Agilent 4288A 1KHZ/1MHZ CAPACITANCE METER Operation Manual

Manual Change

Agilent Part No. N/A

Sep 2007

Change 1

Following note is added on page 84 to use on firmware revision 1.30 or later.

Auto Range can be set ON/OFF during the measurement of Load Standard using the CORR:COLL:LOAD:STAN3:RANG:AUTO command. This functionality is not available in the front panel. For more information about Auto Range, refer to Command Reference section in Programming Manual.

マニュアル　チェンジ

変更１

F/W rev 1.3、あるいはそれ以上の revision では下記注記を８４ページに追加してください。

オートレンジは CORR:COLL:LOAD:STAN3:RANG:AUTO コマンドを利用したロードスタンダード測定が行われる場合にオン、オフにセットできます。この機能はフロントパネルではサポートされません。オートレンジに関する詳細につきましてはプログラミングマニュアルのコマンドリファレンスの章をご参照下さい。

Caution

Do not apply DC voltage or current to the UNKNOWN terminal to prevent failure. Special care must be taken for capacitors since they may be charged. Be sure to connect the DUT to the UNKNOWN terminal (or test fixture) after discharging them sufficiently

Safety Summary

When you notice any of the unusual conditions listed below, immediately terminate operation and disconnect the power cable.
Contact your local Agilent Technologies sales representative or authorized service company for repair of the instrument. If you continue to operate without repairing the instrument, there is a potential fire or shock hazard for the operator.

- Instrument operates abnormally.
- Instrument emits abnormal noise, smell, smoke or a spark-like light during the operation.
- Instrument generates high temperature or electrical shock during operation.
- Power cable, plug, or receptacle on instrument is damaged.
- Foreign substance or liquid has fallen into the instrument.

DECLARATION OF CONFORMITY

According to ISO/IEC Guide 22 and CEN/CENELEC EN 45014

Manufacturer's Name: Agilent Technologies Japan, Ltd.

Manufacturer's Address: 1-3-2, Murotani, Nishi-ku, Kobe-shi, Hyogo, 651-2241 Japan

Declares, that the product:

Product Name: Capacitance Meter

Model Number: 4288A

Product Options: This declaration covers all options of the above product

Conforms with the following product standards:

	Standard	Limit
EMC:	IEC 61326-1:1997 +A1:1998 / EN 61326-1:1997 +A1:1998	
	CISPR 11:1997 / EN 55011:1998 / AS/NZS 2064.1/2	Group 1, Class A [1]
	IEC 61000-4-2:1995 / EN 61000-4-2:1995	4 kV CD, 4 kV AD
	IEC 61000-4-3:1995 / EN 61000-4-3:1996	3 V/m 80% AM 80 - 1000 MHz
	IEC 61000-4-4:1995 / EN 61000-4-4:1995	0.5 kV signal lines, 1 kV power lines
	IEC 61000-4-5:1995 / EN 61000-4-5:1995	0.5 kV line-line, 1 kV line-ground
	IEC 61000-4-6:1996 / EN 61000-4-6:1996	3 V 80% AM 0.15 - 80 MHz
	IEC 61000-4-11:1994 / EN 61000-4-11:1994	1 cycle, 100%
	Canada: ICES-001	

Safety: IEC 61010-1:1990 +A1:1992 +A2:1995 / EN 61010-1:1993 +A2:1995
CAN / CSA C22.2 No. 1010.1-92

Conformity / Supplementary Information:

The product herewith complies with the requirements of the Low Voltage Directive 73/23/EEC and the EMC Directive 89/336/EEC (including 93/68/EEC) and carries the CE-marking accordingly (European Union).

LEDs in this product are Class 1 in accordance with EN 60825-1:1994.

[1] The product was tested in a typical configuration with Agilent Technologies test systems.

Kobe, Japan November 10, 2000
Date

Koichi Yanagawa
Name Koichi Yanagawa / Quality Engineering Manager

For further information, please contact your local Agilent Technologies sales office, agent or distributor.

Herstellerbescheinigung

GERÄUSCHEMISSION

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

Manufacturer's Declaration

ACOUSTIC NOISE EMISSION

LpA < 70 dB
operator position
normal operation
per ISO 7779

Agilent 4288A 1 kHz/1 MHz Capacitance Meter

Operation Manual

Third Edition

FIRMWARE REVISIONS/SERIAL NUMBERS

This manual applies directly to instruments that have the firmware revision 1.2x and serial number prefix JP1KH.
For additional information about firmware revisions and serial numbers, see Appendix A.

Agilent Technologies

Agilent Part No. 04288-90020

December 2001

Printed in Japan

Notices

Agilent Technologies Japan, Ltd.

Component Test PGU-Kobe

1-3-2, Murotani, Nishi-ku, Kobe, Hyogo, 651-2241 Japan

Manual Printing History

The manual’s printing date and part number indicate its current edition. The printing date changes when a new edition is printed (minor corrections and updates that are incorporated at reprint do not cause the date to change). The manual part number changes when extensive technical changes are incorporated.

December 2000	First Edition (part number: 04288-90000)
July 2001	Second Edition (part number: 04288-90010)
December 2001	Third Edition (part number: 04288-90020)

Safety Summary

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific WARNINGS elsewhere in this manual may impair the protection provided by the equipment. Such noncompliance would also violate safety standards of design, manufacture, and intended use of the instrument.

Agilent Technologies assumes no liability for the customer's failure to comply with these requirements.

NOTE The 4288A complies with INSTALLATION CATEGORY II and POLLUTION DEGREE 2 in IEC61010-1. The 4288A is an INDOOR USE product.

NOTE The LEDs in the 4288A are Class 1 in accordance with IEC60825-1,
CLASS 1 LED PRODUCT

- Ground the Instrument

  To avoid electric shock, the instrument chassis and cabinet must be grounded with the supplied power cable's grounding prong.

- DO NOT Operate in an Explosive Atmosphere

  Do not operate the instrument in the presence of inflammable gasses or fumes. Operation of any electrical instrument in such an environment clearly constitutes a safety hazard.

- Keep Away from Live Circuits

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

- DO NOT Service or Adjust the Instrument 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 the Instrument

  To avoid the danger of introducing additional hazards, do not install substitute parts or perform unauthorized modifications to the instrument. Return the instrument to an Agilent Technologies Sales and Service Office for service and repair to ensure that safety features are maintained in operational condition.

- Dangerous Procedure Warnings

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

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

Safety Symbols

The safety symbols and alert flags used on the instrument or in its manuals are defined below.

⚠ Instruction Manual symbol: the product is marked with this symbol when it is necessary for the user to refer to the instrument manual.

∼ Alternating current.

⎓ Direct current.

| On (Supply).

O Off (Supply).

In-position of push-button switch.

Out-position of push-button switch.

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

WARNING **This warning flag in the left margin denotes a hazard. It calls attention to a procedure, practice, or condition that, if not correctly performed or adhered to, could result in injury or death to personnel.**

CAUTION This Caution flag in the left margin denotes a hazard. It calls attention to a procedure, practice, or condition that, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the product.

NOTE This Note flag in the left margin denotes important information. It calls attention to a procedure, practice, or condition that is essential for the user to understand.

Certification

Agilent Technologies certifies that this product met its published specifications at the time of shipment from the factory. Agilent Technologies further certifies that its calibration measurements are traceable to the United States National Institute of Standards and Technology, to the extent allowed by the Institution's calibration facility or by the calibration facilities of other International Standards Organization members.

Warranty

This Agilent Technologies instrument product is warranted against defects in material and workmanship for a period corresponding to the individual warranty periods of its component products. Instruments are warranted for a period of one year. Fixtures and adapters are warranted for a period of 90 days. During the warranty period, Agilent Technologies will, at its option, either repair or replace products that prove to be defective.

For warranty service or repair, this product must be returned to a service facility designated by Agilent Technologies. Buyer shall prepay shipping charges to Agilent Technologies, and Agilent Technologies shall pay shipping charges to return the product to Buyer. However, Buyer shall pay all shipping charges, duties, and taxes for products returned to Agilent Technologies from another country.

Agilent Technologies warrants that its software and firmware designated by Agilent Technologies for use with an instrument will execute its programming instruction when properly installed on that instrument. Agilent Technologies does not warrant that the operation of the instrument, or software, or firmware will be uninterrupted or error free.

Limitation of Warranty

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by Buyer, Buyer-supplied software or interfacing, unauthorized modification or misuse, operation outside the environmental specifications for the product, or improper site preparation or maintenance.

IMPORTANT No other warranty is expressed or implied. Agilent Technologies specifically disclaims the implied warranties of merchantability and fitness for a particular purpose.

Exclusive Remedies

The remedies provided herein are Buyer’s sole and exclusive remedies. Agilent Technologies shall not be liable for any direct, indirect, special, incidental, or consequential damages, whether based on contract, tort, or any other legal theory.

Assistance

Product maintenance agreements and other customer assistance agreements are available for Agilent Technologies products.

For any assistance, contact your nearest Agilent Technologies Sales and Service Office. Addresses are provided at the back of this manual.

Typeface Conventions

Bold	Boldface type is used when a term is defined. For example: **icons** are symbols.
Italic	Italic type is used for emphasis and for titles of manuals and other publications.
[Key]	Indicates a hardkey whose key label is Key.
[Blue] - **[Key]**	Indicates that you press the blue shift key to activate the shift function (2nd function printed in blue) and then press the hardkey whose key label (printed in dark gray) is Key.
[Key] - **Item**	Indicates a series of key operations in which you press the **[Key]** key, make the item called Item on the displayed menu blink by using the **[← ↓]** and other keys, and then press the **[Enter]** key.

4288A Documentation Map

The following manuals are available for the 4288A.

- ***Operation Manual*** **(P/N: 04288-900x0)**

  Most of the basic information necessary for using the 4288A is provided in the *Operation Manual*. It describes installation, preparation, measurement operation including calibration, performances (specifications), and error messages. For GPIB programming, see the *Programming Manual*.

- ***Programming Manual*** **(P/N: 04288-900x1)**

  The *Programming Manual* shows how to write and use the BASIC program to control the 4288A.

1 Contents of This Manual

This chapter provides an overview of this manual as well as useful information to help you navigate through the manual.

Contents of this Manual

This manual provides most of the basic information necessary for properly using the Agilent 4288A 1 kHz/1 MHz capacitance meter. The chapter-by-chapter contents of this manual are as follows.

Chapter 1 “Contents of This Manual”

This chapter provides an overview of this manual as well as useful information to help you navigate through the manual.

Chapter 2 “Installation Guide”

This chapter guides you through the tasks required to prepare your newly delivered Agilent 4288A 1 kHz/1 MHz capacitance meter for use.

Chapter 3 “Overview”

This chapter gives an overview of the Agilent 4288A and the functionality of each part of the front and rear panels.

Chapter 4 “Getting Started”

This chapter describes the basic operations of the Agilent 4288A. “Key Operation Basics” explains how to use the basic key operations. “Learning Basic Measurement Procedure” describes how to take basic measurements of capacitors (capacitance) with the 4288A.

Chapter 5 “Setting up Measurement Conditions and Display”

This chapter describes how to set up the measurement conditions and display. It also describes how to save/recall the instrument setup state, including the measurement conditions.

Chapter 6 “Preparation for Accurate Measurement (Executing Compensation)”

This chapter gives an overview and the operational procedures of the compensation function.

Chapter 7 “Executing Measurement”

This chapter describes how to generate a trigger to start measurement. It also provides helpful information for measurement.

Chapter 8 “Sorting Based on Measured Result (Comparator Function)”

This chapter describes how to use the function that performs sorting based on the measured results (comparator function).

Chapter 9 “Avoiding Mistakes Related to Work and Performing Daily Checks”

This chapter describes how to avoid simple mistakes related to work and how to carry out the required maintenance of the Agilent 4288A.

Chapter 10 “Using Handler Interface”

You can output the measurement end signal, the sorting result of the comparator function, and other data from the Agilent 4288A, as well as input an external trigger signal or a key lock signal to the 4288A, through the handler interface. This chapter also gives information required to configure an auto-sorting system that combines the 4288A and a handler in using the handler interface and the comparator function.

Chapter 11 “Using Scanner Interface”

You can select compensation data for each channel (up to 64 sets, multi-compensation function) or input/output a timing control signal for measurement and scanner operation through the scanner interface. This chapter gives information required to configure a scanning system using the scanner interface and multi-compensation function.

Chapter 12 “Specifications and Supplemental Information”

This chapter gives the specifications and supplemental information of the Agilent 4288A capacitance meter.

Chapter 13 “Troubleshooting”

This chapter lists items to check if you encounter a problem while using the Agilent 4288A. All of these items should be carefully investigated before you determine that your 4288A instrument is faulty.

Appendix A “Manual Changes”

This appendix contains the information required to adapt this manual to earlier versions or configurations of the Agilent 4288A than that indicated by the current printing date of this manual. The information in this manual applies directly to the 4288A model that has the serial number prefix listed on the title page of this manual.

Appendix B “Functional Comparison between 4278A and 4288A”

This appendix provides a table showing a functional comparison between the Agilent 4278A and the Agilent 4288A. For a detailed comparison of each function, refer to the Programming Manual.

Appendix C “Initial Settings”

This appendix provides initial settings, settings that can be saved/recalled, and settings that can be backed up.

Appendix D “At-a-glance Table of Operations When Overload or Low C is Detected”

This appendix describes display output, GPIB output, and handler interface output when an overload or Low C is detected.

Appendix E “Error Messages”

The Agilent 4288A provides error messages to indicate its operating status. This appendix describes the error messages of the 4288A in alphabetical order. To search error messages by error number, refer to the Programming Manual.

Appendix F “Test Fixtures/Test Leads”

This appendix lists available test fixtures and test leads for the Agilent 4288A.

Contents of this Manual

Appendix G “Technical Information”

This chapter provides technical information on the operating principles of the 4288A and the basic principles of capacitance measurement.

2 Installation Guide

This chapter guides you through the tasks required to prepare your newly delivered Agilent 4288A 1 kHz/1 MHz capacitance meter for use.

Incoming Inspection

WARNING **To avoid hazardous electrical shock, do not turn on the power if there are signs of shipping damage to any portion of the outer enclosure (upper cover, lower cover, side cover, front panel, rear panel, LCD display, connectors, or power switch).**

Follow the steps below to perform the incoming inspection.

Step 1. Check the shipping container and cushioning material for damage.

If the shipping container or cushioning material is damaged, it should be kept until the contents of the shipment (the instrument and accessories) have been inspected for completeness and have been checked mechanically and electrically.

Step 2. Check the contents of the shipment using Table 2-1 to confirm that all of your specified options are complete.

Table 2-1 **Contents of 4288A package**

Ordered model/option number	Agilent part number	Item	Qty.	Check (√)
Agilent 4288A	—	Agilent 4288A 1 kHz/1 MHz Capacitance Meter (Main Unit)	1	
	—	Power cable	1	
Option ABA	04288-900x0	*Operation Manual*[*1]	1	
	04288-900x1	*Programming Manual*[*1]	1	
	04288-180x0	3.5-inch flexible disk (Sample Programs)[*1]	1	
	04288-905xx	CD-ROM (*Operation Manual*, *Programming Manual*, Sample Programs)[*1]	1	
Option 1CM	5063-9241	Rackmount kit	1	
Option 1CN	5063-9226	Handle kit	1	
Option 1CP	5063-9241	Rackmount kit	1	
	5063-9226	Handle kit	1	

*1. The number indicated by “x” in the part number of each manual or sample program disk, 0 for the first edition, is incremented by 1 each time a revision is made. The latest edition comes with the product.

Step 3. Check the contents of the shipment (the instrument and accessories) for mechanical damage or defects.

Step 4. If you detect any of the following in the inspection, contact you nearest Agilent Technologies sales office.

1. The shipping container or cushioning material is damaged or the cushioning material shows signs of unusual stress.
2. The contents of the shipment are not complete.
3. You find any mechanical damage or defect of the contents.
4. You find any faulty operation of the product during the operational checks described below.

In the case of 1, notify the carrier as well as your nearest Agilent Technologies sales office. Save the shipping container, cushioning material, and the contents of the shipment for the carrier's inspection.

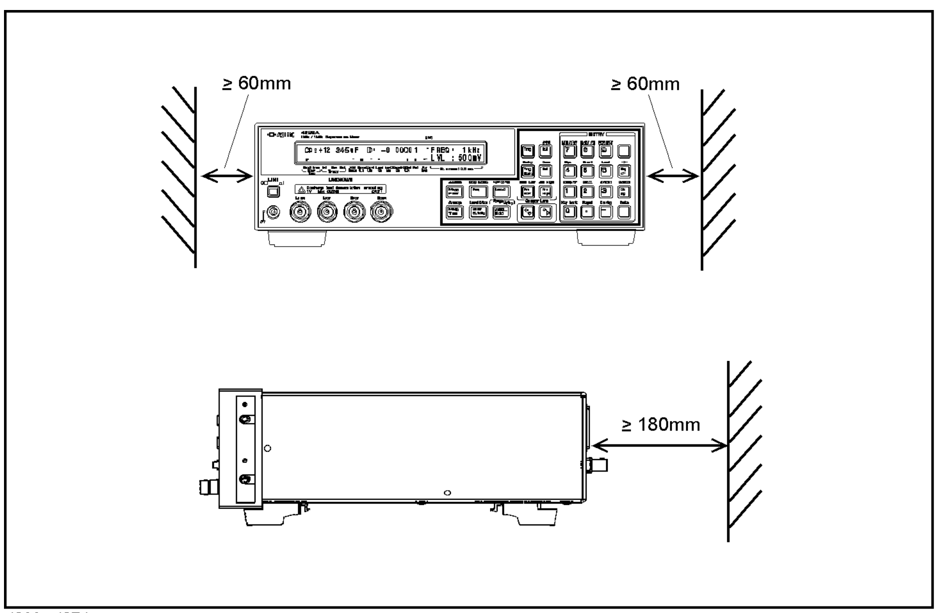
Providing Clearance to Dissipate Heat at Installation Site

To ensure the specifications and measurement accuracy of the product, you must maintain the proper ambient temperature around the product within the specified range by providing appropriate cooling clearance around the product or, for the rackmount type, by forcefully air-cooling the area inside the rack housing. For information on the ambient temperature required to satisfy the specifications and measurement accuracy of the product, refer to “Definitions” on page 152 and “Measurement accuracy” on page 156 in Chapter 12

When the ambient temperature around the product is kept within the temperature range of the operating environment specification (refer to “Operating environment” on page 166), the product conforms to the requirements of the safety standard. Under that temperature environment, it has been confirmed that the product still conforms to the requirements of the safety standard when it is enclosed within the following cooling clearance.

	Conditions
Rear	≥ 180 mm
Side	≥ 60 mm (each for right and left)

Figure 2-1 **Providing clearance to dissipate heat at installation site**



4288aoj074

2. Installation Guide

Preparation Before Turning On Power

Before turning on the instrument, be sure to check the following.

Checking power source

Check that the power source to the 4288A meets the following requirements.

	Requirements
Voltage	90 to 132 Vac or 198 to 264 Vac*1
Frequency	47 to 66 Hz*2
Power consumption	Maximum 100 VA

*1. The 4288A switches between these levels automatically depending on the AC outlet voltage.
*2. The 4288A requires no manual switching of the frequency (50 or 60 Hz)

⚠ Setting up the fuse

Use a fuse that meets the following specifications.

UL/CSA type, Slo-Blo, 5x20 mm miniature fuse, 3A 250V (part number: 2110-1017)

Spare fuses are available from Agilent Technologies sales offices. To check or replace the fuse, disconnect the power cable and pull out the fuse holder (refer to Figure 2-2). Then gently push up on the fuse from under the holder with a small screw driver to remove it (refer to Figure 2-3).

Figure 2-2 **Fuse holder and power cable socket**

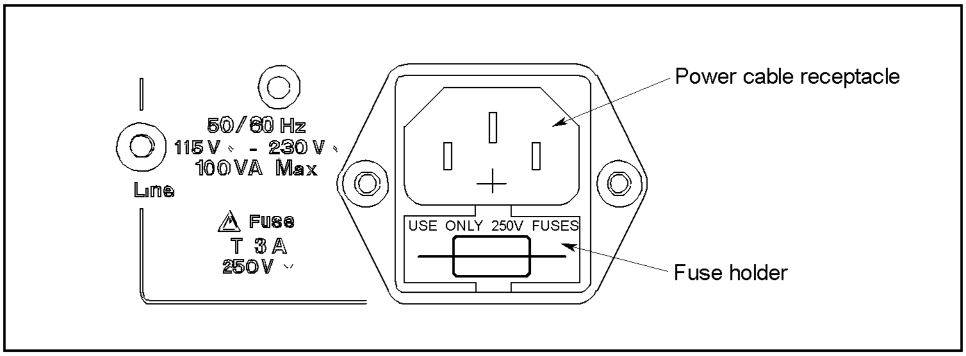


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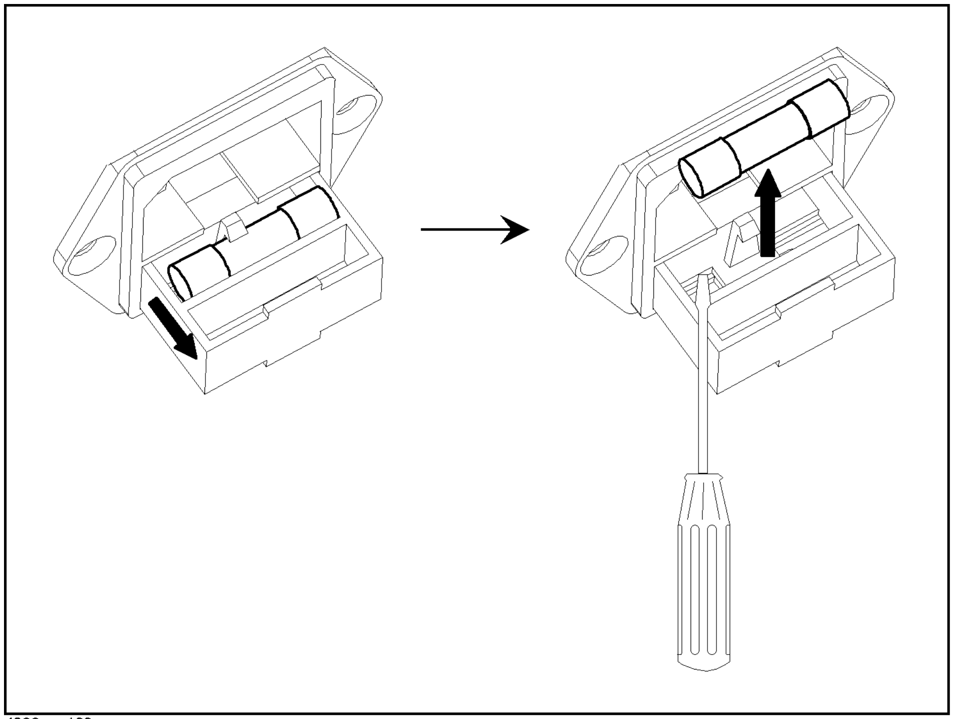
Figure 2-3 **Removing the fuse**



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Verification and connection of power cable

The three-wire power cable attached to the Agilent 4288A has one wire serving as a ground. Use of this power cable allows the Agilent 4288A to be connected to ground, thereby protecting you against electrical shock via the power outlet.

Step 1. Confirm that the power cable is not damaged.

WARNING **NEVER use a power cable showing any sign of damage. Faulty cables can cause electrical shock.**

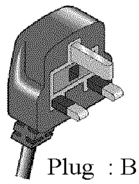
Step 2. Use the supplied cable to connect between the power terminal on the rear panel of the Agilent 4288A and a three-wire power outlet with the grounding prong firmly connected in the ground slot.

WARNING **Use the attached three-wire power cable with grounding wire to securely ground the Agilent 4288A.**

Figure 2-4 shows the power cable options.

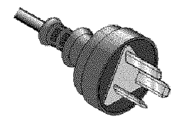
Figure 2-4 **Power cable options**

OPTION 900 United Kingdom



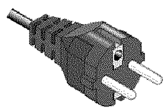
Plug : BS 1363/A, 250V, 10A
Cable: 8120-1351

OPTION 901 Australia/ New Zealand



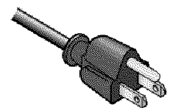
Plug : AS 3112, 250V, 10A
Cable: 8120-1369

OPTION 902 Continental Europe



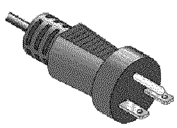
Plug : CEE 7 Standard Sheet VII, 250V, 10A
Cable: 8120-1689

OPTION 903 U.S./ Canada



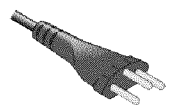
Plug : NEMA 5-15P, 125V, 10A
Cable: 8120-1378

OPTION 904 U.S./ Canada



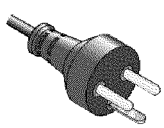
Plug : NEMA 6-15P, 250V, 6A
Cable: 8120-0698

OPTION 906 Switzerland



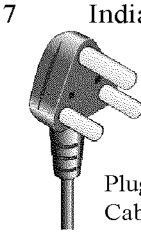
Plug : SEV Type 12, 250V, 10A
Cable: 8120-2104

OPTION 912 Denmark



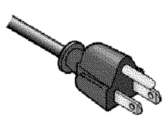
Plug : SR 107-2-D, 250V, 10A
Cable: 8120-2956

OPTION 917 India/ Republic of S.Africa



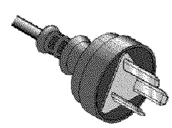
Plug : IEC 83-B1, 250V, 10A
Cable: 8120-4211

OPTION 918 Japan



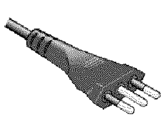
Plug : JIS C 8303, 125V, 12A
Cable: 8120-4753

OPTION 920 Argentina



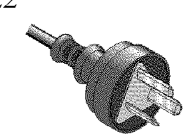
Plug : Argentine Resolution 63, Annex IV, 250V, 10A
Cable: 8120-6870

OPTION 921 Chile



Plug : CEI 23-16, 250V, 10A
Cable: 8120-6978

OPTION 922 China



Plug : GB 1002, 250V, 10A
Cable: 8120-8376

If you want to use a power cable other than the supplied one, contact your nearest Agilent sales office for information.

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Setting Up System For Configuration

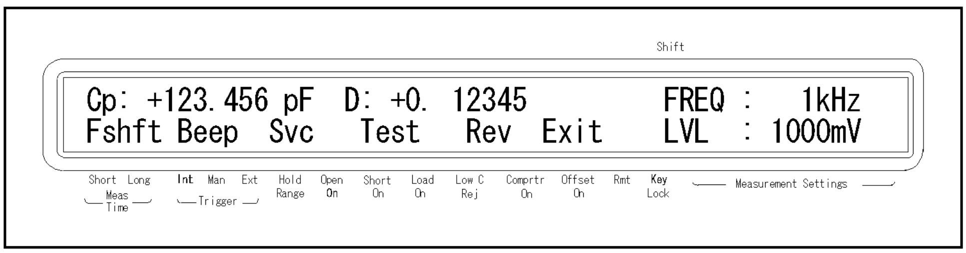
Setting up frequency shift

When you integrate several 4288A units into a single system, you can shift the measurement frequency (1 MHz) (by +1%, – 1%, or +2%) to avoid interference between their measurement signals.

The procedure is given below.

Step 1. Press the **[Config]**(**[Blue]** - **[–]**) key. The screen shown in Figure 2-5 appears.

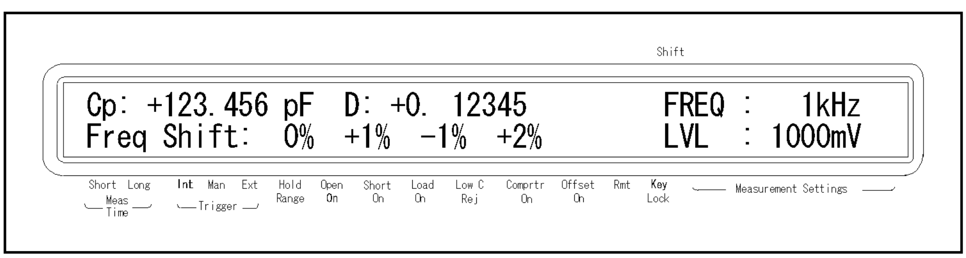
Figure 2-5 **Menu screen when [Config] key is pressed**



4288aoj006

Step 2. Use the **[↑→]** and other applicable keys to make "Fshft" blink and press the **[Enter]** key. The frequency shift setup screen shown in Figure 2-6 appears.

Figure 2-6 **Frequency shift setup screen**



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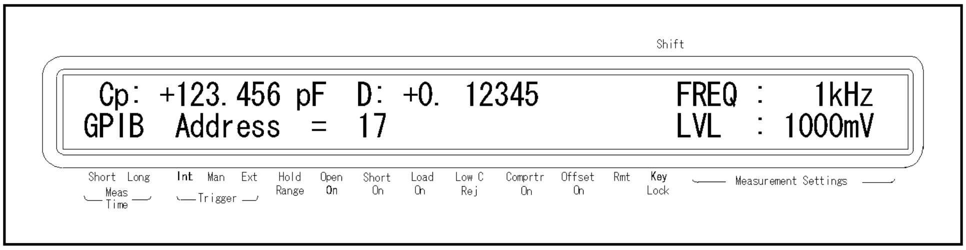
Step 3. A blinking item ("0%", "+1%", "– 1%", or "+2%") is the current setup. Use the **[↑→]** and other applicable keys to make the item you want to set up blink and press the **[Enter]** key.

Setting GPIB address

The procedure to set up the GPIB address is given below.

Step 1. Press the **[Adrs]** (**[Blue]** - **[Lcl]**) key. The GPIB address setup screen shown in Figure 2-7 appears. The number that appears first (in this example, 17) is the current address setting value.

Figure 2-7 **GPIB address setup screen**



4288apj002

Step 2. Use the numeric and other keys to enter an address value and press the **[Enter]** key.

Setting up the handler interface

For the setup procedure to use the handler interface, refer to “Preparing for Using the Handler Interface” on page 134.

Setting up the scanner interface

For the setup procedure to use the scanner interface, refer to “Setting Up Input Signal Resistance” on page 150.

3 Overview

This chapter gives an overview of the Agilent 4288A and the functionality of each part of the front and rear panels.

Product Overview

The Agilent 4288A 1 kHz/1 MHz capacitance meter's built-in comparator function makes it ideal for high-speed sorting tests of ceramic capacitors.

The 4288A lets you select measurement parameters (Cp-D/Q/Rp/G and Cs-D/Q/Rs) covering the following measurement display ranges: for capacitance, 0.001 pF to 20.000 µF (for 1 kHz) or 0.00001 pF to 1500.00 pF (for 1 MHz); for dissipation factor, 0.00001 to 9.99999. Up to 6 digits can be displayed. The fundamental measurement accuracy is ±0.07% (in the long mode). You can specify the measurement signal level within a range of 0.1 V to 1 Vrms in steps of 0.1 Vrms. You can select the measurement time from either the 6.5 ms or 16.5 ms mode.

The built-in comparator sorts capacitance into a maximum of 9 bins and performs pass/fail judgment for the loss parameter, outputting the sorting result to a handler interface or GPIB. Using an optical-isolated handler interface, you can easily integrate the 4288A into your handler system. In addition, you can use the scanner to perform error compensation for each channel independently.

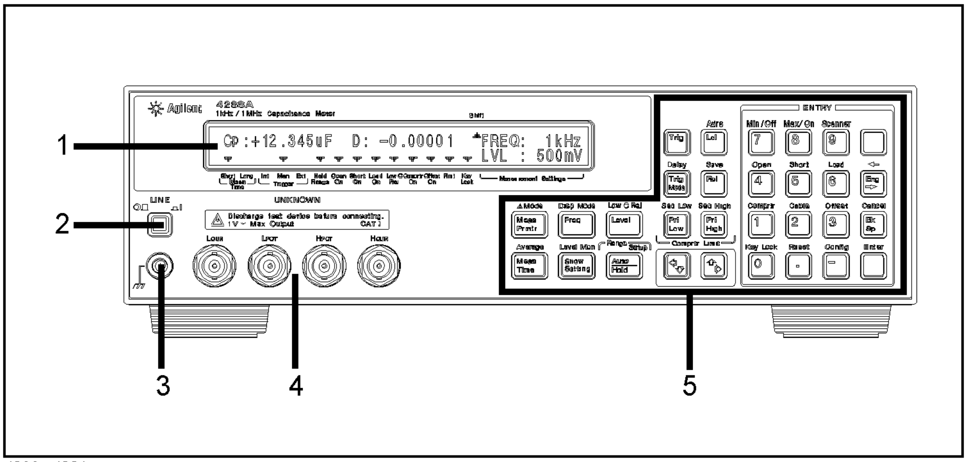
Using GPIB enables scalable system development, from automated setup and data acquisition to a centralized/distributed network for more efficient data processing.

Functions Available on the Panels

Front panel

This section describes the functions available from the front panel. The number preceding each description corresponds to the same number in Figure 3-1.

Figure 3-1 **Front Panel**



4288aoj001

1. Display: Displays measurement results, instrument setups, and messages. For details, refer to "Display" on page 34.
2. LINE switch: Turns ON/OFF the 4288A.
3. Guard terminal: Connected to the chassis of the instrument.
4. UNKNOWN terminal: A test fixture or measurement cable is connected here. The type of connector is BNC(f) (Installation Category I).

CAUTION To prevent failure, do not apply DC voltage or current to the UNKNOWN terminal. Special care must be taken for capacitors because they may be charged. Discharge DUTs sufficiently before connecting them to the UNKNOWN terminal or a test fixture.

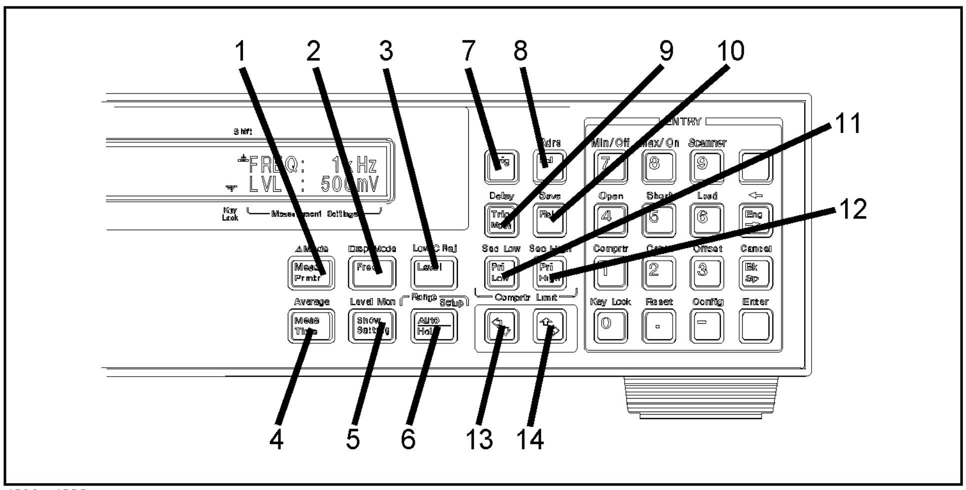
5. Front panel keys: Used to operate the 4288A. For details, refer to "Front Panel Keys" on page 30.

Front Panel Keys

This section describes the front panel keys. The name of each key is printed on or above the key. The print in dark gray (on the key) shows the function (standard function) when the key is pressed alone, while the print in blue (above the key) shows the 2nd function (shift function) that becomes active when pressed after pressing the **[Blue]** key (refer to number 18 in Table 3-2).

Table 3-1 and Table 3-2 describe the function of each key. Each number in the table corresponds to the same number in Figure 3-2 and Figure 3-3. For the key of a given number, the row indicated as “Standard” describes its standard function and the row indicated as “Shift” describes its shift function.

Figure 3-2 Front Panel Key Locations



4288aoj002

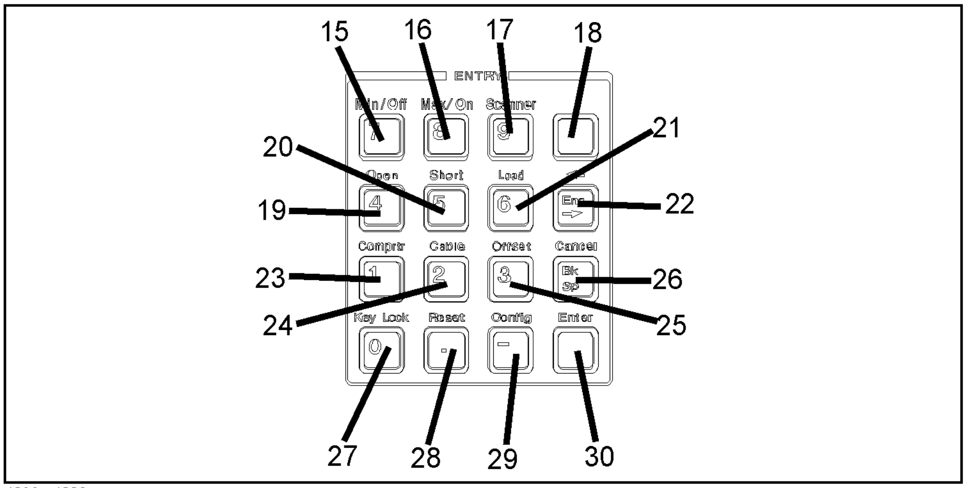
Table 3-1 Functions of Front Panel Keys (excluding the entry block)

No.	Name		Function
1	Standard	**[Meas Prmtr]** key	Selects a measurement parameter.
	Shift	**[∆ Mode]** key	Sets the deviation measurement mode (on/off, mode selection, and reference value).
2	Standard	**[Freq]** key	Selects the measurement signal frequency.
	Shift	**[Disp Mode]** key	Sets the measurement result display (on/off, number of display digits, floating point display/fixed point display, and value of the highest digit).
3	Standard	**[Level]** key	Sets the measurement signal level.
	Shift	**[Low C Rej]** key	Sets the Low C reject function (on/off and detection boundary value).
4	Standard	**[Meas Time]** key	Selects the measurement time mode.
	Shift	**[Average]** key	Sets the measurement averaging count.

Table 3-1 **Functions of Front Panel Keys (excluding the entry block)**

No.	Name		Function
5	Standard	**[Show Setting]** key	Changes the displayed page (displayed items) in the instrument setup display area on the far-right portion of the display (measurement settings, refer to Figure 3-4).
	Shift	**[Level Mon]** key	Sets the monitor function of the measurement signal level.
6	Standard	**[Auto/Hold]** key	Selects the switching method of the measurement range (measurement ranging mode).
	Shift	**[Range Setup]** key	Sets an arbitrary measurement range.
7	Standard	**[Trig]** key	Generates a trigger when the trigger mode is set to manual (Man).
	Shift	N/A	N/A
8	Standard	**[Lcl]** key	Goes back to the local mode when the instrument has been set in the GPIB remote mode.
	Shift	**[Adrs]** key	Sets the GPIB address.
9	Standard	**[Trig Mode]** key	Selects the trigger mode.
	Shift	**[Delay]** key	Sets the trigger delay time.
10	Standard	**[Rcl]** key	Reads out the instrument setups from the built-in nonvolatile memory (EEPROM) and restores them.
	Shift	**[Save]** key	Saves the current instrument setups into the built-in nonvolatile memory (EEPROM).
11	Standard	**[Pri Low]** key	Sets the lower limit of the primary parameter limit range (BIN1 only) for the comparator function.
	Shift	**[Sec Low]** key	Sets the lower limit of the secondary parameter limit range for the comparator function.
12	Standard	**[Pri High]** key	Sets the upper limit of the primary parameter limit range (BIN1 only) for the comparator function.
	Shift	**[Sec High]** key	Sets the upper limit of the secondary parameter limit range for the comparator function.
13	Standard	**[← ↓]** key	Decreases the set value or changes the selection leftward/downward.
	Shift	N/A	N/A
14	Standard	**[↑→]** key	Increases the set value or changes the selection rightward/upward.
	Shift	N/A	N/A

Figure 3-3 **Placement of Front Panel Keys (entry block)**



4288aoj003

Table 3-2 **Function of Front Panel Keys (entry block)**

No.	Name		Function
15	Standard	**[7]** key	Enters 7 when setting a value.
	Shift	**[Min/Off]** key	Specifies the minimum possible value when setting a value and enters OFF when setting ON/OFF.
16	Standard	**[8]** key	Enters 8 when setting a value.
	Shift	**[Max/On]** key	Specifies the maximum possible value when setting a value and enters ON when setting ON/OFF.
17	Standard	**[9]** key	Enters 9 when setting a value.
	Shift	**[Scanner]** key	Sets the scanner function (ON/OFF, channel selection, and definition method of standard for the LOAD compensation).
18	Standard	**[Blue]** key (Shift key)	Activates the function printed in blue (same color as this key) above each front panel key (shift function). To execute the Shift function, press this key and then press the key for the desired function as indicated by the name printed in blue above it.
	Shift	N/A	N/A
19	Standard	**[4]** key	Enters 4 when setting a value.
	Shift	**[Open]** key	Turns ON/OFF the OPEN compensation function. Lets you measure/check the data for the OPEN compensation.

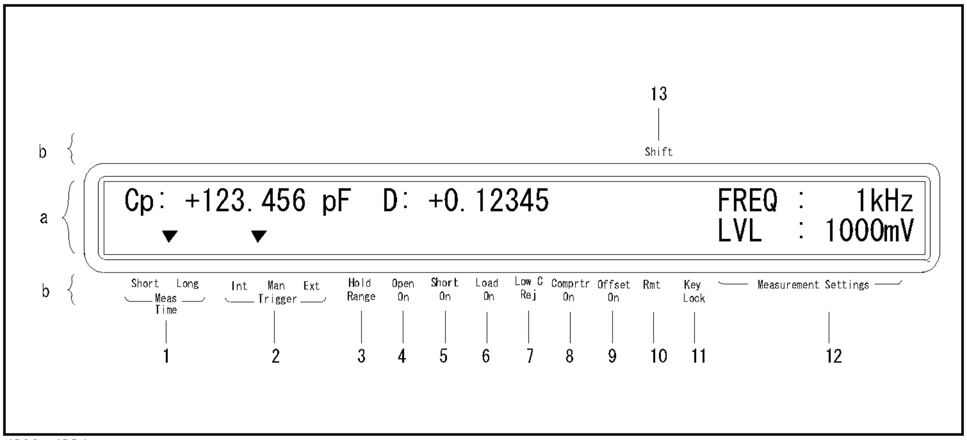
Table 3-2 Function of Front Panel Keys (entry block)

No.	Name		Function
20	Standard	**[5]** key	Enters 5 when setting a value.
	Shift	**[Short]** key	Turns ON/OFF the SHORT compensation function. Lets you measure/check the data for the SHORT compensation.
21	Standard	**[6]** key	Enters 6 when setting a value.
	Shift	**[Load]** key	Turns ON/OFF the LOAD compensation function. Lets you measure/check the data for the LOAD compensation. Sets the reference value for the LOAD compensation.
22	Standard	**[Eng(→)]** key	Enters a unit prefix (p, n, μ, m, k, M, and so on) when setting a value. Each press changes the prefix in ascending order of magnitude.
	Shift	**[Eng(←)]** key	Enters a unit prefix (p, n, μ, m, k, M, and so on) when setting a value. Each press changes the prefix in decreasing order of magnitude.
23	Standard	**[1]** key	Enters 1 when setting a value.
	Shift	**[Comprtr]** key	Turns ON/OFF the comparator function. Sets the limit range (mode, range, and reference value).
24	Standard	**[2]** key	Enters 2 when setting a value.
	Shift	**[Cable]** key	Selects the cable length.
25	Standard	**[3]** key	Enters 3 when setting a value.
	Shift	**[Offset]** key	Sets the offset compensation function (ON/OFF and compensation value).
26	Standard	**[Bk Sp]** key	Erases the last entered character when entering a value.
	Shift	**[Cancel]** key	Returns to the previous screen.
27	Standard	**[0]** key	Enters 0 when setting a value.
	Shift	**[Key Lock]** key	Locks all keys (except this key).
28	Standard	**[.]** key	Enters a decimal point (.) when setting a value.
	Shift	**[Reset]** key	Resets the 4288A.
29	Standard	**[–]** key	Enters a minus symbol (–) when setting a value.
	Shift	**[Config]** key	Sets the frequency shift and the beep operation. Executes the test for service. Executes the self-test. Checks the firmware version.
30	Standard	**[Enter]** key	Finishes entering a value or confirming a selection.
	Shift	N/A	N/A

Display

This section describes the display screen of the 4288A. Table 3-2 explains each part of the display. Each letter/number in the table corresponds to the same letter/number in Figure 3-4.

Figure 3-4 **Interpreting the Display Screen**



4288aoj004

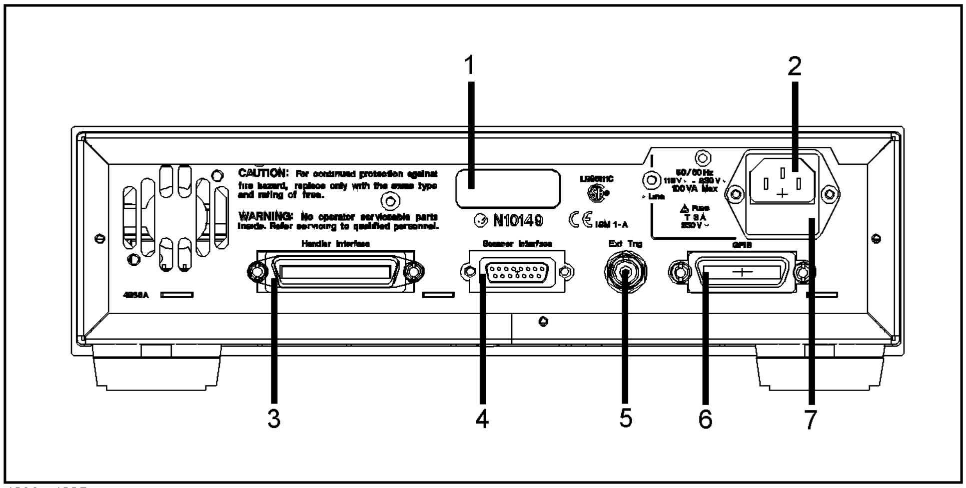
Table 3-3 **Function of Each Part of Display**

Ltr.	Name		Function
a	Character display area		Displays measurement results, instrument setup menus, instrument setup display (Measurement Settings), and messages.
b	Setup display label area		Shows you the instrument setup state using the combination of the ▼ symbol displayed in the character display area (a in Figure 3-4) and setup display labels.
	No.	**Label**	**Explanation**
	1	Meas Time	Indicates the measurement time mode setting. The current setting, Short or Long, is shown with the ▼ symbol displayed above.
	2	Trigger	Indicates the trigger mode setting. The current setting, Int, Man, or Ext, is shown with the ▼ symbol displayed above. Note that if the Bus mode, which can only be set with a GPIB command, has been specified, the ▼ symbol is not displayed.
	3	Hold Range	Indicates the ranging mode of the 4288A. When the ▼ symbol is displayed, the instrument is in the Hold ranging mode; when nothing is displayed, it is in the Auto ranging mode.
	4	Open On	Indicates ON/OFF state of the OPEN compensation function. The ▼ symbol indicates ON.
	5	Short On	Indicates ON/OFF state of the SHORT compensation function. The ▼ symbol indicates ON.
	6	Load On	Indicates ON/OFF state of the LOAD compensation function. The ▼ symbol indicates ON.
	7	Low C Rej	Indicates ON/OFF state of the Low C reject function. The ▼ symbol indicates ON.
	8	Comprtr On	Indicates ON/OFF state of the comparator function. The ▼ symbol indicates ON.
	9	Offset On	Indicates ON/OFF state of the offset compensation function. The ▼ symbol indicates ON.
	10	Rmt	The ▼ symbol is displayed when the 4288A is in the GPIB remote mode.
	11	Key Lock	The ▼ symbol is displayed when the front panel keys are locked.
	12	Measurement Settings	Indicates the instrument setup display area. It displays the measurement conditions including the measurement signal level and measurement frequency as well as comparator sorting result. (The ▼ symbol is not displayed in this area.)
	13	Shift	When the **[Blue]** key (Shift key) has been pressed and the shift functions (the functions printed in blue above the key) are available, the ▲ symbol is displayed.

Rear panel

This section describes the functions that can be accessed through the rear panel. The number preceding each description correspond to the same number in Figure 3-5.

