HP 4286A RF LCR Meter

Function Reference

SERIAL NUMBERS

This manual applies directly to instruments with serial number prefix JP3KC, or firmware revision 2.0x. For additional important information about serial numbers, read "Serial Number" in Appendix A.

HEWLETT® PACKARD

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Notice

The information contained in this document is subject to change without notice.

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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.

June, 1995 .... First Edition

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April, 1999 .... Forth Edition

Safety Summary

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

Note HP 4286A is designed for use in INSTALLATION CATEGORY II according to IEC 61010-1 and POLLUTION DEGREE 1 according to IEC 61010-1 and IEC 60664-1. HP 4286A is an INDOOR USE product.

Note LEDs in HP 4286A are Class 1 in accordance with IEC60825-1.
CLASS 1 LED PRODUCT

Ground The Instrument

To avoid electric shock hazard, the instrument chassis and cabinet must be connected to a safety earth ground by the supplied power cable with earth blade.

DO NOT Operate In An Explosive Atmosphere

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

Keep Away From Live Circuits

Operating personnel 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 voltages may exist even with the power cable removed. To avoid injuries, always disconnect power and discharge circuits before touching them.

DO NOT Service Or Adjust Alone

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

DO NOT Substitute Parts Or Modify Instrument

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

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

Safety Symbols

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

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

Alternating current.

Direct current.

On (Supply).

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 include all exposed metal structures.

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

Caution — This **Caution** sign denotes a hazard. It calls attention to a procedure, practice, condition or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the product.

Note — This **Note** sign denotes important information. It calls attention to a procedure, practice, condition or the like, which is essential to highlight.

Affixed to product containing static sensitive devices use anti-static handling procedures to prevent electrostatic discharge damage to component.

Certification

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

Warranty

This Hewlett-Packard instrument product is warranted against defects in material and workmanship for a period of one year from the date of shipment, except that in the case of certain components listed in *General Information* of this manual, the warranty shall be for the specified period. During the warranty period, Hewlett-Packard Company 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 HP. Buyer shall prepay shipping charges to HP and HP shall pay shipping charges to return the product to Buyer. However, Buyer shall pay all shipping charges, duties, and taxes for products returned to HP from another country.

HP warrants that its software and firmware designated by HP for use with an instrument will execute its programming instruction when property installed on that instrument. HP 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.

No other warranty is expressed or implied. HP 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. HP 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 Hewlett-Packard products.

For any assistance, contact your nearest Hewlett-Packard 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.
Italics	Italic type is used for emphasis and for titles of manuals and other publications.
	Italic type is also used for keyboard entries when a name or a variable must be typed in place of the words in italics. For example: `copy` *filename* means to type the word `copy`, to type a space, and then to type the name of a file such as `file1`.
`Computer`	Computer font is used for on-screen prompts and messages.
(HARDKEYS)	Labeled keys on the instrument front panel are enclosed in ▢.
SOFTKEYS	Softkeys located to the right of the CRT are enclosed in ▒.

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Introduction

Introduction

This chapter provides an overview of the HP 4286A system and descriptions of the main features of the LCR meter (also referred to as the mainframe). The system includes the LCR meter, test head, and test fixture stand. "HP 4286A features" include the front and rear panels and the three key blocks. "Front and Rear Panels" section provides information on the input/output connectors, the CRT, and other panel features. The three key block sections describe the keys and their associated menus and how they function together.

System Overview

The HP 4286A system is shown in Figure 1-1 and Figure 1-2.

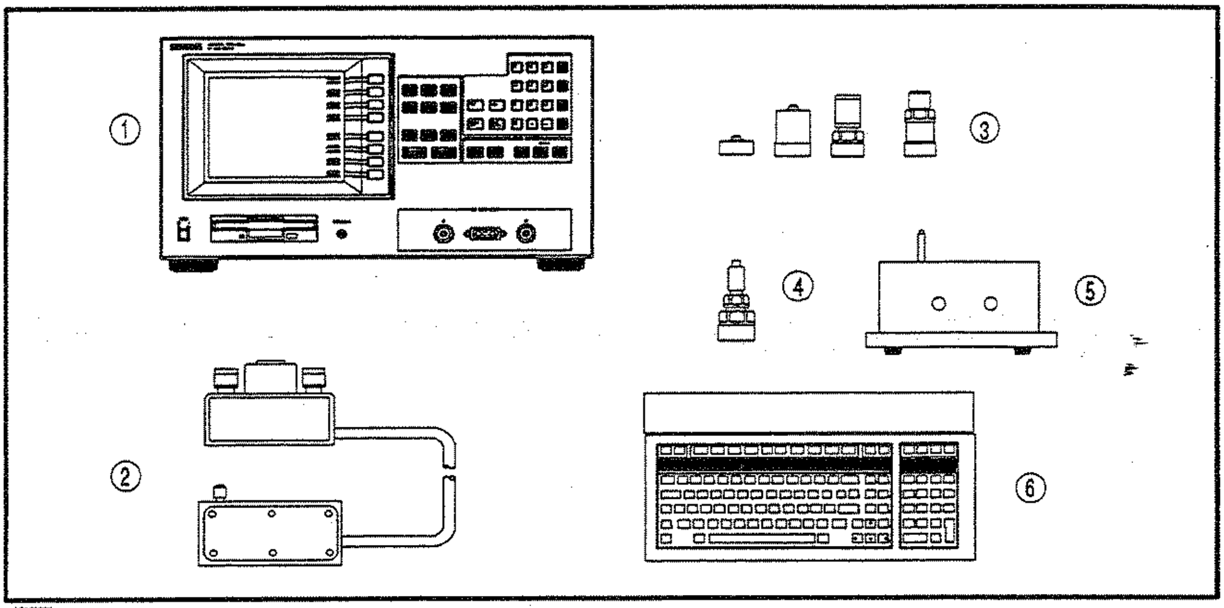
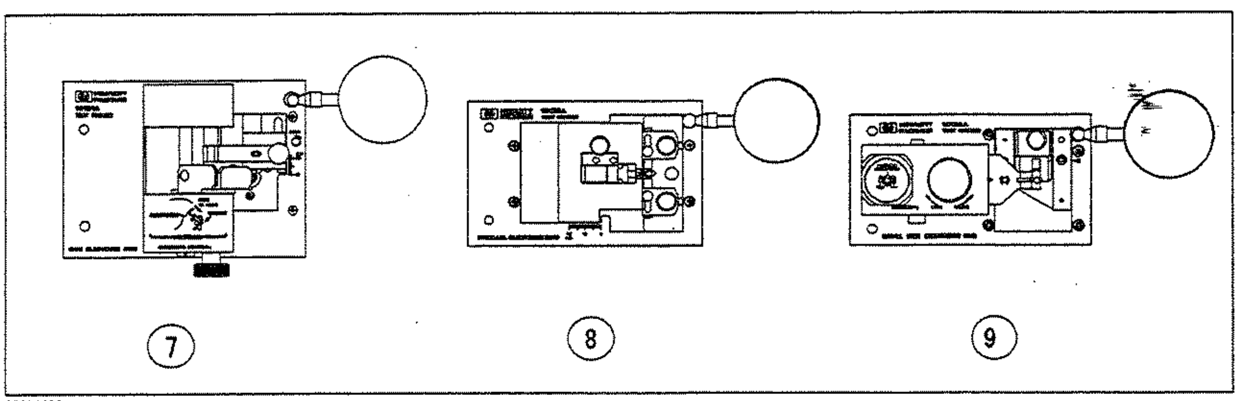


Figure 1-1. HP 4286A System Overview

① Mainframe
② Test Head (furnished with the mainframe)
③ Calibration Kit (furnished with the mainframe)
④ APC-3.5 to 7mm Adapter (furnished with the mainframe)
⑤ Test Fixture Stand (furnished with the mainframe)
⑥ Keyboard (furnished with Option 1C2)



C6001002

Figure 1-2. Test Fixtures

⑦ HP 16191A Side Electrode SMD Fixture (optional)
⑧ HP 16192A Parallel Electrode SMD Fixture (optional)
⑨ HP 16193A Small Side Electrode Fixture (optional)

Note For more information on accessories available, see manuals furnished with each accessory.

HP 4286A features

The following sections describe the LCR meter's features. Individual chapters following this chapter describe each block of controls in more detail.

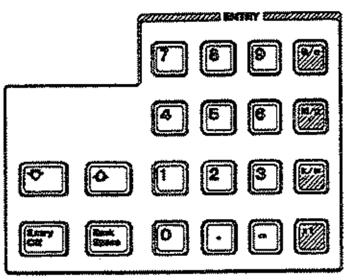
Front and Rear Panels

LCR meter functions are activated from the front panel by using front panel hardkeys or softkeys. Measurement results are displayed on the CRT (which also displays the measurement conditions and the instrument status). The front panel has input, output, and control ports to connect to the test station and a flexible disk drive to store data and instrument status.

The rear panel has input and output connectors to control the LCR meter from an external controller or to control external devices from the LCR meter. When Option 1C2 is installed, the rear panel also has a connector used to control a BASIC program, a connector for an external keyboard, and a parallel I/O port controlled by the program.

For more information, see Chapter 2.

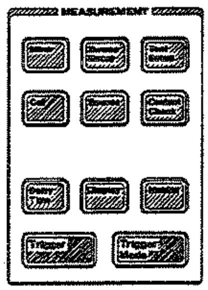
ENTRY Block



This block provides the numerical and units keypad, the knob, and the step keys. These controls are used in combination with other keys to enter or change numeric data.

For more information, see Chapter 3.

MEASUREMENT Block

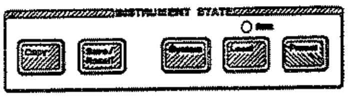


This block controls the measurement and display functions. Each key provides access to softkey menus.

- **(Meas)** Provides access to a series of menus used to select the parameters to be measured.
- **(Sweep Setup)** Provides access to a series of menus used to edit list sweep tables.
- **(Test Setup)** Provides access to a series of menus used to select conditions for limit test or BIN sorting. This key also provides access to menus for the handler interface output modes.
- **(Cal)** Provides access to a series of menus that implement the calibration and fixture compensation procedures.
- **(Source)** Provides access to a series of menus used to control test signals.
- **(Contact Check)** Provides access to a series of menus used to measure and determine the electric contact between the DUT and test head.
- **(Delay Time)** Provides access to a series of menus used to select the delay time during list sweep measurement.
- **(Display)** Provides access to a series of menus used to display instrument states and data. These menus include display of title, allocation of screen between LCR meter and HP Instrument BASIC, and selection of whether to update the screen.
- **(Monitor)** Provides access to menus for monitoring the OSC level.
- **(Trigger)** Is used to output a trigger for manual measurements.
- **(Trigger Mode)** Provides access to a series of menus used for selecting trigger mode and trigger source.

See Chapter 4 for details.

INSTRUMENT STATE Block



This block provides control of system functions. These include the controller modes, real-time clock, limit line and limit testing, HP Instrument BASIC (option 1C2), plotting or printing, saving instrument states and trace data to a built-in disk or memory.

(Copy) Provides access to the menus used for controlling external plotters and printers and defining the plot parameters.

(Save/Recall) Provides access to the menus used for saving the instrument state and data to the flexible disk or RAM disk memory. This key also displays the menu used to recall the contents of disk files or RAM disk memory back into the LCR meter.

(System) Provides access to a series of menus used for programming HP Instrument BASIC (optional) and controlling the real-time clock and the beeper.

(Local) Returns front panel control to the user from an external controller. When this meter is controlled externally, key operations on the front panel are disabled. At this time, press this key to enable key operations. Also, press this key to display a series of menus used to select the HP-IB mode and modify the HP-IB addresses.

(Preset) Sets the LCR meter to the preset state. See Appendix C for a listing of the preset values.

Front and Rear Panels

This chapter describes the features of the LCR meter. It provides illustrations and descriptions of the LCR meter's front panel features, the CRT display and its labels, and the rear panel features and connectors. It also includes illustrations and descriptions of the test station and test heads.

Front Panel

LCR meter functions are activated from the front panel (Figure 2-1) by using the front panel hardkeys or softkeys. In this manual, all front panel hardkeys and softkey labels are shown as (Hardkey) and Softkey, respectively.

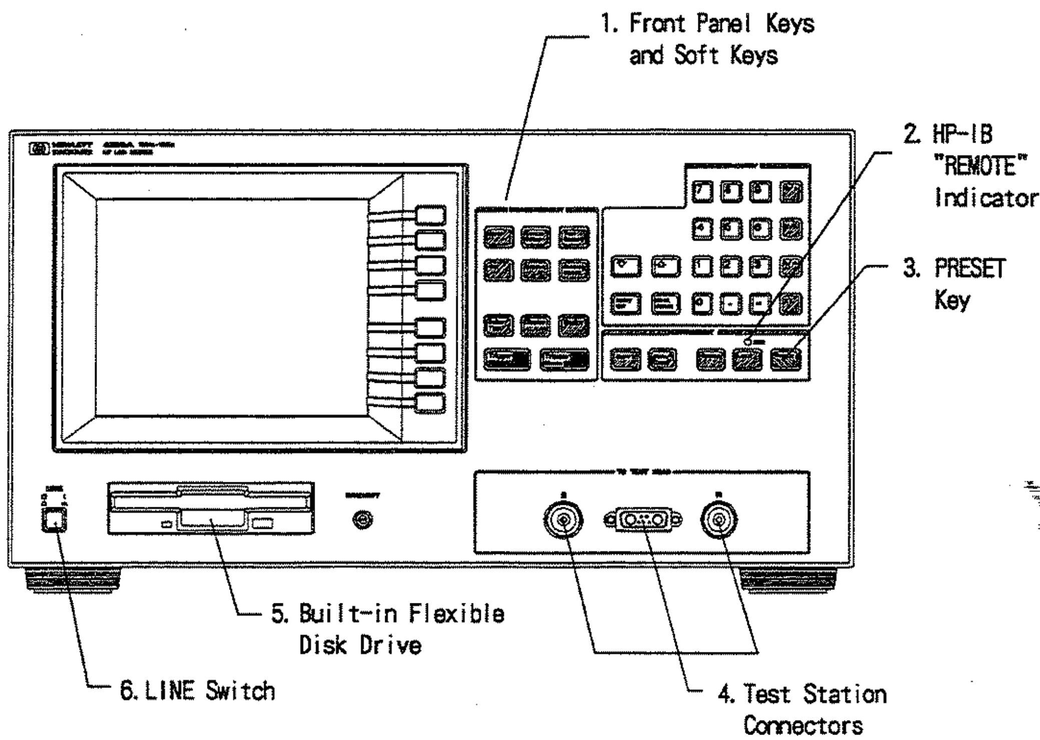


Figure 2-1. HP 4286A Front Panel

1. Front Panel Keys and Softkeys

Some of the front panel keys change instrument functions directly, and others provide access to additional functions available in softkey menus. Softkey menus are lists of up to eight related functions that can be displayed in the softkey label area at the right-hand side of the display. The eight keys to the right of the CRT are the softkeys. Pressing one of the softkeys selects the adjacent menu function. This either executes the labeled function and makes it the active function, causes instrument status information to be displayed, or presents another softkey menu.

Some of the LCR meter's menus are accessed directly from front panel keys and some from other menus. For example, the sweep menu accessed by pressing the (Sweep Setup) key presents all the sweep functions. Pressing SEGMENT FREQ allows the required measurement frequency to be entered directly from the number pad. RETURN softkeys return to previous menus. DONE indicates completion of a specific procedure and then returns to an earlier menu.

Usually, when a menu changes, the present active function is cleared.

Softkeys that are Joined by Vertical Lines

When several possible choices are available for a function, the softkeys are joined by vertical lines. For example, in the OSC level monitoring menu under the (Monitor) key, the available measurement parameters are listed: AC-V, AC-I, OFF with a vertical line between them. Note that only one softkey can be selected at a time. When a selection has been made from the listed alternatives, that selection is underlined until another selection is made.

Softkeys That Toggle On or Off

Some softkey functions can be toggled ON or OFF, for example contact check. This is indicated in the softkey label. The current state, ON or OFF, is capitalized in the softkey label.

Example:

RDC MEAS ON off	The word on is capitalized, showing that contact check is currently on.
RDC MEAS on OFF	The word off is capitalized, showing that contact check is currently off.

Softkeys that Show Status Indications in Brackets

Some softkey labels show the current status of a function in brackets. These include simple toggle functions and status-only indicators. An example of a toggled function is the CAL POINTS [USER] or CAL POINTS [USER] softkey.

2. HP-IB "REMOTE" Indicator

This lights when the LCR meter is controlled by an external controller through the HP-IB interface (remote state). When this lamp is lit, all keys other than (Local) on the front panel are disabled.

3. (Preset)

This key returns the instrument to a known standard preset state from any step of any manual procedure. A complete listing of the instrument preset conditions is provided in Appendix C.

4. Test Head Connectors

The test head connects to these connectors.

5. Built-in Flexible Disk Drive

Stores the measurement data, instrument status, list sweep tables, and HP Instrument BASIC programs. The applicable disk formats are LIF (logical interchange format) and DOS (disk operating system) format.

6. LINE Switch

This controls ac power to the LCR meter. 1 is ON, 0 is OFF.

Screen Display

Displays a grid on which the measurement data is plotted, currently selected measurement traces, and other information describing the measurement. Figure 2-2 shows the locations of the different information labels.

In addition to the full-screen display shown in Figure 2-2, a split display is also available (see "(Display)" in Chapter 4.) In this case, information labels are provided for each half of the display.

The screen can also be used as the HP Instrument BASIC display. HP Instrument BASIC uses either a full-screen display or a half-screen display below the graticule display as a text screen.

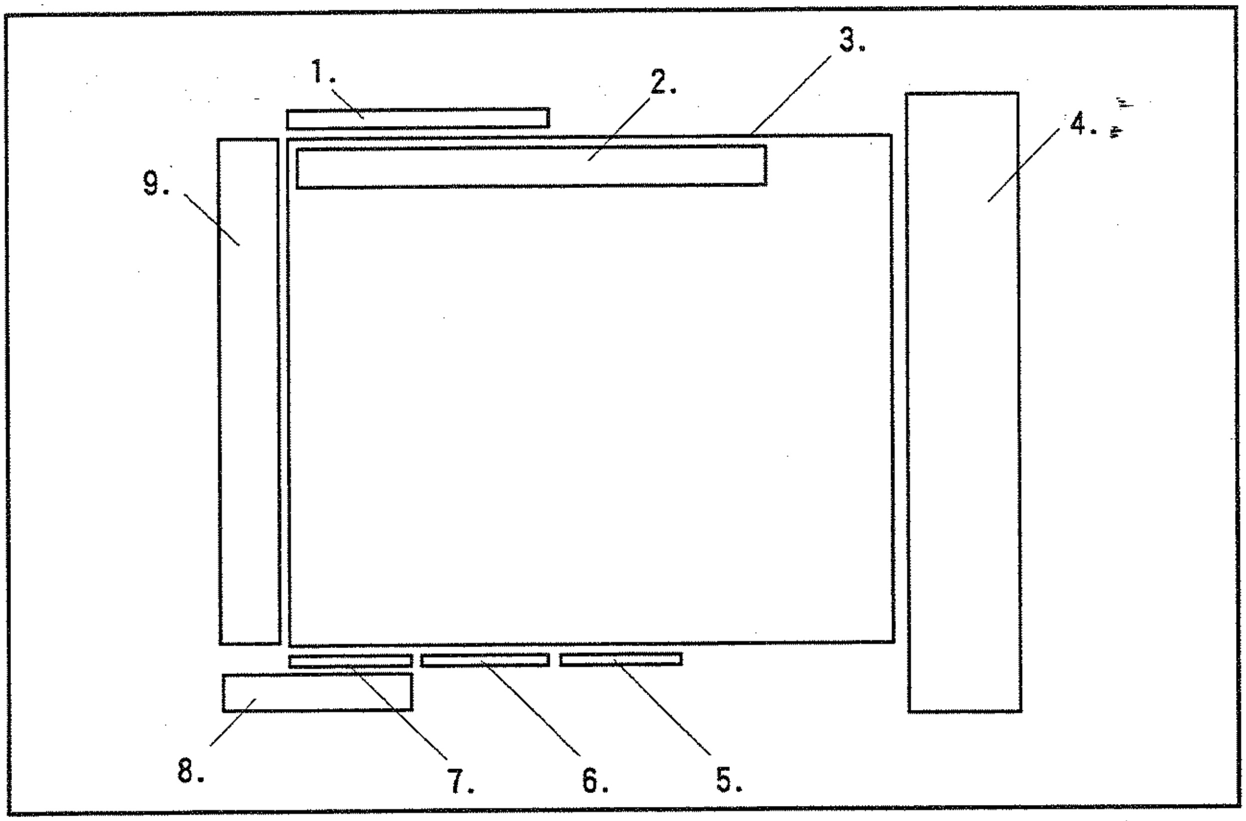


Figure 2-2. HP 4286A Screen Display

Message Area	Displays a warning message.
Title Area	Displays an title for measurement settings title.
Measurement Data Area	Displays measurement data.
Softkey Label Area	Displays a softkey label.
Point Delay	Displays a point delay.
Sweep Delay	Displays a sweep delay.
OSCLevel	Displays an OSC level.
Active Entry Area	Displays characters and numbers you are entering.

Status Display Area Displays the current status of various functions for the active channel. The following notations are used:

*	Stimulus parameters changed: measured data in doubt until a complete fresh sweep has been taken.
COR	Error correction in fixed cal points is on
C0+	Error correction with low-loss capacitor in fixed cal points is on
Cor	Error correction in user cal points is on
C+	Error correction with low-loss capacitor in user cal points is on
C?	Stimulus parameters have changed and interpolated error correction in user cal points is on
C+?	Stimulus parameters have changed and interpolated error correction with low-loss capacitor in user cal points is on
C!	Error correction in user cal points is on but questionable. Caused by extrapolation.
C+!	Error correction with low-loss capacitor in user cal points is on but questionable. Caused by extrapolation.
CMP	Fixture compensation in fixed compensation points is on
Cmp	Fixture compensation in user compensation points is on
Cm?	Stimulus parameters have changed and interpolated fixture compensation is on
Cm!	Fixture compensation in user compensation points is on but questionable. Caused by extrapolation.
Del	Port extension has been added or subtracted (Del stands for "delay".)
Hld	Hold sweep.
ext	Waiting for external trigger (BNC in rear panel).
man	Waiting for manual trigger.
bus	Waiting for HP-IB trigger.
Svc	A service mode is turned on. If this notation is shown, the measurement data will be out of specifications. See *Service Manual* for more information. (Service manual is furnished with Option 0BW.)

2 Front and Rear Panels

Rear Panel Features and Connectors

Figure 2-3 shows the features and connectors on the rear panel. Requirements for the input signals to the rear panel connectors are provided in *Specifications*.

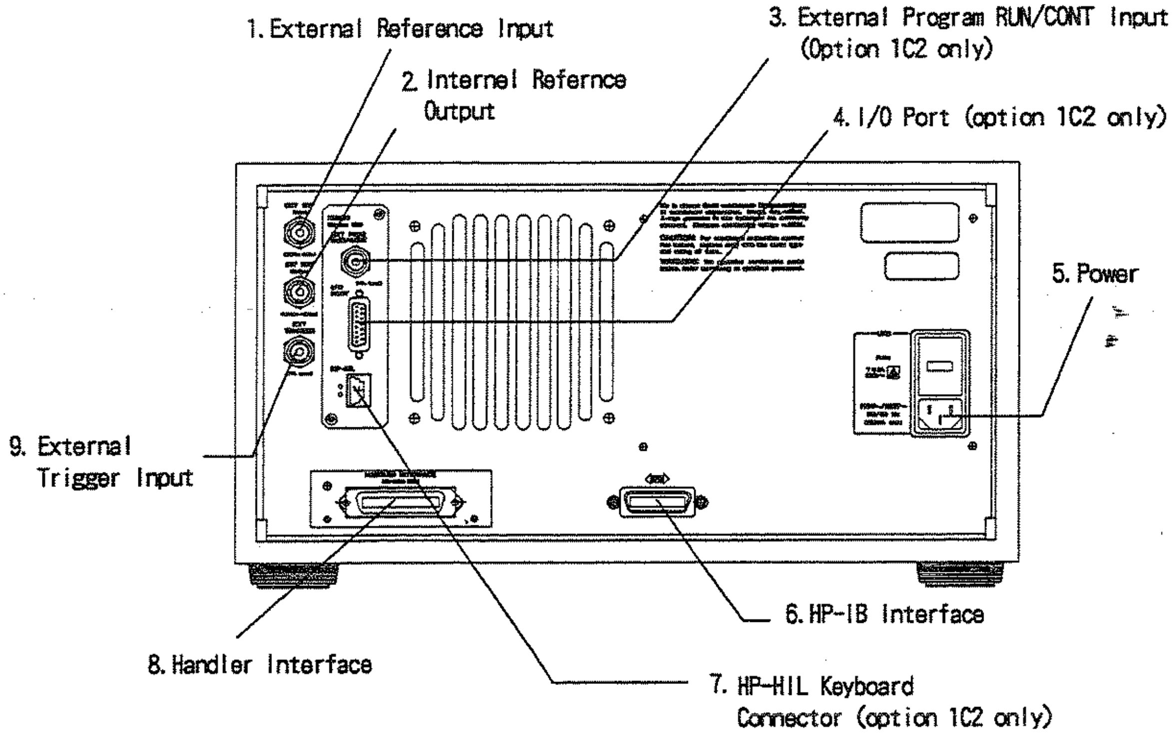


Figure 2-3. HP 4286A Rear Panel

1. External Reference Input

Inputs a highly stable external frequency reference signal and phase locks the internal frequency to this reference signal for improved stability.

The external frequency reference function is automatically enabled when a signal is connected to this input. When the signal is removed, the LCR meter automatically switches back to its internal frequency reference.

2. Internal Reference Output

Connects to the frequency reference input of an external instrument to phase lock it to the LCR meter.

3. External Program RUN/CONT Input (Option 1C2 Only)

Externally triggers RUN or CONT of the HP Instrument BASIC program. The positive edge of a pulse more than 20 μs wide in the LOW state triggers RUN or CONT. The signal is TTL-compatible.

4. I/O Port (Option 1C2 Only)

Connects to external devices such as a handler on a production line. For more information on I/O port, see "I/O Port (Option 1C2 only)".

5. Power

This is input for the main power cable. Insert the main-power cable plug only into a socket outlet that has a protective ground contact.

6 HP-IB Interface

Connects the LCR meter to an external controller and other instruments in an automated system. This connector is also used when the LCR meter itself is the controller of compatible peripherals. See "HP-IB" in Chapter 5.

7. HP-HIL Keyboard Connector (Option 1C2 Only)

Connects the keyboard that is usually used with HP Instrument BASIC. The HP-HIL keyboard is optional.

8. External Trigger Input

Triggers a measurement sweep. The positive (or negative) edge of a pulse more than 20 μs wide in the LOW (or HIGH) state starts a measurement. The signal is TTL-compatible. To use this connector, set the trigger mode to external using softkey functions (see "[Trigger Mode]" in Chapter 4).

9. Handler Interface

This connector is provided for a handler when it is used with the HP 4286A. Be sure to select mode 1 or 2 for the handler interface output using the softkey when you wish to use this connector.

I/O Port (Option 1C2 only)

Figure 2-4 shows the pin assignment of I/O port on the rear panel. The I/O port is available when the Option 1C2 is installed.

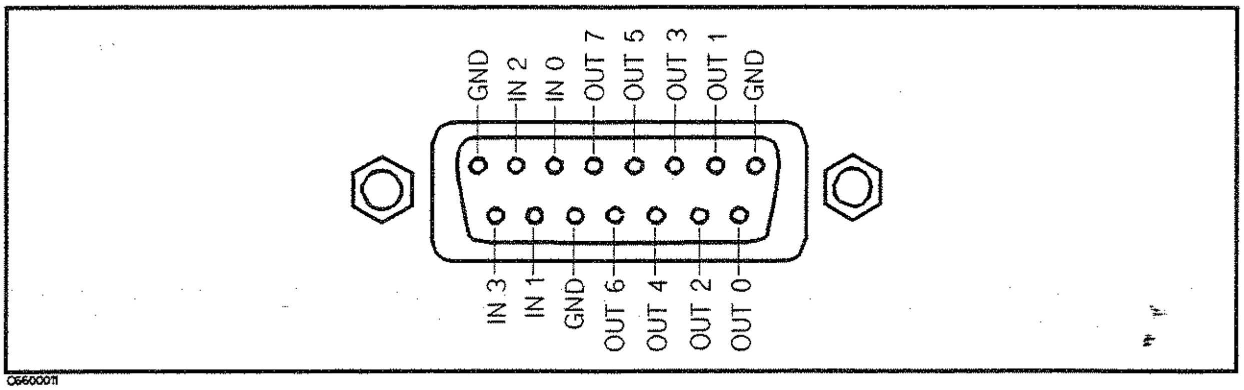


Figure 2-4. Pin Assignment of I/O Port

The signals carried through each pin are described below.

OUT 0 thru 7 — Output signals to external devices. Controlled by HP-IB commands and HP Instrument BASIC statements and functions, as described below. Once `SYST:COMM:PAR:TRAN:DATA` is executed, the signal is latched until this command is executed again or power OFF.

IN 0 thru 3 — Input signals from external devices. Read by the HP-IB command `SYST:COMM:PAR:DATA?`, as described below.

■ Related HP-IB Commands

There are two HP-IB commands that directly control an I/O port.

- `SYST:COMM:PAR:TRAN:DATA`

  This command outputs 8-bit data to the OUT 0 thru 7 lines. The OUT 0 signal is the LSB (least significant bit). The OUT 7 signal is the MSB (most significant bit).

- `SYST:COMM:PAR:DATA?`

  This command inputs data from the 4-bit parallel input port to the LCR meter, and outputs the data to the controller.

■ Related HP Instrument BASIC Statement and Function

HP Instrument BASIC can access an I/O port directly by using the following statement and function.

- `WRITEIO 15,0;`*A*

  This statement outputs decimal value, *A*, as 8-bit data to the OUT 0 thru 7 lines. The OUT 0 signal is the LSB (least significant bit). The OUT 7 signal is the MSB (most significant bit).

- `READIO(15,0)`

  This function inputs data from the 4-bit parallel input port to the LCR meter, and returns the data to the HP Instrument BASIC program.

■ Circuit of I/O Port

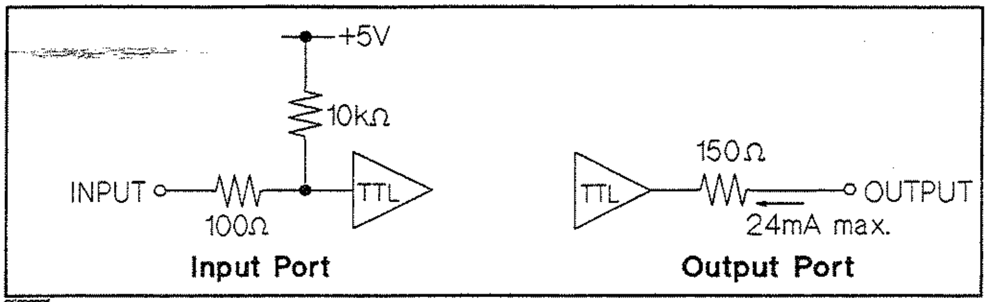


Figure 2-5. Circuit of I/O Port

- **Connector**
  - D-SUB 15 pin

Handling and Storage APC-7® Connectors

- Keep connectors clean.
- Do not touch the mating plane surfaces.
- Do not set connectors contact-end down.
- Before storing, extend the sleeve.
- Use end caps over the mating plane surfaces.
- Never store connectors loose in a box or a drawer.

Microwave connectors must be handled carefully, inspected before use, and when not in use stored in a way that gives them maximum protection.

Avoid touching the connector mating plane surfaces and avoid setting the connector's contact-end down on any hard surface. Natural skin oils and microscopic particles of dirt are easily transferred to the connector interface and are very difficult to remove. Damage to the plating and to the mating plane surface occurs readily when the interface comes in contact with any hard surface.

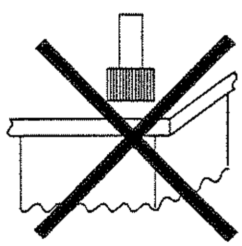
Never store connectors with the contact end exposed. End caps are provided with all Hewlett-Packard connectors, and these should be retained after unpacking and placed over the ends of the connectors whenever they are not in use.

Above all, never store any devices loose in a box or in a desk or a bench drawer. Careless handling of this kind is the most common cause of connector damage during storage.

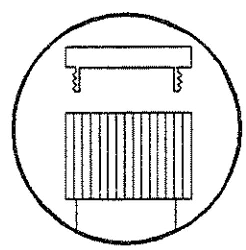
Calibration devices and test fixtures should be stored in a foam-lined storage case, and protective end caps should always be placed over the ends of all connectors.

The following figure summarizes these Hewlett-Packard recommendations on handling and storing devices that have microwave connectors.

Handle and Store Connectors Carefully



Never Place Connectors Contact-End Down



Use End Caps

- Extend threads fully when end caps are not used.
- Use foam-lined storage cases if available.
- Never store devices loose in a box or in a desk or bench drawer.

Entry Block

The ENTRY block (Figure 3-1) contains the numeric and unit's keypad, and step keys. These controls are used in combination with other front panel keys and softkeys to modify the active entry and to enter or change numeric data. In most cases, the step keys provide easier numeric entering than numeric keys.

Before a function can be modified, it must be made the active function by pressing a front panel key or softkey. It can then be modified directly with the knob, the step keys, or the digits' keys and a terminator.

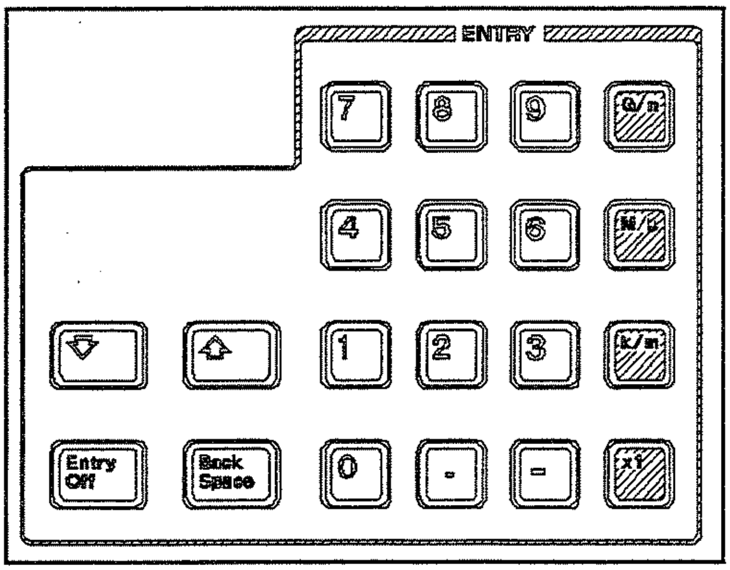


Figure 3-1. Entry Block

Numeric Keypad

The numeric keypad selects digits, decimal point, and minus sign for numerical entries. A unit's terminator is required to complete the entry.

Terminator Keys

The unit's terminator keys are the four keys in the right-hand column of the keypad. These specify units of numerical entries from the keypad and also terminate the entries. A numerical entry is incomplete until a terminator is entered. When a terminator is required, the underline "_" points at the last entered digit in the active entry area. When the unit's terminator key is pressed, the underline is replaced by the units selected. The units are abbreviated on the terminator keys as follows:

(G/n)	Giga/nano (10^9 / 10^{-9})
(M/μ)	Mega/micro (10^6 / 10^{-6})
(k/m)	kilo/milli (10^3 / 10^{-3})
(x1)	May be used to terminate unitless entries such as averaging factor.

(⇧) and (⇩)

The (⇧) and (⇩) keys step the current value of the active function up or down. The steps of values other than the center value are predetermined and cannot be altered. You can select the desired steps for the center value by accessing the center menu with (Center). No unit's terminator is required with these two keys.

(Entry Off)

Clears and turns off the active entry area and any displayed prompts, error messages, or warnings. Use (Entry Off) to clear the display before plotting. This key also prevents active values from being accidentally changed. The next function selected turns the active entry area back on.

(Back Space)

Deletes the last entry (or the last digit entered from the numeric keypad).

4

Measurement Block

The measurement block keys and associated menus provide control of measurement parameters, display, averaging, calibration, calibration, fixture compensation, sweep, trigger, and signal source. The following figure shows the functions controlled by each key in the measurement block.

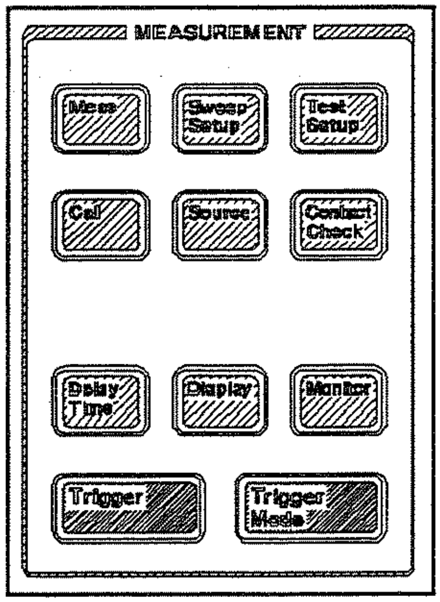


Figure 4-1. Measurement Block

Meas	Selecting parameter to be measured
Display	Allocating screen between LCR meter and HP Instrument BASIC. (option 1C2 only) Displaying titles and text
Cal	Performing calibration and fixture compensation measurement Defining standard kits for calibration and fixture compensation Selecting test fixture Setting up port extension
Sweep Setup	Setting measurement frequency Setting averaging function Creating list sweep table
Test Setup	Performing limit test Performing BIN sorting Setting up handler interface
Monitor	Monitoring OSC level
Delay Time	Controlling delay time
Source	Selecting parameters for OSC level measurement
Contact Check	Performing contact check between DUT and test fixture or handler contact
Trigger Mode	Selecting trigger mode Selecting trigger signal source Selecting event when trigger is output

For additional information	See ...
Preset Values and Setting Range	Appendix C in this manual
All Softkey Trees	Appendix B in this manual
HP-IB Command Reference	*Programming Guide*
How to control the HP 4286A using an external controller or the HP Instrument BASIC capability through the HP-IB.	*Programming Guide*

Meas

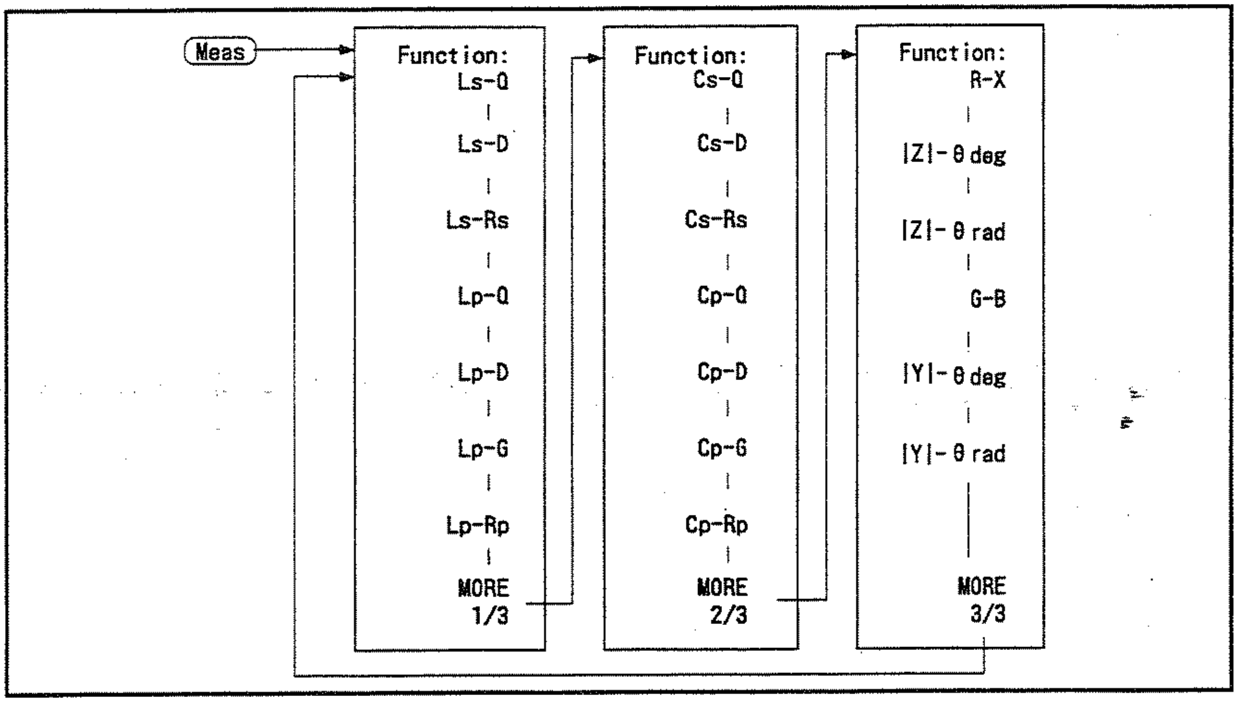


Figure 4-2. Softkey Menus Accessed from the Meas Key

- L_s - Q Measures serial inductance (L_s) and quality factor (Q).
- L_s - D Measures serial inductance (L_s) and dissipation factor (D).
- L_s - R_s Measures serial inductance (L_s) and serial resistance (R_s).
- L_p - Q Measures parallel inductance (L_p) and quality factor (Q).
- L_p - D Measures parallel inductance (L_p) and dissipation factor (D).
- L_p - G Measures parallel inductance (L_p) and conductance (G).
- L_p - R_p Measures parallel inductance (L_p) and parallel resistance (R_p).
- C_s - Q Measures serial capacitance (C_s) and quality factor (Q).
- C_s - D Measures serial capacitance (C_s) and dissipation factor (D).
- C_s - R_s Measures serial capacitance (C_s) and serial resistance (R_s).
- C_p - Q Measures parallel capacitance (C_p) and quality factor (Q).
- C_p - D Measures parallel capacitance (C_p) and dissipation factor (D).
- C_p - G Measures parallel capacitance (C_p) and conductance (G).
- C_p - R_p Measures parallel capacitance (C_p) and parallel resistance (R_p).
- R - X Measures resistance (R) and reactance (X).
- |Z| - θ deg Measures absolute magnitude of impedance (|Z|) and its phase component (θ_z).
- |Z| - θ rad Measures absolute magnitude of impedance (|Z|) and its phase component (θ_z).
- G - B Measures conductance (G) and susceptance (B).
- |Y| - θ deg Measures absolute magnitude of admittance (|Y|) and its phase component (θ_y).
- |Y| - θ rad Measures absolute magnitude of admittance (|Y|) and its phase component (θ_y).

Measurement Parameters	
Complex Impedance Parameters	■ Absolute magnitude of impedance $\|Z\|$ ■ Impedance phase component θ_z ■ Resistance R ■ Reactance X
Complex Admittance Parameters	■ Absolute magnitude of admittance $\|Y\|$ ■ Admittance phase component θ_y ■ Conductance G ■ Susceptance B
Serial Circuit Parameters	■ Serial capacitance C_s ■ Serial inductance L_s ■ Serial resistance R_s
Parallel Circuit Parameters	■ Parallel capacitance C_p ■ Parallel inductance L_p ■ Parallel resistance R_p
Loss	■ Dissipation factor D ■ Quality factor Q

Note

For more information on measurement parameters and serial and parallel circuit models (such as definitions, conversion between parameters, and the selection guide for circuit models), see "Impedance parameters" in Chapter 7 and "Series and Parallel Circuit Models" in Chapter 7.

(Display)

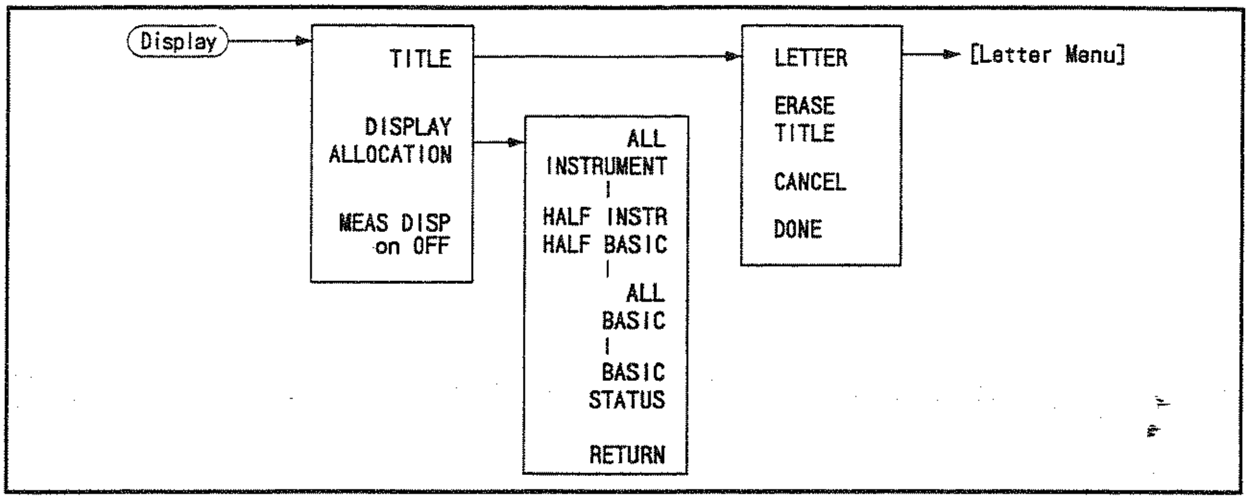


Figure 4-3. Softkey Menu Accessed from (Display) Key

- TITLE Displays the menu in the softkey labels. This menu is used to edit titles and labels.
  - LETTER MENU Displays the Letter menu which allows you to enter characters. See "Letter Menu" for the Letter menu.
  - ERASE TITLE Deletes the character string displayed in the active entry area.
  - CANCEL Exits the Title Entry menu and returns to the previous menu without making any modification.
  - DONE Confirms entry of the character string in the active entry area and returns to the previous menu.
- DISPLAY ALLOCATION Displays the *Display Allocation menu*, which is used to allocate the BASIC screen area on the display. This function is only available with HP 4286A that has HP Instrument BASIC (Option 1C2) installed.
  - ALL INSTRUMENT Selects a full screen or two half-screen measurement.
  - HALF INSTR HALF BASIC Selects two half-screens, one measurement display above the HP Instrument BASIC display.
  - ALL BASIC Selects a full screen single HP Instrument BASIC display.
  - BASIC STATUS Selects a full screen measurement and three status lines for HP Instrument BASIC under the measurement.
- MEAS DISP on_OFF Turns measurement display function ON and OFF. Measurement data do not appear on the screen when this key is OFF.

