

Errata

Title & Document Type: 4291A Operating and Function Reference

Manual Part Number: 04291-90000

Revision Date: June 1995

HP References in this Manual

This manual may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, semiconductor products and chemical analysis businesses are now part of Agilent Technologies. We have made no changes to this manual copy. The HP XXXX referred to in this document is now the Agilent XXXX. For example, model number HP8648A is now model number Agilent 8648A.

About this Manual

We've added this manual to the Agilent website in an effort to help you support your product. This manual provides the best information we could find. It may be incomplete or contain dated information, and the scan quality may not be ideal. If we find a better copy in the future, we will add it to the Agilent website.

Support for Your Product

Agilent no longer sells or supports this product. You will find any other available product information on the Agilent Test & Measurement website:

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Search for the model number of this product, and the resulting product page will guide you to any available information. Our service centers may be able to perform calibration if no repair parts are needed, but no other support from Agilent is available.

HP 4291A
RF Impedance/Material Analyzer
Operating Manual Set

DECLARATION OF CONFORMITY

according to ISO/IEC Guide 22 and EN 45014

Manufacturer's Name: Hewlett-Packard Japan, LTD.

Manufacturer's Address: 1-3-2, Murotani, Nishi-ku, Kobe-shi,
Hyogo, 651-22 Japan

declares, that the product

Product Name : RF Impedance / Material Analyzer

Model Number : HP 4291A

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

conforms to the following Product Specifications :

Safety : IEC 348 (1978) / HD 401 S1 (1981)


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

Supplementary Information:

The Product herewith complies with the requirements of the Low Voltage Directive 73/23/EEC and the EMC Directive 89/336/EEC.

The product was tested in a typical configuration with a Hewlett-Packard Measurement System.

Kobe, June 1, 1995


Yukio Iwasaki / QA Manager

Herstellerbescheinigung

Hiermit wird bescheinigt, daß das GerXt HP 4194A Impedance/Gain-Phase Analyzer in Xbereinstimmung mit den Bestimmungen von PostverfXgung 1046/84 funkentstXrt ist.

Der Deutschen Bundespost wurde das Inverkehrbringen dieses GerXtes angezeigt und die Berechtigung zur XberprXfung der Serie auf Einhaltung der Bestimmungen eingerXumt.

Anm: Werden MeÃ- und TestgerXte mit ungeschirmten Kabeln und/oder in offenen MeÃaufbauten verwendet, so ist vom Betreiber sicherzustellen, daß die Funk-EntstXrbestimmungen unter Betriebsbedingungen an seiner GrundstXcksgrenze eingehalten werden.

GERXUSCHEMISSION

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

Manufacturer's Declaration

This is to certify that this product, the HP 4194A Impedance/Gain-Phase Analyzer, meets the radio frequency interference requirements of directive 1046/84. The German Bundespost has been notified that this equipment was put into circulation and was granted the right to check the product type for compliance with these requirements.

Note: If test and measurement equipment is operated with unshielded cables and/or used for measurements on open set-ups, the user must insure that under these operating conditions, the radio frequency interference limits are met at the border of his premises.

ACOUSTIC NOISE EMISSION

LpA < 70 dB
operator position
normal operation
per ISO 7779

HP 4291A RF Impedance/Material Analyzer
Operating Manual Set

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Hewlett-Packard Japan, LTD.
Kobe Instrument Division
1-3-2, Murotani, Nishi-ku, Kobe-shi,
Hyogo, 651-22 Japan

Safety Summary

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific **WARNINGS** given elsewhere in this manual 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.

DO NOT Exceed The Appropriate Signal Level

Do not exceed the operating input power, voltage, and current level and signal type appropriate for the instrument being used, refer to your instrument's operation manual.

Caution



Electrostatic discharge (ESD) can damage the highly sensitive microcircuits in your instrument. ESD damage is most likely to occur as the test fixtures are being connected or disconnected. Protect them from ESD damage by wearing a grounding strap that provides a high resistance path to ground. Alternatively, ground yourself to discharge any static charge built-up by touching the outer shell of any grounded instrument chassis before touching the test port connectors.

Never touch the test clip contacts.

Use a work station equipped with an anti-static work surface.

Ground The Instrument

This is a Safety Class 1 product (provided with a protective earth terminal). An uninterruptible safety earth ground must be provided from the main power source to the product input wiring terminals, power source to the product input wiring terminals, power cord, or supplied power cord set. Whenever it is likely that the protection has been impaired, the product must be made inoperative and secured against any unintended operation.

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 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 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 the 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.

The voltage levels found in this test fixture when used with the intended instruments do not warrant more than normal safety precautions for operator safety.

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 *Instrument Specifications* 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 which 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 properly 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 of 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.

Safety Symbols

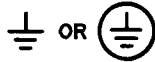
General definitions of safety symbols used on equipment or in manuals.



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



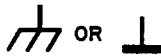
Indicates dangerous voltage (terminals fed from the interior by voltage exceeding 1000 volts must be so marked).



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



Low-noise or noiseless, clean ground (earth) terminal. Used for a signal common, as well as providing protection against electrical shock in case of fault. A terminal marked with this symbol must be connected to ground in the manner described in the installation (Operation) manual, and before operating the equipment.



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



Alternating current (power line).



Direct current (power line).



Alternating or direct current (power line).

Warning



Warning 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



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 damage to or destruction of part or all of the product.

Note



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

Documentation Map

The following manuals are available for the analyzer:

- **Operating Manual Set (HP Part Number 04291-90000)**

The *Operating Manual Set* shows how to use the analyzer. The manual set contains the following manuals:

User's Guide

The *User's Guide* walks you through system setup and initial power-on, shows how to make basic measurements, explains commonly used features, and typical application measurement examples. After you receive your analyzer, begin with this manual.

Specifications Manual

The *Specifications Manual* contains the performance standards or limits against which the analyzer is tested. It describes the analyzer's warranted performance.

Function Reference

The *Function Reference* describes all functions accessed from the front panel keys and softkeys. It also provides information on options and accessories available, and the analyzer's features.

- **Programming Manual Set (HP Part Number 04291-90007)**

The *Programming Manual Set* provides information on HP-IB programming. The manual set contains the following:

Programming Guide

The *Programming Guide* shows how to write BASIC programs to control the analyzer using HP-IB commands.

HP-IB Command Reference

The *HP-IB Command Reference* provides a summary of all available HP-IB commands.

- **HP Instrument BASIC Users Handbook (Option 1C2 only), (HP Part Number E2083-90000)**

The *HP Instrument BASIC Users Handbook* introduces you to the HP Instrument BASIC programming language, provides some helpful hints on getting the most use from it, and provides a general programming reference. It is divided into three books, *HP Instrument BASIC Programming Techniques*, *HP Instrument BASIC Interface Techniques*, and *HP Instrument BASIC Language Reference*.

- **HP Instrument BASIC Users Handbook Supplement (Option 1C2 Only), (HP Part Number 04291-90005)**

The *HP Instrument BASIC Users Handbook Supplement* describes how HP Instrument BASIC works with the analyzer.

■ **Service Manual (Option 0BW only), (HP Part Number 04291-90101)**

The *Service Manual* explains how to do performance tests, and to adjust, troubleshoot, and repair the instrument.

Microfiche Copies of the Manual

Use the microfiche part number on the title page to order a package of 10 × 15 centimeter (4 × 6 inch) microfilm transparencies of the *Operating Manual Set*, the *Programming Manual Set*, the *HP Instrument BASIC User's Handbook Supplement*, and the *Service Manual*.

HP 4291A RF Impedance/Material Analyzer Specifications

These specifications are the performance standards or limits against which the instrument is tested. When shipped from the factory, the HP 4291A meets the specifications listed in this section. The performance test procedures are covered in the *HP 4291A Service Manual*. (HP 4291A Service Manual is furnished with Option 0BW.)

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 on the test head connected to the instrument.

Measurement Parameter

Impedance parameters

..... $|Z|, \theta_z, |Y|, \theta_y, R, X, G, B, C_p, C_s, L_p, L_s, R_p, R_s, D, Q, |\Gamma|, \theta_\gamma, \Gamma_x, \Gamma_y$

Stimulus Characteristics

Frequency Characteristics

Operating frequency	1 MHz to 1.8 GHz
Frequency resolution	1 mHz
Frequency reference	
Accuracy	
@ 23±5°C	< ±10 ppm
Precision frequency reference (Option 1D5)	
Accuracy	
@ 0°C to 55°C	< ±1 ppm

Source Characteristics

OSC level

Voltage range

@1 MHz \leq Frequency \leq 1 GHz (When terminal is open) 0.2 mV_{rms} to 1 V_{rms}

@1 GHz < Frequency \leq 1.8 GHz (When terminal is open) 0.2 mV_{rms} to 0.5 V_{rms}

Current range

@1 MHz \leq Frequency \leq 1 GHz (When terminal is shorted) 4 μ A_{rms} to 20 mA_{rms}

@1 GHz < Frequency \leq 1.8 GHz (When terminal is shorted) 4 μ A_{rms} to 10 mA_{rms}

Power range

@1 MHz \leq Frequency \leq 1 GHz (When terminating with 50 Ω) -67 dBm to 7 dBm

@1 GHz < Frequency \leq 1.8 GHz (When terminating with 50 Ω) -67 dBm to 1 dBm

OSC level resolution

AC voltage resolution

@ 0.22 V_{rms} < V_{OSC} \leq 1 V_{rms} 2 mV

@ 70 mV_{rms} < V_{OSC} \leq 220 mV_{rms} 0.5 mV

@ 22 mV_{rms} < V_{OSC} \leq 70 mV_{rms} 0.2 mV

@ 7 mV_{rms} < V_{OSC} \leq 22 mV_{rms} 0.05 mV

@ 2.2 mV_{rms} < V_{OSC} \leq 7 mV_{rms} 0.02 mV

@ 0.7 mV_{rms} < V_{OSC} \leq 2.2 mV_{rms} 0.005 mV

@ 0.2 mV_{rms} \leq V_{OSC} \leq 0.7 mV_{rms} 0.002 mV

AC current resolution

@ 4.4 mA_{rms} < I_{OSC} \leq 20 mA_{rms} 40 μ A

@ 1.4 mA_{rms} < I_{OSC} \leq 4.4 mA_{rms} 10 μ A

@ 0.44 mA_{rms} < I_{OSC} \leq 1.4 mA_{rms} 4 μ A

@ 140 μ A_{rms} < I_{OSC} \leq 440 μ A_{rms} 1 μ A

@ 44 μ A_{rms} < I_{OSC} \leq 140 μ A_{rms} 0.4 μ A

@ 14 μ A_{rms} < I_{OSC} \leq 44 μ A_{rms} 0.1 μ A

@ 4 μ A_{rms} \leq I_{OSC} \leq 14 μ A_{rms} 0.04 μ A

AC power resolution 0.1 dBm

OSC level accuracy $A + B + \frac{6_{[dB]} \times f_{[MHz]}}{1800}$ dB

where,

A depends on temperature conditions as follows:

@ within referenced to 23 \pm 5 $^{\circ}$ C 2 dB

@ other environmental temperature conditions 4 dB

B depends on OSC level as follows:

@ V_{osc} \geq 250mV_{rms} 0 dB

(I_{osc} \geq 5 mA_{rms})

(P_{osc} \geq -5 dBm)

@ 250 mV_{rms} > V_{osc} \geq 2.5 mV_{rms} 1 dB

(5 mA_{rms} > I_{osc} \geq 50 μ A_{rms})

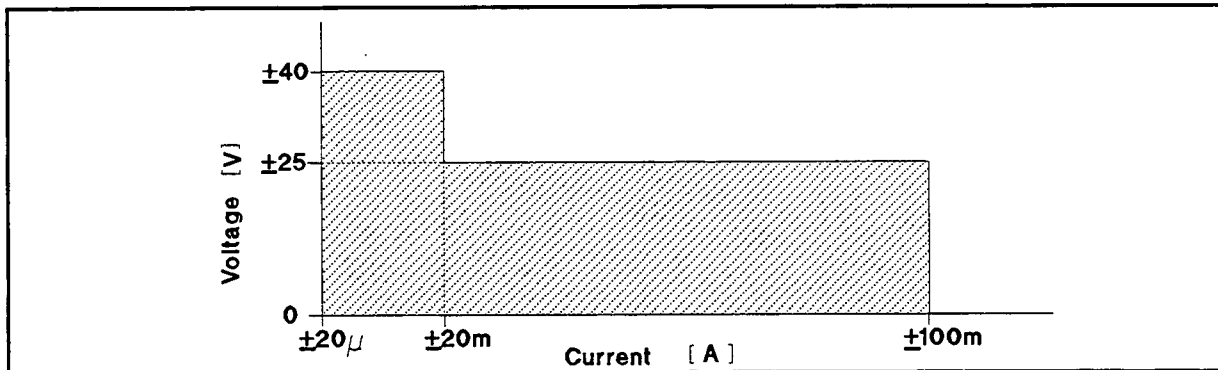
(-5 dBm > P_{osc} \geq -45 dBm)

@ other OSC level 2 dB

Definition of OSC level

- Voltage level : 2 \times 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 \times 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 accuracy	1/2 of specification value (typical)
Connector	APC7®
Output impedance	50 Ω (Nominal value)
DC bias (Option 001)	
DC voltage level	0 to ±40V
DC current level	20 μA to 100 mA and -20 μA to -100mA
DC level resolution	1mV, 20μA
DC level accuracy	
@23±5 °C	
Voltage	0.1 % + 4 mV + (I _{dc} [mA] × 5 [Ω]) mV
Current	0.5 % + 30 μA + (V _{dc} [V]/10 [kΩ]) mA
@ 8 to 18°C and 28 to 38°C	
Voltage	0.2 % + 8 mV + (I _{dc} [mA] × 10 [Ω]) mV
Current	1 % + 60 μA + (V _{dc} [V]/5 [kΩ]) mA
@ 0 to 8°C and 38 to 55°C	
Voltage	0.3 % + 12 mV + (I _{dc} [mA] × 15 [Ω]) mV
Current	1.5 % + 90 μA + (V _{dc} [V] × 3/10 [kΩ]) mA
Level monitor	
Monitor parameters	OSC level (voltage, current), DC bias (voltage, current)
Monitor accuracy	
OSC level	Same as OSC level accuracy (typical)
DC bias	Twice as bad as specifications of dc level accuracy (typical)



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Figure 1-1. DC Voltage and Current Level Range (Typical)

Sweep Characteristics

Sweep parameter	.....	Frequency, OSC level (voltage), DC bias voltage/current
Sweep setup	.....	Start Stop, or Center Span
Sweep type		
Frequency sweep	.....	Linear, Log, Zero-span, List
Other sweep parameters	.....	Linear, Log, Zero-span
Sweep mode	.....	Continuous, Single, Manual, Number of groups
Sweep direction		
AC level, DC bias (voltage and current)	.....	Up sweep, Down sweep
Other sweep parameters	.....	Up sweep
Number of measurement point	.....	2 to 801 points
Averaging	.....	Sweep average, Point average
Delay time	.....	Point delay time, Sweep delay time
Measurement circuit mode	.....	series circuit mode, parallel circuit mode

Calibration/Compensation

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

Measurement Accuracy

Conditions of accuracy specifications
<ul style="list-style-type: none"> ■ 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.

|Z|, |Y| Accuracy ±(E_a + E_b) [%]

The illustrations of |Z| and |Y| accuracy are shown in Figure 1-2 to Figure 1-5.

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

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

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

D Accuracy (ΔD)

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

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

Q Accuracy (ΔQ)

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

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

where,

D_x : Measured value of D

E_a : depends on measurement frequency as follows:

- @ 1 MHz ≤ Frequency ≤ 100 MHz 0.6
- @ 100 MHz < Frequency ≤ 500 MHz 0.8
- @ 500 MHz < Frequency ≤ 1000 MHz 1.2
- @ 1000 MHz < Frequency ≤ 1800 MHz 2.0

E_b = (Z_s/|Z_x| + Y_o/|Z_x|) × 100

Q_x : Measured value of Q

Z_x : impedance measurement value [Ω]

Z_s and **Y_o** depend on number of point averaging (N_{av}), OSC level (V_{osc}), impedance measurement value (Z_x) and the test head used as follows:

Specifications

Table 1-1. Z_o and Y_o when High Impedance Test Head is used

Measurement Conditions			Z_o [Ω]	Y_o [S]
Number of Point Averaging (N_{av})	OSC Signal Level (V_{osc})	Meas. Impedance (Z_x)		
$1 \leq N_{av} \leq 7$	$V_{osc} < 0.02$ V	—	$\frac{0.02}{V_{osc}} \times (0.2 + 0.001 \times f_{[MHz]})$	$\frac{0.02}{V_{osc}} \times (5 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]})$
	0.02 V $\leq V_{osc} < 0.12$ V	—	$0.2 + 0.001 \times f_{[MHz]}$	$5 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]}$
	0.12 V $\leq V_{osc}$	$Z_x \geq 500 \Omega$	$0.2 + 0.001 \times f_{[MHz]}$	$5 \times 10^{-6} + 2 \times 10^{-7} \times f_{[MHz]}$
		$Z_x < 500 \Omega$	$0.2 + 0.001 \times f_{[MHz]}$	$2 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]}$
$N_{av} \geq 8$	$V_{osc} < 0.02$ V	—	$\frac{0.02}{V_{osc}} \times (0.1 + 5 \times 10^{-4} \times f_{[MHz]})$	$\frac{0.02}{V_{osc}} \times (2 \times 10^{-5} + 1 \times 10^{-7} \times f_{[MHz]})$
	0.02 V $\leq V_{osc} < 0.12$ V	—	$0.1 + 5 \times 10^{-4} \times f_{[MHz]}$	$2 \times 10^{-5} + 1 \times 10^{-7} \times f_{[MHz]}$
	0.12 V $\leq V_{osc}$	$Z_x \geq 500 \Omega$	$0.1 + 5 \times 10^{-4} \times f_{[MHz]}$	$2 \times 10^{-6} + 1 \times 10^{-7} \times f_{[MHz]}$
		$Z_x < 500 \Omega$	$0.1 + 5 \times 10^{-4} \times f_{[MHz]}$	$7 \times 10^{-6} + 1 \times 10^{-7} \times f_{[MHz]}$

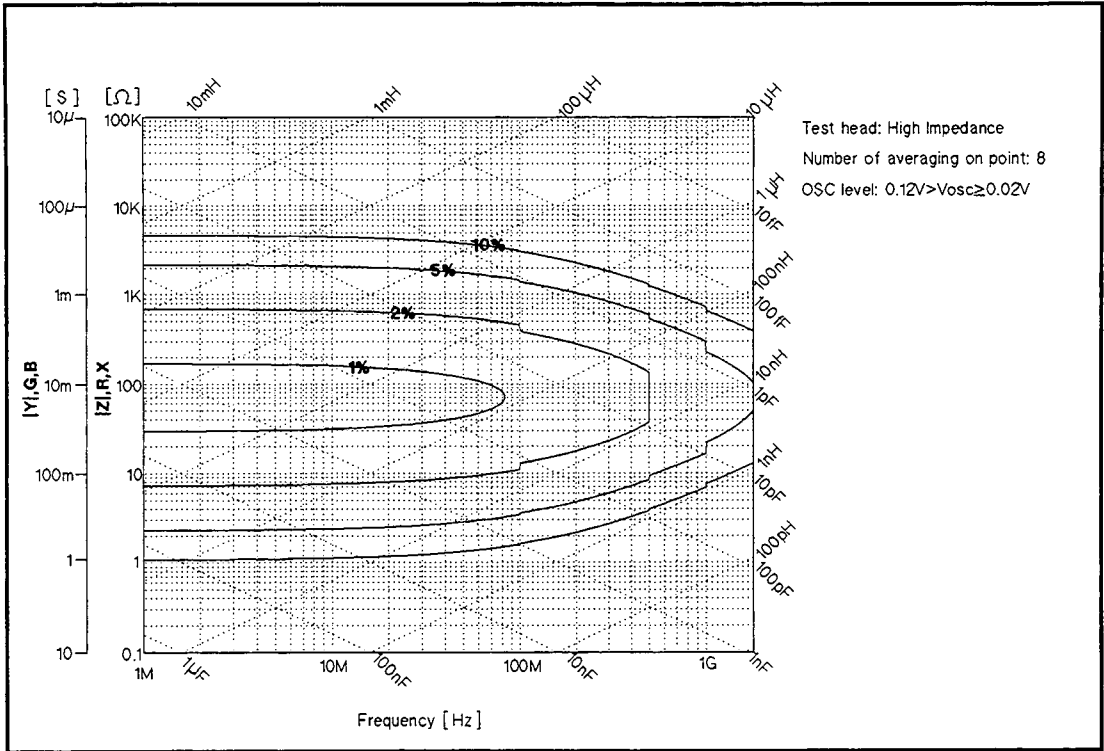
Table 1-2. Z_o and Y_o when Low Impedance Test Head is used

Measurement Conditions			Z_o [Ω]	Y_o [S]
Number of Point Averaging (N_{av})	OSC Signal Level (V_{osc})	Meas. Impedance (Z_x)		
$1 \leq N_{av} \leq 7$	$V_{osc} < 0.02$ V	—	$\frac{0.02}{V_{osc}} \times (0.1 + 0.001 \times f_{[MHz]})$	$\frac{0.02}{V_{osc}} \times (1 \times 10^{-4} + 2 \times 10^{-7} \times f_{[MHz]})$
	0.02 V $\leq V_{osc} < 0.12$ V	—	$0.1 + 0.001 \times f_{[MHz]}$	$1 \times 10^{-4} + 2 \times 10^{-7} \times f_{[MHz]}$
	0.12 V $\leq V_{osc}$	$Z_x \leq 5 \Omega$	$0.01 + 0.001 \times f_{[MHz]}$	$1 \times 10^{-4} + 2 \times 10^{-7} \times f_{[MHz]}$
		$Z_x > 5 \Omega$	$0.05 + 0.001 \times f_{[MHz]}$	$1 \times 10^{-4} + 2 \times 10^{-7} \times f_{[MHz]}$
$N_{av} \geq 8$	$V_{osc} < 0.02$ V	—	$\frac{0.02}{V_{osc}} \times (0.05 + 5 \times 10^{-4} \times f_{[MHz]})$	$\frac{0.02}{V_{osc}} \times (3 \times 10^{-5} + 1 \times 10^{-7} \times f_{[MHz]})$
	0.02 V $\leq V_{osc} < 0.12$ V	—	$0.05 + 5 \times 10^{-4} \times f_{[MHz]}$	$3 \times 10^{-5} + 1 \times 10^{-7} \times f_{[MHz]}$
	0.12 V $\leq V_{osc}$	$Z_x \leq 5 \Omega$	$0.01 + 5 \times 10^{-4} \times f_{[MHz]}$	$3 \times 10^{-5} + 1 \times 10^{-7} \times f_{[MHz]}$
		$Z_x > 5 \Omega$	$0.02 + 5 \times 10^{-4} \times f_{[MHz]}$	$3 \times 10^{-5} + 1 \times 10^{-7} \times f_{[MHz]}$

At the following frequency points, instrument spurious characteristics could occasionally cause measurement errors to exceed specified value because of instrument spurious characteristics.

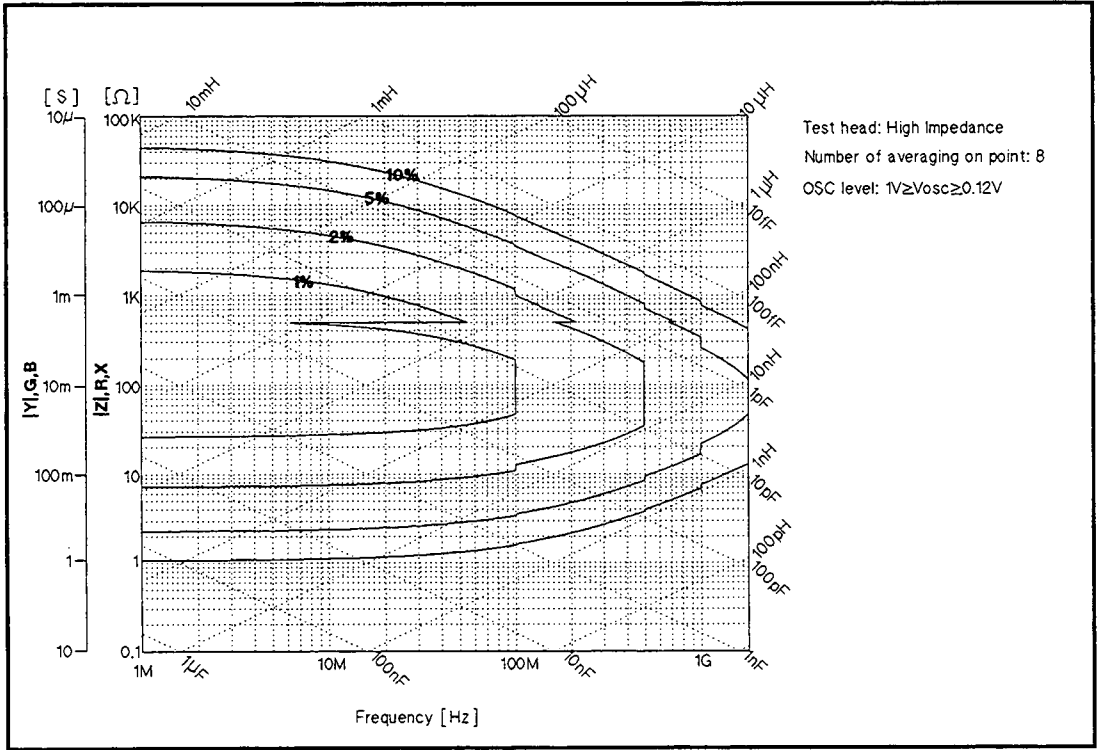
10.71 MHz	17.24 MHz	21.42 MHz	42.84 MHz
514.645 MHz	686.19333 MHz	1029.29 MHz	1327.38666 MHz

See "EMC" under "Others" in "General Characteristics".



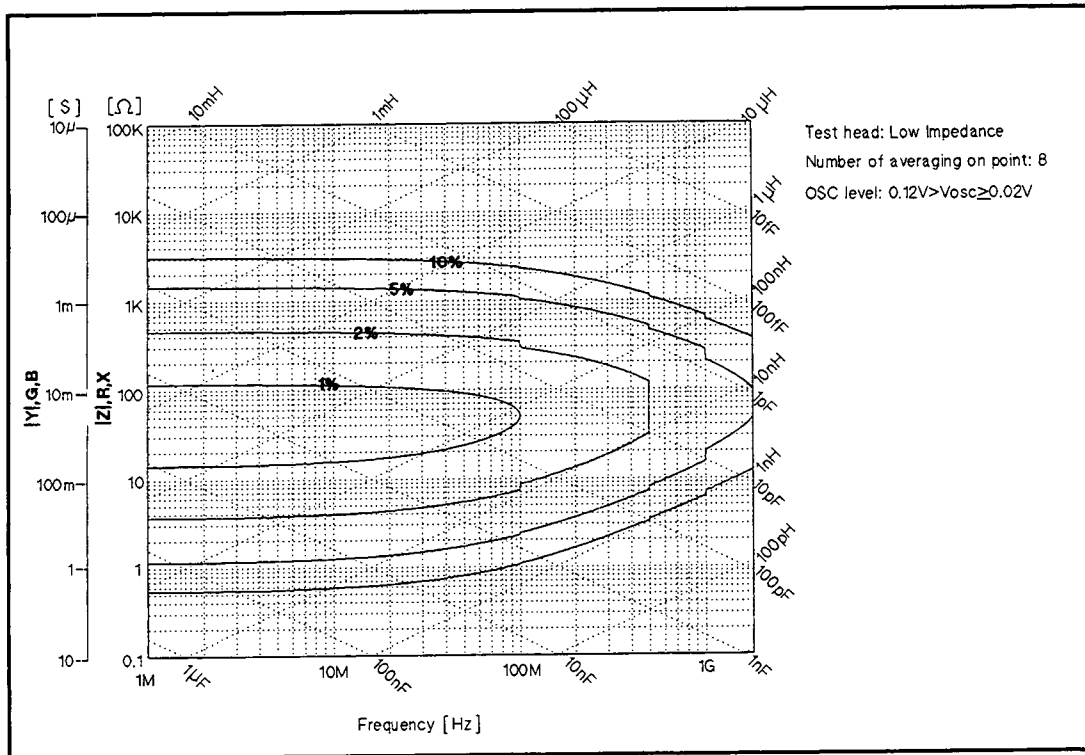
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Figure 1-2.
Impedance Measurement Accuracy Using High Impedance Test Head (@ Low OSC Level)



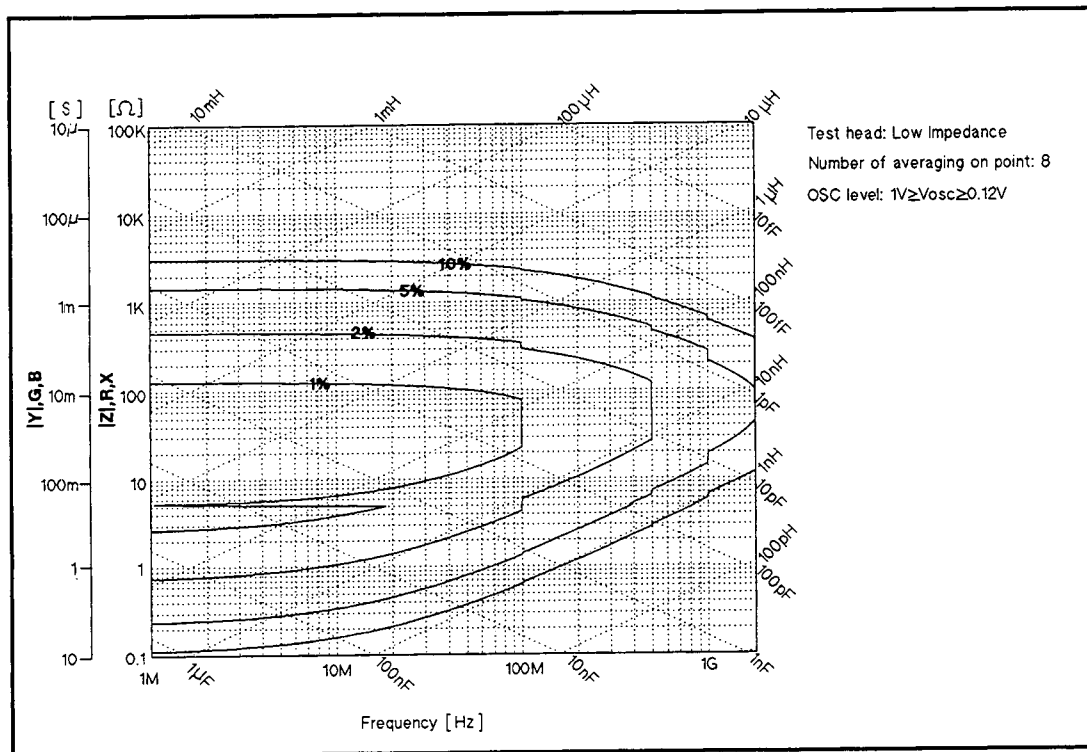
C6600004

Figure 1-3.
Impedance Measurement Accuracy Using High Impedance Test Head (@ High OSC Level)



C6600007

Figure 1-4.
Impedance Measurement Accuracy Using Low Impedance Test Head (@ Low OSC Level)



C6600008

Figure 1-5.
Impedance Measurement Accuracy Using Low Impedance Test Head (@ High OSC Level)

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

Conditions

- Averaging on point factor is larger 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.

|Z|, |Y| Accuracy ±(E_a + E_b) [%]

θ Accuracy ± $\frac{E_c}{100}$ [rad]

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

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

D Accuracy

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

Especially, D_x ≤ 0.1 ± $\frac{E_c}{100}$

Q Accuracy

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

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

Where,

D_x : Actual D value of DUT

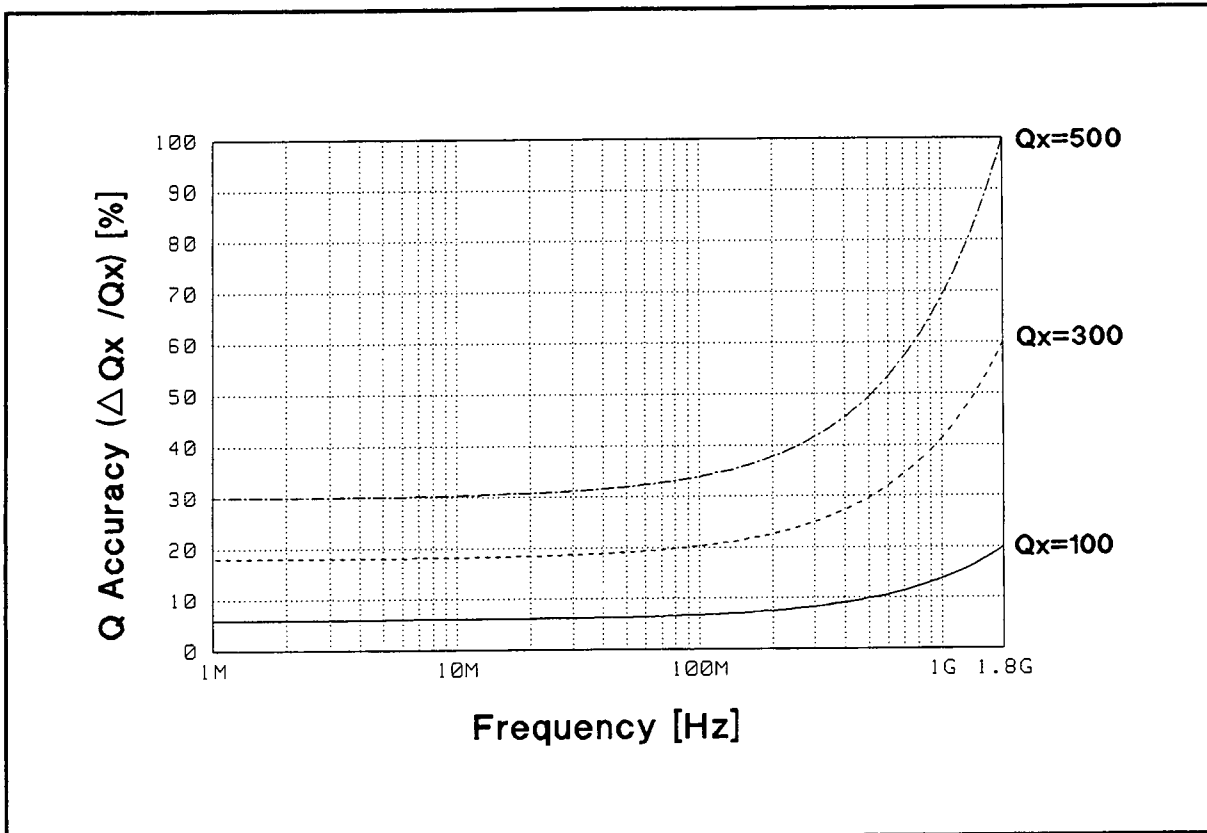
E_a, E_b : are as same as E_a and E_b of the measurement accuracy when OPEN/SHORT/50 Ω calibration is done.

E_c = 0.06 + 0.14 × $\frac{F}{1800}$ (Typical)

F : measurement frequency [MHz]

Q_x : Actual Q value of DUT

Specifications



C6600043

Figure 1-6.
Typical Q Measurement Accuracy (when open/short/50 Ω /low-loss-capacitor calibration are done)

Display

CRT	
type/size	Color CRT, 7.5 inch
Resolution	512 × 400
Number of display channels	2
Format	single, dual split or overwrite, graphic, and tabular
Number of traces	
For measurement	1 trace/channel
For memory	16 traces/channel (maximum)
Data math functions	
	gain × data – offset
	gain × memory – offset
	gain × (data – memory) – offset
	gain × (data + memory) – offset
	gain × (data/memory) – offset
	gain × (data×memory) – offset
Marker	
Number of markers	
Main marker	1 for each channel
Sub-marker	7 for each channel
ΔMarker	1 for each channel

Data Storage

Type	Built-in flexible disk drive, Volatile RAM disk memory
Capacity	
Built-in flexible disk	720 kB/1.44 MB
Volatile RAM disk memory	448 kB (maximum)
Disk format	LIF, DOS

HP-IB

Interface	IEEE 488.1-1987, IEC625, JIS C 1901-1987 standard compatible.
Interface function	SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PPO, 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

General Characteristics

Input and 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

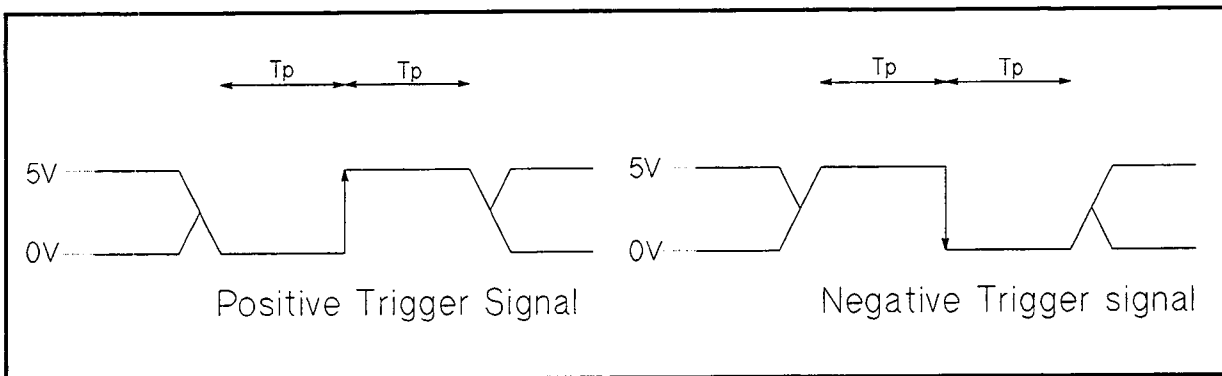


Figure 1-7. Trigger Signal

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

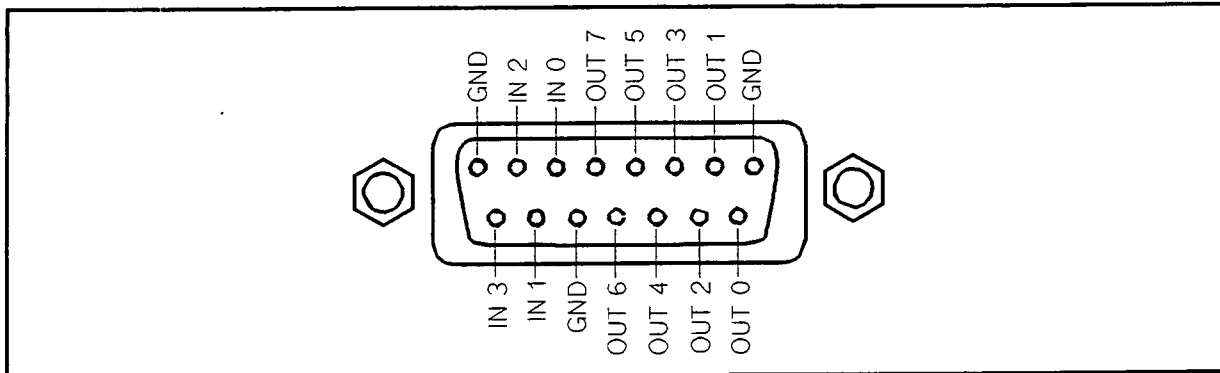
Altitude 0 to 4,572 meters (15,000 feet)

Warm up time 30 minutes

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



06600011

Figure 1-8. I/O Port Pin Assignment

Specifications for Option 1D5 High Stability Frequency Reference

Reference Oven Output

Frequency 10 MHz (nominal)
Level 0 dBm (typically)
Output Impedance 50 Ω (nominal)
Connector BNC female

Specification for Option 002 Material Measurement

Measurement Frequency Range

- @ Using with HP 16453A 1 MHz to 1.8 GHz * (Typical)
- @ Using with HP 16454A 1 MHz to 1.8 GHz (Typical)

* When some material which has large value of ϵ_r is measured, since the measurement circuit occasionally oscillates over 1 GHz, the measurement error may be increased.

Measurement Parameter

Permittivity parameters

..... $|\epsilon_r|, \epsilon_r', \epsilon_r'', \tan\delta$

Permeability parameters

..... $|\mu_r|, \mu_r', \mu_r'', \tan\delta$

Typical Measurement Accuracy

Conditions of accuracy characteristics
<ul style="list-style-type: none"> ■ Use the High Z Test Head for permittivity measurement ■ Use the Low Z Test Head for permeability measurement ■ 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 if Cal point is set to USER DEF. ■ Environment temperature is within $\pm 5^\circ\text{C}$ 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.

ϵ_r' Accuracy $\left(\frac{\Delta\epsilon'_{rm}}{\epsilon'_{rm}}\right)$

@ $\tan\delta < 0.1$

..... $5 + \left(10 + \frac{0.04}{f}\right)\frac{t}{\epsilon'_{rm}} + 0.25\frac{\epsilon'_{rm}}{t} + \frac{100}{|1 - (13/\sqrt{\epsilon'_{rm}/f})^2|}$ [%] (Typical)

Loss Tangent Accuracy of ϵ_r ($\Delta\tan\delta$)

@ $\tan\delta < 0.1$ $E_a + E_b$ (Typical)

Where,

@ frequency ≤ 1 GHz

$$E_a = 0.002 + \frac{0.0004}{f} \frac{t}{\epsilon'_{rm}} + 0.004f + \frac{0.1}{|1 - (13/\sqrt{\epsilon'_{rm}/f})^2|} \text{ (Typical)}$$

@ frequency > 1 GHz

$$E_a = 0.002 + \frac{0.0004}{f} \frac{t}{\epsilon'_{rm}} + 0.004f + \frac{1.1}{|1 - (13/\sqrt{\epsilon'_{rm}/f})^2|} \text{ (Typical)}$$

$$E_b = \left(\frac{\Delta\epsilon'_{rm}}{\epsilon'_{rm}} \frac{1}{100} + \epsilon'_{rm} \frac{0.002}{t}\right) \tan\delta \text{ (Typical)}$$

f is measurement frequency [GHz]
t is thickness of MUT [mm]

Specifications

Option 002 Material Measurement

ϵ_{rm}' is measured value of ϵ_r'
 $\tan \delta$ is measured value of dielectric loss tangent

μ_r' Accuracy $\left(\frac{\Delta\mu_{rm}'}{\mu_{rm}'}\right)$

@ $\tan\delta < 0.1$ $4 + \frac{25}{F\mu_{rm}'} + F\mu_{rm}'\left(1 + \frac{15}{F\mu_{rm}'}\right)^2 f^2$ [%] (Typical)

Loss Tangent Accuracy of μ_r ($\Delta\tan\delta$)

@ $\tan\delta < 0.1$ $E_a + E_b$ (Typical)

Where,

$E_a = 0.002 + \frac{0.001}{F\mu_{rm}'f} + 0.004f$ (Typical)

$E_b = \frac{\Delta\mu_{rm}' \tan \delta}{\mu_{rm}' 100}$ (Typical)

f is measurement frequency [GHz]

$F = h \ln \frac{c}{b}$ [mm]

h is the height of MUT [mm]

b is the inner diameter of MUT

c is the outer diameter of MUT

$\tan \delta$ is the measured value of loss tangent

μ_{rm}' is the measured value of permeability

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
514.645 MHz	686.19333 MHz	1029.29 MHz	1327.38666 MHz

See "EMC" under "Others" in "General Characteristics".

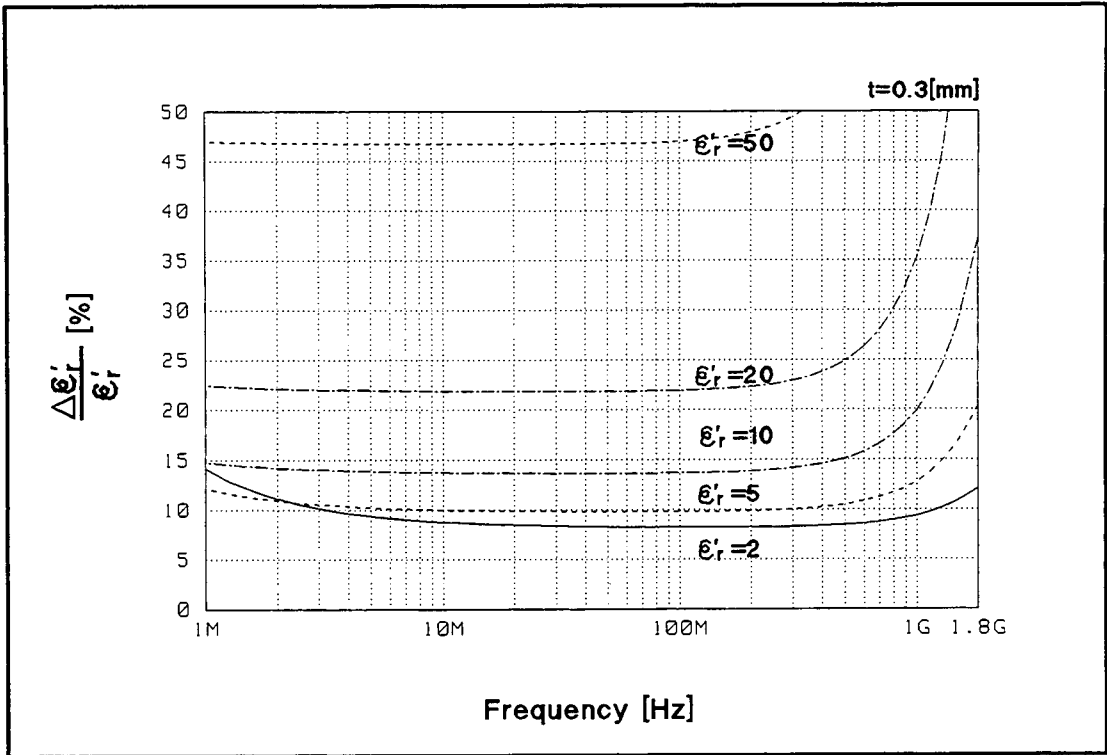


Figure 1-9. Typical Permittivity Measurement Accuracy (@thickness = 0.3 mm)

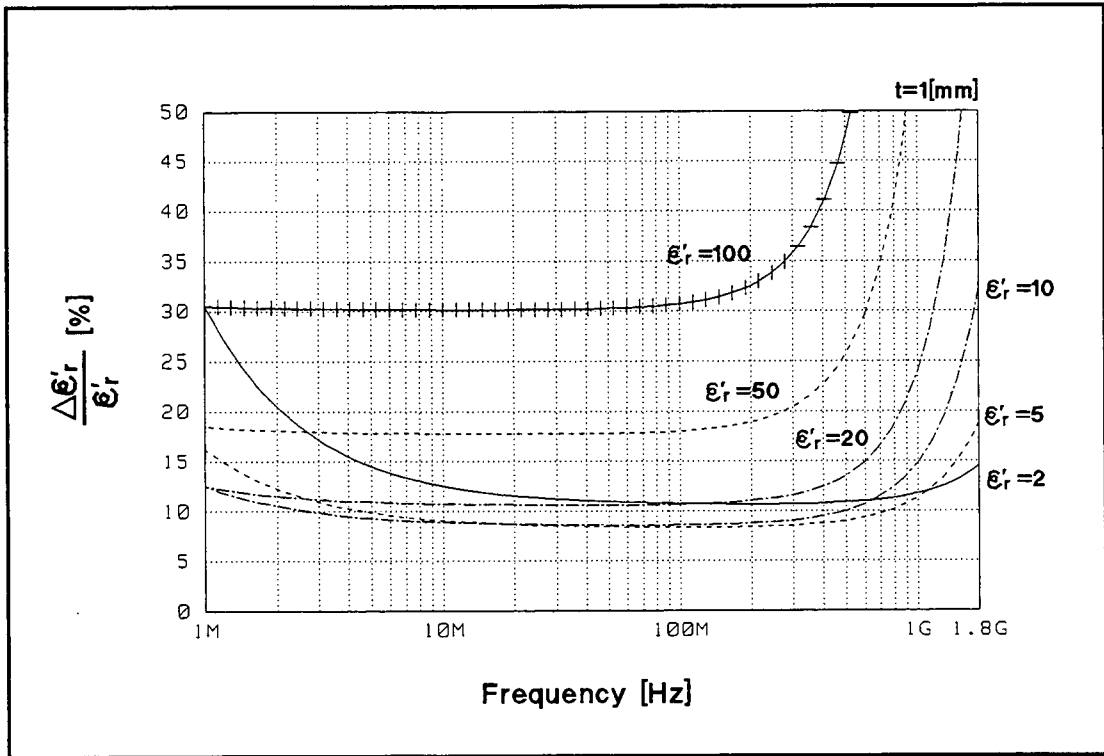
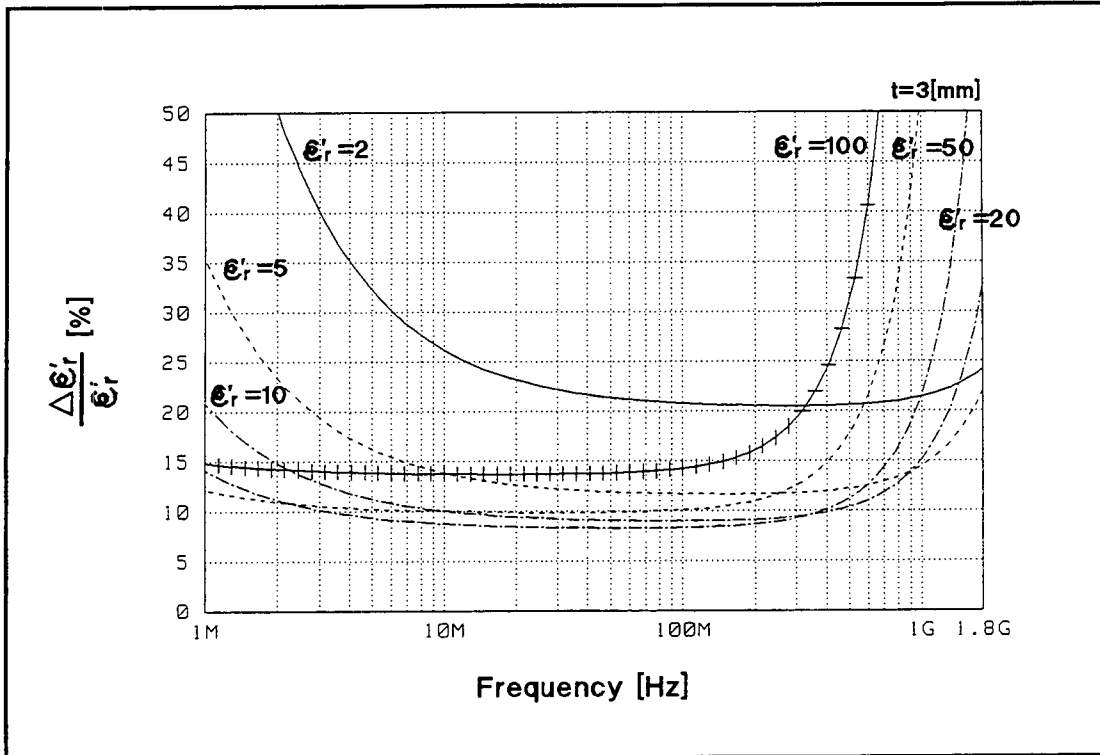
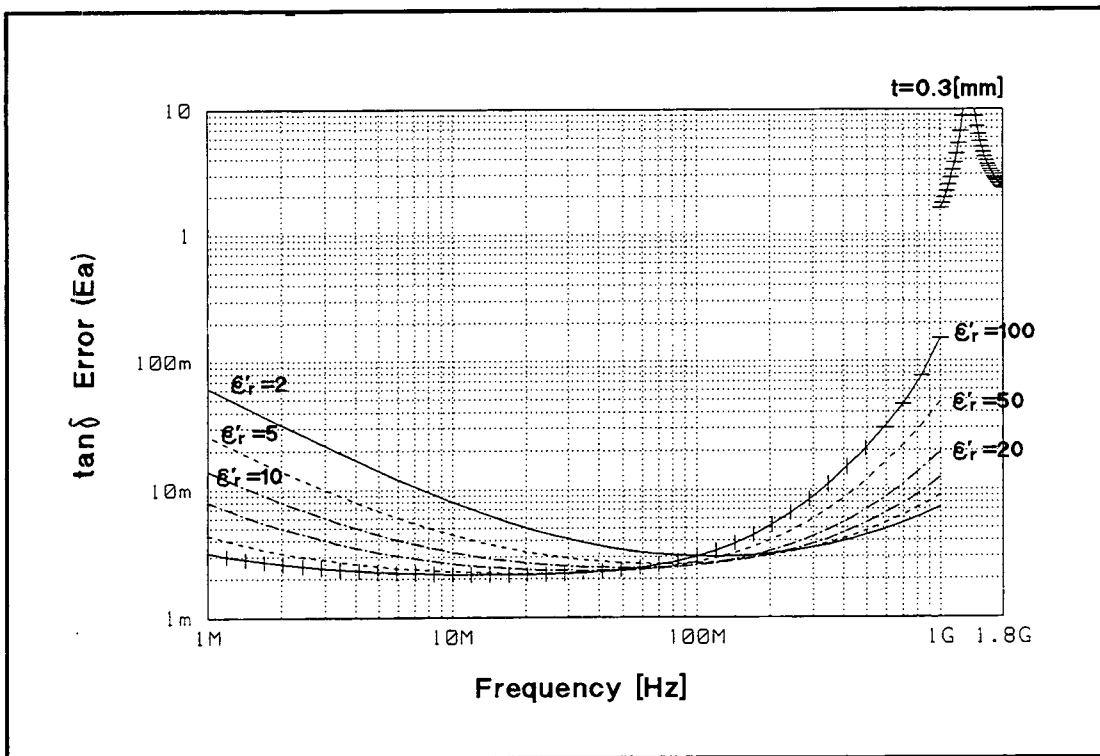


Figure 1-10. Typical Permittivity Measurement Accuracy (@thickness = 1 mm)



C6600033

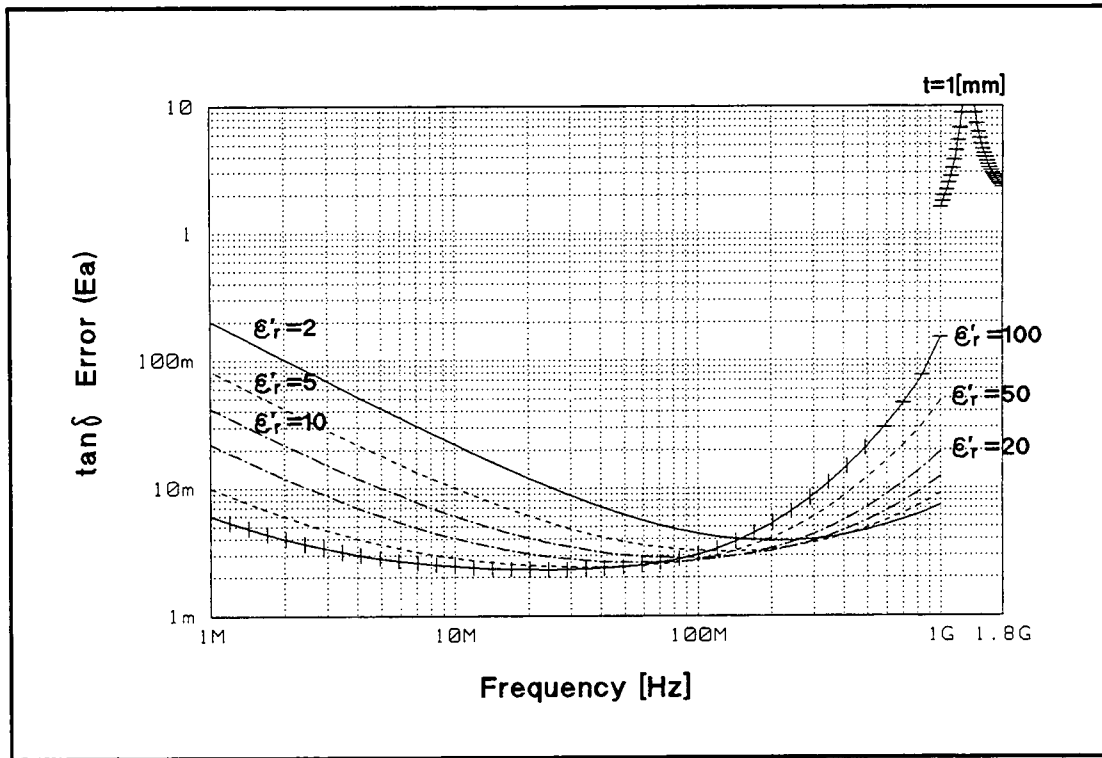
Figure 1-11. Typical Permittivity Measurement Accuracy (@thickness = 3 mm)



C6600034

Figure 1-12.

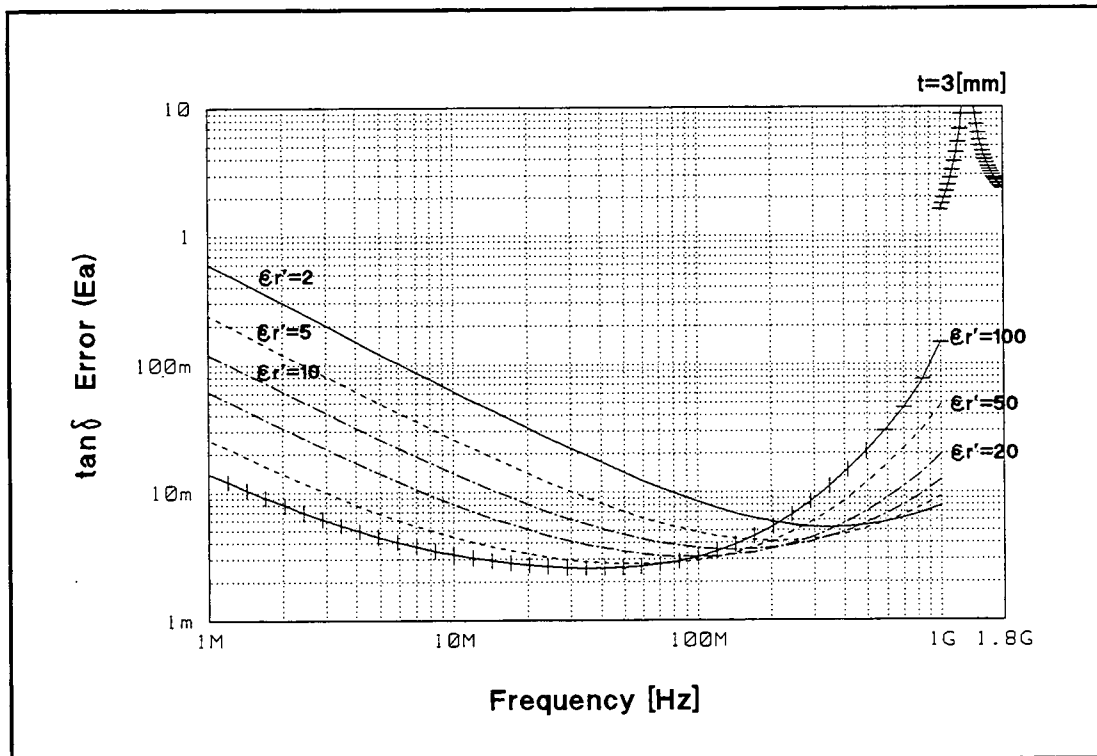
Typical Dielectric Loss Tangent ($\tan \delta$) Measurement Accuracy (@thickness = 0.3 mm)



C6600035

Figure 1-13.

Typical Dielectric Loss Tangent ($\tan\delta$) Measurement Accuracy (@thickness = 1 mm)

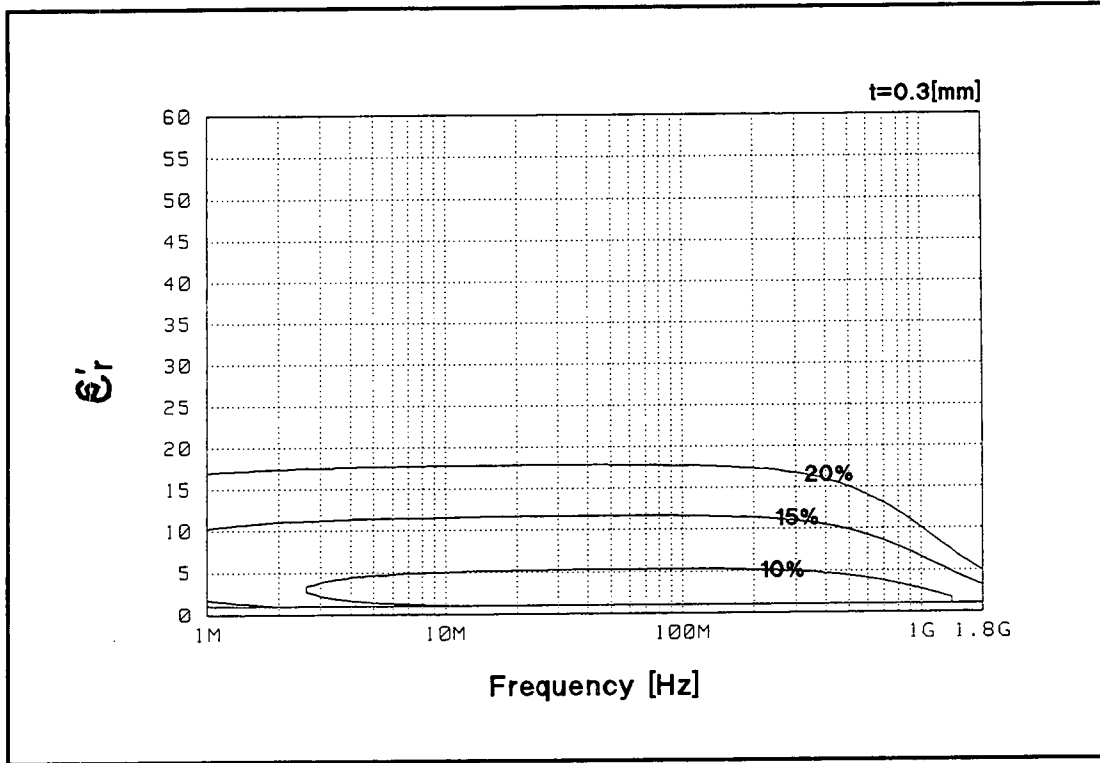


C6600036

Figure 1-14.

Typical Dielectric Loss Tangent ($\tan\delta$) Measurement Accuracy (@thickness = 3 mm)

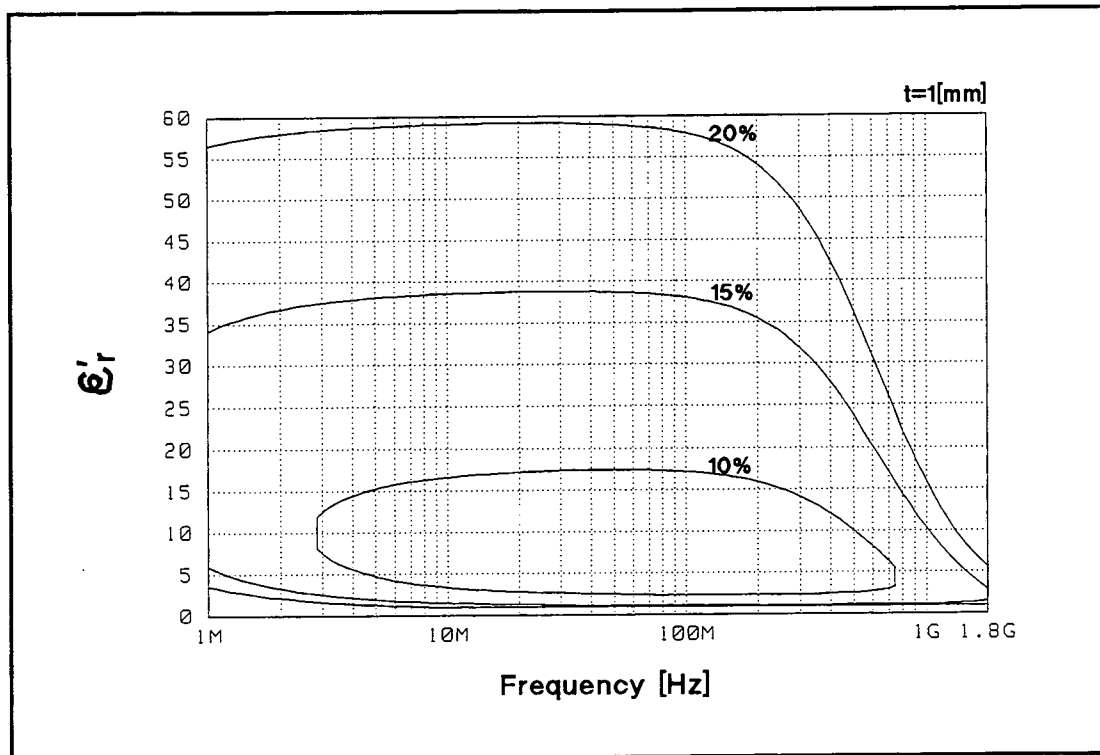
Option 002 Material Measurement



C6600039

Figure 1-15.

Typical Permittivity Measurement Accuracy (ϵ_r v.s. Frequency, @thickness = 0.3 mm)



C6600040

Figure 1-16.

Typical Permittivity Measurement Accuracy (ϵ_r v.s. Frequency, @thickness = 1 mm)

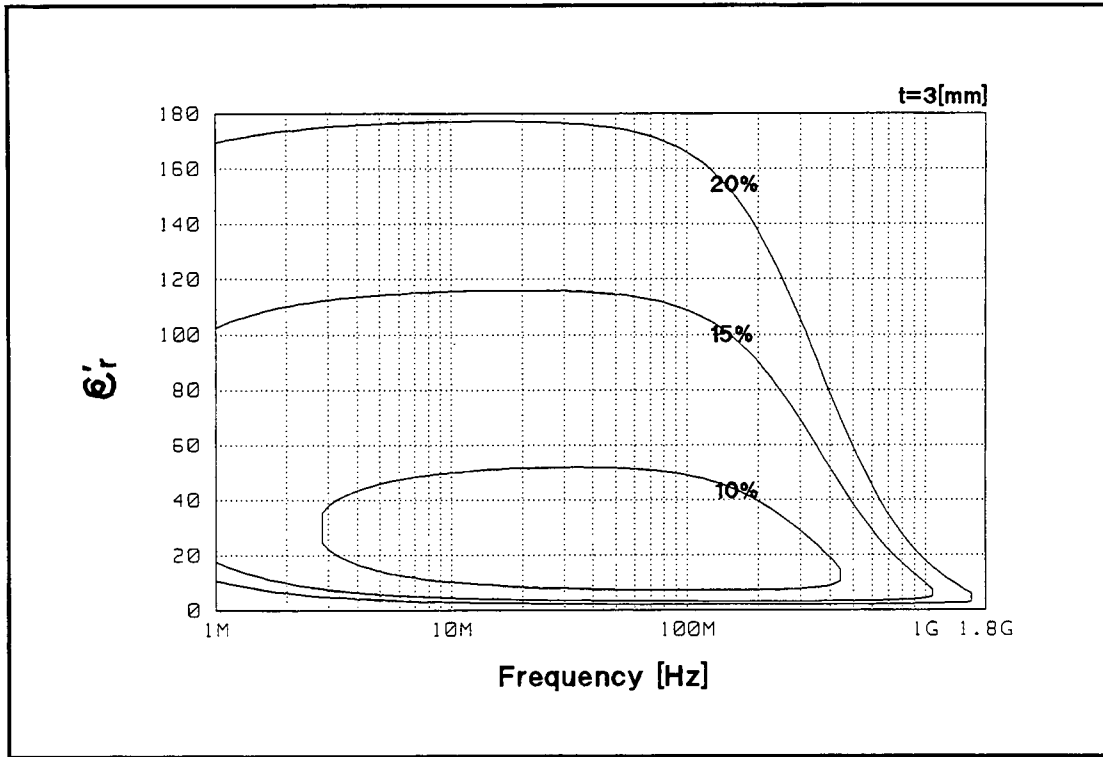
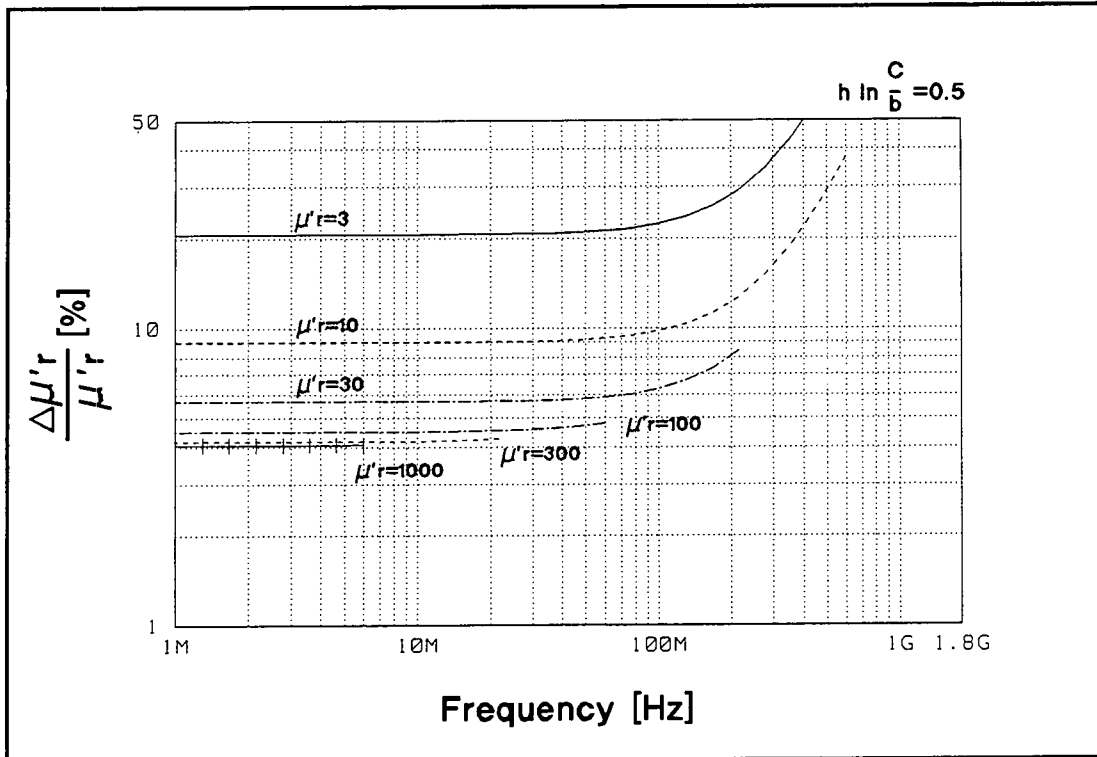


Figure 1-17.
Typical Permittivity Measurement Accuracy (ϵ_r v.s. Frequency, @thickness = 3 mm)

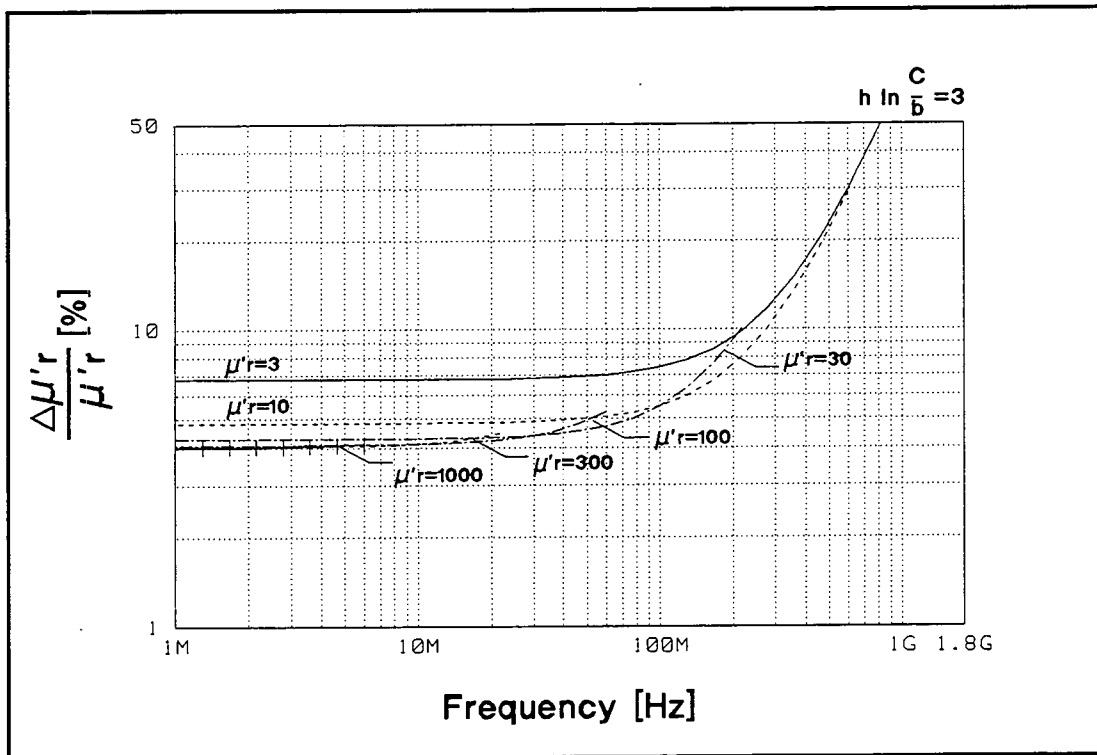
Specifications

Option 002 Material Measurement



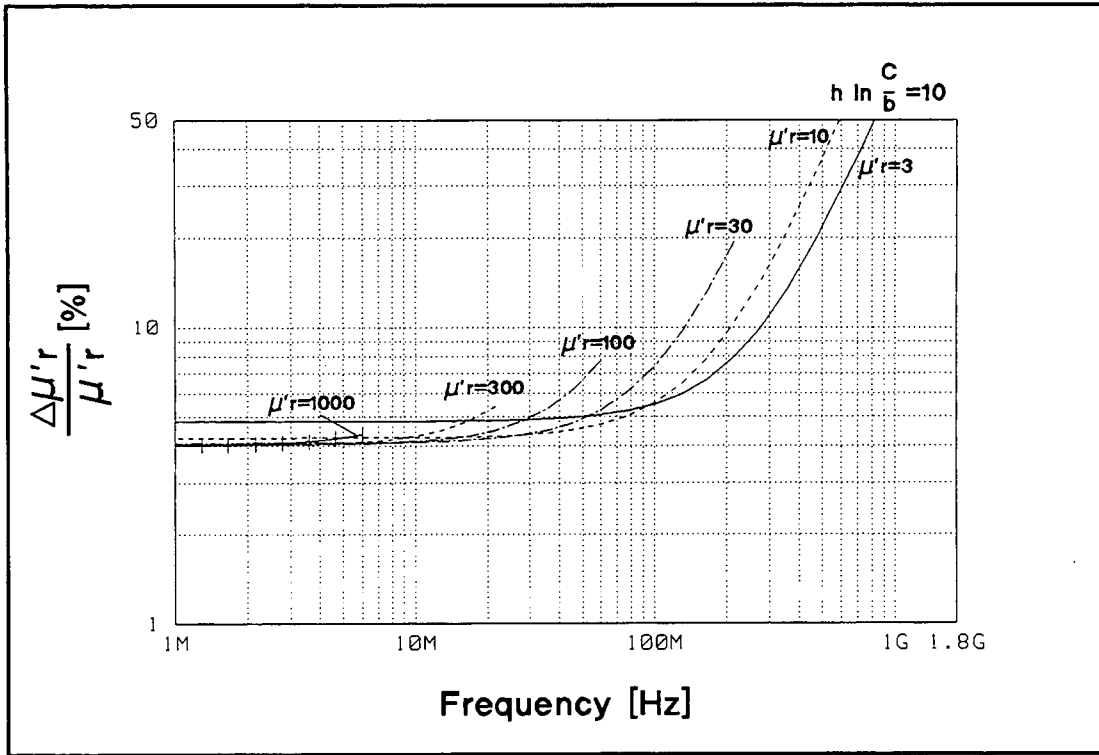
C660019

Figure 1-18. Typical Permeability Measurement Accuracy (@ $F^* = 0.5$)



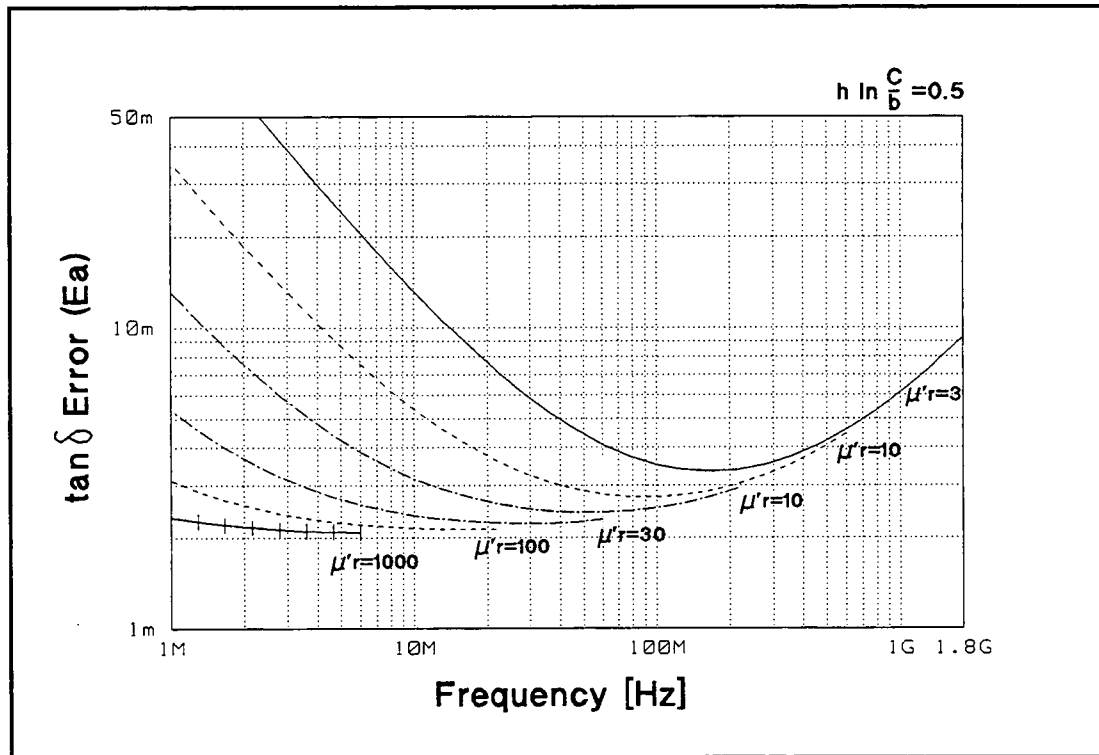
C660021

Figure 1-19. Typical Permeability Measurement Accuracy (@ $F^* = 3$) * $F = h \ln \xi$



C6600020

Figure 1-20. Typical Permeability Measurement Accuracy (@F* = 10)

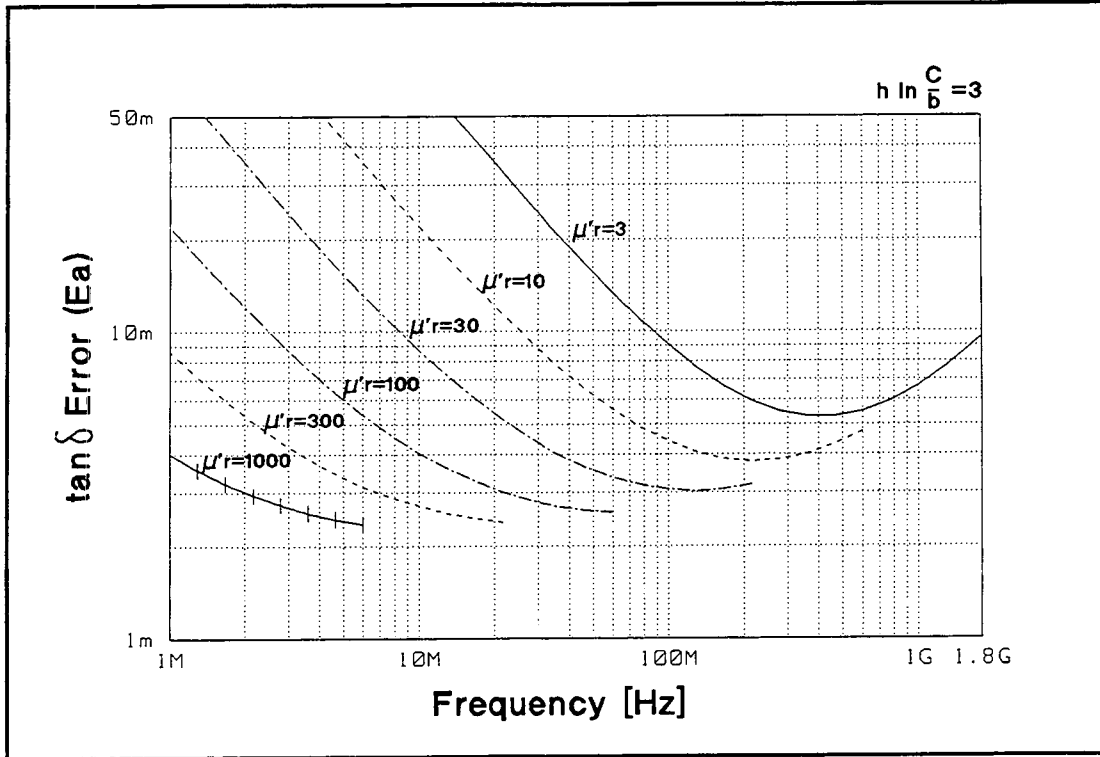


C6600028

Figure 1-21. Typical Permeability Loss Tangent ($\tan \delta$) Measurement Accuracy (@F* = 0.5)

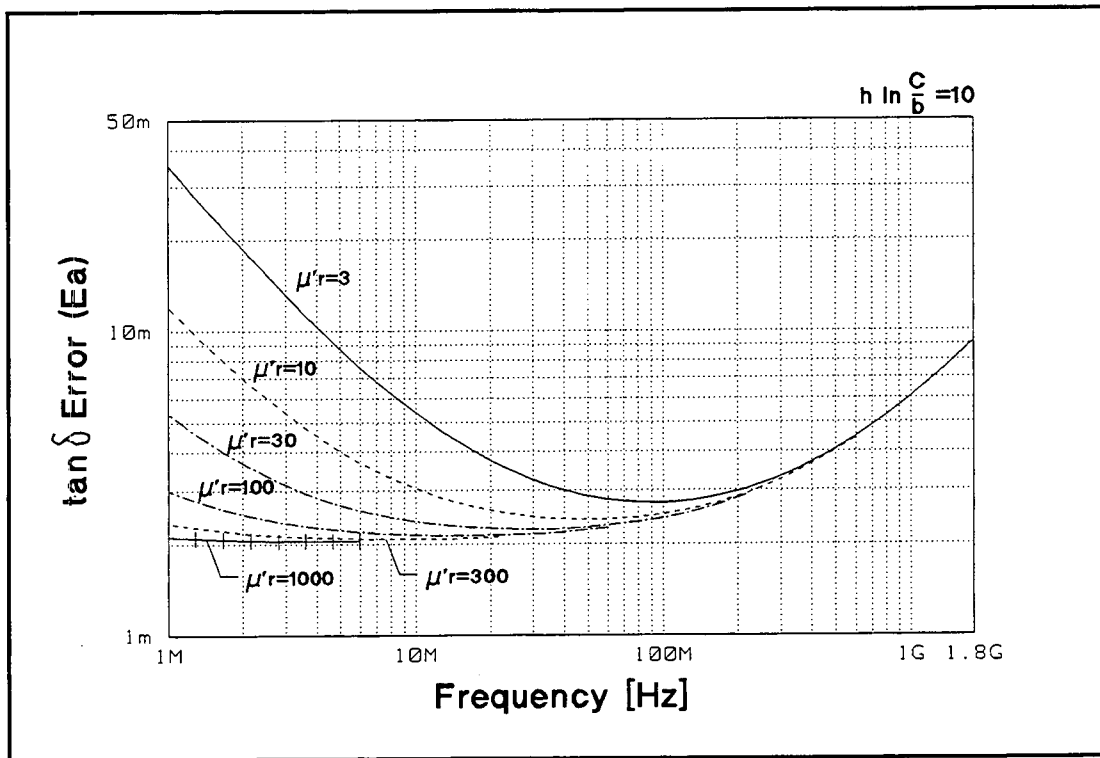
* $F = h \ln \frac{C}{b}$

Option 002 Material Measurement



C660029

Figure 1-22. Typical Permeability Loss Tangent ($\tan\delta$) Measurement Accuracy (@ $F^* = 3$)



C660030

Figure 1-23. Typical Permeability loss Tangent ($\tan\delta$) Measurement Accuracy (@ $F^* = 10$)
 * $F^* = h \ln \frac{C}{b}$

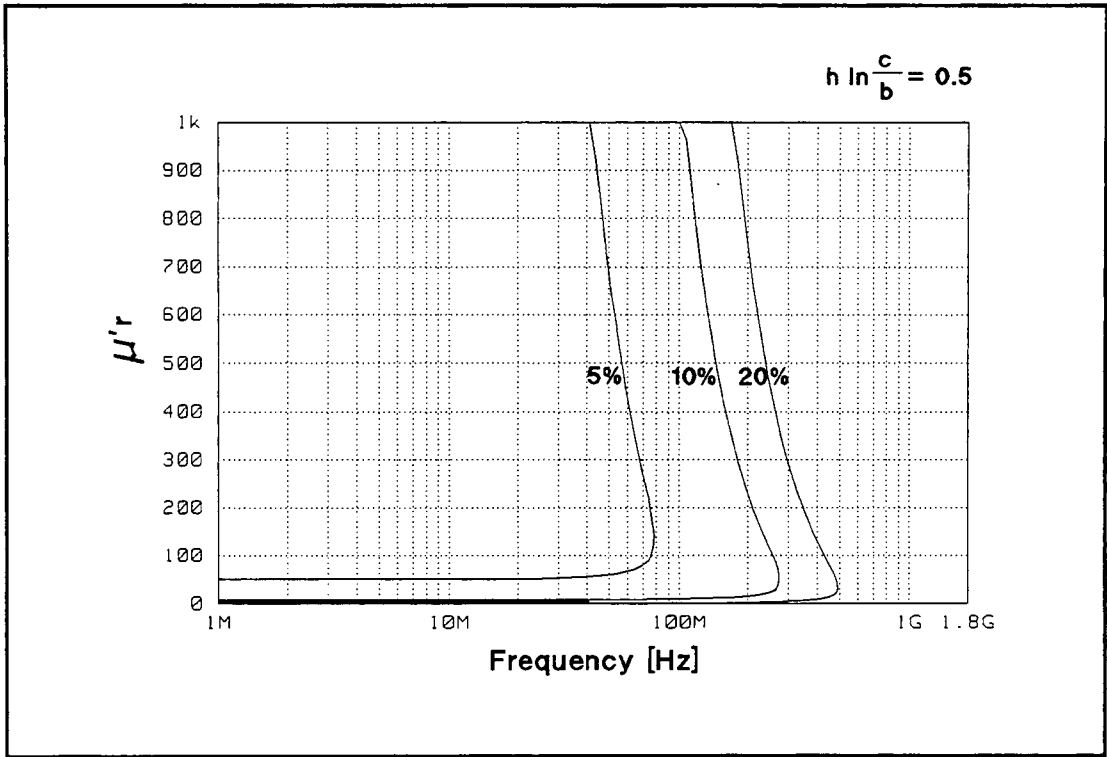


Figure 1-24. Typical Permeability Measurement Accuracy (μ_r v.s. Frequency, @ $F^* = 0.5$)

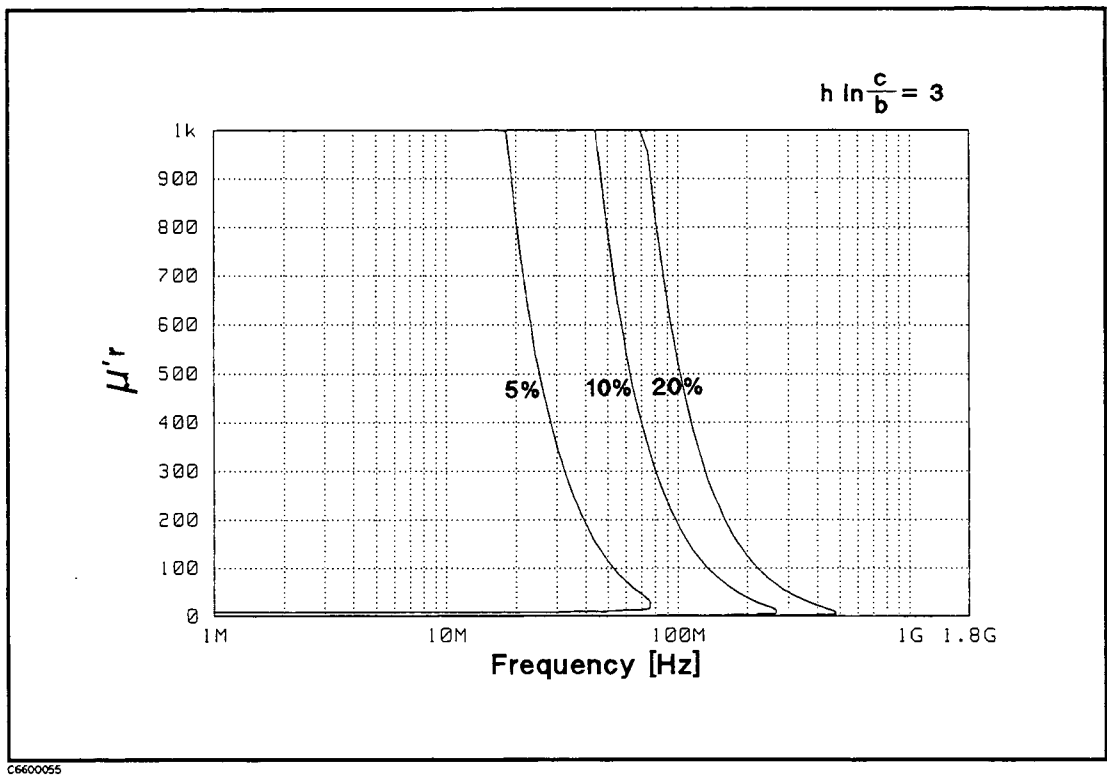
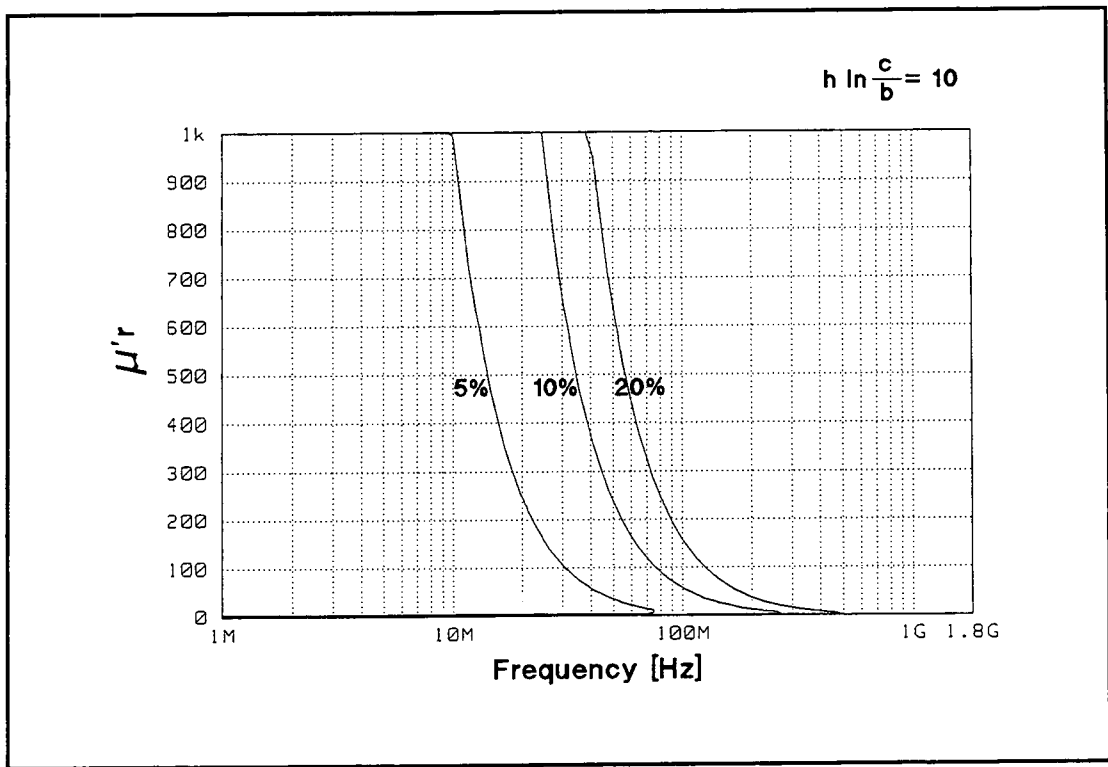


Figure 1-25. Typical Permeability Measurement Accuracy (μ_r v.s. Frequency, @ $F^* = 3$)
 $* F = h \ln \frac{c}{b}$



C6600057

Figure 1-26. Typical Permeability Measurement Accuracy (μ_r v.s. Frequency, @ $F^* = 10$)
 * $F^* = h \ln \frac{c}{b}$

Applicable MUT (Material Under Test) Size See Table 1-3 and Table 1-4

Maximum DC Bias Voltage / Current

@Using with HP 16453A ± 40 V

@Using with HP 16454A ± 500 mA

Operating Temperature

@Using with HP 16453A or HP 16454A -55°C to $+200^{\circ}\text{C}$

Operating Humidity

@ wet bulb temperature $<40^{\circ}\text{C}$

@Using with HP 16453A or HP 16454A up to 95% RH

Table 1-3. Applicable Dielectric Material Size Using with HP 16453A

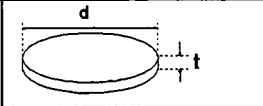
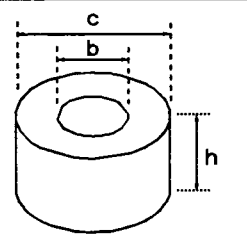
	t	≤ 3 mm
	d	$\geq \phi 15$ mm

Table 1-4. Applicable Magnetic Material Size Using with HP 16454A

	Fixture	Small		Large	
	Holder	A	B	C	D
	c	$\leq \phi 8$ mm	$\leq \phi 6$ mm	$\leq \phi 20$ mm	$\leq \phi 20$ mm
	b	$\geq \phi 3.1$ mm	$\geq \phi 3.1$ mm	$\geq \phi 6$ mm	$\geq \phi 5$ mm
h	≤ 3 mm	≤ 3 mm	≤ 10 mm	≤ 10 mm	

Specifications

Specification for Option 013 and 014 High Temperature Test Heads

Frequency Characteristics

Operating frequency 1 MHz to 1.8 GHz

Source Characteristics

OSC level

Voltage Range

@1 MHz ≤ Frequency < 1 GHz 0.2 mV_{rms} to 500 mV_{rms}

@1 GHz ≤ Frequency ≤ 1.8 GHz 0.2 mV_{rms} 250 mV_{rms}

OSC level resolution

AC voltage resolution

@ 110 mV_{rms} < V_{osc} ≤ 500 mV_{rms} 2 mV

@ 11 mV_{rms} < V_{osc} ≤ 110 mV_{rms} 0.2 mV

@ 1.1 mV_{rms} < V_{osc} ≤ 11 mV_{rms} 20 μV

@ 0.2 mV_{rms} ≤ V_{osc} ≤ 1.1 mV_{rms} 2 μV

AC current resolution

@ 2.75 mA_{rms} < I_{osc} ≤ 12.5 mA_{rms} 50 μA

@ 0.275 mA_{rms} < I_{osc} ≤ 2.75 mA_{rms} 5 μA

@ 27.5 μA_{rms} < I_{osc} ≤ 275 μA_{rms} 0.5 μA

@ 5 μA ≤ I_{osc} ≤ 27.5 μA 0.05 μA

AC power resolution

@ -66.1 dBm ≤ P_{osc} ≤ 1.9 dBm 0.2 dBm max

OSC level accuracy

@ 1 MHz ≤ Frequency ≤ 1GHz, V_{osc} ≤ 0.25 V_{rms} (I_{osc} ≤ 6.3 mA, P_{osc} ≤ -4.1 dBm)
 $A + B + \frac{8_{[dB]} \times frequency_{[MHz]}}{1800}$ dB

where,

A depends on temperature conditions as follows:

within referenced to 23±5°C 4 dB

@ 0°C to 18°C, 28°C to 55°C 6 dB

B depends on OSC level as follows:

@ 0.5 V_{rms} ≥ V_{osc} ≥ 120 mV_{rms} 0 dB

(12.5 mA_{rms} ≥ I_{osc} ≥ 3mA_{rms})

(1.9 dBm ≥ P_{osc} ≥ -10 dBm)

@ 120 mV_{rms} > V_{osc} ≥ 1.2 mV_{rms} 1 dB

(3 mA_{rms} > I_{osc} ≥ 30 μA_{rms})

(-10 dBm > P_{osc} ≥ -50 dBm)

@ 1.2 mV_{rms} > V_{osc} ≥ 0.2 mV_{rms} 2 dB

(30 μA_{rms} > I_{osc} ≥ 5 μA_{rms})

(-50 dBm > P_{osc} ≥ -66.1 dBm)

Output impedance 40 Ω (Nominal value)

Level Monitor

Monitor accuracy

OSC level Same as OSC level accuracy (typical)

DC bias Twice as bad as specifications of dc level accuracy (typical)

Basic Measurement Accuracy

Conditions of accuracy specifications	
■	OPEN/SHORT/50 Ω calibration must be done. Calibration ON.
■	Averaging (on point) factor must be larger than 32 at which calibration is done.
■	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, and within 0°C to 55°C, accuracy is twice as bad as specified.
■	Bending cable should be smooth and the bending angle is less than 30°.
■	Cable position should be kept in the same dposition after calibration measurement.
■	OSC level must be same as level at which calibration is done.
■	OSC level is less than or equal to 0.25 V, or OSC level is greater than 0.25 V and frequency range is within 1 MHz to 1 GHz.