Figure 3-5 **Rear Panel**



4288aoj005

1. Serial number plate: The serial number is printed here.
2. Power cable receptacle
3. Handler Interface connector: The connector for an external handler.
4. Scanner Interface connector: The connector for the scanner.
5. External trigger (Ext Trig) terminal: The trigger input terminal when using an external trigger signal to trigger a measurement.
6. GPIB connector: Used to control the 4288A from an external controller through GPIB.
7. Fuse holder

4 Getting Started

This chapter describes the basic operations of the Agilent 4288A. “Key Operation Basics” explains how to use the basic key operations. “Learning Basic Measurement Procedure” describes how to take basic measurements of capacitors (capacitance) with the 4288A.

Key Operation Basics

Three types of operations can take place when you press a front panel key of the 4288A:

- A single key press completes the operation.
- A menu (for item selection) appears on the screen.
- A value entry screen appears.

NOTE When a menu selection screen or value entry screen appears (also when you are entering a value), pressing the **[Cancel]** (**[Blue]** - **[Bk Sp]**) key returns the display to the previous screen.

NOTE To execute a function printed in blue on the front panel (shift function), first press the **[Blue]** key to enable the shift function and then press the key below the appropriate name printed in blue (for example, to execute Cancel, press the **[Blue]** key and the **[Bk Sp]** key (the key labeled Bk Sp in dark gray)).

The basic operation for each case is described below.

A single key press completes the operation

Single-key operation turns ON/OFF the function or changes the setup. In this case, the instrument setup is switched as a toggle. Specifically, each key press turns the setup ON/OFF or cycles through several possible settings in order. Two examples are given below:

- Each press of the **[Key Lock]** (**[Blue]** - **[0]**) key alternately turns ON/OFF the key lock function.
- Each press of the **[Trig Mode]** key changes the setup of the trigger mode from the current setup in this order:
  ... → Int → Man → Ext → Int → ...

A menu (for item selection) appears on the screen

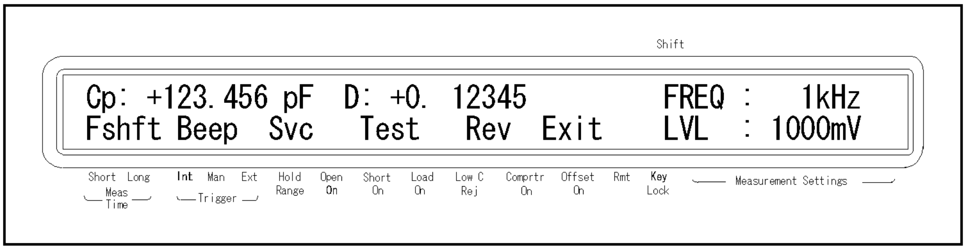
In this case, pressing a key changes the lower half of the display (the part where the ▼ symbol is displayed) to the menu screen for selecting items. The item blinking in the menu screen is the currently selected item. Use the **[← ↓]** key and **[↑→]** key or press the same key again to change the selection. When the desired item is blinking, press the **[Enter]** key to confirm the selection. An example is given below.

Step 1. Press the **[Config]** (**[Blue]** - **[–]**) key. The menu screen (where “Exit” is blinking) shown in Figure 4-1 appears on the display.

Step 2. Press the **[← ↓]** key twice to make “Rev” blink and then press the **[Enter]** key.

Step 3. The 4288A displays the model number, firmware version and serial number for several seconds and then returns to the menu.

Figure 4-1 **Menu screen when [Config] key is pressed**



4288aoj006

Step 4. Confirm that "Exit" is blinking (otherwise, perform the key operation to make "Exit" blink) and then press the **[Enter]** key to exit from the menu.

NOTE After a selection is made with the menu, another menu screen for selection or a value entry screen (described below) may appear. In this case, perform a similar operation until you finish the setup.

A value entry screen appears

In this case, pressing a key changes the screen display from the measurement screen to the value entry screen. Use the following keys to enter a value and then press the **[Enter]** key.

- Numeric (**[0]**, **[1]**, **[2]**, **[3]**, **[4]**, **[5]**, **[6]**, **[7]**, **[8]**, **[9]**, **[.]** (decimal point), and **[–]** (minus)) keys
- Backspace (**[Bk Sp]**) key
- Maximum value (**[Max/On]**) key and minimum value (**[Min/Off]**) key
- Unit (**[Eng]**) key
- Arrow (**[← ↓]** and **[↑→]**) keys

NOTE After the displayed value is changed, the previous setting remains in effect until you press the **[Enter]** key. Therefore, if you press a key that is not in the ENTRY block (refer to Figure 3-3 on page 32) before pressing the **[Enter]** key, the entered value is discarded and the instrument setup before the entry remains.

How to use each key is described below.

Numeric keys

Combine numerics to enter a value.

Backspace key

Use this key to correct an entered value. Each press deletes one character to the left of the displayed value.

NOTE Basically, you can enter values by using only the numeric keys and the backspace key. The maximum value key, minimum value key, unit key, left/down arrow key, and up/right arrow key are also provided to facilitate entry. However, depending on the instrument setup state when you try to enter a value, some of these keys may be unavailable.

Maximum value key and minimum value key

By only pressing these keys you can enter the allowable maximum and minimum values.

Unit key

Adds a unit (engineering unit) to a value you have entered using the numeric keys. Each press of this key changes the unit. The unit that appears first and available units (that appear by each press of the key) differ depending on the instrument setup state when you try to enter a value.

Arrow keys

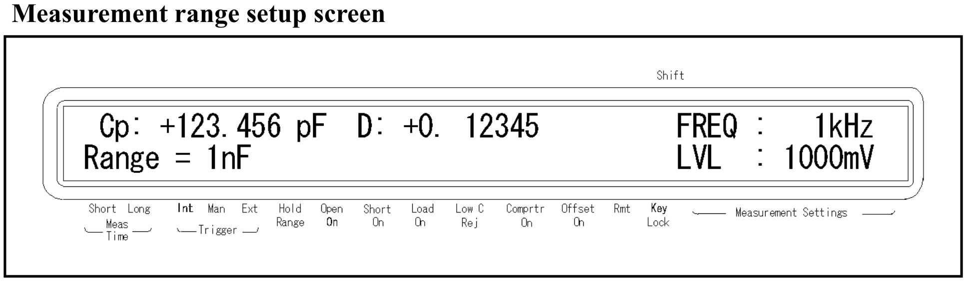
Increment or decrement the entered value. The amount of increment/decrement for each press differs depending on the instrument setup state.

Example of operation used to enter a value

To learn how to enter a value, follow the steps below to change the measurement range setup from 1 nF to the minimum measurement range of 100 pF (when the measurement frequency is 1 kHz) in the following four ways: entry using the numeric keys only, entry using the minimum value key, entry using the numeric keys and unit key, and entry using the arrow keys. Each procedure is described below.

Step 1. Press the **[Range Setup]** (**[Blue]** - **[Auto/Hold]**) key. The measurement range setup screen shown in Figure 4-2 appears.

Figure 4-2 **Measurement range setup screen**



4288aoj007

Step 2. Enter 100 pF.

Entry using the numeric keys only:

Press the **[0]** key, **[.]** key, **[0]** key, **[0]** key, **[0]** key, **[0]** key, **[0]** key, **[0]** key, **[0]** key, **[0]** key, **[0]** key, and **[1]** key in this order.

Entry using the minimum value key:

Press the **[Min/Off]** (**[Blue]** - **[7]**) key.

Entry using the numeric keys and unit key:

Press the **[1]** key, **[0]** key, and **[0]** key. Then, press the **[Eng]** key until pF appears.

Entry using the arrow keys:

Press the **[← ↓]** key three times.

Step 3. Press the **[Enter]** key to finish the setup.

Learning Basic Measurement Procedure

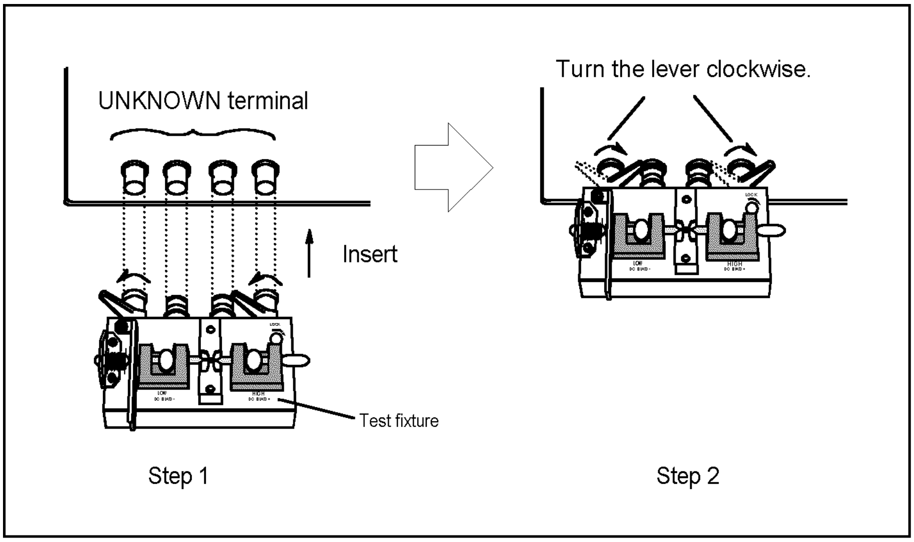
This section describes the procedure used to measure a capacitor with the test fixture. This description is intended to help you learn the basic measurement procedure of the 4288A.

Connecting test fixture

CAUTION To avoid failure, do not apply DC voltage or current to the UNKNOWN terminal. Special care must be taken for capacitors because they may be charged. Fully discharge DUTs before connecting them to the UNKNOWN terminal (or the test fixture).

It is difficult to connect the DUT (capacitor) directly to the 4288A. Therefore, a test fixture is generally used to connect the DUT to the 4288A. Use the test fixture that is suitable for the shape of the DUT. Refer to Appendix F, “Test Fixtures/Test Leads,” which describes the available test fixtures. Figure 4-3 shows an example of making a connection by using the 16034G, which is suitable for measuring chip capacitors.

Figure 4-3 **Connecting test fixture (16034G)**



4288aoe024

Setting up basic measurement conditions

This section describes how to set up basic measurement conditions for capacitor measurement. For an actual measurement (for example, measurement that provides better accuracy or measurement based on measurement time), you need to set up measurement conditions that are appropriate to the task, not necessarily those described here.

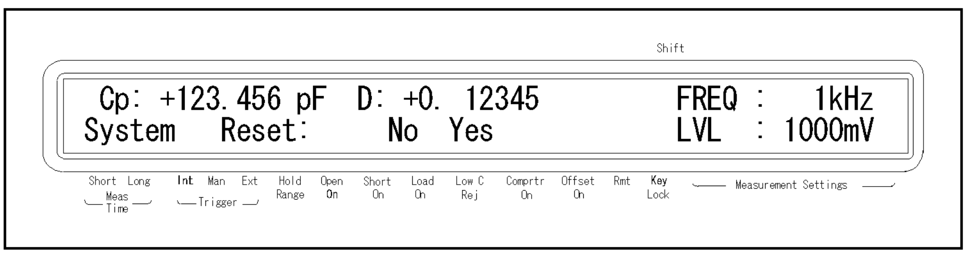
Returning settings to their preset values (executing reset)

This section describes how to return (reset) the settings of the 4288A to their preset values.

When you want to perform measurement under your desired setup conditions (especially when you do not have definite knowledge of the current settings), it is effective to return the instrument to its preset state once. Refer to Table C-1 on page 185, which lists the defined preset values, to determine which settings you must change to achieve your desired measurement conditions.

Step 1. Press the **[Reset]** (**[Blue]** - **[.]**) key. The screen shown in Figure 4-4 appears.

Figure 4-4 **Reset execution screen**



4288aoj008

Step 2. Press the **[↑→]** key to make "Yes" blink and then press the **[Enter]** key.

Setting up measurement parameters

Set up the primary parameter and secondary parameter you want to measure. The 4288A allows you to select the parameters from the following combinations.

Primary parameter	Secondary parameter
Cp	D, Q, G, Rp
Cs	D, Q, Rs

Each parameter is described below.

Cp: Capacitance value when considering equivalent parallel resistance

Cs: Capacitance value when considering equivalent series resistance

D: Dissipation factor

Q: Quality factor (inverse of D)

G: Equivalent parallel conductance

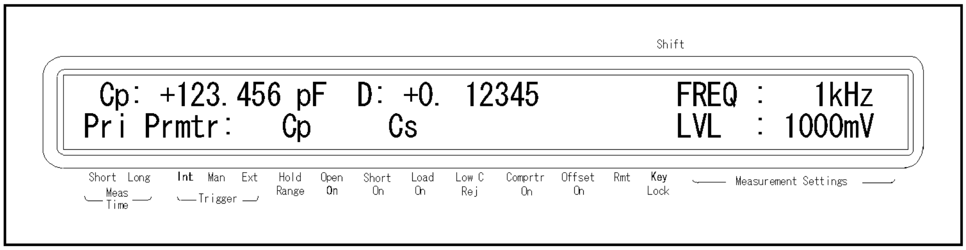
Rp: Equivalent parallel resistance

Rs: Equivalent series resistance

The procedure to set up the measurement parameters is described below.

Step 1. Press the **[Meas Prmtr]** key. The menu screen to select the primary parameter as shown in Figure 4-5 appears.

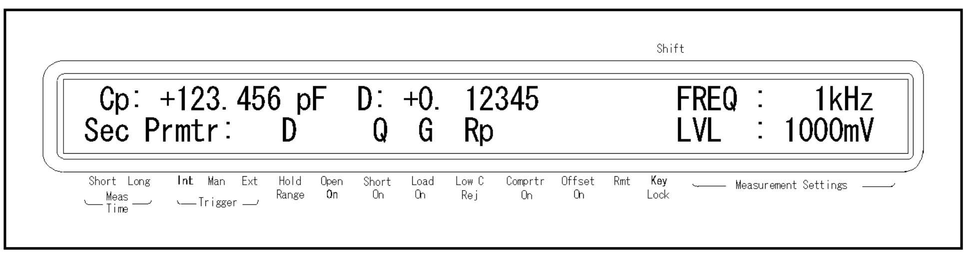
Figure 4-5 **Primary parameter selection menu screen**



4288aoj009

Step 2. The blinking parameter is the current setup value of the primary parameter. If you want to change it, use the **[↑→]** key to make the parameter you want to set up blink and then press the **[Enter]** key. The menu screen to select the secondary parameter as shown in Figure 4-6 appears.

Figure 4-6 **Secondary parameter selection menu screen (Cp selected as the primary parameter)**



4288aoj010

The secondary parameters in the menu differ depending on the selected primary parameter. Figure 4-6 shows the screen when Cp is selected.

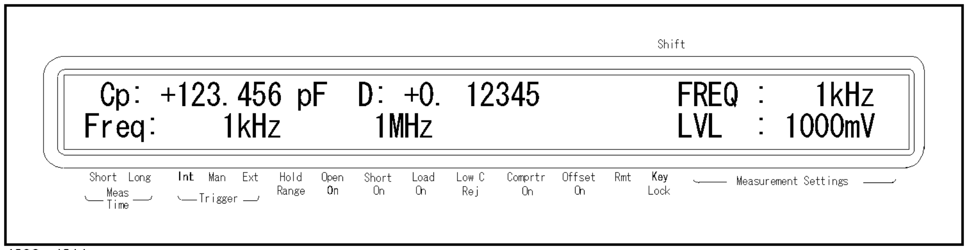
Step 3. In the same way as done for the primary parameter, use the **[↑→]** key to make the parameter you want to set up as a secondary parameter blink and then press the **[Enter]** key.

Setting up measurement signal frequency

Set up the frequency of the signal applied to the DUT (capacitor) during measurement.

Step 1. Press the **[Freq]** key. The menu screen shown in Figure 4-7 appears.

Figure 4-7 **Measurement signal frequency selection menu screen**



4288aoj011

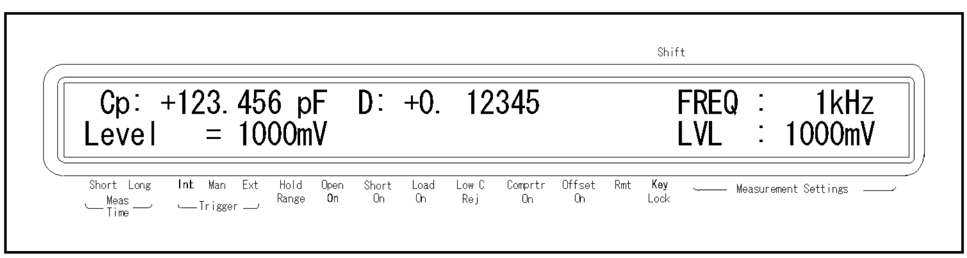
Step 2. The blinking value is the current setup for the frequency. If you want to change it, use the **[↑→]** key or press the **[Freq]** key again to make the measurement frequency value (1kHz or 1MHz) you want to set up blink and then press the **[Enter]** key.

Setting up measurement signal level

Set up the voltage level of the signal applied to the DUT (capacitor) during measurement.

Step 1. Press the **[Level]** key. This brings up the screen shown in Figure 4-8, where the initial value is the current setup of the measurement signal level (in this example, 1000 mV).

Figure 4-8 **Measurement signal level setup screen**



4288aoj012

Step 2. Use the numeric and other necessary keys to enter the level you want to set up and press the **[Enter]** key.

Setting up cable length

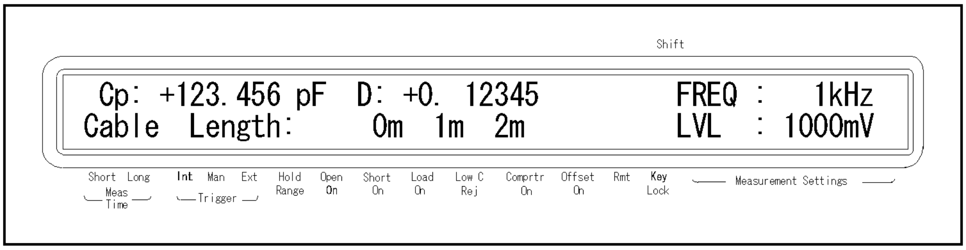
Select the length of the measurement cable from 0 m, 1 m, or 2 m, depending on the test lead you use.

0 m	When you do not use a test lead (in other words, when you connect the test fixture directly to the UNKNOWN terminal).
1 m	When you use the Agilent 16048A or Agilent 16089A/B/C/D test lead.
2 m	When you use the Agilent 16048D test lead.

The procedure used to set up the length of the measurement cable is described below.

Step 1. Press the **[Cable]** (**[Blue]** - **[2]**) key. The menu screen shown in Figure 4-9 appears.

Figure 4-9 **Cable length selection menu screen**



4288aoj013

Step 2. The blinking value is the current setup value for the cable length. If you want to change it, use the **[↑→]** key to make the cable length value you're using blink and then press the **[Enter]** key.

Executing measurement to compensate errors

You can compensate for errors in the measurement results by measuring the parameters that cause test fixture errors before actually connecting the DUT to the test fixture.

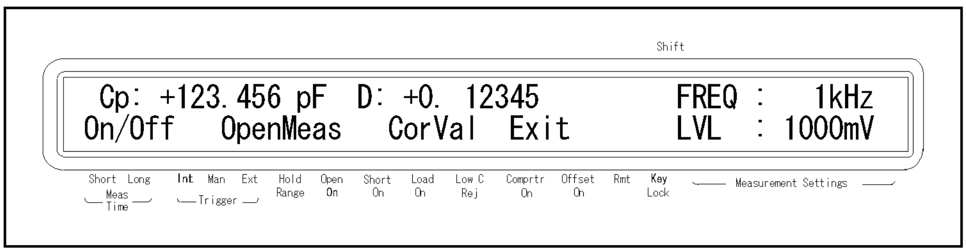
Measuring data for OPEN compensation

The OPEN compensation is provided to remove stray admittance parallel to the DUT. The procedure to measure the data for OPEN compensation is described below.

Step 1. Bring the electrodes of the test fixture connected to the UNKNOWN terminal into the OPEN state or a state suitable for OPEN compensation.

Step 2. Press the **[Open]** (**[Blue]** - **[4]**) key. The OPEN compensation menu screen shown in Figure 4-10 appears.

Figure 4-10 **OPEN compensation menu screen**



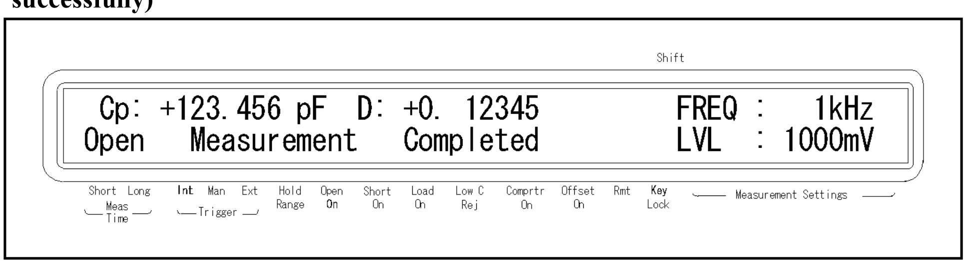
4288aoj129

Step 3. Use the **[↑→]** key to make “OpenMeas” blink and press the **[Enter]** key. The data for the OPEN compensation is then measured.

NOTE The data for OPEN compensation is stored as data for the measurement frequency used in the measurement.

When measurement of the data for OPEN compensation is successfully completed, the measured data is displayed for several seconds and then the message shown in Figure 4-11 is displayed for several seconds.

Figure 4-11 **Screen upon completion of measuring data for OPEN compensation (when completed successfully)**

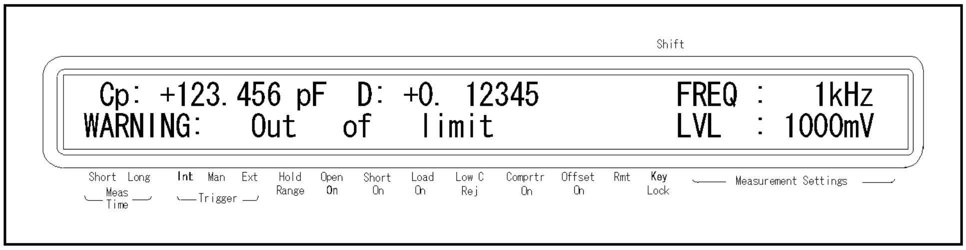


4288aoj015

If open admittance |Yo| (= $\sqrt{G^2 + B^2}$) is greater than 20 µS (an unsuitable level for the data used in OPEN compensation), the warning message shown in Figure 4-12 appears instead of the message in Figure 4-11.

NOTE Even if this warning message appears, the data for OPEN compensation is still used. However, you should recheck the connection between the test fixture and the UNKNOWN terminal and confirm that the OPEN compensation procedure was done correctly.

Figure 4-12 **Screen upon completion of measuring data for OPEN compensation (when |Yo| ≥ 20 μS)**

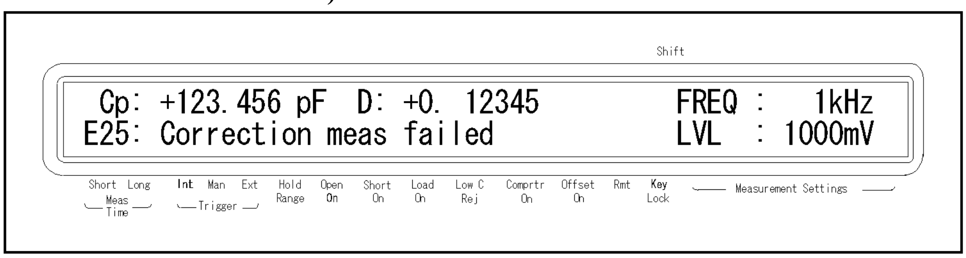


4288aoj016

If a measurement failure occurs while measuring the data for compensation, the error message shown in Figure 4-13 appears instead of the message in Figure 4-11.

NOTE If this error occurs, the data for compensation before the measurement remains without change.

Figure 4-13 **Screen upon completion of measuring data for OPEN compensation (when a measurement failure occurs)**



4288aoj017

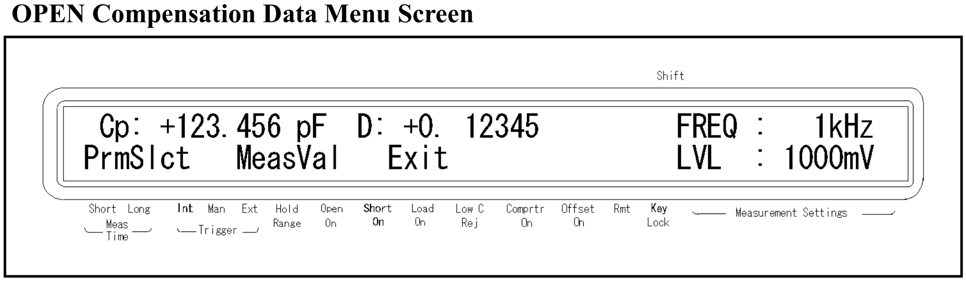
Checking data for OPEN compensation

You can check the measured open admittance value (data for the OPEN compensation). The procedure is given below.

Step 1. Press the **[Open]** (**[Blue]** - **[4]**) key to display the OPEN compensation menu screen (refer to Figure 4-10).

Step 2. Use the **[↑→]** key to make "CorVal" blink and then press the **[Enter]** key. The OPEN Compensation Data Menu Screen appears as shown in Figure 4-14.

Figure 4-14 **OPEN Compensation Data Menu Screen**



4288aoj130

Step 3. Press the **[↑→]** key to make "MeasVal" blink and press the **[Enter]** key. The measured G (conductance) value is displayed.

Step 4. Press the **[Enter]** key. The measured B (susceptance) value is displayed.

Step 5. Press the **[Enter]** key to return to the OPEN compensation menu screen.

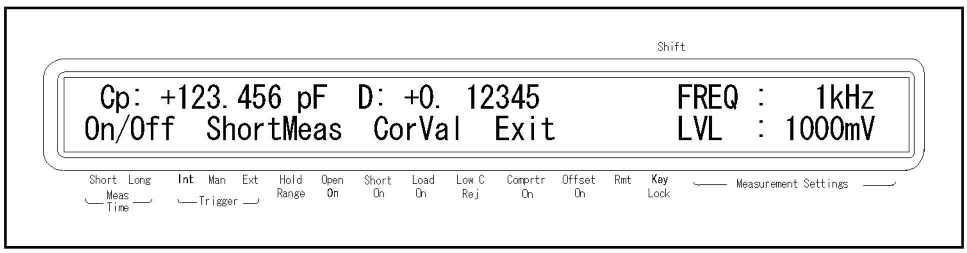
Measuring data for SHORT compensation

The SHORT compensation removes residual impedance in series with the DUT. The procedure to measure the data for SHORT compensation is described below.

Step 1. Contact the electrodes of the test fixture directly or connect the short bar to the test fixture to bring the measuring electrodes into the SHORT state.

Step 2. Press the **[Short]** (**[Blue]** - **[5]**) key. The SHORT compensation menu screen as shown in Figure 4-15 appears.

Figure 4-15 **SHORT compensation menu screen**



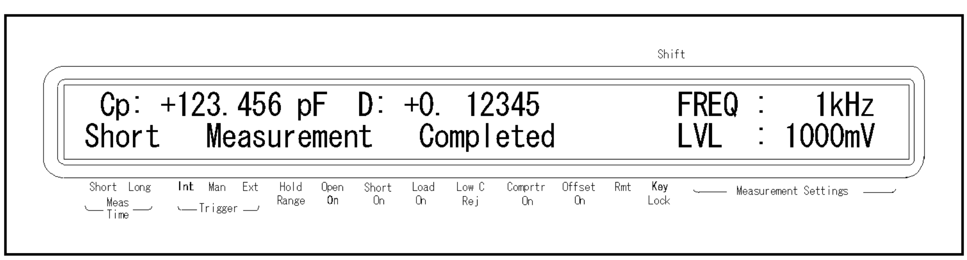
4288aoj131

Step 3. Use the **[↑→]** key to make “ShortMeas” blink and then press the **[Enter]** key. The data for SHORT compensation is then measured.

NOTE The data for SHORT compensation is stored as data for the measurement frequency used in the measurement.

When measurement of the data for SHORT compensation is successfully completed, the measured data is displayed for several seconds and then the message shown in Figure 4-16 is displayed for several seconds.

Figure 4-16 **Screen upon completion of measuring data for SHORT compensation (when completed successfully)**

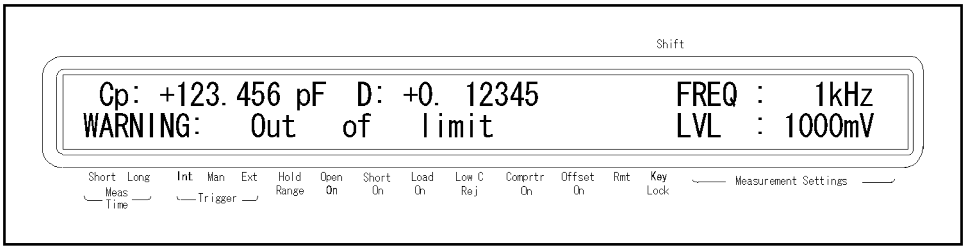


4288aoj019

If SHORT impedance |Zs| ($=\sqrt{R^2+X^2}$) is greater than 20 Ω (an unsuitable level for the data used in SHORT compensation), the warning message in Figure 4-17 appears instead of the message in Figure 4-16.

NOTE Even if this warning message appears, the data for SHORT compensation is still used. However, you should recheck the connection between the test fixture and the UNKNOWN terminal and confirm that the SHORT compensation procedure was done correctly.

Figure 4-17 **Screen upon completion of measuring data for SHORT compensation (when |Zs| ≥ 20 Ω)**

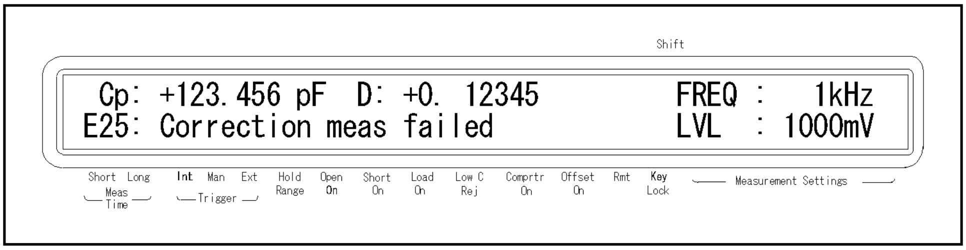


4288aoj016

If a measurement failure occurs while measuring the data for the compensation, the error message shown in Figure 4-18 appears instead of the message in Figure 4-16.

NOTE If this error occurs, the data for the compensation before the measurement remains without change.

Figure 4-18 **Screen upon completion of measuring data for SHORT compensation (when a measurement failure occurs)**



4288aoj017

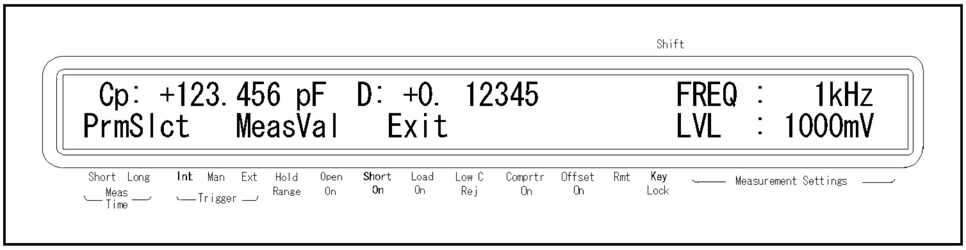
Checking data for SHORT compensation

You can check the measured SHORT impedance value (the data for SHORT compensation). The procedure is given below.

Step 1. Press the **[Short]** (**[Blue]** - **[5]**) key to display the SHORT compensation menu screen (refer to Figure 4-15).

Step 2. Use the **[↑→]** key to make “CorVal” blink and then press the **[Enter]** key. The SHORT Compensation Data Menu Screen appears as shown in Figure 4-19.

Figure 4-19 **SHORT Compensation Data Menu Screen**



4288aoj130

Step 3. Use the **[↑→]** key to make “MeasVal” blink and then press the **[Enter]** key. The R (resistance) value is displayed.

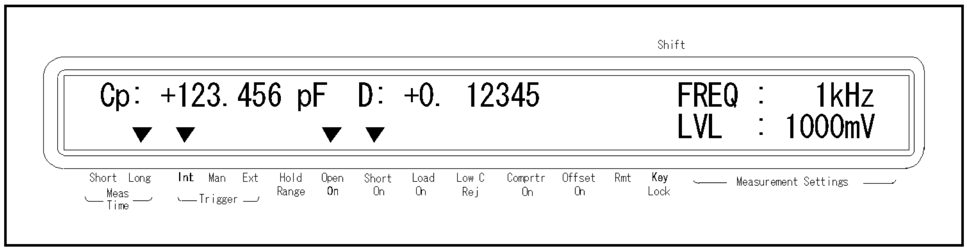
Step 4. Press the **[Enter]** key. The X (reactance) value is displayed.

Step 5. Press the **[Enter]** key to return to the SHORT compensation menu screen.

Connecting the DUT (capacitor)

Mount a capacitor on the test fixture. The impedance measurement result for the parameter selected in “Setting up measurement parameters” on page 42 is displayed. Figure 4-16 shows an example when the primary parameter is Cp and the secondary parameter is D.

Figure 4-20 **Measurement result display screen (when primary parameter is Cp and secondary parameter is D)**



4288aoj020

5 Setting up Measurement Conditions and Display

This chapter describes how to set up the measurement conditions and display. It also describes how to save/recall the instrument setup state, including the measurement conditions.

Selecting Measurement Parameters

You can select one of the measurement parameter combinations shown in Table 5-1.

Table 5-1 **Measurement parameters**

Primary parameter	Secondary parameter
Cp	D, Q, G, Rp
Cs	D, Q, Rs

Each parameter is described below.

Cp: Capacitance value measured using the parallel equivalent circuit model

Cs: Capacitance value measured using the series equivalent circuit model

D: Dissipation factor

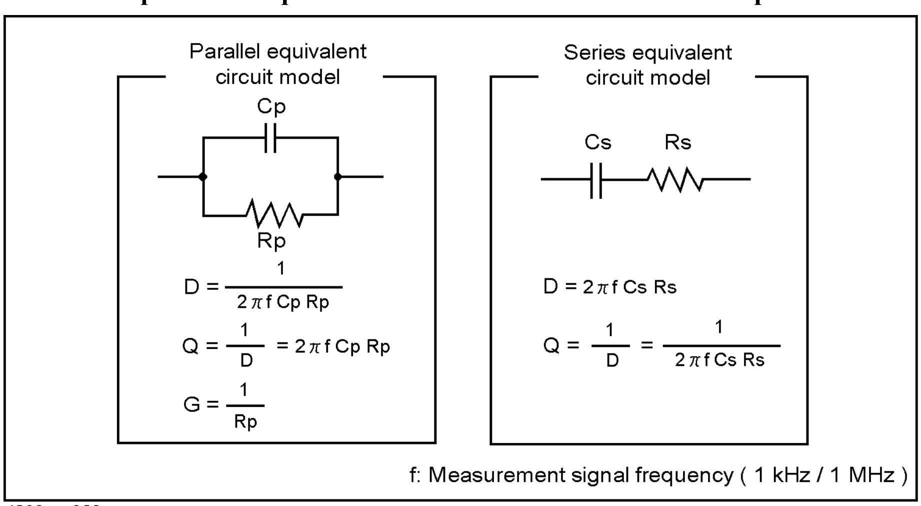
Q: Quality factor (inverse of D)

G: Equivalent parallel conductance measured using the parallel equivalent circuit model

Rp: Equivalent parallel resistance measured using the parallel equivalent circuit model

Rs: Equivalent series resistance measured using the series equivalent circuit model

Figure 5-1 **Relationship between equivalent circuit model and measurement parameters**



4288aoe023

For information on the selection criteria for the equivalent circuit model, refer to "Selection criteria of parallel/series equivalent circuit models" on page 207.

Setup procedure

Press the **[Meas Prmtr]** key, use the **[↑→]** and other necessary keys to make the primary parameter you want to set up blink, and press the **[Enter]** key. Then, use the **[↑→]** key to make the secondary parameter you want to set up blink and press the **[Enter]** key.

For details on the setup procedure, refer to "Setting up measurement parameters" on page 42.

Setting Up Measurement Signals (frequency and level)

Setting up frequency

You can set the frequency of the measurement signal applied to the DUT as either 1 kHz or 1 MHz.

Setup procedure

Press the **[Freq]** key, use the **[↑→]** and other necessary keys to make the frequency you want to set up blink, and press the **[Enter]** key.

For details on the setup procedure, refer to “Setting up measurement signal frequency” on page 44.

Setting up level

You can set up the level of the measurement signal applied to the DUT within a range of 0.1 V to 1.0 V in steps of 0.1 V.

Setup procedure

Press the **[Level]** key, use the numeric and other necessary keys to enter the level you want to set up, and press the **[Enter]** key.

For details on the setup procedure, refer to “Setting up measurement signal level” on page 44.

Selecting Measurement Range

Setting measurement range to be automatically selected (auto ranging)

Two modes can be used to select the measurement range as shown in Table 5-2. To enable automatic selection, select the auto range mode.

Table 5-2 **Measurement range mode**

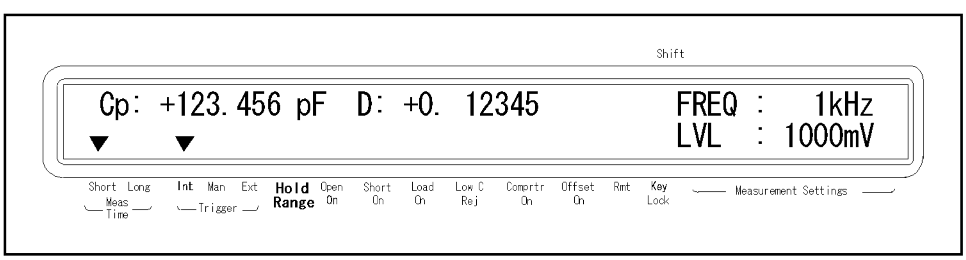
Mode	Function overview	Advantage	Disadvantage
Auto range (auto selection)	The instrument automatically selects a proper measurement range depending on the value of the DUT and performs measurement.	You do not need to select the measurement range.	The measurement time is longer due to the ranging time.
Hold (fixed) range (manual selection)	Measurement is performed with a fixed measurement range regardless of the value of the DUT.	No ranging time is required.	You need to select a proper range depending on the value of the DUT.

The procedure to set up the measurement range mode is described below.

Setup procedure

Press the **[Auto/Hold]** key. Each press toggles the measurement range mode. The setup state of the mode is indicated by whether the ▼ symbol is displayed above the "Hold Range" instrument setup display label. As shown in Figure 5-2, if the ▼ symbol is not displayed, the auto range mode is enabled; if displayed, the hold range mode is enabled.

Figure 5-2 **State display of measurement range mode (for auto range mode)**



4288aoj021

When you press the **[Auto/Hold]** key to set up the measurement range mode to the hold range mode, the measurement range is fixed to the range set when the key is pressed.

Selecting your desired measurement range (hold range)

The selectable measurement ranges are shown in Table 5-3. As this table shows, selectable measurement ranges differ depending on the measurement signal frequency. Therefore, if a newly selected measurement frequency conflicts with the current measurement range setting, the setting is automatically changed to cover the allowable range.

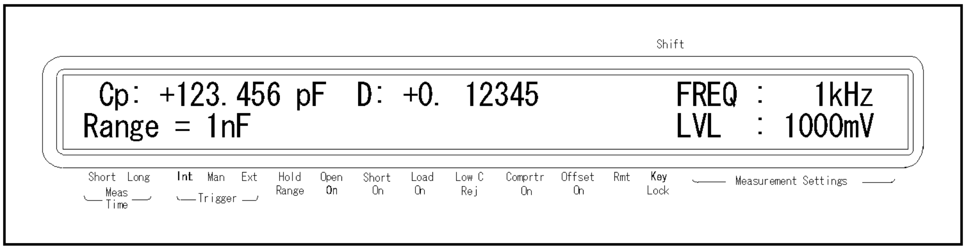
Table 5-3 **Selectable measurement ranges**

For 1 kHz measurement signal frequency:			For 1 MHz measurement signal frequency:		
			1 pF	2.2 pF	4.7 pF
			10 pF	22 pF	47 pF
100 pF	220 pF	470 pF	100 pF	220 pF	470 pF
1 nF	2.2 nF	4.7 nF	1 nF		
10 nF	22 nF	47 nF			
100 nF	220 nF	470 nF			
1 µF	2.2 µF	4.7 µF			
10 µF					

Setup procedure

Step 1. Press the **[Range Setup]** (**[Blue]** - **[Auto/Hold]**) key. This brings up the measurement range setup screen shown in Figure 5-3, where the initial measurement range displayed is the currently selected measurement range (in this example, 1 nF).

Figure 5-3 **Measurement range setup screen**



4288aoj007

Step 2. Use the numeric and other necessary keys to enter the range and press the **[Enter]** key.

NOTE Setting up the measurement range automatically sets the measurement range mode to the hold range mode.

Selecting Measurement Time

Two modes can be used for the measurement (integration) time as shown in Table 5-4.

Table 5-4 **Measurement time mode**

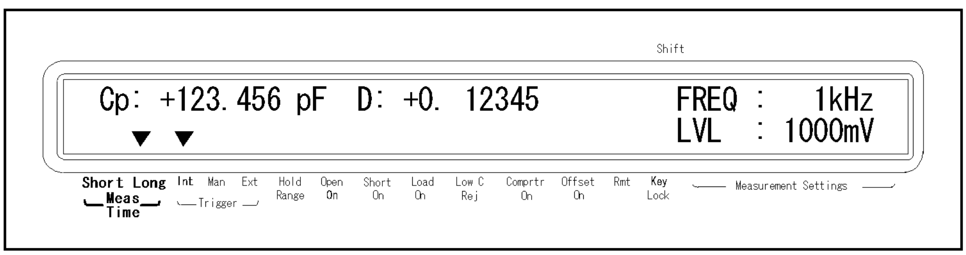
Mode	Measurement speed	Measurement accuracy
Short	Faster ↑ Slower	Worse ↓ Better
Long		

For details on the actual measurement time, refer to “Measurement time” on page 161.

Setup procedure

Press the **[Meas Time]** key. Each press toggles the measurement time mode. The setup state of the mode (Short or Long) is indicated above the Meas Time instrument setup display area by the ▼. Figure 5-4 shows an example when the long mode is selected.

Figure 5-4 **State display of measurement time mode (for long mode)**



4288aoj022

Selecting cable length

Set up the length of the measurement cable to compensate errors due to the extension of the measurement cable. The 4288A lets you select the length from 0 m, 1 m, or 2 m, depending on the measurement cable you use.

0 m	When you do not use the test lead (in other words, when you connect the test fixture directly to the UNKNOWN terminal).
1 m	When you use the Agilent 16048A or Agilent 16089A/B/C/D test lead.
2 m	When you use the Agilent 16048D test lead.

Setup procedure

Press the **[Cable]** (**[Blue]** - **[2]**) key, use the **[↑→]** and other necessary keys to make the cable length you want to set up blink, and press the **[Enter]** key.

For details on the setup procedure, refer to "Setting up cable length" on page 45.

Setting Up Averaging Count

Turning ON/OFF averaging function

You cannot turn ON/OFF the averaging function directly from the front panel. The ON/OFF operation of the averaging function can only be done with a GPIB command.

Turning ON averaging function

Setting up the averaging count from the front panel automatically turns the averaging function ON.

Turning OFF averaging function

You cannot turn OFF the averaging function from the front panel. However, can set the averaging count to 1 to get the same setup as when the averaging function is OFF.

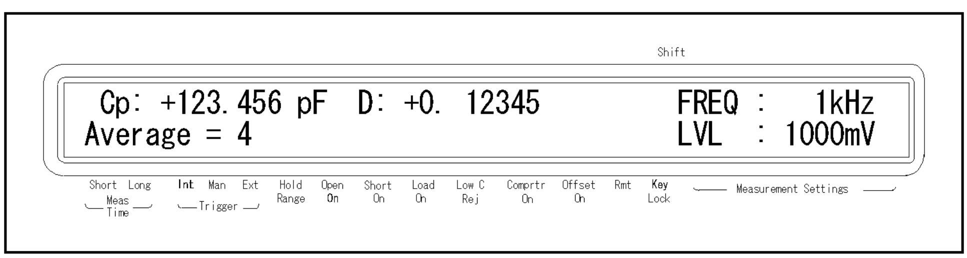
Setting up averaging count

You can set up any averaging count within a range of 1 to 256.

Setup procedure

Step 1. Press the **[Average]** (**[Blue]** - **[Meas Time]**) key. This brings up the averaging count setup screen shown in Figure 5-5, where the initial number displayed (in this example, 4) is the current setup of the averaging count.

Figure 5-5 **Averaging count setup screen**



4288aoj042

Step 2. Use the numeric and other necessary keys to enter the count you want to set up and press the **[Enter]** key.

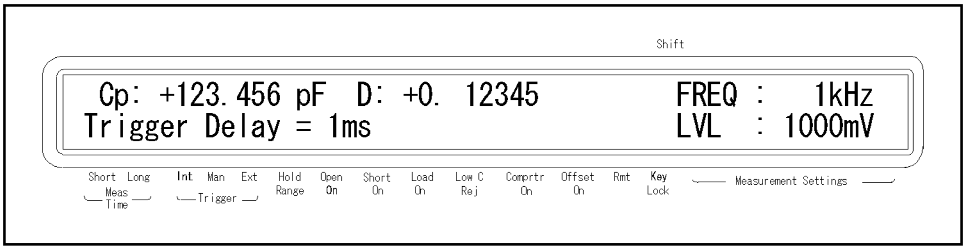
Setting Up Trigger Delay Time

You can set up a wait time (trigger delay time) between when a trigger is detected and when the measurement is started. You can set up the trigger delay time within the range of 0 s to 1 s in steps of 1 ms.

Setup procedure

Step 1. Press the [Delay] ([Blue] - [Trig Mode]) key. This brings up the trigger delay time setup screen shown in Figure 5-6, where the initial displayed value (in this example, 1 ms) is the current setup of the trigger delay time.

Figure 5-6 **Trigger delay time setup screen**



4288aoj043

Step 2. Use the numeric and other necessary keys to enter the value you want to set up and press the **[Enter]** key.

Setting Up Display

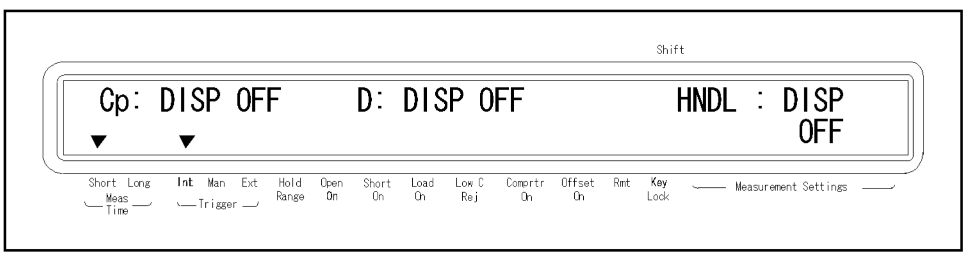
Turning ON/OFF display

You can turn ON/OFF the display of the following items:

- Measurement result of the measurement parameter (primary parameter or secondary parameter)
- Handler output (comparator sorting result)
- Measurement signal level monitor value
- Multi-compensation settings
- Compensation data

If you turn OFF the display, DISP OFF is always displayed in the display area for the above items, as shown in Figure 5-7, and you cannot read the measurement result. However, the measurement time is shortened because no additional time is required for updating the display.

Figure 5-7 **Screen when the display is OFF**

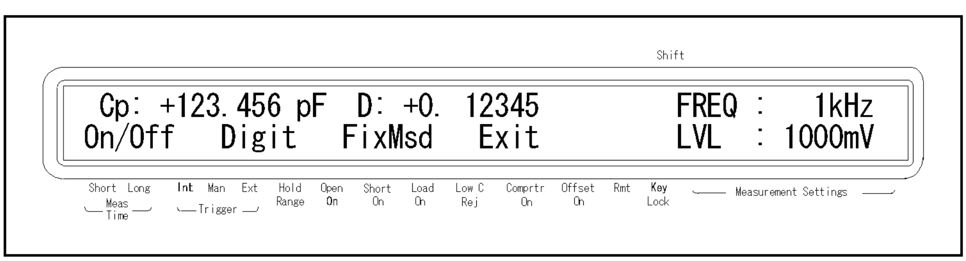


4288aoj025

Setup procedure

Step 1. Press the **[Disp Mode]** (**[Blue]** - **[Freq]**) key. The display setup screen shown in Figure 5-8 appears.