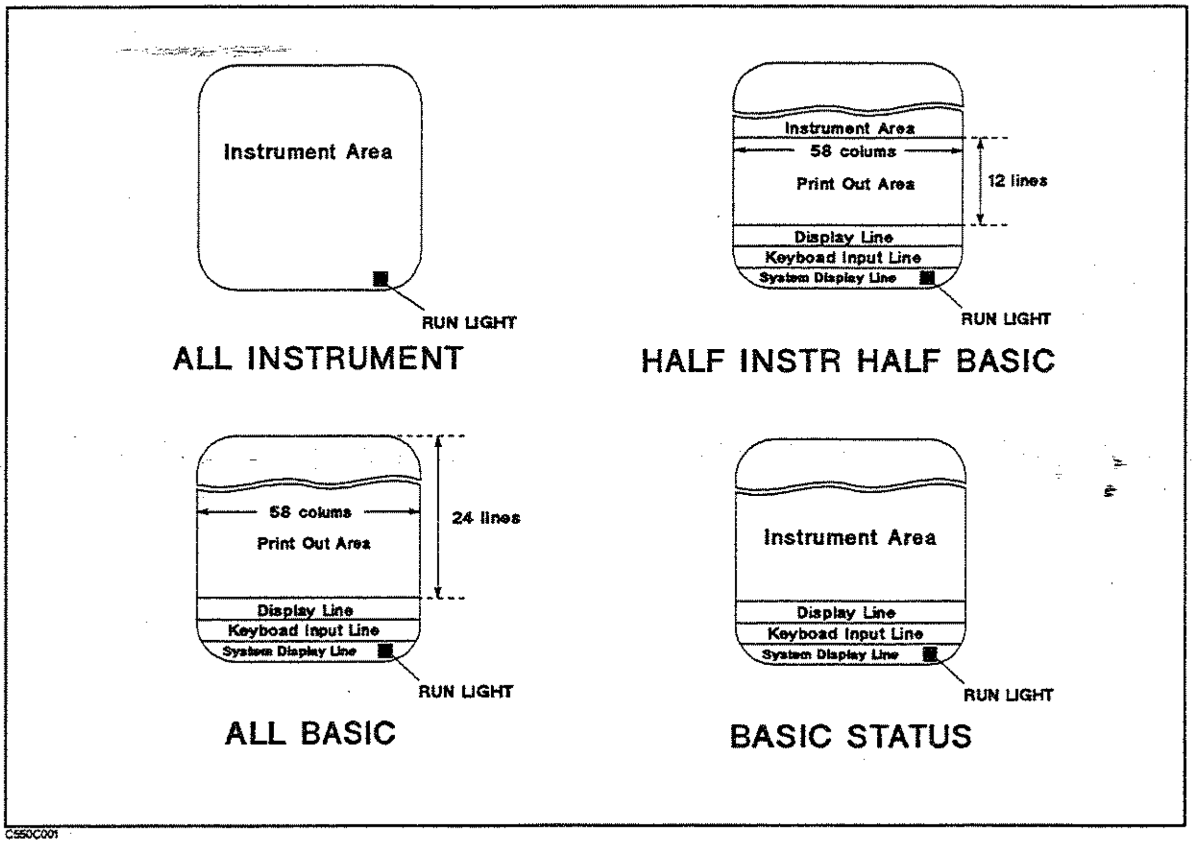


Figure 4-4. Screen Allocation between LCR Meter and HP Instrument BASIC

4. Measurement Block

Cal

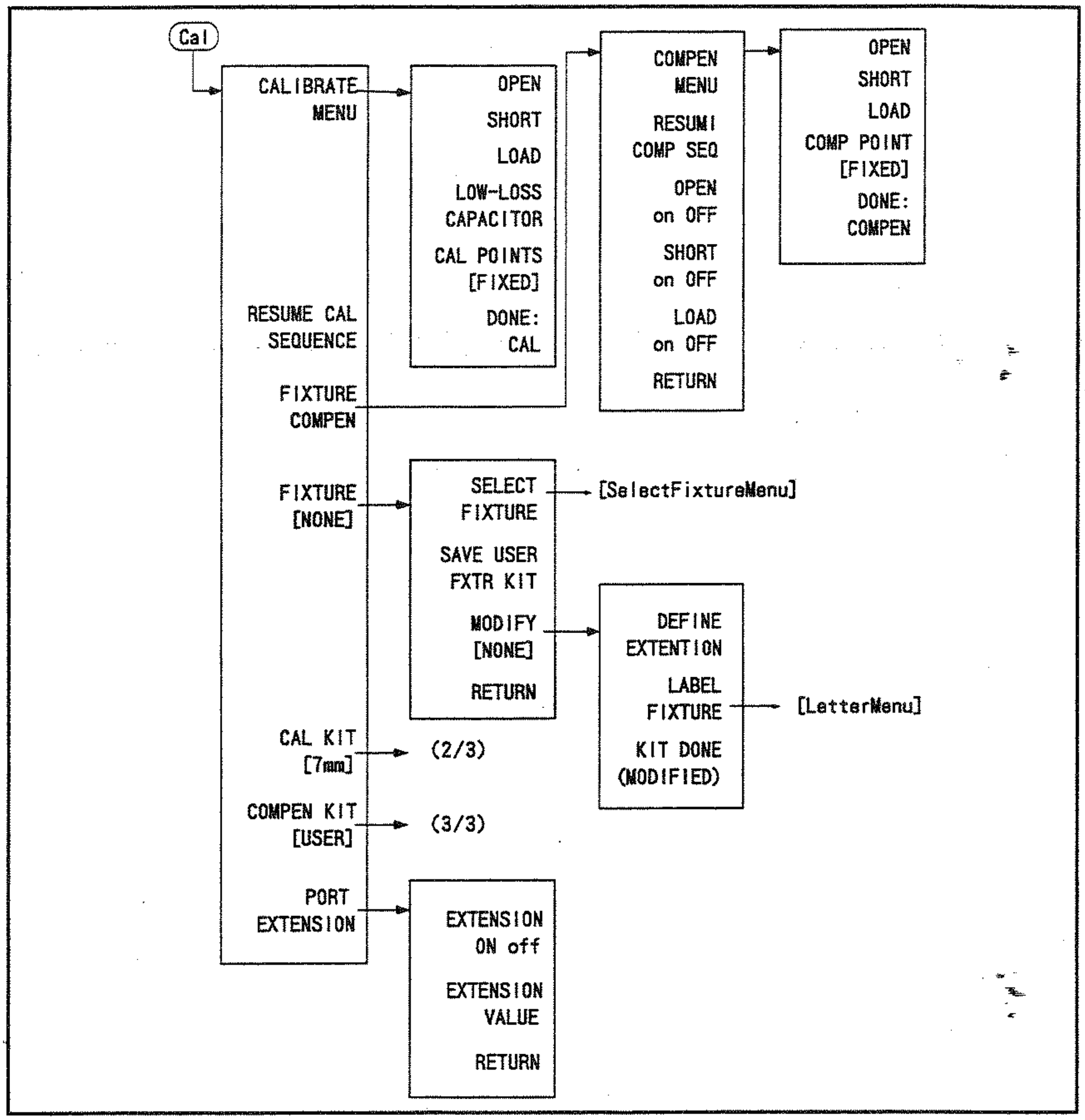


Figure 4-5. Softkey Menu Accessed from Cal key (1/3)

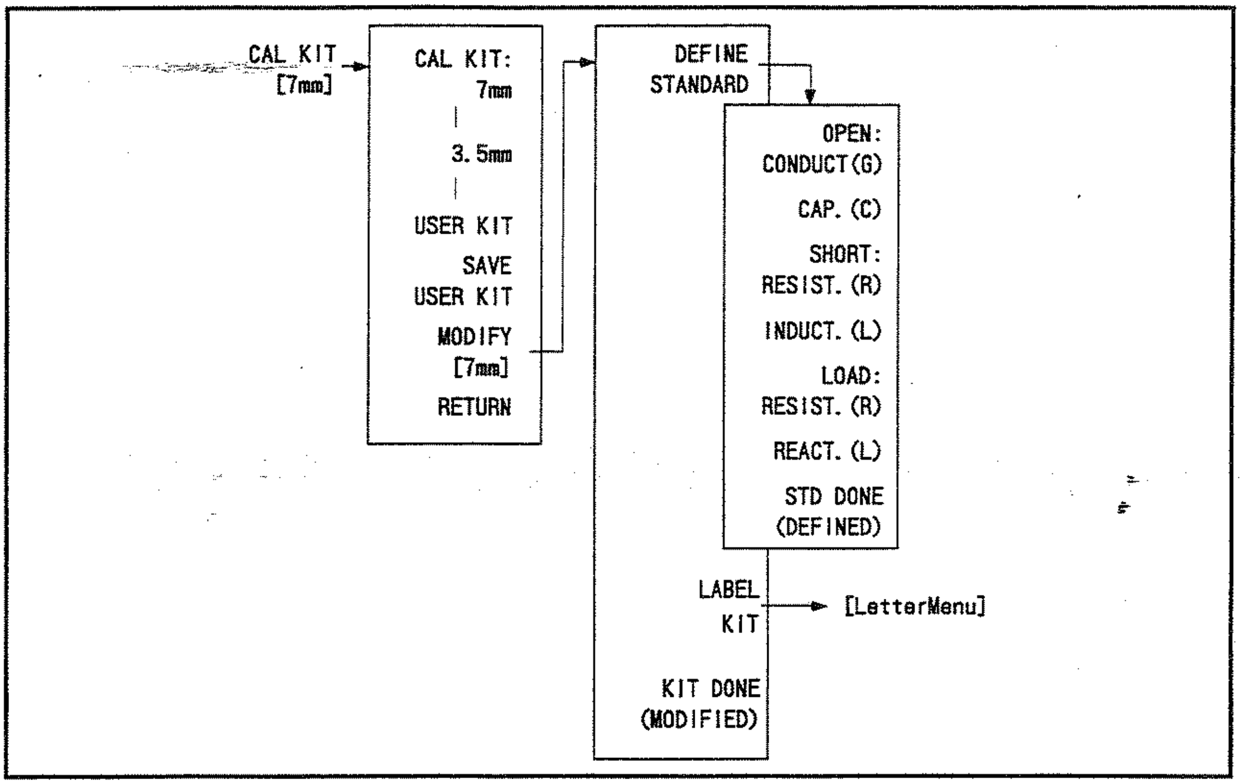


Figure 4-6. Softkey Menu Accessed from Cal key (2/3)

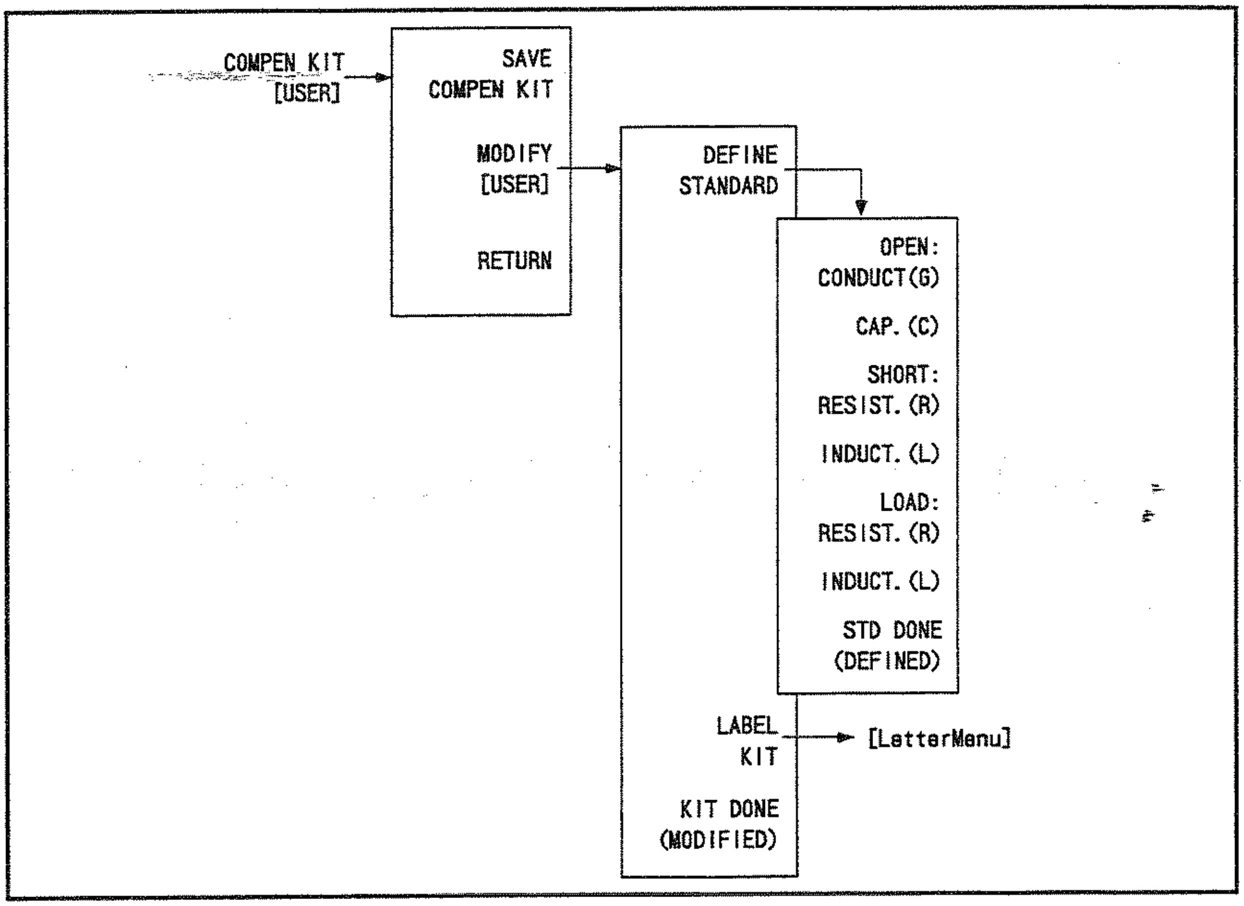


Figure 4-7. Softkey Menu Accessed from (Cal) key (3/3)

- CALIBRATE MENU Leads to the following softkeys, which are used to perform a calibration measurement.
  - OPEN Measures OPEN standard of the cal kit for the calibration. The key becomes underlined when measurement is complete.
  - SHORT Measures SHORT standard of the cal kit for the calibration. The key becomes underlined when measurement is complete.
  - LOAD Measures LOAD standard of the cal kit for the calibration. The key becomes underlined when measurement is complete.
  - LOW-LOSS CAPACITOR Measures LOW-LOSS CAPACITOR standard of the cal kit for the calibration. The key becomes underlined when measurement is complete.
  - CAL POINTS [ ] Toggles between FIXED and USER DEFINED, to select the calibration measurement points. When [FIXED] is displayed, the LCR meter performs calibration measurements on points fixed across the full frequency sweep range, and the effective value for the points between these measured points will be calculated using the interpolation method. When [USER] is displayed, the LCR meter performs calibration measurements on the same points as the current stimulus setting. See Table 4-1 for fixed point frequency.
  - DONE:CAL Completes the calibration and then computes and stores the error coefficients. The notation COR (calibration on fixed cal point is ON) or Cor (calibration in user cal points is ON) is displayed on the left side of the screen.
- RESUME CAL SEQUENCE Eliminates the need to restart a calibration sequence that was interrupted to access some other menu. Goes back to the point where the calibration sequence was interrupted.
- FIXTURE COMPEN Displays the *Fixture Compensation menu*, which is used to perform the fixture compensation measurements in order to reduce measurement errors existing along the test fixture.
  - COMPEN MENU Leads to the following softkeys, which are used to perform a fixture compensation measurement.
    - OPEN Measures OPEN standard.The key becomes underlined when measurement is complete.
    - SHORT Measures SHORT standard.The key becomes underlined when measurement is complete.
    - LOAD Measures LOAD standard.The key becomes underlined when measurement is complete.
    - COMP POINT [FIXED] Allows the LCR meter to perform fixture compensation measurements on points fixed across the full frequency sweep range, and the effective value for the points between these measured points will be calculated using the interpolation method.
    - DONE:COMPEN Completes the fixture compensation and then computes and stores the error coefficients.
  - RESUME COMP SEQ Stores compensation status if compensation is halted to execute other menu. This function allows compensation to be resumed from the point following the last point where fixture compensation was performed.
  - OPEN on OFF
  - SHORT on OFF
  - LOAD on OFF
    Displays OFF when compensation measurements are in progress and ON when they are complete. When compensation measurements are complete, this key can be toggled ON and OFF. When it is toggled OFF, measurements are performed with no fixture compensation.

- **FIXTURE** Leads to the following softkeys, which are used to select test fixtures for impedance measurements.
  - □ **SELECT FIXTURE** Displays fixture menu.
  - □ **SAVE USER FXTR KIT** Stores the user-modified or user-defined fixture compensation into memory, after it has been modified.
  - □ **MODIFY [ ]** Modify a default definition of the electrical length of the fixture.
    - **DEFINE EXTENSION** Leads to the following softkeys, which are used to define the electrical length of the fixture.
    - **LABEL FIXTURE** Leads to the *Title Entry menu* to define a label for a new set of user-defined OPEN, SHORT, and LOAD. This label appears in the **COMPEN KIT** softkey label in the *Calibration menu* and the **MODIFY** label in the *Compen Kit menu*. It is saved with the data of OPEN, SHORT, and LOAD. See "(Display)" for details on the *Title Entry menu*.
    - **KIT DONE (MODIFIED)** Completes the procedure to define user-defined OPEN, SHORT, and LOAD for fixture compensation.
- **CAL KIT [ ]** Leads to the *Cal Kit menu* that selects the default calibration kit and a user kit. This in turn displays additional softkeys used to define calibration standards other than those in the default kits. When a calibration kit has been specified, its label is displayed in brackets in the softkey label.
  - □ **CAL KIT:7 mm** Selects the 7 mm cal kit (standard cal kit) model.
  - □ **CAL KIT:3.5 mm** Selects the 3.5 mm cal kit (standard cal kit) model.
  - □ **USER KIT** Selects a cal kit model modified and stored into memory using **SAVE USER KIT** by the user.
  - □ **SAVE USER KIT** Stores the current cal kit into memory as USER KIT, after it has been modified.
  - □ **MODIFY [ ]** Displays the following softkeys, which are used to modify definitions of standard calibration kits.
    - **DEFINE STANDARD** Leads to the following softkeys, which are used to define the OPEN, SHORT and LOAD.
      - □ **OPEN: CONDUCT(G)** Makes conductance value (G) of OPEN the active function.
      - □ **CAP. (C)** Makes capacitance value (C) of OPEN the active function.
      - □ **SHORT: RESIST. (R)** Make resistance value (R) of SHORT the active function.
      - □ **INDUCT. (L)** Makes inductance value (L) of SHORT the active function.
      - □ **LOAD: RESIST. (R)** Make resistance value (R) of LOAD the active function.
      - □ **INDUCT. (X)** Makes inductance value (L) of LOAD the active function.
      - □ **STD DONE (DEFINED)** Terminates the standard definition. Press this after each standard is defined.
    - **LABEL KIT** Leads to the *Title Entry menu* to define a label for a new calibration kit. This label appears in the **CAL KIT** softkey label in the *Calibration menu* and the **MODIFY** label in the *Cal Kit menu*. It is saved with the cal kit data. See "(Display)" for details on the *Title Entry menu*.
    - **KIT DONE (MODIFIED)** Completes the procedure to define a current cal kit.

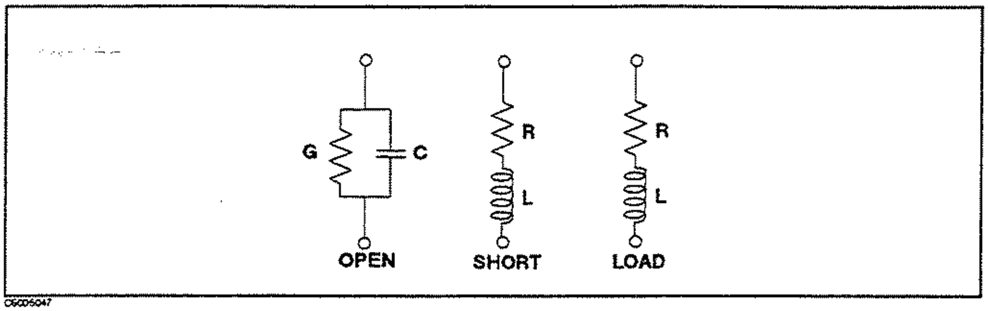


Figure 4-8. Calibration Standard Model

- COMPEN KIT [ ] Leads to the *Compen Kit menu* that is used to define user-define OPEN, SHORT, and LOAD for fixture compensation measurements. When a set of user-defined OPEN, SHORT, and LOAD values has been specified, its label is displayed in brackets in the softkey label.
  - SAVE USER KIT Stores the current compensation kit into memory as USER KIT, after it has been modified.
  - MODIFY [ ] Displays the following softkeys, which are used to modify standard definitions.
    - DEFINE STANDARD Leads to the following softkeys, which are used to define the OPEN, SHORT and LOAD.
      - OPEN: CONDUCT(G) Makes conductance value (G) of OPEN the active function.
      - CAP. (C) Makes capacitance value (C) of OPEN the active function.
      - SHORT: RESIST. (R) Make resistance value (R) of SHORT the active function.
      - INDUCT. (L) Makes inductance value (L) of SHORT the active function.
      - LOAD: RESIST. (R) Make resistance value (R) of LOAD the active function.
      - INDUCT. (L) Makes inductance value (L) of LOAD the active function.
      - STD DONE (DEFINED) Terminates the standard definition. Press this after each standard is defined.
    - LABEL KIT Leads to the *Title Entry menu* to define a label for a new compensation kit. This label appears in the CAL KIT softkey label in the *Calibration menu* and the MODIFY label in the *Cal Kit menu*. It is saved with the cal kit data. See "Display" for details on the *Title Entry menu*.
    - KIT DONE (MODIFIED) Completes the procedure to define a current cal kit.

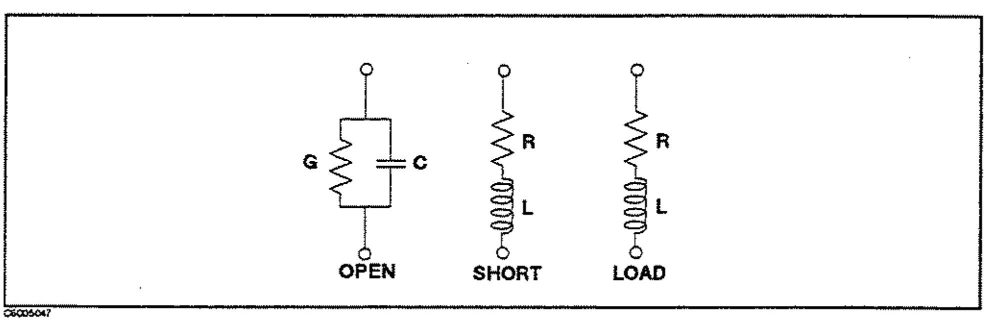


Figure 4-9. OPEN, SHORT, and LOAD Models for Fixture Compensation

- PORT EXTENSIONS Leads to *Port Extension menu.* Used when the cable needs to be extended from the reference place (APC-7® connector end).

Table 4-1.

Frequency Points for Fixed Point Cal and Compensation

When FIXED is selected for calibration measurement points using CAL POINTS[ ] , the LCR meter measures the standards at the following 178 frequency points. When FIXED is selected for compensation measurement points using COMP POINT [ ], the LCR meter also measures the OPEN, SHORT, and LOAD standards at the same 178 frequency points. At this time, other measurement parameters are set as follows:

- Averaging factor:32
- OSC level:Current setting

(Unit:MHz)

1	1.03	1.06	1.09	1.12	1.15	1.18	1.21
1.24	1.26	1.29	1.32	1.35	1.38	1.41	1.44
1.47	1.5	1.55	1.6	1.65	1.7	1.75	1.8
1.85	1.9	1.95	2.0	2.1	2.2	2.3	2.4
2.5	2.6	2.8	3.0	3.2	3.4	3.6	3.8
4.0	4.3	4.6	5.0	5.5	6.0	6.5	7.0
7.5	8	9	10	11	12	13	14
15	16	18	20	22	24	26	28
30	33	36	39	42	45	48	51
55	60	65	70	75	80	85	90
95	100	110	120	130	140	150	160
170	180	190	200	220	240	260	280
300	320	340	360	380	400	420	440
460	480	500	520	540	560	580	600
620	640	660	680	700	720	740	760
780	800	820	840	860	880	900	920
940	960	980	1000	1020	1040	1060	1080
1100	1120	1140	1160	1180	1200	1220	1240
1260	1280	1300	1320	1340	1360	1380	1400
1420	1440	1460	1480	1500	1520	1540	1560
1580	1600	1620	1640	1660	1680	1700	1720
1740	1760	1780	1800				

User-defined and Fixed Point Calibration

- **User-defined calibration assures more accurate measurements.**
  With user-defined point calibration, you can make actual measurements at the same frequencies as those used for measuring standards, thus assuring more accurate measurements. Note, however, that you will need to make calibration again if you change measurement frequencies after calibration.
- **Fixed-point calibration is a better choice when you make frequent changes in measurement frequencies.**
  With fixed-point calibration, data are measured across the full frequency range. This allows measurement data to be properly calibrated by interpolating calibration data. Therefore, you will not need to make calibration again even when you change measurement frequencies after calibration. Fixed-point calibration will save you a great deal of time when you frequently change frequencies.

Make fixture compensation and calibration at the same points.

To make compensation measurements at fixed points, you must make calibration at fixed points. If you have made calibration at the points you defined, you must make compensation measurements at these points.

Fixture Selection Menu

- FIXTURE [-] Leads to the following softkeys, used to select fixtures for impedance measurements.
  - FIXTURE:NONE Sets the electrical length to 0
  - 16191 Sets the appropriate electrical length for HP 16191A.
  - 16192 Sets the appropriate electrical length forHP 16192A.
  - 16193 Sets the appropriate electrical length forHP 16193A.
  - 16194 Sets the appropriate electrical length forHP 16194A.
  - USER Sets the electrical length to the user-defined value.

Fixture Setup
Fixture menu sets the electrical length to eliminate phase errors caused by signal transmission line between coaxial connector terminals (APC-7 connector) and fixture contact electrodes. For more information on fixture characteristics, see "Fixture Compensation" in Chapter 7.

Title Entry Menu

- LABEL Allows label texts to be entered.

Port Extension Menu

- EXTENSIONS ON off Turns port extension ON or OFF. When this function is ON, all extensions defined below it are enabled; when OFF, none of the extensions are enabled.
- EXTENSION VALUE Makes the port extension value the active function. Used to add electrical delay in seconds to extend the reference plane at the APC-7 connector on a test head to the end of the cable.

Note For more information on port extension, see "Port Extension" in Chapter 7.

(Sweep Setup)

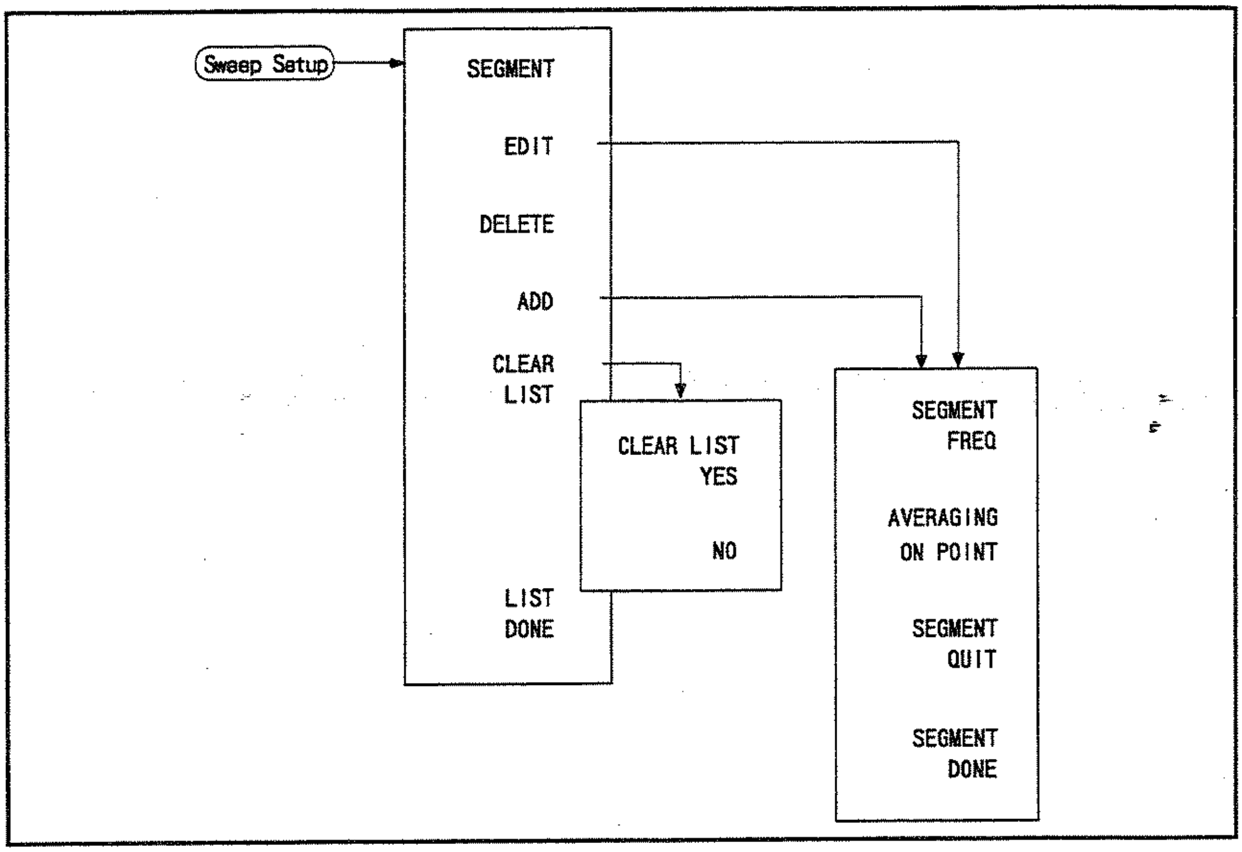


Figure 4-10. Softkey Menus Accessed from (Sweep Setup) Key

- SEGMENT: Leads to the following softkeys, which are used to create or modify the list sweep table:
- EDIT Provides access to the *Segment menu* used to define or modify the segment selected with SEGMENT. Specify the segment to be modified from those in the list sweep table. To specify the desired segment, enter the segment number in the list, or use the step keys to move the pointer ">" at the left of the desired segment number. The specified segment can then be edited or deleted.
  - □ SEGMENT: FREQ Defines or modifies segment frequency.
  - □ AVARAGING ON POINT Enters or modifies point averaging factor. Any number (positive integer) up to 999 can be specified for averaging factor.

Point Averaging
Point Averaging averages each data point by a user-specified averaging factor. The HP 4286A repeats measuring the same point until the averaging factor is reached. It then divides the vector summation of measurement values by the averaging factor and starts measuring the next point. The larger the number of measurements, the longer the sweep time. The algorithm of point averaging is as follows: $$M = \frac{1}{F}\sum_{n=1}^{F} S_{(n)}$$ where M = Measurement result by averaging $S(n)$ = Current measured value F = Number of measurements for averaging

  - □ SEGMENT QUIT Returns to the previous softkey menu without saving the modified segment.
  - □ SEGMENT DONE Saves the modified segment and returns to the previous softkey menu.
- DELETE Deletes the segment indicated by the pointer ">" at the left.
- ADD Adds a new segment to the list. The *Segment menu* can be accessed by this key as by as EDIT. The active entry area shows the frequency of the segment selected by the pointer ">". Enter the desired value to update this frequency.
- CLEAR LIST Leads to the following softkeys, which are used to clear the list table.
  - □ CLEAR LIST YES Clears the entire list.
  - □ NO Cancels list clearing and returns to the previous menu.
- LIST DONE Defines the frequency sweep list and softkeys, and returns to the previous menu.

The LCR meter always sweeps from lower frequencies to higher frequencies regardless of the order in which segments were defined.

(Test Setup)

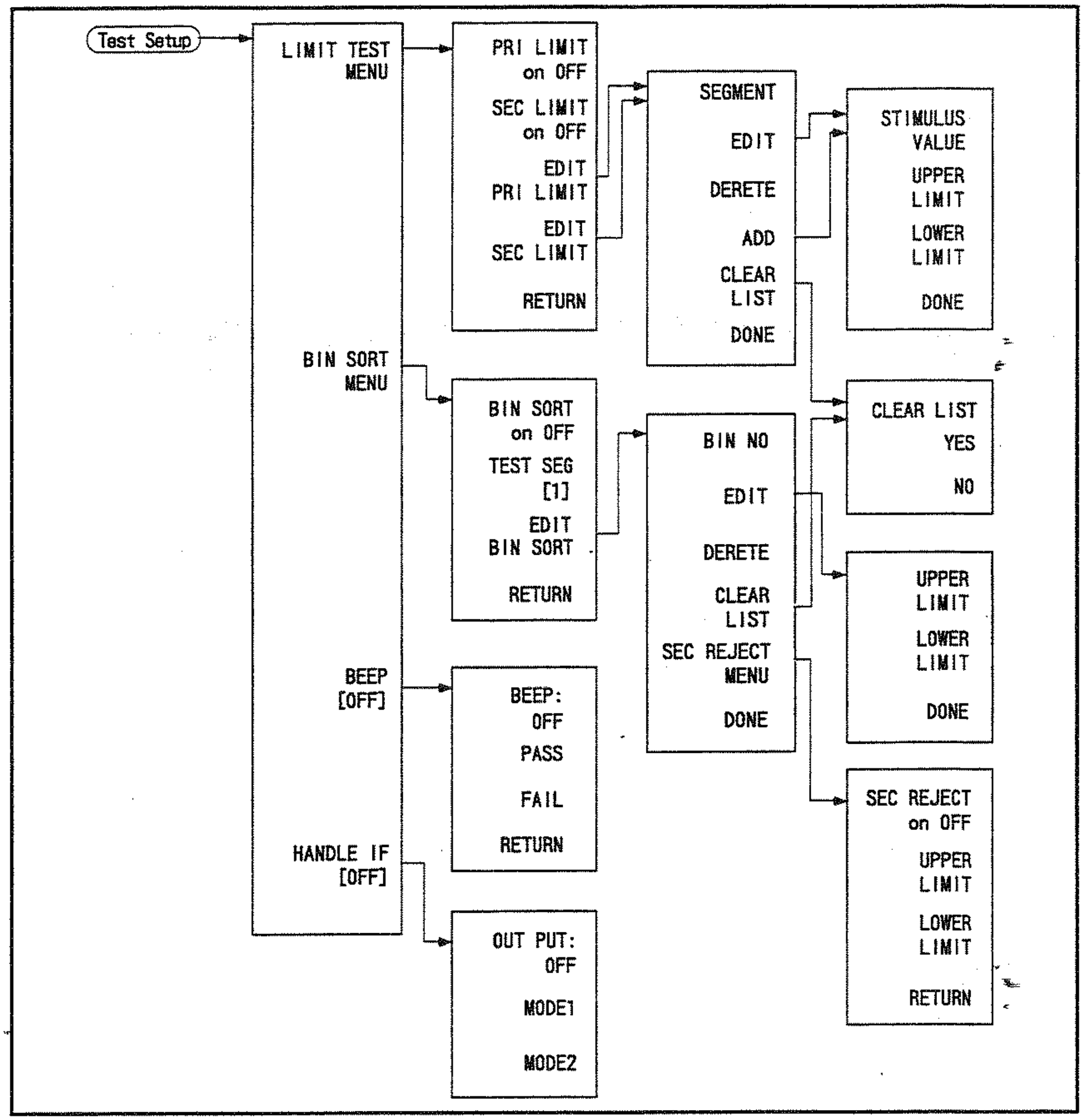


Figure 4-11. Softkey Menus Accessed from (Test Setup) Key

- **LIMIT TEST MENU** Provides access to the menu used to make limit test settings.
  - □ **PRI LIMIT on OFF** Turns ON/OFF the limit test function using master parameters.
  - □ **SEC LIMIT on OFF** Turns ON/OFF the limit test function using slave parameters.
  - □ **EDIT PRI LIMIT**
  - □ **EDIT SEC LIMIT**

    Provides access to the menu used to edit limits for master and slave parameters.
    - **SEGMENT** Specifies the segment to be edited. The selected segment is pointed to by the pointer >. When a segment is selected, its definition can be edited or modified. You can scroll the table up and down to display all segment definitions. To move the point to the desired segment, use keys on the ENTRY block. When EMPTY appears on the limit table, you can add a new segment using **ADD** or **EDIT**.
    - **EDIT** Displays the following soft keys used to define or modify limits for the specified segment. When there is no segment in the limit table, a default segment is displayed.
      - □ **STIMULUS VALUE** Sets stimulus break point.
      - □ **UPPER LIMIT** Sets the UPPER LIMIT. You must specify both the upper and lower limits. When you do not need an upper limit, specify a very large value. (See example 1G.) If the upper limit is smaller than the lower limit, or the lower limit larger than the upper limit, then both limits are automatically set to the same value.
      - □ **LOWER LIMIT** Sets the LOWER LIMIT. You must specify both the upper and lower limits. When you do not need a lower limit, specify a very small value. (See example −1G.)
      - □ **DONE** Stores limits and returns to the previous softkey menu.
    - **DELETE** Deletes the segment pointed to by the pointer > .
    - **ADD** Displays the same soft keys that located under **EDIT**, which is used to add a new segment at the end of the table. This new segment can be set in the same manner as with the segment selected using **SEGMENT** and pointed to by the pointer > . When there is no segment in the table, a default segment is displayed. Up to 18 segments can be displayed in the table.
    - **CLEAR LIST** Displays the following softkey menu and clears all segments in the limit table.
      - □ **CLEAR LIST YES** Clears all segments in the limit table and returns to the previous menu.
      - □ **NO** Cancels segment clearing and returns to the previous menu.
    - **DONE** Terminates segment setting and arranges segments in the limit table in the ascending order of stimulus value.
- **BIN SORT MENU** Provides access to the menu used to make settings for BIN sorting.
  - □ **BIN SORT on OFF** Turns ON/OFF BIN sorting function.
  - □ **TEST SEG [1]** Sets segment (measurement frequency) used for BIN sorting
  - □ **EDIT BIN SORT** Sets master parameters.
    - **BIN NO** Specifies segment to set or modify its limits.
    - **EDIT**
      - □ **UPPER LIMIT** Sets upper limit.
      - □ **LOWER LIMIT** Sets lower limit.
      - □ **DONE** Terminates master parameter setting.

- DELETE Deletes BIN table.
- ADD Adds a new BIN table.
- CLEAR LIST Displays the following softkey menu used to clear all segments in the limit table.
  - CLEAR LIST YES Clears all segments in the BIN table and returns to the previous menu.
  - NO Cancels segment clearing and returns to the previous menu.
- SEC REJECT MENU Displays the following softkey menu and specifies BIN sorting using slave parameters.
  - SEC REJECT on OFF Turns ON/OFF BIN sorting using slave parameters.
  - UPPER LIMIT Sets upper limit.
  - LOWER LIMIT Sets lower limit.
  - DONE Terminates slave parameter setting.
- DONE Terminates BIN table editing.

- RETURN Returns to the previous menu.

- BEEP [OFF] Specifies whether to announce results of limit test and BIN sorting by beeping.
  - BEEP: OFF Turns the beeper OFF.
  - PASS Sounds the beeper when the DUT is not rejected.
  - FAIL Sounds the beeper when the DUT is rejected.
  - RETURN Returns to the previous menu.
- HANDLER IF Sets up the handler interface.
  - OUTPUT OFF Turns OFF outputs to the handler interface board.
  - MODE 1 Sets the handler interface to Mode 1.
  - MODE 2 Sets the handler interface to Mode 2.

Monitor

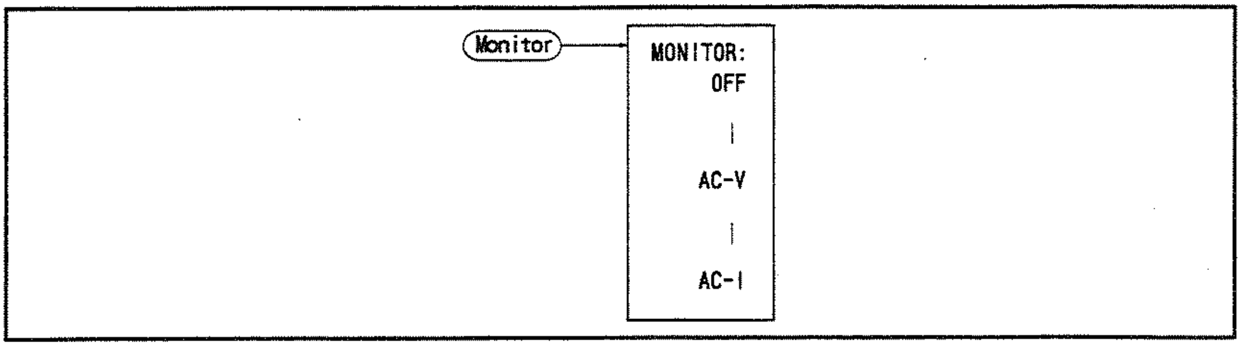


Figure 4-12. Softkey Menu Accessed from Monitor Key

- OFF Does not monitor the OSC level.
- AC-V Monitors the voltage currently applied to the DUT.
- AC-I Monitors the current currently flowing through the DUT.

4.Measurement Block

(Delay Time)

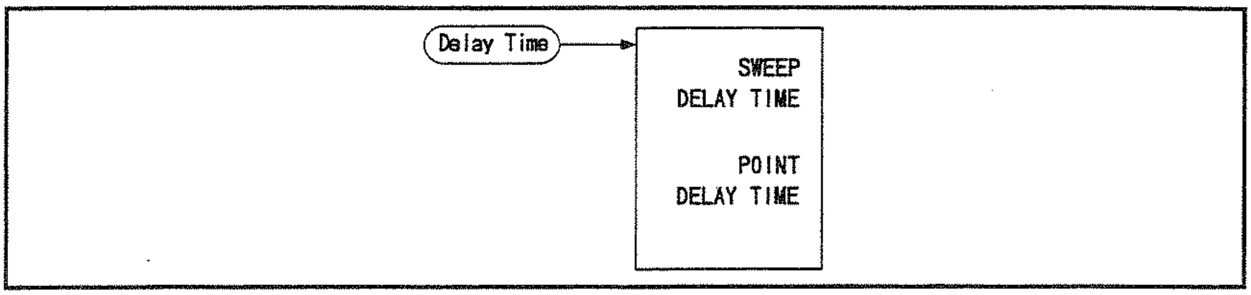


Figure 4-13. Softkey Menu Accessed from (Delay Time) Key

- SWEEP DELAY TIME Sets sweep delay time. The HP 4286A waits for the time specified with this key to elapse before starting sweep.
- POINT DELAY TIME Sets point delay time. After stimulus has been applied to each point, the HP 4286A waits for the time specified with this key to elapse before starting measurement at that point.

Figure 4-14 shows how sweep time changes with each of delay time. Sweep delay time is not included in sweep time. However, total point delay time is included in sweep time. When you specify both the point delay and sweep delay time, sweep starts only after the time specified for both delays has elapsed.

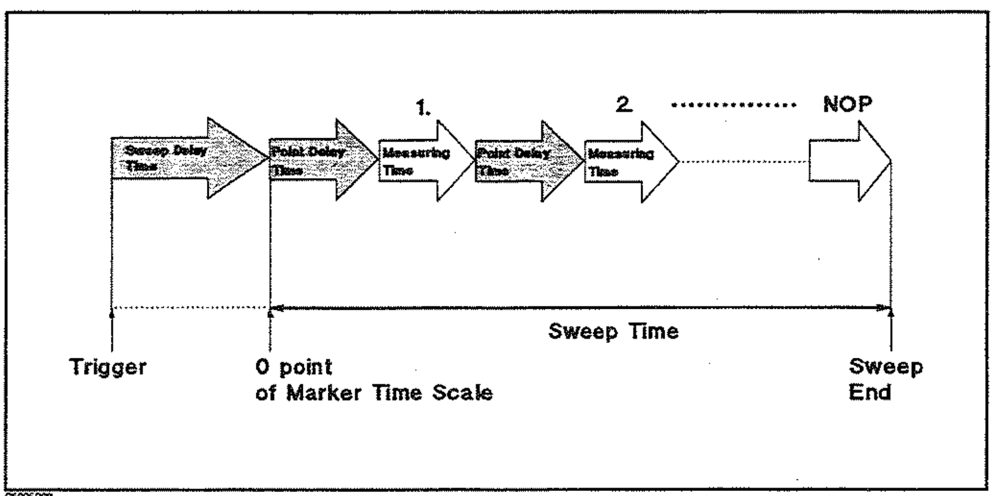


Figure 4-14. Sweep Delay and Point Delay Time

Source

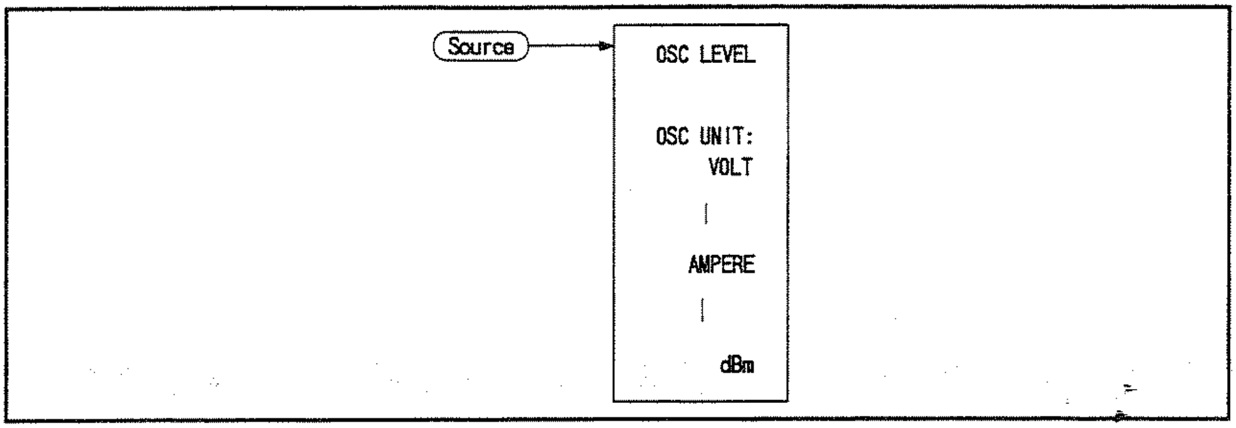


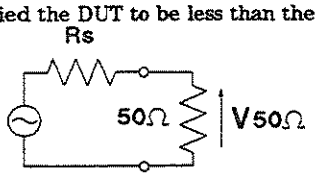
Figure 4-15. Softkey Menus Accessed from the Source Key

- OSC LEVEL Sets OSC level.
- OSC UNIT : VOLT Selects voltage (V) as the OSC level and sets the desired voltage level. The currently selected level is displayed in the active entry area.
- AMPERE Selects current (A) as the OSC level and sets the desired current value. The currently selected value is displayed in the active entry area.
- dBm Selects dBm as the OSC level and sets the desired dBm value. The currently selected value is displayed in the active entry area.

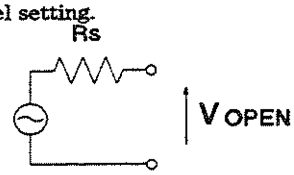
Source

Source level value entered is not equal to the value applied to the DUT

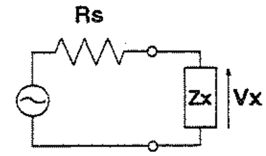
For example, the OSC level voltage value displayed (or entered) is twice the value when terminating with 50Ω. (In other words, the OSC level displayed is approximately equal to the value when the terminal is open.) When the DUT is connected to the test terminal, the voltage dropped by the DUT's impedance causes the voltage value applied the DUT to be less than the OSC level setting.



$V_{50\Omega} = \frac{1}{2} V_{osc}$



$V_{open} \simeq V_{osc}$

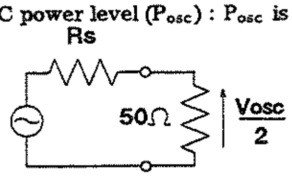


$V_X \neq V_{osc}$

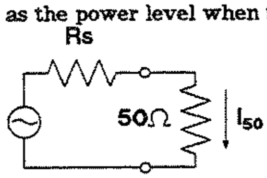
Definition of the OSC Level

The definitions of the OSC level are as follows:

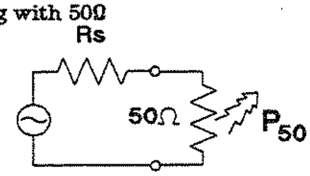
- OSC voltage level (V_{osc}) : V_{osc} is twice as large as the voltage value when terminating with 50Ω (approximately same as open voltage).
- OSC current level (I_{osc}) : I_{osc} is twice as large as the current value when terminating with 50Ω (approximately same as short current).
- OSC power level (P_{osc}) : P_{osc} is as the same as the power level when terminating with 50Ω



Voltage Level $V_{osc} = 2 \times V_{50}$



Current Level $I_{osc} = 2 \times I_{50}$



Power Level $P_{osc} = P_{50}$

Contact Check

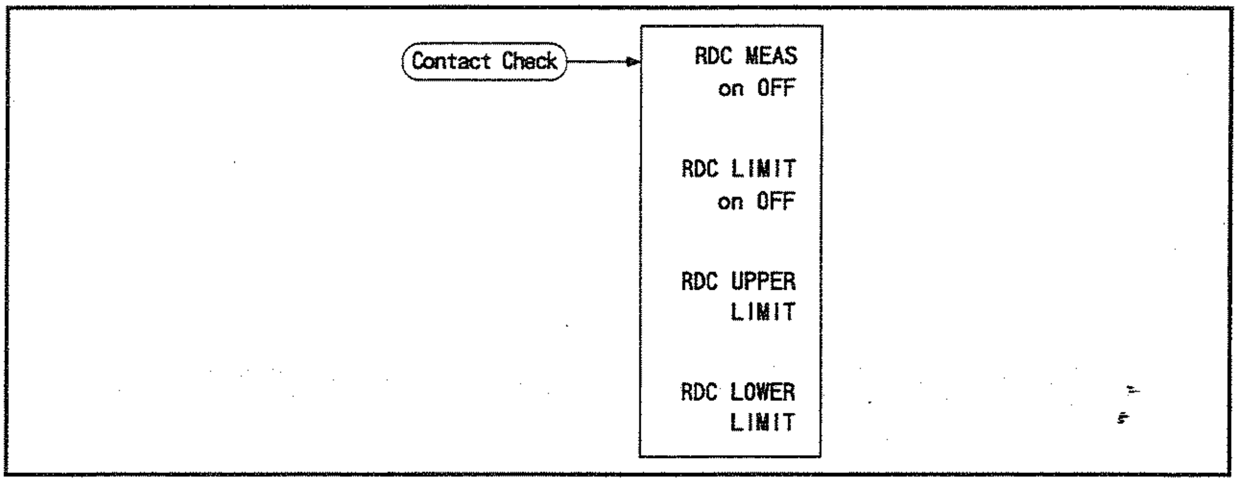


Figure 4-16. Softkey Menu Accessed from Contact Check Key

- RDC MEAS on OFF Turns ON/OFF the dc contact resistance (RDC) measurement function.
- RDC LIMIT on OFF Turns ON/OFF the contact check function used to check sufficient electrical contact between the test head and DUT.
- RDC UPPER LIMIT Sets upper limit of dc resistance between the test head and DUT.
- RDC LOWER LIMIT Sets lower limit of dc resistance between the test head and DUT.