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

Where,

E_a : depends on measurement frequency as follows:

- @ 1 MHz ≤ frequency ≤ 100 MHz 0.6 [%]
- @ 100 MHz < frequency ≤ 500 MHz 0.8 [%]
- @ 500 MHz < frequency ≤ 1 GHz 1.5 [%]
- @ 1 GHz < frequency ≤ 1.8 GHz 3.0 [%]

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

Z_s and **Y₀** depend on number of point averaging (**N_{av}**) and OSC level (**V_{osc}**) as follows:

Z_x : Impedance measurement value [Ω]

Option 013 and 014 High Temperature Test Heads

Table 1-5. Z_0 and Y_0 when High Impedance Test Head is used

Measurement Conditions		Z_0 [Ω]	Y_0 [S]
Number of Point Averaging (N_{av})	OSC Signal Level (V_{osc}) ¹		
$1 \leq N_{av} \leq 7$	$V_{osc} < 0.02$	$\frac{0.02}{V_{osc}} \times (0.2 + 0.001 \times f_{[MHz]})$	$\frac{0.02}{V_{osc}} \times (5 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]})$
	$0.02 \text{ V} \leq V_{osc} < 0.12$	$0.2 + 0.001 \times f_{[MHz]}$	$5 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]}$
	$0.12 \text{ V} \leq V_{osc}$	$0.2 + 0.001 \times f_{[MHz]}$	$3 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]}$
$8 < N_{av}$	$V_{osc} < 0.02$	$\frac{0.02}{V_{osc}} \times (0.1 + 0.001 \times f_{[MHz]})$	$\frac{0.02}{V_{osc}} \times (2 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]})$
	$0.02 \text{ V} \leq V_{osc} < 0.12$	$0.1 + 0.001 \times f_{[MHz]}$	$2 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]}$
	$0.12 \text{ V} \leq V_{osc}$	$0.1 + 0.001 \times f_{[MHz]}$	$1 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]}$

¹ $V_{osc} = 0.12 \text{ V} \equiv I_{osc} = 3 \text{ mA} \equiv P_{osc} = -10 \text{ dBm}$, $V_{osc} = 0.02 \text{ V} \equiv I_{osc} = 0.5 \text{ mA} \equiv P_{osc} = -26 \text{ dBm}$

Table 1-6. Z_0 and Y_0 when Low Impedance Test Head is used

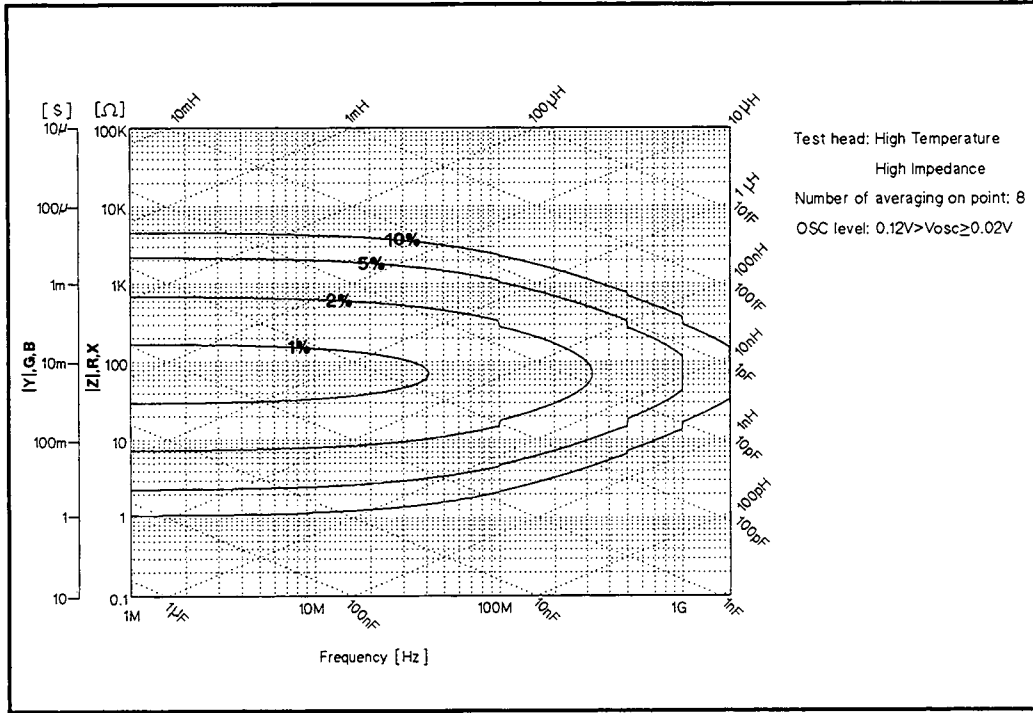
Measurement Conditions		Z_0 [Ω]	Y_0 [S]
Number of Point Averaging (N_{av})	OSC Signal Level (V_{osc}) ¹		
$1 \leq N_{av} \leq 7$	$V_{osc} < 0.02$	$\frac{0.02}{V_{osc}} \times (0.1 + 0.001 \times f_{[MHz]})$	$\frac{0.02}{V_{osc}} \times (1 \times 10^{-4} + 2 \times 10^{-7} \times f_{[MHz]})$
	$0.02 \text{ V} \leq V_{osc} < 0.12$	$0.1 + 0.001 \times f_{[MHz]}$	$1 \times 10^{-4} + 2 \times 10^{-7} \times f_{[MHz]}$
	$0.12 \text{ V} \leq V_{osc}$	$0.05 + 0.001 \times f_{[MHz]}$	$1 \times 10^{-4} + 2 \times 10^{-7} \times f_{[MHz]}$
$8 < N_{av}$	$V_{osc} < 0.02$	$\frac{0.02}{V_{osc}} \times (0.05 + 0.001 \times f_{[MHz]})$	$\frac{0.02}{V_{osc}} \times (3 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]})$
	$0.02 \text{ V} \leq V_{osc} < 0.12$	$0.05 + 0.001 \times f_{[MHz]}$	$3 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]}$
	$0.12 \text{ V} \leq V_{osc}$	$0.03 + 0.001 \times f_{[MHz]}$	$3 \times 10^{-5} + 2 \times 10^{-7} \times f_{[MHz]}$

¹ $V_{osc} = 0.12 \text{ V} \equiv I_{osc} = 3 \text{ mA} \equiv P_{osc} = -10 \text{ dBm}$, $V_{osc} = 0.02 \text{ V} \equiv I_{osc} = 0.5 \text{ mA} \equiv P_{osc} = -26 \text{ dBm}$

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
514.645 MHz	686.19333 MHz	1029.29 MHz	1327.38666 MHz

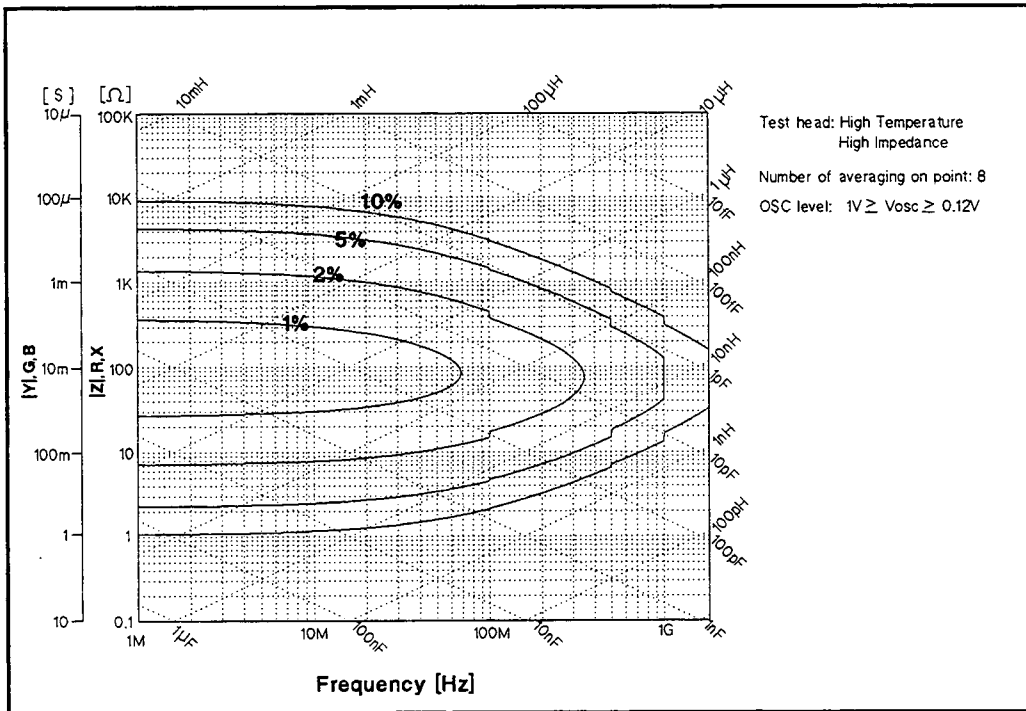
See "EMC" under "Others" in "General Characteristics".

The excessive vibration and shock could occasionally cause measurement errors to exceed specified value.



C6600047

Figure 1-27.
Impedance Measurement Accuracy Using High Temperature High Impedance Test Head (@ Low OSC Level)



C6600037

Figure 1-28.
Impedance Measurement Accuracy Using High Temperature High Impedance Test Head (@ High OSC Level)

Specifications

Option 013 and 014 High Temperature Test Heads

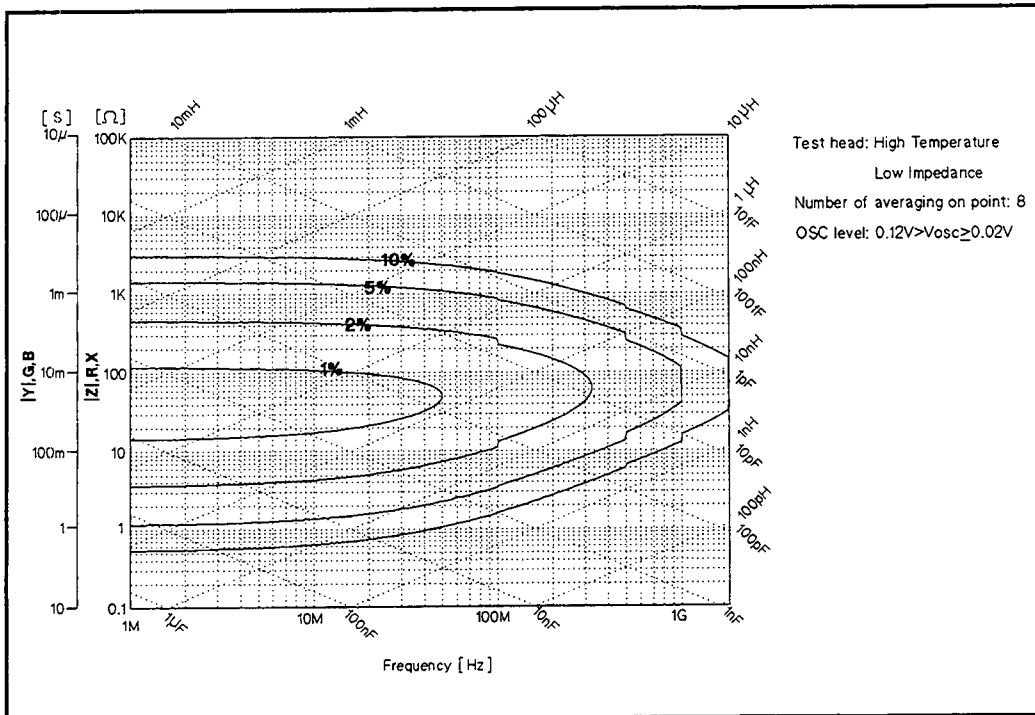


Figure 1-29.

Impedance Measurement Accuracy Using High Temperature Low Impedance Test Head (@ Low OSC Level)

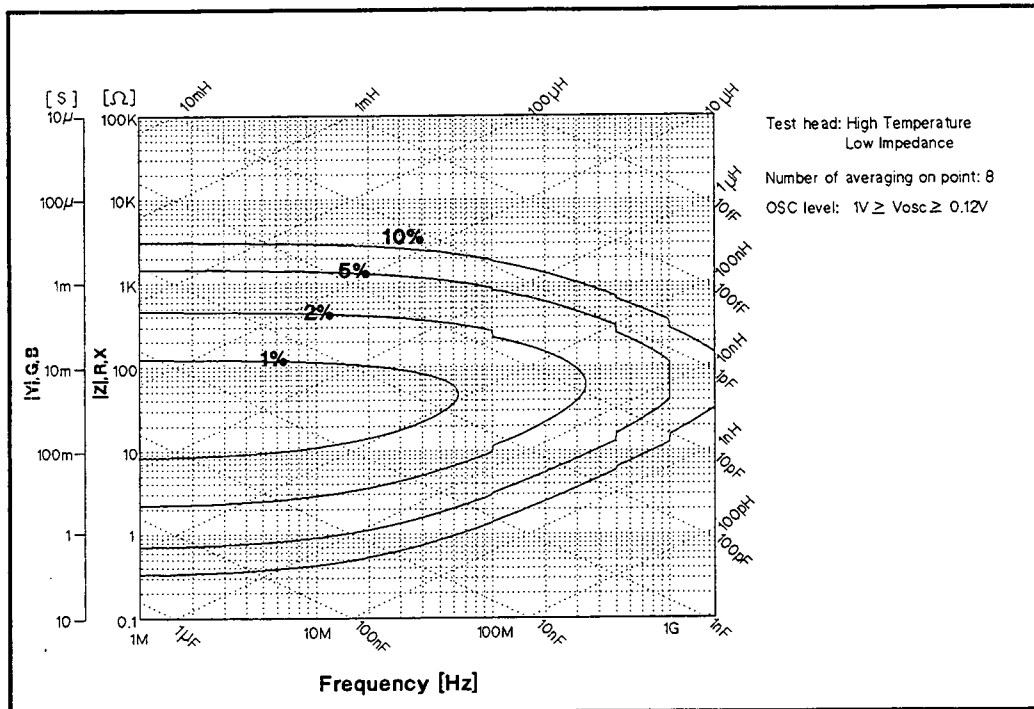


Figure 1-30.

Impedance Measurement Accuracy Using High Temperature Low Impedance Test Head (@ High OSC Level)

Typical Effects of Temperature Drift on Measurement Accuracy

When environment temperature is without $\pm 5^\circ\text{C}$ of temperature at which calibration is done, add the following measurement error.

Conditions of Typical Effects of Temperature Drift
<ul style="list-style-type: none"> ■ Environment temperature of a test head is within -55°C to 0°C or 55°C to 200°C. ■ Environment temperature of the mainframe is within $\pm 5^\circ\text{C}$ of temperature at which calibration is done, and within 0°C to 55°C. ■ Other conditions are as same as the conditions of the basic measurement accuracy of option 013/014.

$|Z|$ Accuracy $\pm(E_{a2} + E_{b2})$ [%]
 θ Accuracy $\pm \frac{(E_{a2} + E_{b2})}{100}$ [rad]

where,

$E_{a2} = (\Delta A_1 \Delta T + \Delta A_2) \times 10^8$
 $E_{b2} = (Z_{s2} / Z_x + Y_{o2} Z_x) \times 100$

ΔA_1 is the effect of temperature drift on the impedance measurement value as follows:
 $(50 + 300 \times f)$ [ppm/ $^\circ\text{C}$] (typical)

ΔA_2 is the hysteresis of the effect of temperature drift on the impedance measurement value as follows:
 $\frac{\Delta A_1 \Delta T}{3}$ [ppm] (typical)

f : Measurement Frequency [GHz]

ΔT : Difference of temperature between measurement condition and calibration measurement condition. [$^\circ\text{C}$]

$Y_{o2} = (\Delta Y_{o1} \Delta T + \Delta Y_{o2}) \times 10^{-6}$ [S]

$Z_{s2} = (\Delta Z_{s1} \Delta T + \Delta Z_{s2}) \times 10^{-3}$ [Ω]

Z_x : Impedance measurement value [Ω]

ΔY_{o1} is the temperature coefficient for OPEN residual as follows:

@ High Temperature High Impedance Test Head is used
 $(0.2 + 8 \times f^2)$ [$\mu\text{S}/^\circ\text{C}$] (typical)

@ High Temperature Low Impedance Test Head is used
 $(1 + 30 \times f)$ [$\mu\text{S}/^\circ\text{C}$] (typical)

ΔY_{o2} is the hysteresis of the OPEN residual as follows:

..... $\frac{\Delta Y_{o1} \Delta T}{3}$ [$\mu\text{S}/^\circ\text{C}$] (typical)

ΔZ_{s1} is the temperature coefficient for SHORT residual as follows:

@ High Temperature High Impedance Test Head is used
 $(4 + 50 \times f)$ [$\text{m}\Omega/^\circ\text{C}$] (typical)

@ High Temperature Low Impedance Test Head is used
 $(1 + 10 \times f^2)$ [$\text{m}\Omega/^\circ\text{C}$] (typical)

ΔZ_{s2} is the hysteresis of the SHORT residual as follows:

..... $\frac{\Delta Z_{s1} \Delta T}{3}$ [$\text{m}\Omega/^\circ\text{C}$] (typical)

Option 013 and 014 High Temperature Test Heads

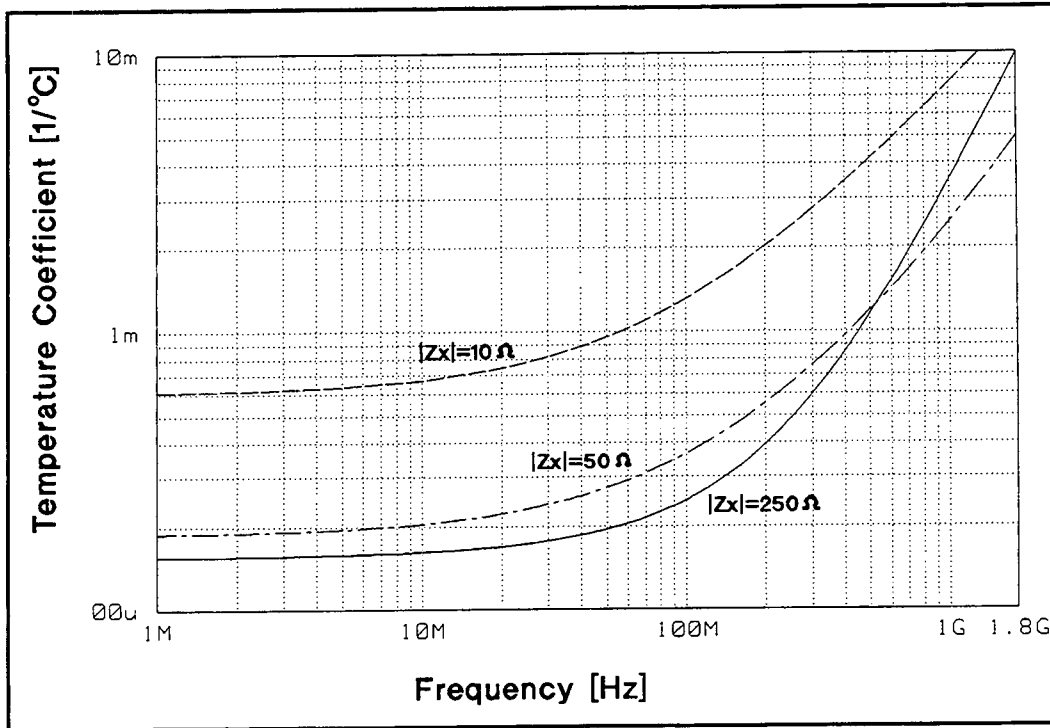


Figure 1-31.

Typical Frequency Characteristics of Temperature Coefficient Using High Temperature High Impedance Test Head

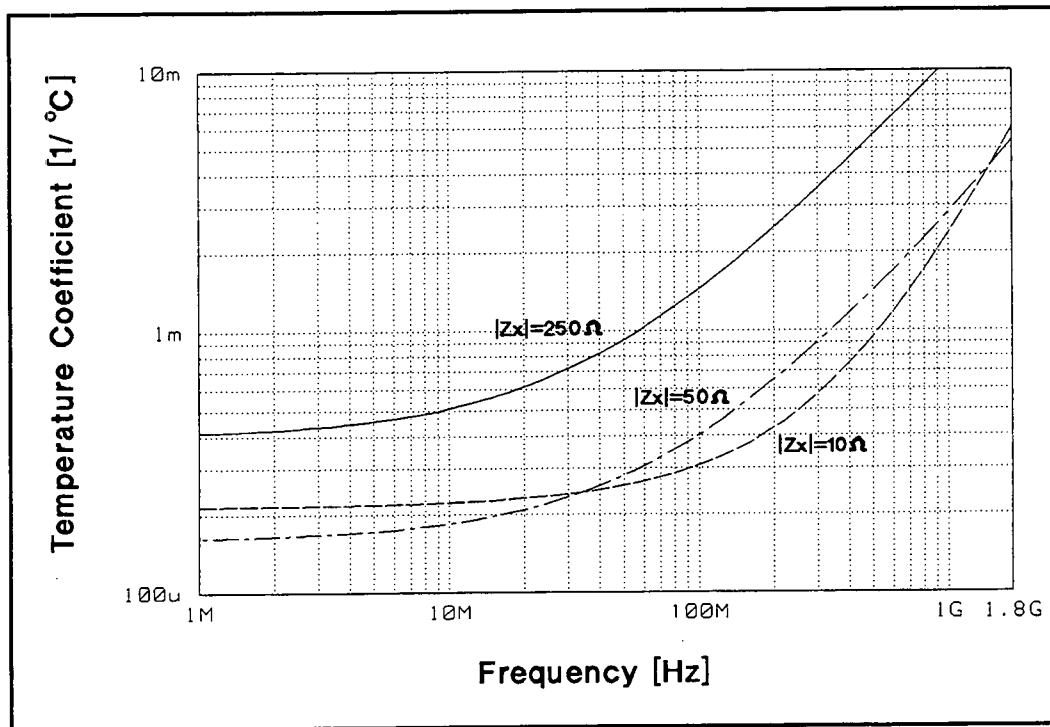


Figure 1-32.

Typical Frequency Characteristics of Temperature Coefficient Using High Temperature Low Impedance Test Head

Operation Conditions of the Test Head

The cable at least 15 cm from the test head must be in the normal condition of the main frame.

.....-55°C to +200°C

Dimensions of High Temperature Test Head

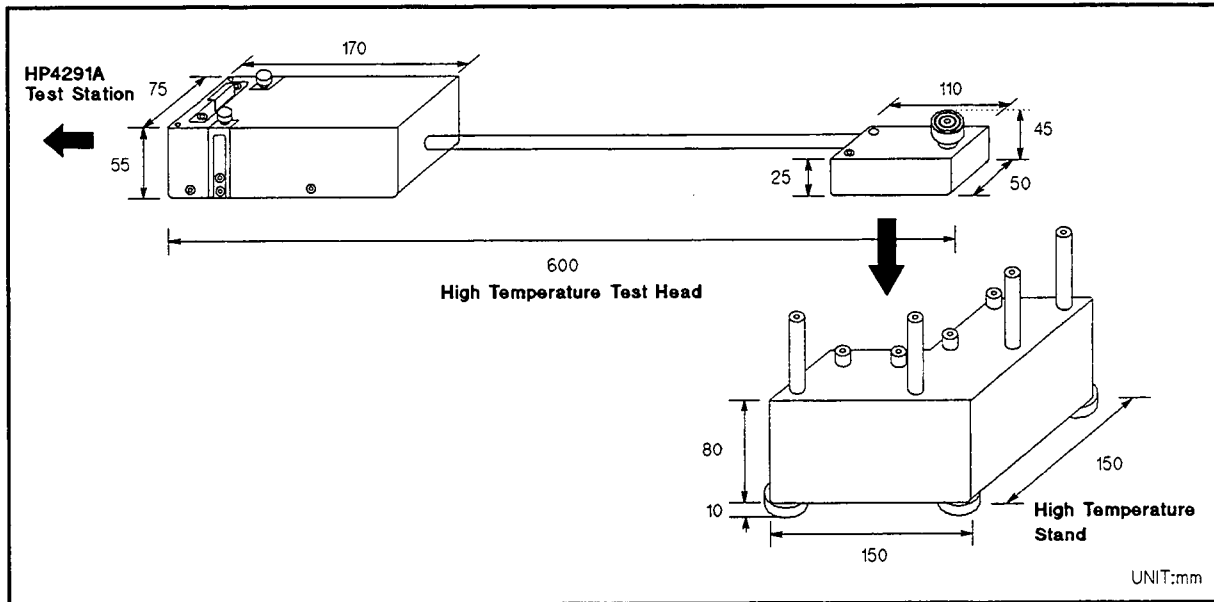


Figure 1-33. Dimensions of High Temperature Test Head

Specifications

Material Measurement Accuracy with High Temperature Test Head (Typical)

Dielectric Material Measurement Accuracy with High Temperature Test Head (Typical)

Conditions of Dielectric Material Measurement Accuracy with High Temperature Test Head
<ul style="list-style-type: none"> ■ Environment temperature is within $\pm 5^{\circ}\text{C}$ of temperature at which calibration is done, and within 0°C to 55°C. ■ High Temperature High Impedance Test Head must be used. ■ Bending cable should be smooth and the bending angle is less than 30°. ■ Cable position should be kept in the same position after calibration measurement. ■ OPEN/SHORT/$50\ \Omega$ calibration must be done. Calibration ON. ■ Measurement points are same as the calibration points. ■ Averaging (on point) factor must be larger than 32 at which calibration is done. ■ Environment temperature is within $+5^{\circ}\text{C}$ to $+50^{\circ}\text{C}$ when calibration is done. ■ OSC level must be same as level at which calibration is done. ■ OSC level is less than or equal to $0.25\ V_{\text{rms}}$, or greater than $0.25\ V_{\text{rms}}$ and frequency range is within 1 MHz to 1 GHz. ■ Environment temperature of the main frame is within $\pm 5^{\circ}\text{C}$ of temperature at which calibration is done, and within 0°C to 55°C.

ϵ_r' Accuracy $\left(\frac{\Delta\epsilon_r'}{\epsilon_r'}\right)$ Same as accuracy at which a normal test head is used

Loss Tangent Accuracy of ϵ_r ($\Delta\tan\delta$) .Same as accuracy at which a normal test head is used

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
514.645 MHz	686.19333 MHz	1029.29 MHz	1327.38666 MHz

See "EMC" under "Others" in "General Characteristics".

The excessive vibration and shock could occasionally cause measurement errors to exceed specified value.

Typical Effects of Temperature Drift on Dielectric Material Measurement Accuracy

When environment temperature is without $\pm 5^\circ\text{C}$ of temperature at which calibration is done, add the following measurement error.

$$\epsilon_r' \text{ Accuracy } \left(\frac{\Delta\epsilon_{rm}'}{\epsilon_{rm}'} \right) \dots\dots\dots E_\epsilon + E_{a3} + E_{b3} [\%]$$

$$\text{Loss Tangent Accuracy of } \epsilon_r \text{ } (\Delta\tan\delta) \dots\dots\dots E_{\tan\delta\epsilon} + \frac{(E_{a3} + E_{b3})}{100}$$

Where,

E_ϵ is ϵ_r' accuracy when a normal test head is used.

$E_{\tan\delta\epsilon}$ is loss tangent accuracy when a normal test head is used.

E_{a3} is the effect of temperature drift on the accuracy as follows:

$$E_{a3} = T_c \Delta T$$

E_{b3} is the hysteresis of the effect of temperature drift on the accuracy as follows:

$$E_{b3} = \frac{T_c \Delta T}{3}$$

where,

T_c is temperature coefficient as follows:

$$T_c = K_1 + K_2 + K_3$$

$$K_1 = 1 \times 10^{-6} \times (50 + 300f)$$

$$K_2 = 3 \times 10^{-6} \times (4 + 50f) \left(\frac{\epsilon_{rm}'}{t} \frac{1}{|1 - (f/f_0)^2|} + 10 \right) f$$

$$K_3 = 5 \times 10^{-3} \times (0.2 + 8f^2) \frac{1}{\left(\frac{\epsilon_{rm}'}{t} \frac{1}{|1 - (f/f_0)^2|} + 10 \right) f}$$

f : Measurement Frequency [GHz]

$$f_0 = \frac{13}{\sqrt{\epsilon_{rm}'}} \text{ [GHz]}$$

t : Thickness of MUT [mm]

ϵ_{rm}' : measured value of ϵ_r'

The illustrations of temperature coefficient T_c are shown in Figure 1-34 to Figure 1-36.

ΔT is difference of temperature between measurement condition and calibration measurement condition as follows:

$$\Delta T = |T_{meas} - T_{cal}|$$

T_{meas} : Temperature of Test Head at measurement condition

Material Measurement Accuracy with High Temperature Test Head

T_{cal} : Temperature of Test Head at calibration measurement condition

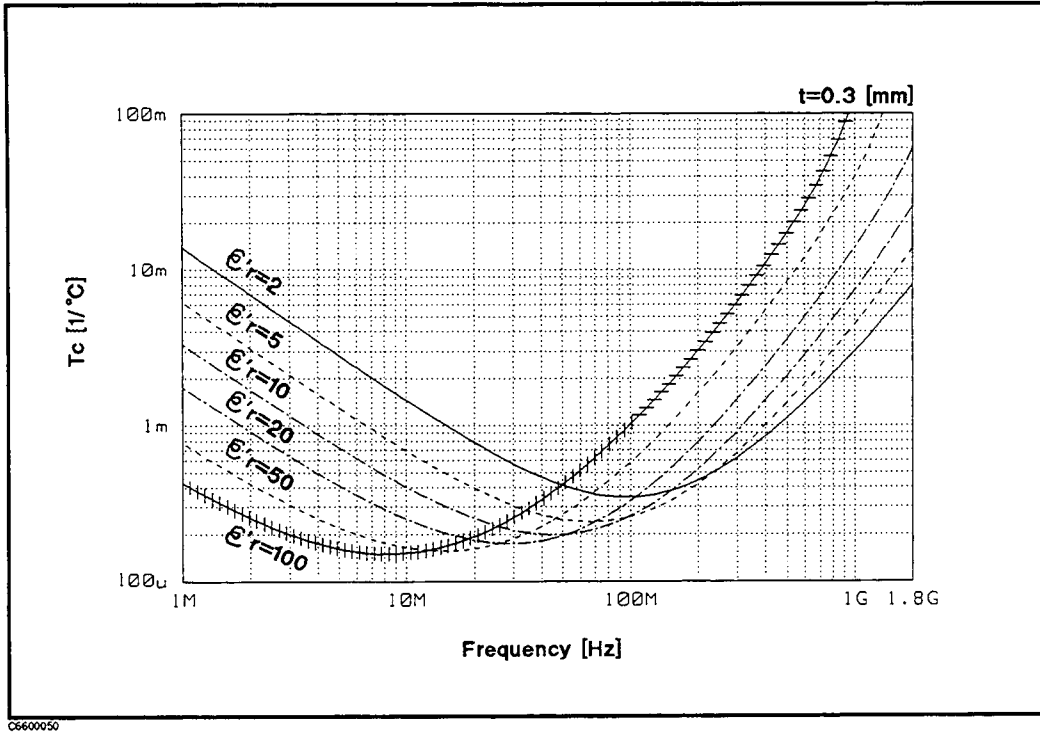


Figure 1-34.
Typical Frequency Characteristics of Temperature Coefficient of ϵ_r' and Loss Tangent Accuracy (Thickness = 0.3 mm)

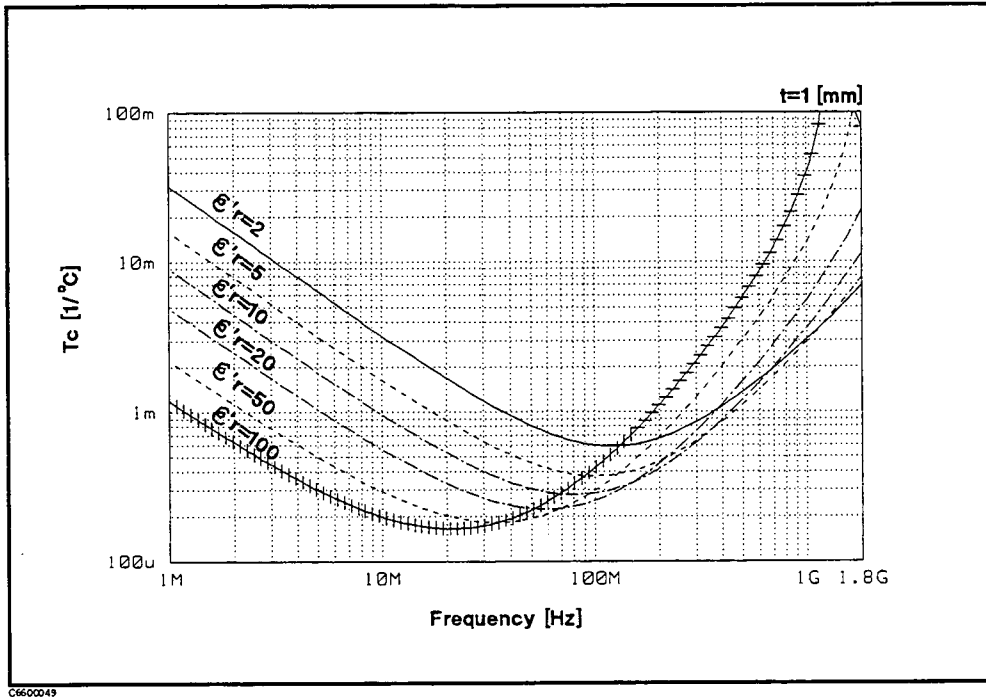


Figure 1-35.
Typical Frequency Characteristics of Temperature Coefficient of ϵ_r' and Loss Tangent Accuracy (Thickness = 1 mm)

Specifications

Material Measurement Accuracy with High Temperature Test Head

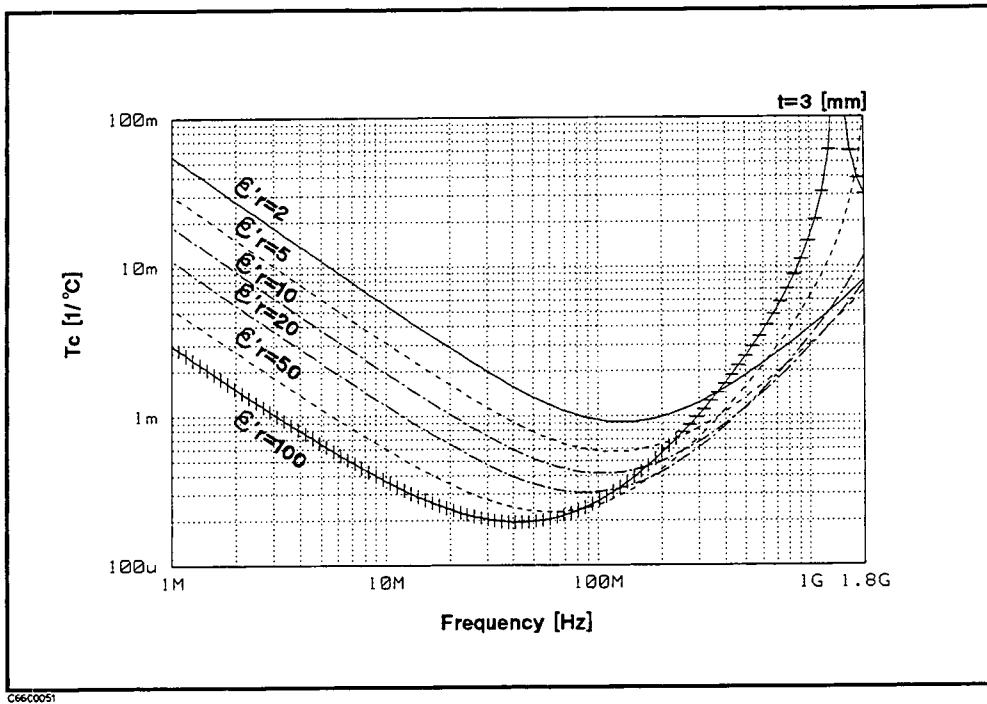


Figure 1-36.

Typical Frequency Characteristics of Temperature Coefficient of ϵ_r' and Loss Tangent Accuracy (Thickness = 3 mm)

Magnetic Material Measurement Accuracy with High Temperature Test Head (Typical)

Conditions of Dielectric Material Measurement Accuracy with High Temperature Test Head
<ul style="list-style-type: none"> ■ Environment temperature is within $\pm 5^{\circ}\text{C}$ of temperature at which calibration is done, and within 0°C to 55°C. ■ High Temperature Low Impedance Test Head must be used. ■ Bending cable should be smooth and the bending angle is less than 30°. ■ Cable position should be kept in the same position after calibration measurement. ■ OPEN/SHORT/$50\ \Omega$ calibration must be done. Calibration ON. ■ Measurement points are same as the calibration points. ■ Averaging (on point) factor must be larger than 32 at which calibration is done. ■ Environment temperature is within $+5^{\circ}\text{C}$ to $+50^{\circ}\text{C}$ when calibration is done. ■ OSC level must be same as level at which calibration is done. ■ OSC level is less than or equal to $0.25 V_{\text{rms}}$, or greater than $0.25 V_{\text{rms}}$ and frequency range is within 1 MHz to 1 GHz. ■ Environment temperature of the main frame is within $\pm 5^{\circ}\text{C}$ of temperature at which calibration is done, and within 0°C to 55°C.

μ_r' Accuracy ($\frac{\Delta\mu_{rm}'}{\mu_{rm}'}$) Same as accuracy at which a normal test head is used

Loss Tangent Accuracy of $\dot{\mu}_r$ ($\Delta\tan\delta$) Same as accuracy at which a normal test head is used

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
514.645 MHz	686.19333 MHz	1029.29 MHz	1327.38666 MHz

See "EMC" under "Others" in "General Characteristics".

The excessive vibration and shock could occasionally cause measurement errors to exceed specified value.

Specifications

Material Measurement Accuracy with High Temperature Test Head

Typical Effects of Temperature Drift on Magnetic Material Measurement Accuracy

When environment temperature is without $\pm 5^\circ\text{C}$ of temperature at which calibration is done, add the following measurement error.

$$\mu_r' \text{ Accuracy } \left(\frac{\Delta\mu_{rm}'}{\mu_{rm}'} \right) \dots\dots\dots E_\mu + E_{a3} + E_{b3}$$

$$\text{Loss Tangent Accuracy of } \dot{\mu}_r (\Delta \tan \delta) \dots\dots\dots E_{\tan \delta \mu} + \frac{(E_{a3} + E_{b3})}{100}$$

Where,

E_μ is μ_r' accuracy at which a normal test head is used.

$E_{\tan \delta \mu}$ is loss tangent accuracy at which a normal test head is used.

E_{a3} is the effect of temperature drift on the accuracy as follows:

$$E_{a3} = T_c \Delta T$$

E_{b3} is the hysteresis of the effect of temperature drift on the accuracy as follows:

$$E_{b3} = \frac{T_c \Delta T}{3}$$

where,

T_c is temperature coefficient as follows:

$$T_c = K_1 + K_2 + K_3$$

$$K_1 = 1 \times 10^{-6} \times (50 + 300f)$$

$$K_2 = 1 \times 10^{-2} \times (1 + 10f^2) \frac{|1 - 0.01\{F(\mu_{rm}' - 1) + 10\}f^2|}{\{F(\mu_{rm}' - 1) + 20\}f}$$

$$K_3 = 2 \times 10^{-6} \times (1 + 30f) \frac{\{F(\mu_{rm}' - 1) + 20\}f}{|1 - 0.01\{F(\mu_{rm}' - 1) + 10\}f^2|}$$

f : Measurement Frequency [GHz]

$$F = h \ln \frac{c}{b} \text{ [mm]}$$

h is the height of MUT [mm]

b is the inner diameter of MUT

c is the outer diameter of MUT

μ_{rm}' is the measured value of permeability

The illustrations of temperature coefficient T_c are shown in Figure 1-37 to Figure 1-39.

ΔT is difference of temperature between measurement condition and calibration measurement condition as follows:

$$\Delta T = |T_{\text{meas}} - T_{\text{cal}}|$$

Material Measurement Accuracy with High Temperature Test Head

T_{meas} : Temperature of Test Head at measurement condition

T_{cal} : Temperature of Test Head at calibration measurement condition

Material Measurement Accuracy with High Temperature Test Head

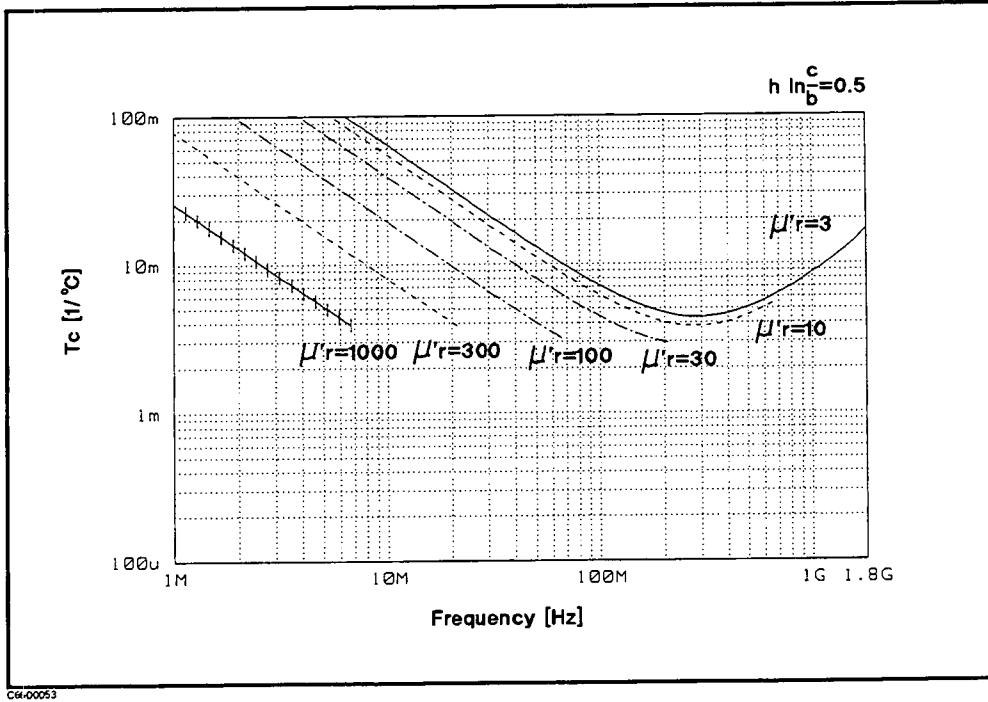


Figure 1-37.

Typical Frequency Characteristics of Temperature Coefficient of μ_r' and Loss Tangent Accuracy ($F^* = 0.5$)

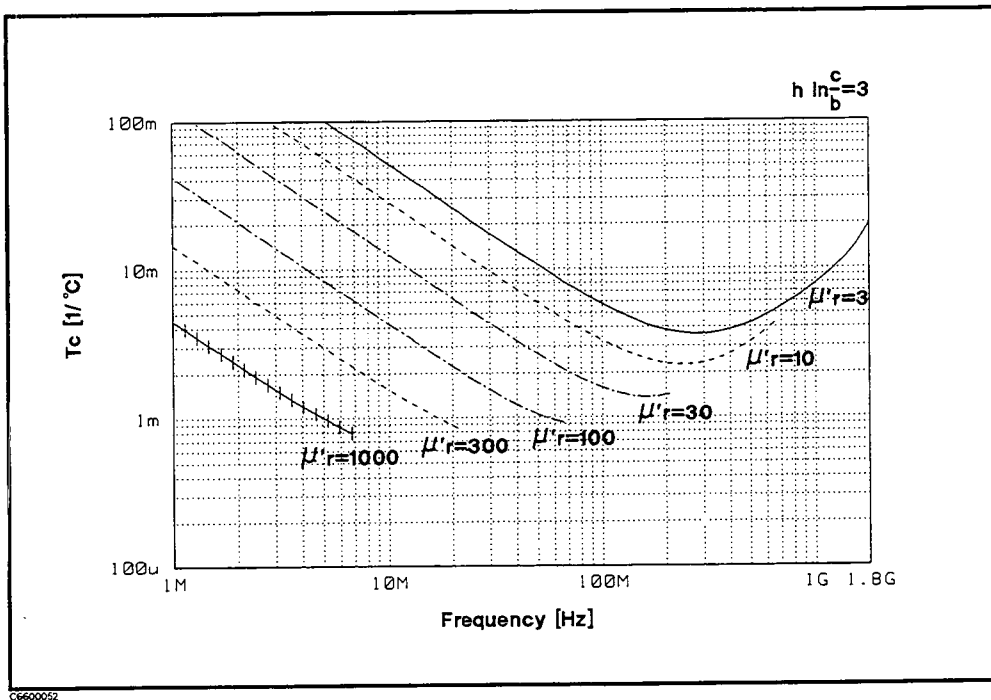
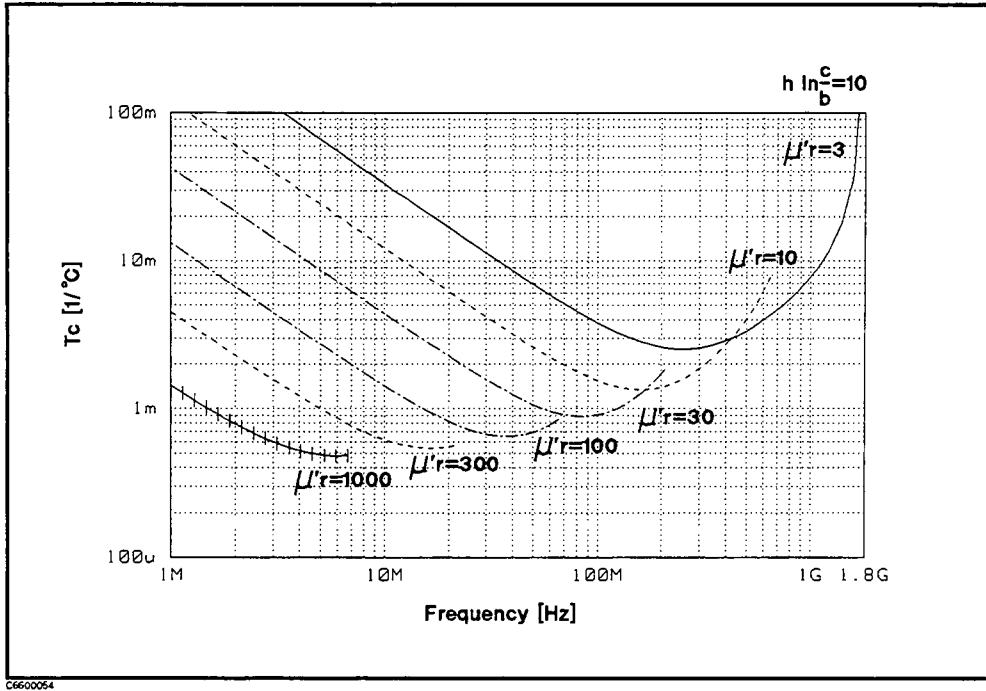


Figure 1-38.

Typical Frequency Characteristics of Temperature Coefficient of μ_r' and Loss Tangent Accuracy ($F^* = 3$)

$$* F^* = h \ln \frac{c}{b}$$

Material Measurement Accuracy with High Temperature Test Head



C6600054

Figure 1-39.
Typical Frequency Characteristics of Temperature Coefficient of μ_r' and Loss Tangent Accuracy ($F^* = 10$)

$$* F^* = h \ln \frac{c}{b}$$

Specifications

Furnished Accessories

Furnished Accessories

Accessory	HP part number
Operating Manual Set	04291-90000
Programming Manual Set	04291-90007
Service Manual ¹	04291-90101
Program Disk Set	04291-61002
Power Cable ²	
50 Ω Termination	04291-65006
0 Ω Termination	04191-85300
0 S Termination	04191-85302
Low-Loss Capacitor	04291-60042
Calibration Kit Carrying Case	04291-60041
APC-7 End Cap	16190-25011
Fixture Stand ³	04291-60121
Pad ³	04291-09001
BNC Adapter ⁴	1250-1859
Keyboard Template ⁵	08751-87111
Keyboard ⁵	HP 46021B #ABA
HP Instrument BASIC User's Handbook Supplement ⁵	04291-90005
HP Instrument BASIC Users Handbook ⁵	E2083-90000
Handle Kit ⁶	5062-3991
Rack Mount Kit ⁷	5062-3979
Rack Mount and Handle Kit ⁸	5062-3985

- 1 Option 0BW only
- 2 The power cable depends on where the instrument is used, see Figure 1-40.
- 3 Option 013 and 014 only
- 4 Option 1D5 only
- 5 Option 1C2 only
- 6 Option 1CN only
- 7 Option 1CM only
- 8 Option 1CP only

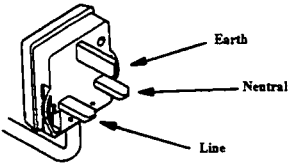
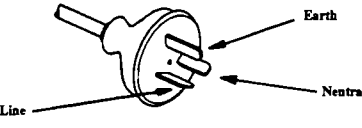
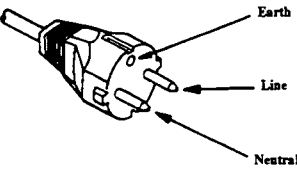
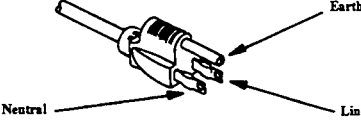
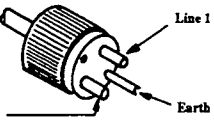
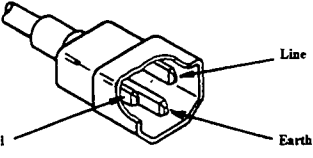
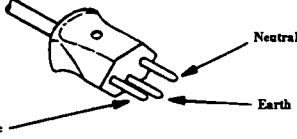
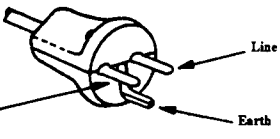
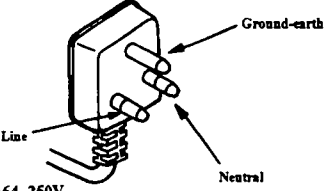
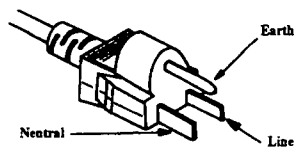
<p>OPTION 900 United Kingdom</p>  <p>Plug : BS 1363A, 250V Cable : HP 8120-1351</p>	<p>OPTION 901 Australia / New Zealand</p>  <p>Plug : NZSS 198/AS C112, 250V Cable : HP 8120-1369</p>
<p>OPTION 902 European Continent</p>  <p>Plug : CEE-VII, 250V Cable : HP 8120-1689</p>	<p>OPTION 903 U.S. / Canada</p>  <p>Plug : NEMA 5-15P, 125V, 15A Cable : HP 8120-1378</p>
<p>OPTION 904 U.S. / Canada</p>  <p>Plug : NEMA 6-15P, 250V, 15A Cable : HP 8120-0698</p>	<p>OPTION 905* Any country</p>  <p>Plug : CEE 22-VI, 250V Cable : HP 8123-1396</p>
<p>OPTION 906 Switzerland</p>  <p>Plug : SEV 1011.1959-24507 Type 12, 250V Cable : HP 8120-2104</p>	<p>OPTION 912 Denmark</p>  <p>Plug : DHCR 107, 220V Cable : HP 8120-2956</p>
<p>OPTION 917 India / Republic of S.Africa</p>  <p>Plug : SABS 164, 250V Cable : HP 8120-4211</p>	<p>OPTION 918 Japan</p>  <p>Plug : JIS C 8303, 125V, 15A Cable : HP 8120-4753</p>
<p>NOTE: Each option number includes a 'family' of cords and connectors of various materials and plug body configurations (straight, 90° etc.).</p> <p>* Plug option 905 is frequently used for interconnecting system components and peripherals.</p>	

Figure 1-40. Power Cables Supplied

HP 4291A RF Impedance/Material Analyzer

Function Reference

SERIAL NUMBERS

This manual applies directly to instruments with serial number prefix JP3KA and above, or whose firmware is version 3.0.
For additional important information about serial numbers, read "Serial Number" in Appendix A of this Manual.



Printed in JAPAN March 1994

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Hyogo, 651-22 Japan

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Manual Printing History

The manual 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.

March 1994. . . . First 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* given elsewhere in this manual 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.

Ground The Instrument

This is a Safety Class 1 product (provided with a protective earth terminal). An uninterruptible safety earth ground must be provided from the main power source to the product input wiring terminals, power source to the product input wiring terminals, power cord, or supplied power cord set. Whenever it is likely that the protection has been impaired, the product must be made inoperative and secured against any unintended operation.

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 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 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 the safety features are maintained.

Dangerous Procedure Warnings

Warning, 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.

Typeface Conventions

Bold	Boldface type is used when a term is defined. For example: icons are symbols.
<i>Italics</i>	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 <i>filename</i> 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 .

Safety Symbols

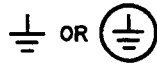
General definitions of safety symbols used on equipment or in manuals.



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



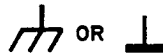
Indicates dangerous voltage (terminals fed from the interior by voltage exceeding 1000 volts must be so marked).



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



Low-noise or noiseless, clean ground (earth) terminal. Used for a signal common, as well as providing protection against electrical shock in case of fault. A terminal marked with this symbol must be connected to ground in the manner described in the installation (Operation) manual, and before operating the equipment.



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



Alternating current (power line).



Direct current (power line).



Alternating or direct current (power line).

Warning



Warning 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



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 damage to or destruction of part or all of the product.

Note



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

How to Use This manual

The Function Reference describes all functions accessed from the front panel keys and softkeys. It also provides information on options and accessories available, and the analyzer features.

Chapter 1 Introduction

Chapter 1 provides overviews of the system and main features of the analyzer.

Chapter 2 Front and Rear Panel

Chapter 2 shows front and rear panel, test station, and test heads with descriptions. This chapter also provides the information on I/O port on the rear panel. The I/O port is furnished with the analyzer which is installed option 1C2.

The following chapter 3 through 8 provides front keys and softkeys reference. Each key and softkey are categorized by the key blocks on the front panel keys.

Chapter 3 Active Channel Block

Chapter 3 describes **Ch1** or **Ch2** keys in the active channel block, which is used to select channel.

Chapter 4 Entry Block

Chapter 4 describes the Entry Block, which is used to enter parameter value to the analyzer or to change setting of the analyzer.

Chapter 5 Measurement Block

Chapter 5 describes **Meas**, **Format**, **Display**, **Scale Ref**, **Cal**, **Bw/Avg** keys in the measurement block, which is used to corneal measurement capability of the analyzer. The equivalent circuit function is also explained in this chapter.

Chapter 6 Stimulus Block

Chapter 6 describes **Sweep**, **Source**, **Trigger**, **Start**, **Stop**, **Center**, and **Span** keys in the Stimulus Block, which is used to control the stimulus source, sweep functions.

Chapter 7 Marker Block

Chapter 7 describes **Marker**, **Search**, **Marker→**, **Utility** keys in the marker block, which is used to control the marker function.

Chapter 8 Instrument State Block

Chapter 8 describes **System**, **Local**, **Preset**, **Copy**, **Save**, and **Recall** keys in the Instrument State block. **System** key section describes the capability to control channel-independent system function; controlling the HP Instrument BASIC capability, adjusting internal clock, turning beeper on/off, controlling, and making limit line and executing limit testing. **Local** key section describes the capability to control HP-IB, **Copy** key section describes making hard copy of the CRT image or listing measurement value or the analyzer setting. **Save** and **Recall** section describes the storage

capability of analyzer and also provides the information on file structure to be saved in a disk.

Chapter 9 Analyzer Features

Chapter 10 shows analyzer's simplified block diagram and explains the data processing flow in the analyzer.

Chapter 10 Options and Accessories Available

Chapter 10 provides the information on the options and accessories available.

Chapter 11 Measurement Basic

Chapter 11 provides basic theory for impedance and material measurements.

Appendix A Manual Changes

Appendix A contains the information required to adapt this manual to earlier version or configurations of the analyzer than the current printing date of this manual.

Appendix B Softkey Trees

Appendix B provides softkey trees accessed from all front panel keys.

Appendix C Input Range and Default Settings

Appendix C lists input ranges, preset values when **Preset** key is pressed or the analyzer receives *RST command through HP-IB, and power ON default setting.

Error Messages

Error messages lists all error messages with an explanations for each error.

Contents

1. Introduction	
Introduction	1-1
System Overview	1-2
Analyzer features	1-4
Front and Rear Panels	1-4
ACTIVE CHANNEL Block	1-4
ENTRY Block	1-4
MEASUREMENT Block	1-4
STIMULUS Block	1-5
MARKER Block	1-5
INSTRUMENT STATE Block	1-6
2. Front and Rear Panel, Test Station, and Test Heads	
Front Panel	2-1
1. Front Panel Keys and Softkeys	2-2
Softkeys that are Joined by Vertical Lines	2-2
Softkeys That Toggle On or Off	2-2
Softkeys that Show Status Indications in Brackets	2-2
2. HP-IB "REMOTE" Indicator	2-3
3. Preset	2-3
4. Test Station Connectors	2-3
5. Built-in Flexible Disk Drive	2-3
6. LINE Switch	2-3
Screen display	2-4
1. Active Channel	2-4
2. Measured parameter	2-5
3. Scale/Div	2-5
4. Reference Level	2-5
5. Marker Data Readout	2-5
6. Level Monitor, Marker Statistics and Width Value	2-5
7. Softkey Labels	2-5
8. Pass/Fail	2-5
9. DC BIAS ON notation	2-6
10. dc Bias Level	2-6
11. Instrument BASIC Status (Run Light)	2-6
12. Stimulus Span/Stop Value	2-6
13. CW Frequency	2-6
14. Stimulus Center/Start Value	2-6
15. OSC Level	2-6
16. Status Notations	2-7
17. Equivalent Circuit Parameters	2-7
18. External Reference	2-7
19. Active Entry Area	2-8
20. Message Area	2-8
21. Title	2-8
Rear Panel Features and Connectors	2-9

Function Reference

1. External Reference Input	2-9
2. Internal Reference Output	2-10
3. External Program RUN/CONT Input (Option 1C2 Only)	2-10
4. I/O Port (Option 1C2 Only)	2-10
5. Power	2-10
6 HP-IB Interface	2-10
7. HP-HIL Keyboard Connector (Option 1C2 Only)	2-10
8. External Trigger Input	2-10
9. Reference Oven Output (Option 1D5 Only)	2-10
I/O Port (Option 1C2 only)	2-11
Test Station	2-13
1. Cable	2-13
2. Test Fixture Mounting Posts	2-13
3. Test Fixture Mounting Screws	2-13
4. Test Head Connectors	2-13
5. Heat Sink	2-14
6. Test Station Mounting Screws	2-14
Test Heads	2-15
1. Connectors	2-15
2. APC-7® Connector	2-15
3. Knobs	2-15
High Impedance Measurement Test Head	2-15
Low Impedance Measurement Test Head (Option 012 only)	2-16
High Temperature High Impedance Test Head (Option 013 only)	2-16
High Temperature Low Impedance Test Head (Option 014 only)	2-16
3. Active Channel Block	
(Ch 1) and (Ch 2)	3-2
Active Channel	3-2
Coupling Channels	3-2
Stimulus Coupling	3-2
Marker Coupling	3-2
4. Entry Block	
Numeric Keypad	4-2
Terminator Keys	4-2
Knob	4-2
(↑) and (↓)	4-2
(Entry Off)	4-3
(Back Space)	4-3
5. Measurement Block	
(Meas)	5-3
Impedance Measurement Menu	5-9
Complex Impedance Measurement Menu	5-11
Dual Parameter Menu	5-12
Impedance Fixture Menu (No option 002)	5-14
Impedance Fixture Menu (Option 002 only)	5-15
Permittivity Measurement Menu (Option 002 only)	5-17
Complex Permittivity Measurement Menu (Option 002 only)	5-19

Dual Parameter Menu (Dielectric Material Measurement)	5-20
Dielectric Material Fixture Menu (Option 002 only)	5-21
Dielectric Material Size Menu (Option 002 only)	5-22
Permeability Measurement Menu (Option 002 only)	5-23
Complex Permeability Measurement Menu (Option 002 only)	5-25
Dual Parameter Menu (Magnetic Material Measurement)	5-26
Magnetic Material Fixture Menu (Option 002 only)	5-27
Magnetic Material Size Menu (Option 002 only)	5-29
Format	5-30
Format Menu	5-30
User Trace Format Menu	5-31
Display	5-32
Display Menu	5-33
Display Allocation Menu	5-36
Data Math Menu	5-38
Equivalent Circuit Menu	5-40
Adjust Display Menu	5-42
Color Adjust Menu	5-44
Label Menu	5-45
Title menu	5-46
User Trace Display Menu	5-47
Scale Ref	5-49
Scale Reference Menu	5-49
User Trace Scale Menu	5-51
Bw/Avg	5-52
Averaging Menu	5-52
Cal	5-54
Calibration Menu	5-55
Fixture Compensation Menu (for Impedance Measurement)	5-57
Fixture Compensation Menu (for Permittivity Measurement)	5-58
Fixture Compensation Menu (for Permeability Measurement)	5-59
Calkit Menu	5-60
CAL KIT	5-60
Compen Kit Menu (for Impedance Measurement Fixture)	5-62
Compen Kit Menu (for Permittivity Measurement Fixture)	5-64
Port Extension Menu	5-66

6. Stimulus Block

Sweep	6-3
Sweep Menu	6-4
List Menu	6-7
Segment Menu	6-9
Source	6-10
Source Menu	6-10
Trigger	6-12
Trigger Menu	6-12
Start Stop Center Span	6-14

7. Marker Block	
Marker	7-3
Marker Menu	7-4
Delta mode menu	7-6
Marker⇒	7-8
Marker→ menu	7-8
Search	7-11
Search Menu	7-12
Target Menu	7-13
Peak Menu	7-14
Search Range Menu	7-16
Widths Menu	7-17
Utility	7-19
Utility Menu	7-19
Marker Function	7-21
Three Types of Markers	7-21
Marker Value	7-21
X-axis Value to be Displayed	7-21
Stimulus Value	7-21
Time	7-21
Relaxation Time ($1/2\pi f$)	7-21
Marker Level Monitor	7-22
OSC level monitor value	7-22
Continuous/Discrete Mode	7-22
Marker on the Data Trace or on the Memory Trace	7-22
Δ Mode	7-22
Marker Search Function	7-23
Width Function	7-23
Width Value	7-24
Peak Definition	7-27
Peak Definition	7-27
8. Instrument State Block	
System	8-3
System Menu	8-4
Instrument BASIC menu	8-5
Memory Partition Menu	8-7
Clock Menu	8-8
Beeper Menu	8-10
Limit Test Menu	8-11
Limit Line Entry Menu	8-14
Local	8-16
Local Menu	8-16
Preset	8-18
Copy	8-19
Copy Menu	8-20
Print Plot Setup Menu	8-23
Select Quadrant Menu	8-24
Define Plot Menu	8-25
Copy Limit Test Menu	8-27
Copy List Sweep Menu	8-27
Screen Menu	8-28
Save	8-29
Save Menu	8-30
Define Save Data Menu	8-32

Define Extension Menu	8-33
Re-Save File Menu	8-34
Purge File Menu	8-35
Purge Yes No Menu	8-35
Initialize Yes No Menu	8-36
Recall	8-37
Recall Menu	8-37
Limit Line Concept	8-38
How Limit Lines are Entered	8-38
Turning Limit Lines and Limit Testing On and Off	8-39
Segment Entering Order	8-40
Saving the Limit Line Table	8-40
Offsetting the Stimulus or Amplitude of the Limit Lines	8-40
Supported Display Formats	8-40
Use a Sufficient Number of Points or Errors May Occur	8-40
Displaying, Printing, or Plotting Limit Test Data	8-40
Results of Plotting or Printing the Display with Limit Lines ON	8-41
HP-IB	8-42
What is HP-IB?	8-42
How HP-IB Works	8-42
Talker	8-42
Listener	8-43
Controller	8-43
HP-IB Requirements	8-43
Analyzer HP-IB Capabilities	8-43
Bus Mode	8-44
System Controller	8-44
Addressable	8-44
Setting Addresses	8-45
Saving and Recalling Instrument States and Data	8-46
Storage Devices	8-46
Disk Requirements	8-46
Disk Formats	8-46
RAM Disk Memory Capacity	8-46
Copy Files Between the RAM Disk and the Flexible Disk	8-46
File Types and Data Groups	8-46
File Types	8-46
Data Groups	8-47
Graphics Images (GRAPHICS)	8-47
File Type and Data Group Combinations	8-47
File Names	8-48
Valid Characters for File Names	8-48
Suffixes (LIF) and Extensions (DOS)	8-48
Auto Recall Function	8-49
File Structure of Internal Data Arrays File for Binary Files	8-49
File Header	8-49
Data Group	8-50
File Structure of Internal Data Arrays File for ASCII File	8-54
Status Block	8-54
Data Block	8-54
File Structure for Single Channel and Dual Channel	8-56

9. Analyzer Features	
Introduction	9-1
System Overview	9-1
Data Processing	9-2
Overview	9-2
Data Processing Flow	9-3
AD converter (ADC)	9-3
Digital Filter	9-3
Ratio Processing	9-4
Fixed Point Calibration Coefficient Arrays and User Defined Point Calibration Coefficient Arrays	9-4
Calibration Coefficient Interpolation	9-4
Calibration Coefficient Arrays	9-4
Error Collection	9-4
Averaging	9-4
Raw Data Arrays	9-4
Port Extension	9-5
Fixture Compensation Coefficient Arrays	9-5
Fixed Point Fixture Compensation Coefficient Arrays and User Defined Point Fixture Compensation Coefficient Arrays	9-5
Compensation Coefficient Interpolation	9-5
Fixture Compensation	9-5
Data Arrays	9-5
Memory Arrays	9-5
Format	9-6
Data Math	9-6
Data Trace Arrays	9-6
Memory Trace Arrays	9-6
Scaling	9-6
10. Options and Accessories	
Introduction	10-1
Options Available	10-1
Option 001 Add dc bias	10-1
Option 002 Add material measurement firmware	10-1
Option 011 Delete high impedance test head	10-1
Option 012 Add low impedance test head	10-1
Option 013 Add high temperature high impedance test head	10-1
Option 014 Add high temperature low impedance test head	10-1
Option 0BW Add Service Manual	10-2
Option 1C2 Add HP IBASIC, HP-HIL keyboard and cable	10-2
Option 1D5 Add high stability frequency reference	10-2
Option 1CM Rack mount kit	10-2
Option 1CN Handle Kit	10-2
Option 1CP Rack mount and handle kit	10-2
Measurement accessories available	10-3
HP 16191A Side electrode SMD test fixture	10-3
HP 16192A Parallel electrode SMD test fixture	10-3
HP 16193A Small side electrode SMD test fixture	10-3
HP 16194A High temperature component fixture	10-3
HP 16453A Dielectric material test fixture	10-3
HP 16454A magnetic material test fixture	10-3

HP 16091A Coaxial termination fixture set	10-3
HP 16092A Spring clip test fixture	10-4
HP 16093A/B Binding post test fixtures	10-4
HP 16094A Probe test fixture	10-4
System accessories available	10-4
System rack	10-4
Plotter and printer	10-4
HP-IB cable	10-5
Disks	10-5
Service Accessories Available	10-5
Collet removing tool (HP part number 5060-0236)	10-5
Collet removing tool guide (HP part number 04291-21002)	10-5
6-Slot collet (HP part number 85050-20001)	10-5

11. Impedance Measurement Basics

Impedance parameters	11-3
Impedance (Z)	11-3
Admittance (Y)	11-4
Reflection Coefficient (Γ)	11-5
Series and Parallel Circuit Models	11-6
Parallel-Series Equivalent Circuit Conversion	11-6
Selecting Circuit Mode of Capacitance	11-7
Small Capacitance	11-7
Large Capacitance	11-8
Selecting Circuit Mode of Inductance	11-8
Large Inductance	11-8
Small Inductance	11-9
Smith Chart	11-10
Calibration Concepts	11-12
OPEN SHORT LOAD Calibration	11-12
Ideal Measurement Circuit	11-12
General Impedance Measurement Schematic	11-13
Low Loss Capacitor Calibration	11-14
Port Extension	11-16
Fixture Compensation	11-19
Actual Measuring Circuit	11-19
Residual Parameter Effects	11-19
Characteristics of Test Fixture	11-20
Electrical Length of Coaxial Coupling Terminal Section	11-20
Elimination of Electrical Length Effects in Test Fixture	11-20
Residual and Stray Parameters of Contact Electrode Section	11-20
Elimination of Residual Parameter Effects in Test Fixture (Fixture Compensation)	11-21
Compensation Coefficient for Each Compensation	11-22
OPEN Compensation	11-22
SHORT Compensation	11-22
LOAD Compensation	11-23
OPEN-SHORT Compensation	11-23
OPEN-LOAD Compensation	11-24
SHORT-LOAD Compensation	11-24
OPEN-SHORT-LOAD Compensation	11-24

Permittivity Measurements	11-26
Complex Permittivity	11-26
Characteristics of Test Fixture	11-27
Edge Effect	11-27
Residual Parameter	11-28
Permeability Measurements	11-29
Complex Permeability	11-30
Characteristics of the Test Fixture	11-31
Residual Parameter	11-31
Elimination of Residual Impedance Effects in the Test Fixture (SHORT Fixture Compensation)	11-31
Impedance Parameter Value Displayed for Magnetic Material Measurement	11-32
A. Manual Changes	
Introduction	A-1
Manual Changes	A-1
Serial Number	A-2
B. Softkey Tree	
Measurement Block	B-1
Meas	B-2
Format	B-8
Display	B-9
Scale Ref	B-11
Bw/Avg	B-12
Cal	B-13
Stimulus Block	B-14
Source	B-14
Sweep	B-15
Trigger	B-16
Marker Block	B-17
Marker	B-17
Marker→	B-18
Search	B-19
Utility	B-20
Instrument State Block	B-21
Local	B-21
System	B-22
Copy	B-23
Save	B-24
Recall	B-25
C. Input Range and Default Setting	
Meas	C-2
Format	C-2
Display	C-3
Scale Ref	C-4
Bw/Avg	C-6
Cal	C-6
Cal (ϵ)	C-7
Cal (μ)	C-7
Sweep	C-8
Source	C-8
Trigger	C-8

Start , Stop , Center , Span	C-9
Marker	C-9
Marker →	C-10
Search	C-10
Utility	C-10
System	C-11
Local	C-12
Copy	C-12
Save	C-12

Messages

Index

Figures

1-1. HP 4291A System Overview	1-2
1-2. Test Fixtures	1-2
1-3. Material Test Fixtures for Option 002	1-3
1-4. High Temperature Test Heads and High Temperature Test Fixtures for Option 013/014	1-3
2-1. Analyzer Front Panel	2-1
2-2. Screen Display (Single Channel, Cartesian Format)	2-4
2-3. Analyzer Rear Panel	2-9
2-4. Pin Assignment of I/O Port	2-11
2-5. Circuit of I/O Port	2-12
2-6. Test Station	2-13
2-7. Keeping Space Around the Heat Sink	2-14
2-8. Dimensions of Test Station	2-14
2-9. Test Heads	2-15
3-1. Active Channel Keys	3-1
4-1. Entry Block	4-1
5-1. Measurement Block	5-1
5-2. Softkey Menus Accessed from the Meas Key for Impedance Measurement	5-3
5-3. Softkey Menus Accessed from the Meas Key for Permittivity Measurement	5-4
5-4. Softkey Menus Accessed from the Meas Key for Permeability Measurement	5-5
5-5. Softkey Menus Accessed from the Meas Key for Impedance Measurement (when Smith/Polar/Admittance or Complex-Plane Format is selected)	5-6
5-6. Softkey Menus Accessed from the Meas Key for Permittivity Measurement (when Smith/Polar/Admittance or Complex-Plane Format is selected)	5-7
5-7. Softkey Menus Accessed from the Meas Key for Permeability Measurement (when Smith/Polar/Admittance or Complex-Plane Format is selected)	5-8
5-8. Impedance Measurement Menu	5-9
5-9. Complex Impedance Measurement Menu	5-11
5-10. Dual Parameter Menu	5-12
5-11. Impedance Fixture Menu (No option 002)	5-14
5-12. Impedance Fixture Menu (Option 002 only)	5-15
5-13. Permittivity Measurement Menu (Option 002 only)	5-17
5-14. Complex Permittivity Measurement Menu (Option 002 only)	5-19
5-15. Dual Parameter Menu (Dielectric Material Measurement)	5-20
5-16. Dielectric Material Fixture Menu (Option 002 only)	5-21

5-17. Dielectric Material Size Menu (Option 002 only)	5-22
5-18. Dielectric Material Size	5-22
5-19. Permeability Measurement Menu (Option 002 only) . .	5-23
5-20. Complex Permeability Measurement Menu (Option 002 only)	5-25
5-21. Dual Parameter Menu (Magnetic Material Measurement)	5-26
5-22. Magnetic Material Fixture Menu (Option 002 only) . .	5-27
5-23. Magnetic Material Size Menu (Option 002 only)	5-29
5-24. Magnetic Material Size	5-29
5-25. Format Menu	5-30
5-26. User Trace Format Menu	5-31
5-27. Softkey Menu Accessed from Display Key	5-32
5-28. Display Menu	5-33
5-29. Display Allocation Menu	5-36
5-30. Display Allocations	5-37
5-31. Data Math Menu	5-38
5-32. Equivalent Circuit Menu	5-40
5-33. Adjust Display Menu	5-42
5-34. Color Adjust Menu	5-44
5-35. Label Menu	5-45
5-36. Title Menu	5-46
5-37. User Trace Display Menu	5-47
5-38. Scale Reference Menu	5-49
5-39. User Trace Scale Menu	5-51
5-40. Averaging Menu	5-52
5-41. Softkey Menu Accessed from Cal key	5-54
5-42. Calibration Menu	5-55
5-43. Fixture Compensation Menu	5-57
5-44. Fixture Compensation Menu (for Permittivity Measurement)	5-58
5-45. Fixture Compensation Menu (for Permeability Measurement)	5-59
5-46. Calkit Menu	5-60
5-47. Calibration Standard Model	5-61
5-48. Compen Kit Menu (for Impedance Measurement Fixture)	5-62
5-49. Parameters of OPEN, SHORT, and LOAD for the Impedance Fixture Compensation	5-63
5-50. Compen Kit Menu (for Permittivity Measurement Fixture)	5-64
5-51. Parameters of LOAD for the Permittivity Fixture Compensation	5-65
5-52. Port Extension Menu	5-66
6-1. Stimulus Block	6-1
6-2. Softkey Menus Accessed from the Sweep Key	6-3
6-3. Sweep Menu	6-4
6-4. Sweep Delay Time and Point Delay Time	6-5
6-5. List Menu	6-7
6-6. Segment Menu	6-9
6-7. Softkey Menus Accessed from the Source Key	6-10
6-8. Softkey Menus Accessed from the Trigger Key	6-12
7-1. Marker Block	7-1
7-2. Softkey Menus Accessed from the Marker Key	7-3
7-3. Marker Menu	7-4
7-4. Delta Mode Menu	7-6

7-5. Marker→ Menu	7-8
7-6. Softkey Menus Accessed from the Search Key	7-11
7-7. Search Menu	7-12
7-8. Target Menu	7-13
7-9. Peak Menu	7-14
7-10. Search Range Menu	7-16
7-11. Widths Menu	7-17
7-12. Utility Menu	7-19
7-13. Bandwidth Search Example	7-24
7-14. Q Measurement Examples	7-26
7-15. Peak Definition	7-27
8-1. Instrument State Block	8-1
8-2. Softkey Menus Accessed from the System Key	8-3
8-3. System Menu	8-4
8-4. Instrument BASIC Menu	8-5
8-5. Memory Partition Menu	8-7
8-6. Clock Menu	8-8
8-7. Beeper Menu	8-10
8-8. Limit Test Menu	8-11
8-9. Limit Line Entry Menu	8-14
8-10. Local Menu	8-16
8-11. Softkey Menus Accessed from the Copy Key	8-19
8-12. Copy Menu	8-20
8-13. Print Plot Setup Menu	8-23
8-14. Select Quadrant Menu	8-24
8-15. Define Plot Menu	8-25
8-16. Full, Upper, and Lower Graticule	8-26
8-17. Copy Limit Test Menu	8-27
8-18. Copy List Sweep Menu	8-27
8-19. Screen Menu	8-28
8-20. Softkey Menus Accessed from the Save Keys	8-29
8-21. Save Menu	8-30
8-22. Define Save Data Menu	8-32
8-23. Define Extension Menu	8-33
8-24. Re-Save File Menu	8-34
8-25. Purge File Menu	8-35
8-26. Purge Yes No Menu	8-35
8-27. Initialize Yes No Menu	8-36
8-28. Recall Menu	8-37
8-29. The Concept of Segments as a Point between Two Sets of Limit Lines	8-38
8-30. Analyzer Bus Concept	8-45
8-31. File Header Structure	8-49
8-32. RAW, DATA, and DATA-TRACE Data Group Structure	8-50
8-33. CAL Data Group Structure	8-51
8-34. MEMORY and MEMORY TRACE Data Group Structure	8-52
8-35. User Trace Data Group Structure	8-53
9-1. Analyzer Simplified Block Diagram	9-1
9-2. Data Processing	9-3
11-1. Definition of Impedance	11-3
11-2. Vector Representation of Admittance	11-5
11-3. Small Capacitance Circuit Mode Selection	11-7
11-4. Large Capacitance Circuit Mode Selection	11-8
11-5. Large Inductance Circuit Mode Selection	11-9
11-6. Small Inductance Circuit Mode Selection	11-9

11-7.	Smith Chart	11-10
11-8.	Impedance Read-out	11-11
11-9.	Phase Sift by Transmission Line	11-11
11-10.	Measurement Circuits for I-V Method	11-12
11-11.	General Schematic for Impedance Measurement Using Two Vector Voltmeters	11-13
11-12.	Modifying the Standard Value of a 50 Ω LOAD using a Low-Loss Air-Capacitor	11-15
11-13.	Port Extension	11-16
11-14.	Residual Parameters in the Circuit	11-19
11-15.	Characteristics of Test Fixture	11-20
11-16.	Test Fixture Represented by the F matrix of a Two Terminal Pair Network	11-21
11-17.	Schematic Electrode Structure of the HP 16453A	11-26
11-18.	Material has some loss	11-26
11-19.	Edge Effect	11-27
11-20.	Basic Relationship of Magnetic Flux Density, Magnetic Flux, and Current	11-29
11-21.	Schematic Fixture Structure of HP 16454A	11-29
11-22.	Material Has Loss	11-30
11-23.	Residual Impedance of the HP 16454A	11-31
A-1.	Serial Number Plate	A-2
B-1.	Softkey Menus Accessed from the Meas Key for Impedance Measurement	B-2
B-2.	Softkey Menus Accessed from the Meas Key for Permittivity Measurement	B-3
B-3.	Softkey Menus Accessed from the Meas Key for Permeability Measurement	B-4
B-4.	Softkey Menus Accessed from the Meas Key for Impedance Measurement (when Smith/Polar/Admittance or Complex-Plane Format is selected)	B-5
B-5.	Softkey Menus Accessed from the Meas Key for Permittivity Measurement (when Smith/Polar/Admittance or Complex-Plane Format is selected)	B-6
B-6.	Softkey Menus Accessed from the Meas Key for Permeability Measurement (when Smith/Polar/Admittance or Complex-Plane Format is selected)	B-7
B-7.	Softkey Menus Accessed from the Format	B-8
B-8.	Softkey Menus Accessed from the Format When User Trace is Turned ON	B-8
B-9.	Softkey Menus Accessed from the Display Key	B-9
B-10.	Softkey Menus Accessed from the Display Key When User Trace is Turned ON	B-10
B-11.	Softkey Menus Accessed from the Scale Ref Key	B-11
B-12.	Softkey Menus Accessed from the Scale Ref Key When User Trace is Turned ON	B-11
B-13.	Softkey Menus Accessed from the Bw/Avg Key	B-12
B-14.	Softkey Menus Accessed from the Cal Key	B-13
B-15.	Softkey Menus Accessed from the Source Key	B-14
B-16.	Softkey Menus Accessed from the Sweep Key	B-15
B-17.	Softkey Menus Accessed from the Trigger Key	B-16
B-18.	Softkey Menus Accessed from the Marker Key	B-17

B-19. Softkey Menus Accessed from the Marker→ Key . . .	B-18
B-20. Softkey Menus Accessed from the Search Key . . .	B-19
B-21. Softkey Menus Accessed from the Utility Key . . .	B-20
B-22. Softkey Menus Accessed from the Local Key . . .	B-21
B-23. Softkey Menus Accessed from the System Key . . .	B-22
B-24. Softkey Menus Accessed from the Copy key . . .	B-23
B-25. Softkey Menus Accessed from the Save Key . . .	B-24
B-26. Softkey Menus Accessed from the Recall Key . . .	B-25

Tables

5-1. Equivalent Circuit Selection Guide	5-41
8-1. List Value Format	8-21
8-2. Contents of ASCII Files	8-55
8-3. Data Groups and Data Array Names	8-56
11-1. Parallel/Series Circuit Model and Measurement Parameter	11-6
11-2. Dissipation Factor Equations and Parallel-Series Equivalent Circuit Conversion	11-7
A-1. Manual Changes by Serial Number	A-1
A-2. Manual Changes by Firmware Version	A-1

Function Reference

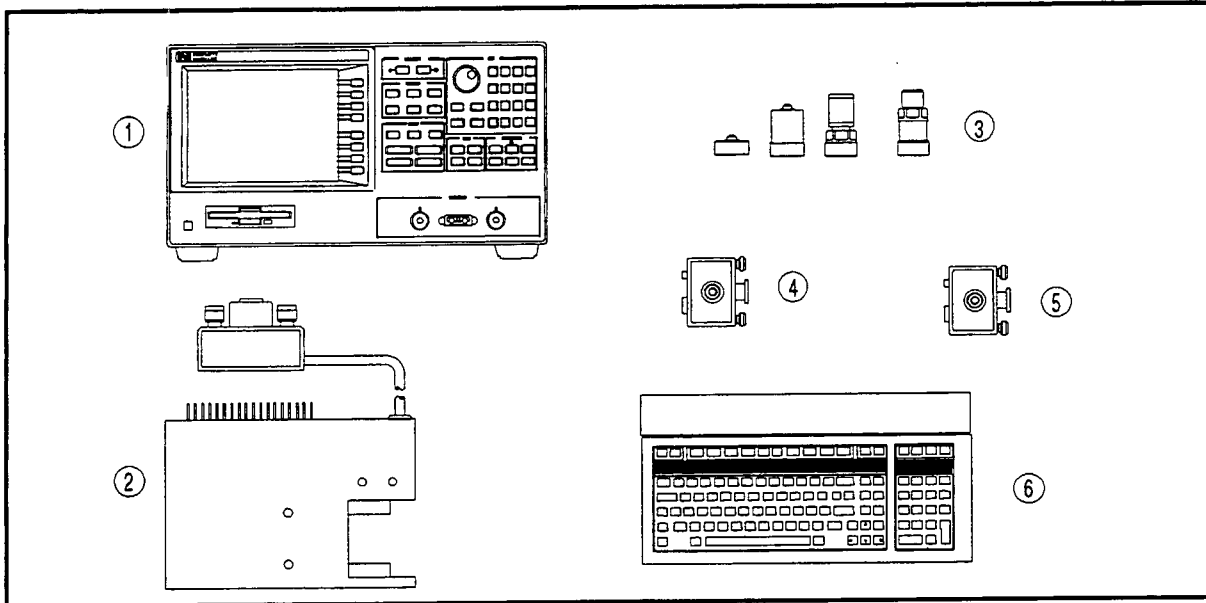
Introduction

Introduction

This chapter provides an overview of the HP 4291A system and descriptions of the main features of the analyzer (also referred to as the main frame). The system includes the analyzer, test station, test heads, fixtures, and keyboard. The analyzer features include the front and rear panels and the six key blocks. The front and rear panel sections provide information on the input/output connectors, the CRT, and other panel features. The six key block sections describe the keys and their associated menus and how they function together.

System Overview

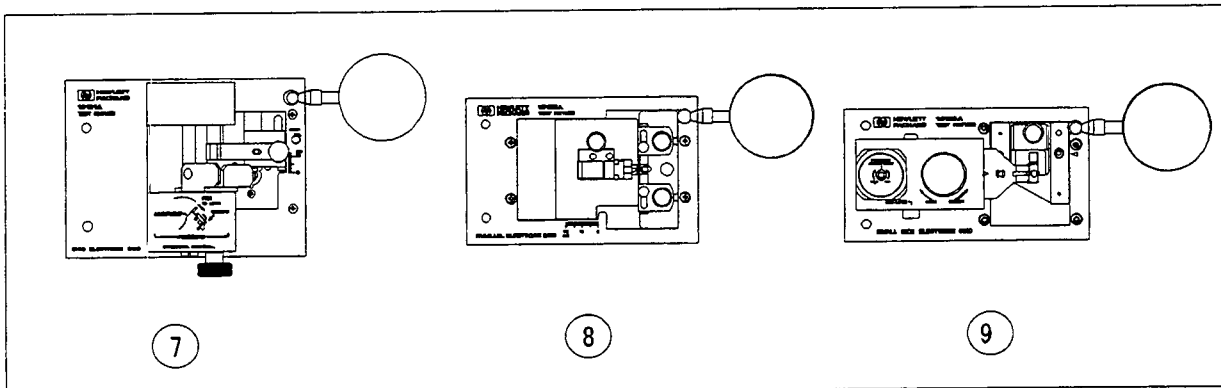
The HP 4291A system is shown in Figure 1-1, Figure 1-2, and Figure 1-3.



