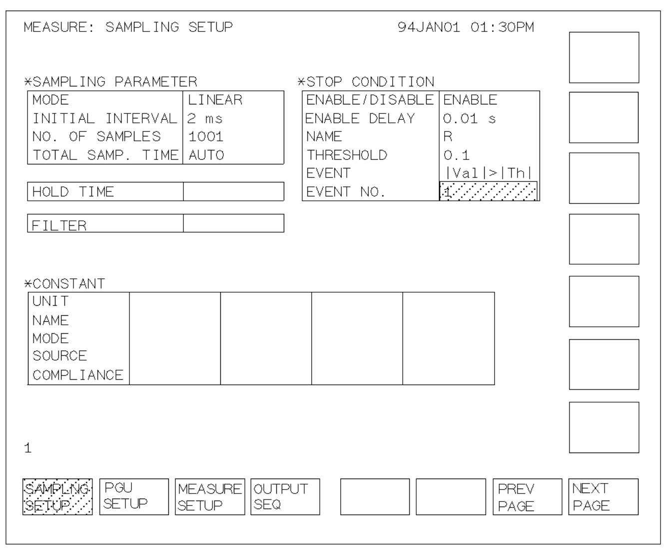
The following figure shows the relation between the sampling parameters and sampling measurement.



You can set a hold time by entering a number (units: seconds) in the HOLD TIME field.

Example

The following figure shows example setup of the sampling parameters.



UGT01043,100x70

To Set up Constant Output

1. Define CONST units as described in “To Define Measurement Units” on page 4-42.
2. Press Meas key in the PAGE CONTROL key group.
3. Select SAMPLNG SETUP primary softkey.
4. In the SOURCE field of the desired unit in the CONSTANT area, enter the desired output value.

To modify the UNIT, NAME, and MODE field

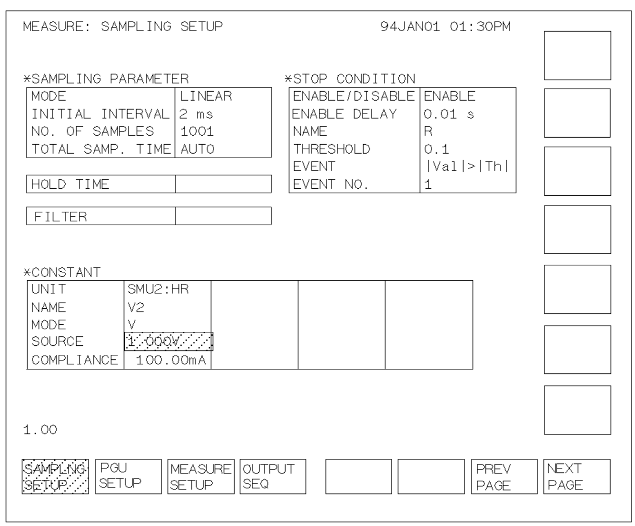
Modify the UNIT, NAME, and MODE fields on the CHANNELS: CHANNEL DEFINITION screen.

To set up compliance value for constant output

Set desired value in the COMPLIANCE field of the CONSTANT table. For details about compliance, see “Compliance” in Chapter 3.

Example

The following example shows the constant output conditions:



UGT01047,100x70

To Define Stop Conditions

The measurement stop condition defines the condition to stop the sampling measurement. The stop condition is one of the sampling completion conditions. For the sampling completion conditions, see “Sampling Measurement Mode” in Chapter 2.

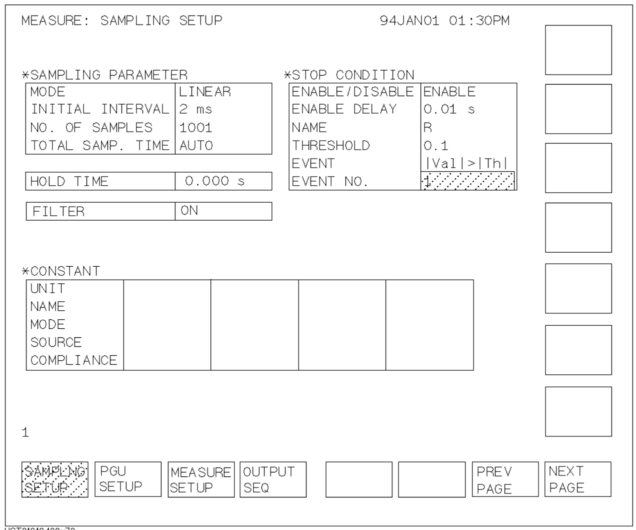
1. Press Meas key in the PAGE CONTROL key group.
2. Select SAMPLNG SETUP primary softkey.
3. In the ENABLE/DISABLE field of the STOP CONDITION area, select ENABLE secondary softkey.
4. In NAME field of STOP CONDITION area, select the secondary softkey for the desired variable name or user function name to be used for EVENT comparison.
5. In THRESHOLD field of STOP CONDITION area, enter the threshold value for the name selected in the previous step.
6. In EVENT field of STOP CONDITION area, select:
   - Val > Th secondary softkey to stop the sampling when the sampled value is greater than the threshold value.
   - Val < Th secondary softkey to stop the sampling when the sampled value is less than the threshold value.
   - |Val| > |Th| secondary softkey to stop the sampling when the absolute sampled value is greater than the absolute threshold value.
   - |Val| < |Th| secondary softkey to stop the sampling when the absolute sampled value is less than the absolute threshold value.
7. In EVENT NO. field, enter a value which specifies the sampling to stop when EVENT occurs EVENT NO. times.

If you select DISABLE in the ENABLE/DISABLE field, the sampling measurement continues until:

- Stop key in the MEASUREMENT key group is pressed.
- Specified total sample time has elapsed.
- The 4155B/4156B receives GPIB command to stop sampling.
- An emergency condition occurs on the 4155B/4156B.
- Interlock terminal opens due to high voltage. (See Chapter 2 of *User's Guide General Information*.)

Example

The following figure shows an example setup of stop condition.



UGT01010,100x70

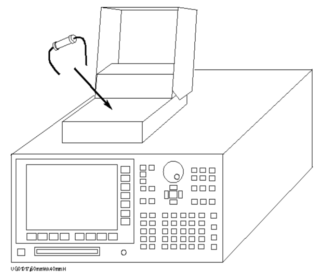
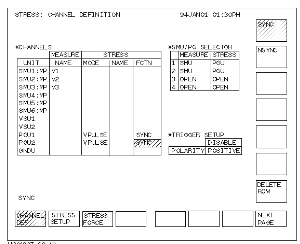
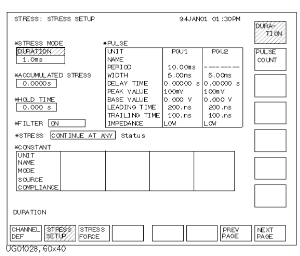
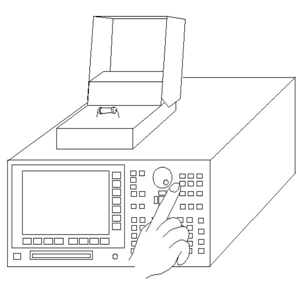
Stress Force

This section covers the tasks for stress forcing.

Two types of stress can be forced by the 4155B/4156B:

- *dc stress*
  - Dc voltage stress can be forced from SMUs, VSUs, or PGUs.
  - Dc current stress can be forced from SMUs.
- *ac stress* (also called *pulsed stress*)
  - Ac voltage stress can be forced from PGUs.
  - Ac current stress *cannot* be forced from the 4155B/4156B.

The following illustrates the basic procedures for stress forcing.

	1. Connecting your DUT to the 4155B/4156B. See “Connecting DUT” on page 4-3 for procedures.
	2. Defining the stress units and constant output units. The following tasks are described: • “To Set up Stress Source Channels” on page 4-51 • “To Use Selector” on page 4-60
	3. Setting the stress forcing parameters and constant output value. The following tasks are described: • “To Set up Stress Condition/Timing” on page 4-53 • “To Set up ac (Pulse) Output” on page 4-55 • “To Set up dc Output” on page 4-57
	4. Executing the stress forcing. The following task is described in “To Force Stress” on page 4-58.

To Set up Stress Source Channels

1. Press Stress key in the PAGE CONTROL key group.
2. Select CHANNEL DEF primary softkey.
3. In the MODE field of desired unit in CHANNELS area, select:
   - V secondary softkey for dc voltage stress forcing mode (SMU, VSU, and PGU).
   - I secondary softkey for dc current stress forcing mode (SMU).
   - VPULSE secondary softkey for ac voltage stress forcing mode (PGU).
   - COMMON secondary softkey for circuit common (SMU and GNDU).
4. In the NAME field of desired unit in the CHANNELS area, enter the stress channel name.
5. In the FCTN field of units that will be stress force channels, select SYNC secondary softkey.

The stress channel name is only used for reference on the STRESS SETUP screen, not on any results screen. So, you can omit the name if desired.

In the FCTN column, you can set up to four units to SYNC. At least one unit must be set to SYNC in the FCTN column. The SYNC (stress force) units all start forcing stress at the same time. The NSYNC (non-stress force units) channels start forcing stress in sequence when state changes to stress force state. For this timing, see “Stress Force Sequence” in Chapter 3.

If the row of a unit does not have settings, the unit is not used.

To disable a unit

In the row of the unit, select the DELETE ROW secondary softkey. The settings in the row are deleted.

To set up non-stress output channels

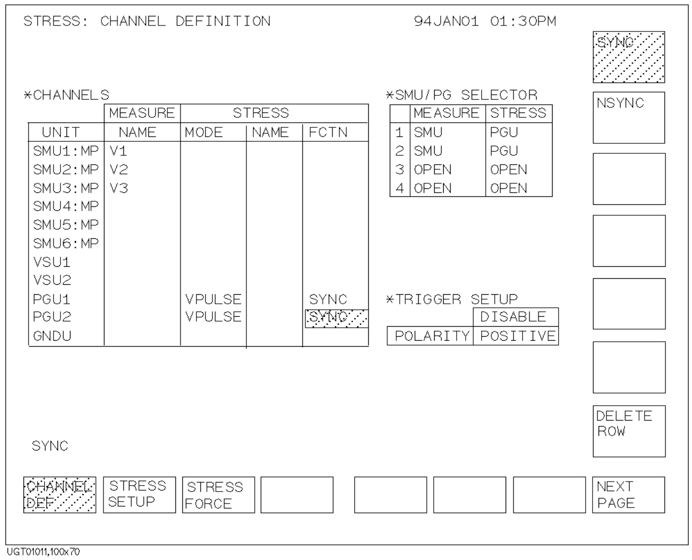
Perform the following procedure.

1. Perform first 3 steps described above.
2. In the FCTN field, select NSYNC secondary softkey.

If you use two PGUs as pulsed sources (`VPULSE`), both must be `SYNC` or both `NSYNC`.

Example

The following figure shows an example setup to set two PGUs to ac stress source.



To Set up Stress Condition/Timing

1. Press Stress key in the PAGE CONTROL key group.
2. Select STRESS SETUP primary softkey.
3. In the MODE field of the STRESS MODE area, select:
   - DURATION secondary softkey to specify how long to force stress.
   - PULSE COUNT secondary softkey to specify how many pulses to output for force stress (for ac stress only).
4. In the DURATION or PULSE COUNT field, enter the duration or pulse count. You can select FREE RUN secondary softkey to output stress continuously.
5. In the `STRESS Status` field, select:
   - CONT AT ANY secondary softkey to continue forcing the stress even if an abnormal status occurs.
   - STOP AT ANY ABNORM secondary softkey to stop forcing the stress when any abnormal status occurs.
   - STOP AT COMPLIANCE secondary softkey to stop forcing the stress only when 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.

In the duration mode, you set time (in seconds) for stress forcing. In the pulse count mode, you set an integer to specify how many pulses to output for stress forcing.

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.

To set hold time

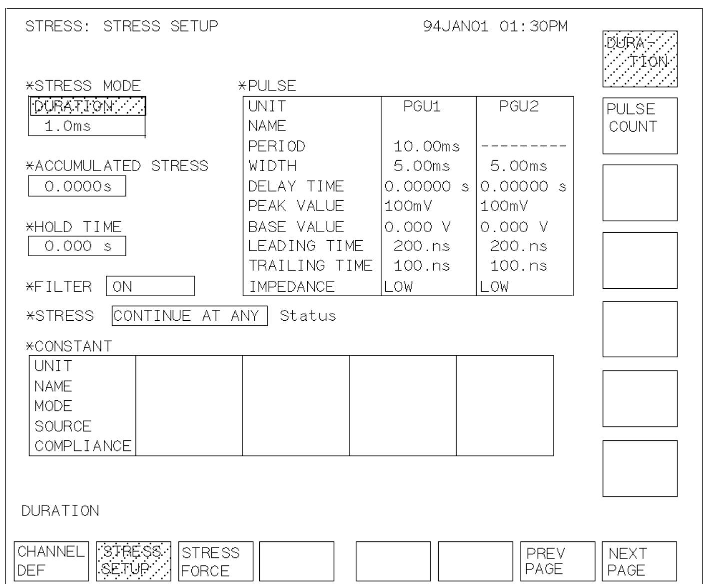
In the HOLD TIME field, set desired value. For the meaning of hold time, see “Stress Force Sequence” in Chapter 3.

Setting the Accumulated Stress Time

The ACCUMULATED STRESS field shows the total stress that has been forced. If necessary, you can change the value in this field. If so, the ACCUMULATED STRESS field on the STRESS: STRESS FORCE screen also changes to the new value.

Example

The following figure shows an example setup of stress condition.



UG01012, 100x70

To Set up ac (Pulse) Output

1. Press the Stress key in the PAGE CONTROL key group. Confirm that the following is set on the STRESS: CHANNEL DEFINITION screen for the *PGUs* that you want to set up for ac stress:
   - `VPULSE` is set in the MODE field.
   - `SYNC` is set in the FCTN field.
2. Select STRESS SETUP primary softkey.
3. In the PERIOD field, enter the pulse period.
4. In the WIDTH field, enter the pulse width.
5. In the DELAY TIME field, enter the delay time, which is the time from the stress start to the beginning of the pulse leading edge. See “Delay time” on page 4-56.
6. In the PEAK VALUE field, enter the pulse peak value.
7. In the BASE VALUE field, enter the pulse base value.
8. In LEADING TIME field, enter the leading-edge transition time of pulse.
9. In TRAILING TIME field, enter the trailing-edge transition time of pulse.

The same period you set for PGU1 is also used for PGU2. For the other parameters, you can set different values for PGU1 and PGU2.

To set other areas of the STRESS: STRESS SETUP screen, see “To Set up Stress Condition/Timing” on page 4-53.

To modify the UNIT and NAME fields

Modify UNIT and NAME fields on STRESS: CHANNEL DEFINITION screen.

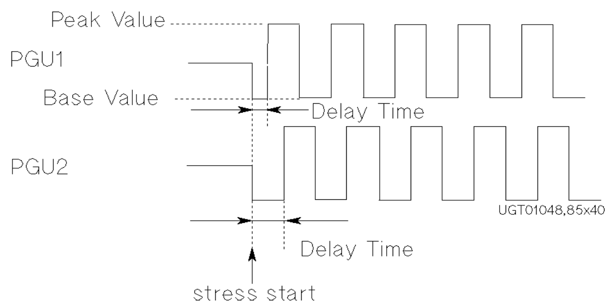
To set output impedance of PGU1 or PGU2

In the IMPEDANCE field, select:

- LOW secondary softkey to set output impedance to low (approximately zero).
- 50 ohm secondary softkey to set output impedance to 50 Ω.

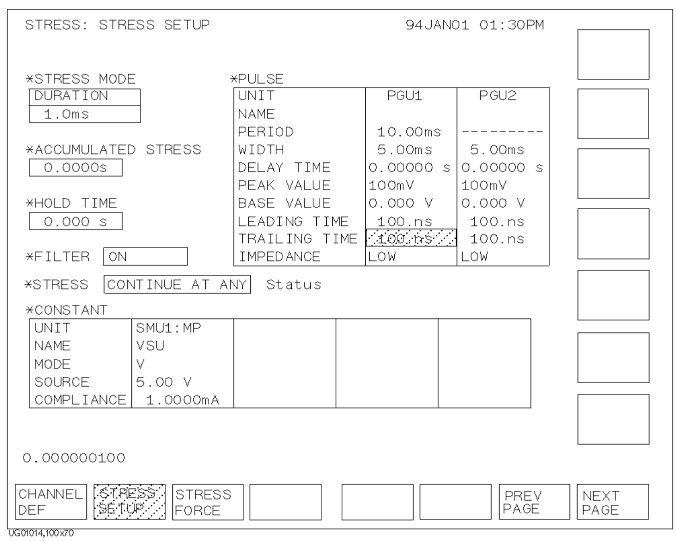
Delay time

The following figure shows the meaning of delay time.



Example

The following figure shows an example to set up ac stress.



To Set up dc Output

1. Press Stress key in the PAGE CONTROL key group. Confirm that the following is set on the STRESS: CHANNEL DEFINITION screen for the units that you want to set up for dc stress:
   - `V` or `I` is set in the MODE field.
   - `SYNC` is set in the FCTN field.
2. Select STRESS SETUP primary softkey.
3. In the SOURCE field for the desired unit in the CONSTANT area, enter the desired dc stress value.
4. In the COMPLIANCE field in the CONSTANT area, enter the compliance value.

The non-stress (`NSYNC`) constant units also appear in the CONSTANT area. You can set SOURCE and COMPLIANCE values for these units the same way as you set the dc stress units.

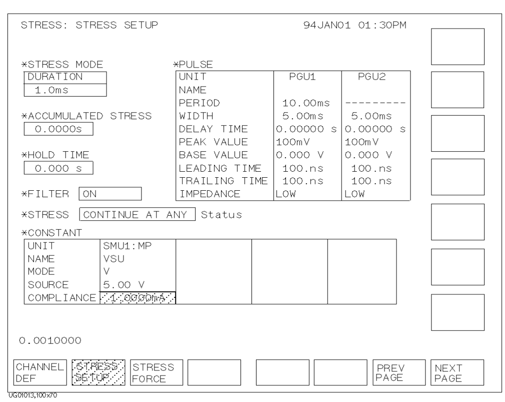
To set other areas of the STRESS: STRESS SETUP screen, see "To Set up Stress Condition/Timing" on page 4-53.

To modify the UNIT, NAME, and MODE fields

Modify the UNIT, NAME, and MODE fields on the STRESS: CHANNEL DEFINITION screen.

Example

The following figure shows an example setup to set source (SMU1) to 5.00 V and compliance (SMU1) to 1.00 mA.



To Force Stress

Press Stress key in the MEASUREMENT key group.

The STRESS area shows the specified stress duration time. Even if you set STRESS MODE to PULSE COUNT, the stress duration time is calculated and shown in seconds.

The ACCUMULATED STRESS area shows the total stress that has already been forced.

To change the stress time (duration mode)

Select CHANGE DURATON secondary softkey, then enter desired value.

The CHANGE DURATON secondary softkey is displayed only if the DURATION mode is selected on the STRESS: STRESS SETUP screen.

To change pulse count (pulse count mode)

Select CHANGE PLS CNT secondary softkey, then enter desired value.

The CHANGE PLS CNT secondary softkey is displayed only if the PULSE COUNT mode is selected on the STRESS: STRESS SETUP screen.

To reset STATUS value to 0 s and 0 %

Select RESET STATUS secondary softkey.

To reset ACCUMULATED STRESS value to 0 s

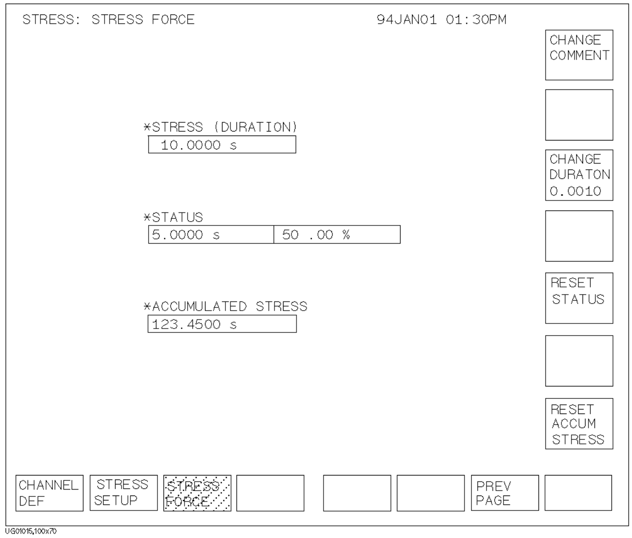
Select RESET ACCUM STRESS secondary softkey.

To change ACCUMULATED STRESS value

On the STRESS: STRESS SETUP screen, enter the desired value in the ACCUMULATED STRESS field.

Example

The following figure shows an example of STRESS: STRESS FORCE screen.



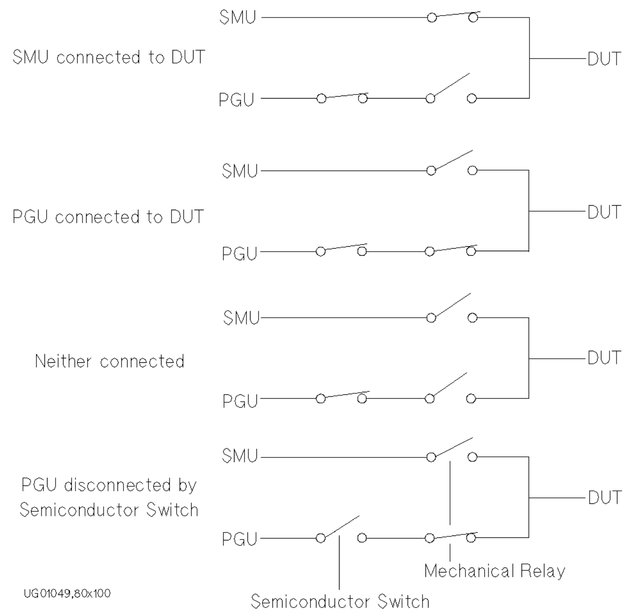
To Use Selector

1. Press Stress key in the PAGE CONTROL key group.
2. Select CHANNEL DEF primary softkey.
3. In the MEASURE field of the desired channel in the SMU/PG SELECTOR area, select:
   - SMU secondary softkey to connect SMU to DUT during measurement state.
   - PGU secondary softkey to connect PGU to DUT during measurement state.
   - OPEN secondary softkey to disconnect SMU, PGU, and DUT during measurement state.
   - PGU OPEN secondary softkey to disconnect PGU from DUT by semiconductor switch during measurement state.
4. In the STRESS field of the desired channel in the SMU/PG SELECTOR area, select:
   - SMU secondary softkey to connect SMU to DUT during stress force state.
   - PGU secondary softkey to connect PGU to DUT during stress force state.
   - OPEN secondary softkey to disconnect SMU, PGU, and DUT during stress force state.
   - PGU OPEN secondary softkey to disconnect PGU from DUT by semiconductor switch during stress force state.

SMU/Pulse Generator Selector

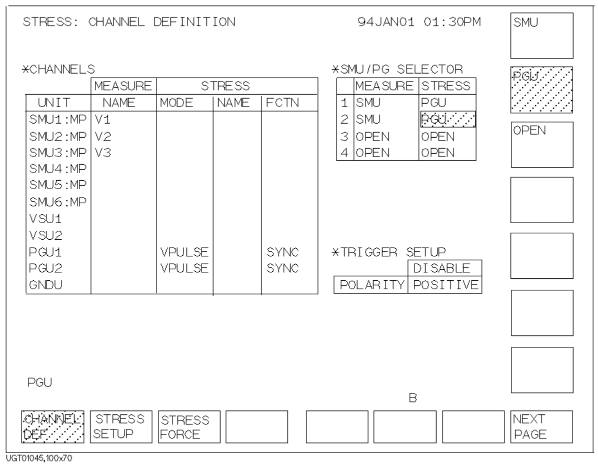
The selector has two types of switches: relay switch and semiconductor switch.

Normally, the relay switch has three states: SMU is connected to DUT, PGU is connected to DUT, and neither is connected to DUT. The semiconductor switch, which is in the PGU line, is used for high-speed switching.



Example

Following shows an example setup that connects two SMUs to DUT during measurement state, and connects two PGUs to DUT during stress force state.



5 Analyzing Measurement Results

Agilent 4155B/4156B can analyze measurement results of the GRAPH/LIST screen group by using lines, markers, and cursors. You can perform manual or automatic analysis.

For automatic analysis function, you set up the DISPLAY: ANALYSIS SETUP screen before starting measurements. Then, after the measurements are performed, the lines and markers are positioned automatically according to the setup.