Figure 5-8 **Display setup screen**



4288aoj026

Step 2. Use the **[↑→]** and other necessary keys to make “On/Off” blink and press the **[Enter]** key. The display’s ON/OFF setup screen appears.

Step 3. Use the **[↑→]** and other keys to make “On” or “Off” blink and press the **[Enter]** key.

Selecting number of display digits for measurement result

You can select the number of display digits for the measurement result of the measurement parameter from 4 digits, 5 digits, or 6 digits. (The number of display digits for the measurement signal level monitor value is fixed to 4 digits and cannot be changed.)

Setup procedure

Step 1. Press the **[Disp Mode]** (**[Blue]** - **[Freq]**) key to display the display setup screen (refer to Figure 5-8).

Step 2. Use the **[↑→]** and other necessary keys to make “Digit” blink and press the **[Enter]** key. The display digit number selection screen appears (the blinking value is the current setup value of the number of display digits).

Step 3. Use the **[↑→]** and other keys to make 4, 5, or 6 blink and press the **[Enter]** key.

Using fixed point display for measurement result

The following two display modes can be used to display the measurement result of the measurement parameter.

	Description
Floating point display (default setup)	The value displayed at each digit is not fixed and changes depending on the measured value.
Fixed point display	The value displayed at each digit is fixed to the value defined by the user.

NOTE The fixed point display is always used to display the deviation percentage (refer to “Displaying measurement result in deviation from reference value (deviation measurement mode)”) as well as to display D and Q.

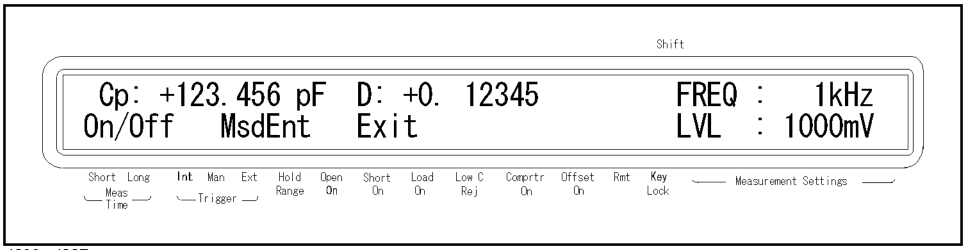
Setup procedure

Selecting floating/fixed point display

Step 1. Press the **[Disp Mode]** (**[Blue]** - **[Freq]**) key to display the display setup screen (refer to Figure 5-8).

Step 2. Use the **[↑→]** and other necessary keys to make “FixMsd” blink and press the **[Enter]** key. The fixed point display setup menu screen shown in Figure 5-9 appears.

Figure 5-9 **Fixed point display setup menu screen**



4288aoj027

Step 3. Use the **[↑→]** and other keys to make “On/Off” blink and press the **[Enter]** key. The screen to select whether to use the fixed point display (the blinking item is the current setup) appears.

Step 4. Use the **[↑→]** and other necessary keys to make “On” (fixed point display) or “Off” (floating point display) blink and press the **[Enter]** key.

Setting up highest digit for fixed point display

Step 1. Press the **[Disp Mode]** (**[Blue]** - **[Freq]**) key to display the display setup screen (refer to Figure 5-8).

Step 2. Use the **[↑→]** and other necessary keys to make “FixMsd” blink and press the **[Enter]** key to display the fixed point display setup menu screen (refer to Figure 5-9).

Step 3. Use the **[↑→]** and other necessary keys to make “MsdEnt” blink and press the **[Enter]** key.

Step 4. Use the numeric and other keys to enter the value of the highest digit of the primary parameter and press the **[Enter]** key. Then, enter the value of the highest digit of the secondary parameter and press the **[Enter]** key.

Displaying measurement result in deviation from reference value (deviation measurement mode)

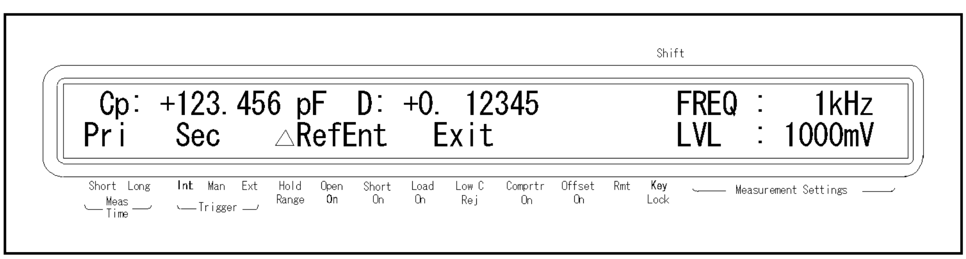
You can use the deviation measurement mode to display a relative measurement result as deviation from the reference value instead of displaying the basic measurement result. You can select from two deviation measurement modes: displaying the deviation as an absolute value or displaying the deviation as a percentage relative to a reference value.

Setup procedure

Setting up the reference value

Step 1. Press the **[Δ Mode]** (**[Blue]** - **[Meas Prmtr]**) key. The deviation measurement mode menu screen shown in Figure 5-10 appears.

Figure 5-10 **Deviation measurement mode menu screen**



4288aoj028

Step 2. Use the **[↑→]** key to make “ΔRefEnt”, and press the **[Enter]** key. The reference value setup screen appears.

Step 3. Set up the reference value in one of the following two ways.

Setting up any reference value

Use the numeric and other necessary keys to enter the reference value of the primary parameter and press the **[Enter]** key. Then, enter the reference value of the secondary parameter and press the **[Enter]** key.

Setting up measured value as the reference value

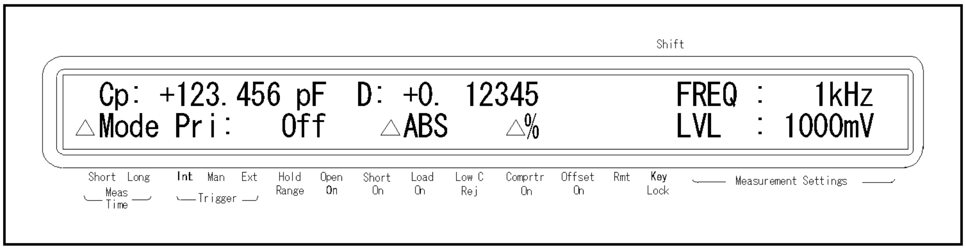
Press the **[Trig]** key. The primary parameter value is measured once and the result is displayed in the reference value entry filed. If the measured value is appropriate, press the **[Enter]** key. Then, press the **[Trig]** key to display the measured secondary parameter value and press the **[Enter]** key.

Selecting deviation display method (equation to calculate deviation)

Step 1. Press the **[Δ Mode]** (**[Blue]** - **[Meas Prmtr]**) key to display the deviation measurement mode menu screen.

Step 2. Use the **[↑→]** key to make “Pri” blink and press the **[Enter]** key. The primary parameter deviation measurement mode setup screen shown in Figure 5-11 appears.

Figure 5-11 **Primary parameter deviation measurement mode setup screen**



4288aoj029

Step 3. Use the **[↑→]** key to make “OFF,” “ΔABS,” or “Δ%” blink and press the **[Enter]** key.

Table 5-5 **Deviation display of measurement result**

	Description
OFF	The measurement result (*Meas*) is displayed as it is. (The deviation measurement mode is OFF.)
ΔABS	The deviation ($Meas - Ref$) between measurement result (*Meas*) and the reference value (*Ref*) is displayed.
Δ%	The deviation ($Meas - Ref$) between the measurement result (*Meas*) and the reference value (*Ref*) is displayed as a percentage relative to the reference value ($\frac{Meas - Ref}{Ref} \times 100$).

NOTE The measured value read out using the GPIB command is the result of calculation according to the above setup. For judgment in the comparator function, the measurement result is used as it is regardless of the setup. (Refer to Figure 6-1, “Data processing flow,” on page 72.)

Step 4. Use the **[↑→]** key to make “Sec” blink and press the **[Enter]** key. The secondary parameter deviation measurement mode setup screen appears. Set it up in the same way as the primary parameter.

When the display is in the deviation measurement mode (you have selected ΔABS or Δ%), “Δ” is displayed in front of the parameter on the screen.

Difference between deviation measurement mode and offset compensation

The offset compensation function is similar to the deviation measurement mode with respect to the behavior when a predefined value is subtracted from the measured value. On the other hand, the two functions differ as explained below.

	Purpose	**Effect on comparator**
Deviation measurement mode	Used when calculating the deviation of the measured value from any given value (for example, nominal value).	Not affected. The absolute value of the measurement result is always used for sorting judgment.
Offset compensation	Used to bring the measured value close to any given value (for example, to compensate variations of the measured value among instruments for the same DUT).	Affected. Values compensated by this function are used for sorting judgment.

If the deviation measurement mode and the offset compensation are both ON, the offset compensation is executed first and then, using the result as the measurement result, the value calculated using the equation of Table 5-5 on page 63 is displayed. (Refer to Figure 6-1, “Data processing flow,” on page 72.)

Selecting items displayed in instrument setup display area

You can select from 24 different display pages for the area that displays the instrument setup at the right of the display (instrument setup display area). Table 5-6 describes each display page.

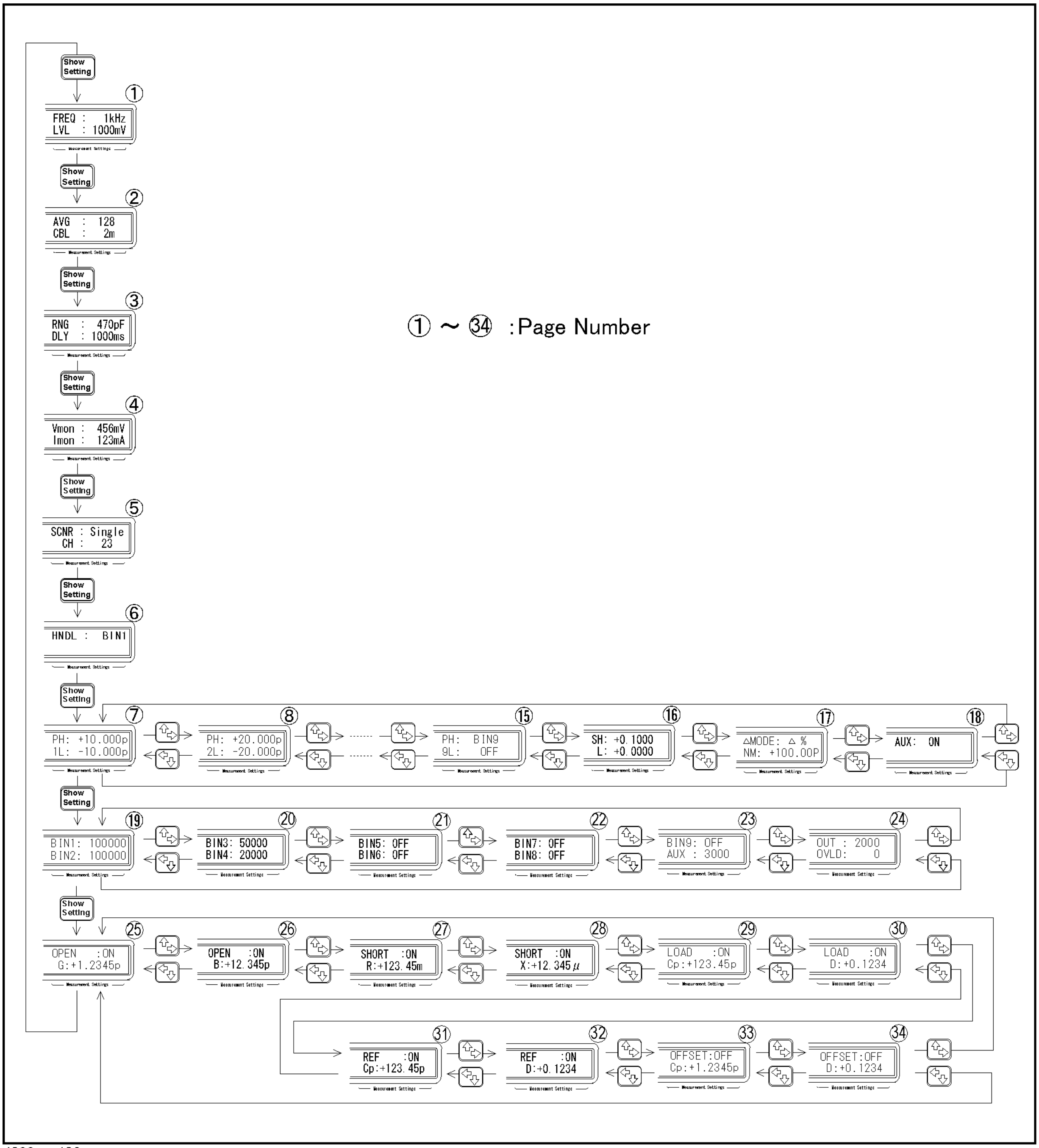
Table 5-6 **Pages displayed in instrument setup display area**

Display page number	Sample display	Description
1	FREQ : 1kHz LVL : 1000mV Measurement Settings	To the right of FREQ (upper half), the setup value of the measurement signal frequency is displayed; to the right of LVL (lower half), the setup value of the measurement signal level is displayed.
2	AVG : 128 CBL : 2m Measurement Settings	To the right of AVG (upper half), the setup value of the averaging count is displayed; to the right of CBL (lower half), the setup value of the cable length is displayed. If the averaging function is set to OFF with a GPIB command, 1 is displayed as the setup value of the averaging count.
3	RNG : 470pF DLY : 1000ms Measurement Settings	To the right of RNG (upper half), the selected measurement range is displayed; to the right of DLY (lower half), the setup value of the trigger delay time is displayed.
4	Vmon : 456mV Imon : 123mA Measurement Settings	To the right of Vmon (upper half), the voltage monitor result of the measurement signal level is displayed; to the right of Imon (lower half), the current monitor result is displayed. If the level monitor function is set to OFF, OFF is displayed.
5	SCNR : Single CH : 23 Measurement Settings	To the right of SCNR (upper half), the load standard definition method (Single: defines for all the channels, Multi: defines for each channel individually) of the multi compensation function is displayed; to the right of CH (lower half), the selected channel number is displayed. If the multi compensation function is set to OFF, OFF is displayed in the upper half.
6	HNDL : BIN1 Measurement Settings	The handler output (the sorting judgment result of the comparator) is displayed. If the comparator function is set to OFF, COMP OFF is displayed using both the upper and lower halves. If Low C is detected, LowC is displayed in the upper half.
7 to 18	PH: +10.000p 1L: -10.000p Measurement Settings	The upper limit (upper half) and the lower limit (lower half) of the limit range of the comparator function are displayed on 12 pages changed with the **[↑→]** key. If the comparator function is set to OFF, COMP OFF is displayed using both the upper and lower halves, and the display page cannot be changed with **[↑→]** key. For more information, see "Checking (displaying) Limit Ranges" on page 109
19 to 24	BIN1: 100000 BIN2: 100000 Measurement Settings	BIN count values are displayed on 6 pages changed with the **[↑→]** key. If the BIN count function is set to OFF, OFF is displayed using the upper half and the display page cannot be changed with **[↑→]** key. For more information, see "Displaying BIN count value" on page 114
25 to 34	OPEN :ON G:+1.2345p Measurement Settings	Compensation data is displayed on 10 pages changed with the **[↑→]** key. For more information, see "Checking (displaying) Every Kind of Compensation Data Successively" on page 90

Setup procedure

Press the **[Show Setting]** key and **[↑→]** / **[← ↓]** keys until the desired page appears.

Figure 5-12 **Selecting pages displayed in instrument setup display area**



4288aoe126

Monitoring Measurement Signal Level

You can monitor the measurement signal level by selecting one of the settings shown in Table 5-7. You can also display the monitor result in the instrument setup display area.

Table 5-7 **Level monitor**

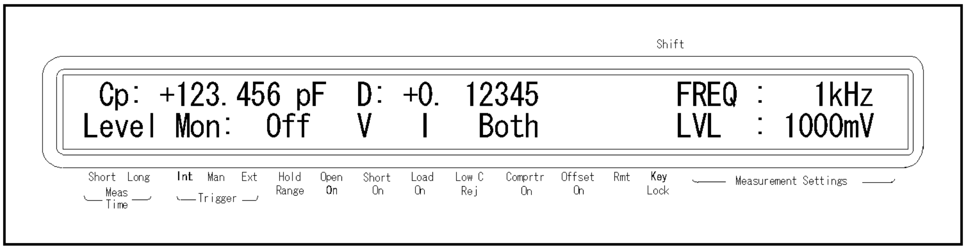
Setup*1		Monitor target (❍: monitored, ×: not monitored)	
		Voltage level	Current level
Monitor OFF (Off)		×	×
Monitor ON	Voltage only (V)	❍	×
	Current only (I)	×	❍
	Voltage and current (Both)	❍	❍

*1. Symbols in ( ) indicate items in the setup menu in Figure 5-13.

Setup procedure

Step 1. Press the **[Level Mon]** (**[Blue]** - **[Show Setting]**) key. The level monitor function setup screen shown in Figure 5-13 appears.

Figure 5-13 **Level monitor setup screen**



4288aoj030

Step 2. Use the **[↑→]** key to make the item you want to set up blink and press the **[Enter]** key.

NOTE Setting the level monitor function to ON (selecting V, I, or Both) automatically changes the instrument setup display area to the page that displays the level monitor value.

Setting Up Condition To Make A Beep

The condition to make a beep sound differs depending on the beep mode, as shown in Table 5-8.

Table 5-8 **Condition to make a beep**

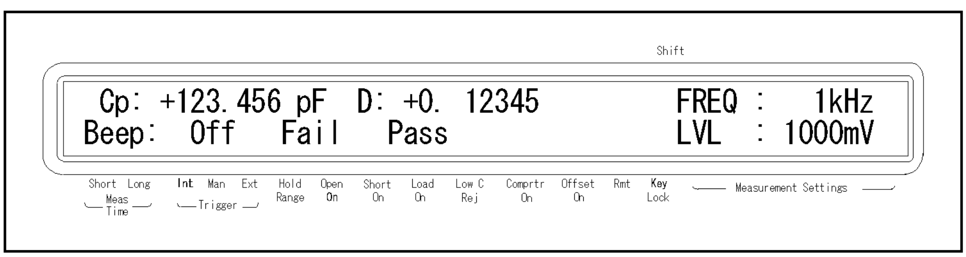
<table>
<tr><th>Mode</th><th colspan="2">Condition to make a beep</th></tr>
<tr><td>Off</td><td colspan="2">Never makes a beep.</td></tr>
<tr><td>Fail</td><td rowspan="2">When wrong key operation is performed.
When an error, alarm, or other message is outputted.</td><td>When the sorting judgment result of the comparator is OUT_OF_BIN or AUX_BIN.</td></tr>
<tr><td>Pass</td><td>When the sorting judgment result of the comparator is from BIN1 to BIN9.</td></tr>
</table>

Setup procedure

Step 1. Press the **[Config]** (**[Blue]** - **[–]**) key. The menu screen shown in Figure 4-1 on page 39 appears.

Step 2. Use the **[↑→]** key to make “Beep” blink and press the **[Enter]** key. The beep setup screen shown in Figure 5-14 appears.

Figure 5-14 **Beep setup screen**



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Step 3. Use the **[↑→]** key to make the beep mode you want to set up blink and press the **[Enter]** key.

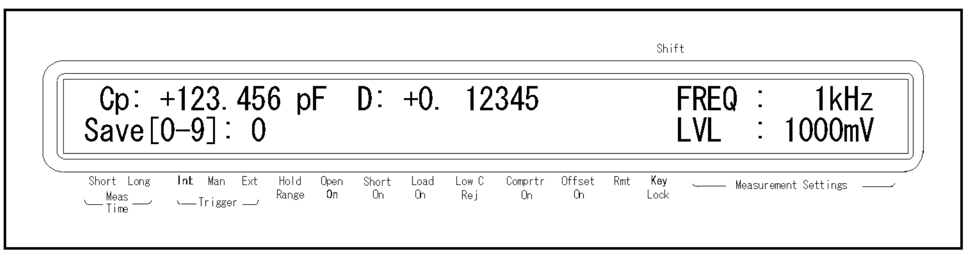
Saving/Recalling Instrument Setup State (save/recall function)

You can save/recall up to 10 instrument setup states using the built-in nonvolatile memory (EEPROM). For information on the instrument settings you can save/recall, refer to Table C-1, “Initial settings, settings that can be saved/recalled, settings that can be backed up,” on page 185.

Saving instrument setup state

Step 1. Press the **[Save]** (**[Blue]** - **[Rcl]**) key. The save location (nos. 0 to 9) entry screen shown in Figure 5-15 appears.

Figure 5-15 **Save execution screen**



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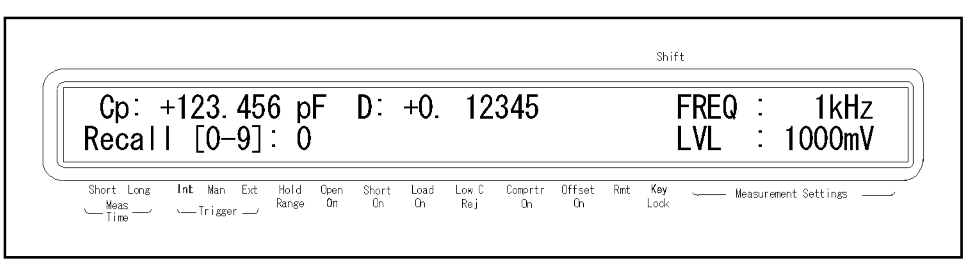
Step 2. Use the numeric and other necessary keys to enter the number you desire and press the **[Enter]** key. We recommend that you record the relationship between the saved instrument setup state and the entered number because it is required for later recall.

NOTE If the instrument setup state data has been recorded already at the specified save location (number), the existing data is overwritten with new data and lost. Check that no necessary recorded data are being saved before entering a save number.

Recalling saved instrument setup state

Step 1. Press the **[Rcl]** key. The recall location (nos. 0 to 9) entry screen shown in Figure 5-16 appears.

Figure 5-16 **Recall execution screen**



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Step 2. Use the numeric and other necessary keys to enter the number of the location where the instrument setup state you want to read out is saved and press the **[Enter]** key.

6 Preparation for Accurate Measurement (Executing Compensation)

This chapter gives an overview and the operational procedures of the compensation function.

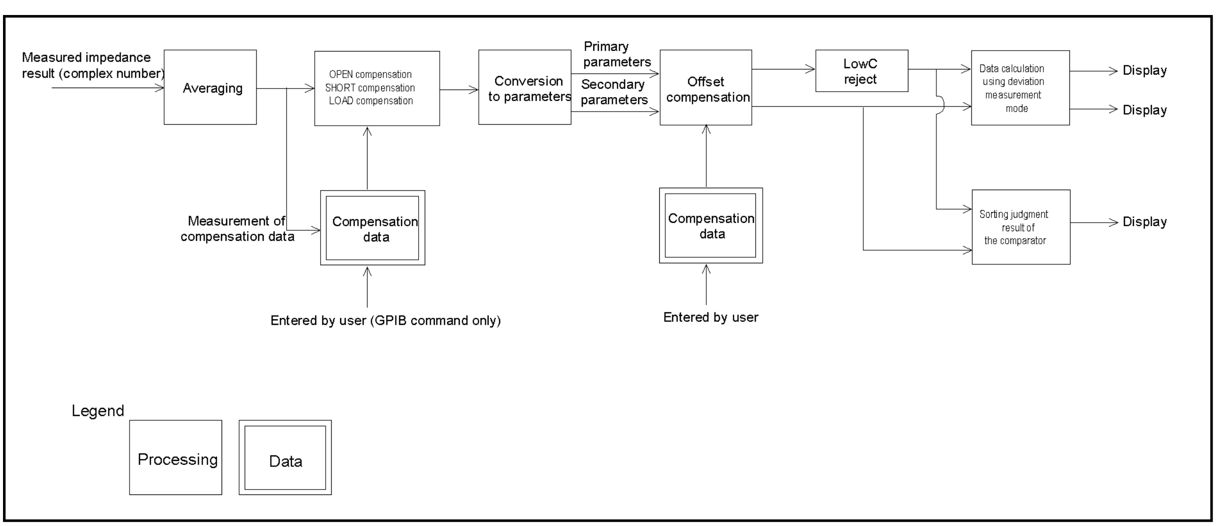
Overview of Compensation Function

The 4288A provides four types of compensation functions: OPEN compensation, SHORT compensation, LOAD compensation, and offset compensation. The following table gives a brief description of each compensation function.

Type of compensation	Description
OPEN compensation	Compensates errors caused by the parallel stray admittance of the test fixture. This compensation is based on the results of admittance measurement in the OPEN state that is performed in advance.
SHORT compensation	Compensates errors caused by the series residual impedance of the test fixture. This compensation is based on the results of impedance measurement in the SHORT state that is performed in advance.
LOAD compensation	Compensates complex errors related to amplitude/phase errors, the scanner, and so on caused by the cable and test fixture. This compensation is based on the results of impedance measurement of the standard having a known value that is performed in advance.
Offset compensation	Compensates errors between the actual measured value and the ideal value that the user desires by subtracting any value that the user enters from the measured result (for example, difference between a known standard value and its measured value, or instrument-by-instrument differences in the measured values of the same DUT).

As shown in the data processing flow of Figure 6-1, the OPEN/SHORT/LOAD compensation is first performed for the measured impedance result (complex number), and the result is converted to the primary/secondary parameters. Then, for the primary/secondary parameter values (real number), the offset compensation is performed.

Figure 6-1 **Data processing flow**



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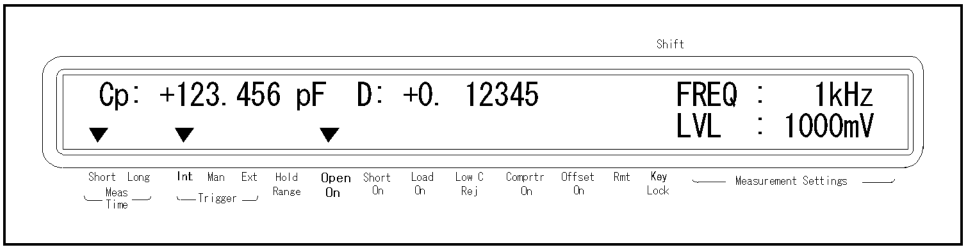
Turning ON/OFF Compensation Functions

You can turn ON/OFF each compensation function separately.

Turning on OPEN compensation

The ON/OFF state of the OPEN compensation is indicated by whether the ▼ symbol is displayed above the “Open On” instrument setup display label. The ▼ symbol, if displayed as shown in Figure 6-2, indicates ON.

Figure 6-2 **ON/OFF state display of OPEN compensation (for ON)**



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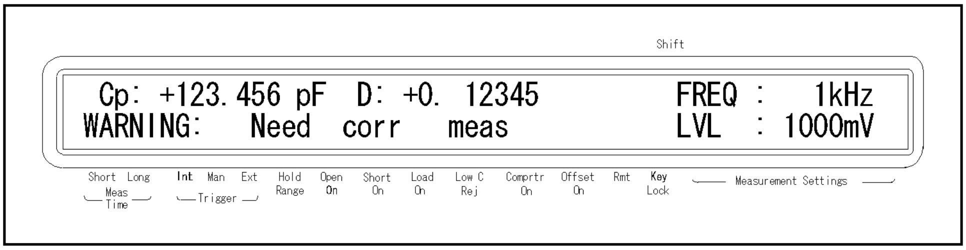
NOTE If you change the setup of the cable length or frequency shift (1 MHz) with the OPEN compensation ON, the warning message shown in Figure 6-3 appears and the OPEN compensation is automatically set to OFF.

Figure 6-3 **Warning message that prompts you to measure compensation data**



4288aoj121

Use one of the following two ways to set the OPEN compensation to ON.

Measuring data for OPEN compensation

Execute measurement of the data for the OPEN compensation. When the measurement finishes successfully, the OPEN compensation is automatically set to ON. For information on the measurement procedure for the data used in the OPEN compensation, refer to “Measuring data for OPEN compensation” on page 46.

Setting up ON/OFF directly

Use the following procedure to set the OPEN compensation to ON/OFF.

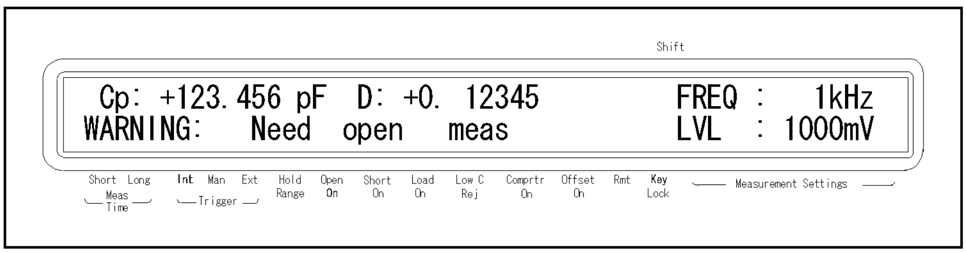
Step 1. Press the **[Open]** (**[Blue]** - **[4]**) key to display the OPEN compensation menu screen (refer to Figure 4-10 on page 46).

Step 2. Use the **[↑→]** key to make “On/Off” blink and then press the **[Enter]** key. The OPEN compensation ON/OFF setup screen appears.

Step 3. The blinking item is the current setup value. Use the **[↑→]** key to make the item you want to set up (“Off” or “On”) blink and then press the **[Enter]** key.

NOTE If you set the OPEN compensation to ON by using the above procedure when the setup of the cable length or frequency shift differs from that during measurement of the data for OPEN compensation, the warning message shown in Figure 6-4 appears. Even if this warning message appears, the OPEN compensation is set to ON. However, you must again measure the data for OPEN compensation to ensure accurate measurement.

Figure 6-4 **Warning message that prompts you to measure data for OPEN compensation**



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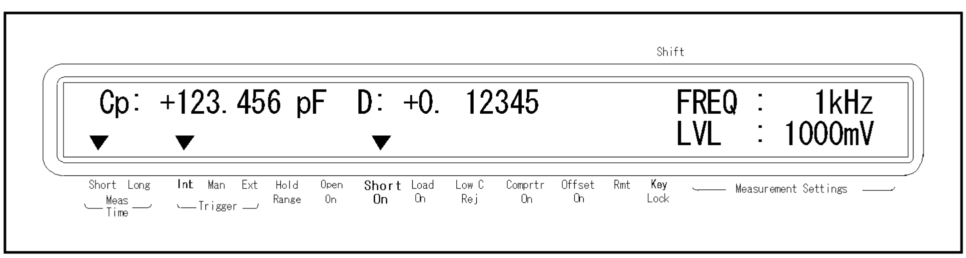
Turning on SHORT compensation

The ON/OFF state of the SHORT compensation is indicated by whether the ▼ symbol is displayed above the “Short On” instrument setup display label. The ▼ symbol, if displayed as shown in Figure 6-5, indicates ON.

Figure 6-5 **ON/OFF state display of SHORT compensation (for ON)**



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NOTE If you change the setup of the cable length or frequency shift (1 MHz) with the SHORT compensation ON, the warning message shown in Figure 6-3 on page 73 appears and the SHORT compensation is automatically set up to OFF.

Use one of the following two ways to set the SHORT compensation to ON.

Measuring data for SHORT compensation

Execute measurement of the data for the SHORT compensation. When the measurement finishes successfully, the SHORT compensation is automatically set to ON. For information about the measurement procedure for the data used in the SHORT compensation, refer to “Measuring data for SHORT compensation” on page 48.

Setting up ON/OFF directly

Use the following procedure to set the SHORT compensation to ON/OFF.

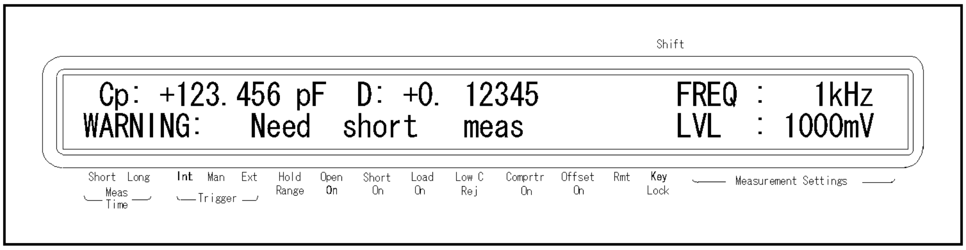
Step 1. Press the **[Short]** (**[Blue]** - **[5]**) key to display the SHORT compensation menu screen (refer to Figure 4-15 on page 48).

Step 2. Use the **[↑→]** key to make “On/Off” blink and then press the **[Enter]** key. The SHORT compensation ON/OFF setup screen appears.

Step 3. The blinking item is the current setup value. Use the **[↑→]** key to make the item you want to set up (“Off” or “On”) blink and then press the **[Enter]** key.

NOTE If you set the SHORT compensation to ON using the above procedure when the setup of the cable length or frequency shift differs from that during measurement of the data for SHORT compensation, the warning message shown in Figure 6-6 appears. Even if this warning message appears, the SHORT compensation is set to ON. However, you must again measure the data for SHORT compensation to ensure accurate measurement.

Figure 6-6 **Warning message that prompts you to measure data for SHORT compensation**

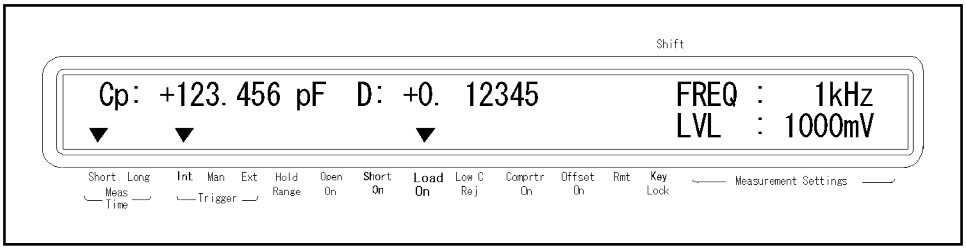


4288aoj058

Turning ON LOAD compensation

The ON/OFF state of the LOAD compensation is indicated by whether the ▼ symbol is displayed above the Load On instrument setup display label. The ▼ symbol, if displayed as shown in Figure 6-7, indicates ON.

Figure 6-7 **ON/OFF state display of LOAD compensation (for ON)**



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NOTE If you change the setup of the cable length or frequency shift (1 MHz) with the LOAD compensation ON, the warning message shown in Figure 6-3 on page 73 appears and the LOAD compensation is automatically set to OFF.

Use one of the following two ways to set the LOAD compensation to ON.

Measuring LOAD compensation data

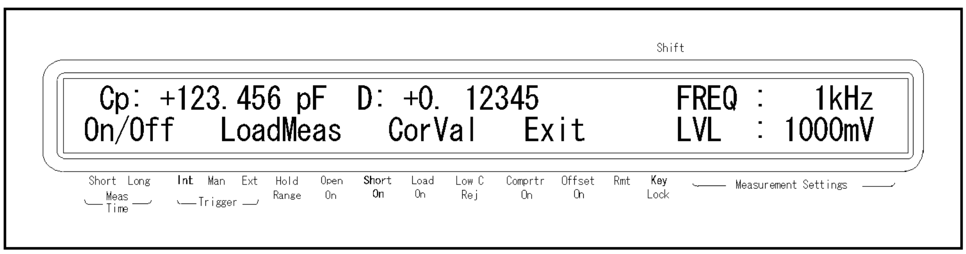
Execute measurement of the data for the LOAD compensation. When the measurement finishes successfully, the LOAD compensation is automatically set to ON. For information about the measurement procedure for the data used in the LOAD compensation, refer to “Obtaining (measuring) data for LOAD compensation” on page 81.

Setting up ON/OFF directly

Use the following procedure to set the LOAD compensation to ON/OFF.

Step 1. Press the **[Load]** (**[Blue]** - **[6]**) key. The LOAD compensation menu screen shown in Figure 6-8 appears.

Figure 6-8 **LOAD compensation menu screen**



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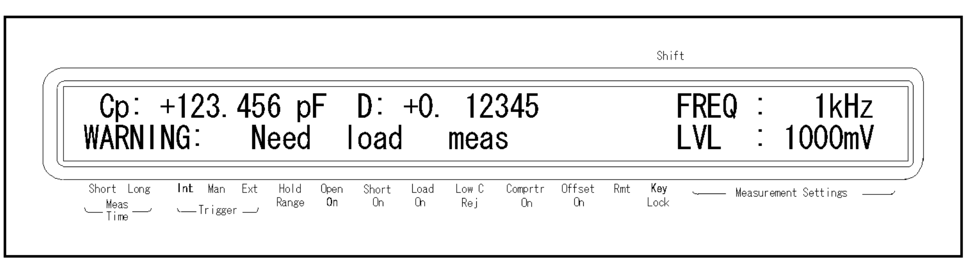
Step 2. Use the **[↑→]** key to make “On/Off” blink and then press the **[Enter]** key. The LOAD compensation ON/OFF setup screen appears.

Step 3. The blinking item is the current setup value. Use the **[↑→]** key to make the item you want to set up (“Off” or “On”) blink and then press the **[Enter]** key.

NOTE If you set up the LOAD compensation to ON using the above procedure when the setup of the cable length or frequency shift differs from that during measurement of the data for LOAD compensation, the warning message shown in Figure 6-9 appears. Even if this warning message appears, the LOAD compensation is set to ON. However, you must again measure the data for the LOAD compensation to ensure accurate measurement.

Figure 6-9 **Warning message that prompts you to measure data for LOAD compensation**



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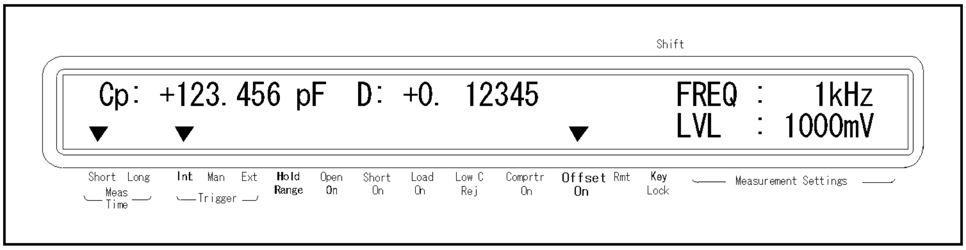
Turning ON Offset Compensation

The ON/OFF state of the Offset compensation is indicated by whether the ▼ symbol is displayed above the "Offset On" instrument setup display label. The ▼ symbol, if displayed as shown in Figure 6-10, indicates ON.

Figure 6-10 **ON/OFF state display of offset compensation (for ON)**



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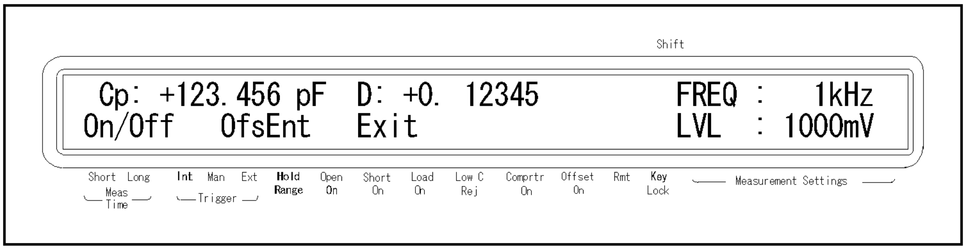
NOTE If you change the setup of the measurement parameter with the offset compensation ON, the offset compensation is automatically set to OFF.

Use the following procedure to set the offset compensation to ON/OFF.

Step 1. Press the **[Offset]** (**[Blue]** - **[3]**) key. The offset compensation menu screen shown in Figure 6-11 appears.

Figure 6-11 **Offset compensation menu screen**



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Step 2. Use the **[↑→]** key to make "On/Off" blink and then press the **[Enter]** key. The offset compensation ON/OFF setup screen appears.

Step 3. The blinking item is the current setup value. Use the **[↑→]** key to make the item you want to set up ("Off" or "On") blink and then press the **[Enter]** key.

NOTE You cannot separately set the ON and OFF states as the primary parameter and secondary parameter. However, if you set the compensation value to 0, the state is effectively the same as OFF even if the offset compensation is ON. Therefore, you can set up separate ON/OFF states by setting the compensation value of either parameter to 0.

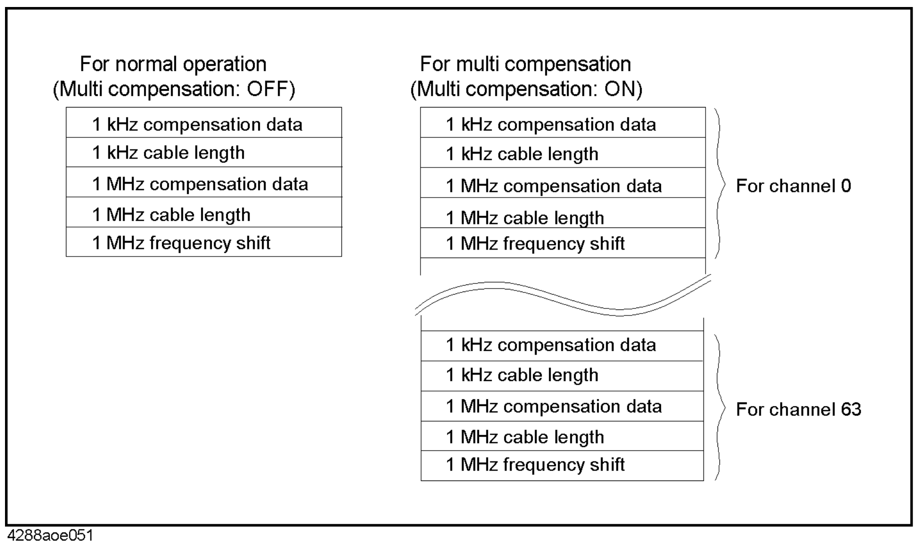
Obtaining Compensation Data

Obtaining (measuring) data for OPEN compensation

Data structure

The 1 kHz and 1 MHz data used in the OPEN compensation is divided into the data for normal operation and the data of each channel (64 channels) for multi-compensation, as shown in Figure 6-13.

Figure 6-12 **Structure of data for OPEN compensation**



Measured data

The data for the OPEN compensation can only be measured at the measurement frequency set by the user (1 kHz or 1 MHz) at the time of execution. The result is set up as the data for normal operation when the multi-compensation function is OFF and as the data for multi-compensation when the function is ON (for the channel that has been selected at execution).

The table below summarizes how data is set up, depending on the setup at execution.

Multi-compensation	Setup of measurement signal frequency	Data
OFF	1 kHz	1 kHz compensation data and 1 kHz cable length for normal operation
	1 MHz	1 MHz compensation data, 1 MHz cable length, and 1 MHz frequency shift for normal operation
ON	1 kHz	1 kHz compensation data and 1 kHz cable length for the channel selected at the time of multi-compensation measurement
	1 MHz	1 MHz compensation data, 1 MHz cable length and 1 MHz frequency shift for the channel selected at the time of multi-compensation measurement

Measurement conditions during data measurement

The data for the OPEN compensation is measured under the following conditions.

- Measurement range mode: auto range mode
- Measurement time mode: long mode
- Low C reject function: OFF

For other settings, the measurement conditions set up at execution are used for measurement.

Measurement procedure

Press the **[Open]** (**[Blue]** - **[4]**) key to display the OPEN compensation menu screen (refer to Figure 4-10 on page 46), use the **[↑→]** key to make "OpenMeas" blink, and press the **[Enter]** key. The data for the OPEN compensation will be measured.

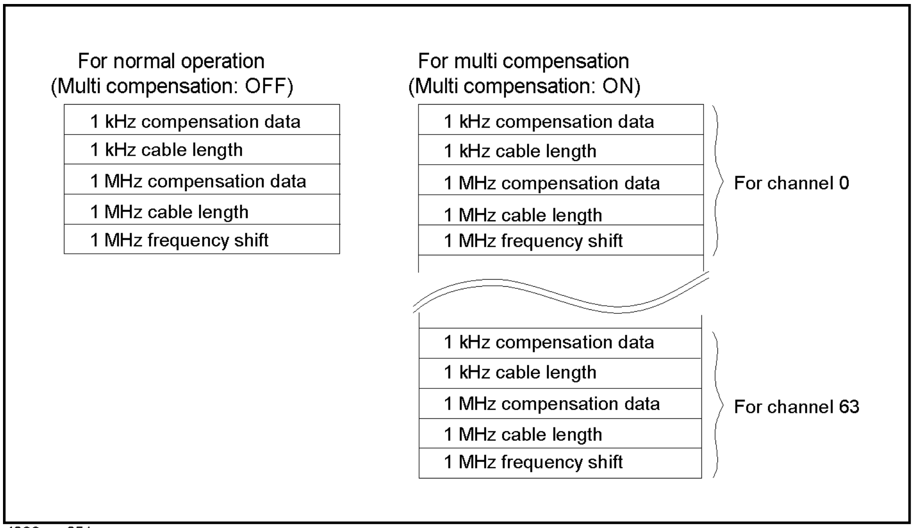
For more information on the measurement procedure for the data used in the OPEN compensation, refer to "Measuring data for OPEN compensation" on page 46.

Obtaining (measuring) data for SHORT compensation

Data structure

The 1 kHz and 1 MHz data used in the SHORT compensation is divided into the data for normal operation and the data of each channel (64 channels) for multi-compensation, as shown in Figure 6-13.

Figure 6-13 **Structure of data for SHORT compensation**



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Measured data

The data for the SHORT compensation can only be measured at the measurement frequency set by the user (1 kHz or 1 MHz) at the time of execution. The result is set up as the data for normal operation when the multi-compensation function is OFF and as the data for multi-compensation when the function is ON (for the channel that has been selected at execution).

The table below summarizes how data is set up, depending on the setup at execution.

Multi compensation	Setup of measurement signal frequency	Data
OFF	1 kHz	1 kHz compensation data and 1 kHz cable length for normal operation
	1 MHz	1 MHz compensation data, 1 MHz cable length, and 1 MHz frequency shift for normal operation
ON	1 kHz	1 kHz compensation data and 1 kHz cable length for the channel selected at the time of multi-compensation measurement
	1 MHz	1 MHz compensation data, 1 MHz cable length and 1 MHz frequency shift for the channel selected at the time of multi-compensation measurement

Measurement conditions during data measurement

The data for the SHORT compensation is measured under the following measurement conditions.

- Measurement range mode: auto range mode
- Measurement time mode: long mode
- Low C reject function: OFF
- Output impedance of measurement signal source: 20 Ω

For other settings, the measurement conditions set up at execution are used for measurement.

Measurement procedure

Press the **[Short]** (**[Blue]** - **[5]**) key to display the SHORT compensation menu screen (refer to Figure 4-15 on page 48), use the **[↑→]** key to make “ShortMeas” blink and then press the **[Enter]** key. The data for the SHORT compensation will be measured.

For more information about the measurement procedure for the data used in the SHORT compensation, refer to “Measuring data for SHORT compensation” on page 48.

Obtaining (measuring) data for LOAD compensation

Preparing the standard for LOAD compensation

To measure the data for the LOAD compensation, you must first prepare a device as the standard used for this measurement. You can use any device that has a stable known value as the standard. Also, the type of standard and the type of DUT can be different. For example, even if you measure a capacitor, you can use a resistor as the standard.

When using an existing standard:

Any device that has an accurate value (guaranteed as the specification) can be used as the standard.

When using a general purpose LCR component as the standard:

If you cannot prepare an existing standard, value a general purpose device (capacitor, resistor, and so on) by using a high-accuracy LCR meter and use it as the standard. Notes on selecting a device to use as the standard are given below.

- When you measure DUTs with a fixed impedance value, use a device with an impedance close to the fixed value. On the other hand, when you measure DUTs of several different values, use a device whose impedance can be valued accurately within a range of approximately 100 to 1 kΩ.
- Use a stable device that is not sensitive to factors of the measuring environment such as temperature and magnetic field.

You must value the standard as accurately as possible. The valuing procedure is described below.

Step 1. Connect the direct coupled test fixture to a high-accuracy LCR meter and execute OPEN/SHORT compensation.

Step 2. Set the measurement frequency of the high-accuracy LCR meter to the frequency (1 kHz/1 MHz) actually used when measuring the data for the LOAD compensation.

Step 3. Set up the high-accuracy LCR meter under measurement conditions that allow high-accuracy valuing (measurement) (for example, setting up the measurement time to the long mode or increasing the averaging count).