(Trigger Mode)

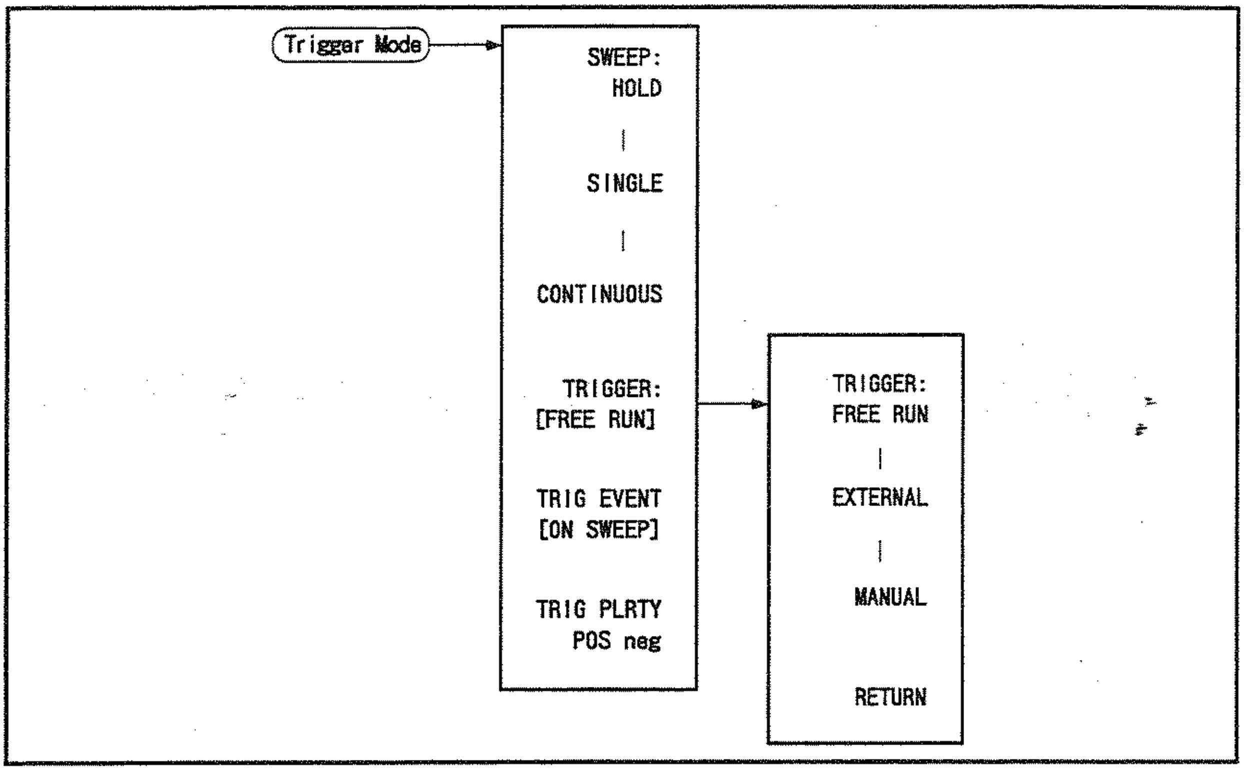


Figure 4-17. Softkey Menus Accessed from the (Trigger Mode) Key

- SWEEP:HOLD Freezes the data trace on the display and the analyzer stops sweeping and taking data. The notation "Hld" is displayed at the left of the Measurement data area. If the "*" indicator is on (at the left side of the display), trigger a new sweep by pressing SINGLE.
- SINGLE Makes one sweep of the data and returns to the hold mode.
- CONTINUOUS Selects the continuous mode. In this mode the LCR meter sweeps automatically and continuously (the trace is updated with each sweep).
- TRIGGER: [ ] Displays the following softkeys, which are used to select the trigger source and to select trigger event mode. The trigger source is common to both channels.
  The BUS trigger source that triggers sweep through the HP-IB interface can only be selected by using the HP-IB command.
  - FREE RUN Selects the internal trigger.
  - EXTERNAL Selects the external trigger input from the EXT TRIGGER input BNC on the rear panel. "ext" appears at the status area.
  - MANUAL Selects the manual trigger and triggers a sweep. "man" appears at the status area.
- TRIG EVENT [ ] Toggles the trigger event mode.

  [ON SWEEP] The LCR meter sweeps across over all segments by each trigger.
  [ON POINT] The LCR meter sweeps one segment by each trigger. (See the note below.)

- TRIG PLRTY POS neg Selects the trigger signal polarity of an externally generated signal connected to the rear panel EXT TRIGGER input. This key is enabled when EXTERNAL has been selected for trigger source.

  POS neg The sweep is started by a low-to-high transition of a TTL signal.
  pos NEG The sweep is started by a high-to-low transition of a TTL signal.

Note

The RDC measurement is performed in addition to those performed according to the segments in the sweep list.
The first trigger initiates the RDC measurement. Then, the following triggers sequentially initiate those measurements specified by the segments in the sweep list, starting from segment 1.

Letter Menu

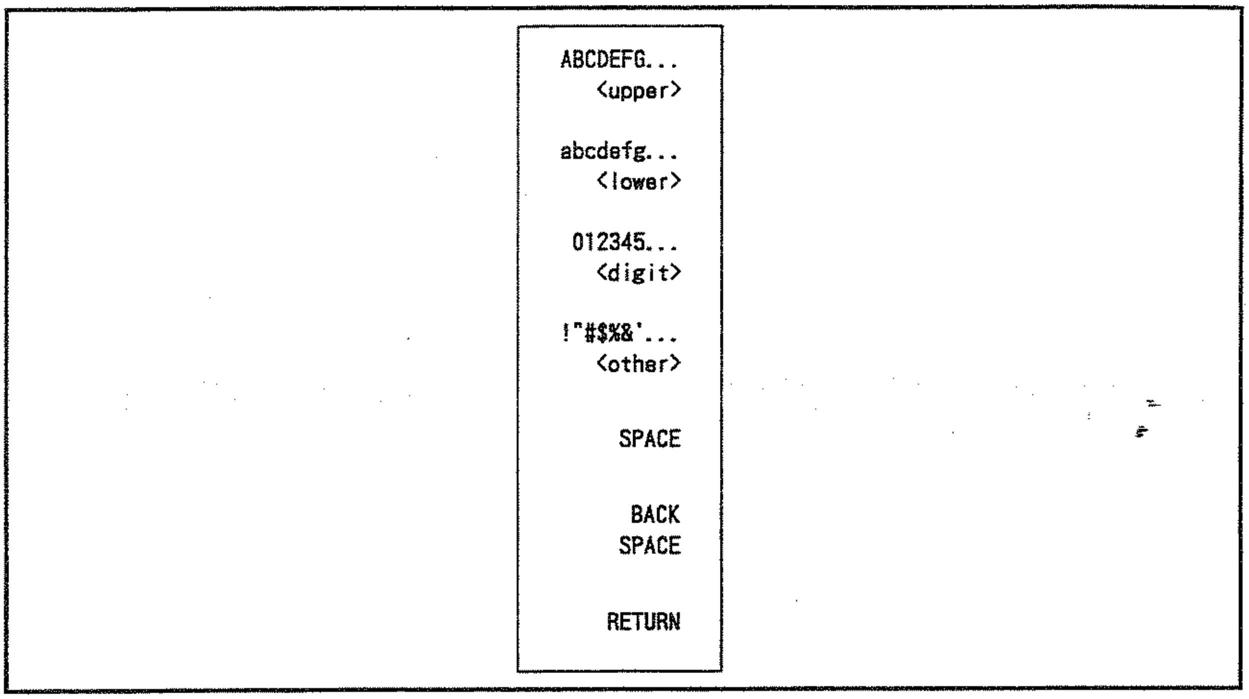


Figure 4-18. Letter Menu

- LETTER MENU Displays the Letter menu.
  - ABCDEFG...<upper> Allows uppercase characters to be entered. The softkey label area displays the characters that can be entered. If you cannot find the desired character, press MORE to display other available characters. The selected character appears in the active entry area.
  - abcdefg...<lower> Allows lowercase characters to be entered. Find the desired character in the same manner as for uppercase characters.
  - _12345...<digit> Allows numbers and underscore character (_) to be entered. Find the desired number in the same manner as for uppercase characters.
  - !#%&...<other> Allows symbols to be entered. Find the desired symbol in the same manner as for uppercase characters. See Table 4-2 for available symbols.

Table 4-2. Characters Available with the Letter Menu

Softkey	Character
ABCDEFG...<upper>	A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z
abcdefg...<lower>	a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t,u, v, w, x, y, z
_12345...<digit>	_, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
!#%&...<other>	!, ", #, $, %, &, ', (,), *, +, −, /, :, ;, <, &=, &>, ?, [, \,], ^, ', ', {, |, }, Δ, ε μ, °, Ω, Γ, θ, σ, @

Instrument State Block

The instrument state block keys and associated menus control measurement-independent system functions. These include controller modes, LCR meter addresses, real time clock, limit lines and limit testing, HP Instrument BASIC (Option 1C2), beeper, plotting or printing, saving instrument states and data on a built-in disk or RAM disk memory, and the preset state.

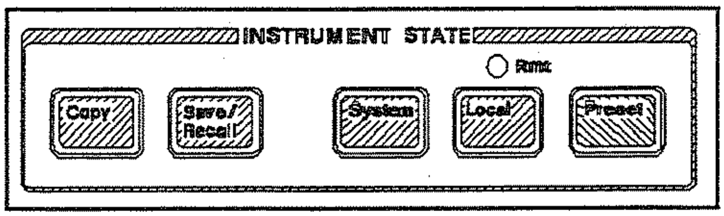


Figure 5-1. Instrument State Block

(System)	Controlling HP Instrument BASIC (Option 1C2 only)
	Adjusting the internal real time clock that is used to print the current time and date on the head of a hard copy.
	Toggling Beeper ON/OFF.
	Service Menu (used for testing). See the *Service Manual* for more information. The *Service Manual* is furnished with Option 0BW.
(Local)	Setting HP-IB mode and addresses.
(Preset)	Presetting State.
(Copy)	Printing and plotting screen image, listing measurement data and operating parameters, calibration kit parameters, list sweep table, and limit test table.
(Save/Recall)	Saving data to and recalling them from the built-in disk or RAM disk memory.

For Additional Information on ...	See ...
Preset values and Setting Range of each function setting value	Appendix C in this manual
All Softkey Trees	Appendix B in this manual
HP-IB Command Reference	*Programming Guide*
How to control the HP 4286A using an external controller or the HP Instrument BASIC capability through the HP-IB.	*Programming Guide*

System

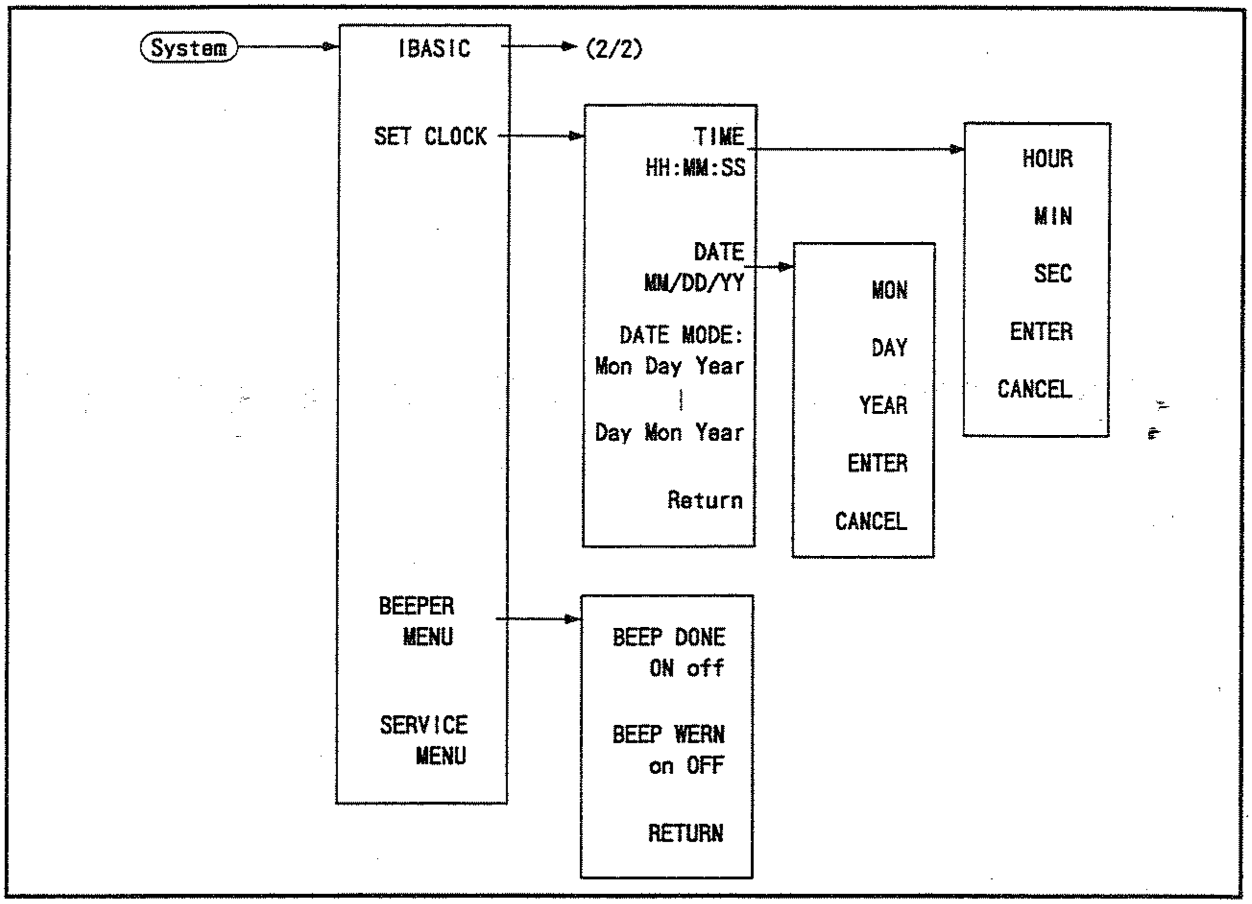


Figure 5-2. Softkey Menus Accessed from the System Key (1/2)

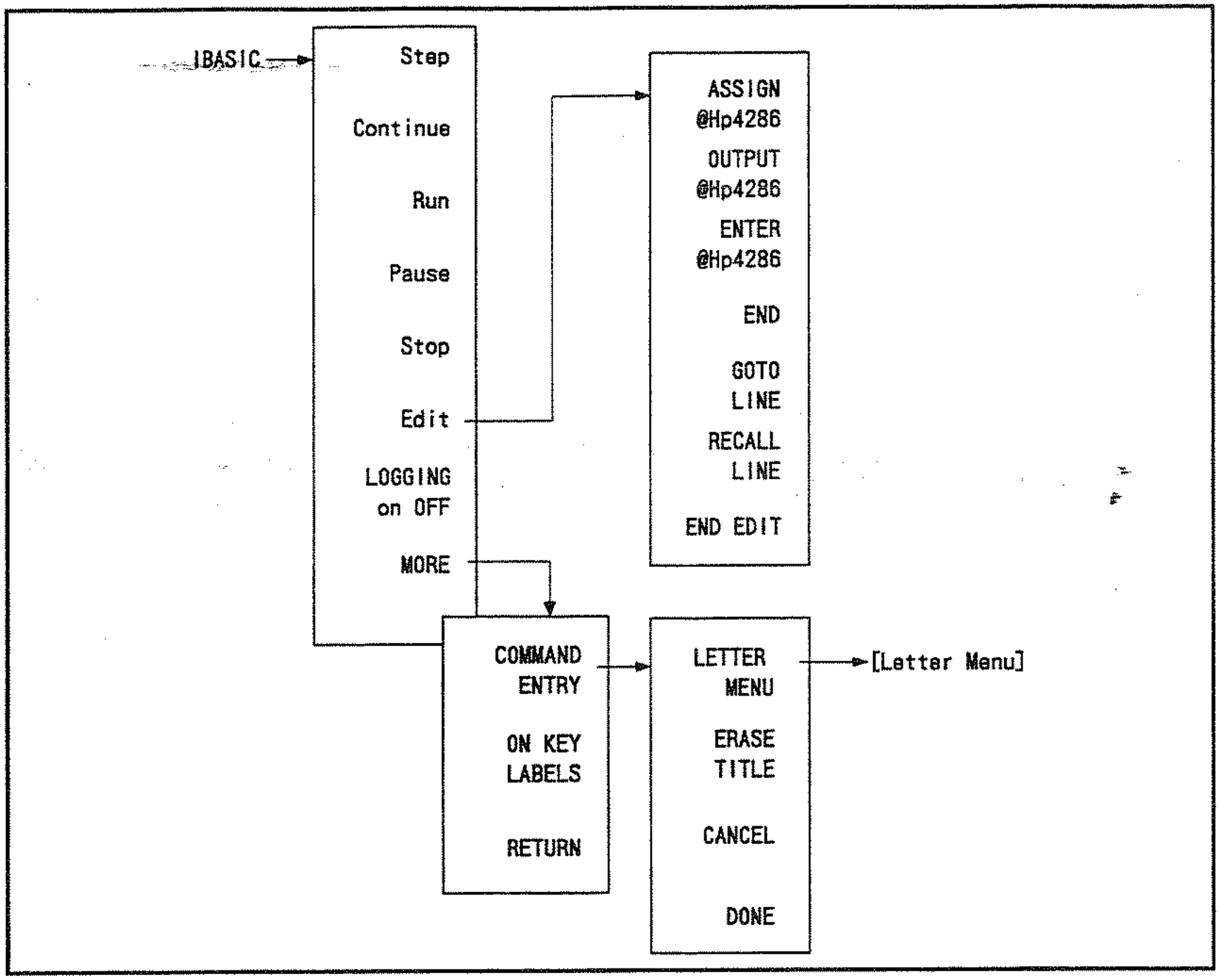


Figure 5-3. Softkey Menus Accessed from the System Key (2/2)

- IBASIC Displays the menu used to operate HP Instrument BASIC. This softkey appears only if the LCR meter is equipped with Option 1C2.
  - Step Allows you to execute one program line at a time. This is particularly useful for debugging.
  - Continue Resumes program execution from the point where it paused.
  - Run Starts a program from its beginning.
  - Pause Pauses program execution after the current program line is executed.
  - Stop Stops program execution after the current line. To restart the program, press Run.
  - Edit Enters into the EDIT mode. In the EDIT mode, the following softkeys are displayed on the softkey menu area.
    - ASSIGN @Hp4286 Produces the command `ASSIGN @Hp4286 TO 800` at the cursor's current position.
    - OUTPUT @Hp4286 Produces the command `OUTPUT @Hp4286;""` at the cursor's current position.
    - ENTER @Hp4286 Produces the command `ENTER @Hp4286;` at the cursor's current position.
    - END Produces the command `END`.

- GOTO LINE Allows you to move the cursor to any line number or to a label. After pressing GOTO LINE, type a line number or a label and then press (x1) or (Return) on the keyboard. The cursor moves to the specified line or label.
- RECALL LINE Recalls the last deleted line.
- END EDIT Exits the edit mode.

□ LOGGING ON off Turns the logging mode on or off. When logging is ON, the LCR meter logs the equivalent HP-IB commands of all front panel key inputs into the HP Instrument BASIC program.

Logging Function

- When an Instrument BASIC program is running, waiting for an input, or being edited, logging cannot be turned on.
- When the LCR meter does not have a program loaded, the following statements are automatically inserted at the beginning and the end of the program.

```
ASSIGN @Hp4286 TO 800
END
```

- When there are already some statements in the Interment BASIC editor, the program lines logged are inserted at the current cursor line.
- The short form of the command is logged and the suffix (unit of parameter) is omitted.
- If the command logged exceeds the memory capacity for the Instrument BASIC, error will occur.
- If you make an input error when logging is ON, the LCR meter generates the equivalent codes faithfully and the resulting program is incorrect.
- The logging function does not truncate the repeated nodes of the SCPI command. This makes program lines longer than necessary.
- The logging function does not take into consideration the requirements of a timing sensitive operation such as triggering or a fixture compensation procedure. Therefore, you need to add or rewrite the lines for that part of a program to run correctly.

□ COMMAND ENTRY Displays the softkeys that are used to enter BASIC commands.

- LETTER MENU Leads to *Letter menu*. See "Letter Menu" in Chapter 4 for details.
- BACK SPACE Deletes the last character entered.
- CANCEL Cancels command and returns to the previous menu.

□ ON KEY LABELS Displays the softkey labels, which are defined in the Instrument BASIC program.

- SET CLOCK Displays the menus used to set an internal clock.

□ TIME HH:MM:SS Displays the current time on the active entry area and displays the next page to adjust time.

- HOUR Enables changing the hour setting using the knob or the numeric entry keys. After you change the hour setting, press ENTER to restart the clock.
- MIN Enables changing the minute setting using the knob or the numeric entry keys. After you change the minute setting, press ENTER to restart the clock.
- SEC Enables changing the second setting using the knob or the numeric entry keys. After you change the second setting, press ENTER to restart the clock.
- ENTER Restarts the internal clock.
- CANCEL Returns to the previous page. Pressing this key does not affect the internal clock setting.

□ DATE DD/MM/YY Displays the current date on the active entry area to adjust date.

- MON Enables changing the month setting using the knob or the numeric entry keys. After you change the month setting, press ENTER to restart the clock.
- DAY Enables changing the day setting using the knob or the numeric entry keys. After you change the day setting, press ENTER to restart the clock.
- YEAR Enables changing the year setting using the knob or the numeric entry keys. After you change the year setting, press ENTER to restart the clock.
- ENTER Restarts the internal clock.
- CANCEL Returns to the previous page. Pressing this key does not affect the internal clock setting.

□ DATE MODE:MonDayYear Changes the displayed date to the "month:day:year" format.

□ DayMonYear Changes the displayed date to the "day:month:year" format.

- BEEPER MENU Displays the menu used to turn ON/OFF the beeper for announcing the completion of calibration measurement and storing of settings. This menu also includes the softkey used to inform that a warning message has appeared.

□ BEEP DONE ON off Toggles an annunciator that sounds to indicate the completion of operations such as calibration or instrument state save.

□ BEEP WARN ON off Toggles the warning annunciator. When the annunciator is ON it sounds a warning when a cautionary message is displayed.

- SERVICE MENU Displays a series of service menus described in the *Service Manual*.

(Local)

HP 4286A ignores all front panel keys (except the local key) when under the control of an external computer. The LCR meter is in "local mode" when the user has front panel control. The LCR meter is in the "remote mode" when an external computer controls the LCR meter. The LCR meter is in "system controller mode" when the controller in the LCR meter controls this meter and peripheral equipment.

(Local) has the following functions:

- Returns front panel control of the LCR meter in remote mode (with Rmt indicator on) to the user.
- Gives access to the HP-IB menu that sets the controller mode and to the address menu (where the HP-IB addresses of the LCR meter and peripheral devices are entered). Only one active controller can control the bus in a multiple-controller system. The controller mode determines which device is system controller and which acts as the master controller (and can regain active control at any time in a multiple-controller system).

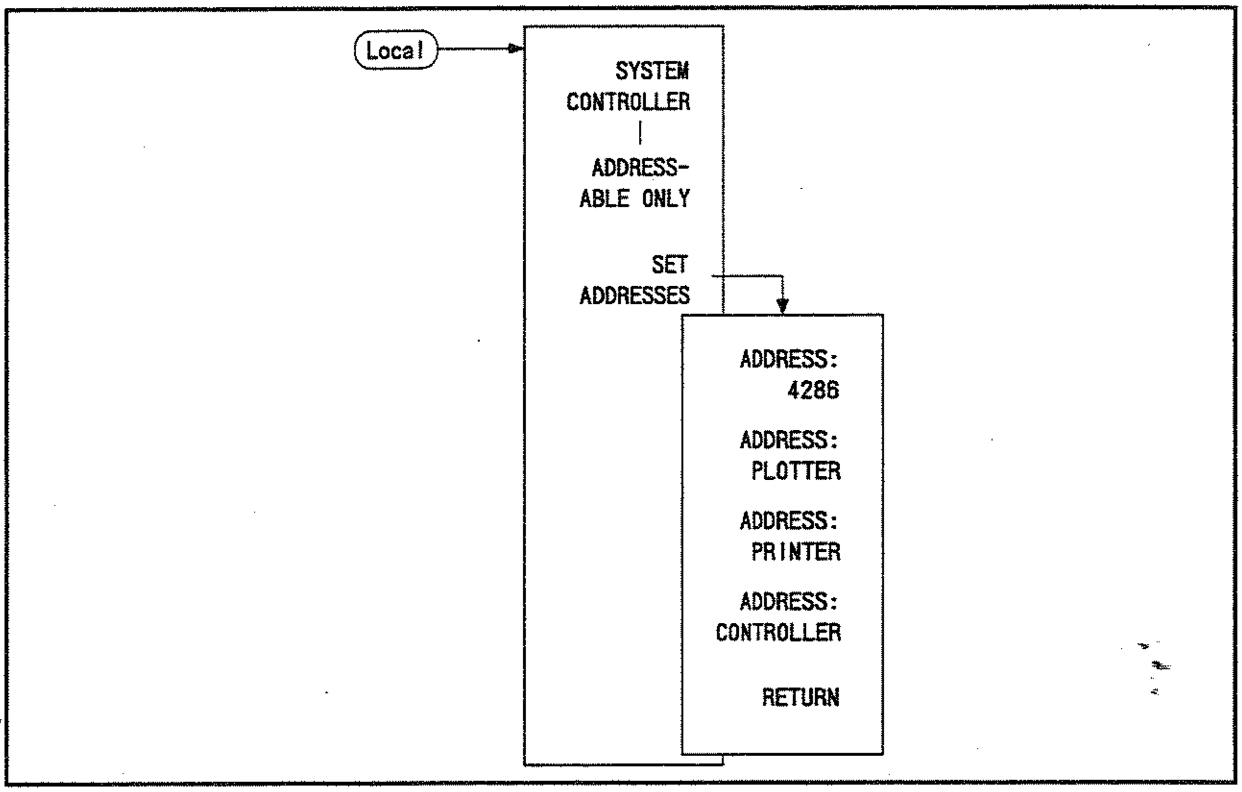


Figure 5-4. Softkey Menu Accessed from (Local) Key

- SYSTEM CONTROLLER Sets the LCR meter as the system controller. This mode is used when peripheral devices are to be used and there is no external controller. This mode can only be selected manually from the LCR meter's front panel and can be used only if no active system controller is connected to the system through HP-IB. If you try to set system controller mode when another system controller is present, the message "CAUTION: CAN'T CHANGE - ANOTHER CONTROLLER ON BUS" is displayed.
- ADDRESSABLE ONLY Sets the LCR meter as addressable only. This mode is used when an external controller controls peripheral devices or the LCR meter. This mode is also used when control is transferred from external controller to the LCR meter.

- SET ADDRESS: Displays the following softkeys:
  - ADDRESS:4286 Sets the HP-IB address of the LCR meter. There is no physical address switch to set in HP 4286A.
  - ADDRESS:PLOTTER Sets the HP-IB address the LCR meter will use to communicate with the plotter.
  - ADDRESS:PRINTER Sets the HP-IB address the LCR meter will use to communicate with the printer.
  - ADDRESS:CONTROLLER Sets the HP-IB address the LCR meter will use to communicate with the external controller.

The LCR meter keeps the setting of the HP-IB mode and HP-IB addresses in the battery backup memory, even if the LCR meter is turned off.

(Preset)

(Preset) key presets the instrument state to the preset default value. The preset default values are listed in Appendix C. (Preset) has no effect on the following states:

- Display Allocation
- Display Adjustment
- Clock Time/Date
- Limit Table
- HP-IB Address
- HP-IB Mode (system controller and addressable)
- User Cal Kit Definition
- User Compensation Kit Definition
- Fixture Selection (Impedance, Permittivity, and Permeability)

Copy

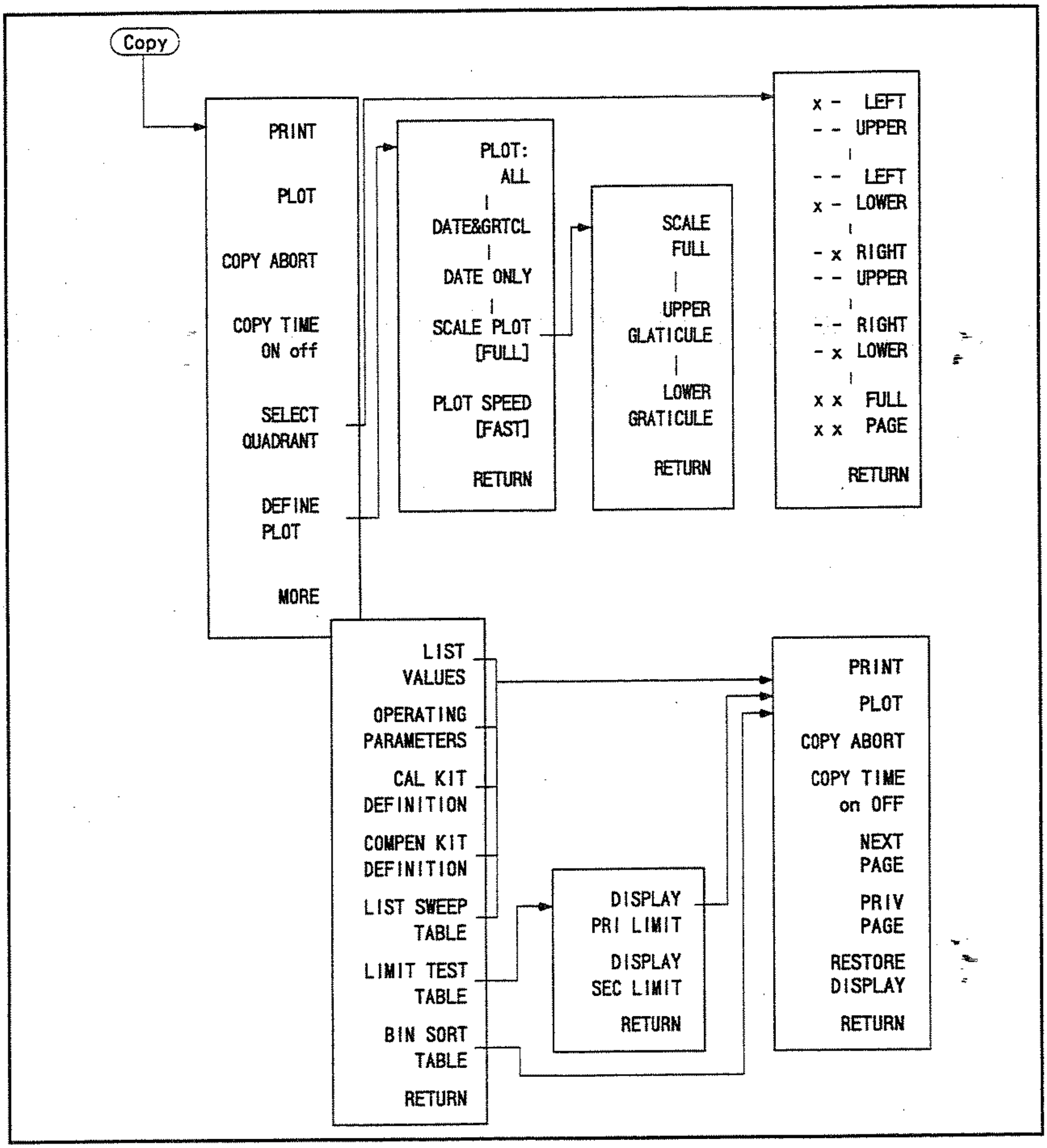


Figure 5-5. Softkey Menus Accessed from the Copy Key

(Copy)

- PRINT [ ] Prints an exact copy of the display. The softkey label identifies the printer selected in the print/plot setup menu:
- PLOT Plots the current screen display.
- COPY ABORT Aborts plotting or printing in progress.
- COPY TIME ON off Turns the "time stamp" on or off for a print or plot. When you select print, the time and date are printed out first, followed by the information shown on the display. When you select plot, the time and date are plotted on the message area. See "SET CLOCK" in the (System) section for setting the internal clock.
- SELECT QUADRANT Displays the *Select Quadrant menu* that provides the capability of drawing quarter-page plots. This is not used for printing.
  - x - LEFT - - UPPER Draws a quarter-page plot in the upper left quadrant of the page.
  - - - LEFT x - LOWER Draws a quarter-page plot in the lower left quadrant of the page.
  - - x RIGHT - - UPPER Draws a quarter-page plot in the upper right quadrant of the page.
  - - - RIGHT - x LOWER Draws a quarter-page plot in the lower right quadrant of the page.
  - x x FULL x x PAGE Draws a full-size plot according to the scale defined with SCALE PLOT in the define plot menu (described next).
- LIST VALUES Provides a tabular listing of all the measured data points and their current values. When LIMIT TEST is ON, the limit information is also listed together with the measured values.The *Screen menu* is presented to allow hard copy listings and access new pages of the table.
- OPERATING PARAMETERS Displays a tabular listing of the key parameters. The *Screen menu* is presented to allow hard copy listings and access new pages of the table.

Parameters listed by OPERATION PARAMETERS
The following operating parameters are listed in four pages: □ Sweep Source □ Sweep Type □ Number of Points □ CAL Kit □ CAL Type □ Test Head □ Fixture □ Port Extension □ Material Size (Option 002 only) □ Calibration States □ Compensation States □ Trigger Source □ Trigger Polarity

- CAL KIT DEFINITION Displays the *Screen menu* and lists the standard definition of the cal kit.
- COMPEN KIT DEFINITION Displays the *Screen menu* and lists the standard definition of the OPEN, SHORT and LOAD standard for fixture compensation.
- LIST SWEEP TABLE Displays the *copy list sweep menu* that can display a tabular listing of the list sweep table and print or plot it.

- LIMIT TEST TABLE Displays the *copy limit test menu* that can display a tabular listing of the limit value for limit testing and print or plot it.
  - DISPLAY PRI LIMIT Displays the limit testing table for primary parameters, and *Screen menu* to prepare for hard copy and to switch display.
  - DISPLAY SEC LIMIT Displays the limit testing table for secondary parameters, and *Screen menu* to prepare for hard copy and to switch display.
- BIN SORT TABLE Displays BIN sorting table values.

Screen Menu

- PRINT [ ] Copies one page of the tabular listings to a compatible HP graphics printer.
- PLOT Plots the list on the screen using the HP or HP-compatible plotter.
- COPY ABORT Aborts plotting or printing in progress.
- COPY TIME ON off Turns printing or plotting time and date ON or OFF. When you select print, the time and date are printed first then the information displayed. When you select plot, time and date are plotted just below the title area. See "SET CLOCK" in the (System) section for setting the internal clock.
- NEXT PAGE Displays the next page of information in a tabular listing .
- PREV PAGE Displays the previous page of information in a tabular listing.
- RESTORE DISPLAY Turns off the tabular listing and returns the measurement display to the screen.

Save/Recall

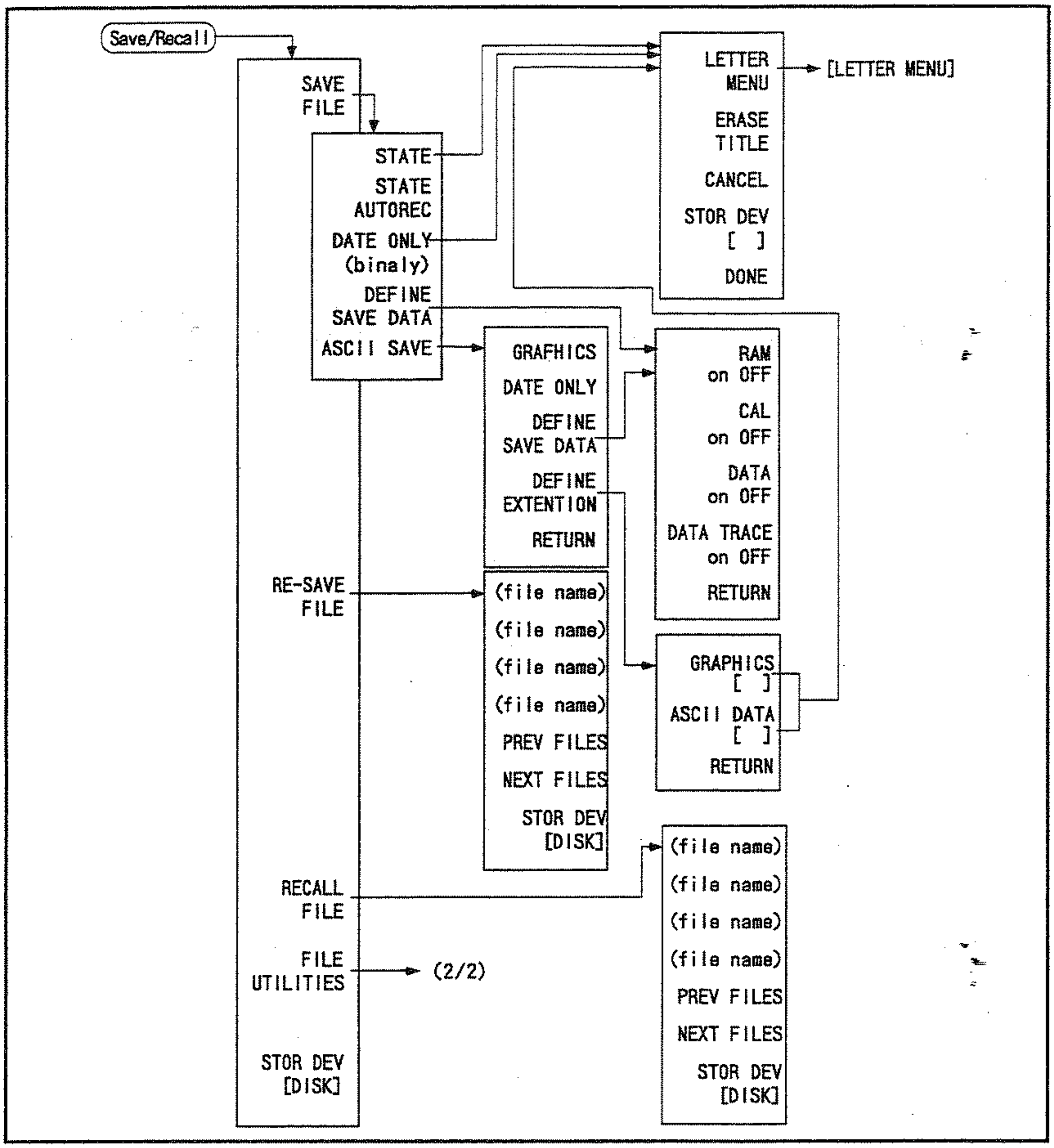


Figure 5-6. Softkey Menus Accessed from the Save/Recall Key (1/2)

5. Instrument State Block

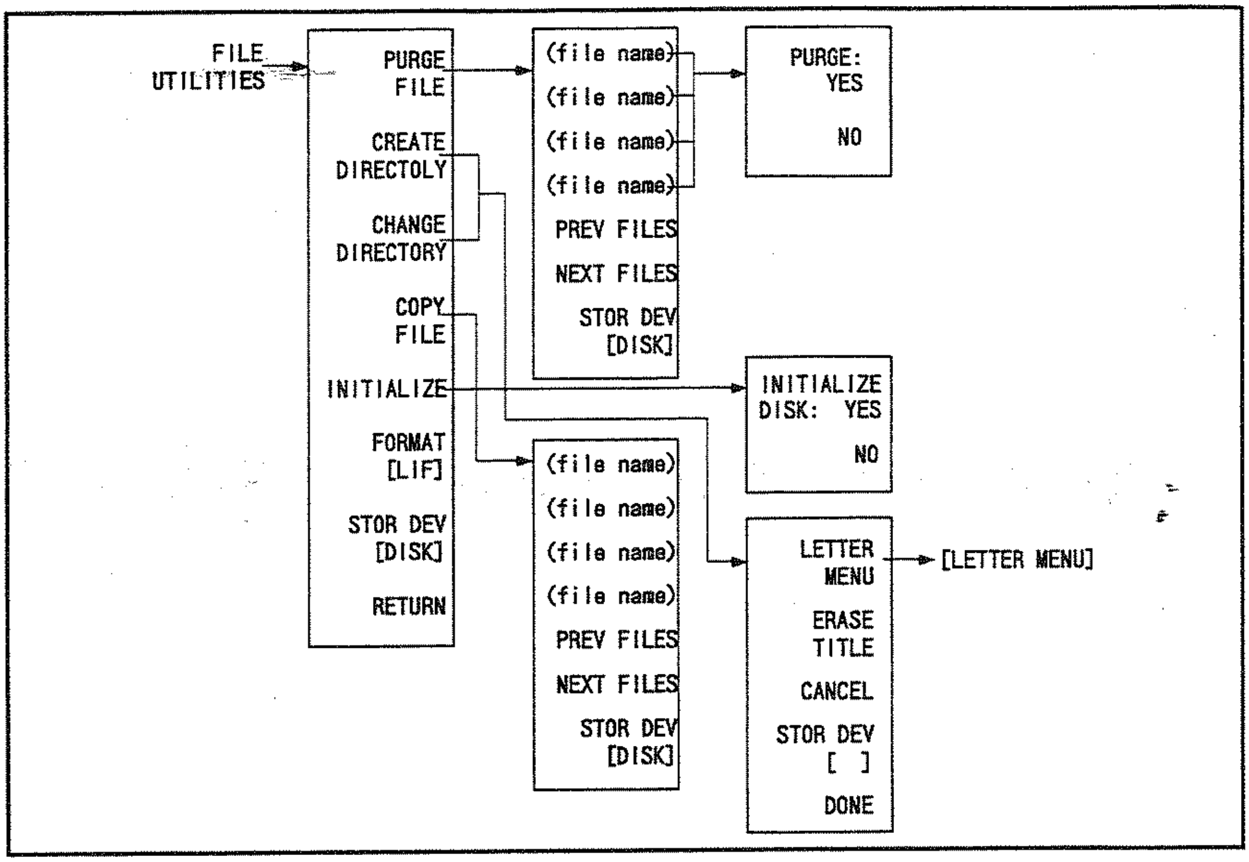


Figure 5-7. Softkey Menus Accessed from the (Save/Recall) Key (2/2)

Recalling Instrument BASIC program
The Save/Recall key does not provide access Instrument BASIC programs. Instrument BASIC has its own menus that are accessed from the keyboard. See the *HP Instrument BASIC Users Handbook Supplement* for more information.

- SAVE FILE Provides access to the menu used to store settings and measurement data.
  - STATE Allows filename to be entered. The softkey label area displays the *State menu.*
  - STATE → AUTOREC Stores a file by the name ofAUTOREC.

Auto Recall
When the HP 4286A is turned on, it searches the flexible and RAM disks for a file by the name of AUTOREC. When it finds this file, it automatically reads the contents of this file to recall settings and measurement data. When the file by this name is saved on both the flexible and RAM disks, the contents of the file on the flexible disk are read by the HP 4286A.

  - DATA ONLY (binary) Specifies storing of internal data arrays defined using DEFINE SAVE DATA. The softkey label area displays the *State menu.*
  - DEFINE SAVE DATA Provides access to the *Define Save Data menu* to select the internal data arrays to be saved.
  - ASCII SAVE Provides access to the menu used to store data and graphic images in an ASCII file.

You cannot recall ASCII files.
You cannot read data stored as an ASCII file with the HP 4286A. Be sure to store data as a binary file when you know that you will recall this file later. Binary file can be recalled at any time and stored as an ASCII file.

    - GRAPHICS Stores on-screen graphic images as an HP-GL file. The softkey label area displays the *State menu.*
    - DATA ONLY Stores internal data arrangement as an ASCII file. The softkey label area displays the *State menu.* Define the desired data arrangement using DEFINE SAVE DATA.
    - DEFINE SAVE DATA Provides access to the *Define Save Data menu* used to select the internal data arrangement to be stored.
    - DEFINE EXTENSION Modifies ASCII file extension. This key provides access to the following menu:
      - GRAPHICS [ ] Specifies graphic image file extension. The softkey label area displays the *State menu.*
      - ASCII [ ] Specifies internal data arrangement file extension. The softkey label area displays the *State menu.*
      - RETURN Modifies file extension as specified and returns to the previous menu.
- RE-SAVE FILE Overwrites data in a stored file. Select the target file using the *File menu.* File extension indicates which data to be stored. See "Saving and Recalling Instrument States and Data" laster in this chapter for details on extensions.
- RECALL FILE Reads stored file. Select the target file using the *File menu.*
- FILE UTILITIES Displays the following softkey menu:

- PURGE FILE Deletes a stored file. Select the file to be deleted using the *File menu*. When you select the desired file, the following menu is displayed:
  - PURGE:YES Delete the file and returns to the previous menu.
  - NO Does not delete the file and returns to the previous menu.
- CREATE DIRECTORY Creates a new directory in the DOS format disk. You cannot use this function for the LIF format disk. The softkey label area displays the *State menu*.
- CHANGE DIRECTORY Modifies the current directory in the DOS format disk. You cannot use this function for the LIF format disk. The softkey label area displays the *State menu*.
- COPY FILE Copies a file. When you copy a file between the flexible disk and RAM disk, both disks must have the same format. You cannot copy a file between the LIF format and DOS format disks. The softkey label area displays the *State menu*.

Be sure to use disks of the same format.
You can copy a file between two disks only when these disks have the same format.

- INITIALIZE Provides access to the *INITIALIZE YES/NO menu*. Be sure to initialize the new disk before storing data. You can initialize the disk in the DOS or LIF format.
- FORMAT [LIF] Selects the DOS or LIF format for initializing a new disk. The selected format does not change even when the HP 4286A is turned off or (Preset) is pressed. The HP 4286A has been set to the LIF format before shipment.
- STOR DEV [ ] Selects the flexible or RAM disk as the storage device. [DISK] and [MEMORY] are displayed respectively when the flexible disk and RAM disk are selected.

■ STOR DEV [ ] Selects the flexible or RAM disk as the storage device. [DISK] and [MEMORY] are displayed respectively when the flexible disk and RAM disk are selected. The disk selected using STOR DEV [ ] does not change even when the HP 4286A is turned off or (Preset) is pressed.

Contents of the RAM disk are stored for 3 days after power-off.
The RAM disk in the HP 4286A contains a battery-powered SRAM disk memory. The battery for this memory can be fully charged in 10 minutes after the HP 4286A power-on.
However, note that contents of the RAM disk are stored only for 3 days after power-off. Be sure to save important data in the flexible disk.

The storage selection does not change even when the power is turned off or the (Preset) key is pressed.

State Menu

- LETTER MENU Provides access to the *Letter menu*. See "Letter Menu" in Chapter 4 for details.
- ERASE TITLE Erases the file name in the active entiry area.
- CANCEL Cancels specifying file name and returns to the previous menu.
- STOR DEV[ ] Selects between the flexible disk drive and the RAM disk memory as the storage device. [DISK] shows the built-in flexible disk is selected and [MEMORY] shows the RAM disk memory is selected. This setting does not change even when the line power is cycled or the Preset key is pressed.
- DONE Stores file specification and returns to the previous menu.

Select File Menu

- file name Displays the list of files in the storage specified in [ ] of STORE DEV[ ]. Select the desired file in this list. Note that only the files that can be read by the HP 4286A are displayed.
- PREV FILES Displays the previous file names in the softkey label to purge file.
- NEXT FILES Displays the next file names in the softkey label to purge file.
- STOR DEV[ ] Selects between the flexible disk drive and the RAM disk memory as the storage device. [DISK] shows the built-in flexible disk is selected and [MEMORY] shows the RAM disk memory is selected. This setting does not change even when the line power is cycled or the Preset key is pressed.

Define Save Data Menu

- RAM on OFF Toggles saving or not saving the data contained in the RAM disk.
- CAL ON off Toggles saving or not saving the calibration coefficients arrays.
- DATA ON off Toggles saving or not saving the data arrays.
- DATA TRACE ON off Toggles saving or not saving the trace arrays.

Initialize Yes No Menu

- INITIALIZE DISK-YES Initializes the disk or the RAM disk. When the flexible disk is selected for initialization, DISK is displayed in the softkey label, When the RAM disk memory is selected, MEMORY is displayed.
- NO Returns to the previous menu without initializing the flexible disk or the RAM disk memory.

HP-IB

What is HP-IB?

HP 4286A is factory-equipped with a remote programming digital interface based on the Hewlett-Packard Interface Bus (HP-IB). (HP-IB is Hewlett-Packard's hardware, software, documentation, and support for IEEE 488.1, IEC-625, IEEE 488.2, and JIS-C1901 worldwide standards for interfacing instruments.) This allows the LCR meter to be controlled by an external computer that sends commands or instructions to and receives data from HP 4286A using the HP-IB. In this way, a remote operator has the same control of the instrument available to a local operator from the front panel, except for the line power switch.

In addition, HP 4286A itself can use HP-IB to directly control compatible peripherals, without the use of an external controller. It can output measurement results directly to a compatible printer or plotter.