The information about these functions is organized into the following two sections:

- "Manual Analysis"
- "Automatic Analysis"

For details about line modes and specifying points, refer to Chapter 7. Also, see "GRAPH/LIST Screen Group" in Chapter 6.

Manual Analysis

You can position lines, markers, and cursors by using front-panel keys, rotary knob, and softkeys.

This section covers the following manual analysis tasks:

To Specify a Measurement Point on Curve

1. Select MARKER/CURSOR primary softkey.
2. Set MARKER secondary softkey to `ON`. Marker and marker coordinates are displayed. Selecting MARKER secondary softkey toggles between `ON` and `OFF`.
3. (if both Y1 and Y2 axis are set up) Select the desired marker (axis) by using AXIS primary softkey. The selected marker is highlighted. Selecting AXIS primary softkey toggles between `Y1` and `Y2`.
4. Rotate the rotary knob to move the marker to desired measurement point.

If both Y1 and Y2 axis are set up, a circle marker (o) is displayed on measurement curve of Y1 axis, and an asterisk marker (*) is displayed on measurement curve of Y2 axis.

The `MARKER` coordinate fields indicate the location of markers. The first, second, and third fields are X, Y1, and Y2 coordinates, respectively. X and Y1 indicate location of marker on Y1 curve. X and Y2 indicate location of marker on Y2 curve.

To turn off markers

Set MARKER secondary softkey to `OFF`.

To move marker to maximum or minimum value of measurement curve

Select MARKER MIN/MAX secondary softkey. The marker searches for minimum or maximum value in measurement order from the present location every time you select the MARKER MIN/MAX secondary softkey.

To move marker to next VAR2 step or append curve

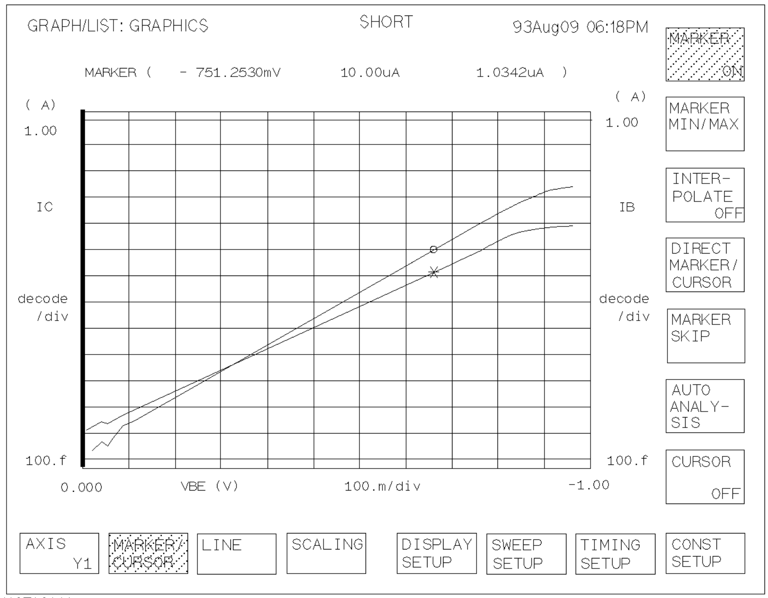
Select MARKER SKIP secondary softkey. Marker moves to next VAR2 step curve or next append curve every time you select MARKER SKIP secondary softkey.

To move marker fast

Press Fast front-panel key of the MARKER/CURSOR key group while rotating rotary knob.

Example

The following figure shows an example to move marker to desired measurement point and to set the Y1 axis marker to active.



UGT02001

To Specify between Measurement Points on Curve

1. Select MARKER/CURSOR primary softkey.
2. Set MARKER secondary softkey to `ON`. Marker and marker coordinates are displayed. Selecting MARKER toggles between `ON` and `OFF`.
3. (if both Y1 and Y2 axis are set up) Select the desired marker (axis) by using AXIS primary softkey. The selected marker is highlighted. Selecting AXIS primary softkey toggles between `Y1` and `Y2`.
4. Set INTERPOLATE secondary softkey to `ON`. Selecting INTERPOLATE secondary softkey toggles between `ON` and `OFF`.
5. Rotate rotary knob to move the marker to desired measurement point.

If both Y1 and Y2 axis are set up, a circle marker (o) is displayed on measurement curve of Y1 axis, and an asterisk marker (*) is displayed on measurement curve of Y2 axis.

The `MARKER` coordinate fields indicate the location of markers. The first, second, and third fields are X, Y1, and Y2 coordinates, respectively. X and Y1 indicate location of marker on Y1 curve. X and Y2 indicate location of marker on Y2 curve.

To turn off markers

Set the MARKER secondary softkey to `OFF`.

To move marker to maximum or minimum value of measurement curve

Select MARKER MIN/MAX secondary softkey. The marker searches for minimum or maximum value in measurement order from the present location every time you select the MARKER MIN/MAX secondary softkey.

To move marker to next VAR2 step or append curve

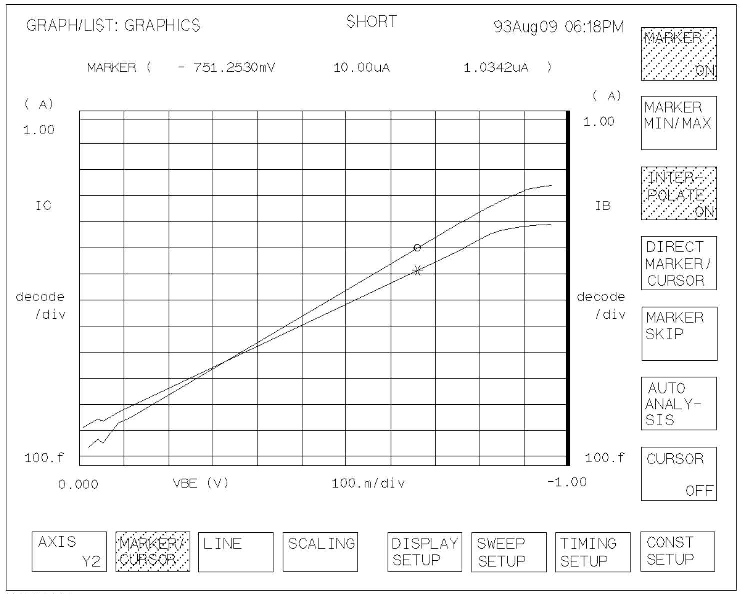
Select MARKER SKIP secondary softkey. Marker moves to next VAR2 step curve or next append curve every time you select MARKER SKIP.

To move marker fast

Press Fast front-panel key of the MARKER/CURSOR key group while rotating rotary knob.

Example

The following figure shows an example to move marker to points between measurement points by setting INTERPOLATE softkey to ON.



UGT02002

To Display or Move Cursor

1. Select MARKER/CURSOR primary softkey.
2. Set CURSOR secondary softkey to `SHORT` or `LONG`. Short or long cursor and cursor coordinates are displayed. Selecting CURSOR secondary softkey toggles as follows:

   `OFF` → `SHORT` → `LONG` → `OFF`

3. Move the cursor by using arrow keys of the MARKER/CURSOR key group.

The `CURSOR` coordinate fields indicate the location of cursor. The first, second, and third fields are X, Y1, and Y2 coordinates, respectively.

To move cursor diagonally

Press two adjacent arrow keys of the MARKER/CURSOR key group simultaneously.

To turn off cursor

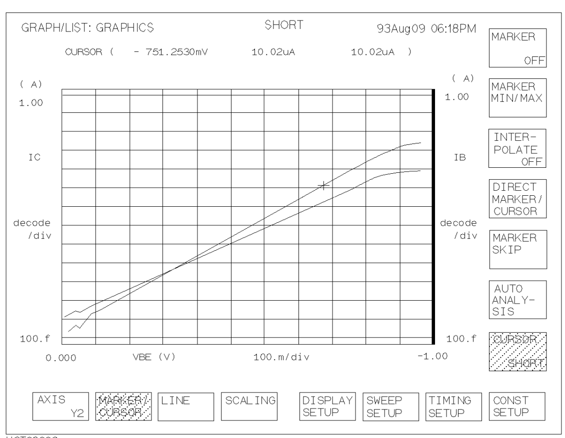
Set CURSOR secondary softkey to `OFF`.

To move cursor fast

Press arrow keys and Fast key of the MARKER/CURSOR key group simultaneously.

Example

The following figure shows an example to display a short cursor.



UGT02003

To Adjust Display Range to Measurement Curve Automatically

1. Select SCALING primary softkey.
2. (if both Y1 and Y2 axis are set up) Select desired measurement curve by using AXIS primary softkey.
3. Select AUTO SCALING secondary softkey. Scale is changed automatically to fit the selected measurement curve.

When you set VAR2 parameter, or when you perform append measurement, the scale is changed so that all measurement curves can be displayed.

To cancel auto scaling

Select CANCEL SCALING secondary softkey.

To Zoom the Display Range

1. Position the cursor at the center of area that you want to zoom. (For details about displaying and moving cursor, see “To Display or Move Cursor” on page 5-8.)
2. Select SCALING primary softkey.
3. Select:
   - ZOOM IN secondary softkey to change the X and Y scaling to half the present scaling. This enlarges measurement curve on the plot area.
   - ZOOM OUT secondary softkey to change the X and Y scaling to double the present scaling. This reduces measurement curve on the plot area.
   - The X and Y scaling is changed, and cursor is moved to the center of the plotting area.

If no cursor is displayed before step 3, performing step 3 displays a long cursor at the center of the plotting area, then zoom is performed.

To return to original scaling

Select CANCEL SCALING secondary softkey.

To Center Display at Cursor Location

1. Position cursor at the point where you want to center the plotting area. (For details about displaying and moving cursor, see “To Display or Move Cursor” on page 5-8.)
2. Select SCALING primary softkey.
3. (if both Y1 and Y2 axis are set up) Select desired measurement curve by using AXIS primary softkey.
4. Select CENTER AT CURSOR secondary softkey. The plotting area is centered around the cursor location.

If no cursor is displayed before step 4, performing step 4 displays a long cursor at the center of the plotting area.

To return plotting area to original position

Select CANCEL SCALING secondary softkey.

To Draw Line through Two Specified Points

1. Select LINE primary softkey.
2. Set LINE SELECT softkey to `1` or `2`. Selecting this softkey toggles the setting.
3. Set LINE secondary softkey to `ON`. A line and two cursors are displayed. Selecting LINE secondary softkey toggles as follows:

   `OFF` → `ON` → `OFF`

   The line mode should be normal. So (GRAD MODE, TANGENT MODE, or REGRESS MODE) softkeys should not be highlighted. If one of these softkeys is highlighted, turn off by pressing the softkey.
4. Move cursors to desired locations by using arrow keys of the MARKER/CURSOR key group. To select the cursor you want to move, use the SELECT CURSOR secondary softkey.

If it seems that only one cursor is displayed, the cursors are at the same location.

When lines are displayed and when `ON` is set in the LINE PARAMETER field on the DISPLAY: DISPLAY SETUP screen, their X and Y intercepts and gradients are also displayed in the plotting area.

To turn off the line intercept and gradient display

Select DISPLAY SETUP primary softkey, then set LINE PRMTRS secondary softkey to OFF.

To turn off the data variable display area

Use the following procedure:

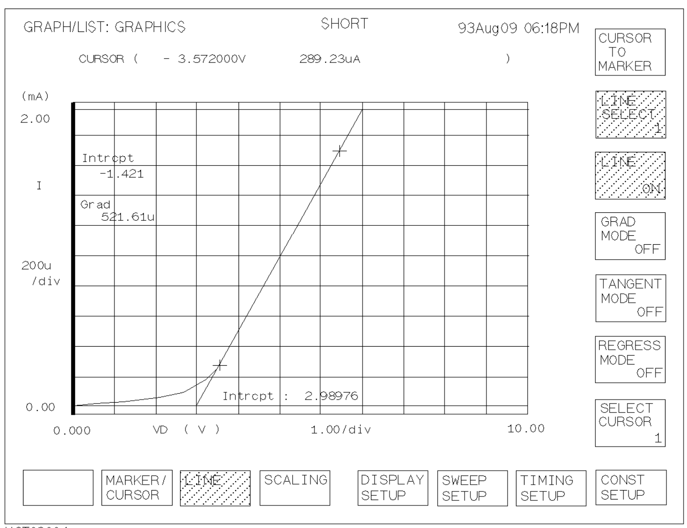
1. Select DISPLAY SETUP primary softkey.
2. Set DATA VAR secondary softkey to OFF.

To move the selected cursor to the selected marker position

Select CURSOR TO MARKER secondary softkey.

Example

The following figure shows an example to draw a line through two specified points.



UGT02004

To Draw Line through Specified Point with Specified Gradient

1. Select LINE primary softkey.
2. Set LINE SELECT softkey to `1` or `2`. Selecting this softkey toggles the setting.
3. Set LINE secondary softkey to `ON`. A line and two cursors are displayed. Selecting LINE secondary softkey toggles as follows:

   `OFF` → `ON` → `OFF`
4. Select GRAD MODE secondary softkey if it is not highlighted. Softkey becomes highlighted. One cursor disappears (if there are two cursors in the plotting area before this step). Selecting GRAD MODE secondary softkey toggles between highlighted and not highlighted.
5. Move the cursor to desired location by using arrow keys of the MARKER/CURSOR key group.
6. Select GRAD VALUE secondary softkey, then enter gradient value. The line goes through the cursor with specified gradient.

When lines are displayed and when `ON` is set in the LINE PARAMETER field on the DISPLAY: DISPLAY SETUP screen, the X and Y intercepts and gradients of selected line are also displayed in the plotting area.

To turn off the line intercept and gradient display

Select DISPLAY SETUP primary softkey, then set LINE PRMTRS secondary softkey to `OFF`.

To turn off the data variable display area

Use the following procedure:

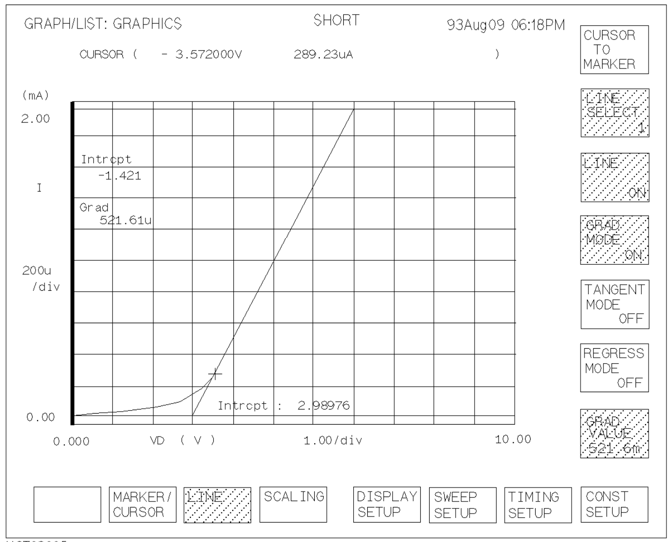
1. Select DISPLAY SETUP primary softkey.
2. Set DATA VAR secondary softkey to `OFF`.

To move the selected cursor to the selected marker position

Select CURSOR TO MARKER secondary softkey.

Example

The following figure shows an example to draw a line through specified point with specified gradient.



UGT02005

To Draw Tangent to Specified Point of Measurement Curve

1. Press LINE primary softkey.
2. Set LINE SELECT softkey to `1` or `2`. Selecting this softkey toggles the setting.
3. Set LINE secondary softkey to `ON`. A line and two cursors are displayed. Selecting the LINE secondary softkey toggles as follows:

   `OFF` → `ON` → `OFF`

4. Select TANGENT MODE secondary softkey if it is not highlighted. Softkey becomes highlighted. The cursors disappear and marker appears. Selecting TANGENT MODE toggles between highlighted and not highlighted.
5. Move marker to the desired measurement point by rotating rotary knob.

When lines are displayed and when `ON` is set in the LINE PARAMETER field on the DISPLAY: DISPLAY SETUP screen, the X and Y intercepts and gradients of selected line are also displayed in the plotting area.

To move marker to next VAR2 or next append curve

Select MARKER SKIP secondary softkey. Marker moves to next VAR2 step curve or next append curve every time you press MARKER SKIP.

To turn off the line intercept and gradient display

Select DISPLAY SETUP primary softkey, then set LINE PRMTRS secondary softkey to `OFF`.

To turn off the data variable display area

Use the following procedure:

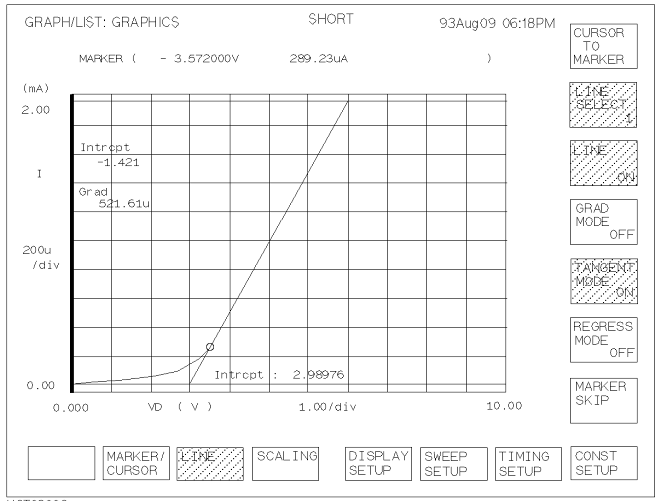
1. Select DISPLAY SETUP primary softkey.
2. Set DATA VAR secondary softkey to `OFF`.

To move marker between two adjacent measurement points

See “To Specify between Measurement Points on Curve” on page 5-6.

Example

The following figure shows an example to draw a tangent to a specified measurement point.



UGT02006

To Draw Regression Line for Specified Region

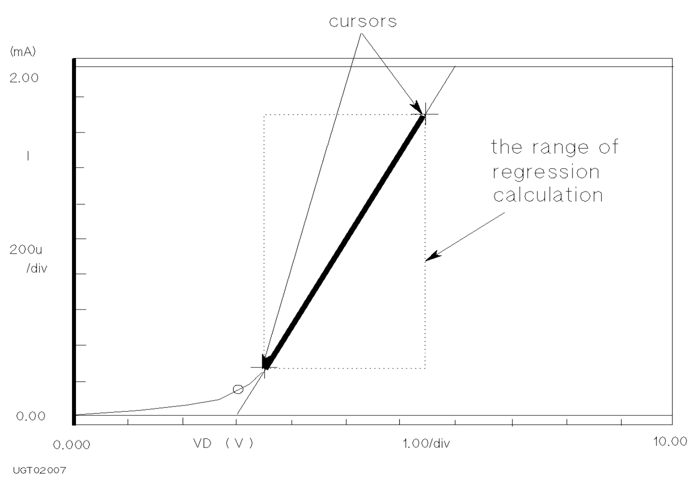
1. Select MARKER/CURSOR primary softkey, then set the MARKER secondary softkey to `ON`.
2. Select the desired axis for regression calculation by selecting AXIS primary softkey (if both Y1 and Y2 axis are set up). Then, if necessary, move marker to desired measurement curve by selecting MARKER SKIP secondary softkey.
3. Select LINE primary softkey.
4. Set LINE SELECT softkey to `1` or `2`. Selecting this softkey toggles the setting.
5. Set LINE secondary softkey to `ON`. A line and two cursors are displayed. Selecting LINE secondary softkey toggles as follows:

   `OFF` → `ON` → `OFF`

6. Select REGRESS MODE secondary softkey if it is not highlighted. Softkey becomes highlighted. Selecting REGRESS MODE secondary softkey toggles between highlighted and not highlighted.
7. Move cursors to specify range of regression calculation. (Use arrow keys of the MARKER/CURSOR key group to move cursors to desired location.)

   - To select the cursor you want to move, use the SELECT CURSOR secondary softkey.

The range used for calculating the regression line is defined by the position of the two cursors as shown in the following figure.



If it seems that only one cursor is displayed, the cursors are at the same location.

When regression lines are displayed and when ON is set in the LINE PARAMETER field on the DISPLAY: DISPLAY SETUP screen, the X and Y intercepts and gradient of selected line are also displayed in the plotting area.

To turn off the line intercept and gradient display

Select DISPLAY SETUP primary softkey, then set LINE PRMTRS secondary softkey to OFF.

To turn off the data variable display area

Use the following procedure:

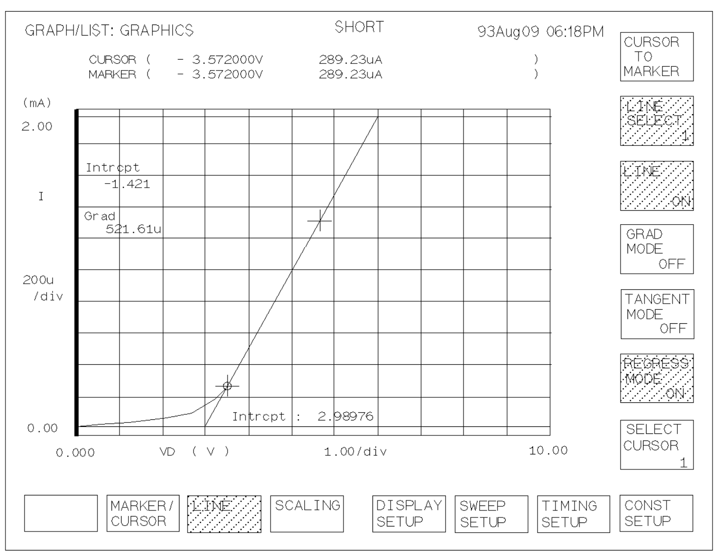
1. Select DISPLAY SETUP primary softkey.
2. Set DATA VAR secondary softkey to OFF.

To move selected cursor to the selected marker position

Select CURSOR TO MARKER secondary softkey.

Example

The following figure shows an example to draw a regression line for the specified region.



UGT02008

To Display and Select a Line

1. Select LINE primary softkey.
2. Set LINE SELECT softkey to `1` or `2`. Selecting this softkey toggles the setting.
3. Set LINE secondary softkey to `ON`. Selected line and two cursors are displayed. Selecting the LINE secondary softkey toggles as follows:

   `OFF` → `ON` → `OFF`

Set LINE SELECT secondary softkey to desired line (`1` or `2`). Selected line is highlighted.

To select line to analyze

Selecting LINE SELECT secondary softkey toggles as follows:

`1` → `2` → `NONE` → `1`

The following are independent for each line. So, changing the active line also changes the following:

- locations of marker and cursors
- X and Y intercepts and gradient

To Display Grid on the Graph

1. Select DISPLAY SETUP primary softkey.
2. Set GRID secondary softkey to `ON`. Grid is displayed. Selecting GRID secondary softkey toggles between `ON` and `OFF`.

To turn off grid

Set GRID secondary softkey to `OFF`.

To Change Data Variable on Graph

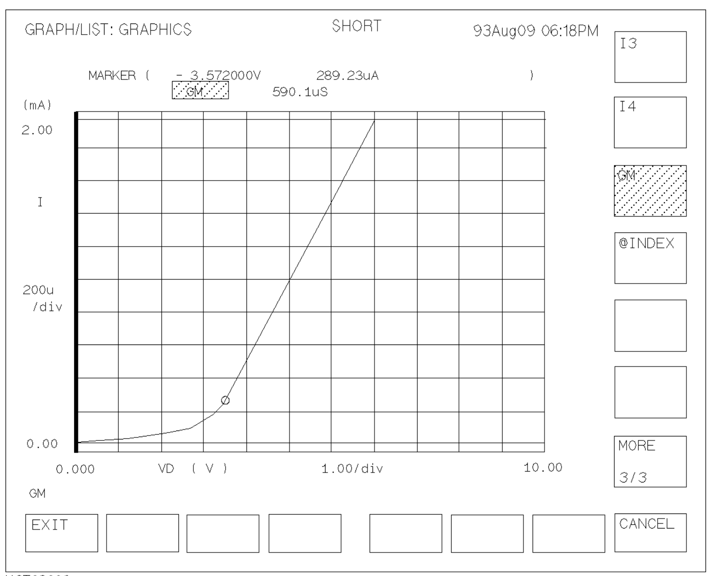
1. Select DISPLAY SETUP primary softkey.
2. Select RE-SETUP GRAPH secondary softkey.
3. Move the pointer to desired data variable field by using the arrow keys, then select secondary softkey to enter the desired variable name.
4. Select EXIT primary softkey to exit the RE-SETUP GRAPH mode.

To exit without changing data variable

Select CANCEL primary softkey.

Example

The following figure shows an example setup to change the data variable to be displayed.