Step 4. Connect a device you use as the standard to the direct coupled test fixture and perform the measurement. Use the obtained measured value as the standard for the LOAD compensation.

Defining standard for LOAD compensation (setting up LOAD reference value)

Before measuring the data for the LOAD compensation, you must define the value of the standard used in LOAD compensation. You can define the standard for the LOAD compensation by using one the following parameter combinations.

Table 6-1 Definition parameters of the standard for LOAD compensation

Primary parameter	Secondary parameter
Cp	D, Q, G, Rp
Cs	D, Q, Rs

Defining parameters when using a resistance standard

When using a resistance standard (a standard that has been valued in the *R-X* format) as the standard for LOAD compensation, you must convert it to the *Cs-Rs* format because the 4288A does not allow you to enter a value directly in the *R-X* format as the definition value. The conversion expression is given below.

Equation 6-1 **Conversion expression for a standard valued in the *R-X* format**

$$Rs = R$$

$$Cs = -\frac{1}{2\pi f X}$$

where *f* denotes the measurement frequency.

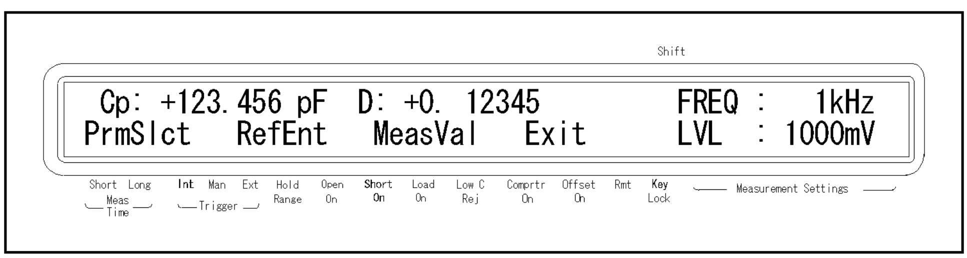
Definition procedure

The procedure to define the standard value for the LOAD compensation is described below.

Step 1. Press the **[Load]** (**[Blue]** - **[6]**) key to display the LOAD compensation menu screen (refer to Figure 6-8).

Step 2. Use the **[↑→]** key to make “CorVal” blink and then press the **[Enter]** key. The LOAD compensation standard setup menu screen shown in Figure 6-14 appears.

Figure 6-14 **LOAD compensation standard setup menu screen**



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Step 3. Use the **[↑→]** key to make “PrmSlct” blink and press the **[Enter]** key. The definition parameter selection screen appears.

Step 4. Use the **[↑→]** and other related keys to make the primary parameter you want to select blink and then press the **[Enter]** key. Next, use the **[↑→]** key to make the second parameter you want to select blink and then press the **[Enter]** key to return to the LOAD compensation standard setup menu screen.

Step 5. Use the **[↑→]** key to make “RefEnt” blink and then press the **[Enter]** key. The definition value setup screen appears.

Step 6. Enter the value of the primary parameter with the numeric and other related keys and then press the **[Enter]** key. Next, enter the value of the secondary parameter and press the **[Enter]** key.

The entered values are set up as the data shown in the below table, depending on the setup at execution.

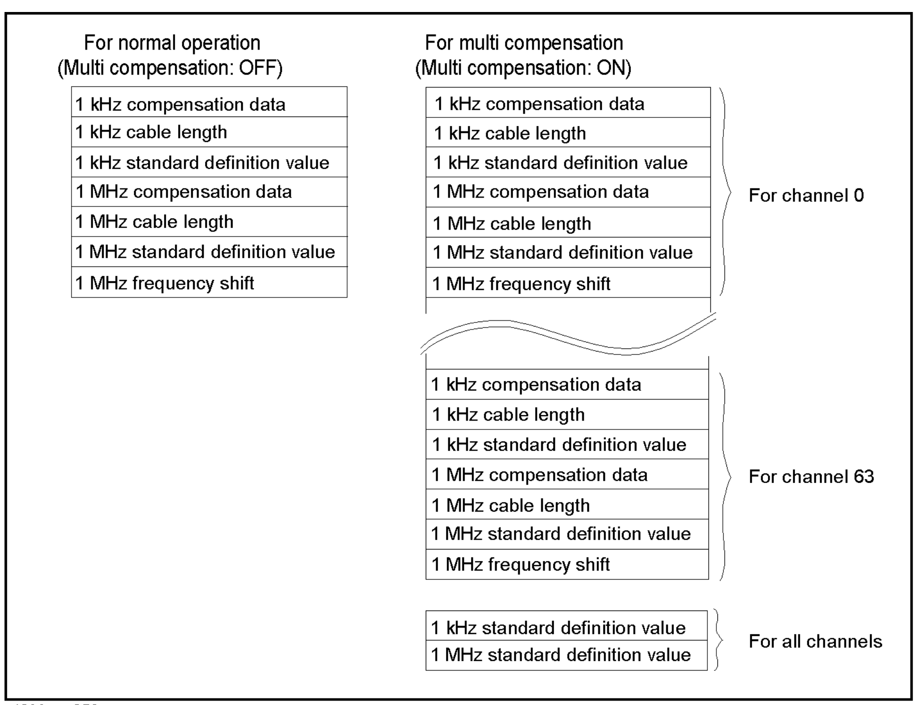
Multi-compensation setup		**Setup of measurement signal frequency**	**Data to be set up**
ON/ OFF	**Definition method for the LOAD standard value**		
OFF	———	1 kHz	1 kHz definition value for normal operation
		1 MHz	1 MHz definition value for normal operation
ON	Common to all channels	1 kHz	1 kHz definition value for all channels in the multi-compensation
		1 MHz	1 MHz definition value for all channels in the multi-compensation
	For each channel	1 kHz	1 kHz definition value for the channel selected at time of multi-compensation measurement
		1 MHz	1 MHz definition value for the channel selected at the time of multi-compensation measurement

Measuring data for LOAD compensation

Data structure

The 1 kHz and 1 MHz data used in the LOAD compensation is divided into the data for normal operation and the data of each channel (64 channels) for multi-compensation, as shown in Figure 6-13. Each set of data consists of the compensation data, cable length, standard definition value, and frequency shift (only for 1 MHz).

Figure 6-15 **Structure of data for LOAD compensation**



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Measured data

The data for the LOAD compensation can only be measured at the measurement frequency set by the user (1 kHz or 1 MHz) at the time of execution. The result is set up as the data for normal operation when the multi-compensation function is OFF and as the data for multi-compensation when the function is ON (for the channel that has been selected at execution).

The table below summarizes how data is set up, depending on the setup at execution.

Multi compensation	Setup of measurement signal frequency	Data
OFF	1 kHz	1 kHz compensation data and 1 kHz cable length for normal operation
	1 MHz	1 MHz compensation data, 1 MHz cable length, and 1 MHz frequency shift for normal operation
ON	1 kHz	1 kHz compensation data and 1 kHz cable length for the channel selected at the time of multi-compensation measurement
	1 MHz	1 MHz compensation data, 1 MHz cable length and 1 MHz frequency shift for the channel selected at the time of multi-compensation measurement

Measurement conditions during data measurement

The data for the LOAD compensation is measured under the following measurement conditions.

- Measurement range mode: auto range mode
- Measurement time mode: long mode
- Low C reject function: OFF

For other settings, the measurement conditions set up at execution are used for measurement.

Measurement procedure

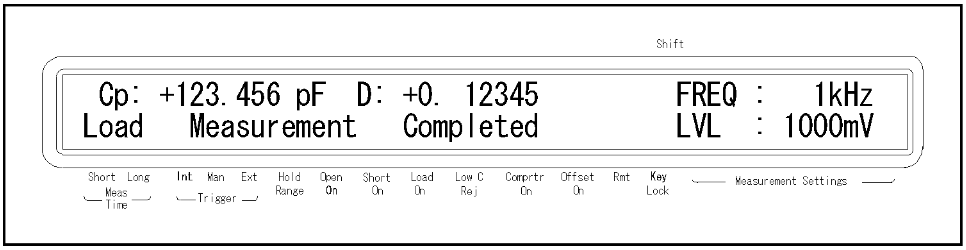
Step 1. Connect the standard for the LOAD compensation to the test fixture.

Step 2. Press the **[Load]** (**[Blue]** - **[6]**) key to display the LOAD compensation menu screen (refer to Figure 6-8).

Step 3. Use the **[↑→]** key to make "LoadMeas" blink and then press the **[Enter]** key. Measuring the data for the LOAD compensation is executed.

When measuring the data for the LOAD compensation is completed successfully, the measured data is displayed for several seconds and then the message shown in Figure 6-16 is displayed for several seconds.

Figure 6-16 Screen after measuring data for LOAD compensation (when completed successfully)



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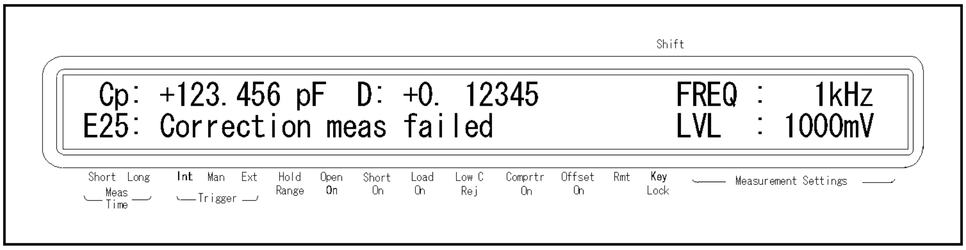
If the difference between the measured value and definition value of the standard for the LOAD compensation exceeds 10% (not suitable for the data for LOAD compensation), the warning message shown in Figure 6-22 on page 91 appears instead of the message in Figure 6-16.

NOTE Even if this warning message appears, data for the LOAD compensation is still used. However, we recommend that you confirm that the connection between the test fixture and the UNKNOWN terminal as well as the measurement procedure are correct.

If a measurement failure occurs while measuring the data for compensation, the error message shown in Figure 6-17 appears instead of the message in Figure 6-16.

NOTE If this error occurs, the data used for compensation before the measurement remains without change.

Figure 6-17 Screen after measuring data for LOAD compensation (when a measurement failure occurs)



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Setting up Data for Offset Compensation

You can define a certain value and set it up as the data for offset compensation.

When the offset compensation is ON, taking the measured value before compensation as $Meas$ and the data for the offset compensation as $Offset$, the measured value is compensated as $Meas - Offset$. Therefore, to compensate the measurement result to your desired value, set up the difference between the desired value and the measurement result as the data for the offset compensation. For example, to compensate the current measured value of the primary parameter of 1.012 nF to the measured value of 1.000 nF, set up the data for the offset compensation for the primary parameter to 12 pF.

The data for the offset compensation consists of 1 kHz and 1 MHz data for both the primary and secondary parameters, as shown in Figure 6-18.

Figure 6-18 **Structure of data for offset compensation**

For primary parameters	For secondary parameters
1 kHz compensation data	1 kHz compensation data
1 MHz compensation data	1 MHz compensation data

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Setup procedure

Step 1. Press the **[Offset]** (**[Blue]** - **[3]**) key to display the Offset compensation menu screen (refer to Figure 6-11).

Step 2. Use the **[↑→]** key to make "OfsEnt" blink and then press the **[Enter]** key. The offset compensation data setup screen appears.

Step 3. Enter the compensation data for the primary parameter using the numeric and other related keys and then press the **[Enter]** key. Next, enter the compensation data for the secondary parameter and press the **[Enter]** key.

The entered values are set up as the data for the offset compensation for the measurement frequency at the time of data entry.

Checking (displaying)/Setting up Compensation Data

Checking (displaying)/setting up data for OPEN compensation

You can display and check the data for the OPEN compensation in the G-B or Cp-G format.

You can set up the data for the OPEN compensation only by using the GPIB command (this cannot be done by using the front panel). For how to set up the data for OPEN compensation by using the GPIB command, refer to the *Programming Manual*.

Displaying data for OPEN compensation (6 digits)

Press the **[Open]** (**[Blue]** - **[4]**) key to display the OPEN compensation menu screen (refer to Figure 4-10 on page 46), use the **[↑→]** key to make “MeasVal” blink, and press the **[Enter]** key. The G (conductance) value is displayed. Pres the **[Enter]** key again to display the B (susceptance) value.

For more information on the procedure to display the data for OPEN compensation, refer to “Checking data for OPEN compensation” on page 47.

Displaying data for OPEN compensation (5 digits) and measurement result

Refer to “Checking (displaying) Every Kind of Compensation Data Successively” on page 90.

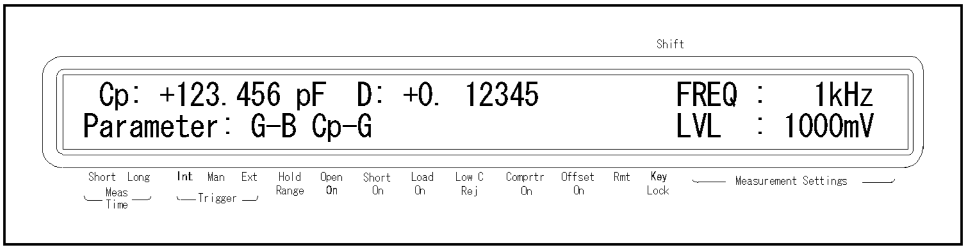
Selecting parameter format of OPEN compensation data

Step 1. Press the **[Open]**(**[Blue]** - **[4]**) key to display the OPEN compensation menu screen (refer to Figure 4-10 on page 46).

Step 2. Use the **[↑→]** key to make “CorVal” blink and press the **[Enter]** key. The OPEN compensation data menu screen (refer to Figure 4-14 on page 47) appears

Step 3. Use the **[↑→]** key to make “PrmSlct” blink and press the **[Enter]** key. The OPEN compensation data parameter format selection screen appears as shown in Figure 6-19.

Figure 6-19 **OPEN Compensation Data Parameter Format Selection Screen**



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Step 4. Use the **[↑→]** and other related keys to make your desired parameter format blink and press the **[Enter]** key to select it.

Checking (displaying)/setting up data for SHORT compensation

You can display and check the data for SHORT compensation in the R-X or Ls-Rs format.

You can set up the data for the SHORT compensation only by using the GPIB command (this cannot be done by using the front panel). For how to set up the data for SHORT compensation by using the GPIB command, refer to the *Programming Manual*.

Displaying data for SHORT compensation (6 digits)

Press the **[Short]** (**[Blue]** - **[5]**) key to display the SHORT compensation menu screen (refer to Figure 4-15 on page 48), use the **[↑→]** key to make “MeasVal” blink, and press the **[Enter]** key. The R (resistance) value is displayed. Press the **[Enter]** key again to display the X (reactance) value.

For more information on the procedure to display the data for SHORT compensation, refer to “Checking data for SHORT compensation” on page 49.

Displaying data for SHORT compensation (5 digits) and measurement result

Refer to “Checking (displaying) Every Kind of Compensation Data Successively” on page 90.

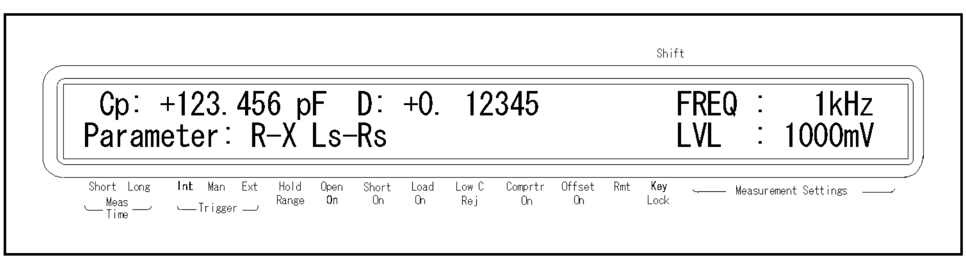
Selecting parameter format of SHORT compensation data

Step 1. Press the **[Short]** (**[Blue]** - **[5]**) key to display the SHORT compensation menu screen (refer to Figure 4-15 on page 48).

Step 2. Use the **[↑→]** key to make “CorVal” blink and press the **[Enter]** key. The SHORT compensation data menu screen (refer to Figure 4-19 on page 49) appears

Step 3. Use the **[↑→]** key to make “PrmSlct” blink and press the **[Enter]** key. The SHORT compensation data parameter format selection screen appears as shown in Figure 6-20.

Figure 6-20 **SHORT Compensation Data Parameter Format Selection Screen**



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Step 4. Use the **[↑→]** and other related keys to make your desired parameter format blink and press the **[Enter]** key to select it.

Checking (displaying)/setting up data for LOAD compensation

You can display and check the LOAD compensation data in the defined parameter format for the standard for LOAD compensation.

You can set up the data for the LOAD compensation only by using the GPIB command (this cannot be done by using the front panel). For how to set up the data for LOAD compensation by using the GPIB command, refer to the *Programming Manual*.

Displaying data for LOAD compensation (6 digits)

Step 1. Press the **[Load]** (**[Blue]** - **[6]**) key to display the LOAD compensation menu screen (refer to Figure 6-8 on page 76).

Step 2. Use the **[↑→]** key to make “CorVal” blink and press the **[Enter]** key. The LOAD compensation menu screen (refer to Figure 6-14 on page 82) appears.

Step 3. Use the **[↑→]** key to make “MeasVal” blink and press the **[Enter]** key. The primary parameter value is displayed.

Step 4. Press the **[Enter]** key. The secondary parameter value is displayed.

Step 5. Press the **[Enter]** key to return to the LOAD compensation menu screen.

Displaying data for LOAD compensation (5 digits) and measurement result

Refer to “Checking (displaying) Every Kind of Compensation Data Successively” on page 90.

Selecting parameter format of LOAD compensation data

The parameter format of LOAD compensation data depends on the parameter format of the standard value for the LOAD compensation and cannot be selected independently.

Refer to “Defining standard for LOAD compensation (setting up LOAD reference value)” on page 81.

Checking (displaying) Every Kind of Compensation Data Successively

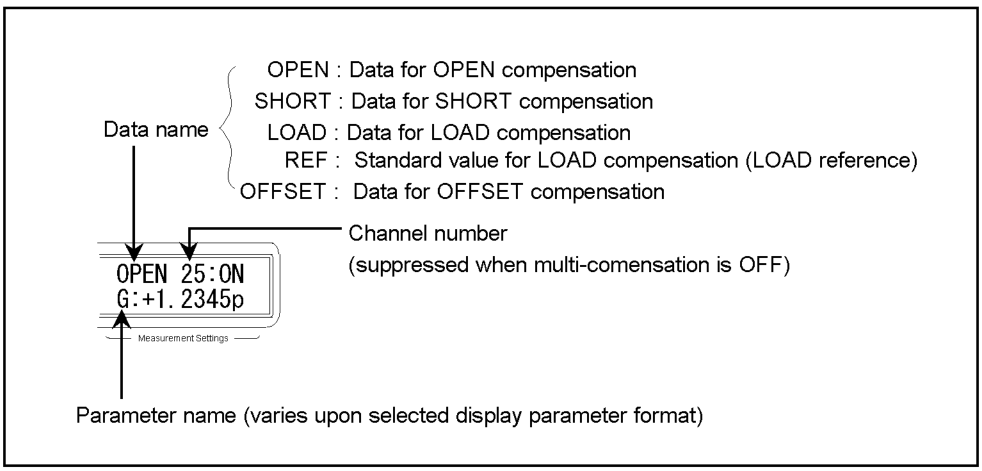
You can successively display and check the OPEN/SHORT/LOAD compensation data, LOAD compensation standard definition, and OFFSET compensation data in the Instrument Setting Display Area.

This check procedure is given below.

Step 1. Press the **[Show Setting]** key several times until the Compensation Data Display Page appears in the Instrument Setting Display Area.

Step 2. Use the **[↑→]** key or the **[← ↓]** key to select the display from the OPEN/SHORT/LOAD compensation data, LOAD compensation standard definition, and OFFSET compensation data.

Figure 6-21 **Displaying compensation data**



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Avoiding Mistakes Related to Work in Obtaining Compensation Data

To avoid simple work-related mistakes in measuring the data for OPEN/SHORT/LOAD compensation (for example, setting up the OPEN state and SHORT state inversely), it is important to confirm that the measured data is correct.

Using warning messages

If the measured data is out of the valid range shown in Table 6-1 when measuring the data for OPEN/SHORT/LOAD compensation, the warning message shown in Figure 6-22 appears, which allows you to detect an error of the measured data.

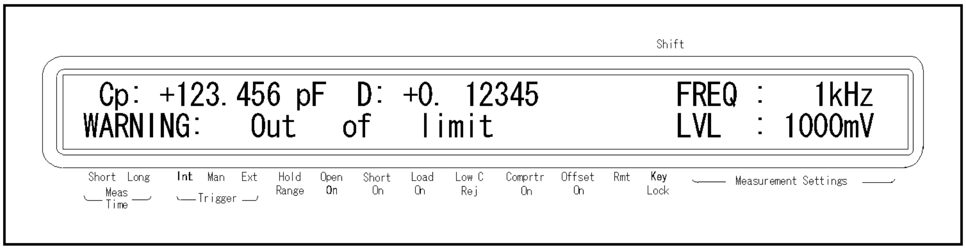
NOTE The valid ranges are fixed and cannot be changed. The warning message is displayed for several seconds and then disappears automatically. Therefore, please pay special attention to any warning message. Even after the warning message is displayed, the compensation data is used as is.

Table 6-2 **Valid ranges of compensation data**

Type of compensation	Valid range
OPEN compensation	$\|Y\| < 20\ \mu S$
SHORT compensation	$\|Z\| < 20\ \Omega$
LOAD compensation	$\|Zref\| \times 0.9 < \|Z\| < \|Zref\| \times 1.1$

In Table 6-2, Y is the measured admittance value, Z is the measured impedance value, and Zref is the definition value of the standard for the LOAD compensation.

Figure 6-22 **Screen after measuring the compensation data (when the data is out of the valid range)**



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Checking the measured data directly

Display the measured data for OPEN/SHORT/LOAD compensation to confirm that the value displayed after measuring the compensation data is proper. You can make programs that use an external controller and GPIB commands to judge whether the compensation data is correct and, if not, execute measurement of the compensation data again.

For how to display the compensation data, refer to "Checking (displaying)/Setting up Compensation Data" on page 87. For how to check the compensation data with an external controller and GPIB commands, refer to the *Programming Manual*.

7 Executing Measurement

This chapter describes how to generate a trigger to start measurement. It also provides helpful information for measurement.

Starting (triggering) Measurement

The method used to start (trigger) measurement varies depending on the setup of the trigger mode, as shown in Table 7-1 below.

Table 7-1 **Trigger mode**

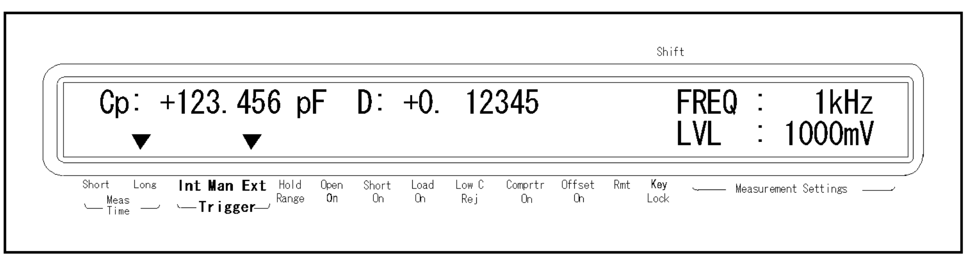
Trigger mode	Method to generate a trigger
Internal trigger (Int)	The internal trigger is used to generate a trigger.
Manual trigger (Man)	Pressing the **[Trig]** key on the front panel generates a trigger.
External trigger (Ext)	Inputting an external trigger signal through the Ext Trig terminal, handler interface, or scanner interface generates a trigger.

The trigger mode is changed each time you press the **[Trig Mode]** key.

The current setting of the trigger mode is displayed in the Trigger area of the instrument display screen. The ▼ symbol is displayed above Int, Man, or Ext to indicate the current trigger mode. When the GPIB trigger (Bus) mode, which can only be selected by using the GPIB command, is specified, the ▼ symbol is not displayed (refer to the *Programming Manual*).

Figure 7-1 shows an example when the external trigger mode is selected.

Figure 7-1 **Trigger mode state display (external trigger mode)**



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Perform successive measurements automatically

Press the **[Trig Mode]** key until the ▼ symbol is displayed above Int to select the internal trigger mode. In this mode, measurements are automatically repeated, triggered by the internal trigger signal.

Specifying measurement timing

Generating a trigger manually

Step 1. Press the **[Trig Mode]** key until the ▼ symbol is displayed above Man to select the manual trigger mode.

Step 2. Press the **[Trig]** key to perform a single measurement.

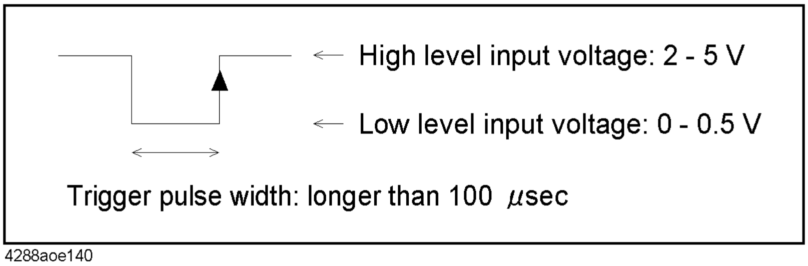
Step 3. To repeat measurement, repeat Step 2.

Generating a trigger with an external signal

Step 1. Press the **[Trig Mode]** key until the ▼ symbol is displayed above Ext to select the external trigger mode.

Step 2. Input a trigger signal (TTL pulse signal) from the Ext Trig terminal on the rear panel or input EXT_TRIG through the handler/scanner interface to perform a single measurement.

The trigger signal input from the Ext Trig terminal on the rear panel must meet the following requirements (input voltage and pulse width).



Step 3. To repeat measurement, repeat Step 2.

Notes on inputting a trigger signal

A trigger signal is not recognized until measurement with the previous input trigger is finished (the /EOM signal turns to LOW).

- ❏ If a trigger is input twice (double trigger), only the first one is valid.
- ❏ A trigger is valid if it is input while display output is being updated after a measurement.

Tips for More Accurate Measurement

You can use the following techniques to increase measurement accuracy.

Setting measurement time to the long mode

Set the measurement time to the long mode, which provides better measurement accuracy.

For the setup procedure, refer to “Selecting Measurement Time” on page 56.

Selecting an appropriate measurement range

When making a measurement in the fixed range mode, select the measurement range so that measurement is performed within the recommended range (refer to Table 12-2 on page 155 and Table 12-3 on page 155).

For the setup procedure, refer to “Selecting your desired measurement range (hold range)” on page 55.

Using the compensation functions

The OPEN compensation eliminates the error due to the parallel stray admittance of the measurement cable and test fixture.

The SHORT compensation eliminates the error due to the series residual impedance of the measurement cable and test fixture.

The LOAD compensation eliminates the complex error due to the amplitude/phase error of the measurement cable and test fixture, scanner, and so on.

For details, refer to Chapter 6, “Preparation for Accurate Measurement (Executing Compensation).”

Making stable measurement

In a high-noise measurement environment, you can obtain more reliable measurement results by performing averaging.

For the setup procedure, refer to “Setting Up Averaging Count” on page 58.

Avoiding chattering at the time of contact

To eliminate measurement errors due to chattering at the time of contact between the contact pin and the DUT, you can set up a wait time (trigger delay time) between when a trigger is generated and when measurement starts.

For the setup procedure, refer to “Setting Up Trigger Delay Time” on page 59.

Making measurements using a four-terminal pair

You can use four-terminal pair measurement to eliminate measurement errors.

For details, refer to “Principle of four-terminal pair measurement” on page 208.

Tips for Increasing Measurement Speed (throughput)

You can use the following methods to increase the measurement speed.

Setting measurement time to the short mode

Set the measurement time to the short mode, which provides a shorter measurement time.

For the setup procedure, refer to “Selecting Measurement Time” on page 56.

Setting measurement range mode to the fixed rage

If you set the measurement range mode to the auto range, the measurement time is lengthened because a ranging time is required. Therefore, specify the fixed range for quicker measurements.

For the setup procedure, refer to “Selecting Measurement Range” on page 54.

Optimizing display settings

You can decrease, or eliminate, the number of items that must be updated on the display to shorten the measurement time. Turning OFF the measurement result display produces the greatest effect. When the measurement result display is ON, because the measurement time varies depending on the display page of the instrument setup display area, select an appropriate page by referring to “Measurement time” on page 161.

For the procedure to turn ON/OFF the measurement result display, refer to “Turning ON/OFF display” on page 60. For the procedure to select the display page of the instrument setup display area, refer to “Selecting items displayed in instrument setup display area” on page 65.

Decreasing averaging count

If you use the averaging function, set the averaging count to as small a value as possible.

For the setup procedure, refer to “Setting Up Averaging Count” on page 58.

Setting the trigger delay time to 0

If you do not need to use the trigger delay function, confirm that the trigger delay time is set to 0.

For the check procedure, refer to “Selecting items displayed in instrument setup display area” on page 65. For the setup procedure, refer to “Setting Up Trigger Delay Time” on page 59.

8 Sorting Based on Measured Result (Comparator Function)

This chapter describes how to use the function that performs sorting based on the measured results (comparator function).

Overview of Comparator Function

The 4288A’s comparator function lets you set up to 9 limit ranges for the primary parameter (BIN1 to BIN9) and 1 limit range for the secondary parameter and sort DUTs into up to 11 categories: BIN1 to BIN9, OUT_OF_BINS, and AUX_BIN. If you need only simple pass/fail judgment and do not need BIN sorting, use the comparator function while setting up only 1 limit range for the primary parameter (BIN1) (and, if necessary, 1 limit range for the secondary parameter) to judge whether the measured result of the DUT falls into the specified limit range.

You can specify the upper and lower limit values for the primary parameter with not only absolute values but also relative values (deviation) from the reference value (nominal value).

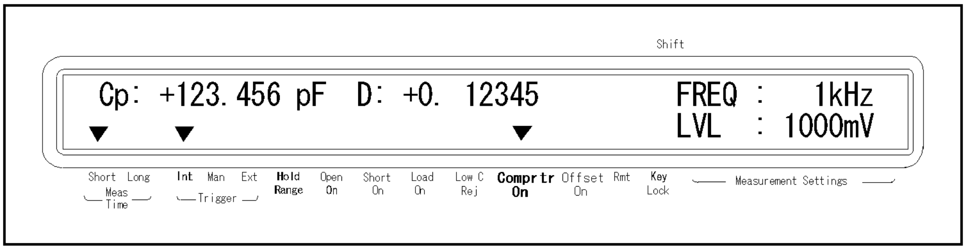
The sorting judgment result of the comparator function is displayed on the screen and also output from the handler interface. In addition, you can read out the sorting judgment result from an external controller by using the GPIB command together with the measured value.

You can use the BIN count function to count the number of DUTs sorted into each BIN, display the counts on the screen, and read them out with the GPIB command.

Turning ON/OFF Comparator Function

The ON/OFF state of the comparator function is indicated by whether the ▼ symbol is displayed above the Comprtr On instrument setup display label. When the ▼ symbol is displayed as shown in Figure 8-1, the function is ON.

Figure 8-1 ON/OFF state display of comparator function (ON)



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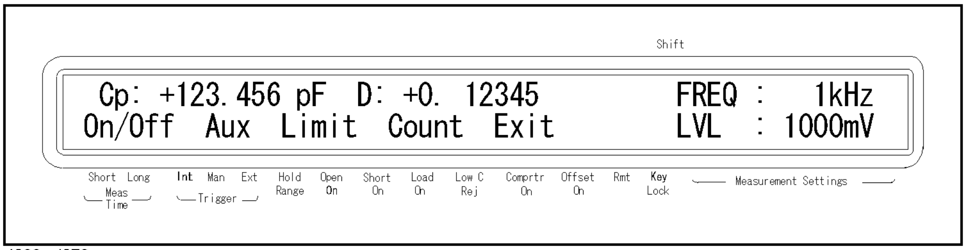
The ON/OFF state of the comparator function also controls the ON/OFF state of the output of the handler interface signal.

Setup procedure

Step 1. Press the **[Comprtr]**(**[Blue]** - **[1]**) key. The comparator function setup screen shown in Figure 8-2 appears.

Figure 8-2 Comparator function setup screen



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Step 2. Use the **[↑→]** and other necessary keys to make “On/Off” blink and then press the **[Enter]** key. The comparator function ON/OFF setup screen appears.

Step 3. The blinking item is the current setup value. Use the **[↑→]** key to make the item (“Off” or “On”) you want to set up blink and press the **[Enter]** key.

NOTE Turning ON the comparator function automatically changes the display page of the instrument setup display area to the page that displays the comparator sorting result (page number: 6).

Setting Up Sorting Judgment Conditions

Clearing (resetting) limit ranges

Clearing the limit ranges returns the settings of the following items to the factory-default preset values (refer to Table C-1 on page 185).

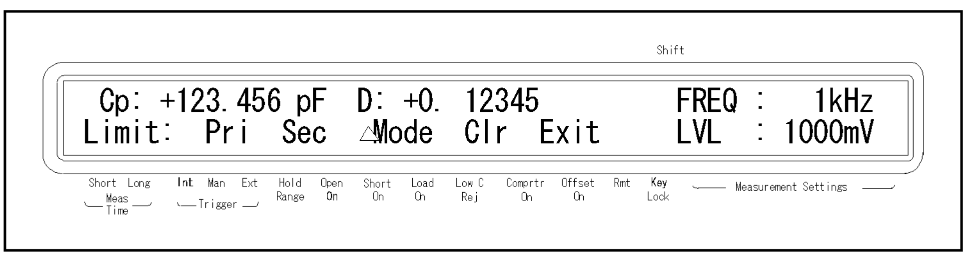
- ON/OFF, lower limit value, and upper limit value of all limit ranges (BIN1 to BIN9 and secondary parameter limit range)
- Limit range designation method
- Reference value for the tolerance mode

Execution procedure

Step 1. Press the **[Comprtr]**(**[Blue]** - **[1]**) key. The comparator function setup screen (refer to Figure 8-2) appears.

Step 2. Use the **[↑→]** and other necessary keys to make “Limit” blink and then press the **[Enter]** key. The limit setup menu screen shown in Figure 8-3 appears.

Figure 8-3 **Limit setup menu screen**



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Step 3. Use the **[↑→]** and other necessary keys to make “Clr” blink and press the **[Enter]** key. The clear execution confirmation screen appears.

Step 4. Use the **[↑→]** and other necessary keys to make “Yes” blink and press the **[Enter]** key.

Selecting a limit range designation method

Two methods can be used to designate the limit ranges for the primary parameter (BIN1 to BIN9). One is to designate the limit boundary value using an absolute value (absolute mode) and the other is to designate it using a relative value (deviation) from the reference value (nominal value) (tolerance mode). The tolerance mode is further divided into a method to designate the deviation using an absolute value (absolute tolerance mode) and a method to designate the deviation using the percentage of the reference value (percent tolerance mode).

NOTE Only the absolute mode can be used to designate the secondary parameter limit range.

Setup procedure for the limit range designation method and reference value

Step 1. Press the **[Comprtr]**(**[Blue]** - **[1]**) key. The comparator function setup screen (refer to Figure 8-2) appears.

Step 2. Use the **[↑→]** and other necessary keys to make “Limit” blink and then press the **[Enter]** key. The limit setup menu screen (refer to Figure 8-3) appears.

Step 3. Use the **[↑→]** and other necessary keys to make “ΔMode” blink and press the **[Enter]** key. The limit range setup mode selection screen appears.

Step 4. The blinking mode (correspondence between the display on the screen and the mode is shown in the below table) is the current setup. Use the **[↑→]** key to make the mode you want to select blink and press the **[Enter]** key.

	Mode	
Off	Absolute mode	
ΔABS	Tolerance mode	Absolute tolerance mode
Δ%		Percent tolerance mode

Step 5. If you have selected the absolute mode, the procedure is now complete. If you have selected the tolerance mode, the reference value setup screen appears. Use the numeric and other necessary keys to enter the reference value and press the **[Enter]** key.

Relationship between the limit range designation method and the setup value

Table 8-1 and Table 8-2 compare the setup values between the limit designation methods when setting up the limit ranges shown in Figure 8-4 and Figure 8-5, respectively.

Figure 8-4 **Example of limit range settings (case 1)**

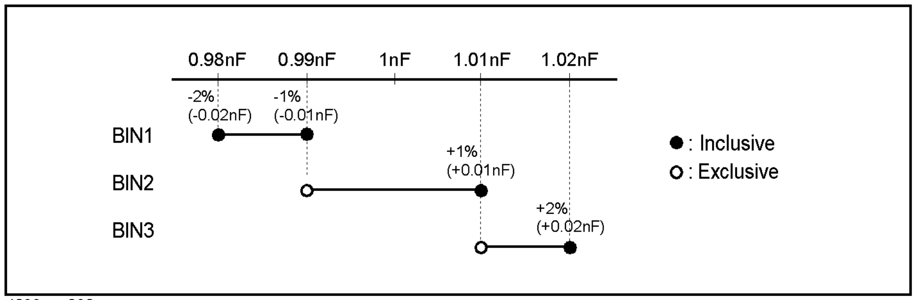

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Table 8-1 **Lower and upper limit values of limit ranges for Figure 8-4 (comparison of modes)**

	Absolute mode		Tolerance mode (reference value: 1 nF)			
			Absolute		Percent	
	Lower limit value	Upper limit value	Lower limit value	Upper limit value	Lower limit value	Upper limit value
BIN1	0.98 nF	0.99 nF	-0.02 nF	-0.01 nF	-2%	-1%
BIN2	0.99 nF	1.01 nF	-0.01 nF	0.01 nF	-1%	1%
BIN3	1.01 nF	1.02 nF	0.01 nF	0.02 nF	1%	2%

Figure 8-5 **Example of limit range settings (case 2)**

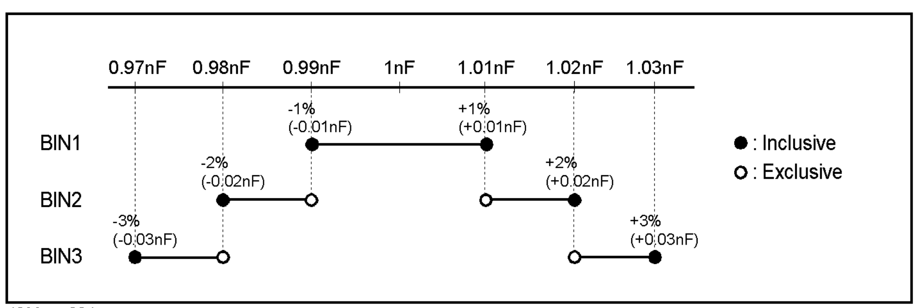

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Table 8-2 **Lower and upper limit values of limit ranges for Figure 8-5 (comparison of modes)**

	Absolute mode		Tolerance mode (reference value: 1 nF)			
			Absolute		Percent	
	Lower limit value	Upper limit value	Lower limit value	Upper limit value	Lower limit value	Upper limit value
BIN1	0.99 nF	1.01 nF	-0.01 nF	0.01 nF	-1%	1%
BIN2	0.98 nF	1.02 nF	-0.02 nF	0.02 nF	-2%	2%
BIN3	0.97 nF	1.03 nF	-0.03 nF	0.03 nF	-3%	3%

Setting up limit ranges

Notes on setup

- ❑ If you set up the upper limit value to a value equal to or less than the lower limit value, the limit range is not used. This operation is equivalent to setting the limit range to OFF.
- ❑ If BINs overlap, the resulting measurement is sorted into the BIN of the smallest number (refer to Figure 8-15, “Sorting judgment flow,” on page 113). Therefore, you need to set up the limit ranges starting from the narrowest to the widest as shown in Figure 8-5.
- ❑ For the tolerance mode, the reference value is not required to be within the limit range (between the lower limit value and upper limit value).
- ❑ Gaps between the limit ranges are allowed. Therefore, you can set up the limit ranges as shown in Figure 8-6.

Figure 8-6 **Example of gap between limit ranges**

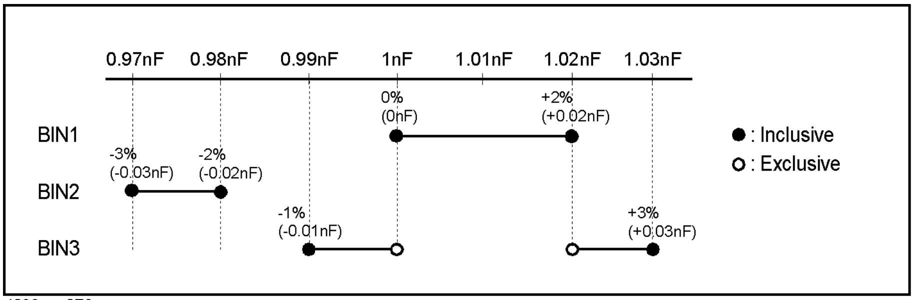


Table 8-3 **Lower and upper limit values of limit ranges for Figure 8-6**

	Absolute mode		Tolerance mode (reference value: 1nF)			
			Absolute		Percent	
	Lower limit value	Upper limit value	Lower limit value	Upper limit value	Lower limit value	Upper limit value
BIN1	1 nF	1.02 nF	0 nF	0.02 nF	0%	2%
BIN2	0.97 nF	0.98 nF	-0.03 nF	-0.02 nF	-3%	-2%
BIN3	0.99 nF	1.03 nF	-0.01 nF	0.03 nF	-1%	3%

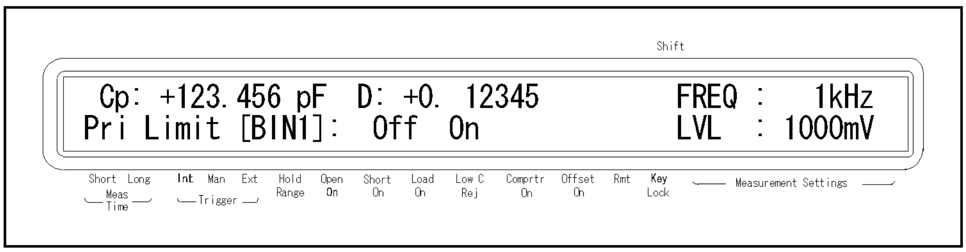
Procedure to set up BIN1 to BIN9 (ON/OFF and lower and upper limit values)

Step 1. Press the **[Comprtr]**(**[Blue]** - **[1]**) key. The comparator function setup screen (refer to Figure 8-2) appears.

Step 2. Use the **[↑→]** and other necessary keys to make “Limit” blink and then press the **[Enter]** key. The limit setup menu screen (refer to Figure 8-3) appears.

Step 3. Use the **[↑→]** and other necessary keys to make “Pri” blink and press the **[Enter]** key. The BIN1 ON/OFF setup screen shown in Figure 8-7 appears.

Figure 8-7 **BIN1 ON/OFF setup screen**



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Step 4. The blinking item is the current setup value. Use the **[↑→]** key to make the item (“Off” or “On”) you want to set up blink and press the **[Enter]** key.

Step 5. If you have selected On, The BIN1 lower limit value entry screen appears. Use the numeric and other necessary keys to enter the lower limit value and press the **[Enter]** key. Then, the BIN1 upper limit value entry screen appears. Use the numeric and other necessary keys to enter the upper limit value and press the **[Enter]** key. When you have entered the above values, the BIN2 ON/OFF setup screen appears. If you have selected Off, the procedure to enter the BIN1 lower and upper limit values is skipped and the BIN2 ON/OFF setup screen appears.

Step 6. The setup screen for each BIN appears in the order of BIN2 → BIN9. Repeat the setup procedure in the same way as BIN1. If you made a wrong setup, press the **[Blue]** key and **[← ↓]** key in this order. You can return to the immediately previous setup screen.

Procedure to set up BIN1 (lower and upper limit values only)

Step 1. Press the **[Pri Low]** key. The BIN1 lower limit value entry screen appears.

Step 2. Use the numeric and other necessary keys to enter the lower limit value and press the **[Enter]** key.

Step 3. Press the **[Pri High]** key. The BIN1 upper limit value entry screen appears.

Step 4. Use the numeric and other necessary keys to enter the upper limit value and press the **[Enter]** key.

NOTE You cannot turn ON/OFF BIN1 in this setup procedure.

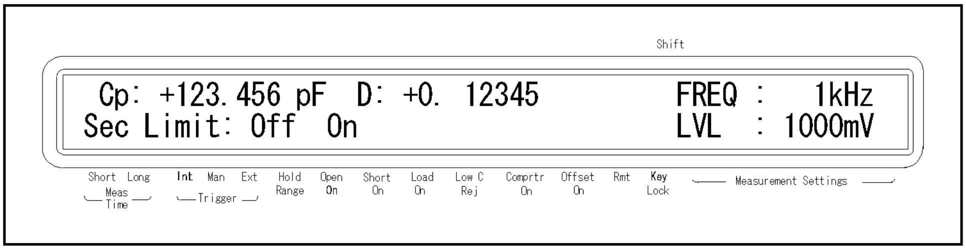
Procedure to set up secondary parameter limit range (ON/OFF and lower and upper limit values)

Step 1. Press the **[Comprtr]**(**[Blue]** - **[1]**) key. The comparator function setup screen (refer to (Figure 8-2) appears.

Step 2. Use the **[↑→]** and other necessary keys to make "Limit" blink and then press the **[Enter]** key. The limit setup menu screen (refer to Figure 8-3) appears.

Step 3. Use the **[↑→]** and other necessary keys to make "Sec" blink and press the **[Enter]** key. The secondary parameter limit range ON/OFF setup screen shown in Figure 8-8 appears.

Figure 8-8 **Secondary parameter limit range ON/OFF setup screen**



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Step 4. The blinking item is the current setup value. Use the **[↑→]** key to make the item ("Off" or "On") you want to set up blink and press the **[Enter]** key.

Step 5. If you have selected Off, the procedure is now complete. If you have selected On, the lower limit value entry screen appears. Use the numeric and other necessary keys to enter the lower limit value and press the **[Enter]** key. Then, the upper limit value entry screen appears. Use the numeric and other necessary keys to enter the upper limit value and press the **[Enter]** key.

Procedure to set up secondary parameter limit range (lower and upper limit values only)

Step 1. Press the **[Sec Low]**(**[Blue]** - **[Pri Low]**) key. The lower limit value entry screen appears.

Step 2. Use the numeric and other necessary keys to enter the lower limit value and press the **[Enter]** key.

Step 3. Press the **[Sec High]**(**[Blue]** - **[Pri High]**) key. The upper limit value entry screen appears.

Step 4. Use the numeric and other necessary keys to enter the upper limit value and press the **[Enter]** key.

NOTE You cannot turn ON/OFF the secondary parameter limit range in this setup procedure.

Setting up AUX BIN function

If the secondary parameter limit range is ON, the sorting result varies when it exceeds the secondary parameter limit range, depending on the ON/OFF state of the AUX BIN function (Table 8-4).

Table 8-4 **Sorting result when measured secondary parameter value exceeds limit range**

Primary parameter sorting result	AUX BIN function	Sorting result
One of BIN1 to BIN9	OFF	OUT_OF_BINS
	ON	AUX_BIN
Not sorted to any BINs	No relation	OUT_OF_BINS

Setup procedure

Step 1. Press the **[Comprtr]**(**[Blue]** - **[1]**) key. The comparator function setup screen (refer to Figure 8-2) appears.

Step 2. Use the **[↑→]** and other necessary keys to make “Aux” blink and press the **[Enter]** key. The AUX BIN function ON/OFF setup screen appears.

Step 3. The blinking item is the current setup value. Use the **[↑→]** key to make the item (“Off” or “On”) you want to set up blink and press the **[Enter]** key.

Checking (displaying) Limit Ranges

You can check setup of the limit ranges in the instrument setup display area at the right of the display.

The check procedure is described below.

Step 1. Press the **[Show Setting]** key until the limit range display page appears in the instrument setup display area.

Step 2. Use the **[↑→]** key or **[← ↓]** key to check the lower and upper limit values of the limit ranges (BIN1 to BIN9 and secondary parameter), the limit range designation method and reference value, and the ON/OFF state of the AUX BIN function.