This section provides an overview of HP-IB operation. The *User's Guide* provides information on how to use HP 4286A to control peripherals. It also explains how to use HP 4286A as a controller to print and plot.

More complete information on programming HP 4286A remotely over HP-IB is provided in *Programming Guide*. The *Programming Guide* includes examples of remote measurements using an HP 9000 series 200 or 300 computer with BASIC programming. The *Programming Guide* assumes familiarity with front panel operation of the instrument.

A complete general description of the HP-IB is available in *Tutorial Description of the Hewlett-Packard Interface Bus*, HP publication 5952-0156. For more information on the IEEE 488.1 and 488.2 standard, see *IEEE Standard Digital Interface for Programmable Instrumentation*, published by the Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York 10017, USA.

How HP-IB Works

The HP-IB uses a party-line bus structure in which up to 15 devices can be connected on one contiguous bus. The interface consists of 16 signal lines and 6 grounded lines in a shielded cable. With this cabling system, many different types of devices including instruments, computers, plotters and printers can be connected in parallel.

Every HP-IB device must be capable of performing one or more of the following interface functions:

Talker

A talker is a device capable of sending device-dependent data when addressed to talk. There can be only one active talker at any given time. Examples of this type of device are voltmeters, counters, and tape readers. HP 4286A is a talker when it sends trace data or marker information over the bus.

Listener

A listener is a device capable of receiving device-dependent data when addressed to listen. There can be any number of active listeners at any given time. Examples of this type of device are printers, power supplies, and signal generators. HP 4286A is a listener when it is controlled over the bus by a computer.

Controller

A controller is a device capable of managing the operation of the bus and addressing talkers and listeners. There can be only one active controller at any time. Examples of controllers include desktop computers and minicomputers. In a multiple-controller system, active control can be passed between controllers, but there can only be one *system controller* that acts as the master, and can regain active control at any time. HP 4286A is an active controller when it plots or prints in the addressable mode. HP 4286A is a system controller when it is in the system controller mode.

HP-IB Requirements

- **Number of Interconnected Devices**

  15 maximum
- **Interconnection Path/Maximum Cable Length**

  20 meters maximum or 2 meters per device, whichever is less.
- **Message Transfer Scheme**

  Byte serial/bit parallel asynchronous data transfer using a 3-line handshake system.
- **Data Rate**

  Maximum of 1 megabyte per second over limited distances with tri-state drivers. Actual data rate depends on the transfer rate of the slowest device involved.
- **Address Capability**

  Primary addresses: 31 talk, 31 listen. A maximum of 1 active talker and 14 active listeners at one time.
- **Multiple Controller Capability**

  In systems with more than one controller, only one can be active at any given time. The active controller can pass control to another controller, but only one system controller is allowed.

HP 4286A's HP-IB Capabilities

As defined by the IEEE 488.1 standard, HP 4286A has the following capabilities:

SH1	Full source handshake.
AH1	Full acceptor handshake.
T6	Basic talker, answers serial poll, unadresses if MLA is issued. No talk-only mode.
TE0	Does not have extended address of talker.
L4	Basic listener, unadresses if MTA is issued. No listen-only mode.
LE0	Does not have extended address of listener.
SR1	Complete service request (SRQ) capabilities.
RL1	Complete remote/local capability including local lockout.
PP0	Does not respond to parallel poll.
DC1	Complete device clear.
DT1	Responds to a group execute trigger.
C1, C2, C3, C4	System controller capabilities in system controller mode.
C11	Pass control capabilities in addressable mode.
E2	Tri-state drivers.

Bus Mode

HP 4286A uses a single-bus architecture. The single bus allows both HP 4286A and the host controller to have complete access to the peripherals in the system.

Two different modes are possible, system controller and addressable.

System Controller

This mode allows HP 4286A to control peripherals directly in a stand-alone environment (without an external controller). This mode can only be selected manually from HP 4286A front panel. Use this mode for operation when no computer is connected to HP 4286A and for printing or plotting.

Addressable

This is the traditional programming mode, in which the external computer is involved in all peripheral access operations. When the external controller is connected to HP 4286A through HP-IB (as shown in Figure 5-8), this mode allows the external controller to control HP 4286A over HP-IB in the talker mode in order to send data, and in the listener mode to receive commands. It also allows HP 4286A to take or pass control in order to plot and print.

Programming information for the addressable mode is provided in the *Programming Guide.*

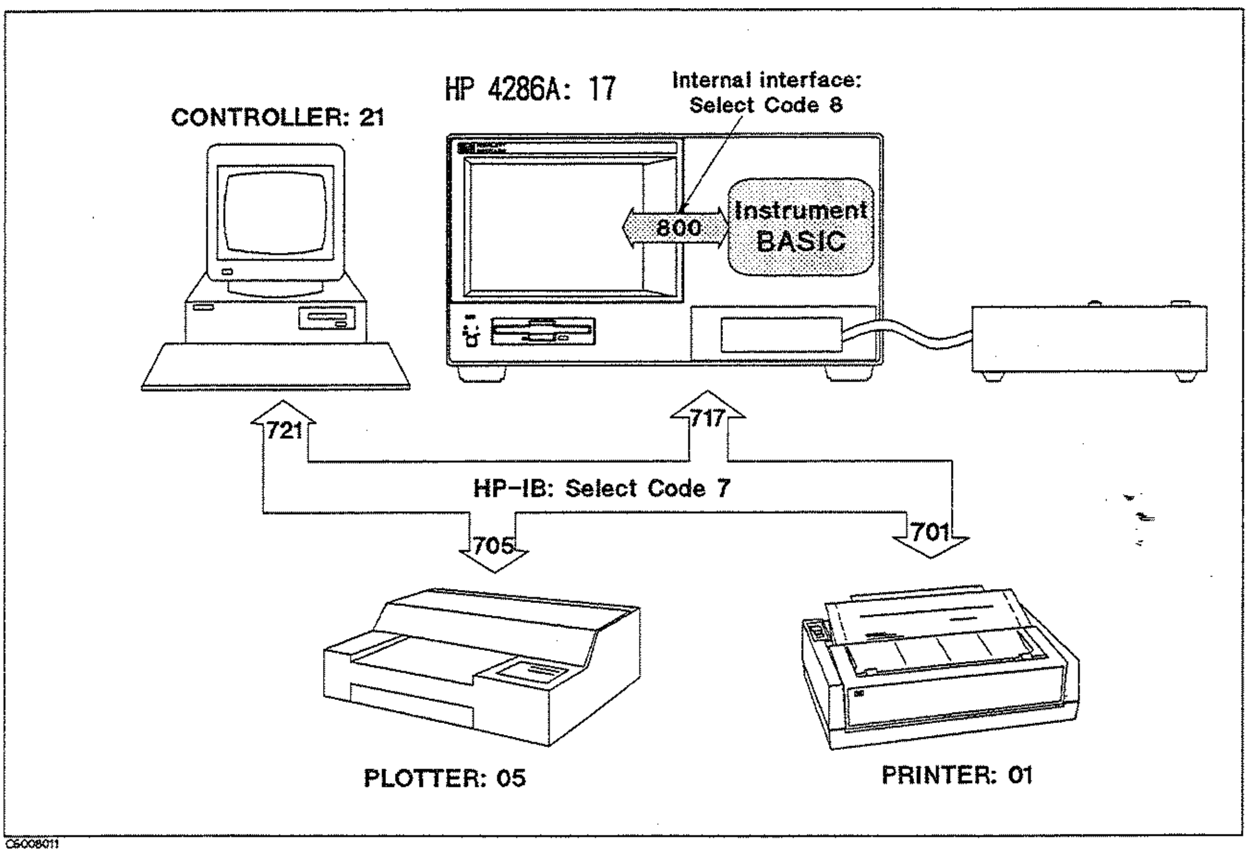


Figure 5-8. HP 4286A Bus Concept

Setting Addresses

In HP-IB communications, each instrument on the bus is identified by an HP-IB address. This address code must be different for each instrument on the bus. See Appendix C for information on default addresses, and on setting and changing addresses. These addresses are not affected when you press (Preset) or cycle the power.

Saving and Recalling Instrument States and Data

Storage Devices

The LCR meter supports two storage devices, a built-in flexible disk drive and a battery-powered SRAM disk memory. The flexible disk drive is suited to storing large numbers of files and long term data storage. The RAM disk is suited to storing tentative data and instrument states and to storing or recalling data quickly. However, data in the RAM disk can be stored for 3 days and will be lost when the battery is dead.

Disk Requirements

The LCR meter's disk drive uses a 720 Kbyte or 1.44 Mbyte 3.5 inch micro-flexible disk. See the "System accessories available" in Chapter 8 for disk part numbers.

Disk Formats

The LCR meter's built-in disk drive can access both LIF (logical interchange format) and DOS formatted disks. The disk drive and the RAM disk memory can also initialize a new disk in either LIF or DOS format.

The following list shows the applicable DOS formats for the LCR meter:

- 720 Kbyte, 80 tracks, double-sided, 9 sectors/track
- 1.44 Mbyte, 80 tracks, double-sided, 18 sectors/track

RAM Disk Memory Capacity

The RAM disk memory capacity is 512 Kbyte when option 1C2 is not installed. It can be changed when option 1C2 is installed. This capacity includes the directory area. The capacity of data area depends on the disk format type.

Copy Files Between the RAM Disk and the Flexible Disk

A copy function is provided to copy files between the RAM disk and the flexible disk. `FILE UTILITIES` in the SAVE menu displays the softkeys used to copy files. The HP-IB command `MMEMory:COPY` is also available to copy files (See the *HP-IB Command Reference*). When the format of the RAM disk is different from the format of the flexible disk, the copy function and the command can not be used.

File Types and Data Groups

File Types

The LCR meter supports two file types, binary and ASCII, that are used to save data on a disk.

- **Binary File**
  Binary files are used to save measurement conditions and data using the SAVE function and to retrieve binary data using the RECALL function. External controllers and Instrument BASIC can read measurement data from binary data files.
- **ASCII file**
  ASCII measurement data or screen image files can be read by commonly available IBM PC based software for data analysis or other secondary functions. The RECALL function cannot read ASCII files.

Data Groups

- **Instrument States and Internal Data Arrays (STATE)**

  This group consists of the instrument states that include raw calibration coefficients and the data arrays. (Binary Files Only)

- **Internal Data Arrays (DATA ONLY)**

  The internal data arrays that are stored in the LCR meter's memory consist of the following four data arrays (Binary and ASCII Files).

  - □ **Raw data arrays** contain the calibrated data obtained using the calibration coefficients.
  - □ **Calibration Coefficients arrays** contain the expanded calibration coefficients obtained by calibration and fixture compensation.
  - □ **Data arrays** contain the compensated data obtained using the compensation coefficients.
  - □ **Data-Trace arrays** contain the formatted data.

These arrays can be saved selectively to suit the application. For example, when measuring several devices with the same measurement settings, you may need to save only the ***data-trace arrays*** for each device. Saving only the necessary arrays reduces the disk space required and the disk access time. In addition, saving internal data also allows the analysis of the measurement results using an external controller. See "File Structure of Internal Data Arrays File for Binary Files" for more information.

Graphics Images (GRAPHICS)

- Graphics consist of the graphic images on the screen created using HP-GL (Hewlett-Packard Graphics Language). The HP-GL format is supported by most drawing software and is the format used by most plotters. (ASCII Files Only)

File Type and Data Group Combinations

You can select and save to a disk one of the following four combinations of the two file types and the four data groups.

- Binary File
  - □ Instrument states and internal data arrays (STATE)
  - □ Internal data arrays (DATA ONLY binary)
- ASCII File
  - □ Internal data arrays (DATA ONLY ascii)
  - □ Graphics image (GRAPHICS)

File Names

All data saved using the built-in disk drive and the RAM disk memory has an identifying file name. A file name consists of the lower and upper case alphabet, numbers, and valid symbol characters. Up to 8 characters can be used for a file name. The following table shows the valid characters for LIF and DOS file names.

Valid Characters for File Names

Valid Characters for LIF	Valid Characters for DOS Format
A - Z (Upper case alphabet)[1]	A - Z (Upper case alphabet)[2]
a - z (Lower case alphabet)[1]	a - z (Lower case alphabet)[2]
0 - 9 (Numeric characters)	0 - 9 (Numeric characters)
_ (under line)	$ & # % ' ! () - _ @ ˜ {} ˆ (Symbol)

1 LIF is case sensitive

2 DOS is not case sensitive

Suffixes (LIF) and Extensions (DOS)

One of the following suffixes or extensions is automatically added to the file name depending on the data group type stored in the file.

- **Suffixes for LIF**

  _S : Instrument States and Internal Data Arrays (STATE)

  _D : Internal Data Arrays (DATA ONLY (binary))

  _I: Internal Data Arrays as an ASCII File (DATA ONLY (ASCII))

  _G : Graphics Image as an HP-GL File (GRAPHICS)

- **Extensions for DOS**

  .STA : Instrument States and Internal Data Arrays (STATE)

  .DAT : Internal Data Arrays (DATA ONLY (binary))

  .TXT : Internal Data Arrays as an ASCII File (DATA ONLY (ASCII))

  .HPG : Graphics Image as an HP-GL File (GRAPHICS)

Auto Recall Function

When the HP 4286A is turned on, it searches the flexible and RAM disks for a file by the name of AUTOREC. When it finds this file, it automatically reads the contents of this file to recall settings and measurement data. When the file by this name is saved on both the flexible and RAM disks, the contents of the file on the flexible disk are read by the HP 4286A.

We recommend that you save the AUTOREC file in the flexible disk because data in the battery-powered RAM disk memory are stored only for 3 days after power-off.

File Structure of Internal Data Arrays File for Binary Files

When internal data arrays are saved as a binary file, the arrays' file consists of a file header at the top of the file and the data groups following the file header.

File Header

Every internal data array file begins with a file header. The following figure shows the header structure.

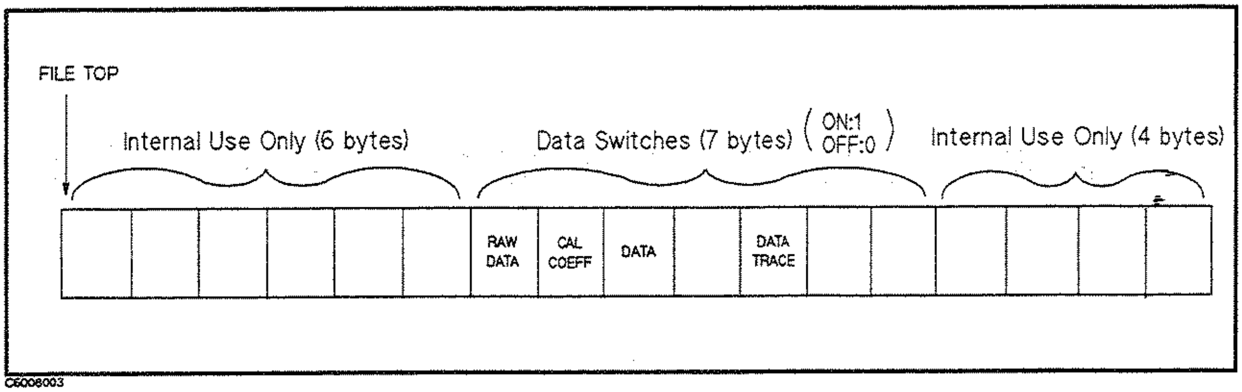


Figure 5-9. File Header Structure

Seven data switches define the data group that follows the file head. Each one-byte switch is either 1 or 0 (decimal value) if the applicable data group exists or not, respectively. The data group to be followed is in the same order of these switches. For example, when the data switches, RAW DATA and DATA-TRACE are 1 (ON), while the others are OFF, only the RAW DATA and DATA-TRACE (in this order) groups will follow the header.

Data Group

The data file structure begins with a header and consists of the same structured data segments. The number of data segments depends on the data group type as follows:

- **RAW DATA** consists of a header and four data segments as shown in the following figure. They will follow the file header in this order:
- **DATA** consists of a header and a data segment.
- **DATA-TRACE** consists of a header and a data segment.

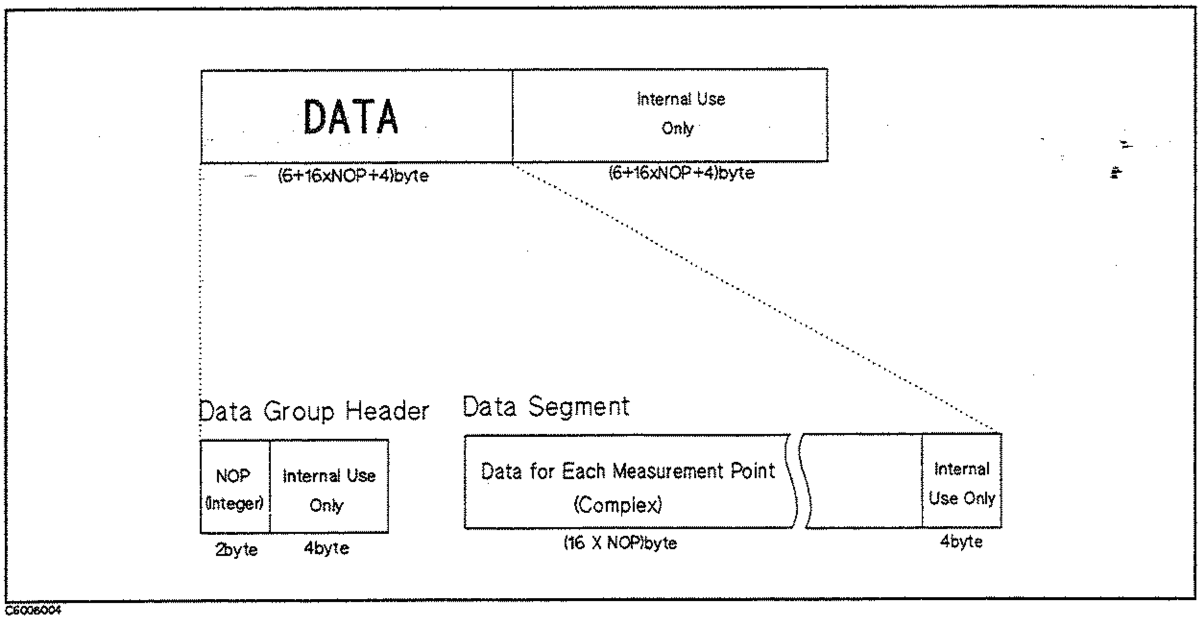


Figure 5-10. RAW DATA, DATA, and DATA-TRACE Data Group Structure

- **CAL** consists of data segments as shown in Figure 5-11.

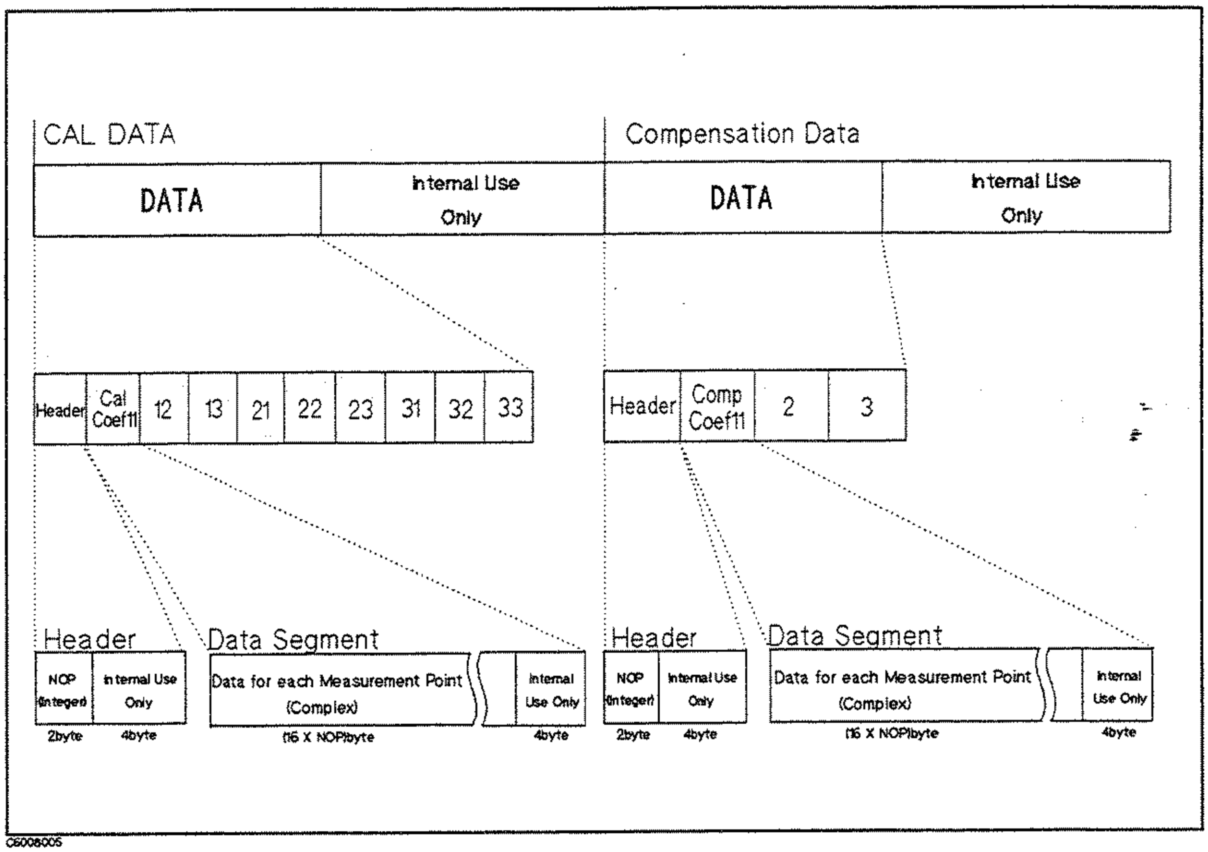


Figure 5-11. CAL Data Group Structure

Number Of Points (NOP) is a two-byte INTEGER value. This number is equal to the number of complex data that follows the NOP.

DATA SEGMENT is a set of the values for each measurement point. The values are IEEE 754 double precision floating number. The values are two numbers (the first value is the real part, the second value is the imaginary part). The data size in bytes can be determined by 16×NOP.

File Structure of Internal Data Arrays File for ASCII File

Numerical data and strings in an ASCII data file are separated by a tab, and a string is bound by double quotation marks. An ASCII data file consists of a status block and data blocks.

Status Block

The status block consists of two lines, the revision number and the date code.

Data Block

The data block consists of three parts, the state part, the title line, and the data part.

- **State**
  The state part consists of the following instrument states:
  - Title on the screen
  - Measurement parameter
  - Number of points
  - Sweep delay time
  - Point delay time
  - Sweep type
  - Source power
  - RDC measurement value
- **Title**
  The title part consists of the data array names saved. Data array names are described in the next section.
- **Data**
  The data part consists of sweep parameter and numerical data of data arrays.

Table 5-1 shows an example of an ASCII data file.

Table 5-1. Contents of ASCII Files

Block Names		Contents
Status Block		"4286A REV1.00" "DATE: Apr 24 1995"[1]
Data Block	State	"TITLE: This is a title."[2] "MEASURE PARAMETER: Ls-Q" "NUMBER of POINTS: 1" "SWEEP DELAY TIME: 62.5 us" "POINT DELAY TIME: 325 us" "SWEEP TYPE: LIST FREQ" "OSC LEVEL: 500 mV" "RDC Meas Val: 5.00000E+01"[3]
	Title	"Frequency"→"Raw Real"→"Raw Imag"→...[4,5,6]
	Data[7]	3.00000E+5→1→8.20007E-1→4.09729E-1→...[4] 1.52238E+7→1→9.32143E-1→-4.1914E-2→... ⋮

1 This is the date when the file is saved.

2 This line is listed when the title is defined (displayed).

3 Displays when contact check is set ON.

4 "→" means tab code. Data is separated by the tab code.

5 This line lists the names of the data array saved in this file.

6 The followint format is used when averaging is set ON.
"Frequency"→"Point Avg"→"Raw Real"→"Raw Imag"→...

7 Each line lists the measurement data at each measurement point. The number of lines in the data block is the same as the number of points.

6

LCR Meter Features

Introduction

This chapter provides additional information on the LCR meter features. The following subjects are covered in this chapter.

- System Overview
- Data Processing Flow

System Overview

Impedance analyzers, including LCR meters, usually apply a stimulus signal to the DUT. The analyzer then measures the complex voltage value (which is applied between the terminals of the DUT) and the complex current (which is flowing through the DUT). The impedance value is derived from both the voltage and current values.

Figure 6-1 is a simplified block diagram of the LCR meter. A detailed block diagram of the LCR meter is provided in the *Service Manual*, together with a complete theory of system operation.

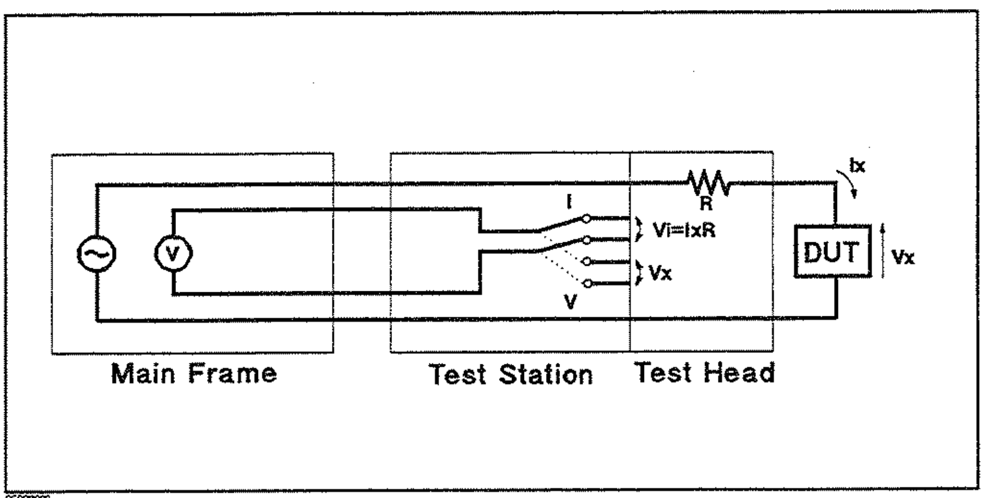


Figure 6-1. HP 4286A Simplified Block Diagram

Data Processing

Overview

The LCR meter's receiver converts the input signal into useful measurement information. This conversion occurs in two main steps. First, the high frequency input signal is translated to fixed low frequency IF signals using analog mixing techniques. Second, the IF signals are converted into digital data by an analog-to-digital converter (ADC). From this point on, all further signal processing is performed mathematically by the LCR meter microprocessor and digital signal processor. The following paragraphs describe the sequence of math operations and the resulting data arrays as the information flows from the ADC to the display. They provide a good foundation for understanding most of the measurement functions and the order in which they are performed.

Figure 6-2 is a data processing flow diagram that shows the flow of numerical data from the ADC to the display. The data passes through several math operations (shown as single-line boxes). Most of these operations can be selected and controlled by the front panel MEASUREMENT block menus. The data is also stored in data arrays (shown as double-line boxes). These arrays are places in the flow path where the data is accessible via HP-IB or by using the internal disk drive or the RAM disk memory. Figure 6-2 also shows other data arrays (shown as double-dotted-line boxes). These arrays are not accessible via HP-IB, but showing them may help you better understand the behavior of the instrument.

Data Processing Flow

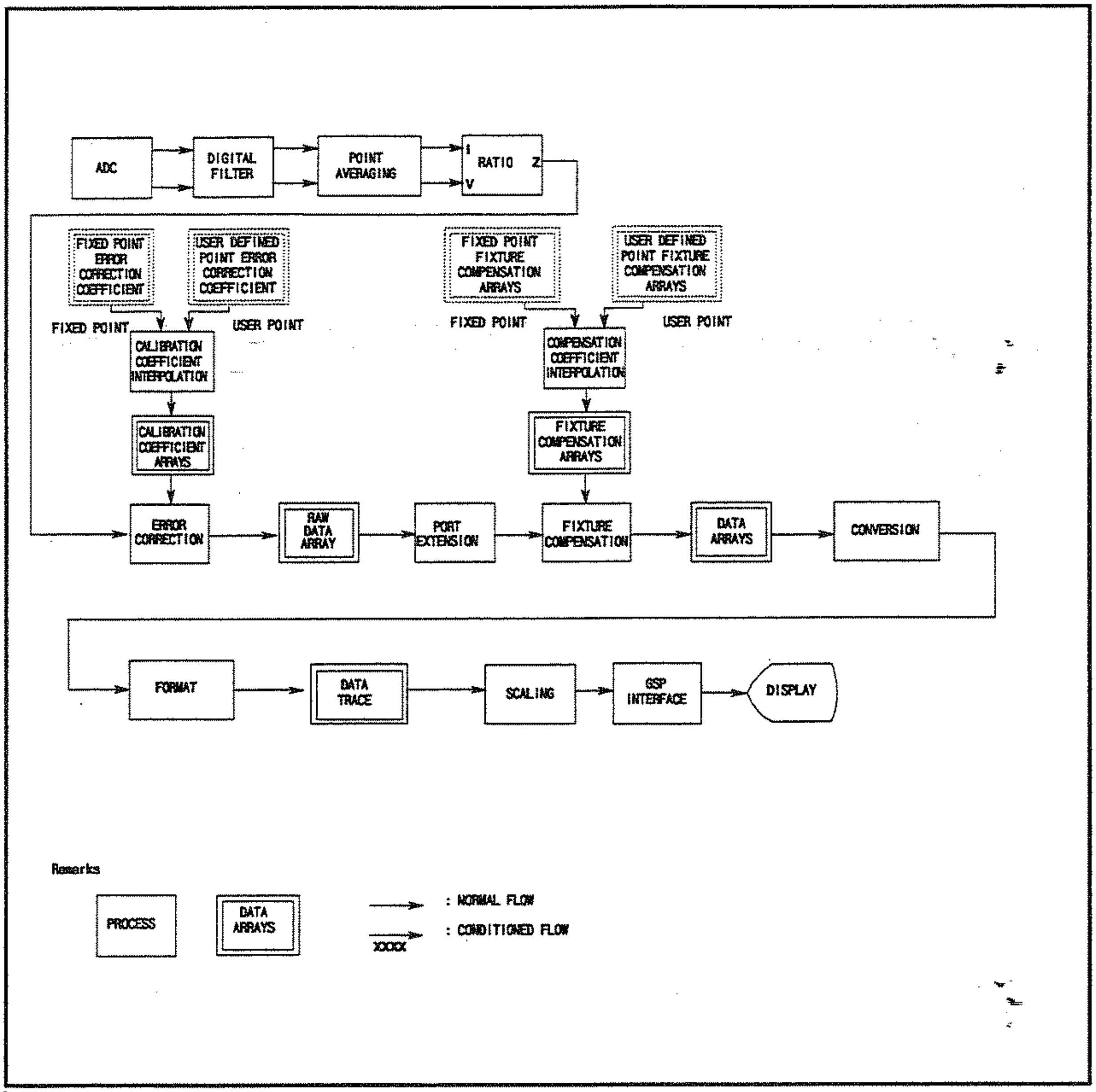


Figure 6-2. Data Processing

AD converter (ADC)

The ADC converts an analog signal (which is already down-converted to a fixed low frequency IF) into digital data.

Digital Filter

The digital filter detects the IF signal by performing a discrete Fourier transform (DFT) on the digital data. The samples are converted into complex number pairs (real plus imaginary, R+jX) that represent both the magnitude and phase of the IF signal.

Ratio Processing

The ratio processing calculates the ratio of the current and voltage values (V/I) in order to convert them to an impedance value.

Fixed Point Calibration Coefficient Arrays and User Defined Point Calibration Coefficient Arrays

When a calibration measurement is performed, the coefficient values at each calibration measurement point are stored in these arrays. These arrays are not accessible via HP-IB.

Calibration Coefficient Interpolation

When calibration measurements have been performed or stimulus settings have been changed, the calibration coefficients at the current measurement points are calculated from either the fixed point calibration coefficient arrays or the user defined point calibration coefficient arrays. When the current measurement point is different from the calibration measurement point, the coefficient value is interpolated from the fixed point calibration coefficient arrays or the user defined point calibration coefficient arrays.

Calibration Coefficient Arrays

Because the LCR meter measures the three standards at three different OSC levels automatically when the calibration measurement is performed, calibration data arrays consist of nine arrays. These arrays are directly accessible via HP-IB, or by using the internal disk drive or the RAM disk memory.

Error Collection

When a measurement calibration has been performed, error correction removes the repeatable systematic errors (stored in the calibration coefficient arrays) from the raw data arrays. See "[Cal]" in Chapter 4 and "Calibration Concepts" in Chapter 7 for details.

Averaging

This is one of the noise reduction techniques. The point averaging processes before the ratio processing. The averaging calculation involves taking the complex average of up to 999 measurements on each measurement point.

Raw Data Arrays

These arrays store the results of all the preceding data processing operations. These arrays are directly accessible via HP-IB, or using the internal disk drive or the RAM disk memory. Note that the numbers here are still complex pairs.

Port Extension

This is equivalent to "line-stretching" or artificially moving the measurement reference plane.

Fixture Compensation Coefficient Arrays

When a fixture compensation measurement has been performed and fixture compensation is turned on, the fixture compensation removes the repeatable systematic error. This error is caused by stray and residual impedance along the fixture used. This error information is stored in the fixture compensation arrays by the port extension process. See "[Cal]" in Chapter 4 and "Calibration Concepts" in Chapter 7 for details. When the permittivity measurement test fixture is selected, these arrays are not used. These arrays are directly accessible via HP-IB, or by using the internal disk drive or the RAM disk memory.

Fixed Point Fixture Compensation Coefficient Arrays and User Defined Point Fixture Compensation Coefficient Arrays

When a compensation measurement is performed, the coefficient values at each compensation measurement point are stored in these arrays. These arrays are not accessible via HP-IB.

Compensation Coefficient Interpolation

When compensation measurements have been performed, stimulus settings have been changed, or compensation is turned on, the compensation coefficient at the current measurement points is calculated from either the fixed point fixture compensation coefficient arrays or the user defined point fixture compensation coefficient arrays. When the current measurement point is different from the compensation measurement point, the coefficient value is interpolated from the fixed point fixture compensation coefficient arrays or user defined point fixture compensation coefficient arrays.

Fixture Compensation

When a fixture compensation measurement has been performed and this function is turn on, fixture compensation removes the errors caused by the test fixture. See "Fixture Compensation" in Chapter 7 for details.

Data Arrays

The results of error correction are stored in the data arrays as complex number pairs. These arrays are accessible via HP-IB or by using the internal disk drive or the RAM disk memory.

Format

This converts the complex number pairs into a scalar representation for display, according to the selected format. For HP 4286A, a scalar representation is always selected.

Data Trace Arrays

The results are stored in the data trace arrays. It is important to note those marker values and marker functions are all derived from the data trace arrays. Limit testing is also performed on this array. The data trace arrays are accessible via HP-IB, or using the internal disk drive or the RAM disk memory.

Impedance Measurement Basics

This chapter introduces the following basic concepts of impedance measurements:

- Impedance Parameters
- Series and Parallel Circuit Models
- Calibration Concepts
- Port Extension
- Fixture Compensation

Impedance parameters

All circuit components, resistors, capacitors, or inductors, have parasitic components lurking in the shadows waiting for the unwary, for example unwanted resistance in capacitors, unwanted capacitance in inductors, and unwanted inductance in resistors. Thus, simple components should be modeled as complex impedances, for in fact that is what they are.

Impedance ($\dot{Z}$)

Figure 7-1 (a) shows the complex impedance definitions and Figure 7-1 (b) shows the vector representation of complex impedance. Impedance, $\dot{Z}$ is the total opposition that a circuit or device offers to the flow of alternating current at a given frequency. $\dot{Z}$ contains a real and an imaginary part, and it is expressed in rectangular form as Resistance and Reactance, or in polar form as magnitude of Impedance and Phase as follows.

$$\dot{Z} = R + jX = |Z| \angle \theta \qquad (11-1)$$

$$|Z| = \sqrt{R^2 + X^2} \qquad (11-2)$$

$$\theta = \arctan\left(\frac{|X|}{R}\right) \qquad (11-3)$$

$$R = R_s \qquad (11-4)$$

Where,

$\dot{Z}$: Complex Impedance [Ω]
R : Resistance [Ω]
X : Reactance [Ω]
|Z| : Magnitude of Impedance [Ω]
θ : Phase of Impedance [deg or rad]
R_s : Series Resistance [Ω]

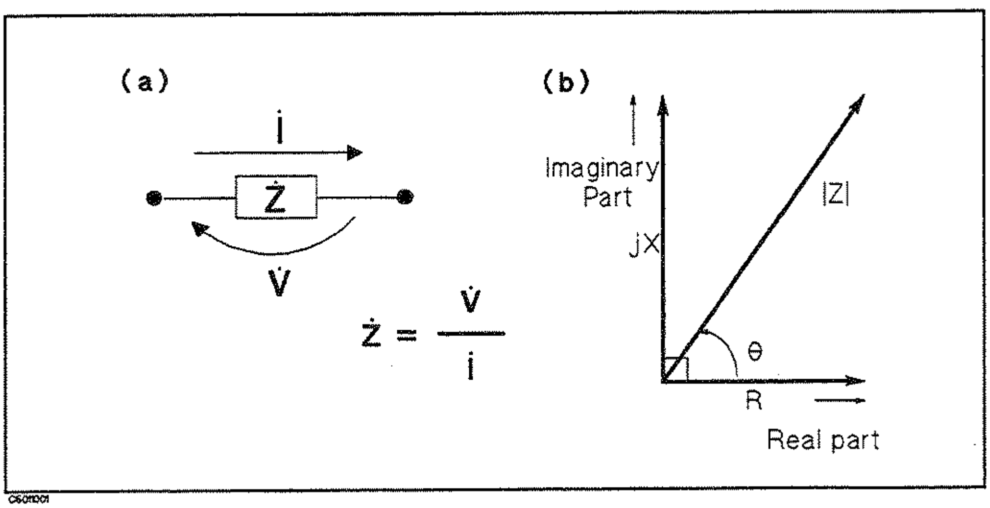


Figure 7-1. Definition of Impedance

The following parameters can be used to represent the reactance.

$$X = 2\pi f L \qquad (11-5)$$

Where,

f : Frequency [Hz]

L : Inductance [H]

In addition to these parameters, the Quality Factor (Q) and Dissipation Factor (D) are used to describe the quality of components.

$$Q = \frac{1}{D} = \frac{|X|}{R} \qquad (11-6)$$

Where,

Q : Quality Factor
D : Dissipation Factor

Admittance ($\dot{Y}$)

In some case, the dual of impedance (Admittance), $\dot{Y}$ is used. Figure 7-2 shows the vector representation of admittance. As $\dot{Z}$ (Complex Impedance), $\dot{Y}$ is composed of a real and an imaginary part, and is expressed in rectangular form as Conductance and Susceptance, or in polar form as magnitude of Admittance and Phase. The following are expressions for Admittance.

$$\dot{Y} = \frac{1}{\dot{Z}} \qquad (11-7)$$

$$\dot{Y} = G + jB = |Y| \angle \phi \qquad (11-8)$$

$$|Y| = \sqrt{G^2 + B^2} = \frac{1}{|Z|} \qquad (11-9)$$

$$\phi = \arctan\left(\frac{|B|}{G}\right) = -\theta \qquad (11-10)$$

$$B = 2\pi fC \qquad (11-11)$$

$$Q = \frac{1}{D} = \frac{|B|}{G} \qquad (11-12)$$

$$G = \frac{1}{R_p} \qquad (11-13)$$

Where,

$\dot{Y}$: Complex Admittance [S]
G : Conductance [S] (real)
B : Susceptance [S] (imaginary)
|Y| : Magnitude of Admittance [S]
ϕ : Phase of Admittance [deg or rad]
C : Capacitance [F]
R_p : Parallel Resistance [Ω]

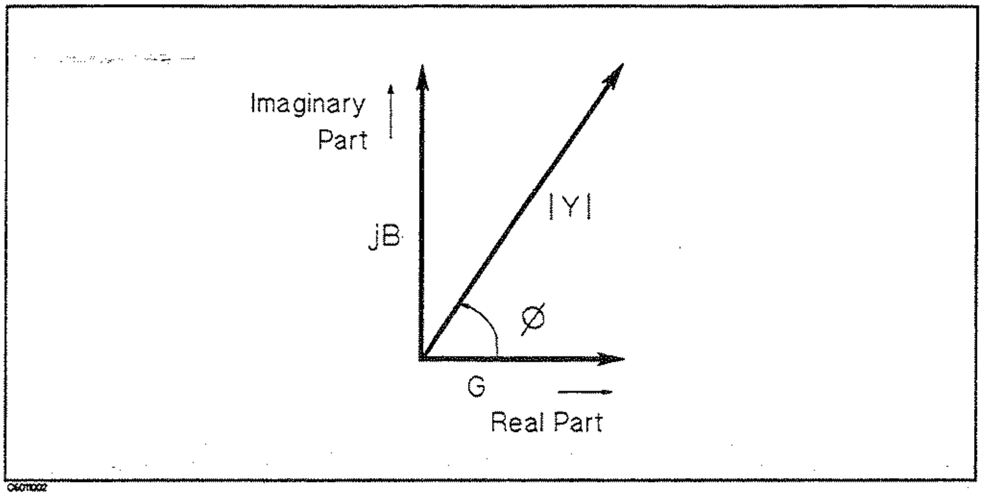


Figure 7-2. Vector Representation of Admittance

Reflection Coefficient ($\dot{\Gamma}$)

When measuring RF impedance , the reflection and/or transmission coefficient parameter values are usually measured by a network analyzer or RF impedance analyzer. The HP 4286A provides the reflection coefficient $\dot{\Gamma}$ as measurement parameter.

The reflection coefficient $\dot{\Gamma}$ is defined as:

$$\dot{\Gamma} = \frac{\dot{V}_{ref}}{\dot{V}_{inc}} = \Gamma_x + j\Gamma_y = |\dot{\Gamma}|(\cos\theta + j\sin\theta) = |\dot{\Gamma}|\angle\theta \qquad (11-14)$$

where,
$\dot{V}_{ref}$ is voltage of the reflected wave
$\dot{V}_{inc}$ is voltage of the incident wave

The reflection coefficient value and the impedance value of the sample is interrelated, each with the other, by the following formulas:

$$\dot{\Gamma} = \frac{\dot{Z}_x - Z_0}{\dot{Z}_x + Z_0} \qquad (11-15)$$

$$\dot{Z}_x = Z_0\frac{1+\dot{\Gamma}}{1-\dot{\Gamma}} \qquad (11-16)$$

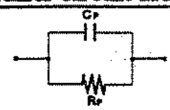
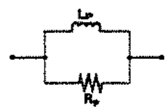
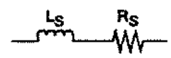
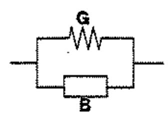
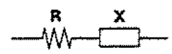
where, Z_0 is characteristic impedance.

Series and Parallel Circuit Models

An impedance element can be represented by a simple equivalent circuit consisting of resistive and reactive elements (connected in series with or in parallel with each other). This representation is possible by either of the equivalent (series or parallel) circuits because both have identical impedances at the selected measurement frequency. These values are obtained by properly selecting the value of the equivalent circuit elements.

The HP 4286A can select the model by setting the measurement parameter (R, X, G, B, C_p, C_s, L_p, or L_s) using the (Meas) key. To determine which circuit model is best, consider the relative impedance magnitude of the reactance and R_s and R_p.

Table 7-1. Parallel/Series Circuit Model and Measurement Parameter

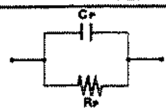
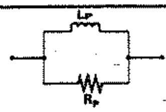
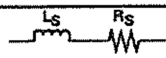
Parallel Circuit Model	Series Circuit Model
	
	
	

Parallel-Series Equivalent Circuit Conversion

Parameter values for a component measured in a parallel equivalent circuit and that measured in a series equivalent circuit are different from each other. The difference in measured values is related to the loss factor of the sample to be measured. If no series resistance or parallel conductance is present, the two equivalent circuits are identical.

However, the sample value measured in a parallel measurement circuit can be correlated with that of a series circuit by a simple conversion formula that considers the effect of the dissipation factor (D). See Table 7-2. The dissipation factor of a component always has the same value at a given frequency for both parallel and series equivalent circuits.

Table 7-2.
Dissipation Factor Equations and Parallel-Series Equivalent Circuit Conversion

Device	Circuit Mode	Dissipation Factor	Conversion to other modes
C		$D = \frac{1}{2\pi f C_p R_p} = \frac{1}{Q}$	$C_s = (1 + D^2)C_p$ $R_s = \frac{D^2}{1 + D^2}R_p$
C		$D = 2\pi f C_s R_s = \frac{1}{Q}$	$C_p = \frac{1}{1 + D^2}C_s$ $R_p = \frac{1 + D^2}{D^2}R_s$
L		$D = \frac{2\pi f L_p}{R_p} = \frac{1}{Q}$	$L_s = \frac{1}{1 + D^2}L_p$ $R_s = \frac{D^2}{1 + D^2}R_p$
L		$D = \frac{R_s}{2\pi f L_s} = \frac{1}{Q}$	$L_p = (1 + D^2)L_s$ $R_p = \frac{1 + D^2}{D^2}R_s$

Selecting Circuit Mode of Capacitance

The following description gives some practical guide lines for selecting the capacitance measurement circuit mode.

Small Capacitance

Small capacitance yields a large reactance, that implies that the effect of the parallel resistance (R_p) has relatively more significance than that of the series resistance (R_s). The low value of resistance represented by R_s has negligible significance compared with the capacitive reactance, so the parallel circuit mode (C_p) should be used (see Figure 7-3).

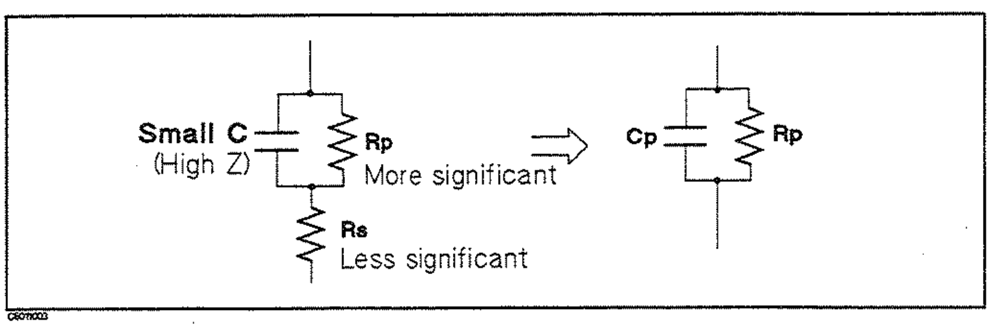


Figure 7-3. Small Capacitance Circuit Mode Selection

Large Capacitance

When the opposite is true and the measurement involves a large value of capacitance (low impedance), R_s has relatively more significance than R_p, so the series circuit mode (C_s-D or C_s-Q) should be used (see Figure 7-4).

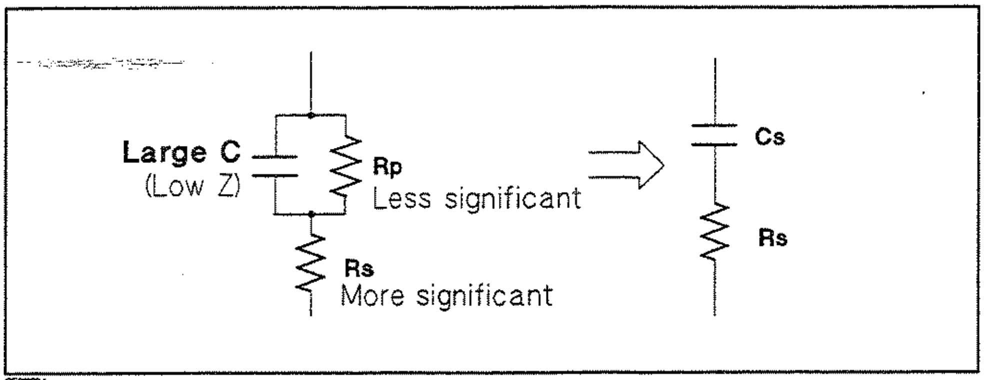


Figure 7-4. Large Capacitance Circuit Mode Selection

Selecting Circuit Mode of Inductance

The following description gives some practical guide lines for selecting the inductance measurement mode (that is, which circuit mode to use).

Large Inductance

The reactance at a given frequency is relatively large (compared with that of a small inductance), so the parallel resistance becomes more significant than the series component. Therefore, a measurement in the parallel equivalent circuit mode (L_p-D, L_p-Q or L_p-G) is more suitable (see Figure 7-5).