UGT02009

To Change Range of X or Y Axis Scale

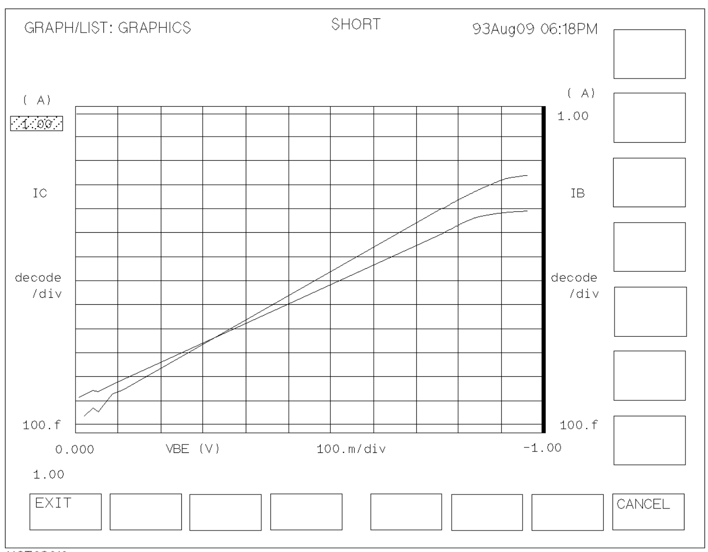
1. Select DISPLAY SETUP primary softkey.
2. Select RE-SETUP GRAPH secondary softkey.
3. Move pointer to maximum or minimum value field of X or Y axis scale by using the arrow keys, then edit the setup value by using ENTRY keys or rotary knob.
4. Select EXIT primary softkey to exit RE-SETUP GRAPH mode.

To exit without changing range of X or Y axis scale

Select CANCEL primary softkey.

Example

The following figure shows an example setup to change maximum value of Y1 axis.



UGT02010

To Change Variable Assigned to X, Y1, or Y2 Axis

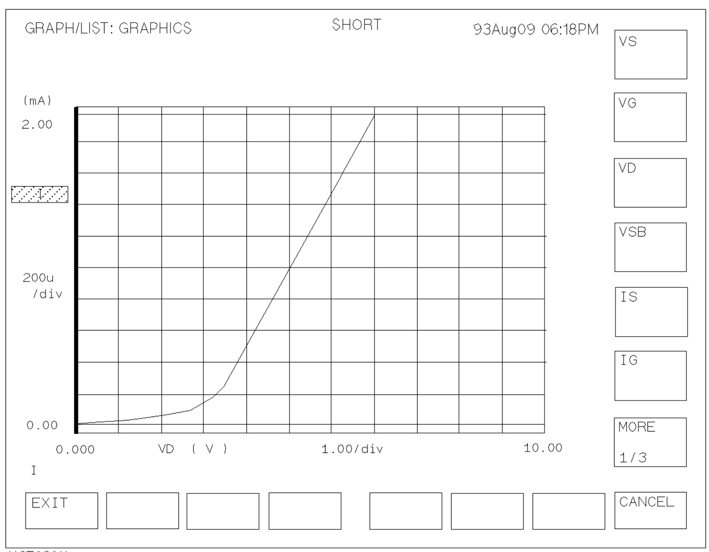
1. Select DISPLAY SETUP primary softkey.
2. Select RE-SETUP GRAPH secondary softkey.
3. Move pointer to variable field of X, Y1, or Y2 axis by using arrow keys, then select secondary softkey to set the desired variable.
4. Select EXIT primary softkey to exit RE-SETUP GRAPH mode.

To exit without changing variable assigned to X, Y1, or Y2 axis

Select CANCEL primary softkey.

Example

The following figure shows an example setup to change the variable that is assigned to Y1 axis.



UGT02011

To Overlay an Internal Memory Measurement Curve onto Plotting Area

This section explains how to overlay a measurement curve (that was stored into an internal memory) onto plotting area. To store a measurement curve into an internal memory, refer to Chapter 3 of *User's Guide General Information*.

1. Select DISPLAY SETUP primary softkey.
2. Set OVERLAY PLANE secondary softkey to the desired memory number. Selected measurement curve is overlaid onto plotting area. Selecting OVERLAY PLANE secondary softkey toggles as follows:

   `OFF → 1 → 2 → 3 → 4 → OFF`

To display information of overlay measurement curve

Select SHOW OVERLAY INFO secondary softkey. The following information of overlay measurement curve overwrites the information of the present curve.

- axis names and axis scales
- cursor and marker coordinates, line x-, y1-, y2-interrupt and gradient
- data variables

To display information of original curve again, select the EXIT primary softkey.

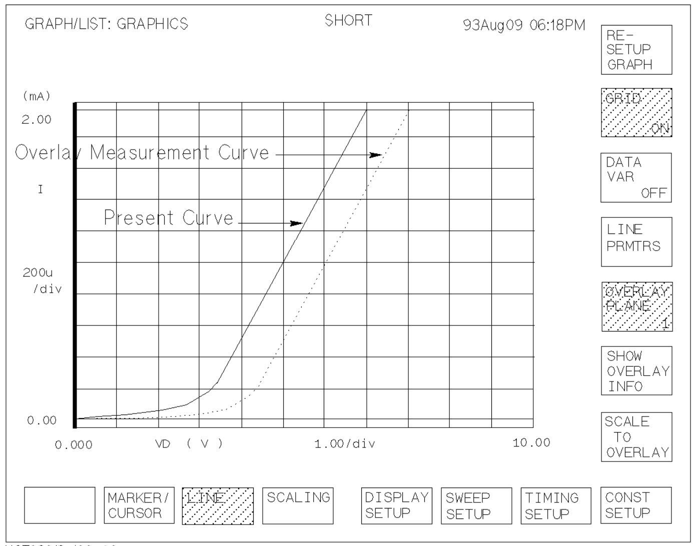
To change the present scale to the same scale as overlay curve

Select SCALE TO OVERLAY secondary softkey.

To return to the original scale, you need to select SCALING primary softkey, then select CANCEL SCALING secondary softkey.

Example

The following figure shows an example to overlay a measurement curve (that is stored in internal memory 1) onto the presently displayed measurement curve.



UGT02012, 100*80

To Scroll the LIST screen

- Press an arrow key of the MARKER/CURSOR key group. List scrolls in direction of selected arrow.

List can be scrolled even while performing measurements.

When marker is displayed, marker does not move during scrolling.

To scroll list fast

Press Fast key of the MARKER/CURSOR key group while pressing an arrow key of the MARKER/CURSOR key group.

To Display or Move Marker on LIST screen

1. Select MARKER primary softkey.
2. Set MARKER secondary softkey to ON. The marker is displayed. Selecting MARKER secondary softkey toggles between ON and OFF.
3. Rotate rotary knob to move the marker to desired measurement point.

To turn off marker

Set MARKER secondary softkey to OFF.

To move marker to next VAR2 step

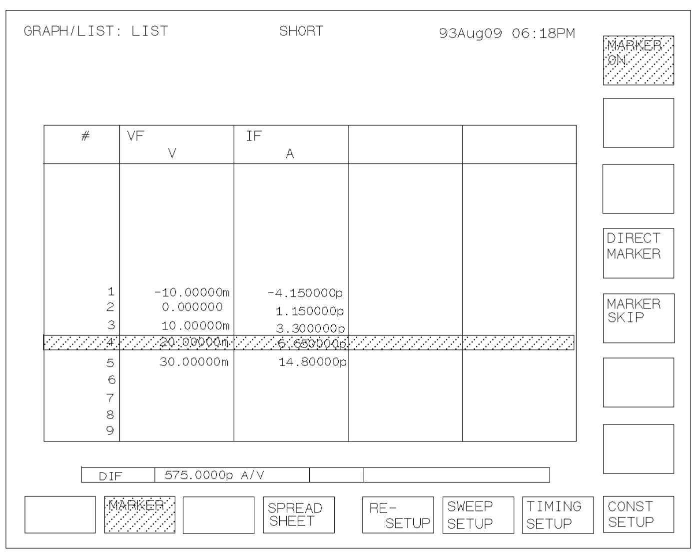
Select MARKER SKIP secondary softkey. Marker moves to next VAR2 step data or next append data every time you select MARKER SKIP secondary softkey.

To move marker to next append data

Select NEXT APPEND secondary softkey. Marker moves to next append data every time you select NEXT APPEND secondary softkey.

Example

The following figure shows an example to display marker.



UGT02013, 100x80

To Change Variables of LIST screen

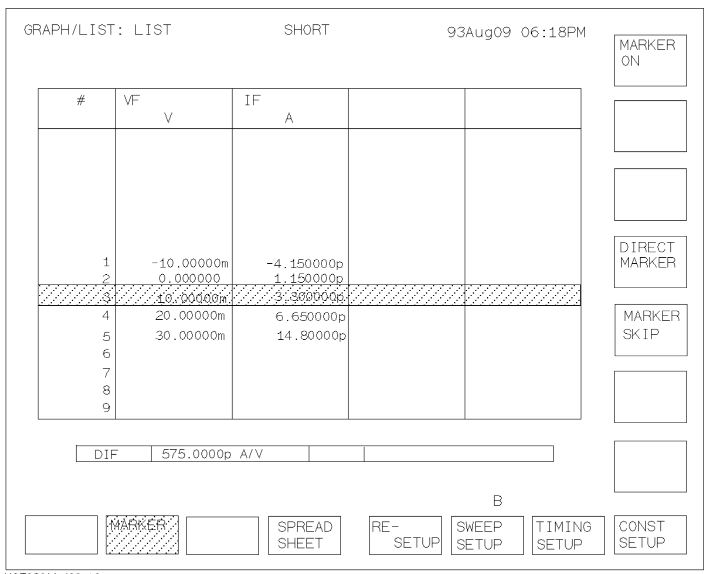
1. Select RE-SETUP primary softkey.
2. Move pointer to desired column variable or data variable field by using arrow keys, then select secondary softkey of desired variable.
3. Select EXIT primary softkey to exit RE-SETUP LIST mode.

To exit without changing LIST variables

Select CANCEL primary softkey.

Example

The following figure shows an example to change the LIST variables.



UGT02014, 100x80

Automatic Analysis

You set up automatic analysis before the measurement by using the DISPLAY: ANALYSIS SETUP screen. Then, after measurement is performed, the marker and lines are automatically positioned according to automatic analysis setup.

This section covers the following automatic analysis tasks:

NOTE

Execution Timing of the Automatic Analysis Function

You set up automatic analysis on the DISPLAY: ANALYSIS SETUP screen.

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 screen.
- when you return to the GRAPH/LIST: GRAPH or GRAPH/LIST: LIST screen after changing the condition of the automatic analysis function on the DISPLAY: ANALYSIS SETUP screen.

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.

To Draw Line by Specifying Two Points

1. Press Display front-panel key.
2. Confirm that `ON` is set on the LINE *secondary* softkey on the GRAPH/LIST: GRAPHICS screen.
3. Select ANLYSIS SETUP primary softkey. The DISPLAY: ANALYSIS SETUP screen is displayed.
4. In field (1), select NORMAL secondary softkey.
5. In field (2), select secondary softkey to specify desired axis.
6. In field (3), select:
   - BY X-Y COORDINATE secondary softkey to specify a point by X-Y coordinate mode. (Go to step 6.)
   - BY DATA CONDITION secondary softkey to specify a point by data condition mode. (Go to step 7.)
7. If you selected BY X-Y COORDINATE secondary softkey:
   a. In the X field, enter desired expression to specify X coordinate.
   b. In the Y field, enter desired expression to specify Y coordinate.
   c. Go to step 8.
8. If you selected BY DATA CONDITION secondary softkey:
   a. In field (4), select secondary softkey to set desired data variable name.
   b. In field (5), enter desired expression.
   c. In field (6), select:
      - AFTER secondary softkey if you want to set a search start condition for finding specified point.
      - DISABLE secondary softkey to disable (clear) the `AFTER` settings.

   d. If you selected AFTER, select secondary softkey to enter desired data variable in field (7).
   e. If you selected AFTER, enter desired expression in field (8).
9. Specify the other point by step 5, then step 6 or 7.

Data condition mode specifies a point related to the measurement curve. So, if no measurement data satisfy the specified condition, the nearest measurement point is used.

For the meaning of expression that you can enter in step 6 or 7, see “Expression” in Chapter 7.

To specify a point between two measurement points

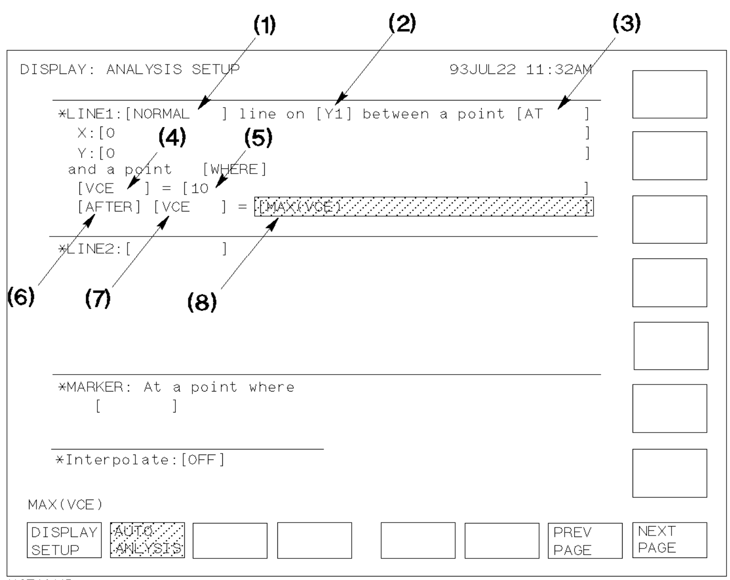
Set Interpolate field to ON.

To disable (clear) the settings

Move the pointer to field (1), then select DISABLE secondary softkey. Setup fields disappear.

Example

The following figure shows an example setup to automatically draw a line through two specified points. One point is specified by X-Y coordinate mode and other point is specified by data condition mode.



UGT02015

To Draw Line by Specifying Gradient and One Point

1. Press Display front-panel key.
2. Confirm that `ON` is set on the LINE *secondary* softkey on the GRAPH/LIST: GRAPHICS screen.
3. Select ANLYSIS SETUP primary softkey. The DISPLAY: ANALYSIS SETUP screen is displayed.
4. In field (1), select GRAD secondary softkey.
5. In field (2), select secondary softkey to specify desired axis.
6. In field (3), select:
   - BY X-Y COORDINATE secondary softkey to specify a point by X-Y coordinate mode. (Go to step 6.)
   - BY DATA CONDITION secondary softkey to specify a point by data condition mode. (Go to step 7.)
7. If you selected BY X-Y COORDINATE secondary softkey:
   a. In the X field, enter desired expression to specify X coordinate.
   b. In the Y field, enter desired expression to specify Y coordinate.
   c. Go to step 8.
8. If you selected BY DATA CONDITION secondary softkey:
   a. In field (4), select secondary softkey to set desired data variable name.
   b. In field (5), enter desired expression.
   c. In field (6), select:
      - AFTER secondary softkey if you want to set a search start condition for finding specified point.
      - DISABLE secondary softkey to disable (clear) the `AFTER` settings.
   d. If you selected AFTER, select secondary softkey to enter desired data variable in field (7).
   e. If you selected AFTER, enter desired expression in field (8).
9. In the Gradient field, enter gradient expression.

Data condition mode specifies a point related to the measurement curve. So, if no measurement data satisfy the specified condition, the nearest measurement point is used.

For the meaning of expression that you can enter in step 6 or 7, see “Expression” in Chapter 7.

To specify a point between two measurement points

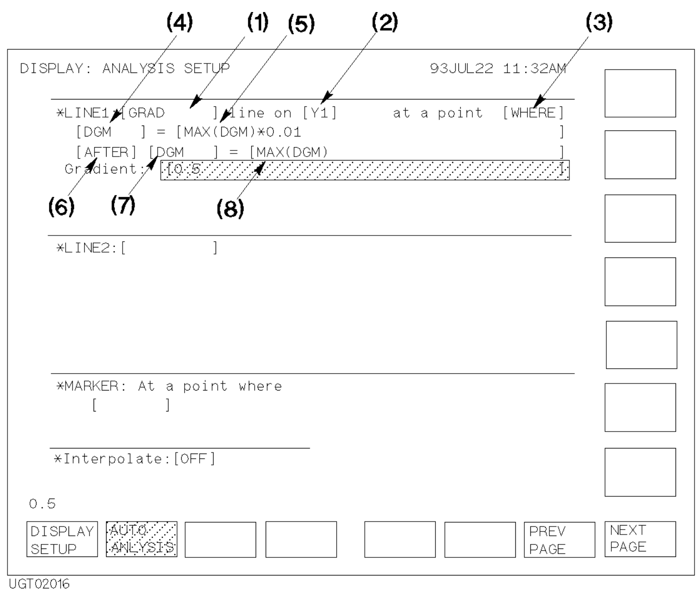
Set Interpolate field to `ON`.

To disable (clear) the settings

Move the pointer to field (1), then select DISABLE secondary softkey. Setup fields disappear.

Example

The following figure shows an example setup to automatically draw a line through the specified point with the specified gradient.



To Draw Tangent to Specified Measurement Point

1. Press Display front-panel key.
2. Confirm that `ON` is set on the LINE *secondary* softkey on the GRAPH/LIST: GRAPHICS screen.
3. Select ANLYSIS SETUP primary softkey. The DISPLAY: ANALYSIS SETUP screen is displayed.
4. In field (1), select TANGENT secondary softkey.
5. In field (2), select secondary softkey to specify desired axis.
6. In field (3), select secondary softkey to select desired data variable name.
7. In field (4), enter desired expression.
8. In field (5), select:
   - AFTER secondary softkey if you want to set a search start condition for finding specified point.
   - DISABLE secondary softkey to disable (clear) the `AFTER` settings.
9. If you selected AFTER, select secondary softkey to enter desired data variable in field (6).
10. If you selected AFTER, enter desired expression in field (7).

Data condition mode specifies a point related to the measurement curve. So, if no measurement data satisfy the specified condition, the nearest measurement point is used.

For the meaning of expression that you can enter in step 6 and 9, see “Expression” in Chapter 7.

To specify a point between two measurement points

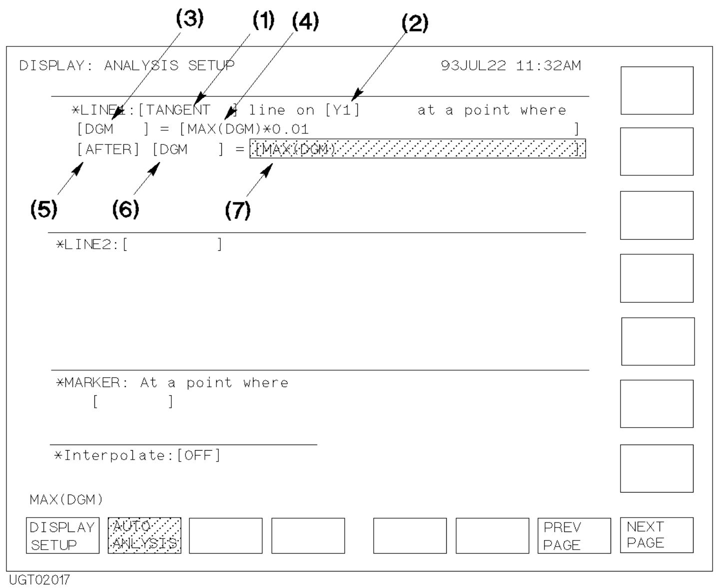
Set Interpolate field to `ON`.

To disable (clear) the settings

Move the pointer to field (1), then select DISABLE secondary softkey. Setup fields disappear.

Example

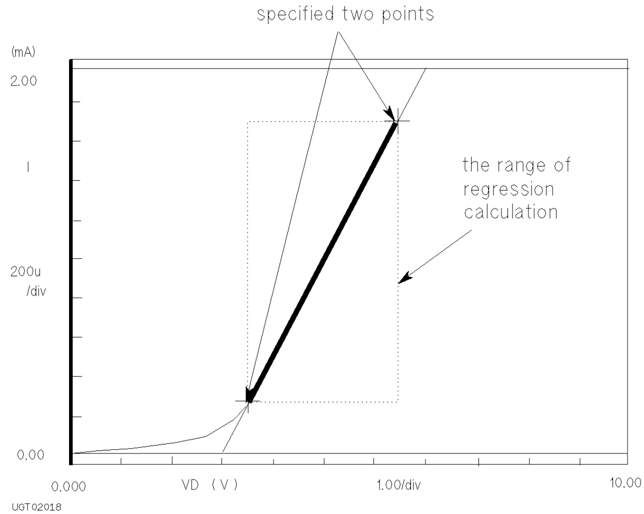
The following figure shows an example setup to automatically draw a tangent line to a specified measurement point.



To Draw Regression Line by Specifying Two Points

1. Press Display front-panel key.
2. Confirm that `ON` is set on the LINE *secondary* softkey on the GRAPH/LIST: GRAPHICS screen.
3. Select ANLYSIS SETUP primary softkey. The DISPLAY: ANALYSIS SETUP screen is displayed.
4. In field (1), select REGRESSION secondary softkey.
5. In field (2), select secondary softkey to specify desired axis.
6. In field (3), select:
   - BY X-Y COORDINATE secondary softkey to specify a point by X-Y coordinate mode. (Go to step 6.)
   - BY DATA CONDITION secondary softkey to specify a point by data condition mode. (Go to step 7.)
7. If you selected BY X-Y COORDINATE secondary softkey:
   a. In the X field, enter desired expression to specify X coordinate.
   b. In the Y field, enter desired expression to specify Y coordinate.
   c. Go to step 8.
8. If you selected BY DATA CONDITION secondary softkey:
   a. In field (4), select secondary softkey to set desired data variable name.
   b. In field (5), enter desired expression.
   c. In field (6), select:
      - AFTER secondary softkey if you want to set a search start condition for finding specified point.
      - DISABLE secondary softkey to disable (clear) the `AFTER` settings.
   d. If you selected AFTER, select secondary softkey to enter desired data variable in field (7).
   e. If you selected AFTER, enter desired expression in field (8).
9. Specify the other point by step 5, then step 6 or 7.

Regression calculation is performed in the range defined by the two specified points as shown in the following figure.



Data condition mode specifies a point related to the measurement curve. So, if no measurement data satisfy the specified condition, the nearest measurement point is used.

For the meaning of expression that you can enter in step 6 and 7, see “Expression” in Chapter 7.

To specify a point between two measurement points

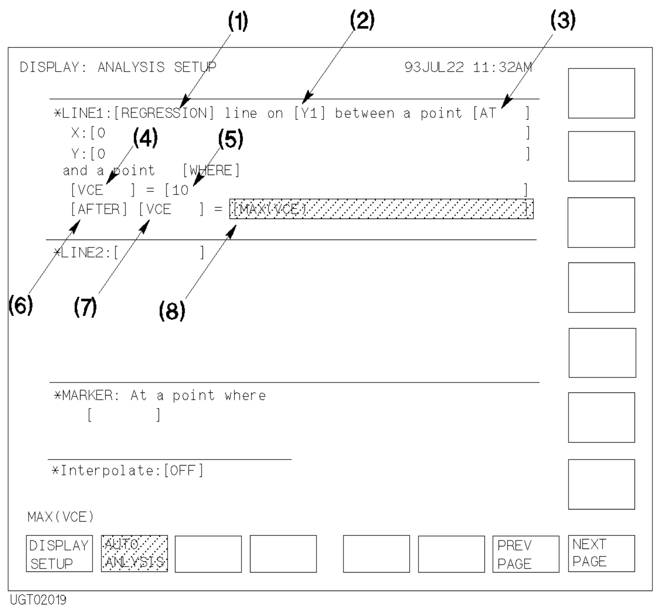
Set Interpolate field to `ON`.

To disable (clear) the settings

Move the pointer to field (1), then select DISABLE secondary softkey. Setup fields disappear.

Example

The following figure shows an example setup to automatically draw a regression line. The range for the regression calculation is specified by two points. One point is specified by X-Y coordinate mode and other point is specified by data condition mode.



To Display Marker at Specified Point

1. Press Display front-panel key.
2. Select ANLYSIS SETUP primary softkey. The DISPLAY: ANALYSIS SETUP screen is displayed.
3. Move pointer to field (1), then select secondary softkey to set desired data variable name.
4. In field (2), enter desired expression.
5. In field (3), select:
   - AFTER secondary softkey if you want to set a search start condition for finding specified point.
   - DISABLE secondary softkey to disable (clear) the `AFTER` settings.
6. If you selected AFTER in field (4), select secondary softkey to set desired data variable.
7. If you selected AFTER in field (5), enter desired expression.