Figure 8-9 **Display of lower and upper limit values**

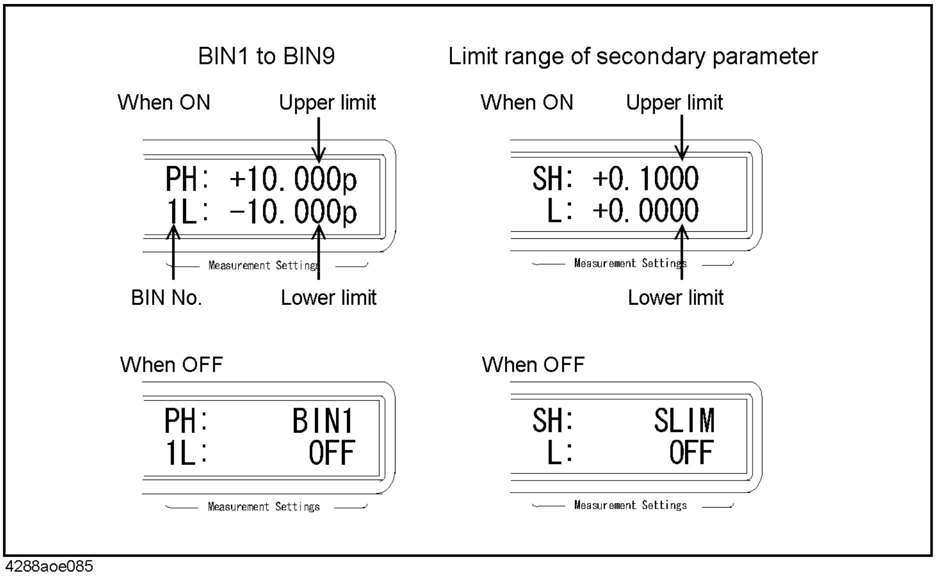
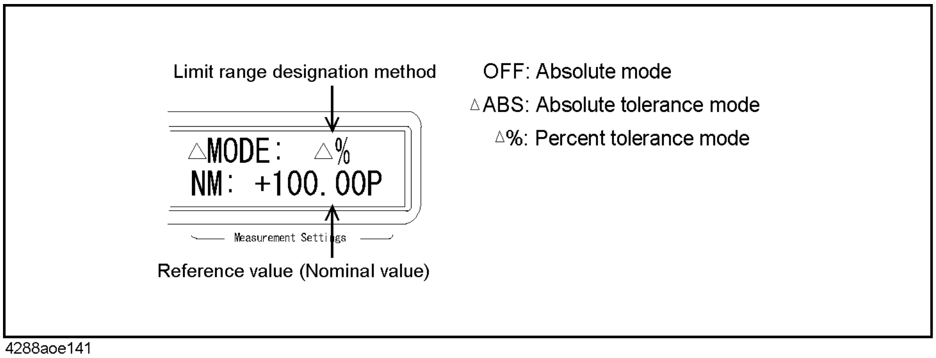


Figure 8-10 **Display of limit range designation method and reference value**



Rejecting Excessively Low Measured Results (Low C reject function)

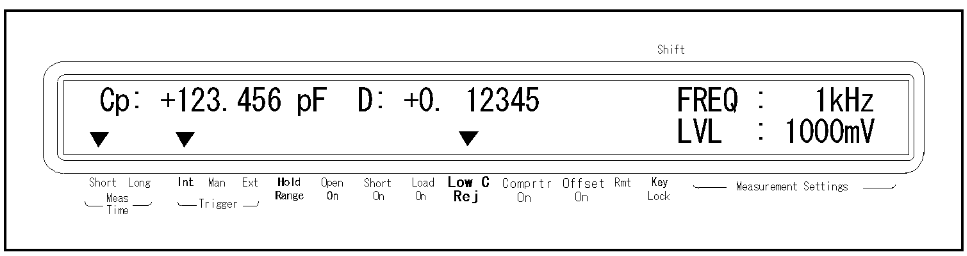
The 4288A has a function to detect extremely low measured primary parameter values (Cp or Cs) that are equal to or less than the preset boundary value as Low C (abnormal measurement status). This is called the Low C reject function.

NOTE When the comparator function is ON, normal sorting judgment will be performed even if Low C is detected. However, the sorting judgment result displayed on the screen is LOWC and, on the handler interface, the /LOW_C_REJECT signal becomes active (low level) in addition to the sorting judgment signal.

Turning ON/OFF Low C reject function

The ON/OFF state of the Low C reject function is indicated by whether the ▼ symbol is displayed above the Low C Rej instrument setup display label. When the ▼ symbol is displayed as shown in Figure 8-11, the function is ON.

Figure 8-11 **ON/OFF state display of Low C reject function (ON)**

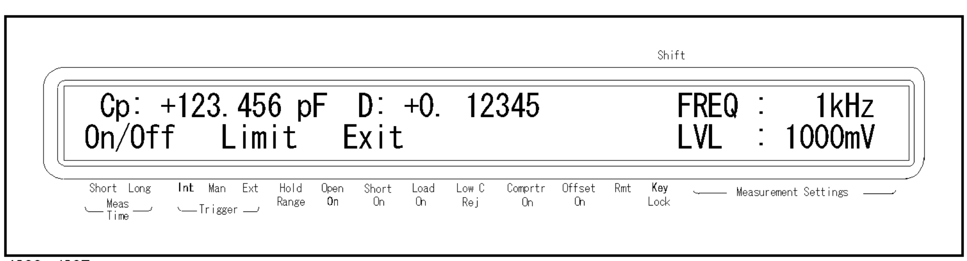


4288aoj086

Setup procedure

Step 1. Press the **[Low C Rej]**(**[Blue]** - **[Level]**) key. The Low C reject function setup screen shown in Figure 8-12 appears.

Figure 8-12 **Low C reject function setup screen**



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Step 2. Use the **[↑→]** and other necessary keys to make "On/Off" blink and then press the **[Enter]** key. The Low C reject function ON/OFF setup screen appears.

Step 3. The blinking item is the current setup value. Use the **[↑→]** key to make the item ("Off" or "On") you want to set up blink and press the **[Enter]** key.

Setting up limit (boundary value) of Low C reject function

Set up the limit of the Low C reject function (boundary value of the range to detect Low C) as a percentage of the measurement range (full scale). The applicable measurement range varies depending on the setting of the measurement range mode:

- For the auto range mode

  The minimum measurement range is applicable regardless of whether the measurement is actually performed. Specifically, it is one of the following measurement ranges:

  When measurement frequency is 1 kHz: 100E-12 F (100 pF) range

  When measurement frequency is 1 MHz: 1E-12 F (1 pF) range

- For the fixed range mode

  The measurement range currently selected is applicable, that is, it is the range in which the measurement is actually performed.

For example, if you make a measurement with the 1 μF range fixed and set the limit to 1%, Low C is detected when the measured primary parameter value (Cs or Cp) is equal to or less than 10 nF.

Setup procedure

Step 1. Press the **[Low C Rej]**(**[Blue]** - **[Level]**) key. The Low C reject function setup screen (refer to Figure 8-12) appears.

Step 2. Use the **[↑→]** and other necessary keys to make “Limit” blink and then press the **[Enter]** key. The Low C reject function limit setup screen appears.

Step 3. Use the numeric and other necessary keys to enter the limit value and press the **[Enter]** key.

Displaying Sorting Judgment Result

The sorting judgment is obtained through the comparator function according to the flow shown in Figure 8-15. It is displayed in the instrument setup display area at the right of the display shown in Figure 8-13.

Figure 8-13 **Display of comparator sorting judgment result**

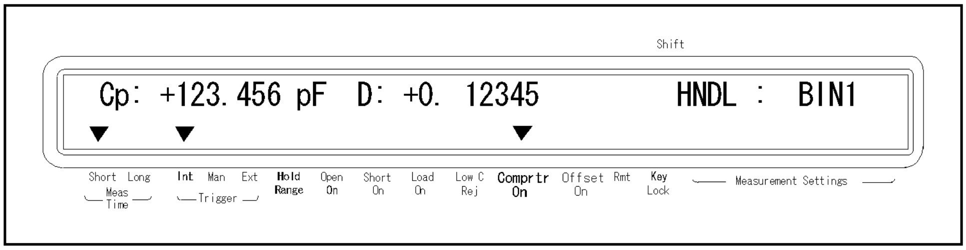

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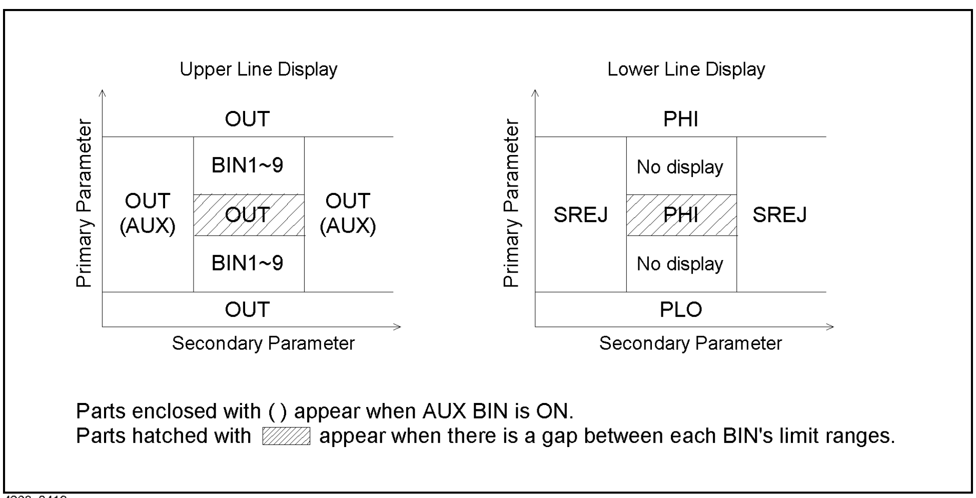
Figure 8-14 shows the relationship between the screen display and the sorting result.

Figure 8-14 **Relationship between display output and comparator sorting result**



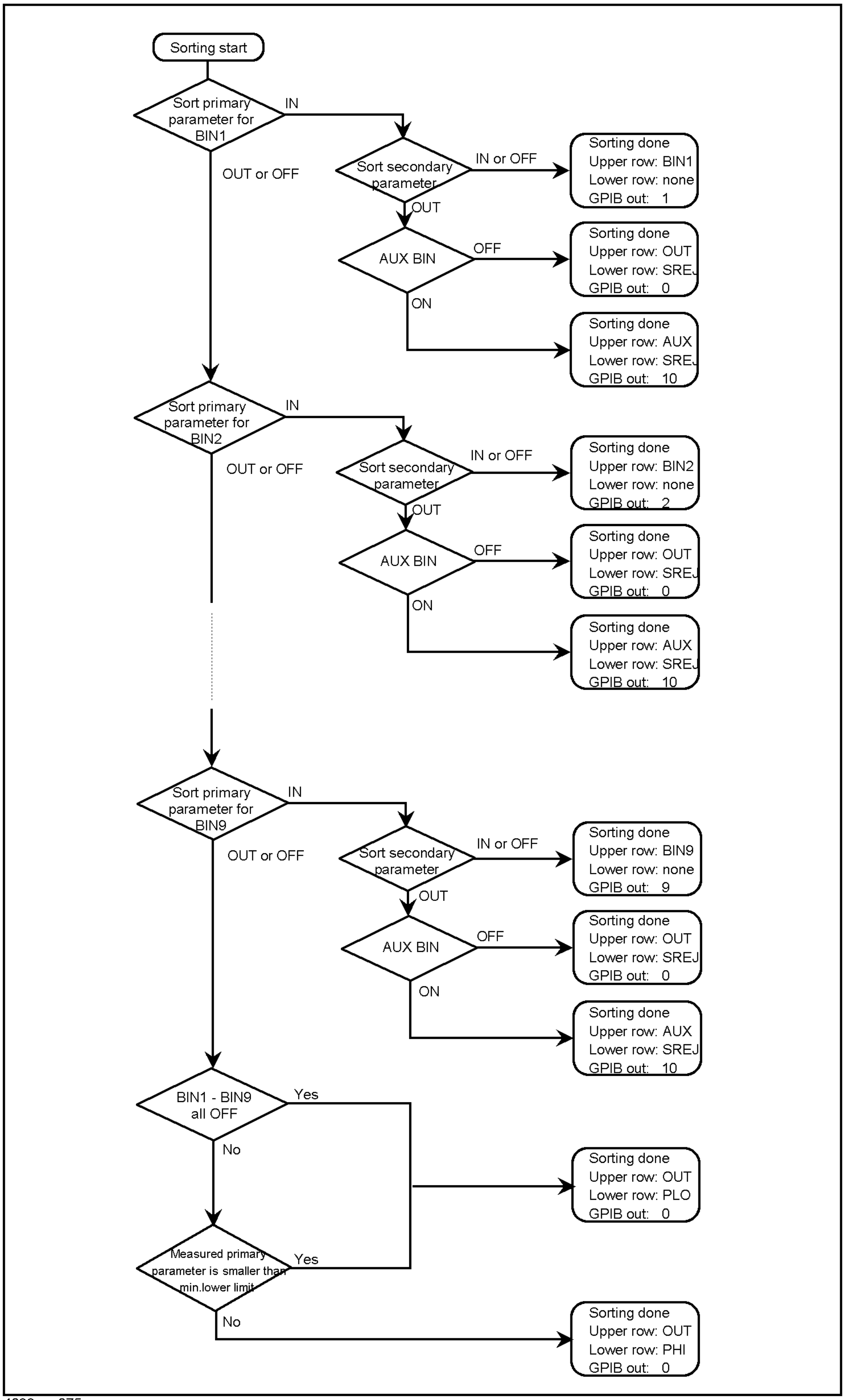
4268e0419

NOTE If an overload is detected, the sorting judgment cannot be performed and therefore **** is displayed in the upper row. If Low C reject is detected, normal sorting judgment is performed but LOWC is displayed in the upper row instead of the sorting judgment result (OUT, AUX, or BIN1 to BIN9).

Display procedure

Press the **[Show Setting]** key until the sorting result display page (page number: 6) appears in the instrument setup display area.

Figure 8-15 **Sorting judgment flow**



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Displaying Number of DUTs Sorted into Each BIN (BIN count function)

You can count the number of DUTs sorted into each BIN by turning ON the BIN count function. The maximum value of the count is 999999. If this value is exceeded, the count will not increase but remain at 999999 (it does not return to 0).

When the MULTI compensation function is ON, channel-by-channel count is performed separately from the usual count (total of all channels). You can read out the result by using the GPIB command.

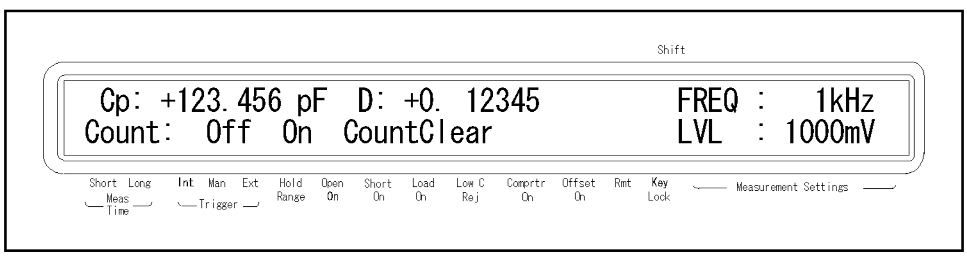
Turning ON/OFF BIN count function

The setup procedure is given below.

Step 1. Press the **[Comprtr]**(**[Blue]** - **[1]**) key. The comparator function setup screen (refer to Figure 8-2) appears.

Step 2. Use the **[↑→]** and other necessary keys to make “Count” blink and then press the **[Enter]** key. The BIN count setup screen shown in Figure 8-16 appears.

Figure 8-16 **BIN count setup screen**



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Step 3. The blinking item is the current setup value. Use the **[↑→]** key to blink the item (“Off” or “On”) you want to set up and press the **[Enter]** key.

Displaying BIN count value

The BIN count value is displayed in the setup display area at the right of the display screen.

The setup procedure is given below.

NOTE The BIN count value for each channel when the MULTI compensation function is ON can be checked only through GPIB and cannot be displayed on the screen.

Step 1. Press the **[Show Setting]** key until the BIN count value display page appears in the instrument setup display area.

Step 2. Use the **[↑→]** key or **[← ↓]** key to select the count value display from BIN1 - BIN9, AUX_BIN, OUT_OF_BINS, or OVLD.

NOTE You cannot display all of the BIN count values simultaneously.

Clearing (resetting) BIN count values

Clearing the BIN count values initializes all of the count values to 0.

The setup procedure is given below.

Step 1. Press the **[Comprtr]**(**[Blue]** - **[1]**) key. The comparator function setup screen appears (refer to Figure 8-2).

Step 2. Use the **[↑→]** and other necessary keys to make "Count" blink and then press the **[Enter]** key. The BIN count setup screen (refer to Figure 8-16) appears.

Step 3. Use the **[↑→]** and other necessary keys to make "CountClear" blink and press the **[Enter]** key. A screen appears to confirm the clearing operation.

Step 4. Use the **[↑→]** and other necessary keys to make "Yes" blink and press the **[Enter]** key.

Making a Beep based on Sorting Judgment Result

You can set the conditions for making a beep sound, based on the sorting judgment result, to one of the following.

- Makes a beep when the sorting judgment result is OUT_OF_BINS or AUX_BIN.
- Makes a beep when the sorting judgment result is BIN1 to BIN9.

You can also disable the beep sound.

For the procedure on how to set up the beep output, refer to "Setting Up Condition To Make A Beep" on page 68.

9 Avoiding Mistakes Related to Work and Performing Daily Checks

This chapter describes how to avoid simple mistakes related to work and how to carry out the required maintenance of the Agilent 4288A.

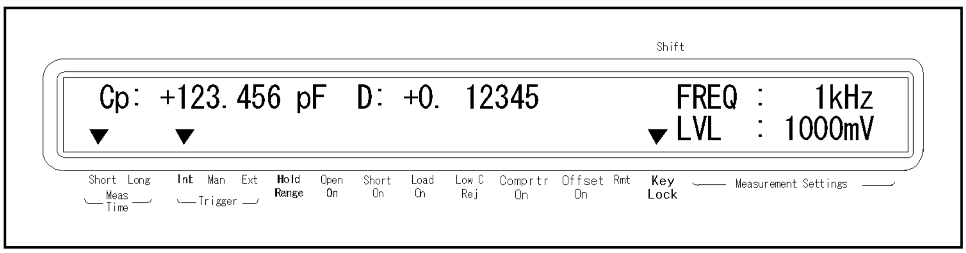
Avoiding Mistakes Related to Work

Avoiding improper input from the front panel (key lock function)

When you do not need to operate the keys on the front panel, you can disable entry from the front panel keys (key lock function) to avoid improper input due to touching the front panel keys accidentally.

The ON/OFF state of the key lock function is indicated by whether the ▼ symbol is displayed above the Key Lock instrument setup display label. When the ▼ symbol is displayed as shown in Figure 9-1, the function is ON.

Figure 9-1 **ON/OFF state display of key lock function (when ON)**



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Setup procedure

Press the **[Key Lock]**(**[Blue]** - **[0]**) key. Each time you perform this key operation, the key lock function is toggled ON/OFF.

When the key lock function is ON, only the **[Key Lock]** key (that is, the **[Blue]** key and **[0]** key) is available.

Avoiding mistakes related to work in obtaining compensation data

By confirming that the measured data is correct, you can avoid simple mistakes related to work in measuring the data for OPEN/SHORT/LOAD compensation (for example, setting up the OPEN state and SHORT state inversely).

For details, refer to "Avoiding Mistakes Related to Work in Obtaining Compensation Data" on page 91.

Daily Checks

Checking for faults (self-test function)

The 4288A provides a self-test function that consists of an internal test and external test.

Executing the internal test

The internal test checks the operation of digital parts like memory as shown in Table 9-1.

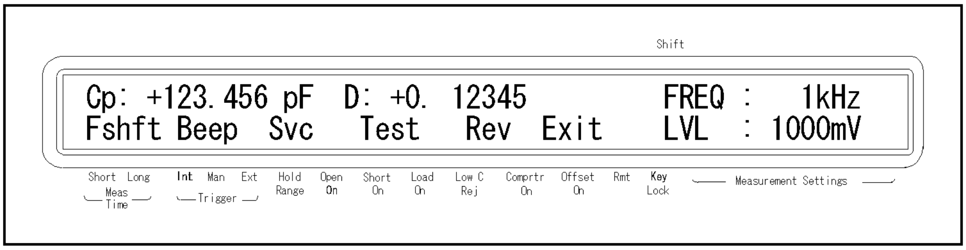
Table 9-1 **Internal test items**

Test item	Description of test	Error code
RAM	Checks if the data bus of RAM is connected properly and there is no faulty memory cell.	1
Boot ROM	Checks if the checksum of the boot ROM is correct.	2
Flash ROM	Checks if the checksum of the flash ROM is correct.	4
Calibration data	Checks if the checksum of the calibration data (factory calibration data) in EEPROM is correct.	8
Compensation data	Checks if the checksum of the compensation data (correction data) in EEPROM is correct. However, the compensation data is not initialized in the event of a test failure; this must be done manually.	16
A/D converter	Checks if the A/D converter is operating properly.	32
Backup RAM	Checks if the instrument setup values in backup memory (RAM) are correct. However, the compensation data is not initialized in the event of a test failure; this must be done manually.	64

The execution procedure is described below.

Step 1. Press the **[Config]**(**[Blue]** - **[–]**) key. The menu screen shown in Figure 9-2 appears.

Figure 9-2 **The menu screen when the [Config] key is pressed**



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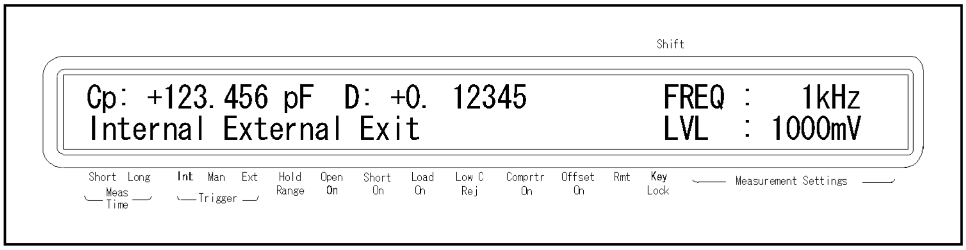
Step 2. Use the **[↑→]** and other necessary keys to make “Test” blink and then press the **[Enter]** key. The test menu screen shown in Figure 9-3 appears.

Figure 9-3 **Test menu screen**



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Step 3. Use the **[↑→]** and other necessary keys to make “Internal” blink and press the **[Enter]** key. The message SELF TESTING appears, and the self test is executed.

Step 4. After completion of the test, the 4288A displays PASS to the right of SELF TEST: for several seconds and returns to the menu (if an error occurs, one of the error codes shown in Table 9-1 is displayed).

NOTE If several errors are detected simultaneously, the sum of the error code numbers is displayed.

Executing the external test

The external test performs a simple operational testing of the analog circuitry shown in Table 9-2.

Table 9-2 **External test items**

Test number	Test item
1	Entire analog circuitry
2	Signal part (signal level)
3	Signal part (frequency)
4	Measurement part

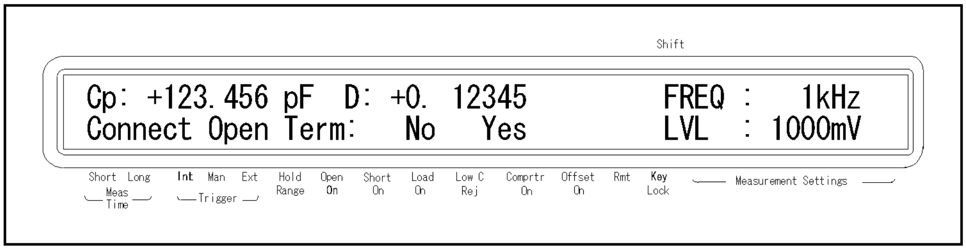
The execution procedure is described below.

Step 1. Press the **[Config]**(**[Blue]** - **[–]**) key to display the menu screen as shown in Figure 9-2.

Step 2. Use the **[↑→]** and other necessary keys to make “Test” blink. Press the **[Enter]** key to display the test menu screen shown in Figure 9-3.

Step 3. Use the **[↑→]** and other necessary keys to make “External” blink. Press the **[Enter]** key. The screen shown in Figure 9-4 appears.

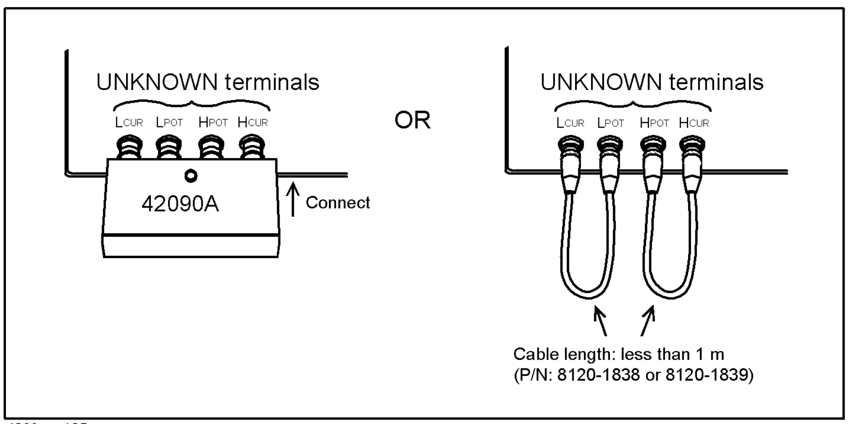
Figure 9-4 **External test execution wait screen**



4288aoj123

Step 4. As shown in Figure 9-5, connect the 42090A to the UNKNOWN terminal of the 4288A (or directly connect between L_{CUR} and L_{POT} and between H_{CUR} and H_{POT} with BNC cables).

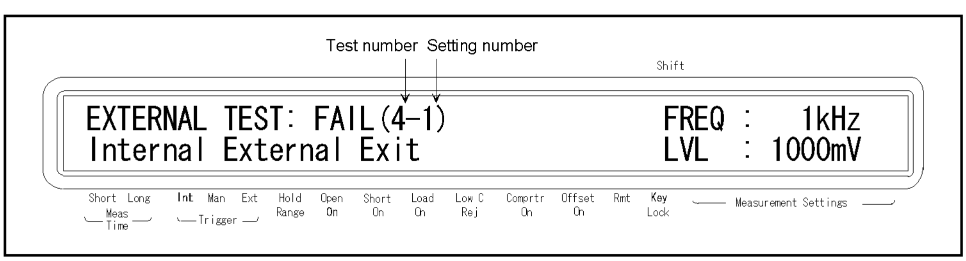
Figure 9-5 **Preparation for external test**



4288aoe125

Step 5. Use the **[↑→]** and other necessary keys to make “Yes” blink and press **[Enter]**.The external test is performed in the order of test number. When the tests are completed, the result (PASS or FAIL) is displayed to the right of EXTERNAL TEST: as shown in Figure 9-6 and the test menu returns. When the test result is FAIL, failed test numbers (see Table 9-2) and setting numbers (refer to the *4288A Service Manual*) of the test are also displayed.

Figure 9-6 **Test result display screen (when setup 1 of measurement range switching part test fails)**



4288aoe142

NOTE When the test fails, the instrument may be at fault. Contact an Agilent Technologies sales office or the company from which you purchased this instrument. When any test item fails, the entire test immediately aborts.

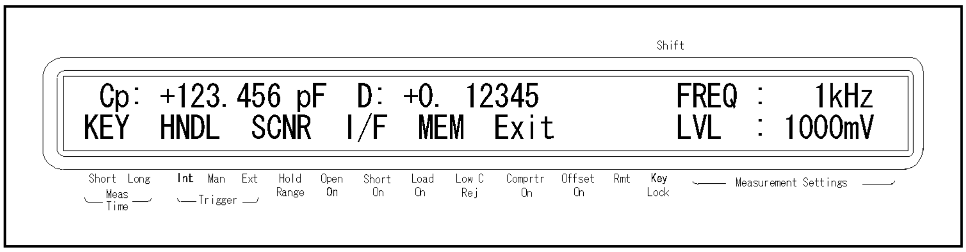
Executing a test to confirm functioning of the front panel keys

The procedure to test the functioning of the front panel keys is described below.

Step 1. Press the **[Config]**(**[Blue]** - **[–]**) key to display the menu screen shown in Figure 9-2.

Step 2. Use the **[↑→]** and other necessary keys to make “Svc” blink and press the **[Enter]** key. The service menu screen shown in Figure 9-7 appears.

Figure 9-7 **Service function menu screen**



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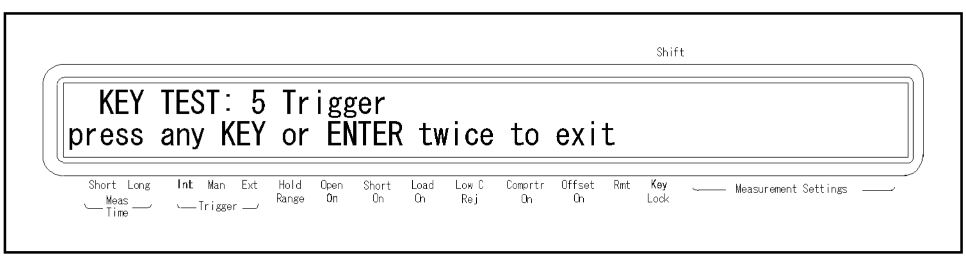
Step 3. Use the **[↑→]** and other necessary keys to make “KEY” blink and press the **[Enter]** key. The front panel key test screen appears.

NOTE For information on items other than KEY (for service personnel of Agilent Technologies), refer to the *4288A Service Manual*.

Step 4. Press the key you want to test. The name of the pressed key is displayed to the right of KEY TEST:. The figure below shows an example when the **[Trig]** key is pressed. If the key name is not displayed correctly, the key does not work. In this case, contact your nearest Agilent Technologies sales office or the VAR from which you purchased your instrument.

Figure 9-8 **Key test screen**



4288aoj093

Step 5. To finish the test, press the **[Enter]** key twice.

Cleaning the instrument

To avoid shock hazards, be sure to disconnect the power cable of the instrument from the outlet before cleaning.

Gently wipe the surface of the instrument clean of dirt, using a soft dry cloth or a sufficiently wrung soft damp cloth.

Do not clean the interior of the instrument.

10 Using Handler Interface

You can output the measurement end signal, the sorting result of the comparator function, and other data from the Agilent 4288A, as well as input an external trigger signal or a key lock signal to the 4288A, through the handler interface. This chapter also gives information required to configure an auto-sorting system that combines the 4288A and a handler in using the handler interface and the comparator function.

Output of Comparator Sorting Result

When the comparator function is ON, the comparator sorting result is output through the handler interface. Figure 10-1 and Table 10-1 show the relationship between the comparator sorting result and the output signals of the handler interface (/BIN1 - /BIN9, /AUX_BIN, /OUT_OF_BINS, /PHI, /PLO, and /SREJ).

NOTE

When the comparator function is OFF, no signals are output, except for /INDEX, /EOM, and /ALARM. /INDEX and /EOM stay LOW. /ALARM, as when the comparator is ON, is output when an error occurs.

EXT_TRIG, regardless of the ON/OFF state of the comparator function, is active when the trigger mode is set to the external trigger (Ext). When /KEY_LOCK is LOW, regardless of the ON/OFF state of the comparator function, the key lock state remains unchanged.

Figure 10-1 **Output of comparator sorting result to the handler interface**

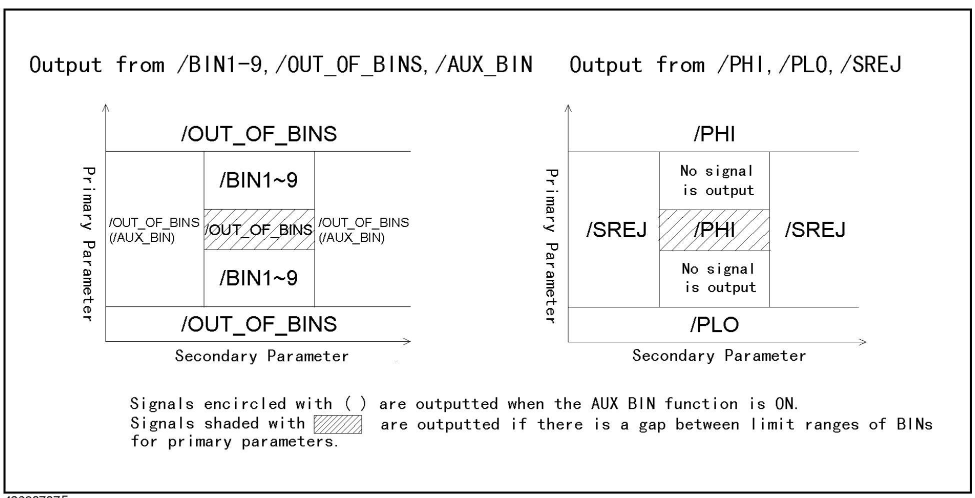


Table 10-1 Relationship between comparator sorting result and output signals of the handler interface

Measurement status	Judgment result				Handler interface signals that become active	GPIB output		
	Primary parameter		Secondary parameter			Measu rement status	Measured value	BIN sorting result
No error	IN	BIN1	IN		/BIN1	0	Measured value	1
		BIN2			/BIN2			2
		BIN3			/BIN3			3
		BIN4			/BIN4			4
		BIN5			/BIN5			5
		BIN6			/BIN6			6
		BIN7			/BIN7			7
		BIN8			/BIN8			8
		BIN9			/BIN9			9
		One of BIN1 to BIN9	OUT	AUX BIN: OFF	/OUT_OF_BINS /SREJ			0
				AUX BIN: ON	/AUX_BIN /SREJ			10
	OUT	Less than the minimum lower limit	N/A		/OUT_OF_BINS /PLO			0
		Other than above			/OUT_OF_BINS /PHI			
Overload	Cannot be sorted.				/OVLD	1	9.9E37	11
Low C	Normal sorting judgment				/LOW_C_REJECT *1	2	Measured value	0 - 10

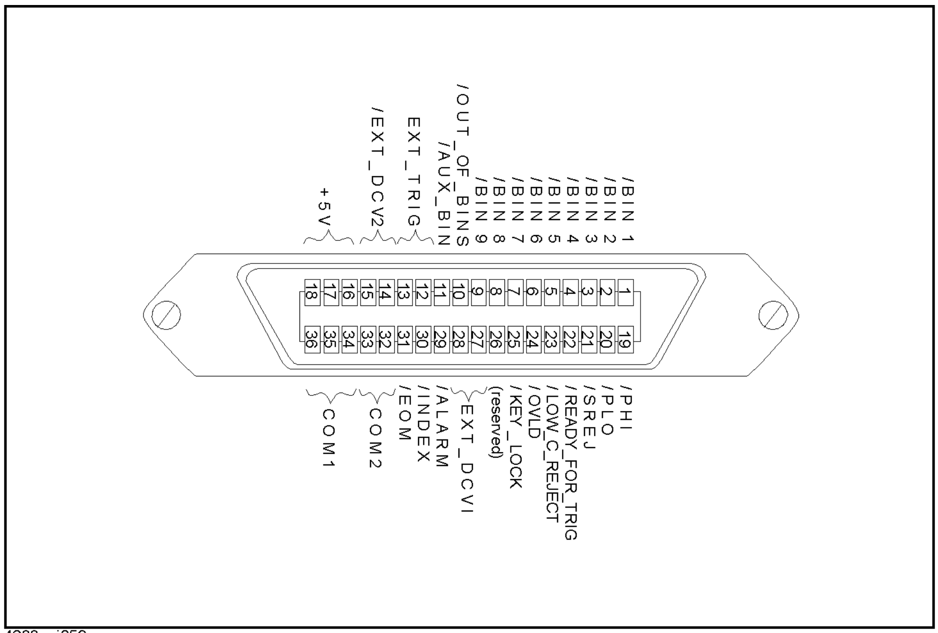
*1./LOW_C_REJECT becomes active together with the signal that corresponds to the result of normal sorting judgment (judgment result when no error occurs).

Input/Output Signal Pin Assignment

Figure 10-2 shows the input/output signal pin assignment of the handler interface connector. Table 10-2 gives a description of the input/output signals.

NOTE A slash (/) symbol preceding signal names means that they are negative logic (active low).

Figure 10-2 **Pin assignment of the handler interface connector**



4288aoj059

Table 10-2 **Description of the handler interface input/output signals**

Pin number	Signal name	Input/output	Description
1	/BIN1	Output	Sorting judgment signals. A BIN signal of the sorting result (one of pin numbers 1 - 11) becomes LOW. These signals do not become LOW if measurement is not possible (overload).
2	/BIN2		
3	/BIN3		
4	/BIN4		
5	/BIN5		
6	/BIN6		
7	/BIN7		
8	/BIN8		
9	/BIN9		
10	/OUT_OF_BINS		
11	/AUX_BIN		
12, 13	EXT_TRIG	Input	External trigger signal. This is active when the trigger mode is set to the external trigger (Ext). The trigger is generated at the rising edge of a pulse.

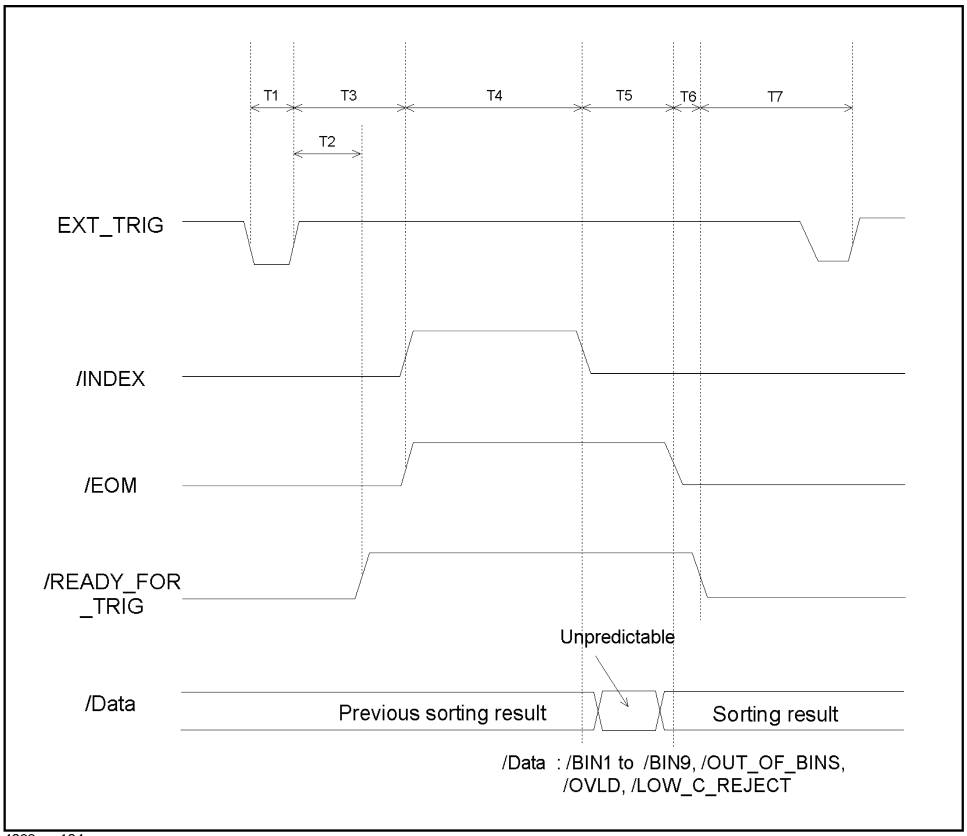
Table 10-2 Description of the handler interface input/output signals

Pin number	Signal name	Input/output	Description
14, 15	EXT_DCV2	Input	External dc voltage. This supplies the voltage to the input signals (EXT_TRIG and /KEY_LOCK) and the operation output signals (/ALARM, /INDEX, /EOM, and /READY_FOR_TRIG). The input voltage range is between +5V and +24V.
16, 17, 18	+5V	Output	Internal dc voltage.
19	/PHI		Primary-parameter-upper-limit-exceeded signal. When the upper limit of BIN1 - BIN9 is exceeded, this becomes LOW.
20	/PLO		Primary-parameter-lower-limit-not-reached signal. When the lower limit of BIN1 - BIN9 is not reached, this becomes LOW.
21	/SREJ		Secondary-parameter-out-of-limit signal. If the secondary parameter is out of the limit, this becomes LOW.
22	/READY_FOR_TRIG		Trigger-acceptable signal. When a trigger-signal-acceptable state is established, this becomes LOW. When the handler receives this signal, an external trigger signal can be input.
23	/LOW_C_REJECT		Low-C-reject-detection signal. If the measured Cp or Cs result is equal to or less than the preset boundary value (percentage of the measurement range), this becomes LOW.
24	/OVLD		Measurement-impossible signal. If measurement is impossible in the analog measurement part (overload), this becomes LOW.
25	/KEY_LOCK	Input	Key-lock signal. If you set this signal to LOW, the front panel keys of the 4288A are disabled.
26	(reserved)	———	Not used in the current release. Do not connect anything.
27, 28	EXT_DCV1	Input	External dc voltage. This supplies the voltage to the judgment output signals (/BIN1 - /BIN9, /AUX_BIN, /OUT_OF_BINS, /PHI, /PLO, /SREJ, /OVLD, and /LOW_C_REJECT). The input voltage range is between +5V and +24V.
29	/ALARM	Output	Error-occurrence signal. If a problem (an error in the self test result, power supply interruption, malfunction of a specific circuit, etc.) occurs, this becomes LOW. For power supply interruption, this stays LOW only while the power is down.
30	/INDEX		Analog measurement end signal. When an analog measurement finishes, this becomes LOW. When the handler receives this signal, you can connect the next DUT. You cannot obtain the measurement data until the /EOM signal is received.
31	/EOM		Measurement cycle end signal. When a series of measurement processes finishes and the measured data sorting judgment result becomes available, this becomes LOW.
32, 33	COM2	———	Common pins for the external dc voltage EXT_DCV2 (pin numbers 14 and 15).
34, 35, 36	COM1		Common pins for the external dc voltage EXT_DCV1 (pin numbers 27 and 28).

Timing Chart

Figure 10-3 shows the timing chart. The section where /Data is unpredictable in the figure indicates that the 4288A is processing data after analog measurement and the output signals are invalid. For details of the time periods of T1 - T7 in the figure, refer to "Measurement time" on page 161

Figure 10-3 **Timing chart of the handler interface**



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Electrical Characteristics

Output signals

The output signals are available as open collector outputs with photo coupler isolated. You can obtain each voltage output by connecting a pull-up resistor (refer to Table 10-3) to the interior or exterior of the 4288A. For information on how to connect pull-up resistors to the interior of the 4288A, refer to “Preparing for Using the Handler Interface” on page 134.

Table 10-3 Guide for pull-up resistor values

Pull-up voltage [V]	Resistance value [Ω]	Typical resistance	
		Resistance value [Ω]	Agilent part number
5	1.7 k (5 V / 3 mA)	1.78 k	0757-0278
9	3.0 k (9 V / 3 mA)	3.16 k	0757-0279
12	4.0 k (12 V / 3 mA)	4.22 k	0698-3154
15	5.0 k (15 V / 3 mA)	5.11 k	0757-0438
24	8.0 k (24 V / 3 mA)	8.25k	0757-0441

The output signals are divided into two groups: judgment output signals and operation output signals. You can specify a different pull-up voltage for each of them. Table 10-4 shows the electrical characteristics of the output signals. Figure 10-4 and Figure 10-5 show the circuit diagrams of the judgment output signals and operation output signals, respectively.

Table 10-4 Electrical characteristics of the handler interface output signals

Output signal	Output voltage [V]		Maximum current [mA]
	LOW	HIGH	
Judgment output signals: /BIN1 - /BIN9, /AUX_BIN, /OUT_OF_BINS, /PHI, /PLO, /SREJ, /OVLD, /LOW_C_REJECT	0 - 0.5	DCV1*1	6
Operation output signals: /INDEX, /EOM, /READY_FOR_TRIG, /ALARM	0 - 0.5	DCV2*2	6

*1. When the internal voltage supply is used, +5 V or +12 V.
When an external voltage supply is used, EXT_DCV1 (+5 V - +24 V).
*2. When the internal voltage supply is used, +5 V or +12 V.
When an external voltage supply is used, EXT_DCV2 (+5 V - +24 V).

Figure 10-4 **Circuit diagram of judgment output signals of the handler interface**

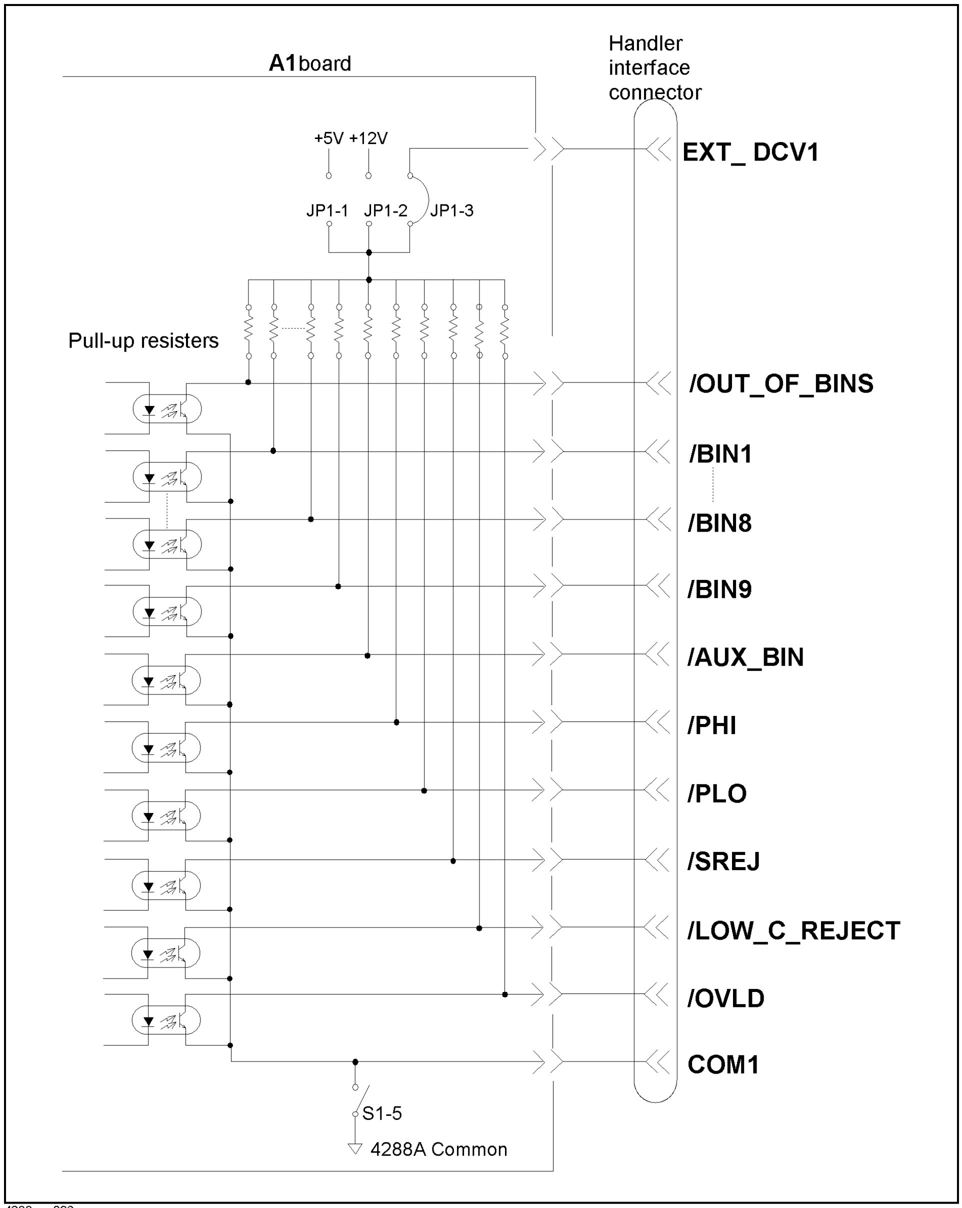

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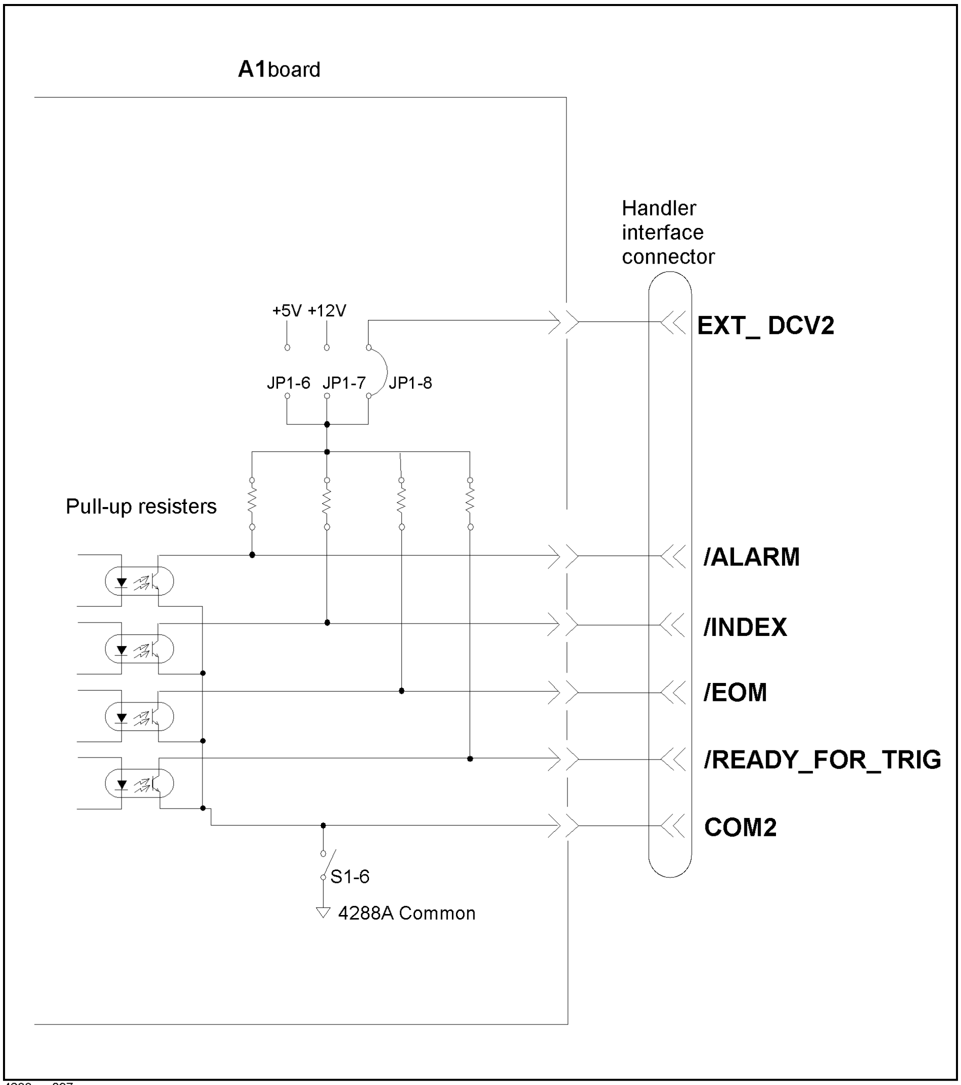
Figure 10-5 **Circuit diagram of operation output signals of the handler interface**



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Input signal

Each input signal is supplied to the cathode of the photo coupler LED. The anode of the LED is connected to the drive source voltage. Table 10-5 shows the electrical characteristics of the input signals. Figure 10-6 shows the circuit diagram of the input signals. The amount of current flowing through the LED depends on the setups of the drive source voltage and the input signal resistor.