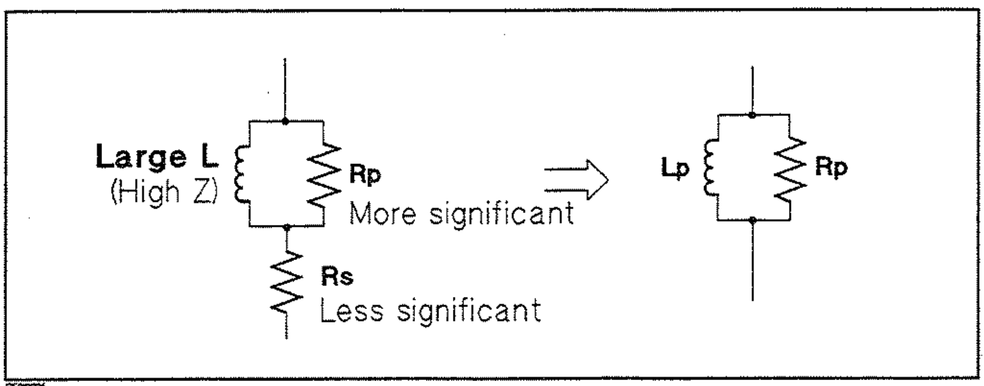


Figure 7-5. Large Inductance Circuit Mode Selection

Small Inductance

For low values of inductance, the reactance becomes relatively small (compared with that of a large inductance) so the series resistance component is more significant. Therefore, the series equivalent circuit mode (L_s-D or L_s-Q) is appropriate (see Figure 7-6).

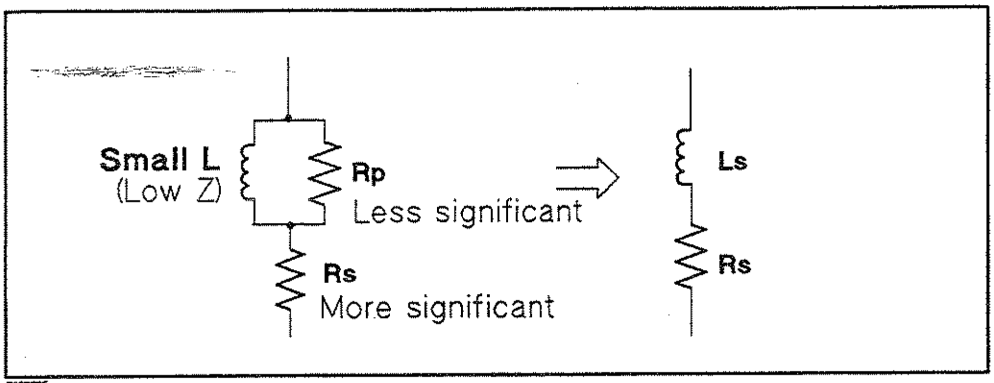


Figure 7-6. Small Inductance Circuit Mode Selection

Calibration Concepts

This section describes the basic concepts of OPEN SHORT LOAD calibration and Low-Loss air-capacitor calibration. The Low-Loss air-capacitor calibration improves the accuracy of the phase measurements.

OPEN SHORT LOAD Calibration

Ideal Measurement Circuit

Figure 7-7 (a) shows the basic measurement circuits for the I-V method. This method uses two vector voltmeters V_v and V_i (V_v detects the vector voltage applied to the DUT and V_i detects the vector current flowing through the DUT). Assuming that the measurement circuit is ideal (which means there is no stray admittance and no residual impedance), and the impedance values of all the components in the measurement circuit are exactly correct, the DUT's impedance value $\dot{Z}_x$ is calculated using the following equations:

$$\dot{Z}_x = R\frac{\dot{V}_v}{\dot{V}_i} \qquad (11-17)$$

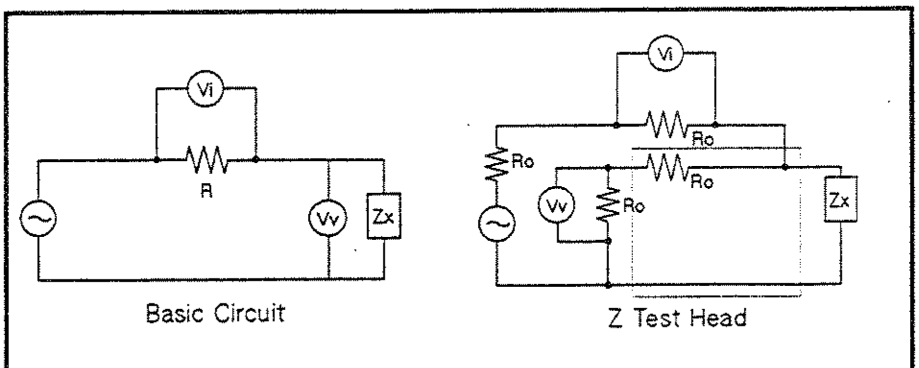


Figure 7-7. Measurement Circuits for I-V Method

Figure 7-7 show the simplified measurement circuits of the test head of the LCR meter. The DUT's impedance value ($\dot{Z}_x$) is calculated using the following equations (if the measurement circuit is ideal):

$\dot{Z}_x$ is :

$$\dot{Z}_x = \frac{2R_0}{\frac{\dot{V}_i}{\dot{V}_v} - 1} \qquad (11-18)$$

General Impedance Measurement Schematic

However, actual measurement circuits have some error terms (such as stray admittance and residual impedance) plus, the components of the circuit also have some errors. In addition, the four resistances (R_0) in the measurement circuit do not have exactly the same impedance value. In fact, the impedance values calculated from the above equations do not correspond with the actual impedance value of the DUT. Generally, an impedance measurement circuit using two vector voltmeters is represented as shown in Figure 7-8.

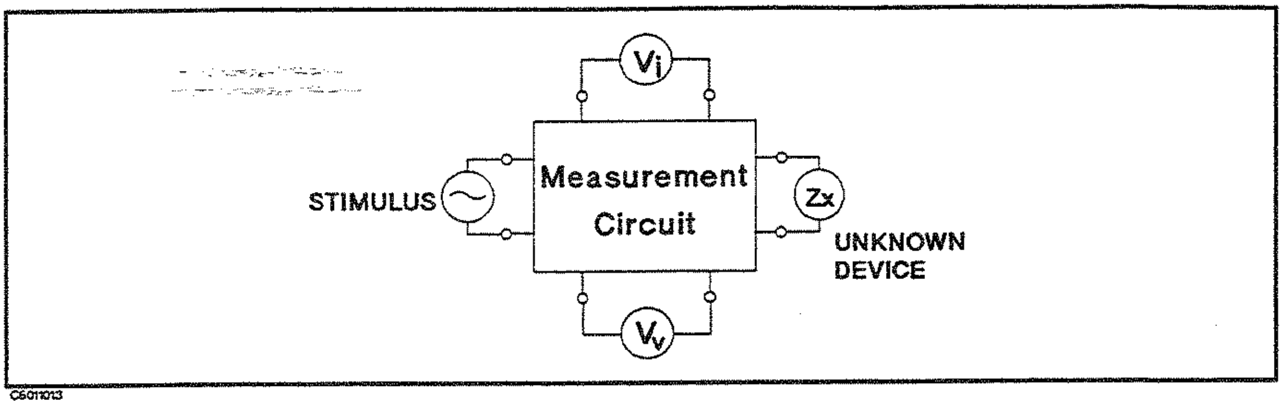


Figure 7-8. General Schematic for Impedance Measurement Using Two Vector Voltmeters

This general impedance measurement circuit uses two vector voltmeters. These two voltmeters can measure at any two different points in a linear circuit. In this case, the DUT's impedance can be expressed by the measured voltage values ($\dot{V}_v$ and $\dot{V}_i$) using a bilinear form as follows:

$$\dot{Z}_x = \dot{a}\frac{1 + \dot{b}\dot{r}}{1 + \dot{c}\dot{r}} \qquad (11-19)$$

Where,

$\dot{a}$, $\dot{b}$, $\dot{c}$ are complex constants

$\dot{r}$ is a ratio between $\dot{V}_v$ and $\dot{V}_i$ as follows:

$$\dot{r} = \frac{\dot{V}_v}{\dot{V}_i} \qquad (11-20)$$

In general, $\dot{Z}_x$ can be expressed using the above bilinear form whenever the measurement circuit is linear.

By using the measurement impedance value ($\dot{Z}_m$) instead of the voltage ratio $\dot{r}$ and modifying the equation, $\dot{Z}_x$ can also be expressed using the following bilinear form:

$$\dot{Z}_x = \dot{A}\frac{\dot{Z}_m - \dot{B}}{1 - \dot{C}\dot{Z}_m} \qquad (11-21)$$

Where, $\dot{A}$, $\dot{B}$, and $\dot{C}$ are complex constants (calibration coefficients) related to the circuit.

If three standards that have known impedance value are measured, these three constants can be calculated. The LCR meter uses the OPEN, SHORT, and LOAD standards (furnished) for the calibration. Once these constants are known, any impedance of the DUT can be calculated from the measured impedance value.

> Where, $\dot{B}$ represents residual impedance when the circuit is perfectly shorted and $\dot{C}$ represents stray admittance when the circuit is perfectly open.

Low Loss Capacitor Calibration

Accurate Q measurements require good instrument stability and correct phase reading on the LCR meter. In particular, high Q (or low D : dissipation factor) measurements at high frequencies require high accuracy for phase measurements.

The phase accuracy of the LCR meter is determined entirely by the OPEN SHORT LOAD calibration. But, it is not guaranteed that the phase uncertainty for a 50 Ω LOAD at high frequencies is lower than the uncertainty requirement for a high Q measurement.

For example, if you want to measure the Q factor with 10% of uncertainty for a DUT whose Q value is almost 100, the uncertainty for phase scaling must be less than 10^{-3}. But, it is difficult to ensure that the phase uncertainty for the 50 Ω LOAD is less than 10^{-3} at high frequencies.

To reduce the uncertainty of the measured phase, the LCR meter uses a low-loss air-capacitor as a phase standard, whose dissipation factor (D) is kept below 10^{-3} at around 1 GHz.

The following steps show how the LCR meter improves phase measurement accuracy using a low-loss air-capacitor:

1. Measure the OPEN, SHORT, and LOAD standards and the Low-Loss air-capacitor.
2. Assuming the impedance of the 50 Ω LOAD is $\dot{Z}_{ls} = 50\, e^{j0}$ (that is, the phase of 50 Ω LOAD is zero) as shown in Figure 7-9-(a)), calculate the calibration coefficient $\dot{A}$, $\dot{B}$, and $\dot{C}$.
3. Execute the correction for the Low-Loss air-capacitor and get the corrected impedance value of the Low-Loss air-capacitor. ($\dot{Z}_{cc}$)
4. Calculate the phase difference ($\Delta\theta$) between the phase of $\dot{Z}_{cc}$ and the true phase of the Low-Loss air-capacitor (see Figure 7-9-(b)).

   $$\Delta\theta = \theta_{cc} - \theta_{cs} \qquad (11\text{-}22)$$

   Where,

   $\theta_{cc} = \arg(\dot{Z}_{cc})$

   θ_{cs} is standard phase value of the Low-Loss air-capacitor.

5. Modify the impedance of the 50 Ω LOAD to $\dot{Z}_{lc}$ whose phase is $-\Delta\theta$ and whose impedance magnitude is still 50 Ω (see Figure 7-9-(c)). The modified impedance value of 50 Ω LOAD $\dot{Z}_{lc}$ is expressed in the following equation:

   $$\dot{Z}_{lc} = 50\, e^{-j\Delta\theta} \qquad (11\text{-}23)$$

6. Calculate the calibration coefficients $\dot{A}$, $\dot{B}$, and $\dot{C}$ again by normal OPEN SHORT LOAD calibration using the modified 50 Ω LOAD impedance value $\dot{Z}_{lc}$.

The LCR meter performs this procedure automatically when a Low-Loss air-capacitor is measured in the calibration menu. Although this is an approximate method, just performing these procedures make the LCR meter accurate enough to perform high Q measurements.

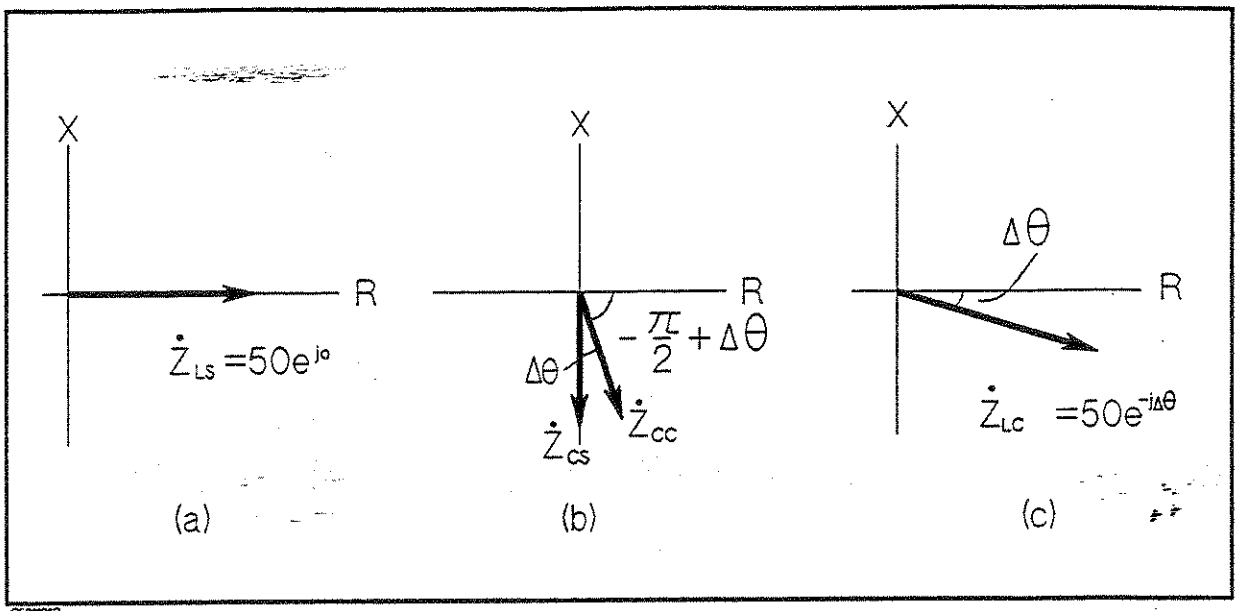


Figure 7-9. Modifying the Standard Value of a 50 Ω LOAD using a Low-Loss Air-Capacitor

Port Extension

When the extension cable is used to extend the measurement plane from APC-7® of the head to the tip of the cable, the measurement error increases because of the additional impedance in a distributed element circuit of the cable.

To minimize the measurement errors, the port extension function simulates a variable length lossless cable that can be added to or removed from the test port to compensate for interconnecting cables, test fixtures, etc. The value of port extension is annotated in units of time with secondary labeling in distance for the velocity of light.

An estimated impedance value through this function is calculated according to the following concept:

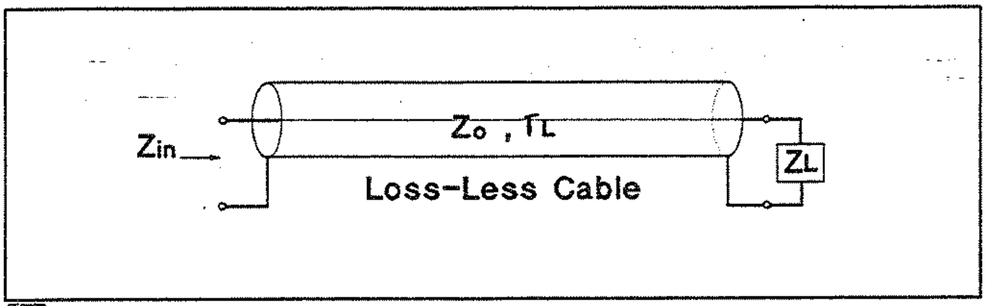


Figure 7-10. Port Extension

When impedance Z_L is connected to one tip of extension cable as shown in Figure 7-10, the input impedance from the other tip of cable is expressed using the following equation:

$$Z_{in} = Z_0 \frac{Z_L + Z_0 \tanh(\dot{\gamma} l)}{Z_0 + Z_L \tanh(\dot{\gamma} l)} \quad (11-24)$$

Where,
Z_0 is the characteristic impedance of the cable.
l is the electrical length of the cable representing the physical length of the cable (l_0) and the relative permittivity of the material in the cable (ε_r) :

$$l = \sqrt{\varepsilon_r} l_0 \quad (11-25)$$

$\dot{\gamma}$ is propagation coefficient and expressed as:

$$\dot{\gamma} = \alpha + j\beta \quad (11-26)$$

where,
α is attenuation constant
β is phase constant

Assuming that the cable is lossless, α and β satisfy the following conditions:

$$\alpha = 0 \quad (11-27)$$

$$\beta = \frac{\omega}{c_0} \quad (11-28)$$

where,

c_0 is the velocity of light

Therefore,

$$\tanh(\dot{\gamma} l) = \tanh(j\frac{\omega}{c_0}l)$$
$$= j\tan(\frac{\omega}{c_0}l) \qquad (11-29)$$

Because the characteristic impedance of the extension cable for the LCR meter should be 50 Ω, Z_0 is constant as follows:

$$Z_0 = 50 + j0 \qquad (11-30)$$

Substitute these conditions into the equation for Z_{in}. Then modify it in order to calculate Z_L from Z_{in}. Z_L can be determined by using the following equation:

$$Z_L = 50\frac{Z_{in} - j50\tan(\omega\Delta t)}{50 - jZ_{in}\tan(\omega\Delta t)} \qquad (11-31)$$

Another Method of Canceling the Measurement Error Caused by Extension Cable
The OPEN-SHORT-LOAD fixture compensation cancels the error caused by port extension. To cancel the error:
1. Perform calibration at the tip of APC-7® on the test head without using an extension cable.
2. Connect the extension cable and the test fixture to be used.
3. Perform OPEN, SHORT, and LOAD fixture compensations.
■ It is necessary to perform calibration measurement *at the APC-7® connector of the test head.* If calibration is performed at the tip of the extension cable, the calibration error would increase.
■ OPEN, SHORT or OPEN and SHORT compensations can not cancel the error caused by the extension cable. It is the best way to perform the OPEN SHORT LOAD fixture compensation if the LOAD performance is perfectly known.

Fixture Compensation

Actual Measuring Circuit

The measuring circuit connecting a test sample to the test port (that is, the test fixture) actually becomes part of the sample that the instrument measures. In addition, component electrodes or leads, which should essentially be of negligibly low impedance, also influence the measured sample values because of the presence of certain parasitic impedances. Diverse parasitic impedances existing in the measuring circuit between the test port and the unknown device affect the measurement result. These parasitic impedances are present as resistive or reactive factors in parallel or in series with the sample device. Furthermore, in the high frequency region, the equivalent electrical length of the measuring circuit, including component leads, rotates the measured impedance vector as function of the test signal wavelength. Let's discuss the effects that increase measurement uncertainties.

Residual Parameter Effects

Figure 7-11 shows an equivalent circuit model of the measuring circuit that includes unknown component and parasitic parameters (usually called residual parameters). These residual parameters cause two kinds of measurement errors, which are described in the following paragraphs.

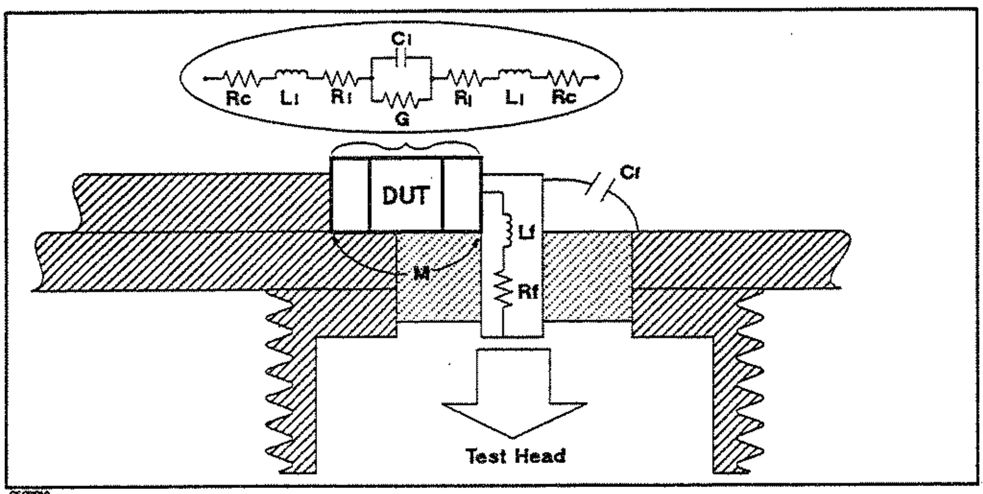


Figure 7-11. Residual Parameters in the Circuit

Where,

R_l	Lead (or electrodes) resistance of DUT
R_c	Contact resistance
R_f	Residual resistance of test fixture
L_l	Lead (or electrodes) inductance of DUT
L_f	Residual inductance of test fixture
C_l	Stray capacitance of DUT
C_f	Stray capacitance of test fixture
G	Residual conductance of DUT
M	Mutual inductance between leads (or electrodes) of DUT

Characteristics of Test Fixture

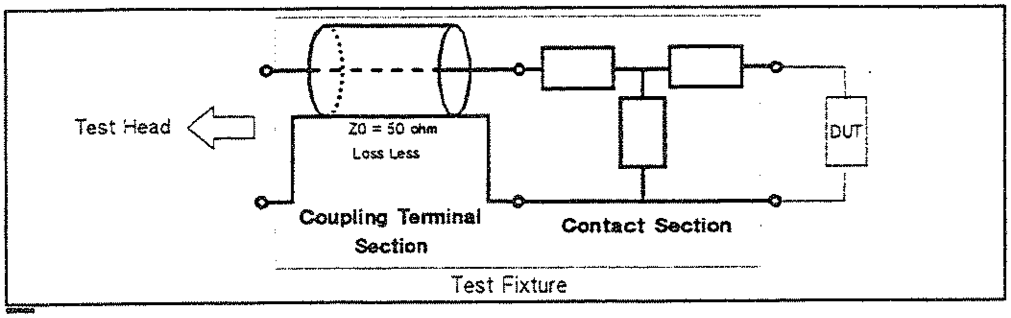


Figure 7-12. Characteristics of Test Fixture

Electrical Length of Coaxial Coupling Terminal Section

The test fixtures are basically composed of two major components, a coaxial coupling terminal and the contact electrodes (terminals), combined in one unit. The electrical length value specified for each type of fixture is calculated for the coaxial coupling terminal and does not include the electronic factors in the electrodes.

As the coaxial coupling terminal section of the fixtures is a distributed constant circuit design (50Ω), this fixture section is virtually an extension of the test port. The inherent effect in the coaxial coupling terminal is represented by the electrical length value particular to the test fixture. On the other hand, the contact section (that is, the electrodes on the fixtures) has different characteristics from the 50Ω distributed constant test port.

Elimination of Electrical Length Effects in Test Fixture

The HP 4286A has a typical electrical length for the specified test fixtures. When a test fixture is selected, the HP 4286A automatically sets the typical electrical length value for the fixture selected. The technique to eliminate the electrical length uses the same technique as the port extension function. See "Port Extension", for more information on port extension.

Residual and Stray Parameters of Contact Electrode Section

The contact electrode (terminal) section can not be regarded as part of the distributed constant circuit.

Because a correction calculation performed on the basis of the test fixture selection (provided by the HP 4286A) does not compensate for the residual and stray parameters in the contact section, these residuals and strays contribute to measurement errors. The residual and stray factors in the test fixtures is illustrated in Figure 7-11 and Figure 7-12.

Elimination of Residual Parameter Effects in Test Fixture (Fixture Compensation)

In general, these residual and stray factors can be represented by F parameters of 2 terminal-pair as shown in Figure 7-13. Using this model, the residual and stray factors can be eliminated.

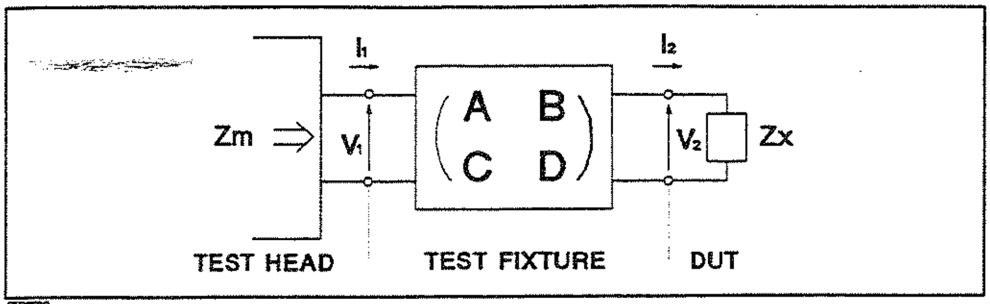


Figure 7-13. Test Fixture Represented by the F matrix of a Two Terminal Pair Network

$$\begin{pmatrix} V_1 \\ I_1 \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} V_2 \\ I_2 \end{pmatrix} \qquad (11-32)$$

The actual impedance value of the DUT (Z_x) and the measurement value (Z_m) are represented by the input and output current and voltage as follows:

$$Z_m = \frac{V_1}{I_1} \qquad (11-33)$$

$$Z_x = \frac{V_2}{I_2} \qquad (11-34)$$

Then, Z_x is:

$$Z_x = A_{compen} \frac{Z_m - B_{compen}}{1 - Z_m C_{compen}} \qquad (11-35)$$

Where,

A_{compen} = D/A

B_{compen} = B/D

C_{compen} = C/A

There are three unknown parameters. Therefore, three standards are needed for perfect compensation. When A_{compen}, B_{compen}, and C_{compen} are given, Z_x is calculated. To get A_{compen}, B_{compen}, and C_{compen}, the HP 4286A executes measurements for OPEN, SHORT, and LOAD compensation.

Compensation Coefficient for Each Compensation

For fixture compensation, three compensations (OPEN, SHORT, and LOAD) are provided for the LCR meter. These compensations can be turned on individually. After the compensation measurements have been done and tuned on, the compensation coefficients, A_{compen}, B_{compen}, and C_{compen}, are automatically calculated and the measurement value Z_m is transformed to Z_x through the equation (11-45). Some assumptions are made for compensations except for OPEN-SHORT-LOAD fixture compensation. The following paragraphs show the conditions assumed for each combination and the equations used for each combination of the OPEN, SHORT and LOAD fixture compensations.

OPEN Compensation

When only the OPEN compensation is used for the fixture compensation, two additional conditions are required to solve the Z_x equation. One condition assumes that the equivalent circuit model of the fixture used is a symmetric circuit. The other condition assumes that SHORT measurement capability is ideal, that is, the measurement value for perfect SHORT standard equals to perfect SHORT value. These conditions are explained as follows:

Fixture Compensation

Assuming that :

$A = D$ (symmetric circuit) (11-36)

$B = 0$ (11-37)

Then, the compensation coefficients are:

$A_{compen} = 1 + j0$ (11-38)

$B_{compen} = 0 + j0$ (11-39)

$C_{compen} = Y_{om} - Y_{os}$ (11-40)

Where,

Y_{om} is the admittance value measured under open condition

Y_{os} is the admittance value defined as OPEN as the fixture compensation kit

SHORT Compensation

When only the SHORT compensation is used for the fixture compensation, two additional conditions are required to solve the Z_x equation. One condition assumes that the equivalent circuit model of the fixture used is a symmetric circuit. The other condition assumes that OPEN measurement capability is ideal, that is, the measurement value for perfect OPEN standard equals to perfect OPEN value. These conditions are explained as follows:

Assuming that :

$A = D$ (symmetric circuit) (11-41)

$C = 0$ (11-42)

Then, the compensation coefficients are:

$A_{compen} = 1 + j0$ (11-43)

$B_{compen} = Z_{sm} - Z_{ss}$ (11-44)

$C_{compen} = 0 + j0$ (11-45)

Where,

Z_{sm} is the impedance of the value measured for shorted device.

Z_{ss} is the impedance value defined as SHORT for the fixture compensation kit

LOAD Compensation

When only the LOAD compensation is used for the fixture compensation, two additional conditions are required to solve the Z_x equation. One condition assumes that the value measuring shorted device is the same as the value defined as SHORT for the fixture compensation kit. The other condition assumes that SHORT measurement capability is ideal and OPEN measurement capability is ideal. These conditions are explained as follows:

Assuming that :

$B = 0$ (11-46)

$C = 0$ (11-47)

Then, the compensation coefficients are:

$A_{compen} = \frac{Z_l}{Z_{lm}}$ (11-48)

$B_{compen} = 0 + j0$ (11-49)

$$C_{compen} = 0 + j0 \quad (11\text{-}50)$$

Where,

Z_{lm} is the impedance value measured for load device

Z_{ls} is the impedance value defined as LOAD of the fixture compensation kit

OPEN-SHORT Compensation

When OPEN and SHORT compensations are used for the fixture compensation, one additional condition is required to solve the Z_x equation. This condition is explained as follows:

Assuming that :

$$A = D \text{ (symmetric circuit)} \quad (11\text{-}51)$$

Then, the compensation coefficients are:

$$A_{compen} = 1 + j0 \quad (11\text{-}52)$$

$$B_{compen} = \frac{Z_{sm} - (1 - Y_{om}Z_{sm})Z_{ss} - Z_{sm}Y_{os}Z_{ss}}{1 - Y_{om}Z_{sm}Y_{os}Z_{ss}} \quad (11\text{-}53)$$

$$C_{compen} = \frac{Y_{om} - (1 - Y_{om}Z_{sm})Y_{os} - Y_{om}Y_{os}Z_{ss}}{1 - Y_{om}Z_{sm}Y_{os}Z_{ss}} \quad (11\text{-}54)$$

OPEN-LOAD Compensation

When OPEN and LOAD compensations are used for the fixture compensation, one additional condition is required to solve the Z_x equation. The condition assumes that SHORT measurement capability is ideal, that is, the measurement value for perfect SHORT standard equals to perfect SHORT value. This condition is explained as follows:

Assuming that :

$$B = 0 \quad (11\text{-}55)$$

Then, the compensation coefficients are:

$$A_{compen} = \frac{Y_{lm} - Y_{om}}{Y_{ls} - Y_{os}} \quad (11\text{-}56)$$

$$B_{compen} = 0 + j0 \quad (11\text{-}57)$$

$$C_{compen} = \frac{Y_{om}Y_{ls} - Y_{lm}Y_{os}}{Y_{ls} - Y_{os}} \quad (11\text{-}58)$$

SHORT-LOAD Compensation

When SHORT and LOAD compensations are used for the fixture compensation, one additional condition is required to solve the Z_x equation. The condition assumes that SHORT measurement capability is ideal, that is, the measurement value for perfect OPEN standard equals to perfect OPEN value. This condition is explained as follows:

Assuming that :

$$C = 0 \quad (11\text{-}59)$$

Then, the compensation coefficients are:

$$A_{compen} = \frac{Z_{ss} - Z_{ls}}{Z_{sm} - Z_{lm}} \quad (11\text{-}60)$$

$$B_{compen} = \frac{Z_{lm}Z_{ss} - Z_{sm}Z_{ls}}{Z_{ss} - Z_{ls}} \quad (11\text{-}61)$$

Fixture Compensation

$$C_{compen} = 0 + j0 \qquad (11\text{-}62)$$

OPEN-SHORT-LOAD Compensation

When OPEN, SHORT and LOAD compensations used for the fixture compensation, no more conditions are required to solve the Z_x equation. The compensation coefficients are:

$$A_{compen} = \frac{Y_{om}(Z_{sm} - Z_{lm})Y_{os}Z_{ss}Z_{ls} - (1 - Z_{lm}Y_{om})Z_{ls} + (1 - Y_{om}Z_{sm})Z_{ss}}{(Z_{sm} - Z_{lm}) - (1 - Z_{lm}Y_{om})Z_{sm}Y_{os}Z_{ss} + (1 - Y_{om}Z_{sm})Z_{lm}Z_{ls}Y_{os}} \qquad (11\text{-}63)$$

$$B_{compen} = \frac{(Z_{sm} - Z_{lm})Y_{os}Z_{ss}Z_{ls} - Z_{sm}(1 - Z_{lm}Y_{om})Z_{ls} + Z_{lm}(1 - Y_{om}Z_{sm})Z_{ss}}{Y_{om}(Z_{sm} - Z_{lm})Y_{os}Z_{ss}Z_{ls} - (1 - Z_{lm}Y_{om})Z_{ls} + (1 - Y_{om}Z_{sm})Z_{ss}} \qquad (11\text{-}64)$$

$$C_{compen} = \frac{Y_{om}(Z_{sm} - Z_{lm}) - (1 - Z_{lm}Y_{om})Y_{os}Z_{ss} + (1 - Y_{om}Z_{sm})Z_{ls}Y_{os}}{(Z_{sm} - Z_{lm}) - (1 - Z_{lm}Y_{om})Z_{sm}Y_{os}Z_{ss} + (1 - Y_{om}Z_{sm})Z_{lm}Z_{ls}Y_{os}} \qquad (11\text{-}65)$$

Options and Accessories

Introduction

This chapter lists available options and accessories for the HP 4286A.

Options Available

Option 001 Delete HP 16195A Calibration Kit

This option deletes the HP 16195A Calibration kit.

Option 002 Delete Test Fixture Stand

This option deletes the test fixture stand.

Option 004 Add Working Standard Set

This option adds the working standard set.

Option 021 Add Straight Angle Test Head (1m)

This option adds the straight angle test head. (Cable length is 1 m.)

Option 022 Add Straight Angle Test Head (3m)

This option adds the straight angle test head. (Cable length is 3 m.)

Option 031 Delete Right Angle test Head (1m)

This option deletes the straight angle test head. (Cable length is 1 m.)

Option 032 Add Right Angle Test Head (3m)

This option adds the right angle test head. (Cable length is 3 m.)

Option 0BW Add Service Manual

This option adds the *HP 4286A Service Manual*, which describes the performance test procedures and troubleshooting. If you need the service manual, order HP part number 04286-90101.

Option 1C2 Add HP IBASIC, HP-HIL keyboard and cable

This option provides analyzer programmability without any external controller. HP Instrument BASIC is a subset of HP BASIC and allows all the analyzer's measurement capabilities and any other HP-IB compatible instrument to be programmed. (See the *HP Instrument BASIC Users Handbook Supplement*.) This option can be retrofitted using the HP 4286U Option 1C2.

Option 1CM Rack mount kit

This option is a rack mount kit containing a pair of flanges and the necessary hardware to mount the instrument, with handles detached, in an equipment rack with 482.6 mm (19 inches) horizontal spacing.

Option 1CN Handle Kit

This option is a rack mount kit containing a pair of handles and the necessary hardware to mount the instrument.

Option 1CP Rack mount and handle kit

This option is a rack mount kit containing a pair of flanges, and the necessary hardware to mount the instrument with handles attached in an equipment rack with 482.6 mm (19 inches) horizontal spacing.

Option UK6 Commercial Calibration Certificate with Test Data

This option adds commercial calibration certificate with test data.

Measurement accessories available

HP 16191A Side electrode SMD test fixture

The HP 16191A is used to measure a side electrodes surface mount device (SMD) with high repeatability. The usable operating frequency is up 2 GHz.

HP 16192A Parallel electrode SMD test fixture

The HP 16192A is used to measure a parallel electrodes surface mount device (SMD) with high repeatability. The usable operating frequency is up 2 GHz.

HP 16193A Small side electrode SMD test fixture

The HP 16193A is used to measure a small, side electrodes surface mount device (SMD) with high repeatability. The usable operating frequency is up 2 GHz.

HP 16194A High temperature component fixture

The HP 16194A is used to measure a component in wide temperature range. The operating temperature range is from −55°C through 200°C. The usable operating frequency is up to 2 GHz.

HP 16092A Spring clip test fixture

The HP 16092A provides a convenient capability for easily connecting and disconnecting samples. It has a usable operating frequency up to 500 MHz.

HP 16093A/B Binding post test fixtures

The HP 16093A/B are suited for the measurement of relatively large size, axial and radial lead components or devices that do not fit other fixtures. The HP 16093A is provided with two small binding post measurement terminals set at 7 mm intervals. The usable frequency operating of the HP 16093A is up to 250 MHz. The HP 16093B employs a common type three binding post terminal arrangement that includes an extra guard post terminal. The terminal interval is 15 mm. The usable frequency operating of the HP 16093B is below 125 MHz.

HP 16094A Probe test fixture

The HP 16094A provides probing capability for measuring circuit impedance and components mounted on circuit assemblies. The usable frequency operating of the HP 16094A is below 125 MHz.

System accessories available

System rack

The HP 85043B system rack is a 124 cm (49 inch) high metal cabinet designed to rack mount the analyzer in a system configuration. The rack is equipped with a large built-in work surface, a drawer for calibration kits and other hardware, a bookshelf for system manuals, and a locking rear door for secured access. Lightweight steel rails support the instrument along their entire depth. Heavy-duty casters make the cabinet easily movable even with the instruments in place. Screw-down lock feet permit leveling and semi-permanent installation. The cabinet is extremely stable when the lock feet are down. Power is supplied to the cabinet through a heavy-duty grounded primary power cable and to the individual instruments through special power cables included with the cabinet.

Plotter and printer

The analyzer is capable of plotting displayed measurement results directly to a peripheral without the use of an external computer. The compatible plotters are:

- HP 7440A Option 002 ColorPro Eight-Pen Color Graphics Plotter, plots on ISO A4 or 8 1/2 × 11 inch charts.
- HP 7475A Option 002 Six-Pen Graphics Plotter, plots on ISO A4/A3 or 8 1/2 × 11 inch or 11 × 17 inch charts.
- HP 7550B Option 005 High-Speed Eight-Pen Graphics Plotter, plots on ISO A4/A3 or 8 1/2 × 11 inch or 11 × 17 inch charts.

The compatible printers for both printing and plotting are:

- HP 3630A Option 002 Paint Jet color printer
- HP 2227B QuietJet printer
- HP C2614A DeskJet Portable *1
- HP C2106A DeskJet 500 *1
- HP C2114A DeskJet 500C *1,2
- HP C2121A DeskJet 550C *1,2
- HP C2608A DeskJet 505J with HP C3054A, color print is not supported *1

*1 : These printers require HP 92203J/K HP-IB/Centronics converter, HP 92284A Centronics cable, and HP 10833A HP-IB cable or compatible cable.

*2 : Color print is not supported.

HP-IB cable

An HP-IB cable is required to interface the analyzer with a plotter, printer, computer, or other external instrument. The following cables are available:

- HP 10833A (1 m)
- HP 10833B (2 m)
- HP 10833C (3 m)
- HP 10833D (0.5 m)

Disks

Hewlett-Packard disks are listed below.

- HP 92192A Box of 10 3.5 inch, 720 k bye micro flexible disks
- HP 92192X Box of 10 3.5 inch, 1.44M byte micro flexible disks

Service Accessories Available

Collet removing tool (HP part number 5060-0236)

This tool is used to remove the center conductor collet from an APC-7 connector. This is required in order to repair the collet, if the collect is damaged.

Collet removing tool guide (HP part number 04291-21002)

This tool is used with the collet removing tool when the collet of the low loss capacitor of the calibration kit is removed.

6-Slot collet (HP part number 85050-20001)

The repair part of the collet.

Specifications

Specifications describe the instrument's warranted performance over the temperature range of 0°C to 55°C (except as noted). Supplemental characteristics are intended to provide information that is useful in applying the instrument by giving non-warranted performance parameters. These are denoted as *typical*, *typically*, *nominal* or *approximate*. Warm up time must be greater than or equal to 30 minutes after power on for all specifications.

Specifications of the stimulus characteristics and measurement accuracy are defined at the tip of APC-7® connector of 3.5mm-7mm adapter connected to the test head.

Test Signal

Frequency Characteristics

Operating Frequency .... 1 MHz to 1000 MHz

A maximum of 10 frequencies can be programmed. An averaging factor can be set at each frequency point.

Frequency Resolution .... 10 kHz

Frequency Accuracy .... < ±10 ppm @23±5°C

Source Characteristics

Definition of OSC level
■ Voltage level : 2 × voltage level across the 50 Ω which is connected to the output terminal. (this level is approximately equal to the level when a terminal is open)
■ Current level : 2 × current level through the 50 Ω which is connected to the output terminal. (this level is approximately equal to the level when a terminal is shorted)
■ Power level : when terminating with 50 Ω.

OSC Level

Voltage Range .... 10 mV_{rms} to 1 V_{rms}

Current Range .... 200 μA to 20 mA

Power Range .... −33 dBm to +7 dBm

OSC Level Resolution

Voltage Resolution

@ 0.22 V < V_{osc} ≤ 1 V .... 2 mV

@ 70 mV < V_{osc} ≤ 220 mV .... 0.5 mV

@ 22 mV < V_{osc} ≤ 70 mV .... 0.2 mV

@ 10 mV ≤ V_{osc} ≤ 22 mV .... 0.05 mV

Current Resolution

@ 4.4 mA < I_{osc} ≤ 20 mA .... 40 μA

@ 1.4 mA < I_{osc} ≤ 4.4 mA .... 10 μA

@ 0.44 mA < I_{osc} ≤ 1.4 mA .... 4 μA

@ 200 μA ≤ I_{osc} ≤ 440 μA .... 1 μA

Power Resolution .... 0.1 dBm

OSC Level Accuracy

Table 9-1. OSC Level Accuracy at Cable Length = 3 m, 23±5°C

Test Signal Voltage	Frequency Rage	OSC Level Accuracy
0.5 V < V_{osc} ≤ 1 V	1 MHz≤ frequency ≤ 500 MHz	±2 dB
	500 MHz < f ≤ 1000 MHz	+3 dB/−10 dB[1]
0.25 V ≤ V_{osc} ≤ 0.5 V	1 MHz≤ frequency ≤ 1000 MHz	±2 dB
0.01 V ≤ V_{osc} < 0.25 V	1 MHz≤ frequency ≤ 1000 MHz	±3 dB

1 Typical data at temperature range is 5 through +40°C

Table 9-2. OSC Level Accuracy at Cable Length = 3 m, 0°C to +55°

Test Signal Voltage	Frequency Rage	OSC Level Accuracy	
		5°C to 40°C	0°C to 55°C
0.5 V < V_{osc} ≤ 1 V	1 MHz≤ frequency ≤ 500 MHz	±4 dB	±6 dB
	500 MHz < frequency ≤ 1000 MHz	+3 dB/−10 dB[1]	+5 dB/−12 dB[1]
0.25 V ≤ V_{osc} ≤ 0.5 V	1 MHz≤ frequency ≤ 1000 MHz	±4 dB	±6 dB
0.01 V ≤ V_{osc} < 0.25 V	1 MHz≤ frequency ≤ 1000 MHz	±5 dB	±7 dB

1 Typical value

Table 9-3. OSC Level Accuracy at Cable Length = 1 m, 23±5°C

Test Signal Voltage	Frequency Rage	OSC Level Accuracy
0.5 V < V_{osc} ≤ 1 V	1 MHz≤ frequency ≤ 1000 MHz	±2 dB
0.25 V ≤ V_{osc} ≤ 0.5 V	1 MHz≤ frequency ≤ 1000 MHz	±2 dB
0.01 V ≤ V_{osc} < 0.25 V	1 MHz≤ frequency ≤ 1000 MHz	±3 dB

Table 9-4. OSC Level Accuracy at Cable Length = 1 m, 0°C to +55°

Test Signal Voltage	Frequency Rage	OSC Level Accuracy	
		5°C to 40°C	0°C to 55°C
0.5 V < V_{osc} ≤ 1 V	1 MHz≤ frequency ≤ 1000 MHz	±4 dB	±6 dB
0.25 V ≤ V_{osc} ≤ 0.5 V	1 MHz≤ frequency ≤ 1000 MHz	±4 dB	±6 dB
0.01 V ≤ V_{osc} < 0.25 V	1 MHz≤ frequency ≤ 1000 MHz	±5 dB	±7 dB

Typical OSC Level Accuracy .... 2 times of specification value
Connector .... APC-3.5®
Output Impedance .... 50 Ω (Nominal Value)
Level Monitor
  Monitor Parameters .... OSC level (voltage, current)
  Monitor Accuracy
    Voltage .... $20\log(1 + Y_0 \cdot 50 + Z_s/Z_x + E_a(\%) / 100)$ [dB] (Typical)

Current .... $20\log(1 + Y_0 \cdot Z_x + Z_s/50 + E_a(\%)/100)$ [dB] (Typical)

Where,

E_a : depends on measurement frequency and connector type. See measurement accuracy.