CS001001

Figure 1-1. HP 4291A System Overview

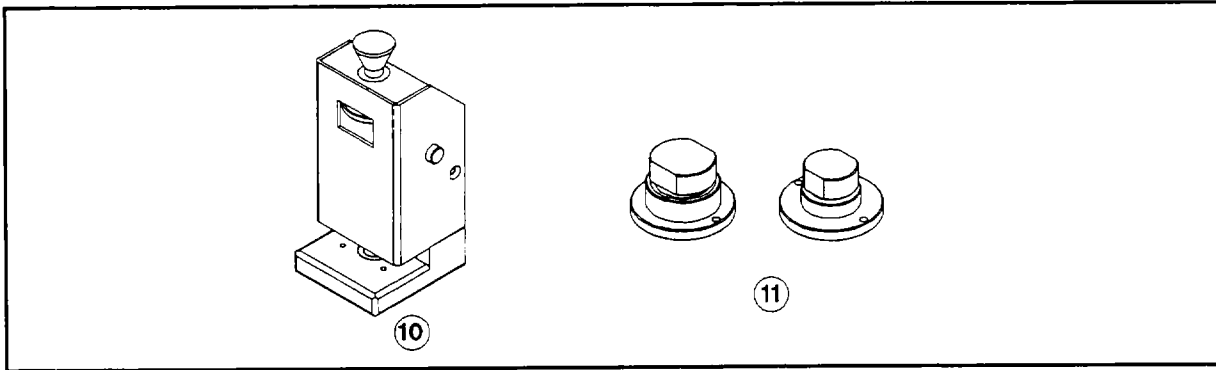
1. Main frame
2. Test station (furnished with the main frame)
3. Cal kit (furnished with the main frame)
4. High impedance test head (furnished with the main frame)
5. Low impedance test head (furnished with option 012)
6. HP-HIL Keyboard (furnished with option 1C2)



CS001002

Figure 1-2. Test Fixtures

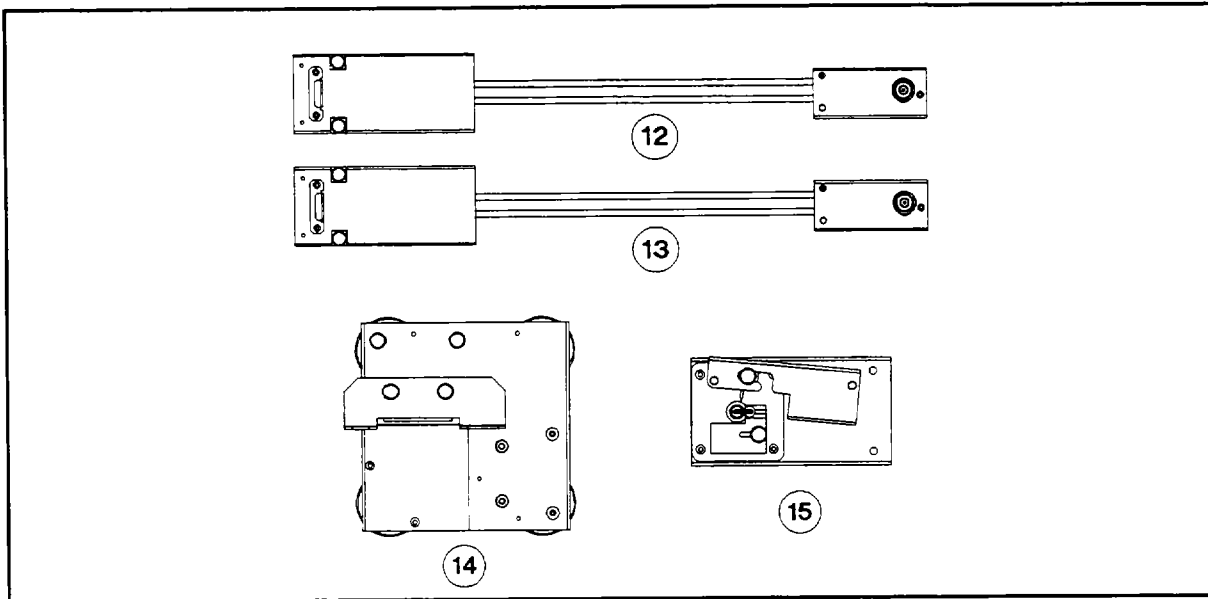
7. HP 16191A Component test fixture (optional)
8. HP 16192A Component test fixture (optional)
9. HP 16193A Component test fixture (optional)



06001003

Figure 1-3. Material Test Fixtures for Option 002

- 10. HP 16453A Dielectric material test fixture (optional)
- 11. HP 16454A Magnetic material test fixture (optional)



06001004

Figure 1-4. High Temperature Test Heads and High Temperature Test Fixtures for Option 013/014

- 12. High temperature high impedance test head (furnished with option 013)
- 13. High temperature low impedance test head (furnished with option 014)
- 14. Fixture Stand (furnished with option 013 and option 014)
- 15. HP 16194A High temperature component test fixture (optional)

Note



For more information on options and accessories available, see Chapter 2 and manuals furnished with each accessory. Also other options and accessories are available, see Chapter 10 for details.

Analyzer features

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

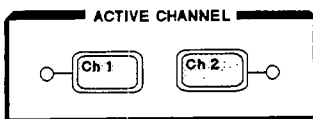
Front and Rear Panels

Analyzer 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 analyzer from an external controller or to control external devices from the analyzer. 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.

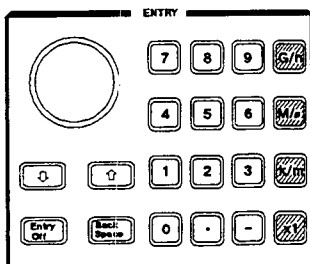
For more information, see Chapter 2.

ACTIVE CHANNEL Block



The analyzer has two channels for independent measurement of parameters and display of data. This block has two keys that select the active channel. Once an active channel is selected, you can control it using the front panel keys and display its trace and data annotations. If you want to use the other channel, you must select the new channel before you make any other changes. For more information, see Chapter 3.

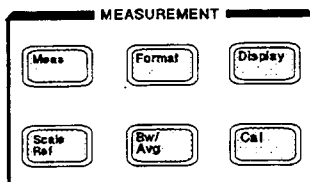
ENTRY Block



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 4.

MEASUREMENT Block



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

Because the measurement functions are different for impedance, permittivity ϵ , and permeability μ measurements, the menus accessed from the **Meas** and **Cal** keys are different for each measurement of operation.

Meas Provides access to a series of menus used to select the parameters to be measured. This menu is also used to select fixtures to be used for material (ϵ and μ) measurements.

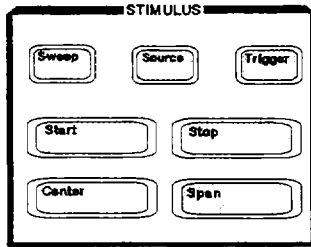
Format Displays the menu used to select the display format of the data. Various rectangular and polar formats are available

for display of measurement parameters selected by **Meas** key.

- Display** Provides access to a series of menus used for instrument state and active channel display functions. These menus include dual channel display (overlaid or split), definitions of the displayed active channel trace in terms of the mathematical relationship between data and trace memory, display intensity, color selection, active channel display title, frequency blanking, and equivalent circuit function.
- Scale Ref** Displays the menu used to modify the axis scales and the reference line value.
- Bw/Avg** Provides access to two different noise reduction techniques: sweep-to-sweep averaging, and on-point averaging.
- Cal** Provides access to a series of menus that implement the calibration and fixture compensation procedures.

For more information, see Chapter 5.

STIMULUS Block



This block defines the sweep range, and controls the trigger function, test signal and DC bias source.

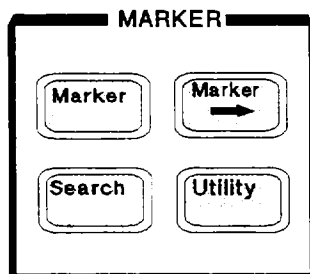
- Sweep** Provides access to a series of menus used for selecting the sweep type, editing the list sweep table, specifying the number of points to be displayed, and specifying the delay time.
- Source** Displays the menu used to control the test signal, and DC bias.
- Trigger** Provides access to a series of menus used for selecting trigger mode and trigger source.

Start, **Stop**, **Center**, and **Span**

Used to specify frequency or power range of the stimulus.

For more information, see Chapter 6.

MARKER Block

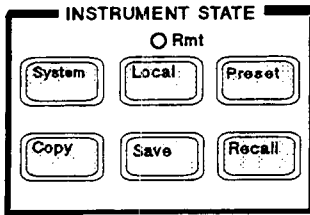


This block displays the marker on the screen and controls the marker function.

- Marker** Displays the marker and provides access to a series of menus used for selecting the marker mode and displaying the sub-markers and the Δ marker.
- Marker →** Provides access to a series of menus used for changing selected measurement parameters to the current marker value.
- Search** Displays menus used for searching the trace for a specific amplitude related point and placing the marker on that point.
- Utility** Displays a menu used for listing all marker values, calculating and displaying statistical values of the display trace, indicating the time elapsed since the sweep started, monitoring OSC or dc bias level applied to a DUT.

For more information, see Chapter 7.

INSTRUMENT STATE Block



This block provides control of channel-independent 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.

- System** Provides access to a series of menus used for programming HP Instrument BASIC (option 1C2), controlling the real-time clock and the beeper, defining the limit line table, performing limit line testing, and change memory size for HP Instrument BASIC and the RAM disk.
- Local** Returns front panel control to the user from an external controller and displays a series of menus used to select the HP-IB mode and modify the HP-IB addresses.
- Preset** Sets the analyzer to the preset state. See Appendix C, for a listing of the preset values.
- Copy** Provides access to the menus used for controlling external plotters and printers and defining the plot parameters.
- Save** Provides access to the menus used for saving the instrument state and data to the flexible disk or RAM disk memory.
- Recall** Displays the menu used to recall the contents of disk files or RAM disk memory back into the analyzer.

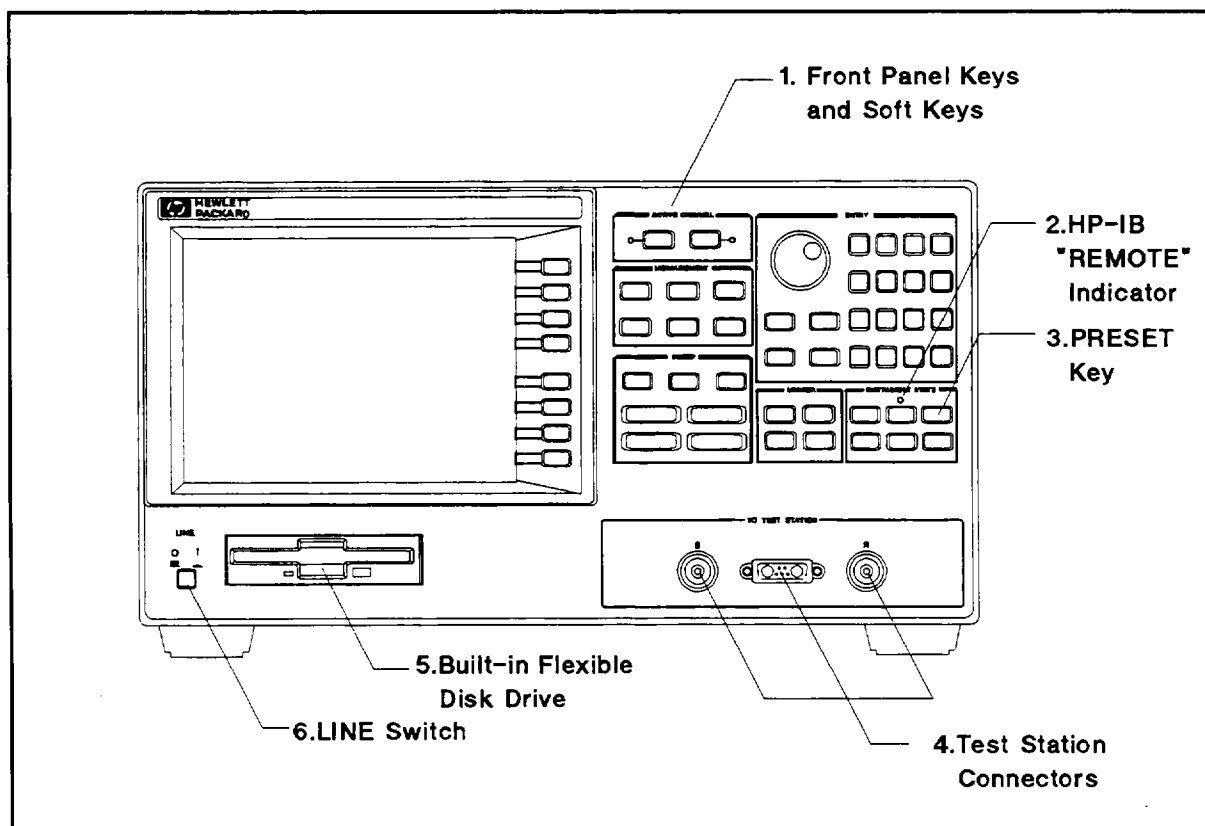
For more information, see Chapter 8.

Front and Rear Panel, Test Station, and Test Heads

This chapter describes the features of the analyzer, the test station, and the test heads. It provides illustrations and descriptions of the analyzer'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

Analyzer 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.



C6002001

Figure 2-1. Analyzer 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 analyzer's menus are accessed directly from front panel keys and some from other menus. For example, the sweep menu accessed by pressing the **Sweep** key presents all the sweep functions such as sweep type, number of points, and sweep time. Pressing **NUMBER of POINTS** allows the required number of points displayed per sweep 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 impedance measurement menu under the **Meas** key, the available measurement parameters are listed: **MAG(|Z|)**, **PHASE(θ_z)**, **RESIST(R)**, **REACT(X)** 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 averaging. This is indicated in the softkey label. The current state, **ON** or **OFF**, is capitalized in the softkey label.

Example:

SWEEP AVG ON off The word **on** is capitalized, showing that sweep averaging is currently on.

SWEEP AVG on OFF The word **off** is capitalized, showing that sweep averaging 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 **PLOT SPEED [FAST]** or **PLOT SPEED [SLOW]** softkey. The **DATA MATH[]** softkey is an example of a status-only indicator, where the selected equation of the data math function is shown in brackets in the softkey label.

2. HP-IB "REMOTE" Indicator

This lights when the analyzer is in the remote state.

3.

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 Station Connectors

The test station 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

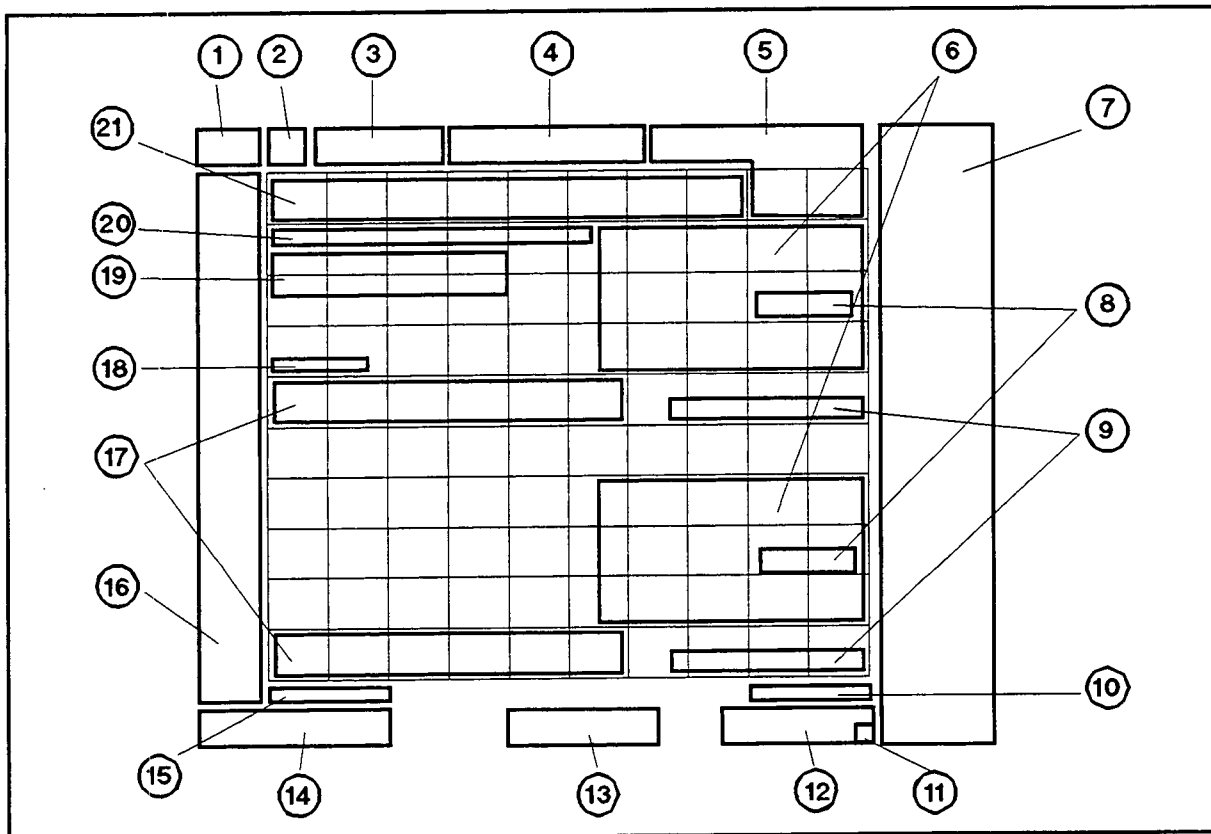
This controls ac power to the analyzer. 1 is ON, 0 is OFF.

Screen display

Displays a grid on which the measurement data is plotted the 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 available (see “**Display**” in Chapter 5). 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.



C6002002

Figure 2-2. Screen Display (Single Channel, Cartesian Format)

1. Active Channel

Displays the number of the current active channel (selected with the keys in the active channel block). If dual channel is ON with an overlaid display, both ch 1 (channel 1) and ch 2 (channel 2) appear in this area.

2. Measured parameter

Shows the measurement parameter selected using the **Meas** key.

3. Scale/Div

Displays the scale set by the **Scale Ref** key in units appropriate to the current measurement or displays top and bottom value of the graticule. When polar, Smith chart or admittance chart formats are selected, this area displays Fsc1 and the value of the outer circle. (Fsc1 stands for 'full scale'.)

4. Reference Level

Displays the value of a reference line in Cartesian formats. It is selected using the **Scale Ref** key. However, the reference line is invisible (it is indicated by a small triangle adjacent to the graticule at the left). The reference levels of the complex plane format are not displayed.

When TOP VALUE and BOTTOM VALUE are used for scaling traces, these values are displayed in the area of "3. Scale/Div" and "4. Reference Level" with T&B. (T&B stands for 'top and bottom'.)

5. Marker Data Readout

Displays the values of the marker in units appropriate to the current measurement (see Chapter 7). The status of the marker is also displayed under the marker values. The following status notations are used:

Cpl	Marker couple is tuned on. (When single channel is displayed, this notation is not displayed even if the marker couple is on.)
Peak	PEAK search tracking is turned on.
Max	MAX search tracking is turned on.
Min	MIN search tracking is turned on.
Targ	TARGET search tracking is turned on.

6. Level Monitor, Marker Statistics and Width Value

Displays the level monitor value, the statistical marker values determined by using the menus accessed with the **Utility** key, and the width value determined by using the menus accessed with the **Search** key. See Chapter 7.

7. Softkey Labels

Displays the menu labels that define the function of the softkeys immediately to the right of the label.

8. Pass/Fail

Indicates the values used for limit testing when using limit lines. See "Limit Line Concept" in Chapter 8.

9. DC BIAS ON notation

When dc bias is turned on, DC BIAS ON is displayed in this area. This notation is not display when the screen displays user trace.

10. dc Bias Level

Displays the dc bias level and limit value of the dc bias when it is turned on. The dc bias limit level is displayed in brackets.

11. Instrument BASIC Status (Run Light)

Shows current status of Instrument BASIC (Option 1C2 only)

□(blank)	Program stopped; can execute commands; CONTINUE not allowed.
-	Program paused; can execute commands; CONTINUE is allowed.
?	BASIC program waiting for input from keyboard; cannot execute commands.
*	This indication has two possible meanings: <ul style="list-style-type: none">■ Program running; CANNOT execute BASIC commands. CONTINUE not allowed.■ System executing command entered from keyboard; CANNOT enter commands.

12. Stimulus Span/Stop Value

Displays the stop frequency of the sweep range in frequency domain measurements or the upper limit of a OSC level or dc bias sweep. When the stimulus is in center/span mode, the span is shown in this space. The stimulus values can be blanked (see “Display” in Chapter 5).

13. CW Frequency

Displays the measurement frequency when the OSC level or dc bias sweep is selected. When the frequency sweep is selected, this area is blank.

14. Stimulus Center/Start Value

Displays either the start frequency of the sweep range for frequency domain measurements or the lower power value in OSC level or dc bias sweep. When the stimulus is in center/span mode, the center stimulus value is shown in this space.

15. OSC Level

Displays the OSC level of the test signal output when the stimulus is frequency or dc bias. When the OSC level is selected as stimulus, this area is blank.

16. Status Notations

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.
V↓	DC bias output is clamped to the current limit.
I↓	DC bias output is clamped to the voltage limit.
COR	Error correction in fixed cal points is on.
CO+	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".)
Avg	Sweep-by-sweep averaging is on. The averaging count is shown below.
D-M	Data math (Data Trace - Memory Trace) is on.
D+M	Data math (Data Trace + Memory Trace) is on.
D/M	Data math (Data Trace/Memory trace) is on.
D*M	Data math (Data Trace×Memory trace) is on.
G*	Data math Gain is on.
-0	Data math Offset is on.
G&0	Data math Gain and Offset are on.
Hld	Hold sweep.
↑	Fast sweep indicator.
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 <i>Service Manual</i> for more information. (Service manual is furnished with Option 0BW.)

17. Equivalent Circuit Parameters

Displays equivalent circuit parameters by using menu accessed with **Display** key. See "Equivalent Circuit Menu" in Chapter 5.

18. External Reference

ExtRef is displayed when an external reference signal is connected to the external reference input on the rear panel (even if phase is not locked).

19. Active Entry Area

Displays the active function and its current value.

20. Message Area

Displays prompts or error messages. See “Error Messages” for more information on error messages.

21. Title

Displays a descriptive alpha-numeric string title defined by you and entered as described in “**Display**” in Chapter 5.

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*.

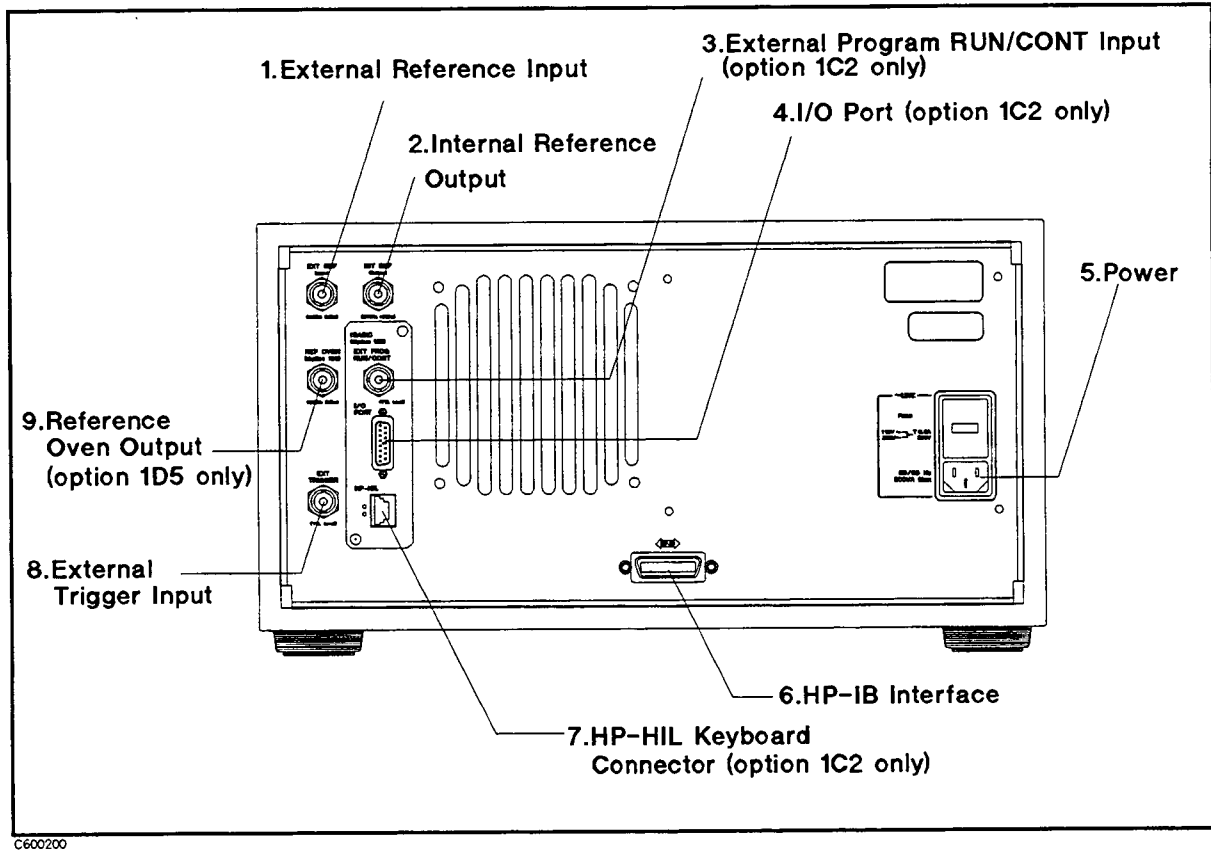


Figure 2-3. Analyzer Rear Panel

1. External Reference Input

Connects an external frequency reference signal to the analyzer that is used to phase lock the analyzer for increased frequency accuracy.

When the analyzer is equipped with the external oven (option 1D5), this connector must be connected to REF OVEN connector.

The external frequency reference function is automatically enabled when a signal is connected to this input. When the signal is removed, the analyzer 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 analyzer.

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 μ s 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 analyzer to an external controller and other instruments in an automated system. This connector is also used when the analyzer itself is the controller of compatible peripherals. See "HP-IB" in Chapter 8.

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 μ s 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**" in Chapter 6).

9. Reference Oven Output (Option 1D5 Only)

Connects to the EXT REF INPUT connector when option 1D5 is installed. Option 1D5 improves the frequency accuracy and stability of the analyzer.

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.

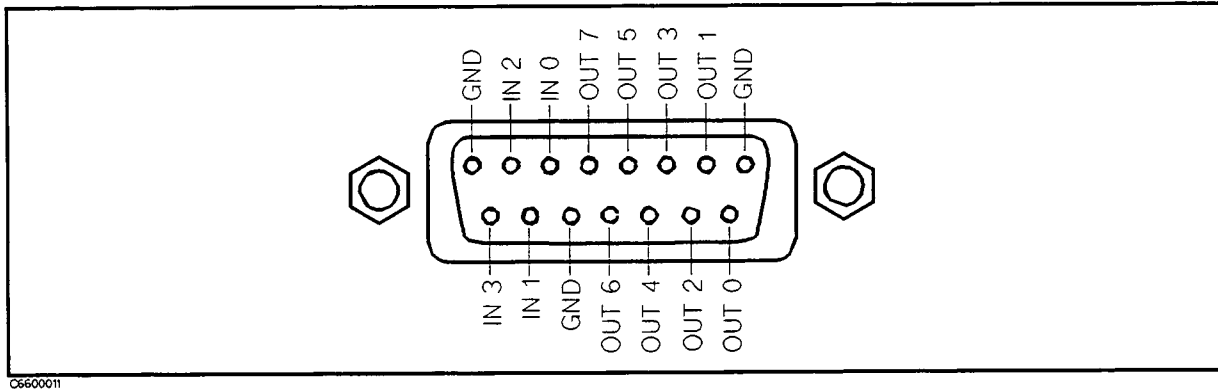


Figure 2-4. Pin Assignment of I/O Port

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 4 | 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 analyzer, 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 analyzer, and returns the data to the HP Instrument BASIC program.

■ Circuit of I/O Port

Figure 2-5 shows the internal circuits of the I/O port.

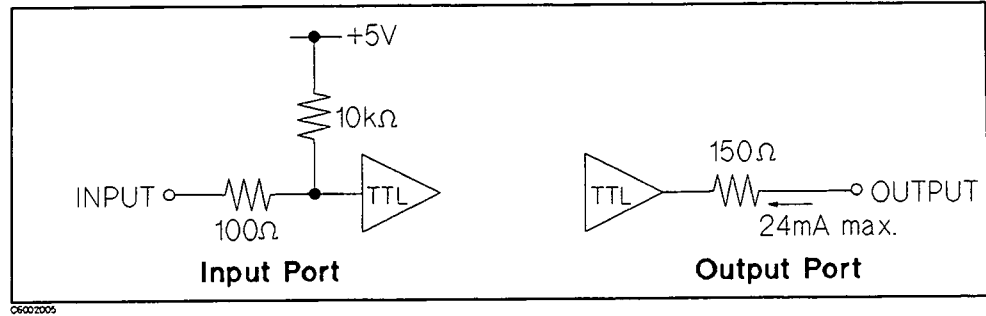


Figure 2-5. Circuit of I/O Port

■ Connector

- D-SUB 15 pin

5. Heat Sink

Sinks heat of the test station. When you install the test station, you keep space around heat sink in order to radiate heat as shown in Figure 2-7.

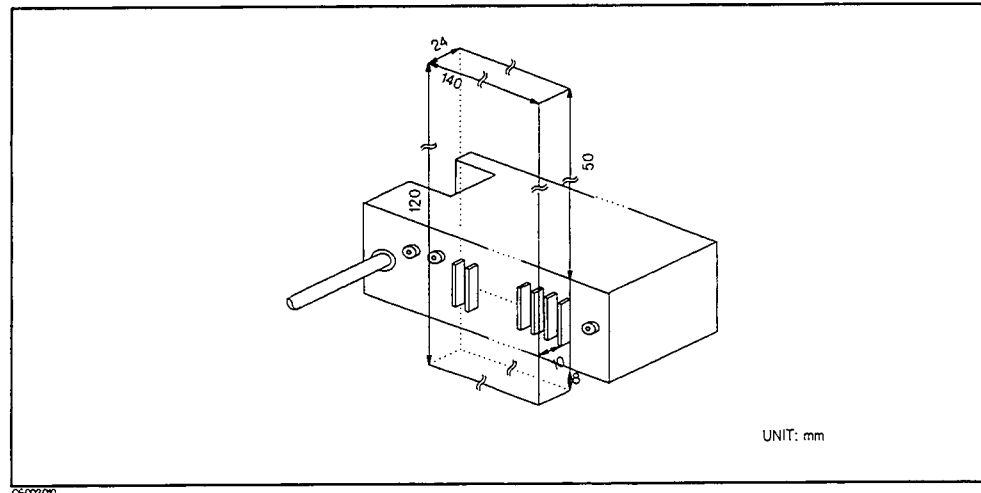


Figure 2-7. Keeping Space Around the Heat Sink

6. Test Station Mounting Screws

Fixes the test station to the peripheral, such as handler. See Figure 2-8 for the dimensions of the test station mounting screws.

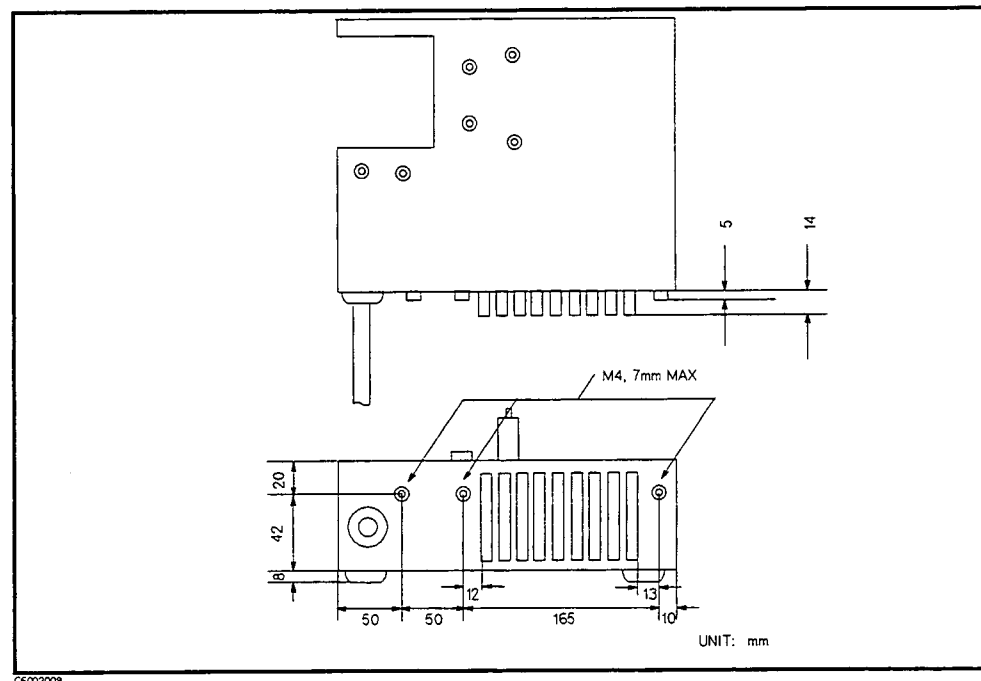
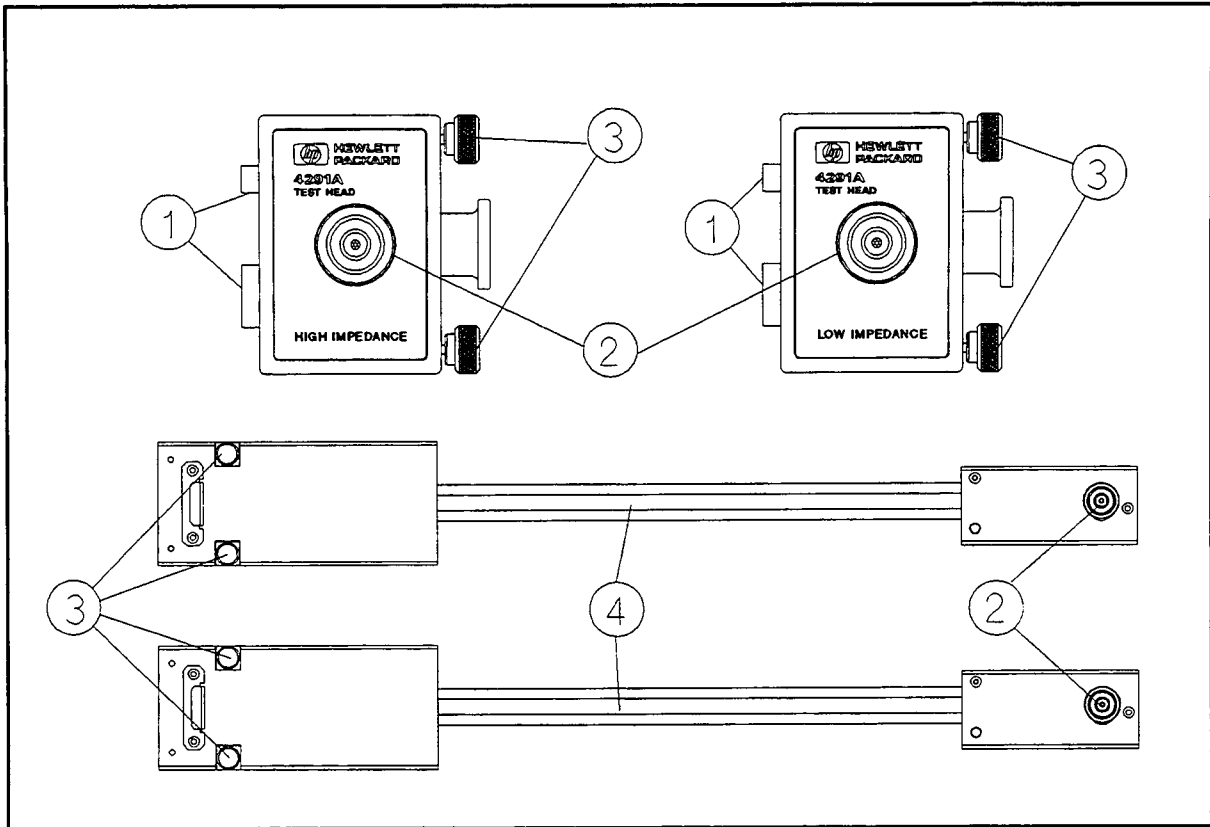


Figure 2-8. Dimensions of Test Station

Test Heads



C6002007

Figure 2-9. Test Heads

- 1. Connectors** Connects to the test station.
- 2. APC-7® Connector** Connects to a test fixture.
- 3. Knobs** Fixes the test head to the test station.

High Impedance Measurement Test Head

This test head is designed to measure high impedance with better accuracy. As a guide, when the impedance value of a DUT is greater than about 300 Ω , use the high impedance measurement test head. This test head is furnished with HP 4291A. This test head is also used with the HP 16453A Dielectric Material Test Fixture.

The impedance measurement accuracy using this test set is shown in the *Specifications* (bound with this manual).

Low Impedance Measurement Test Head (Option 012 only)

This test head is designed to measure low impedance with better accuracy. As a guide, when the impedance value of a DUT is less than about $5\ \Omega$, use the low impedance measurement test head. This test head is furnished with Option 012. This test head is also used with the HP 16454A Magnetic Material Test Fixture.

The impedance measurement accuracy using this test set is shown in the *Specifications* (bound with this manual).

When impedance of a DUT is almost in the range from $5\ \Omega$ to $300\ \Omega$, either or both test heads can be used.

High Temperature High Impedance Test Head (Option 013 only)

This test head is designed to measure high impedance components or materials in wide temperature range. The analyzer can measure components or materials in temperature range from -55°C through $+200^{\circ}\text{C}$, when this test head is used with the HP 16194A High temperature component fixture or the HP 16453A Dielectric Material Test Fixture. This test head is furnished with Option 013.

The dimensions of this test head and the impedance measurement accuracy using this test set is shown in the *Specifications* (bound with this manual).

High Temperature Low Impedance Test Head (Option 014 only)

This test head is designed to measure low impedance component or material in high temperature condition. The analyzer can measure components or materials in temperature range from -55°C through $+200^{\circ}\text{C}$, when this test head is used with the HP 16194A High temperature component fixture or the HP 16454A Magnetic Material Test Fixture. This test head is furnished with Option 014.

The dimensions of this test head and the impedance measurement accuracy using this test set is shown in the *Specifications* (bound with this manual).

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.

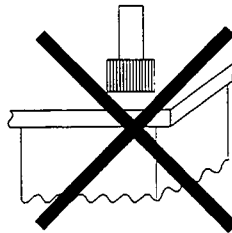
Above all, never store any devices loose in a box or in a desk or a bench drawer. Careless handling of this kind is the most common cause of connector damage during storage.

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.

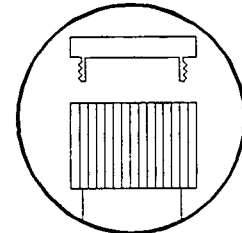
Cables should be stored in the same shape as they have when they are used - they should not be straightened - and end caps should be placed over both connectors.

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

Active Channel Block

The analyzer has two active channels (Figure 3-1) that provide independent display of data. Two different sets of data can be measured simultaneously (for example, one measurement with two different frequency spans). The data can be displayed separately or simultaneously.

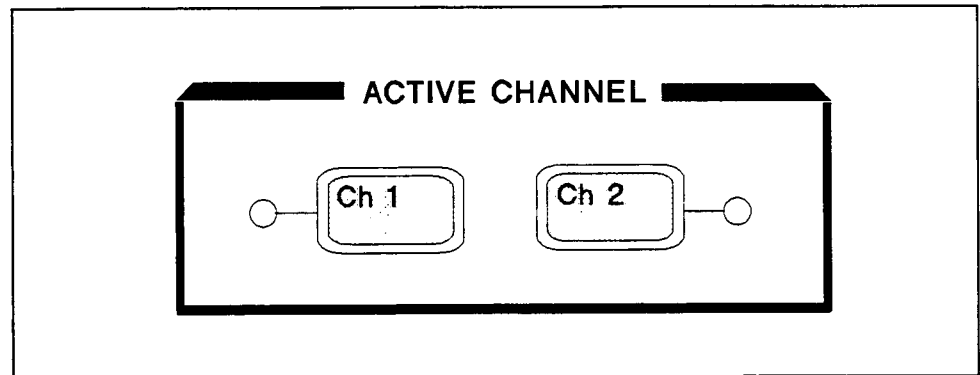


Figure 3-1. Active Channel Keys

Ch 1 and **Ch 2**

The **Ch 1** and **Ch 2** keys select which channel is the *active channel*.

Active Channel

This is the channel currently controlled by the front panel keys. The active channel trace and data annotations are displayed on the display. All the channel specific functions that are selected apply to the active channel. The current active channel is indicated by an amber LED adjacent to the corresponding channel key.

The analyzer has dual trace capability, so that both the active and inactive channel traces can be displayed, either overlaid or on separate graticules (split display). The dual channel and split display features are available in the display menus.

Coupling Channels

Stimulus Coupling

The stimulus values can be coupled or uncoupled between the two channels (independent of the dual channel and split display functions). See "Sweep Menu" in Chapter 6 for a listing of the stimulus value that are coupled in the channel couple mode.

Marker Coupling

Another coupling capability is coupled markers. The measurement markers can have the same stimulus values for the two channels or they can be uncoupled for independent control in each channel. See Chapter 7 for more information about markers.

Entry Block

The ENTRY block (Figure 4-1) contains the numeric and unit's keypad, the knob, and the step keys. These controls are used in combination with other front panel keys and softkeys to modify the active entry, to enter or change numeric data, and to change the value of the marker. In most cases, the keypad, knob, and step keys can be used interchangeably.

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.

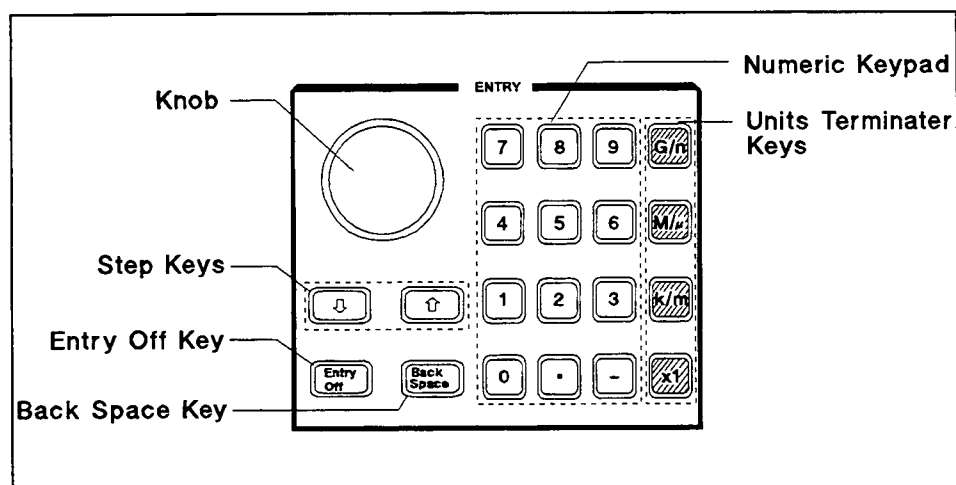


Figure 4-1. Entry Block

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 data entry arrow "←" points at the last entered digit in the active entry area. When the unit's terminator key is pressed, the arrow 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	basic units: dB, dBm, degrees, seconds, Hz, V, A, F, H, Ω, or S. (may be used to terminate unitless entries such as averaging factor).

Knob

The knob adjusts the current values continuously for functions such as scale, reference level, and others. If a marker is on, and no other function is active, the knob can adjust the marker position. Values changed by the knob are effective immediately and require no terminator.

and

The  and  keys step the current value of the active function up or down. The steps are predetermined and cannot be altered. 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 changed by accidentally moving the knob. 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).

Measurement Block

The measurement block keys and associated menus provide control of measurement parameter, display, equivalent circuit analysis, averaging, calibration, and fixture compensation. The following list shows the functions controlled by each key in the measurement block.

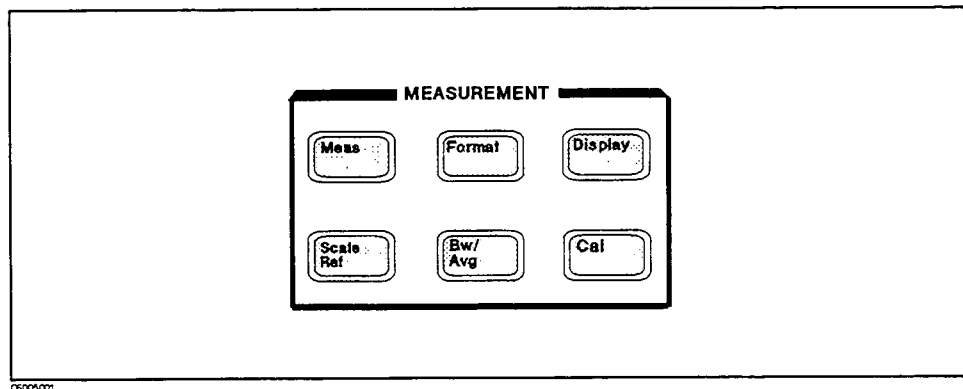
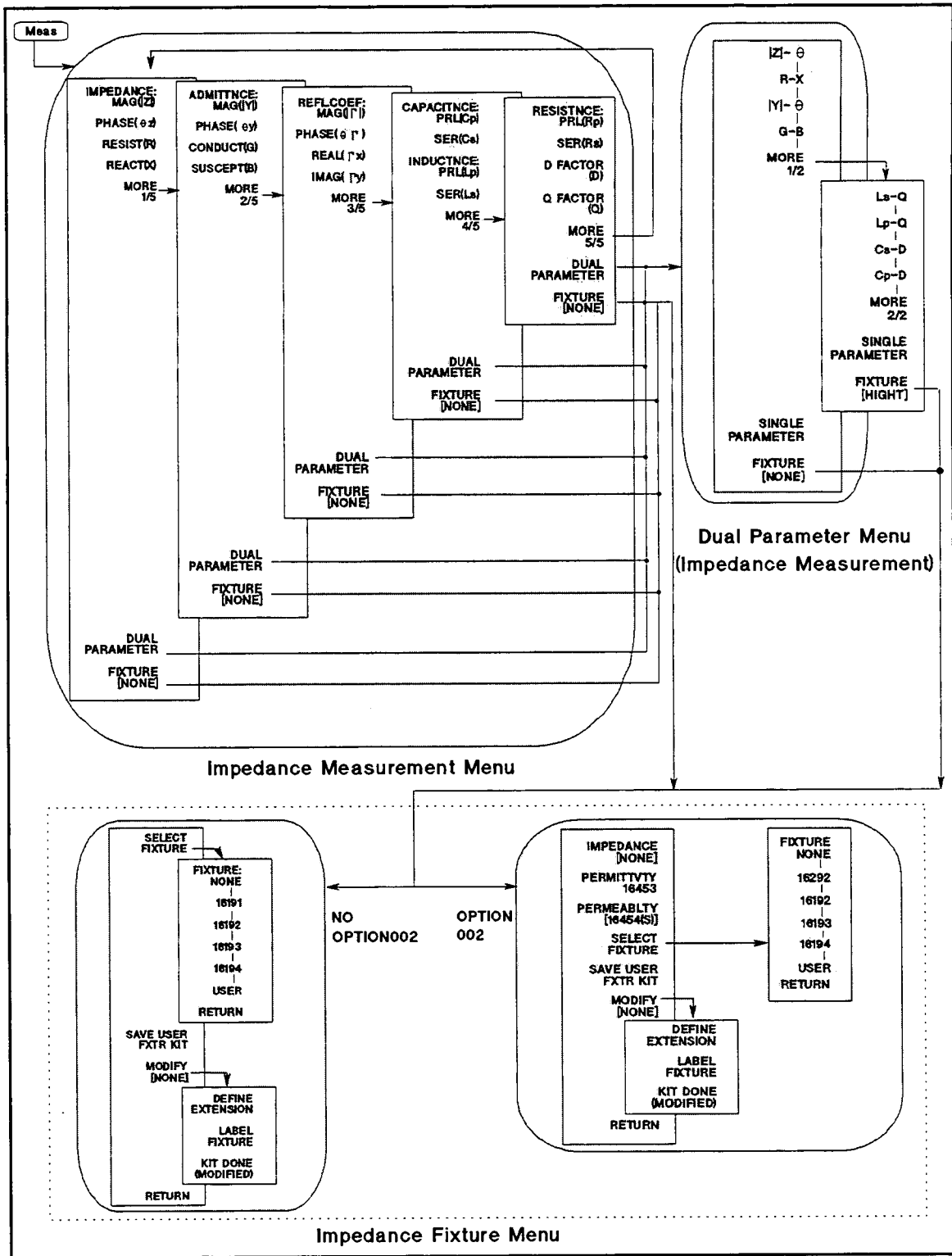


Figure 5-1. Measurement Block

- | | |
|--|--|
| <p>Meas</p> <p>Format</p> <p>Display</p> <p>Scale Ref</p> <p>Bw/Avg</p> <p>Cal</p> | <p>Selecting parameter to be measured
Selecting test fixture (impedance, permittivity ϵ, and permeability μ fixtures)</p> <p>Selecting display format such as rectangular, Smith chart, admittance chart, polar chart, and complex plane.</p> <p>Selecting display trace (data and memory)
Storing data trace to memory trace
Selecting display mode
 <ul style="list-style-type: none"> ■ Dual/Single channel ■ Split/Override Allocating screen between analyzer and HP Instrument BASIC. (option 1C2 only)
 Performing trace math
 Displaying titles and text
 Erase frequency display
 Adjusting display color and intensity
 Calculating equivalent circuit parameters and simulating equivalent circuit
 Displaying user traces</p> <p>Scaling trace</p> <p>Controlling averaging function</p> <p>Performing calibration and fixture compensation measurement
Defining standard kits for calibration and fixture compensation</p> |
|--|--|

Functions accessed from this block	You can access from ...	See the following section in this chapter:
Admittance chart format	Format	<i>Format menu</i>
Averaging	Bw/Avg	<i>Averaging menu</i>
BASIC screen	Display	<i>Display menu</i>
Cal kit definition	Cal	<i>Calibration menu</i>
Calibration	Cal	<i>Calibration menu</i>
Complex plan format	Format	<i>Format menu</i>
Display adjust (Color adjust)	Display	<i>Display menu</i>
Dual parameter setting	Meas	<i>Measurement menu</i>
Equivalent circuit	Display	<i>Display menu</i>
Fixture compensation	Cal	<i>Calibration menu</i>
Frequency Blank	Display	<i>Display menu</i>
Linear rectangular format	Format	<i>Format menu</i>
Log rectangle format	Format	<i>Format menu</i>
Material measurement	Meas	<i>Fixture menu</i>
Measurement parameter selection	Meas	<i>Impedance Measurement Menu</i>
Memory trace	Display	<i>Display menu</i>
OPEN, SHORT, or LOAD definition for fixture compensation	Cal	<i>Calibration menu</i>
Polar chart format	Format	<i>Format menu</i>
Scaling trace	Scale/Ref	<i>Scale menu</i>
Smith chart format	Format	<i>Format menu</i>
Single parameter setting	Meas	<i>Measurement menu</i>
Split display and override	Display	<i>Display menu</i>
Test fixture selection	Meas	<i>Test Fixture Selection</i>
Trace math	Display	<i>Display menu</i>
Title and text on the screen (labeling graphics)	Display	<i>Display menu</i>

For Additional Information on ...	See ...
Preset values and Setting Range of each function setting value	Appendix B in this manual
All Softkey Trees	Appendix C in this manual
HP-IB Command Reference	<i>HP-IB Command Reference</i> in the <i>Programming Manual Set</i> binder
How to control the HP 4291A using an external controller or the HP Instrument BASIC capability through the HP-IB.	<i>Programming Guide</i> in the <i>Programming Manual Set</i> binder.



C6005006

Figure 5-2. Softkey Menus Accessed from the **Meas** Key for Impedance Measurement

5 Measurement Block

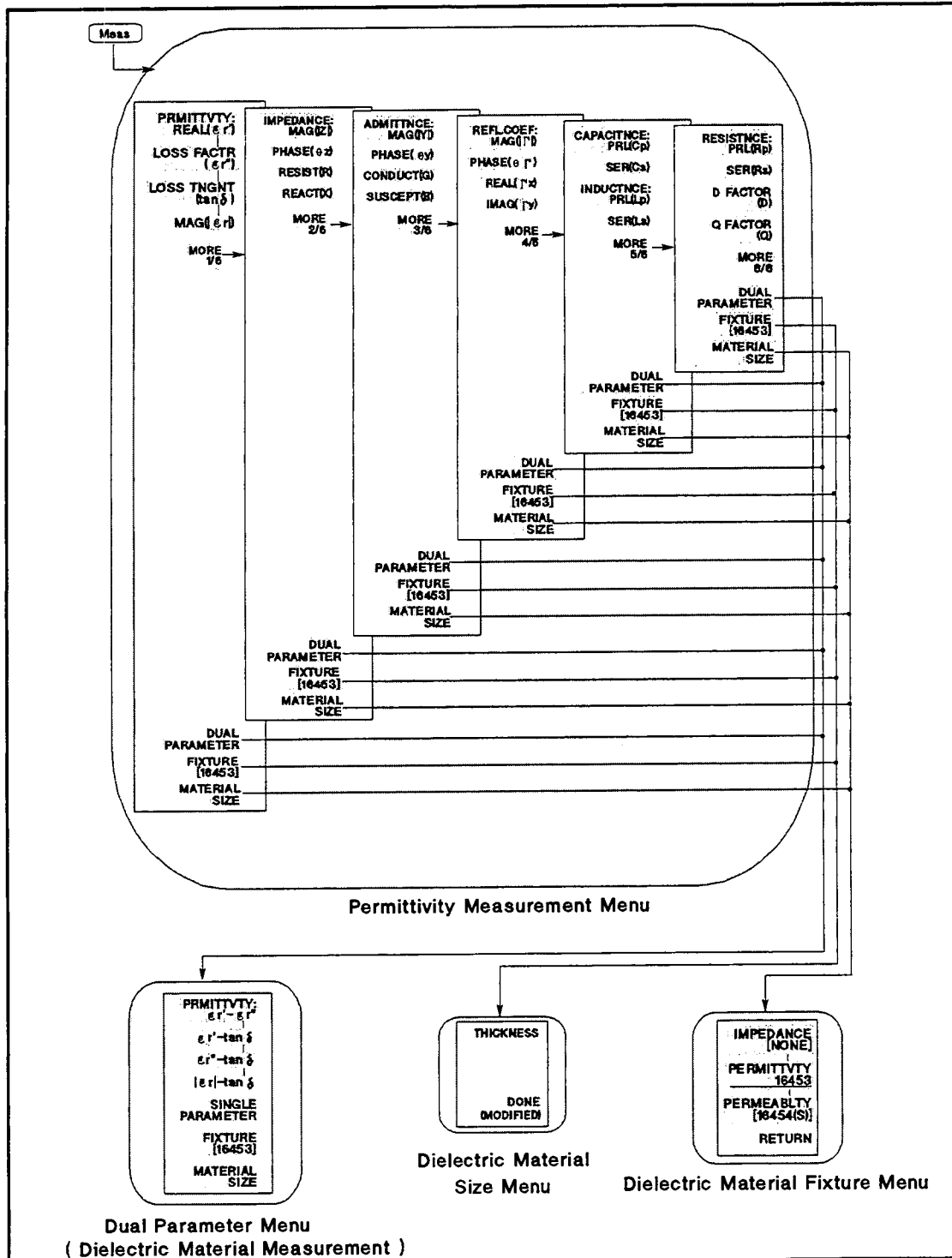
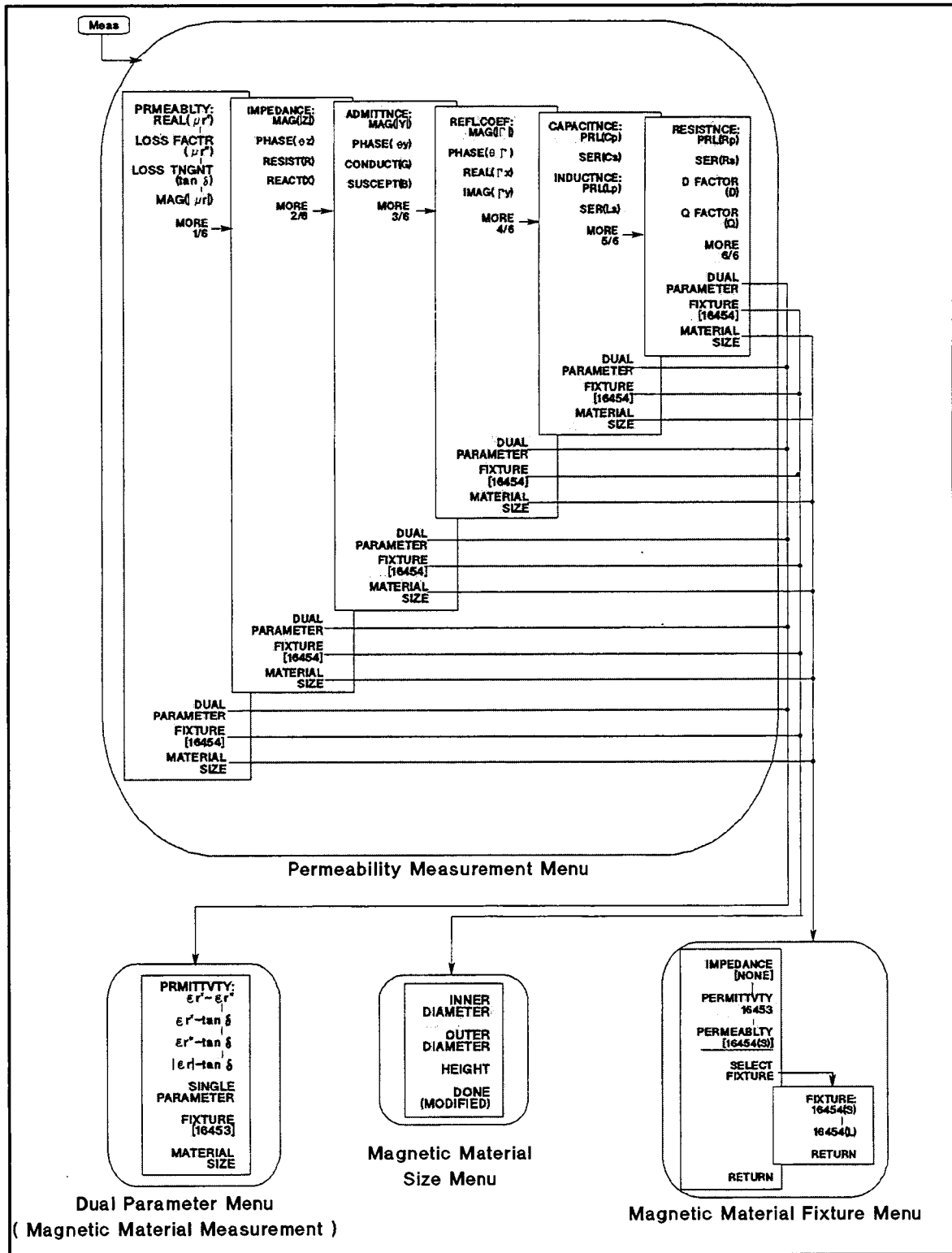


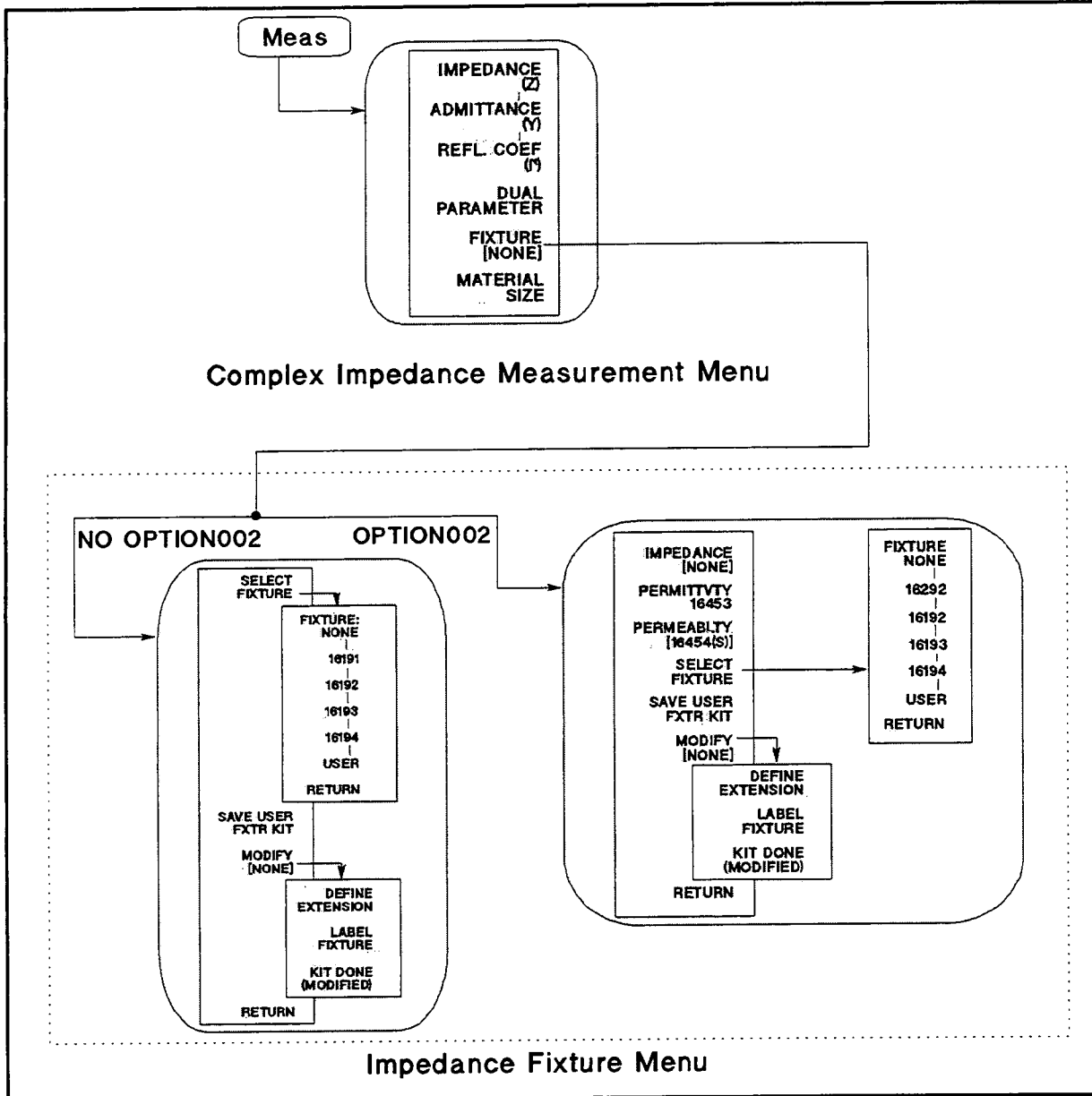
Figure 5-3. Softkey Menus Accessed from the **Meas** Key for Permittivity Measurement



5 Measurement Block

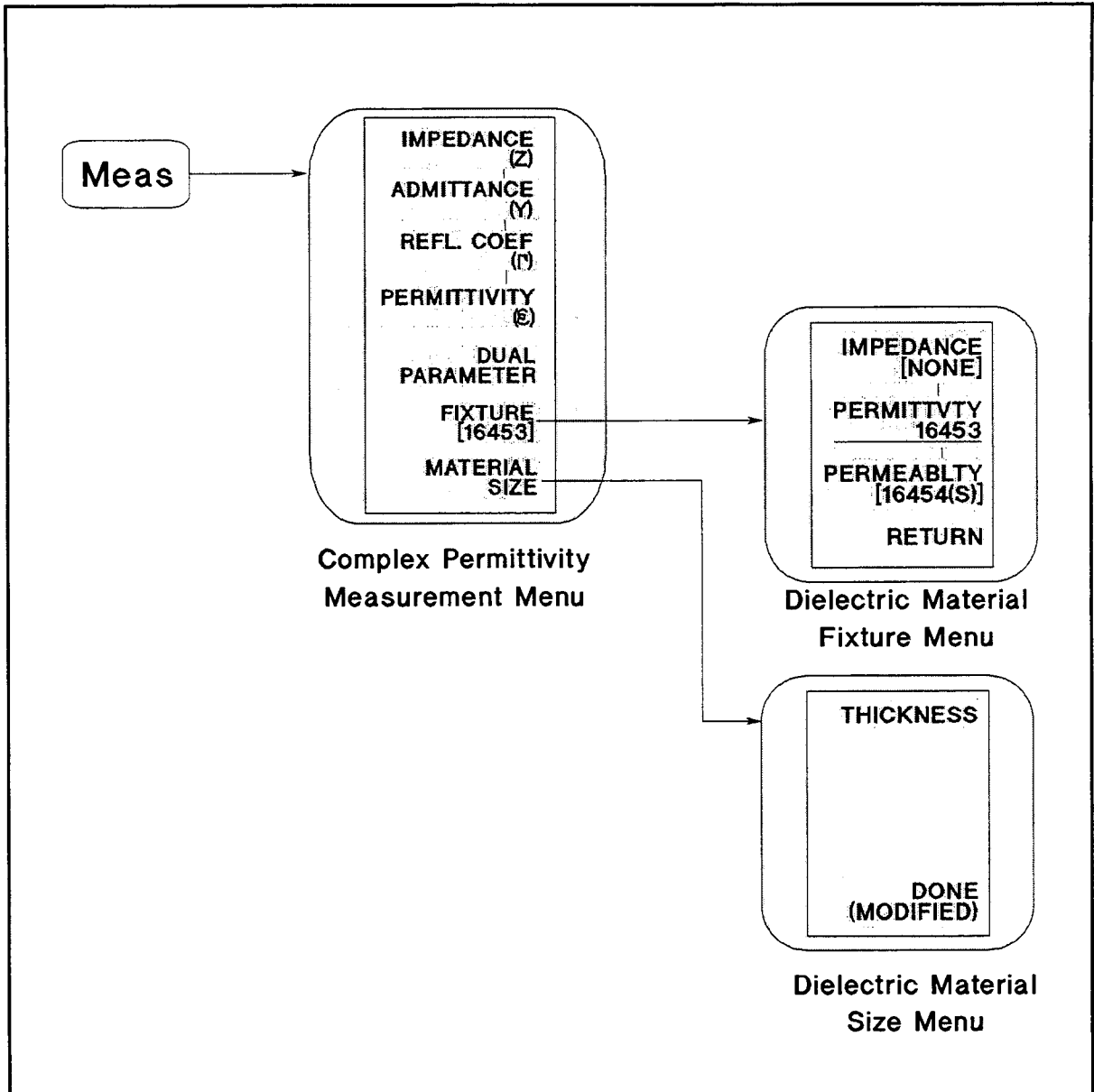
06005061

Figure 5-4. Softkey Menus Accessed from the [Meas] Key for Permeability Measurement



C605048

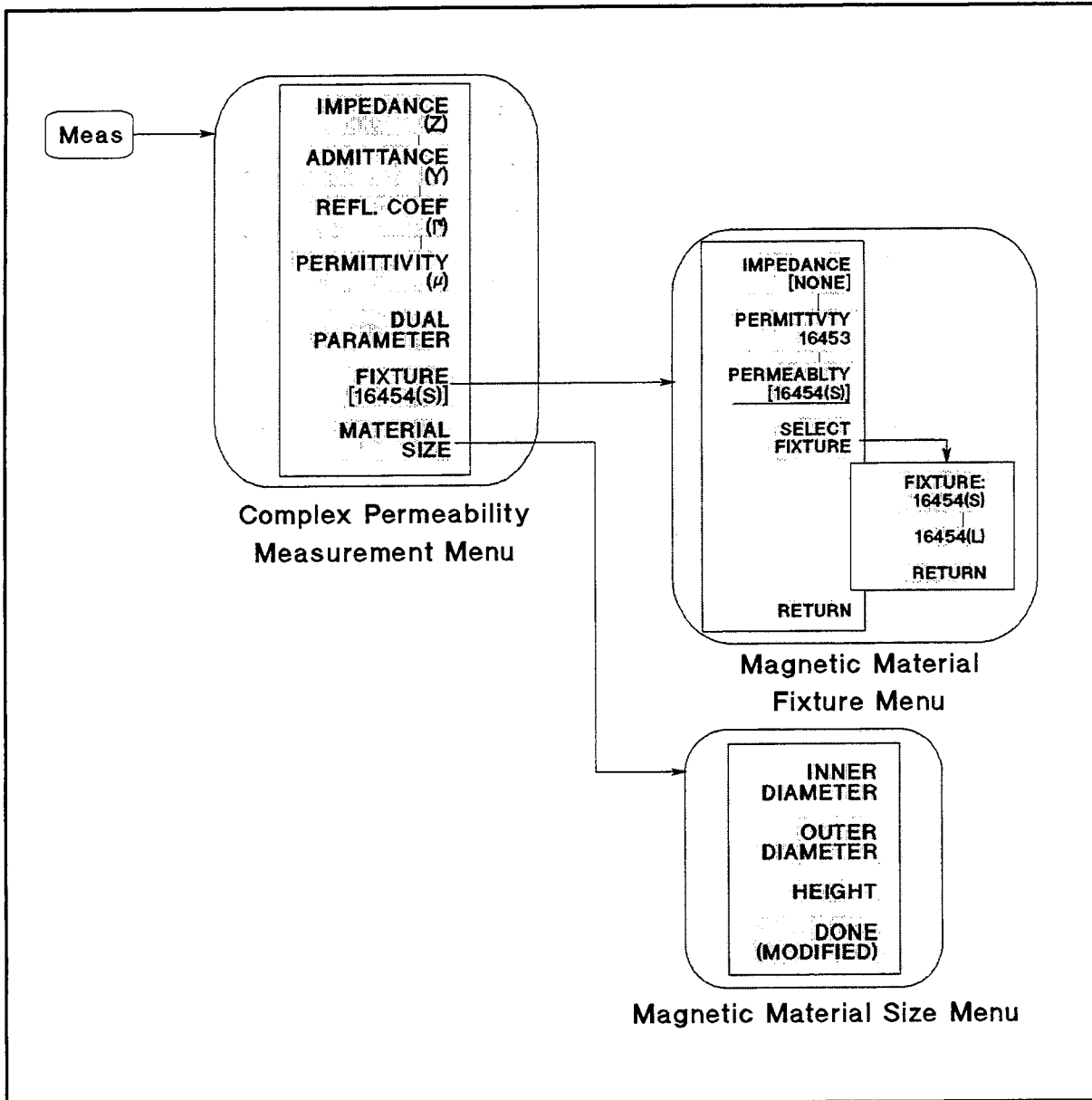
Figure 5-5.
Softkey Menus Accessed from the (Meas) Key for Impedance Measurement (when Smith/Polar/Admittance or Complex-Plane Format is selected)



C6005049

Figure 5-6.
Softkey Menus Accessed from the **Meas** Key for Permittivity Measurement (when Smith/Polar/Admittance or Complex-Plane Format is selected)

5 Measurement Block



C6005050

Figure 5-7.
Softkey Menus Accessed from the **Meas** Key for Permeability Measurement (when Smith/Polar/Admittance or Complex-Plane Format is selected)

Impedance Measurement Menu

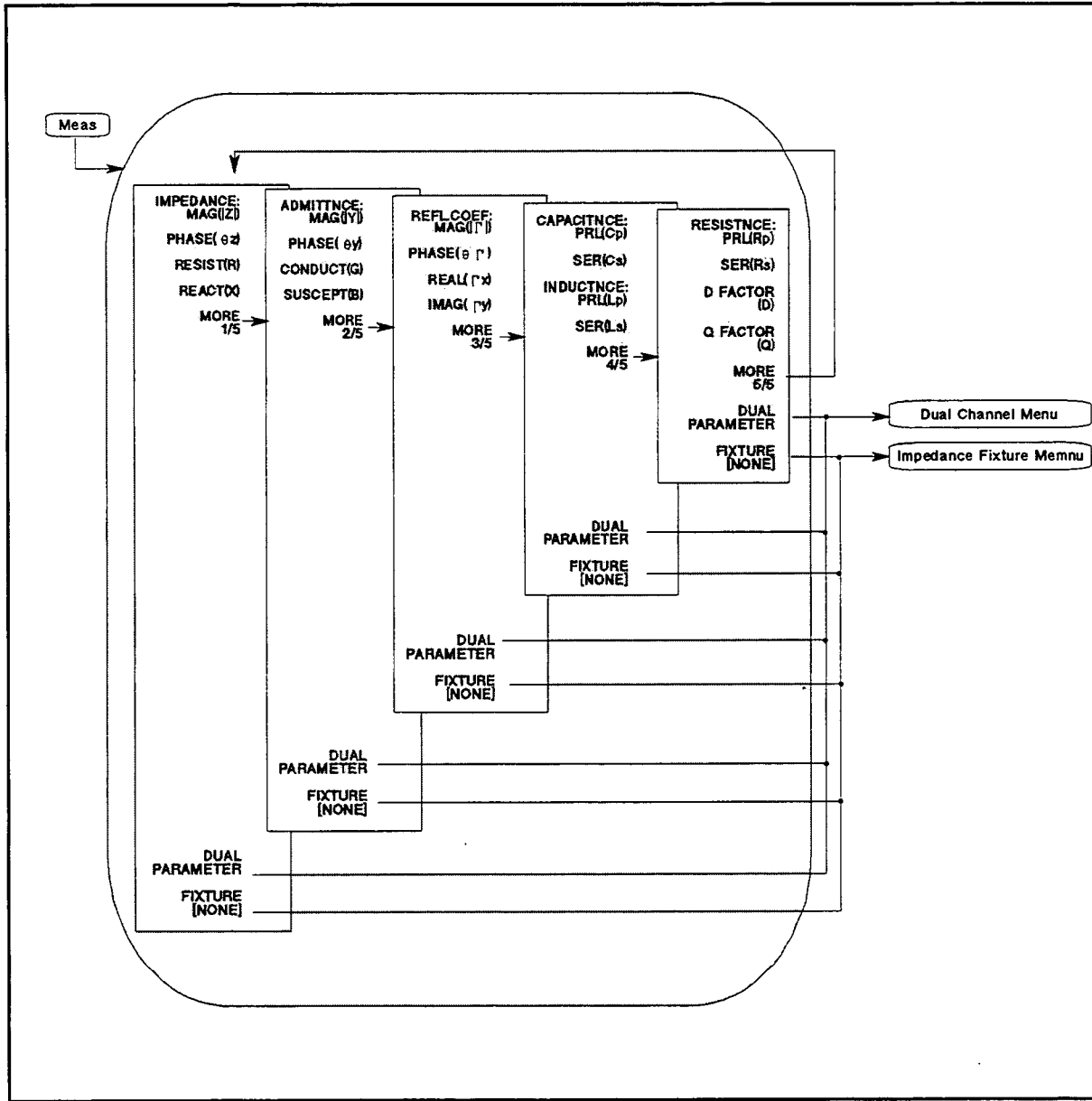


Figure 5-8. Impedance Measurement Menu

- IMPEDANCE:MAG(|Z|) Measures absolute magnitude value of impedance (|Z|).
- PHASE(θz) Measures phase value of impedance (θz).
- RESIST(R) Measures resistance value (R).
- REACT(X) Measures reactance value (X).
- ADMITTNCE:MAG(|Y|) Measures absolute magnitude value of admittance (|Y|).
- PHASE(θy) Measures phase value of admittance (θy).

5 Measurement Block

Meas (Impedance Measurement)

- CONDUCT(G) Measures conductance value (G).
- SUSCEPT(B) Measures susceptance value (B).
 - REFL. COEF:MAG(| Γ |) Measures absolute magnitude value of reflection coefficient ($|\Gamma|$).
 - PHASE($\theta\Gamma$) Measures phase value of reflection coefficient (θ_γ).
 - REAL(Γ_x) Measures real part of reflection coefficient (Γ_x).
 - IMAG(Γ_y) Measures imaginary part of reflection coefficient (Γ_y).
 - CAPCITNCE:PRL(C_p) Measures parallel capacitance (C_p), which is used for small capacitance measurement.
 - SER(C_s) Measures series capacitance (C_s), which is used for large capacitance measurement.
 - INDUCTNCE:PRL(L_p) Measures parallel inductance (L_p), which is used for large inductance measurement.
 - SER(L_s) Measures series inductance (L_s), which is used for small inductance measurement.
 - RESISTNCE:PRL(R_p) Measures parallel resistance (R_p), which is used for large resistance, large inductance, or small capacitance.
 - SER(R_s) Measures series resistance (R_s), which is used for small resistance, small inductance, or large capacitance.
 - D FACTOR (D) Measures dissipation factor (D).
 - Q FACTOR (Q) Measures quality factor (Q).
- DUAL PARAMETER Leads to the *Dual Parameter Menu*, which is used to select parameters to be measured for both channels with one-key stroke.
- FIXTURE [] Leads to the *Fixture Menu*, which is used to select the test fixture used with the analyzer. The selected test fixture is displayed in brackets in the softkey label.

Complex Impedance Measurement Menu

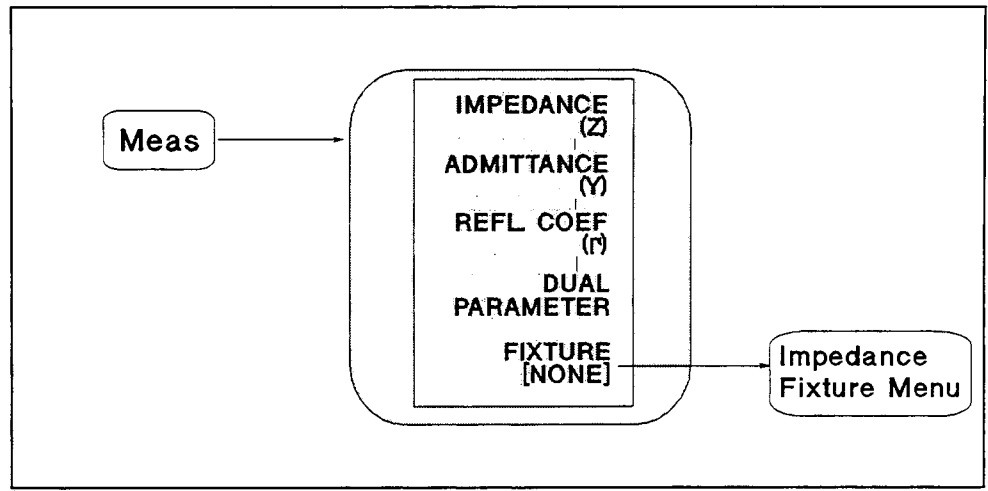


Figure 5-9. Complex Impedance Measurement Menu

This softkey menu can be accessed at the following conditions:

- Format : the polar, Smith, admittance, or complex plane format is selected.
- Fixture : Impedance is selected.

- **IMPEDANCE (Z)** Measures complex impedance when the polar or complex plane format is selected. This softkey is not available when Smith chart or admittance chart is selected.
- **ADMITTANCE (Y)** Measures complex admittance when the polar or complex plane format is selected. This softkey is not available when Smith chart or admittance chart is selected.
- **REFL. COEF (Γ)** Measures reflection coefficient when the Smith, admittance, polar or complex plane format is selected.
- **DUAL PARAMETER** This softkey is not available for Smith, admittance, polar chart, and complex plane formats.
- **FIXTURE []** Leads to the *Fixture Menu*, which is used to select the test fixture used with the analyzer. The selected test fixture is displayed in brackets in the softkey label.
- **MATERIAL SIZE** This softkey is not available when the fixture for impedance measurement is selected.

Dual Parameter Menu

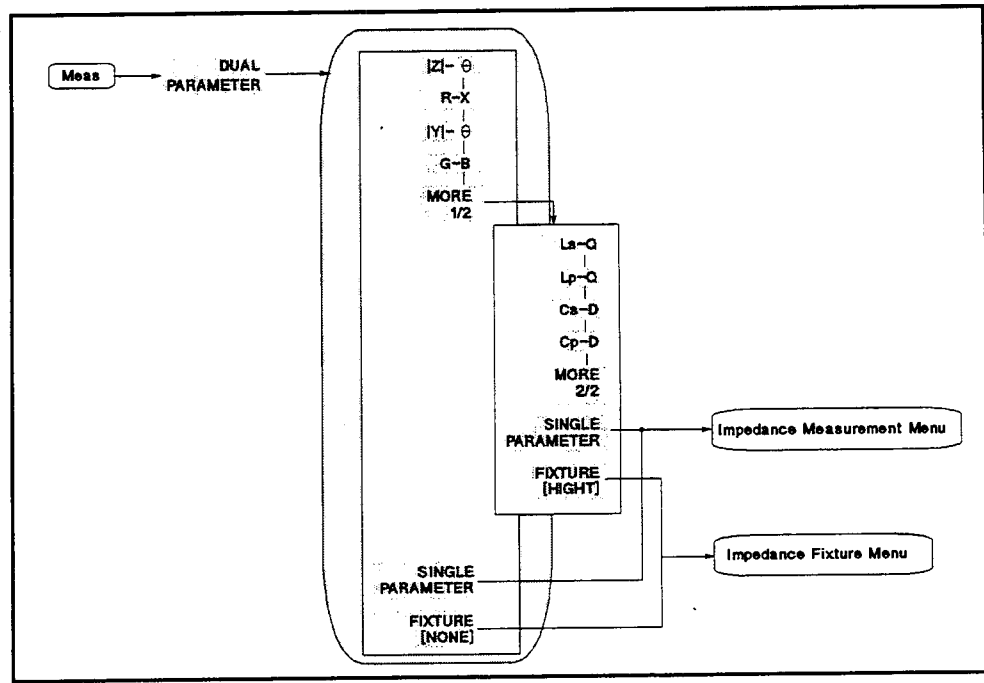


Figure 5-10. Dual Parameter Menu

- **|Z|-θ** Measures $|Z|$ on channel 1 and measures θ on channel 2.
- **R-X** Measures R on channel 1 and measures X on channel 2.
- **|Y|-θ** Measures $|Y|$ on channel 1 and measures θ on channel 2.
- **G-B** Measures G on channel 1 and measures B on channel 2.
 - **Ls-Q** Measures L_s on channel 1 and measures Q on channel 2.
 - **Lp-Q** Measures L_p on channel 1 and measures Q on channel 2.
 - **Cs-D** Measures C_s on channel 1 and measures D on channel 2.
 - **Cp-D** Measures C_p on channel 1 and measures D on channel 2.
 - **SINGLE PARAMETER** Leads to the *Impedance Measurement Menu*.
- **FIXTURE []** Leads to the *Fixture Menu*, which is used to select the test fixture used with the analyzer. The selected test fixture is displayed in brackets in the softkey label.

Measurement Parameters Summary
<p align="center">Complex Impedance Parameters</p> <ul style="list-style-type: none"> ■ Impedance magnitude |Z| ■ Impedance phase θ_z ■ Resistance R ■ Reactance X
<p align="center">Complex Admittance Parameters</p> <ul style="list-style-type: none"> ■ Admittance magnitude |Y| ■ Admittance phase θ_y ■ Resistance G ■ Reactance B
<p align="center">Reflection Coefficient</p> <ul style="list-style-type: none"> ■ Reflection coefficient magnitude |Γ| ■ Reflection coefficient phase θ_γ ■ Real part of reflection coefficient Γ_x ■ Imaginary part of reflection coefficient Γ_y
<p align="center">Serial Circuit parameter</p> <ul style="list-style-type: none"> ■ Serial capacitance C_s ■ Serial inductance L_s ■ Serial resistance R_s
<p align="center">Parallel Circuit parameter</p> <ul style="list-style-type: none"> ■ Parallel capacitance C_p ■ Parallel inductance L_p ■ Parallel resistance R_p
<p align="center">Loss</p> <ul style="list-style-type: none"> ■ 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 11 and “Series and Parallel Circuit Models” in Chapter 11.

Impedance Fixture Menu (No option 002)

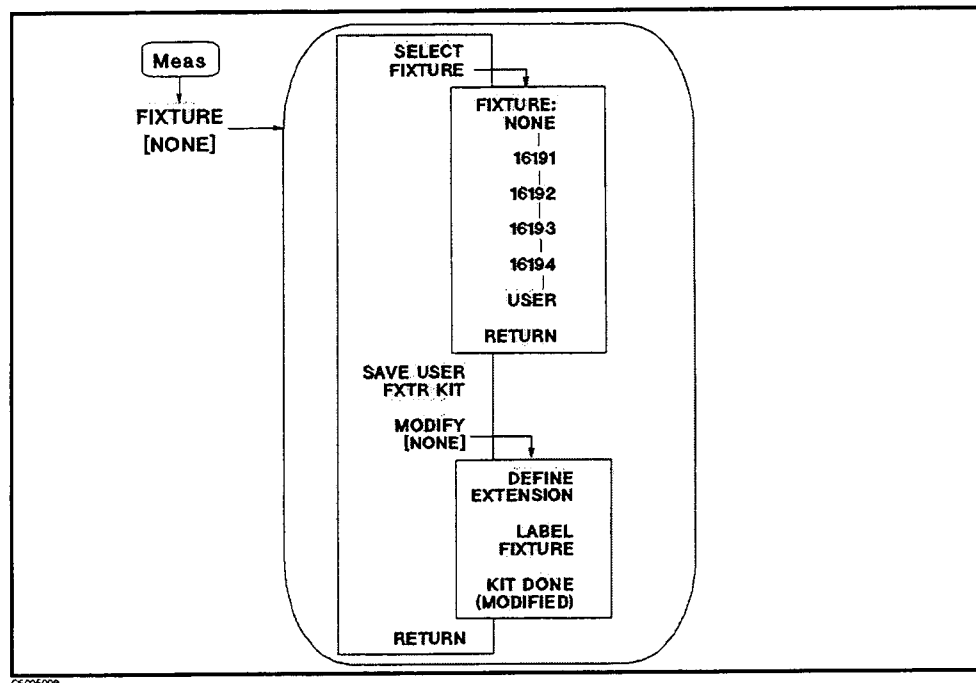


Figure 5-11. Impedance Fixture Menu (No option 002)

- **FIXTURE []** Leads to the following softkeys, which are used to select test fixture for impedance measurement.
 - **FIXTURE:NONE** Sets zero as the electrical length value.
 - **16191** Sets the electrical length that is suitable for the HP 16191A.
 - **16192** Sets the electrical length that is suitable for the HP 16192A.
 - **16193** Sets the electrical length that is suitable for the HP 16193A.
 - **16194** Sets the electrical length that is suitable for the HP 16194A.
 - **USER** Sets the electrical length that is a user defined value.
 - **SAVE USER FXTR** Saves extension value and label as a user defined fixture.
 - **MODIFY []** Leads to the following softkeys, which are used to define the electrical length and label of a selected fixture.
 - **DEFINE EXTENSION** Makes the extension value of the selected fixture the active function to define extension value.
 - **LABEL FIXTURE** Makes the fixture label name the active function to define it.
 - **KIT DONE (MODIFIED)** Completes the procedure to define the selected fixture.

Impedance Fixture Menu (Option 002 only)

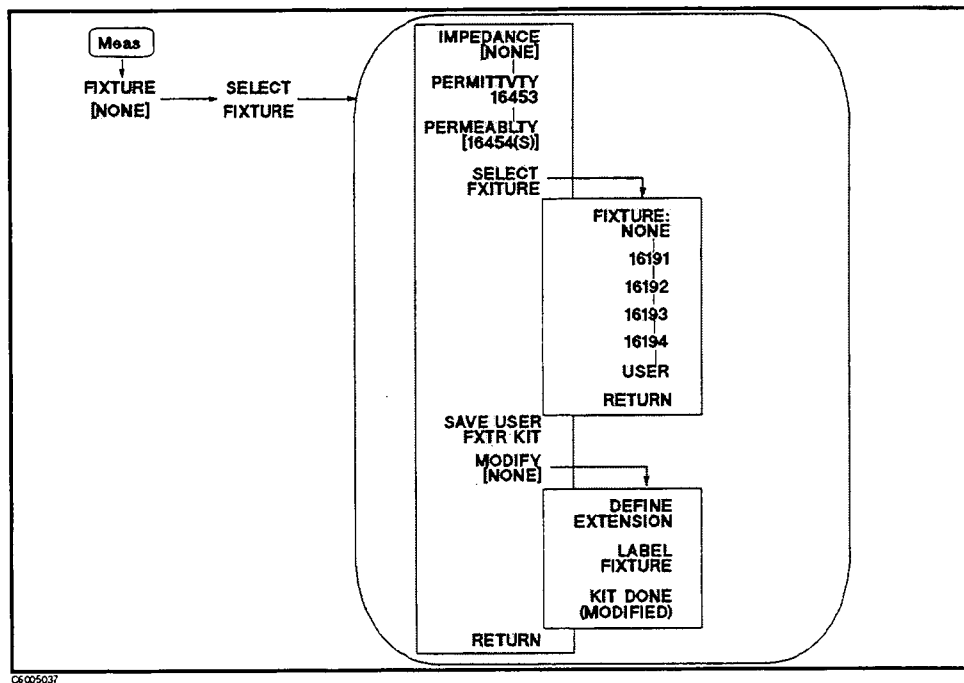


Figure 5-12. Impedance Fixture Menu (Option 002 only)

This section describes the softkeys that can be accessed when Option 002 (Material Measurement) is installed and **IMPEDANCE []** is selected in this menu.

- **IMPEDANCE []** Selects the impedance measurement. When this softkey is selected, the menu accessed from the **SELECT FIXTURE** softkey lists only the impedance fixtures. The (Meas) and (Cal) keys lead only to the menus related to the impedance measurement. When a fixture has been specified, its label is displayed in brackets in the softkey label.
- **PERMITTIVITY 16453** Selects permittivity measurement and sets the electrical length that is suitable for the HP 16453A. When this softkey is selected, the (Meas) and (Cal) keys lead only to the menus related to the permittivity measurement.
- **PERMEABILITY [16454()]** Selects the permeability measurement. When this softkey is selected, the menu accessed from the **SELECT FIXTURE** softkey lists only magnetic material fixtures. The (Meas) and (Cal) keys lead only to the menus related to the permeability measurement. When a fixture size has been specified, the size is displayed in parenthesis in the softkey label.
- **SELECT FIXTURE** Leads to the following softkeys, which are used to select test fixture for impedance measurement.
 - **FIXTURE: NONE** Sets zero as the electrical length value.
 - **16191** Sets the electrical length that is suitable for the HP 16191A.

Meas (Impedance Measurement)

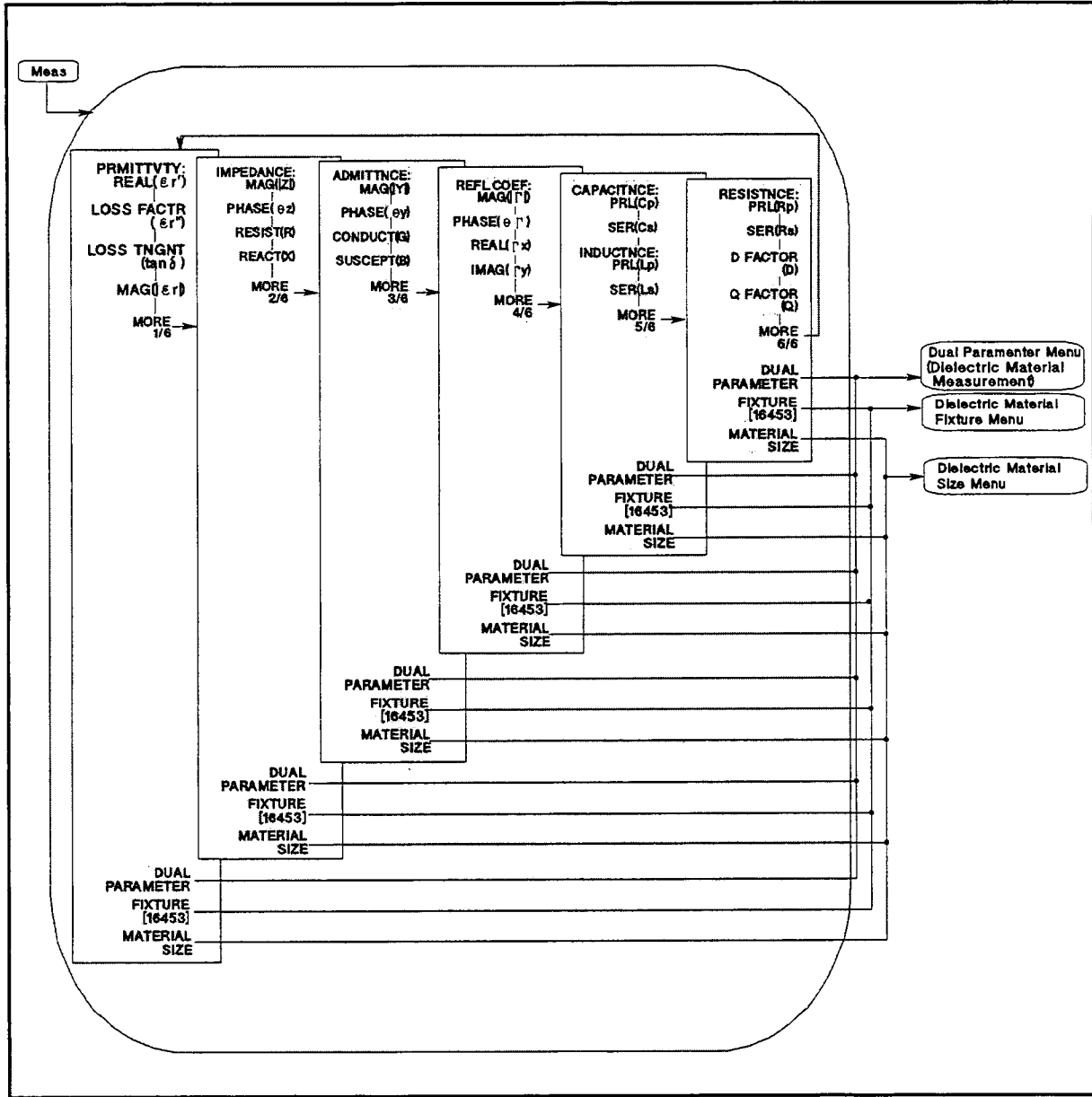
- **16192** Sets the electrical length that is suitable for the HP 16192A.
- **16193** Sets the electrical length that is suitable for the HP 16193A.
- **16194** Sets the electrical length that is suitable for the HP 16194A.
- **USER** Sets the electrical length, which is a user defined value.
- **SAVE USER FXTR** Saves the extension value and label of a user defined fixture.
- **MODIFY []** Leads to the following softkeys, which are used to define the electrical length and label of a user's fixture.
 - **DEFINE EXTENSION** Makes the extension value of the user defined fixture the active function to define its value.
 - **LABEL FIXTURE** Makes the fixture label name the active function to define it.
 - **KIT DONE (MODIFIED)** Completes the procedure to define the user fixture and save it.