The marker can be displayed on the measurement curve only. So, if no measurement data satisfy the specified condition, the nearest measurement point is used.

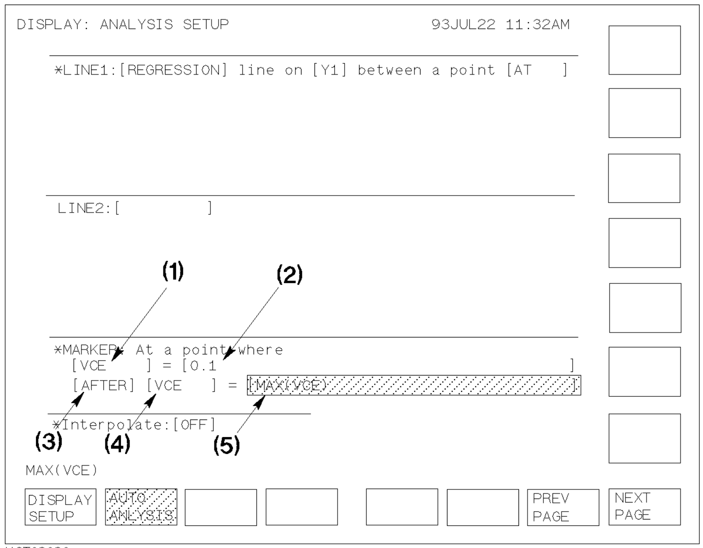
For the meaning of expression that you can enter in step 4 and 7, see “Expression” in Chapter 7.

To specify a point between two measurement points

Set Interpolate field to `ON`.

Example

The following figure shows an example setup to automatically display marker at specified point.



UGT02020

6 Screen Organization

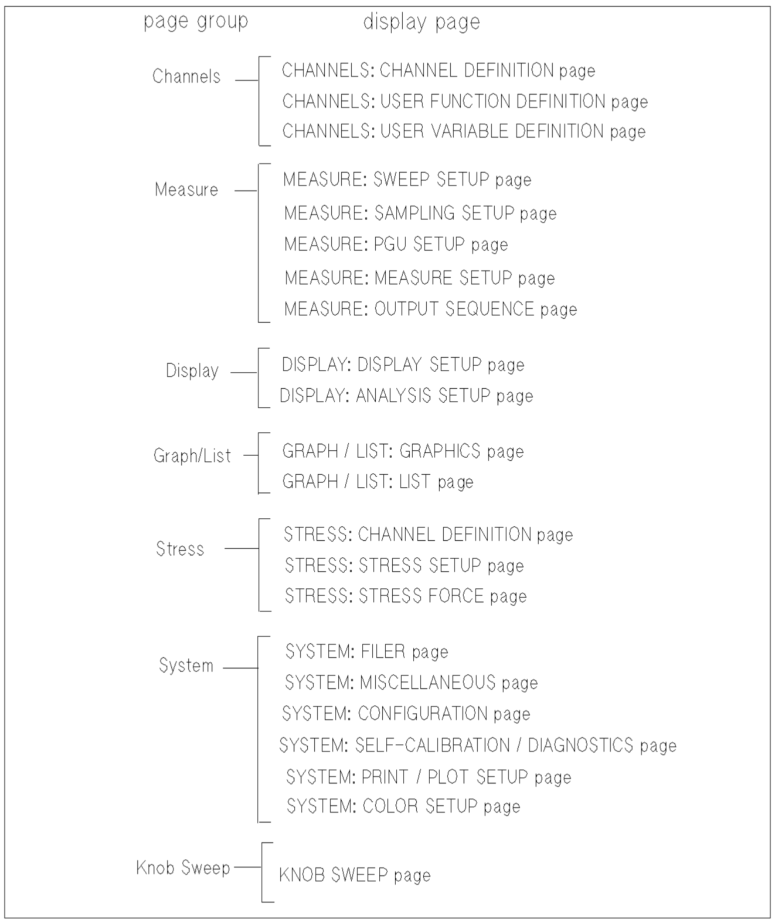
This chapter is a reference for operating Agilent 4155B/4156B by using the front-panel controls. The 4155B/4156B is operated by setup screens and results screen displayed on the screen. The following sections explain these setup screen structure.

- "Screen Structure"
- "CHANNELS Screen Group"
- "MEASURE Screen Group"
- "DISPLAY Screen Group"
- "GRAPH/LIST Screen Group"
- "STRESS Screen Group"
- "Screen Operation"
- "Status Indicators"

Screen Structure

The 4155B/4156B has seven screen groups that have a total 22 setup screens as shown in Figure 6-1.

Figure 6-1 **Screen Structure of 4155B/4156B**



UGD05019 , 110wx125h

CHANNELS screen group	Defines the measurement modes, measurement channels, and user functions.
MEASURE screen group	Sets the measurement parameters.
DISPLAY screen group	Sets up the display of measurement results.
GRAPH/LIST screen group	Displays the measurement results.
STRESS screen group	Sets and monitors the stress force.
SYSTEM screen group	Controls mass storage, sets system parameters for the 4155B/4156B, sets the print/plot parameters, and so on.
KNOB SWEEP screen group	Displays the measurement results when the knob sweep function is used.

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

Chan	Displays the CHANNELS screen group.
Meas	Displays the MEASURE screen group.
Disp	Displays the DISPLAY screen group.
Graph/List	Displays the GRAPH/LIST screen group.
Stress	Displays the STRESS screen group.
System	Displays the SYSTEM screen group.

For details about the System screen Group, refer to "System Screen Organization" in *User's Guide General Information*.

To display the KNOB SWEEP screen, press:

1. the front-panel green key
2. Single key

For details about the KNOB SWEEP screen, see “Knob Sweep Function” in Chapter 3.

CHANNELS Screen Group

CHANNELS screen group has the following screens:

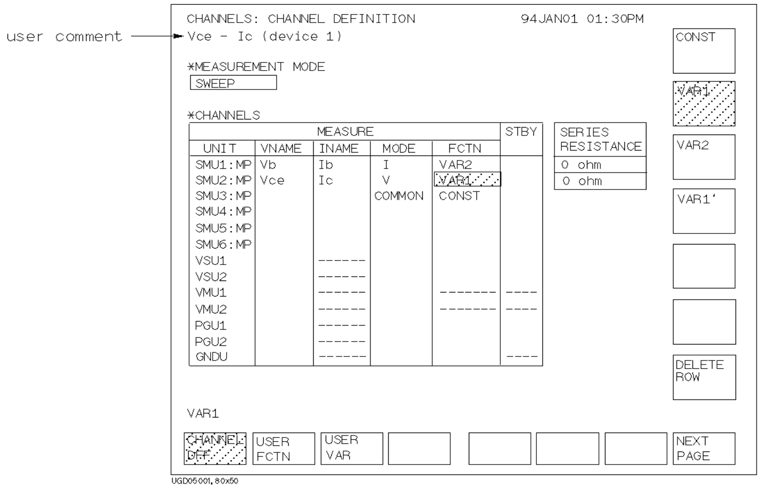
Channel Definition:	For defining the measurement mode and measurement channels of the 4155B/4156B.
User Function Definition:	For defining the user functions.
User Variable Definition:	For defining the user variables.

To move to the CHANNELS screen group, press Chan front-panel key. 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 screen.
- Select USER FCTN softkey to move to CHANNELS: USER FUNCTION DEFINITION screen.
- Select USER VAR softkey to move to CHANNELS: USER VARIABLE DEFINITION screen.

CHANNELS: CHANNEL DEFINITION screen



On the "CHANNELS: CHANNEL DEFINITION" screen, 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 screen 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 screen group) to default initial settings, select DEFAULT MEASURE SETUP secondary softkey.

NOTE

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 the 4155B/4156B without a diskette or network disk, 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 screens.

See "Initial Settings" in *User's Guide General Information*.

CHANNELS

UNIT.

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

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 screens. 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 softkey 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.

NOTE

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 screens. 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 softkey 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	Yes	Yes	Yes[a]	Yes[a]	Yes	
VSU	Yes					
PGU	Yes		Yes			
GNDU					Yes	
VMU	Yes					Yes

a. 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 Agilent 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.

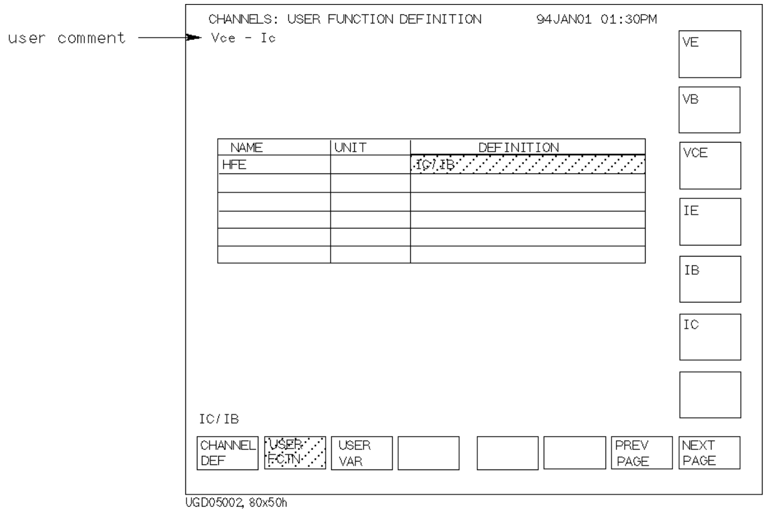
Normally, SMU1 and SMU2 have SERIES RESISTANCE fields. However, if the SMU and Pulse Generator Expander is installed and if the expander has an HPSMU, then SMU1 and SMU5 have SERIES RESISTANCE fields.

If the 16441A R-box is *not* installed, you must set 0 Ω 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 screen



On this screen, you define user functions. For details about user functions, refer to "User Function" in Chapter 7.

User Comment

In this field, you can enter a desired comment, which is also displayed in the CHANNELS, MEASURE, DISPLAY, and GRAPH/LIST screen 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 softkey to delete the NAME, UNIT, and DEFINITION entries.

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

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 screens.

Restriction: UNIT must be 6 or less alphanumeric characters.

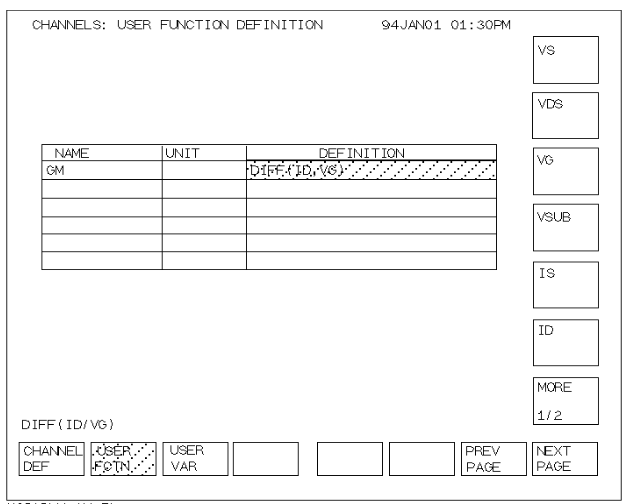
To delete a user function, you can select DELETE ROW softkey to delete the NAME, UNIT, and DEFINITION entries.

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 screen.

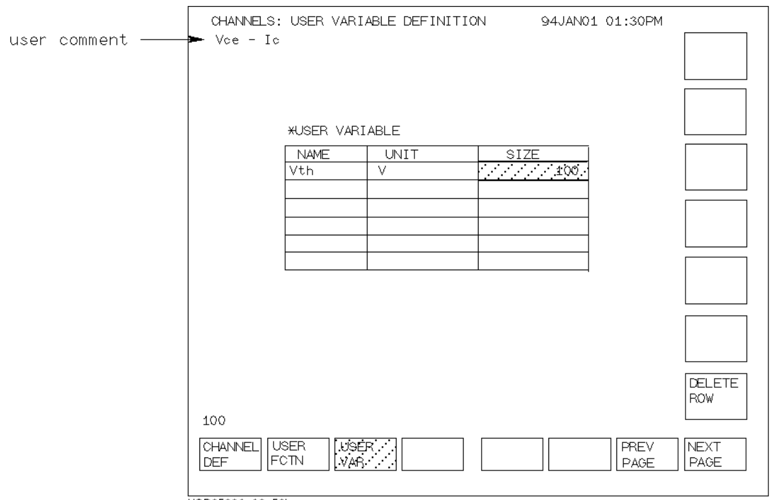
For syntax, see “Expression” in Chapter 7. For example, to define a user function for mutual conductance *gm* of an FET, define *gm* on this screen as follows:



UGD05020, 100x70

CHANNELS: USER VARIABLE DEFINITION screen

On this screen, you register user variables that were defined by GPIB. To use a user variable, you must register it on this screen. For details about user variables, refer to “User Variable” in Chapter 7.



UGD05028, 80x50h

User Comment

In this field, you can enter a desired comment, which is also displayed in the CHANNELS, MEASURE, DISPLAY, and GRAPH/LIST screen 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 softkey to delete the NAME, UNIT, and SIZE entries.

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

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 screens. You can enter the unit by using the keyboard or front-panel keys.

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

MEASURE Screen Group

MEASURE screen group has the following screens:

Sweep Setup or Sampling Setup:	For setting the parameters for sweep or sampling measurement, which was defined in the CHANNELS: CHANNEL DEFINITION screen.
PGU Setup:	For setting the PGU parameters. This screen is available when PGU is installed and the MODE and FCTN field of PGUs are set on the CHANNELS: CHANNEL DEFINITION screen.
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 screen group, press Meas front-panel key. The following primary softkeys appear:

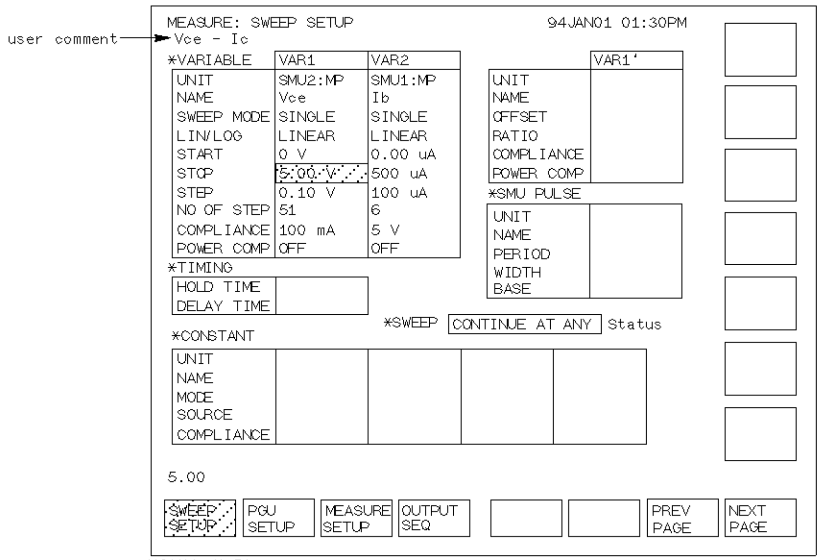
SWEEP SETUP	PGU SETUP	MEASURE SETUP	OUTPUT SEQ			PREV PAGE	NEXT PAGE

or

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

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

MEASURE: SWEEP SETUP screen



UG01019,40x50

On this screen, 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 screen groups.

VAR1 parameters

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

- 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 screen.

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 screen.

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

- 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 × *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: 100 µs.

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 screen, 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 screen.

- SOURCE

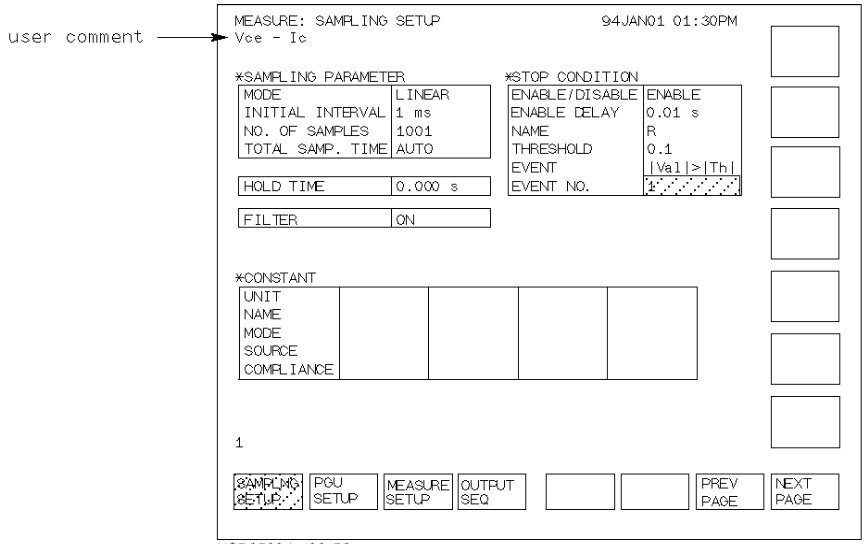
  In the SOURCE field, you specify the output value.

- 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 the right arrow or left arrow MARKER/CURSOR front-panel key.

MEASURE: SAMPLING SETUP screen



UGD05004, 100x50

On this screen, you set sampling parameters for each unit. For details, see "Sampling Measurement Mode" in Chapter 2.

User Comment

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

SAMPLING PARAMETER

- MODE

  MODE field sets the **sampling mode**. 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 softkey to specify the thinned-out sampling mode, which discards less recent samples.

- INITIAL INTERVAL

  In the INITIAL INTERVAL field, you set the **initial interval** which is the interval of measurement trigger. Not measurement interval. Measurement unit executes measurement if it is ready to measure at the trigger. If the unit is busy or in measurement, the unit waits for the next trigger.

- 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 screen.

- TOTAL SAMP. TIME (for linear and thinned-out sampling mode)

  TOTAL SAMP. TIME field sets the **total sampling time**. The total sampling time must satisfy the following condition:

  $$\textit{total sampling time} \geq \textit{initial interval} \times (\textit{number of samples} - 1)$$

  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, **initial interval** must be more than 480 μs.
  - (for linear sampling mode only) AUTO secondary softkey to set the total sampling time to *initial interval* × (*number of samples* −1).

- 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 100 μs resolution.

  (for *initial interval* ≥ 2 ms) 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 screen.

- SOURCE

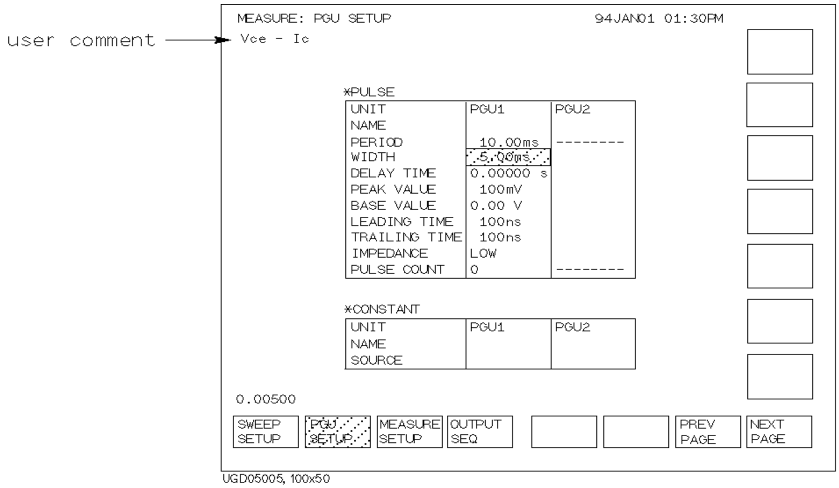
  In the SOURCE field, you specify the output value.

- 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 the right arrow or left arrow MARKER/CURSOR front-panel key.

MEASURE: PGU SETUP screen



On the "MEASURE: PGU SETUP" screen, 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 screen groups.

PULSE

You set the pulse output parameters in the PULSE area.

UNIT and NAME are defined on the CHANNELS: CHANNEL DEFINITION screen.

- PERIOD

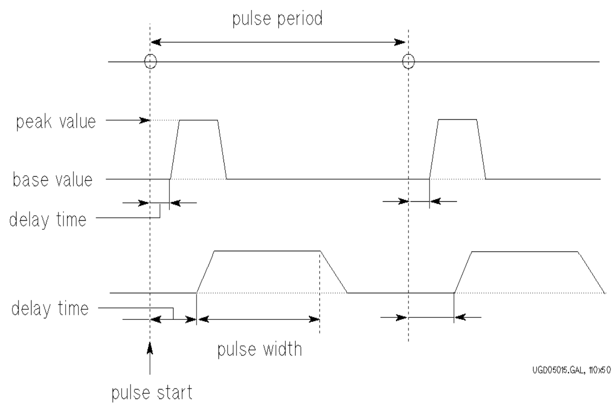
  PERIOD field specifies the pulse period of the PGU. Note that the pulse period of PGUs is independent from that of the SMUs.

- 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.



- 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 0 Ω.
  - 50 ohm secondary softkey to set output impedance to 50 Ω.

- PULSE COUNT

  PULSE COUNT field specifies the number of pulses for the sampling measurement (for sweep measurements, only `FREE RUN` is available).

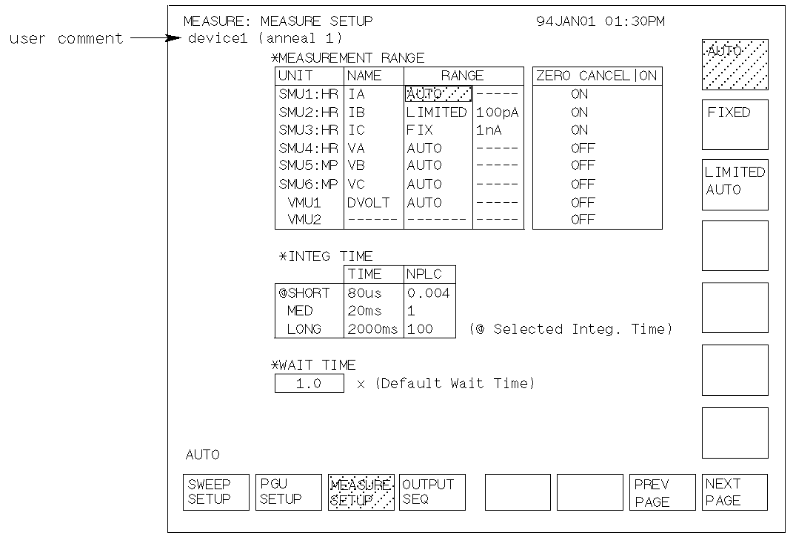
  - Enter a pulse count value (only for sampling measurements).
  - Select FREE RUN or enter 0 (zero) to set continuous pulse output. If either PGU1, PGU2, or both are set to standby ON on the CHANNELS: CHANNEL DEFINITION screen, this field is automatically set to *free run* mode.

CONSTANT

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

In the SOURCE field, you specify the output value.

MEASURE: MEASURE SETUP screen



UGD05006, 100x50

On the "MEASURE: MEASURE SETUP" screen, 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 screen 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 screen. 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 Range 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 screen.

- 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.

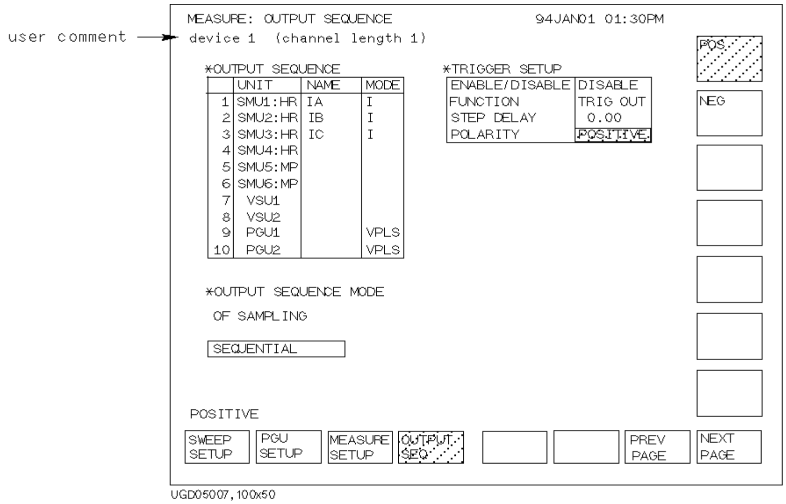
WAIT TIME

For each unit, the 4155B/4156B 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 screen



On this screen, you set the output sequence and triggering parameters for measurement state.