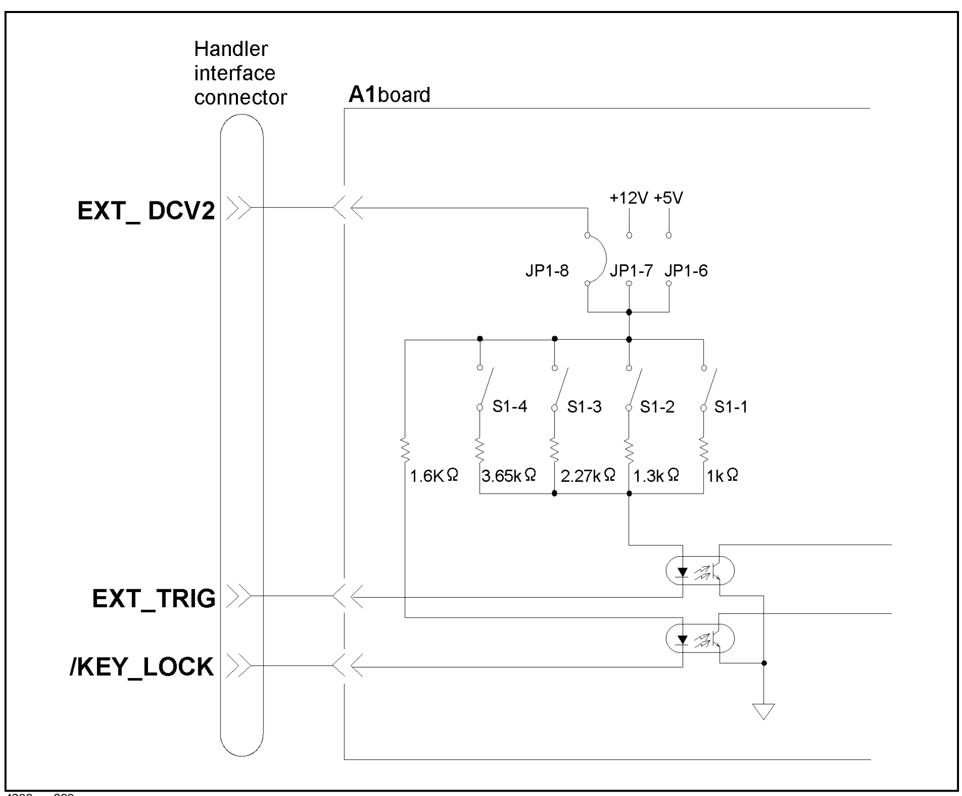
For how to set up the drive source voltage and the input signal resistance, refer to “Preparing for Using the Handler Interface” on page 134.

Table 10-5 Electrical characteristics of the handler interface input signals

Input signal	Input voltage [V]		Input current (LOW) [mA] (typical)			
			Drive source voltage: DCV2*1			
	LOW	HIGH	5 V (S1-1:ON)	12 V (S1-3:ON)	15 V (S1-3:ON)	24 V (S1-4:ON)
EXT_TRIG	0 - 1	DCV2*1	2.7	3.6	4.4	6.3
/KEY_LOCK			2.8	7.0	9.0	14.5

*1. When the internal voltage supply is used, +5 V or +12 V.
When an external voltage supply is used, EXT_DCV2 (+5 V - +24 V).

Figure 10-6 Circuit diagram of the handler interface input signals



Power source

You can separately set up a power source for judgment output signal pull-up and a power source for operation output signal pull-up and input signal drive. As shown in Table 10-6, you can choose from +5V/+12V of the internal power source or external power source (Table 10-7) for each of them.

For how to make this selection, refer to “Preparing for Using the Handler Interface” on page 134.

Table 10-6 Selecting power source for input/output signal pull-up/drive

	Internal power source		External power source
Judgment output signal pull-up	+5V	+12V	EXT_DCV1
Operation output signal pull-up and input signal drive	+5V	+12V	EXT_DCV2

Table 10-7 Voltage range when using an external power source

	Voltage range [V]
EXT_DCV1	+5 - +24
EXT_DCV2	+5 - +24

The circuit common point of each power source is set up as shown in Table 10-8. You can independently connect COM1 or COM2 in the table to the internal common point.

For how to make this setup, refer to “Preparing for Using the Handler Interface” on page 134.

Table 10-8 Circuit common point settings

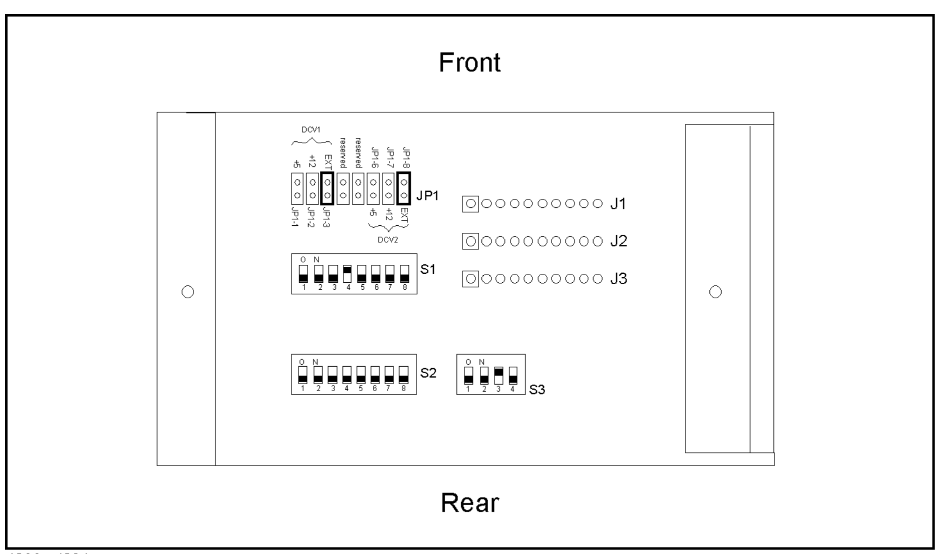
	When the internal power source is used	When an external power source is used
Judgment output signal pull-up power source	Internal common point	COM1
Operation output signal pull-up power source	Internal common point	COM2

Preparing for Using the Handler Interface

Before using the handler interface, you must set up the drive/pull-up power source and pull-up resistor for input/output signals. To set up the drive/pull-up power source, use the jumper (JP1) and DIP switch (S1) on the A1 board. To connect the pull-up resistor to the interior of the 4288A, mount resistor networks to J1, J2, and J3 on the A1 board.

JP1	JP1-1	Selecting judgment output signal pull-up power source (DCV1)	Internal power source (+5 V)
	JP1-2		Internal power source (+12 V)
	JP1-3		External power source (EXT_DCV1)
	JP1-6	Selecting operation output signal pull-up & input signal drive power source (DCV2)	Internal power source (+5 V)
	JP1-7		Internal power source (+12 V)
	JP1-8		External power source (EXT_DCV2)
S1	S1-1	Setting up input signal resistor	
	S1-2		
	S1-3		
	S1-4		
	S1-5	Setting up common point of judgment output signal pull-up power source (DCV1)	
	S1-6	Setting up common point of operation output signal pull-up & input signal drive power source (DCV2)	
J1		Setting up judgment output signal pull-up resistor	
J2			
J3		Setting up operation output signal pull-up resistor	
(S2, S3)		(Used for setting up scanner interface)	

Figure 10-7 **Locations of JP1, S1, S2, S3, J1, J2, and J3**



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Setting up judgment output signal pull-up power source

Selecting power source

As shown in the below table, set up either the JP1-1, JP1-2, or JP1-3 jumper to select the judgment output signal pull-up power source (DCV1).

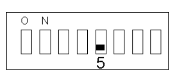
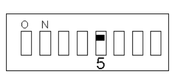
Socket number	Power source selected by setting up jumper (circuit shortened)	Factory-default
JP1-1	Internal power source (+5 V)	Open
JP1-2	Internal power source (+12 V)	Open
JP1-3	External power source (EXT_DCV1: +5 V - +24 V)	Short

NOTE Set up (short-circuit) only one jumper from among the JP1-1, JP1-2, and JP1-3. Do not set up (short-circuit) two or more jumpers simultaneously.

NOTE The JP1-4 and JP1-5 sockets are not used now. Do not connect anything to them.

Setting up the circuit common point

To set up the circuit common point (COM1), use S1-5 of the switch (S1).

Settings of S1-5	State of the circuit common point
(Factory-default)  	The common point (COM1) of the external power source (EXT_DCV1) and the internal circuit common point of the 4288A are separated. Judgment output signals are isolated.
 	The common point (COM1) of the external power source (EXT_DCV1) and the internal circuit common point of the 4288A are connected. Judgment output signals are not isolated.

NOTE When you select internal power source (when you set a jumper on JP1-1 or JP1-2), you must set S1-5 to ON.

NOTE When you use +5V (pins 16, 17, and 18) of the handler interface connector, set S1-5 to ON to connect the internal circuit common point of the 4288A to COM1 so that COM1 is used as the circuit common point of the power source.

Setting up operation output signal pull-up and input signal drive power source

Selecting power source

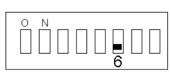
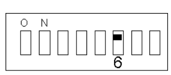
As shown in the below table, set up either the JP1-6, JP1-7, or JP1-8 jumper to select the operation output signal pull-up and the input signal drive power source (DCV2).

Socket number	Power source selected by setting up the jumper (circuit shorten)	Factory-default
JP1-6	Internal power source (+5 V)	Open
JP1-7	Internal power source (+12 V)	Open
JP1-8	External power source (EXT_DCV2: +5 V - +24 V)	Short

NOTE Set up (short-circuit) only one jumper from among the P17-3, P17-2, and P17-1. Do not set up (short-circuit) two or more jumpers simultaneously.

Setting up circuit common point

To set up the circuit common point (COM1), use S1-6 of the switch (S1).

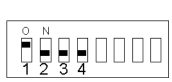
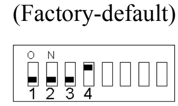
Setup of S1-6	State of the circuit common point
(Factory-default) 	The common point (COM2) of the external power source (EXT_DCV2) and the internal circuit common point of the 4288A are separated. Operation output signals and the input signals are isolated.
	The common point (COM2) of the external power source (EXT_DCV2) and the internal circuit common point of the 4288A are connected. Operation output signals and the input signals are not isolated.

NOTE When you select the internal power source (when you set a jumper on JP1-6 or JP1-7), you must set S1-6 to ON.

NOTE When you use +5V (pins 16, 17, and 18) of the handler interface connector, set S1-6 to ON to connect the internal circuit common point of the 4288A to COM2 so that COM2 is used as the circuit common point of the power source.

Setting up input signal resistor

Depending on the voltage setup of the operation output signal pull-up & input signal drive power source (DCV2), you must set up the input signal resistor using S1-1, S1-2, S1-3, and S1-4 of the switch (S1).

$5 < DCV2 \le 6$	$6 < DCV2 \le 9$	$9 < DCV2 \le 15$	$15 < DCV2 \le 24$
			(Factory-default) 

Setting up pull-up resistor

When you connect pull-up resistors for operation output signals and judgment output signals to the interior of the 4288A, use resistor networks (refer to Table 10-9) that match the pull-up voltage of J1, J2, and J3 (refer to Figure 10-7) on the A1 board.

NOTE

Direction of resistor network

Connect the resistor network so that the mark of the resistor network matches the square mark on the board.

Table 10-9 **Typical resistor network**

Pull-up voltage [V]	Approximate resistance value [Ω]	Typical resistor network	
		Resistance value [Ω]	Agilent part number
5	1.7 k (5 V / 3 mA)	1.5 k	1810-0276
9	3.0 k (9 V / 3 mA)	3.3 k	1810-0278
12	4.0 k (12 V / 3 mA)	4.7 k	1810-0279
15	5.0 k (15 V / 3 mA)	4.7 k	1810-0279
24	8.0 k (24 V / 3 mA)	10 k	1810-0280

Table 10-10 **Correspondence between output signals and J1, J2, and J3**

Signal name	Location of resistor network
/OUT_OF_BINS, /BIN1 - /BIN8	J1
/BIN9, /AUX_BIN, /PHI, /PLO, /SREJ, /LOW_C_REJECT, /OVLD	J2
/INDEX, /EOM, /READY_FOR_TRIG, /ALARM	J3

No resistor network is factory-installed.

Procedure to remove the cover

This section describes how to remove the cover of the small opening in the bottom of the instrument when setting up the drive/pull-up power source and mounting a pull-up resistor.

WARNING **Wait at least 10 minutes after you disconnect the power cable before you begin this procedure. While the 4288A is operating or immediately after power-off, it still contains electrical charge that is dangerous to the human body. For this reason, sufficient time must elapse after removing the power cable until internal capacitors are fully discharged.**

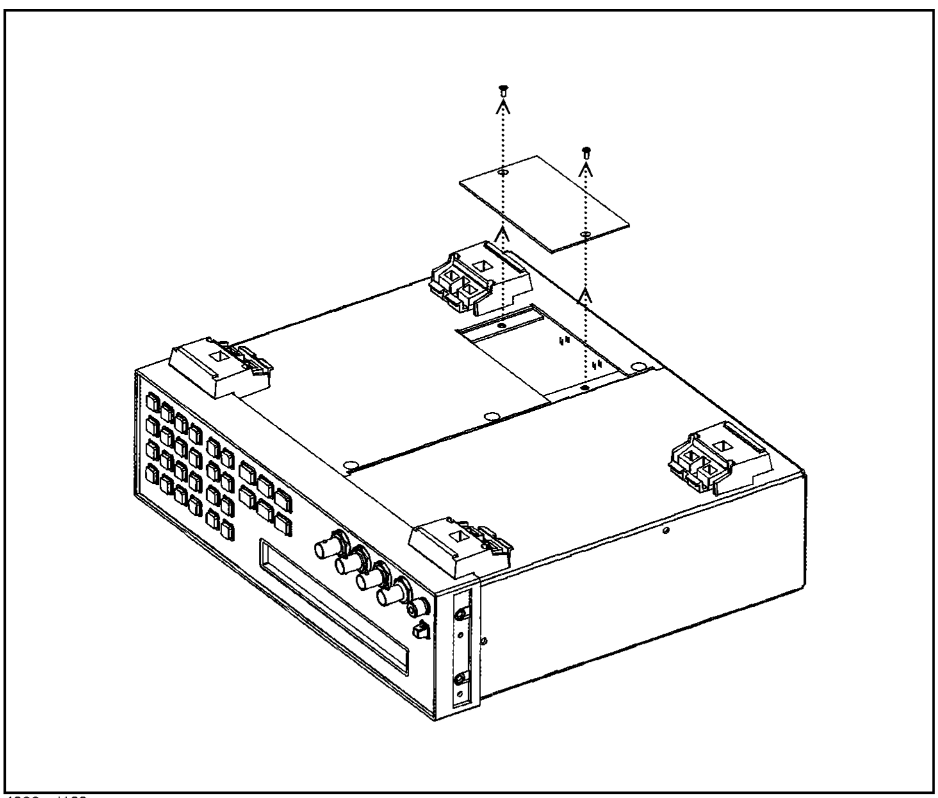
NOTE Remove the cover and set up the drive/pull-up power source or mount a pull-up resistor. Wear a ground strap in an ESD-controlled area.

Step 1. Disconnect the power cable from the 4288A and allow at least 10 minutes to elapse.

Step 2. Turn the 4288A upside down.

Step 3. Remove the two screws that secure the cover to find the opening (Figure 10-8).

Figure 10-8 **Removing the cover**



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11 Using Scanner Interface

You can select compensation data for each channel (up to 64 sets, multi-compensation function) or input/output a timing control signal for measurement and scanner operation through the scanner interface. This chapter gives information required to configure a scanning system using the scanner interface and multi-compensation function.

Using Multi-compensation Function

The 4288A provides a function that lets you select a data set from up to 64 compensation data sets measured and stored in advance and use it (multi-compensation function). This function performs OPEN/SHORT/LOAD compensation for each channel of the scanner to cancel variations in measured values caused by a different measurement path for each channel. Consequently, the function can provide highly reliable measurement.

This section describes how to use the multi-compensation function.

Turning ON/OFF multi-compensation function

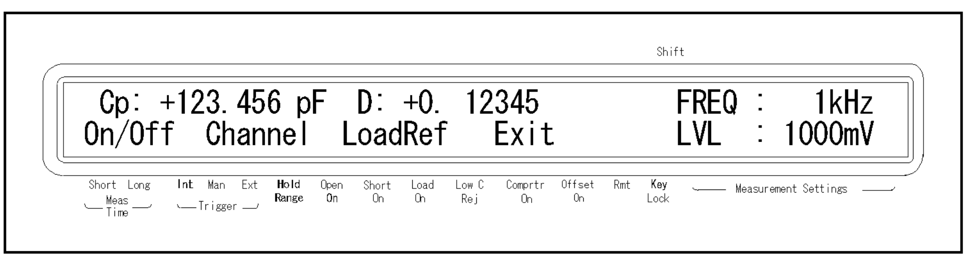
When you turn ON the multi-compensation function, the compensation data for each channel, which has been measured in advance according to the procedure described in “Measuring multi-compensation data”, is used to perform error compensation.

NOTE The ON/OFF state of the multi-compensation function is dependent on the ON/OFF state of the scanner interface. When the multi-compensation function is OFF, the channel number inputs (/CH0 - /CH5 and /CH_VALID) from the scanner interface are ignored and /INDEX and /EOM stay LOW. Regardless of the ON/OFF state of the multi-compensation function, /EXT_TRIG is valid when the trigger mode is set to the external trigger (Ext).

The procedure to turn ON/OFF the multi-compensation function is given below.

Step 1. Press the **[Scanner]**(**[Blue]** - **[9]**) key. The multi-compensation menu screen shown in Figure 11-1 appears.

Figure 11-1 **Multi-compensation menu screen**



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Step 2. Use the **[↑→]** key to make “On/Off” blink and then press the **[Enter]** key. The multi-compensation function ON/OFF setup screen appears.

Step 3. The blinking item is the current setup value. Use the **[↑→]** key to make the item (“Off” or “On”) you want to set up blink and press the **[Enter]** key.

Selecting a channel

Making a selection using the front panel

The procedure to select a channel using the front panel keys is given below.

Step 1. Press the **[Scanner]**(**[Blue]** - **[9]**) key to display the multi-compensation menu screen (refer to Figure 11-1).

Step 2. Use the **[↑→]** key to make "Channel" blink and then press the **[Enter]** key. The channel setup screen appears.

Step 3. Use the numeral keys and other necessary keys to enter the channel number (0 - 63) you want to select and press the **[Enter]** key.

Making a selection using the scanner interface

To select a channel through the scanner interface, use the /CH0 - /CH5 and /CH_VALID signals. For information on these signals, refer to "Input/Output Signal Pin Assignment" on page 144.

A channel number is expressed in binary notation by the HIGH level (0)/LOW level (1) of the /CH0 - /CH5 signals. The /CH5 signal is the most significant bit and the /CH0 signal is the least significant bit. For example, if the /CH5 signal is LOW and the /CH0 - /CH4 signals are HIGH, the expressed number is 32; if the /CH0 - /CH1 signals are LOW and the CH2 - /CH5 signals are HIGH, the expressed number is 3.

The /CH_VALID signal enables/disables the setting of the signals from /CH0 to /CH5. If the /CH_VALID signal is LOW, a trigger will set the channels of the 4288A to the channel numbers specified by the signals from /CH0 to /CH5.

The procedure to set the channel is given below.

Step 1. Set the /CH_VALID signal to HIGH.

Step 2. Set up a channel number using the /CH0 - /CH5 signals.

Step 3. Set the /CH_VALID signal to LOW.

Step 4. Generate a trigger.

NOTE **Difference in execution timing depending on the channel selection method**

When the front panel or GPIB command is used to select a channel, the selection is executed immediately. On the other hand, when the /CH0 to /CH5 and /CH_VALID signals of the scanner interface are used, the channel selection is not executed immediately after setting the signals but when a trigger is generated.

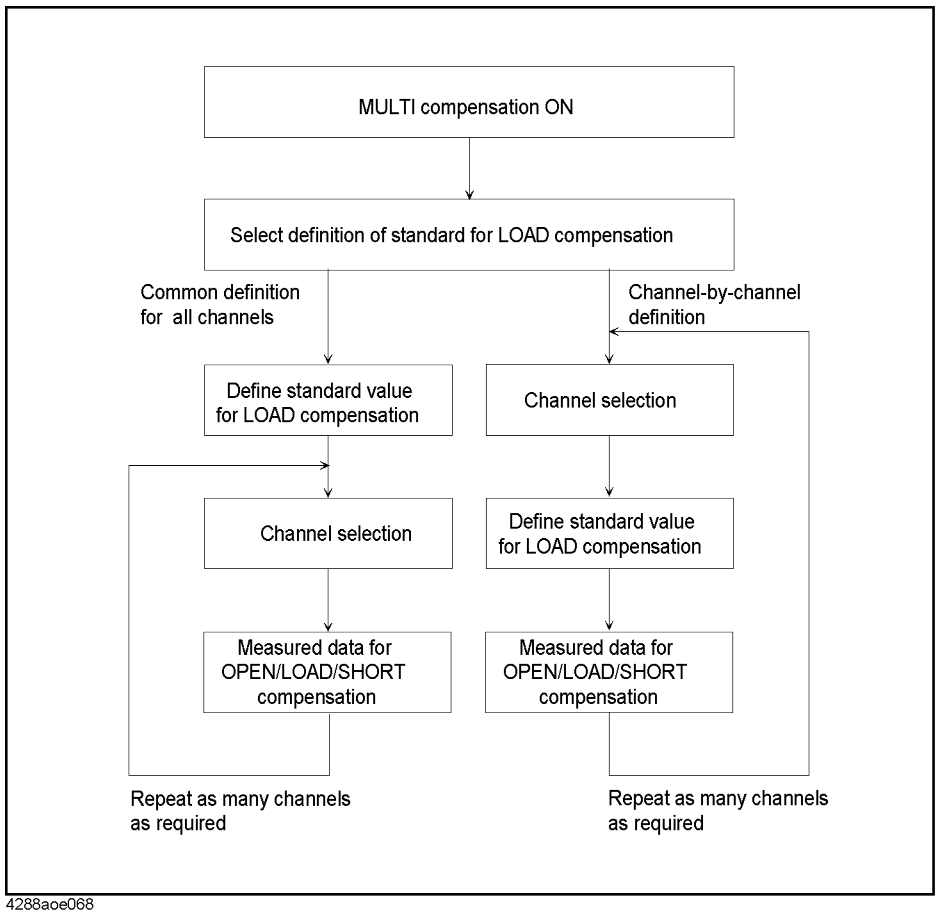
For information on the setup timing of the /CH0 - /CH5 and /CH_VALID signals, refer to Figure 11-5.

Measuring multi-compensation data

Figure 11-2 shows the basic flow of measuring the OPEN/SHORT/LOAD compensation data for the multi-compensation.

NOTE You cannot initialize the compensation data for the multi-compensation function. Even if you trigger a reset or turn OFF the power, the values are maintained.

Figure 11-2 **Flow of measuring compensation data for the multi-compensation**



Selecting definition method of the LOAD compensation standard

You can select how to define the LOAD compensation standard value (LOAD compensation reference value): either defining a value for each channel or defining a common value for all channels. If you select the channel-by-channel definition, the value is set up as the reference value for the channel selected when you enter the reference value. If you select defining a common value for all channels, the value is stored as the value for all channels regardless of the channel selected when setting up the value. Refer to Figure 6-15 on page 83.

The procedure to select the definition method of the LOAD compensation standard value (LOAD compensation reference value) is given below.

Step 1. Press the **[Scanner]**(**[Blue]** - **[9]**) key to display the multi-compensation menu screen (refer to Figure 11-1).

Step 2. Use the **[↑→]** key to make “LoadRef” blink and then press the **[Enter]** key. The LOAD compensation standard definition method setup screen appears.

Step 3. The blinking item (one of the items in the below table) is the current setup value. Use the **[↑→]** key to make the item you want to set up blink and press the **[Enter]** key.

Item	Description
Single	Defines a single LOAD compensation standard value commonly applied to all channels.
Multi	Defines a LOAD compensation standard value for each channel.

Measuring OPEN/SHORT/LOAD compensation data

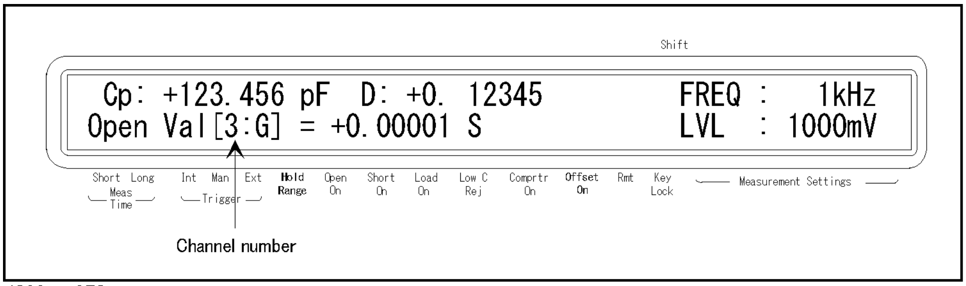
The procedure to measure OPEN/SHORT/LOAD compensation data for multi-compensation is the same as that for the usual compensation data, except that you need to select a proper channel before the measurement. For more information, refer to “Obtaining Compensation Data” on page 78.

When you measure the OPEN/SHORT/LOAD compensation data with the multi-compensation function ON, the measured value is stored as the compensation data for the channel selected at the time of measurement. For information on the structure of the compensation data, refer to Figure 6-12 on page 78, Figure 6-13 on page 79, and Figure 6-15 on page 83.

Checking OPEN/SHORT/LOAD compensation data

The procedure to check OPEN/SHORT/LOAD compensation data for multi-compensation is the same as that for the usual compensation data, except that you need to select a proper channel before the measurement and the information of the channel number is added on the displayed screen (refer to Figure 11-3). For more information, refer to “Checking (displaying)/Setting up Compensation Data” on page 87.

Figure 11-3 Compensation data display screen when multi-compensation is ON (when OPEN compensation data is G)



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Input/Output Signal Pin Assignment

Figure 11-4 shows the pin assignment of the input/output signals of the scanner interface connector. Table 11-3 gives a description of the input/output signals.

NOTE A slash (/) symbol preceding signal names means that they are negative logic (active low).

Figure 11-4 **Pin assignment of the scanner interface connector**

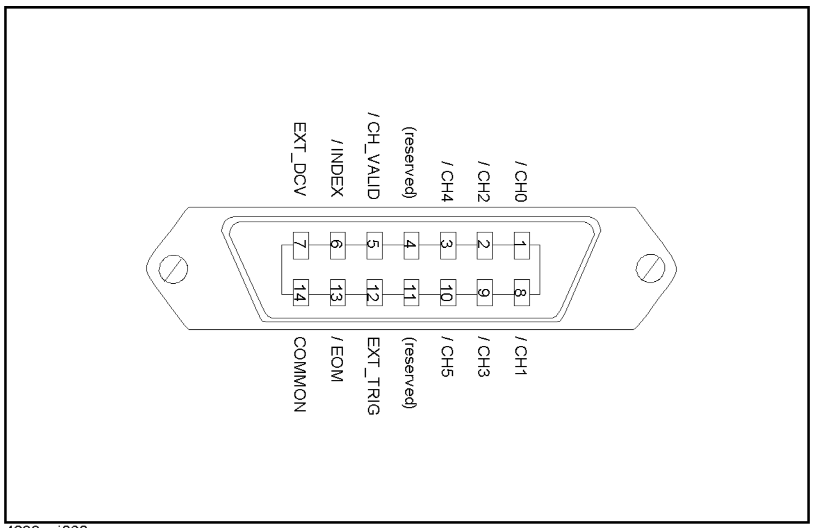

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Table 11-1 Description of input/output signals of the scanner interface

Pin number	Signal name	Input/output	Description
1	/CH0	Input	Channel number selection signal (6-bit binary input). Selects the compensation data for each channel of the scanner. The most significant bit is /CH5 (pin number 10). The least significant bit is /CH0 (pin number 1).
2	/CH2		
3	/CH4		
4	(reserved)	———	Not used in the current release.
5	/CH_VALID	Input	Channel number identification signal. If the /CH_VALID signal is LOW, a trigger will set the channels of the 4288A to the channel numbers specified by the signals from /CH0 to /CH5.
6	/INDEX	Output	Analog measurement end signal. When an analog measurement finishes, this becomes LOW. When this signal is received, you can change the channel of the scanner. You cannot obtain the measured data until the /EOM signal is received.
7	EXT_DCV	Input	External dc voltage. Supplies the voltage to the output signals (/INDEX and /EOM) and input signals (EXT_TRIG, /CH0 - /CH5, and /CH_VALID). The input voltage range is between +5V and +15V.
8	/CH1		Channel number selection signal (6-bit binary input). Selects the compensation data for each channel of the scanner. The most significant bit is /CH5 (pin number 10). The least significant bit is /CH0 (pin number 1).
9	/CH3		
10	/CH5		
11	(reserved)	———	Not used in the current release.
12	EXT_TRIG	Input	External trigger signal. This is available when the trigger mode is set to the external trigger (Ext). The trigger is generated at the rising edge of a pulse.
13	/EOM	Output	Measurement cycle end signal. When a series of measurement processes finishes and the measured data becomes available, this becomes LOW.
14	COMMON	———	Common pin for the external dc voltage EXT_DCV (pin number 7).

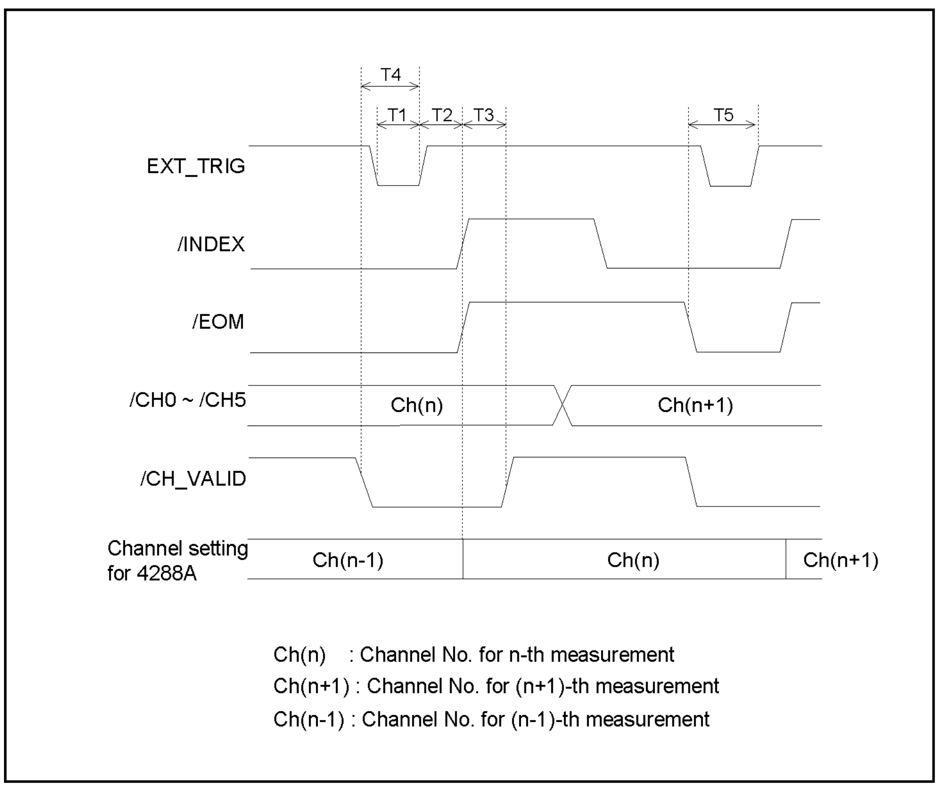
Timing Chart

Figure 11-5 shows the timing chart. The time periods of T1–T5 in the figure are described in the following table.

		Minimum value (SPC)	Maximum value (SPC)
T1	Trigger pulse width	1 μs	——
T2	Trigger response time of /INDEX and /EOM	——	400 μs [*1]
T3	Channel number input hold time	0 μs	——
T4	Channel number input setup time	0 μs	——
T5	Trigger wait time	0 μs	——

*1. When the display has been turned off.

Figure 11-5 **Timing chart of the scanner interface**



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Electrical Characteristics

Output signal

The output signals (/INDEX and /EOM) are available as open collector outputs with photo coupler isolated. You can obtain each voltage output by connecting a pull-up resistor (refer to Table 11-2) to the exterior of the 4288A.

Table 11-2 **Guide for pull-up resistor values**

Pull-up voltage [V]	Resistance value [Ω]	Typical resistance	
		Resistance value [Ω]	Agilent part number
5	1.7 k (5 V / 3 mA)	1.78 k	0757-0278
9	3.0 k (9 V / 3 mA)	3.16 k	0757-0279
12	4.0 k (12 V / 3 mA)	4.22 k	0698-3154
15	5.0 k (15 V / 3 mA)	5.11 k	0757-0438

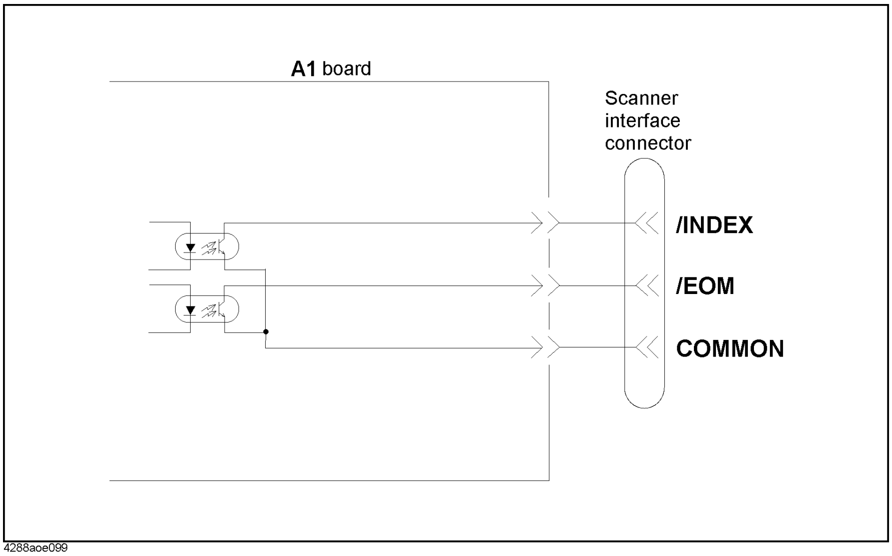
Table 11-3 shows the electrical characteristics of the output signals. Figure 11-6 shows the circuit diagram of the output signals.

Table 11-3 **Electrical characteristics of the scanner interface output signals**

Output signal	Output voltage [V]		Maximum current [mA]
	LOW	HIGH	
/INDEX, /EOM	0 - 0.5	EXT_DCV[*1]	6

*1. EXT_DCV: +5V - +15V

Figure 11-6 **Circuit diagram of the scanner interface output signals**



Input signal

Each input signal is connected to the cathode side of the photo coupler LED. The anode side of the LED is connected to the drive source voltage.

Table 11-4 shows the electrical characteristics of the input signals. Figure 11-7 and Figure 11-8 show the circuit diagram of the input signals. The amount of current flowing through the LED depends on the setups of the drive source voltage, the channel control (/CH0 - /CH5 and /CH_VALID) signal resistance setup switch (S1), and the external trigger (EXT_TRIG) signal resistance setup switch (S3).

For how to set up S1 and S3, refer to "Setting Up Input Signal Resistance" on page 150.

Table 11-4 Electrical characteristics of the scanner interface input signals

Input signal	Input voltage [V]		Input current (LOW) [mA] (typical)*1		
			Pull-up source voltage: EXT_DCV		
	LOW	HIGH	5 V	12 V	15 V
/CH0 - /CH5, /CH_VALID	0 - 1	EXT_DCV	9.0	12.7	16.2
EXT_TRIG			3.7	4.6	5.9

*1. When S2 and S3 have been set up according to Table 11-5 on page 150

Figure 11-7 Circuit diagram of scanner interface input signals (channel control signals)

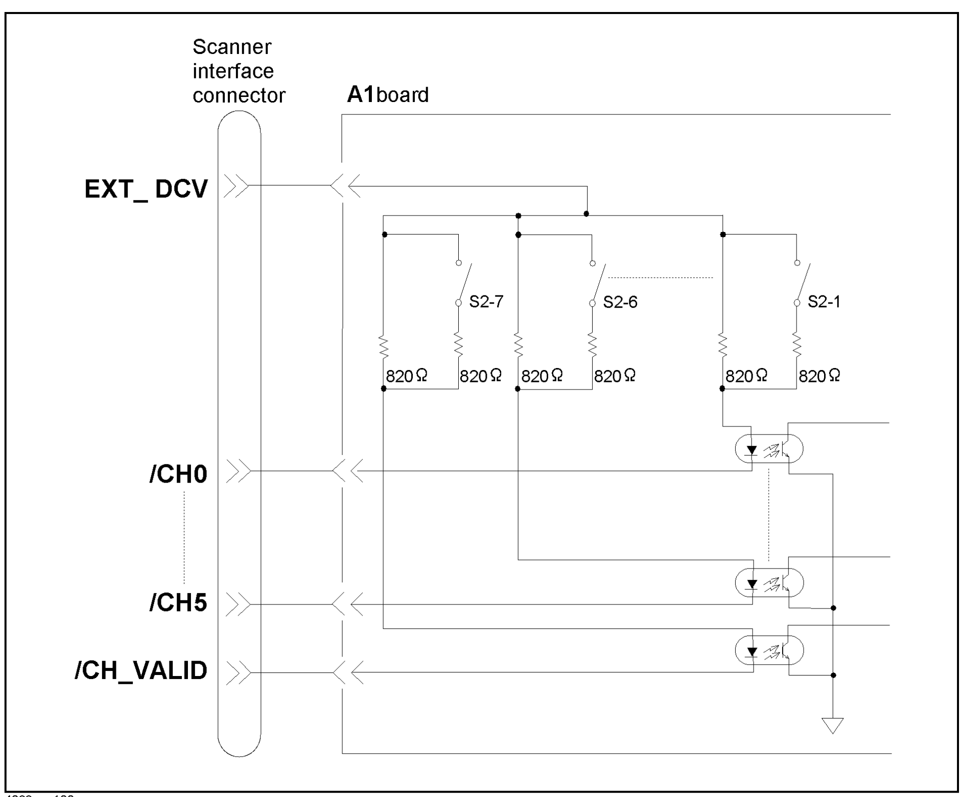
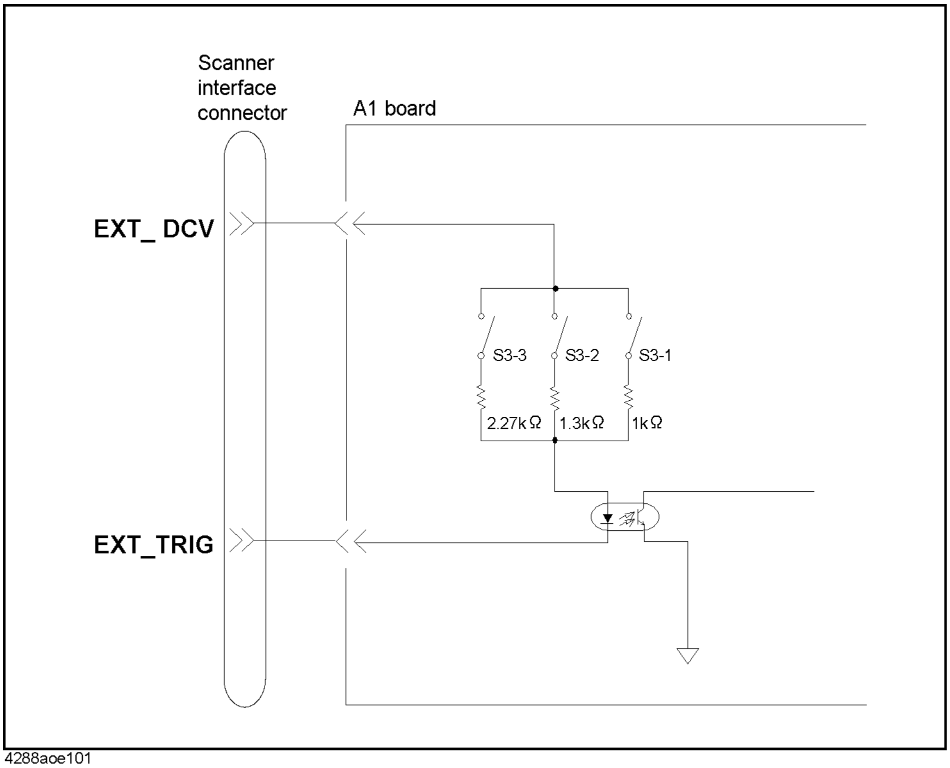


Figure 11-8 **Circuit diagram of scanner interface input signals (external trigger signal)**



Power source

You can use only the external power source (EXT_DCV). Set its power output within the following voltage range.

	Voltage range [V]
EXT_DCV	+5 - +15

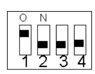
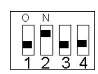
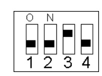
Setting Up Input Signal Resistance

Depending on the voltage setting of the external power source (EXT_DCV), you need to set up the input signal resistance using the channel control (/CH0 - /CH5 and /CH_VALID) signal resistance setup switch (S2) and the external trigger (EXT_TRIG) signal resistance setup switch (S3).

Follow the procedure in “Procedure to remove the cover” on page 138 to remove the cover of the small opening in the bottom of the 4288A. Then you can change the setups of S2 and S3. For the locations of S2 and S3, refer to Figure 10-7 on page 134.

Table 11-5 **Setups of S2 and S3**

<table>
<tr><th rowspan="2"></th><th colspan="4">Voltage setup of external power source (EXT_DCV) [V]</th></tr>
<tr><th>5 < EXT_DCV ≤ 6</th><th>6 < EXT_DCV ≤ 8</th><th>8 < EXT_DCV ≤ 9</th><th>9 < EXT_DCV ≤ 15V</th></tr>
<tr><td>S2</td><td colspan="2">
</td><td colspan="2">(Factory-default)

</td></tr>
<tr><td>S3</td><td>
</td><td colspan="2">
</td><td>(Factory-default)

</td></tr>
</table>

12 Specifications and Supplemental Information

This chapter gives the specifications and supplemental information of the Agilent 4288A capacitance meter.

Definitions

All specifications apply to the conditions of a 0°C to 45°C temperature range, unless otherwise stated, and 10 minutes after the instrument has been turned on.

Specification (spec.):	Warranted performance. Specifications include guardbands to account for the expected statistical performance distribution, measurement uncertainties, and changes in performance due to environmental conditions.

Supplemental Information is provided as information that is useful in operating the instrument but that is not covered by the product warranty. This information is classified as either typical or nominal.

Typical (typ.):	Expected performance of an average unit that does not take guardbands into account.
Nominal (nom.):	A general descriptive term that does not imply a level of performance.

Basic Specifications

Measurement parameters

- Cp-D, Cp-Q, Cp-Rp, Cp-G
- Cs-D, Cs-Q, Cs-Rs

where

Cp:	Capacitance value measured using the parallel equivalent circuit model
Cs:	Capacitance value measured using the series equivalent circuit model
D:	Dissipation factor
Q:	Quality factor (inverse of D)
G:	Equivalent parallel conductance measured using the parallel equivalent circuit model
Rp:	Equivalent parallel resistance measured using the parallel equivalent circuit model
Rs:	Equivalent series resistance measured using the series equivalent circuit model

Measurement signals

<table>
<tr><td rowspan="2">Frequency</td><td colspan="2">Allowable frequencies</td><td>1 kHz
1 MHz
0.99 MHz (1 MHz -1%)
1.01 MHz (1 MHz +1%)
1.02 MHz (1 MHz +2%)</td></tr>
<tr><td colspan="2">Accuracy</td><td>± 0.02%</td></tr>
<tr><td rowspan="3">Level</td><td colspan="2">Range</td><td>0.1 V–1.0 V</td></tr>
<tr><td colspan="2">Resolution</td><td>0.1 V</td></tr>
<tr><td colspan="2">Accuracy</td><td>± 5%</td></tr>
<tr><td rowspan="3">Output impedance</td><td rowspan="2">Frequency:
1 kHz</td><td>Measurement range:
100 pF–100 nF</td><td>20 Ω (nominal)</td></tr>
<tr><td>Measurement range:
220 nF–10 μF</td><td>1 Ω (nominal)</td></tr>
<tr><td colspan="2">Frequency: 1 MHz</td><td>20 Ω (nominal)</td></tr>
</table>

Measurement cable lengths

0 m, 1 m, 2 m

Measurement time modes

Short mode, long mode

For information on the measurement time in each mode, refer to “Measurement time” on page 161.

Measurement range selection

Auto (auto range mode), manual (hold range mode)

Measurement range

Measurement signal frequency: 1 kHz			**Measurement signal frequency: 1 MHz**		
100 pF	220 pF	470 pF	1 pF	2.2 pF	4.7 pF
1 nF	2.2 nF	4.7 nF	10 pF	22 pF	47 pF
10 nF	22 nF	47 nF	100 pF	220 pF	470 pF
100 nF	220 nF	470 nF	1 nF		
1 μF	2.2 μF	4.7 μF			
10 μF					

For information on measurable range in each measurement mode, refer to “Available measurement ranges” on page 155.

Averaging

Range	1–256 measurements
Resolution	1

Trigger mode

Internal trigger (Int), manual trigger (Man), external trigger (Ext), GPIB trigger (Bus)

Trigger delay time

Range	0–1.000 s
Resolution	1 ms

Measurement display ranges

Table 12-1 shows the range of the measured value that can be displayed on the screen.