What is fixture setting?
<i>Fixture menu</i> sets the electrical length in order to cancel errors caused by an additional impedance in a distributed element of a coaxial coupling terminal between the APC-7 connector and the contact electrode of a fixture. For more information on fixture characteristics, see "Fixture Compensation" in Chapter 11.

User fixture definition is backed up by battery
The analyzer keeps the definition of a user fixture in the battery backup memory to ensure that the definition is retained even if the analyzer is turned off.

It is <i>not</i> necessary to set test fixture in this menu when ...
When you perform all three fixture compensation measurements (OPEN, SHORT, and LOAD), it is not necessary to specify the test fixture in this menu. Because OPEN, SHORT and LOAD compensation will remove errors caused by the phase shift, be sure to select FIXTURE:NONE before the compensation measurements are performed.
When you perform only one or two compensation measurements (OPEN and/or SHORT), you should specify the applicable fixture using this menu.

Permittivity Measurement Menu (Option 002 only)



CS005056

Figure 5-13. Permittivity Measurement Menu (Option 002 only)

- PRMITTVTY:REAL(ϵ'_r) Measures effective relative permittivity (ϵ'_r).
- LOSS FACTR (ϵ''_r) Measures relative dielectric loss factor (ϵ''_r).
- LOSS TNGNT ($\tan\delta$) Measures dielectric dissipation factor (dielectric loss tangent; $\tan\delta$).
- MAG($|\epsilon_r|$) Measures absolute magnitude value of permittivity ($|\epsilon_r|$).
- MORE 1/6 leads the following softkeys, which is used to measure impedance parameter as same as the *Impedance Measurement* menu.

5 Measurement Block

Meas (Dielectric Material Measurement)

- **IMPEDANCE:MAG(|Z|)** Measures absolute magnitude value of impedance ($|Z|$).
- **PHASE(θ_z)** Measures phase value of impedance (θ_z).
- **RESIST(R)** Measures resistance value (R).
- **REACT(X)** Measures reactance value (X).
 - **ADMITTANCE:MAG(|Y|)** Measures absolute magnitude value of admittance ($|Y|$).
 - **PHASE(θ_y)** Measures phase value of admittance (θ_y).
 - **CONDUCT(G)** Measures conductance value (G).
 - **SUSCEPT(B)** Measures susceptance value (B).
 - **REFL.COEF:MAG(| Γ |)** Measures absolute magnitude value of reflection coefficient ($|\Gamma|$).
 - **PHASE(θ_Γ)** Measures phase value of reflection coefficient (θ_Γ).
 - **REAL(Γ_x)** Measures real part of reflection coefficient (Γ_x).
 - **IMAG(Γ_y)** Measures imaginary part of reflection coefficient (Γ_y).
 - **CAPCITANCE:PRL(C_p)** Measures parallel capacitance (C_p), which is used for small capacitance measurement.
 - **SER(C_s)** Measures series capacitance (C_s), which is used for large capacitance measurement.
 - **INDUCTANCE:PRL(L_p)** Measures parallel inductance (L_p), which is used for large inductance measurement.
 - **SER(L_s)** Measures series inductance (L_s), which is used for small inductance measurement.
 - **RESISTANCE:PRL(R_p)** Measures parallel resistance (R_p), which is used for large resistance, large inductance, or small capacitance.
 - **SER(R_s)** Measures series resistance (R_s), which is used for small resistance, small inductance, or large capacitance.
 - **D FACTOR (D)** Measures dissipation factor (D).
 - **Q FACTOR (Q)** Measures quality factor (Q).
- **DUAL PARAMETER** Leads to the *Dual Parameter menu*, which are used to select parameters to be measured for both channels with one-key stroke.
- **FIXTURE [16453]** Leads to the *Fixture Menu*, which is used to select the test fixture used with the analyzer. 16453 is displayed in brackets in the softkey label when the permittivity measurement menu is accessed.
- **MATERIAL SIZE** Leads to the *Material Size Menu*, which is used to set the thickness of the dielectric material to be measured.

Complex Permittivity Measurement Menu (Option 002 only)

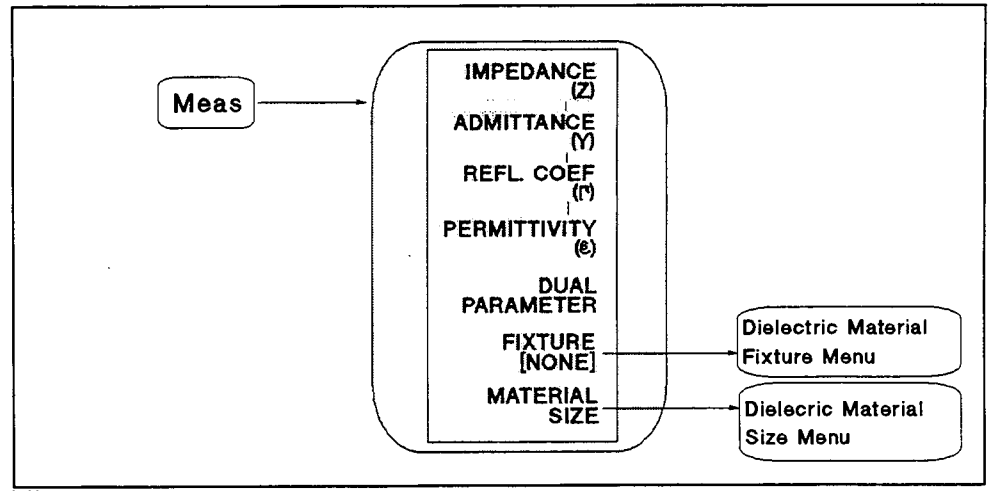


Figure 5-14. Complex Permittivity Measurement Menu (Option 002 only)

This softkey menu can be accessed at the following conditions:

- Format : the polar, Smith, admittance, or complex plane format is selected.
- Fixture : HP 16453A is selected.

- **IMPEDANCE (Z)** Measures complex impedance on the polar or complex plane format. This softkey is not available when Smith or admittance chart is selected.
- **ADMITTANCE (Y)** Measures complex admittance on the polar or complex plane format. This softkey is not available when Smith or admittance chart is selected.
- **REFL. COEF (Γ)** Measures complex impedance on Smith, admittance, polar or complex plane format.
- **PERMITTIVITY (ε)** Measures complex relative permittivity on the polar or complex plane format. This softkey is not available when Smith or admittance chart is selected.
- **DUAL PARAMETER** This softkey is not available for Smith, admittance, polar chart, and complex plane formats.
- **FIXTURE []** Leads to the *Fixture Menu*, which is used to select the test fixture used with the analyzer. The selected test fixture is displayed in brackets in the softkey label.
- **MATERIAL SIZE** Leads to the *Material Size Menu*, which is used to set thickness of the dielectric material to be measured.

Meas (Dielectric Material Measurement)

Dual Parameter Menu (Dielectric Material Measurement)

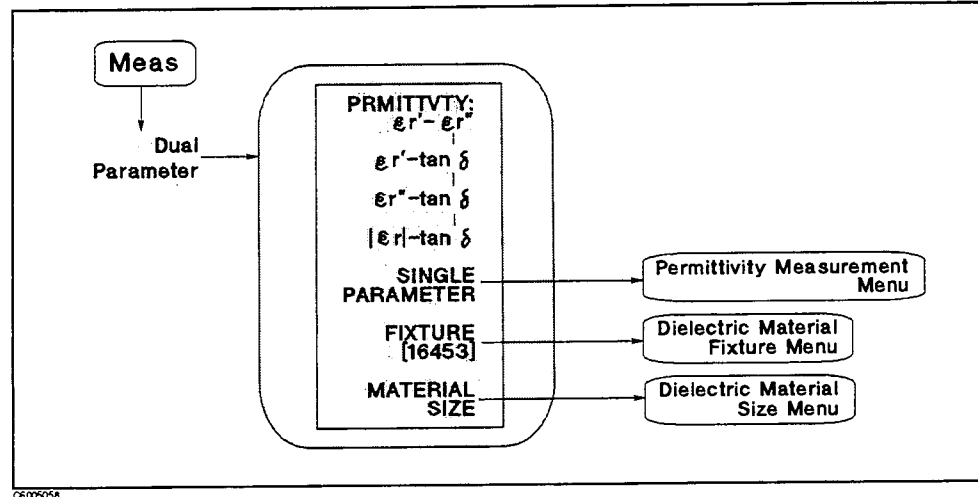


Figure 5-15.
Dual Parameter Menu (Dielectric Material Measurement)

- $\epsilon_r' - \epsilon_r''$ Measures ϵ_r' on channel 1 and measures ϵ_r'' on channel 2.
- $\epsilon_r' - \tan \delta$ Measures ϵ_r' on channel 1 and measures $\tan \delta$ on channel 2.
- $\epsilon_r'' - \tan \delta$ Measures ϵ_r'' on channel 1 and measures $\tan \delta$ on channel 2.
- $|\epsilon_r| - \tan \delta$ Measures $|\epsilon_r|$ on channel 1 and measures $\tan \delta$ on channel 2.
- SINGLE PARAMETER Leads to the *Permittivity Measurement Menu*.
- FIXTURE [16453] Leads to the *Dielectric Material Fixture Menu*, which is used to select test fixture used with the analyzer. The selected test fixture is displayed in brackets in the softkey label.
- MATERIAL SIZE Leads to the *Dielectric Material Size Menu*, which is used to set thickness of the dielectric material to be measured.

Dielectric Material Fixture Menu (Option 002 only)

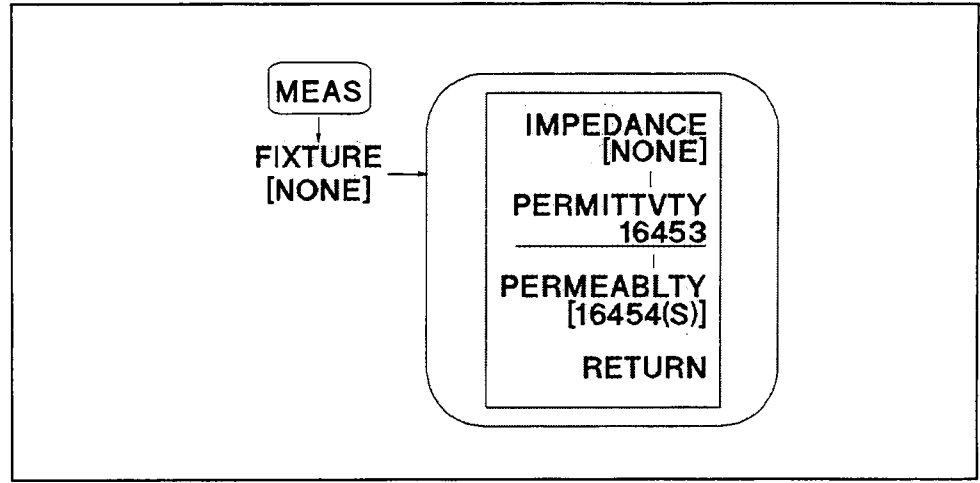
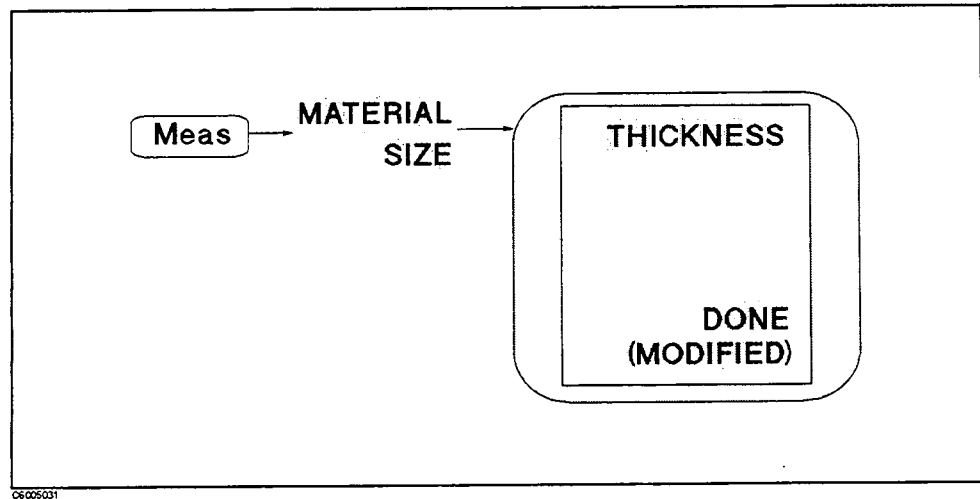


Figure 5-16. Dielectric Material Fixture Menu (Option 002 only)

This section describes the softkeys that can be accessed when Option 002 (Material Measurement) is installed and PERMITTVTY 16453 is selected in this menu.

- **IMPEDANCE []** Selects the impedance measurement. When this softkey is selected, the menu accessed from the **SELECT FIXTURE** softkey lists only impedance fixtures. The (Meas) and (Cal) keys lead only to the menus related to the impedance measurement. When a fixture has been specified, its label is displayed in brackets in the softkey label.
- **PERMITTVTY 16453** Selects the permittivity measurement and sets the electrical length that is suitable for the HP 16453A. When this softkey is selected, the (Meas) and (Cal) keys lead only to the menus related to the permittivity measurement.
- **PERMEABILITY 16454()** Selects the permeability measurement. When this softkey is selected, the menu accessed from the **SELECT FIXTURE** softkey lists only magnetic material fixtures. The (Meas) and (Cal) keys lead only to the menus related to the permeability measurement. When a fixture size has been specified, the size is displayed in parenthesis in the softkey label.

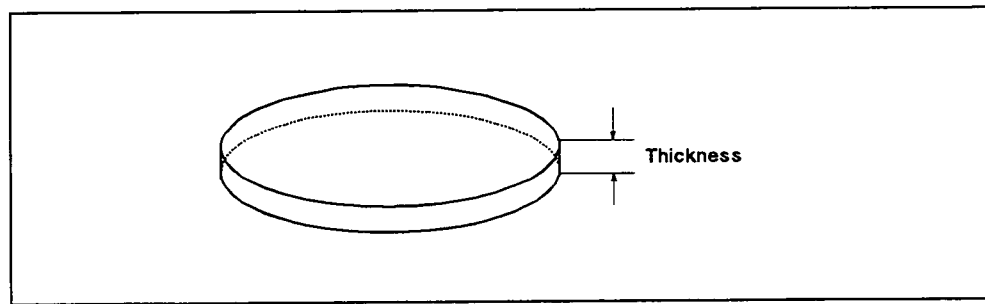
Dielectric Material Size Menu (Option 002 only)



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Figure 5-17. Dielectric Material Size Menu (Option 002 only)

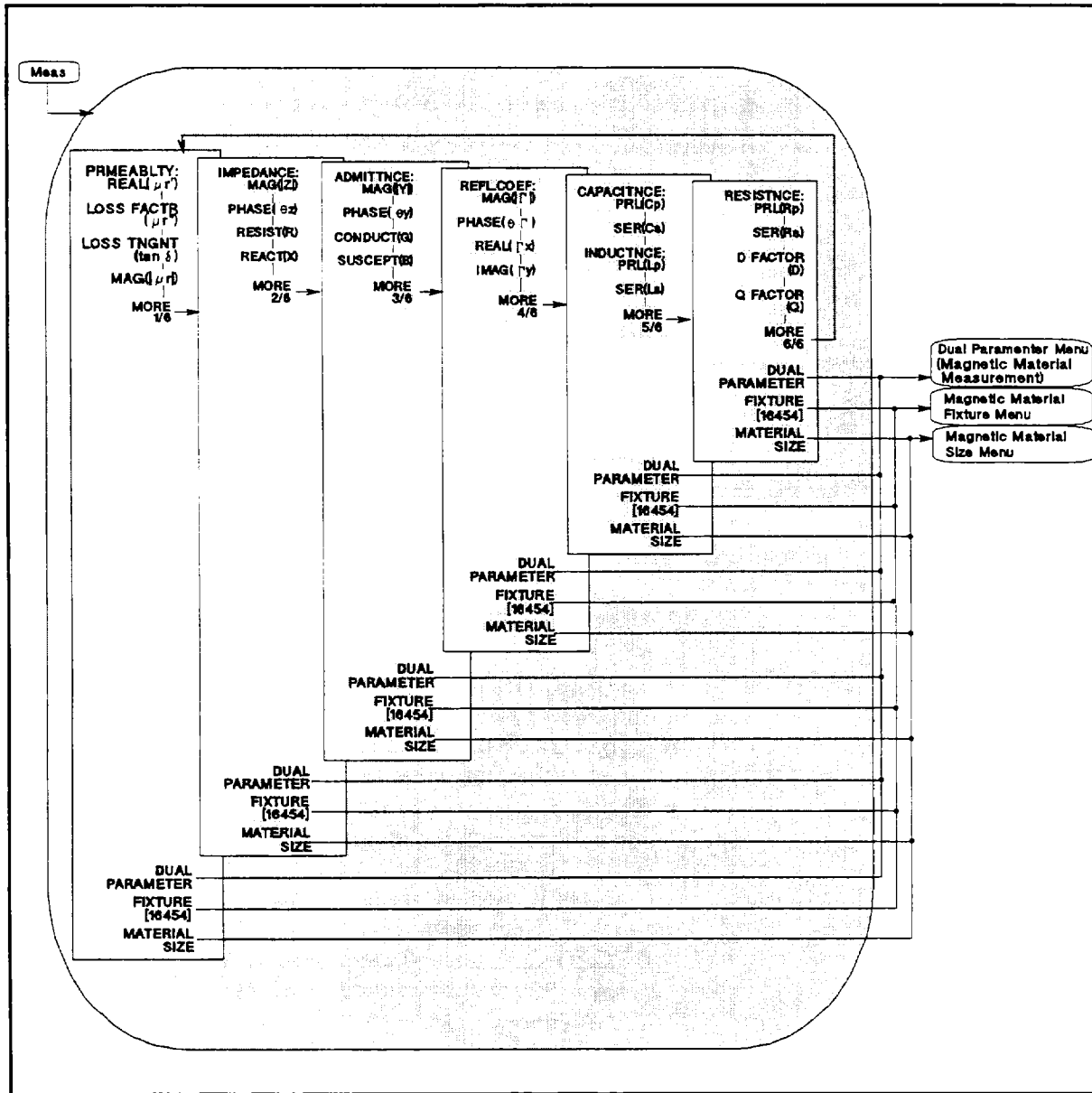
- **THICKNESS** Sets the thickness of the dielectric material to be measured.
- **DONE (MODIFIED)** Completes the procedure to define material size.



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Figure 5-18. Dielectric Material Size

Permeability Measurement Menu (Option 002 only)



5 Measurement Block

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Figure 5-19. Permeability Measurement Menu (Option 002 only)

- PRMEABLY:REAL(μ'_r) Measures real part of complex permeability (μ'_r).
- LOSS FACTR (μ''_r) Measures loss factor of complex permeability (μ''_r).
- LOSS TNGNT ($\tan\delta$) Measures loss tangent ($\tan\delta$).
- MAG($|\mu_r|$) Measures absolute magnitude value of complex permeability ($|\mu_r|$).

- **MORE 1/6** leads the following softkeys, which is used to measure impedance parameter as same as the *Impedance Measurement* menu.
 - **IMPEDANCE:MAG(|Z|)** Measures absolute magnitude value of impedance ($|Z|$).
 - **PHASE(θ_z)** Measures phase value of impedance (θ_z).
 - **RESIST(R)** Measures resistance value (R).
 - **REACT(X)** Measures reactance value (X).
 - **ADMITTANCE:MAG(|Y|)** Measures absolute magnitude value of admittance ($|Y|$).
 - **PHASE(θ_y)** Measures phase value of admittance (θ_y).
 - **CONDUCT(G)** Measures conductance value (G).
 - **SUSCEPT(B)** Measures susceptance value (B).
 - **REFL. COEF:MAG(| Γ |)** Measures absolute magnitude value of reflection coefficient ($|\Gamma|$).
 - **PHASE(θ_Γ)** Measures phase value of reflection coefficient (θ_Γ).
 - **REAL(Γ_x)** Measures real part of reflection coefficient (Γ_x).
 - **IMAG(Γ_y)** Measures imaginary part of reflection coefficient (Γ_y).
 - **CAPCITANCE:PRL(C_p)** Measures parallel capacitance (C_p), which is used for small capacitance measurement.
 - **SER(C_s)** Measures series capacitance (C_s), which is used for large capacitance measurement.
 - **INDUCTANCE:PRL(L_p)** Measures parallel inductance (L_p), which is used for large inductance measurement.
 - **SER(L_s)** Measures series inductance (L_s), which is used for small inductance measurement.
 - **RESISTANCE:PRL(R_p)** Measures parallel resistance (R_p), which is used for large resistance, large inductance, or small capacitance.
 - **SER(R_s)** Measures series resistance (R_s), which is used for small resistance, small inductance, or large capacitance.
 - **D FACTOR (D)** Measures dissipation factor (D).
 - **Q FACTOR (Q)** Measures quality factor (Q).
- **DUAL PARAMETER** Leads to the *Dual Parameter* menu, which are used to select parameters to be measured for both channels with one-key stroke.
- **FIXTURE [16454()]** Leads to the *Fixture Menu*, which is used to select the test fixture used with the analyzer. The selected test fixture is displayed in brackets in the softkey label.
- **MATERIAL SIZE** Leads to the *Material Size Menu*, which is used to set the diameters of the magnetic material to be measured.

Complex Permeability Measurement Menu (Option 002 only)

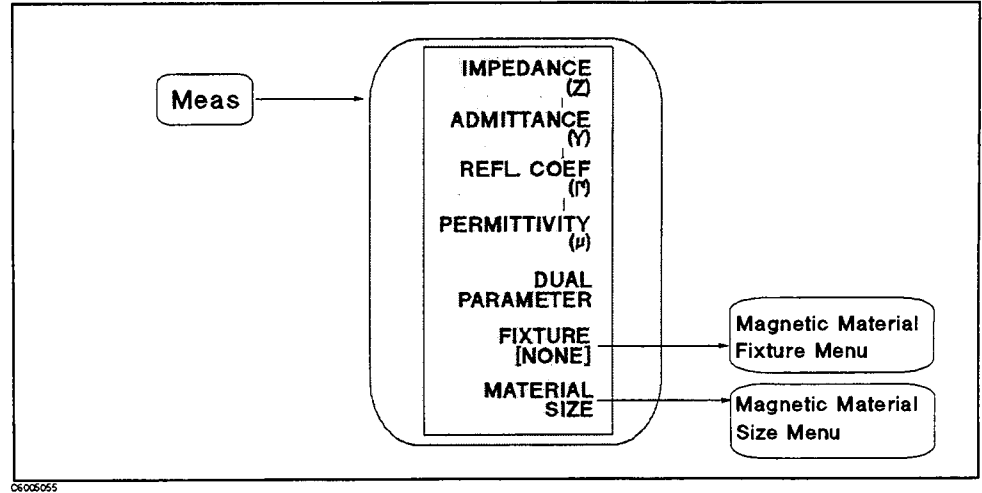


Figure 5-20. Complex Permeability Measurement Menu (Option 002 only)

This softkey menu can be accessed at the following conditions:

- Format : the polar, Smith, admittance, or complex plane format is selected.
- Fixture : HP 16454A is selected.

- **IMPEDANCE (Z)** Measures complex impedance on the polar or complex plane format. This softkey is not available when Smith or admittance chart is selected.
- **ADMITTANCE (Y)** Measures complex admittance on the polar or complex plane format. This softkey is not available when Smith or admittance chart is selected.
- **REFL. COEF (Γ)** Measures complex impedance on Smith, admittance, polar or complex plane format.
- **PERMEABILITY (μ)** Measures complex relative permeability on the polar or complex plane format. This softkey is not available when Smith or admittance chart is selected.
- **DUAL PARAMETER** This softkey is not available for Smith, admittance, polar chart, and complex plane formats.
- **FIXTURE []** Leads to the *Fixture Menu*, which is used to select the test fixture used with the analyzer. The selected test fixture is displayed in brackets in the softkey label.
- **MATERIAL SIZE** Leads to the *Material Size Menu*, which is used to set the diameters of the magnetic material to be measured.

Dual Parameter Menu (Magnetic Material Measurement)

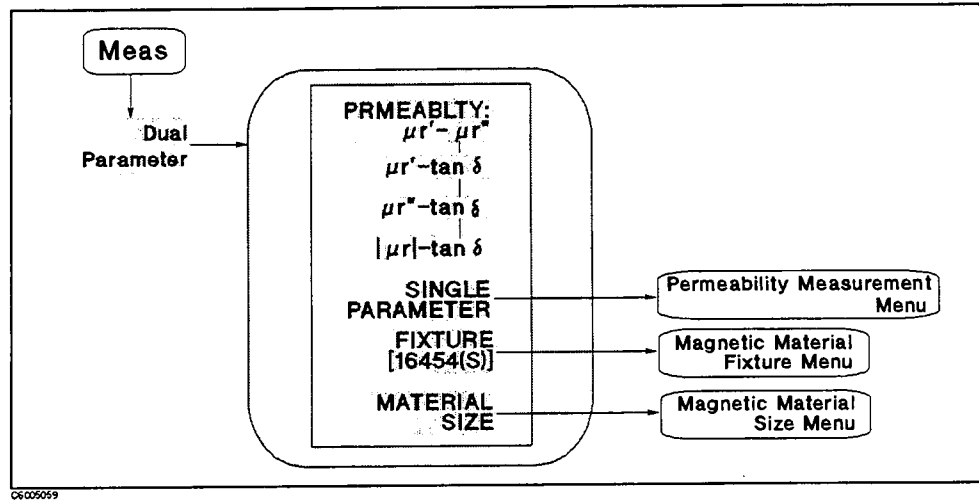


Figure 5-21.
Dual Parameter Menu (Magnetic Material Measurement)

- $\mu_r' - \mu_r''$ Measures μ_r' on channel 1 and measures μ_r'' on channel 2.
- $\mu_r' - \tan \delta$ Measures μ_r' on channel 1 and measures $\tan \delta$ on channel 2.
- $\mu_r'' - \tan \delta$ Measures μ_r'' on channel 1 and measures $\tan \delta$ on channel 2.
- $|\mu_r| - \tan \delta$ Measures $|\mu_r|$ on channel 1 and measures $\tan \delta$ on channel 2.
- SINGLE PARAMETER Leads to the *Permeability Measurement Menu*.
- FIXTURE [16454] Leads to the *Magnetic Material Fixture Menu*, which is used to select test fixture used with the analyzer. The selected test fixture is displayed in brackets in the softkey label.
- MATERIAL SIZE Leads to the *Material Size Menu*, which is used to set the diameters of the magnetic material to be measured.

Magnetic Material Fixture Menu (Option 002 only)

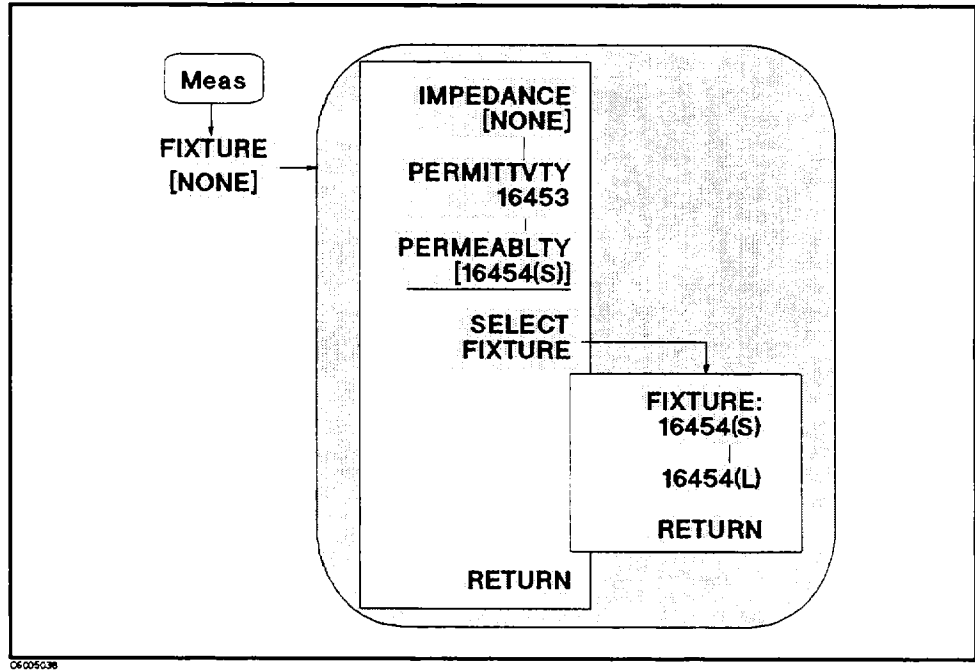


Figure 5-22. Magnetic Material Fixture Menu (Option 002 only)

This section describes the softkeys that can be accessed when Option 002 (Material Measurement) is installed and **PERMEABILITY 16454** is selected in this menu.

- **IMPEDANCE []** Selects the impedance measurement. When this softkey is selected, the menu accessed from the **SELECT FIXTURE** softkey lists only impedance fixtures. The **Meas** and **Cal** keys lead only to the menus related to the impedance measurement. When a fixture has been specified, its label is displayed in brackets in the softkey label.
- **PERMITTVTY 16453** Selects the permittivity measurement and sets the electrical length that is suitable for the HP 16453A. When this softkey is selected, the **Meas** and **Cal** keys lead only to the menus related to the permittivity measurement.
- **PERMEABILITY 16454()** Selects the permeability measurement. When this softkey is selected, the menu accessed from the **SELECT FIXTURE** softkey lists only magnetic material fixtures. The **Meas** and **Cal** keys lead only to the menus related to the permeability measurement. When a fixture size has been specified, the size is displayed in parenthesis in the softkey label.
- **SELECT FIXTURE** Leads to the following softkeys, which are used to select a test fixture for the permeability measurement.
 - **FIXTURE:16454(S)** Sets the electrical length that is suitable for the HP 16454A Small.

Meas (Magnetic Material Measurement)

- 16454(L)** Sets the electrical length that is suitable for the HP 16454A Large.

Magnetic Material Size Menu (Option 002 only)

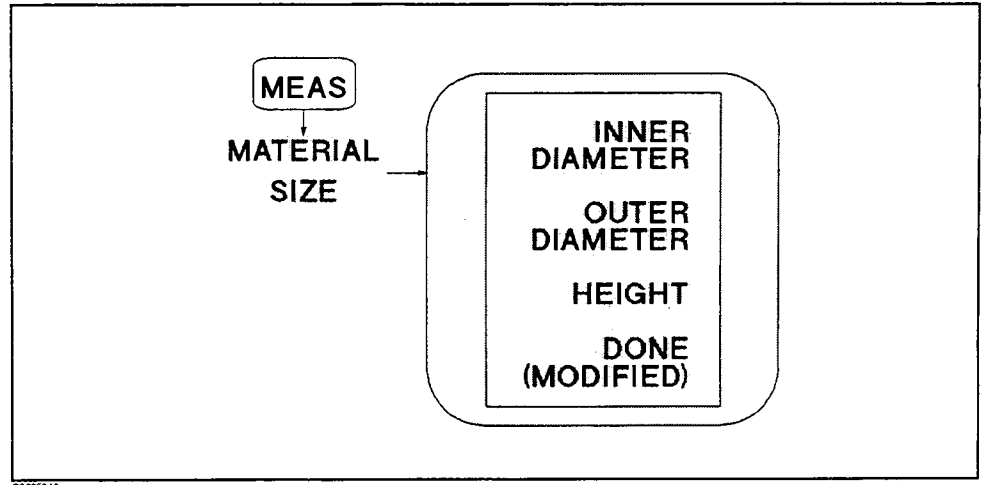


Figure 5-23. Magnetic Material Size Menu (Option 002 only)

- **OUTER DIAMETER** Sets outer diameter of magnetic material to be measured, which is ring shaped.
- **INNER DIAMETER** Sets inner diameter of magnetic material to be measured, which is ring shaped.
- **HEIGHT** Sets height of magnetic material to be measured, which is ring shaped.
- **DONE (MODIFIED)** Completes the procedure to define material size.

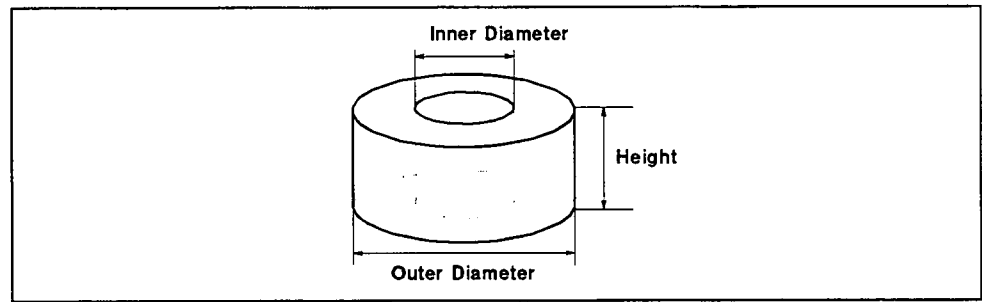


Figure 5-24. Magnetic Material Size

Format

Format

Format Menu

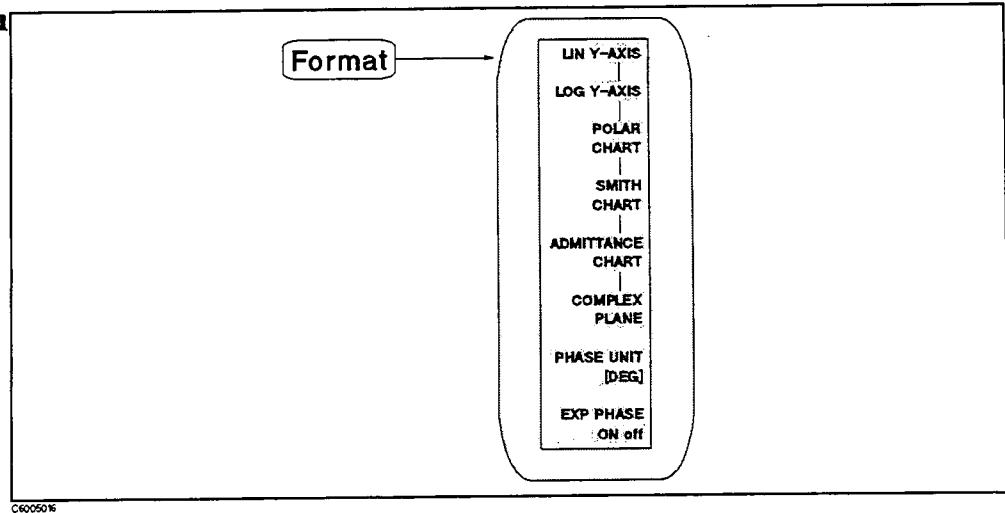


Figure 5-25. Format Menu

- **LIN Y-AXIS** Displays the linear magnitude format.
- **LOG Y-AXIS** Displays the log scale format.
- **POLAR CHART** Displays a polar chart format.
- **SMITH CHART** Displays a Smith chart format.
- **ADMITTANCE CHART** Displays an admittance Smith chart format.
- **COMPLEX PLANE** Displays a complex plane format.
- **PHASE UNIT []** Selects the unit for phase measurement. The unit selected is shown in brackets.
- **EXP PHASE ON off** Turns the expanded phase ON or OFF. When this is turned OFF, the analyzer wraps the phase plot around every $\pm 180^\circ$. When this is ON, the analyzer avoids the wrap and displays the phase plot over $\pm 180^\circ$.

User Trace Format Menu

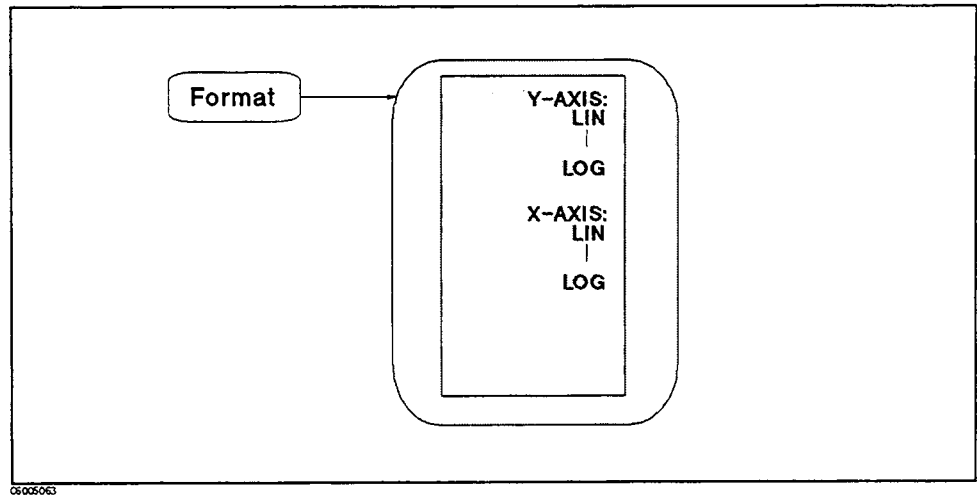


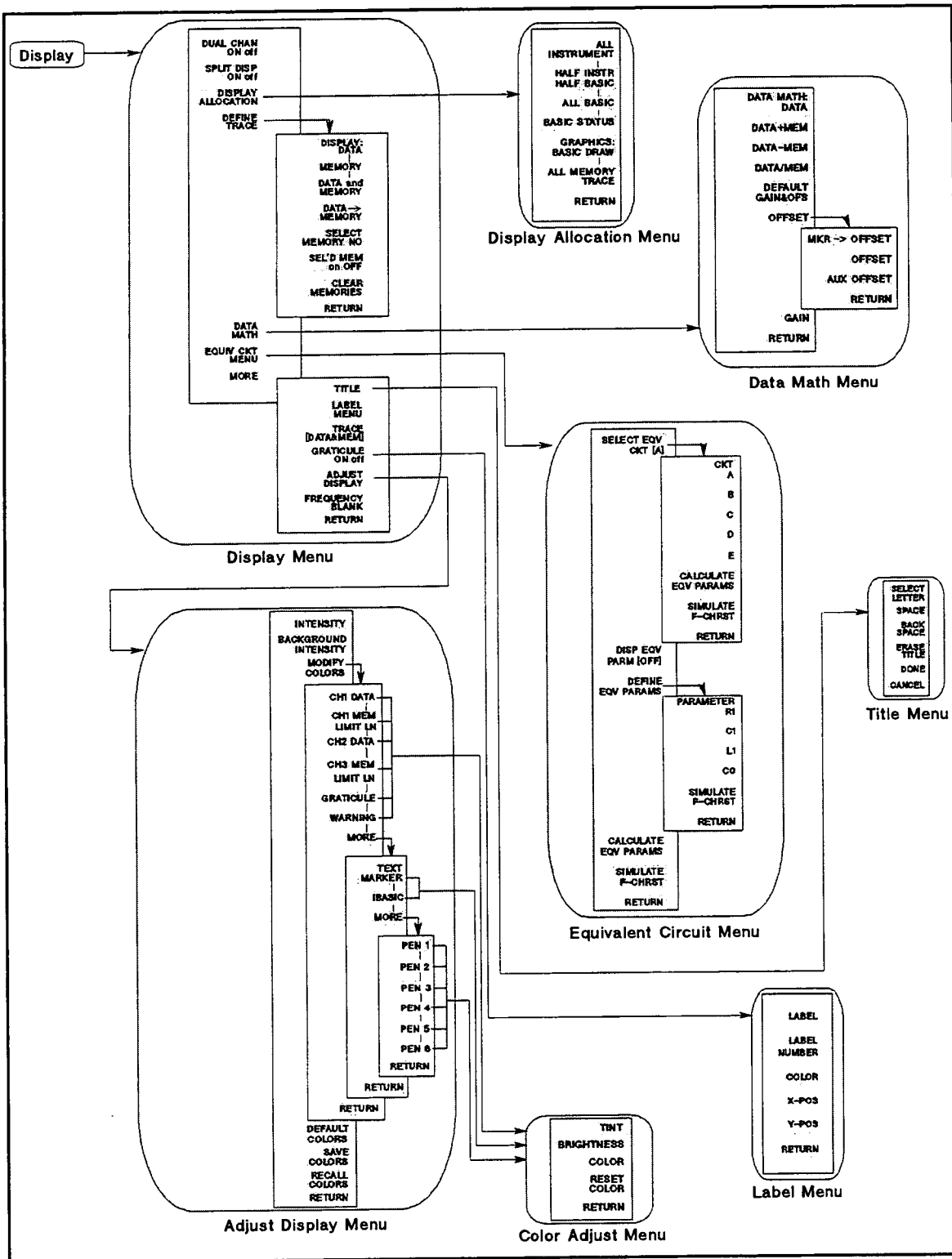
Figure 5-26. User Trace Format Menu

This menu can be accessed when the user trace is turned on.

- Y-AXIS:LIN Selects linear scale along the y-axis.
- LOG Selects logarithm scale along the y-axis.
- X-AXIS:LIN Selects linear scale along the x-axis.
- LOG Selects logarithm scale along the x-axis.

Display

Display



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Figure 5-27. Softkey Menu Accessed from **Display** Key

Display Menu

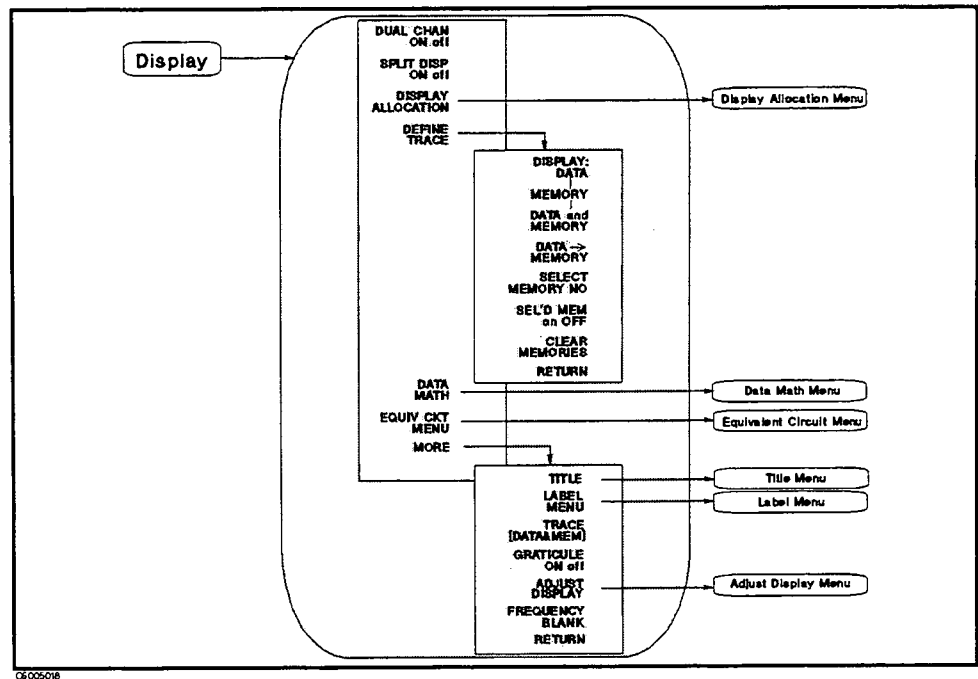


Figure 5-28. Display Menu

- **DUAL CHAN ON off** Toggles between the display of both measurement channels or the active channel only. This is used in conjunction with **SPLIT DISP ON off** to display both channels.
- **SPLIT DISP ON off** Toggles between a full-screen single graticule display of one or both channels, and a split display with two half-screen graticules one above the other. The split display can be used in conjunction with **DUAL CHAN ON** to show the measured data of each channel simultaneously on separate graticules.
- **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 an analyzer that has HP Instrument BASIC (Option 1C2) installed.
- **DEFINE TRACE** Leads to the following softkeys, which are used to select traces displayed (the data trace and the memory traces).
 - **DISPLAY: DATA** Displays the current measurement data trace for the active channel.
 - **MEMORY** Displays the trace memory for the active channel. If no data is stored in memory for this channel, a warning message is displayed.
 - **DATA and MEMORY** Displays both the current data and the memory traces.
 - **DATA→MEMORY** Stores the current active measurement data in the active memory of the active channel. It then becomes the memory trace (for use in subsequent math manipulations or display). When the NOP is changed, the memory trace becomes invalid.
 - **SELECT MEMORY NO** Selects a memory trace as the active memory trace. The analyzer can store traces into several memory traces (maximum number of memory traces depends on the NOP).

However, the display functions (such as scaling) and marker functions affect the active memory trace specified by this softkey.

- **SEL'D MEM ON off** Sets the state of the memory trace always to display the memory trace or to erase the memory trace, even each memory trace is inactive. (Regardless of this setting, the active memory trace is always displayed.) The state of each memory trace can be set to display or erase traces individually, and pressing this key changes the state of the current active memory trace selected by **SELECT MEMORY NO**. Therefore, it is necessary to select a memory trace before changing this state. See the following example:

For example: To erase memory trace No.2

Assuming that two memory traces have been used:

1. Press **SELECT MEMORY NO** **2** **x1**. (No.2 memory trace is selected)
2. Press **SEL'D MEM ON off** to turn to off. (Softkey label will change from **ON off** to **on OFF**. No.2 memory trace is set to be erased when another trace is selected.)
3. Press **SELECT MEMORY NO** **1** **x1**. (NO.1 memory trace is selected and No.2 memory trace is not displayed.)

If you cannot display memory traces ...

1. When you cannot turn on **MEMORY** or **DATA** and **MEMORY**.

In this case, check if the softkey labels of **MEMORY** and **DATA** and **MEMORY** are dim. If they are dim, no data is stored in the memory trace. Press **Display** **DEFINE TRACE DATA→MEMORY** to store data into the memory trace before turning on the memory trace.

2. When a memory trace selected using **SELECT MEMORY NO** can be displayed, but other memory traces cannot be displayed.

In this case, please check if the softkey label of **SEL'D MEM ON off** is dim, if it is dim, press **Display** **DISPLAY ALLOCATION ALL MEMORY TRACE** to make all memory traces available.

- **CLEAR MEMORY** Clear all memory traces.

The analyzer will lose all data in the memory traces after you press this softkey. If the memory traces are to be recalled, you must save the data to the disk or the RAM disk memory.

The following operations also clear the memory traces:

- Pressing **Preset**.
- Turning the analyzer off.
- Changing NOP.
- Recalling data from the disk or RAM disk memory.

Pressing **SIMULATE F-CHAR** in the *Equivalent Circuit menu* changes the data in memory trace NO.1 because the equivalent circuit function uses this memory trace in order to display the result of simulating the frequency characteristics.

- **DATA MATH** Leads to the *Data Math Menu*. The data math function selected is shown in brackets ([DATA-MEM] shows that the data math function selected DATA-MEM).
- **EQUIV CKT MENU** Leads to the *Equivalent Circuit menu*, which is used to derive values of equivalent circuit parameters and simulate frequency characteristics of equivalent circuits.
- **TITLE** Displays the title menu in the softkey labels and the character set in the active entry area to display the title in the active channel title area on the screen.
- **LABEL MENU** Leads to the *Label menu*, which is used to label text on any area of the screen.
- **TRACE []** Turns the user trace display on or off. When the user traces are turned on, the normal data/memory trace is not displayed.

[USER] shows the user trace is displayed

[DATA&MEM] shows the normal data trace is displayed

- **GRATICULE ON off** Turns the graticule of the active channel on or off.

If the graticule is not erased when GRATICULE ON off is turned off

When Dual channel is on, Split display is off, and both channels are using the same format, the graticule is not erased, even if the graticule setting of either channel is tuned off. In this case, turn the **GRATICULE ON off** of both channels to off.

When a user trace is displayed, the graticule cannot be erased using **GRATICULE ON off**.

5 Measurement Block

- **ADJUST DISPLAY** Provides a menu for adjusting display intensity, colors, and accessing save and recall functions for modified display color sets.
- **FREQUENCY BLANK** Blanks the displayed frequency notation for security purposes. Frequency labels cannot be restored except by pressing (Preset) or by turning the power off and then on.

Display Allocation Menu

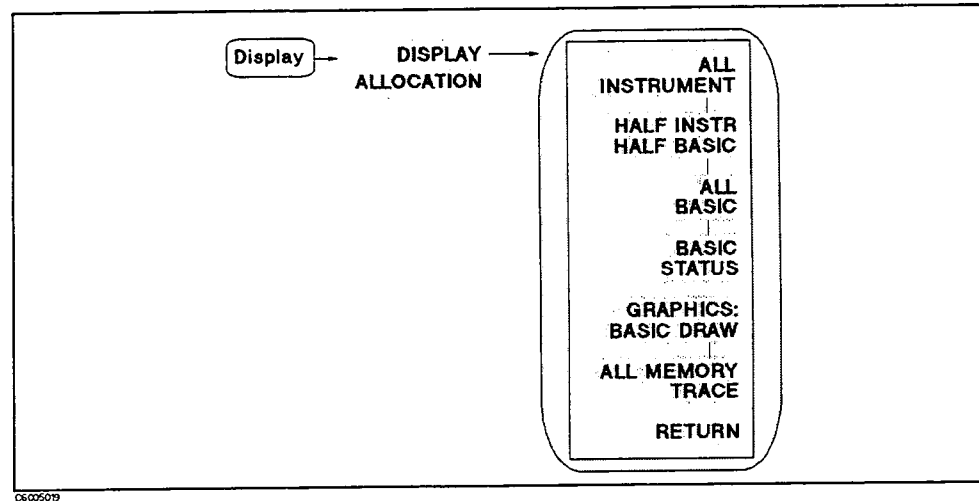
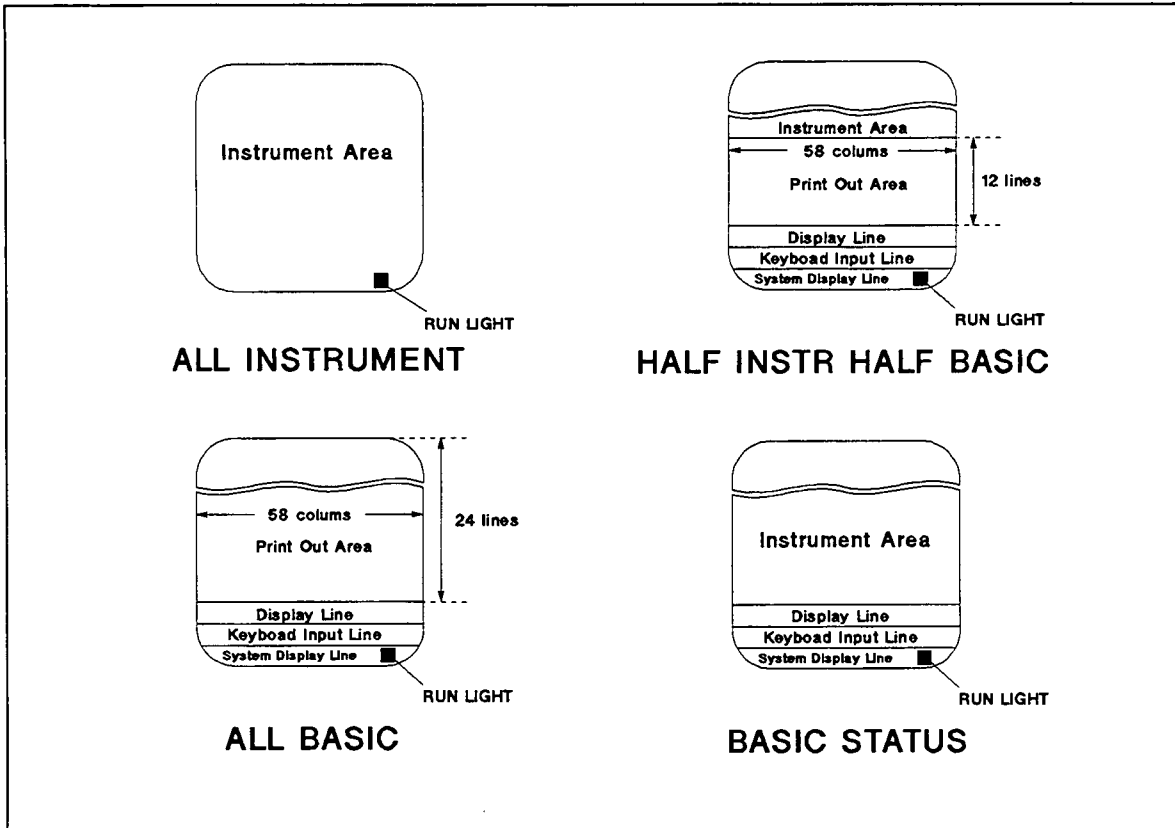


Figure 5-29. Display Allocation Menu

- **ALL INSTRUMENT** Selects a full screen or two half-screen graticules.
- **HALF INSTR HALF BASIC** Selects two half-screens, one graticule display above the HP Instrument BASIC display.
- **ALL BASIC** Selects a full screen single HP Instrument BASIC display.
- **BASIC STATUS** Selects a full screen graticule and three status lines for HP Instrument BASIC under the graticule.
- **GRAPHICS: BASIC DRAW** Makes Instrument BASIC graphic capability available. Because the Instrument BASIC graphic capability uses the same resources as the memory trace capability, the analyzer cannot display memory traces except for a memory trace selected using **SELECT MEMORY NO** when this softkey is selected.
- **ALL MEMORY TRACE** Makes all memory trace displays available. Because the multiple memory trace display capability uses the same resources as the Instrument BASIC graphic capability, the analyzer cannot display Instrument BASIC graphics when this softkey is selected.



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Figure 5-30. Display Allocations

Data Math Menu

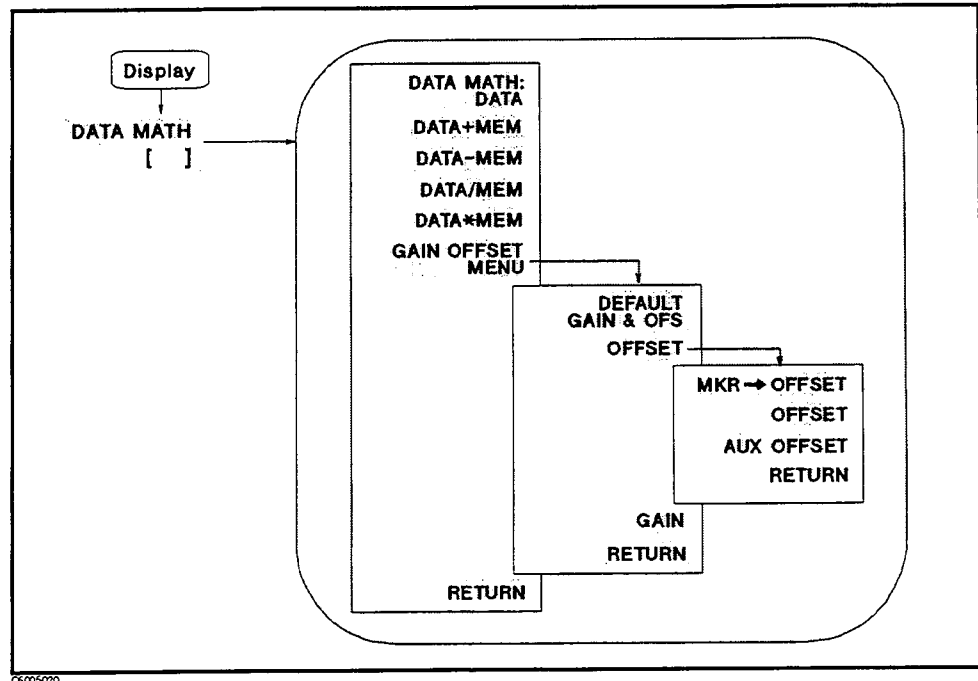


Figure 5-31. Data Math Menu

- **DATA** Turns off all data math functions.
- **DATA+MEM** Adds the memory trace to the data trace.
- **DATA-MEM** Subtracts the memory trace from the data trace.
- **DATA/MEM** Divides the data trace by the memory trace.
- **DATA*MEM** Multiplies the data trace by the memory trace.
- **GAIN OFFST MENU** Leads to the following softkeys, which are used to set gain and offset values for the data math function.
 - **DEFAULT GAIN & OFS** Returns gain and offset value back to the default values (gain = 1, offset = 0).
 - **OFFSET** Displays the menu used to define the offset value and activates the offset value. When using Smith, polar, admittance chart, and complex plane format, **OFFSET** defines the real part of the offset value.
 - **MKR→OFFSET** Enters the marker's amplitude value into the offset value.
 - **OFFSET** Makes the offset value the active function.
 - **AUX OFFSET VALUE** Defines the imaginary part of the offset value when using the Smith, polar, admittance chart, and complex plane format. If the format is not one of the above formats, this softkey performs no function.
 - **GAIN** Defines the gain value for the data math function.

The data math functions displays the result of the following calculations:

- $(GAIN \times DATA) - OFFSET$
- $(GAIN \times MEMORY) - OFFSET$
- $(GAIN \times (DATA + MEMORY)) - OFFSET$
- $(GAIN \times (DATA - MEMORY)) - OFFSET$
- $(GAIN \times (DATA / MEMORY)) - OFFSET$
- $(GAIN \times (DATA \times MEMORY)) - OFFSET$

Where,

GAIN is a scalar value defined by **GAIN**

DATA is the data trace value (measurement value)

MEMORY is the memory trace value (stored by **DATA→MEMORY**)

OFFSET is an offset value defined by **OFFSET**

Equivalent Circuit Menu

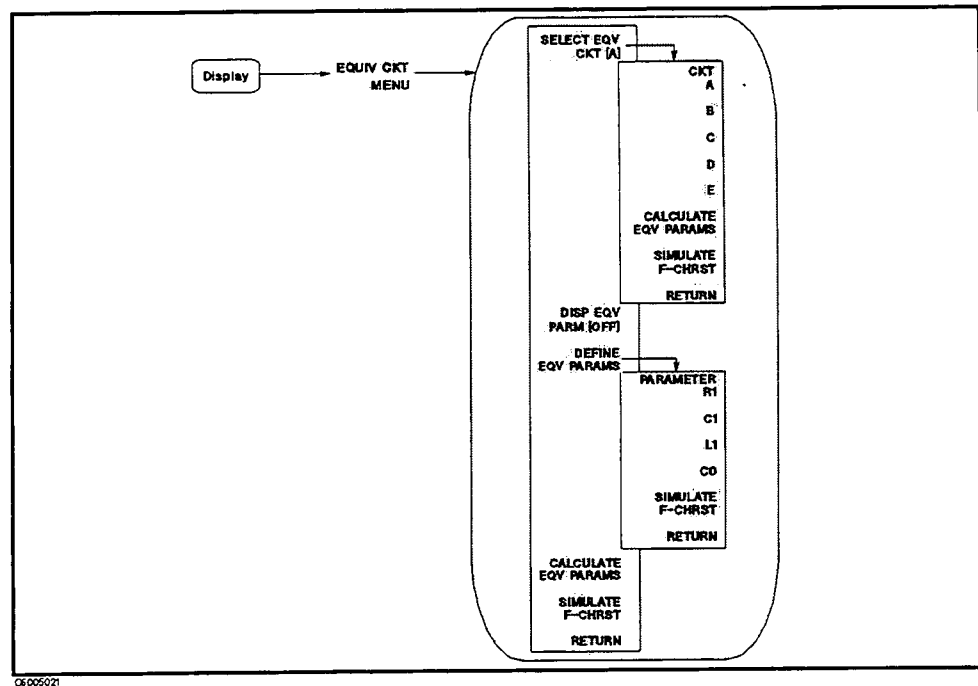
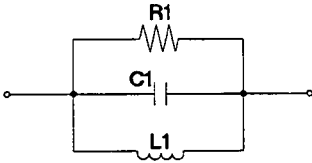
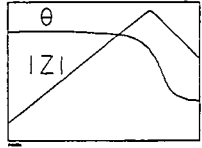
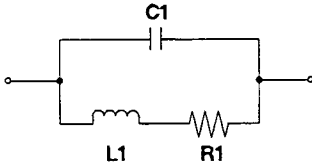
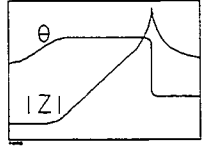
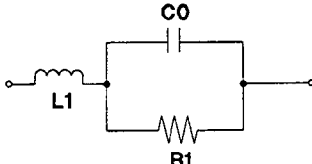
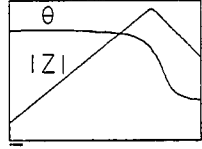
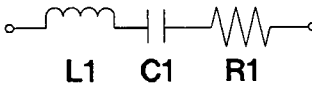
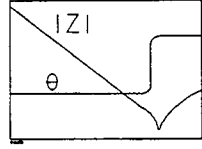
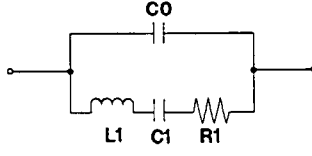
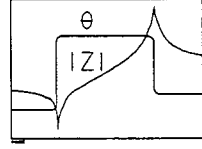


Figure 5-32. Equivalent Circuit Menu

- **SELECT EQV CIRCUIT** Leads to the following softkeys, which are used to select the equivalent circuit. (See Table 5-1.)
 - **A** Selects equivalent circuit A, which is used to simulate inductors with high core loss.
 - **B** Selects equivalent circuit B, which is used to simulate inductors in general and resistors.
 - **C** Selects equivalent circuit C, which is used to simulate high-value resistors.
 - **D** Selects equivalent circuit D, which is used to simulate capacitors.
 - **E** Selects equivalent circuit E, which is used to simulate resonators.
- **CALCULATE EQV PARAMS** Calculates the equivalent circuit parameters. While the calculation is being performed, the message Calculating EQV parameters is displayed. After the calculation is completed, the values of the equivalent parameters are displayed.
- **DEFINE EQV PARMS** Leads to the following softkeys, which are used to enter the equivalent circuit parameters.
 - **PARAMETER R1** makes R_1 the active function in order to enter its value.
 - **L1** makes L_1 the active function in order to enter its value.
 - **C0** makes C_0 the active function in order to enter its value.
 - **C1** makes C_1 the active function in order to enter its value.

- **SIMULATE F-CHRST** Simulates the frequency characteristics by using the current equivalent circuit parameters and shows simulation result on the screen using memory trace NO.1. In other words, simulation results are stored into the NO.1 memory trace.
- **DISP EQV PARM [ON]** Toggles the display of the equivalent circuit parameter value.

Table 5-1. Equivalent Circuit Selection Guide

Equivalent Circuit	Type of devices	Typical Frequency Characteristics
<p>A</p> 	inductors with high core loss	
<p>B</p> 	inductors and resistors	
<p>C</p> 	high-value resistors	
<p>D</p> 	capacitors	
<p>E</p> 	resonators	

5 Measurement Block

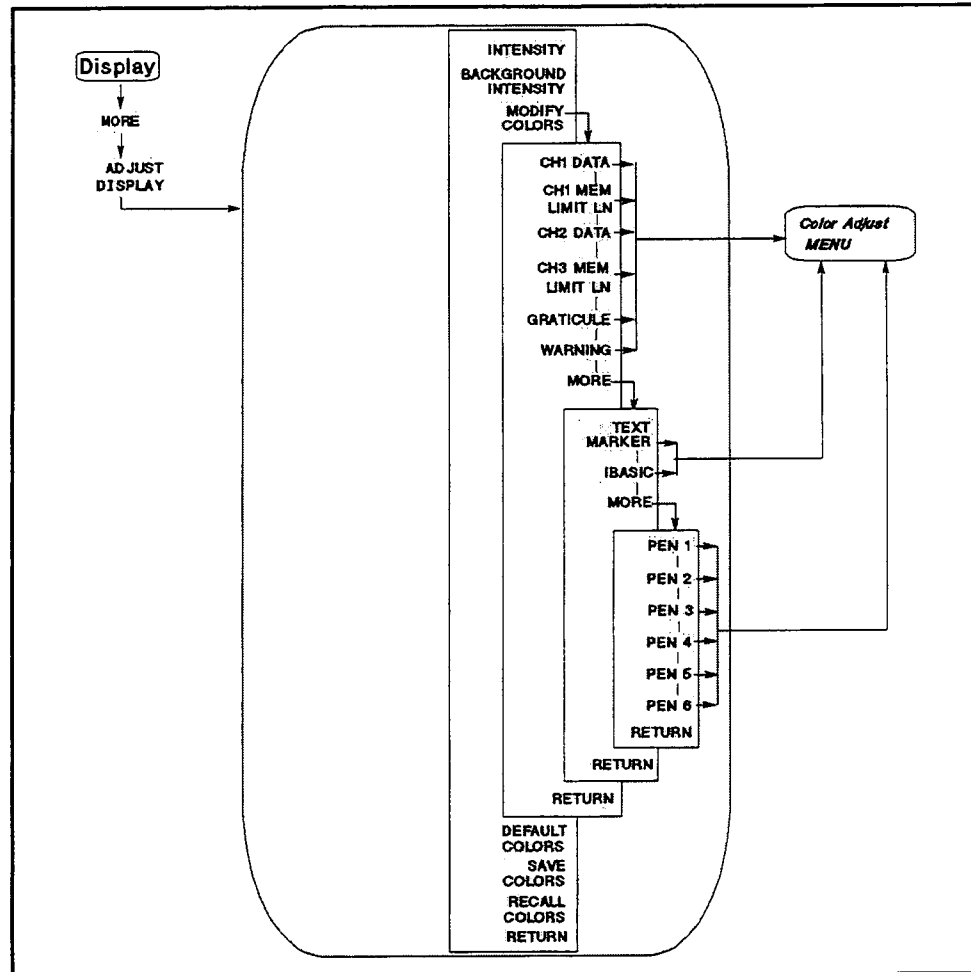
Available Only for the Frequency Sweep

The equivalent circuit function is available only for the frequency sweep. The equivalent circuit function is not available for OSC level and dc bias sweep.

Analysis Range can be specified

The frequency range used to calculate parameters can be specified using the menu accessed from the **SEARCH RANGE MENU** under the **Search** key.

Adjust Display Menu



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Figure 5-33. Adjust Display Menu

- **INTENSITY** Sets the display intensity as a percentage of the brightest setting.
- **BACKGROUND INTENSITY** Sets the background intensity of the display as a percentage of the white level.
- **MODIFY COLORS** Displays the menu used for color modification of the display elements.
 - **CH1 DATA** Selects channel 1 data trace for color modification and displays the *Color Adjust menu*.
 - **CH1 MEM/LIMIT LINE** Selects channel 1 memory trace and limit lines for color modification and displays the *Color Adjust menu*.
 - **CH2 DATA** Selects channel 2 data trace for color modification and displays the *Color Adjust menu*.
 - **CH2 MEM/LIMIT LINE** Selects channel 2 memory and the reference line and limit line for color modification and displays the *Color Adjust menu*.
 - **GRATICULE** Selects the graticule and a portion of softkey text (where there is a choice of a feature being ON or OFF) for color modification and displays the *Color Adjust menu*.

- **WARNING** Selects the warning annotation for color modification and displays the *Color Adjust menu*.

MORE (in this menu) displays softkeys to select other elements for color modification. This softkey is active for Option 1C2 only. If Option 1C2 is not installed in the analyzer, the **TEXT MARKER** softkey is displayed instead of the **MORE** softkey.

- **TEXT MARKER** Selects all the non-data text for color modification (for example, softkey labels) and displays the *Color Adjust menu*.
- **IBASIC** Selects the text on the BASIC screen for color modification and displays the *Color Adjust menu* (Option 1C2 only).

MORE (in this menu) displays softkeys to select a numbered pen for color modification. This softkey is for Option 1C2 only. The pens are used by the HP Instrument BASIC graphic commands.

- **PEN 1** Selects pen 1 for color modification and displays the *Color Adjust menu*.
- **PEN 2** Selects pen 2 for color modification and displays the *Color Adjust menu*.
- **PEN 3** Selects pen 3 for color modification and displays the *Color Adjust menu*.
- **PEN 4** Selects pen 4 for color modification and displays the *Color Adjust menu*.
- **PEN 5** Selects pen 5 for color modification and displays the *Color Adjust menu*.
- **PEN 6** Selects pen 6 for color modification and displays the *Color Adjust menu*.
- **DEFAULT COLORS** Returns all the color settings back to the default values.
- **SAVE COLORS** Saves the modified version of the color set to the non-volatile memory.
- **RECALL COLORS** Recalls the previously saved modified version of the color set from the non-volatile memory. **RECALL COLORS** appears only when a color set has been saved.

Color Adjust Menu

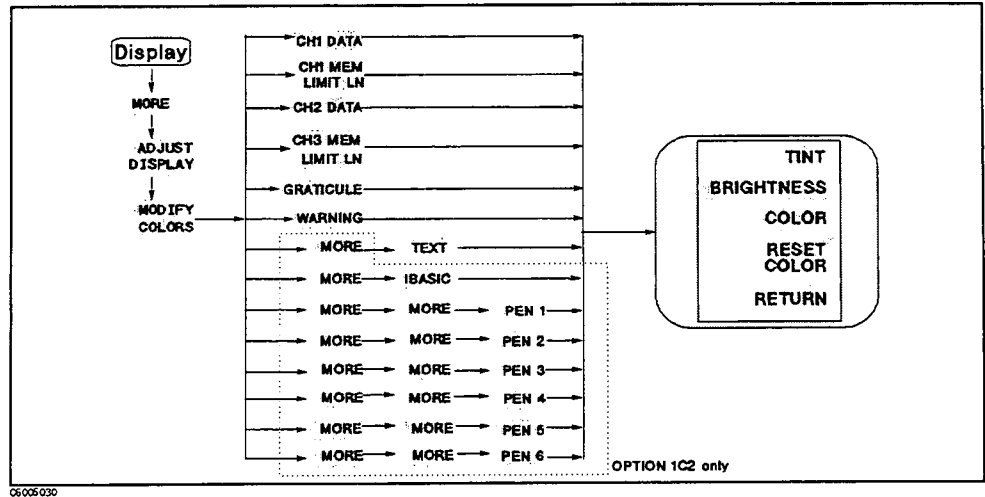
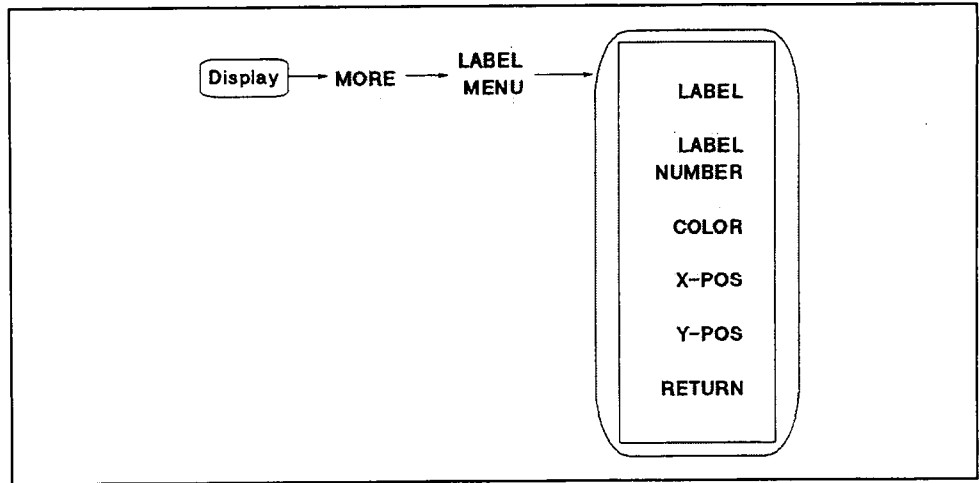


Figure 5-34. Color Adjust Menu

- **TINT** Adjusts the hue of the chosen attribute.
- **BRIGHTNESS** Adjusts the brightness of the color being modified.
- **COLOR** Adjusts the degree of whiteness of the color being modified.
- **RESET COLOR** Resets the color being modified to the default color.

Color consists of the following three parameters:	
Tint	The continuum of hues on the color wheel, ranging from red through green and blue, and back to red.
Brightness	A measure of the brightness of the color.
Color	The degree of whiteness of the color. A scale from white to pure color.

Label Menu



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Figure 5-35. Label Menu

- LABEL Makes label the active function to define the label.
- LABEL NUMBER Select the number of labels.
- COLOR Selects the color of the label text.
- X-POS Sets the X-axis position of the label selected by LABEL NUMBER .
- Y-POS Sets the Y-axis position of the label selected by LABEL NUMBER .

Display

Title menu

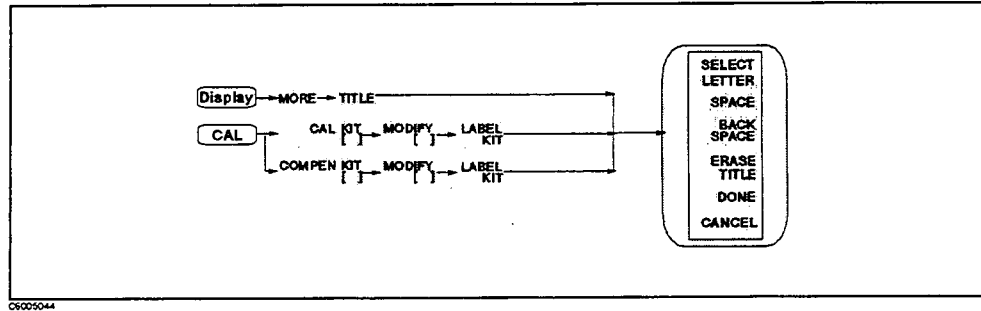


Figure 5-36. Title Menu

- **SELECT LETTER** Selects the letter pointed to by the arrow “↑” on the screen. The arrow can be moved by rotating the knob.
- **SPACE** Inserts a space in the title.
- **BACK SPACE** Deletes the last character entered.
- **ERASE TITLE** Deletes the entire title.
- **DONE** Terminates the title entry and returns to the display more menu.
- **CANCEL** Cancels the title entry and returns to the display more menu without any change.

User Trace Display Menu

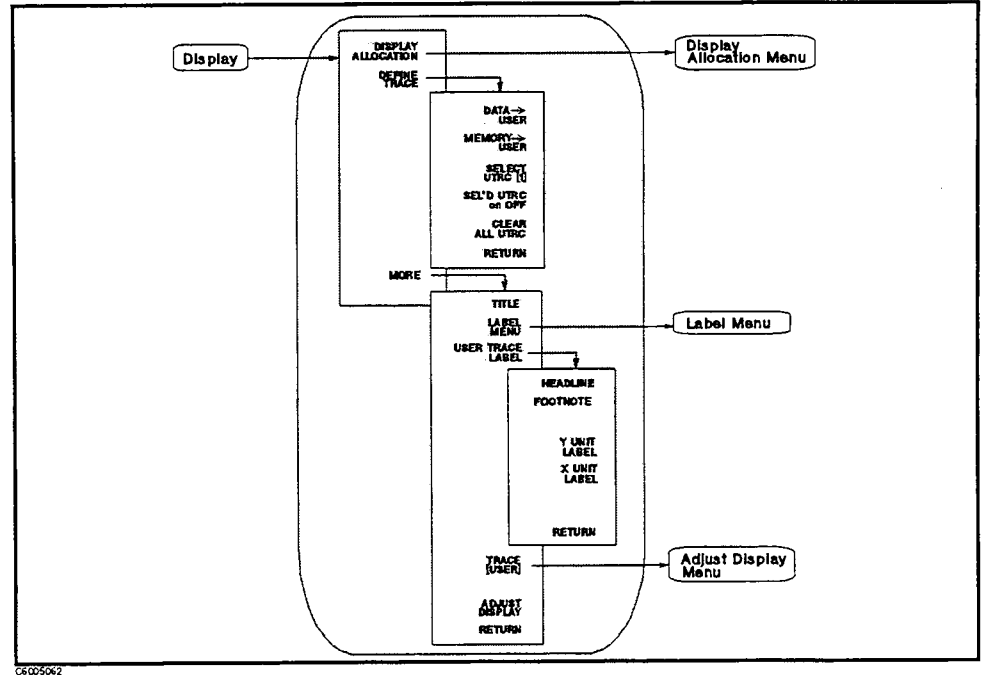


Figure 5-37. User Trace Display Menu

This menu can be accessed when the user trace is turned on.

- **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 an analyzer that has HP Instrument BASIC (Option 1C2) installed.
- **DEFINE TRACE** Leads to the following softkeys, which are used to select traces displayed (the data and memory traces and the user trace).
 - **DATA → USER** Stores the active measurement data in the user trace selected and copies the unit and NOP of the data trace to the user trace selected.
 - **MEMORY → USER** Stores the active memory data in the user trace selected and copies the unit and NOP of the memory trace to the user trace selected.
 - **SELECT UTRC [1]** Leads to the following softkeys, which are used to select one user trace from the four traces available in order to copy data or memory trace to the user trace. You can read the value of the trace using the marker and scale the trace.
 - **USER TRC 1** Selects user trace number 1.
 - **USER TRC 2** Selects user trace number 2.
 - **USER TRC 3** Selects user trace number 3.
 - **USER TRC 4** Selects user trace number 4.

- **SEL'D UTRC ON off** Sets the state of the selected user trace to display it (ON) or to erase it (OFF). The trace is not displayed when the trace is unselected after the state was set to OFF. The state of each user trace can be set ON and OFF individually.
- **CLEAR ALL UTRC** Clears all user trace data and settings, and turns off the user trace display.
- **MORE** Leads the following softkey menu.
 - **TITLE** Displays the title menu in the softkey labels and the character set in the active entry area to display the title in the active channel title area on the screen.
 - **LABEL MENU** Leads to the *Label menu*, which is used to label text on any area of the screen.
 - **USER TRACE LABEL** Displays the following softkeys, which are used to put characters on the top or bottom area, or to enter the x and y axis unit labels of the user trace display screen.
 - **HEADLINE** Displays the *Letter menu* to enter characters for a headline at the top left corner of the user trace display screen. The headline can be defined for each user trace individually.
 - **FOOTNOTE** Displays the *Letter menu* to enter characters as a footnote at the bottom of the user trace display screen. The footnote can be defined for each user trace individually.
 - **X UNIT LABEL** Displays the *Letter menu* to enter the x-axis unit label of a current selected user trace.
 - **Y UNIT LABEL** Displays the *Letter menu* to enter the y-axis unit label of a current selected user trace.
 - **TRACE []** Turns the user trace display on or off. When the user traces are turned on, the normal data/memory trace is not displayed.

[USER] shows the user trace is displayed

[DATA&MEM] shows the normal data trace is displayed

- **ADJUST DISPLAY** Provides a menu for adjusting display intensity, colors, and accessing save and recall functions for modified display color sets.

Scale Reference Menu

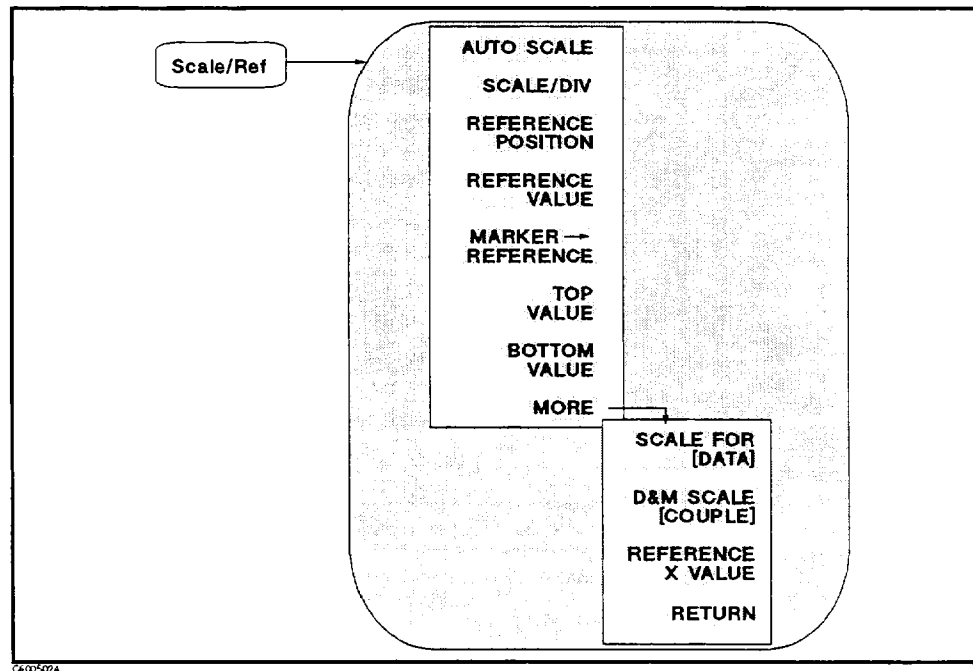
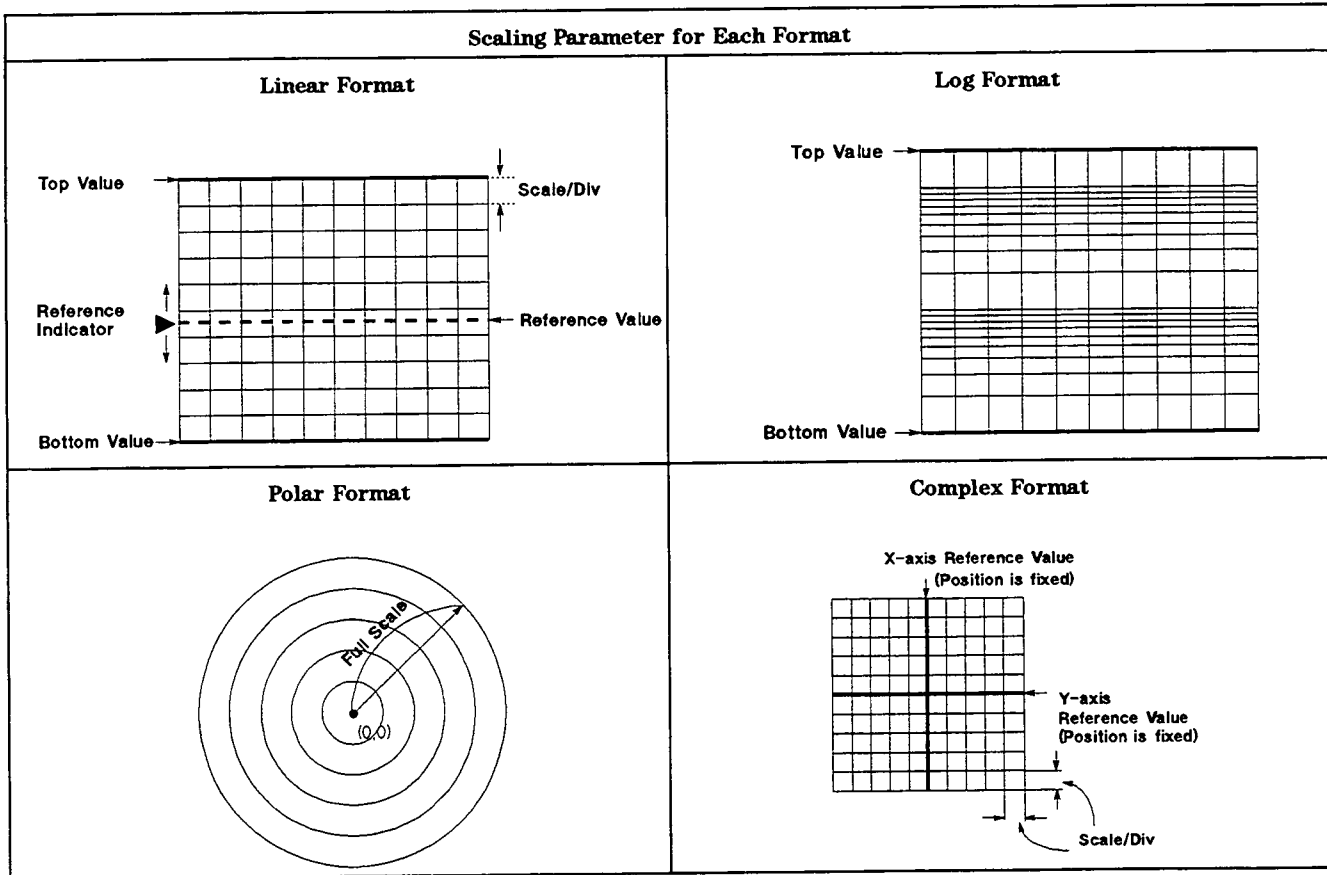


Figure 5-38. Scale Reference Menu

- **AUTO SCALE** Brings the trace data (defined by the **SCALE FOR** key) in view on the display with one keystroke. Sweep values are not affected, only scale and reference values. The analyzer determines the smallest possible scale factor that will put all displayed data onto the vertical graticule.
- **SCALE/DIV** Changes the response value scale per division of the displayed trace. In Smith, polar, and admittance chart formats, this refers to the full scale value at the outer circumference and is identical to the reference value.
- **REFERENCE POSITION** Sets the position of the reference line on the graticule of a Cartesian display (with 0 at the bottom line of the graticule and 10 at the top line). It has no effect on a Smith, polar or admittance chart format. The reference position is indicated with a small triangle just outside the graticule, on the left.
- **REFERENCE VALUE** Changes the value of the reference line, moving the measurement trace correspondingly. In Smith, polar and admittance chart formats, the reference value is the same as the scale and is the value of the outer circle.
- **MARKER → REFERENCE** Makes the reference value equal to the marker's absolute value (regardless of the delta marker value). The marker is effectively moved to the reference line position. In Smith, polar and admittance chart formats this function makes the full scale value at the outer circle equal to the marker response value.
- **TOP VALUE** Changes the value at the top line of the graticule, moving the measurement trace correspondingly.

- **BOTTOM VALUE** Changes the value at the bottom line of the graticule, moving the measurement trace correspondingly.
- **REFERENCE X VALUE** Changes the value of the center position of the X axis, moving the measurement trace correspondingly. This softkey is only available for the complex plane format.
- **REFERENCE Y VALUE** Changes the value of the center position of the Y axis, moving the measurement trace correspondingly. This softkey is only available for the complex plane format.
- **SCALE FOR []** Selects one of the "DATA" and "MEMORY" traces to be scaled by prior functions in this menu. The "DATA" and "MEMORY" traces are available using the *Display menu* accessed from the **Display** key. All memory traces are displayed with the same scaling size.
- **D&M SCALE []** Couples or uncouples the "DATA" and "MEMORY" traces to be scaled by prior functions in this menu. This is valid only for those traces obtained by the *Display menu* accessed from the **Display** key.



User Trace Scale Menu

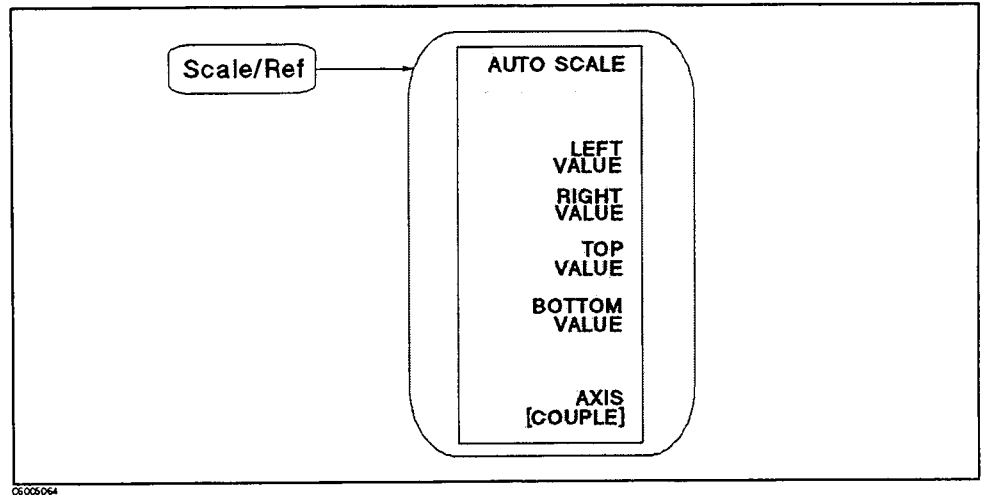


Figure 5-39. User Trace Scale Menu

This menu can be accessed when the user trace is turned on.

- **AUTO SCALE** Brings the trace data in view on the display with one keystroke. The analyzer determines the smallest possible scale factor that will put all displayed data onto the graticule.
- **LEFT VALUE** Changes the value at the left line of the graticule, moving the current selected user trace correspondingly.
- **RIGHT VALUE** Changes the value at the right line of the graticule, moving the current selected user trace correspondingly.
- **TOP VALUE** Changes the value at the top line of the graticule, moving the current selected user trace correspondingly.
- **BOTTOM VALUE** Changes the value at the bottom line of the graticule, moving the current selected user trace correspondingly.
- **AXIS [COUPLE]** Couples or uncouples all user traces to be scaled along the x and y axes by prior functions in this menu.

[COUPLE] Shows parameters for the x and y axes of all user traces are coupled to the current selected user trace setting.

[UNCOUPLE] Shows parameters for the x and y axes of each user trace can be set individually.

Averaging Menu

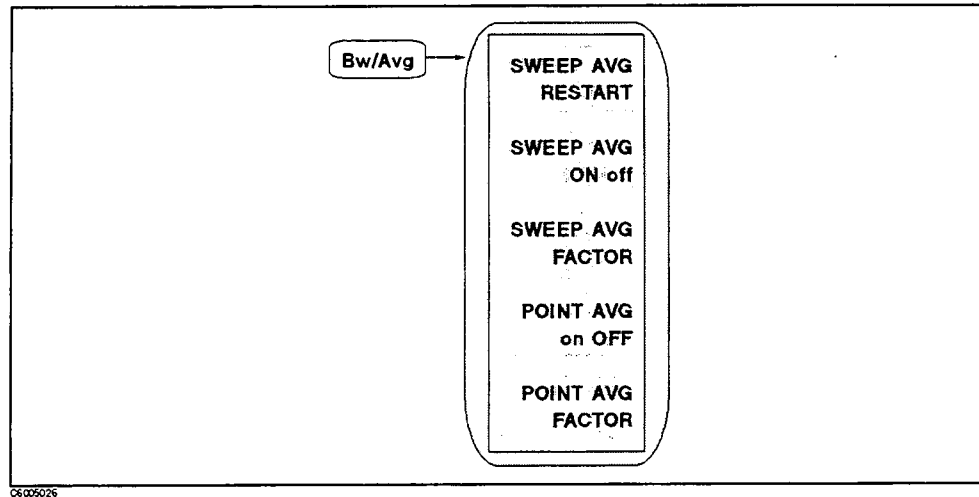


Figure 5-40. Averaging Menu

- **SWEEP AVG RESTART** Resets the sweep-to-sweep averaging and on-point averaging, and restarts the sweep count at 1 at the beginning of the next sweep. The sweep count for averaging is displayed at the left of the display.
- **SWEEP AVG ON off** Turns the sweep-to-sweep averaging function ON or OFF for the active channel. When averaging is ON, "Avg" is displayed in the status notations area at the left of the display (along with the sweep count for the averaging factor). Whenever an instrument state change affecting the measured data is made, the sweep count for averaging is reset to 1.