The output sequence set on this screen 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 screen 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 screen 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 screen. 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, the 4155B/4156B outputs an edge-trigger signal when a measurement starts for each step.
    - For a pulsed sweep measurement, the 4155B/4156B 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 4155B/4156B 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 Screen Group

DISPLAY screen group has the following screens:

Display Setup: For setting the graphics/list display mode, the parameters for graphics/list screen, and measurement channels.

Analysis Setup: For defining where to automatically display lines and marker after a measurement.

To move into the DISPLAY screen group, do one of the following:

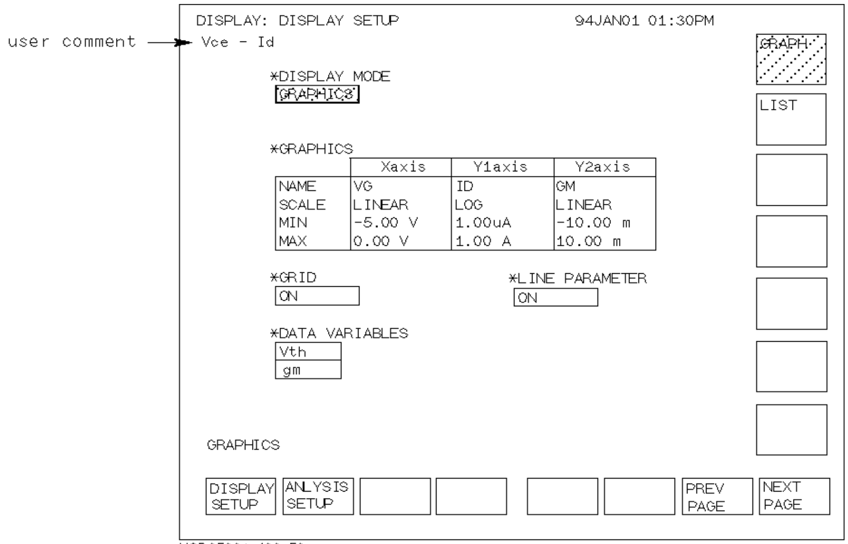
- Press Display front-panel key in the PAGE CONTROL key group.
- Select NEXT PAGE primary softkey in the MEASURE: OUTPUT SEQUENCE screen.

Then, the following primary softkeys appear:

DISPLAY SETUP	ANALYSIS SETUP					PREV PAGE	NEXT PAGE

- Select DISPLAY SETUP softkey to move to the DISPLAY: DISPLAY SETUP screen.
- Select ANLYSIS SETUP softkey to move to DISPLAY: ANALYSIS SETUP screen.

DISPLAY: DISPLAY SETUP screen for graphic results



UGD05008, 100x50

On the "DISPLAY: DISPLAY SETUP" screen for graphics results, you set axes, grid, and data variable names for the "GRAPHICS" screen. The channels that actually perform measurements are determined by the axis names and data variables that you set on this screen.

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 screen 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 screen. 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.

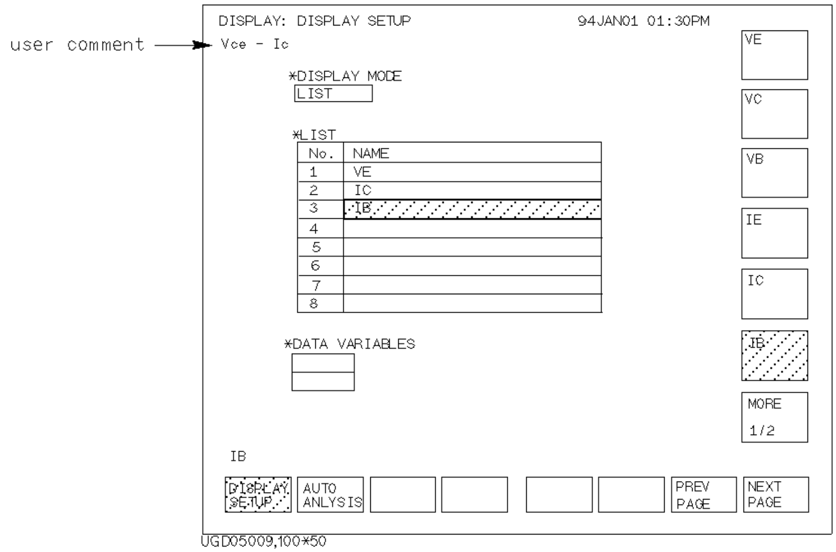
ON The line parameters are displayed when lines are displayed on the graph.

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 screen 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 screen for list results



On the "DISPLAY: DISPLAY SETUP" screen 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 screen.

User Comment

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

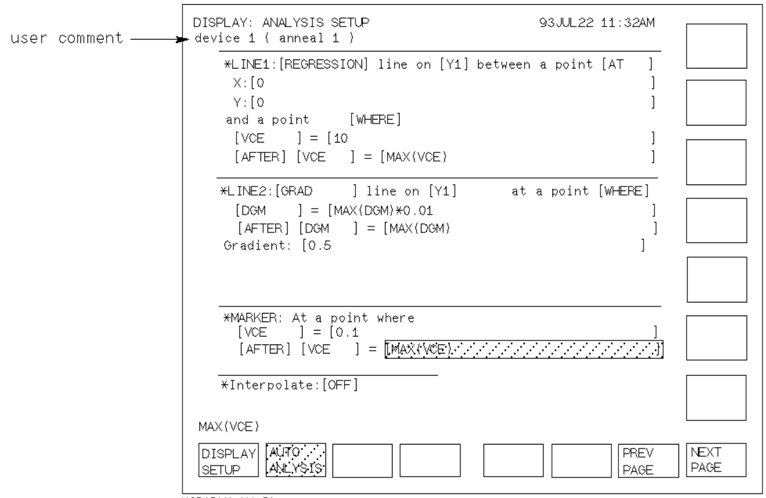
NAME fields of LIST area specify variables that you want to display on LIST screen. You can enter the desired variable names. Entries in this area and data variable area determine which channels will actually make measurements. You can enter up to eight variable names. When the pointer is located in 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 screen. The numerical values of these variables will be shown on the LIST screen 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 screen



UGD05010, 100x50

On the "DISPLAY: ANALYSIS SETUP" screen, you set up the automatic analysis function. When a measurement finishes, the function automatically draws lines, a marker, or both as specified on this screen.

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 7.

User Comment

In this field, you can enter a desired comment. This comment is also displayed in the CHANNELS, MEASURE, DISPLAY, and GRAPH/LIST screen 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 screen, 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] between 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] between 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] between 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 screen, 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] between 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] between 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] between a point where
 [DGM   ] = [MAX(DGM)*0.01                             ]
 [AFTER] [DGM   ] = [MAX(DGM)                          ]
```

On GRAPH/LIST: GRAPHICS screen, 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 7.

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 screen, 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 Screen Group

GRAPH/LIST screen group has the following screens:

Graphic Results:	For displaying the measurement results graphically. You can use lines or a marker on the graphics screen to analyze the measurement results graphically.
List Results:	For listing the measurement results.

To move into the GRAPH/LIST screen group, do one of the following:

- Press Graph/List front-panel key in the PAGE CONTROL key group (if present screen is not GRAPHICS or LIST screen).
- Press Single, Repeat, or Append front-panel key (if present screen is not GRAPHICS or LIST screen). Measurement is performed.

If the present screen is the GRAPHICS or LIST screen, you can toggle between these screens by pressing the Graph/List front-panel key.

On the GRAPHICS result screen

In the primary softkey area of the GRAPHICS screen, 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	SAMPLING SETUP	STOP COND	CONST SETUP

On the LIST result screen

In the primary softkey area of the LIST screen, the following softkeys are available for performing the manual analysis functions:

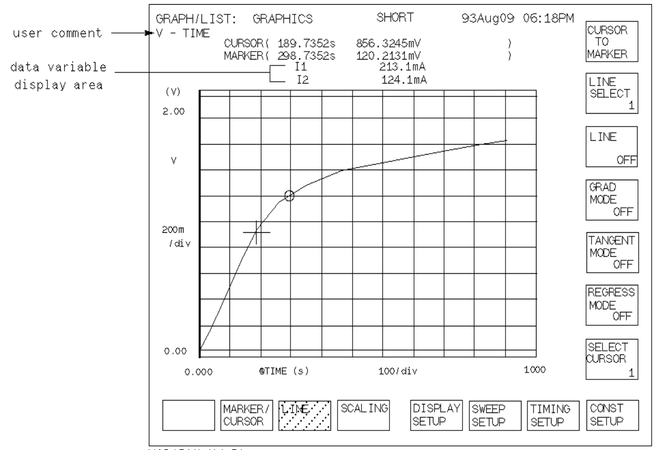
For sweep measurements:

AXIS Y2	MARKER		SPREAD SHEET	RE- SETUP	SWEEP SETUP	TIMING SETUP	CONST SETUP

For sampling measurements:

AXIS Y2	MARKER		SPREAD SHEET	RE- SETUP	SAMPLING SETUP	STOP COND	CONST SETUP

GRAPH/LIST: GRAPHICS screen



UGD05011, 100x50

On the "GRAPH/LIST: GRAPHICS" screen, 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 screen 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 screen. 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 softkey

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 softkey

Select MARKER/CURSOR primary softkey to display secondary softkeys for performing analysis with marker and cursor.

- MARKER softkey

  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 (o). For Y2 axis, marker is an asterisk (*). Active marker is highlighted for the axis that is selected by AXIS softkey.

  The 4155B/4156B remembers the location of marker. That is, when marker is turned off, then redisplayed, it appears at its previous location.

- MARKER MIN/MAX softkey

  Select MARKER MIN/MAX secondary softkey to move the marker to the maximum or minimum measurement point. If this softkey moves the marker to the maximum point, pressing the softkey again moves it to the minimum point.

- INTERPOLATE softkey

  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 softkey

  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 the left arrow, upper arrow, right arrow and down arrow MARKER/CURSOR keys. 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.

NOTE

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 softkey

  Select MARKER SKIP secondary softkey to move the marker to the next measurement curve that was added by VAR2 variable or append measurement.

- CURSOR softkey

  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 softkey

  Select AUTO ANALYSIS secondary softkey to redisplay the auto-analysis that was originally displayed after the measurement was finished.

LINE softkey

Select LINE primary softkey to display the secondary softkeys for performing manual analysis that uses lines.

- CURSOR TO MARKER softkey

  Select CURSOR TO MARKER secondary softkey to move the cursor to the marker position.

- LINE SELECT softkey

  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 softkey

  Select LINE secondary softkey to toggle the line mode between `OFF` and `ON`. You can set line on/off for line 1 and line 2 independently.

  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 softkey

  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 softkey

  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 softkey

  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 softkey

  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 softkey

  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 softkey

  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 softkey

Select SCALING primary softkey to display secondary softkeys for enlarging or reducing the plotting area.

- AUTO SCALING softkey

  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 softkey

  Select ZOOM IN secondary softkey to change the X and Y scaling to half the present scaling. This enlarges measurement curve on the plot area. If the cursor is not displayed, long cursor appears at the center, then zoom is performed.

- ZOOM OUT softkey

  Select ZOOM OUT secondary softkey to change the X and Y scaling to double the present scaling. This reduces measurement curve on the plot area. If the cursor is not displayed, long cursor appears at the center, then zoom is performed.

- CENTER AT CURSOR softkey

  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 softkey

  Select CURSOR TO MARKER secondary softkey to move the cursor to the marker position. Both marker and cursor must be displayed.

- CANCEL SCALING softkey

  Select CANCEL SCALING secondary softkey to redraw the plotting area with the original settings (most recent DISPLAY: DISPLAY SETUP screen settings or RE-SETUP GRAPH settings).

DISPLAY SETUP softkey

Select DISPLAY SETUP primary softkey to display secondary softkeys for setting or changing the display.

- RE-SETUP GRAPH softkey

  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 the left arrow, upper arrow, right arrow and down arrow MARKER/CURSOR keys.

  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 softkey

  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 softkey

  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 softkey

  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 softkey

  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 softkey

  Select SHOW OVERLAY INFO secondary softkey to display the following for the overlay plane: axes, cursor, marker, line, and data variables. Select EXIT primary softkey to remove information.

- SCALE TO OVERLAY softkey

  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 softkey

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 screen.

To change the values on the secondary softkeys: enter number by *using numeric keys* or change number by *rotating rotary knob*.

- VAR1 START softkey

  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 softkey

  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 softkey

  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 softkey

  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 softkey (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 softkey (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 softkey (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 softkey

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 screen.

To change the values on the secondary softkeys: enter number by *using numeric keys* or change number by *rotating rotary knob*.

- HOLD TIME softkey

  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 softkey

  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 screen.

- PULSE BASE softkey (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 softkey (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 softkey (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 softkey

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 screen.

To change the values on the secondary softkeys: enter number by *using numeric keys* or change number by *rotating rotary knob*.

- SAMPLNG MODE softkey

  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 softkey

  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 softkey

  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 softkey

  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 softkey

  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 softkey

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 screen.

To change the values on the secondary softkeys: enter number by *using numeric keys* or change number by *rotating rotary knob*.

- STOP COND softkey

  Select STOP COND secondary softkey to enable or disable the stop condition. Selecting this softkey toggles between `ENABLE` and `DISABLE`.

- ENABLE DELAY softkey

  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 softkey

  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 softkey

  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 softkey

  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 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 screen.

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
```

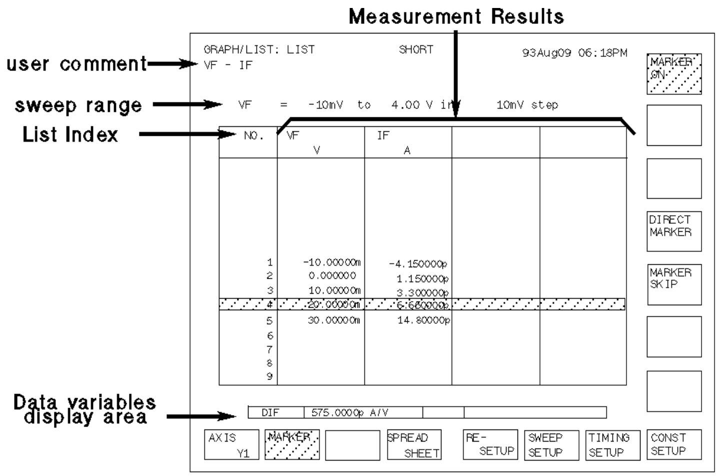
Select the secondary softkey that you want to change. The selected softkey is highlighted, and the present output value appears in the data entry area. You can change the value.

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 screen



UGD05031, 120x50

On the "GRAPH/LIST: LIST" screen, 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 screen 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 screen. The GRAPH/LIST: LIST screen shows only four columns for the data. If you have defined more than four variable values, you can scroll right or left by using the left arrow or right arrow front-panel key.

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 screen. This is the value of the variable at the marker position.

AXIS Y1 softkey

For GRAPH/LIST: GRAPHICS screen, this softkey is used to toggle active axis to analyze between the Y1 and Y2 axis.

For GRAPH/LIST: LIST screen, 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.

This softkey is displayed only if Y2 axis is set up.

MARKER softkey

Select MARKER primary softkey to display secondary softkeys for operation with marker.

- MARKER softkey

  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 screen is linked to marker on the GRAPH/LIST: GRAPHICS screen. So, if marker is moved on the GRAPH/LIST: GRAPHICS screen, the marker also moves on the GRAPH/LIST: LIST screen.

  The 4155B/4156B 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 softkey

  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 the left arrow, up arrow, right arrow, and down arrow MARKER/CURSOR keys.

  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 softkey

  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 softkey

  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 softkey

  Select MARKER SKIP secondary softkey to move the marker to the next VAR2 value or to the next appended measurement data.

- MARKER SKIP softkey

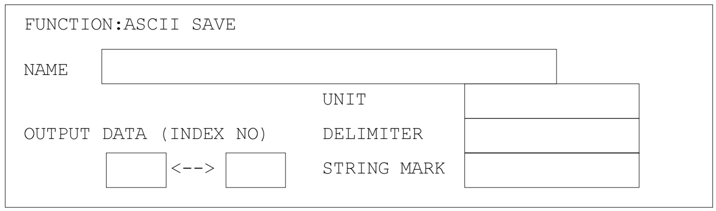
  Select MARKER SKIP secondary softkey to move the marker to the next VAR2 value or to the next appended measurement data.

- NEXT APPEND softkey

  Select NEXT APPEND secondary softkey to move the marker to the next appended measurement data.

SPREADSHEET softkey

Select SPREAD SHEET primary softkey to display ASCII SAVE window. The following entry fields appear:



Also, the following softkeys appear:

- Select EXECUTE softkey to store result data to diskette file or network disk.
- 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 or network disk. 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 screen.

  - right field: upper limit
  - left 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.

RE-SETUP softkey

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 the left arrow, up arrow, right arrow, and down arrow MARKER/CURSOR keys.

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 softkey

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 screen.

To change the values on the secondary softkeys: enter number by *using numeric keys* or change number by *rotating rotary knob*.

- VAR1 START softkey

  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 softkey

  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 softkey

  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 softkey

  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 softkey (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 softkey (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 softkey (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 softkey

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 screen.

To change the values on the secondary softkeys: enter number by *using numeric keys* or change number by *rotating rotary knob*.

- HOLD TIME softkey

  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 softkey

  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 screen.

- PULSE BASE softkey (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 softkey (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 softkey (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 softkey

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 screen.

- SAMPLNG MODE softkey

  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 softkey

  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 softkey

  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 softkey

  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 softkey

  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 softkey

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 screen.

- STOP COND softkey

  Select STOP COND secondary softkey to enable or disable the stop condition. Selecting this softkey toggles between ENABLE and DISABLE.

- ENABLE DELAY softkey

  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 softkey

  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 softkey

  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 softkey

  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 softkey

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 screen.

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 Screen Group

STRESS screen group has the following screens:

Stress channel definition:	For defining the stress channels of the 4155B/4156B, 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 screen group, do the following:

- Press Stress front-panel key in the PAGE CONTROL key group.

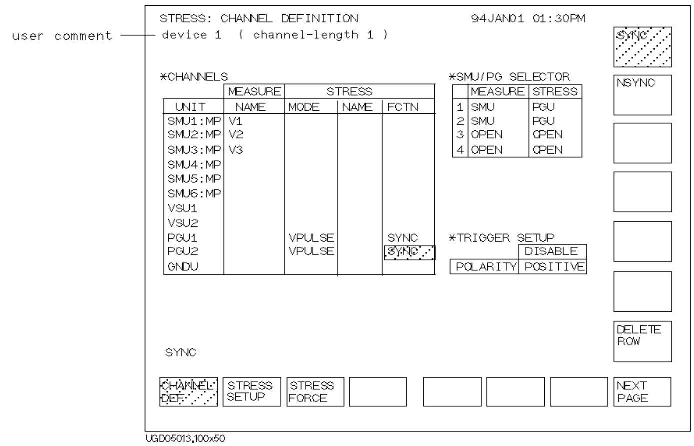
Then the following softkeys appear in the primary softkey area:

CHANNEL DEF	STRESS SETUP	STRESS FORCE				PREV PAGE	NEXT PAGE

- Select CHANNEL DEF softkey to move to the STRESS: CHANNEL DEFINITION screen.
- Select STRESS SETUP softkey to move to the STRESS: STRESS SETUP screen.
- Select STRESS FORCE softkey to move to the STRESS: STRESS FORCE screen.

When you press the **Stress** front-panel key in the MEASUREMENT key group, the STRESS: STRESS FORCE screen appears and stress forcing starts.

STRESS: CHANNEL DEFINITION screen



On the "STRESS: CHANNEL DEFINITION" screen, 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 screens.

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 4155B/4156B.

- NAME of MEASURE

  Source name that was defined for the measurement state (on CHANNELS: CHANNEL DEFINITION screen). 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	yes	yes		yes	yes
VSU	yes				yes
PGU	yes		yes		yes
GNDU				yes	yes

When pointer is at *top of this column*, CHANNEL ASSIGN softkey appears:

NOTE

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 screen. 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 screen *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

Agilent 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 “SMU/PG Selector Control” in Chapter 3 or *Agilent 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:

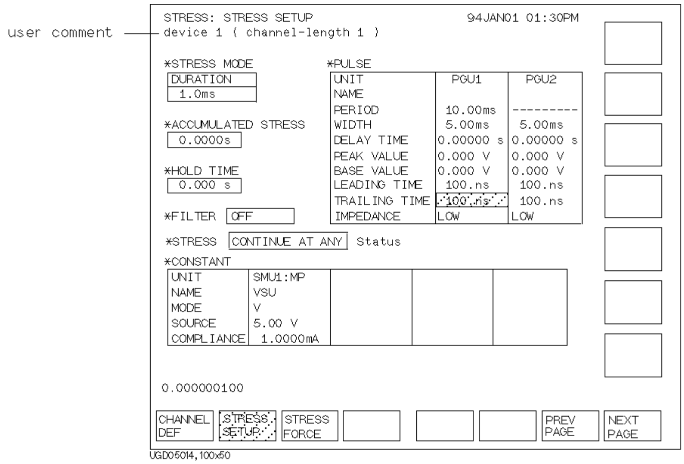
  - ENABLE secondary softkey to enable the trigger function.
  - DISABLE secondary softkey to disable the trigger function.

- 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 screen



On the "STRESS: STRESS SETUP" screen, 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 screens.

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 screen and on STRESS: STRESS FORCE screen are linked. So, if value is changed on this screen, value is changed to same value on STRESS: STRESS FORCE screen 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 screen.

On the STRESS: CHANNEL DEFINITION screen 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

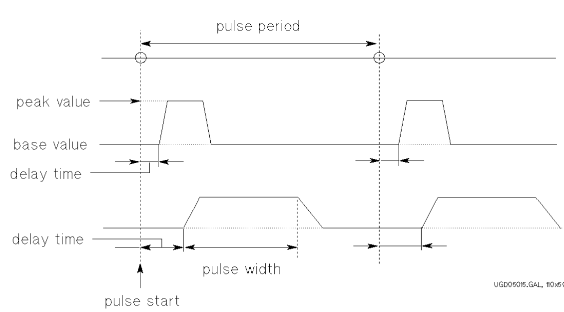
  This field specifies the pulse period of the PGU. Both PGUs are set to same value.

- 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.



- 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 0 Ω.
  - 50 ohm secondary softkey to set output impedance to 50 Ω.

CONSTANT

The UNIT, NAME, and MODE are defined on STRESS: CHANNEL DEFINITION screen.

On the STRESS: CHANNEL DEFINITION screen 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

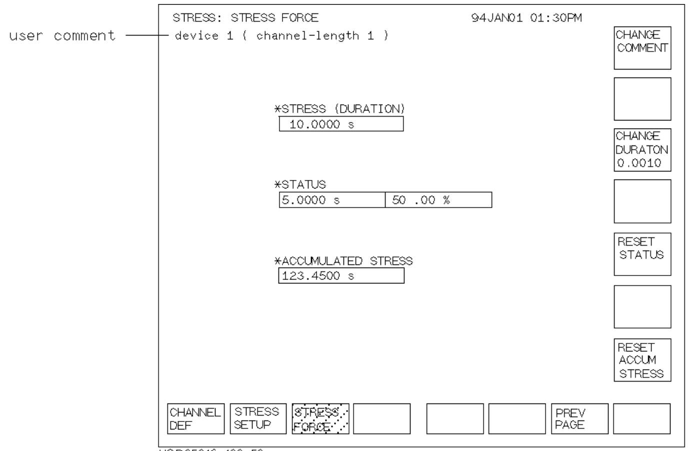
  In the SOURCE field, you specify the output value.

- 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 screen, 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 the left arrow or right arrow MARKER/CURSOR front-panel keys.

STRESS: STRESS FORCE screen



UGD05016, 100x50

On the "STRESS: STRESS FORCE" screen, 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 screens.

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 screen. If the STRESS MODE is set to pulse count mode in the STRESS: STRESS SETUP screen, 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 screen. 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

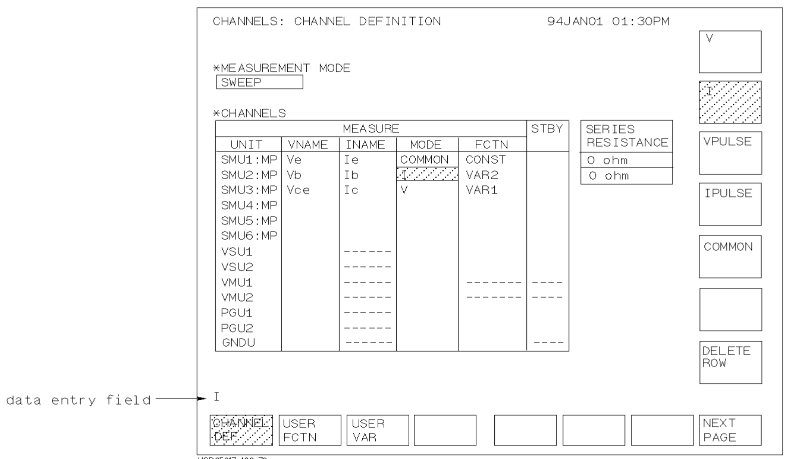
As the time in the STATUS field increases, the time in the ACCUMULATED STRESS field on this screen and also on STRESS: STRESS SETUP screen increases by the same amount.