Z_s and Y_0 : depend on number of point averaging and OSC level. See measurement accuracy

Z_x : Measurement impedance

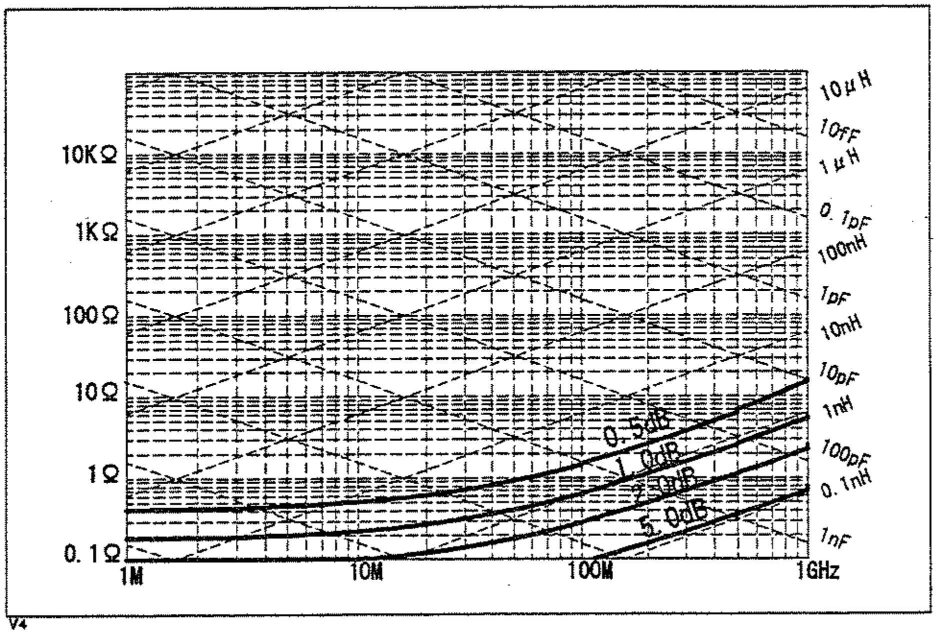


Figure 9-1. Typical Voltage Level Monitor Accuracy (@$N_{av}=8$, V_{osc} = 0.2 V)

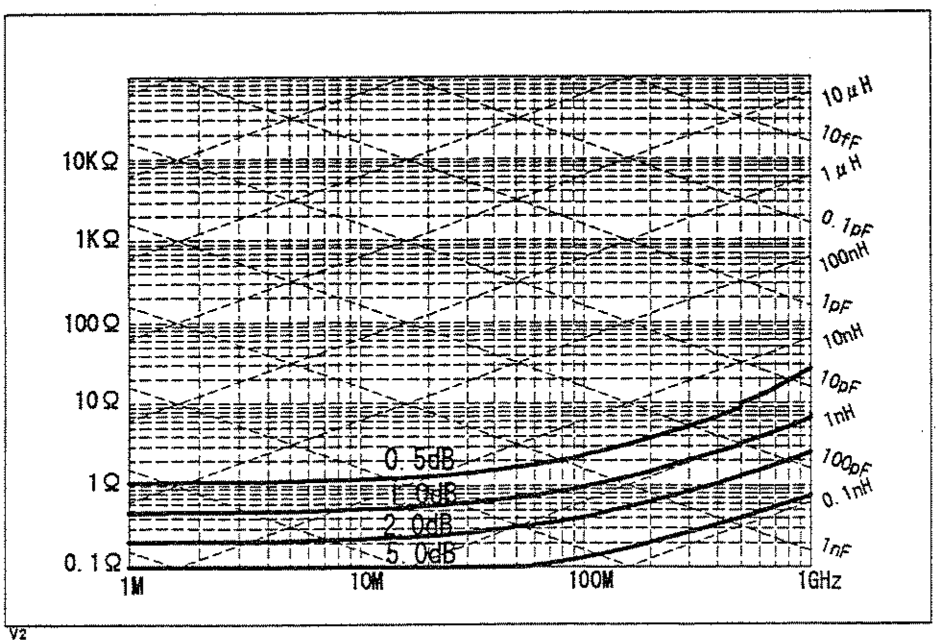


Figure 9-2. Typical Voltage Level Monitor Accuracy(@$N_{av}=1$, V_{osc} = 0.2 V)

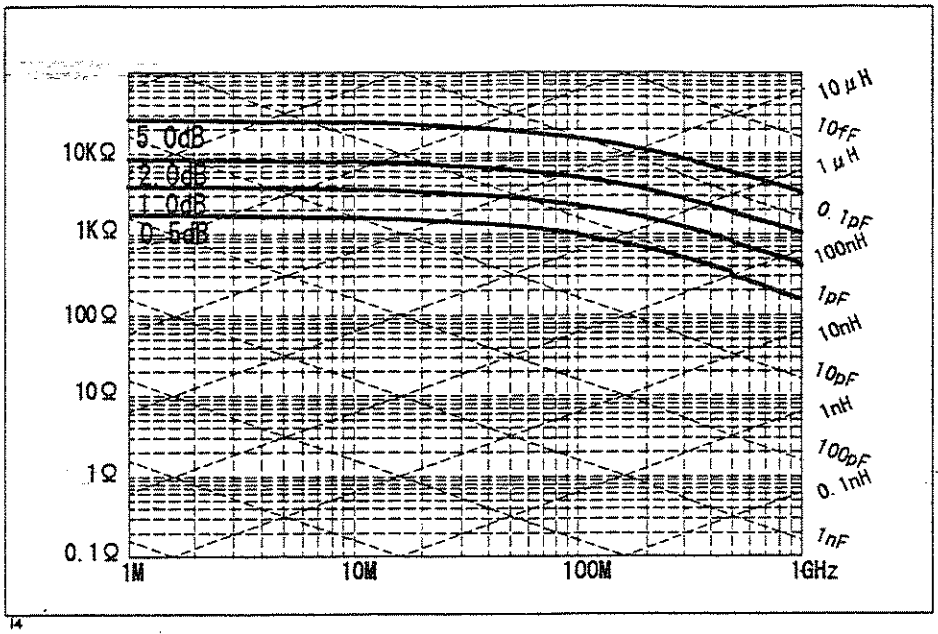


Figure 9-3. Typical Current Level Monitor Accuracy (@$N_{av}=8$, V_{osc} = 0.2 V)

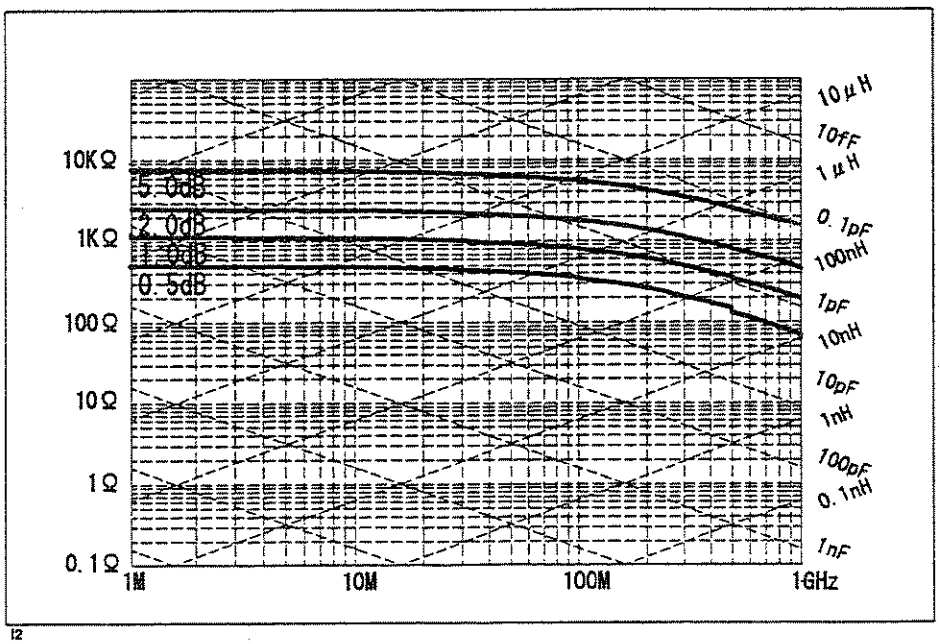


Figure 9-4. Typical Current Level Monitor Accuracy(@$N_{av}=1$, V_{osc} = 0.2 V)

Measurement Function

Measurement Parameters

.... L_p-D, L_p-Q, L_p-G, L_p-R_p, L_s-D, L_s-Q, L_s-R_s, R-X, $|Z|$-θ_{rad}, $|Z|$-θ_{deg}, C_p-D, C_p-Q, C_p-G, C_p-R_p, C_s-D, C_s-Q, C_s-R_s, G-B, $|Y|$-θ_{rad}, $|Y|$-θ_{deg}

Measurement Range

Impedance

@1MHz, accuracy $< 10\%$, $N_{av} \geq 8$, $V_{osc} \geq 0.2$ V .... 200 mΩ to 3 kΩ

Inductance

@ $Q < 100$, depends on frequency .... 1 nH to 100 μH

Contact Check Function

Measurement Current .... < 1 mA

List Sweep Characteristics

Sweep Mode .... Continuous, Single, Manual
Sweep Direction .... Up sweep
Number of Measurement Point .... 1 to 10 points
Averaging .... Point average
Delay Time .... Point delay time, Sweep delay time

Calibration / Compensation Function

Calibration Function .... Open/Short/50Ω calibration ,Low loss calibration
Compensation Function .... Open/Short/Load compensation, Port extension, Electric length
Calibration Measurement Points

Fixed Cal

This calibration measures the following FIXED points :

1.0	1.03	1.06	1.09	1.12	1.15	1.18	1.21	1.24	1.26
1.29	1.32	1.35	1.38	1.41	1.44	1.47	1.5	1.55	1.6
1.65	1.7	1.75	1.8	1.85	1.9	1.95	2.0	2.1	2.2
2.3	2.4	2.5	2.6	2.8	3.0	3.2	3.4	3.6	3.8
4.0	4.2	4.4	4.6	4.8	5.0	5.5	6.0	6.5	7.0
7.5	8.0	9.0	10	10	12	13	14	15	16
18	20	22	24	26	28	30	33	36	39
42	45	48	51	55	60	65	70	75	80
85	90	95	100	100	120	130	140	150	160
170	180	190	200	210	220	230	240	250	260
270	280	290	300	310	320	330	340	350	360
370	380	390	400	410	420	430	440	450	460
470	480	490	500	510	520	530	540	550	560
570	580	590	600	610	620	630	640	650	660
670	680	690	700	710	720	730	740	750	760
770	780	790	800	810	820	830	840	850	860
870	880	890	900	910	920	930	940	950	960
970	980	990	1000						(UNIT:MHz)

User Cal

This calibration measures the frequency points that are defined by the list sweep table.

Measurement Accuracy

Conditions of accuracy specifications
■ Open/Short/50 Ω calibration must be done. Calibration ON.
■ Averaging (on point) factor is larger than 32 at which calibration is done if Cal points is set to USER DEF.
■ Measurement points are same as the calibration points.
■ Environment temperature is within ±5°C of temperature at which calibration is done, and within 13°C to 33°C. Beyond this environmental temperature condition, accuracy is twice as bad as specified.
■ 7 mm connector is used.
■ When the analyzer frequency is identical to the transmitted interference signal frequency, refer to "EMC" in "General Characteristics".

Contact Check Measurement Accuracy

@ measurement range : 0.1 Ω to 100 Ω, resolution : 1 mΩ

$\pm\{3+(25\text{m}\Omega/R_{dut}+R_{dut}/10\text{k}\Omega)\times 100\}$ [%]

|Z|, |Y| Accuracy .... $\pm(E_a + E_b)$ [%]

θ Accuracy .... $\pm\frac{(E_a + E_b)}{100}$ [rad]

L, C, X, B Accuracy .... $\pm(E_a + E_b) \times \sqrt{(1 + D_x^2)}$ [%]

R, G Accuracy .... $\pm(E_a + E_b) \times \sqrt{(1 + Q_x^2)}$ [%]

D Accuracy (ΔD)

@ $|D_x \tan(\frac{E_a + E_b}{100})| < 1$ .... $\pm\frac{(1 + D_x^2)\tan(\frac{E_a + E_b}{100})}{1 \mp D_x \tan(\frac{E_a + E_b}{100})}$

Especially, @ $D_x \leq 0.1$ .... $\pm\frac{(E_a + E_b)}{100}$

Q Accuracy (ΔQ)

@ $|Q_x \tan(\frac{E_a + E_b}{100})| < 1$ .... $\pm\frac{(1 + Q_x^2)\tan(\frac{E_a + E_b}{100})}{1 \mp Q_x \tan(\frac{E_a + E_b}{100})}$

Especially, @ $\frac{10}{(E_a + E_b)} \geq Q_x \geq 10$ .... $\pm Q_x^2 \frac{(E_a + E_b)}{100}$

Where,

E_a : depends on measurement frequency as follows:

1 MHz≤Frequncy≤100 MHz .... $0.65 + \frac{0.03}{V_{osc}}$ [%]

100 MHz<Frequncy≤500 MHz .... $0.8 + \frac{0.03}{V_{osc}}$ [%]

500 MHz<Frequncy≤1000 MHz .... $1.2 + \frac{0.03}{V_{osc}}$ [%]

E_b : $(Z_s / |Z_x| + Y_0 |Z_x|) \times 100$ [%]

V_{osc} : OSC level [V]

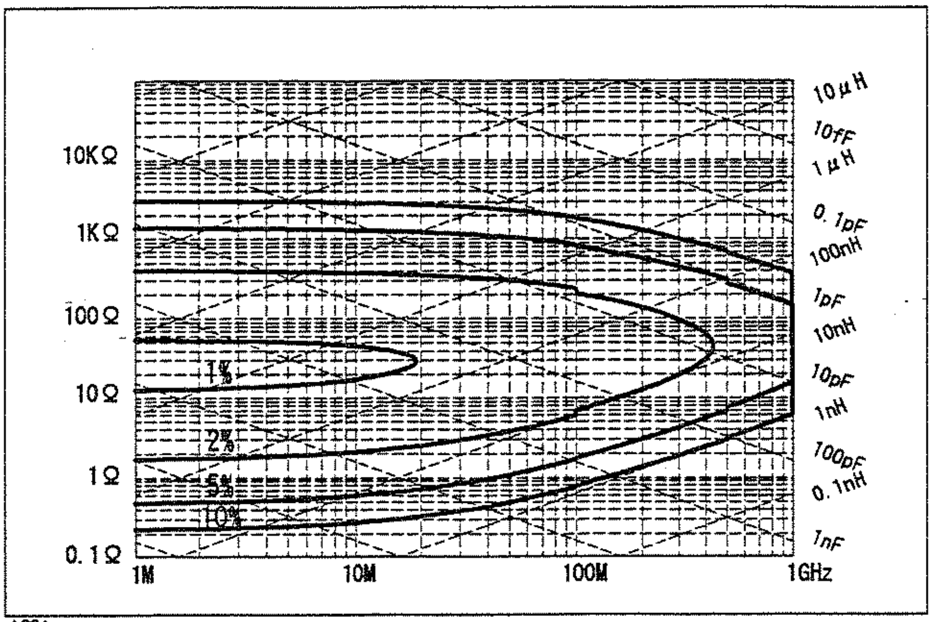
Z_x : impedance measurement value [Ω]

Z_s and Y_o depend on number of point averaging (N_{av}) and OSC level (V_{osc}) as follows:

9.Specifications

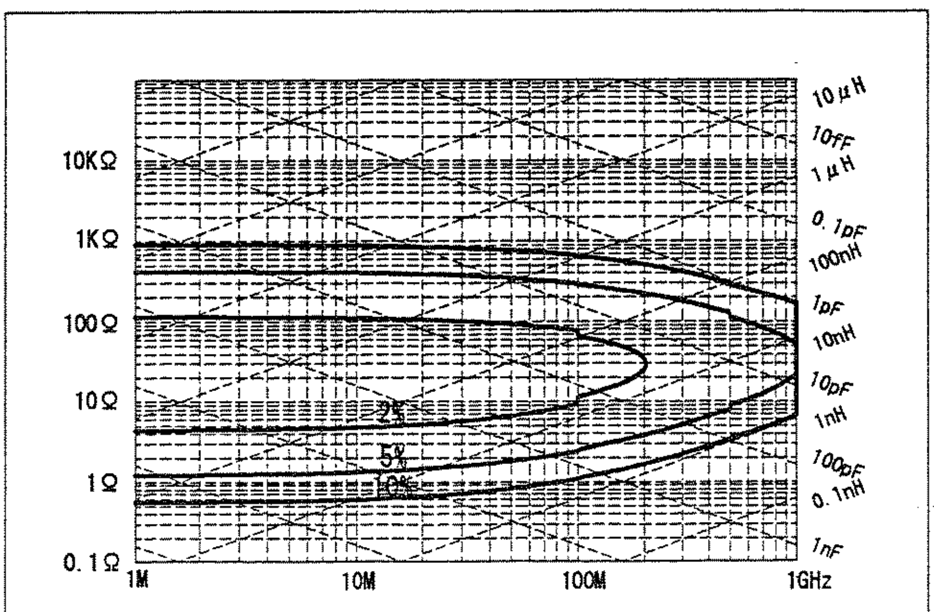
Measurement Conditions		Z_s [mΩ]	Y_o [μS]
Number of Point Averaging (N_{av})	OSC Signal Level (V_{osc})		
$1 \leq N_{av} \leq 7$	$0.2\ V \leq V_{osc} \leq 1\ V$	$50 + 0.5 \times f_{[MHz]}$	$100 + 0.4 \times f_{[MHz]}$
	$0.01\ V \leq V_{osc} < 0.2\ V$	$\frac{0.2}{V_{osc}} \times (50 + 1 \times f_{[MHz]})$	$\frac{0.2}{V_{osc}} \times (100 + 0.4 \times f_{[MHz]})$
$N_{av} \geq 8$	$0.2\ V \leq V_{osc} \leq 1\ V$	$20 + 0.5 \times f_{[MHz]}$	$30 + 0.2 \times f_{[MHz]}$
	$0.01\ V \leq V_{osc} < 0.2\ V$	$\frac{0.2}{V_{osc}} \times (20 + 0.5 \times f_{[MHz]})$	$\frac{0.2}{V_{osc}} \times (30 + 0.2 \times f_{[MHz]})$

At the following frequency points, instrument spurious characteristics could occasionally cause measurement errors to exceed specified value because of instrument spurious characteristics.			
10.71 MHz	17.24 MHz	21.42 MHz	42.84 MHz
514.65 MHz	686.19 MHz		



ACC4

Figure 9-5. Measurement Accuracy (@N_{av} = 8, V_{osc} = 0.2 V)



ACC2

Figure 9-6. Measurement Accuracy (@N_{av} = 1, V_{osc} = 0.2 V)

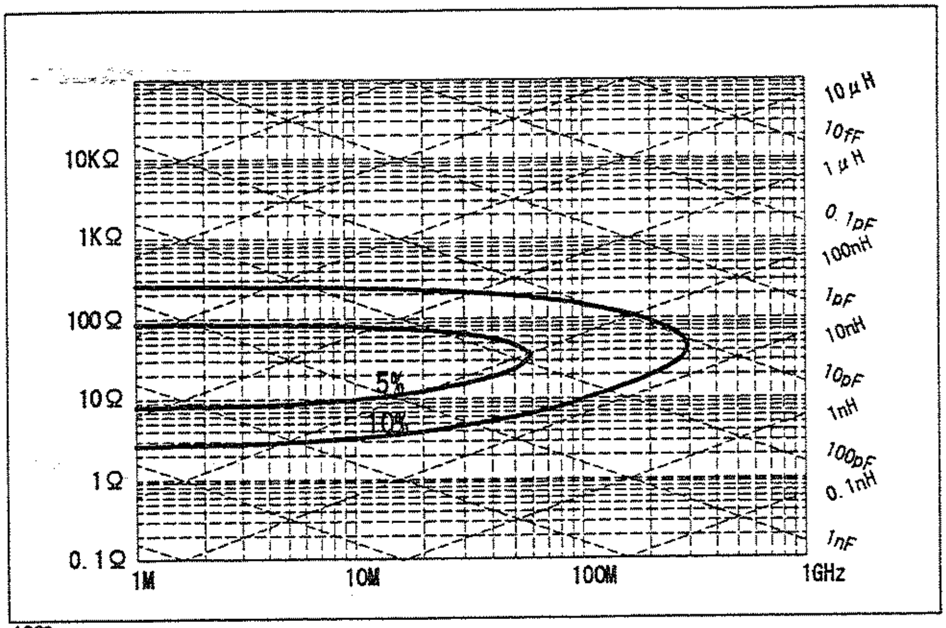


Figure 9-7. Measurement Accuracy (@N_{av} = 8, V_{osc} = 0.02 V)

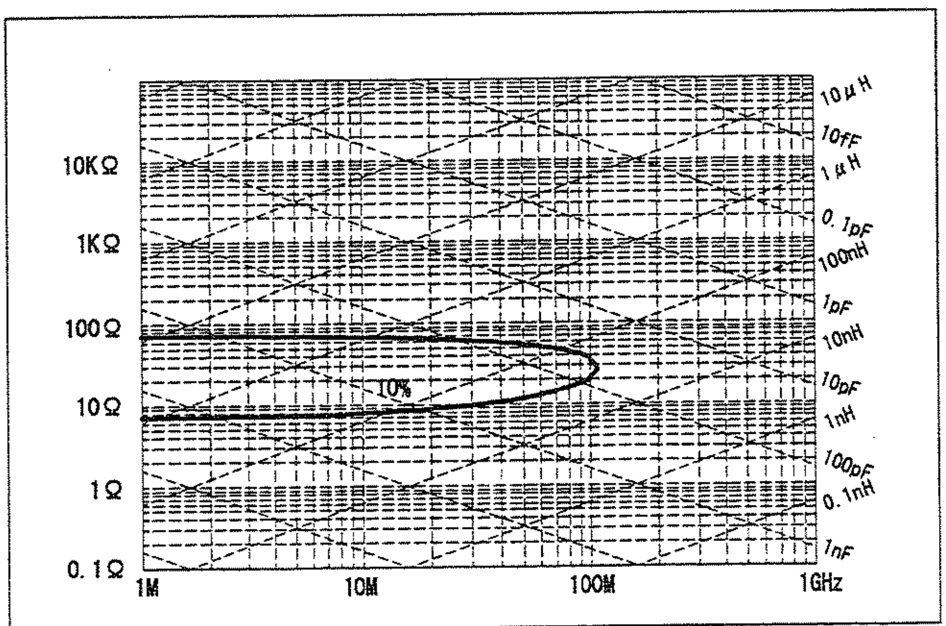


Figure 9-8. Measurement Accuracy (@N_{av} = 1, V_{osc} = 0.02 V)

Typical Measurement Accuracy

Conditions of typical accuracy specifications
■ Open/Short/50 Ω calibration must be done. Calibration ON. ■ Averaging (on point) factor is larger than 32 at which calibration is done if Cal points is set to USER DEF. ■ Measurement points are same as the calibration points. ■ Environment temperature is within ±5°C of temperature at which calibration is done, and within 13°C to 33°C. Beyond this environmental temperature condition, accuracy is twice as bad as specified. ■ 7 mm connector is used.

|Z|, |Y| Accuracy .... $\pm(E_a + E_b)$ [%]

θ Accuracy .... $\pm\frac{(E_a + E_b)}{100}$ [rad]

L, C, X, B Accuracy .... $\pm(E_a + E_b) \times \sqrt{(1 + D_x^2)}$ [%]

R, G Accuracy .... $\pm(E_a + E_b) \times \sqrt{(1 + Q_x^2)}$ [%]

D Accuracy (ΔD)

@ $|D_x \tan(\frac{E_a + E_b}{100})| < 1$ .... $\pm\frac{(1 + D_x^2)\tan(\frac{E_a + E_b}{100})}{1 \mp D_x \tan(\frac{E_a + E_b}{100})}$

Especially, @ $D_x \leq 0.1$ .... $\pm\frac{(E_a + E_b)}{100}$

Q Accuracy (ΔQ)

@ $|Q_x \tan(\frac{E_a + E_b}{100})| < 1$ .... $\pm\frac{(1 + Q_x^2)\tan(\frac{E_a + E_b}{100})}{1 \mp Q_x \tan(\frac{E_a + E_b}{100})}$

Especially, @ $\frac{10}{(E_a + E_b)} \geq Q_x \geq 10$ .... $\pm Q_x^2\frac{(E_a + E_b)}{100}$

Where,

E_a : depends on measurement frequency as follows:

1 MHz≤Frequncy≤100 MHz .... $0.56 + \frac{0.03}{V_{osc}}$ [%](*Typical*)

100 MHz<Frequncy≤500 MHz .... $0.63 + \frac{0.03}{V_{osc}}$ [%](*Typical*)

500 MHz<Frequncy≤1000 MHz .... $0.70 + \frac{0.03}{V_{osc}}$ [%](*Typical*)

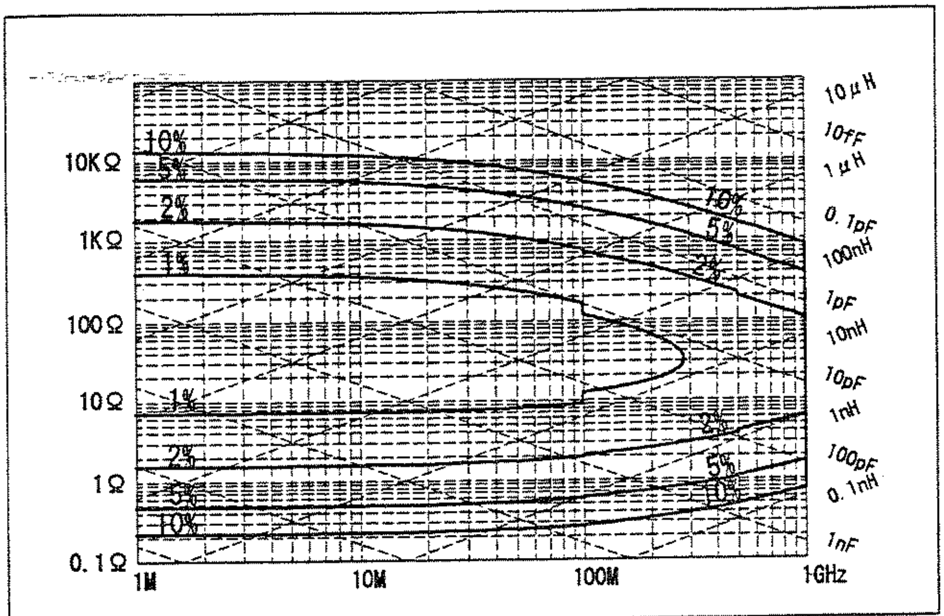
E_b : $(Z_s / |Z_x| + Y_0|Z_x|) \times 100$ [%]

V_{osc} : OSC level [V]

Z_x : impedance measurement value [Ω]

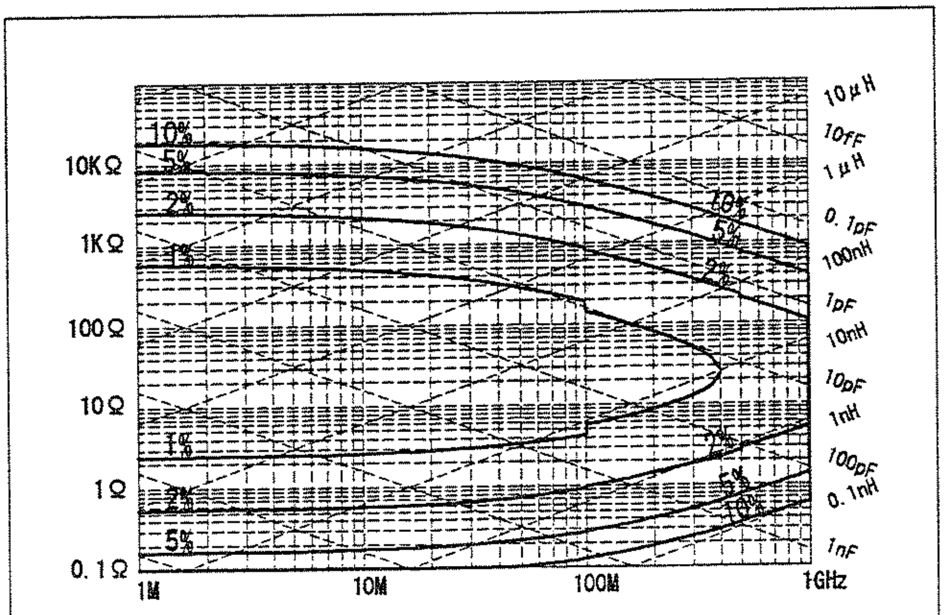
Z_s and **Y_o** depend on number of point averaging (N_{av}) and OSC level (V_{osc}) as follows:

Measurement Conditions		Z_s [mΩ] (*Typical*)	Y_o [μS] (*Typical*)
Number of Point Averaging (N_{av})	OSC Signal Level (V_{osc})		
$1 \leq N_{av} \leq 7$	$0.2\ V \leq V_{osc} \leq 1\ V$	$20 + 0.05 \times f_{[MHz]}$	$7 + 0.1 \times f_{[MHz]}$
	$0.01\ V \leq V_{osc} < 0.2\ V$	$\frac{0.2}{V_{osc}} \times (20 + 0.05 \times f_{[MHz]})$	$\frac{0.2}{V_{osc}} \times (7 + 0.1 \times f_{[MHz]})$
$N_{av} \geq 8$	$0.2\ V \leq V_{osc} \leq 1\ V$	$7 + 0.05 \times f_{[MHz]}$	$5 + 0.1 \times f_{[MHz]}$
	$0.01\ V \leq V_{osc} < 0.2\ V$	$\frac{0.2}{V_{osc}} \times (7 + 0.05 \times f_{[MHz]})$	$\frac{0.2}{V_{osc}} \times (5 + 0.1 \times f_{[MHz]})$



L1_12T

Figure 9-9. Typical Measurement Accuracy (@$N_{av}=1$, V_{osc} = 0.2 V)



L8_12T

Figure 9-10. Typical Measurement Accuracy (@$N_{av}=8$, V_{osc} = 0.2 V)

Typical measurement accuracy when open/short/50 Ω/low-loss-capaciter calibration is done

Conditions

- Averaging on point factor is lager than 32 at which calibration is done.
- Cal Points is set to USER DEF.
- Environment temperature is within ±5 °C of temperature at which calibration is done, and within 13 °C to 33 °C. Beyond this environmental temperature condition, accuracy is twice as bad as specified.
- 7 mm connector is used.

|Z|, |Y| Accuracy .... $\pm(E_a + E_b)$ [%]

θ Accuracy .... $\pm\frac{E_c}{100}$ [rad]

L, C, X, B Accuracy .... $\pm\sqrt{(E_a + E_b)^2 + (E_c D_x)^2}$ [%]

R, G Accuracy .... $\pm\sqrt{(E_a + E_b)^2 + (E_c Q_x)^2}$ [%]

D Accuracy

@ $|D_x \tan(E_c/100)| < 1$ .... $\pm\frac{(1 + D_x^2)\tan(E_c/100)}{1 \mp D_x \tan(E_c/100)}$

Especially, $D_x \leq 0.1$ .... $\pm\frac{E_c}{100}$

Q Accuracy

@ $|Q_x \tan(E_c/100)| < 1$ .... $\pm\frac{(1 + Q_x^2)\tan(E_c/100)}{1 \mp Q_x \tan(E_c/100)}$

Especially, $\frac{10}{E_c} \geq Q_x \geq 10$ .... $\pm Q_x^2 \frac{E_c}{100}$

Where,

D_x: Actual D value of DUT

E_a, E_b : are as same as E_a and E_b of the measurement accuracy when OPEN/SHORT/50 Ω calbration is done.

E_c $= 0.06 + 0.08 \times \frac{F}{1000}$ (Typical)

F : measurement frequency [MHz]

Q_x : Actual Q value of DUT

9. Specifications

Trigger Function

Trigger Source … Internal, Manual, External, Bus

Throughput

For a time from triggering to EOM … ≤ 15 msec / point

Display

Type/Size … Monochrome CRT. 7 inch, Text screen only
Resolution … 512 dots × 304 lines

Data Storage

Type … Built-in flexible disk drive, Battery backup SRAM disk memory
Capacity
  Built-in flexible disk … 720 kB/1.44 MB
  Battery backup SRAM disk memory … 256 kB
Operatin time of battery backup SRAM disk memory … 3 days
Disk format … LIF, DOS

Interface

HP-IB

Interface … IEEE 488.1-1987, IEC625, JIS C 1901-1987 standard compatible.
Interface function … SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C1, C2, C3, C4, C11, E2
Numeric Data Transfer formats … ASCII
32 and 64 bit IEEE 754 Floating point format,
DOS PC format (32 bit IEEE with byte order reversed)
Protocol … IEEE 488.2-1987

Handler Interface

Interface … All output signals are negative logic, opto-isolated open collector outputs.
Output Signals … Sort Judgments (BIN1 to BIN9, AUX_BIN, OUT_OF_BIN, PHI, PLO, SREJ), Contact Check (NO_CONTACT), /FAIL, End Of Analog Processing (INDEX), End-Of-Measurement (EOM), Power Line Fail (ALARM)
Input Signals … External trigger (EXT_TRIG), Front panel key lock (KEY_LOCK)

Input Output Characteristics

External reference input
- **Frequency** .... 10 MHz±100 Hz (typically)
- **Level** .... > −6 dBm (typically)
- **Input impedance** .... 50Ω (nominal)
- **Connector** .... BNC female

Internal Reference Output
- **Frequency** .... 10 MHz (nominal)
- **Level** .... 2 dBm (typically)
- **Output Impedance** .... 50 Ω (nominal)
- **Connector** .... BNC female

External trigger input
- **Level** .... TTL Level
- **Pulse width (Tp)** .... > 2 μs (typically)
- **Polarity** .... positive/negative selective
- **Connector** .... BNC female

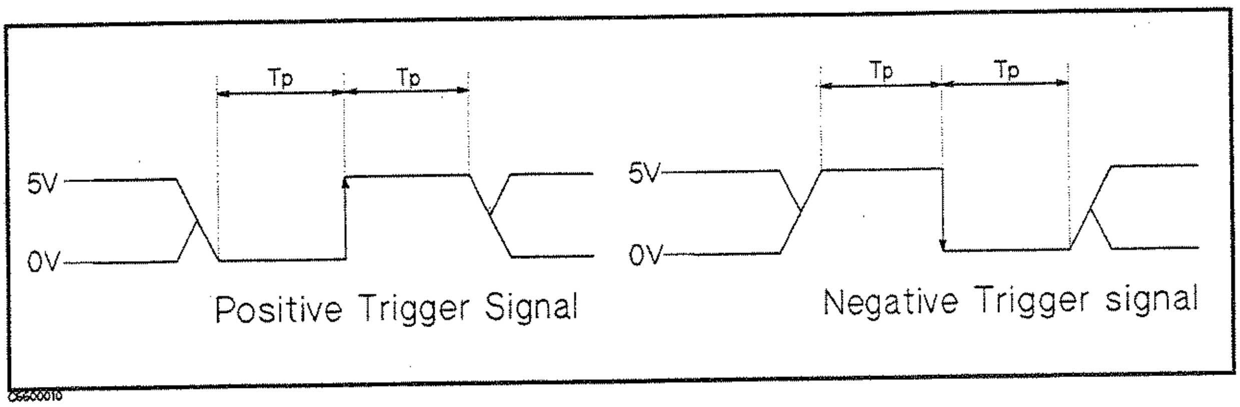


Figure 9-11. Trigger Signal

General Characteristics

Operation Conditions

Temperature
- Disk drive non-operating condition .... 0°C to 55°C
- Disk drive operating condition .... 10°C to 50°C

Humidity
- @wet bulb temperature <29°C, without condensation
  - Disk drive non-operating condition .... 15 % to 95 % RH
  - Disk drive operating condition .... 15 % to 80 % RH

Altitude .... 0 to 2,000 meters

Warm up time .... 30 minutes

Non-operation conditions

Temperature .... –40°C to 65°C
Humidity
@wet bulb temperature <29°C, without condensation .... 15 % to 95 % RH
Altitude .... 0 to 15,240 meters (50,000 feet)

Others

EMC .... Complies with CISPR 11 (1990) / EN 55011 (1991) : Group 1, Class A
Complies with IEC 801-2 (1991) / EN 50082-1 (1992) : 4 kV CD, 8 kV AD
Complies with IEC 801-3 (1984) / EN 50082-1 (1992) : 3 V/m
Complies with IEC 801-4 (1988) / EN 50082-1 (1992) : 1 kV Power lines / 0.5 kV Signallines

Note: When tested at 3 V/m according to IEC 801-3/1984, the measurement accuracy will be within specifications over the full immunity test frequency range of 26 to 1000 MHz except when the analyzer frequency is identical to the transmitted interference signal test frequency.

Power requirements .... 90V to 132V, or 198V to 264V, 47 to 66 Hz, 500VA max
Weight
Mainframe .... 28 kg
Test head .... 0.3 kg
Dimensions
Mainframe .... 426 (W) × 234 (H) × 537 (D) mm
Test Head .... See Figure 9-12 and Figure 9-13.

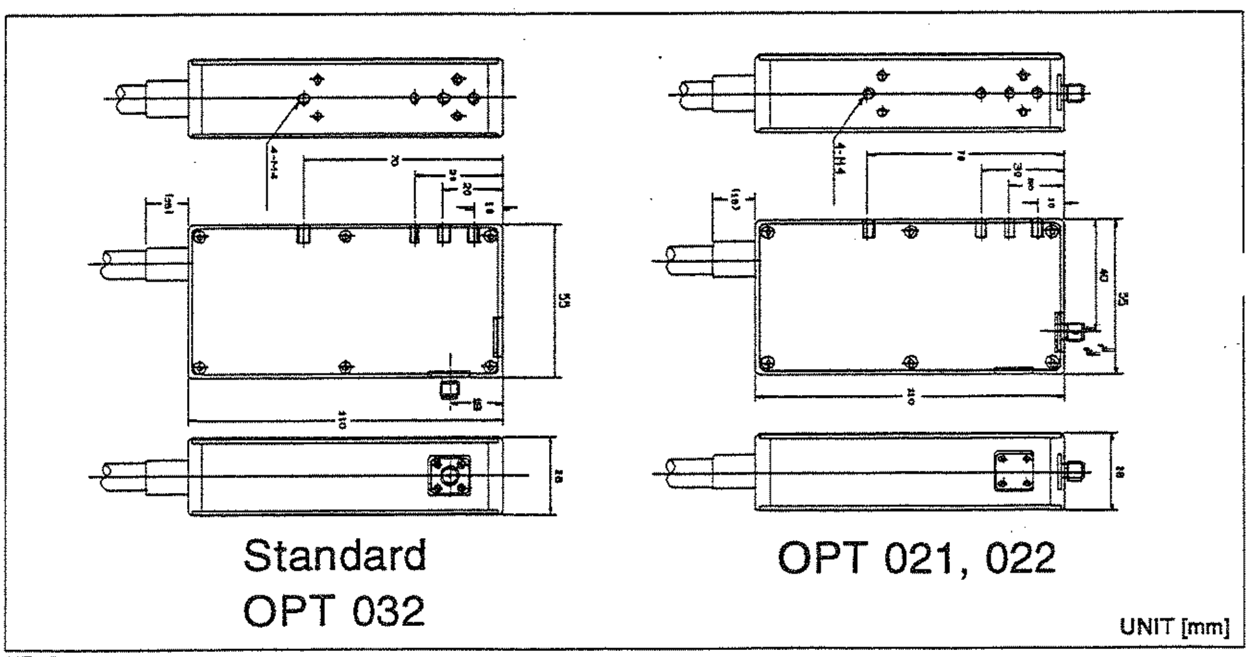


Figure 9-12. Dimensions of Test Heads (1/2)

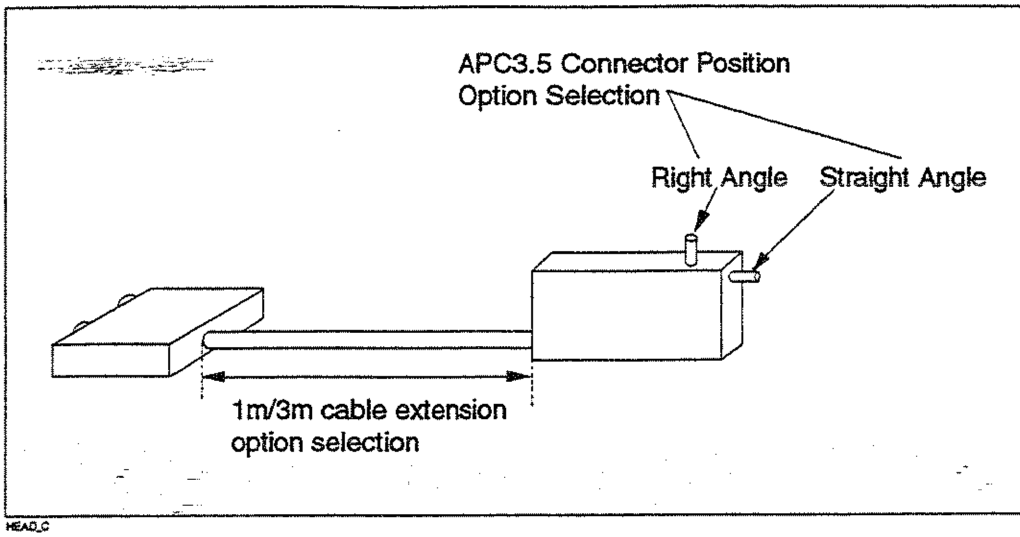


Figure 9-13. Dimensions of Test Heads (2/2)

Specification for Option 1C2 HP Instrument BASIC

External program Run/Cont input

Connector .... BNC female
Level .... TTL
Keyboard connector .... HP-HIL
I/O port .... 4 bit in/ 8 bit out port, TTL Level
I/O port pin assignments

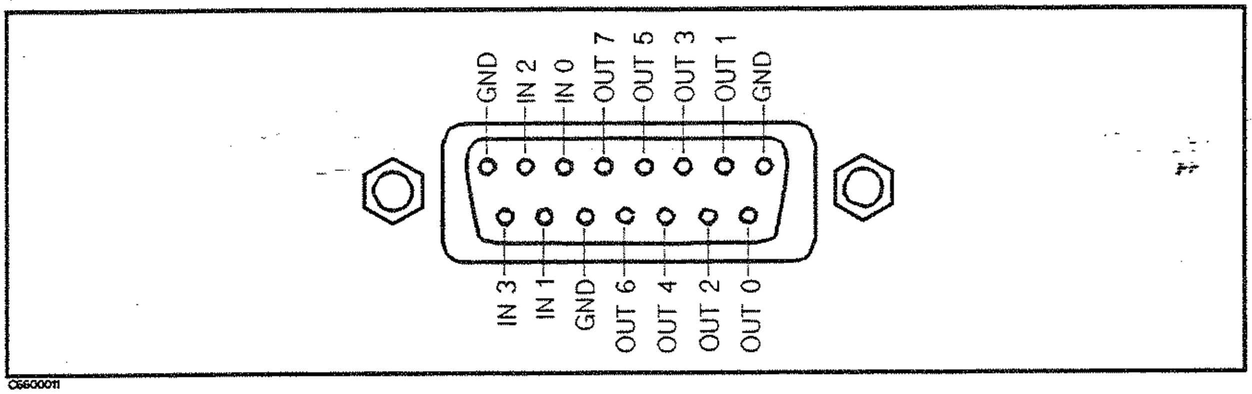


Figure 9-14. I/O Port Pin Assignment

Specification for Option 004 Working Standard

Supplied shorting device size
- P/N 16191-29005 .... 1.0 x 0.5 mm
- P/N 16191-29006 .... 1.6 x 0.8 mm
- P/N 16191-29007 .... 2.0 x 1.25 mm
- P/N 16191-29008 .... 3.2 x 1.6 mm

Supplied resistor size
- P/N 5182-0433 .... 1.0 x 0.5 mm
- P/N 5182-0434 .... 1.6 x 0.8 mm
- P/N 5182-0435 .... 2.0 x 1.25 mm
- P/N 5182-0436 .... 3.2 x 1.6 mm

DC resistance of supplied chip resistor .... 51Ω ±0.5 %

Manual Changes

Introduction

This appendix contains the information required to adapt this manual to earlier versions or configurations of the analyzer than the current printing date of this manual. The information in this manual applies directly to the HP 4286A RF Impedance/Material Analyzer serial number prefix listed on the title page of this manual.

Manual Changes

To adapt this manual to your HP 4286A, see Table A-1 and Table A-2, and make all the manual changes listed opposite your instrument's serial number and firmware version.

Instruments manufactured after the printing of this manual may be different from those documented in this manual. Later instrument versions will be documented in a manual changes supplement that will accompany the manual shipped with that instrument. If your instrument's serial number is not listed on the title page of this manual or in Table A-1, it may be documented in a *yellow MANUAL CHANGES* supplement.

In additions to change information, the supplement may contain information for correcting errors (Errata) in the manual. To keep this manual as current and accurate as possible, Hewlett-Packard recommends that you periodically request the latest *MANUAL CHANGES* supplement.

For information concerning serial number prefixes not listed on the title page or in the *MANUAL CHANGE* supplement, contact the nearest Hewlett-Packard office.

Turn on the line switch or execute the *IDN? command by HP-IB to confirm the firmware version. See the *HP-IB Command Reference* manual for information on the *IDN? command.

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

Serial Number

Hewlett-Packard uses a two-part, ten-character serial number that is stamped on the serial number plate (see Figure A-1) attached to the rear panel. The first five characters are the serial prefix and the last five digits are the suffix.

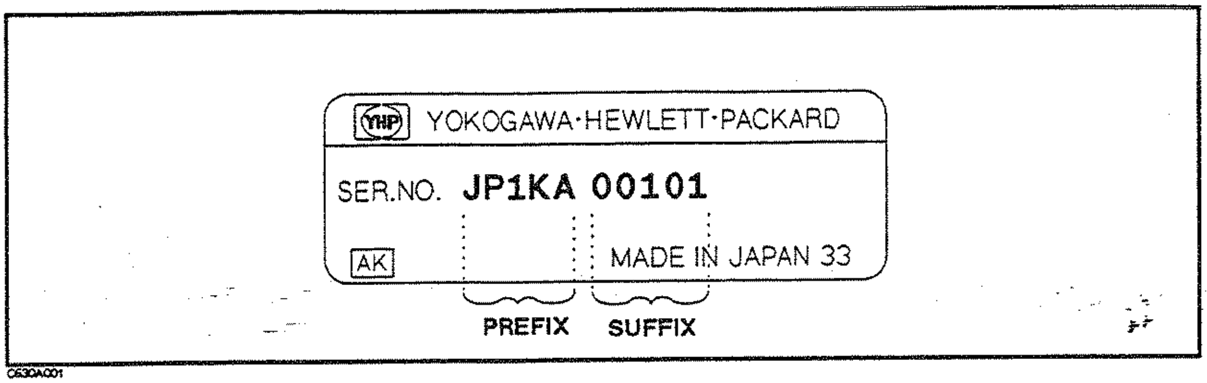


Figure A-1. Serial Number Plate

Softkey Tree

Measurement Block

(Meas)

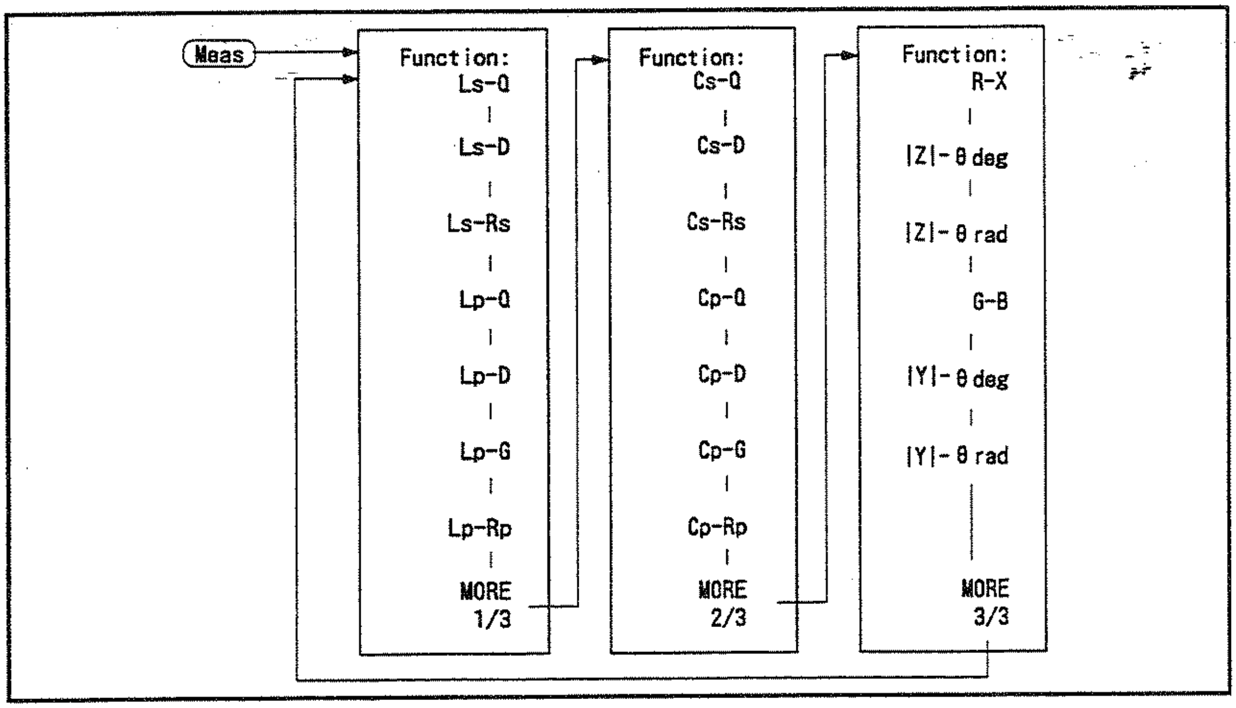


Figure B-1. Softkey Menus Accessed from the (Meas) Key

Measurement Block : (Display)

(Display)

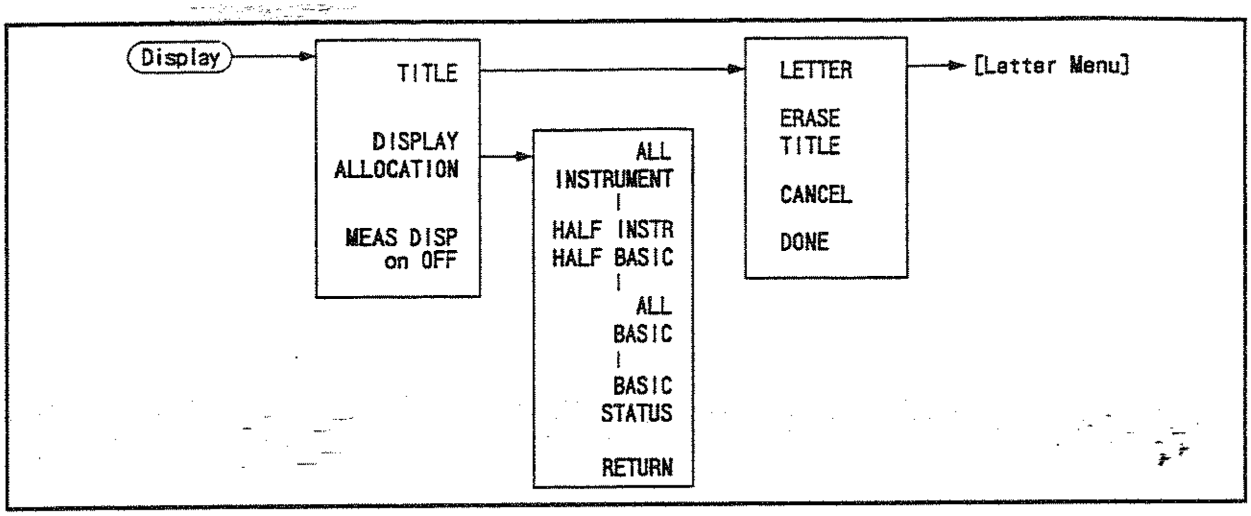


Figure B-2. Softkey Menus Accessed from the (Display) Key

Cal

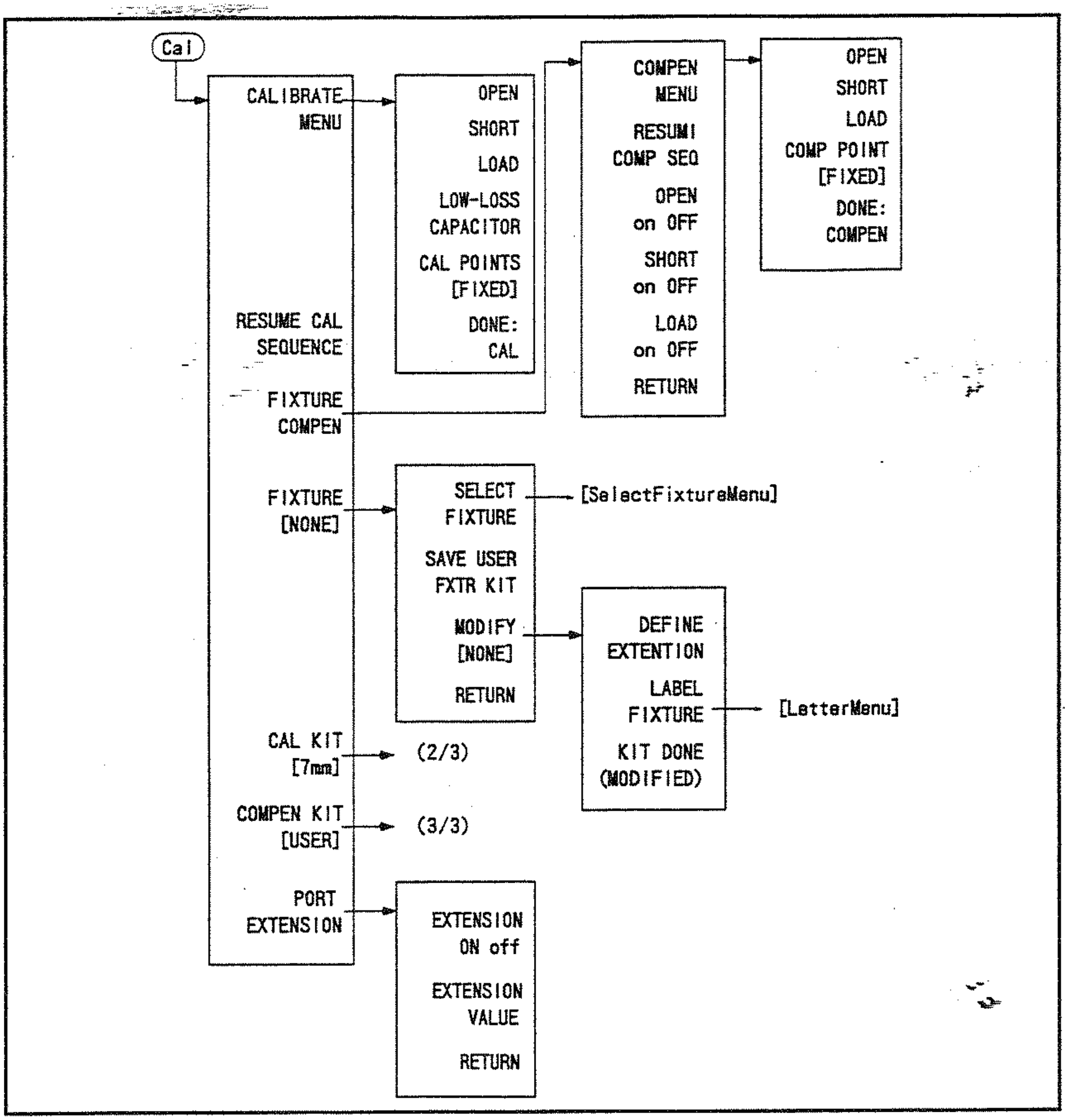


Figure B-3. Softkey Menus Accessed from the Cal Key (1/3)