At the start of averaging or following **AVERAGING RESTART**, averaging starts at 1 and averages each new sweep into the trace until it equals the specified averaging factor. The sweep count is displayed in the status notation area below "Avg" and updated each sweep as it increments. When the specified averaging factor is reached, the trace data continues to be updated, weighted by that averaging factor.

- **SWEEP AVG FACTOR** Makes the sweep-to-sweep averaging factor the active function. Any value up to 999 can be used.
- **POINT AVG on OFF** Turns the on-point averaging function ON or OFF for the active channel.
- **POINT AVG FACTOR** Makes the point averaging factor the active function. Any value up to 999 can be used.

Averaging On Sweep and Averaging On Points

Averaging On Sweep

Averaging-on-sweep computes each data point based on an exponential average of consecutive sweeps weighted by a user-specified averaging factor. Each new sweep is averaged into the trace until the total number of sweeps is equal to the averaging factor, for a fully averaged trace. Each point on the trace is the vector sum of the current trace data and the data from the previous sweep. A high averaging factor gives the best signal-to-noise ratio, but slows the trace update time. Doubling the averaging factor reduces the noise by 3 dB. The algorithm used for averaging-on-sweep is:

$$A(n) = \frac{S(n)}{F} + \left(1 - \frac{1}{F}\right) \times A(n-1)$$

Where,

$A(n)$ = current average

$S(n)$ = current measurement

F = average factor

Averaging On Points

Averaging-on-points averages each data point by a user-specified averaging factor. The analyzer repeats measuring the same point until the averaging factor is reached. It then divides the vector summation of measurement value by the averaging factor and starts measuring the next point. The sweep time increases in proportion to the averaging factor. The algorithm used for averaging-on-points is:

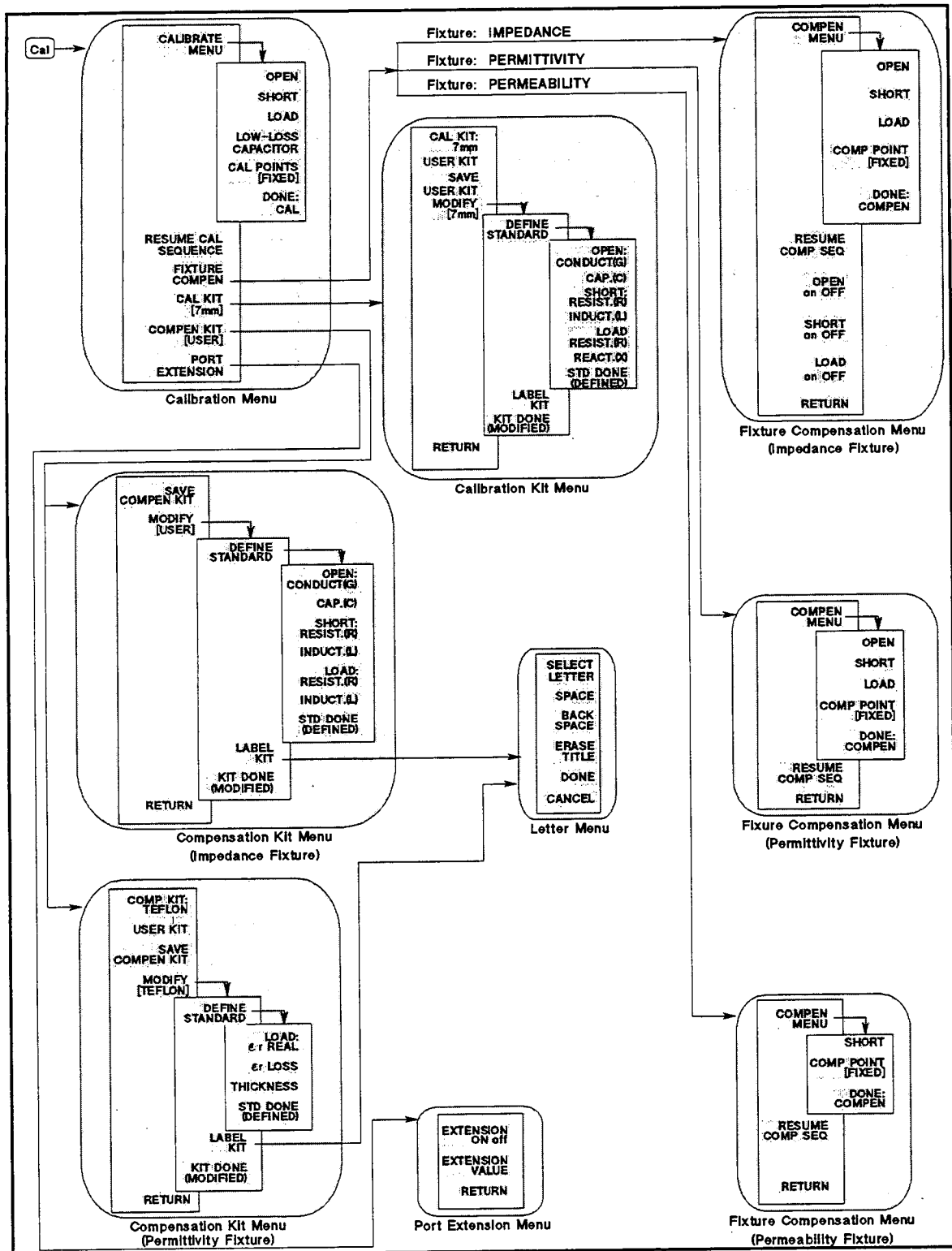
$$M = \frac{1}{F} \sum_{n=1}^F S(n)$$

Where,

M = Measurement Result

$S(n)$ = current measurement

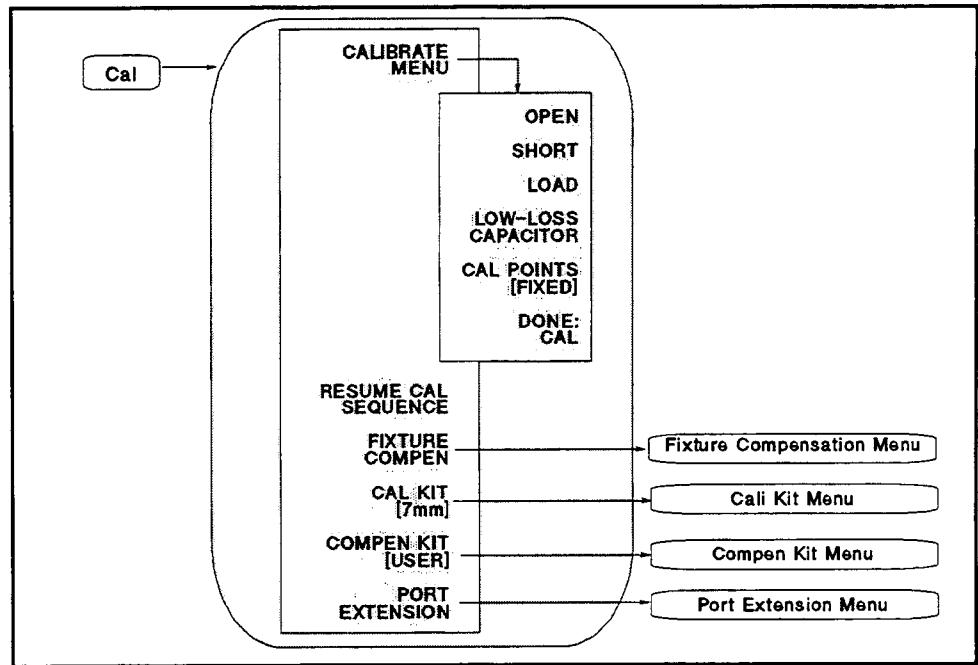
F = average factor



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Figure 5-41. Softkey Menu Accessed from **Cal** key

Calibration Menu



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Figure 5-42. Calibration Menu

- **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.
 - **SHORT** Measures SHORT standard of the cal kit for the calibration.
 - **LOAD** Measures LOAD standard of the cal kit for the calibration.
 - **LOW-LOSS CAPACITOR** Measures LOW-LOSS CAPACITOR standard of the cal kit for the calibration.
 - **CAL POINTS []** Toggles between FIXED and USER DEFINED, to select the calibration measurement points. When [FIXED] is displayed, the analyzer 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 analyzer performs calibration measurements on the same points as the current stimulus setting.
 - **DONE:CAL** Completes the calibration and then computes and stores the error coefficients. The notation CDR (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.
- **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.

- **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.
- **PORT EXTENSIONS** Leads to the *Port Extension menu*, which is used to extend the apparent location of the measurement reference plane.

FIXED Cal and Compensation Points							
When FIXED is selected for the calibration measurement points using CAL POINTS [] , the analyzer measures the standards on the following 178 frequency points. The analyzer also measures the OPEN, SHORT, and LOAD compensation measurement points for the fixture compensation at the same frequency points.							
(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				

FIXED Compensation Points require FIXED CAL Points
When the compensation measurements are performed at the FIXED points, the calibration measurements must have been performed at the FIXED Cal Points. If the calibration was performed at the USER points, the compensation measurements must be performed at the USER points.

Fixture Compensation Menu (for Impedance Measurement)

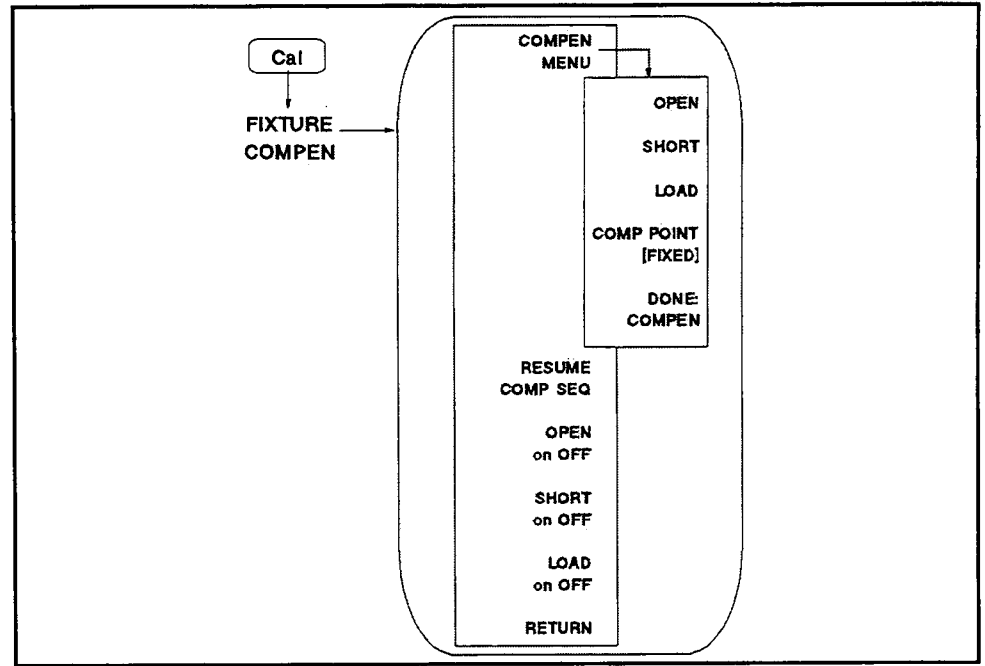


Figure 5-43. Fixture Compensation Menu

- **COMPEN MENU** Leads to the following softkeys, which are used to perform a fixture compensation measurement.
 - **OPEN** Measures OPEN for the fixture compensation.
 - **SHORT** Measures SHORT standard for the fixture compensation.
 - **LOAD** Measures LOAD standard for the fixture compensation.
 - **COMP POINT []** Toggles between **FIXED** and **USER DEFINED**, to select the fixture compensation measurement points. When **[FIXED]** is displayed, the analyzer performs 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. When **[USER]** is displayed, the analyzer performs fixture compensation measurements on the same points as the current stimulus setting.
 - **DONE:COMPEN** Completes the fixture compensation and then computes and stores the error coefficients.
- **RESUME COMP SEQ** Eliminates the need to restart a fixture compensation sequence that was interrupted to access some other menu. Goes back to the point where the fixture compensation sequence was interrupted.
- **OPEN ON off** Turns OPEN fixture compensation ON or OFF.
- **SHORT ON off** Turns SHORT fixture compensation ON or OFF.
- **LOAD ON off** Turns LOAD fixture compensation ON or OFF.

Fixture Compensation Menu (for Permittivity Measurement)

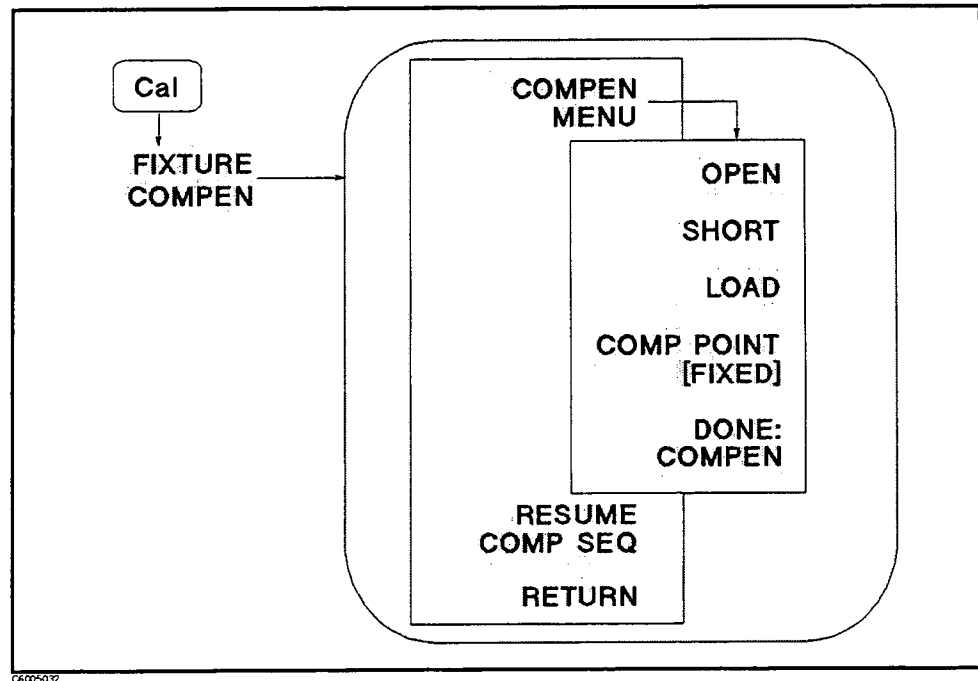


Figure 5-44.

Fixture Compensation Menu (for Permittivity Measurement)

This menu can be accessed when Option 002 is installed and the HP 16453A is selected as the fixture to be used.

- **COMPEN MENU** Leads to the following softkeys, which are used to perform a fixture compensation measurement.
 - **OPEN** Measures OPEN for the fixture compensation.
 - **SHORT** Measures SHORT for the fixture compensation.
 - **LOAD** Measures the standard device furnished with the HP 16453A for the fixture compensation.
 - **COMP POINT []** Toggles between FIXED and USER DEFINED, to select the fixture compensation measurement points. When [FIXED] is displayed, the analyzer performs fixture compensation measurements on points fixed across the full 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 analyzer performs fixture compensation measurements on the same points as the current stimulus setting.
 - **DONE:COMPEN** Completes the fixture compensation and then computes and stores the error coefficients.
- **RESUME COMP SEQ** Eliminates the need to restart a fixture compensation sequence that was interrupted to access some other menu. Goes back to the point where the fixture compensation sequence was interrupted.

Fixture Compensation Menu (for Permeability Measurement)

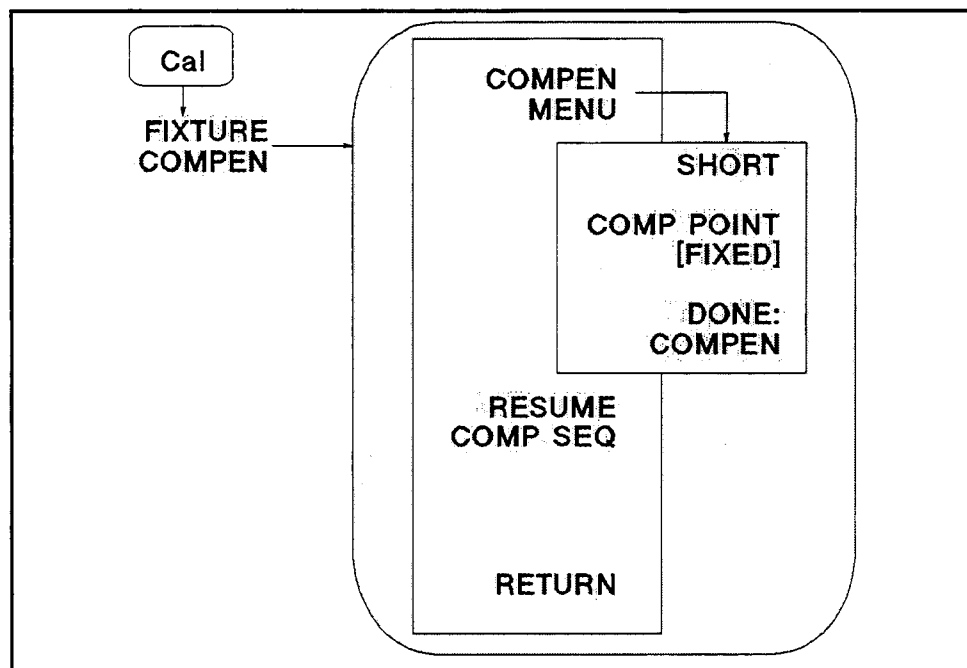


Figure 5-45.

Fixture Compensation Menu (for Permeability Measurement)

This menu can be accessed when Option 002 is installed and HP 16454A is selected as fixture to be used.

- **COMPEN MENU** Leads to the following softkeys, which are used to perform a fixture compensation measurement.
 - **SHORT** Measures SHORT for the fixture compensation.
 - **COMP POINT []** Toggles between **FIXED** and **USER DEFINED**, to select the fixture compensation measurement points. When **[FIXED]** is displayed, the analyzer performs fixture compensation measurements on points fixed across the full 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 analyzer performs fixture compensation measurements on the same points as the current stimulus setting.
 - **DONE:COMPEN** Completes the fixture compensation and then computes and stores the error coefficients.
- **RESUME COMP SEQ** Eliminates the need to restart a fixture compensation sequence that was interrupted to access some other menu. Goes back to the point where the fixture compensation sequence was interrupted.

Calkit Menu

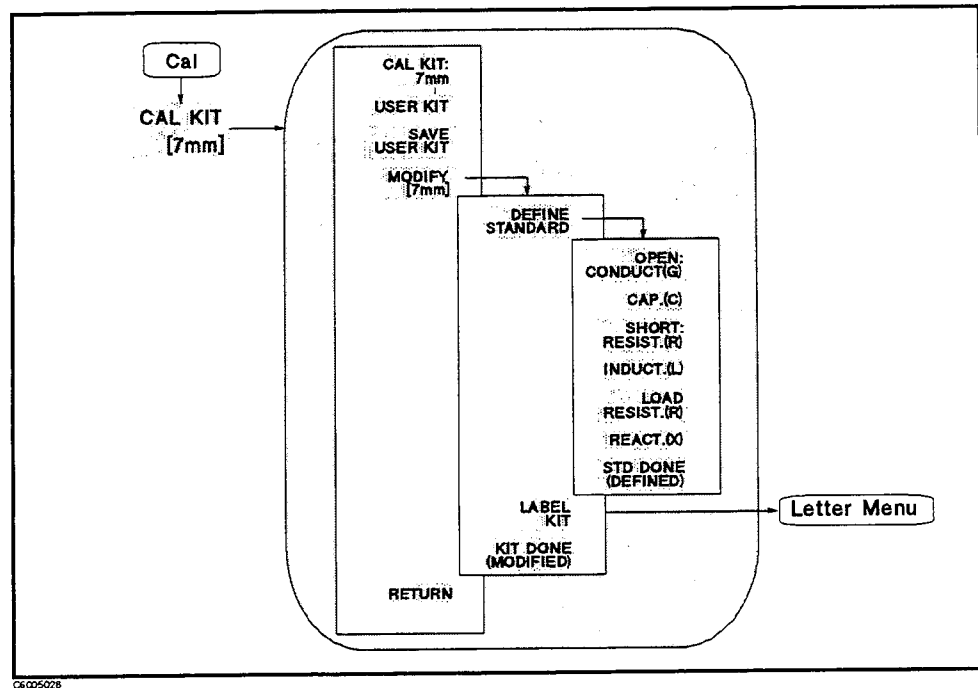


Figure 5-46. Calkit Menu

CAL KIT

- **CAL KIT: 7 mm** Selects the 7 mm cal kit (the furnished 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 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.
 - **REACT. (X)** Make reactance value (X) of LOAD the active function.
 - **STD DONE (DEFINED)** Terminates the standard definition. press this after each standard is defined.
 - **LABEL KIT** Leads to the *Letter 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.

- **KIT DONE (MODIFIED)** Completes the procedure to define a current cal kit.

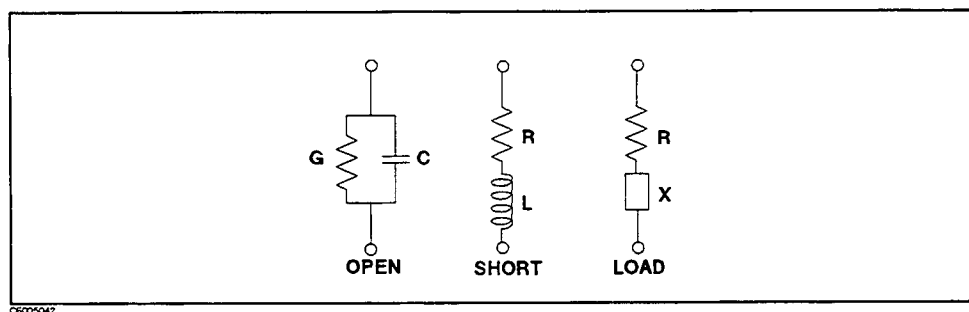


Figure 5-47. Calibration Standard Model

Compen Kit Menu (for Impedance Measurement Fixture)

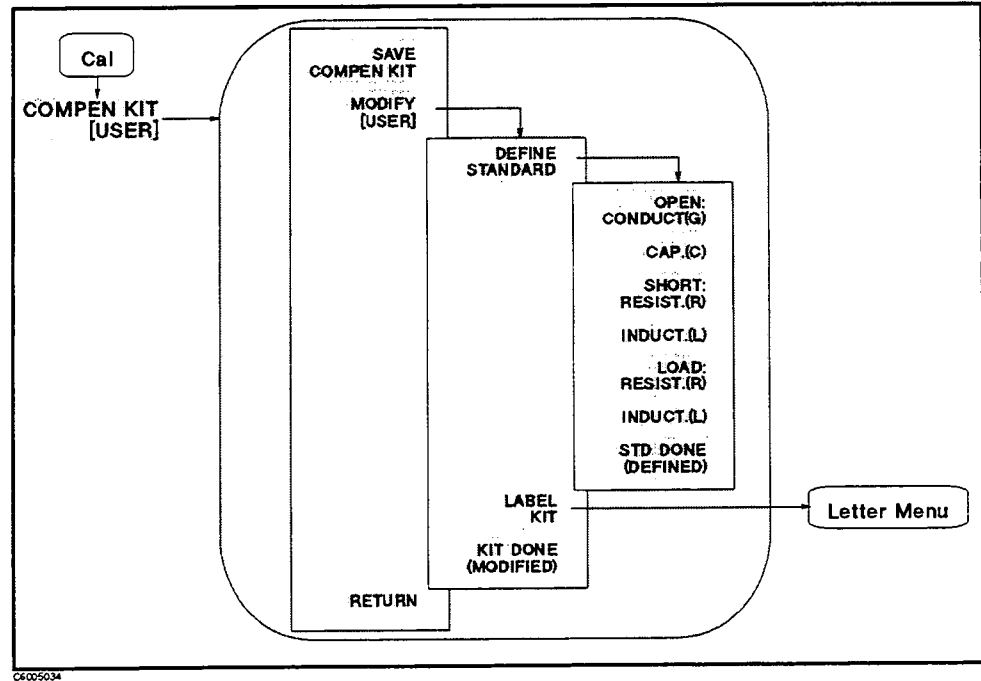
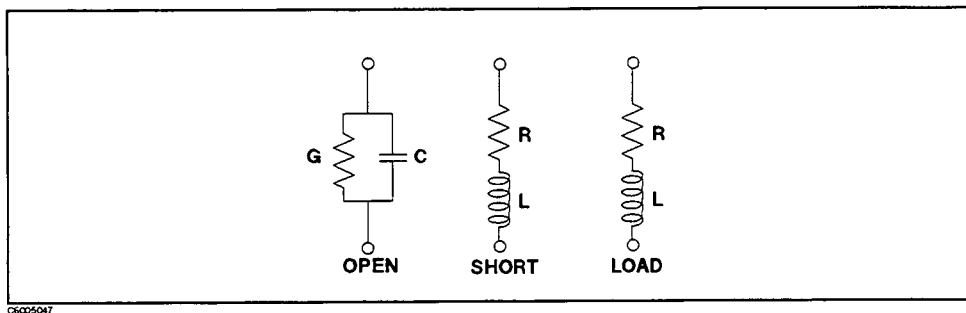


Figure 5-48.
Compen Kit Menu (for Impedance Measurement Fixture)

- **SAVE COMPEN KIT** Stores the user-modified or user-defined OPEN, SHORT, and LOAD for fixture compensation into memory, after it has been modified.
- **MODIFY []** Leads to the following softkeys, which are used to modify a default definition of OPEN, SHORT, and LOAD for the fixture compensation.
 - **DEFINE STANDARD** Leads to the following softkeys, which are used to define the parameters of OPEN, SHORT, and LOAD for the fixture compensation.
 - **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)** Makes resistance value (R) of SHORT the active function.
 - **INDUCT.(L)** Makes inductance value (L) of SHORT the active function.
 - **LOAD:RESIST.(R)** Makes resistance value (R) of LOAD the active function.
 - **INDUCT.(L)** Makes inductance value (L) of LOAD the active function.
 - **STD DONE (DEFINED)** Completes the procedure to define user-defined OPEN, SHORT, and LOAD.

- **LABEL KIT** Leads to the *Letter 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.
- **KIT DONE (MODIFIED)** Completes the procedure to define user-defined OPEN, SHORT, and LOAD for fixture compensation.



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Figure 5-49.
**Parameters of OPEN, SHORT, and LOAD for the Impedance
Fixture Compensation**

Compen Kit Menu (for Permittivity Measurement Fixture)

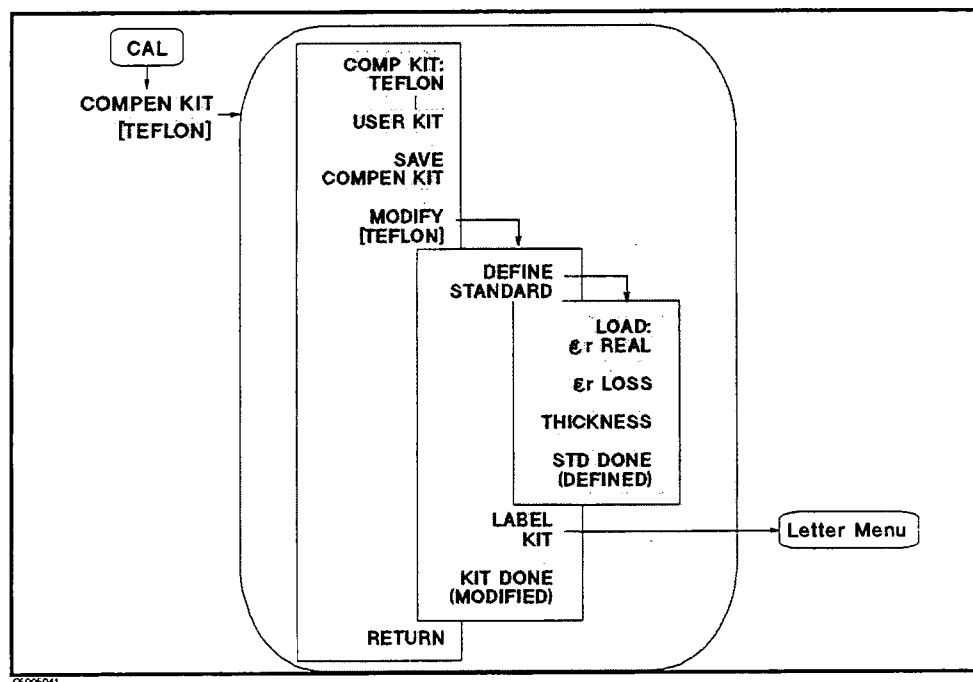


Figure 5-50.
Compen Kit Menu (for Permittivity Measurement Fixture)

This menu can be accessed when Option 002 is installed and the HP 16453A is selected as the test fixture to be used.

- **COMP KIT:TEFLON** Selects Teflon as the LOAD standard.
- **USER KIT** Selects a cal kit model defined or modified by the user using **SAVE COMPEN KIT** key.
- **SAVE COMPEN KIT** Stores the user-modified or user-defined OPEN, SHORT, and LOAD for fixture compensation into memory, after it has been modified.
- **MODIFY []** Leads to the following softkeys, which are used to modify a default definition of OPEN, SHORT, and LOAD for the fixture compensation.
 - **DEFINE STANDARD** Leads to the following softkeys, which are used to define the parameters of OPEN, SHORT, and LOAD for the fixture compensation.
 - **LOAD: ϵ_r REAL** Makes the effective relative permittivity of the LOAD standard the active function.
 - **ϵ_r LOSS** Makes the relative dielectric loss factor of the LOAD standard the active function.
 - **THICKNESS** Makes thickness of LOAD standard the active function.
 - **LABEL KIT** Leads to the *Letter 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 calibration data.

- **KIT DONE (MODIFIED)** Completes the procedure to define user-defined OPEN, SHORT, and LOAD for fixture compensation.

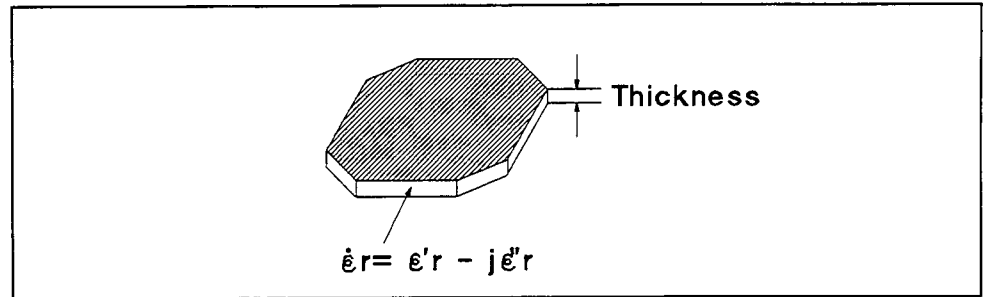


Figure 5-51.
Parameters of LOAD for the Permittivity Fixture Compensation

Port Extension Menu

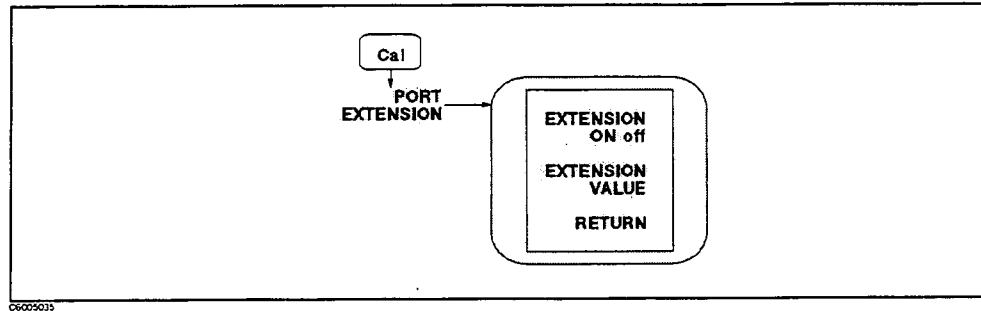


Figure 5-52. Port Extension Menu

- **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 the port extension, see "Port Extension" in Chapter 11

Stimulus Block

The stimulus block keys and associated menus provide control of the sweep, trigger, and source functions. The following list shows the functions controlled by each key in the stimulus block.

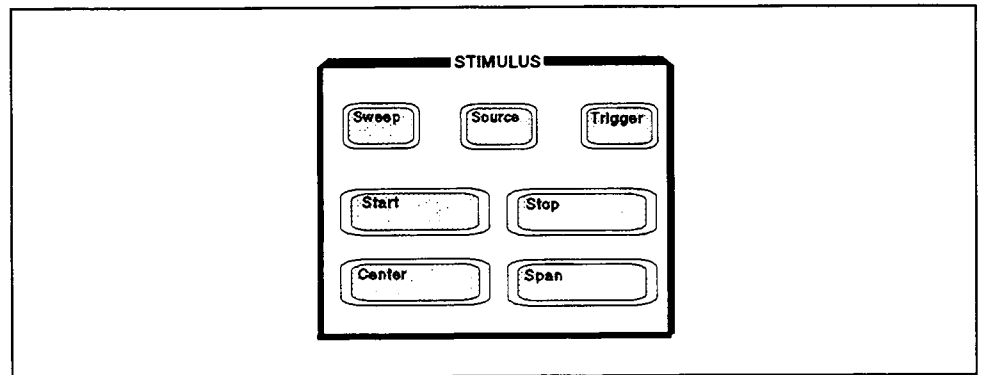
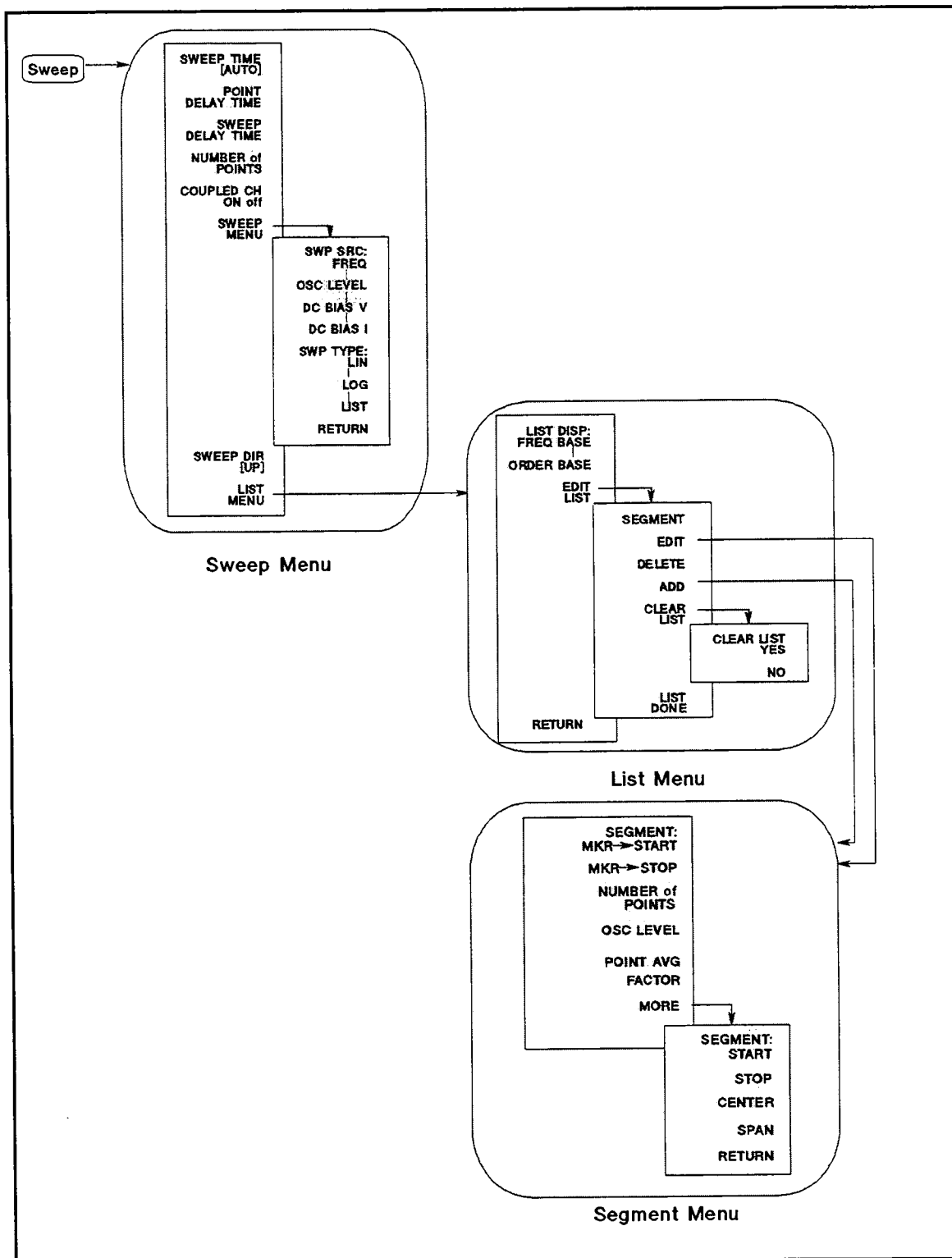


Figure 6-1. Stimulus Block

Sweep	Controlling delay time Specifying number of points to be measured Selecting sweep source Selecting sweep type and sweep direction Editing table for list sweep Selecting channel coupling
Source	Specifying output level of stimulus source Selecting OSC level unit Setting CW frequency for power sweep and dc bias sweep Controlling dc bias source
Trigger	Selecting trigger mode Selecting trigger source Selecting event caused by trigger Restarting measurement
Start	Setting start value of stimulus
Stop	Setting stop value of stimulus
Center	Setting center value of stimulus
Span	Setting span of stimulus

Functions accessed from this block	You can access from ...	See the following section in this chapter:
Channel Coupling	Sweep	<i>Sweep Menu</i>
Continuous sweep	Trigger	<i>Trigger menu</i>
DC bias sweep	Sweep	<i>Sweep Menu</i>
DC bias	Source	<i>Source Menu</i>
Delay time (sweep delay, point delay)	Sweep	<i>Sweep Menu</i>
External trigger	Trigger	<i>Trigger menu</i>
Linear sweep	Sweep	<i>Sweep Menu</i>
List sweep	Sweep	<i>Sweep Menu</i>
List sweep table edit	Sweep	<i>List Menu and Edit Segment Menu</i>
Log sweep	Sweep	<i>Sweep Menu</i>
Manual trigger	Trigger	<i>Trigger menu</i>
Measurement Restart	Trigger	<i>Trigger menu</i>
Number of points	Sweep	<i>Test Head Selection</i>
OCS level sweep	Sweep	<i>Sweep Menu</i>
OSC level	Source	<i>Source Menu</i>
Single sweep	Trigger	<i>Trigger menu</i>
Stimulus sweep range	Start Stop Center Span	Start Stop Center Span
Sweep direction	Sweep	<i>Sweep Menu</i>
Sweep hold	Trigger	<i>Trigger menu</i>
Trigger signal polarity	Trigger	<i>Trigger menu</i>
User-specified number of sweeps	Trigger	<i>Trigger menu</i>

For Additional Information on ...	See ...
Preset values and Setting Range of each function setting value	Appendix B in this manual
All Softkey Trees	Appendix C in this manual
HP-IB Command Reference	<i>HP-IB Command Reference</i> in the <i>Programming Manual Set</i> binder
How to control the HP 4291A using an external controller or the HP Instrument BASIC capability through the HP-IB.	<i>Programming Guide</i> in the <i>Programming Manual Set</i> binder.



CS006010

Figure 6-2. Softkey Menus Accessed from the Sweep Key

6 Stimulus Block

Sweep Menu

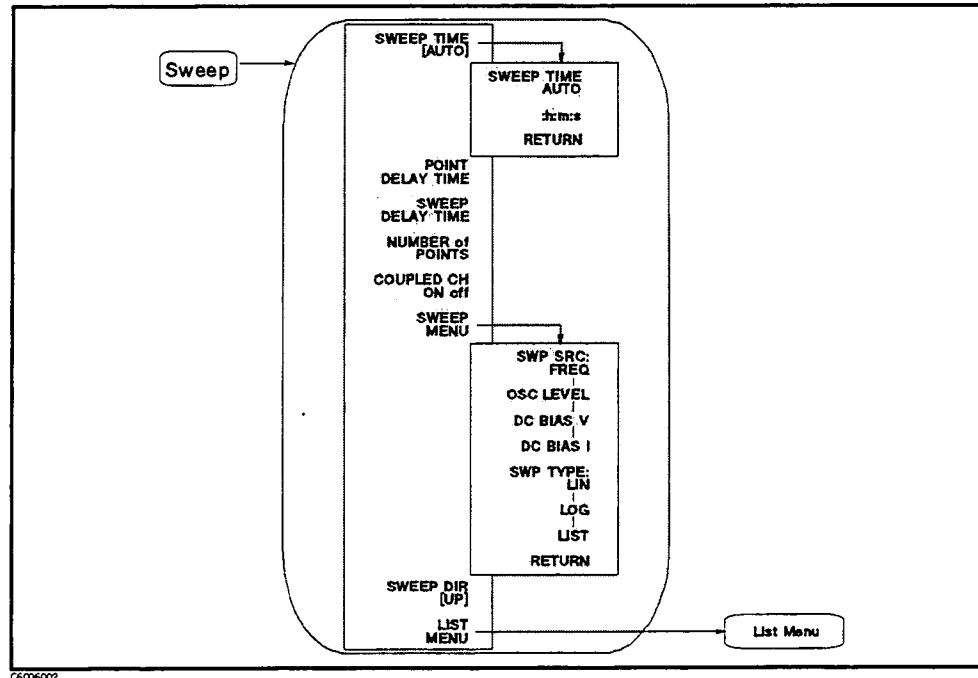


Figure 6-3. Sweep Menu

- **SWEEP TIME []** Makes sweep time the active function and leads to the following softkeys, which are used to specify sweep time and set automatic sweep time.
 - **SWEEP TIME AUTO** Selects the optimum (fastest) sweep time automatically. Pressing this softkey sets the point delay time to zero.
 - **:h:m:s** Makes manual time entry the active function. Enters “:” automatically.
- **POINT DELAY TIME** Makes point delay time the active function. When the point delay time is set, the analyzer delays the start of the measurement for the delay time specified at each measurement point. (See Figure 6-4.)
- **SWEEP DELAY TIME** Makes sweep delay time the active function. When the sweep delay time is set, the analyzer delays the start of the sweep for the delay time specified at each sweep. (See Figure 6-4.)
- **NUMBER of POINTS** Sets the number of data points per sweep. Using fewer points allows a faster sweep time but the displayed trace shows less horizontal detail. Using more points gives greater data density and improved trace resolution, but slows the sweep.

In list frequency sweep, the number of points displayed is the total number of frequency points for the defined list.
- **COUPLED CH ON off** Toggles channel coupling of the stimulus values. With **COUPLED CH ON** (the preset condition), both channels have the same stimulus values (the inactive channel takes on the stimulus values of the active channel). For information on the parameters that are coupled or uncoupled by the coupling function, see the table after Figure 6-4.

- **SWEEP MENU** Leads to the following softkeys, which are used to select sweep source and sweep type.
 - **SWP SRC:FREQ** Selects frequency sweep.
 - **OSC LEVEL** Selects OSC level sweep.
 - **DC-V** Selects dc bias voltage sweep (Option 001 only).
 - **DC-I** Selects dc bias current sweep (Option 001 only).
 - **SWEEP TYPE:LINEAR** Selects linear sweep.
 - **LOG** Selects Logarithmic sweep mode. The source is stepped in logarithmic increments and the data is displayed on a logarithmic graticule. If the sweep range includes zero, the sweep type is automatically changed to linear.
 - **LIST** Selects list frequency sweep. If a list is not defined, this softkey performs no function.
- **SWEEP DIR []** Toggles direction of sweep between up and down. When DOWN is selected, the analyzer sweep starts from the stimulus STOP value and sweeps to the START value. DOWN is only available for the OSC level, dc voltage, and dc current sweep. The down sweep is not available for frequency sweep.
- **LIST MENU** Leads to the *List menu*, which is used to control the list sweep and define the list sweep table.

Figure 6-4 shows the relationship between delay time and sweep time. The sweep delay time is not included in the sweep time. The summation of all point delay times is added to the sweep time. When both the sweep delay time and the point delay time are set, the analyzer starts the sweep after waiting for both of sweep delay time and point delay time.

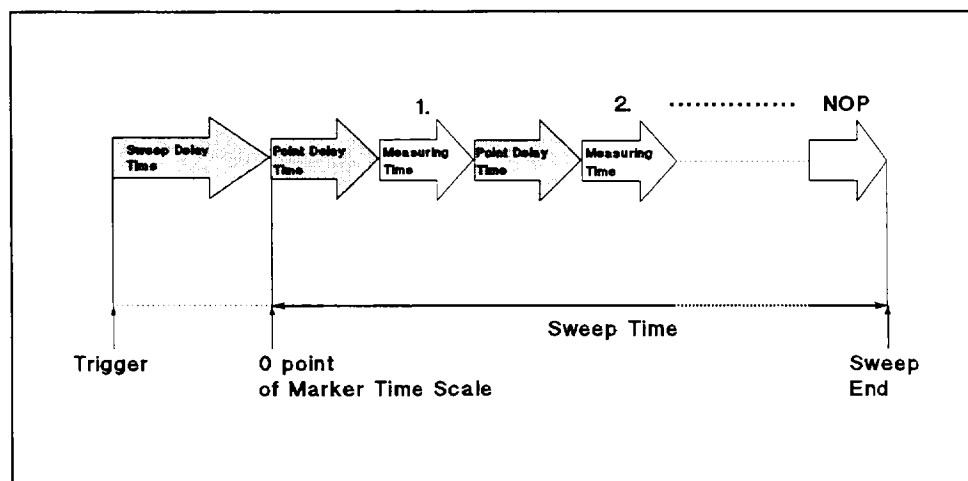


Figure 6-4. Sweep Delay Time and Point Delay Time

Parameters that are coupled or uncoupled by stimulus channel coupling		
If the stimulus is coupled, the following parameters are coupled:	The following parameters are always common to both channels, even if the stimulus is not coupled.	The following parameters are always set separately for each channel, even if the stimulus is coupled.
<ul style="list-style-type: none"> ■ Frequency ■ OSC Level ■ dc Bias ■ Delay Time ■ Sweep Source ■ Sweep Type ■ Sweep Direction ■ Number of Points ■ Trigger Mode ■ Correction/Compensation ■ Calibration Coefficients ■ Define Trace ■ Averaging (on/off, factor) ■ Limit Test (on/off) ■ OSC Level Unit 	<ul style="list-style-type: none"> ■ List Sweep Table ■ Trigger Source ■ Trigger Event ■ Port Extensions ■ Fixture Selection ■ Port Extension ■ Beep Off/Pass/Fail ■ Frequency Blank 	<ul style="list-style-type: none"> ■ Measurement Parameter ■ Format ■ Scale ■ Graticule (on/off) ■ Level Monitor ■ Limit Line

Use USER DEFINED calibration points for stable dc bias sweep measurements

To get a stable dc bias sweep measurement result, use the user defined calibration point.

1. Set NOP to 2 points.
2. Set START frequency to CW frequency.
3. Select USER DEF POINTS as the calibration points.
4. Perform OPEN, SHORT, and LOAD calibration measurements.
5. After calibration measurement, select dc bias sweep as the sweep mode and also you can change NOP or any other settings.

List Menu

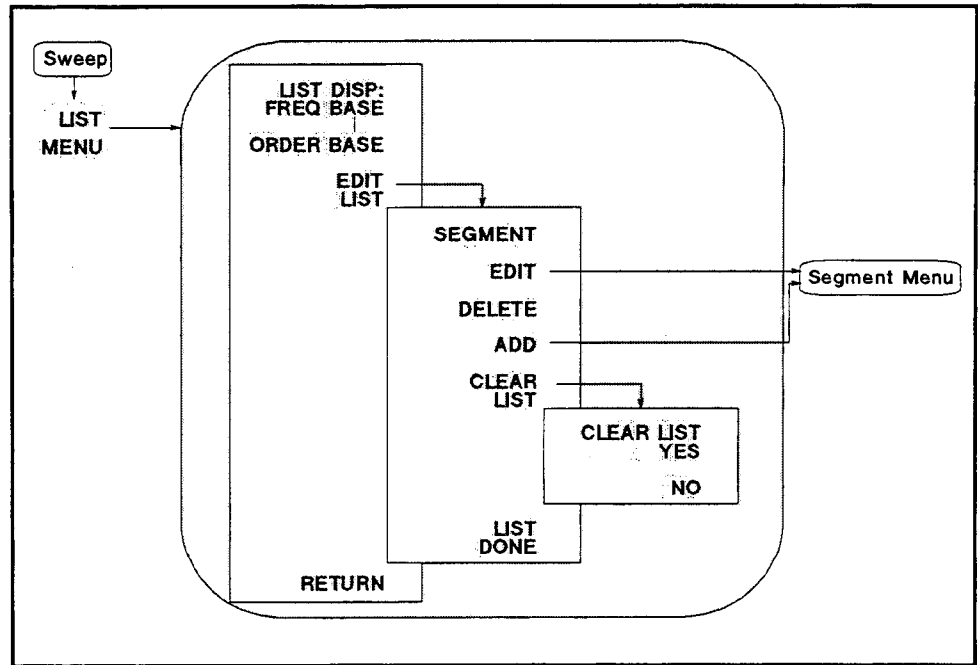


Figure 6-5. List Menu

- **LIST DISP: FREQ BASE**. Displays data measured as frequency base in the frequency list mode. The frequency scale is linear across the total range. Because the frequency points may not distribute evenly across the graticule, the display resolution may be uneven. This causes the points to be more compressed in some parts of the trace than in other parts.
- **ORDER BASE**. Displays data measured as order base in the frequency list mode. The displayed frequency resolution is even across the graticule, even though the frequency points are not distributed evenly. For more information, see the explanation of “Frequency Base and Order Base” on the next page.
- **EDIT SEGMENT**: Leads to the following softkeys, which are used to define or modify the frequency sweep list:
 - **SEGMENT**. Determines a segment on the list to be modified. Enter the number of a segment in the list, or use the step keys to scroll the pointer “>” at the left to the required segment number. The indicated segment can then be edited or deleted.
 - **EDIT**. Provides the *Segment menu*, which is used to define or modify the segment selected using **SEGMENT**. The segment indicated by the pointer “>” at the left can be modified.
 - **DELETE**. Deletes the segment indicated by the pointer “>” at the left.
 - **ADD**. Adds a new segment to be defined with the *Segment menu*. If the list is empty, a default segment is added and the *Segment menu* is displayed so it can be modified. If the list is not empty, the segment indicated by the pointer “>” is copied and the *Segment menu* is displayed.
 - **CLEAR LIST**. Leads to the following softkeys, which are used to clear the list table.

- **CLEAR LIST YES** Clears the entire list.
- **NO** Cancels the task and softkeys and returns to the edit list menu.
- **LIST DONE** Defines the frequency sweep list and softkeys, and returns to the previous menu.

The stimulus range of a segment can not be overlapped with other segments.

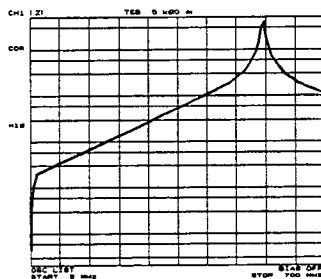
The analyzer always sweeps from a lower frequency to a higher frequency (independent of the definition of the segments).

Frequency Base and Order Base

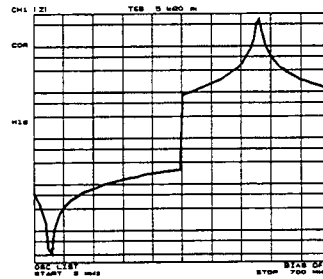
The result of a list sweep is displayed using one of the two display modes; *frequency base display mode* or *order base display mode*.

- **Frequency base:** The X-axis is linearly scaled by frequency. The analyzer automatically scales linearly from the sweep list. When the stimulus range of a segment is discontinuous from another segment, the segment traces are connected by a straight line.
- **Order base:** The X-axis is linearly scaled by the number of sweep points according to the sweep list.

The following figures show an example of the difference between these modes. This measurement has two segments, one is resonance frequency and another is anti-resonance frequency. The span of the lower segment is narrower than the span of the higher segment. If the trace of this list is displayed on the frequency base scale, the sweep points of interest cannot be displayed visibly (as shown in the left graph below). The order base can display this trace as shown in the right graph.



Frequency Base



Order Base

Segment Menu

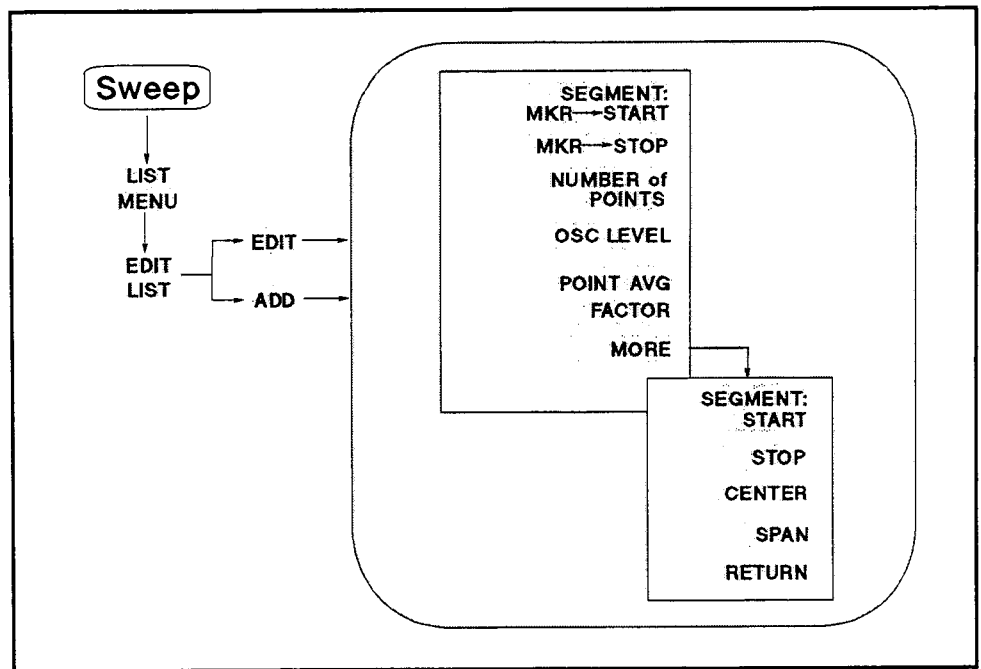


Figure 6-6. Segment Menu

- **SEGMENT:MKR→START** Sets the stimulus start value to the stimulus value of the marker.
- **MKR→STOP** Sets the stimulus stop value to the stimulus value of the marker.
- **NUMBER of POINTS** Sets the number of points for the segment. The total number of points for all segments cannot exceed 801.
- **OSC LEVEL** Sets the OSC level segment by segment.
- **POINT AVG FACTOR** Sets the averaging factor of the averaging on point for the segment.
- **MORE** Leads to the following softkeys:
 - **SEGMENT:START** Sets the **START** frequency of a segment.
 - **STOP** Sets the **STOP** frequency of a segment.
 - **CENTER** Sets the **CENTER** frequency of a segment.
 - **SPAN** Sets the frequency **SPAN** of a segment about a specified center frequency.
- **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.

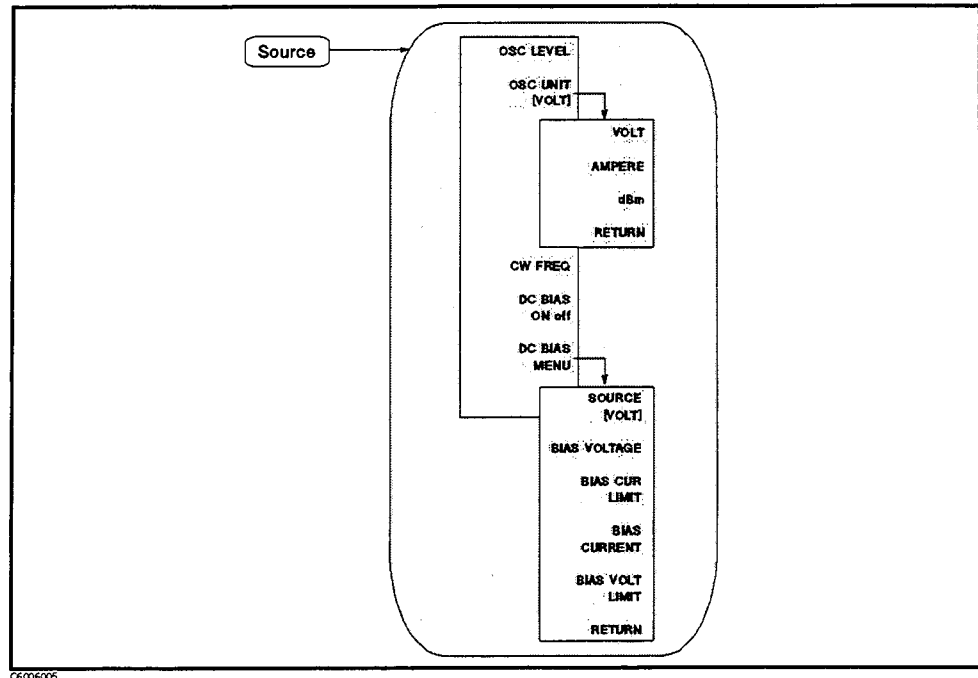


Figure 6-7. Softkey Menus Accessed from the **Source** Key

Source Menu

- **OSC LEVEL** Makes OSC level the active function.
- **OSC UNIT []** Leads to the following softkeys, which are used to select the OSC level unit. The OSC level unit is displayed in brackets in the softkey label.
 - **VOLTAGE** Selects voltage as the OSC level unit.
 - **AMPERE** Selects ampere as the OSC level unit.
 - **dBm** Selects dBm as the OSC level unit.
- **CW FREQ** Sets the frequency for the OSC level sweep and DC bias sweep.
- **DC BIAS on OFF** Turn dc bias ON or OFF.
- **DC BIAS MENU** Leads to the following softkeys, which are used to specify level, unit, and voltage or current limit of dc bias.
 - **SOURCE []** Toggles the dc bias mode between the voltage setting (current compliance) mode and the current setting (voltage compliance) mode. The dc bias setting mode (VOLT or CURRENT) is displayed in brackets in the softkey label.
 - **BIAS VOLTAGE** Sets voltage of dc bias for voltage setting mode.
 - **BIAS CUR LIMIT** Sets current limit value of dc bias for voltage setting mode.
 - **BIAS CURRENT** Sets current value of dc bias for current setting mode.
 - **BIAS VOLT LIMIT** Sets voltage limit value of dc bias for current setting mode.

Note



The dc bias setting is common to both channels. In other words, you cannot turn on or off the dc bias of either channel 1 or 2.

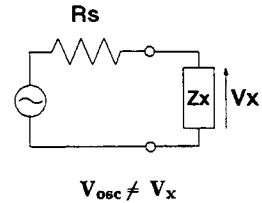
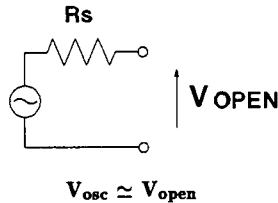
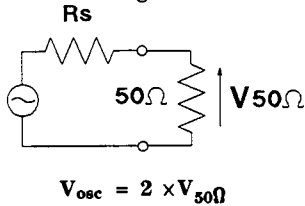
The dc bias is automatically turned off when the calibration or fixture compensation measurement is done.

Marker Level Monitor Function

The analyzer can monitor the OSC level output and dc bias level applied to the DUT at each stimulus point using the marker. The softkey for the marker level monitor can be accessed from the **Utility** key in the MARKER block. See "**Utility**" in Chapter 7.

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

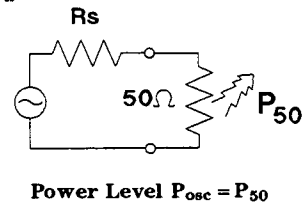
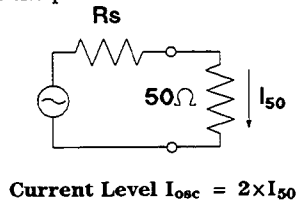
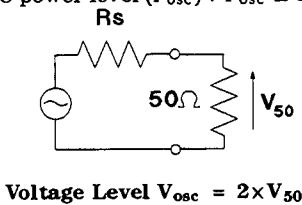
For example, the OSC level voltage value displayed (or entered) is twice the value when terminating with 50Ω. (In other words, the OSC level displayed is approximately equal to the value when the terminal is open.) When the DUT is connected to the test terminal, the voltage dropped by the DUT's impedance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



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



Trigger

Trigger

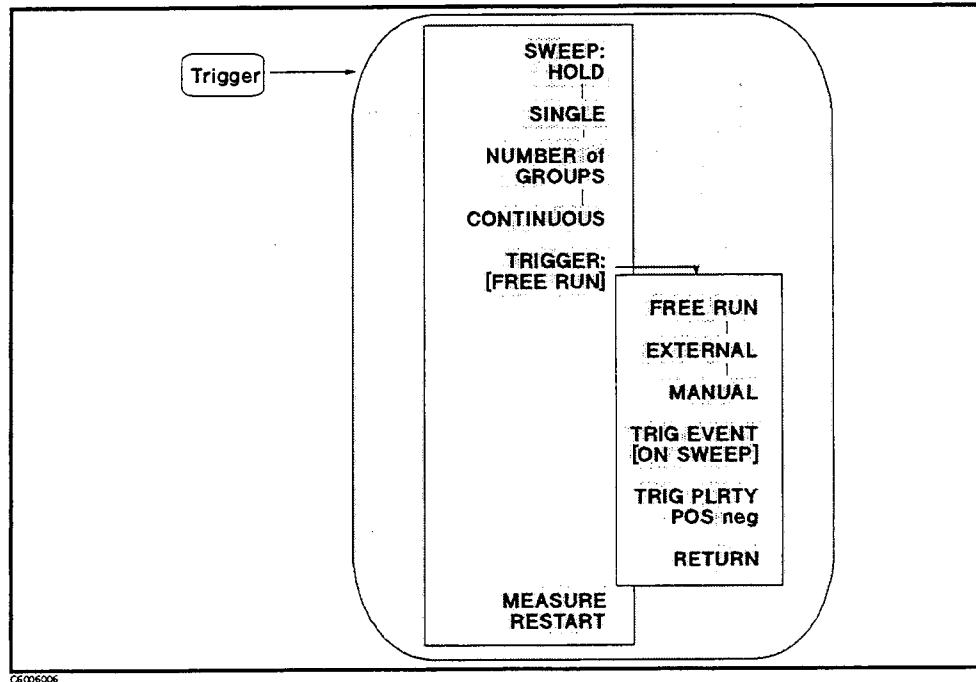


Figure 6-8. Softkey Menus Accessed from the **Trigger** Key

Trigger Menu

- **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 graticule. 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.
- **NUMBER of GROUPS** Selects the group sweep and makes the number of groups the active function. After the number of groups is entered and the analyzer is triggered, the analyzer sweeps a user-specified number and returns to the hold mode. If averaging on sweep is ON, set the number of groups at least equal to the selected averaging factor to allow the measurement of a fully averaged trace. Entering the number of groups resets the averaging counter to 1.
- **CONTINUOUS** Selects the continuous mode. In this mode the analyzer 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 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.
- MANUAL** Selects the manual trigger and triggers a sweep.

TRIG EVENT [] Toggles the trigger event mode.

[ON POINT] The analyzer triggers on each data point in a sweep.

[ON SWEEP] The analyzer triggers a sweep.

TRIG PLRTY POS neg Selects the trigger signal polarity of an externally generated signal connected to the rear panel EXT TRIGGER input.

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.

■ **MEASURE RESTART** Aborts the sweep in progress and then restarts the measurement. This can be used to update a measurement following an adjustment of the DUT or test signal source.

- If the analyzer is measuring a number of groups, the sweep counter is reset to 1.
- If averaging on sweep is on, **MEASURE RESTART** resets the sweep-to-sweep averaging and is effectively the same as **AVERAGING RESTART**.
- If the sweep trigger is in the **HOLD** mode, **MEASURE RESTART** executes a single sweep.
- If **DUAL CHAN** is on (screen displays both measurement channels), **MEASURE RESTART** executes a single sweep of both channels even if **COUPLED CH** is off.

Start Stop Center Span

Start Stop Center Span

These keys define the start value, the stop value, the center value and the span value of the frequency range, OSC level range, or dc bias range of the stimulus. When one of these keys is pressed, its function becomes the active function. The value is displayed in the active entry area and can be changed with the knob, step keys, or numeric keypad. Current stimulus values for the active channel are also displayed along the bottom of the graticule.

The range can be expressed as either start/stop or center/span.

Marker Block

The marker block keys and associated menus provide control of the marker function. The following list shows the functions controlled by each key in the maker block.

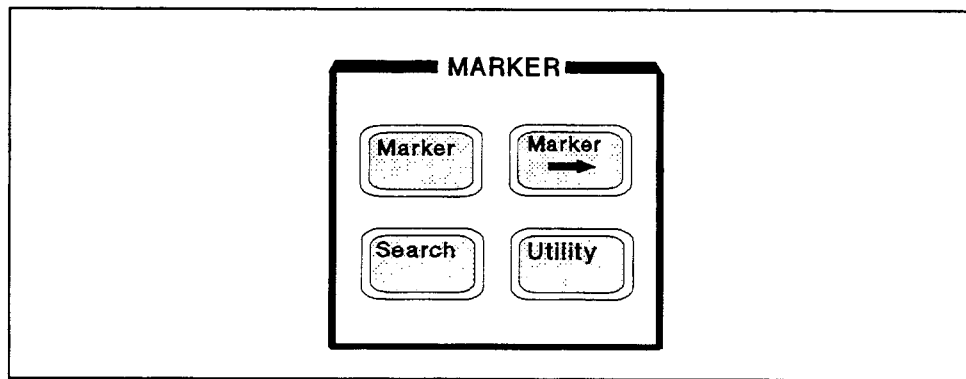






Figure 7-1. Marker Block

	Controlling the marker, sub-markers, and delta-marker Coupling markers on both channels
	Changing stimulus value and amplitude values to the current marker's value Zooming traces
	Searching for peak, maximum, minimum, or point specified by amplitude value Setting peak definition
	Listing marker values Calculating statistics value Displaying marker time Selecting marker form for Smith, polar, and admittance chart

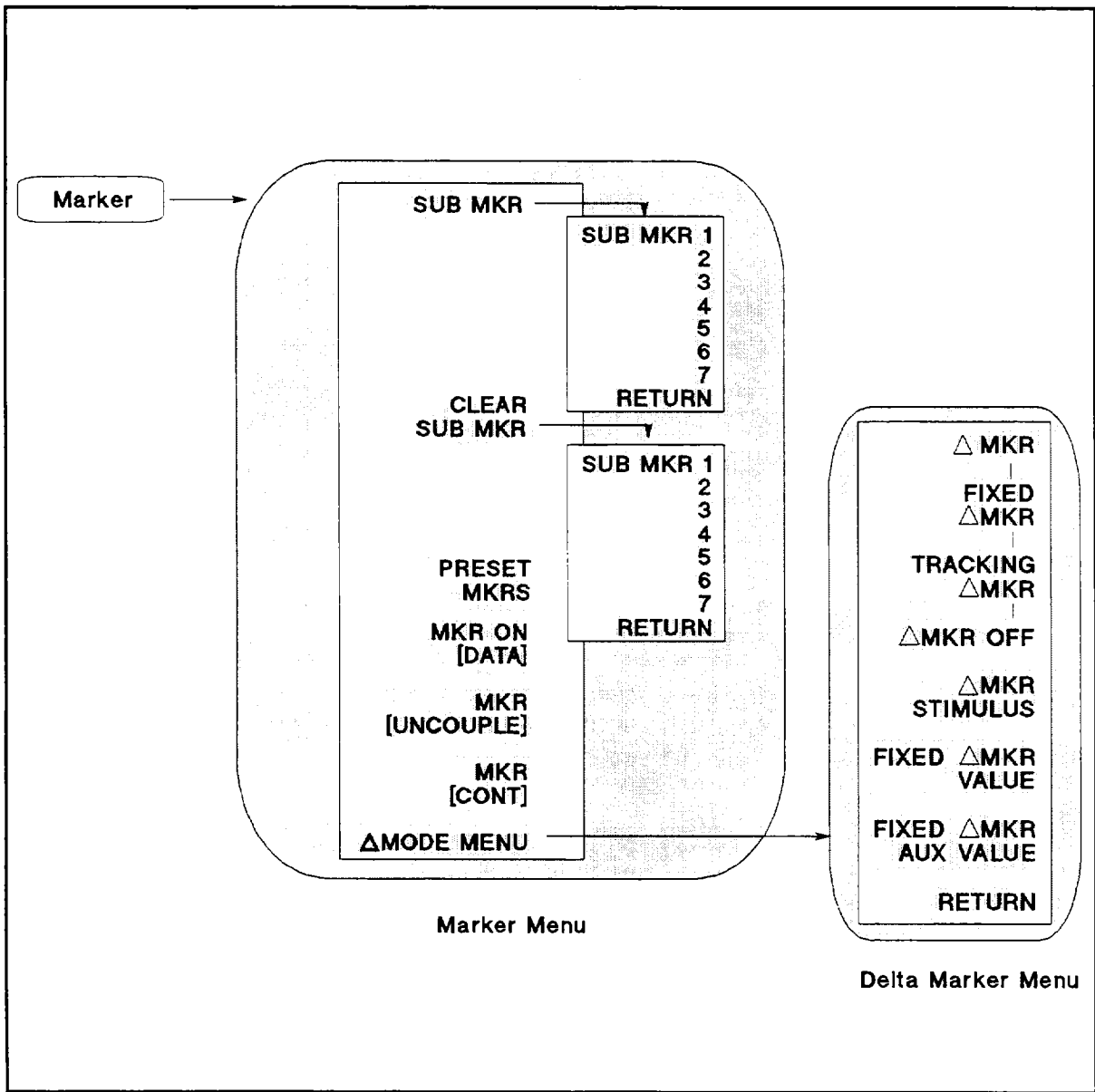
Functions accessed from this block	You can access from ...	See the following section in this chapter:
Δmarker	Marker	<i>Marker Menu</i>
Coupling marker	Marker	<i>Marker Menu</i>
Level monitor	Utility	<i>Utility menu</i>
Marker, Sub-marker	Marker	<i>Marker Menu</i>
Marker list	Utility	<i>Utility menu</i>
Marker time	Utility	<i>Utility menu</i>
Marker→ function	Marker→	<i>Marker→ menu</i>
Mean value	Utility	<i>Utility menu</i>
Partial search	Search	<i>Search range menu</i>
Peak definition	Search	<i>Peak definition menu</i>
Peak search, MAX/MIN search and target search	Search	<i>Search menu</i>
Peak-to-peak	Utility	<i>Utility menu</i>
Relaxation time	Utility	<i>Utility menu</i>
Smith/polar maker ($\Gamma_x - \Gamma_y$, $|\Gamma| - \theta$, $R + jX$, $G + jB$)	Utility	<i>Utility menu</i>
Standard deviation	Utility	<i>Utility menu</i>
Zooming traces	Marker→	<i>Marker→ menu</i>

For Additional Information on ...	See ...
Preset values and Setting Range of each function setting value	Appendix B in this manual
All Softkey Trees	Appendix C in this manual
HP-IB Command Reference	<i>HP-IB Command Reference</i> in the <i>Programming Manual Set</i> binder
How to control the HP 4291A using an external controller or the HP Instrument BASIC capability through the HP-IB.	<i>Programming Guide</i> in the <i>Programming Manual Set</i> binder.

Note



The marker function is summarized in the last section of this chapter.



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Figure 7-2. Softkey Menus Accessed from the **Marker** Key

7 Marker Block

Marker Menu

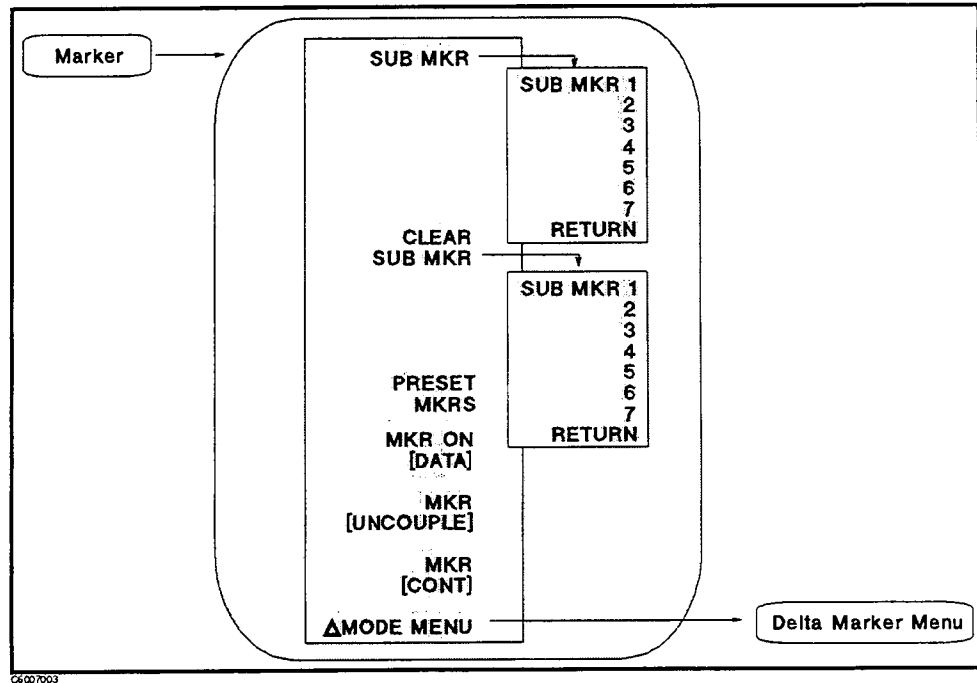


Figure 7-3. Marker Menu

- **SUB MKR** Displays the following softkeys, which are used to turn on sub-markers.
 - SUB MKR 1, 2, 3, 4, 5, 6, 7 These keys put a sub-marker at the present marker position.
- **CLEAR SUB MKR** Displays the following softkeys, which are used to turn off sub-markers.
 - SUB MKR 1, 2, 3, 4, 5, 6, 7 These keys turn a sub-marker OFF.
- **PRESET MKRS** Turns off all markers and cancels all settings of the marker functions.
- **MKR ON []** Selects a trace from data or memory to be applied for the marker values. This softkey does not appear if the user trace display is turned on.

[DATA] Shows that the data trace is selected.

[MEMORY] Shows that the memory trace is selected.

- **MKR [COUPLE] MKR [UNCOUPLE]** Toggles between the coupled and uncoupled marker mode. This softkey does not appear if the user trace display is turned on.

MKR [COUPLE] Couples the marker stimulus values for the two display channels. Even if the stimulus is uncoupled and two sets of stimulus values are shown, the markers track the same stimulus values on each channel as long as they are within the displayed stimulus range.

MKR [UNCOUPLE] Allows the marker stimulus values to be controlled independently on each channel.

- **MKR [DISCRETE] MKR [CONT]** Toggles between the continuous and discontinuous marker mode.

MKR [DISCRETE] Places markers only on the measured trace points as determined by the stimulus settings.

MKR [CONT] Interpolates between the measured points to allow the markers to be placed at any point on the trace. Displayed marker values are also interpolated. This is the default marker mode

- **ΔMODE MENU** Displays the *Delta Mode menu* that is used to define the difference in values between the marker and a Δ marker.

Delta mode menu

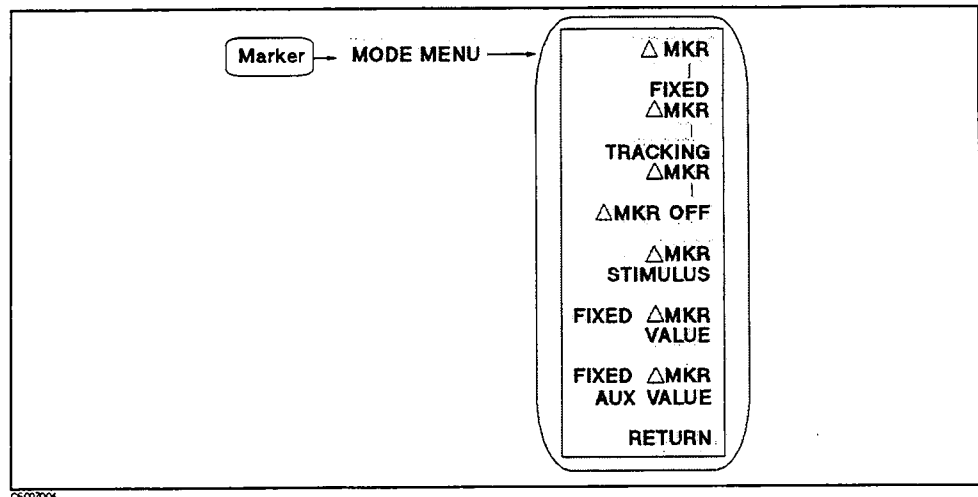


Figure 7-4. Delta Mode Menu

- **ΔMKR** Puts the delta-marker on the current position of the marker.
- **FIXED ΔMKR** Sets a user-specified fixed reference marker. The stimulus and amplitude values can be set arbitrarily and can be anywhere in the display area. Unlike other markers, the fixed Δmarker need not be on the trace. The fixed Δmarker is indicated by a small triangle Δ, and the marker stimulus and measurement values are shown relative to this point. The notation ΔMkr is displayed at the top right corner of the graticule.
- **TRACKING ΔMKR** Makes the active marker a Δmarker (Tracking Δmarker). When this softkey is pressed a Δmarker moves to the active marker position. Then the Δmarker moves with the active marker. It looks as if the Δmarker tracks the active marker. In other words, the tracking Δmarker can be moved using the knob or a marker search function such as **SEARCH: PEAK**.
- **ΔMODE OFF** Turns off the delta marker mode. Therefore, the values displayed for the marker and sub-marker are now absolute values.
- **ΔMKR STIMULUS** Changes the stimulus value of the fixed Δmarker. Fixed Δmarker stimulus values can be different for the two channels if the channel markers are uncoupled. This softkey label is changed to **ΔMKR SWP PARAM** if the user trace display is turned on. **ΔMKR SWP PARAM** changes the x-axis value of the fixed Δmarker on the user trace.
- **FIXED ΔMKR VALUE** Changes the amplitude value of the fixed Δmarker. In a Cartesian format, this is the y-axis value. In a polar, Smith chart, admittance chart, or complex plane format, this is the first part (real part) of the complex data pair. It applies to a magnitude/phase marker, a real/imaginary marker, an R+jX marker, or a G+jB marker. Fixed Δmarker amplitude values are always uncoupled in the two channels.
- **FIXED ΔMKR AUX VALUE** Changes the auxiliary amplitude value of the fixed Δmarker (used only with a polar, Smith, admittance, or complex plane format). This is the second part (imaginary part) of a complex data pair. It applies to a magnitude/phase marker, a real/imaginary marker, an R+jX marker, or a G+jB marker. Fixed

Δ marker auxiliary amplitude values are always uncoupled in the two channels. This softkey does not appear if the user trace display is turned on.

Marker→

Marker⇒

The **Marker→** key activates the marker (if it is not already active) and provides access to the **Marker→** functions. The **Marker→** functions change the stimulus and amplitude values to make them equal to the current marker value. Use the knob or the numeric keypad to move the marker to the desired position on the trace and then press the appropriate softkey to set the specified parameters to that trace value. When the values are changed, the marker can again be moved within the range of the new parameters. The **Marker→** functions can select either channel 1 or 2 as the destination channel whose value will be changed by the performing the **Marker→** functions.

Marker→ menu

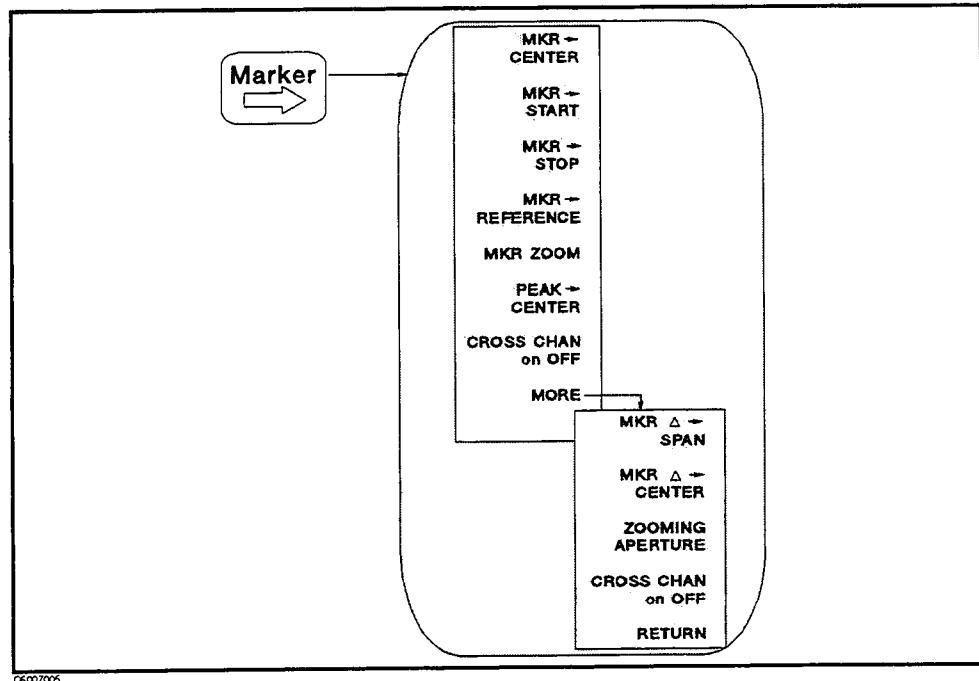


Figure 7-5. Marker→ Menu

- **MKR→CENTER** Changes the stimulus center value to the stimulus value of the marker and centers the new span about that value. When the cross channel (**CROSS CHAN**) is turned off, this softkey changes the center value of the active channel. When the cross channel is turned on, this softkey changes the parameter of the inactive channel.
- **MKR→START** Changes the stimulus start value to the stimulus value of the marker. When the cross channel (**CROSS CHAN**) is turned off, this softkey changes the start value of the active channel. When the cross channel is turned on, this softkey changes the parameter of the inactive channel.
- **MKR→STOP** Changes the stimulus stop value to the stimulus value of the marker. When the cross channel (**CROSS CHAN**) is turned off, this softkey changes the stop value of the active channel. When the cross channel is turned on, this softkey changes the parameter of the inactive channel.

- **MKR→REFERENCE** Sets the reference value to the marker's amplitude value. When the cross channel (**CROSS CHAN**) is turned off, this softkey changes the reference value of the active channel. When the cross channel is turned on, this softkey changes the parameter of the inactive channel.
- **MKR ZOOM** Changes the stimulus center value to the stimulus value of the marker and changes the stimulus span value to the value specified by the zooming aperture. When the cross channel (**CROSS CHAN**) is turned off, this softkey changes the parameters of the active channel. When the cross channel is turned on, this softkey changes the parameters of the inactive channel.
- **PEAK→CENTER** Moves the marker to the maximum or minimum peak and changes the stimulus center value to the stimulus value of the peak. When the cross channel (**CROSS CHAN**) is turned off, this softkey changes the center value of the active channel. When the cross channel is turned on, this softkey moves the marker to the peak of the active channel and changes the parameter of the inactive channel.
- **MKRA→SPAN** Changes the stimulus span value to the difference value between the marker and Δ marker values. When the cross channel (**CROSS CHAN**) is turned off, this softkey changes the span value of the active channel. When the cross channel is turned on, this softkey changes the parameter of the inactive channel.
- **MKRA→CENTER** Changes the stimulus center value to the difference value between the marker and Δ marker values. When the cross channel (**CROSS CHAN**) is turned off, this softkey changes the center value of the active channel. When the cross channel is turned on, this softkey changes the parameter of the inactive channel.
- **ZOOMING APERTURE** Sets the zooming aperture value as a percentage of the span.
- **CROSS CHAN on OFF** Selects the destination channel of the Marker→ functions. When the cross channel is turned off, a Marker→ function changes the stimulus or the amplitude value of the active channel. When the cross channel is turned on, a Marker→ function changes the parameters of the inactive channel.

CROSS CHAN ON off Selects the current inactive channel as the destination channel.

CROSS CHAN on OFF Selects the current active channel as the destination channel.

Turn off the channel coupling when the cross channel function is used

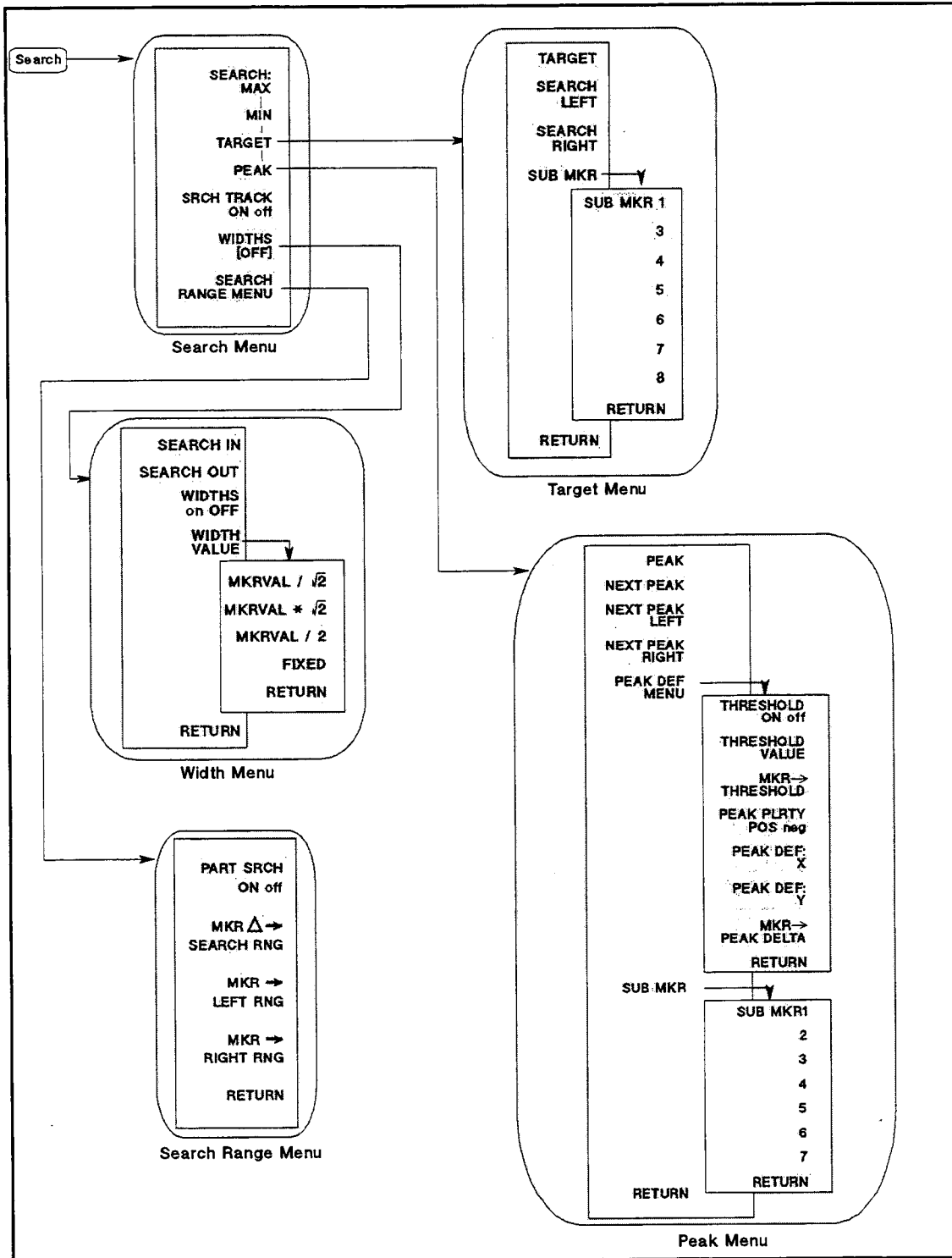
When you want to change one of channel 1 or 2 using marker → functions, turn off the channel coupling.
 If the channel coupling (**COUPLED CHAN**) is on, a marker → functions always changes the settings of both channels.

The active channel is NOT changed to the destination channel after a Marker→ function is performed, even when the cross channel is turned on.

The cross channel can be turned on when the dual channel is turned on.



The **Search** key activates the marker (if it is not already active) and provides access to the marker search functions. The marker search functions can quickly search the trace for specified information.



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Figure 7-6. Softkey Menus Accessed from the **Search** Key

Search Menu

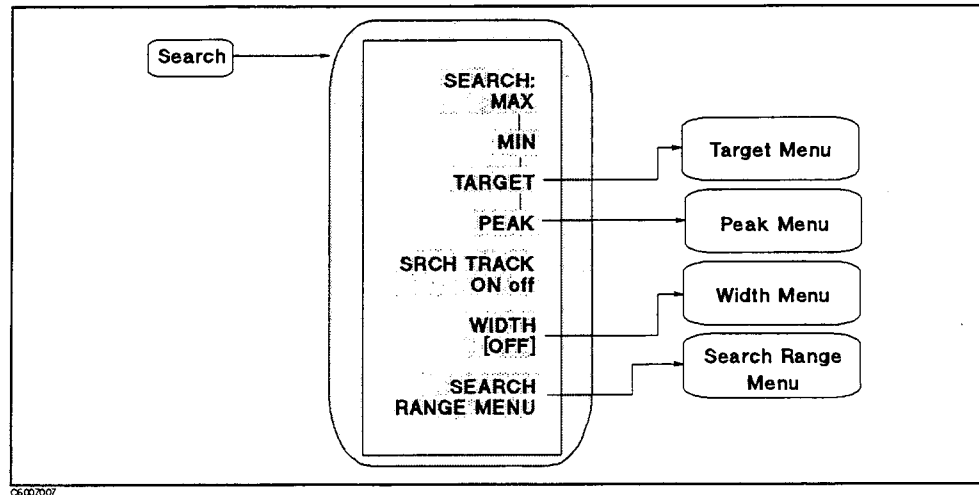


Figure 7-7. Search Menu

- **SEARCH:MAX** Moves the marker to the maximum amplitude point on the trace.
- **MIN** Moves the marker to the minimum amplitude point on the trace.
- **TARGET** Moves the marker to a specified target point on the trace and displays the *Target menu* that is used to search right or left to resolve multiple solutions.
- **PEAK** Moves the marker to the maximum or minimum peak and displays *Peak menu* that is used to search for the next peak. The search function searches for a peak that meets the peak definition specified in the *Peak Definition menu*. See the *Peak Definition menu* for more information on peak definition. This softkey does not appear if the user trace display is turned on.
- **SEARCH TRK ON off** Toggles the search tracking. This is used in conjunction with other search features (such as, sarch MAX, MIN, TARGET, and PEAK) to search each new sweep. This softkey does not appear if the user trace display is turned on.

SEARCH TRK ON off Directs the analyzer to search every new trace for the specified target value and puts the active marker on that point.

SEARCH TRK on OFF When the target is found on the current sweep, it remains at the same stimulus value regardless of changes in trace amplitude values in subsequent sweeps.

- **WIDTHS []** Displays the menu that is used to define the start and stop points for a width search and to turn width search ON and OFF. This softkey does not appear if the user trace display is turned on.

[OFF] Shows the width search is turned off.

[ON] Shows the width search is turned on.

- **SEARCH RANGE MENU** Displays the *Search Range menu*.

Target Menu

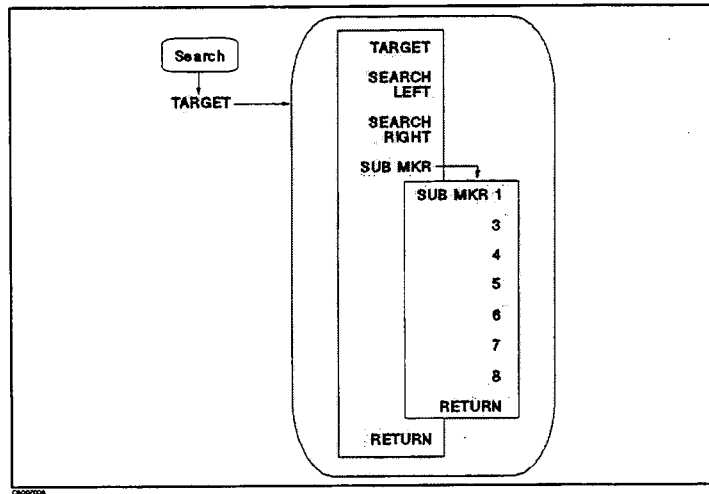


Figure 7-8. Target Menu

- **TARGET** Makes the target value the active function in which to enter a value and moves the marker to a specified target point on the trace.