Table 12-1 Allowable measured value display range

Parameter	Measurement display range
Cs, Cp	– 99.9999 µF to – 0.00001 pF, 0, 0.00001 pF to 99.9999 µF
D	– 9.99999 to – 0.00001, 0, 0.00001 to 9.99999
Q	– 99999.9 to – 0.1, 0, 0.1 to 99999.9
Rs, Rp	– 999.999 MΩ to – 0.001 mΩ, 0, 0.001 mΩ to 999.999 MΩ
G	– 9.99999 kS to – 0.00001 µS, 0, 0.00001 µS to 9.99999 kS
Δ%	– 999.999% to – 0.001%, 0, 0.001% to 999.999%

Available measurement ranges

Table 12-2 and Table 12-3 show recommended measurement ranges (recommended for accurate measurement) and significant measurement ranges (ranges that do not cause overload) for each measurement value under the condition D (dissipation factor) ≤ 0.5.

Table 12-2 Measurable capacitance ranges when measurement frequency is 1 kHz

Measurement value	Recommended measurement range	Significant measurement range
100 pF	68 pF–150 pF	0 F–150 pF
220 pF	150 pF–330 pF	0 F–330 pF
470 pF	330 pF–680 pF	0 F–680 pF
1 nF	680 pF–1.5 nF	0 F–1.5 nF
2.2 nF	1.5 nF–3.3 nF	0 F–3.3 nF
4.7 nF	3.3 nF–6.8 nF	0 F–6.8 nF
10 nF	6.8 nF–15 nF	0 F–15 nF
22 nF	15 nF–33 nF	0 F–33 nF
47 nF	33 nF–68 nF	0 F–68 nF
100 nF	68 nF–150 nF	0 F–150 nF
220 nF	150 nF–330 nF	0 F–330 nF
470 nF	330 nF–680 nF	0 F–680 nF
1 µF	680 nF–1.5 µF	0 F–1.5 µF
2.2 µF	1.5 µF–3.3 µF	0 F–3.3 µF
4.7 µF	3.3 µF–6.8 µF	0 F–6.8 µF
10 µF	6.8 µF–20 µF	0 F–20 µF

Table 12-3 Measurable capacitance ranges when measurement frequency is 1 MHz

Measurement value	Recommended measurement range	Significant measurement range
1 pF	680 fF–1.5 pF	0 F–1.5 pF
2.2 pF	1.5 pF–3.3 pF	0 F–3.3 pF
4.7 pF	3.3 pF–6.8 pF	0 F–6.8 pF
10 pF	6.8 pF–15 pF	0 F–15 pF
22 pF	15 pF–33 pF	0 F–33 pF
47 pF	33 pF–68 pF	0 F–68 pF
100 pF	68 pF–150 pF	0 F–150 pF
220 pF	150 pF–330 pF	0 F–330 pF
470 pF	330 pF–680 pF	0 F–680 pF
1 nF	680 pF–1.5 nF	0 F–1.5 nF

Measurement accuracy

The measurement accuracy is defined when all of the following conditions are met.

- ❏ Warm-up time: 10 minutes or longer
- ❏ Ambient temperature: 18°C–28°C
- ❏ Execution of OPEN compensation
- ❏ Measurement cable length: 0 m, 1 m, or 2 m (16048A/B/D)
- ❏ D (dissipation factor) ≤ 0.5

Accuracy of Cp, Cs, D, G, and Rs

Table 12-4 and Table 12-5 show the measurement accuracy of Cp, Cs, D, G, and Rs when D ≤ 0.1. The following points should be noted when you calculate accuracy with these tables.

- The equation to calculate accuracy varies depending on the measurement time mode. In the tables, the upper equation is for the short mode, and the lower is for the long mode.
- Interpret your calculated accuracy as ± (percentage of measured value of an error) for Cp and Cs, ± (absolute value of an error) for D, G, and Rs.

When 0.1 < D ≤ 0.5, multiply the accuracy obtained from Table 12-4 or Table 12-5 by the coefficient in the below table.

Parameter	Coefficient
Cp, Cs, G, Rs[*1]	$1 + D^2$
D	1 + D

*1. If you select a secondary measurement parameter other than D, calculate D by using an equation that gives the relationship between parameters shown in Figure 5-1 on page 52.

Accuracy when ambient temperature exceeds the range of 18°C to 28°C (Typical)

When the ambient temperature exceeds the range of 18°C to 28°C, multiply the accuracy obtained above by the coefficient shown in the table below.

	Coefficient
0°C ≤ ambient temperature < 8°C	3
8°C ≤ ambient temperature < 18°C	2
18°C ≤ ambient temperature ≤ 28°C	1
28°C < ambient temperature ≤ 38°C	2
38°C < ambient temperature ≤ 45°C	3

Figure 12-1, Figure 12-2, Figure 12-3, and Figure 12-4 show the accuracy of Cp, Cs, and D measured within the recommended measurement range for each measurement value (refer to Table 12-2 and Table 12-3) when D ≤ 0.1 and the ambient temperature is between 18°C and 28°C.

Table 12-4 Measurement accuracy of Cp, Cs, D, G, and Rs (measurement frequency: 1 kHz)

Measurement range	Measurement parameter			
	Cp, Cs [%]	D	G [nS]	Rs [Ω]
100 pF	0.055 + 0.070 × K 0.055 + 0.030 × K	0.00035 + 0.00070 × K 0.00035 + 0.00030 × K	(3.5 + 4.5 × K) × Cx (3.5 + 2.0 × K) × Cx	(90 + 120 × K) / Cx (90 + 50 × K) / Cx
220 pF	0.055 + 0.045 × K 0.055 + 0.020 × K	0.00035 + 0.00045 × K 0.00035 + 0.00020 × K	(3.5 + 3.0 × K) × Cx (3.5 + 1.5 × K) × Cx	(90 + 75 × K) / Cx (90 + 35 × K) / Cx
470 pF 1 nF 2.2 nF 4.7 nF 10 nF 22 nF 47 nF 100 nF 220 nF 470 nF 1 μF 2.2 μF 4.7 μF 10 μF	0.055 + 0.030 × K 0.055 + 0.015 × K	0.00035 + 0.00030 × K 0.00035 + 0.00015 × K	(3.5 + 2.0 × K) × Cx (3.5 + 1.0 × K) × Cx	(90 + 50 × K) / Cx (90 + 25 × K) / Cx

Table 12-5 Measurement accuracy of Cp, Cs, D, G, and Rs (measurement frequency: 1 MHz)

Measurement range	Measurement parameter			
	Cp, Cs [%]	D	G [nS]	Rs [Ω]
1 pF	0.055 + 0.070 × K 0.055 + 0.030 × K	0.00035 + 0.00070 × K 0.00035 + 0.00030 × K	(3.5 + 4.5 × K) × Cx (3.5 + 2.0 × K) × Cx	(90 + 120 × K) / Cx (90 + 50 × K) / Cx
2.2 pF	0.055 + 0.045 × K 0.055 + 0.020 × K	0.00035 + 0.00045 × K 0.00035 + 0.00020 × K	(3.5 + 3.0 × K) × Cx (3.5 + 1.5 × K) × Cx	(90 + 75 × K) / Cx (90 + 35 × K) / Cx
4.7 pF 10 pF 22 pF 47 pF 100 pF 220 pF 470 pF 1 nF	0.055 + 0.030 × K 0.055 + 0.015 × K	0.00035 + 0.00030 × K 0.00035 + 0.00015 × K	(3.5 + 2.0 × K) × Cx (3.5 + 1.0 × K) × Cx	(90 + 50 × K) / Cx (90 + 25 × K) / Cx

In tables Table 12-4 and Table 12-5, Cx is a measured value of the capacitance (Cp or Cs) [nF (for 1 kHz)/pF (for 1 MHz)] and K is defined as follows:

Cx≤ Cr: K = (1/Vs) × (Cr/Cx)
Cx>Cr: K = 1/Vs

where Cr is a measurement range [nF (for 1 kHz)/pF (for 1 MHz)] and Vs is a measurement signal level [V].

Figure 12-1 **Accuracy of Cp and Cs when measurement frequency is 1 kHz (measurement signal level: 1V)**

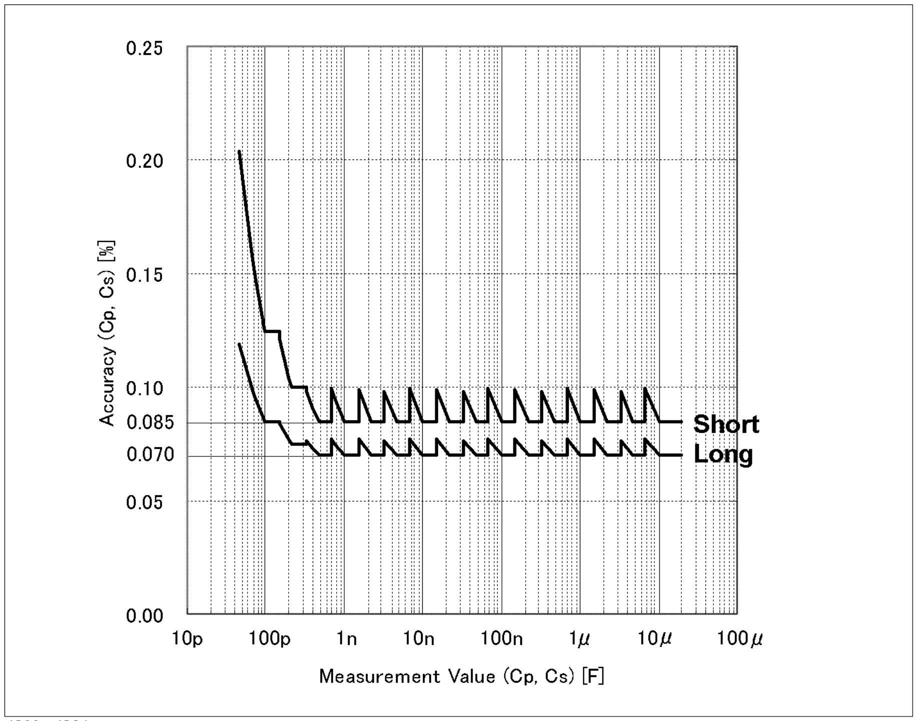


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Figure 12-2 **Accuracy of D when measurement frequency is 1 kHz (measurement signal level: 1V)**

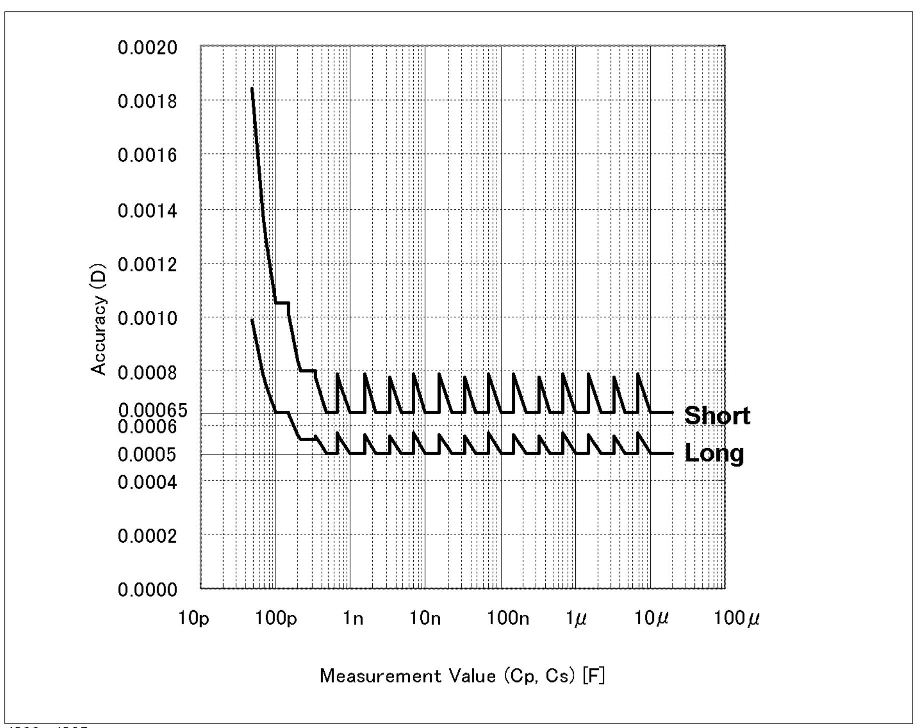

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Figure 12-3 **Accuracy of Cp and Cs when measurement frequency is 1 MHz (measurement signal level: 1V)**

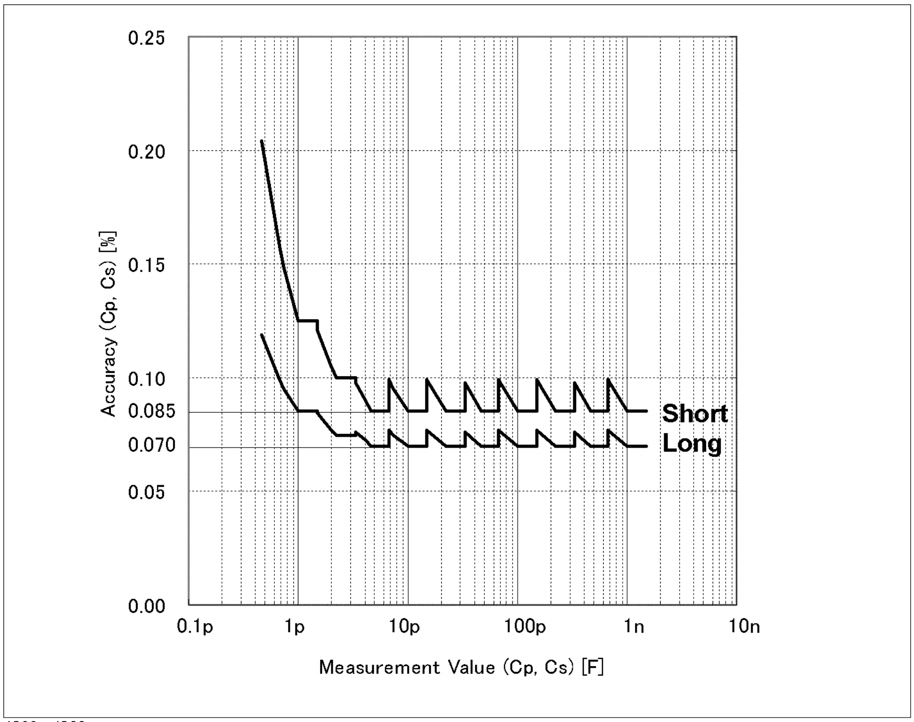

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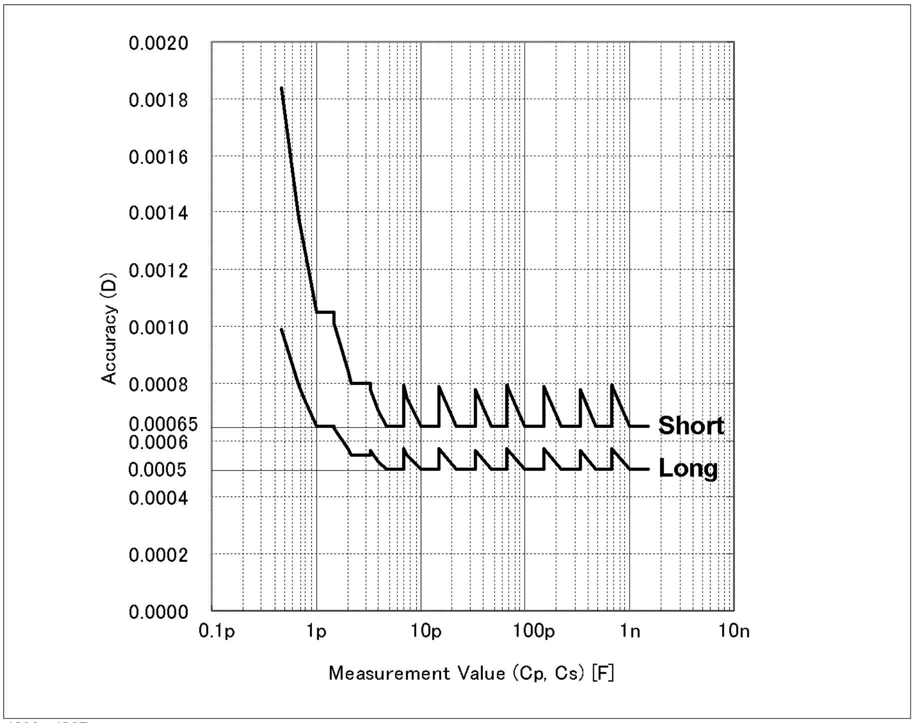
Figure 12-4 **Accuracy of D when measurement frequency is 1 MHz (measurement signal level: 1V)**



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Accuracy of Q

The following equation is used to calculate the accuracy of Q from the accuracy of D.

Equation 12-1 **Equation to calculate Q**

$$Qe = \frac{\pm Qx^2 \times De}{1 \mp Qx \times De}$$

where Qe is the accuracy of Q, De is the accuracy of D, and Qx is the measured Q value.

Accuracy of Rp

The following equation is used to calculate the accuracy of Rp from the accuracy of G.

Equation 12-2 **Equation to calculate Rp**

$$Rpe = \frac{\pm Rpx^2 \times Ge}{1 \mp Rpx \times Ge}$$

where Rpe is the accuracy of Rp, Ge is the accuracy of G, and Rpx is the measured Rp value.

Measurement time

Table 12-6 shows the measurement time for each measurement time mode.

Table 12-6 **Measurement time**

Measurement time mode	Measurement time (T3+T4+T5 of Figure 12-5)
Short	6.5 ± 0.5 ms
Long	16.5 ± 1.0 ms

Figure 12-5 **Timing chart and measurement time**

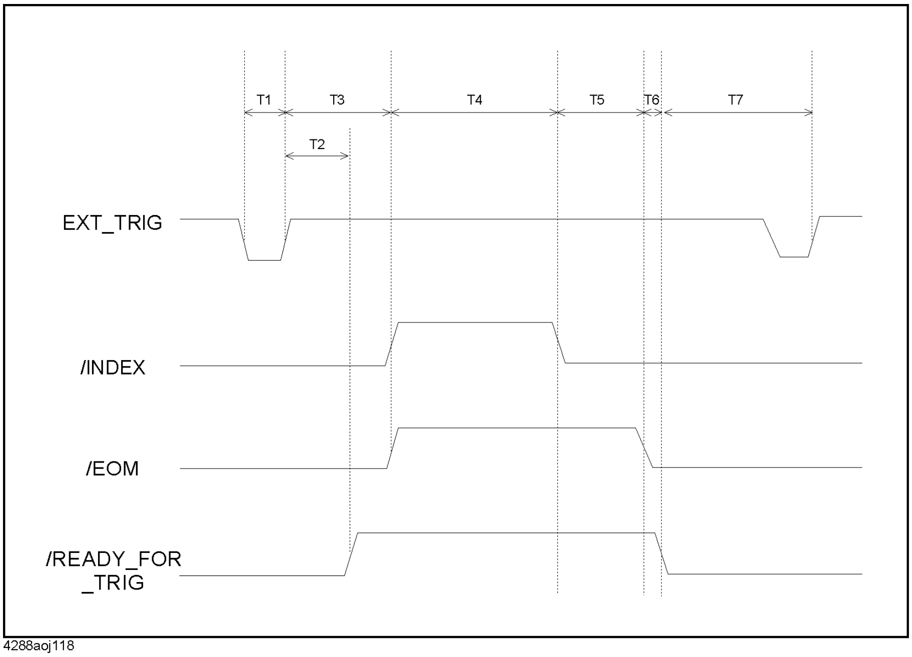


Table 12-7 shows the values of T1–T7 when the following conditions are met.

Display:	OFF
Measurement range mode:	Hold range mode (Hold)
Trigger delay time:	0 ms
Averaging factor:	1

(The ON/OFF states of the compensation and comparator functions do not affect the values of T1–T7)

Table 12-7 **Values of T1–T7 (Typical)**

			Measurement time mode	Minimum value	Typical value	Maximum value
T1	Trigger pulse width		Independent	1 μs[*1]	—	—
T2	Trigger response time of /READY_FOR_TRIG		Independent	—	200 μs	350 μs
T3	Measurement time (T3+T4+T5)	Trigger response time of /INDEX and /EOM	Independent	—	250 μs	400 μs
T4		Analog measurement time (/INDEX)	Short	—	4.25 ms	—
			Long	—	14.25 ms	—
T5		Measurement computation time	Independent	—	2.0 ms	—
T6	READY_FOR_TRIG setup time		Independent	—	15 μs	30 μs
T7	Trigger wait time		Independent	0 μs	—	—

*1. When trigger signal is input through the handler interface.

Display time

When the display is ON, the instrument needs a certain amount of time (display time) to refresh the displayed items. The display time shown in Table 12-8 depends on the display page of the instrument setup display area (use the **[Show Setting]** key to select the item you want to display). The ON/OFF state of the deviation measurement mode does not affect the display time.

Table 12-8 **Display time**

Display page of instrument setup display area			Typical value
Page number	Display item		
1	Frequency and level of measurement signal		2.5 ms
2	Averaging factor and measurement cable length		
3	Measurement range and trigger delay time		4.0 ms
4	Measurement signal level monitor values		
5	Multi-compensation settings		
6	Handler output (Comparator sorting result)		
7 to 18	Limit range settings of comparator		
19 to 24	BIN count results		
25 to 34	Compensation data	Multi-compensation: off	2.5 ms
		Multi-compensation: on	4.0 ms

Display refresh timing

The display is refreshed immediately after the measurement is completed (the /EOM signal goes to low level). However, the display is also refreshed after transferring the measurement data if the external controller transmits a request to read the measurement data before the end of measurement. In addition, the measurement data are transferred after the display refresh is completed if the external controller has transmitted a request to read the measurement data after the start of display refresh.

Measurement time (T4) when Averaging Function is used

When the averaging factor is set to more than 1, T4 is calculated as follows.

Measurement frequency	Measurement time mode	Equation to calculate T4 [ms] *1 (Typical)
1 kHz	Short	$T4 = 4.85 \times Ave - 0.6$
	Long	$T4 = 14.85 \times Ave - 0.6$
1 MHz	Short	$T4 = \left(4 \times \frac{100}{100 + Fshift} + 0.85\right) \times Ave - 0.6$
	Long	$T4 = \left(14 \times \frac{100}{100 + Fshift} + 0.85\right) \times Ave - 0.6$

*1. *Ave*: Averaging factor, *Fshift*: Frequency shift setting (-1, 0, 1 or 2)

Measurement data transfer time through GPIB

Table 12-9 shows the measurement data transfer time under the following conditions.

Host computer:	HP9000 Series, Model C200
Display:	ON
Measurement range mode:	Hold range mode (Hold)
OPEN/SHORT/LOAD compensation:	ON
Measurement signal monitor:	OFF
BIN count function:	OFF

Table 12-9 Measurement Data Transfer Time (Typical)

		Data transfer format	Comparator ON	Comparator OFF
Required time for data readout of a measurement using **:FETC?** command (Total time of command transmission and data transfer)		ASCII	2.3 ms	2.1 ms
		Binary	2.5 ms	2.3 ms
Required time for data readout of a measurement using **:READ?** command	Command transmission	ASCII	1.9 ms	1.9 ms
	Data transfer		1.7 ms	1.5 ms
	Command transmission	Binary	1.9 ms	1.9 ms
	Data transfer		1.4 ms	1.2 ms
Required time for data readout of 1000 measurements using **:DATA? BUF3** command (Total time of command transmission and data transfer)		ASCII	1.40 s	1.15 s
		Binary	0.65 s	0.49 s

Measurement assistance functions

Compensation function

The OPEN compensation, SHORT compensation, LOAD compensation, and OFFSET compensation are available.

MULTI compensation function

- OPEN/SHORT/LOAD compensation for 64 channels
- The LOAD compensation's standard value can be defined for each channel.

Display

40-column × 2-row LCD display.

Deviation measurement function

Deviation from reference value and percentage of deviation from the reference value can be outputted as the result.

Comparator function

BIN sort	The primary parameter can be sorted into 9 BINs, OUT_OF_BINS, AUX_BIN, and LOW_C_REJECT. The secondary parameter can be sorted into High, In, and Low.
Limit setup	An absolute value, deviation value, and % deviation value can be used for setup.
Bin count	Countable from 0 to 999999.

Low C reject function

Extremely low measured capacitance values can be automatically detected as measurement errors.

Measurement signal level monitor function

- Measurement voltage and measurement current can be monitored.
- Level monitor accuracy (typical): ±(3%+1 mV)

Data buffer function

Up to 1000 measurement results can be read out in batch.

Save/recall function

Up to 10 setup conditions can be written to/read from the built-in nonvolatile memory.

Resume function

- At power-on, recovers the instrument setup automatically saved at power-down.
- Memory retention time (typical): 72 hours (23 ±5°C)

Key lock function

The front panel keys can be locked.

GPIB interface

Complies with IEEE488.1, 2 and SCPI.

Handler interface

The input/output signals are negative logic and optically isolated open collector signals.

Output signal: Bin1–Bin9, Out of Bins, Aux Bin, P-Hi, P-Lo, S-Reject, INDEX, EOM, Alarm, OVLD, Low C Reject

Input signal: Keylock, Ext-Trigger

Scanner interface

The input/output signals are negative logic and optically isolated open collector signals.

Output signal: INDEX, EOM

Input signal: Ch0–Ch5, Ch valid, Ext-Trigger

Measurement circuit protection

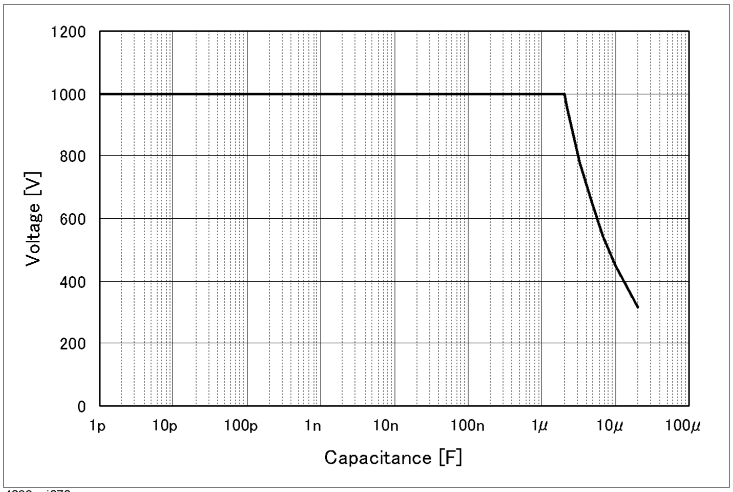
The maximum discharge withstand voltage, where the internal circuit remains protected if a charged capacitor is connected to the UNKNOWN terminal, is illustrated below.

NOTE Discharge capacitors before connecting them to the UNKNOWN terminal or a test fixture.

Table 12-10 Maximum discharge withstand voltage (typical)

Maximum discharge withstand voltage	Range of capacitance value C of DUT
1000 V	C < 2 μF
$\sqrt{2/C}$ V	C ≥ 2 μF

Figure 12-6 Maximum discharge withstand voltage (typical)



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General Specifications

Power source

Voltage	90 VAC–132 VAC, 198 VAC–264 VAC
Frequency	47 Hz–66 Hz
Power consumption	Max. 35 W /Max. 100 VA

Operating environment

Temperature	0°C–45°C
Humidity (≤ 40°C, no condensation)	15%–95% RH
Altitude	0 m–2000 m

Storage environment

Temperature	-40°C–70°C
Humidity (≤ 65°C, no condensation)	0%–90% RH
Altitude	0 m–4572 m

Weight

3 kg (nominal)

Outer dimensions

320 (width) × 100 (height) × 300 (depth) mm (nominal)

Figure 12-7 Front view

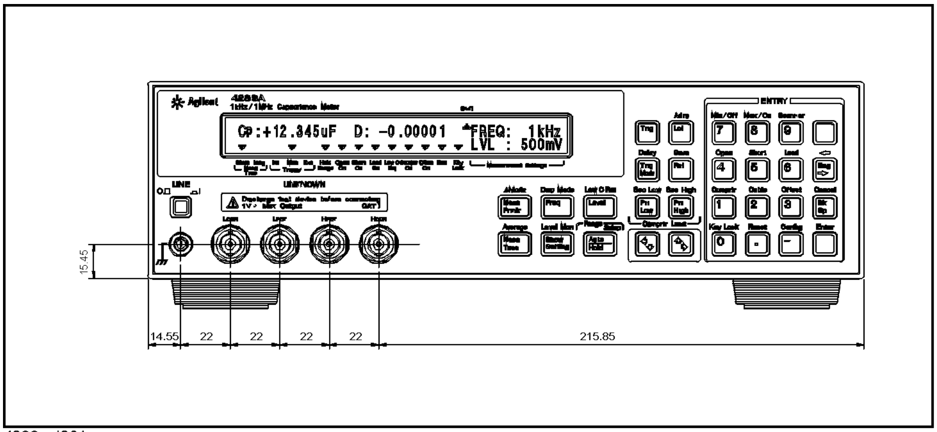

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Figure 12-8 Rear view

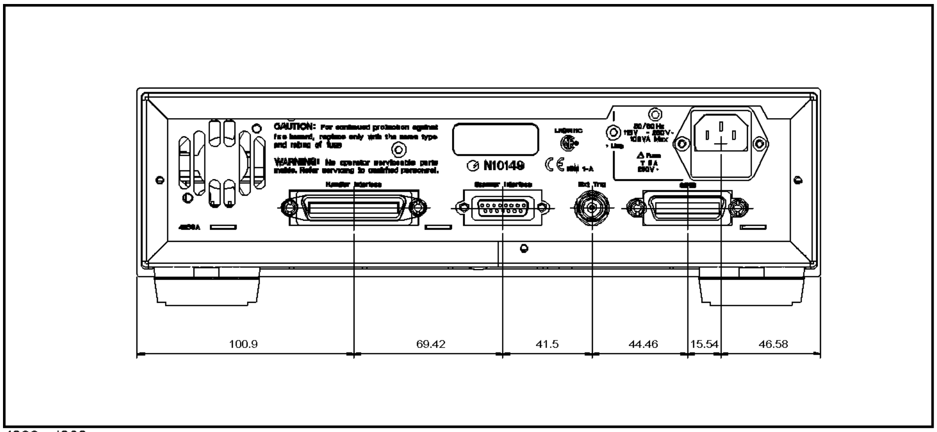

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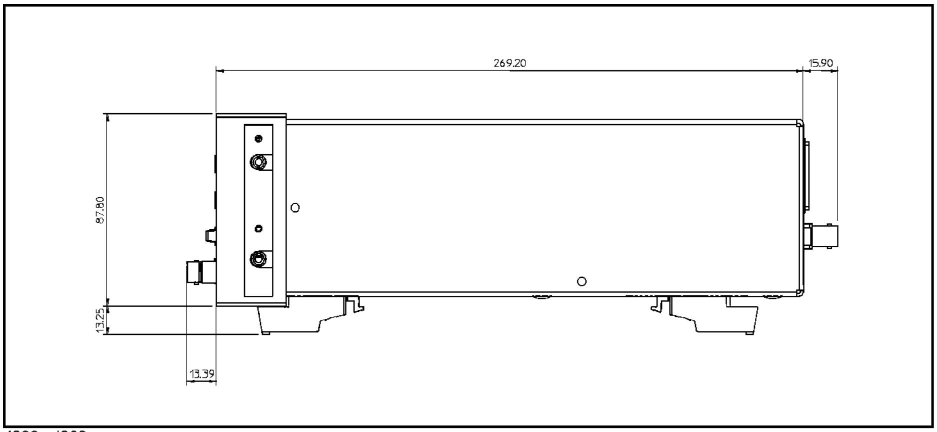
Figure 12-9 Side view



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EMC

ISM 1-A	European Council Directive 89/336/EEC IEC 61326-1:1997+A1 CISPR 11:1990 / EN 55011:1991 Group 1, Class A IEC 61000-4-2:1995 / EN 61000-4-2:1995 4 kV CD / 4 kV AD IEC 61000-4-3:1995 / EN 61000-4-3:1996 3 V/m, 80-1000 MHz, 80% AM IEC 61000-4-4:1995 / EN 61000-4-4:1995 1 kV power / 0.5 kV Signal IEC 61000-4-5:1995 / EN 61000-4-5:1995 0.5 kV Normal / 1 kV Common IEC 61000-4-6:1996 / EN 61000-4-6:1996 3 V, 0.15-80 MHz, 80% AM IEC 61000-4-11:1994 / EN 61000-4-11:1994 100% 1cycle Note: When tested at 3 V/m according to IEC 61000-4-3:1995/EN 61000-4-3:1996, measurement accuracy is double the accuracy of the basic specification when the test frequency is 1 kHz and the instrument measurement range is 100 pF.
ICES/NMB-001	This ISM device complies with Canadian ICES-001. Cet appareil ISM est conforme à la norme NMB-001 du Canada.
N10149	AS/NZS 2064.1/2 Group 1, Class A

Safety

ISM 1-A	European Council Directive 73/23/EEC IEC 61010-1:1990+A1+A2/EN 61010-1:1993+A2 INSTALLATION CATEGORY II, POLLUTION DEGREE 2 INDOOR USE IEC60825-1:1994 CLASS 1 LED PRODUCT
LR95111C	CAN/CSA C22.2 No. 1010.1-92

Sample Calculation of Measurement Accuracy

This section describes an example of calculating the measurement accuracy for each measurement parameter, assuming the following measurement conditions:

Measurement signal frequency	1 kHz
Measurement signal level	0.5 V
Measurement range	10 nF
Measurement time mode	Short mode
Ambient temperature	28°C

When measurement parameter is Cp-D (or Cs-D)

The following is an example of calculating the accuracy of Cp (or Cs) and D, assuming that measured result of Cp (or Cs) is 8.00000 nF and measured result of D is 0.01000.

From Table 12-4, the equation to calculate the accuracy of Cp (or Cs) is 0.055+0.030×K and the equation to calculate the accuracy of D is 0.00035+0.00030×K. The measurement signal level is 0.5, the measurement range is 10 nF, and the measured result of Cp (or Cs) is 8.00000 nF. Therefore, K=(1/0.5)×(10/8.00000) =2.5. Substitute this result into the equation. As a result, the accuracy of Cp (or Cs) is 0.055+0.030×2.5=0.13% and the accuracy of D is 0.00035+0.00030×2.5=0.0011.

Therefore, the true Cp (or Cs) value exists within 8.00000±(8.00000×0.13/100)= 8.00000±0.0104 nF, that is, 7.9896 nF to 8.0104 nF, and the true D value exists within 0.01000±0.0011, that is, 0.0089 to 0.0111.

When measurement parameter is Cp-Q (or Cs-Q)

The following is an example of calculating the accuracy of Cp (or Cs) and Q, assuming that measured result of Cp (or Cs) is 8.00000 nF and measured result of Q is 20.0.

The accuracy of Cp (or Cs) is the same as that in the example of Cp-D.

From Table 12-4, the equation to calculate the accuracy of D is 0.00035+0.00030×K. Substitute K=2.5 (same as Cp-D) into this equation. The accuracy of D is 0.00035+0.00030×2.5=0.0011. Then, substitute the obtained D accuracy into Equation 12-1. The accuracy of Q is $\pm(20.0)^2 \times 0.0011/(1 \mp 20.0 \times 0.0011) = \pm 0.44/(1 \mp 0.022)$, that is, -0.43 to 0.45.

Therefore, the true Q value exists within the range of 19.57 to 20.45.

When measurement parameter is Cp-G

The following is an example of calculating the accuracy of Cp and G, assuming that measured result of Cp is 8.00000 nF and measured result of G is 1.00000 µS.

The accuracy of Cp is the same as that in the example of Cp-D.

From Table 12-4, the equation to calculate the accuracy of G is (3.5+2.0×K)×Cx. Substitute K=2.5 (same as Cp-D) and 8.00000 nF of the measured Cp result into this equation. The accuracy of G is (3.5+2.0×2.5)×8.00000=68 nS(0.068 µS).

Therefore, the true G value exists within 1.00000±0.068 µS, that is, 0.932 µS to 1.068 µS.

When measurement parameter is Cp-Rp

The following is an example of calculating the accuracy of Cp and Rp, assuming that measured result of Cp is 8.00000 nF and measured result of Rp is 2.00000 MΩ.

The accuracy of Cp is the same as that in the example of Cp-D.

From Table 12-4, the equation to calculate the accuracy of G is (3.5+2.0×K)×Cx. Substitute K=2.5 (same as Cp-D) and 8.00000 nF of the measured Cp result into this equation. The accuracy of G is (3.5+2.0×2.5)×8.00000=68 nS. Then, substitute the obtained G accuracy into Equation 12-2. The accuracy of Rp is

$\pm(2\times10^{6})^{2}\times68\times10^{-9}/(1\mp2\times10^{6}\times68\times10^{-9})=\pm0.272\times10^{6}/(1\mp0.136)$, that is, -0.23944 MΩ to 0.31481 MΩ.

Therefore, the true Rp value exists within 1.76056 MΩ to 2.31481 MΩ.

When measurement parameter is Cs-Rs

The following is an example of calculating the accuracy of Cp and Rs, assuming that measured result of Cs is 8.00000 nF and measured result of Rs is 4.00000 kΩ.

Because the Cs accuracy is $D=2\times\pi\times Freq\times Cs\times Rp=2\times\pi\times10^{3}\times8\times10^{-9}\times4\times10^{3}=0.2>0.1$, multiply 0.13% (the result obtained for Cs-D) by $1+D^2$. The result is $0.13\times(1+0.2^2)=0.1352\%$.

From Table 12-4, the equation to calculate the accuracy of Rs is (90+50×K)/Cx. Substitute K=2.5 (same as Cs-D) and 8.00000 nF of the measured Cs result into this equation. The accuracy of G is (90+50×2.5)/8.00000=26.875 Ω. Because D>0.1, multiply the result by $1+D^2$ as in the case of Cs. The final result is 27.95 Ω.

Therefore, the true Cs value exists within 8.00000±(8.00000×0.1352/100)=8.00000±0.01082 nF, that is, 7.98918 nF to 8.01082 nF, and the true Rs value exists within 4.00000±0.02795 kΩ, that is, 3.97205 to 4.02795 kΩ.

13 Troubleshooting

This chapter lists items to check if you encounter a problem while using the Agilent 4288A. All of these items should be carefully investigated before you determine that your 4288A instrument is faulty.

Check Items When Trouble Occurs

The instrument does not start up (nothing is displayed).

- ❑ Check if the power cable is disconnected.
- ❑ Check if the fuse is blown.

  For how to check the fuse, refer to “Setting up the fuse” on page 21.

An overload message (OVLD) is displayed (when nothing is connected to the UNKNOWN terminal).

This is normal operation. An overload is often detected by the 4288A when nothing is connected to the UNKNOWN terminal.

Beeping persists when turning ON the comparator function.

- ❑ Check if the limit range is set up properly.

  When the beep is set up to sound when the comparator function is ON (initial setup), the beep sounds on every completion of measurement if the limit range is set up improperly.

The front panel keys are unavailable.

- ❑ Check if the keys are locked.

  If the keys are locked, the ▼ symbol is displayed above Key Lock in the instrument setup display area at the bottom of the display.

  To unlock the keys, press the **[Key Lock]**(**[Blue]** - **[0]**) key.

NOTE If the keys have been locked through the handler interface, you cannot unlock them by using the front panel keys. Set the /KEY_LOCK signal of the handler interface to HIGH.

NOTE If the keys are locked through GPIB, you cannot unlock them by using the front panel keys. Use the **:SYST:KLOC** GPIB command to unlock them.

- ❑ Check if the instrument is in the remote mode.

  If it is in the remote mode, the ▼ symbol is displayed above Rmt in the instrument setup display area at the bottom of the display.

  To clear the remote mode, press the **[Lcl]** key.

NOTE When the keys are locked, you cannot use the **[Lcl]** key. Therefore, first unlock the keys through GPIB and then press the **[Lcl]** key.

The measured value is abnormal.

- ❏ The measurement of compensation data may have failed.

  Measure the compensation data again. For how to measure the compensation data, refer to “Obtaining Compensation Data” on page 78.

- ❏ When the MULTI compensation is ON, check that the channel and the definition method of the LOAD standard value are selected correctly.

An error message or warning message is displayed.

For information on error messages and warning messages, refer to Appendix E.

Check Items When Trouble Occurs During Remote Control

The instrument does not respond to the external controller or malfunctions.

- ❏ Check that the GPIB address is set up correctly.
- ❏ Check that the GPIB cable is not disconnected.
- ❏ Check that the GPIB address is not the same as that of another instrument connected via the GPIB cable.
- ❏ Check that the GPIB cable connection is not looped.

You cannot read out the measured value.

- ❏ Check that the data transfer format is set up correctly.

An error message is displayed.

- ❏ Check that the program is correct.

  For details on error messages, refer to Appendix E.

A Manual Changes

This appendix contains the information required to adapt this manual to earlier versions or configurations of the Agilent 4288A than that indicated by the current printing date of this manual. The information in this manual applies directly to the 4288A model that has the serial number prefix listed on the title page of this manual.

Manual Changes

To adapt this manual to your Agilent 4288A, refer to Table A-1 and Table A-2.

Table A-1 Manual Changes by Serial Number

Serial Prefix or Number	Make Manual Changes

Table A-2 Manual Changes by Firmware Version

Version	Make Manual Changes
1.00	"Change 1" on page 177, "Change 2" on page 177
1.10	"Change 2" on page 177

Agilent Technologies uses a two-part, ten-character serial number that is stamped on the serial number plate (Figure A-1). The first five characters are the serial prefix and the last five digits are the suffix.

The firmware version is shown on the display immediately after the 4288A is turned on. You can also check the firmware version by the following procedure.

Step 1. Press the **[Config]** (**[Blue]** - **[–]**) key.

Step 2. Use the **[↑→]** key to make "Rev" blink and then press the **[Enter]** key.

Figure A-1 Serial Number Plate (Example)

4288aoj119

Change 1

The firmware revision 1.00 does not support the following function. Please delete the description of this function in the manual.

- External test

Change 2

The firmware revisions 1.00 and 1.10 do not support the following functions. Please delete the descriptions of these functions in the manual.

- Displaying compensation data in the instrument setup display area
- Selecting parameter format of OPEN/SHORT compensation data

Manual Changes

B Functional Comparison between 4278A and 4288A

This appendix provides a table showing a functional comparison between the Agilent 4278A and the Agilent 4288A. For a detailed comparison of each function, refer to the *Programming Manual*.

Functional Comparison between 4278A and 4288A

Table B-1 compares the functions of the 4278A and the 4288A.

Table B-1 Functional comparison between 4278A and 4288A

Function			4278A	4288A
Reset			Can be executed using GPIB command.	Can be executed using the **front panel** or GPIB command.
Measurement parameter			Selectable from Cp-D, Cp-Q, Cp-G, Cs-D, Cs-Q, or Cs-Rs.	Selectable from Cp-D, Cp-Q, Cp-G, **Cp-Rp**, Cs-D, Cs-Q, or Cs-Rs.
Measurement signal	Measurement frequency		Selectable from 1 kHz or 1 MHz.	Selectable from 1 kHz or 1 MHz.
	Frequency shift (1 MHz)		Can be changed to +2%, +1%, or -1% depending on **configuration options**.	Can be changed to +2%, +1%, or -1% by **setup change using the software**.
	OSC level (measurement signal level)		Can be set up within the range of 0.1 to 1 V in steps of 0.1 V.	Can be set up within the range of 0.1 to 1 V in steps of 0.1 V.
	Level monitor function		**N/A**	**Voltage value and current value can be monitored.**
Measurement range	Range mode		Selectable from the auto range or hold range.	Selectable from the auto range or hold range.
	When measurement frequency is 1 kHz:		Selectable from 100 pF, 1 nF, 10 nF, 100 nF, 1 µF, 10 µF, or **100 µF**.	Selectable from 100 pF, **220 pF**, **470 pF**, 1 nF, **2.2 nF**, **4.7 nF**, 10 nF, **22 nF**, **47 nF**, 100 nF, **220 nF**, **470 nF**, 1 µF, **2.2 µF**, **4.7 µF**, or 10 µF.
	When measurement frequency is 1 MHz:	For normal measurement	Selectable from 1 pF, **2 pF**, **4 pF**, **8 pF**, **16 pF**, **32 pF**, **64 pF**, **128 pF**, **256 pF**, **512 pF**, or **1024 pF**.	Selectable from 1 pF, **2.2 pF**, **4.7 pF**, **10 pF**, **22 pF**, **47 pF**, **100 pF**, **220 pF**, **470 pF**, or **1 nF (1000 pF)**.
		For high-accuracy measurement (HI-ACC mode)	±30% relative to the center value that you can specify freely	No HI-ACC mode
Fundamental accuracy (in long mode)	When measurement frequency is 1 kHz:		C: 0.10%, D: 0.0006	C: 0.07%, D: 0.0005
	When measurement frequency is 1 MHz:		C: 0.12%, D: 0.0008	C: 0.07%, D: 0.0005
High-accuracy measurement (HI-ACC) mode (when the measurement frequency is 1 MHz)			**Available**	**N/A**
Integration time (measurement time)			Selectable from Short (6.5 ± 0.5 ms), **Medium** (10.0 ± 1 ms), or Long (21.0 ± 1 ms).	Selectable from Short (6.5 ± 0.5 ms) or Long (16.5 ± 1 ms).
Averaging count			Can be set up at increments within the range of 1 to 256 **(1, 2, 4, 8, 16, 32, 64, 128, and 256 only)**.	Can be set up **freely** within the range of 1 to 256.
Delay time (trigger delay time)			Can be set up within the range of 0 to 1 s in steps of 1 ms.	Can be set up within the range of 0 to 1 s in steps of 1 ms.
Trigger mode			Selectable from the internal trigger (INT), external trigger (EXT), or manual trigger (MAN).	Selectable from the internal trigger (INT), external trigger (EXT), **GPIB trigger (BUS)**, or manual trigger (MAN).

Table B-1 Functional comparison between 4278A and 4288A

Function			4278A	4288A
Cable length			Selectable from 0 m, 1 m, or 2 m.	Selectable from 0 m, 1 m, or 2 m.
Compensation	OPEN compensation /SHORT compensation/ standard (LOAD) compensation	ON/OFF	OPEN compensation, SHORT compensation, and LOAD compensation can be turned ON/OFF separately.	OPEN compensation, SHORT compensation, and LOAD compensation can be turned ON/OFF separately.
		Input/output of measured compensation value (data for compensation)	GPIB command is available for readout.	GPIB command is available for readout and **setup**.
	Definition parameter of the reference value for LOAD compensation (the standard for AD compensation)		Selectable from Cp-D or Cp-G.	Selectable from Cp-D, **Cp-Q**, Cp-G, **Cp-Rp**, **Cs-D**, **Cs-Q**, or **Cs-Rs**.
	Offset compensation		Can be turned ON/OFF for each of the primary and secondary parameters **separately**.	Can be turned ON/OFF for both the primary and secondary parameters **simultaneously**. (Cannot be turned ON/OFF separately.)
	Temperature compensation		**Necessary**	**Not necessary**
Scanner (multi compensation)	Number of channels		**256** channels are available.	**64** channels are available.
	Reference value for LOAD compensation (Definition value of the standard for LOAD compensation)		A single reference value is shared by all of the channels.	A single reference value is shared by all of the channels, or **a different reference value is used for each channel**.
Comparator	Sorting target parameter		Selectable from Cp-D, Cp-Q, Cp-G, Cs-D, Cs-Q, Cs-Rs, **D-Cp**, **Q-Cp**, **G-Cp**, **D-Cs**, **Q-Cs**, or **Rs-Cs**.	Selectable from Cp-D, Cp-Q, Cp-G, **Cp-Rp**, Cs-D, Cs-Q, or Cs-Rs. (**Note that it is dependent on the measurement parameter and cannot be set up separately.**)
	Limit mode (limit range designation method)		Selectable from % tolerance mode, absolute tolerance mode, or **sequential mode**.	Selectable from % tolerance mode, absolute tolerance mode, or **absolute mode**.
	BIN sorting	Primary parameter	Can be sorted into 9 BINs as well as OUT OF BINS.	Can be sorted into 9 BINs as well as OUT OF BINS.
		Secondary parameter	PASS/FAIL judgment is available.	PASS/FAIL judgment is available.
	AUX BIN function		Available	Available
	Low C reject function		The detection limit value can be set to **1%, 2%, 3%, 4%, 5%, and 6%**.	The detection limit value can be **freely** set within the range of 1 to 10%.
	BIN count function		Can be counted up to 999999.	Can be counted up to 999999.