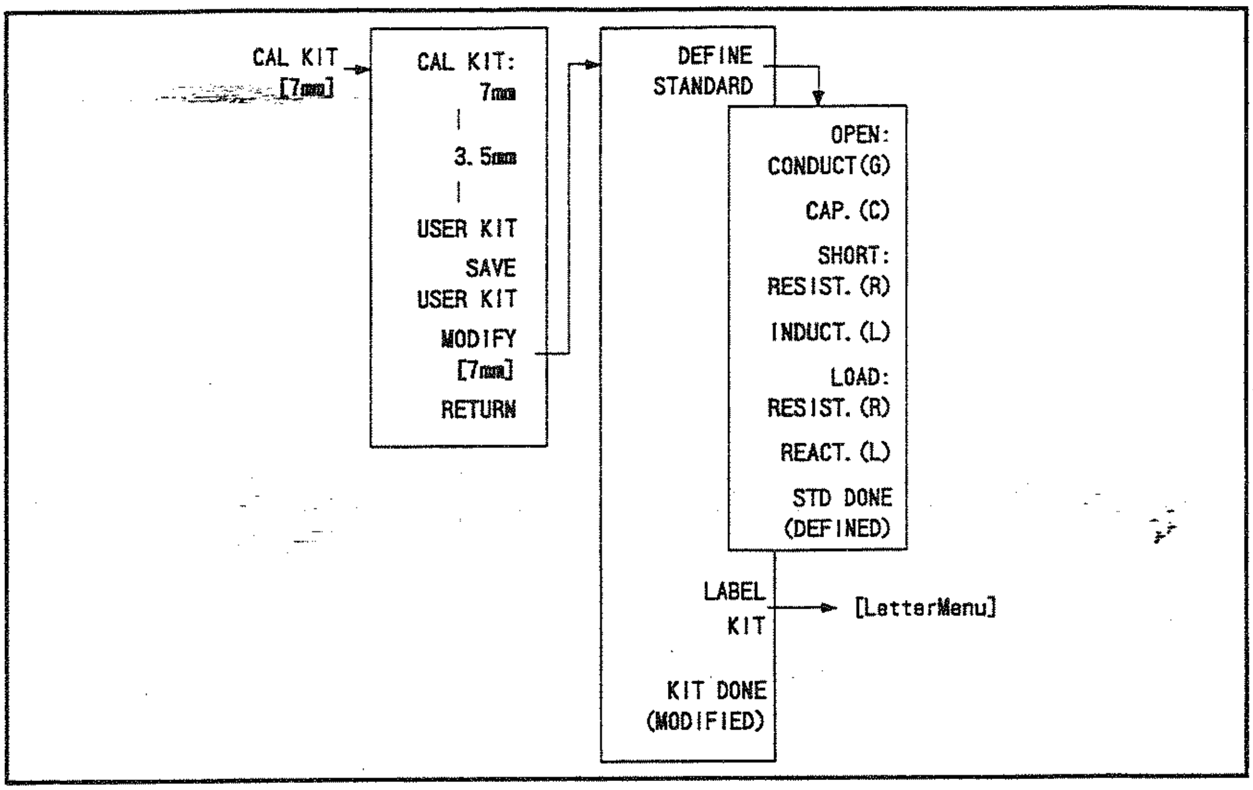


Figure B-4. Softkey Menus Accessed from the (Cal) Key (2/3)

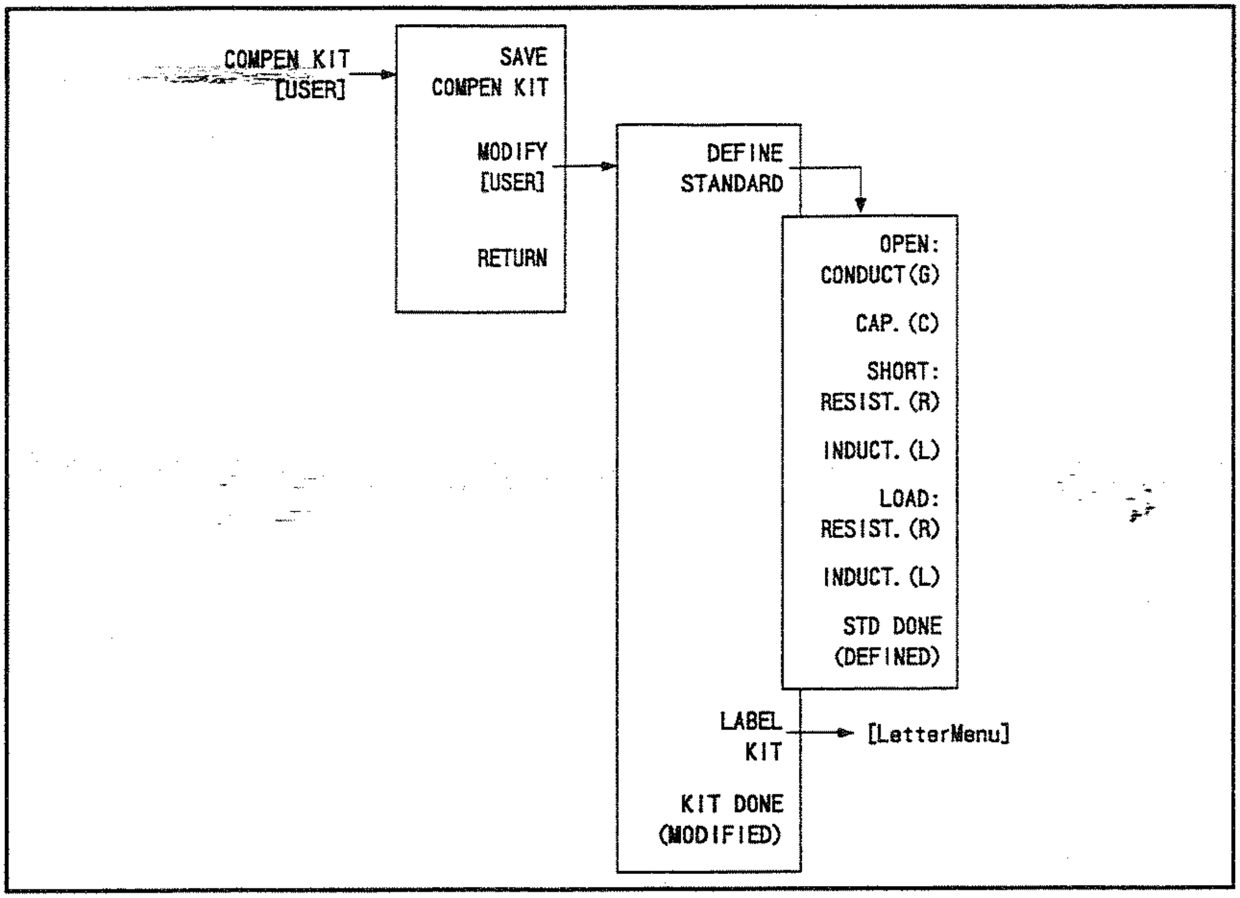


Figure B-5. Softkey Menus Accessed from the Cal Key (3/3)

Measurement Block : (Sweep Setup)

(Sweep Setup)

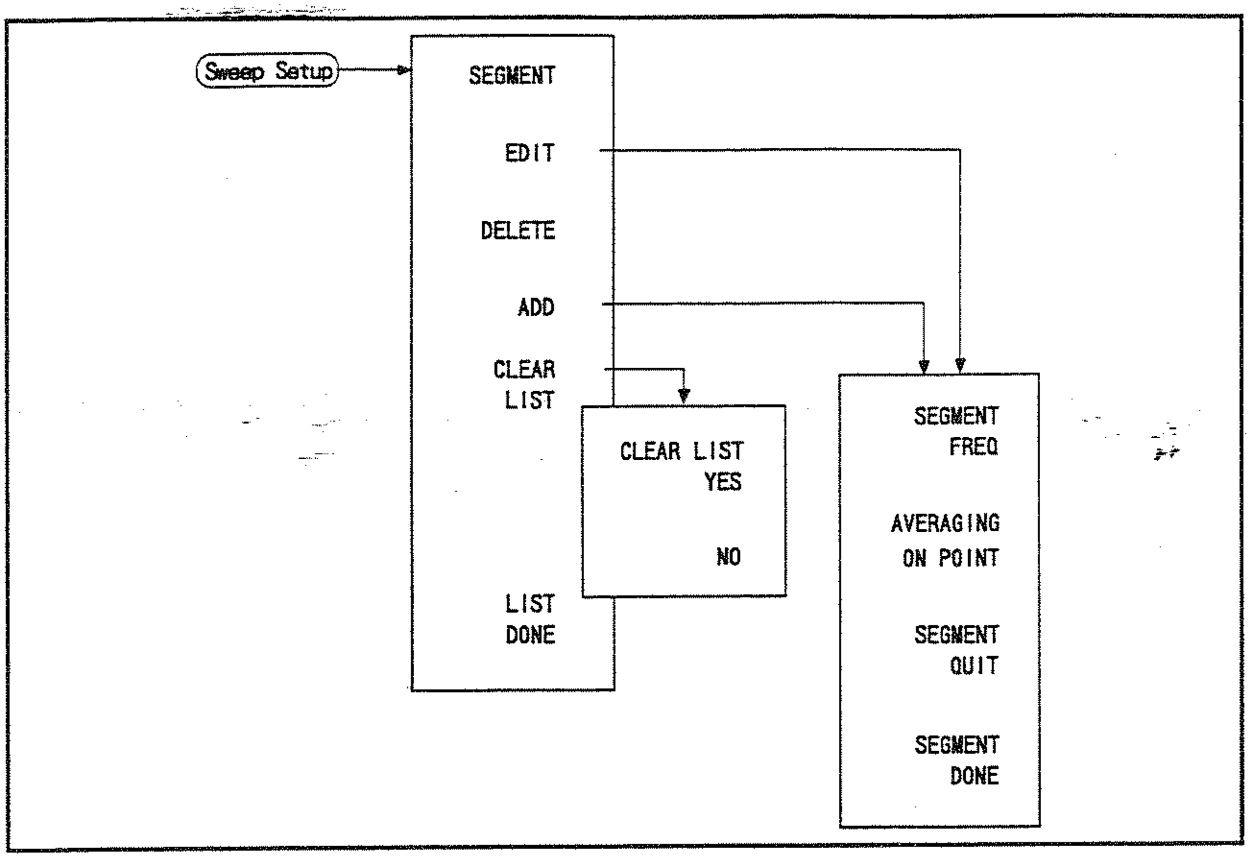


Figure B-6. Softkey Menus Accessed from the (Sweep Setup) Key

Test Setup

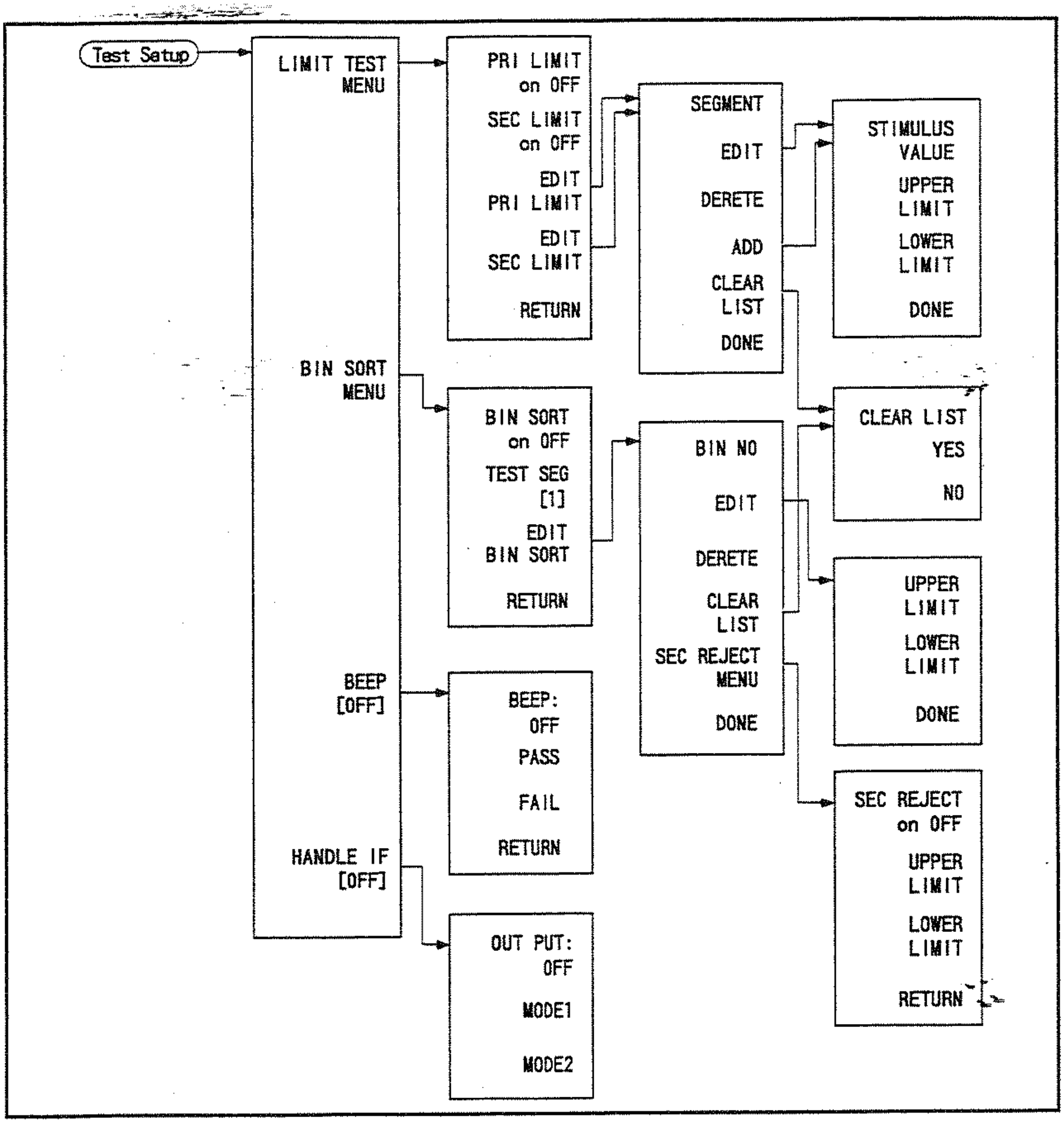


Figure B-7. Softkey Menus Accessed from the Test Setup Key

Measurement Block :- (Monitor)

(Monitor)

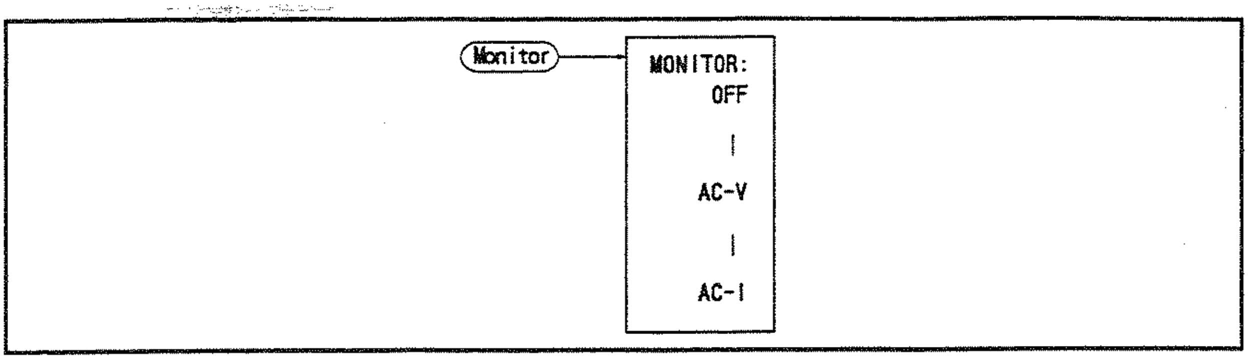


Figure B-8. Softkey Menus Accessed from the (Monitor) Key

(Delay Time)

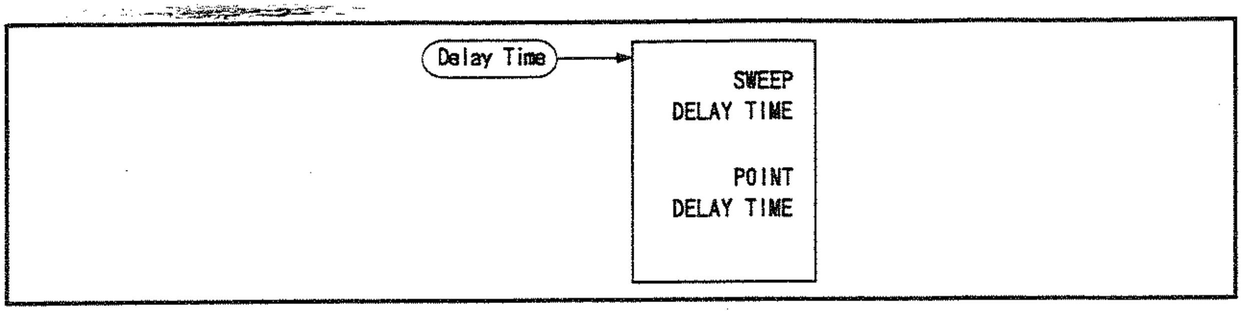


Figure B-9. Softkey Menus Accessed from the (Delay Time) Key

Measurement Block : [Source]

[Source]

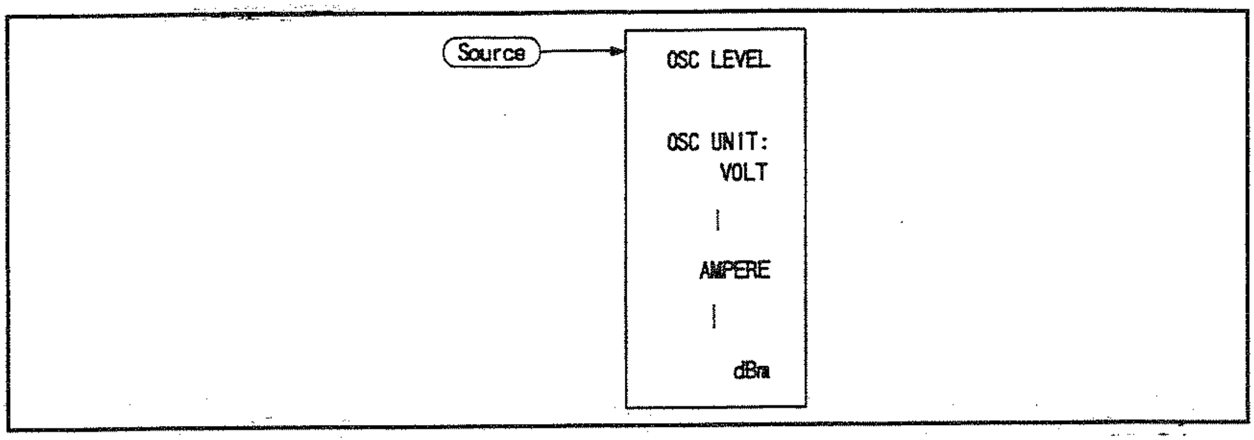


Figure B-10. Softkey Menus Accessed from the [SOURCE] Key

(Contact Check)

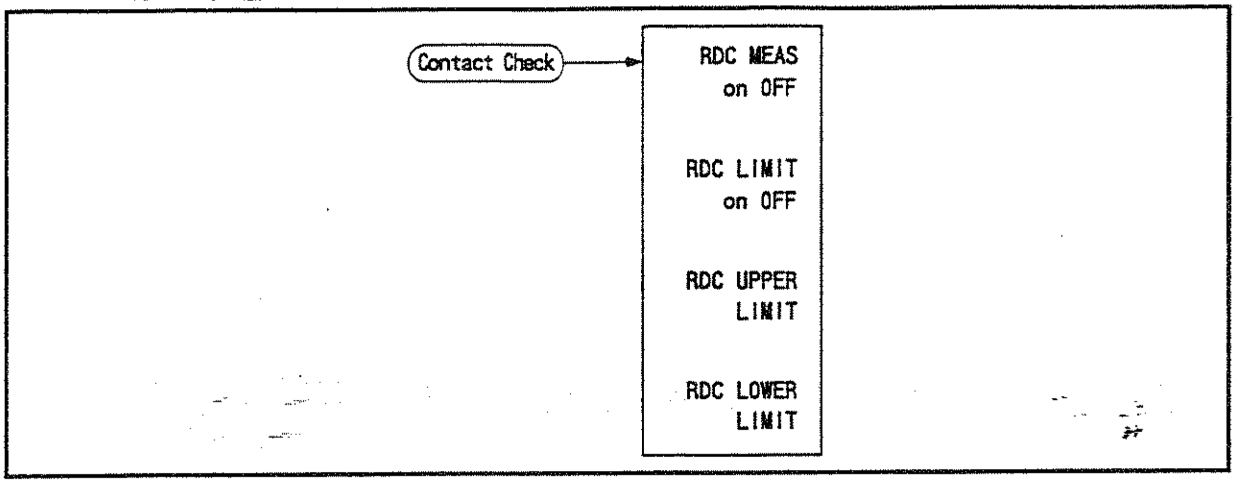


Figure B-11. Softkey Menus Accessed from the (Contact Check) Key

Measurement Block : (Trigger Mode)

(Trigger Mode)

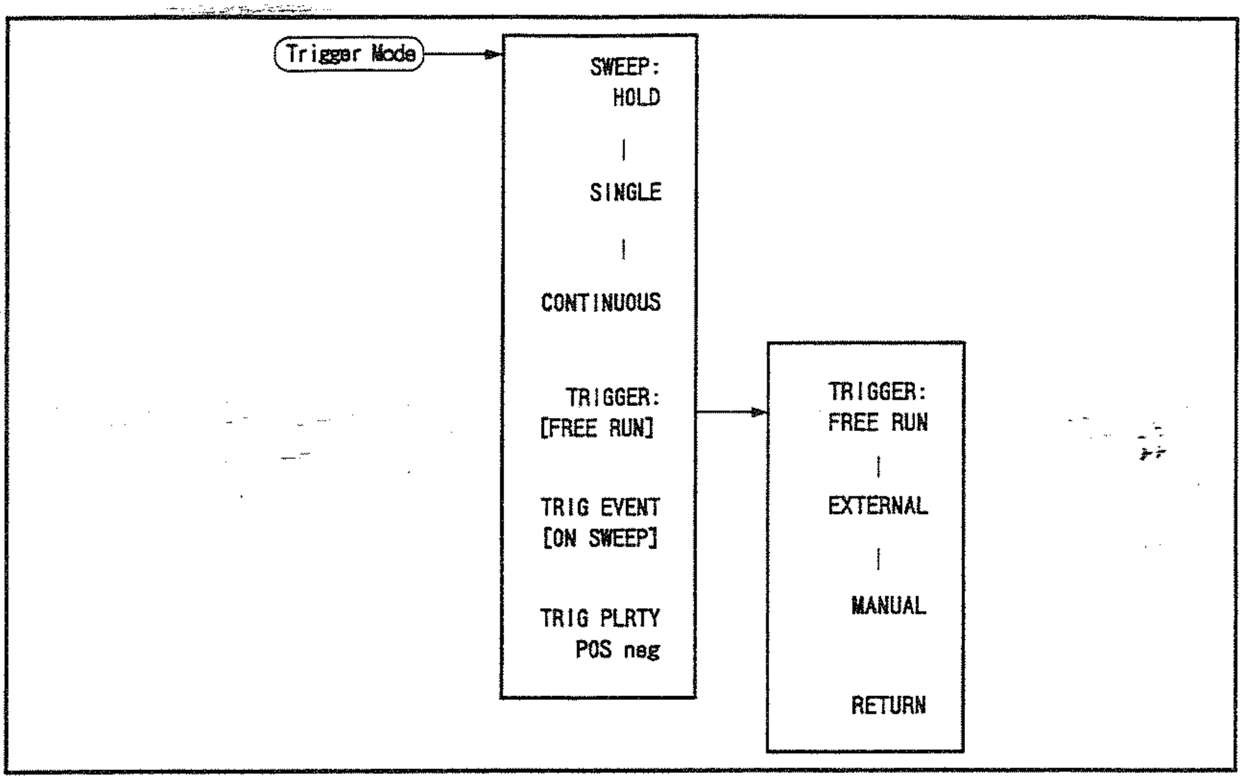


Figure B-12. Softkey Menus Accessed from the (Trigger Mode) Key

Instrument State Block

(Local)

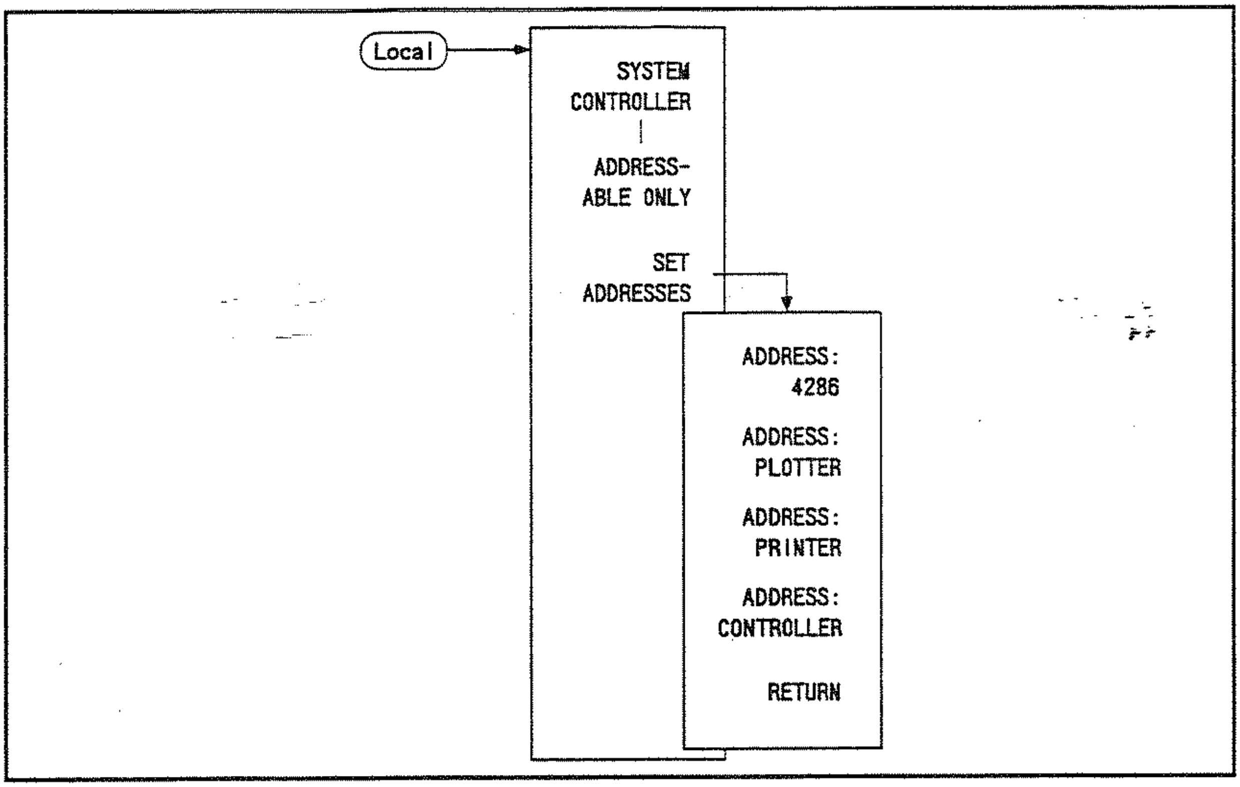


Figure B-13. Softkey Menus Accessed from the (Local) Key

(System)

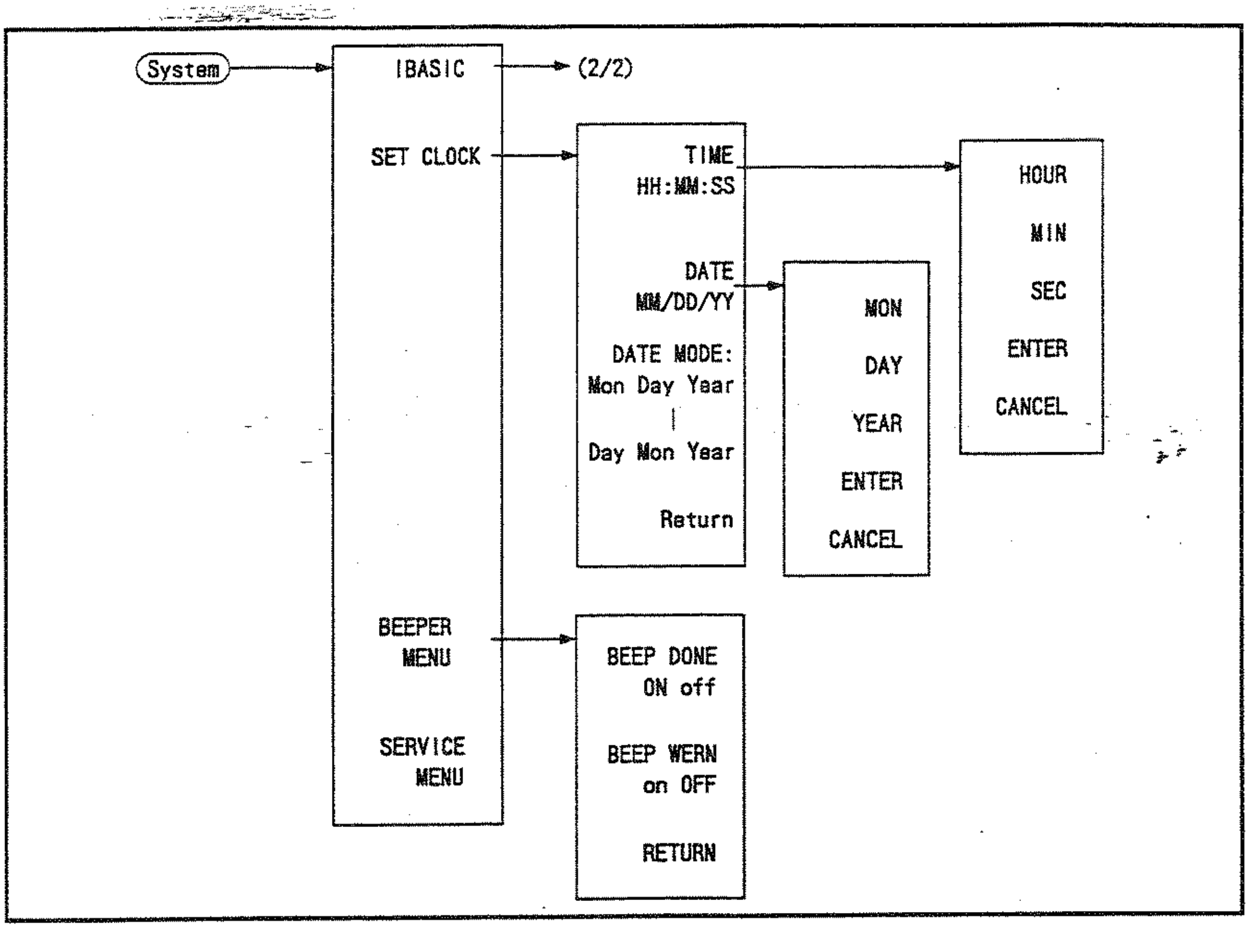


Figure B-14. Softkey Menus Accessed from the (System) Key (1/2)

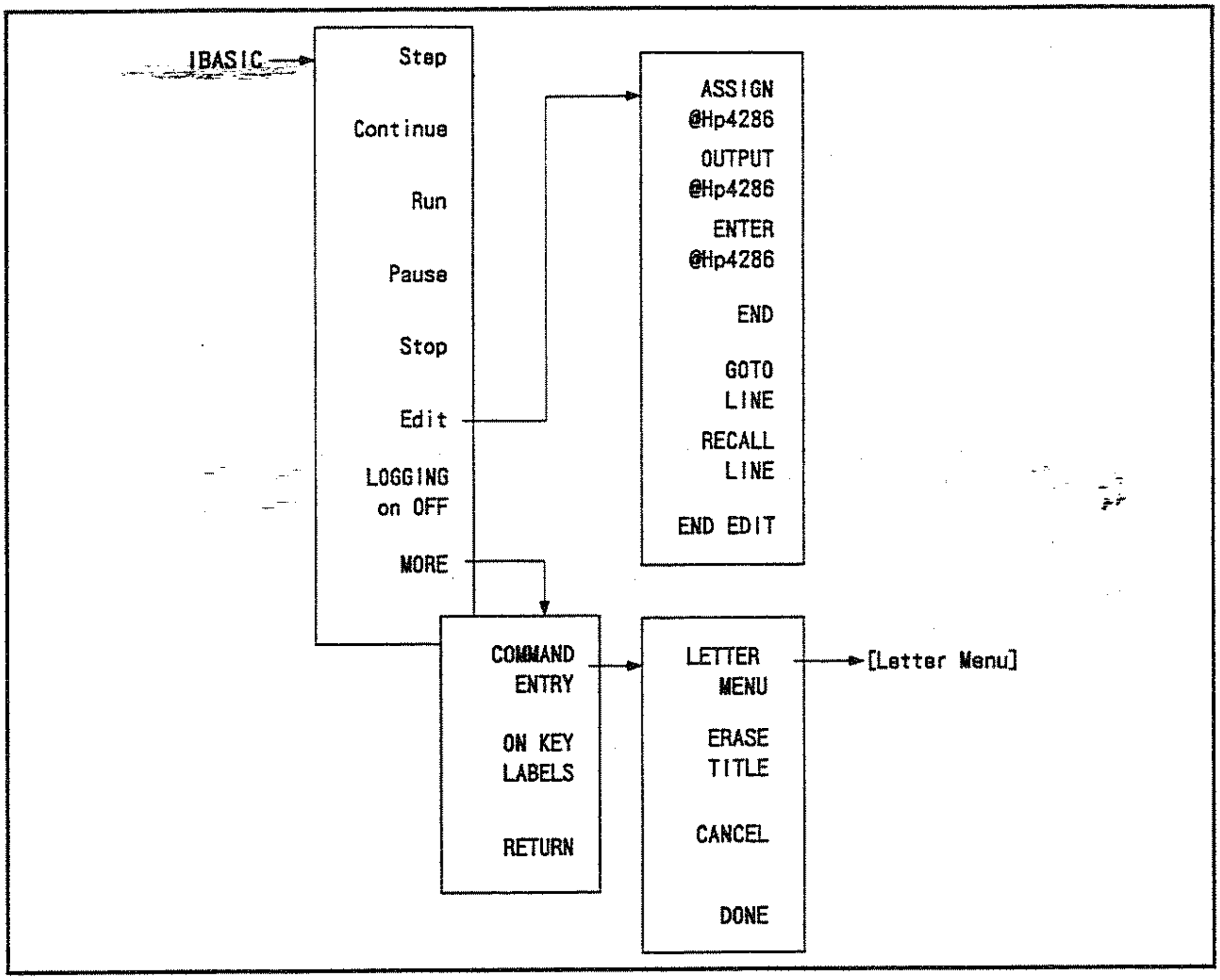


Figure B-15. Softkey Menus Accessed from the (System) Key (2/2)

(Copy)

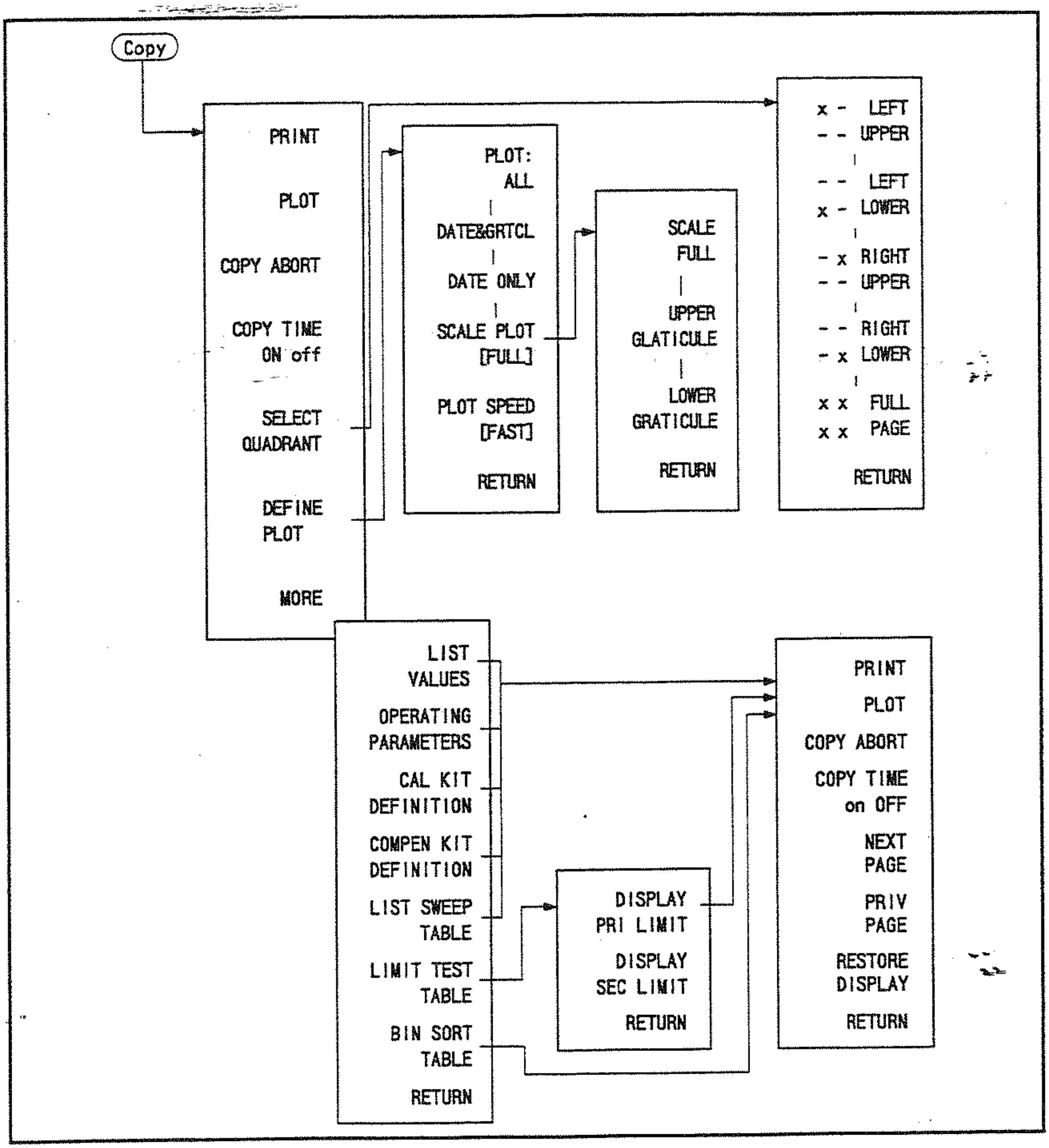


Figure B-16. Softkey Menus Accessed from the (Copy) Key

(Save/Recall)

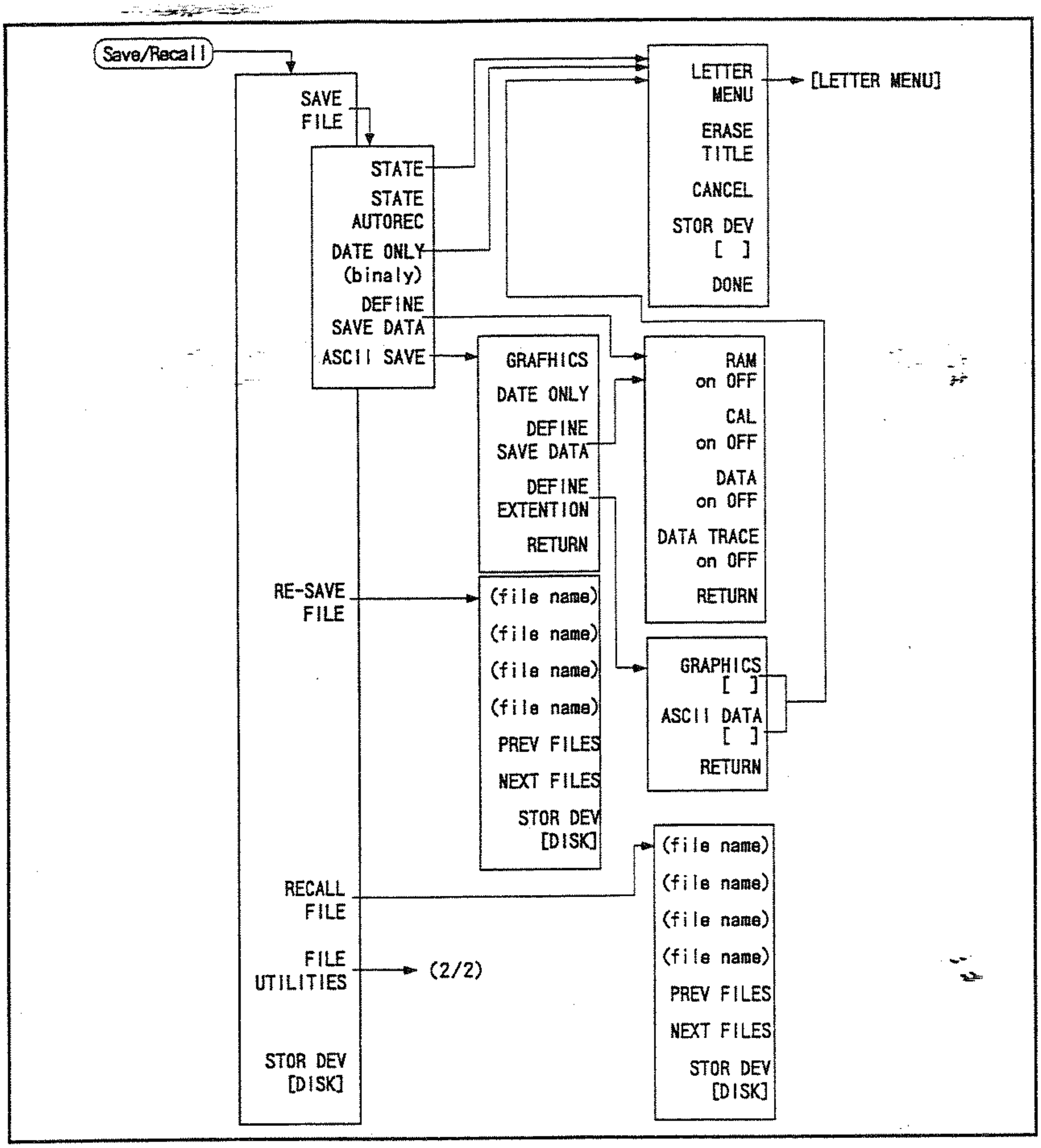


Figure B-17. Softkey Menus Accessed from the (Save/Recall) Key (1/2)

Instrument State Block: (Save/Recall)

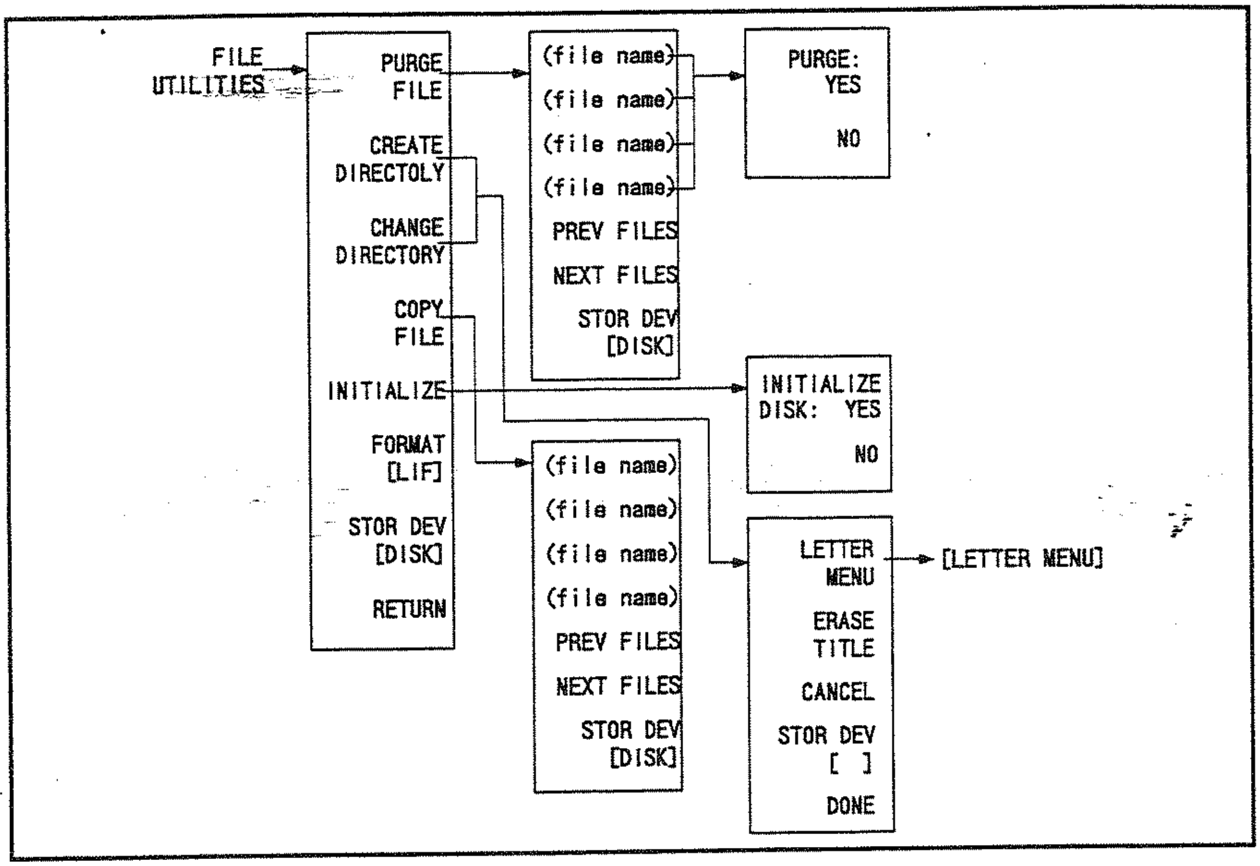


Figure B-18. Softkey Menus Accessed from the (Save/Recall) Key (2/2)

Input Range and Default Setting

When the (Preset) key is pressed or the analyzer is turned ON, the LCR meter is set to a known state. There are subtle differences between the preset state and the power-up state.

Some power-up states are recalled from non-volatile memory (battery backup memory). If power to the non-volatile memory is lost, the LCR meter will have certain parameters set to factory settings. Factory Setting lists the factory settings. The operating time of the battery backup memory is approximately 72 hours. The battery is automatically recharged while the instrument is ON. The recharge time (time required to fully recharge the battery) is approximately 10 minutes.

When line power is cycled the analyzer performs a self-test routine. Upon successful completion of the self-test routine, the instrument state is set to the following preset conditions. The same conditions are true following a "PRES" or "*RST" command via HP-IB.