The target value is in units appropriate to the current format.

In delta marker mode, the target value is the value relative to the Δ marker. If no Δ marker is ON, the target value is an absolute value.

- **SEARCH LEFT** Searches the trace for the next occurrence of the target value to the left.
- **SEARCH RIGHT** Searches the trace for the next occurrence of the target value to the right.
- **SUB MKR** Displays the following softkeys, which are used to put a sub-marker on the present marker position.
 - **SUB MKR 1, 2, 3, 4, 5, 6, 7** These keys put a sub-marker at the present marker position.

Peak Menu

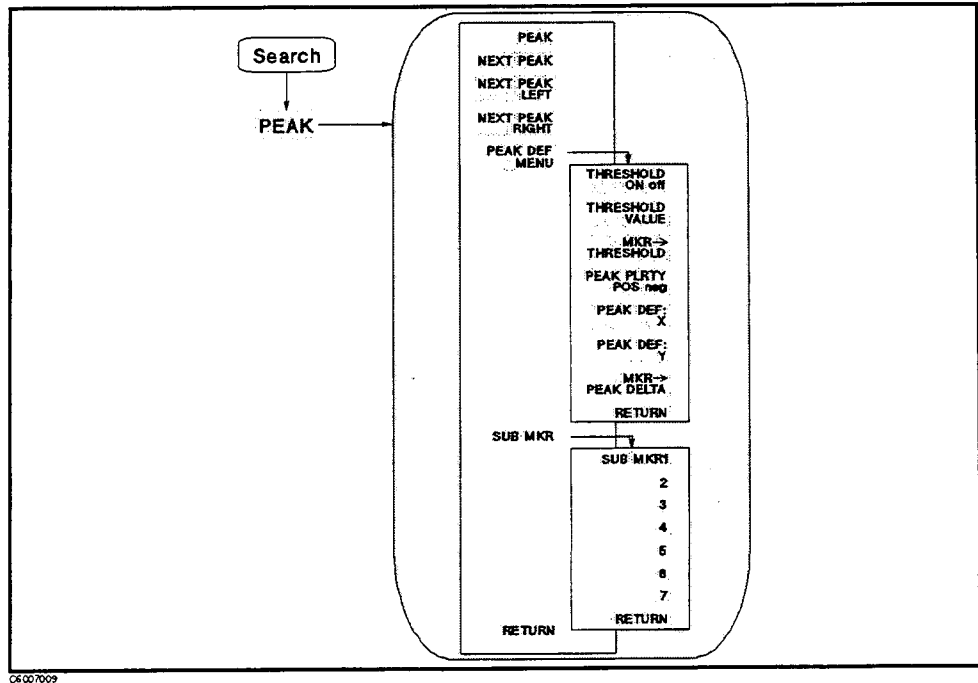


Figure 7-9. Peak Menu

- **PEAK** Moves the marker to the maximum or minimum peak.
- **NEXT PEAK** Moves the marker to the next peak.
- **NEXT PEAK LEFT** Moves the marker to the peak on the left of the present marker position.
- **NEXT PEAK RIGHT** Moves the marker to the peak on the right of the present marker position.
- **PEAK DEF MENU** Displays the following softkeys, which are used to define peak to be searched.
 - **THRESHOLD on OFF** Toggles the threshold on and off.
 - **THRESHOLD VALUE** Sets the threshold values.
 - **MKR->THRESHOLD** Changes the threshold value to the amplitude value of the present marker position.
 - **PEAK PLRTY POS neg** Selects the peak polarity for the marker search functions.

PEAK PLRTY POS neg shows the positive peak is selected.
 PEAK PLRTY pos NEG shows the negative peak is selected.

- **PEAK DELTA: ΔX** Sets the peak delta ΔX value that is used to define the peak.
- **PEAK DELTA: ΔY** Sets the peak delta ΔY value that is used to define the peak.
- **MKR->PEAK DELTA** Changes the peak delta value to the smaller value of the difference of amplitude values between the present maker position and both side display points of the marker.

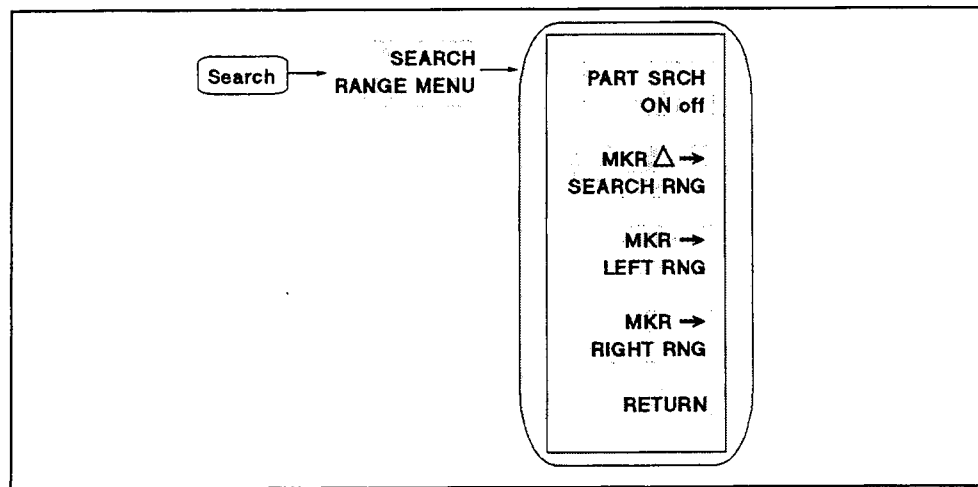
Search Peak Function Definitions	
Peak polarity	Detects either the positive or negative peak that is defined by PEAK PLRTY POS neg .
Threshold	Detects a peak whose amplitude value is greater than or equal to the threshold (even if the peak polarity is negative). Threshold is used in order to reject the noise floor.
Peak Delta	Detects a peak whose differences of amplitude values between the peak and both side display points of the peak are greater than or equal to the peak delta value specified by PEAK DELTA . The peak delta function is used to reject small peaks.

- **SUB MKR** Displays the following softkeys, which are used to put a sub-marker on the present marker position.
 - **SUB MKR 1, 2, 3, 4, 5, 6, 7** These keys put a sub-marker at the present marker position.

Note

For more information on peak definition, see “Peak Definition” in the last part of this chapter.

Search Range Menu



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Figure 7-10. Search Range Menu

- **PART SRCH on OFF** Turns partial search ON or OFF. The search range is defined by two small triangles, "Δ", at the bottom of the graticule. If no search range is defined, the search range is the entire trace.
- **MKRΔ→SEARCH RNG** Sets the partial search range to the range between the marker and Δmarker.
- **MKR→LEFT RNG** Sets the left (lower) border of the partial search range at the current position of the marker.
- **MKR→RIGHT RNG** Sets the right (higher) border of the partial search range at the current position of the marker.

Widths Menu

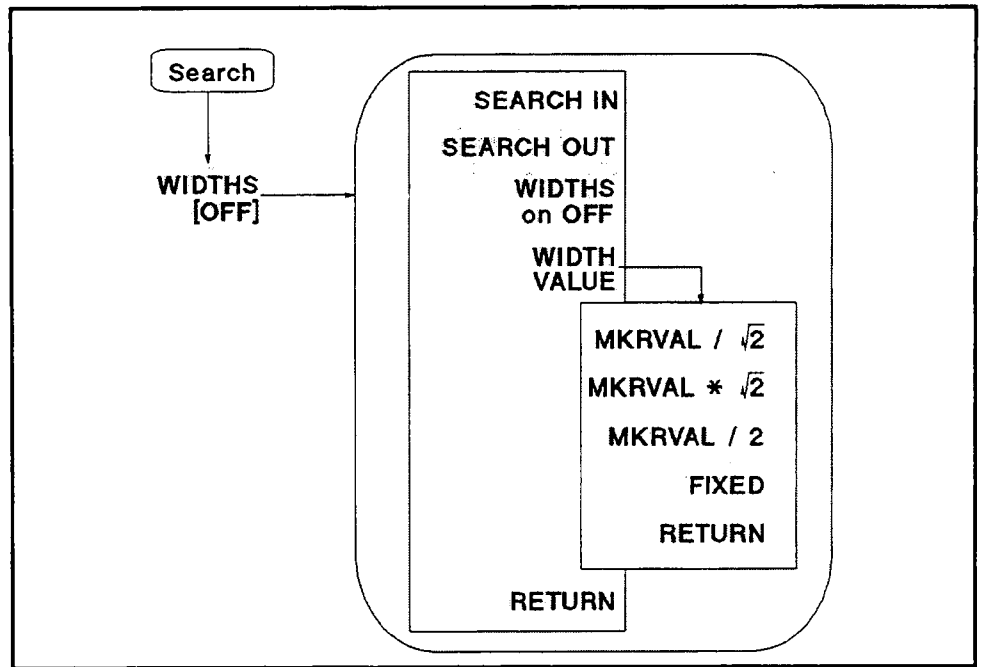


Figure 7-11. Widths Menu

- **SEARCH IN** Searches for the cutoff point on the trace that is within the current cutoff points.
- **SEARCH OUT** Searches for the cutoff point on the trace outside the current cutoff points.
- **WIDTHS on OFF** Turns on the width search feature and calculates the center frequency of a lobe on the trace, width, Q, and cutoff point deviation from the center stimulus value. The cut off point that defines the width parameters is set using the **WIDTH VALUE** softkey. For more information on the width parameters, see “Width Function” in the last part of this chapter.

The Δ marker is automatically changed to the tracking Δ marker when **WIDTHS** is turned on. When **WIDTHS** is ON, the (normal) Δ marker cannot be selected.

- **WIDTH VALUE** Sets a measurement value of a cutoff point that defines the start and stop points for a width search. The width search feature analyzes the center point and the width between the trace down from (or up to) the anti-resonance point or resonance point and the quality factor (Q) for the resonator. Width units are in the units of the current format.
 - **MKRVAL/ $\sqrt{2}$** Sets the width value to the value that equals the marker value divided by the square root of 2.
 - **MKRVAL $\times\sqrt{2}$** Sets the width value to the value that equals the marker value multiplied by the square root of 2.
 - **MKRVAL/2** Sets the width value to the value that equals the marker value divided by 2.
 - **FIXED VALUE** Makes the width value the active function and sets the width value to the value specified by this softkey.

In the expanded phase mode, this function searches for the two cutoff points whose values are "+ WIDTH VALUE" and "- WIDTH VALUE." For example, when the width value is 45°, the cutoff points' values are $\pm 45^\circ$.

Note



For more information on the width function, see "Width Function" in the last part of this chapter.

Utility Menu

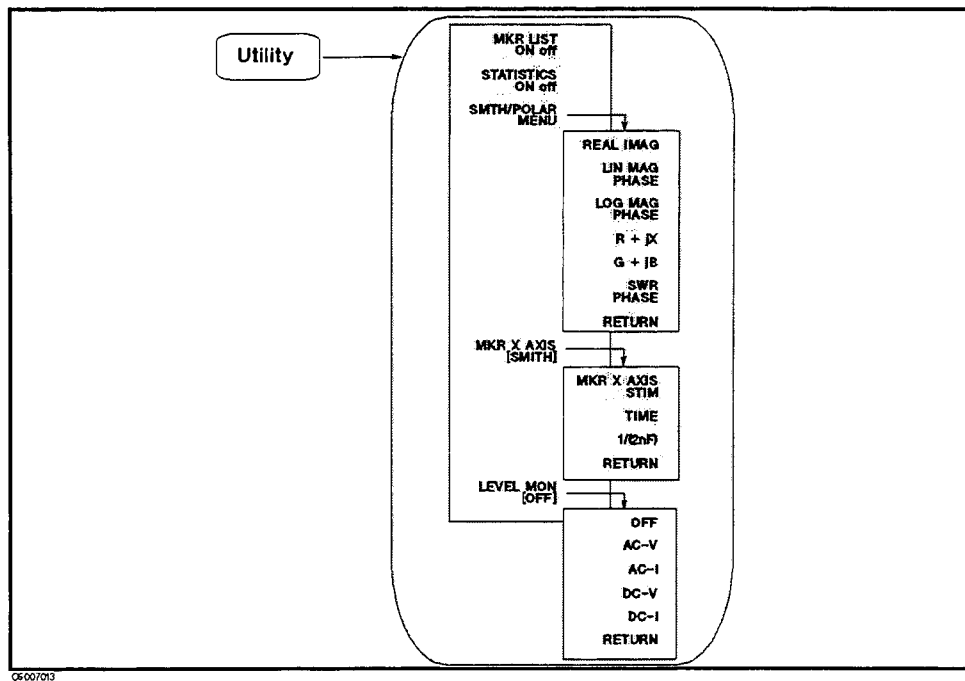


Figure 7-12. Utility Menu

- **MKR LIST on OFF** Toggles the marker list function on and off. This lists the stimulus values and measurement values of all markers. In Δ mode, this also lists Δ marker.
- **STATISTICS on OFF** Calculates and displays the mean, standard deviation, and peak-to-peak values of the section of the displayed trace in the search range. If Partial Search is OFF, the statistics are calculated for the entire trace. The statistics are absolute values.

Statistics for Polar, Smith and Admittance Chart Formats

The statistics are calculated using the absolute value of the complex value.
--

A Convenient Use of Statistics

The statistics function provides a convenient way to find the peak-to-peak value without searching separately for the maximum and minimum values.

- **SMTH/POLAR MENU** Displays softkeys to select the form of the complex marker value on the Smith, polar, and admittance charts. This softkey does not appear if the user trace display is turned on.
 - **REAL IMAG** Displays the values of the marker on a Smith chart, an admittance chart, a polar chart, or a complex plane as a real and imaginary pair. The complex data is separated into its real and imaginary parts. The first marker value given is the real part ($= M \cos\theta$), and the second value is the imaginary part ($= M \sin\theta$), where M = magnitude.

- **LIN MAG PHASE** Displays a readout of the linear magnitude and the phase of the marker. Marker magnitude values are expressed in units of the current format and phase values in degrees.
- **LOG MAG PHASE** Displays the logarithmic magnitude value and the phase of the marker. Magnitude values are expressed in dB and phase values in degrees.
- **R+jX** Converts the marker values into rectangular form. The complex impedance values of the active marker are displayed in terms of resistance and reactance.
- **G+jB** Displays the complex admittance values of the marker in rectangular form. The marker values are displayed in terms of conductance and susceptance (in Siemens).
- **SWR PHASE** Displays the SWR value and phase value of the marker.

Do not use the SWR-Phase marker when the analyzer displays impedance or admittance parameters (SWR values have no meaning). Use SWR-PHASE with Γ measurements.

- **MKR X AXIS []** Leads the following softkeys to select X-axis value to be displayed. This softkey does not appear if the user trace display is turned on.
 - **MKR X AXIS STIM** Displays the marker stimulus value on the right upper corner of the screen. When the Δ mode is ON, this softkey shows a value relative to the Δ marker point.
 - **TIME** Sets the x-axis units to time, (the start point is zero and the stop point is the value of the sweep time). The marker indicates the elapsed time since the sweep started. This function is useful for testing a DUT's time transition characteristics at a certain fixed frequency by setting the span to zero. When the Δ mode is ON, this softkey shows a value relative to the Δ marker point.
 - **$1/2\pi f$** Displays the relaxation time (the value of $1/2\pi$ frequency) instead of the marker stimulus value read-out. This capability is available for the frequency sweep only. When the Δ mode is ON, this softkey shows a value relative to the Δ marker point.
- **LEVEL MON []** Leads to the following softkeys, which are used to monitor output level of OSC level or dc bias. When this function is turned on, the output level on a marker point is displayed on the top right of the screen. This softkey does not appear if the user trace display is turned on.
 - **OFF** Turns off the level monitor function. The marker displays normal marker value.
 - **AC-V** Displays the voltage value of the OSC level on the marker points.
 - **AC-I** Displays the current value of the OSC level on the marker points.
 - **DC-V** Displays the voltage value of the dc bias on the marker points.
 - **DC-I** Displays the current value of the dc bias on the marker points.

Marker Function

Three Types of Markers

Three types of markers are provided for each channel. The first is the **active marker** (or the marker) that is displayed on the screen (as ∇) when **Marker**, **Marker→**, **Search**, or **Utility** is pressed. When a marker is turned on and no other function is active, the marker can be controlled with the knob, or the step keys. The second is the **sub-markers** that appear at the present marker position when a softkey in the sub-marker menu is pressed. The seven sub-markers can be displayed for each channel at the same time (a total of 14). The third is the **Δ marker** that defines a reference position of the delta mode. There are three Δ mode markers, Δ marker (normal), tracking Δ marker, and fixed Δ marker.

Marker Value

Markers have a stimulus value (the x-axis value in a Cartesian format) and a measurement value (the y-axis value in a Cartesian format). In a polar, Smith, admittance chart, or complex plane format, the second part of a complex data pair is also provided as an auxiliary measurement value.

The marker can be moved to any point on the trace. Its measurement and stimulus values are displayed at the top right corner of the graticule for each displayed channel (in units appropriate to the display format). The displayed marker measurement values are valid even when the measured data is above or below the range displayed on the graticule. When marker list is turned on, stimulus values and measurement values of all markers are listed on the graticule. In a polar, Smith, or admittance chart format, auxiliary measurement values of all markers are also listed.

X-axis Value to be Displayed

Stimulus Value

Normally, the marker displays the stimulus value at the current marker position for the x-axis value.

Time

When time is selected as the x-axis value to be displayed (instead of the marker value), the x-axis is changed to the time scale. The start point of the x-axis is 0 seconds and the stop point indicates the sweep time.

Relaxation Time ($1/2\pi f$)

When marker relaxation time ($1/2\pi f$) is selected as the x-axis value to be displayed (instead of the stimulus value), the x-axis is changed to the $1/2\pi f$ scale.

Marker Function

Marker Level Monitor

The analyzer has the capability to monitor the output voltage or current level of the OSC level or dc bias. When the level monitor is turned on, the level monitor value on a marker point is displayed on the screen.

The monitor value displayed is calculated from the current stimulus setting and the impedance value measured.

OSC level monitor value

The voltage value of the OSC level applied to the DUT (V_{dut}) and the current value of the OSC level flowing through the DUT (I_{dut}) are calculated using the following equations:

$$V_{dut} = V_{osc} \times \frac{Z_{meas}}{Z_{meas} + 50}$$

$$I_{dut} = V_{osc} \times \frac{1}{Z_{meas} + 50}$$

or

$$I_{dut} = I_{osc} \times \frac{50}{Z_{meas} + 50}$$

Where,

V_{osc} Voltage setting value of the OSC level

I_{osc} Current setting value of the OSC level

Z_{meas} Current measurement impedance value of the DUT

Continuous/Discrete Mode

Marker values are normally continuous (that is, they are interpolated between measured points). Alternatively, they can be set to read only discrete measured points.

Marker on the Data Trace or on the Memory Trace

If both data and memory are displayed, you can select which marker values apply to the data trace or the memory trace. If data or memory is displayed (not both), the marker values apply to the trace displayed. In a data math display (data+memory, data-memory, or data/memory), the marker values apply to the trace resulting from the memory math function.

Δ Mode

With the use of a delta marker, a delta marker mode is available that displays both the stimulus and measurement values of the marker relative to the reference. Any position on the trace or a fixed point can be designated as the delta marker. The Δ marker can be put on a current position of the marker. If the delta reference is the fixed Δ marker, both its stimulus value and its magnitude value (y-axis value) can be arbitrarily set anywhere in the display area (not necessarily on the trace). If the delta marker is the tracking Δ marker, its stimulus value can be controlled and its measurement value is the value of the trace at that stimulus value.

Marker Search Function

Markers can search for the trace maximum/minimum, any other point, peak maximum/minimum or peak-to-peak value of all or part of the trace. The marker and sub-markers can be used together to search for specified width cutoff points and calculate the width and Q. Statistical analysis uses markers to provide a readout of the mean, standard deviation, and peak-to-peak values of all or part of the trace.

When the format is polar, Smith, admittance chart, or complex plane format, the marker search function searches for the primary marker value (not the AUX value) of the point specified.

Applications for Marker Search on Complex Plan	
To search for the maximum absolute value of the complex impedance:	
1.	Press Utility SMTH/POLAR MENU LOG MAG PHASE
2.	Press Search MAX
To search for the maximum real part value of the complex impedance:	
1.	Press Utility SMTH/POLAR MENU REAL IMAG
2.	Press Search MAX
To search for the maximum resistance value (R) of the complex impedance:	
1.	Press Utility SMTH/POLAR MENU R+jX
2.	Press Search MAX

Width Function

The width search feature analyzes a resonator and calculates the center point, width, and quality factor (Q) for the specified bandwidth. These parameters depend on the Δ marker mode. The following table shows how each parameter is determined for each Δ marker mode.

Marker Function

Parameter	Tracking Δ Marker	Fixed Δ Marker
bandwidth	Displays the bandwidth value between the cutoff points set by WIDTH VALUE .	
Center	Displays the center stimulus value between the cutoff points (this is marked by sub-marker 1).	Displays the stimulus value difference between the center stimulus value of the cutoff points and the fixed Δ marker. (This is marked by sub-marker 1.)
Q	Displays the Q value (= cent/BW) of the trace.	
Peak	Displays the amplitude value at the peak of the lobe.	Displays the amplitude value difference between the amplitude value at the peak of the lobe and the amplitude value of the fixed Δ marker.
ΔF (left)	Displays the stimulus value difference between marker 2 and the center frequency specified by the Center key.	Displays the stimulus value difference between marker 2 and the fixed Δ marker.
ΔF (right)	Displays the stimulus value difference between marker 3 and center frequency specified by the Center key.	Displays the stimulus value difference between marker 3 and the fixed Δ marker.

Figure 7-13 shows an example of the bandwidth search feature.

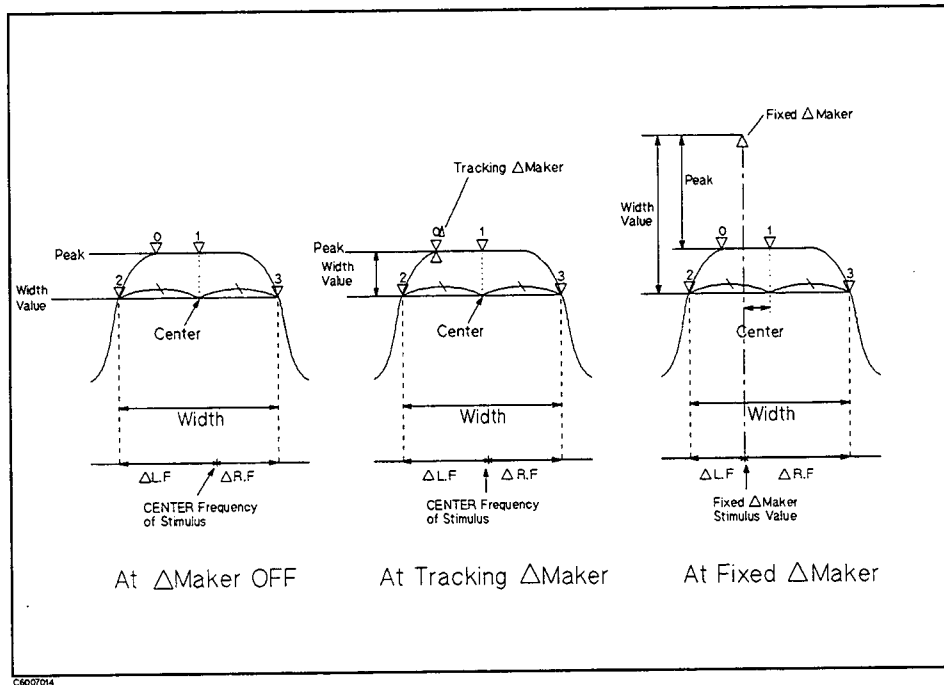


Figure 7-13. Bandwidth Search Example

Width Value

The width search function provides four ways to specify width value as follows:

- Enter the width value directory.
- Set a value that is the marker value divided by the square root of 2.
- Set a value which is the marker value multiplied by the square root of 2.
- Set a value which is the marker value divided by 2.

When Δmode is ON, the width value is relative to the Δmarker.

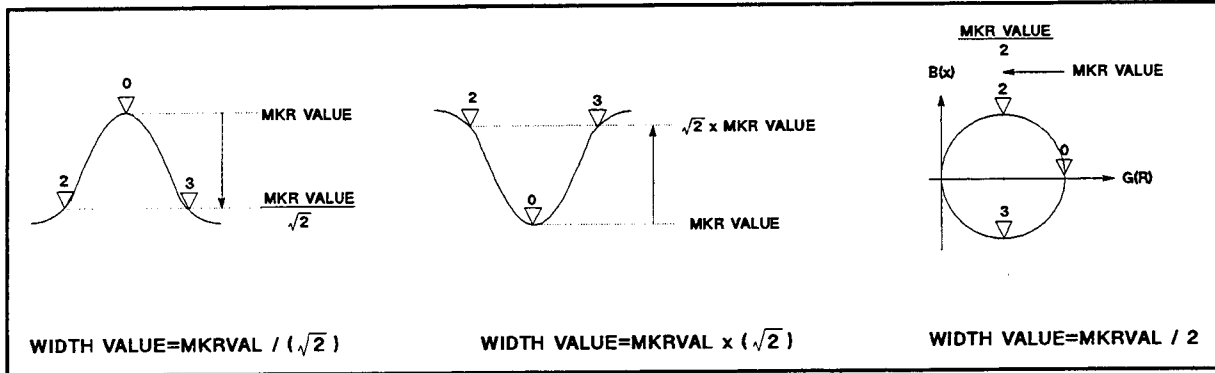
Width Value

Width Value	ΔMarker OFF	ΔMarker ON
MKRVAL/(√2)	The active marker value divided by the square root of 2	The Δmarker value divided by the square root of 2
MKRVAL*(√2)	The active marker value multiplied by the square root of 2	The Δmarker value multiplied by the square root of 2
MKRVAL/2	The active marker value divided by 2	The Δmarker value divided by 2
FIXED	Absolute width value	Relative value to Δmarker

How to determine the quality factor (Q) of resonators
<p>To determine the Q value using the anti-resonance point:</p> <ol style="list-style-type: none"> 1. Press Search to make the marker active. 2. Press SEARCH TRK on OFF to change it to SEARCH TRK ON off. Then press SEARCH:MAX to move the marker to the anti-resonance point on the trace. 3. Press Search WIDTH [off] WIDTH VALUE MKRVAL/(√2) RETURN 4. Press WIDTH on OFF to change it to WIDTH ON off. The width value, Q factor, and several parameters are displayed on the screen.
<p>To determine the Q value using the resonance point:</p> <ol style="list-style-type: none"> 1. Press Search to make the marker active. 2. Press SEARCH TRK on off to change it to SEARCH TRK ON off. Then press MIN to move the marker to the resonance point on the trace. 3. Press Search WIDTH [OFF] WIDTH VALUE MKRVAL*(√2) RETURN 4. Press WIDTH on OFF to change it to WIDTH ON off. The width value, Q factor, and several parameters are displayed on the screen.
<p>To determine the Q value using the admittance chart:</p> <ol style="list-style-type: none"> 1. Press Utility to make marker active. Then press SMTH/POLAR MENU G+jB to read conductance and susceptance (assuming that the admittance circle has been displayed on the admittance chart). 2. Press Search SEARCH TRK on off to change it to SEARCH TRK ON off. Then press Search:MAX to move the marker to the point where the G value is maximum on the trace (resonance point). 3. Press Search WIDTH [OFF] WIDTH VALUE MKRVAL/2 RETURN 4. Press WIDTH on OFF to change it to WIDTH ON off. The width value, Q factor, and several parameters are displayed on the screen.

Marker Block

Marker Function



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Figure 7-14. Q Measurement Examples

There are two kinds of Q parameters

Generally, two kinds of Q factors are used to characterize electric devices, the impedance parameter *Q factor* and the *Q value* of a coil or resonator. However, these Q factors are quite different. The definitions of them are as follows:

Q factor of Impedance Parameter

This Q factor is ratio of the resistance and reactance (or conductance and susceptance):

$$Q = \frac{X}{R}$$

Where, *R* is resistance, *X* is reactance.

Q value of Width Parameter

This Q factor is the ratio of the bandwidth and center frequency of the trace:

$$Q = \frac{BW}{CENTER}$$

Where, *BW* is bandwidth, *CENTER* is center frequency.

Peak Definition

The search function provides the define peak feature, which specifies the properties of the peaks searched for by the peak search function. The define peak feature also allows the peak search function to discriminate peaks from noise.

Peak Definition

The following parameters are used in the peak definition:

- Peak polarity (positive or negative)
- $\Delta X, \Delta Y$ (gradient)
- Threshold value

The search functions search for a peak where the parameters of the peak match the following conditions:

$$\frac{\Delta Y}{\Delta X} \times SPAN \leq \min(\Delta y_L, \Delta y_R)$$

and

$$Threshold \leq Peak \text{ Amplitude Value}$$

Where,

Δy_L and Δy_R are the difference in amplitude value between a peak and the adjacent measurement points on both sides.

That is, the search functions search for a peak where, the gradient is greater than $\Delta Y/\Delta X$, and the amplitude is greater than the threshold value. The search functions ignore a peak when the amplitude value is less than the threshold even if the peak polarity is set to negative.

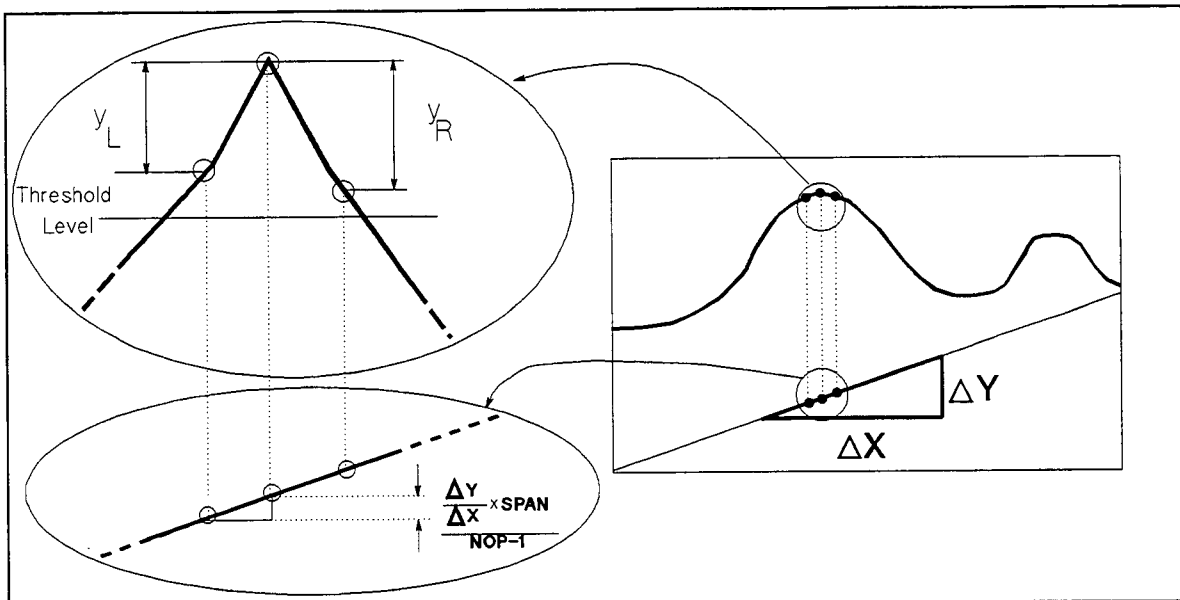


Figure 7-15. Peak Definition

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Instrument State Block

The instrument state block keys and associated menus control channel-independent system functions. These include controller modes, analyzer 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.

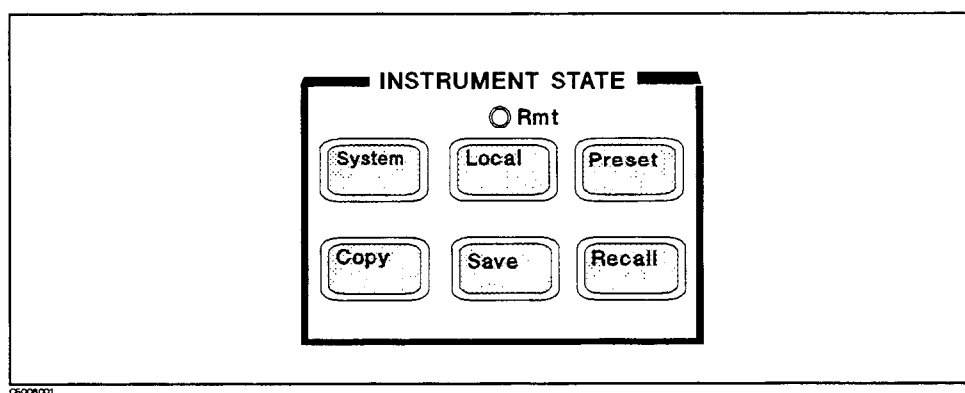
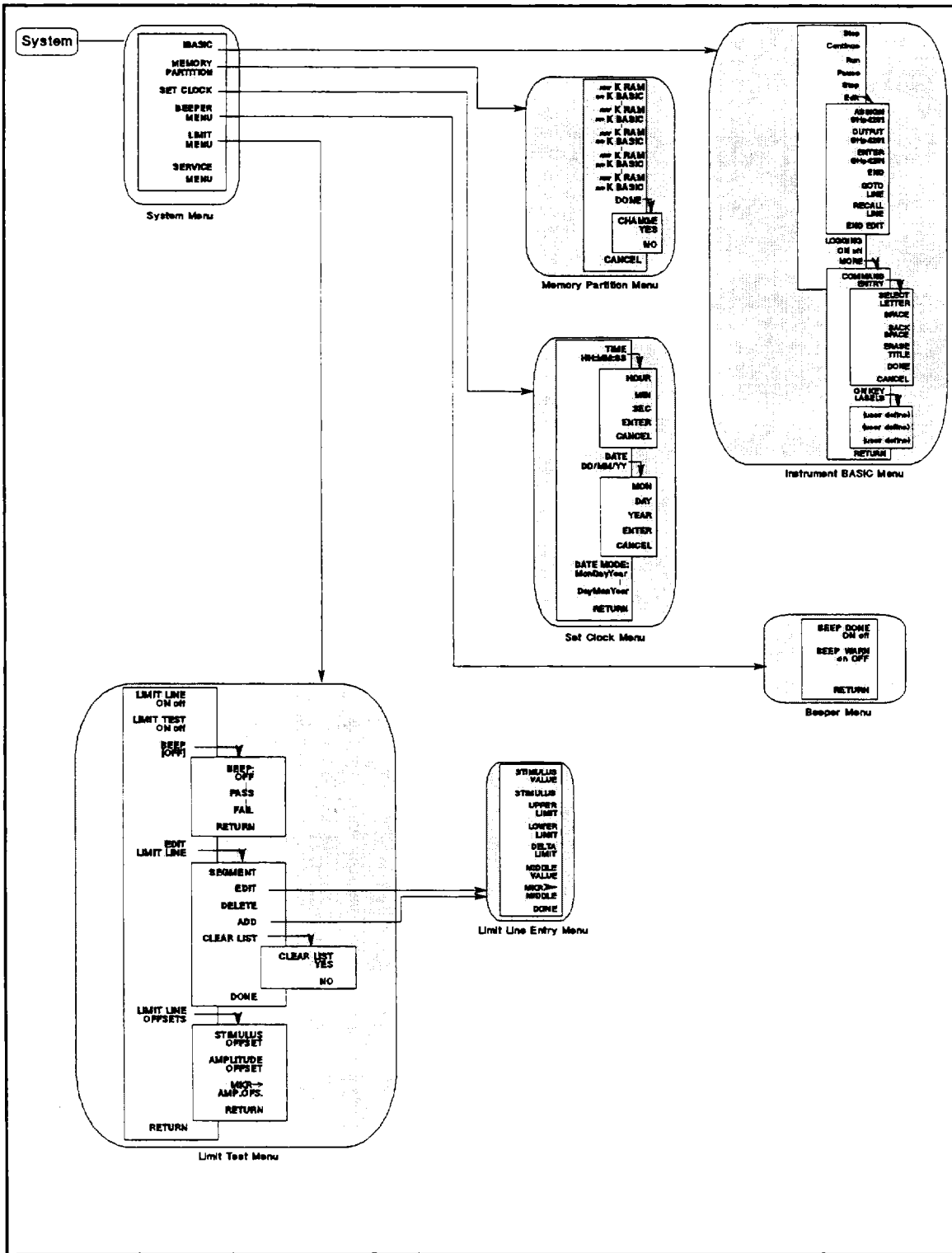


Figure 8-1. Instrument State Block

- 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.
Making Limit Lines and executing Limit Testing.
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** Saving the instrument state and/or data to the built-in disk or RAM disk memory.
- Recall** Recalling the instrument state and/or data from the built-in disk or RAM disk memory.

Functions accessed from this block	You can access from ...	See the following section in this chapter:
Beep on, off	System	Beep menu
Cal kit definition table	Copy	Copy menu
Clock	System	Clock menu
Delete file	Save	Save menu
File extension definition	Save	Define extension menu
HP Instrument BASIC	System	Instrument BASIC menu
HP-IB address	Local	Local menu
Initialize disk	Save	Save menu
Limit test table	Copy	Copy menu
Limit testing/Limit line	System	Limit Test menu
List measurement value	Copy	Copy menu
List sweep table	Copy	Copy menu
Memory size for RAM disk memory	System	Memory partition menu
OPEN, SORT, LOAD definitions for fixture compensation	Copy	Copy menu
Operating parameter list	Copy	Copy menu
Plot display	Copy	Copy menu
Preset instrument	Preset	
Print display	Copy	Copy menu
Recall state/data to the flexible disk and RAM disk	Recall	Recall menu
Save state/data to the flexible disk and RAM disk	Save	Save menu
System controller / Addressable	Local	Local menu
User-defined trace	System	User Trace menu

For Additional Information on ...	See ...
Preset values and Setting Range of each function setting value	Appendix B in this manual
All Softkey Trees	Appendix C in this manual
HP-IB Command Reference	HP-IB Command Reference in the Programming Manual Set binder
How to control the HP 4291A using an external controller or the HP Instrument BASIC capability through the HP-IB.	Programming Guide in the Programming Manual Set binder.



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Figure 8-2. Softkey Menus Accessed from the System Key

System Menu

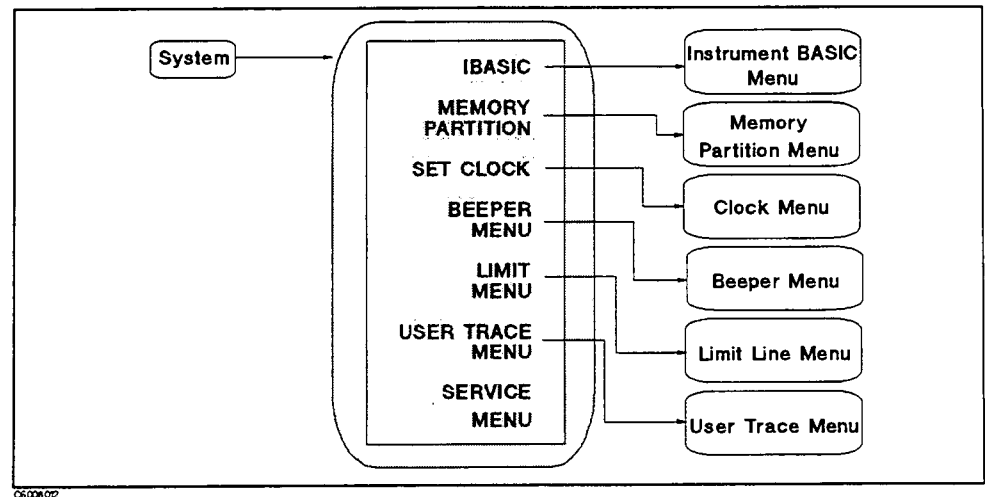


Figure 8-3. System Menu

- **IBASIC** Displays the menu used to operate HP Instrument BASIC. This softkey appears only if the analyzer is equipped with Option 1C2.
- **MEMORY PARTITION** Changes the size of memory areas for HP Instrument BASIC and the RAM Disk. This softkey appears only if the analyzer is equipped with Option 1C2.
- **SET CLOCK** Displays the series of menus that set an internal clock.
- **BEEPER MENU** Displays the series of menus that set a beeper.
- **LIMIT MENU** Displays the series of menus that defines limits or specifications used to test a DUT.
- **SERVICE MENU** Displays the series of service menus described in the *Service Manual*. The *Service Manual* is furnished with Option 0BW.

Instrument BASIC menu

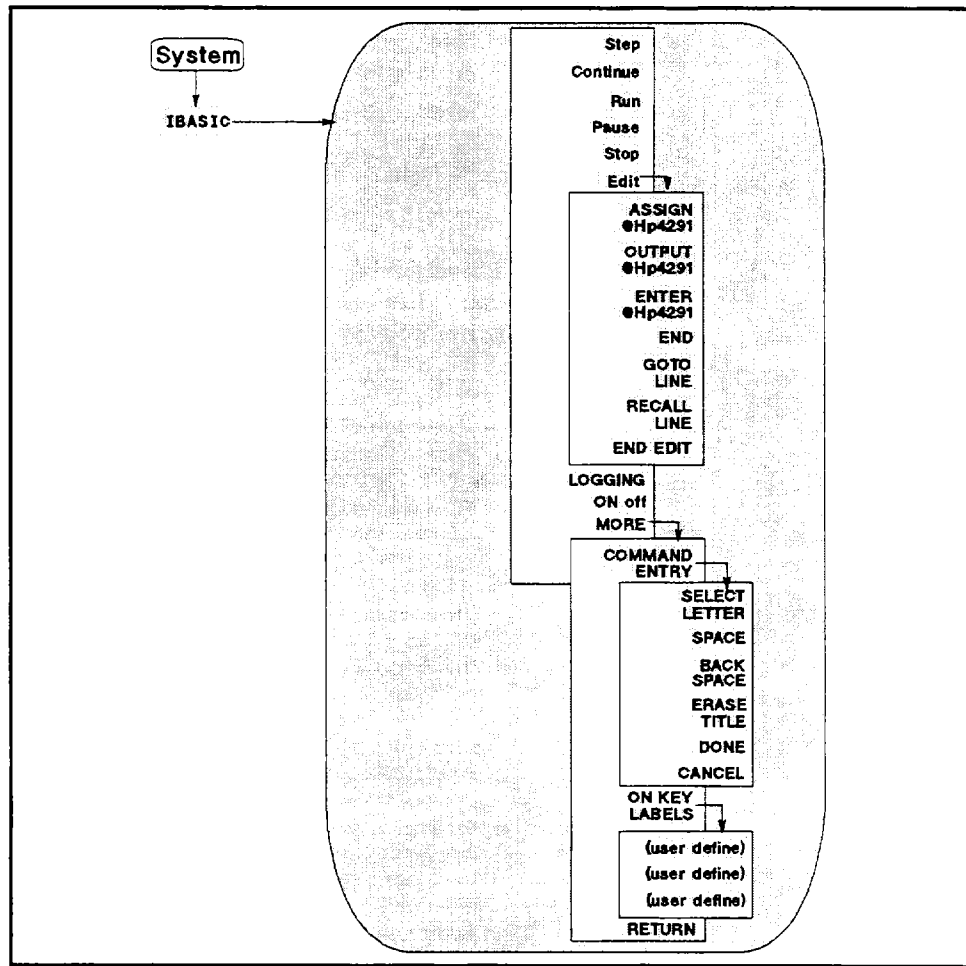


Figure 8-4. Instrument BASIC Menu

- **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 @Hp4291** Produces the command ASSIGN @Hp4291 TO 800 at the cursor's current position.
 - **OUTPUT @Hp4291** Produces the command OUTPUT @Hp4291;" at the cursor's current position.

- ENTER @Hp4291** Produces the command ENTER @Hp4291; 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)**. 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 analyzer logs the equivalent HP-IB commands of all front panel key inputs into the HP Instrument BASIC program.

Logging Function
<ul style="list-style-type: none"> <input type="checkbox"/> When an Instrument BASIC program is running, waiting for an input, or being edited, logging cannot be turned on. <input type="checkbox"/> When the analyzer does not have a program loaded, the following statements are automatically inserted at the beginning and the end of the program. <pre style="margin-left: 20px;">ASSIGN @Hp4291 TO 800 END</pre> <input type="checkbox"/> When there are already some statements in the Instrument BASIC editor, the program lines logged are inserted at the current cursor line. <input type="checkbox"/> The short form of the command is logged and the suffix (unit of parameter) is omitted. <input type="checkbox"/> If the command logged exceeds the memory capacity for the Instrument BASIC, error will occur. <input type="checkbox"/> If you make an input error when logging is ON, the analyzer generates the equivalent codes faithfully and the resulting program is incorrect. <input type="checkbox"/> The logging function does not truncate the repeated nodes of the SCPI command. This makes program lines longer than necessary. <input type="checkbox"/> 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.

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

```
ASSIGN @Hp4291 TO 800
END
```
 - When there are already some statements in the Instrument 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 analyzer 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. The active entry area displays the letters, digits, and some special characters. Three sets of letters can be scrolled using the step keys, **(↑)** and **(↓)**.
 - SELECT LETTER** Selects the character pointed to by "↑."
 - SPACE** Inserts a space.
 - BACK SPACE** Deletes the last character entered.
 - ERASE TITLE** Deletes all characters entered.
 - DONE** Terminates command entry and executes the command you entered.
 - CANCEL** Cancels command and returns to the previous menu.
 - **ON KEY LABELS** Loads the softkey labels, which are defined in the Instrument BASIC program.

Memory Partition Menu

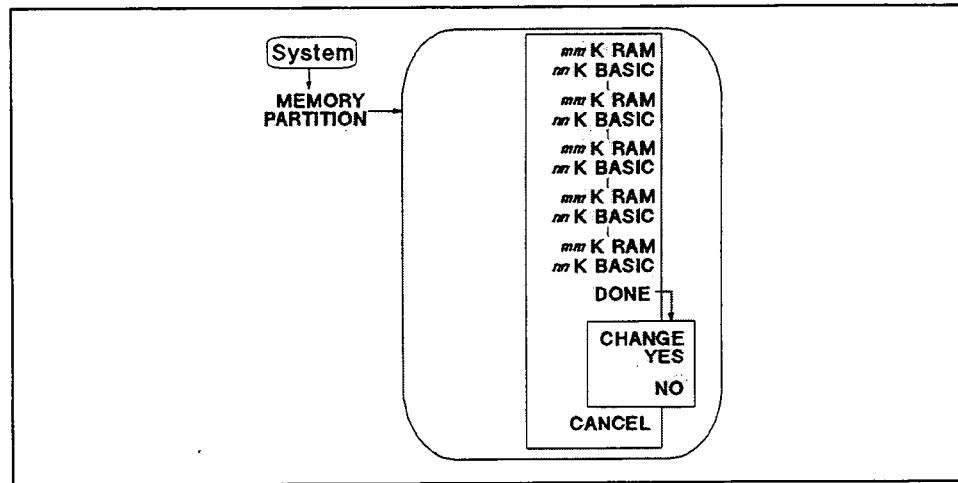


Figure 8-5. Memory Partition Menu

- **nnK RAM mmmK BASIC** Selects the memory partitions so that *mm* Kbytes are used for RAM disk and *nn* Kbytes are used for HP Instrument BASIC. In fact, the analyzer displays the sizes of the RAM disk and the BASIC area, instead of *mm* and *nn*.
- **DONE** Displays **CHANGE YES** and **NO** softkey to execute or cancel the change.
 - **CHANGE YES** Changes the memory partition to the one selected and presets the instrument.
 - **NO** Cancels the change to the memory partition and returns to the previous softkey menu.

When the memory partition is changed ...

When the memory partition is changed, the following settings are also changed:

- The analyzer setting becomes the preset state.
- The Instrument BASIC program in the program editor is lost.
- All data in the RAM disk memory is lost.

Clock Menu

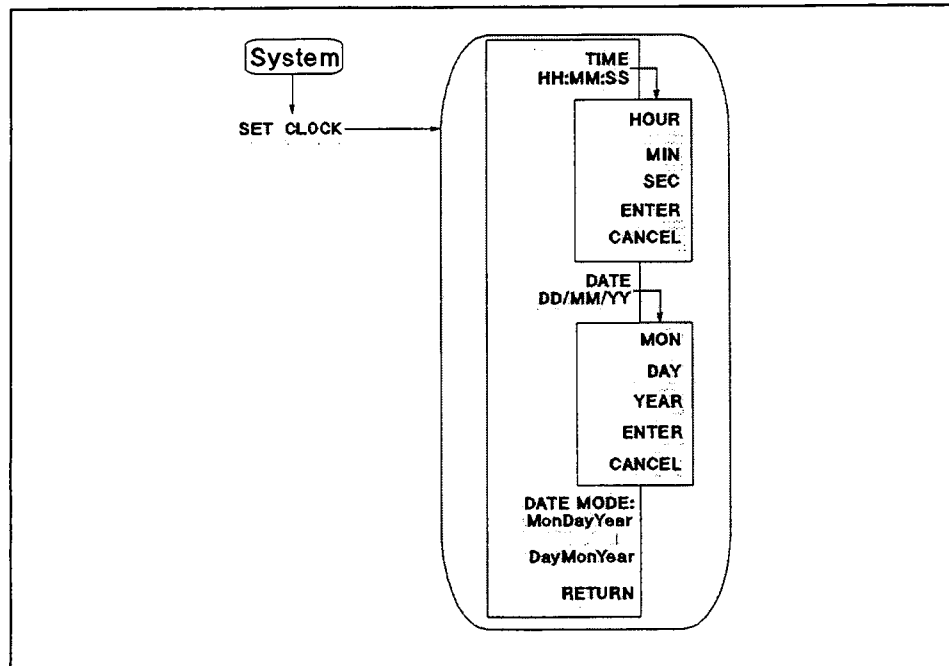


Figure 8-6. Clock Menu

- **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

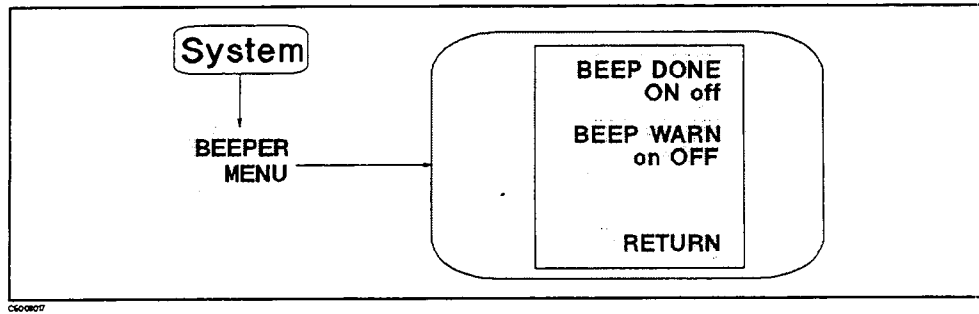


Figure 8-7. Beeper Menu

- **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.

Limit Test Menu

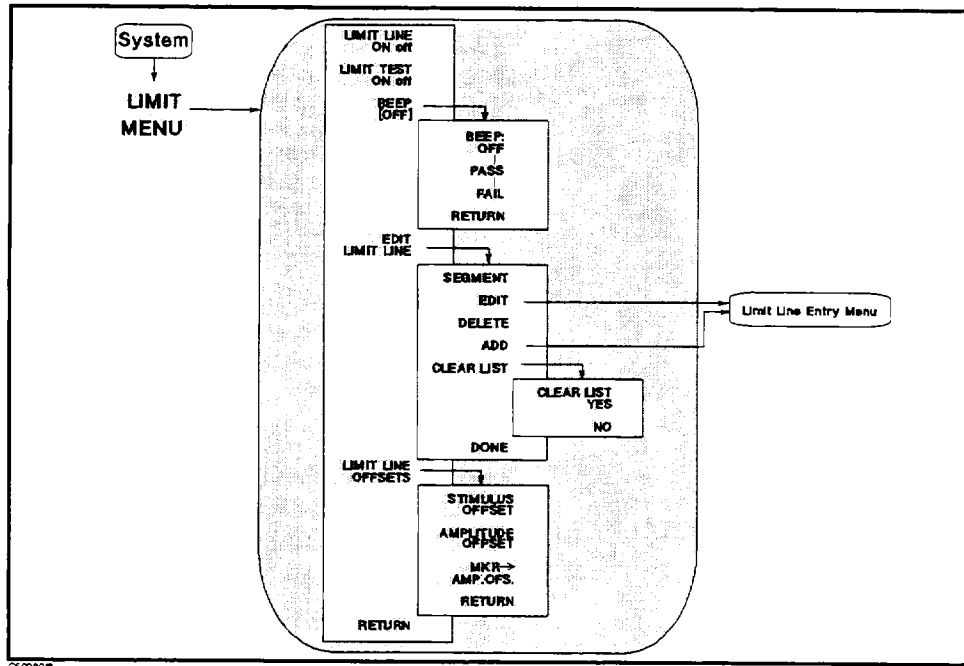


Figure 8-8. Limit Test Menu

- **LIMIT LINE ON off** Turns limit lines ON or OFF. If limits have been defined and limit lines are turned on, the limit lines are displayed for visual comparison of the measured data in all Cartesian formats.

Limit lines can be saved on disk
If limit lines are defined, they are always saved on disk with an instrument state.

Limit line table can be listed.
Copy function (accessed from Copy key) can list a limit line table. In a listing of values with limit lines on and limit test on, the upper limit and lower limit are listed together with the pass or fail margin, as long as other listed data allows sufficient space.

- **LIMIT TEST ON off** Turns limit testing ON or OFF. When limit testing is ON, the data is compared with the defined limits at each measured point. Limit tests occur at the end of each sweep, whenever the data is updated, and when limit testing is first turned ON.

Limit testing is available for both magnitude and phase values in Cartesian formats. In the polar, Smith, admittance chart, and complex plane formats, the value tested depends on the marker mode and is the magnitude or the first value in a complex pair. The message "NO LIMIT LINES DISPLAYED" is displayed in polar, Smith, admittance chart, and complex plane formats if limit lines are turned ON.

Four different ways to indicate pass or fail status

When limit testing is ON, the following four different indications of pass or fail status are provided:

- A PASS or FAIL message is displayed at the right of the display.
- The limit beeper sounds if it is turned on.
- In a listing of values using the copy menu, an asterisk * is shown next to any measured point that is out of limits.
- A bit is set in the HP-IB status byte.

- **BEEP []** Leads to the following softkeys, which are used to turn on or off the limit pass or fail beep. The limit beeper is independent of the warning beeper and the operation complete beeper, both of which are described in the "Beeper Menu."
 - **OFF** Turns the limit beeper off.
 - **PASS** Turns the limit passes beeper on. When limit testing is ON and the pass beeper is ON, a beep is emitted each time a limit test is performed and a pass is detected.
 - **FAIL** Turns the limit fails beeper on. When limit testing is ON and the fail beeper is ON, a beep is emitted each time a limit test is performed and a failure is detected.
- **EDIT LIMIT LINE** Displays a table of limit segments on the lower half of the display. Also leads to the following softkey, which is used to define or change limits.
 - **SEGMENT** Specifies which limit segment in the table to edit. The list can be scrolled up or down to show other segment entries. The pointer ">" shows the segment that can be edited or deleted. The pointer can be moved using the entry block. If the table of limits is designated EMPTY, new segments can be added using ADD or EDIT.
 - **EDIT** Displays the *Limit Line Entry* menu that defines or modifies the stimulus value and limit values of a specified segment. If the table is empty, a default segment is displayed.
 - **DELETE** Deletes the segment indicated by the pointer ">."
 - **ADD** Displays the *Limit Line Entry* menu and adds a new segment to the end of the list. The new segment is initially a duplicate of the segment indicated by the pointer ">" and selected using SEGMENT. If the table is empty, a default segment is displayed. The maximum number of segments is 18.
 - **CLEAR LIST** Displays the following softkeys and clears all the segments in the limit test.
 - **CLEAR LIST YES** Clears all the segments in the limit line table and returns to the previous menu.
 - **NO** Cancels clearing the segments and returns to the edit limit menu.
 - **DONE** Sorts the limit segments and displays them on the display in increasing order of stimulus values.
- **LIMIT LINE OFFSETS** Displays the following three softkeys that offset the complete limit set in either stimulus or amplitude value.
 - **STIMULUS OFFSET** Adds to or subtracts an offset from the stimulus value. This allows limits already defined to be used for testing in a different stimulus range.

- **AMPLITUDE OFFSET** Adds or subtracts an offset in amplitude value. This allows previously defined limits to be used at a different power level.
- **MKR→AMP.OFS** Move the limits so that they are centered an equal amount above and below the marker at that stimulus value.

Note

For information on the limit line concept, see “Limit Line Concept” later in this chapter.

Limit Line Entry Menu

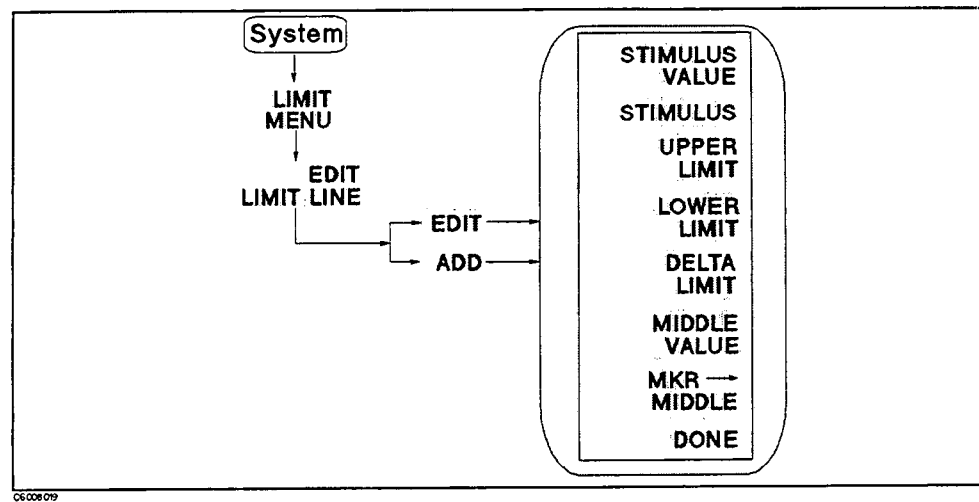


Figure 8-9. Limit Line Entry Menu

- **STIMULUS VALUE** Sets the starting stimulus value of a segment using the entry block controls.
- **MKR → STIMULUS** Changes the segment stimulus value to the present marker stimulus value.
- **UPPER LIMIT** Sets the upper limit value for the segment. Upper and lower limits must be defined. If no upper limit is required for a particular measurement, force the upper limit value out of range (for example, +1 G)

When **UPPER LIMIT** or **LOWER LIMIT** is pressed, all the segments in the table are displayed in terms of upper and lower limits, even if they were defined as delta limits and middle value.

If you attempt to set an upper limit that is lower than the lower limit, or vice versa, both limits will be automatically set to the same value.

- **LOWER LIMIT** Sets the lower limit value for the segment. Upper and lower limits must be defined. If no lower limit is required for a particular measurement, force the lower limit value out of range (for example, -1 G).
- **DELTA LIMIT** Sets the limits an equal amount above and below a specified middle value, instead of setting upper and lower limits separately. This is used in conjunction with **MIDDLE VALUE** or **MARKER → MIDDLE**, to set limits for testing a device that is specified at a particular value plus or minus an equal tolerance.

When **DELTA LIMITS** or **MIDDLE VALUE** is pressed, all the segments in the table are displayed in these terms, even if they were defined as upper and lower limits.

- **MIDDLE VALUE** Sets the midpoint for **DELTA LIMITS**. It uses the entry controls to set a specified amplitude value vertically centered between the limits.

- MKR→MIDDLE Sets the midpoint for DELTA LIMITS using the marker to set the middle amplitude value of a limit segment. Moves the limits so that they are automatically set an equal amount above and below the present marker amplitude value.
- DONE Terminates a limit segment definition and returns to the last menu.

Note

For information on the limit line concept, see “Limit Line Concept” later in this chapter.

Local

Local

This key performs the following functions:

- Returns front panel control to the user. The analyzer ignores all front panel keys (except the local key) when under the control of an external computer. The analyzer is in “local mode” when the user has front panel control. The analyzer is in the “remote mode” when an external computer controls the analyzer.
- Gives access to the HP-IB menu that sets the controller mode and to the address menu (where the HP-IB addresses of the analyzer 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).

Local Menu

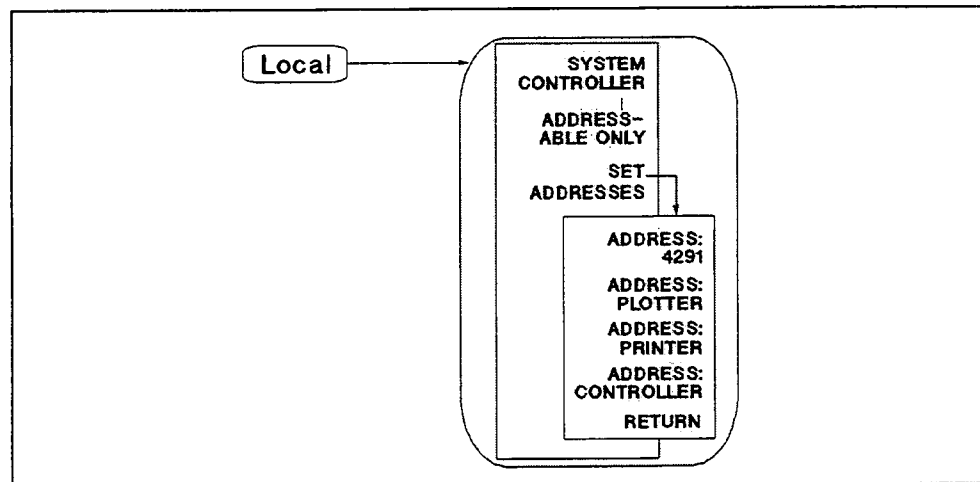


Figure 8-10. Local Menu

- **SYSTEM CONTROLLER** Sets the analyzer 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 analyzer'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 analyzer as addressable only. This mode is used when an external controller controls peripheral devices or the analyzer.
- **SET ADDRESS:** Displays the following softkeys:
 - **ADDRESS:4291** Sets the HP-IB address of the analyzer. There is no physical address switch to set in the analyzer.
 - **ADDRESS:PLOTTER** Sets the HP-IB address the analyzer will use to communicate with the plotter.

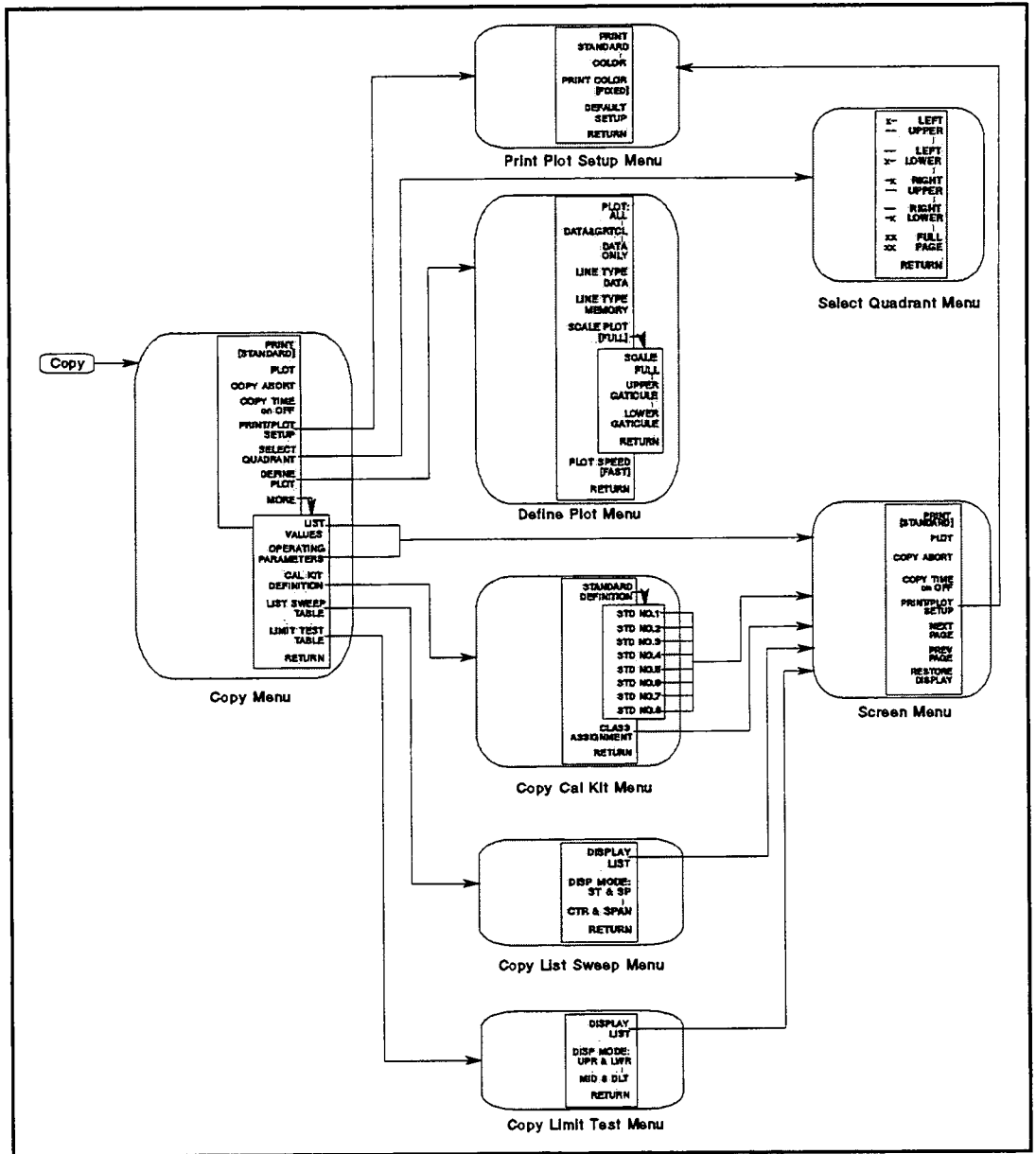
- **ADDRESS:PRINTER** Sets the HP-IB address the analyzer will use to communicate with the printer.
- **ADDRESS:CONTROLLER** Sets the HP-IB address the analyzer will use to communicate with the external controller.

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

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
- Color Adjustment
- Clock Time/Date
- Limit Line 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



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Figure 8-11. Softkey Menus Accessed from the Copy Key

Copy Menu

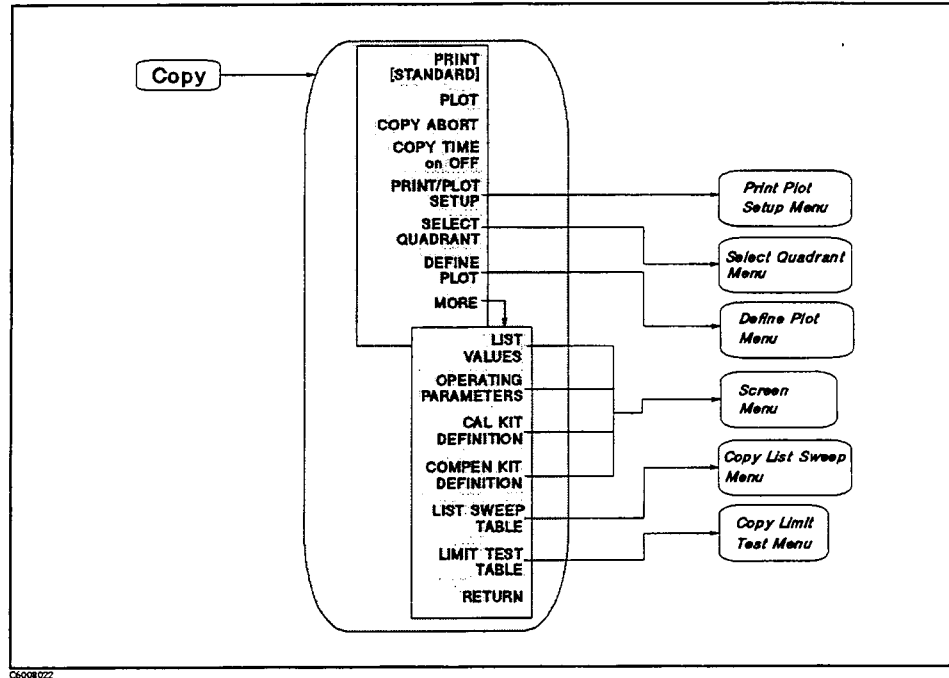


Figure 8-12. Copy Menu

- **PRINT [STANDARD]** Causes an exact copy of the display to be printed. The softkey label identifies the printer selected in the print/plot setup menu:

STANDARD For a black and white printer
COLOR For a color printer.

- **PLOT** Plots the display to a compatible HP graphics plotter, using the currently defined plot parameters (or default parameters). Any or all displayed information can be plotted, except the softkey labels and the frequency list table in EDIT mode, or limit table in EDIT mode. (List values, operating parameters, or cal kit definition can be plotted using the *Screen menu* as explained later in this chapter. However, this is considerably slower than printing.)

Before pressing PRINT or PLOT, you should:

- Make sure the analyzer's printer/plotter HP-IB address and the printer/plotter HP-IB addresses match when the analyzer is set to the system controller mode.
or
- Make sure the analyzer's controller HP-IB address and the controller HP-IB address match when the analyzer is set to the addressable mode.

- **COPY ABORT** Aborts a plot or print 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 "Clock Menu" for setting the internal clock.

- **PRINT/PLOT SETUP** Leads to the *Print Plot Setup menu*, which is used to allow you to copy the display to a printer capable of graphics plotting or tabular listing. For information on compatible printers and plotters, see the *Specifications* in this manual set.
- **SELECT QUADRANT** Displays the *Select Quadrant menu* that provides the capability of drawing quarter-page plots. This is not used for printing.
- **DEFINE PLOT** Displays the *Define Plot menu* that specifies which elements of the display are to be plotted. This is not used for printing.
- **LIST VALUES** provides a tabular listing of all the measured data points and their current values. When **DUAL CHAN** and **COUPLED CHAN** are **ON**, the measured values of both channels are listed at the same time. When **LIMIT LINE** and **LIMIT TEST** are **ON**, the limit information is also listed together with the measured values. The *Screen menu* is displayed to enable hard copy listings and access new pages of the table.

Table 8-1 shows the data listed on the screen when **DUAL CHAN** and/or **COUPLED CHAN** are **OFF**. The margin listed is the smaller of the difference values between the measurement value and either the upper or lower limit. A plus margin means the test passed and a minus margin means it failed.

Table 8-1. List Value Format

Display Format	Values Listed				
	1st column	2nd column	3rd column	4th column	5th column
LIN Y-AXIS LOG Y-AXIS	Sweep Parameter	Measurement Data ¹	Margin ²	Upper Limit Value ²	Lower Limit Value ²
SMITH CHART POLAR ADMITTANCE CHART COMPLEX PLANE	Sweep Parameter	Measurement Data ¹	Measurement Data	Upper Limit Value ²	Lower Limit Value ²

1 An * is displayed at the left of the measurement value when it fails the limit testing.

2 This is listed when the limit test is on.

The analyzer can list the values measured on both channels
When the dual channel is turned on and both channels are coupled, the sweep parameter value is listed in the first column, the measurement data of the active channel is listed in the second and third columns, and the non-active channel data is listed in the fourth and fifth columns. The values listed for each channel are the same as the data listed in the second and third columns in Table 8-1.

- **OPERATING PARAMETERS** Displays the *Screen menu* and provides a tabular listing on the display of the key parameters for both

channels. 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: <input type="checkbox"/> Sweep Source <input type="checkbox"/> Sweep Type <input type="checkbox"/> Number of Points <input type="checkbox"/> CAL Kit <input type="checkbox"/> CAL Type <input type="checkbox"/> Test Head <input type="checkbox"/> Fixture <input type="checkbox"/> Port Extension <input type="checkbox"/> Material Size (Option 002 only) <input type="checkbox"/> Calibration States <input type="checkbox"/> Compensation States <input type="checkbox"/> Trigger Source <input type="checkbox"/> 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.

Print Plot Setup Menu

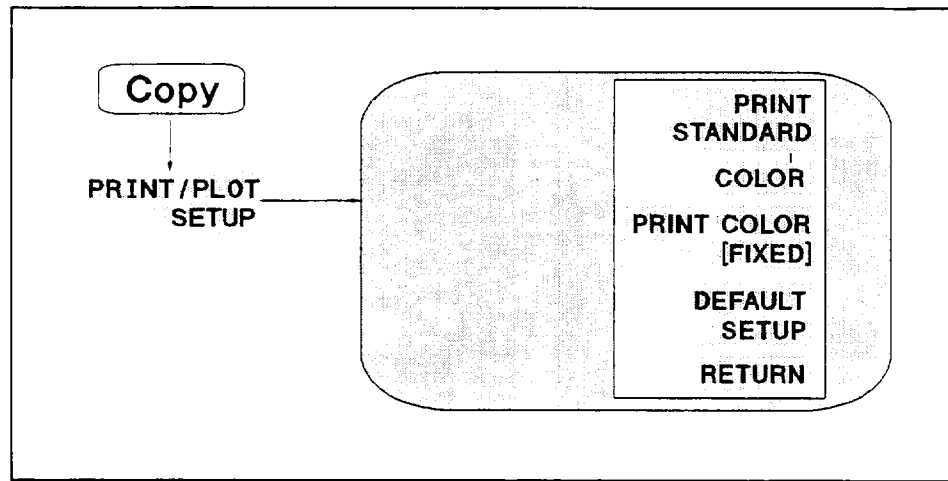


Figure 8-13. Print Plot Setup Menu

- **PRINT STANDARD** Sets the print command to the default selection (a standard printer that prints in black only or a PaintJet color printer to yield a black-only print).
- **COLOR** Sets the print command to a default of color. The **PRINT [COLOR]** command does NOT work with a black and white printer.
- **PRINT COLOR [FIXED]** Toggles the printing color between **[FIXED]** and **[VARIABLE]**. If **FIXED** is selected, the analyzer prints a hard copy with default colors. If **VARIABLE** is selected, the analyzer prints a hard copy with colors as similar as possible to the display colors (that can be adjusted). See “**Display**” in Chapter 5 for display colors adjustment.

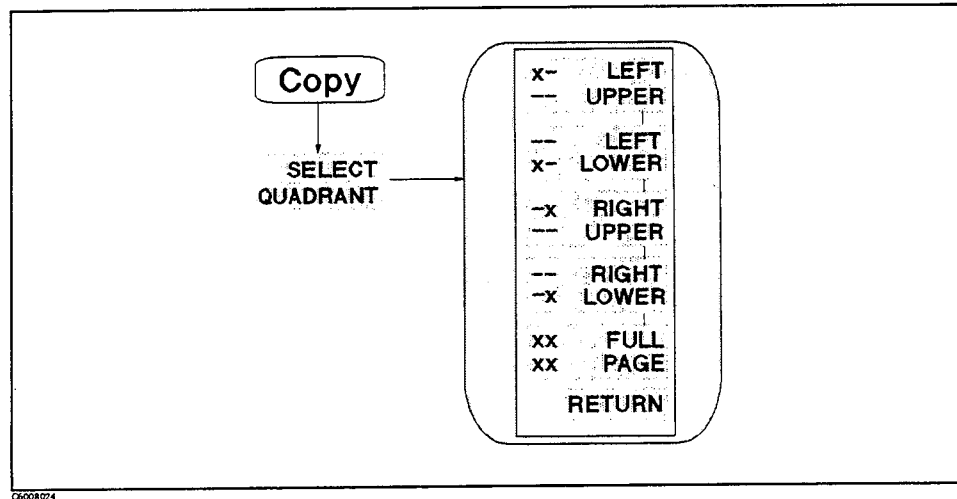
Because of the limited number of printer ink colors, the printed color is not always the same as the displayed color.

- **DEFAULT SETUP** Resets the plotting parameters to their default values. These defaults are as follows:

- Select quadrant: Full page
- Define plot: All plot elements on
- Plot scale: Full
- Plot speed: Fast
- Line type: 7 (solid line) for both trace and memory

Default setups do not apply to printing.

Select Quadrant Menu



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Figure 8-14. Select Quadrant Menu

- **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).

Define Plot Menu

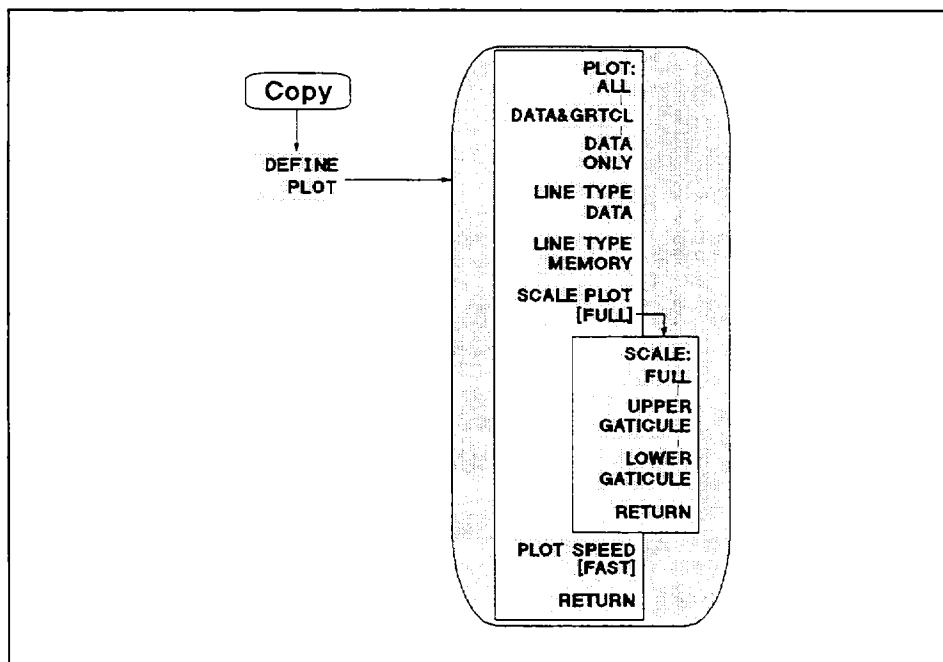


Figure 8-15. Define Plot Menu

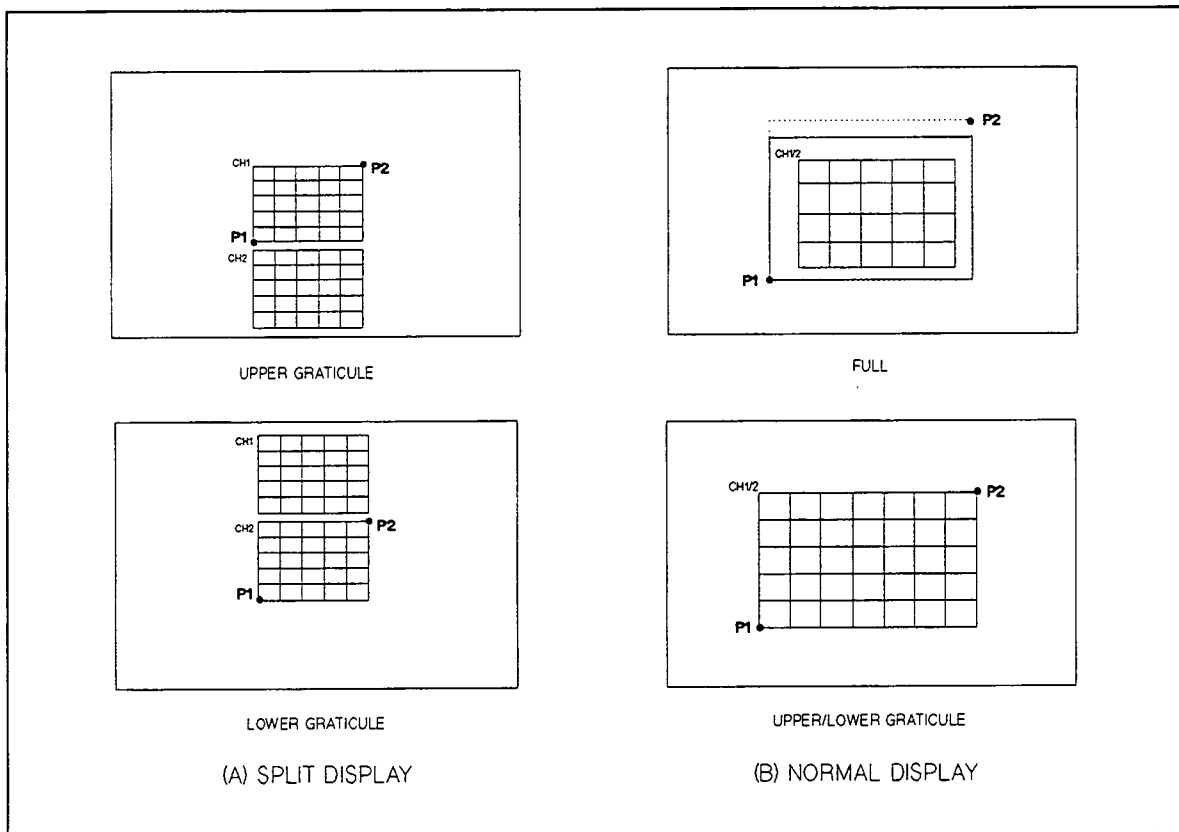
- **PLOT:ALL** Plots all the information on the display except for the softkey labels.
- **DATA&GRTCL** Plots the measured data, the memory data, and the graticule.
- **DATA ONLY** Plots only the measured data and the memory data.
- **LINE TYPE DATA** Selects the line type of the trace data for plotting. The default line is a solid unbroken line.
- **LINE TYPE MEMORY** Selects the line type of the memory trace for plotting. The default line type is a solid unbroken line.
- **SCALE PLOT [FULL]** Displays the menu that selects a plot scale.
 - **SCALE:FULL** Selects the normal, full-size scale for plotting on blank paper and includes space for all display annotations such as marker values, sweep parameter values, etc. The entire display fits within the user-defined boundaries of P1 and P2 on the plotter and maintains the same aspect ratio as the display.
 - **UPPER GRATICULE LOWER GRATICULE** These softkeys expand or reduce the horizontal and vertical scale so that the graticule lower left and upper right corners exactly correspond to the user-defined P1 and P2 scaling points on the plotter. In the dual display mode, the applicable graticule is channel 1 for **UPPER GRATICULE**, or channel 2 for **LOWER GRATICULE**. This is convenient for plotting on preprinted rectangular or polar forms (for example, on a Smith chart).

To plot on a rectangular preprinted graticule, set P1 of the plotter at the lower left corner of the preprinted graticule and set P2 at the upper right corner.

To plot on polar and Smith chart formats as an accurate circle, set P1 and P2 so that a rectangle defined by P1 and P2 become a square because the outer circumference is identical to an inscribed circle in the rectangle.

When the display is split (for example, **SPLIT DISP ON**, **MKR LIST ON**), then **UPPER** sets the upper graticule to the plot area defined by P1 and P2 and **LOWER** sets the lower graticule to the plot area. When the display is not split, **UPPER** and **LOWER** are the same. (See Figure 8-16.)

- **PLOT SPEED [FAST]** Provides two plot speeds, **FAST** and **SLOW**. Fast is the proper plot speed for normal plotting. Slow plot speed is used for plotting directly on transparencies because the slower speed provides a more consistent line width.



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Figure 8-16. Full, Upper, and Lower Graticule

Copy Limit Test Menu

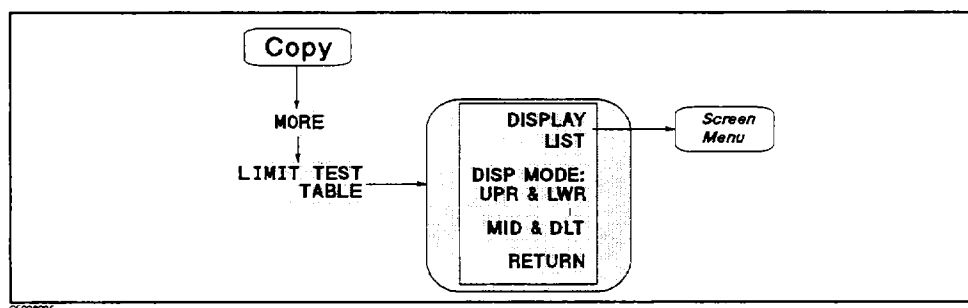


Figure 8-17. Copy Limit Test Menu

- **DISPLAY LIST** Displays the limit testing table and the *Screen menu* to prepare for hard copy.
- **DISP MODE:UPR & LWR** Selects the upper and lower formats that display the upper limit and lower limit values.
- **MID & DLT** Selects the middle and delta formats that display the middle value and the maximum deviation (limit value) from the middle value.

Copy List Sweep Menu

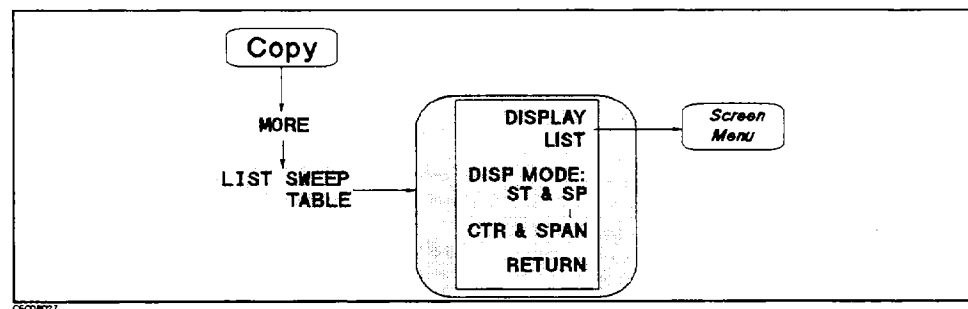


Figure 8-18. Copy List Sweep Menu

- **DISPLAY LIST** Displays the list sweep table and leads to the *Screen menu* to prepare for hard copy.
- **DISP MODE:ST & SP** Selects the start/stop format to list the sweep parameter.
- **CTR & SPAN** Selects the center/span format to list the sweep parameter.

Screen Menu

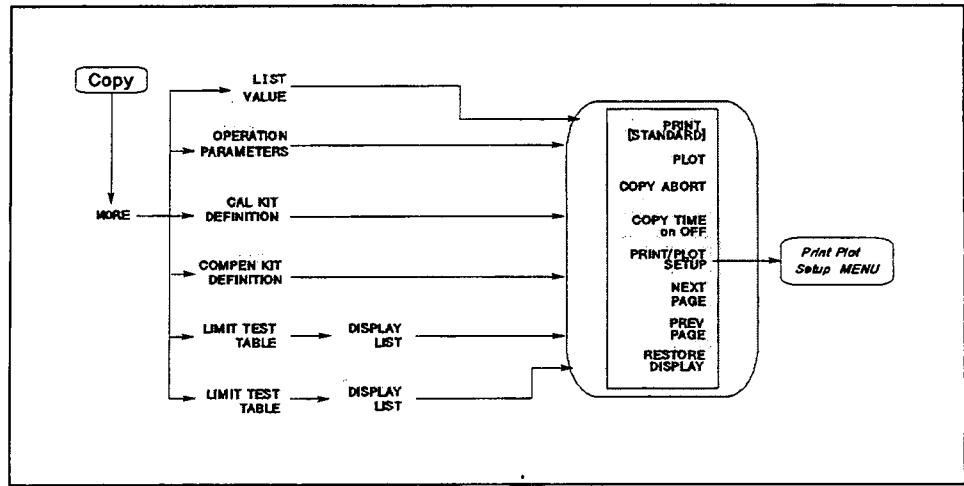


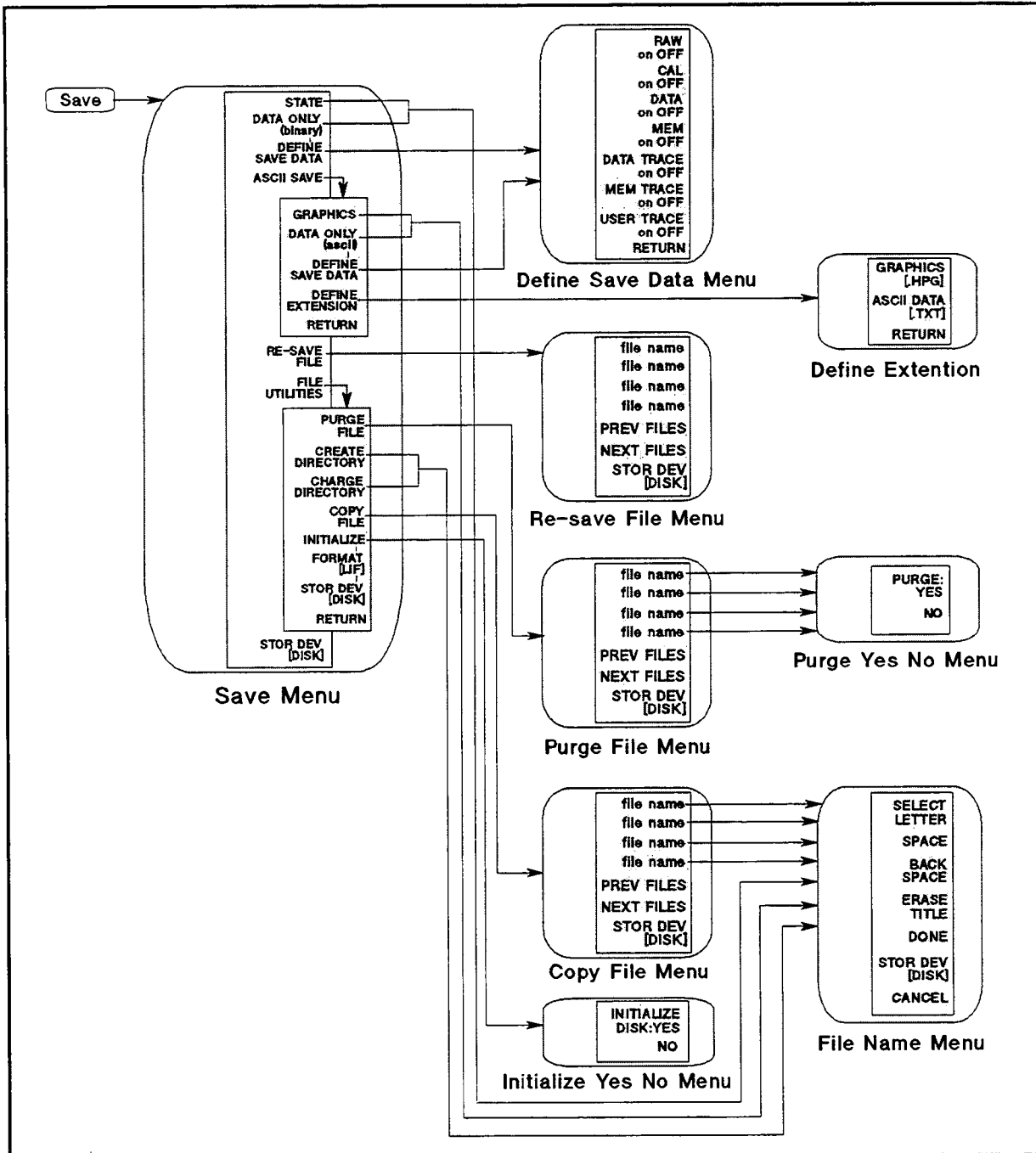
Figure 8-19. Screen Menu

- **PRINT [STANDARD]** Copies one page of the tabular listings to a compatible HP graphics printer. Either **STANDARD**, for a black and white printer, or **COLOR**, for a color printer, is shown in brackets (“[]”). This identifies which printer is selected as the default in the print/plot setup menu. The default setting at power on is standard. Default text for a color printer is black.
- **PLOT** Plots one page of the tabular listing on the display using the current setup (defined in **SELECT QUADRANT** and **DEFINE PLOT**). Plot size and speed can be changed in the **DEFINE PLOT MENU**.

Before pressing PRINT and PLOT, you must perform the following steps:

- Set the analyzer to the system controller mode.
- Verify the analyzer's printer HP-IB address and the printer's HP-IB address match.

- **COPY ABORT** Aborts a plot or print 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 “Clock Menu” for setting the internal clock.
- **PRINT/PLOT SETUP** Displays the print/plot setup menu that is used to setup a graphics printer or plotter.
- **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.