To reset accumulated stress on both screens to 0, select RESET ACCUM STRESS secondary softkey. To change to non-zero value, change accumulated stress on STRESS: STRESS SETUP screen.

Screen Operation

This section explains how to fill in the entry fields on a screen, and the function of the blue, green and Edit front-panel keys.

The setup screens 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 the pointer to a field on a setup screen, 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 4155B/4156B 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 screen, 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 in the lower-right corner of the screen. You can enter numeric values.

Uppercase shift state `B` is displayed in the lower-right corner of the screen. `G` is not displayed. You can enter uppercase alphabet characters.

Lowercase shift state `b` is displayed in the lower-right corner of the screen. You can enter lowercase alphabet characters.

To change between these states:

- toggle between the non-shift/shift state by pressing the blue key.
- toggle between the upper/lowercase shift state by pressing the green key, then the blue key.

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

Present Status	Next Status	Key to be pressed
non-shift	Uppercase blue-key shift	blue key
Uppercase blue-key shift	non-shift	blue key
non-shift	Lowercase blue-key shift	green key, then blue key
Lowercase blue-key shift	non-shift	blue key
Uppercase blue-key shift	Lowercase blue-key shift	green key, then blue key
Lowercase blue-key shift	Uppercase blue-key shift	green key, then blue key

Screen Organization
Screen Operation

Green front-panel key usage

You can use the green front-panel key to enter special (non-alphanumeric) characters, which are 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 "#$", press the green key, 0, green key, and 1.

The green key mode has special functions for entering data, as shown in the following table.

Keys	Label	Function
Green, ⇐	|⇐	Moves the cursor to the first character.
Green, ⇒	⇒|	Moves the cursor to the last character.
Green, Recall↓	Recall↑	Recalls the oldest input from the key buffer. The key buffer stores the 10 most recent entries in the data entry area.
Green, Clear	Clr→End	Clears the entered data from the present cursor position to the end.
Green, Enter	Calc	Calculates any expression entered in the data entry area.

The front-panel green key can also be used to perform dump (Plot/Print key), knob sweep (Single key), and zero offset cancel (Stop key) operations.

Edit front-panel keys

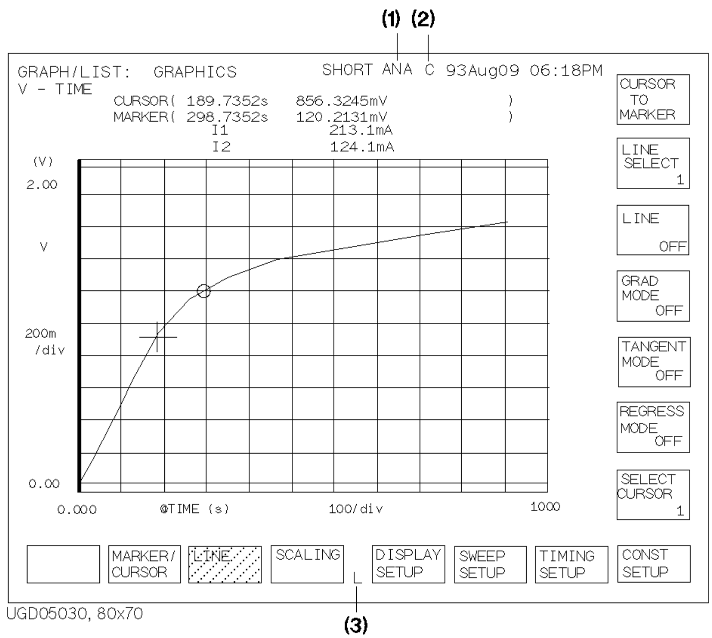
There are six keys in the Edit front-panel key group. Four of these keys also have other functions in the green-key shift mode. The following table shows the function of each key:

Key	Label	Functions
⇐		Moves the cursor left by one column in the data entry area.
⇒		Moves the cursor 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 the first column in the data entry area.
Green, ⇒	⇒|	Moves the cursor to the 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 the present cursor position to the end of the entry.

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

Status Indicators

The status indicators indicates the present status of the 4155B/4156B. The display contains the following status indicators.



(1) indicates the following status:

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

(2) indicates the following status:

`C`	The 4155B/4156B is performing auto-calibration.
`Z`	The 4155B/4156B is performing an offset measurement for the zero offset cancel function.

(3) displays `L` when the screen is locked by an GPIB command.

7 Data Variable and Analysis Function

This chapter explains the display and analysis functions of Agilent 4155B/4156B:

- "Data Variable"
- "Expression"
- "Built-in Function"
- "Read Out Function"
- "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 screen. 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 screen. 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 screen 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 screen.

You can use a user function inside another user function. And you can set up the user function on the DISPLAY: DISPLAY SETUP screens 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 screen. 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.
- Unit name is optional. Length: 1 to 6 characters. Valid characters: any characters.

For the syntax of an expression, refer to "Expression" on page 7-8.

Example

To define a user function for mutual conductance *gm* of an FET, define *gm* on the CHANNELS: USER FUNCTION DEFINITION screen 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 GPIB commands of PAGE:CHANNels:UVARiable and TRACe|DATA subsystems from an external computer or the Internal IBASIC. For information about the PAGE:CHANNels:UVARiable and TRACe|DATA subsystems, refer to *GPIB Command Reference*.

You can perform calculations between measurement results and the numeric list, or plot the numeric list on the GRAPH/LIST: GRAPHICS screen.

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
```

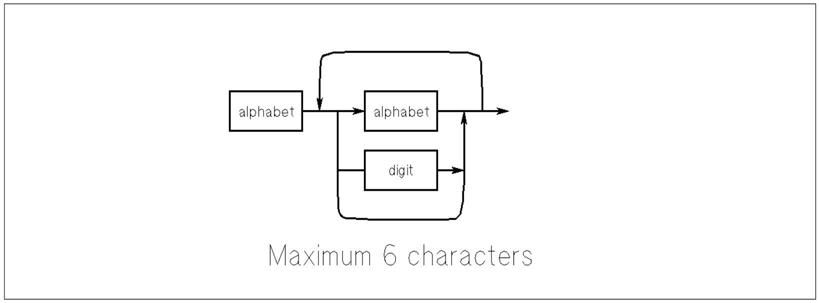
20 Format of data to be transferred is ASCII format.

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 the following figure.



ugd07001 120x40

The name must be unique. Name is case sensitive. For example, Gm is different from GM.

NOTE

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

Figure 7-1 shows the syntax of an expression. Notice that an expression can be used within an expression.

NOTE

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.

NOTE

Operation between data variables

Operation between data variables is performed between data at the same measurement points.

NOTE

Arithmetic operator precedence

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: + -

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.

Figure 7-1 **Expression Syntax**

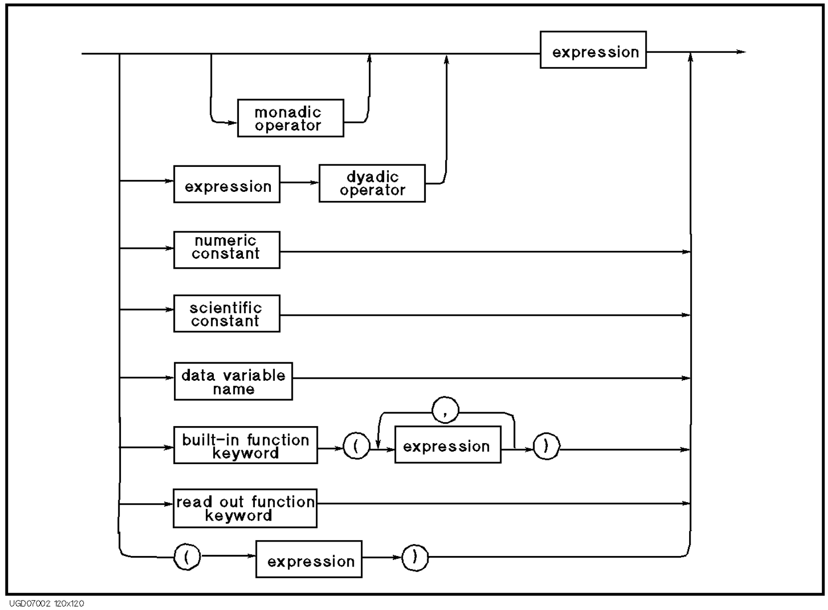
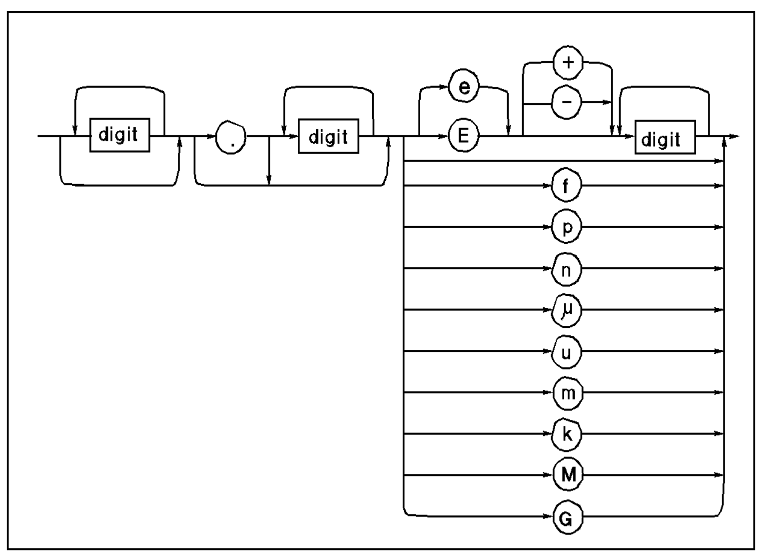


Figure 7-2 **Numeric Constant**



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
```

numeric constant

Numeric constant can consist of digits, decimal point, and optional exponent notation. Refer to Figure 7-2.

Mantissa (decimal part) of greater than seven digits is truncated to seven digits.

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.

built-in function keyword

A keyword that invokes the 4155B/4156B’s built-in function. Refer to “Built-in Function” on page 7-11.

read out function keyword

A keyword that invokes the 4155B/4156B’s built-in read out function. Refer to “Read Out Function” on page 7-20.

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 screen.
- As the condition for an automatic analysis function on the DISPLAY: ANALYSIS SETUP screen.
- 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 absolute value of `ID`:

`AVG(ID)`

COND

This function does the following:

- If *1st expression* < *2nd expression*, returns *3rd expression*.
- 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

`COND(ID-VG,SQRT(ID)-VG,VD,VGS-VTH)`

returns:

- `VD` if `ID-VG` < `SQRT(ID)-VG`.
- `VGS-VTH` if `ID-VG` ≥ `SQRT(ID)-VG`.

DELTA

Returns the difference of the *expression*.

Syntax

`DELTA(`*expression*`)`

The difference is defined as follows:

$$\delta n = (a_2 - a_1) \qquad \text{when } n = 1$$

$$\delta n = (a_{n+1} - a_{n-1})/2 \qquad \text{when } 1 < n < N$$

$$\delta n = (a_N - a_{N-1}) \qquad \text{when } n = N$$

Where,

δn: 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.

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:

$y'_n = (y_2 - y_1)/(x_2 - x_1)$ when $n = 1$

$y'_n = (y_{n+1} - y_{n-1})/(x_{n+1} - x_{n-1})$ when $1 < n < N$

$y'_n = (y_N - y_{N-1})/(x_N - x_{N-1})$ when $n = N$

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.

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:

when n = 1, $\sigma_n = 0$

when n > 1, σ_n is presented by the following equation:

$$\sigma_n = \frac{1}{2}\sum_{i=2}^{n}(y_i + y_{i-1})(x_i - x_{i-1})$$

Where,

σ_n: integral of *1st expression* for measurement index number n.

r_i: value of *1st expression* for measurement index number i.

x_i: value of *2nd expression* for measurement index number i.

If there are some invalid values in the *expression*s, the invalid values are ignored for the calculation.

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	`-Overflow` 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	`-Overflow` 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:

The moving average at measurement index number n is defined as follows:

when $n \le r$

$$\bar{x}_n = \frac{1}{r+n} \sum_{i=1}^{n+r} x_i$$

when $r < n \le N-r$

$$\bar{x}_n = \frac{1}{2r+1} \sum_{i=n-r}^{n+r} x_i$$

when $N-r < n$

$$\bar{x}_n = \frac{1}{r+N-n+1} \sum_{i=n-r}^{N} x_i$$

Where,

$\bar{x}_n$: 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*.

N: number of sweep steps or number of samples.

If there are some invalid values in the *1st expression*, the invalid values are ignored for the calculation.

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 screen.
- As a condition for an automatic analysis function on the DISPLAY: ANALYSIS SETUP screen.
- 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 screen 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 LINE*n*. If the Y axis is logarithmic scale, y_n is the log value of the y intercept of LINE*n*.

α_n : Slope of LINE*n*.

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 value of LINE*n*. If the Y axis is logarithmic scale, y_n is the log value of the y intercept of LINE*n*.

α_n : Slope of LINE*n*.

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 LINE*n*. If the Y1 axis is logarithmic scale, y_n is the log value of the Y1 intercept of LINE*n*.

α_n : Slope of LINE*n*.

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 LINE*n*. If the Y2 axis is logarithmic scale, y_n is the log value of the Y2 intercept of LINE*n*.

α_n : Slope of LINE*n*.

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:

  $\alpha = (y_1 - y_0)/(x_1 - x_0)$

- If X axis is logarithmic scaling, and Y axis is linear scaling:

  $\alpha = (y_1 - y_0)/(\log x_1 - \log x_0)$

- If X axis is linear scaling, and Y axis is logarithmic scaling:

  $\alpha = (\log y_1 - \log y_0)/(x_1 - x_0)$

- If X and Y axes are both logarithmic scaling:

  $\alpha = (\log y_1 - \log y_0)/(\log x_1 - \log x_0)$

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 axes are both linear scaling:

  $\alpha = (y_1 - y_0)/(x_1 - x_0)$

- If X axis is logarithmic scaling, and Y1 axis is linear scaling:

  $\alpha = (y_1 - y_0)/(\log x_1 - \log x_0)$

- If X axis is linear scaling, and Y1 axis is logarithmic scaling:

  $\alpha = (\log y_1 - \log y_0)/(x_1 - x_0)$

- If X and Y1 axes are both logarithmic scaling:

  $\alpha = (\log y_1 - \log y_0)/(\log x_1 - \log x_0)$

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:

  $\alpha = (y_1 - y_0)/(x_1 - x_0)$

- If X axis is logarithmic scaling, and Y2 axis is linear scaling:

  $\alpha = (y_1 - y_0)/(\log x_1 - \log x_0)$

- If X axis is linear scaling, and Y2 axis is logarithmic scaling:

  $\alpha = (\log y_1 - \log y_0)/(x_1 - x_0)$

- If X and Y2 axes are both logarithmic scaling:

  $\alpha = (\log y_1 - \log y_0)/(\log x_1 - \log x_0)$

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:

  $\alpha = (y_1 - y_0)/(x_1 - x_0)$
- If X axis is logarithmic scaling, and Y axis is linear scaling:

  $\alpha = (y_1 - y_0)/(\log x_1 - \log x_0)$
- If X axis is linear scaling, and Y axis is logarithmic scaling:

  $\alpha = (\log y_1 - \log y_0)/(x_1 - x_0)$
- If X and Y axes are both logarithmic scaling:

  $\alpha = (\log y_1 - \log y_0)/(\log x_1 - \log x_0)$

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 axes are both linear scaling:

  $\alpha = (y_1 - y_0)/(x_1 - x_0)$

- If X axis is logarithmic scaling, and Y1 axis is linear scaling:

  $\alpha = (y_1 - y_0)/(\log x_1 - \log x_0)$

- If X axis is linear scaling, and Y1 axis is logarithmic scaling:

  $\alpha = (\log y_1 - \log y_0)/(x_1 - x_0)$

- If X and Y1 axes are both logarithmic scaling:

  $\alpha = (\log y_1 - \log y_0)/(\log x_1 - \log x_0)$

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:

  $\alpha = (y_1 - y_0)/(x_1 - x_0)$

- If X axis is logarithmic scaling, and Y2 axis is linear scaling:

  $\alpha = (y_1 - y_0)/(\log x_1 - \log x_0)$

- If X axis is linear scaling, and Y2 axis is logarithmic scaling:

  $\alpha = (\log y_1 - \log y_0)/(x_1 - x_0)$

- If X and Y2 axes are both logarithmic scaling:

  $\alpha = (\log y_1 - \log y_0)/(\log x_1 - \log x_0)$

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`

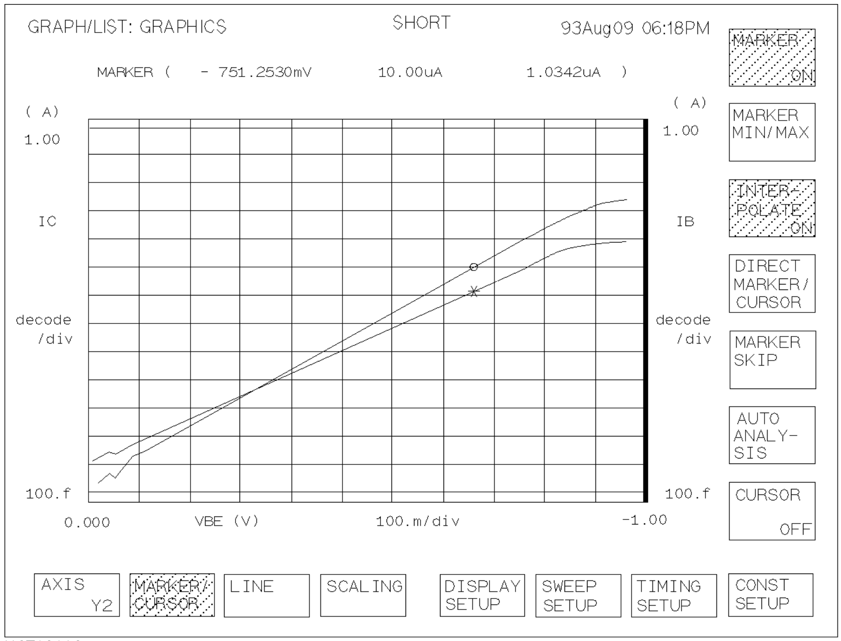
Analysis Function

The 4155B/4156B provides the following functions for analyzing measurement results:

- "Marker on the GRAPH/LIST: GRAPHICS screen"
- "Marker on the GRAPH/LIST: LIST screen"
- "Cursor"
- "Line Drawing"
- "Scaling Functions"
- "Overlay Display Function"
- "Automatic Analysis Function"

Marker on the GRAPH/LIST: GRAPHICS screen

Figure 7-3 **Markers on the GRAPH/LIST: GRAPHICS screen**



UGT02002

You can display the markers on the plotted measurement curves on the GRAPH/LIST: GRAPHICS screen by selecting MARKER/CURSOR primary softkey, then selecting MARKER secondary softkey. The marker for Y1 axis is a circle (o), 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 screen:

- 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” on page 7-39.

- 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 screen, 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

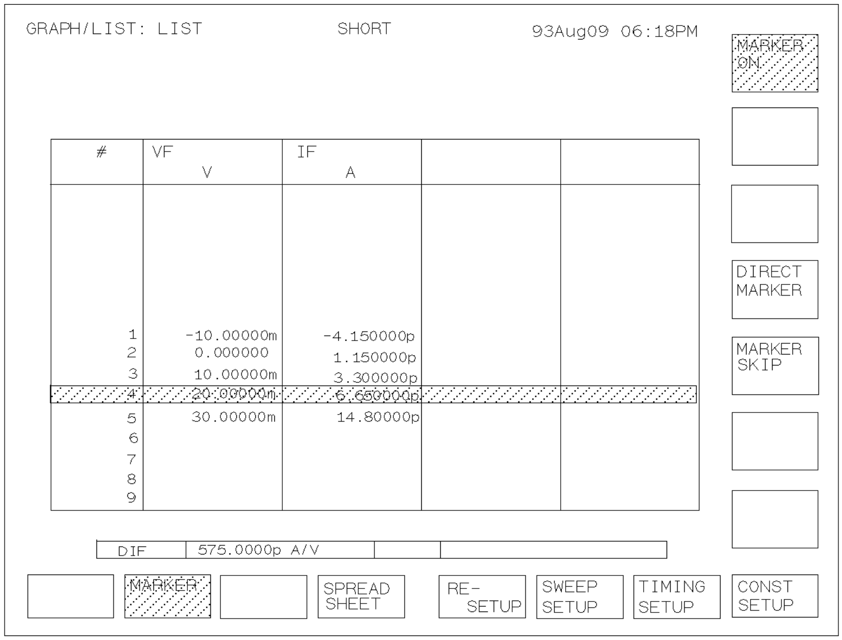
  Moves the marker directly to specified coordinates on measurement curve.

- 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 screen

Figure 7-4 **Marker on the GRAPH/LIST: LIST screen**



UGT02013, 100x80

When marker function is enabled on GRAPH/LIST: LIST screen, a marker (highlighted row) is displayed.

Marker has following functions on this screen:

- 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 screen, 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 upper arrow and down arrow front-panel keys. If you have defined more than four variable values, you can scroll right or left by using the left arrow or right arrow front-panel key.

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.

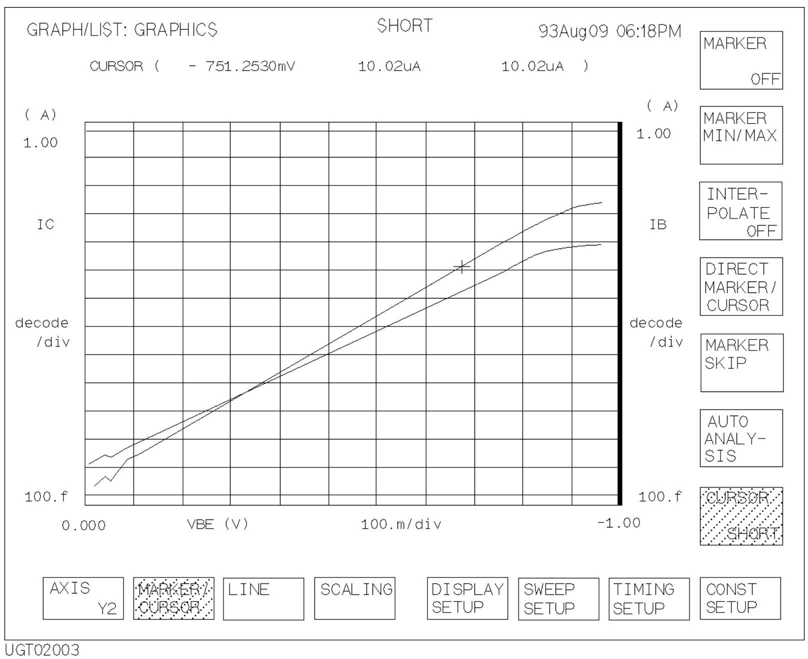
Cursor

Cursors are used to specify the position for line drawing or scaling functions on the GRAPH/LIST: GRAPHICS screen. Refer to “Line Drawing” on page 7-39 and “Scaling Functions” on page 7-41.

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.