Functional Comparison between 4278A and 4288A

Table B-1 Functional comparison between 4278A and 4288A

Function		4278A	4288A
Display	Display format	Selectable from 4 types: measured value display format (MEAS PAGE), sort display format (SORT PAGE), compensation value display format (STATUS PAGE), or limit table display format (LIMIT PAGE). The entire display is changed depending on the selected format.	Only 1 display format but 2 distinct display areas: the main display area on the left shows measured values and instrument settings, which are indicated by the ▼ symbol; the display area on the right can be used to show a variety of other measurement settings.
	Number of display digits	Selectable from 4, 5, or 6 digits.	Selectable from 4, 5, or 6 digits.
	Fixed/floating point display selection	Fixed point display only	Selectable from fixed point display **or floating point display.**
	Display mode (deviation measurement mode)	For **the measured primary parameter value**: Selectable from MEAS display mode (the measured value is displayed as it is) or TOL display mode (displayed in a deviation relative to **the reference value for the tolerance mode of the comparator**).	For **the measured primary/ secondary parameter value**: Selectable from Deviation measurement mode OFF (the measured value is displayed as it is) or Deviation measurement mode ON (displayed in a deviation relative to **any reference value**).
Measured data output (GPIB)	Data output (data transfer) format	Selectable from ASCII format or binary (64-bit) format.	Selectable from ASCII format or binary (64-bit) format.
	Data that can be output	Measured primary/secondary parameter value, comparator sorting result, or BIN count value.	**Measurement status**, measured primary/secondary parameter value, comparator sorting result, BIN count value, or **measurement signal level monitor value**.
	Data buffer	Data for **500** measurements can be outputted in batch (only when the scanner interface is installed).	Data for **1000** measurements can be outputted in batch.
	Continuous data output (spew-out mode)	**Available**	**N/A** (The **:READ?** command is available as an alternative.)
Checking the instrument setup states (readout)		Can be read out **in batch using the *LRN? command**.	Can be read out **individually using each setup command**.
Save/recall		**1 setup** can be stored in **the memory card**.	**10 setups** can be stored in **EEPROM**.
Resume function		**N/A**	**72-hour retention time.**
Key lock function		Available	Available

C Initial Settings

This appendix provides initial settings, settings that can be saved/recalled, and settings that can be backed up.

Initial Settings, Settings that can be Saved/Recalled, Settings that can be Backed Up

The columns of Table C-1 show the following items.

- Initial settings (factory settings)
- Settings reset from the front panel or the GPIB by the **:SYST:PRES** command
- Settings reset from the GPIB by the ***RST** command
- Settings that can be saved/recalled

  Table C-1 uses the following symbols.

  ●: Settings that can be saved/recalled

  ×: Settings that cannot be saved/recalled

- Settings that can be backed up

  Table C-1 uses the following symbols.

  ❍: Settings that can be backed up in the back-up memory (maximum 72 hours)

  ●: Settings that can be backed up in the EEPROM

  ×: Settings that cannot be backed up

The symbol "←" in Table C-1 indicates that the value is the same as that indicated to the left.

Table C-1 Initial settings, settings that can be saved/recalled, settings that can be backed up

Setting items				Initial settings (factory settings)	Reset: Front panel key (:SYST:PRES)	Reset: *RST	Save/Recall	Backup
Measurement parameter	Primary parameter			CP	←	←	●	❍
	Secondary parameter			D	←	←	●	❍
Measurement signal	Frequency			1 kHz	←	←	●	❍
	Level			1 V	←	←	●	❍
	1 MHz frequency shift			0%	No effect	←	×	●
Measurement range	Ranging			Auto	←	←	●	❍
	Range setup			1 nF range	←	←	●	❍
Measurement time mode				LONG mode	←	←	●	❍
Averaging	ON/OFF			ON	←	←	●	❍
	Number of counts			1	←	←	●	❍
Cable length				0	←	←	●	●
Trigger	Mode			Int	←	←	●	❍
	Trigger delay time			0	←	←	●	❍
	Continuous activation (:INIT:CONT) ON/OFF			ON	←	OFF	×	×
OPEN compensation	ON/OFF			OFF	No effect	OFF	●	❍
	Compensation data	Primary parameter	1 kHz	0 S	No effect	0 S	●	●
			1 MHz	0 S	No effect	0 S	●	●
		Secondary parameter	1 kHz	0 S	No effect	0 S	●	●
			1 MHz	0 S	No effect	0 S	●	●
	Parameter type		Primary	G	No effect	G	●	●
			Secondary	B	No effect	B	●	●
SHORT compensation	ON/OFF			OFF	No effect	OFF	●	❍
	Compensation data	Primary parameter	1 kHz	0 Ω	No effect	0 Ω	●	●
			1 MHz	0 Ω	No effect	0 Ω	●	●
		Secondary parameter	1 kHz	0 Ω	No effect	0 Ω	●	●
			1 MHz	0 Ω	No effect	0 Ω	●	●
	Parameter type		Primary	R	No effect	R	●	●
			Secondary	X	No effect	X	●	●
LOAD compensation	ON/OFF			OFF	No effect	OFF	●	❍
	Compensation data	Primary parameter	1 kHz	100 nF	No effect	100 nF	●	●
			1 MHz	100 pF	No effect	100 pF	●	●
		Secondary parameter	1 kHz	0	No effect	0	●	●
			1 MHz	0	No effect	0	●	●
	LOAD standard definition	Primary parameter	1 kHz	100 nF	No effect	100 nF	●	●
			1 MHz	100 pF	No effect	100 pF	●	●
		Secondary parameter	1 kHz	0	No effect	0	●	●
			1 MHz	0	No effect	0	●	●
	Parameter type		Primary	CP	No effect	CP	●	●
			Secondary	D	No effect	D	●	●
Offset compensation	ON/OFF			OFF	No effect	OFF	●	❍
	Compensation data	Primary parameter	1 kHz	0 F	No effect	0 F	●	●
			1 MHz	0 F	No effect	0 F	●	●
		Secondary parameter	1 kHz	0	No effect	0	●	●
			1 MHz	0	No effect	0	●	●

Table C-1 Initial settings, settings that can be saved/recalled, settings that can be backed up

Setting items				Initial settings (factory settings)	Reset: Front panel key (:SYST:PRES)	Reset: *RST	Save/ Recall	Backup
Multi compensation	ON/OFF			OFF	No effect	OFF	●	❍
	Channel number			0	No effect	0	●	❍
	LOAD standard definition method (Single/Multi)			Single	No effect	Single	●	❍
Data transfer format				ASCII	←	←	×	×
Data buffer	Feeding target parameter			None	←	←	×	×
	Control (feed/not feed)			Not feed	←	←	×	×
	Size	Buffer 1 or Buffer 2		200	←	←	×	×
		Buffer 3		1000	←	←	×	×
Comparator	ON/OFF			OFF	←	←	●	❍
	Limit range ON/OFF	BIN1		ON	←	←	●	❍
		BIN2 to BIN9		OFF	←	←	●	❍
		Secondary parameter		ON	←	←	●	❍
	Limit range setting	Upper limit value		0	←	←	●	❍
		Lower limit value		0	←	←	●	❍
		Limit range designation method (mode selection)		ABS	←	←	●	❍
		Reference (nominal) value		0	←	←	●	❍
	AUX BIN ON/OFF			OFF	←	←	●	❍
	Low C reject	ON/OFF		OFF	←	←	●	❍
		Limit value		0%	←	←	●	❍
	BIN count	ON/OFF		OFF	←	←	●	❍
		Count value		0	←	←	×	×
Measurement signal level monitor		Current		OFF	←	←	●	❍
		Voltage		OFF	←	←	●	❍
Display	ON/OFF			ON	←	←	●	❍
	Number of digits			6	←	←	●	❍
	Fixed point display	ON/OFF		OFF	←	←	●	❍
		Value of the highest digit (Msd)	Primary parameter	1 nF	←	←	●	❍
			Secondary parameter	1	←	←	●	❍
	Deviation measurement mode	ON/OFF		OFF	←	←	●	❍
		Mode		DEV	←	←	●	❍
		Reference value		0	←	←	●	❍
	Page number of instrument setup display area			1	←	←	●	❍
Key lock ON/OFF				OFF	No effect	OFF	×	×
Beeper		ON/OFF		ON	←	←	●	❍
		Mode		FAIL	←	←	●	❍
Standard event status enable register value				0	No effect	←	×	×
Service request enable register value				0	No effect	←	×	×
Operation status enable register value				0	←	←	×	×
GPIB address				17	No effect	←	×	●

NOTE The OPEN/SHORT/LOAD compensation data and the LOAD standard definition settings for multi-compensation are not reset regardless of the resetting method used.

D At-a-glance Table of Operations When Overload or Low C is Detected

This appendix describes display output, GPIB output, and handler interface output when an overload or Low C is detected.

Operations When Overload/Low C is Detected

Table D-1 shows operations of the 4288A when one of the following problems is detected:

- ❑ Overload:
  - When the available measurement range is exceeded by more than 18% (refer to Table 12-2 on page 155 and Table 12-3 on page 155)
  - When nothing is connected to the UNKNOWN terminal
- ❑ Low C:
  - When result of primary parameter measurement is equal to or less than the boundary value specified for the Low C reject function
- ❑ Out of display range:
  - When measured result exceeds the allowable display range (refer to Table 12-1 on page 154), regardless of fixed or floating point display
  - When measured result exceeds the allowable display range for fixed point display

Table D-1 At-a-glance table of operations when overload/Low C reject is detected

	Display output			GPIB output			Handler output (handler signal that becomes active)
	Measured value	Voltage/ current monitor value	Comparator sorting result	Measurement status	Measured value	Comparator sorting result	
Overload	OVLD	***	****	1	9.9E37	11	/OVLD
Low C	Normal	Normal	LOWC	2	Normal	Normal	/LOW_C_REJECT*1
Out of display range*2	-------	---	Normal	Normal	Normal	Normal	Normal

*1. /LOW_C_REJECT becomes active together with a signal that corresponds to the result of normal sorting judgment (judgment result when no error occurs).
*2. When an out-of-display-range state is detected, measurement is performed normally but the measured values are not displayed.

E Error Messages

The Agilent 4288A provides error messages to indicate its operating status. This appendix describes the error messages of the 4288A in alphabetical order. To search error messages by error number, refer to the *Programming Manual*.

Error Messages (alphabetical order)

Error messages are displayed in the lower row of the 4288A's display. You can read them out by using the GPIB command. This section provides a description of each error message and its remedy.

NOTE Errors with a negative error number are basically general errors defined by IEEE488.2 for GPIB instruments. On the other hand, errors with a positive error number are defined specifically for the 4288A.

A

15 **A1 board test failed**

The A1 board test at power-on has failed.

If this error occurs, the 4288A makes a beep sound and stops. The hardware is at fault and needs repair.

Contact an Agilent Technologies sales office or the VAR from which you purchased the instrument.

16 **ADC failure**

A problem has occurred in the A/D converter during measurement.

If this error occurs, the 4288A makes a beep sound and stops. The hardware is at fault and needs repair.

Contact an Agilent Technologies sales office or the VAR from which you purchased the instrument.

B

-160 **Block data error**

An error not included in the error numbers between -161 and -169 has occurred during the syntax analysis of block data.

-168 **Block data not allowed**

A block data element has been received where the 4288A does not accept any block data element.

12 **BOOT ROM test failed**

The boot ROM test at power-on has failed.

If this error occurs, the 4288A makes a beep sound and stops. The hardware is at fault and needs repair.

Contact an Agilent Technologies sales office or the VAR from which you purchased the instrument.

C

18 **Calibration memory lost**

The calibration data in EEPROM has been lost at power-on.

If this error occurs, the 4288A makes a beep sound and stops. The hardware is at fault and needs repair.

Contact an Agilent Technologies sales office or the VAR from which you purchased the instrument.

-140 **Character data error**

An error not included in the error numbers between -141 and -149 has occurred during the syntax analysis of a character data element.

-148 **Character data not allowed**

A character data element (that does not violate the standard) has been received where the 4288A does not accept any character data element.

-144 **Character data too long**

The length of the character data element has exceeded 12 characters. (Refer to IEEE488.2,7.7.1.4.)

-100 **Command error**

A comprehensive syntax error has occurred for which the 4288A cannot detect further details of the error. This error code simply indicates the occurrence of a command error that is defined in IEEE488.2,11.5.1.1.4.

25 **Correction meas failed**

A measurement failure has occurred during measuring the compensation data.

If this error occurs, the compensation data before the measurement remains with no change.

Confirm that you have made the correct connection for measuring the compensation data and have performed the compensation procedure correctly.

D

-230 **Data corrupt or stale**

The data is invalid or a newly initiated read operation has not been completed since the latest access.

-222 **Data out of range**

A data element (that does not violate the standard) has been received out of the range defined for the 4288A.

-104 **Data type error**

The parser has recognized impossible data elements. For example, numeric value or string data is expected, but block data is sent.

E

14 **EEPROM test failed**

The EEPROM test at power-on has failed.

If this error occurs, the 4288A makes a beep sound and stops. The hardware is at fault and needs repair.

Contact an Agilent Technologies sales office or the VAR from which you purchased the instrument.

-200 **Execution error**

A comprehensive execution error has occurred for which the 4288A cannot detect further details. This error code simply indicates the occurrence of an execution error that is defined in IEEE488.2,11.5.1.1.5.

-123 **Exponent too large**

The absolute value of the exponent has exceeded 32,000. (Refer to IEEE488.2,7.7.2.4.1.)

-178 **Expression data not allowed**

An equation data element has been received where the 4288A does not accept any equation data element.

-170 **Expression error**

An error not included in the error numbers between -171 and -179 has occurred during the syntax analysis of equation data.

F

17 **Fan stopped**

The fan has stopped.

If this error occurs, the 4288A makes a beep sound and stops. The hardware is at fault and needs repair.

Contact an Agilent Technologies sales office or the VAR from which you purchased the instrument.

13 **FLASH ROM test failed**

The flash ROM test at power-on has failed.

If this error occurs, the 4288A makes a beep sound and stops. The hardware is at fault and needs repair.

Contact an Agilent Technologies sales office or the VAR from which you purchased the instrument.

G

-105 **GET not allowed**

A group execution trigger (GET) has been received in a program message. (Refer to IEEE488.2,7.7.)

H

-241 **Hardware missing**

The received command or Query complied with the standard but could not be executed due to hardware-related reasons (for example, an option was not installed).

I

-213 **Init ignored**

Another measurement has been being executed and the measurement start request (**:INIT** command) has been ignored.

-161 **Invalid block data**

Block data are expected, but the block data received are invalid for some reason. (Refer to IEEE488.2,7.7.6.2.) For example, the END message is received before the length of the block data is reached.

-101 **Invalid character**

Invalid characters have been found in the program message string. For example, in a correct program message "**:CALC1:FORM CP**", an ampersand (&) is inserted by mistake to give "**:CALC1:FORM&CP**".

-141 **Invalid character data**

Invalid characters have been found in a character data element or the received parameter is not valid. For example, though a correct program message was "**:CALC1:FORM CP**," a wrong program message, "**:CALC1:FORM RP**," was received.

-121 **Invalid character in number**

An invalid character for the data type of the syntax analysis target has been received. For example, alphabetical characters exist in a decimal value or "9" exists in octal data.

-171 **Invalid expression**

The equation data element is invalid. (Refer to IEEE488.2,7.7.7.2.) For example, parentheses are not paired or a character violates the standard.

-103 **Invalid separator**

The parser (syntax analysis program) expects a separator, but a character other than a separator has been sent. For example, although the correct way is to use ";" to separate two sent program messages such as "**:CALC1:FORM CP;*OPC?**", the semicolon (;) needed to separate the program messages is missing to give "**:CALC1:FORM CP *OPC?**".

-151 **Invalid string data**

Character string data are expected, but the string data received are invalid for some reason. (Refer to IEEE488.2,7.7.5.2.) For example, the END message is received before the end quotation mark character appears.

-131 **Invalid suffix**

The suffix does not meet the syntax defined in IEEE488.2,7.7.3.2 or is inappropriate for the 4288A.

L

23 **Lockout by handler**

Entry using the front panel keys has been disabled through the handler.

You cannot clear this state by using the front panel keys or GPIB command.

Set the /KEY_LOCK signal of the handler interface to HIGH.

M

-311 **Memory error**

An error has been detected in the memory of the 4288A.

-109 **Missing parameter**

The number of parameters is less than required by the command. For example, although the **:CREJ:LIM** command requires one parameter such as "**:CREJ:LIM 3**", no parameter is added to give "**:CREJ:LIM**".

N

0 **(No error)**

No error has occurred.

This message is not displayed on the LCD. 0 is returned as the error number if no error has occurred in the instrument when the **:SYST:ERR?** command is sent through GPIB.

-128 **Numeric data not allowed**

A numeric value data element (that does not violate the standard) has been received where the 4288A does not accept any numeric value data element.

P

-220 **Parameter error**

An error not included in the error numbers between -221 and -229 has occurred during the analysis of a program data element. This error occurs, for example, when you attempt to specify invalid values (values not finite when converted to an R-X format impedance value) as the LOAD correction data or LOAD correction reference data. If this error occurs, the command is ignored. This error also occurs when you attempt to specify an invalid LOAD correction reference value by using the front panel keys.

Parameter Type Setting		Values not finite when converted to an R-X format impedance value
Primary Parameter	Secondary Parameter	
Cp	D	Independent of D value, Cp is 0
Cp	Q	Independent of Q value, Cp is 0, also Independent of Cp value, Q is 0
Cp	G	Cp and G are both 0
Cp	Rp	Independent of Cp value, Rp is 0
Cs	D	Independent of D value, Cs is 0
Cs	Q	Independent of Q value, Cs is 0, also Q is 0 independent of Cs value
Cs	Rs	Cs is 0 independent of Rs value

-108 **Parameter not allowed**

The number of parameters is larger than required by the command. For example, although the **:CREJ:LIM** command requires one parameter such as "**:CREJ:LIM 3**", two parameters are added to give "**:CREJ:LIM 0,3**".

20 **Previous setting lost**

The instrument setup values in backup memory have been lost at power-on.

These values are initialized to the factory-shipped state. No beep sound is made. Possible causes include 72 hours or more elapsing since turning OFF the power or the hardware becoming faulty.

-112 **Program mnemonic too long**

The length of the header exceeds 12 characters. (Refer to IEEE488.2,7.6.1.4.1.)

Q

-430 **Query DEADLOCKED**

This indicates the status that causes a "DEADLOCKED" Query error. (Refer to IEEE488.2,6.3.1.7.) This error occurs, for example, when both input and output buffers become full and the 4288A cannot continue processing.

-400 **Query error**

A comprehensive Query error has occurred for which the 4288A cannot detect further details. This code simply indicates the occurrence of a Query error that is defined in IEEE488.2,11.5.1.1.7 and 6.3.

-410 **Query INTERRPUTED**

This indicates the status that causes an "INTERRUPTED" Query error. (Refer to IEEE488.1,6.3.2.3.) This error occurs, for example, when data byte (DAB) or GET is received after Query but before the response has been completely sent.

-420 **Query UNTERMINATED**

This indicates the status that causes an "UNTERMINATED" Query error. (Refer to IEEE488.2,6.3.2.) This error occurs, for example, when the 4288A is specified as a talker and an incomplete program message is received.

-440 **Query UNTERMINATED after indefinite response**

In a certain program message, a Query that requests an ambiguous response has not yet been completely executed when a different Query is received. (Refer to IEEE488.2,6.5.7.5.7.)

-350 **Queue overflow**

The queue contains a certain code other than the code that caused this error. This indicates that an error has occurred due to insufficient space in the queue but has not been recorded.

R

11 **RAM test failed**

The RAM test at power-on has failed.

If this error occurs, the 4288A makes a beep sound and stops. The hardware is at fault and needs repair.

Contact an Agilent Technologies sales office or the VAR from which you purchased the instrument.

22 **Recall failed**

Recalling the instrument setup from EEPROM has failed.

This error occurs when no instrument setup has been saved in the specified register on EEPROM. The instrument setup does not change and stays in the state as before executing the recall.

Confirm that you specified the correct register number when executing the recall.

S

21 **Save failed**

Saving the instrument setup into EEPROM has failed.

Although the 4288A will not stop due to this error, the hardware is at fault and needs repair.

Contact an Agilent Technologies sales office or the VAR from which you purchased the instrument.

-221 **Setting conflict**

A program data element complying with the syntax standard has been analyzed, but the 4288A cannot execute it at present.

-150 **String data error**

An error not included in the error numbers between -151 and -159 has occurred during the syntax analysis of a string data element.

-158 **String data not allowed**

A string data element has been received where the 4288A does not accept any string data element. For example, a parameter must be enclosed with double quotation marks ("...") but they are missing.

-138 **Suffix not allowed**

A suffix has been added to a numeric value element that does not permit a suffix.

-102 **Syntax error**

There is a command or data type that cannot be recognized. For example, in the program message "**:SYST:PRES**", a colon (:) is inserted by mistake to give "**:SYST::PRES**".

-310 **System error**

One of the "system errors" defined for the 4288A occurs.

T

-124 **Too many digits**

The number of digits of the mantissa of the decimal value data element exceeds 255 except for preceding 0s. (Refer to IEEE488.27.7.2.4.1.)

-223 **Too much data**

The received block, equation, or string type program data complies with the standard, but the amount of data exceeds the limit that the 4288A can handle due to memory or device-specific conditions related to memory.

-214 **Trigger deadlock**

Indicates that the **:READ?** command was ignored because the trigger source setting was MAN or BUS.

-211 **Trigger ignored**

A trigger command or trigger signal has been received and recognized by the 4288A, but it is ignored due to the timing relationship with the 4288A. For example, this happens when the 4288A's trigger system is not in the Waiting for Trigger state.

U

-113 **Undefined header**

A header not defined for the 4288A has been received. For example, "**`*XYZ`**", which is not defined for the 4288A, is received.

19 **User data lost**

The compensation data in EEPROM has been lost at power-on.

The compensation data is initialized to the factory-shipped state. Possible causes include the hardware being at fault or the power being turned OFF during write to EEPROM.

Contact an Agilent Technologies sales office or the VAR from which you purchased the instrument.

Warning Messages (WARNING)

Warning messages are displayed to warn users. They are displayed in the lower row of the display of the 4288A. You cannot read them out using the GPIB command.

WARNING: Need corr meas

When the OPEN compensation, SHORT compensation or LOAD compensation is ON, this is displayed when you change the setup of the cable length or measurement frequency shift (1 MHz). In this case, the OPEN compensation, SHORT compensation and LOAD compensation are automatically turned OFF.

WARNING: Need load meas

This is displayed when you turn ON the LOAD compensation from the front panel although the setups of the cable length and measurement frequency shift (1 MHz) differ from those when measuring/setting up the LOAD compensation data. In this case, the LOAD compensation is turned ON, but you need to measure the LOAD compensation data again for accurate measurement.

WARNING: Need open meas

This is displayed when you turn ON the OPEN compensation from the front panel although the setups of the cable length and measurement frequency shift (1 MHz) differ from those when measuring/setting up the OPEN compensation data. In this case, the OPEN compensation is turned ON, but you need to measure the OPEN compensation data again for accurate measurement.

WARNING: Need short meas

This is displayed when you turn ON the SHORT compensation from the front panel although the setups of the cable length and measurement frequency shift (1 MHz) differ from those when measuring/setting up the SHORT compensation data. In this case, the SHORT compensation is turned ON, but you need to measure the SHORT compensation data again for accurate measurement.

WARNING: Out of limit

This is displayed if the compensation data is out of the valid range when measuring the compensation data. The valid range for each type of compensation is as follows.

Type of compensation	Valid range
OPEN compensation	$|Y| < 20\ \mu S$
SHORT compensation	$|Z| < 20\ \Omega$
LOAD compensation	$|Zref| \times 0.9 < |Z| < |Zref| \times 1.1$

In the above table, Y is the measured admittance value, Z is the measured impedance value, and Zref is the LOAD compensation standard definition value.

F Test Fixtures/Test Leads

This appendix lists available test fixtures and test leads for the Agilent 4288A.

Test Fixtures/Test Leads

Agilent 16034E	SMD/Chip Test Fixture
Agilent 16034G	SMD/Chip Test Fixture, Small
Agilent 16034H	SMD/Chip Test Fixture, General
Agilent 16044A	SMD/Chip Test Fixture, Four-terminal, 10 MHz
Agilent 16047A	Axial and Radial Test Fixture
Agilent 16047C	Axial and Radial Test Fixture
Agilent 16047D	Axial and Radial Test Fixture
Agilent 16047E	Axial and Radial Test Fixture, 110 MHz
Agilent 16048A	One Meter Test Leads, BNC
Agilent 16048B	One Meter Test Leads, SMC
Agilent 16048D	Two Meter Test Leads, BNC
Agilent 16065A	External Voltage Bias with Safety Cover (≤200 Vdc)
Agilent 16065C	External Bias Adapter (≤40 Vdc)
Agilent 16085B	Four-Terminal Pair to 7-mm Adapter
Agilent 16089A/B/C/D/E	Kelvin Clip Leaders
Agilent 16092A[*1]	RF Spring Clip: Axial, Radial and SMD
Agilent 16093A[*1]	RF Two-Terminal Binding Post
Agilent 16093B[*1]	RF Three-Terminal Binding Post
Agilent 16094A[*1,*2]	RF Probe Tip/Adapter
Agilent 16094A[*3]	LF Impedance Probe
Agilent 16191A[*1]	Side Electrode SMD Test Fixture
Agilent 16192A[*1]	Parallel Electrode SMD Test Fixture
Agilent 16193A[*1]	Small Side Electrode SMD Test Fixture
Agilent 16194A[*1]	High Temperature Component Test Fixture
Agilent 16196A/B/C[*1]	Parallel Electrode SMD Test Fixture
Agilent 16314A	Four-Terminal Balun
Agilent 16334A	SMD/Chip Tweezers
Agilent 16451B	Dielectric Material Test Fixture
Agilent 16452A	Liquid Test Fixture

*1. Compatible when used in conjunction with the 16085B.
*2. 7-mm to 7-mm cable is required.
*3. Do not connect the ground lead to the 4288A.

NOTE Refer to the most recent accessories catalogue for the latest information.

G Technical Information

This chapter provides technical information on the operating principles of the 4288A and the basic principles of capacitance measurement.

Measurement Principle

This section explains the underlying principle of how the 4288A is used to measure the impedance of a DUT.

Figure G-1 **Circuit Model of Impedance Measurement**

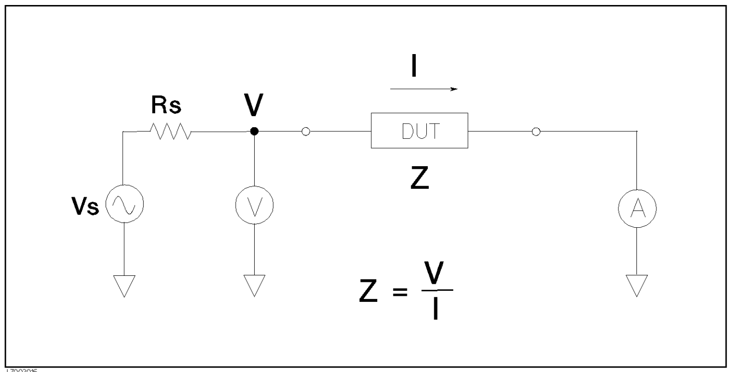
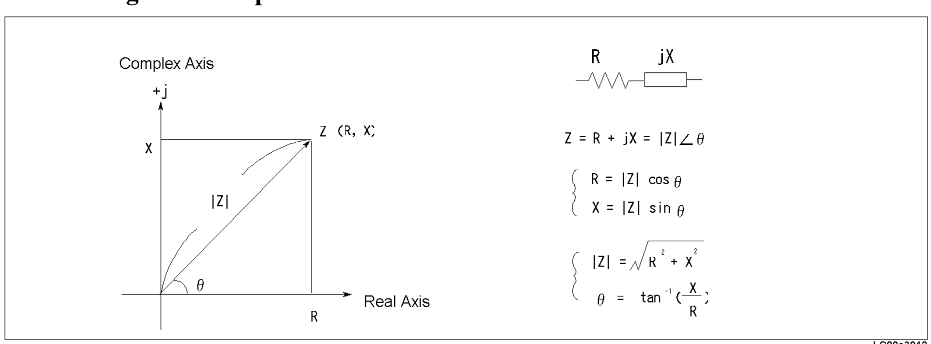


Figure G-1 illustrates the circuit model of impedance measurement using the 4288A. Vs is the measurement power supply voltage, and Rs is the output resistance of the 4288A. When voltage applied to a DUT is V and current flowing through the DUT is I, impedance Z is expressed by the equation Z = V/I.

Z consists of a real part and an imaginary part. Figure G-2 shows the vector diagram of impedance.

Figure G-2 **Vector Diagram of Impedance**

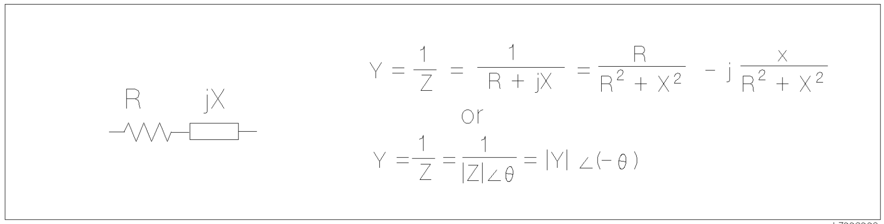


Symbols used in Figure G-2 have the following meanings:

R	Resistance
X	Reactance
|Z|	Absolute value of impedance
θ	Phase of impedance

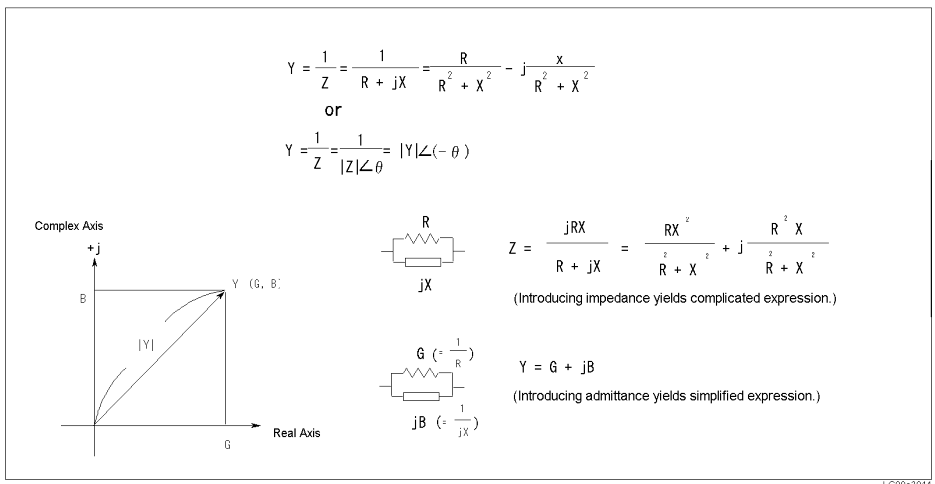
Another way to express impedance Z is the use of admittance Y. The relationship between admittance Y and impedance Z is Y = 1/Z.

Figure G-3 **Relationship between Impedance and Admittance**



For a parallel connection, using admittance Y is more convenient.

Figure G-4 **Vector Diagram of Admittance**

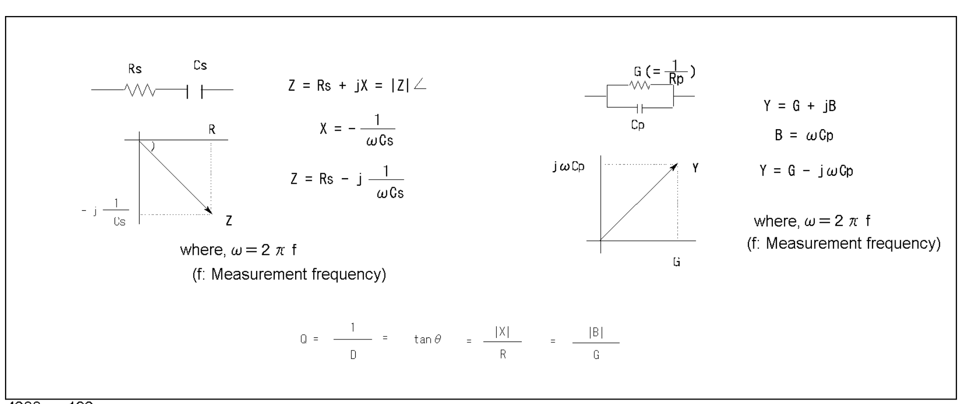


Symbols in Figure G-4 have the following meanings:

G	Conductance
B	Susceptance
|Y|	Absolute value of admittance

The 4288A measures the vector value of a DUT’s impedance Z and indicates the result as the circuit constants of the equivalent circuit shown in Figure G-5.

Figure G-5 **Relationship between Measurement Parameters**



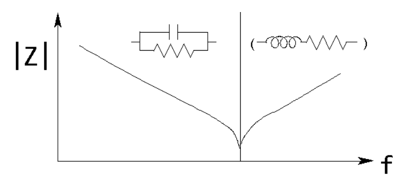
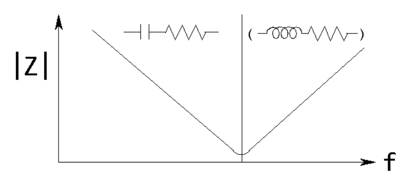
Basic Principles of Capacitance Measurement

This section explains the useful basics when measuring capacitance with the 4288A.

Typical characteristics of capacitance DUT

As shown in Table G-1, the impedance characteristics of capacitance components change depending on the actual operating conditions. Therefore, to measure impedance accurately, it is necessary to take measurements under the actual operating conditions in which the component is used.

Table G-1 **Typical Characteristics of Capacitance DUT**

DUT	Example of Characteristics	Measurement function
Small C		Cp-D, Cp-Q, Cp-G, Cp-Rp
Large C		Cs-D, Cs-Q, Cs-Rs

Selection criteria of parallel/series equivalent circuit models

There are two equivalent circuit models used for capacitance measurement: parallel mode and series mode, as shown in Table G-2. You must select one of these before measurement, depending on the magnitude of reactance and the effect of the equivalent parallel resistance (Rp) and equivalent series resistance (Rs) on it.

Table G-2 Parallel/Series Equivalent Circuit Models and Measurement Functions of the 4288A

Circuit model	Measurement function of 4288A	Definition of D, Q, G
Parallel equivalent circuit model	Cp-D, Cp-Q, Cp-G, Cp-Rp	D = 1/(|2πfCp|Rp) Q = 1/D = |2πfCp|Rp G = 1/Rp
Series equivalent circuit model	Cs-D, Cs-Q, Cs-Rs	D = |2πfCs|Rs Q = 1/D = 1/(|2πfCs|Rs)

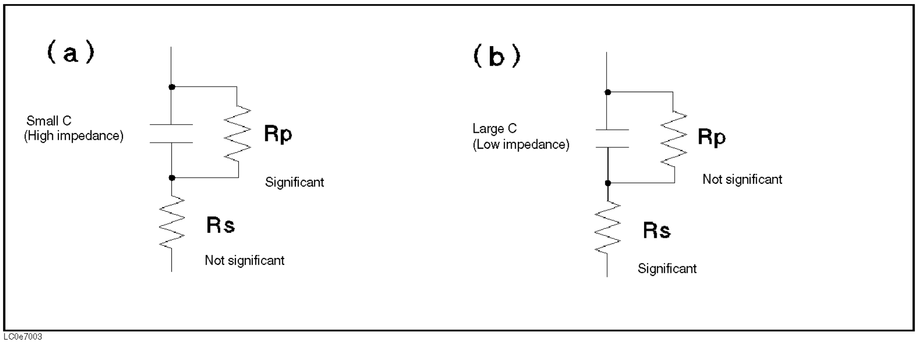
- ❑ When capacitance is small:

  When capacitance is small, reactance is large. Therefore, the effect of Rp is greater than that of Rs. When Rs is small, its effect can be neglected compared to capacitive reactance. In this case, use the parallel equivalent circuit model shown in Figure G-6 (a).

- ❑ When capacitance is large:

  When capacitance is large, reactance is small. Therefore, the effect of Rs is greater than that of Rp. In this case, use the series equivalent circuit model shown in Figure G-6 (b).

Figure G-6 Selection of Capacitance Measurement Circuit Model



G. Technical Information

Principle of four-terminal pair measurement

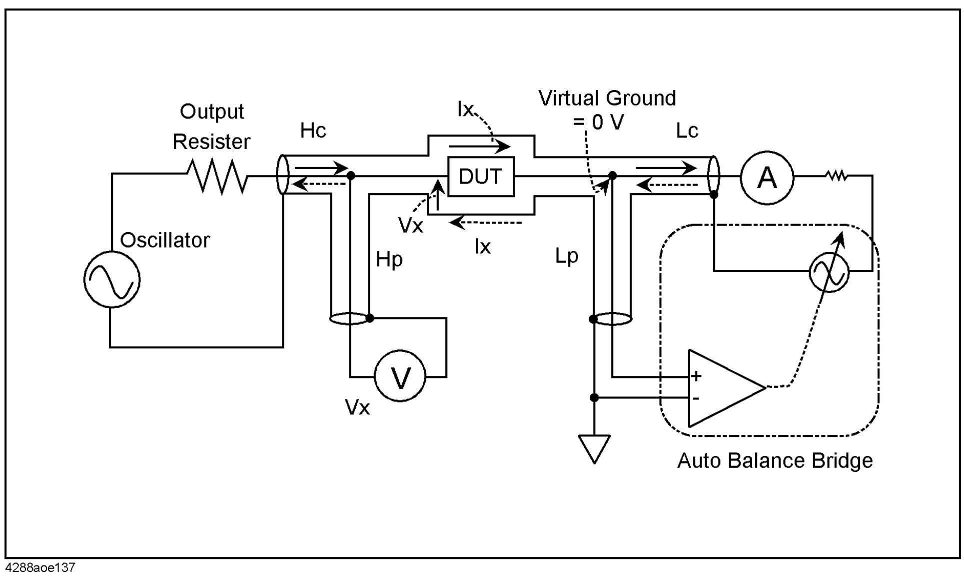
Generally, in connection methods using common terminal structures, mutual inductance, interference between measurement signals, and unnecessary residual elements (especially at higher frequencies) significantly affect measurements.

The 4288A adopts a four-terminal pair structure to reduce the limitations on measurements due to these factors and to facilitate stable and accurate measurements.

Figure G-7 illustrates the principle of four-terminal pair measurement. The UNKNOWN terminals are four coaxial connector terminals.

- H_{CUR}: Current high terminal
- H_{POT}: Voltage high terminal
- L_{POT}: Voltage low terminal
- L_{CUR}: Current low terminal

Figure G-7 Principle of Four-terminal Pair Measurement



The four-terminal pair measurement method has advantages in both low- and high-impedance measurements. The outer shield conductors serve as the return path of the measurement signal current (not grounded). Current of the same amplitude flows through the core conductor and the surrounding shield conductor in opposite directions, and therefore no external magnetic field occurs around either conductor. In other words, the magnetic field caused by the inner conductor and that caused by the outer conductor cancel each other completely. The measurement signal current does not cause any induction field and, therefore, the test leads do not increase the error due to their self-inductance or the mutual inductance between different leads.

Precautions for four-terminal pair measurement

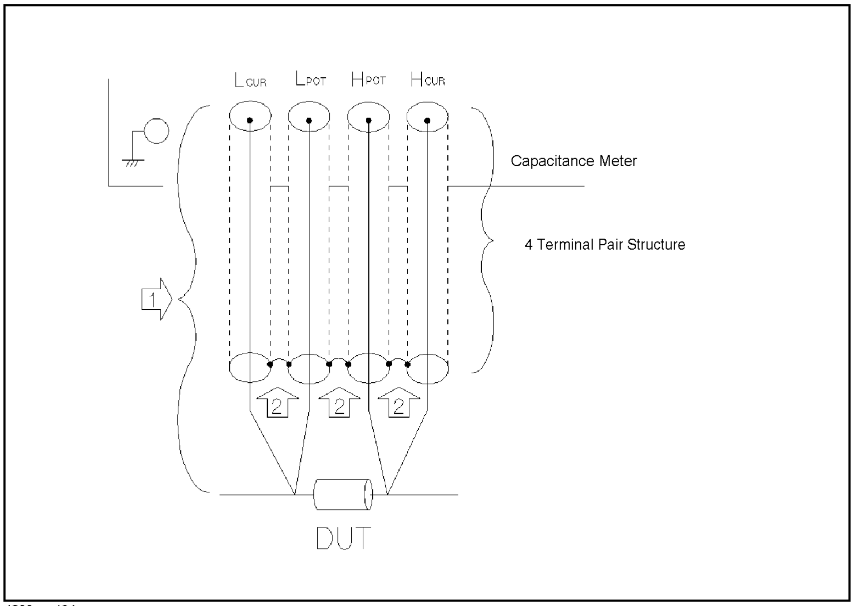
This section describes general precautions and techniques for using the four-terminal structure efficiently.

Measurement contacts

To ensure high accuracy when using the four-terminal pair measurement, the measurement contacts must meet the following requirements.

- Make the signal path between the capacitance meter and the DUT (indicated by 1 in Figure G-8) as short as possible.
- For a four-terminal pair measurement circuit configuration, the outer shields of the H_{CUR}, H_{POT}, L_{CUR}, and L_{POT} terminals must all be connected at the nearest possible point to the DUT. (Refer to 2 in Figure G-8.)

Figure G-8 **Measurement Contacts**

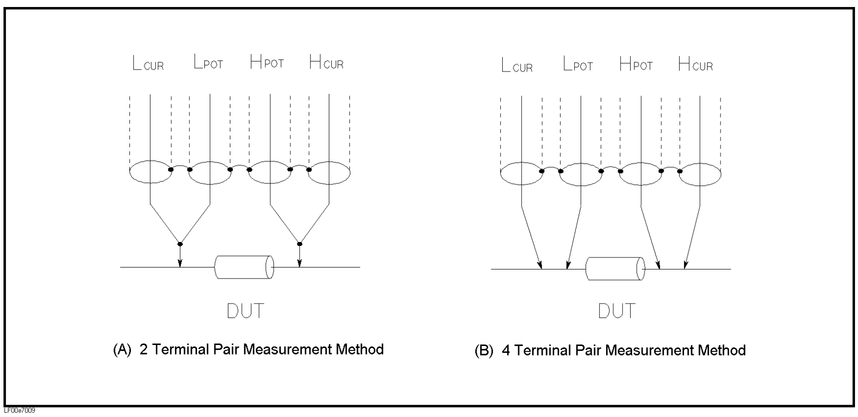


Contact resistance

Due to contact resistance between the DUT contacts and the DUT itself, a measurement error occurs when measuring large capacitance values, especially for measurement of D (dissipation factor).

For measurement of large capacitance values, the four-terminal pair measurement method has an advantage over the two-terminal method in that measurement errors are smaller. Select a four-terminal measurement test fixture that can secure the DUT to stabilize the connection and minimize contact resistance.

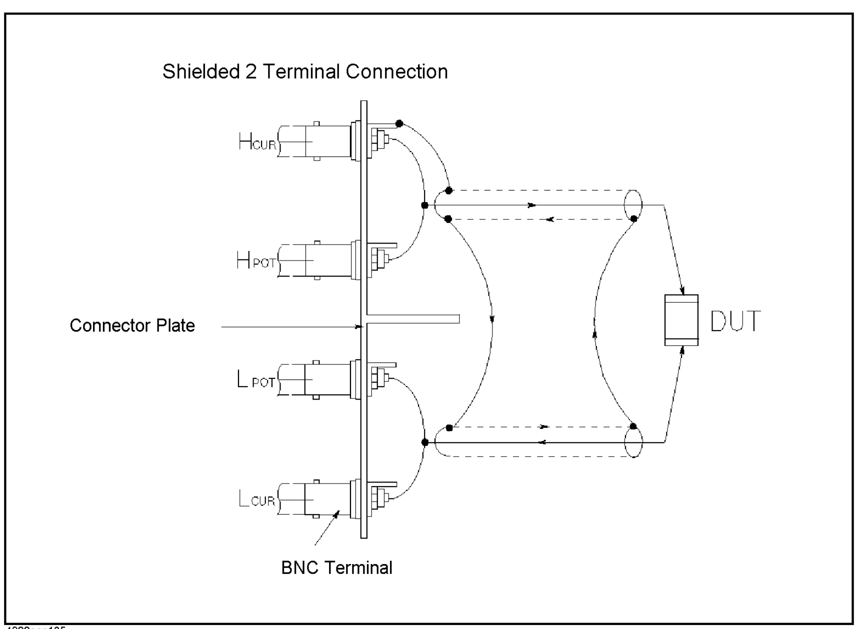
Figure G-9 **Configuration of Contacts**



Extending the test leads

If you cannot make measurement contact with the four-terminal pair structure, use the connection method shown in Figure G-10.

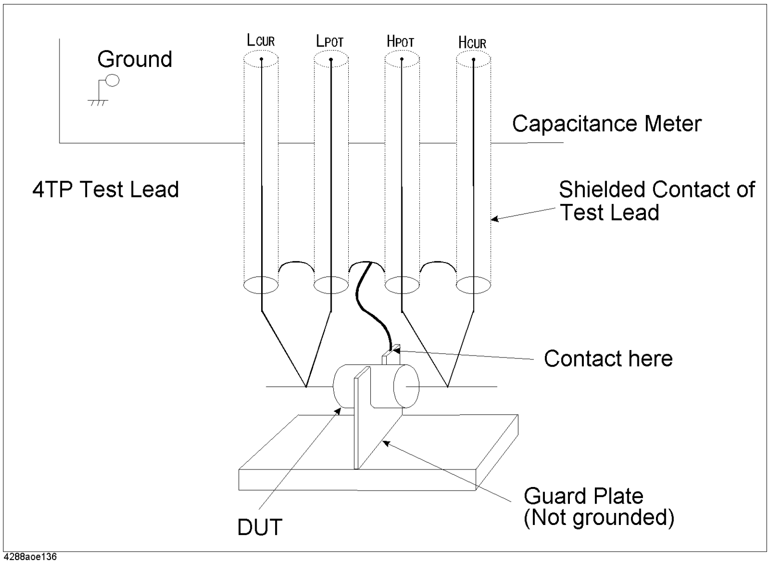
Figure G-10 **Measurement Contacts When Test Leads Are Extended**



Guarding when measuring small capacitance

When measuring small capacitance values, for example those of small-capacitance chip capacitors, use a guard plate to minimize measurement errors caused by stray capacitance. Figure G-11 shows an example of using a guard plate with the measurement contacts of a four-terminal pair structure.

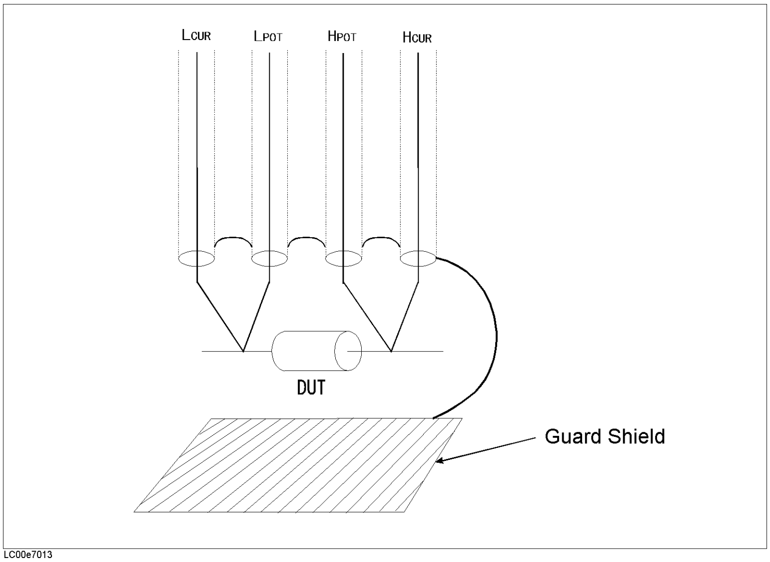
Figure G-11 **Example of Connecting Guard Plate to DUT**



Shield

By using a shield, the effect of electrical noise picked up by the test leads can be significantly decreased. Therefore, prepare a shield plate and connect it to the outer shield conductor of the four-terminal pair test leads, as shown in Figure G-12.

Figure G-12 **Guard Shield**



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