C6008039

Figure 8-20. Softkey Menus Accessed from the **Save** Keys

Recalling Instrument BASIC program

The **Save** and **Recall** keys do not 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 Menu

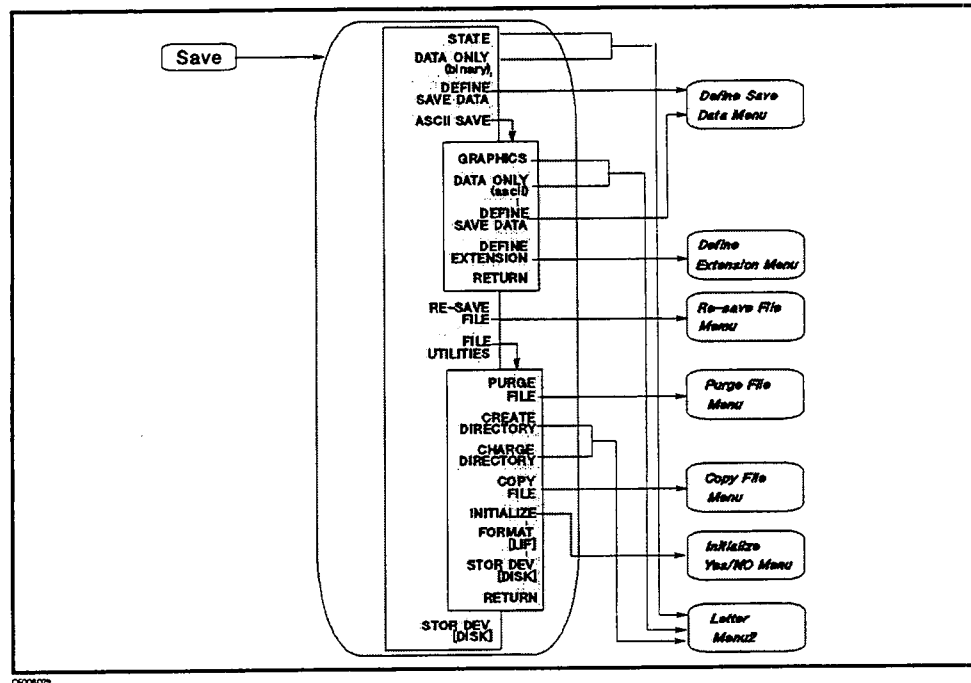


Figure 8-21. Save Menu

- **STATE** Specifies saving the instrument states, the calibration coefficients and measurement data.
- **DATA ONLY(binary)** Specifies saving the internal data arrays which are defined using the **DEFINE SAVE DATA** key.

DATA ONLY does not save instrument settings such as start and stop frequencies. BE CAREFUL! Always make sure that you save the existing STATE if you want to use the setup again.

- **DEFINE SAVE DATA** Displays the *Define Save Data menu* that selects the applicable data arrays to be saved.
- **ASCII SAVE** Displays the menu used to save data or graphic screen images to an ASCII file.

ASCII data files cannot be recalled

When saving internal data arrays, note that ASCII data files cannot be recalled on the analyzer. If you need to recall the data, save the file in binary format. This binary data can be recalled and saved as an ASCII file at any time.

- **GRAPHICS** Specifies saving the graphics image on the screen as an HP-GL file. The graphics portion saved is selected in the define plot menu under the **Copy** key.
- **DATA ONLY(ascii)** Specifies saving the internal data arrays as an ASCII file. The arrays saved are defined by the **DEFINE SAVE DATA** key. Each numerical value in the ASCII file is separated by TAB code.

- **DEFINE SAVE DATA** Displays the *Define Save Data menu* that selects the applicable data arrays to be saved.
- **DEFINE EXTENSION** Provides the *Define Extension menu* that changes the file extensions of ASCII files.
- **RE-SAVE FILE** Displays the Re-save File menu used to update a file that is already saved.
- **FILE UTILITIES** Displays the following softkeys:
 - **PURGE FILE** Displays the Purge File menu used to remove a file saved on the disk.
 - **CREATE DIRECTORY** Specifies creating a new directory in a DOS format disk. This function is not available for LIF files.
 - **CHANGE DIRECTORY** Specifies changing the current directory of a DOS format disk. This function is not available for LIF files.
 - **COPY FILE** Copies files. When a file is copied between the flexible disk and the RAM disk memory, the disk formats of the disk and the RAM disk memory must be same format.

Use the same disk format type for COPY FILE

When you copy files using this function, use the same disk format type for both the RAM disk and the flexible disk. This copy function cannot copy files when the format of the RAM disk is different from the format of the flexible disk.

- **INITIALIZE** Displays the Initialize menu. A new disk must be initialized before data is stored on it. The disk can be formatted in either LIF or DOS format.
- **FORMAT [LIF]** Toggles the disk format between the LIF and DOS formats that are used when initializing a new disk. This setting does not change even when the line power is cycled or the **Preset** key is pressed. The factory setting is LIF.
- **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.

RAM disk data is lost when the power is tuned off

Use the built-in flexible disk to store important data because the RAM disk data is lost when the power is turned off.

The storage selection does not change even when the line power is cycled or the **Preset** key is pressed.

Define Save Data Menu

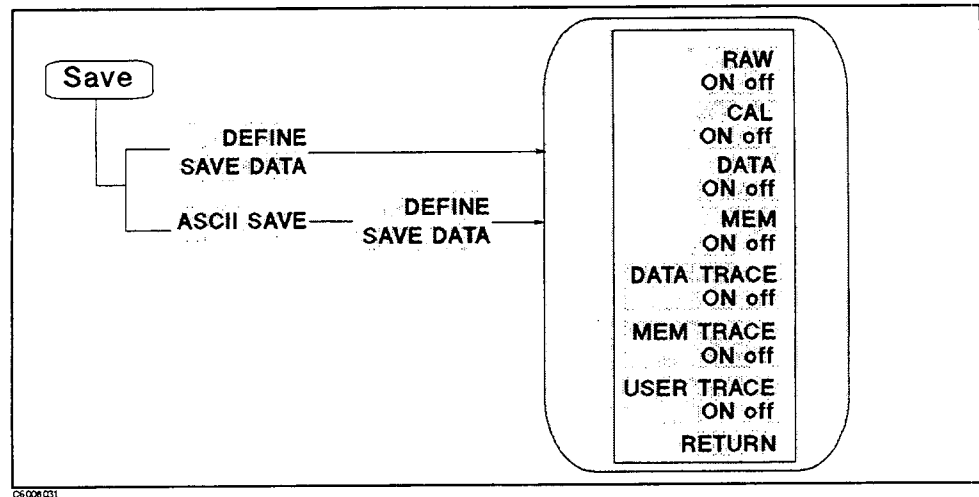


Figure 8-22. Define Save Data Menu

- **RAW DATA ON off** Toggles saving or not saving the raw data arrays.
- **CAL ON off** Toggles saving or not saving the calibration coefficients arrays.
- **DATA ON off** Toggles saving or not saving the data arrays.
- **MEM ON off** Toggles saving or not saving the memory arrays.
- **DATA TRACE ON off** Toggles saving or not saving the trace arrays.
- **MEM TRACE ON off** Toggles saving or not saving the memory trace arrays.
- **USER TRACE ON off** Toggles saving or not saving the user trace arrays.

Define Extension Menu

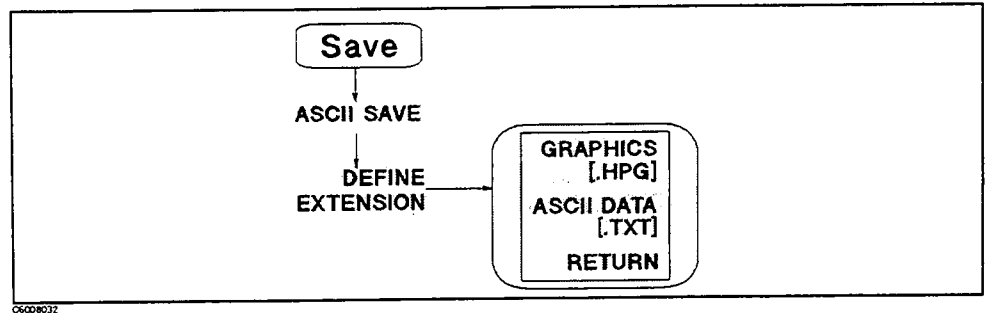


Figure 8-23. Define Extension Menu

- **GRAPHICS [.HPG]** Changes the extension of HP-GL files for DOS format. The extension is automatically attached to the file name when an HP-GL file is saved. The factory setting is .HPG.
- **ASCII DATA [.TXT]** Changes the extension of an ASCII data file for DOS format. The extension is automatically attached to the file name when an ASCII data file is saved. The factory setting is .TXT.

The analyzer keeps the setting of the extensions in the battery backup memory, even if the analyzer is turned off.

The extension definition is valid for DOS format only.

Re-Save File Menu

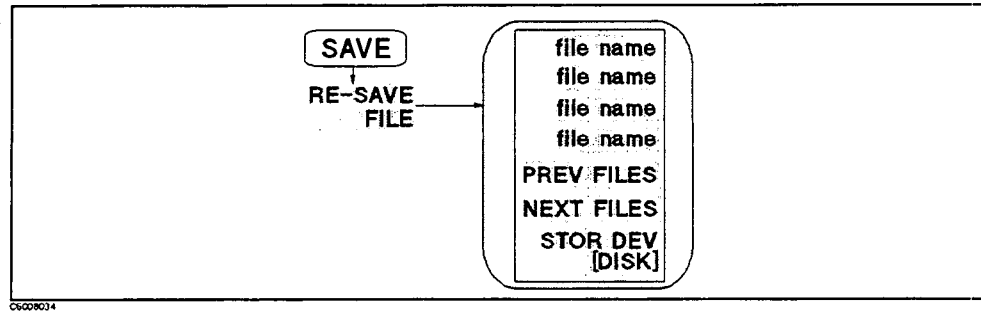


Figure 8-24. Re-Save File Menu

- **file name** Updates the file previously saved with the current instrument states or data. The data group to be saved is determined by the file name's extension. See "Saving and Recalling Instrument States and Data" later in this chapter for more details about file name extensions.
- **PREV FILES** Displays the previous file names in the softkey label to re-save data.
- **NEXT FILES** Displays the next file names in the softkey label to re-save data.
- **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.

Purge File Menu

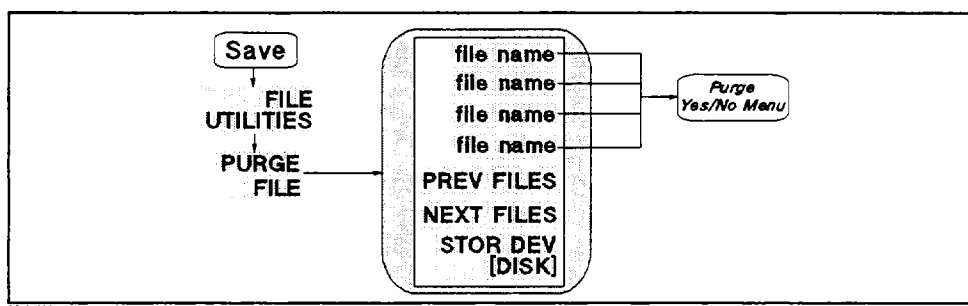


Figure 8-25. Purge File Menu

- **file name** Selects the file to be purged from the disk or the RAM disk.
- **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.

Purge Yes No Menu

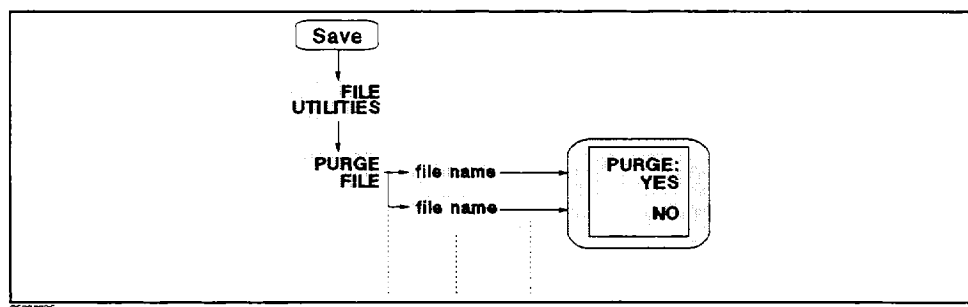


Figure 8-26. Purge Yes No Menu

- **PURGE: YES** Removes the file and returns to the previous menu.
- **NO** Returns to the previous menu without purging the file.

Save

Initialize Yes No Menu

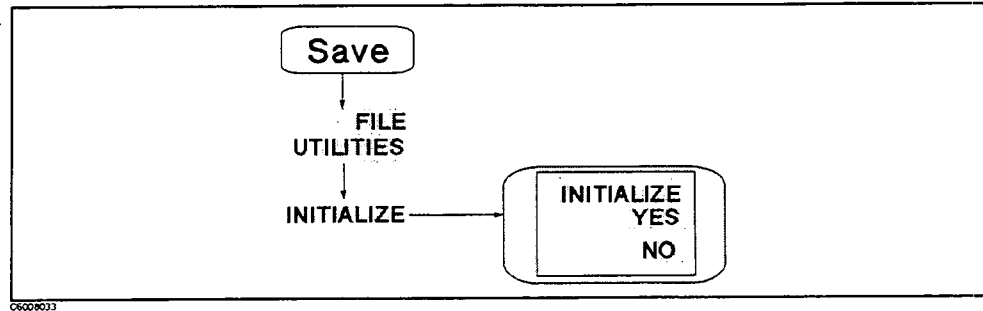


Figure 8-27. Initialize Yes No Menu

- **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.

Recall Menu

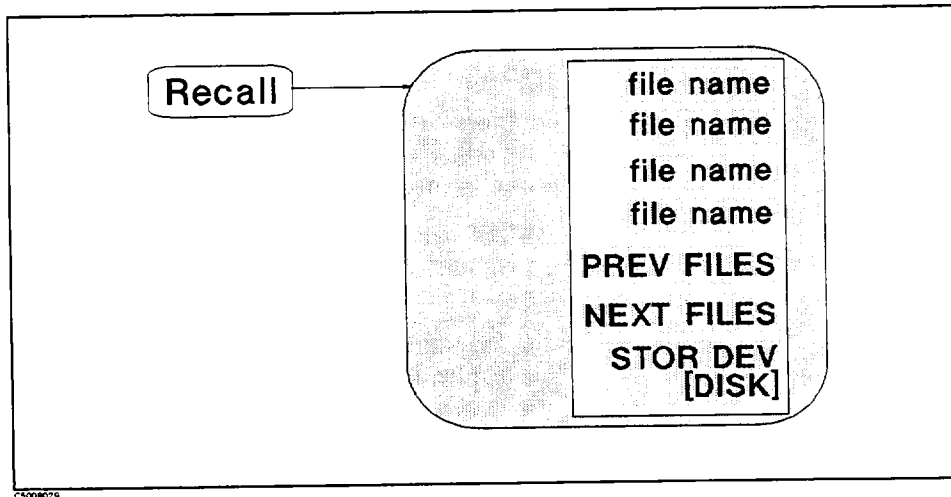


Figure 8-28. Recall Menu

- **file name** Selects a file to be loaded and loads the instrument state or data.
- **PREV FILES** Displays the previous set of file names used to load data.
- **NEXT FILES** Displays the next set of file names used to load data.
- **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.

Auto Recall Function
When the analyzer is turned on, it looks for a file named "AUTOREC" from the built-in flexible disk, and if found, the analyzer automatically reads the file to retrieve its data.

Limit Line Concept

These are lines drawn on the display to represent upper and lower limits or device specifications with which to compare the DUT. Limits are defined by specifying several segments, where each segment is a portion of the stimulus span. Each limit segment has an upper and a lower starting limit value.

Limits can be defined independently for the two channels with up to 18 segments for each channel (a total of 36 for both channels). These can be in any combination of the two limit types.

Limit testing compares the measured data with the defined limits, and provides pass or fail information for each measured data point. An out-of-limit test condition is indicated in the following ways:

- Displaying a FAIL message on the screen.
- Emitting a beep.
- Displaying an asterisk in tabular listings of data.
- Writing a bit into bit 3 and 4 of the instrument status register.

Limits are entered in tabular form. Limit lines and limit testing can be either ON or OFF while limits are defined. As new limits are entered, the tabular columns on the display are updated, and the limit lines (if on) are modified to the new definitions. The complete limit set can be offset in either stimulus or amplitude value.

How Limit Lines are Entered

Before limit lines can be explained, the concept of “segments” must be understood. A segment is the node of two limit lines. See Figure 8-29.

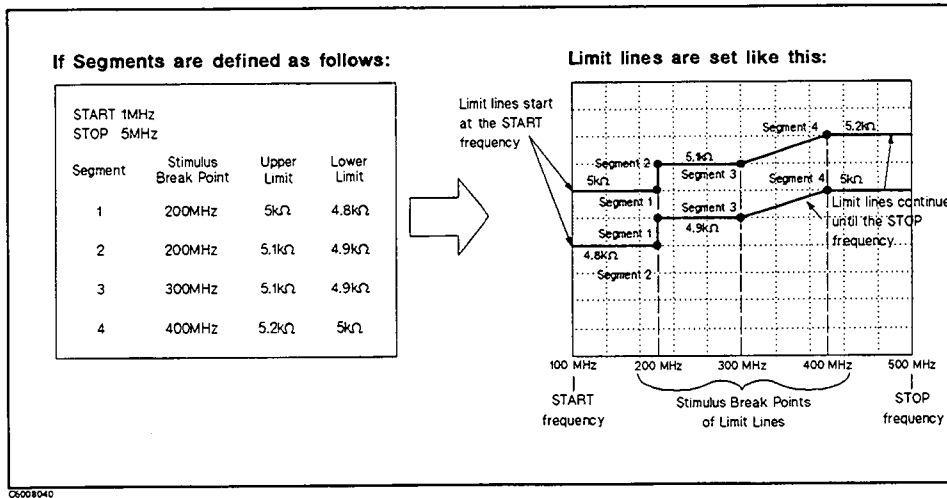


Figure 8-29. The Concept of Segments as a Point between Two Sets of Limit Lines

As you can see in Figure 8-29, segments are distinct points that define where limit lines begin or end. Limit lines span the distance between segments and represent the upper and lower test limits. Figure 8-29 shows another important aspect of limit lines. The far left hand side of a set of limit lines will continue from the minimum stimulus value

(START) and the far right hand side of a set of limit lines will continue until the maximum stimulus value (STOP).

A segment is placed at a specific stimulus value (a single frequency for example). The first segment defines the limit line value from the minimum stimulus value. Once its stimulus value is entered, the upper and lower test limit (5 k Ω and 4.8 k Ω for example) need to be supplied.

Defining a second segment defines where the first set of limit lines ends. This process is repeated to create different sets of limit lines, each having new upper and lower limits. Up to 18 segments can be entered.

Limits can be defined independently for the two channels.

The example in Figure 8-29 shows a combination of limit lines that change instantly and gradually.

Segment 1 is at 200 MHz and has an upper and lower limit of 5 and 4.8 k Ω , respectively. Notice the upper and lower limit lines start at the START frequency (100 MHz) and end at segment 1.

Segment 2 is also at 200 MHz with different upper and lower limits of 5.1 k Ω and 4.9 k Ω , changing the limit values instantly.

Segment 3 is at 300 MHz with the same limit value as segment 2 to obtain a flat limit line.

Segment 4 is at 400 MHz with upper and lower limit values of 5.2 k Ω and 5 k Ω , changing the limit values gradually. Notice the upper and lower limit lines start at the segment and continue until the STOP frequency (500 MHz).

Limit lines cannot be cut
When limit lines are needed partially along the stimulus axis, the non-limit-testing portion must also be entered. Set the non-limit-testing portion by forcing the upper and lower limit values out of range (+1 G Ω and -1 G Ω for example).
Both an upper limit and a lower limit (or delta limits) must be defined.
If only one limit is required for a particular measurement, force the other limit out of range (+1 G or -1 G for example).

Turning Limit Lines and Limit Testing On and Off

Limit lines and limit testing features are OFF unless explicitly turned ON by the user. After entering the limit line information, you can turn ON the limit line feature and optionally the limit testing features. Turning these features OFF has no effect on the entered limit line information.

Limit Line Concept

Segment Entering Order

Generally, the segments do not have to be entered in any particular order. The analyzer automatically sorts them and lists them on the display in increasing order of stimulus value.

One exception is when two segments have the same stimulus value as described in Figure 8-29. If the same stimulus values exist, the analyzer draws the limit lines according to entered segment order. For example, in Figure 8-29, segment 1 should be entered in advance of segment 2.

Saving the Limit Line Table

Limit line information is lost if the LINE switch is turned off. However, the **(Save)** and **(Recall)** keys can save limit line information along with all other current analyzer settings. Limit line table information can be saved on a disk.

Offsetting the Stimulus or Amplitude of the Limit Lines

All limit line entries can be offset in either stimulus or amplitude values. The offset affects all segments simultaneously.

Supported Display Formats

Limit lines are displayed only in Cartesian format. In polar and Smith chart formats, limit testing of one value is available. The value tested depends on the marker mode and is the magnitude or the first value in a complex pair. The message "NO LIMIT LINES DISPLAYED" is shown on the display in polar and Smith formats.

Use a Sufficient Number of Points or Errors May Occur

Limits are checked only at the actual measured data points. If you do not select a sufficient number of points, it is possible for a device to be out of specification without a limit test failure indication.

To avoid this, be sure to specify a high enough number of points. In addition, if specific stimulus points must be checked, use the list sweep features described in "**(Sweep)**" in Chapter 6 so that the actual measured data points are checked.

Displaying, Printing, or Plotting Limit Test Data

The "list values" feature in the copy menu prints or displays a table with each measured stimulus value. The table includes limit line and limit test information (if these functions are turned on). If limit testing is ON, an asterisk "*" is listed next to any measured value that is out of limits.

If the limit lines are ON, and other listed data allows sufficient space, the following information is also displayed:

- Upper limit and lower limit
- The margin by which the device passes or fails the nearest limit

For more information about the list values feature, see "Copy Menu".

Results of Plotting or Printing the Display with Limit Lines ON

If limit lines are on, they are shown when you print or plot the display. If limit testing is ON, the PASS or FAIL message is included as well.

Note



An example of a measurement using limit lines and limit testing is provided in the *User's Guide*.

A sample program performing a limit test using HP-IB commands is provided in the *HP-IB Programming Guide*.

HP-IB

What is HP-IB?

The analyzer is factory-equipped with a remote programming digital interface using 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 analyzer to be controlled by an external computer that sends commands or instructions to and receives data from the analyzer 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, the analyzer 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 the analyzer to control peripherals. It also explains how to use the analyzer as a controller to print and plot.

More complete information on programming the analyzer 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. The analyzer 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. The analyzer 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. The analyzer is an active controller when it plots or prints in the addressable mode. The analyzer 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.

Analyzer HP-IB Capabilities

As defined by the IEEE 488.1 standard, the analyzer has the following capabilities:

HP-IB Function

- SH1 Full source handshake.
- AH1 Full acceptor handshake.
 - T6 Basic talker, answers serial poll, unaddresses if MLA is issued. No talk-only mode.
- TE0 Does not have extended address of talker.
 - L4 Basic listener, unaddresses 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 The analyzer uses a single-bus architecture. The single bus allows both the analyzer 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 the analyzer to control peripherals directly in a stand-alone environment (without an external controller). This mode can only be selected manually from the analyzer front panel. Use this mode for operation when no computer is connected to the analyzer.

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 the analyzer through HP-IB (as shown in Figure 8-30), this mode allows the external controller to control the analyzer over HP-IB in the talker mode in order to send data, and in the listener mode to receive commands. It also allows the analyzer to take or pass control in order to plot and print.

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

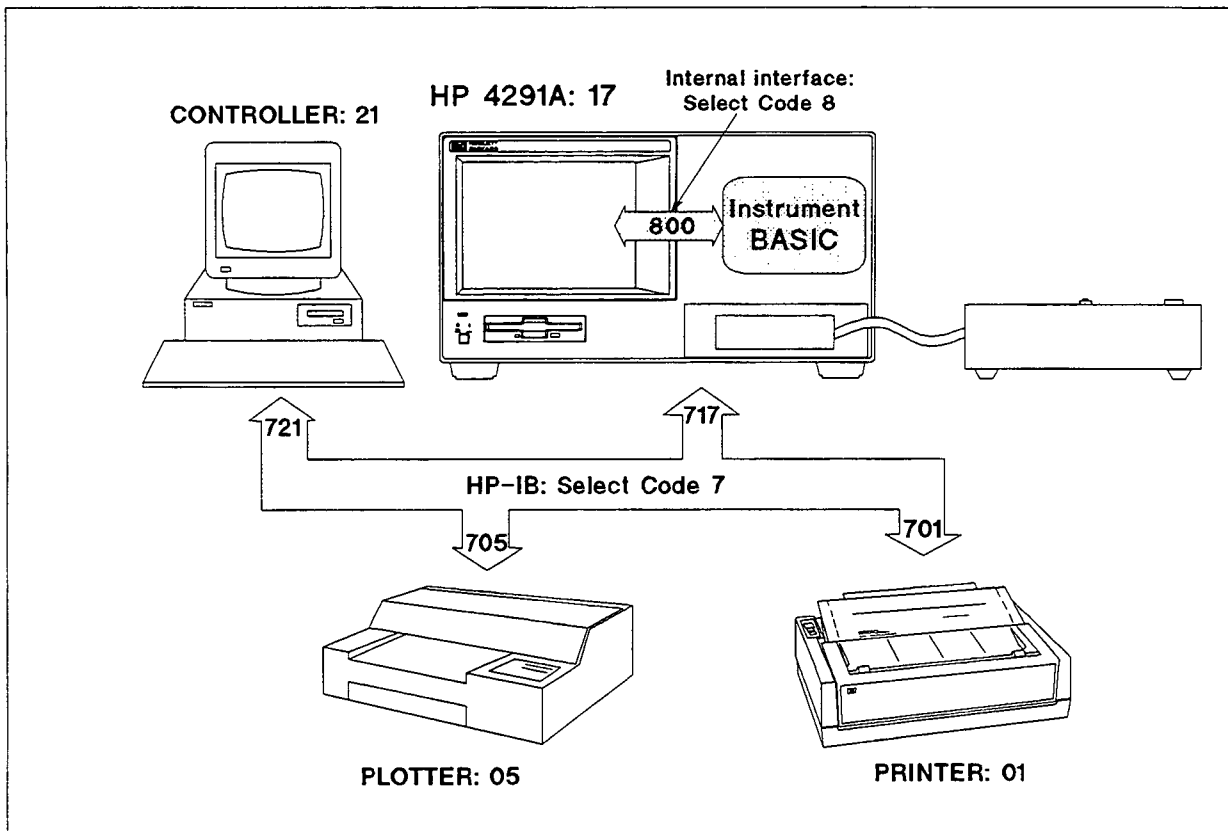


Figure 8-30. Analyzer Bus Concept

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 analyzer supports two storage devices, a built-in flexible disk drive and a RAM disk memory. The flexible disk drive is suited to storing large numbers of files and long term data storage. RAM disk is suited to storing tentative data and instrument states and to store or get data quickly.

Disk Requirements

The analyzer's disk drive uses a 720 Kbyte or 1.44 Mbyte 3.5 inch micro-flexible disk. See the "System accessories available" in Chapter 10 for disk part numbers.

Disk Formats

The analyzer'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 analyzer:

- 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 analyzer 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, the data arrays, and the memory arrays. (Binary Files Only)

■ Internal Data Arrays (DATA ONLY)

The internal data arrays that are stored in the analyzer's memory consist of the following six data arrays. See "Data Processing" in Chapter 9 for complete information on each data array and their relationships. (Binary and ASCII Files)

- Calibration Coefficients arrays** contain the expanded calibration coefficients obtained by calibration and fixture compensation.
- Raw data arrays** contain the calibrated data obtained using the calibration coefficients.
- Data arrays** contain the compensated data obtained using the compensation coefficients.
- Memory arrays** contain the memory data arrays obtained using the DATA→MEM operation.
- Data-Trace arrays** contain the formatted data.
- Memory Trace arrays** contain the formatted data of the "memory arrays."

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 *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)	\$ & # % ' ! () - _ @ ^ { } ~ (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 analyzer is turned on, it looks for a file named "AUTOREC" (from the built-in flexible disk). If the file is found, the analyzer automatically uses the file to retrieve its data.

When both state and data files have been saved, the analyzer recalls only the state file.

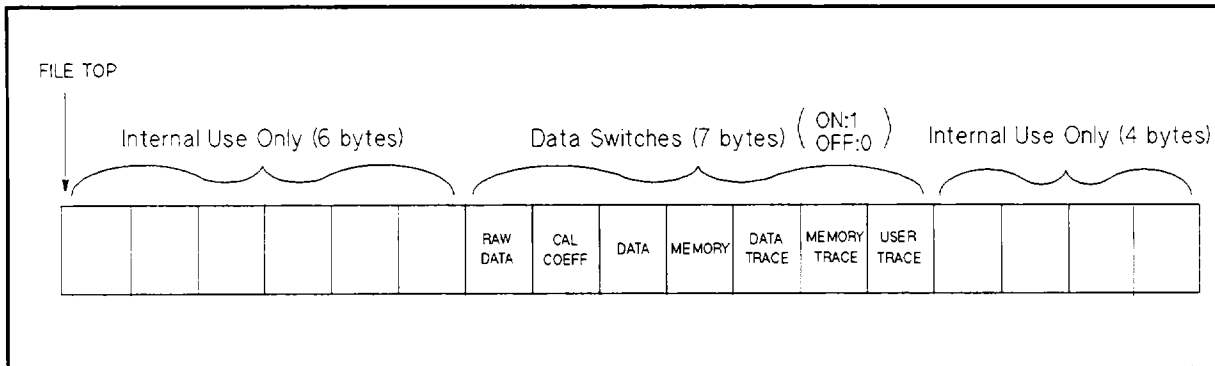
You must save AUTOREC file to the flexible disk. Do not save it to the RAM disk memory because the RAM disk memory loses its data when power is turned off.

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.



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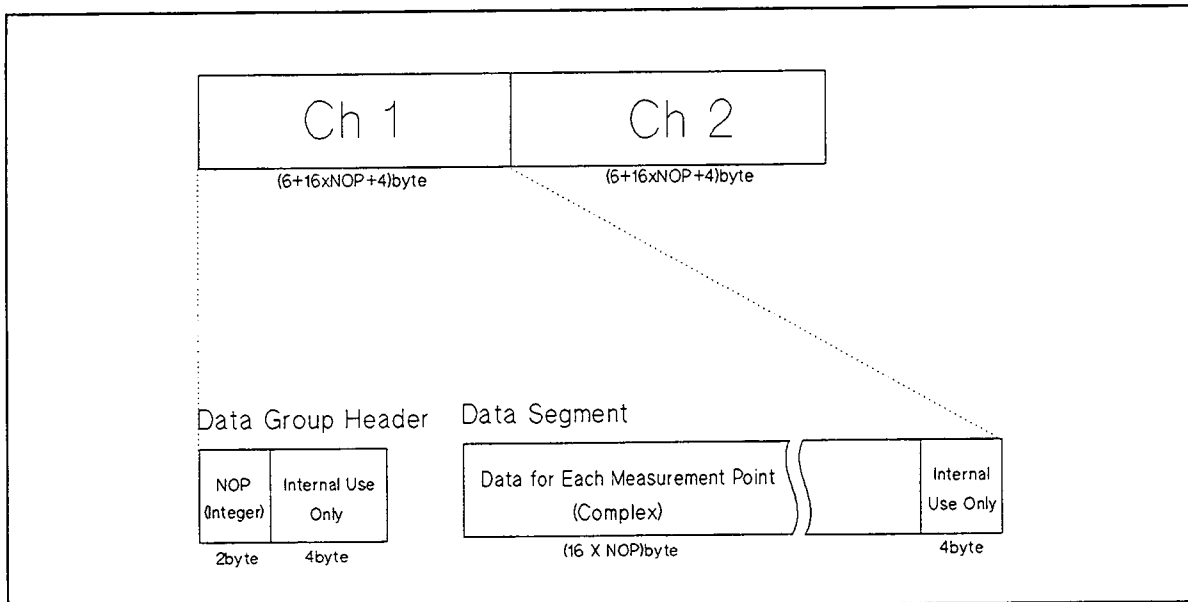
Figure 8-31. File Header Structure

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 of each channel 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:

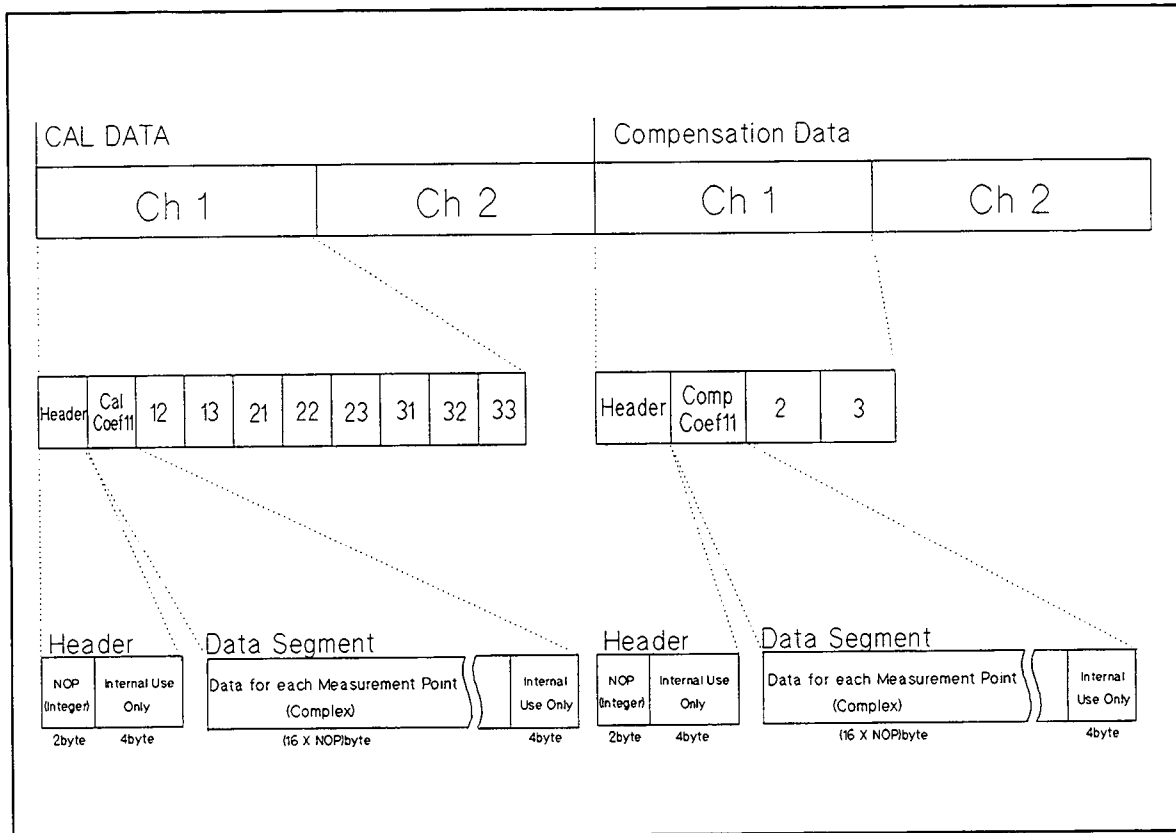
- **RAW DATA** consists of a header and four data segments per channel as shown in the following figure. They will follow the file header in this order:
- **DATA** consists of a header and a data segment by a channel.
- **DATA-TRACE** consists of a header and a data segment by a channel.



C6008004

Figure 8-32. RAW, DATA, and DATA-TRACE Data Group Structure

- **CAL** consists of data segments by a channel as shown in Figure 8-33. The first half of the segments are for channel 1 and the second half of the segments are for channel 2. The contents of each segment depend on the type of calibration performed. (See “**Cal**” in Chapter 5.)



C6008005

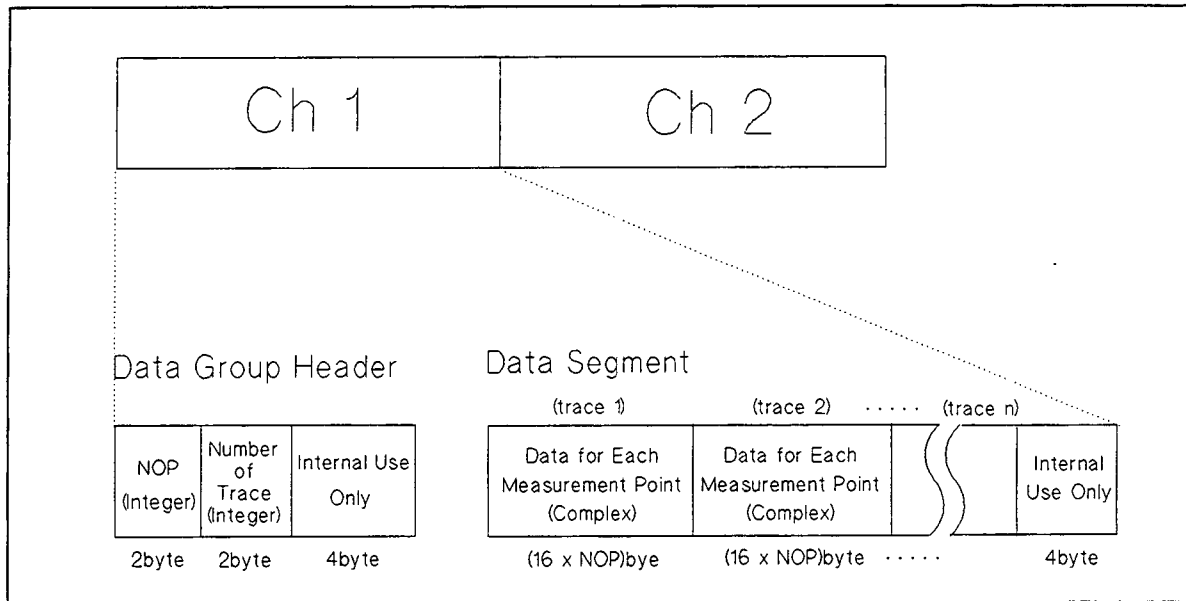
Figure 8-33. CAL Data Group Structure

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 $16 \times \text{NOP}$.

Saving and Recalling

- **MEMORY** consists of a header and a data segment by a channel.
- **MEMORY TRACE** consists of a header and a data segment by a channel.



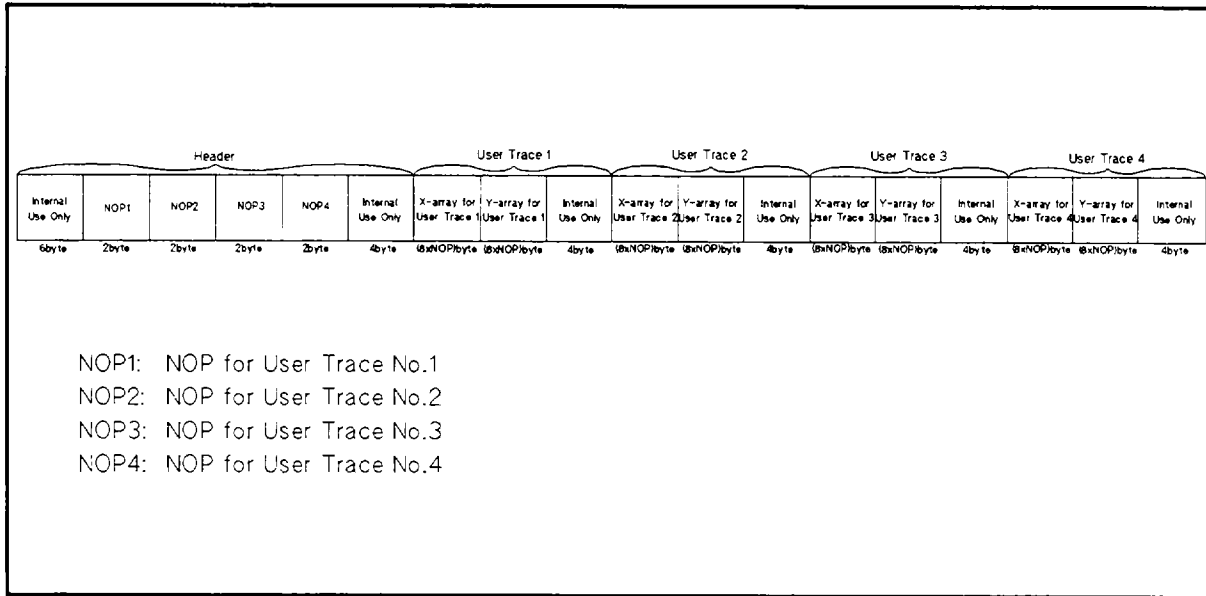
C6008009

Figure 8-34. MEMORY and MEMORY TRACE Data Group Structure

Number Of Points (NOP) of a memory trace is a two-byte INTEGER value.

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).

- **User Trace** consists of a header and 8 data segments that include user trace X-array and Y-array.



06008007

Figure 8-35. User Trace Data Group Structure

- *Number Of Points (NOP)* is a two-byte integer value.
- The values of an X-array and Y-arrays are IEEE 754 double precision floating numbers (8 byte length). The data size in bytes for the X-array of each user trace can be determined by $8 \times \text{NOP}_n$ (n is the User Trace number).

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:

- Channel number
- Title on the screen
- Measurement parameter
- Number of points
- Sweep delay time
- Point delay time
- Sweep time
- Sweep type
- Point average
- Source power or CW frequency
- dc bias

■ 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 8-2 shows an example of an ASCII data file.

Table 8-2. Contents of ASCII Files

Block Names		Contents
Status Block		"4291A REV3.00" "DATE: Apr 24 1994" ¹
Data Block	State	"CHANNEL: 1" "TITLE: This is a title." ² "MEASURE PARAMETER: IMPEDANCE MAG" "NUMBER of POINTS: 201" "SWEEP DELAY TIME: 62.5 us" "POINT DELAY TIME: 325 us" "SWEEP TYPE: LIST FREQ" "POINT AVERAGE: OFF" "OSC LEVEL: 500 mV" "DC BIAS: OFF" ³
	Title	"Frequency"→"Raw Real"→"Raw Imag"→... ^{4,5}
	Data ⁶	3.00000E+5→8.20007E-1→4.09729E-1→... ⁴ 1.52238E+7→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 Shows the power level of the source for a frequency sweep. If power sweep is selected, the CW frequency is listed (for example "CW FREQ: 100 MHz").
- 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. Titles used in the ASCII files are shown in Table 8-3.
- 6 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.

Saving and Recalling

File Structure for Single Channel and Dual Channel

If you save an ASCII file when DUAL CHANNEL is turned OFF, the ASCII data file consists of the active channel's data. If DUAL CHANNEL is turned ON, the ASCII data file consists of the data of both channels 1 and 2. The channel 2 data follows the channel 1 data as follows:

File Structures for Single and Dual Channels

Dual Channel OFF	Dual Channel ON
Status Block	Status Block
Data Block of Active Channel	Data Block of Channel 1
(end of file)	Status Block
	Data Block of Channel 2

Table 8-3. Data Groups and Data Array Names

Data Groups	Data Array Names		Descriptions
	Real Part	Imaginary Part	
Raw Data	Raw Real	Raw Imag	Raw data arrays.
Calibration Data	Cal[1-1] Real	Cal[1-1] Imag	Cal coefficient 11
	Cal[1-2] Real	Cal[1-2] Imag	Cal coefficient 12
	Cal[1-3] Real	Cal[1-3] Imag	Cal coefficient 13
	Cal[2-1] Real	Cal[2-1] Imag	Cal coefficient 21
	Cal[2-2] Real	Cal[2-2] Imag	Cal coefficient 22
	Cal[2-3] Real	Cal[2-3] Imag	Cal coefficient 23
	Cal[3-1] Real	Cal[3-1] Imag	Cal coefficient 31
	Cal[3-2] Real	Cal[3-2] Imag	Cal coefficient 32
	Cal[3-3] Real	Cal[3-3] Imag	Cal coefficient 33
Data	Data Real	Data Imag	Corrected Data arrays
Memory	Memory Real	Memory Imag	Corrected Memory arrays
Data-Trace	Meas Prmtr Data		Data-Trace arrays
Memory-Trace	Meas Prmtr Memory		Memory-Trace arrays

Analyzer Features

Introduction

This chapter provides additional information on analyzer features. The following subjects are covered in this chapter.

- System Overview
- Data Processing Flow

System Overview

Impedance analyzers 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 9-1 is a simplified block diagram of the analyzer. A detailed block diagram of the analyzer is provided in the *Service Manual*, together with a complete theory of system operation.

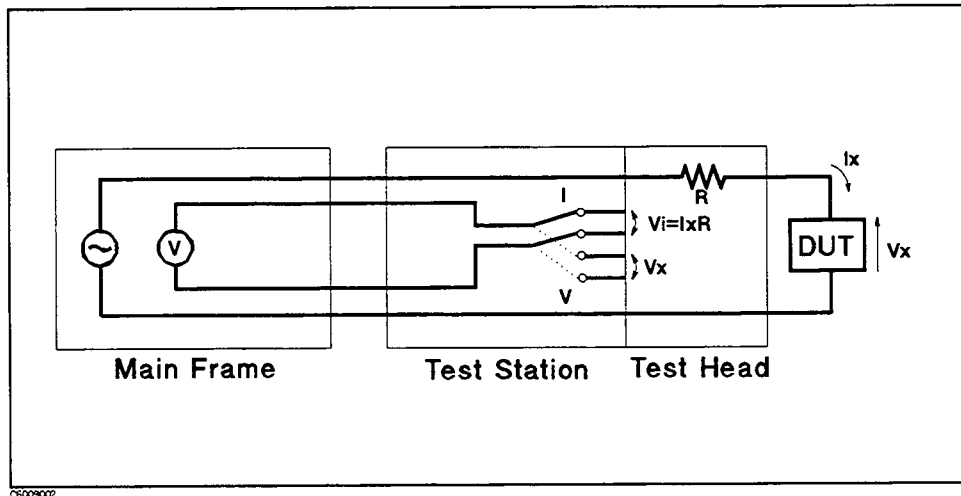


Figure 9-1. Analyzer Simplified Block Diagram

Data Processing

Overview

The analyzer'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 analyzer 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.

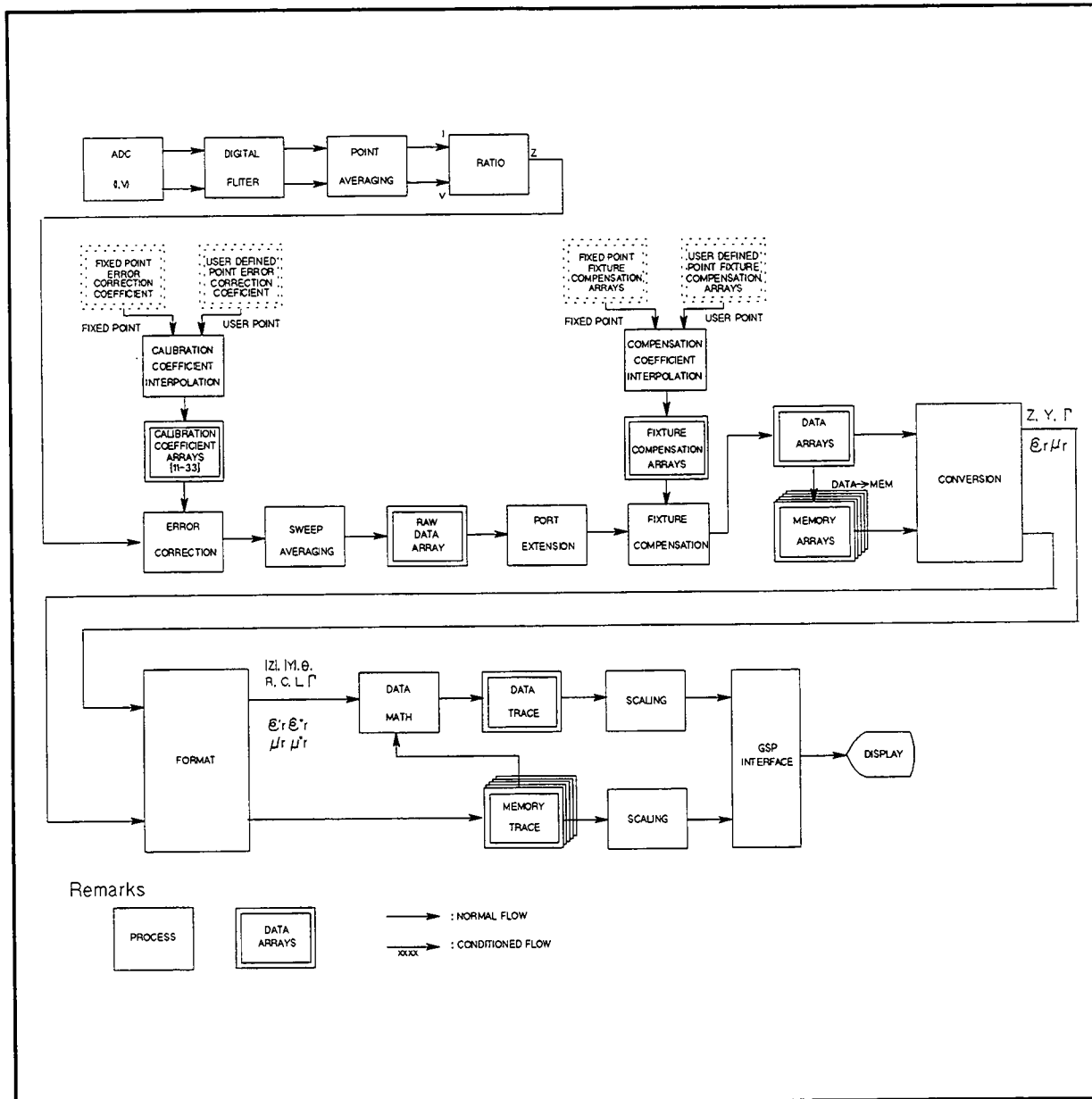
Figure 9-2 is a data processing flow diagram that shows the flow of numerical data from the ADC to the display. The data passes through several math operations (shown as single-line boxes). Most of these operations can be selected and controlled by the front panel MEASUREMENT block menus. The data is 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 9-2 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.

Note



While only a single flow path is shown, two identical paths are available that correspond to channel 1 and channel 2. When the channels are uncoupled, each channel can be independently controlled so that the data processing operations for one can be different from the other.

Data Processing Flow



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Figure 9-2. 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.

9 Analyzer Features

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 analyzer 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 5 and “Calibration Concepts” in Chapter 11 for details.

Averaging

This is one of the noise reduction techniques. Two types of averaging techniques are provided, sweep averaging and point averaging (the point averaging processes before the ratio processing). The sweep averaging calculation involves taking the complex exponential average of up to 999 consecutive sweeps. The point averaging calculation involves taking the complex average of up to 999 measurements on each measurement point. See “**Bw/Avg**” in Chapter 5.

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 5 and “Calibration Concepts” in Chapter 11 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 11 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.

Memory Arrays

If the data-to-memory operation is performed, the data arrays are copied into the memory arrays (data trace arrays are also copied into the memory trace array at same time). See “**Display**” in Chapter 5 in this chapter. These arrays are accessible using the internal disk drive or the RAM disk memory. These arrays are also output via HP-IB, but data cannot be input into this array via HP-IB.

Data Processing

If memory is displayed, the data from the memory arrays goes through the same data processing flow path as the data from the data arrays.

Format

This converts the complex number pairs into a scalar representation for display, according to the selected format. These formats are often easier to interpret than the complex number representation. (Polar, Smith, admittance chart, and complex plane formats are not affected by the scalar formatting.)

Data Math

This calculates the complex ratio of the two (data/memory), the difference (data–memory), summation (data+memory), or multiplication (data×memory) when the data math function is selected. In addition, this function multiplies the ratio, or difference by a constant.

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.

Memory Trace Arrays

If the data-to-memory operation is performed, the data trace arrays are copied into the memory trace arrays (data arrays are also copied into the memory array at same time). These arrays are accessible using the internal disk drive or the RAM disk memory. These arrays are also output via HP-IB, but data cannot be input into these arrays via HP-IB.

Scaling

These operations prepare the formatted data for display on the CRT. This is where the appropriate reference line position, reference line value, and scale calculations are performed. See “Scale Ref” in Chapter 5 in this chapter.

Options and Accessories

Introduction This chapter lists available options and accessories for the HP 4291A.

Options Available

Option 001 Add dc bias

This option adds the dc bias capability to the stimulus of HP 4291A. This option can be retrofitted using HP 4291U Option 001

Option 002 Add material measurement firmware

This option adds the material measurement capability to the HP 4291A. This option can be retrofitted using HP 4291U Option 002.

Option 011 Delete high impedance test head

This option deletes the high impedance test head.

Option 012 Add low impedance test head

This option adds the low impedance test head. This option can be retrofitted using HP 4291U Option 012.

Option 013 Add high temperature high impedance test head

This option adds the high high temperature high impedance test head. This option includes a fixture stand. This option can be retrofitted using HP 4291U Option 013.

Option 014 Add high temperature low impedance test head

This option adds the high temperature low impedance test head. This option includes a fixture stand. This option can be retrofitted using HP 4291U Option 014.

Options Available

Option 0BW Add Service Manual

This option adds the *HP 4291A Service Manual*, which describes the performance test procedures and troubleshooting. If you need the service manual, order HP part number 04391-90101.

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 4291U Option 1C2.

Option 1D5 Add high stability frequency reference

This option, a 10 MHz crystal in a temperature stabilized oven, improves the source signal frequency accuracy and stability. This option can be retrofitted using the HP 4291U Option 1D5.

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.

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 to 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 to 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 to 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 16453A Dielectric material test fixture

The HP 16453A is used to measure the permittivity of a dielectric material. This fixture has been designed to operate specifically with the HP 4291A equipped with the Option 002 (which provides the permittivity measurement function for dielectric material). The usable operating frequency is up to 1 GHz.

HP 16454A magnetic material test fixture

The HP 16454A is used to measure the permeability of a toroidal core. This fixture has been designed to operate specifically with the HP 4291A equipped with the Option 002 (which provides the permeability measurement function for magnetic material). Two types of fixtures are included in the HP 16454A to provide flexibility for various material sizes.

HP 16091A Coaxial termination fixture set

The HP 16091A is suited to the measurement of lead-less material samples or small size, axial lead components whose leads can be shortened. Two types of fixtures are included in the fixture set to provide flexibility for various sample sizes. The usable operating frequency is up to 1 GHz.

Accessories Available

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 byte 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.

Impedance Measurement Basics

This chapter introduces the following basic concepts of impedance measurements:

- Impedance Parameters
- Series and Parallel Circuit Models
- Smith Chart
- Calibration Concepts
- Port Extension
- Fixture Compensation
- Permittivity Measurements
- Permeability Measurements

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 11-1 (a) shows the complex impedance definitions and Figure 11-1 (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.

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

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

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

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

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]

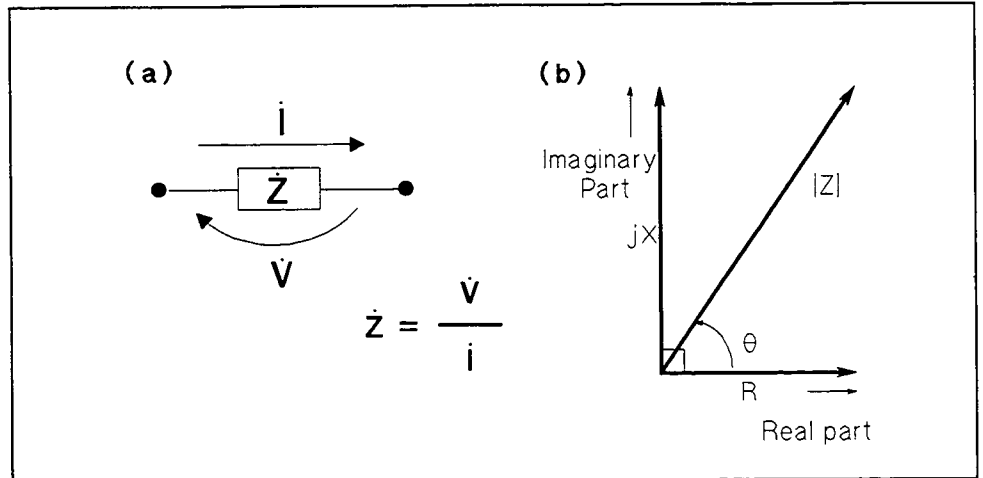


Figure 11-1. Definition of Impedance

The following parameters can be used to represent the reactance.

$$X = 2\pi fL \quad (11 - 5)$$

Impedance Parameter

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.

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

Where,

Q : Quality Factor

D : Dissipation Factor

Admittance (\dot{Y})

In some case, the dual of impedance (Admittance), \dot{Y} is used. Figure 11-2 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.

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

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

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

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

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

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

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

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]

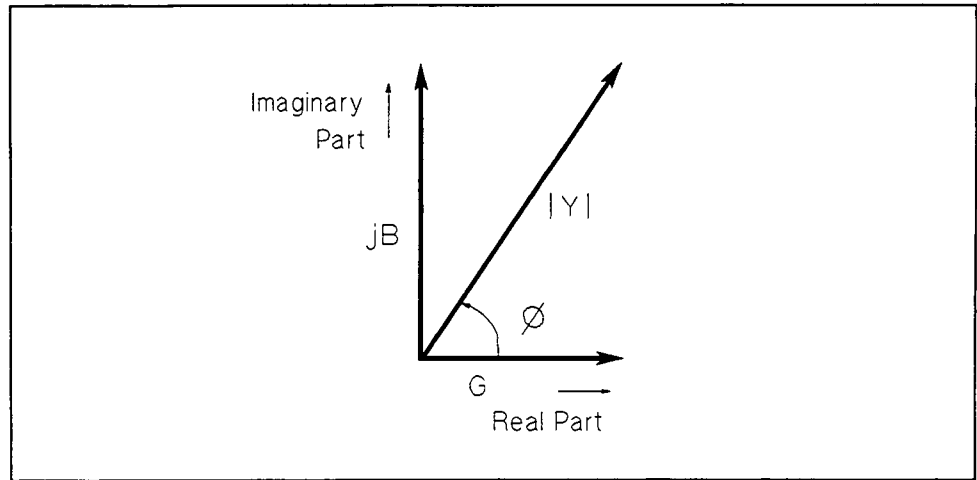


Figure 11-2. Vector Representation of Admittance

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 4291A provides the reflection coefficient $\dot{\Gamma}$ as measurement parameter.

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

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

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:

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

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

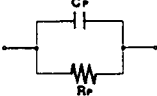
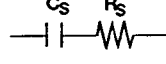
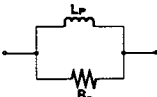
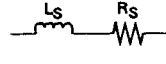
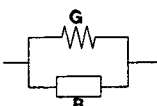
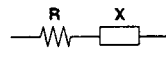
where, Z_0 is characteristic impedance.

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 4291A 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 11-1.
Parallel/Series Circuit Model and Measurement Parameter

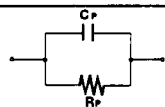
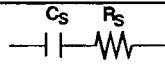
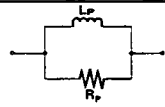
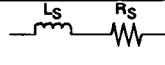
Parallel Circuit Model	Series Circuit Model
	
	
	

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 11-2. The dissipation factor of a component always has the same value at a given frequency for both parallel and series equivalent circuits.

Table 11-2.
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 11-3).

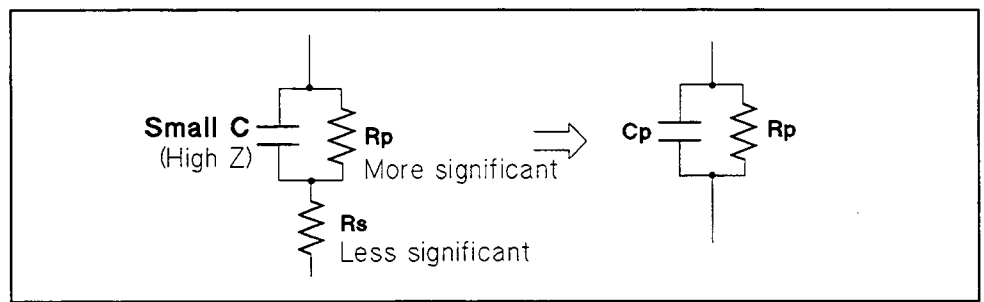


Figure 11-3. Small Capacitance Circuit Mode Selection

Impedance Measurement Basics

Series and Parallel Circuit Models

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 11-4).

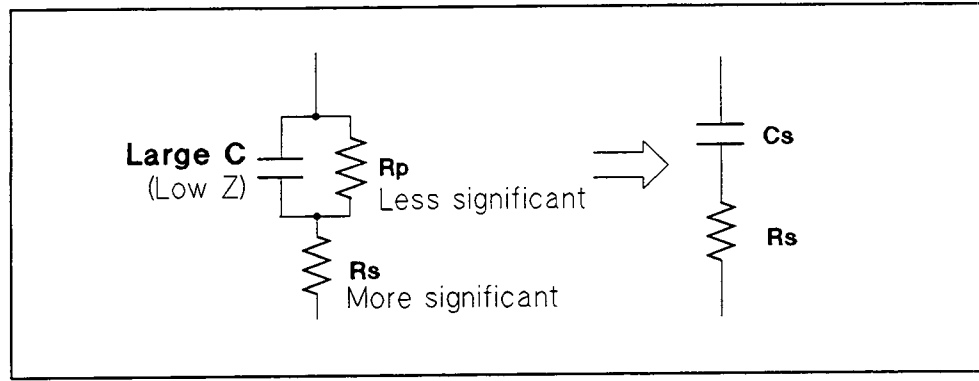


Figure 11-4. Large Capacitance Circuit Mode Selection

The following is a rule of thumb for selecting the circuit model according to the impedance of the capacitor:

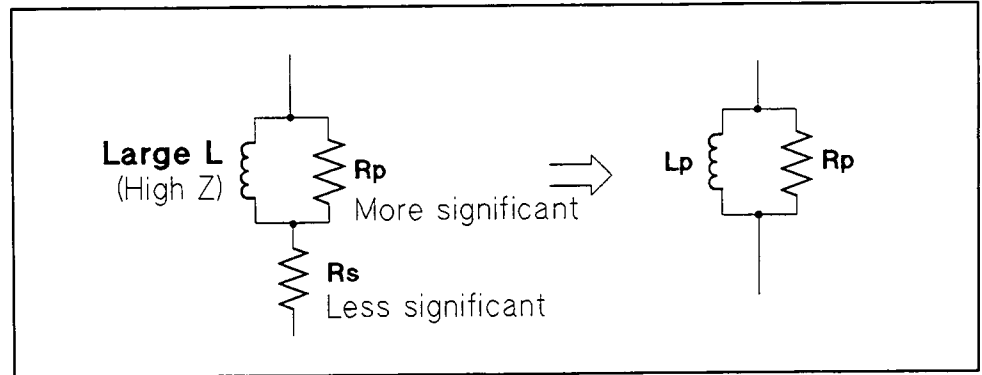
- Above approx. 10 k Ω : Use parallel circuit model.
- Below approx. 10 Ω : Use series circuit model.
- Between above values: Follow the manufacturer's recommendation.

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 11-5).

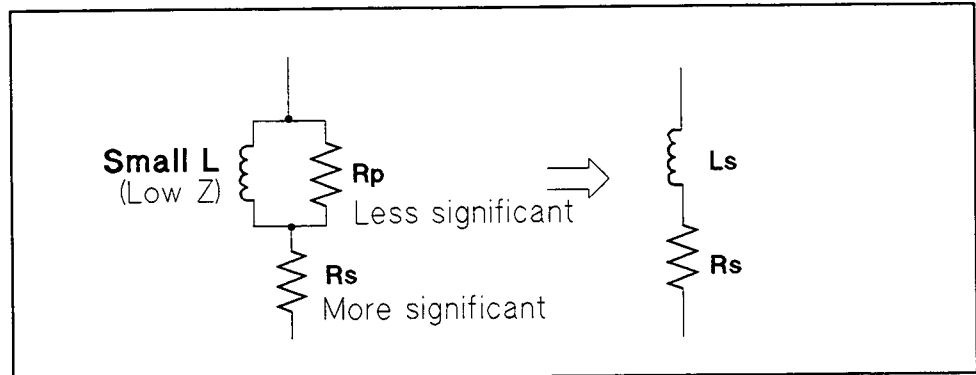


0601005

Figure 11-5. 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 11-6).



0601006

Figure 11-6. Small Inductance Circuit Mode Selection

The following is a rule of thumb for selecting the circuit model according to the impedance of the inductor:

- Below approx. 10 Ω : Use series circuit model.
- Above approx. 10 k Ω : Use parallel circuit model.
- Between above values: Follow the manufacturer's recommendation.

Smith Chart

This section provides a brief description of the Smith Chart for users who are not familiar with its use.

Figure 11-7 shows the Smith Chart plane of impedance coordinates. On the Smith Chart plane, the coordinate scales signify the impedance component quantities.

The circles tangent at point \textcircled{a} are the scales for which the resistance values (R) are constant. The arcs that cross at point \textcircled{a} and intersect the circles at right angles are the scales for which reactance values (X) are constant.

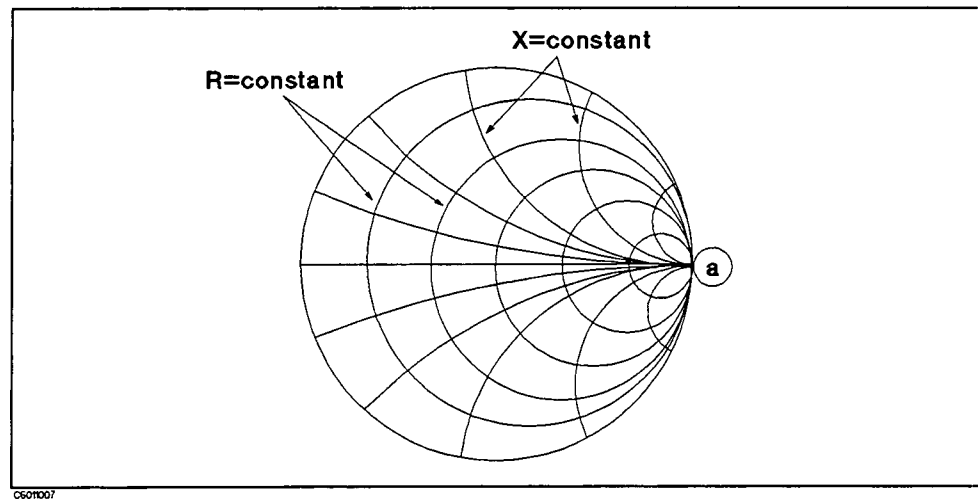


Figure 11-7. Smith Chart

These resistance and reactance scale values are the normalized values. They are calculated by dividing the sample impedance ($Z_x = R_x + jX_x$) by the characteristic impedance ($Z_0 = 50\Omega$) of the measuring circuit. Therefore, the normalized impedance $R_r + jX_r$ is :

$$R_r + jX_r = \frac{Z_x}{Z_0} = \frac{R_x}{50} + \frac{jX_x}{50} \quad (11 - 17)$$

A sample impedance value is represented on the Smith Chart as a point coordinated with the scales corresponding to its normalized impedance (see Figure 11-8). The base impedance Z_0 (characteristic impedance) is located at the center of the Smith Chart plane. The radius vector $Z_0 \cdot Z_r$ represents the reflection coefficient value $|\Gamma| \angle \theta$ of the sample (in this case, the electrical length of the transmission line is not being taken into consideration). The phase angle scales for the reflection coefficient vector are provided along the outer circumference of the Smith Chart. The phase angle of the reflection coefficient can be read from the phase angle scale as indicated by an extension of the vector $Z_0 \cdot Z_r$. The absolute value of the reflection coefficient $|\Gamma|$ is constant at any point on the circle of the radius $Z_0 \cdot Z_r$.

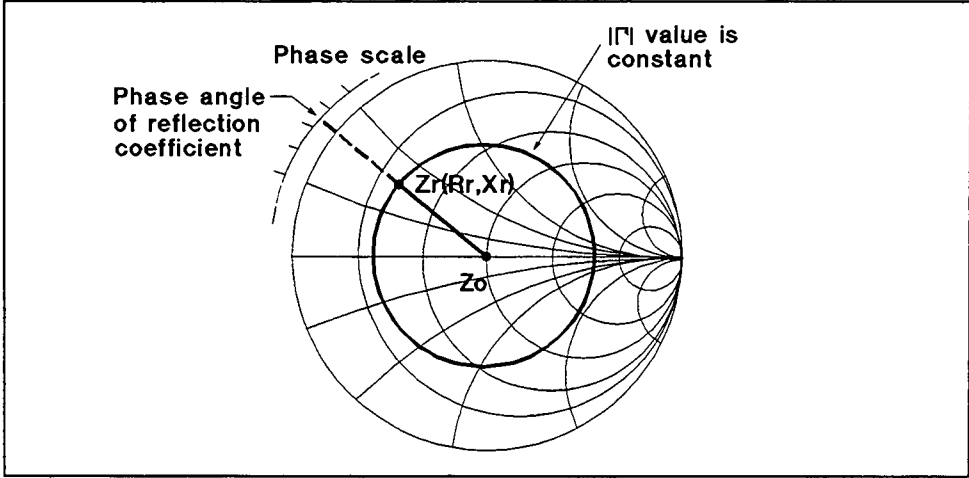


Figure 11-8. Impedance Read-out

When a coaxial cable of line length l is terminated by the sample and the cable is lossless, the impedance value of the sample measured at the other end of the line is derived as follows:

First, the difference in phase angle of the reflection coefficient value Γ (produced by the lead length l) is calculated using the following equation:

$$\theta = \frac{4\pi l}{\lambda} \tag{11 - 18}$$

Where, λ is the wavelength of test signal.

Next, the radius vector Z_0-Z_x is rotated clockwise (towards the generator) by the calculated phase angle θ . The measured impedance value (normalized impedance) coincides with the scale reading at point Z_m (see Figure 11-9).

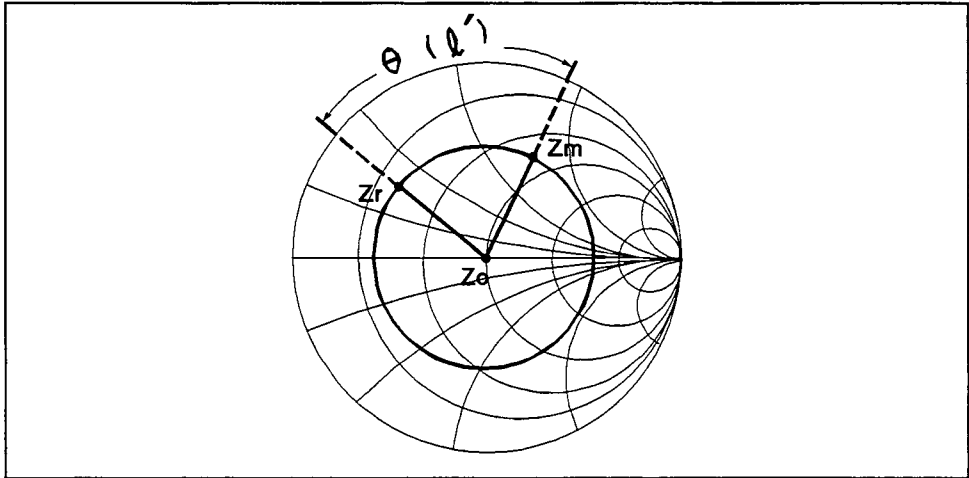


Figure 11-9. Phase Shift by Transmission Line

11 Impedance Measurement
BASIC

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 11-10 (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:

$$\dot{Z}_x = R \frac{\dot{V}_v}{\dot{V}_i} \quad (11 - 19)$$

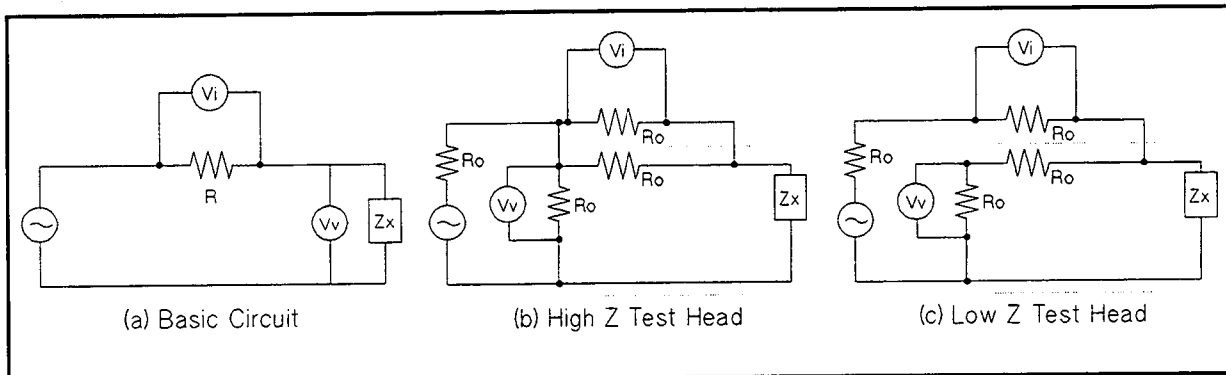


Figure 11-10. Measurement Circuits for I-V Method

Figure 11-10 (b) and (c) show the simplified measurement circuits of the high impedance test head and the low impedance test head of the analyzer. The DUT's impedance value (\dot{Z}_x) is calculated using the following equations (if the measurement circuit is ideal):

For the high impedance test head (Figure 11-10-(b)), \dot{Z}_x is :

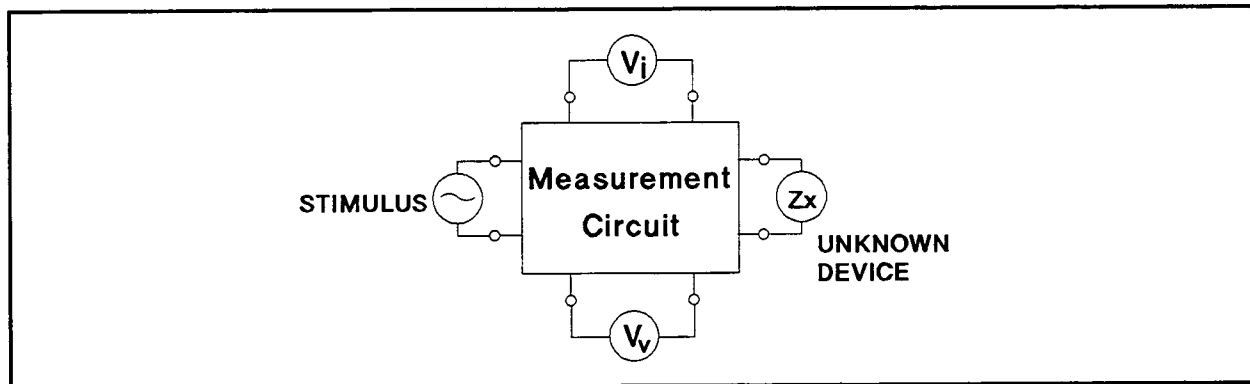
$$\dot{Z}_x = \frac{R_0}{2} \left(\frac{\dot{V}_v}{\dot{V}_i} - 1 \right) \quad (11 - 20)$$

For the low impedance test head (Figure 11-10-(c)), \dot{Z}_x is :

$$\dot{Z}_x = \frac{2R_0}{\frac{\dot{V}_i}{\dot{V}_v} - 1} \quad (11 - 21)$$

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 11-11.



CG01013

Figure 11-11. 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:

$$\dot{Z}_x = \dot{a} \frac{1 + \dot{b}\dot{r}}{1 + \dot{c}\dot{r}} \quad (11 - 22)$$

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:

$$\dot{r} = \frac{\dot{V}_v}{\dot{V}_i} \quad (11 - 23)$$

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:

$$\dot{Z}_x = \dot{A} \frac{\dot{Z}_m - \dot{B}}{1 - \dot{C}\dot{Z}_m} \quad (11 - 24)$$

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 analyzer uses the

Calibration Concepts

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

Low Loss Capacitor Calibration

Accurate Q measurements require good analyzer stability and correct markings on the phase scale of the analyzer. In particular, high Q (or low D : dissipation factor) measurements at high frequencies require high accuracy for phase measurements.

The phase accuracy of the analyzer is determined entirely by the OPEN SHORT LOAD calibration. But, it is not guaranteed that the phase uncertainty for a 50Ω 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 50Ω LOAD is less than 10^{-3} at high frequencies.

To reduce the uncertainty of the measured phase, the analyzer 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 analyzer 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 50Ω LOAD is $\hat{Z}_{ls} = 50 e^{j0}$ (that is, the phase of 50Ω LOAD is zero) as shown in Figure 11-12-(a) , calculate the calibration coefficient \hat{A} , \hat{B} , and \hat{C} .
3. Execute the correction for the Low-Loss air-capacitor and get the corrected impedance value of the Low-Loss air-capacitor. (\hat{Z}_{cc})
4. Calculate the phase difference ($\Delta\theta$) between the phase of \hat{Z}_{cc} and the true phase of the Low-Loss air-capacitor (see Figure 11-12-(b)).

$$\Delta\theta = \theta_{cc} - \theta_{cs} \quad (11-25)$$

Where,

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

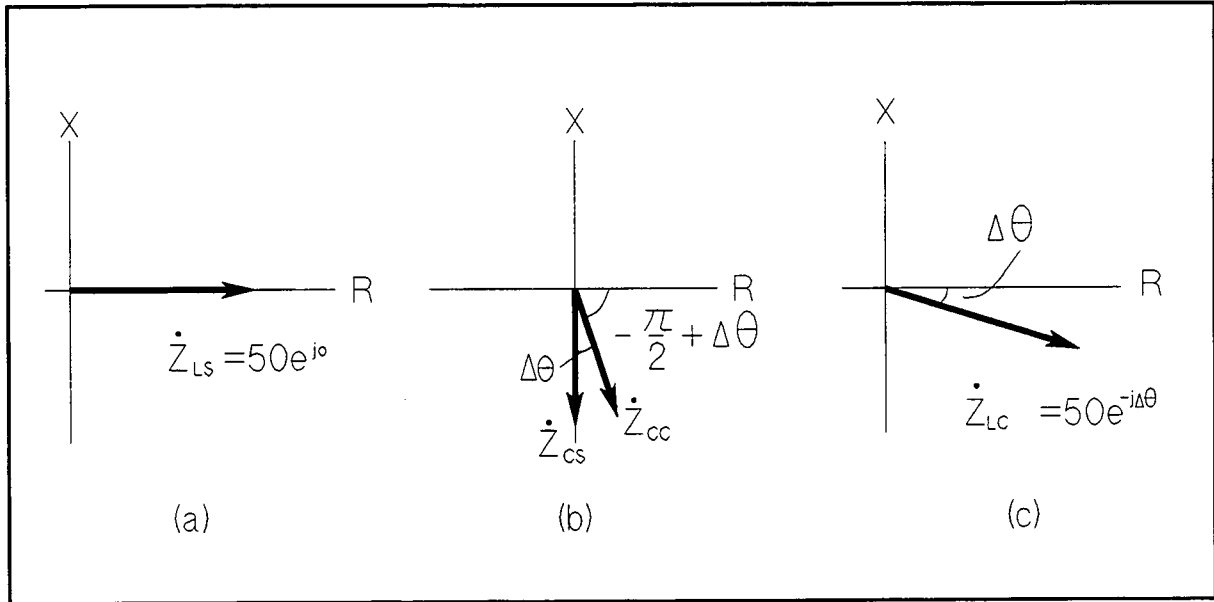
θ_{cs} is standard phase value of the Low-Loss air-capacitor.

5. Modify the impedance of the 50Ω LOAD to \hat{Z}_{lc} whose phase is $-\Delta\theta$ and whose impedance magnitude is still 50Ω (see Figure 11-12-(c)). The modified impedance value of 50Ω LOAD \hat{Z}_{lc} is expressed in the following equation:

$$\hat{Z}_{lc} = 50 e^{-j\Delta\theta} \quad (11-26)$$

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

The analyzer 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 analyzer accurate enough to perform high Q measurements.



CS01012

Figure 11-12. Modifying the Standard Value of a 50 Ω LOAD using a Low-Loss Air-Capacitor

Low-Loss Air-Capacitor calibration does not affect the measurement below 300 MHz

In fact, taking frequency into consideration, the analyzer uses the following equations for \hat{Z}_{lc} :

$$\hat{Z}_{lc} = 50 e^{-jk\Delta\theta}$$

Where,

k is a constant that depends on the measurement frequency. Because the phase of 50 Ω LOAD at a low frequency is regarded as zero, the analyzer uses the following value as k :

- $k = 0$ (at frequency ≤ 300 MHz)
- $k = \frac{f[\text{MHz}] - 300}{500 - 300}$ (at 300 MHz < frequency ≤ 500 MHz)
- $k = 1$ (at frequency > 500 MHz)

11 Impedance Measurement Basic

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:

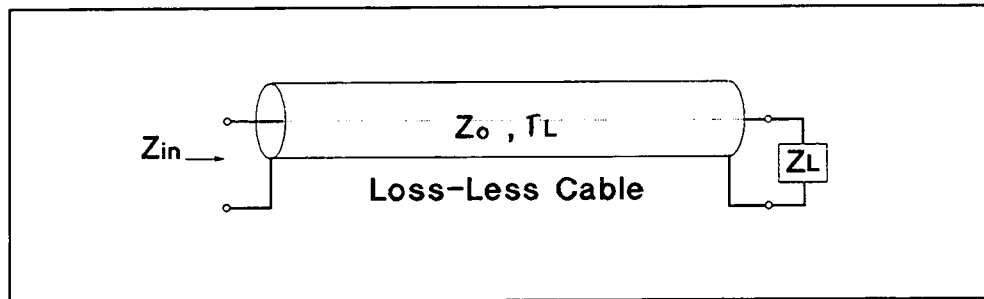


Figure 11-13. Port Extension

When impedance Z_L is connected to one tip of extension cable as shown in Figure 11-13, the input impedance from the other tip of cable is expressed using the following equation:

$$Z_{in} = Z_0 \frac{Z_L + Z_0 \tanh(\gamma l)}{Z_0 + Z_L \tanh(\gamma l)} \quad (11 - 27)$$

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):

$$l = \sqrt{\epsilon_r} l_0 \quad (11 - 28)$$

γ is propagation coefficient and expressed as:

$$\gamma = \alpha + j\beta \quad (11 - 29)$$

where,

α is attenuation constant

β is phase constant

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

$$\alpha = 0 \quad (11 - 30)$$

$$\beta = \frac{\omega}{c_0} \quad (11 - 31)$$

where,

c_0 is the velocity of light

Therefore,

$$\begin{aligned}\tanh(\gamma l) &= \tanh(j\frac{\omega}{c_0}l) \\ &= j \tan(\frac{\omega}{c_0}l)\end{aligned}\quad (11 - 32)$$

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

$$Z_0 = 50 + j0 \quad (11 - 33)$$

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:

$$Z_L = 50 \frac{Z_{in} - j50 \tan(\omega \Delta t)}{50 - jZ_{in} \tan(\omega \Delta t)} \quad (11 - 34)$$

Where,

Δt is port extension in time [sec]

$$\Delta t = \frac{l}{c_0}$$

When the linear portion of the DUT's phase is removed using the port extension function, the electrical length of the DUT can be read in the active entry area of the display.

Setting Proper Electrical Length Compensation

You can easily check to determine whether the electrical length can fit the extended measurement circuit. Proceed as follows:

1. Perform calibration without using an extension cable.
2. Connect the extension cable (or the unknown fixture) to the test port.
3. Set the measurement parameter to $|\Gamma|$.
4. Set the measurement format to Smith chart format.
5. Set the Smith/polar marker to Logmag-Phase.
6. Connect a 0 S termination at the tip of the extension cable (or an open at the tip of the extension cable).
7. Turn the port extension on.
8. Change the port extension value until the θ values measured are 180° (or -180°) at any frequency point.

Port Extension

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 11-14 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.

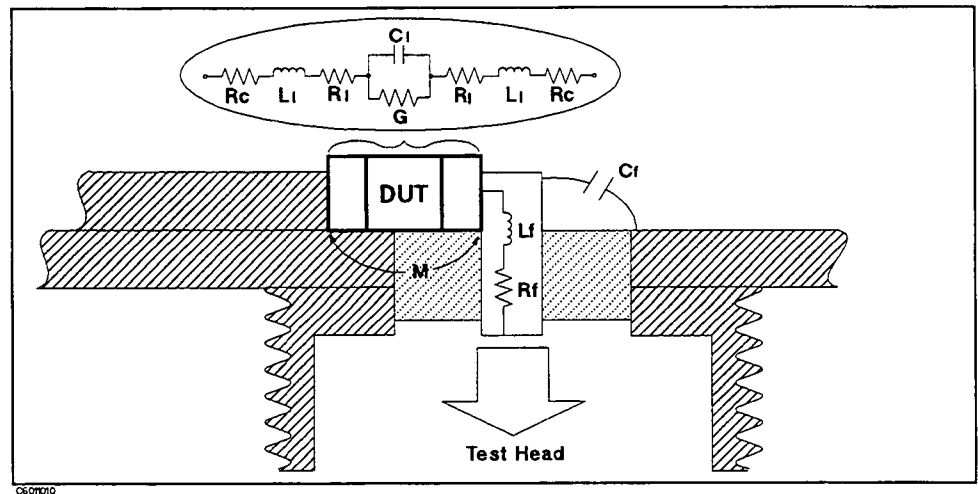


Figure 11-14. Residual Parameters in the Circuit

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 |

Fixture Compensation

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

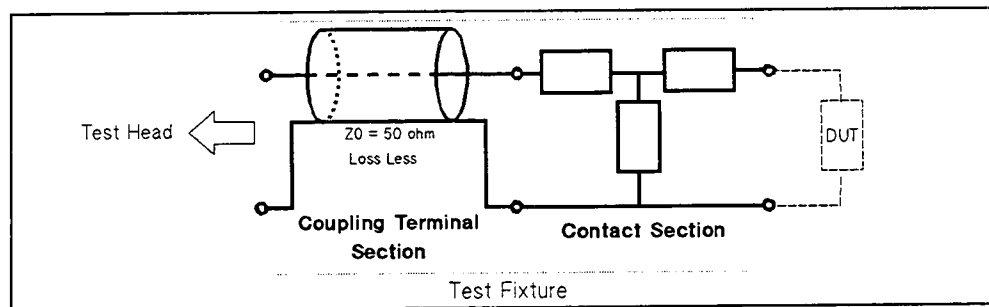


Figure 11-15. Characteristics of Test Fixture

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 4291A has a typical electrical length for the specified test fixtures. When a test fixture is selected, the HP 4291A 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.

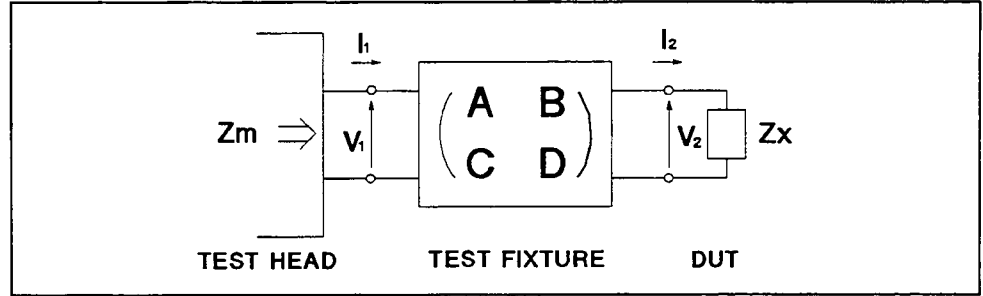
Residual and Stray Parameters of Contact Electrode Section

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 4291A) 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 11-14.

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 11-16. Using this model, the residual and stray factors can be eliminated.



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Figure 11-16.

Test Fixture Represented by the F matrix of a Two Terminal Pair Network

$$\begin{pmatrix} V_1 \\ I_1 \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} V_2 \\ I_2 \end{pmatrix} \quad (11 - 35)$$

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:

$$Z_m = \frac{V_1}{I_1} \quad (11 - 36)$$

$$Z_x = \frac{V_2}{I_2} \quad (11 - 37)$$

Then, Z_x is:

$$Z_x = A_{compen} \frac{Z_m - B_{compen}}{1 - Z_m C_{compen}} \quad (11 - 38)$$

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 4291A executes measurements for OPEN, SHORT, and LOAD compensation.