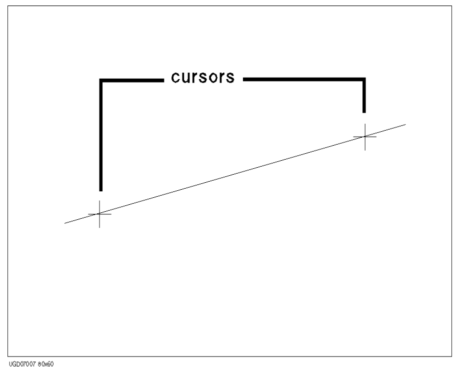
Figure 7-5 **Cursors on the GRAPH/LIST: GRAPHICS screen**



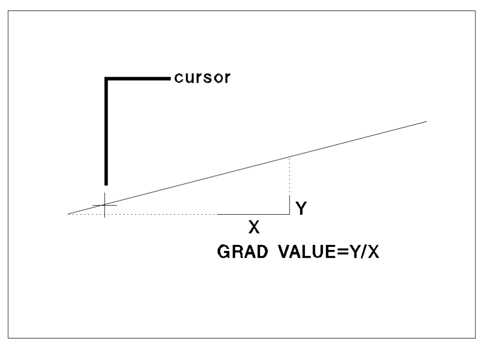
Line Drawing

You can draw up to two lines in plotting area on GRAPH/LIST: GRAPHICS screen. To draw lines, you can select one of following four line modes:

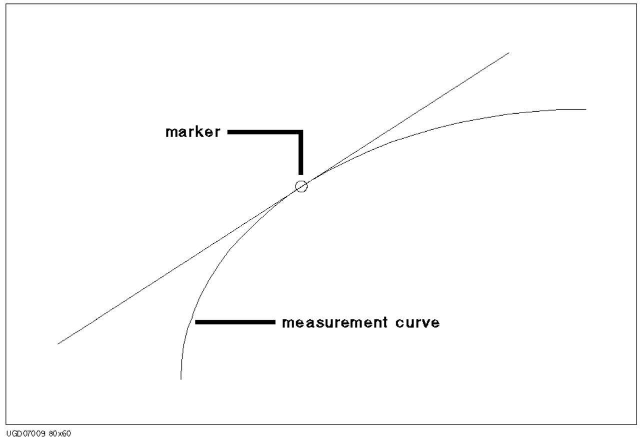
- Normal line mode: can draw a line through two cursors.



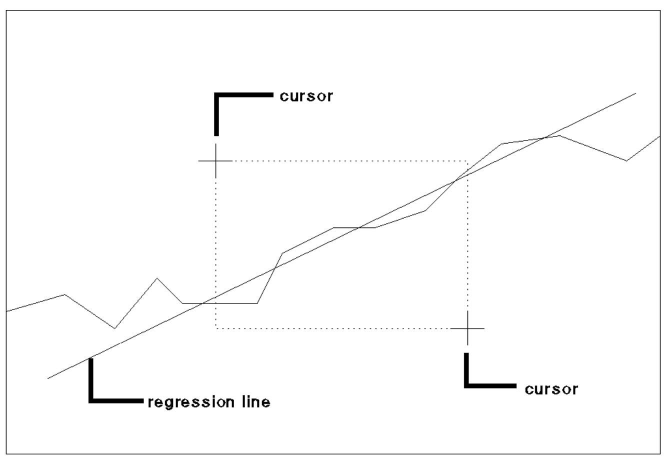
- Grad line mode: can draw a line through a cursor with specified gradient.



- Tangent line mode: can draw tangent line to marker, which is on measurement curve.



- Regression line mode: can draw regression line within area specified by two cursors.



Scaling Functions

You can change the axis scales after plotting the measurement results on the GRAPH/LIST: GRAPHICS screen. The following scaling functions are provided:

- Autoscaling

  Changes X and Y-axis scaling to fit the measurement curve.

- Zooming in

  Changes the scaling to half the present scaling. This enlarges the measurement curve on the plot area.

- Zooming out

  Changes the scaling to double the present scaling. This reduces the measurement curve on the plot area.

- 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 screen. 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 (x, y1, y2)
- Line x interrupt, y1 interrupt and gradient, y2 interrupt and gradient
- 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 screen. You set up this function on the DISPLAY: ANALYSIS SETUP screen. This function is performed automatically when:

- measurement finishes.
- AUTO ANALYSIS secondary softkey is pressed.

8 If You Have A Problem

If You Have A Problem

This chapter explains how to solve a problem or how to read status and error codes, if you encounter some problem.

This chapter is organized into the following sections:

- When you make a measurement
    - This section explains how to solve the problems that may occur when making a measurement.
- If errors occur
    - This section lists error codes and messages that may be displayed when operating Agilent 4155B/4156B. Also, this section describes how to read data status.

NOTE

To Get Help Information

To start help function, press the Help front-panel key. Then, you can select one of the following primary softkeys.

- OVERVIEW

  Briefly explains each help softkey.

- PAGE MAP

  Shows a map of all screens, highlights the present screen name, and gives a brief description of the highlighted screen name. You can use the arrow keys to highlight another screen name, then can display the screen by selecting the SELECT secondary softkey.

- FIELD INFO

  Describes field where the pointer is located on the screen, how to setup the field, and the setting restrictions. This softkey is not displayed for GRAPHICS, LIST, KNOB SWEEP, or STRESS FORCE screen.

- DATA STAT

  Shows how to read data status, which is displayed at the bottom of GRAPHICS, LIST, KNOB SWEEP, or STRESS FORCE screen. This softkey is displayed only for these screens.

- INPUT AID

  Displays variable names, mathematics functions, and read-out functions, and describes the highlighted name or function. This softkey is not displayed for GRAPHICS, LIST, KNOB SWEEP, or STRESS FORCE screen.

You can enter desired variable or function into the selected setup field of a screen by selecting ENTER secondary softkey, then pressing Enter front-panel key.

When You Make A Measurement

This section covers the following basic problems that you may encounter when you making a measurement, and the solutions.

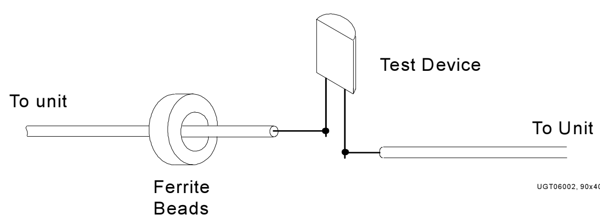
- "If Measured Value Oscillates when Measuring High-Frequency Devices"
- "If Measured Value Oscillates when Measuring Negative Resistance"
- "If Noise Affects the Measured Values"
- "If Measured Voltage has some Error when Forcing a Large Current"
- "If Large Current Causes High Temperature (Thermal Drift)"
- "If Measurement Takes More Time than Specified"
- "If Measurement Damages the Device under Test"
- "If You Get Unexpected Data when Performing Sampling Measurement"

If Measured Value Oscillates when Measuring High-Frequency Devices

When measuring parameters of high-frequency devices, such as GaAs MESFETs or high-frequency bipolar transistors, oscillation may cause measurement problems. Normal measurement cannot be performed because of oscillation.

To solve this problem:

- For FETs, add resistive ferrite beads as close as possible to the gate.
- For bipolar transistors, add resistive ferrite beads as close as possible to the base or emitter.
- Make connection cables as short as possible. Long wires cause oscillation because of their large inductance.



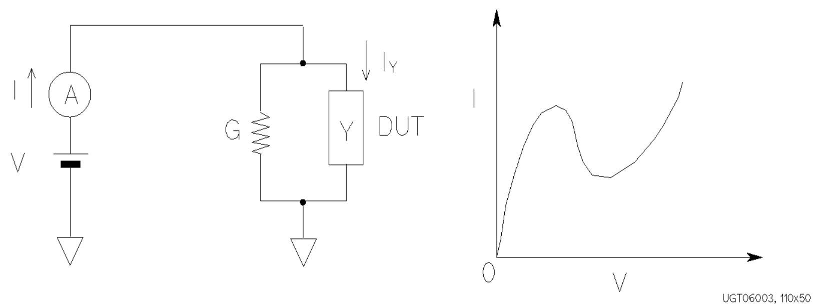
If Measured Value Oscillates when Measuring Negative Resistance

If the DUT has negative resistance characteristics, SMUs may oscillate. Because SMUs operate as negative feedback amplifier.

To solve this problem:

- For voltage controlled negative resistance device
    - Connect G in parallel with your DUT to cancel negative resistance. To obtain an output I-V curve, use the following equation.

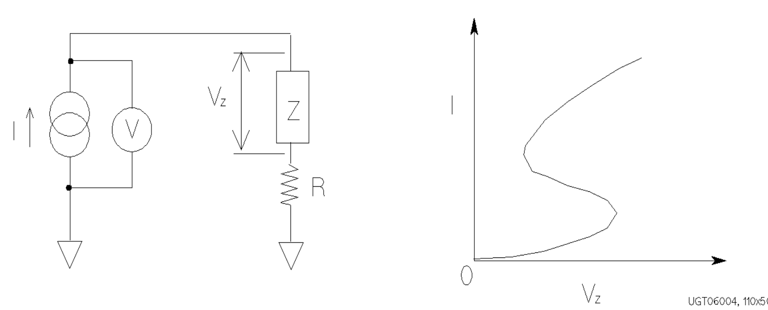
$$I_Y = I - G * V$$



- For current controlled negative resistance device
    - Connect R in series with your DUT to cancel negative resistance. To obtain an output I-V curve, use the following equation.

$$V_Z = V - R * I$$

    - If the resistance of the DUT is less than 1 MΩ, you can use R-Box.



If Noise Affects the Measured Values

When you measure low current of a DUT, the measured values may not be stable.

To solve this problem:

- Use guarding to reduce the leakage current between your prober and the 4155B/4156B. Note that long wires cause oscillation because of their large inductance. For details about connections, refer to “To Make Connections to Reduce Leakage Current” in Chapter 4.
- If some high-power electric machines are operating around the 4155B/4156B, turn off the machines, then perform the measurements. The machines affect the power line waveform.
- Shut the lid of test fixture or shield box to prevent effects of light.
- If these are vibrations due to nearby machines or due to air flow, put cushioning material under prober, cable, and the 4155B/4156B; install stabilizer on the prober; and make the cables stable by taping.
- Wait several minutes after connecting cables or moving probe needles. Because these operations cause electromotive force.
- If you use only Force terminal and triaxial cables for HRSMUs or HPSMU, connect an open cap to sense terminal.
- Keep constant temperature in the room when you use the 4155B/4156B. Shift of 1 °C may shift the measurement values. Temperature change causes the following.
  - Offset current in the 4155B/4156B.
  - Thermoelectromotive force in DUT, which causes low current.
  - Expansion and contraction of cables, which causes noise.

If Measured Voltage has some Error when Forcing a Large Current

Voltage measurement may have some error because of the effects of the cable resistance when forcing a large current.

To solve this problem:

- Use Kelvin connections between SMUs and DUT. To cancel the effects of cable resistance, connect the sense line as close as possible to the terminal of the DUT.

  For details of Kelvin connections, see “Connection to Device Under Test (DUT)” in Chapter 4

If Large Current Causes High Temperature (Thermal Drift)

If a large current is forced to a DUT, the temperature of the DUT may increase, which may cause characteristics to drift.

To solve this problem:

- Use the pulse output mode of the SMU.

  For large currents, the SMU should be set to pulse output mode. This decreases the average power output to prevent temperature rise of DUT.

If Measurement Takes More Time than Specified

When measuring current that is 10 μA or less, SMUs may take longer time to measure than the specified integration time. When measuring in a low current range, the SMUs automatically take longer integration time to perform accurate and stable measurements.

To solve this problem:

- Measure current using a fixed range that is more than 10 μA. The measurement will be performed in the specified integration time.

If you set many measurement channels, measurement takes a longer time.

To solve this problem:

- Decrease measurement channels to reduce measurement time.

  Note that the number of measurement channels automatically increases if you do *both* the following: force voltage from channels that are connected to R-Box *and* display the voltage values or use voltage values in user functions. The channels automatically measure current, which is used to compensate the voltage values.

If Measurement Damages the Device under Test

When Using SMU

When performing breakdown measurements by using SMU, DUTs may be damaged.

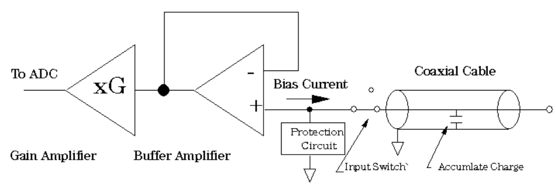
When voltage is forced from an SMU, the current is limited by the compliance setting, which prevents the DUT from being damaged by a large current. But when the current rapidly increases, the current limiter in the SMU cannot follow the rapid current increase, so a large amount of current may flow through the DUT for a moment, which may damage the DUT.

To solve this problem:

- Insert a protecting resistor as close as possible to DUT. You can also use a resistor of Agilent 16441A R-Box.

When Using VMU

When using VMU, the measurement terminal voltage increased by charge of buffer amplifier current in VMU, may damage DUT.

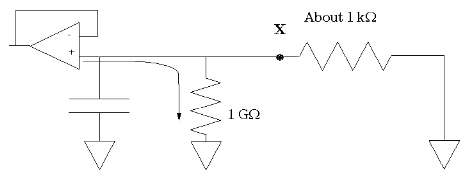


When the measurement terminal of VMU is open and when a coaxial cable is connected to VMU, buffer amplifier current charges increase the VMU terminal voltage. After a long time charge, the increased terminal voltage is discharged by connecting DUT, which may damage the DUT.

To solve this problem:

There are three ways to prevent this problem as follows:

1. Insert a large resistor between VMU and common

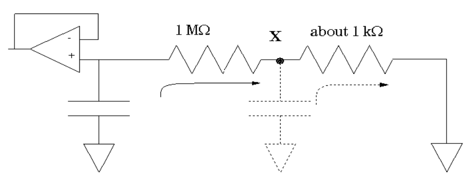


   This method cannot be used for voltage measurement of high resistance. Because the VMU input impedance gets lower.

2. Use SMUs instead of VMUs

   This method degrades measurement accuracy and resolution than VMU due to each unit's specification difference.

3. Insert a resistor in series to device



   This method needs to

   - select an appropriate resistor value for each device resistance value.
   - set wait time before measurement until charge current settles.
   - insert the resistor at close point to DUT to prevent damage due to the charge in a measurement circuit. (See dotted line in the above figure)

If You Get Unexpected Data when Performing Sampling Measurement

If initial interval is set to a short time and if FILTER ON is set, you may get unwanted data. FILTER ON causes a slower rise time, so short initial interval will sample during this rise time.

To solve this problem:

- Set FILTER field to OFF if you set initial interval to a short time.

Some data may be skipped because measurement takes a long time. Measurement takes a long time if measurement is performed in a low current range, if many measurement channels are set up, or if analysis, such as moving a marker, is performed during measurements.

To solve this problem:

- Measure current using a fixed range that is more than 10 µA. For measurement ranges 10 µA or less, measurement takes longer than the specified integration time.
- Decrease measurement channels to reduce measurement time.

  Note that the number of measurement channels automatically increases if you do *both* the following: force voltage from channels that are connected to R-Box *and* display the voltage values or use voltage values in user functions. The channels automatically measure current, which is used to compensate the voltage values.
- Do not perform analysis operation during measurement state

If Errors Occur

If the 4155B/4156B is not operated correctly, or if diagnostics or calibration fails, error codes and error messages are displayed.

If measurement or forcing stress are not performed correctly, measurement data status is displayed at bottom of GRAPHICS, LIST, KNOB SWEEP, or STRESS FORCE screen.

This section describes the following:

- "If Errors Occur when You Perform Self-calibration or Diagnostics"
- "If Errors Occur when You Operate the 4155B/4156B"
- "If a Measurement Data Status is Displayed"

If Errors Occur when You Perform Self-calibration or Diagnostics

The following are the error codes that are displayed at the bottom of the SYSTEM: SELF-CALIBRATION/DIAGNOSTICS screen if errors occur when you perform self-calibration or diagnostics.

If errors occur, write down the displayed error codes and contact the nearest Agilent Technologies Sales and Service office. Up to seven error codes can be displayed at the bottom of the SYSTEM: SELF-CALIBRATION/DIAGNOSTICS screen. To display the error codes, move pointer to a desired test item.

Error codes for measurement unit

The following are the error codes for measurement units. Error codes are 5-digit numbers.

`1`*xxyy*

- *xx*: measurement unit
    - `00`: VSU1,2 and VMU1,2
    - `01` to `06`: SMU1 to SMU6
    - `07`: PGU1,2
    - `08`: GNDU
    - `09`: AD converter
- *yy*: error number

1xx05	AD converter failed ROM or RAM self-test. Measurement unit failed AD converter test as a pretest for calibration or self-test.
1xx06	Successive approximation AD converter failed. Measurement unit failed AD converter test as a pretest for calibration or self-test.
1xx07	Integrating type AD converter failed. Measurement unit failed AD converter test as a pretest for calibration or self-test.
1xx08	AD converter test reached timeout. Measurement unit failed AD converter test as a pretest for calibration or self-test.
1xx11	Overvoltage occurred for a measurement unit.
1xx12	Overcurrent occurred for a measurement unit.

1xx15 Measurement units that are not supported are detected.

1xx19 Emergency occurred but the cause is unknown. This is displayed, for example, when unit is known but cause is unknown.

1xx90 AD converter test reached timeout during calibration or self-test for a measurement unit.

1xx91 FIFO (first-in, first-out) for AD converter overflowed because SMU controller takes long time to read measurement data.

1xx92 Calibration or diagnostics was aborted by an emergency or *RST command.

1xx94 The 4155B/4156B was turned on before the 41501A/B.

1xx97 Communication failed between HOST controller and SMU controller. Or calibration/diagnostics was performed, but HOST controller couldn't receive the result from SMU controller.

10030 VSUs and VMUs failed default test of calibration.

10031 VSUs and VMUs failed function check.

10032 VSUs failed gain or offset calibration.

10033 VMUs failed gain or offset calibration.

10034 VMUs failed differential mode 2 V range gain or offset calibration.

10035 VSUs failed gain and offset calibration, VMUs failed gain and offset calibration, or VMU failed differential mode 2 V range gain and offset calibration.

10036 VMUs failed differential mode 0.2 V range gain or offset measurement.

10037 VMUs failed differential mode 0.2 V range gain and offset calibration.

10038 VMUs and VSUs failed CMR (Common Mode Rejection) amp adjustment.

10040 VSU1 and VMU1 failed ±20 V measurement self-test in 20 V range.

10041 VSU2 and VMU2 failed ±20 V measurement self-test in 20 V range.

10042 VSU1 and VMU2 failed ±20 V measurement self-test in 20 V range.

10043 VMU2 and VMU1 failed ±20 V measurement self-test in 20 V range.

10044 VSU1 and VMU1 failed ±2 V measurement self-test in 2 V range.

10045 VSU2 and VMU2 failed ±2 V measurement self-test in 2 V range.

10046 VSU1 and VMU2 failed ±2 V measurement self-test in 2 V range.

10047 VSU2 and VMU1 failed ±2 V measurement self-test in 2 V range.

10048 VMUs and VSUs failed differential 2 V range self-test. This test measures ±2 V by VMUs in differential mode. (VSU1 is connected to VMU1, and VSU2 is connected to VMU2. VSU1 forces 0 V. VSU2 forces 2 V).

10049 VMUs and VSUs failed differential 2 V range self-test. This test measures 0 V by VMUs in differential mode. (VSU1 is connected to VMU1, and VSU2 is connected to VMU2. VSU1 forces 0 V.)

10050 VMUs and VSUs failed differential 0.2 V range self-test. This test measures 0 V by VMUs in differential mode. (VSU1 is connected to VMU1, and VSU2 is connected to VMU2. VSU1 forces 0 V.)

10051 VMUs and VSUs failed differential 2 V range self-test. This test measures 0 V by VMUs in differential mode. (VSU2 is connected to VMU1 and 2, and forces 0 V.)

10052 VMUs and VSUs failed differential 0.2 V range self-test. This test measures 0 V by VMUs in differential mode. (VSU2 is connected to VMU1 and 2, and forces 0 V.)

10x20 SMU failed function check.

10x21 SMU failed CMR (Common Mode Rejection) amp calibration.

10x22 SMU failed oscillation detector test.

10x23 SMU failed V set and V measure calibration.

10x24 SMU failed I set and I measure calibration.

10x25 SMU failed I bias test.

10x26 SMU failed V switch test.

10760 PGU1 failed pulse gain calibration.

10761 PGU2 failed pulse gain calibration.

10762 PGU1 failed pulse offset calibration.

10763 PGU2 failed pulse offset calibration.

10764 PGU1 failed voltage calibration of base value.

10765 PGU2 failed voltage calibration of base value.

10766 PGU1 failed leading time calibration.

10767 PGU2 failed leading time calibration.

10768 PGU1 failed trailing time calibration.

10769 PGU2 failed trailing time calibration.

10770 PGU1 failed slope offset calibration.

10771 PGU2 failed slope offset calibration.

10772 PGU1 failed slope sampling calibration.

10773 PGU2 failed slope sampling calibration.

10875 GNDU failed offset calibration.

10905 AD converter failed ROM or RAM self-test.

10906 Successive approximation AD converter failed calibration or self-test.

10907 Integrating type AD converter failed calibration or self-test.

10908 AD converter reached timeout. AD converter did not return completion status within certain time after sending calibration or self-test command.

Error code for CPU and peripherals

The following are the error codes for CPU and peripherals. Error codes are 5-digit numbers.

2*wwwz*

- *www*: test item number (on SYSTEM: SELF-CALIBRATION/DIAGNOSTICS screen).
- *z*: test number

23010	Host DRAM failed self-test.
23021	Host ROM failed checksum test.
23022	Host SRAM failed read and write test.
23023	EEPROM failed read and write test.
23030	Real-time clock failed timer test.
23040	GPIB controller failed self-test. This test sets some settings, then checks the status.
23050	Parallel interface controller failed self-test. This test sets some settings, then checks the status.
23061	Host controller sends a command and does not receive acknowledge from SMU controller.
23062	Host controller failed receiving response from SMU controller by sending a command.
23071	SMU controller ROM failed checksum test.
23072	SMU controller on-board SRAM failed read and write test.
23073	SMU controller internal SRAM failed read and write test.
23074	SMU controller internal timer failed self-test.
23075	SMU controller timer does not operate with correct frequency.
23076	SMU controller failed power on self-test.
23077	SMU controller test gets timeout.
23080	Access to graphics system processor failed read and write test.
23091	Graphic memories (SRAM) failed read and write test.

23092	Graphic memories (VRAM) failed read and write test.
24017	Parallel interface failed data line test.
24018	Parallel interface failed control line test.
24021	Trigger output test failed or reached timeout.
24022	Trigger input test failed.
24041	Flexible disk drive controller test failed.
24042	Flexible disk drive 5 V power line test failed.
24051	Flexible disk drive failed diskette change test.
24052	Flexible disk drive failed read and write test.
24062	12 V source on post regulator is not output.
24063	15 V source on post regulator is not output.
24064	3 V source on post regulator is not output.
24065	LAN interface test failed.
24071	A front-panel key is stuck in pressed position.
24072	Front key assembly may be disconnected.
24073	Front-panel key controller is not functioning properly.
24100	External key controller failed self-test.
24120	Selector test reached timeout.
24130	R-Box test reached timeout.

If Errors Occur when You Operate the 4155B/4156B

The following error codes and messages can occur when operating the 4155B/4156B. The error codes and messages are displayed in a message window or in the message display area at the bottom of the screen.

1 `Syntax error. Input should be integer number.`

3 `Syntax error. Input should be real number.`

4 `Syntax error. Unrecognized parameter.`

5 `Illegal setup. The parameter is out of range.`

6 `DATA buffer full. Too many APPEND.`

7 `DATA buffer full. Too many points.`

8 `Cannot define more than 6 User Vars.`

9 `Syntax error. First char should be Alphabet.`

10 `Syntax error. Must be alphanumeric.`

11 `Name must be set for user function/variable.`

Name setup cannot be omitted when setting a user function or a user variable name.

12 `Syntax error. Unknown variable name.`

13 `System error. HOSTC received invalid data.`

The 4155B/4156B may be broken. Contact the nearest Agilent Technologies Sales and Service office.

14 `System error. Unable to communicate with SMUC.`

The 4155B/4156B may be broken. Contact the nearest Agilent Technologies Sales and Service office.

15 `System error. Illegal command to SMUC.`

The 4155B/4156B may be broken. Contact the nearest Agilent Technologies Sales and Service office.

16 `Illegal operation. Too many LIST data.`

17 `Unable to display data list. Not enough memory.`

18 `Device I/O error. Unable to print out.`

The 4155B/4156B, printer, or plotter may be broken. Contact the nearest Agilent Technologies sales and service office.

19 `Filer error. File name is required.`

20 `Filer error. File Type is required.`

21 `System error. Realtime clock has problem.`

The 4155B/4156B may be broken. Contact the nearest Agilent Technologies Sales and Service office.

22 `Not 4155/4156 file.`

23 `File was created by old revision.`

24 `File may be corrupt.`

25 `Zero offset meas failed for <unit name>.`

Offset value is too large, so Zero offset measurement is aborted.

26 `Too big offset for 10 pA Range of <unit name>.`

Offset value is too large, so offset cannot be canceled perfectly.