(Meas)

Function	Range	Preset Value	Power ON default	Factory Setting
Measurement Mode	Active channel, Dual channel	Active channel	Active channel	
Measurement Parameter				
Impedance meas.	L_p-D, L_p-Q, L_p-G, L_p-R_p, L_s-D, L_s-Q, L_s-R_s, C_p-D, C_p-Q, C_p-G, C_p-R_p, C_s-D, C_s-Q, C_s-R_s, R-X, $\|Z\|$ - θ rad, $\|Z\|$ - θ deg, G-B, $\|Y\|$ - θ rad, $\|Y\|$ - θ deg	L_s-Q	L_s-Q	
Test Fixture	HP 16191A, HP 16192A, HP 16193A, User, None, HP 16193A, HP 16194A	None or No effect(when either the HP 16193A or HP 16194A is selected	None	
User Fixture Definition				
Label		No effect	No effect	(empty)
Extension	−10 meter to 10 meter	No effect	No effect	0
Thickness	0 to 3 mm	No effect	0	
Outer diameter		No effect	0	
Inner diameter		No effect	0	

Display

Function	Range	Preset Value	Power ON default	Factory Setting
Title		null string	null string	
Frequency Blank	ON	OFF	OFF	
Display Allocation	All instrument, Half/Half, All BASIC, BASIC status	No effect	All Instrument	
Meas Update	ON/OFF	ON	ON	

Delay Time

Function	Range	Preset Value	Power ON default	Factory Setting
Sweep Delay time	0 to 3600 s	0 ms	0 ms	
Point delay time	0 to 3600 s	0 ms	0 ms	

Sweep Setup

Function	Range	Preset Value	Power ON default	Factory Setting
Default List Table		(empty)	(empty)	
List Segment	0 to 10	1	1	
Segment Frequency	1MHz to 1GHz	1MHz	1MHz	
Average On Point	1 to 999	1	1	

Source

Function	Range	Preset Value	Power ON default	Factory Setting
Osc Level	200 μV to 1.0 V	0.5 V	0.5 V	
Osc Unit	Voltage/Ampere/dBm	Volt	Volt	

(Cal)

Function	Range	Preset Value	Power ON default	Factory Setting
Fixture Compen - OPEN	ON/OFF	OFF	OFF	
Fixture Compen - SHORT	ON/OFF	OFF	OFF	
Fixture Compen - LOAD	ON/OFF	OFF	OFF	
Cal Kit	7 mm, User kit	7 mm	7 mm	
Standard Value - OPEN G	-1×10^{6} to 1×10^{6}	0	0	
Standard Value - OPEN C	-1×10^{-9} to 1×10^{-9}	82 fF	82 fF	
Standard Value - SHORT R	-1×10^{6} to 1×10^{6}	0	0	
Standard Value - SHORT L	-1×10^{6} to 1×10^{6}	0	0	
Standard Value - LOAD R	-1×10^{6} to 1×10^{6}	50 Ω	50 Ω	
Standard Value - LOAD L	-1×10^{6} to 1×10^{6}	0	0	
Compen Kit				
Compen Std. Value - OPEN G	-1×10^{6} to 1×10^{6}	No effect[1]	No effect[1]	0
Compen Std Value - OPEN C	-1×10^{-9} to 1×10^{-9}	No effect[1]	No effect[1]	0
Compen Std. Value - SHORT R	-1×10^{6} to 1×10^{6}	No effect[1]	No effect[1]	0
Compen Std. Value - SHORT L	-1×10^{6} to 1×10^{6}	No effect[1]	No effect[1]	0
Compen Std. Value - LOAD R	-1×10^{6} to 1×10^{6}	No effect[1]	No effect[1]	50 Ω
Compen Std Value - LOAD L	-1×10^{6} to 1×10^{6}	No effect[1]	No effect[1]	0
Compen standard Label		No effect[1]	No effect[1]	user
Port extension	ON/OFF	OFF	OFF	
Port Extension value	−10 to 10	0 s	0 s	

1 When SAVE COMPEN KIT is executed.

(Trigger Mode)

Function	Range	Preset Value	Power ON default	Factory Setting
Sweep	Hold, Single, Continuous	Continuous	Continuous	
Trigger	Free run, External, HP-IB, Manual	Internal	Internal	
Trigger event	ON SWEEP/ON POINT	On Sweep	On Sweep	
Trigger polarity	Positive, Negative	Positive	Positive	

(System)

Function	Range	Preset Value	Power ON default	Factory Setting
Logging	ON/OFF	No effect	No effect	
Clock time	0:00:00 to 23:59:59	No effect	No effect	0:00:00
Clock date	3/1/1990 to 12/31/2099	No effect	No effect	12/6/1982
Date mode	MonDayYear/DayMonYear	MonDayYear	MonDayYear	
Beep done	ON/OFF	ON	ON	
Beep warning	ON/OFF	OFF	OFF	

(Test Setup)

Function	Range	Preset Value	Power ON default	Factory Setting
Limit Test		(empty)	(empty)	
Pri Limit	ON/OFF	OFF	OFF	
Sec Limit	ON/OFF	OFF	OFF	
Limit Segment	0 to 10	No effect	0	
Upper Limit	-1×10^9 to 1×10^9	No effect	0	
Lower Limit	-1×10^9 to 1×10^9	No effect	0	
BIN Sort	(empty)	(empty)	(empty)	
BIN Sort	ON/OFF	OFF	OFF	
Test Seg	1 to 10	1	1	
BIN No	0 to 9	No effect	0	
Upper Limit	-1×10^9 to 1×10^9	No effect	0	
Lower Limit	-1×10^9 to 1×10^9	No effect	0	
Sec Reject	ON/OFF	OFF	OFF	
Upper limit	-1×10^9 to 1×10^9	No effect	0	
Lower limit	-1×10^9 to 1×10^9	No effect	0	
Beep	OFF/Path/Fail	OFF	OFF	
Handler Interface				
Handler Interface	OFF/Mode1/Mode2	No effect	OFF	

Local

Function	Range	Preset Value	Power ON default	Factory Setting
HP-IB controller mode	System controller/addressable	No effect	No effect	addressable
Address: 4286A	0 to 30	No effect	No effect	17
Address: plotter	0 to 30	No effect	No effect	5
Address: printer	0 to 30	No effect	No effect	1
Address: controller	0 to 30	No effect	No effect	21

Copy

Function	Range	Preset Value	Power ON default	Factory Setting
Copy time	ON/OFF	OFF	OFF	
Select Quadrant	Full page, Left upper, Left lower, Right upper, Right lower	Full page	Full page	
Plot definition	All, Data&Graticule, Data only	All	All	
Plot speed	Fast/Slow	Fast	Fast	

Save/Recall

Function	Range	Preset Value	Power ON default	Factory Setting
Save data definition	Raw, Cal, Data, Data trace	ALL OFF	ALL OFF	
HP-GL Graphic file extension	(3 characters)	No effect	No effect	.HPG
ASCII data file extension	(3 characters)	No effect	No effect	.TXT
Store device	Disk/Memory	No effect	No effect	Disk
Initialize disk format	LIF/DOS	No effect	No effect	LIF

Monitor

Function	Range	Preset Value	Power ON default	Factory Setting
Monitor	OFF/AC-V/AC-I	OFF	OFF	

Contact Check

Function	Range	Preset Value	Power ON default	Factory Setting
Contact Check				
Rdc Meas	ON/OFF	OFF	OFF	
Rdc Limit	ON/OFF	OFF	OFF	
Rdc Upper Limit	−100 to 10 K	0.0	0.0	
Rdc Lower Limit	−100 to 10 K	0.0	0.0	

Service Key Menus

INTRODUCTION

The service key menus are used to test, verify, adjust, and troubleshoot the meter. They are also used to install and update the firmware in the meter. The service key menus allow you to perform the following functions:

- Select and execute a built-in diagnostic test. The meter has 37 built-in diagnostic tests. For detailed information, see the *Tests Menu* in this chapter.
- Display the test head is connected or not.
- Display the firmware revision. See the *Service Menu* in this chapter.
- Install and update the firmware in the meter.

When applicable, the HP-IB mnemonic is written in parentheses following the softkey using the following symbol conventions:

{ }	A necessary appendage
<*numeric*>	A necessary numerical appendage
|	A delimiter for applicable appendages. For example, {OFF|ON|0,1|} means OFF, ON, 0, or 1.

For more about the HP-IB commands general information, see the *HP 4286A Programming Manual*.

SERVICE MENU

To display the service menu, press (System), SERVICE MENU. This menu is used to display the tests menu, the service modes menu, and the firmware revision information. Each softkey in the service menu is described below.

TESTS

Displays the tests menu. For more information about the tests menu, see the *Tests Menu* later in this chapter.

SERVICE MODES (:DIAG:SERV:MODE {ON|1})

Activates the service modes and displays the service modes menu. For more information about the service modes menu, see the *Service Manual* .

READ ID

Displays the test head is connected or not.

FIRMWARE REVISION (:DIAG:FREV?)

Displays the current firmware revision information. The number and implementation date appear in the active entry area of the display as shown below. Another way to display the firmware information is to cycle the meter power (off then on).

```
HP 4286A REVN.NN MON DD YEAR HH:MM:SS
```

where	N.NN:	Revision Number
	MON DD YEAR	Implementation Date (Month Day Year)
	HH:MM:SS	Implementation Time (Hour:Minute:Second)

TESTS MENU

To display the tests menu, press (System), SERVICE MENU, and TESTS. The tests menu is used to select and execute one of the 55 built-in diagnostic tests. More information about the diagnostic tests is provided in the *Diagnostic Tests* later in this section.

When entering the tests menu, internal test 0: ALL INT is selected as the default test. The test number, name, and status abbreviation is displayed in the active entry area of the display.

The diagnostic tests are numbered from 0 to 36. To select a test, enter the desired test number using the numeric keypad, (⇑), (⇓) or HP-IB command (:DIAG:TEST <*numeric*>).

Each softkey in the tests menu is described below.

EXECUTE TEST (:DIAG:TEST:EXET)

Runs the selected test. When the executed test requires user interaction, CONT (:DIAG:TEST:CONT) and the instruction appear on the display. Follow the displayed instruction and press CONT to continue the test.

INTERNAL TESTS (:DIAG:TEST 0)

Selects the first internal test `0: ALL INT`.

EXTERNAL TESTS (:DIAG:TEST 16)

Selects the first external test `16: FRONT PANEL DIAG`.

ADJUSTMENT TESTS (:DIAG:TEST 26)

Selects the first adjustment test `26: HOLD STEP ADJ`.

DISPLAY TESTS (:DIAG:TEST 32)

Selects the first display test `32: TEST PATTERN 1`.

Note

After executing a test by pressing **EXECUTE TEST**, an annotation (`Svc`) is displayed to indicate any tests executed and the meter settings changed to the test settings. To return the meter to normal operation, cycle the meter power (off then on), or press (PRESET).

Note

While any test is being executed, do not change the meter setting using the front-panel keys, the HP-IB, or the I-BASIC program (Option 1C2 only). If the setting is changed during test execution, the test result and the meter operation are undefined.

Test Status

When selecting a test, the test status abbreviation is displayed on the screen.

To see the test status of the desired test, enter the desired test number using the numeric keypad, (⇧), (⇩). Also, the three HP-IB commands listed below are available to get the test status using HP-IB.

`:DIAG:TEST:RES?` *<numeric>* — returns the test status. The *<numeric>* specifies the test number and is an integer from 0 to 36.

`*TST?` — executes internal test 0: ALL INT and returns the test result.

`:DIAG:INIT:RES?` — returns the power on self-test result.

A sample program using the command `:DIAG:TEST:RES?` is as shown below. This program displays the test status of internal test 1.

```
10   !
20   ASSIGN @Hp4286 TO 717 ! When IBASIC is used, replace "717" to "800."
30   !
40   OUTPUT @Hp4286;"DIAG:TEST:RES? 1"
50   ENTER @Hp4286;Test_status$
60   PRINT Test_status$
70   !
```

Sample Program Using `:DIAG:TEST:RES?`

Table D-1 shows the test status abbreviation, its definition, and the HP-IB test status code.

Table D-1. Test Status Terms

Status Abbreviation	Definition	HP-IB Code
PASS	Pass	"PASS"
FAIL	Fail	"FAIL"
-IP-	In progress	"BUSY"
-ND-	Not done	"NDON"
DONE	Done	"DONE"

The test status is stored in nonvolatile memory (battery backup memory). If the power to the nonvolatile memory is lost, the meter will set all test status abbreviations to "-ND-" (not done). If a test is aborted by pressing any key during its execution, the test status is undefined.

Diagnostic Tests

The meter has 37 built-in diagnostic tests. The meter performs the power on self-test every time the power on sequence occurs (when the meter is turned on). These tests are used to test, verify, adjust, and troubleshoot the meter.

The 37 built-in diagnostic tests are divided by function into three categories: internal tests, external tests, and adjustment tests. Each group is described below. Descriptions of the tests in each category are given in the *Test Descriptions* section. To access the first test in each category, the category softkey is available in the tests menu.

The power on self-test consists of internal tests 1 and 4 through 14. They are executed in the listed order. If any of the tests fail, that test displays a "POWER ON TEST FAILED" message at the end of the power on sequence. The first failed test indicates the most probable faulty assembly.

Internal Test — These tests are completely internal and self-evaluating. They do not require external connections or user interaction. The meter has 16 internal tests.

External Tests — These are additional self-evaluating tests. However, these tests require some user interaction (such as key entries). The meter has 10 external tests.

Adjustment Tests — These tests are used to adjust the meter. The meter has 6 adjustment tests.

Display Tests — These tests are used to adjust and check for proper operation of the display circuits. The meter has 5 display tests.

Test Descriptions

This section describes all 55 diagnostic tests.

INTERNAL TESTS

This group of tests run without external connections or operator interaction. All return a "PASS" or "FAIL" indication on the display. Except as noted, all are run during the power on self-test and when (Preset) is pressed.

0: ALL INT

Runs only when selected. It consists of internal tests 1 and 4 through 14. If any of these tests fail, this test displays the "FAIL" status indication. Use ⇧ and ⇩ to scroll through the tests to see which test failed. If all pass, the test displays the "PASS" status indication. Each test in the subset retains its own test status.

1: A1 CPU

Verifies the following circuit blocks on the A1 CPU:

- Digital Signal Processor (DSP)
- System Timer
- Real Time Clock
- Front Key Controller
- Flexible Disk Drive Controller
- HP-IB Controller
- EEPROM

2: A1 VOLATILE MEMORY

Runs only when selected. It verifies the A1 volatile memories:

CPU internal SRAM
DSP SRAM
Dual Port SRAM
Backup SRAM

At the end of the test, the meter is set to the power-on default state because the data in the tested memories is destroyed. During this test, a test pattern is written into the memories and then the pattern is read back and checked.

If the test fails, the test displays an error message for a few seconds and then sets the meter to the default state. The error message indicates the faulty memory.

3: A51 GSP

Runs only when selected. It verifies the following circuit blocks on the A51 GSP:

GSP Chip
DRAM
VRAM

4: A2 POST REGULATOR

Verifies all A2 post regulator output voltages:

+5 V(AUX), +15 V(AUX)
−15 V, −12.6 V, −5 V, +5 V, +5.3 V, +8.5 V, +15 V,
+22 V, +65 V, FAN POWER, GND

This test measures the A2 output voltages at DC bus nodes 1 through 12, and 26. It checks that each measured value is within limits.

5: A6 A/D CONVERTER

Verifies the following circuit blocks on the A6 Receiver IF:

A/D Converter
Gain Y
Gain Z
Range R

This test measures the A/D converter's reference voltage (VREF) at DC bus node 25 through the gain Y, the gain Z, and the range R. These circuits are set to several settings in the test. For each setting, this test checks that the measured value is within limits.

6: A5 REFERENCE OSC

Verifies the reference oscillator in the A5 synthesizer. This test measures the VCO tuning voltage at DC bus node 22 and the frequency (2.5 MHz) at frequency bus node 6. It then checks that each measured value is within limits.

7: A5 FRACTIONAL N OSC

Verifies the fractional N oscillator in the A5 synthesizer. This sets the oscillator frequency to several frequencies over the entire range. For each setting, this test measures the VCO tuning voltage at DC bus node 20 and the frequency at frequency bus node 4. It then checks that each measured value is within limits.

8: A4A1 1ST LO OSC

Verifies the 1st LO oscillator in the A4A1 1st LO. This test sets the oscillator frequency to several frequencies over the entire range. For each frequency, the test measures the VCO tuning voltage at DC bus node 18 and checks that each measured value is within limits.

9: A3A2 2ND LO OSC

Verifies the 2nd LO oscillator in the A3A2 2nd LO. This test measures the VCO tuning voltage at DC bus node 14 and checks that the measured value is within limits.

10: A3A1 DIVIDER

Verifies the divider circuit in the A3A1 Source Vernier. This test measures the frequency (40 kHz) at frequency bus node 2 and checks that the measured value is within limits.

11: A6 3RD LO OSC

Verifies the 3rd LO oscillator on the A6 receiver IF. This test measures the VCXO tuning voltage at DC bus node 23 and the frequency (40 kHz) at frequency bus node 6. It then checks that each measured value is within limits.

12: A3A1 SOURCE OSC

Verifies the source oscillator in the A3A1 Source Vernier. This test measures the VCXO tuning voltage at DC bus node 13 and the frequency (40 kHz) at frequency bus node 1. It then checks that each measured value is within limits.

13: A6 SEQUENCER

Verifies the A/D sequencer circuit in the A6 receiver IF. This test measures the frequency (80 kHz) of the A/D sequence output at frequency bus node 7 and checks that the measured value is within limits.

14: SOURCE LEVEL

Verifies the source circuit. This test measures the A3A3 output at DC bus node 15 in A3A1. It then checks that each measured value is within limits.

15: MEMORY DISK

Verifies A33 Backup SRAM circuit.

Note After this test is performed, the data stored on RAM disk memory is lost.

EXTERNAL TESTS

This group of tests require either external equipment and connections or operator interaction to run.

16: FRONT PANEL DIAG.

Checks all front-panel keys on the A30 keyboard. The abbreviated name is displayed when pressing one of the keys.

17: DSK DR FAULT ISOL'N

Checks the FDD (Flexible Disk Drive). When this test is started, a bit pattern is written to the flexible disk. Then the pattern is read back and checked. This write pattern check is repeated from the low to high addresses.

Note After this test is performed, the data stored on the floppy disk is lost.

18: SOURCE FLATNESS

Checks that the source flatness is within limits. As a result, A3A1, A3A2 and A3A3 are verified.

The meter mainframe "S" and "R" connectors are connected, and the "S" output level is measured at the "R" input.

19: OUTPUT ATTENUATOR

Checks that the A7 attenuation accuracy is within limits. As a result, A7 is verified.

The meter mainframe "S" and "R" connectors are connected, and the "S" output level is measured at the "R" input.

20: RECEIVER GAIN

Checks that the receiver circuit gain is within limits. As a result, A4A2 and A6 are verified.

The meter mainframe "S" and "R" connectors are connected, and the "R" input gain is tested using the "S" output.

21: A6 GAIN

Checks that the A6 gain is within limits. As are result, A6 is verified.

The A3A1 21.42 MHz output is directly applied to the A6 input.

22: A6 V/I NORMALIZER

Checks that the A6 V/I normalizer (GAIN X, Y, and Z) gain change is within limits. As a result, A6 is verified.

The meter mainframe "S" and "R" connectors are connected, and the "R" input gain change is tested using the "S" output.

23: FRONT ISOL'N

Checks that the meter mainframe front isolation is sufficient.

The meter mainframe "S" and "R" connectors are connected, and the "S" output level is measured at the "R" input. Then the "S" and "R" connectors are disconnected, and the "R" measurement result is compared with the previous measurement result.

24: TEST HEAD

Checks that the meter test head characteristics are correct. As a result the test head is verified.

25: A33 HANDLER IF

Checks that the A33 Handler Interface circuit is correct. As a result is verified.

ADJUSTMENT TESTS

This group of tests is used when adjusting the meter. These tests make the adjustment procedure easier.

26: HOLD STEP ADJ

Used when the *Hold Step Adjustment* on the A6 receiver IF is performed.

27: BPF ADJ

Used when the *Band Pass Filter Adjustment* on the A6 receiver IF is performed.

28: 3RD VCXO LEVEL ADJ

Used when the *Third Local VCXO Adjustment* on the A6 receiver IF is performed.

29: 2ND LO PLL LOCK ADJ

Used when the *Second Local PLL Lock Adjustment* on the A3A2 2nd LO is performed.

30: SOURCE VCXO LEVEL ADJ

Used when the *Source VCXO Adjustment* on the A3A1 level vernier is performed.

31: SOURCE MIXER LEAK ADJ

Used when the *Source Mixer Local Leakage Adjustment* on the A3A2 2nd LO is performed.

DISPLAY TESTS

These tests are test patterns that are used in the factory for display adjustments, diagnostics, and troubleshooting. They are not used for field service. Test patterns are executed by entering the test number (40 through 54), then pressing EXECUTE TEST, CONTINUE. The test pattern is displayed and the softkey labels are blanked. To exit the test pattern and return to the softkey labels, press softkey 8 (on the bottom). The following is a description of the test patterns.

Note Do NOT press any keys except softkey 8 (on the bottom) while the test pattern is being executed. If you do, you CANNOT quit the test pattern (that is, you can quit the test pattern only when the meter is turned OFF).

32: TEST PATTERN 1

All White. This pattern is used to verify the light output of the CRT display and to check for color purity. In this test, and other solid test patterns, an extremely thin full-screen horizontal line will be seen at about 1/4 screen height from the bottom. This condition is characteristic of the CRT and does not indicate any problem.

33: TEST PATTERN 2

Crosshatch. This pattern is used at the factory to test color convergence, linearity, alignment, and high voltage regulation. No field adjustments are possible.

34: TEST PATTERN 3

H Pattern. This pattern is used to check the focus of the CRT. Under normal conditions, this should never need to be adjusted. However, it is possible to adjust it by accessing the focus control adjustment at the left rear of the display.

35: TEST PATTERN 4

Character Set. The character set is provided to conveniently show the user all the different types and sizes of characters available. Three sets of characters are drawn in each of the three character sizes. 125 characters of each size are displayed. Characters 0 and 3 cannot be drawn and several others are really control characters (such as carriage return and line feed).

36: TEST PATTERN 5

Bandwidth Pattern. This pattern provides a quick visual verification of the display bandwidth. It consists of multiple alternating white and black vertical stripes. Each stripe should be clearly visible. A limited bandwidth would smear these lines together. No field adjustment is possible.

Error Messages

This section lists the error messages that are displayed on the meter display or transmitted by the instrument over HP-IB. Each error message is accompanied by an explanation, and suggestions are provided to help in solving the problem. Where applicable, references are provided to the related chapter of the appropriate manual. The messages are listed in alphabetical order.

In the explanation of many error commands, section numbers of the IEEE standard 488.2 are included. Refer to them for further information about an error with these IEEE section numbers.

222 **1st LO OSC TEST FAILED**

An "internal test 9: A4A1 1ST LO OSC" fails. The 1st LO OSC (first local oscillator) on the A4A1 1st LO does not work properly. See the *Service Manual* for troubleshooting.

223 **2nd LO OSC TEST FAILED**

An "internal test 10: A3A2 2ND LO" fails. The 2nd LO OSC (second local oscillator) on the A3A2 2nd LO does not work properly. See the *Service Manual* for troubleshooting.

225 **3rd LO OSC TEST FAILED**

An "internal test 12: A6 3RD LO OSC" fails. The 3rd LO OSC (third local oscillator) on the A6 receiver IF does not work properly. See the *Service Manual* for troubleshooting.

224 **A3 DIVIDER OUTPUT FREQUENCY OUT OF SPEC**

An "internal test 11: A3A1 DIVIDER" fails. The output frequency of the divider circuit on the A3A1 ALC is out of its limits. See the *Service Manual* for troubleshooting.

243 **A6 GAIN TEST FAILED**

An "external test 23: A6 GAIN" fails. See the *Service Manual* for troubleshooting.

244 **A6 VI NORMALIZER TEST FAILED**

An "external test 24: A6 VI NORMALIZER" fails. See the *Service Manual* for troubleshooting.

6 **ADDITIONAL STANDARDS NEEDED**

Error-correction coefficients cannot be computed until all the necessary standards have been measured. Execute all `OPEN`, `SHORT`, `LOAD` calibration (`SENSe:CORRection1:COLLect[:ACQuire] {STAN1|STAN2|STAN3}`) before press `DONE: CAL` (`SENSe:CORRection1:COLLect:SAVE`).

Error Messages

132 **BACKUP DATA LOST**

Data checksum error on the battery backup memory has occurred. The battery is recharged for approximately 10 minutes after power was turned ON.

-160 **Block data error**

This error, as well as errors −161 and −168, are generated when analyzing the syntax of a block data element. This particular error message is used if the meter cannot detect a more specific error.

-168 **Block data not allowed**

A legal block data element was encountered but was not allowed by the meter at this point in parsing.

240 **CABLE ISOL'N TEST FAILED**

An "external test 27: " fails. See the *Service Manual* for troubleshooting.

10 **CALIBRATION ABORTED**

The calibration in progress was terminated due to a change of the stimulus parameter or calibration measurement points. For example,

- Changing `CAL POINT [FIXED]` between `CAL POINT [USER]` (`SENSe:CORRection1:COLLect:FPOints {FIXed|USER}`).

8 **CALIBRATION ON FIXED POINTS REQUIRED**

`COMP POINT [FIXED]` (`SENSe:CORRection1:COLLect:FPOints FIXed`—the fixture compensation on fixed points) cannot be selected when the calibration has been performed `CAL POINTS [USER]` (`SENSe:CORRection1:COLLect:FPOints USER`—the fixture compensation on user-defined points). If you need to set `COMP POINT [FIXED]`, perform calibration again with `CAL POINTS [FIXED]` setting.

7 **CALIBRATION REQUIRED**

No valid calibration coefficients were found when you attempted to perform fixture compensation. See *Users Guide* for information on how to perform calibration.

74 **CAN'T CHANGE- ANOTHER CONTROLLER ON BUS**

The meter cannot assume the mode of system controller until the system controller is removed from the bus or relinquishes the bus.

108 **CAN'T SAVE GRAPHICS WHEN COPY IN PROGRESS**

If you attempt to save graphics when a print or plot is in progress, this error message is displayed. Wait until print or plot is complete, then save graphics again.

-281 **Cannot create program**

An attempt to create a program was unsuccessful. A reason for the failure might include not enough memory.

-140 **Character data error**

This error, as well as errors −141 through −148, are generated when analyzing the syntax of a character data element. This particular error message is used if the meter cannot detect a more specific error.

-148 **Character data not allowed**

A legal character data element was encountered where prohibited by the meter.

-144 **Character data too long**

The character data element contains more than twelve characters (see IEEE 488.2, 7.7.1.4).

-100 **Command error**

This is a generic syntax error that the meter cannot detect more specific errors. This code indicates only that a command error, as defined in IEEE 488.2, 11.5.1.1.4, has occurred.

-110 **Command header error**

An error was detected in the header. This error message is used when the meter cannot detect the more specific errors described for errors −111 through −119.

67 **COMMAND IGNORED - SEGMENT NOT DONE YET**

(*HP-IB only*) The HP-IB command the meter received is ignored, because the segment is editing . Send `CALCulate:LIMit:SEGMemt:SAVE` (limit segment done) or `SENSe:LIST:SEGMent:SAVE` (segment done) to terminate editing segment.

13 **COMPENSATION ABORTED**

The compensation in progress was terminated due to a change of the stimulus parameter or calibration measurement points. For example,

- Changing `COMP POINT [FIXED]` between `COMP POINT [USER]` (`SENSe:CORRection2:COLLect:FPOints {FIXed|USER}`) before pressing `DONE: COMPEN` (`SENSe:CORRection2:COLLect:SAVE`).

11 **COMPENSATION REQUIRED**

No valid fixture compensation coefficients were found when you attempted to turn fixture compensation ON (`OPEN ON off`—`SENSe:CORRection2:OPEN ON`, `SHORT ON off`—`SENSe:CORRection2:SHORt ON`, `LOAD ON off`—`SENSe:CORRection2:LOAD ON`). See *Users Guide* for information on how to perform compensation.

15 **COMPENSATION STD LIST UNDEFINED**

(*HP-IB only*) You cannot execute `SENSe:CORRection2:CKIT[1]:STANdard{1-3}[:SELect] LIST` when the fixture compensation standard array is not defined.

190 **CORR. CONST. DATA LOST; DEFAULT DATA IS USED**

This message is displayed when the correction constants EEPROM data is lost and turned on in the service mode. See the *Service Manual* for troubleshooting.

190 **CORR. CONST. DATA LOST; DEFAULT DATA IS USED**

This message is displayed when the correction constants EEPROM data is lost and turned on in the service mode. See the *Service Manual* for troubleshooting.

212 **CPU BACKUP SRAM R/W ERROR**

An "internal test 2: A1 VOLATILE MEMORY" fails. The A1 CPU's BACKUP SRAM does not work properly. Replace the A1 CPU with a new one. See the *Service Manual* for troubleshooting.

211 **CPU INTERNAL SRAM R/W ERROR**

An "internal test 2: A1 VOLATILE MEMORY" fails. The A1 CPU's internal SRAM does not work properly. Replace the A1 CPU with a new one. See the *Service Manual* for troubleshooting.

66 **CURRENT EDITING SEGMENT SCRATCHED**

The current editing the table of list sweep or the limit line is scratched. It is occur when the operation other than editing the table is executed before terminate editing the table (`SENSe:LIST:SAVE`, or `CALCulate:LIMit:SAVE`)

-230 **Data corrupt or stale**

Possibly invalid data. New reading started but not completed since last access.

-225 **Data out of memory**

The meter has insufficient memory to perform the requested operation.

-222 **Data out of range**

A legal program data element was parsed but could not be executed because the interpreted value was outside the legal range as defined by the meter (see IEEE 488.2, 11.5.1.1.5).

-231 **Data questionable**

Measurement accuracy is suspect.

-104 **Data type error**

The parser recognized an unallowed data element. For example, numeric or string data was expected but block data was encountered.

127 **DC BIAS OVERLOAD**

Hardware failure. Do not input external DC BIAS. If this message keeps on being displayed, contact your nearest HP service office.

204 **DSP CHIP TEST FAILED**

An "internal test 1: A1 CPU" fails. The A1 CPU's DSP (Digital Signal Processor) does not work properly. Replace the A1 CPU with a new one. See the *Service Manual* for troubleshooting.

213 **DSP SRAM R/W ERROR**

An "internal test 2: A1 VOLATILE MEMORY" fails. The DSP's SRAM on the A1 CPU does not work properly. Replace the A1 CPU with a new one. See the *Service Manual* for troubleshooting.

214 **DUAL PORT SRAM R/W ERROR**

An "internal test 2: A1 VOLATILE MEMORY" fails. The DSP's dual port SRAM on the A1 CPU does not work properly. Replace the A1 CPU with a new one. See the *Service Manual* for troubleshooting.

111 **DUPLICATE FILE EXTENSION**

The extension name (`GRAPHICs [ ]` or `ASCII DATA [ ]` — `MMEMory:FNAMe:EXTension{1|2}`) is already used for other file types. Use other extension name.

203 **EEPROM CHECK SUM ERROR**

An "internal test 1: A1 CPU" fails. The data (Correction Constants and so on) stored in the A1 CPU's EEPROM are invalid. See the *Service Manual* for troubleshooting.

199 **EEPROM WRITE ERROR**

Data cannot be stored properly into the EEPROM on the A1 CPU, when performing the display background adjustment or updating correction constants in the EEPROM using the adjustment program. See the *Service Manual* for troubleshooting.

-200 **Execution error**

This is the generic syntax error that the meter cannot detect more specific errors. This code indicates only that an execution error as defined in IEEE 488.2, 11.5.1.1.5 has occurred.

-123 **Exponent too large**

The magnitude of the exponent was larger than 32000 (see IEEE 488.2, 7.7.2.4.1).

205 **F-BUS TIMER CHIP TEST FAILED**

An "internal test 1: A1 CPU" fails. The A1 CPU's F-BUS (Frequency Bus) timer does not work properly. Replace the A1 CPU with a new one. See the *Service Manual* for troubleshooting.

218 **FAILURE FOUND FROM A/D MUX TO A/D CONVERTER**

An "internal test 5: A6 A/D CONVERTER" fails. A trouble is found on the signal path from the A/D multiplexer to A/D converter on the A6 receiver IF. See the *Service Manual* for troubleshooting.

217 **FAN POWER OUT OF SPEC**

An "internal test 4: A2 POST REGULATOR" fails. The voltage of the fan power supply at the DC bus node 11 is out of its limits. See the *Service Manual* for troubleshooting.

208 **FDC CHIP TEST FAILED**

An "internal test 1: A1 CPU" fails. The A1 CPU's FDC (Flexible Disk drive control) ship does not work properly. Replace the A1 CPU with a new one. See the *Service Manual* for troubleshooting.

-257 **File name error**

A legal program command or query could not be executed because the file name on the device media was in error. For example, an attempt was made to copy to a duplicate file name. The definition of what constitutes a file name error is device-specific.

-256 **File name not found**

A legal program command could not be executed because the file name on the device media was not found: for example, an attempt was made to read or copy a nonexistent file.

230 **FLOPPY DISK DRIVE FAILURE FOUND**

An "external test 18: DSK DR FAULT ISOL'N" fails. The A53 built-in FDD (flexible disk drive) does not work properly. Replace the A53 FDD with a new one. See the *Service Manual* for troubleshooting.

220 **FRACTIONAL N OSC TEST FAILED**

An "internal test 7: A5 FRACTIONAL N OSC" fails. The fractional N oscillator on the A5 synthesizer does not work properly. See the *Service Manual* for troubleshooting.

119 **FREQUENCY SWEEP ONLY**

Equivalent circuit function is executed in OSC level sweep, DC-I sweep, DC-V sweep. The equivalent circuit function is available in frequency sweep only.

239 **FRONT ISOL'N TEST FAILED**

An "external test 25: FRONT ISOL'N" fails. See the *Service Manual* for troubleshooting.

-105 **GET not allowed**

A Group Execute Trigger (GET) was received within a program message (see IEEE 488.2, 7.7).

216 **GND LEVEL OUT OF SPEC**

An "internal test 4: A2 POST REGULATOR" fails. The voltage of the GND (Ground) at the DC bus node 26 is out of its limits. See the *Service Manual* for troubleshooting.

-240 **Hardware error**

A legal program command or query could not be executed because of a hardware problem in the meter. Definition of what constitutes a hard ware problem is completely device-specific. This error message is used when the meter cannot detect the more specific errors described for errors −241 through −249.

-241 **Hardware missing**

A legal program command or query could not be executed because of missing meter hardware. For example, an option was not installed.

-111 **Header separator error**

A character that is not a legal header separator was encountered while parsing the header. For example, no white space followed the header, thus *SRE4 is an error.

-114 **Header Suffix out of range**

The value of a numeric suffix attached to a program mnemonic makes the header invalid.

210 **HP-HIL CHIP TEST FAILED**

An "internal test 1: A1 CPU" fails. The A1 CPU's HP-HIL control chip does not work properly. Replace the A1 CPU with a new one. See the *Service Manual* for troubleshooting.

209 **HP-IB CHIP TEST FAILED**

An "internal test 1: A1 CPU" fails. The A1 CPU's HP-IB chip does not work properly. Replace the A1 CPU with a new one. See the *Service Manual* for troubleshooting.

-224 **Illegal parameter value**

Used where exact value, from a list of possibilities, was expected.

-282 **Illegal program name**

The name used to reference a program was invalid. For example, redefining an existing program, deleting a nonexistent program, or in general, referencing a nonexistent program.

-283 **Illegal variable name**

An attempt was made to reference a nonexistent variable in a program.

-213 **Init ignored**

A request for a measurement initiation was ignored as another measurement was already in progress.

133 **INSUFFICIENT MEMORY**

If a lot of tasks is executed at same time, memory might be insufficient for a while. (For example, running HP Instrument BASIC program, printing a screen, and sending or receiving data array by HP-IB are required at same time.) Please wait until finishing some tasks then execute the next task.

-161 **Invalid block data**

A block data element was expected, but was invalid for some reason (see IEEE 488.2, 7.7.6.2). For example, an END message was received before the length was satisfied.

-101 **Invalid character**

A syntax element contains a character that is invalid for that type. For example, a header containing an ampersand (SENS&).

-141 **Invalid character data**

Either the character data element contains an invalid character or the particular element received is not valid for the header.

-121 **Invalid character in number**

An invalid character for the data type being parsed was encountered. For example, an alpha character in a decimal numeric or a "9" in octal data.

148 **INVALID DATE**

The date entered to set the real time clock is invalid. Reenter correct date.

106 **INVALID FILE NAME**

(*HP-IB only*) The parameter *<file_name>* for `MMEMory:DELete` command must have a "_D" or "_S" extension for LIF format, or "STA" or ".DTA" for DOS format.

-103 **Invalid separator**

The parser was expecting a separator and encountered an illegal character. For example, the semicolon was omitted after a program message unit, *RST:INIT.

-151 **Invalid string data**

A string data element was expected, but was invalid for some reason (see IEEE 488.2, 7.7.5.2). For example, an END message was received before the terminal quote character.

-131 **Invalid suffix**

The suffix does not follow the syntax described in IEEE 488.2, 7.7.3.2, or the suffix is inappropriate for the meter.

207 **KEY CHIP TEST FAILED**

An "internal test 1: A1 CPU" fails. The A1 CPU's front keyboard control chip does not work properly. Replace the A1 CPU with a new one. See the *Service Manual* for troubleshooting.

109 **LIF-DOS COPY NOT ALLOWED**

If you try to copy a file between the RAM disk and the flexible disk when the format of the RAM disk is different from the format of the flexible disk, this message is displayed.

-250 **Mass storage error**

A mass storage error occurred. This error message is used when the meter cannot detect the more specific errors described for errors −251 through −259.

245 **MAX VCXO LEVEL OUT OF SPEC**

Maximum VCXO level is incorrect, in performing an "adjustment test 36: 3RD VCXO LEVEL ADJ" or an "adjustment test 39: SOURCE VCXO LEVEL ADJ". See the *Service Manual* for troubleshooting.

-311 **Memory error**

An error was detected in the meter's memory.

-109 **Missing parameter**

Fewer parameters were received than required for the header. For example, the *SRE command requires one parameter, so receiving only *SRE is not allowed.

9 **NO CALIBRATION CURRENTLY IN PROGRESS**

The RESUME CAL SEQUENCE softkey (No HP-IB command) is not valid unless a calibration is in progress. Start a new calibration. See "(Cal) key" in the *Function Reference* .

12 **NO COMPENSATION CURRENTLY IN PROGRESS**

The RESUME COMP SEQ softkey (No HP-IB command) is not valid unless a fixture compensation is in progress. Start a new calibration. See "(Cal) key" in the *Function Reference* .

+0 **No error**

The error queue is empty. Every error in the queue has been read (SYSTem:ERRor? query) or the queue was cleared by power-on or the *CLS command.

107 **NO STATE/DATA FILES ON DISK**

(*Front-panel key only*) The RE-SAVE FILE, COPY FILE, PURGE FILE, or (Recall) key pressed, but there are no files with extensions ("_D" or "_S" for LIF format, or ".STA" or ".DTA" for DOS format) on the flexible disk.

110 **NO STATE/DATA FILES ON MEMORY**

(*Front-panel key only*) The RE-SAVE FILE, COPY FILE, PURGE FILE, or (Recall) key pressed, but there are no files with extensions ("_D" or "_S" for LIF format, or ".STA" or ".DTA" for DOS format) on the RAM disk memory.

75 **NO TEST HEAD CONNECTED**

Check the test head connection.

189 **NOT ALLOWED IN SVC MODE**

Dual channel cannot be displayed in the service mode.

80 **NOT AVAILABLE FOR THIS FIXTURE**

(*HP-IB only*) You cannot execute CALCulate:MATH1[:EXPRession]:NAME {DCO|PER} when the SYSTem:FIXTure {NONE|HP16191|HP16192|HP16193|HP16194} is selected.

47 **NOT ENOUGH DATA**

(*HP-IB only*) The amount of data sent to the meter is less than that expected when the data transfer format is binary.

-120 **Numeric data error**

This error, as well as errors −121 through −129, are generated when parsing a data element that appears to be numeric, including the nondecimal numeric types. This particular error message is used if the meter cannot detect a more specific error.

-128 **Numeric data not allowed**

A legal numeric data element was received, but the meter does not accept it in this position for a header.

Error Messages

140 **ON POINT NOT ALLOWED FOR THE CURRENT TRIG**

The trigger event mode cannot be changed to the ON POINT mode because the current trigger source setting does not allow the ON POINT mode. The trigger event ON POINT mode is available for only MANUAL, EXTERNAL, and BUS trigger sources.

48 **OPTION NOT INSTALLED**

(*HP-IB only*) This error occurs when an HP-IB command which is optional command is sent and the meter is not installed the option. Please confirm options installed to the meter using *OPT? command (see Chanpter 3 of HP-IB Command Reference.)

233 **OUTPUT ATTENUATOR TEST FAILED**

An "external test 21: OUTPUT ATTENUATOR" fails. See the *Service Manual* for troubleshooting.

-220 **Parameter error**

Indicates that a program data element related error occurred. This error message is used when the meter cannot detect the more specific errors described for errors −221 through −229.

-108 **Parameter not allowed**

More parameters were received than expected for the header. For example, the *SRE command only accepts one parameter, so receiving *SRE 4,16 is not allowed.

40 **PHASE LOCK LOOP UNLOCKED**

Sever error. Contact your nearest Hewlett-Packard office.

25 **PLOTTER NOT READY - PINCH WHEELS UP**

If you attempt to plot when the plotter's pinch wheels are up, this message is displayed.

23 **PLOTTER:not on, not connect, wrong address**

The plotter does not respond to control. Verify power to the plotter, and check the HP-IB connection between the meter and the plotter. Ensure that the plotter address recognized by the meter matches the HP-IB address set on the plotter itself.

215 **POST REGULATOR OUTPUT VOLTAGE OUT OF SPEC**

An "internal test 4: A2 POST REGULATOR" fails. A power supply voltage of the A2 post-regulator is out of its limits. See the *Service Manual* for troubleshooting.

POWER FAILED ON *nnn*

Sever error. Contact your nearest Hewlett-Packard office. One or more power is failed. *nnn* is one of −5 V, −15 V, +5 V, +15 V, +65 V, and PostRegHot. It shows that which power line is failed. When this error occurs, the system halts so a controller cannot read this error by HP-IB.

198 **POWER ON TEST FAILED**

An internal test fails in the power on sequence (the power on self-test fails). Contact your nearest Hewlett-Packard office or see the *Service Manual* for troubleshooting.

22 **PRINTER:not on, not connect, wrong address**

The printer does not respond to control. Verify power to the plotter, and check the HP-IB connection between the meter and the printer. Ensure that the printer address recognized by the meter matches the HP-IB address set on the printer itself.

-284 **Program currently running**

Certain operations dealing with programs may be illegal while the program is running. For example, deleting a running program might not be possible.

-280 **Program error**

A downloaded program-related execution error occurred. This error message is used when the meter cannot detect the more specific errors described for errors −281 through −289.

-112 **Program mnemonic too long**

The header contains more than twelve characters (see IEEE 488.2, 7.6.1.4.1).

-286 **Program runtime error**

A program runtime error of the HP Instrument BASIC has occurred. To get a more specific error information, use the `ERRM$` or `ERRN` command of the HP Instrument BASIC.

-285 **Program syntax error**

A syntax error appears in a downloaded program. The syntax used when parsing the downloaded program is device-specific.

-430 **Query DEADLOCKED**

A condition causing a deadlocked query error occurred (see IEEE 488.2, 6.3.1.7). For example, both input buffer and output buffer are full and the meter cannot continue.

-400 **Query errors**

This is the generic query error that the meter cannot detect more specific errors. This code indicates only that a query error as defined in IEEE 488.2, 11.5.1.1.7 and 6.3 has occurred.

-410 **Query INTERRUPTED**

A condition causing an interrupted query error occurred (see IEEE 488.2, 6.3.2.3). For example, a query followed by DAB or GET before a response was completely sent.

-420 **Query UNTERMINATED**

A condition causing an unterminated query error occurred (see IEEE 488.2, 6.3.2.2). For example, the meter was addressed to talk and an incomplete program message was received by the controller.

-350 **Queue overflow**

A specific code entered into the queue in lieu of the code that caused the error. This code indicates that there is no room in the queue and an error occurred but was not recorded.

105 **RECALL ERROR: INSTR STATE PRESET**

A serious error, for example corrupted data, is detected on recalling a file, and this forced the meter to be PRESET.

242 **RECEIVER GAIN OUT OF SPEC**

An "external test 25: FRONT ISOL'N" fails. A6 receiver IF gain is incorrect. See the *Service Manual* for troubleshooting.

241 **RECEIVER GAIN TEST FAILED**

An "external test 22: RECEIVER GAIN" fails. See the *Service Manual* for troubleshooting.

219 **REF OSC TEST FAILED**

An "internal test 6: A5 REFERENCE OSC" fails. The reference oscillator on the A5 synthesizer does not work properly. See the *Service Manual* for troubleshooting.

206 **RTC CHIP TEST FAILED**

An "internal test 1: A1 CPU" fails. The A1 CPU's RTC (Real Time Clock) does not work properly. Replace the A1 CPU with a new one. See the *Service Manual* for troubleshooting.

227 **SAMPLE FREQUENCY OUT OF SPEC**

An "internal test 14: A6 SEQUENCER" fails. The sampling frequency of the sample/hold circuit on the A6 receiver IF is out of its limits.

104 **SAVE ERROR**

A serious error, for example physically damaged disk surface, is detected on saving a file.

-330 **Self-test failed**

A self-test failed. Contact your nearest Hewlett-Packard office or see the *Service Manual* for troubleshooting.

-221 **Settings conflict**

A legal program data element was parsed but could not be executed due to the current device state (see IEEE 488.2, 6.4.5.3 and 11.5.1.1.5).

228 **SOURCE LEVEL TEST FAILED**

An "internal test 15: SOURCE LEVEL" fails. See the *Service Manual* for troubleshooting.

232 **SOURCE LEVEL TEST FAILED**

An "external test 20: SOURCE LEVEL" fails. See the *Service Manual* for troubleshooting.

226 **SOURCE OSC TEST FAILED**

An "internal test 13: A3A1 SOURCE OSC" fails. The source oscillator on the A3A1 ALC does not work properly. See the *Service Manual* for troubleshooting.

221 **STEP OSC TEST FAILED**

An "internal test 8: A5 STEP OSC" fails. The step oscillator on the A5 synthesizer does not work properly. See the *Service Manual* for troubleshooting.

-150 **String data error**

This error, as well as errors −151 and −158, are generated when analyzing the syntax of a string data element. This particular error message is used if the meter cannot detect a more specific error.

-158 **String data not allowed**

A string data element was encountered but was not allowed by the meter at this point in parsing.

-130 **Suffix error**

This error, as well as errors −131 through −139, are generated when parsing a suffix. This particular error message is used if the meter cannot detect a more specific error.

-138 **Suffix not allowed**

A suffix was encountered after a numeric element that does not allow suffixes.

-134 **Suffix too long**

The suffix contained more than 12 characters (see IEEE 488.2, 7.7.3.4).

-102 **Syntax error**

An unrecognized command or data type was encountered. For example, a string was received when the meter was not expecting to receive a string.

-310 **System error**

Some error, termed "system error" by the meter, has occurred.

-124 **Too many digits**

The mantissa of a decimal numeric data element contains more than 255 digits excluding leading zeros (see IEEE 488.2, 7.7.2.4.1).

56 **TOO MANY SEGMENTS**

The maximum number of segments for the limit table is 10.

69 **TOO MANY SEGMENTS OR POINTS**

Frequency sweep list is limited to 10 points.

-223 **Too much data**

A legal program data element of block, expression, or string type was received that contained more data than the meter could handle due to memory or related device-specific requirements.

46 **TOO MUCH DATA**

(*HP-IB only*) Either there is too much binary data to send to the meter when the data transfer format is binary, or the amount of data is greater than the number of points.

235 **TRD ISOL'N I TO V TEST FAILED**

An "external test 28: TRD ISOL'N I TO V" fails. See the *Service Manual* for troubleshooting.

236 **TRD ISOL'N V TO I TEST FAILED**

An "external test 29: TRD ISOL'N V TO I" fails. See the *Service Manual* for troubleshooting.

234 **TRD LOSS TEST FAILED**

An "external test 22: TRD LOSS" fails. See the *Service Manual* for troubleshooting.

-210 **Trigger error**

A trigger related error occurred. This error message is used when the meter cannot detect the more specific errors described for errors −211 through −219.

-211 **Trigger ignored**

A GET, `*TRG`, or triggering signal was received and recognized by the meter but was ignored because of meter timing considerations. For example, the meter was not ready to respond.

-113 **Undefined header**

The header is syntactically correct, but it is undefined for the meter. For example, `*XYZ` is not defined for the meter.

158 **UNIT STRING TOO LONG**

(*HP-IB only*) `DISPlay[:WINDow]:TRACe{18-21}:X:UNIT` *<string>* or `DISPlay[:WINDow]:TRACe{18-21}:Y:UNIT` *<string>* commands can send *<string>* up to 4 characters.

76 **UNKNOWN TEST HEAD CONNECTED**

The test head get wrong. Contact your nearest Hewlett-Packard office.

246 **VCXO TUNING VOLTAGE OUT OF LIMIT**

VCXO tuning voltage is incorrect, in performing an "adjustment test 36: 3RD VCXO LEVEL ADJ" or an "adjustment test 39: SOURCE VCXO LEVEL ADJ". See the *Service Manual* for troubleshooting.

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