27 `System busy. Measuring.`

28 `System busy. Forcing stress.`

29 `System error. EEPROM write error.`

The 4155B/4156B may be broken. Contact the nearest Agilent Technologies Sales and Service office.

30 `Fixture open. Measurement aborted.`

31 `Auto calibration was aborted.`

32 `Auto calibration failed.`

33 `No data in internal memory.`

34 `Illegal data. File may be corrupt.`

35 `System busy. Unable to save/get when MEAS/STR.`

36 `System busy. Unable to change Y-axis.`

37 `System error. SMUC lost data.`

The 4155B/4156B may be broken. Contact the nearest Agilent Technologies Sales and Service office.

38 `Buffer overflowed. Aborted.`

39 `Syntax error. Undisplayable character.`

40 `Illegal setup. One unit assigned several CH.`

41 `Illegal disk. Revision mismatch.`

42 `Read error occurred.`

43 `File name is not LIF type.`

44 `File name is not DOS type.`

45 `File name is not LIF/DOS type.`

46 `Volume label is not LIF type.`

47 `Volume label is not DOS type.`

48 `Incorrect memory number.`

49 `Source and Target are same.`

50 `Unable to copy. Memory full.`

51 `Unable to copy. SRC and TGT mem num is same.`

You cannot specify same memory number in both SOURCE and TARGET name fields.

52 `Illegal suffix.`

53 `System busy. Emergency handling.`

54 `System busy. Measuring.`

55 `System busy. Executing cal/diag.`

56 `System busy. Executing auto calibration.`

57 `System busy. Printing out hard copy.`

58 `Unable to copy 4145 data file to memory.`

59 `Unable to graph plot. Recover error state.`

Unable to print out or plot out when error message is displayed.

60 `Cal/diag must be performed in the idle state.`

Calibration and Diagnostics cannot be performed unless the 4155B/4156B is in the idle state. For example, this error is displayed if the SCPI calibration command is sent when the 4155B/4156B is not in the idle state.

61 `ADC time out.`

The AD converter has caused a time out. Perform 109: ADC test on the SYSTEM: SELF-CALIBRATION/DIAGNOSTICS screen. If this test fails, the 4155B/4156B may need service. Contact the nearest Agilent Technologies Sales and Service office.

62 `ADC FIFO overflow.`

The AD converter has caused a FIFO overflow. A data transfer error occurred between the AD converter and the SMUC. The 4155B/4156B may need service. Contact the nearest Agilent Technologies Sales and Service office.

63 `SMUC failed to send data to HOSTC.`

The SMU controller failed to send data to the host controller. Retry the measurement. If this error is still displayed, recycle the power by turning the instrument off and then on again.

64 `TIFF format supports SCREEN DUMP only.`

The TIFF format is only supported by the SCREEN DUMP function.

65 `TIFF image can only be written to a FILE.`

A TIFF image can only be written to a FILE. The 4155B/4156B cannot output TIFF format images to a printer or plotter.

66 `HR TIFF format supports DUMP and GRAPH PLOT.`

A high resolution TIFF image is only supported by the DUMP and GRAPH PLOT functions.

67 `HR TIFF image can only be written to a FILE.`

A high resolution TIFF image can only be written to a FILE.

100 `VAR1 is not assigned.`

101 `VAR1 assigned to multiple Channels.`

102 `VAR2 assigned to multiple Channels`

103 `VAR1' assigned to multiple Channels.`

104 `VAR1 and VAR1' must be same MODE.`

105 `Cannot set multiple SMUs to pulse mode`

106 `Cannot use VAR when SAMPLING.`

107 `Cannot use SMU pulse when SAMPLING.`

108 `Duplicate variable names exist.`

109 `The setup is not finished.`

110 `Standby chan cannot use R-BOX resistor`

For standby channel, you cannot use R-Box resistor.

111 `Common chan cannot use R-BOX resistor.`

For common mode channel, you cannot use R-Box resistor.

112 `VAR1 step number is out of range.`

113 `START and STOP have different sign.`

115 `SMU pulse Period must be >= Width+4ms.`

116 `VAR1 output power too large for unit.`

117 `VAR1' output power too large for unit.`

118 `VAR2 output power too large for unit.`

119 `TOT SMP TM=AUTO is for LINEAR only.`

AUTO can be specified for total sampling time *only when* LINEAR sampling mode is selected.

120 `Only LINEAR when init int <= 480 us.`

When initial interval is set to 480 μs or less, you *cannot* specify LOG or THINNED-OUT sampling mode.

121 `For LINEAR set AUTO if init int<=480us`

When initial interval is set to 480 μs or less *and* when LINEAR sampling mode is set, AUTO must be set in TOTAL SAMP. TIME field.

122 `TOT SP TM must be>=INIT INT(NOofSMP−1)`

Total sampling time must be set in the following range:
$\textit{total sampling time} \geq \textit{initial interval} \times (\textit{number of samples} - 1)$

123 `STOP CONDITION NAME is not set.`

124 `PGU pulse Period must be > Width.`

125 `PGU pulse Period must be >= Delay.`

126 PG leading/trailing must be same range

PGU leading and trailing time must be set in the same range. For details about the ranges, see Chapter 1 in this manual.

127 PGU Leading must be <= 0.8 × WIDTH.

Leading time must satisfy the following equation.
$\textit{leading time} \leq \textit{pulse width} \times 0.8$

128 PGU Trailing must be <= 0.8 × (Peri-Wid).

Trailing time must satisfy the following equation.
$\textit{trailing time} \leq (\textit{pulse period} - \textit{pulse width}) \times 0.8$

129 SMU I range must be <= Compliance range.

130 SYNC channel is not assigned.

At least one SYNC channel must be specified.

131 Assigned more than 4 SYNC channels.

132 Set INIT INT>=2ms for multi-CH MEAS.

When you perform multi-channel measurements, initial interval must be 2 ms or more.

133 Use FIXED range when INIT INT<2ms.

When you use auto ranging or limited auto ranging measurement, you must set initial interval to 2 ms or more.

134 Cannot disable STBY-ON ch in stress.

On STRESS: CHANNEL DEFINITION screen, you cannot disable (delete entries in row) channels that are set to STBY ON on the CHANNELS: CHANNEL DEFINITION screen.

135 Undefined symbol in user function.

136 Syntax error in user function.

137 Too few arguments in user function.

138 Too many arguments in user function.

139 User function area is full.

140 Recursive call in user function.

141 User function is undefined.

142 Stack overflow in user function.

143 `COMMON channel FCTN must be CONST.`

144 `COMMON channel FCTN must be NSYNC.`

145 `System busy. Unable to change page when MEAS.`

146 `System busy. Unable to change page when STRS.`

147 `Ineffective page in this setup.`

148 `X axis is not assigned.`

149 `Y1 axis is not assigned.`

150 `ENABLE DELAY must be <= 32767 × INIT INT`

For sampling measurements, when stop condition is set to `ENABLE`, *enable delay* must be *initial interval* × 32767 or less.

151 `No unit is set to STANDBY ON.`

152 `System busy. MEASURING (or 4145 USER MODE).`

153 `MIN, MAX have different sign in LOG.`

154 `Can do such operation only for USER VAR.`

155 `Illegal setup. The name was already used.`

156 `User variable is used in user function.`

If a user variable is used in user functions, the user variable cannot be deleted.

157 `AUTO Analysis is undefined.`

158 `TOT SAMP TIME must be<=INIT INT × 32767.`

Total sampling time must be *initial interval* × 32767 or less and 1×10^{11} or less.

159 `Measure channel is not assigned.`

160 `Unable to find approximate data.`

161 `Illegal graph scale setup.`

163 `The Sweep/Pulse Polarity is not same.`

164 `SYNC can not be set for standby CH.`

165 `Set value is too small for range.`

For LOG sweep measurement, start and stop value must be equal or more than setup resolution. For sweep measurement, step value of VAR1 and VAR2 must be equal or more than setup resolution.

166 `PGU Peak/Base difference must be <= 40V`

170 `Use Sweep/Bias instead of SMU Pulse.`

171 `Knob Sweep sets VAR1' to CONST.`

If you set VAR1' for knob sweep measurement, the VAR1' channel forces a constant value equal to START value. VAR1' cannot be a sweep source for Knob Sweep measurement.

172 `Cannot do SAMPLING when Knob Sweep.`

173 `|STEP| must be <= |STOP-START|.`

174 `Cannot set CONT AT ANY if PCOMP is ON.`

When you set power compliance, you cannot select CONT AT ANY secondary softkey.

175 `CONST setup must be <= unit output range.`

176 `Pulse BASE must be <= unit output range.`

177 `PGU pulse WIDTH must be >= setup res.`

Pulse width of PGUs must be greater than or equal to unit setup resolution.

178 `TRIG OUT DELAY is too long.`

Trigger out delay must be 32.7 ms or pulse width you specified, whichever is shorter.

179 `Cannot ENABLE stop if INIT INT < 2 ms.`

When initial interval is set to less than 2 ms, you cannot set stop condition.

180 `Illegal setup. Target module is not installed.`

181 `Illegal setup. Invalid command.`

182 `Cannot define more than 6 User functions.`

183 `Cannot define more than 8 data vars in lists.`

184 `Cannot define more than 2 display data vars.`

185 `ASCII format does not allow block transfer.`

186 `Block size mismatched with data format.`

187 `Y2 axis is not assigned.`

188 `List name is not assigned.`

189 `The specified name is not list name.`

190 `Illegal file type is requested.`

191 `System busy. Printing out hard copy.`

192 `Unable to set. Another controller is on bus.`

193 `Unable to specify this name here.`

194 `PGU Pulse DELAY must be >= setup res.`

PGU pulse delay time must be ≥ setup resolution.

195 `Cal/Diag failed. Cannot use unit.`

196 `Compliance too low to force pulse.`

197 `Compliance too high to force pulse.`

198 `Two VPULSE PGUs must be same STBY.`

199 `Two VPULSE PGUs must be same FCTN.`

200 `Improper parameter for file operation.`

An option for the file system command has been set up incorrectly.

201 `System error. Filer memory overflow.`

202 `Filer error. Integer overflow.`

203 `Bad volume specifier.`

Volume label for mass storage is incorrect. Initialization may have been performed on an incompatible system, or the disk may be defective.

204 `Filer error. File type is wrong.`

205 `Filer error. EOF found.`

206 `Filer error. EOR found.`

207 `File error. Illegal DISK parameter.`

Illegal disk parameter was detected. The mass storage device is set up incorrectly.

208 `System error. Controller not found.`

Unable to access the file system. The file system controller cannot be found. The 4155B/4156B may need service. Contact the nearest Agilent Technologies Sales and Service office.

210 `File error. Unable to execute. File open.`

Unable to perform the requested file operation. The file is already open. Close the file and retry the operation.

211 `Unable to operate the device. File is open.`

Unable to perform the requested file operation on the specified device because the device has a file open.

212 `File error. DISK or DISK drive may be broken.`

DISK or DISK drive hardware may be in need of service.

213 `Filer error. DISK record is not found.`

214 `File error. DISK record address error.`

Unable to find record because the mass storage device has a problem.

215 `Filer error. DISK record data error.`

216 `File error. DISK system error.`

The hardware or the device are causing a problem.

217 `File error. Bad volume label.`

The mass storage has an incorrect volume label. Verify the volume number is set correctly.

218 `System error. No interface found.`

The network interface was not found because of a wrong select code setup. Verify the select code is set correctly.

219 `File error. Device timeout.`

Time-out occurred on the device.

220 `Filer error. Undefined I/O path.`

221 `Filer error. Permission denied.`

222 `File error. Too many files open.`

Unable to open multiple files at the same time. Close the file that is currently open before opening a second file.

223 `Unable to PURGE the file or directory.`

Unable to purge the file or the directory, for example, permission denied.

224 `Filer error. The directory is not empty.`

225 `Filer error. No DISK in the drive.`

226 `Filer error. Initialization failed.`

227 `Filer error. Invalid DISK volume label.`

228 `File error. DISK volume label is undefined.`

Volume label is undefined or was not found. Verify the volume number is set correctly.

229 `Filer error. DISK is not initialized.`

230 `Filer error. Checkread error.`

231 `Filer error. Bad HFS DISK.`

232 `Filer error. DISK is full.`

233 `Filer error. Directory is full.`

234 `Filer error. File name is undefined.`

235 `Filer error. File name is wrong.`

236 `Filer error. The file name is already used.`

237 `Filer error. Bad device type.`

238 `Filer error. Unable to use wildcard.`

239 `Filer error. Operations failed.`

241 `Filer error. The target type is wrong.`

242 `Filer error. The file is protected.`

243 `Filer error. DISK is protected.`

244 `System error. Unable to verify.`

245 `Filer error. Unable to copy between LIF/DOS.`

246 `Filer error. Reason Unknown.`

265 `HOLD TM must be>=0 when INIT INT>=2ms.`

280 `VAR1' output value is out of range.`

282 `Set INIT INT > 640 us for THINNED-OUT.`

When you perform thinned-out sampling measurements, the initial interval must be more than 640 μs.

284 `Sampling range must be <= 11decades.`

286 `Cannot execute cal/diag after power fail.`

Turn on the 4155B/4156B again to perform calibration or diagnostics.

288 `MEAS not finished. Incomplete data deleted.`

If you press Stop front-panel key before the specified measurement finishes, incomplete measurement data is deleted.

289 `STBY ON ch MODE(MEAS/STR) must be same`

290 `Cannot use unit after power fail.`

292 `VAR1' parameters must be >= output res`

Start, stop, and step value of VAR1' channel must be unit output resolution or more.

293 `Cal/Diag aborted (failed on some units).`

Calibration or diagnostics was aborted by receiving *RST command. So, some units maybe failed.

300 `Over voltage is detected.`

301 `Over Current is detected.`

302 `Power failure at Main Frame.`

Turn on the 4155B/4156B again. You can use filer functions after selecting OK secondary softkey (except when this error occurs during power-on test).

303 `Power failure at Expander Box.`

Turn on the 4155B/4156B again. You can use filer functions after selecting OK secondary softkey (except when this error occurs during power-on test).

305 `Cannot shutdown Main Frame.`

306 `Emergency. Reason unknown.`

An emergency occurred on an empty slot. Or an emergency occurred on an existing slot, but the reason is unspecified.

307 `Cannot shutdown Power Supply.`

Turn on the 4155B/4156B again. You can use filer functions after selecting OK secondary softkey (except when this error occurs during power-on test).

308 `Unknown emergency (SMUC time out).`

Perform 305: HOSTC <--> SMUC I/F test on the SYSTEM: SELF-CALIBRATION/DIAGNOSTICS screen. If this test fails, the 4155B/4156B may need service. Contact the nearest Agilent Technologies Sales and Service office.

309 `The SMU AND PULSE GENERATOR EXPANDER is not turned on.`

Turn on the expander, then cycle mainframe power.

310 `Unsupported unit detected in Slot ##. Turn off the power and remove the unit.`

The displayed unit must be changed. Contact the nearest Agilent Technologies Sales and Service office.

320 `Not enough memory. Cannot display >=200 files.`

The 4155B/4156B cannot display more than 199 files on the FILE CATALOG because of an internal memory limitation. If you create more than 199 files, move the additional files to another directory.

321 `Too many links.`

The file has too many links. Remove extra links or use symbolic links.

322 `File system down or network disconnected.`

Unable to access the network directory. The file system was down or the network was disconnected.

323 `The network address is already used.`

A process has already been bound to the address. The current process must finish before the new process can use the address.

324 `Change dir failed. File is not a directory.`

Change directory failed because you specified a file, not a directory.

325 `Unable to open file. Deadlock occurred.`

Unable to open the file. Deadlock occurred in the resource where you tried to open the file.

326 `Device not present. Unsupported file type.`

Device or driver was not found to open the file. Unable to open file because the file type is not supported.

327 `Interrupted system call.`

The lpr driver received a signal from the system, that interrupted the data transfer from the lpr driver.

328 `lpd time out occurred. Try again ?`

A time out occurred when trying to connect to the lpd server because the lpd server did not respond.

329 `lpd print server cannot be recognized.`

Unable to recognize the lpd print server. Verify the address setup or setup syntax is correct.

330 `lpd server connection failed or was denied.`

The lpd server connection failed, or was denied, because the lpd server was already connected or the server was blocked.

331 `lpr data transfer failed.`

Data transfer from the lpr server failed because lpr data communication was disconnected. Verify the network is working properly and check to see if the server is up.

332 `Unable to print out. Not enough device space.`

Unable to print out because the device connection failed. There is not enough available space in the buffer for the communication.

334 `lpr failed data transfer. Data size mismatch.`

Unable to print out because the lpr server failed data transfer. The size of the data was not the expected size.

335 `lpr Network interface is down. Try again ?`

The network interface cannot be found because the network interface for the lpr server is down.

336 `Unable to print out. Reason unknown.`

Network connection failed. The reason for the failure is unknown.

337 `Cannot set 0.0.0.0 for 4155/4156 IP address.`

When a valid host name for the 4155B/4156B network setup is specified, the IP address of the 4155B/4156B cannot be set to `0.0.0.0`.

338 `Cannot set 0(zero) for 4155/4156 User ID.`

When a valid host name for the 4155B/4156B network setup is specified, the User Id of the 4155B/4156B cannot be set to 0 (zero).

339 `No response from NFS. Try again ?`

There is no response from the Network File System (NFS) when trying to mount a network disk. Verify the network is operating properly and the file export executed properly.

340 `Host name must be <= 15 alphanumeric character.`

The 4155B/4156B host name must be 15 or less alphanumeric characters.

344 `System busy. Cannot execute US/US42 command.`

Unable to move to FLEX command control mode, because the `US` or `US42` command cannot be executed while system is busy; making measurement, operating file functions, executing calibration or diagnostics, printing, emergency, and so on.

345 `Change display page. DISP OFF(0) is not allowed.`

Unable to enter the `:DISP OFF` (or `0`) command when the 4155B/4156B screen displays System screen group or KNOB SWEEP screen.

346 `Enter DISP ON(1) to execute this command.`

Unable to enter the `:PAGE:KSW` command group, `:PAGE:SCON:KSW` command, or `:DIAG:TEST` *test_no* (*test_no*: 201 to 413) command when the 4155B/4156B screen is set to the update *disable* state by the `:DISP OFF` (or `0`) command.

350 `Unable to transfer data. Name buffer full.`

Cannot maintain the buffer required for transferring data.

351 `File operation was interrupted by system call.`

The lpr driver received a signal from the system, which interrupted an open, read, or write operation.

352 `Network is down after receiving a reset.`

The network is down after receiving a reset. Try again after network recovers.

353 `Network is down. No response from server.`

Network is down. There in no response from the server.

354 `Operation canceled.`

Operation canceled by user. For example, an abort command was sent.

355 `Cannot create file/dir. Change permission.`

Write permission is not set for the directory where you are trying to create a file or subdirectory.

357 `Unable to go to the dir. Permission denied.`

Network File System server cannot move to the specified directory. To access the directory, change the permissions.

358 `Select UPDATE/ADD to update/add printer setup.`

To update or add your new or modified network printer setup, the UPDATE or ADD secondary softkey must be selected after finishing the initial setup.

363 `Duplicate file names exist.`

The same file name cannot be used for multiple files.

364 `No such file or directory.`

The Network File System cannot find the specified file or directory.

365 `Unable to read or write to directory.`

A file read or write operation cannot be performed in the specified directory.

366 `Invalid argument. Check command syntax.`

Specified argument did not work when executing the command. Verify the command syntax and argument are correct.

367 `Seek operation failed.`

Seek for file operation failed, or append write failed to open the specified file.

368 `NFS Software caused connection abort.`

Network file system (NFS) was disconnected. Verify the NFS server is operating correctly.

369 `Connection reset by peer. Remote disconnected.`

Remote connection was terminated. Verify the remote setup and the executed operation are correct. Verify the local and remote systems are operating properly.

370 `Unable to transfer data. Communication down.`

Data cannot be transferred because the communication was shutdown.

371 `NFS Connection refused.`

Connection to NFS was refused. Verify the refused device was properly exported.

372 `Connection failed. Socket was not sent.`

NFS Connection failed because the socket was not sent.

373 `Too many levels of symbolic links.`

The file is linked to itself, or the linked file is linked back to the file.

375 `Cross-device link.`

Unable to hard link different physical file systems. Hard link must be done to same file system.

377 `Unable to use this protocol.`

Unable to use this protocol on the network.

378 `This protocol is not supported.`

This protocol is not supported on the network.

381 `This type of protocol is not supported.`

This type of protocol is not supported on the network.

383 `NFS too many references, can't splice.`

386 `System busy. Saving/getting text files.`

The 4155B/4156B cannot be interrupted by other operations. For example, text files cannot be saved or retrieved while making measurements.

387 `Unable to access file. The file is locked.`

Unable to write to this file. The file is locked by another process.

388 `No such device or address.`

The 4155B/4156B cannot find the specified network device or address. Verify the correct device file exists, the select code/major number/minor number are correct, and that the device is correctly connected (high speed or low speed port).

389 `System busy. File operation is in progress.`

File operation is in progress. During a file operation, the 4155B/4156B cannot perform other operations, such as making measurements, changing setup fields, printing and so forth.

391 `Network printer connection time out.`

A time out occurred when connecting the network printer to the print server or NFS server.

392 `Network File System server is down.`

Server for the Network File System is down. Contact your network system administrator.

393 `Communication to desired server failed.`

Communication to desired server failed.

394 `System busy. Mounting device.`

When mounting a device, the 4155B/4156B cannot be interrupted by another operation, such as making a measurement.

400 `System bug. Undefined method.`

401 `System bug. Invalid parameter.`

402 `System bug. Inconsistency.`

410 `Unable to display. Number must be <10001.`

Unable to display the measurement results because the data size of the result is too large. The number of the measurement results must be less than 10001.

411 `Connection failed. Set Destination address.`

Network connection to destination failed. Verify the destination address is set correctly.

412 `Address family not supported.`

Specified address family is not supported for the currently used socket.

If a Measurement Data Status is Displayed

If measurement or stress force cannot be performed correctly, the measurement data status is displayed at the bottom of the GRAPHICS, LIST, KNOB SWEEP, or STRESS FORCE screen. The status indicates hardware and calculation errors.

The status format depends on the displayed screen as follows:

GRAPH/LIST: GRAPHICS and KNOB SWEEP screen

Status is displayed in following format:

`STATUS:` *AB AB AB* (*A A A A A A A A C*)

- *AB AB AB* is for X, Y1, and Y2 axis respectively. No Y2 for KNOB SWEEP.
- *A A A A A A A A C* is for SMU1 to SMU6, VMU1, VMU2, and PGU1/2 respectively.

Where, *A*, *B*, and *C* mean as follows:

A hardware status error. If multiple errors occur, numbers are added and displayed as a hexadecimal number.

- 1 : AD converter overflow.
- 2 : Oscillation
- 4 : Other channel reached compliance limit.
- 8 : This channel reached compliance limit.

B data error. If multiple errors occur, numbers are added and displayed as a hexadecimal number.

- 1 : stack register overflow
- 2 : calculation error
- 4 : only one data for delta measurement. At least 2 data needed.

C PGU status

- 1 : PGU average output current exceeds 100 mA.

For non-measurement channels, "_" is displayed.

GRAPH/LIST: LIST screen

Status on GRAPH/LIST: LIST screen is displayed in following format:

`STATUS:` *AB AB AB AB AB AB AB AB* (*A A A A A A A A C*)

- *AB AB AB AB AB AB AB AB* is for the up to 8 LIST variables that can be set up.
- *A A A A A A A A C* is for SMU1 to SMU6, VMU1, VMU2, and PGU1/2 respectively.

Where, *A*, *B*, and *C* mean as follows:

A hardware status error. If multiple errors occur, numbers are added and displayed as a hexadecimal number.

- 1 : AD converter overflow.
- 2 : Oscillation
- 4 : Other channel reached compliance limit.
- 8 : This channel reached compliance limit.

B data error. If multiple errors occur, numbers are added and displayed as a hexadecimal number.

- 1 : stack register overflow
- 2 : calculation error
- 4 : only one data for delta measurement. At least 2 data needed.

C PGU status

- 1 : PGU average output current exceeds 100 mA.

For non-measurement channels, "_" is displayed.

STRESS: STRESS FORCE screen

Status on STRESS: STRESS FORCE screen is displayed in following format:

`STATUS:`*A C*

Where, *A* and *C* mean as follows:

A hardware status error. If multiple errors occur, numbers are added and displayed as a hexadecimal number.

- 2 : Oscillation.
- 4 : Some channel has reached compliance limit.

C PGU status

- 1 : PGU average current exceeds 100 mA.