Impedance Measurement Basics

Fixture Compensation

Compensation Coefficient for Each Compensation

For fixture compensation, three compensations (OPEN, SHORT, and LOAD) are provided for the analyzer. 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:

Assuming that :

$$A = D \text{ (symmetric circuit)} \quad (11-39)$$

$$B = 0 \quad (11-40)$$

Then, the compensation coefficients are:

$$A_{\text{compen}} = 1 + j0 \quad (11-41)$$

$$B_{\text{compen}} = 0 + j0 \quad (11-42)$$

$$C_{\text{compen}} = Y_{\text{om}} - Y_{\text{os}} \quad (11-43)$$

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 :

$$A = D \text{ (symmetric circuit)} \quad (11-44)$$

$$C = 0 \quad (11-45)$$

Then, the compensation coefficients are:

$$A_{\text{compen}} = 1 + j0 \quad (11-46)$$

$$B_{\text{compen}} = Z_{\text{sm}} - Z_{\text{ss}} \quad (11-47)$$

$$C_{\text{compen}} = 0 + j0 \quad (11-48)$$

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 :

$$B=0 \quad (11-49)$$

$$C=0 \quad (11-50)$$

Then, the compensation coefficients are:

$$A_{\text{compen}} = \frac{Z_l}{Z_{lm}} \quad (11-51)$$

$$B_{\text{compen}} = 0 + j0 \quad (11-52)$$

$$C_{\text{compen}} = 0 + j0 \quad (11-53)$$

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 :

$$A=D \text{ (symmetric circuit)} \quad (11-54)$$

Then, the compensation coefficients are:

$$A_{\text{compen}} = 1 + j0 \quad (11-55)$$

$$B_{\text{compen}} = \frac{Z_{\text{sm}} - (1 - Y_{\text{om}}Z_{\text{sm}})Z_{\text{ss}} - Z_{\text{sm}}Y_{\text{os}}Z_{\text{ss}}}{1 - Y_{\text{om}}Z_{\text{sm}}Y_{\text{os}}Z_{\text{ss}}} \quad (11-56)$$

$$C_{\text{compen}} = \frac{Y_{\text{om}} - (1 - Y_{\text{om}}Z_{\text{sm}})Y_{\text{os}} - Y_{\text{om}}Y_{\text{os}}Z_{\text{ss}}}{1 - Y_{\text{om}}Z_{\text{sm}}Y_{\text{os}}Z_{\text{ss}}} \quad (11-57)$$

Fixture Compensation

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 :

$$B = 0 \quad (11-58)$$

Then, the compensation coefficients are:

$$A_{\text{compen}} = \frac{Y_{lm} - Y_{om}}{Y_{ls} - Y_{os}} \quad (11-59)$$

$$B_{\text{compen}} = 0 + j0 \quad (11-60)$$

$$C_{\text{compen}} = \frac{Y_{om} Y_{ls} - Y_{lm} Y_{os}}{Y_{ls} - Y_{os}} \quad (11-61)$$

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 :

$$C = 0 \quad (11-62)$$

Then, the compensation coefficients are:

$$A_{\text{compen}} = \frac{Z_{ss} - Z_{ls}}{Z_{sm} - Z_{lm}} \quad (11-63)$$

$$B_{\text{compen}} = \frac{Z_{lm} Z_{ss} - Z_{sm} Z_{ls}}{Z_{ss} - Z_{ls}} \quad (11-64)$$

$$C_{\text{compen}} = 0 + j0 \quad (11-65)$$

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:

$$A_{\text{compen}} = \frac{Y_{om}(Z_{sm} - Z_{lm})Y_{os}Z_{ss}Z_{ls} - (1 - Z_{lm}Y_{om})Z_{ls} + (1 - Y_{om}Z_{sm})Z_{ss}}{(Z_{sm} - Z_{lm}) - (1 - Z_{lm}Y_{om})Z_{sm}Y_{os}Z_{ss} + (1 - Y_{om}Z_{sm})Z_{lm}Z_{ls}Y_{os}} \quad (11-66)$$

$$B_{\text{compen}} = \frac{(Z_{sm} - Z_{lm})Y_{os}Z_{ss}Z_{ls} - Z_{sm}(1 - Z_{lm}Y_{om})Z_{ls} + Z_{lm}(1 - Y_{om}Z_{sm})Z_{ss}}{Y_{om}(Z_{sm} - Z_{lm})Y_{os}Z_{ss}Z_{ls} - (1 - Z_{lm}Y_{om})Z_{ls} + (1 - Y_{om}Z_{sm})Z_{ss}} \quad (11-67)$$

$C_{\text{compen}} =$

$$\frac{Y_{\text{om}}(Z_{\text{sm}} - Z_{\text{lm}}) - (1 - Z_{\text{lm}}Y_{\text{om}})Y_{\text{os}}Z_{\text{ss}} + (1 - Y_{\text{om}}Z_{\text{sm}})Z_{\text{ls}}Y_{\text{os}}}{(Z_{\text{sm}} - Z_{\text{lm}}) - (1 - Z_{\text{lm}}Y_{\text{om}})Z_{\text{sm}}Y_{\text{os}}Z_{\text{ss}} + (1 - Y_{\text{om}}Z_{\text{sm}})Z_{\text{lm}}Z_{\text{ls}}Y_{\text{os}}}$$

(11-68)

Permittivity Measurements

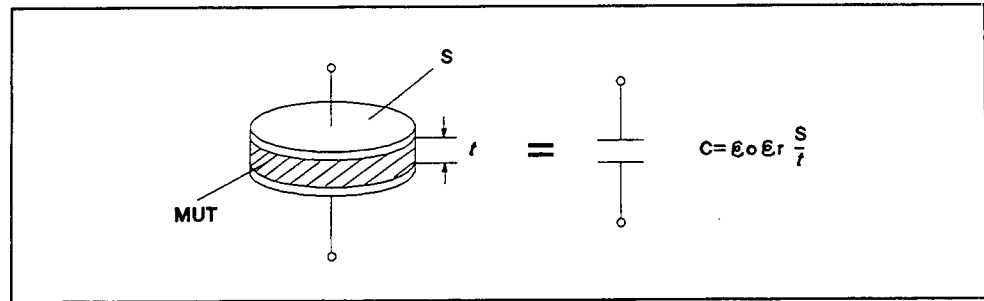


Figure 11-17. Schematic Electrode Structure of the HP 16453A

In general, when a dielectric material is put in a pair of parallel flat electrodes, capacitance C is calculated using the following equation:

$$C = \epsilon_0 \epsilon_r \frac{S}{t} \tag{11 - 69}$$

Complex Permittivity

Strictly speaking, when ac voltage is applied to the dielectric material, the material has some loss and permittivity ϵ_r is defined as the following complex value:

$$\dot{\epsilon}_r = \epsilon'_r - j\epsilon''_r \tag{11 - 70}$$

Now, the capacitor has a loss factor and the capacitance C in equation (11-76) can be modified to the complex admittance \dot{Y} as follows:

$$C \rightarrow \frac{\dot{Y}}{j\omega} \tag{11 - 71}$$

$$\frac{\dot{Y}}{j\omega} = \epsilon_0 \dot{\epsilon}_r \frac{S}{t} \tag{11 - 72}$$

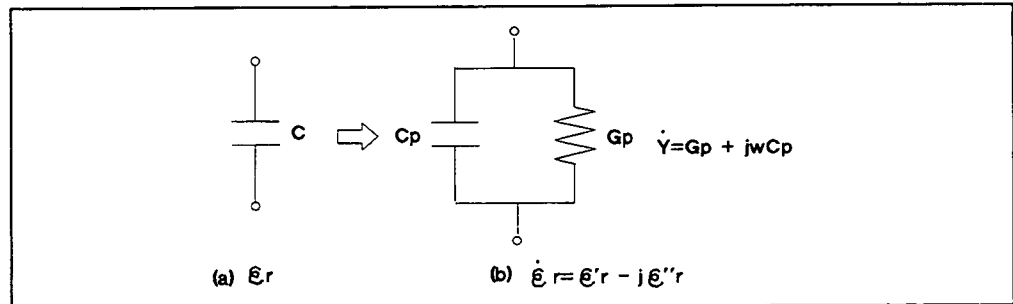


Figure 11-18. Material has some loss

Therefore, the relative permittivity of the MUT can be obtained using the following equation:

$$\dot{\epsilon}_r = \frac{1}{\epsilon_0} \frac{\dot{Y}_m t}{j\omega S}$$

$$= \frac{\dot{Y}_m}{j\omega C_0} \quad (11 - 73)$$

Where,

\dot{Y}_m is the measurement admittance value of the MUT.

C_0 is the capacitance value of the air gap (whose distance between electrodes is same as the thickness of the MUT).

$$C_0 = \epsilon_0 \frac{S}{d} \quad (11 - 74)$$

Characteristics of Test Fixture

Edge Effect

When the capacitance of the material is measured, stray capacitance exists at edge of electrodes (see Figure 11-19).

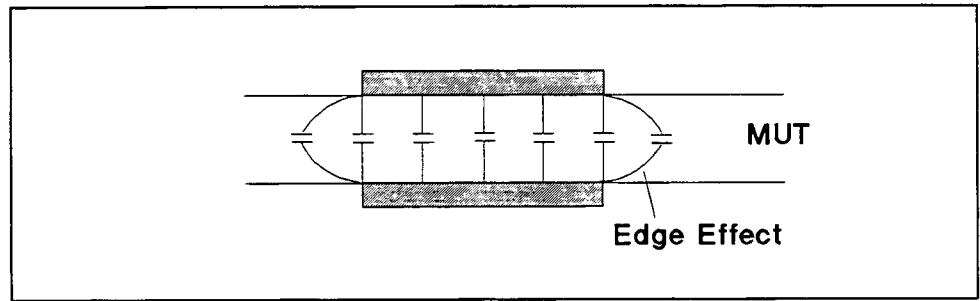


Figure 11-19. Edge Effect

Because measurement result is a summation of the capacitance of a MUT and the stray capacitance caused by the edge effect, the edge effect is generally expressed as follows:

$$C_0(1 + E_{edge}) \quad (11 - 75)$$

Where,

E_{edge} is the compensation coefficient for the edge effect, which is determined by the gap between electrode and relative permittivity of MUT.

Adding the edge effect to C_0 in equation (11-80), the relative permittivity of the MUT can be obtained by using the following equation:

$$\epsilon_r = \frac{\dot{Y}_m}{j\omega C_0(1 + E_{edge})} \quad (11 - 76)$$

Permittivity Measurements

The Analyzer uses an approximately value as E_{edge} of HP 16453A

The analyzer uses the following approximate value of E_{edge} for the HP 16453A:

$$E_{edge} = 434t^{0.825}\epsilon_r^{-0.554}$$

where,

t : [m]

Residual Parameter

In fact the HP 16453A has residual impedance and stray admittance, which cause an increased error when measuring the admittance of the MUT. To eliminate residual and stray admittance, the OPEN, SHORT, and LOAD fixture compensations are required for any permittivity measurement using the HP 16453A.

Because the equation to compensate for measurement admittance value is same as the equation for the OPEN-SHORT-LOAD fixture compensation for impedance measurement, see "Fixture Compensation" for more information on OPEN, SHORT, and LOAD fixture compensation.

Permeability Measurements

In general, when current is flowing along an infinity line (as shown in (a) of Figure 11-20), magnetic flux density B is generated by the current as follows:

$$B = \frac{\mu I}{2\pi r} \quad (11 - 77)$$

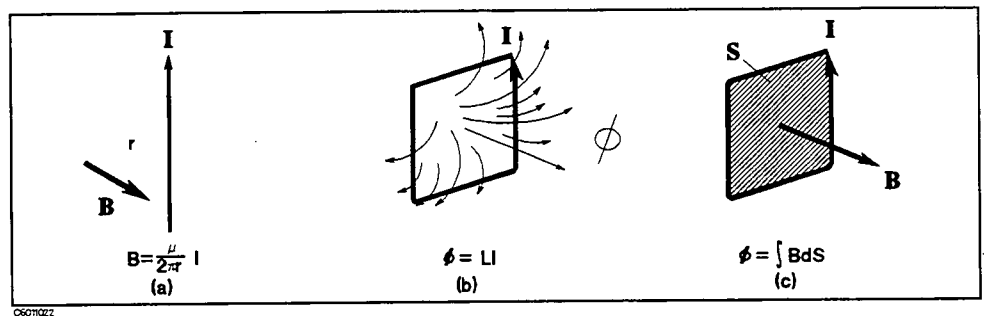
When current is flowing in a closed loop (as shown in (b) of Figure 11-20), the magnetic flux Φ generated by the current is :

$$\Phi = LI \quad (11 - 78)$$

Where, L is the self-inductance of the closed loop.

Because the magnetic flux is calculated by the surface integral of the magnetic flux density B (s shown in (c) of Figure 11-20), Φ is also expressed by the following equations:

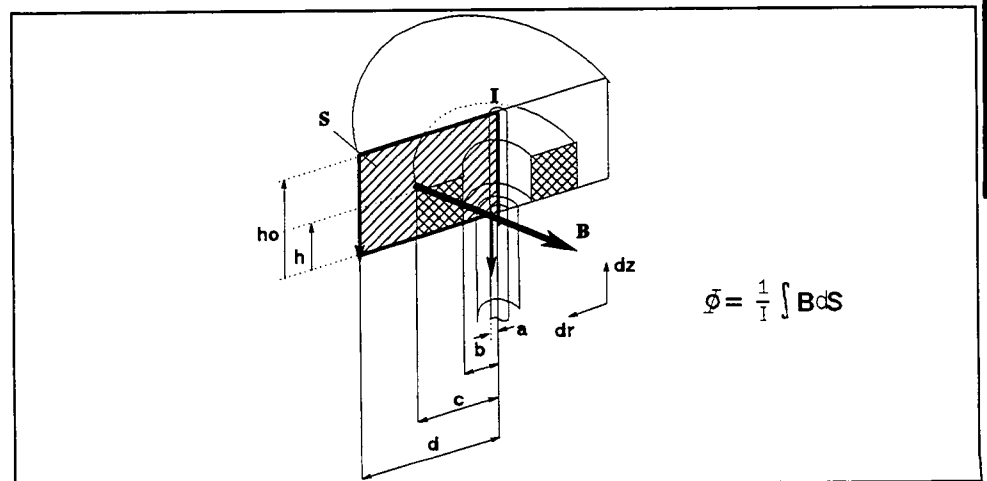
$$\Phi = \int B ds \quad (11 - 79)$$



0607022

Figure 11-20.
Basic Relationship of Magnetic Flux Density, Magnetic Flux, and Current

Figure 11-21 shows the schematic fixture structure of the HP 16454A.



0607023

Figure 11-21. Schematic Fixture Structure of HP 16454A

Permeability Measurements

The HP 16454A measures core shape magnetic material as shown in Figure 11-21. Erasing \mathbf{B} and Φ and considering the physical shape and dimensions of the HP 16454A, the self-inductance of the measurement circuit including MUT is derived as follows:

$$L = \frac{1}{I} \int \mathbf{B} ds$$

$$= \int_a^d \int_0^{h_0} \frac{\mu}{2\pi r} dr dz \quad (11-80)$$

$$= \frac{\mu_0}{2\pi} \left\{ (\mu_r - 1)h \ln \frac{c}{b} + h_0 \ln \frac{d}{a} \right\} \quad (11-81)$$

Modify equation (11-87) to get the relative permeability μ_r of MUT:

$$\mu_r = \frac{2\pi}{\mu_0} \frac{L - L_{ss}}{F} + 1 \quad (11-82)$$

Where,

L_{ss} is the self-inductance of the fixture when it is empty.

$$L_{ss} = \frac{\mu_0}{2\pi} h_0 \ln \frac{b}{a} \quad (11-83)$$

F is the shape function of MUT, which is decided by its dimensions only.

$$F = h \ln \frac{a}{b} \quad (11-84)$$

Complex Permeability

When the magnetic field generated by an ac current is flowing is applied to the magnetic material, the permeability is defined by the complex value shown in equation (11-92).

$$\dot{\mu}_r = \mu'_r - j\mu''_r \quad (11-85)$$

Now, because the inductor has a loss factor, the inductance in equations (11-87) through (11-89) must be modified to a complex impedance, which includes the loss:

$$L \longrightarrow \frac{\dot{Z}}{j\omega} \quad (11-86)$$

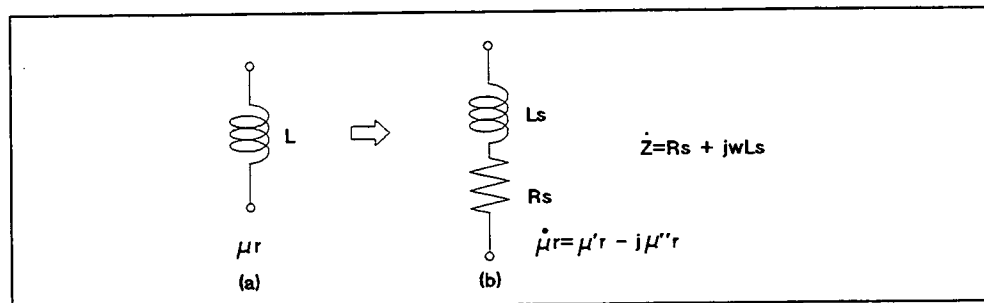


Figure 11-22. Material Has Loss

The complex relative permeability of the MUT can then be determined by the following equation:

$$\dot{\mu}_r = \frac{2\pi}{\mu_0} \frac{j\omega \dot{Z} - L_{ss}}{F} + 1 \quad (11 - 87)$$

The analyzer measures impedance (\dot{Z}) and calculates $\dot{\mu}_r$ using this equation.

Characteristics of the Test Fixture

Residual Parameter

The HP 16454A has residual impedance. The residual impedance \dot{Z}_{res} is represented by a series impedance as shown in Figure 11-23.

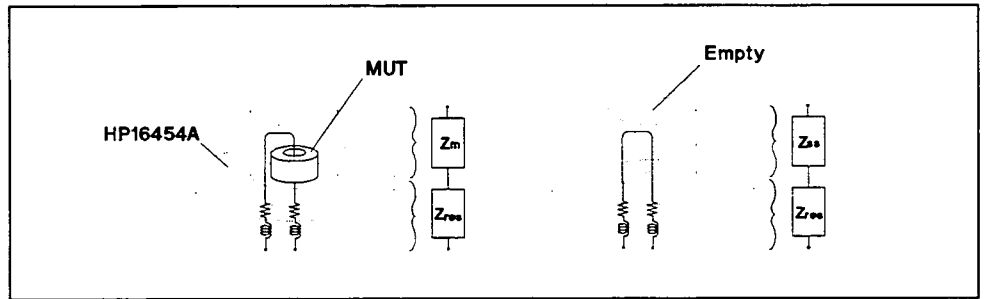


Figure 11-23. Residual Impedance of the HP 16454A

Assuming that the impedance value of the empty test fixture is known, the residual impedance can be specified by measuring the fixture with no MUT (empty).

$$\dot{Z}_{res} = \dot{Z}_{sm} - \dot{Z}_{ss} \quad (11 - 88)$$

Where,

- \dot{Z}_{ss} is the ideal value of the impedance when the fixture is empty.
- \dot{Z}_{sm} is the measurement value of the impedance when the fixture is empty.

Elimination of Residual Impedance Effects in the Test Fixture (SHORT Fixture Compensation)

The SHORT fixture compensation can eliminate the residual impedance effect. When the SHORT (empty) compensation measurement has been performed, the compensated impedance \dot{Z}_{comp} can be expressed by the following equation:

$$\dot{Z}_{comp} = \dot{Z}_m - \dot{Z}_{res} \quad (11 - 89)$$

Assuming that \dot{Z}_{ss} has only an inductance factor ($\dot{Z}_{ss} = j\omega L_{ss}$), and using the compensated impedance value \dot{Z}_{comp} , the permeability of the MUT can be derived from \dot{Z}_m and \dot{Z}_{sm} as follows:

$$\dot{\mu}_r = \frac{2\pi}{\mu_0} \frac{\dot{Z}_m - \dot{Z}_{sm}}{j\omega F} + 1 \quad (11 - 90)$$

Impedance Measurement Basics

Permeability Measurements

Impedance Parameter Value Displayed for Magnetic Material Measurement

When the HP 4291A measures magnetic materials, the impedance parameter value displayed is calculated from the following impedance value (\dot{Z}):

$$\dot{Z} = \frac{\dot{\mu}_m \mu_0}{2\pi} \ln \frac{c}{b}$$

Where,

$\dot{\mu}_m$ is measurement complex permeability value of MUT

b is inner diameter of MUT

c is outer diameter of MUT

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 4291A RF Impedance/Material Analyzer serial number prefix listed on the title page of this manual.

Manual Changes

To adapt this manual to your HP 4291A, 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

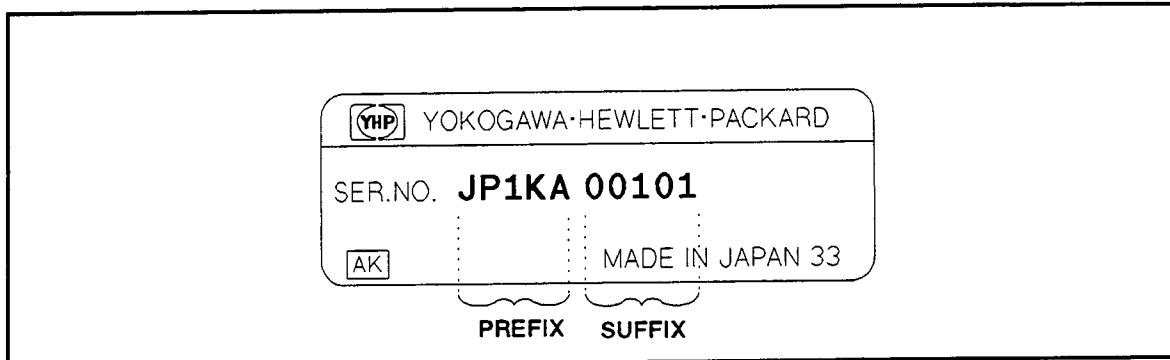
Serial Prefix or Number	Make Manual Changes

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.



C630A001

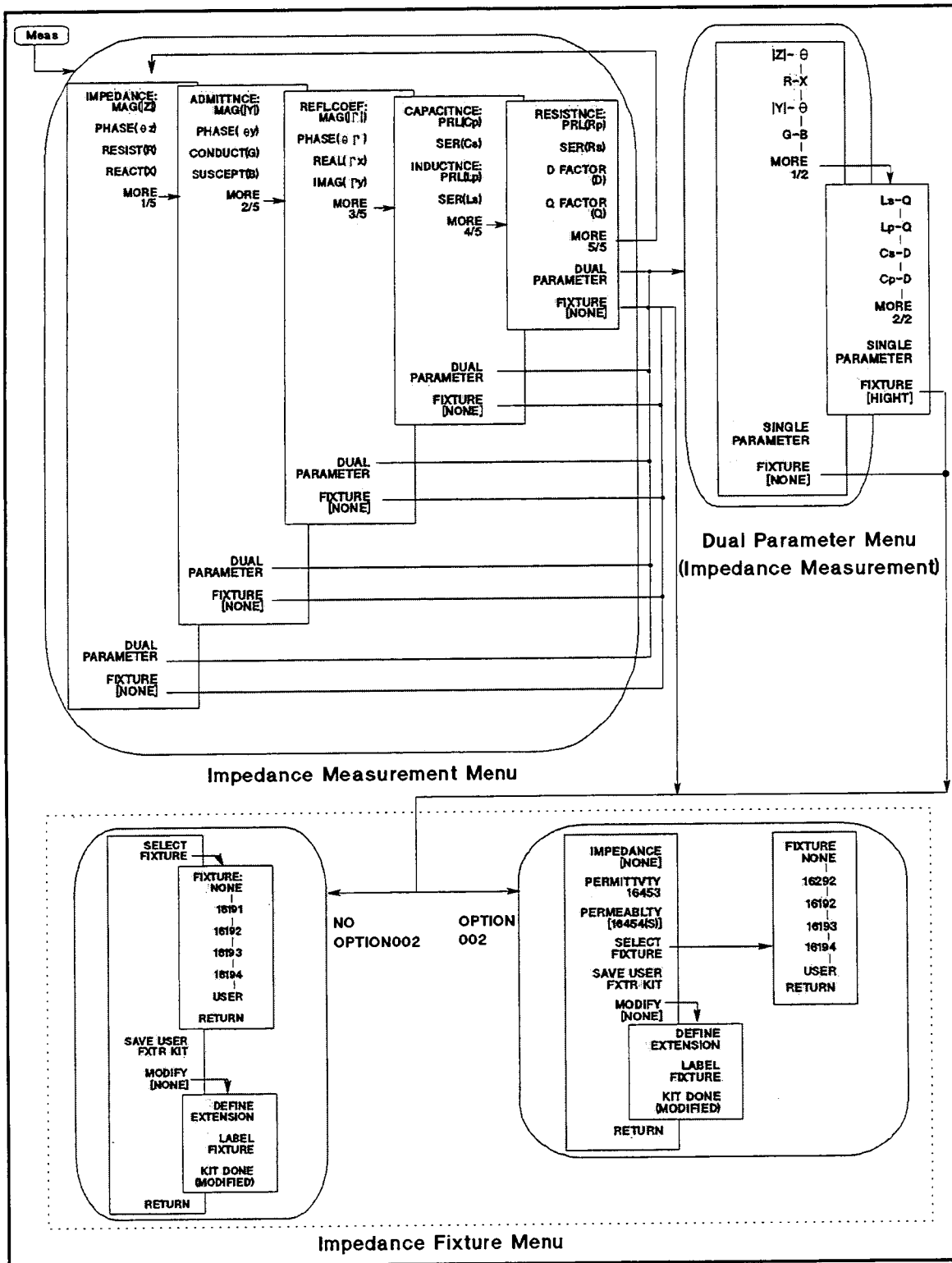
Figure A-1. Serial Number Plate

Softkey Tree

Measurement Block

Measurement Block : **Meas**

Meas



06005006

Figure B-1. Softkey Menus Accessed from the **Meas** Key for Impedance Measurement

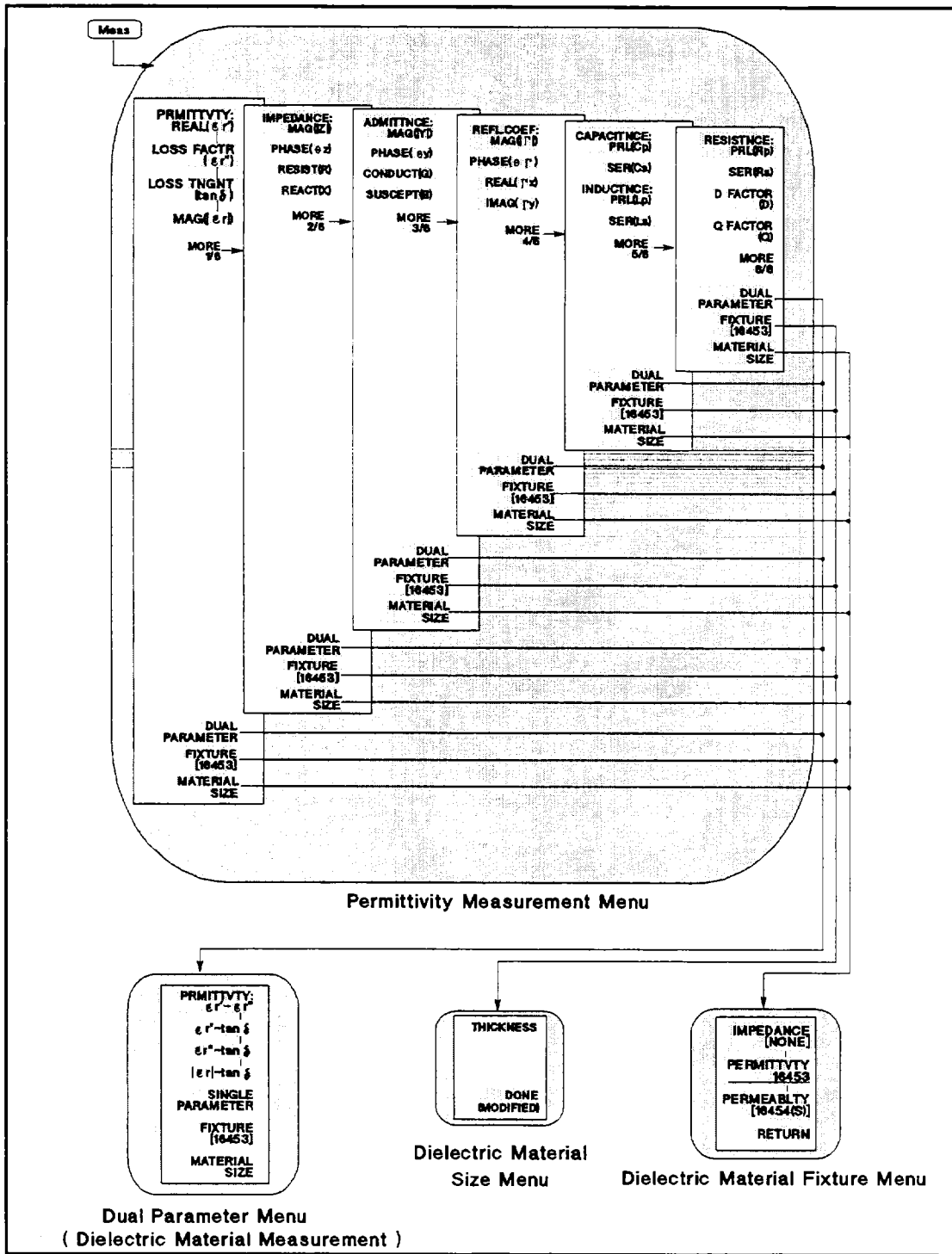
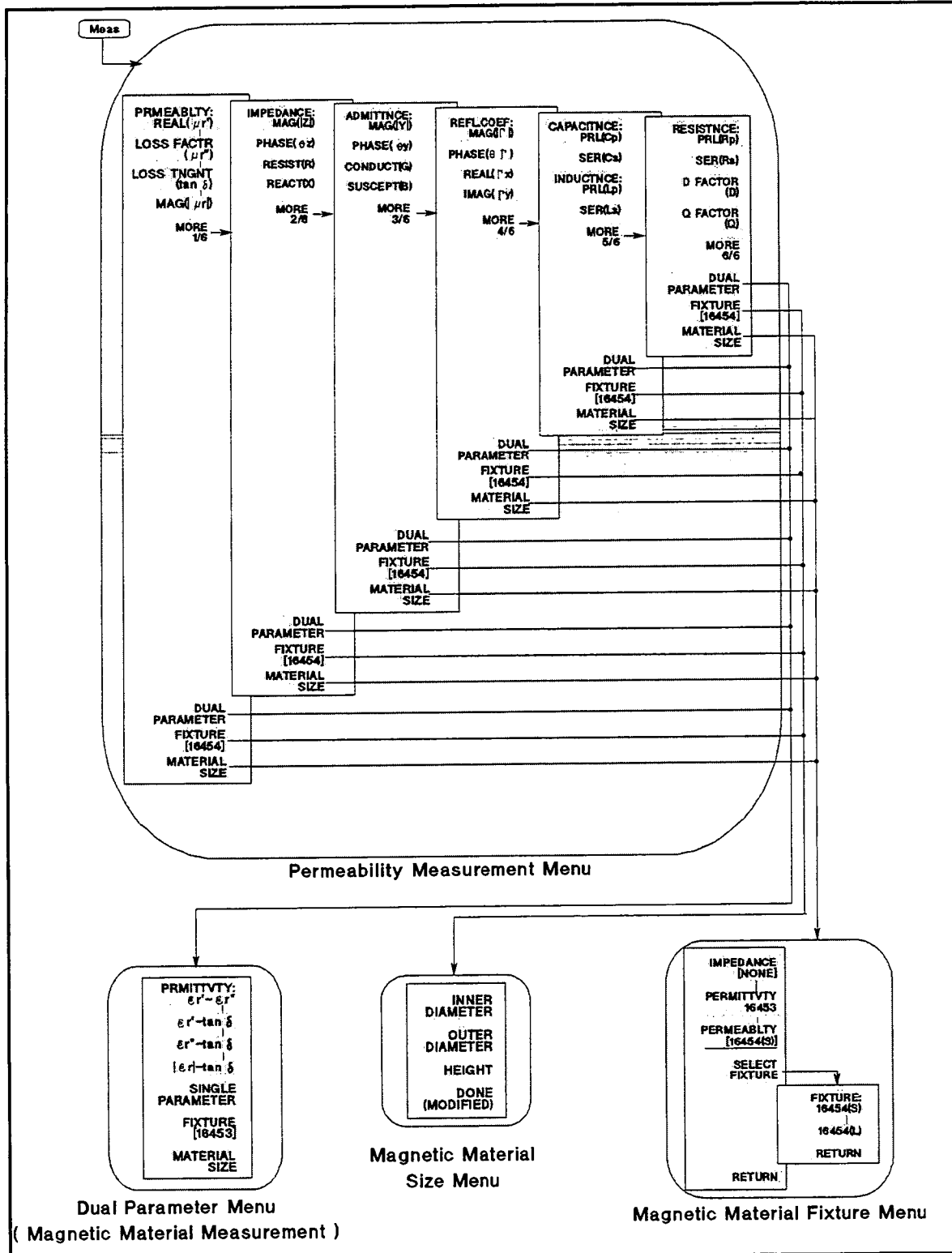


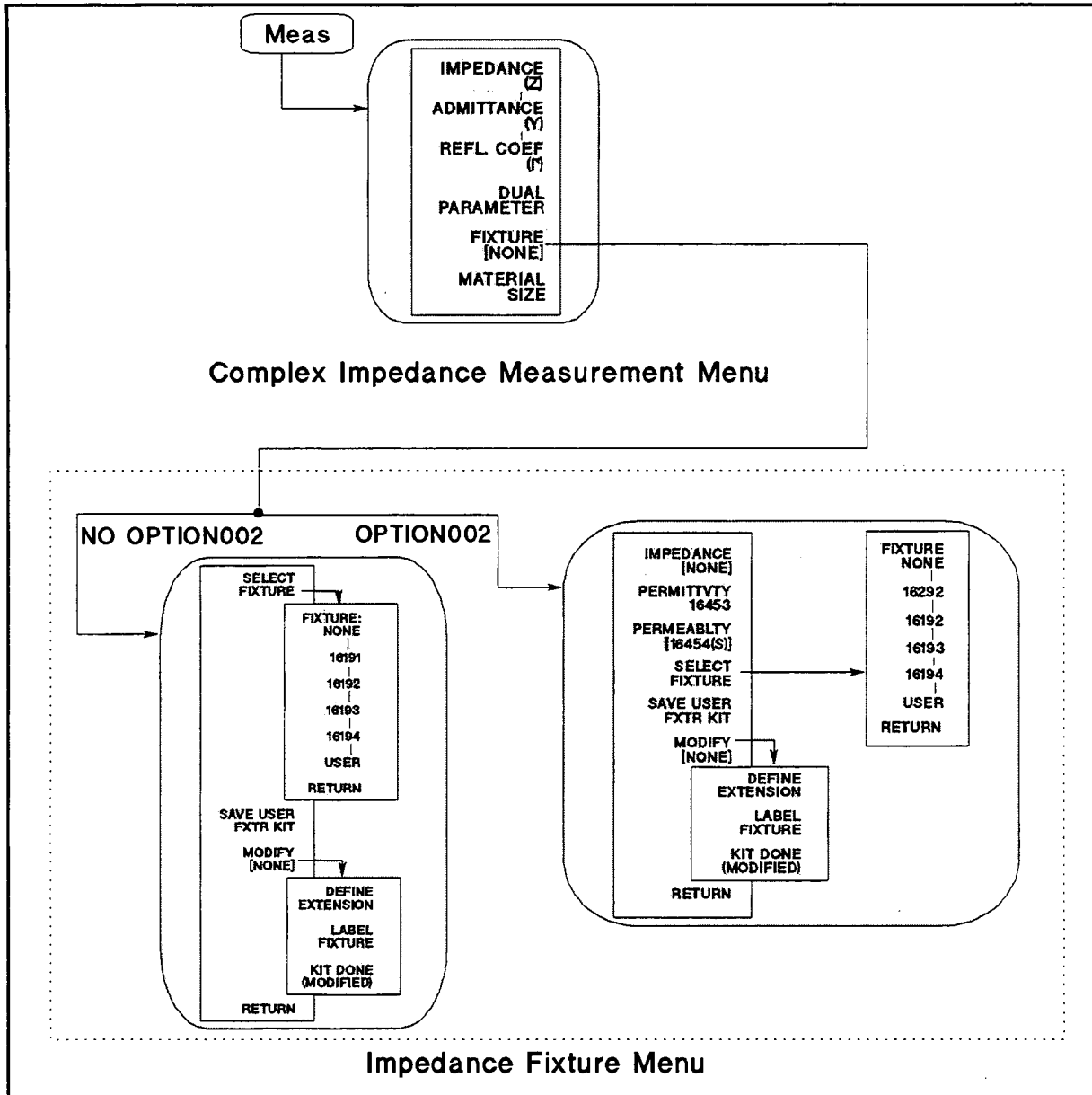
Figure B-2. Softkey Menus Accessed from the **Meas** Key for Permittivity Measurement

Measurement Block : **Meas**



06005061

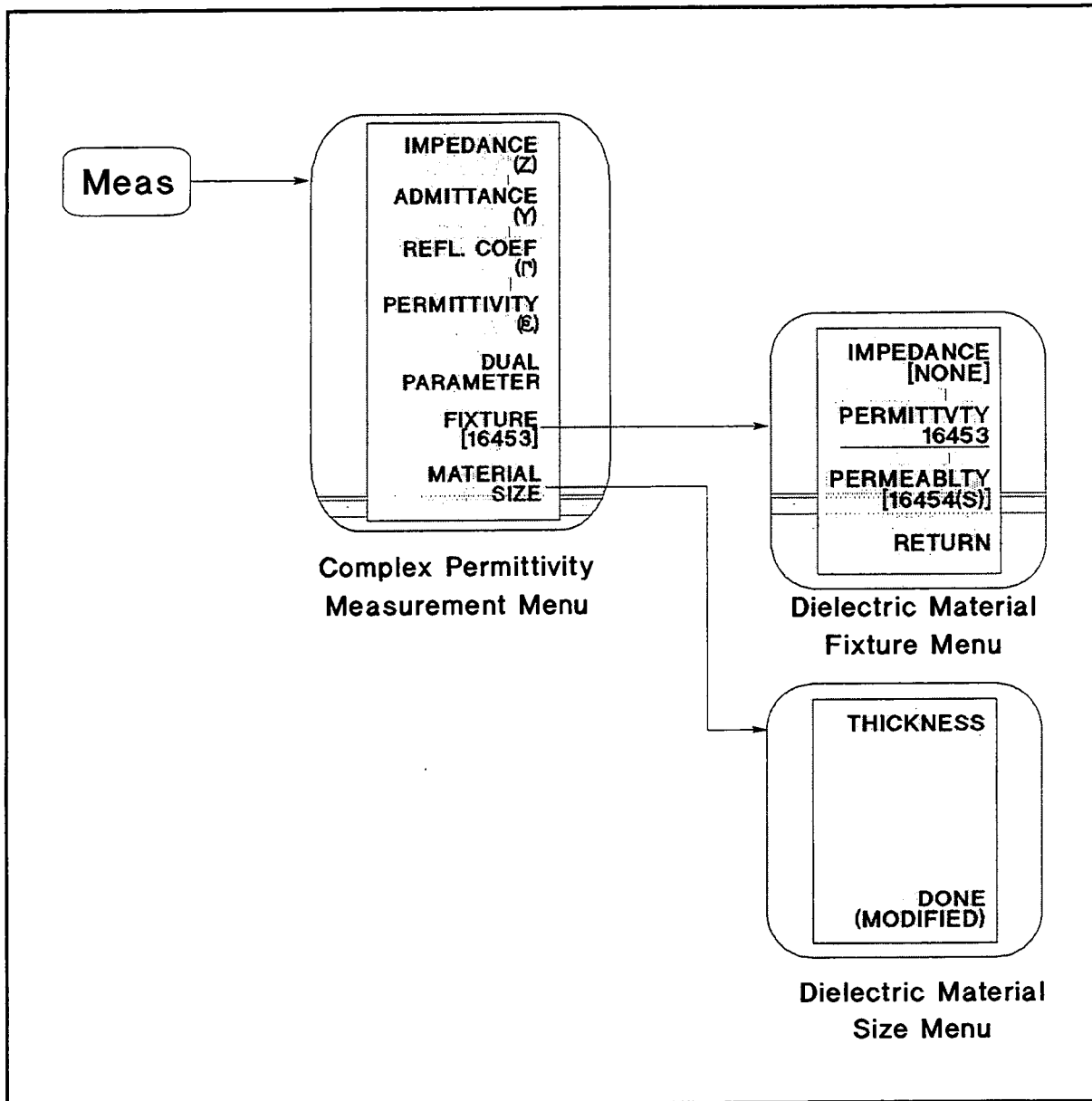
Figure B-3. Softkey Menus Accessed from the **Meas** Key for Permeability Measurement



C6065048

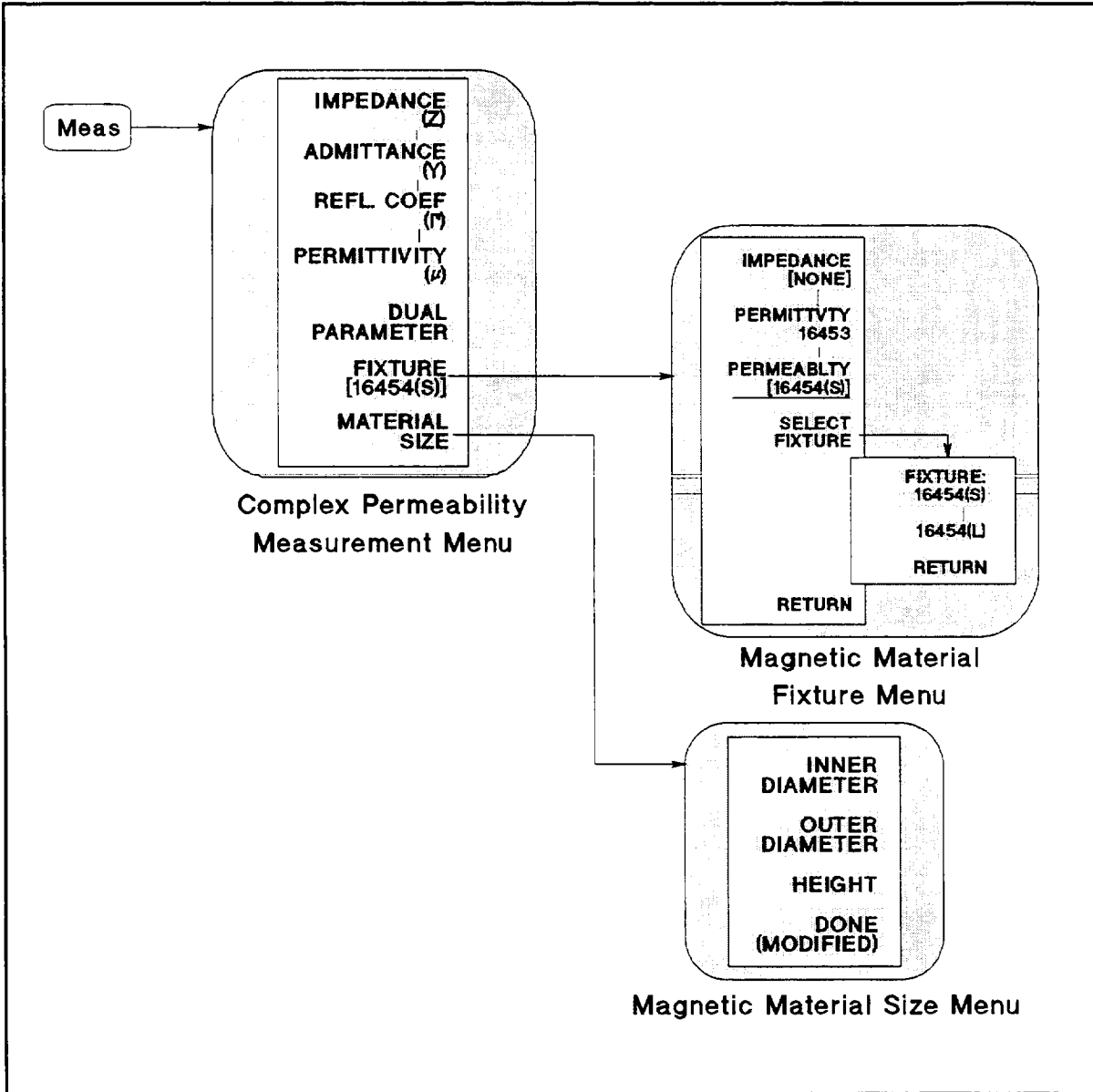
Figure B-4.
 Softkey Menus Accessed from the **Meas** Key for Impedance Measurement (when Smith/Polar/Admittance or Complex-Plane Format is selected)

Measurement Block : **Meas**



C6005049

Figure B-5.
Softkey Menus Accessed from the **Meas** Key for Permittivity Measurement (when Smith/Polar/Admittance or Complex-Plane Format is selected)



C6005050

Figure B-6.

Softkey Menus Accessed from the **Meas Key for Permeability Measurement (when Smith/Polar/Admittance or Complex-Plane Format is selected)**

Measurement Block : **Format**

Format

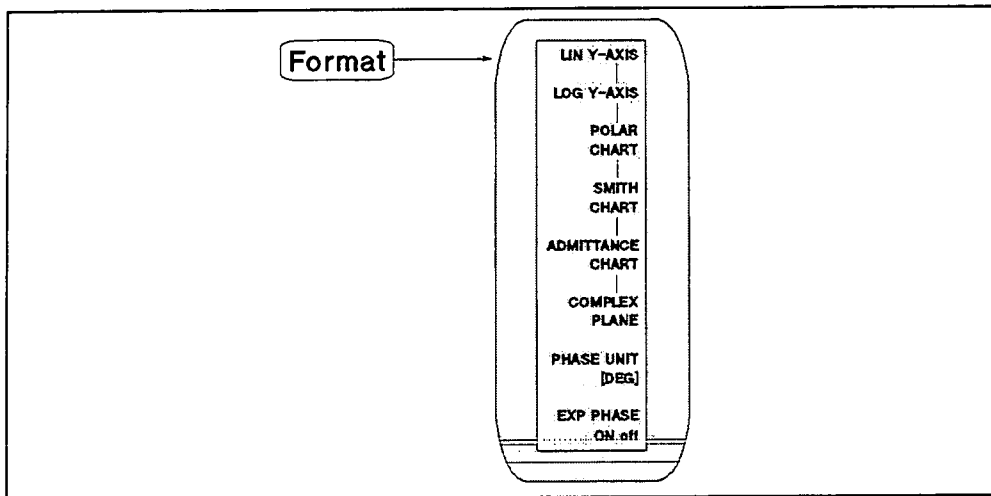


Figure B-7. Softkey Menus Accessed from the **Format**

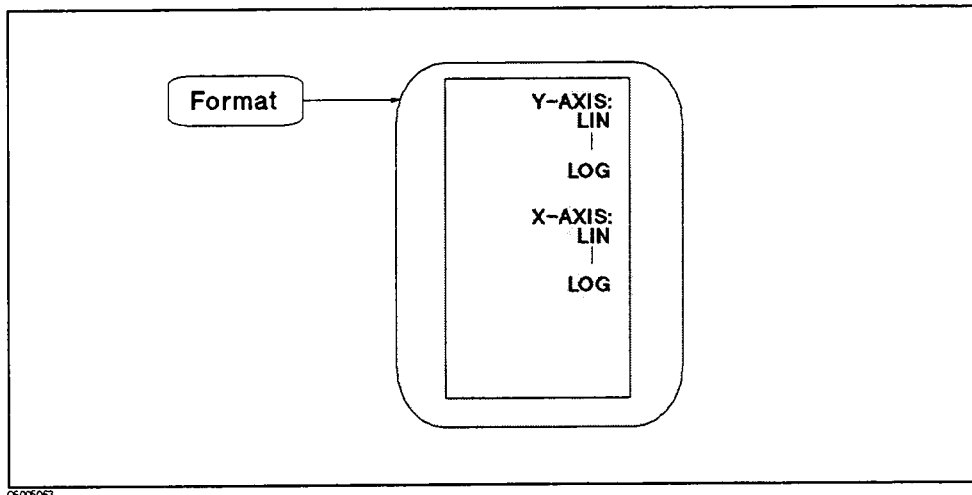
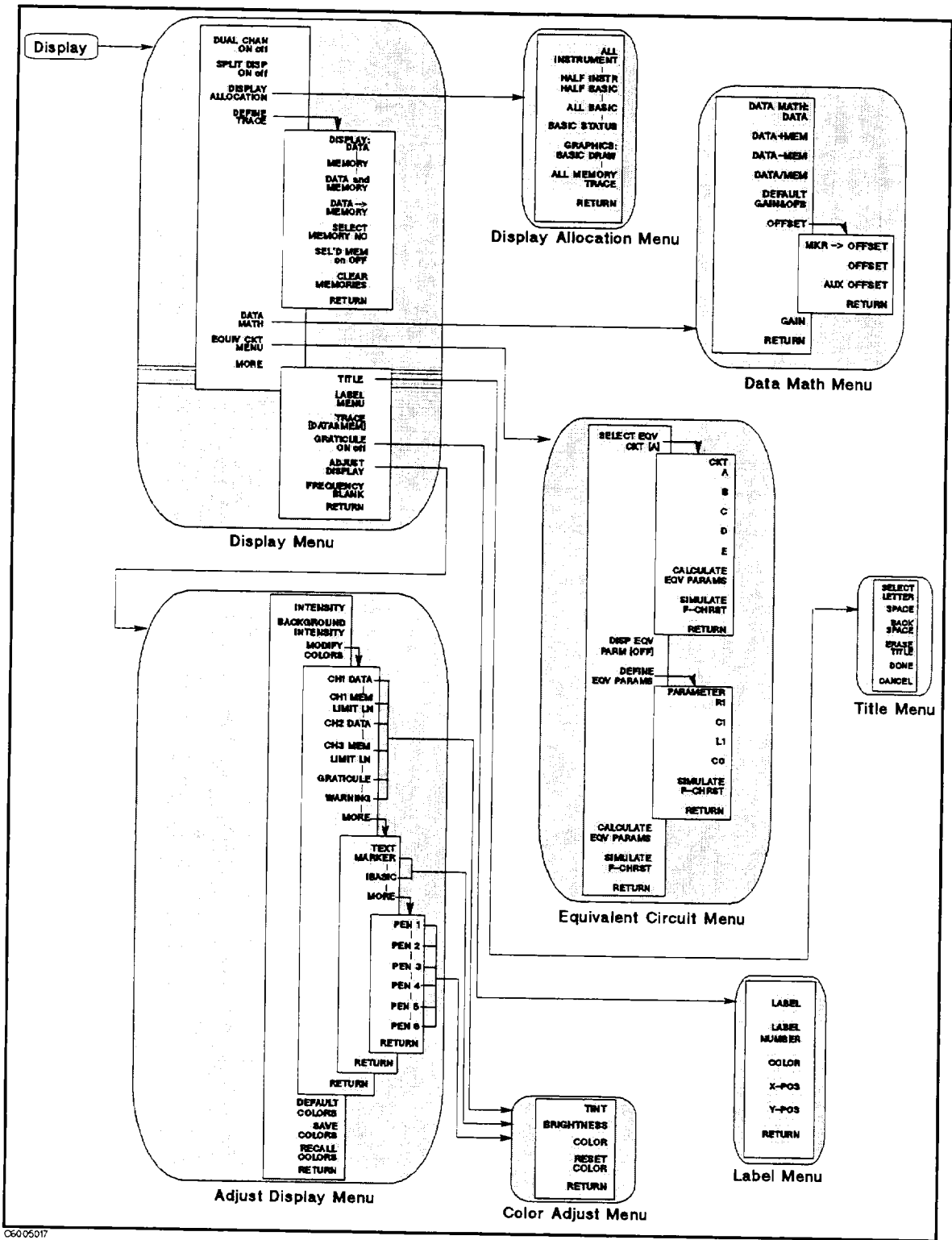


Figure B-8. Softkey Menus Accessed from the **Format** When User Trace is Turned ON

Display



06005017

Figure B-9. Softkey Menus Accessed from the Display Key

Measurement Block : **Display**

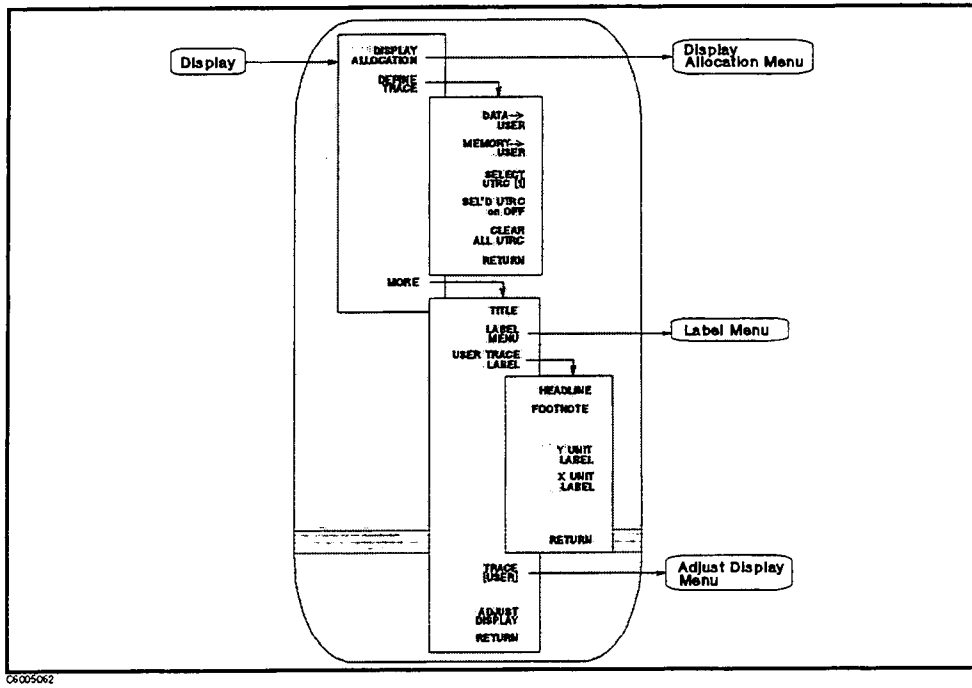
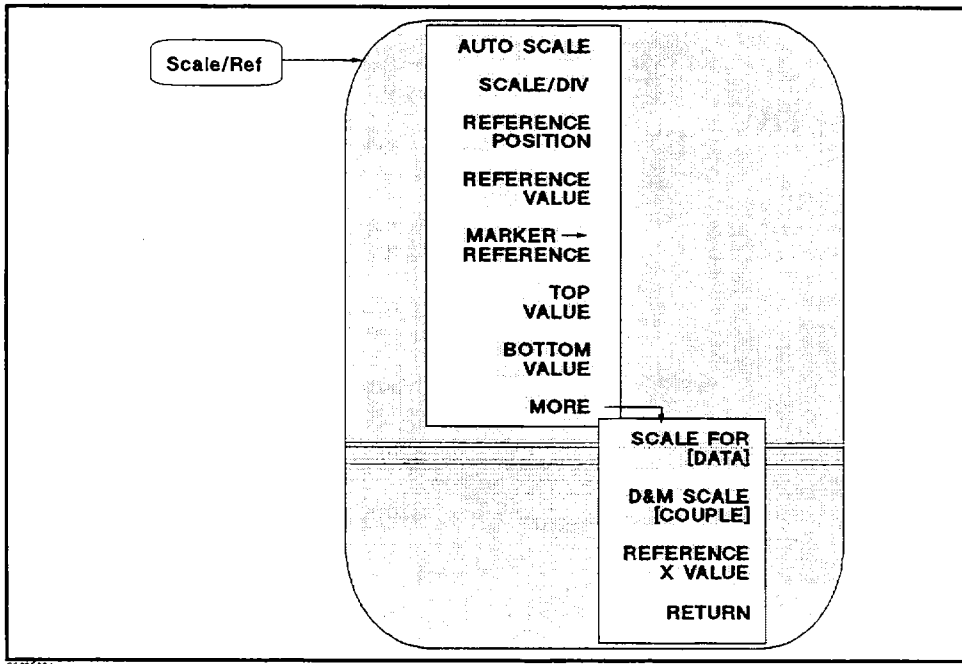


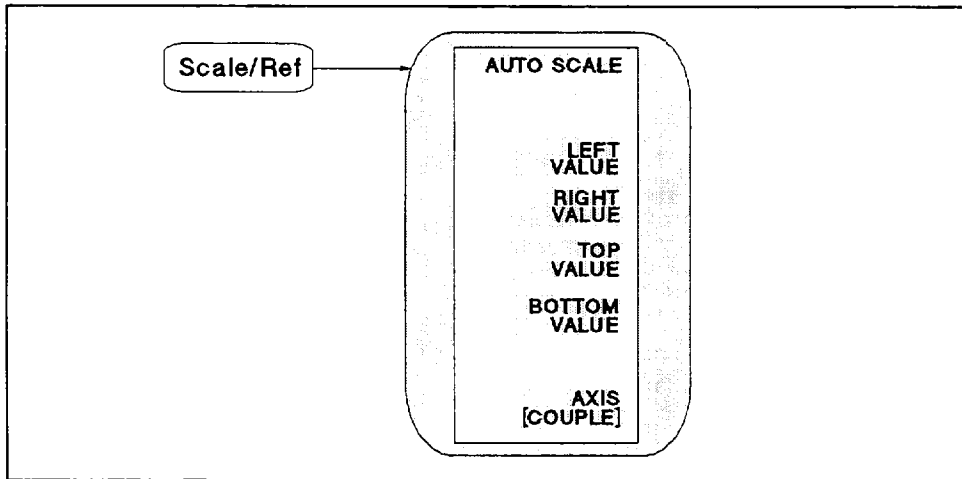
Figure B-10. Softkey Menus Accessed from the **Display** Key When User Trace is Turned ON

Scale Ref



04005024

Figure B-11. Softkey Menus Accessed from the Scale Ref Key



06005064

Figure B-12. Softkey Menus Accessed from the Scale Ref Key When User Trace is Turned ON

Measurement Block : **Bw/Avg**

Bw/Avg

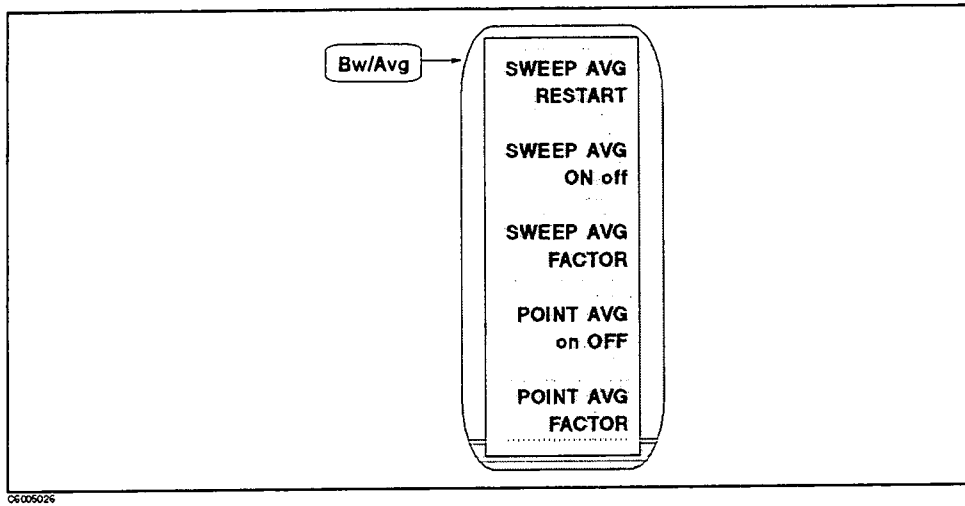
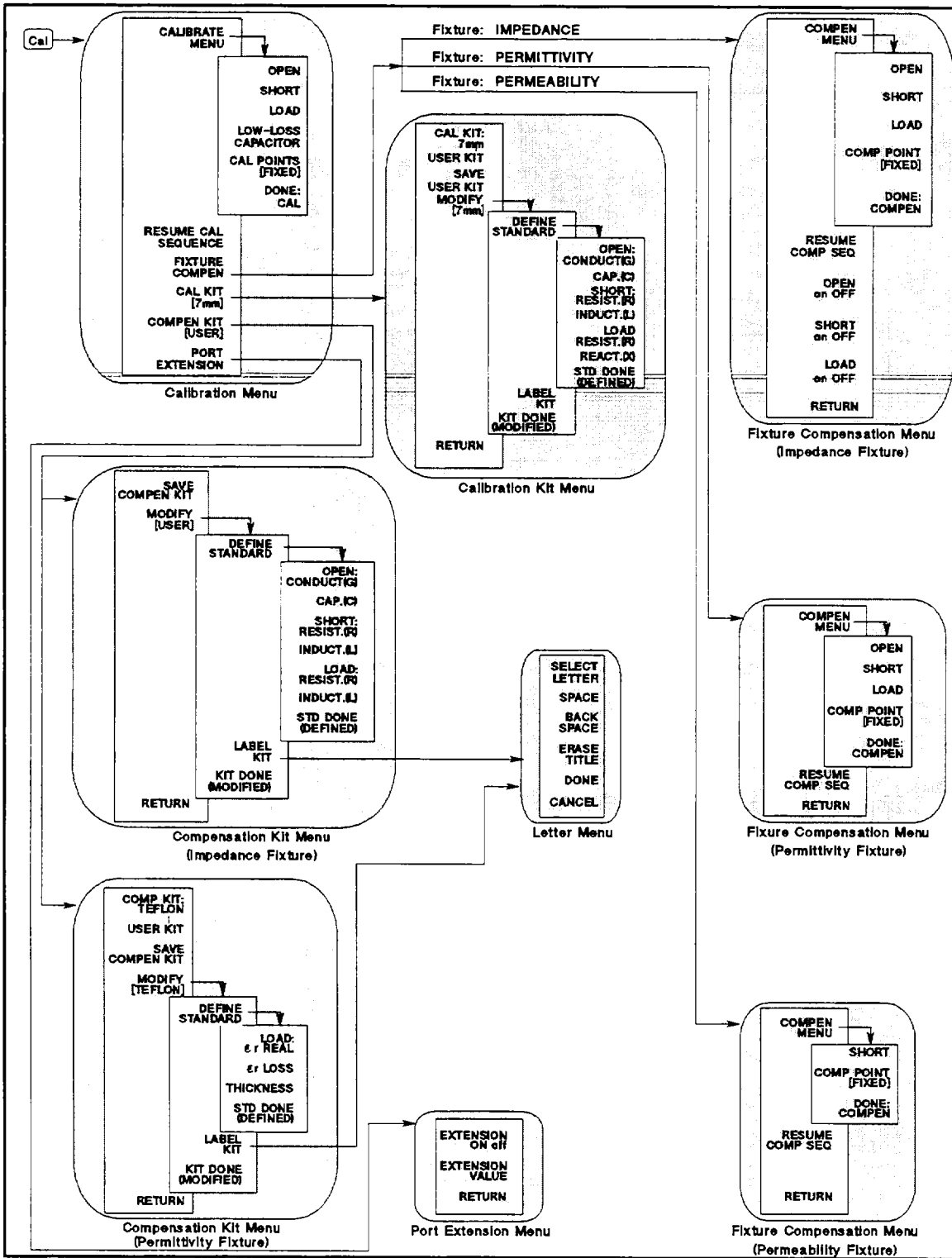


Figure B-13. Softkey Menus Accessed from the **Bw/Avg** Key

Cal



06005014

Figure B-14. Softkey Menus Accessed from the Cal Key

Stimulus Block

Source

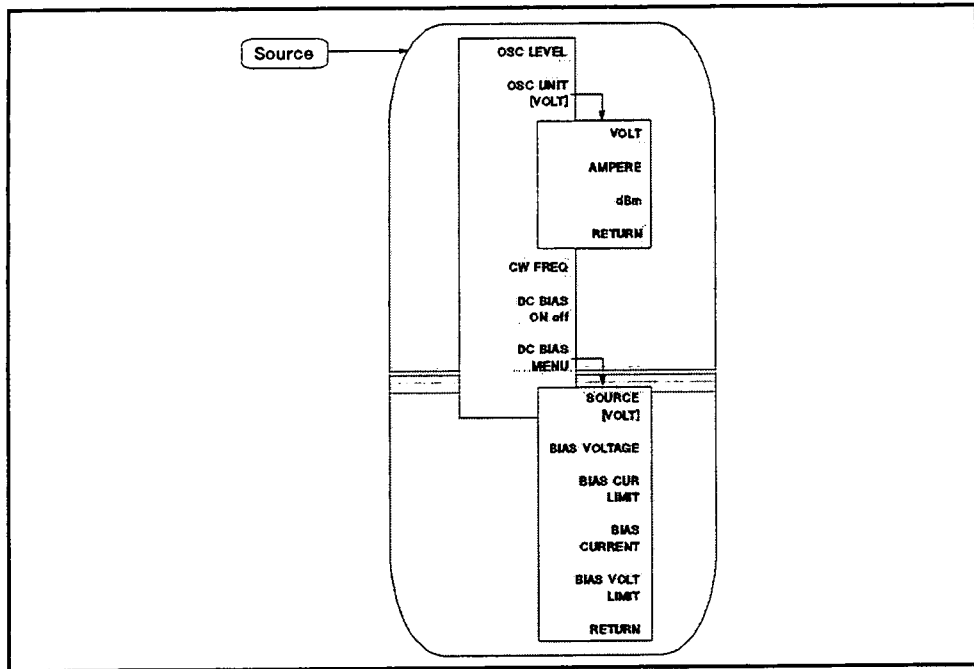
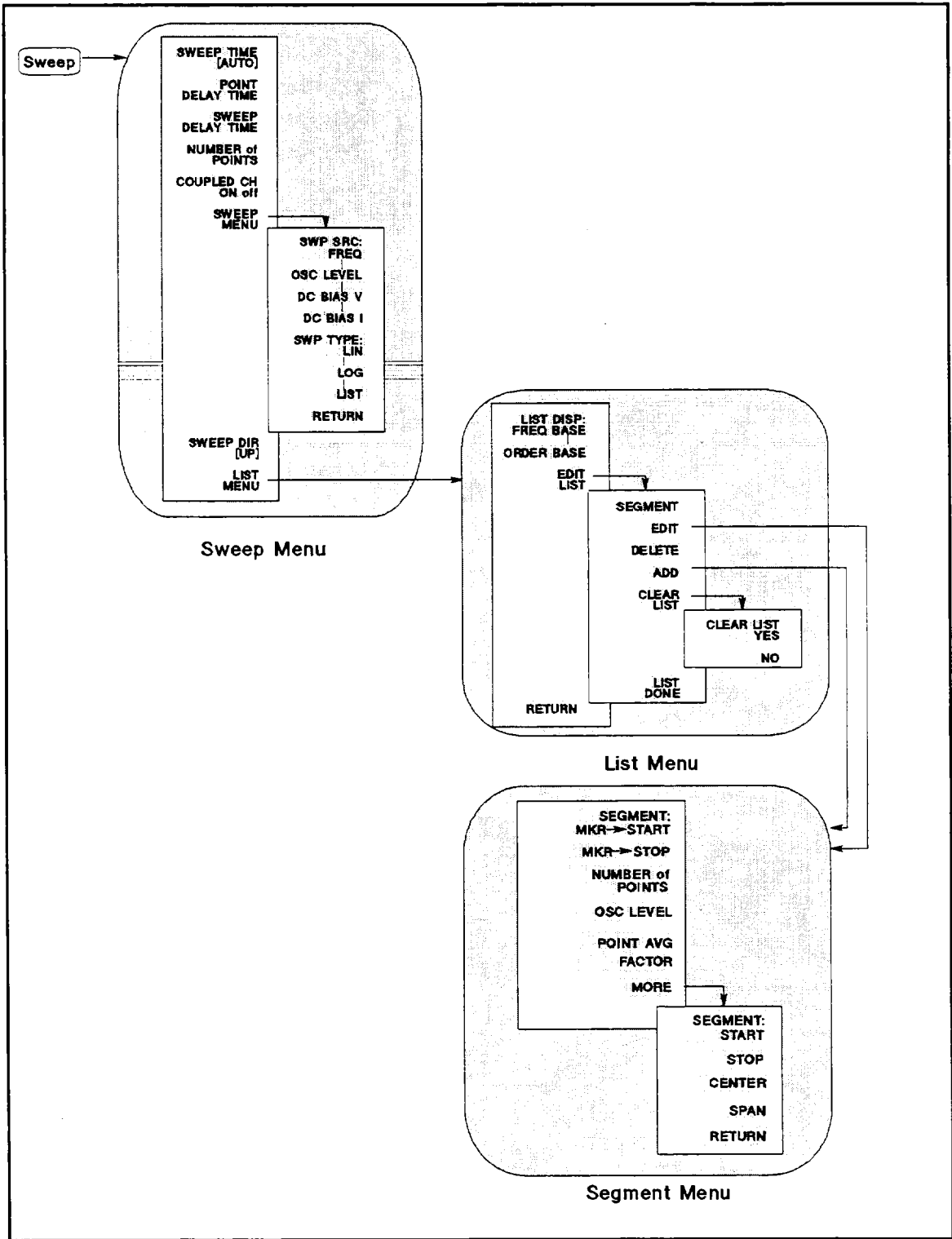


Figure B-15. Softkey Menus Accessed from the **Source** Key

Sweep

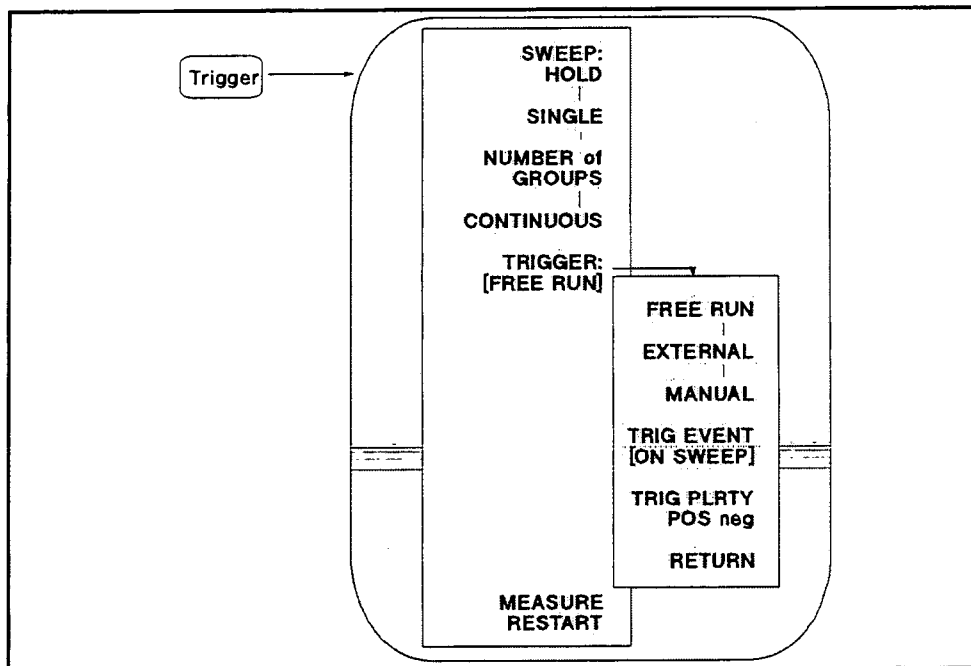


CE006010

Figure B-16. Softkey Menus Accessed from the Sweep Key

Stimulus Block : **Trigger**

Trigger

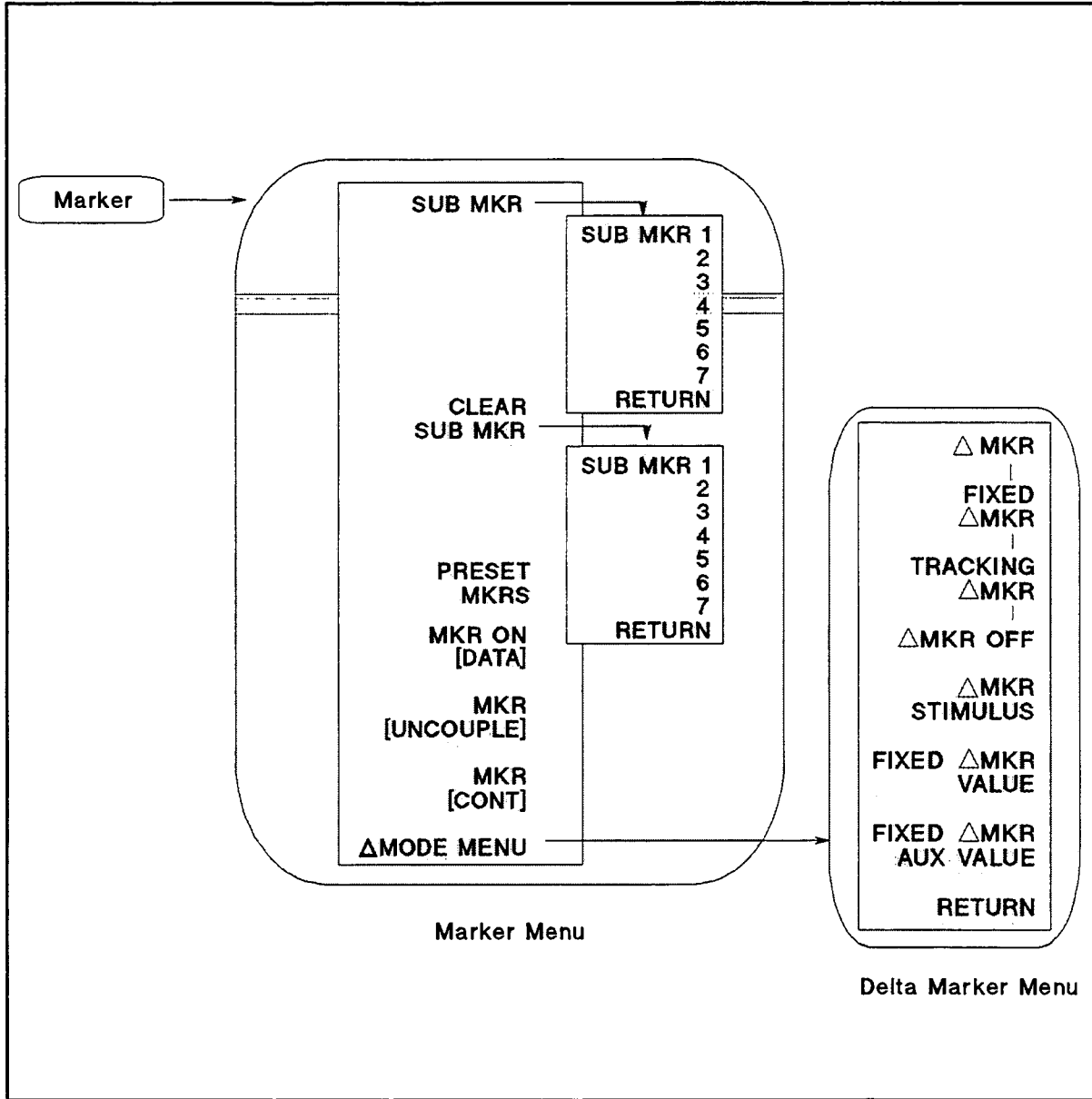


06 006006

Figure B-17. Softkey Menus Accessed from the **Trigger** Key

Marker Block

Marker

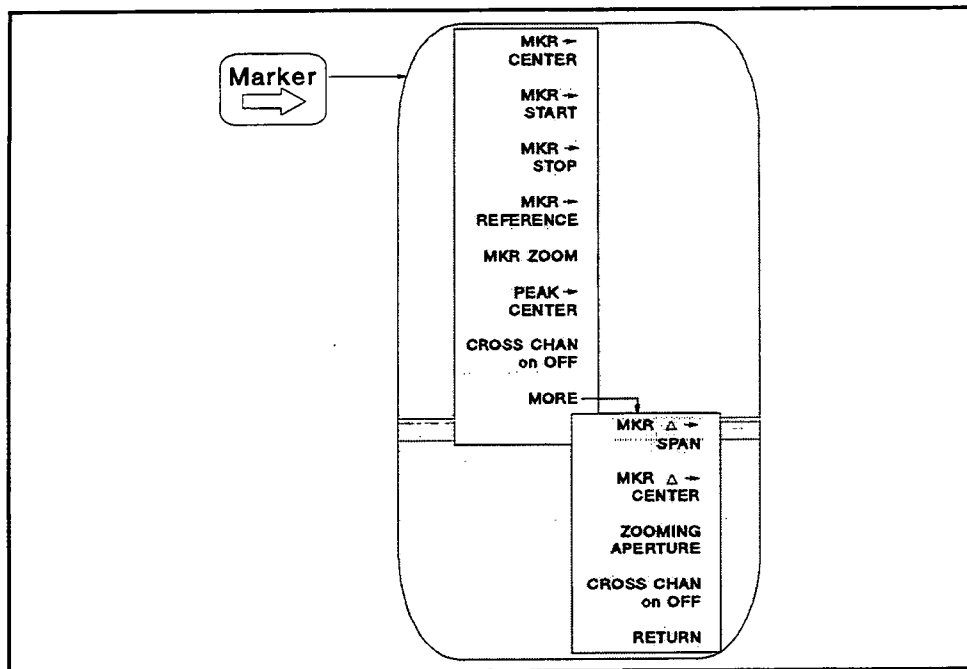


C6007002

Figure B-18. Softkey Menus Accessed from the **Marker** Key

Marker Block : **Marker→**

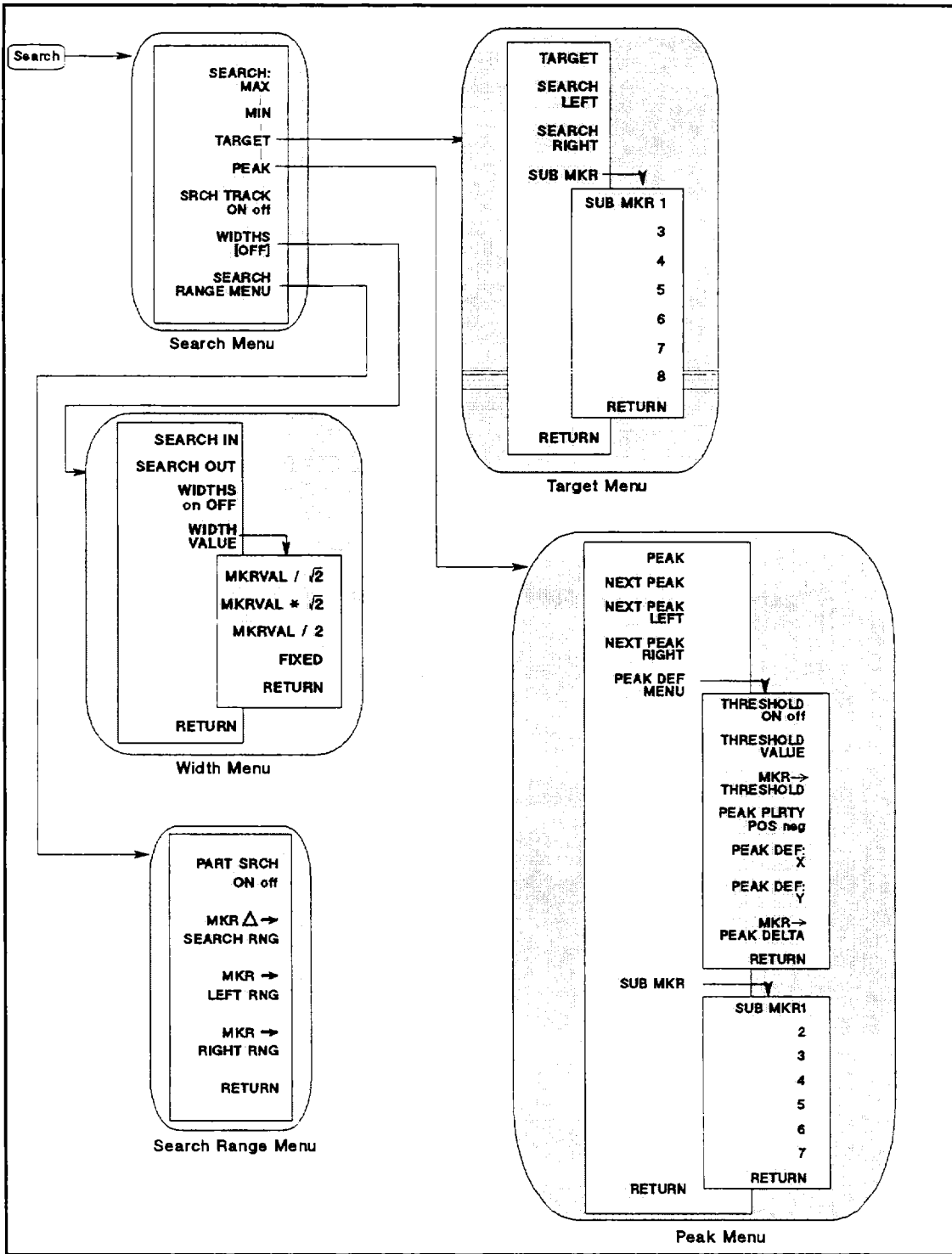
Marker→



06007005

Figure B-19. Softkey Menus Accessed from the **Marker→** Key

Search



06007006

Figure B-20. Softkey Menus Accessed from the Search Key

Marker Block : Utility

Utility

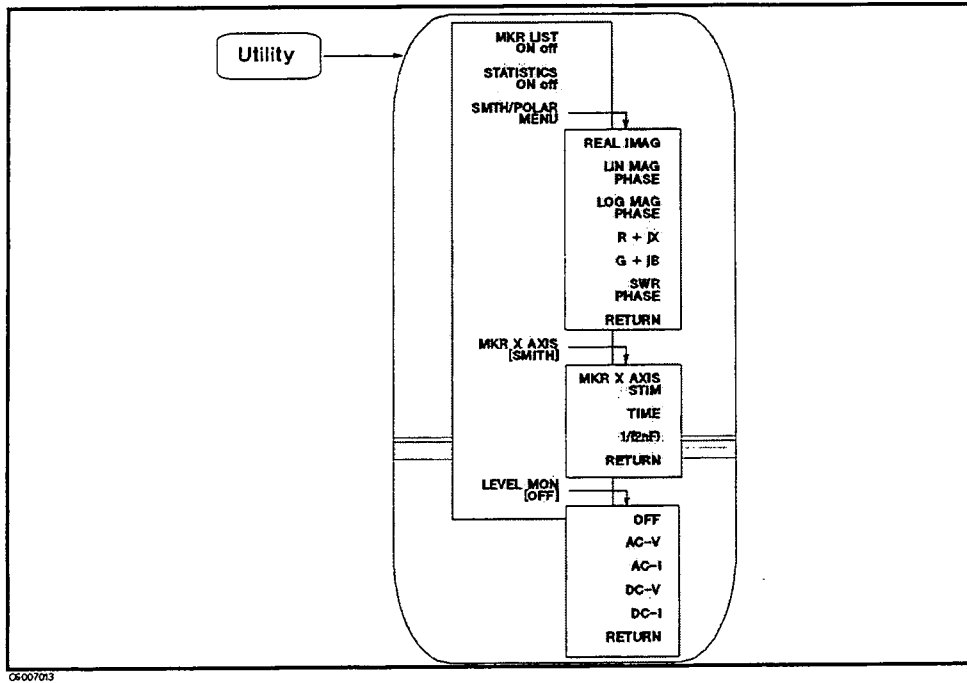


Figure B-21. Softkey Menus Accessed from the Utility Key

Instrument State Block

Local

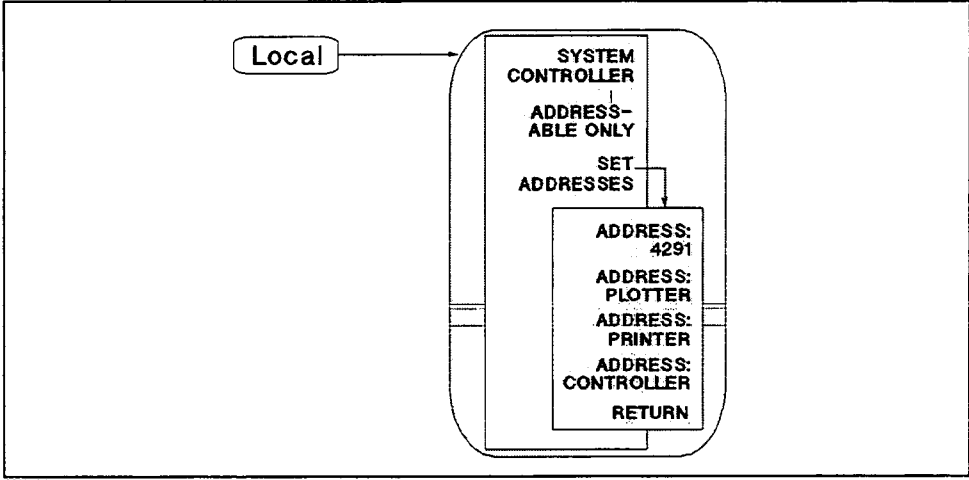
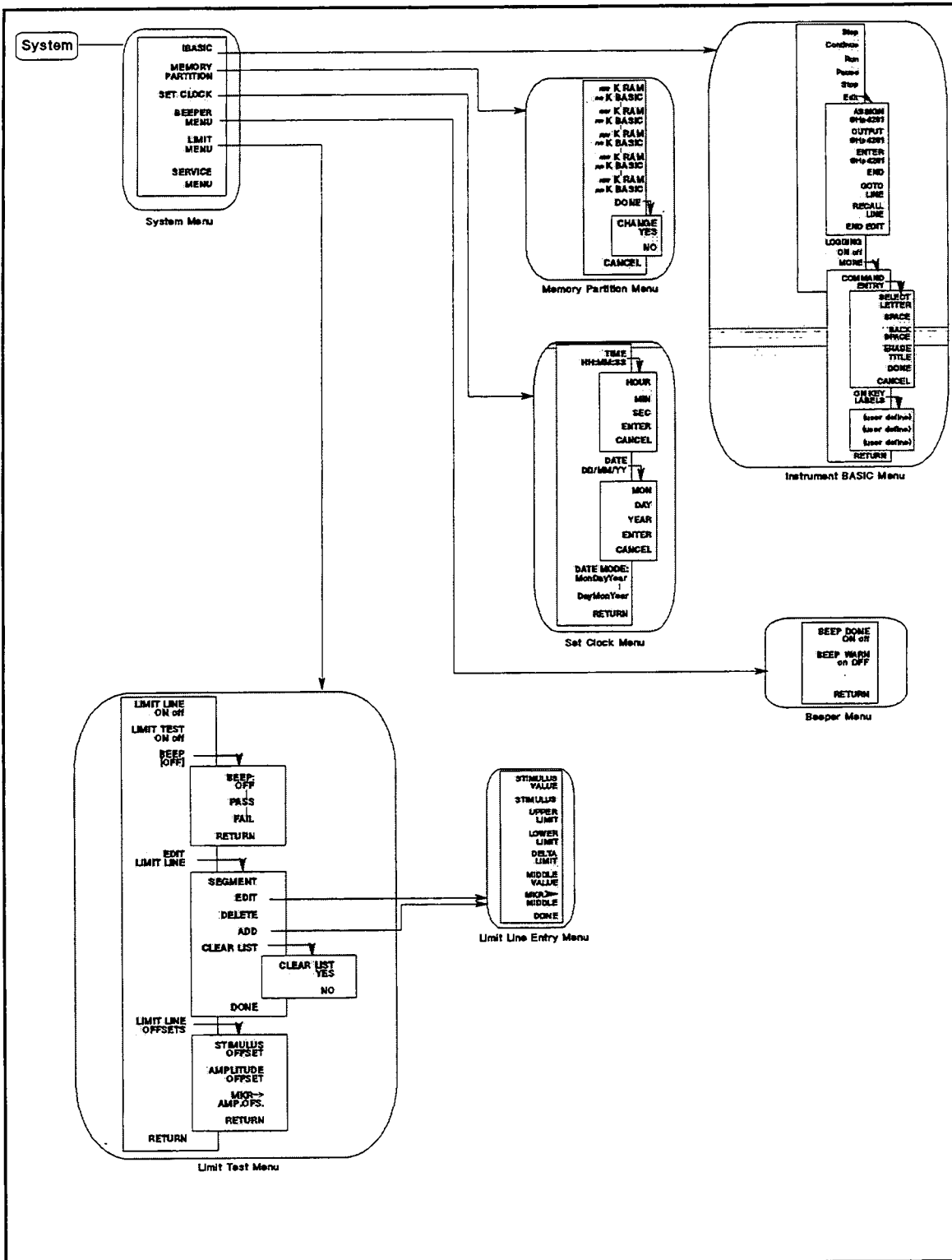


Figure B-22. Softkey Menus Accessed from the Local Key

Instrument State Block : **System**

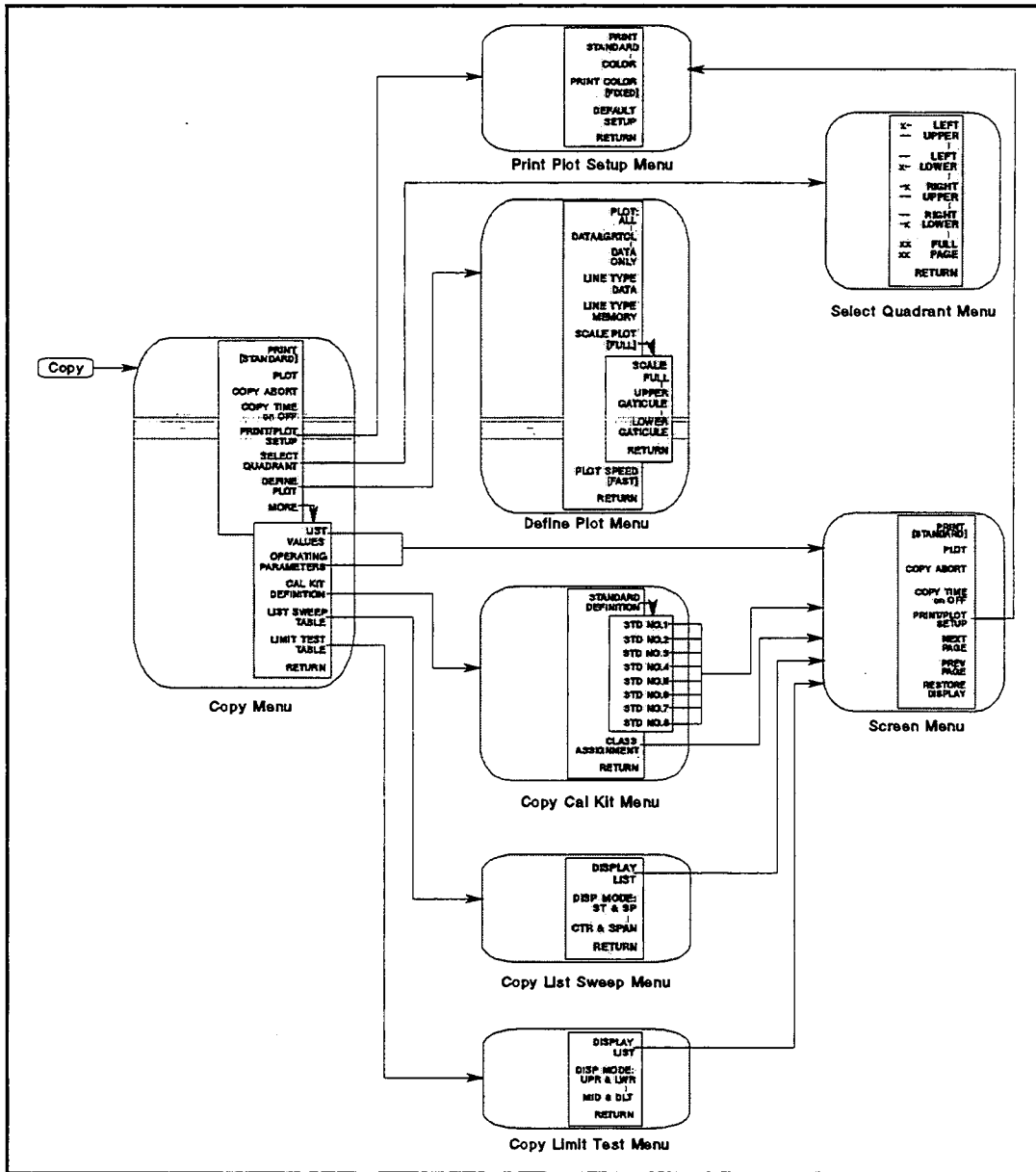
System



C6008037

Figure B-23. Softkey Menus Accessed from the **System** Key

Copy

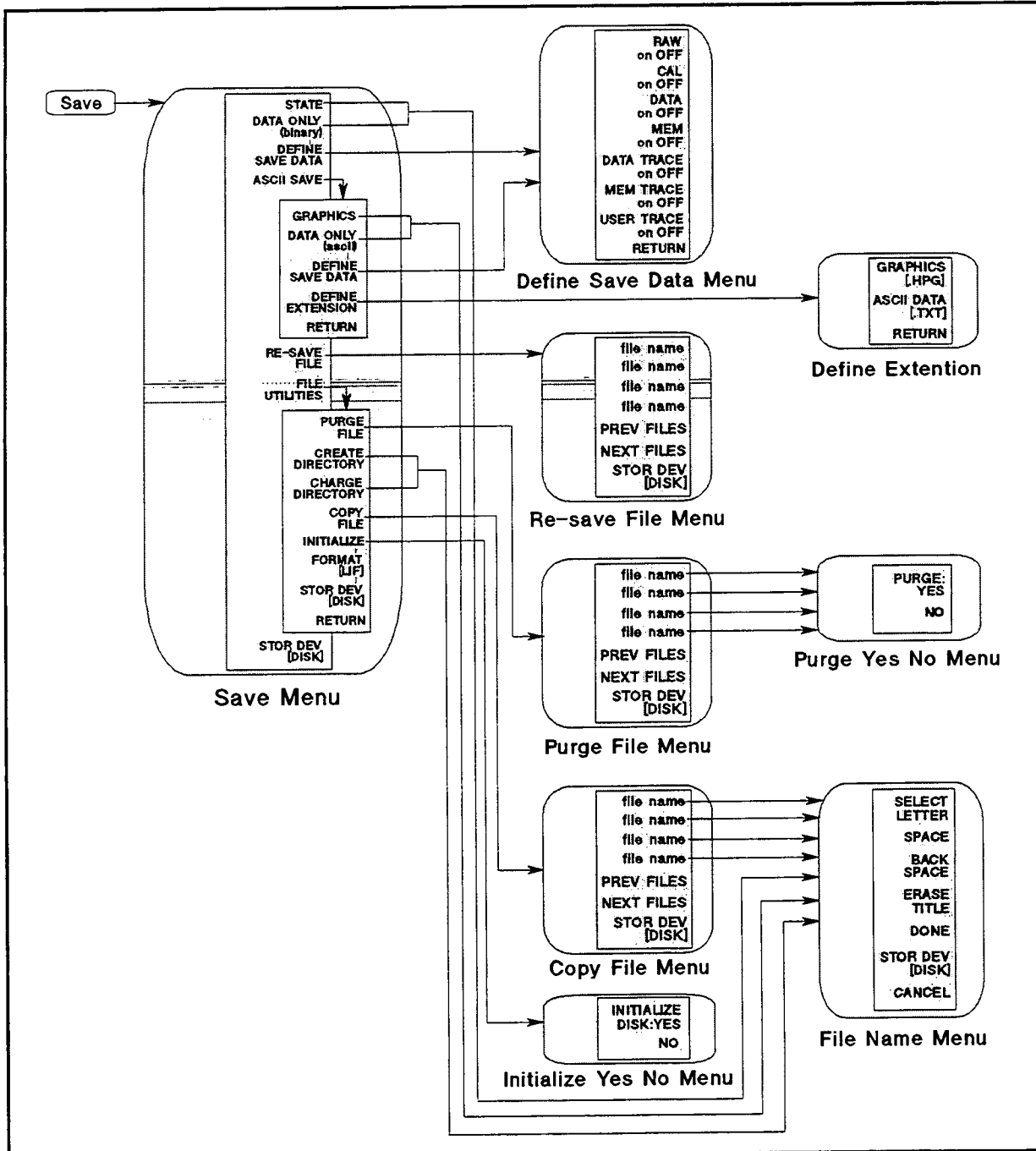


C6008038

Figure B-24. Softkey Menus Accessed from the Copy key

Instrument State Block : **Save** **Recall**

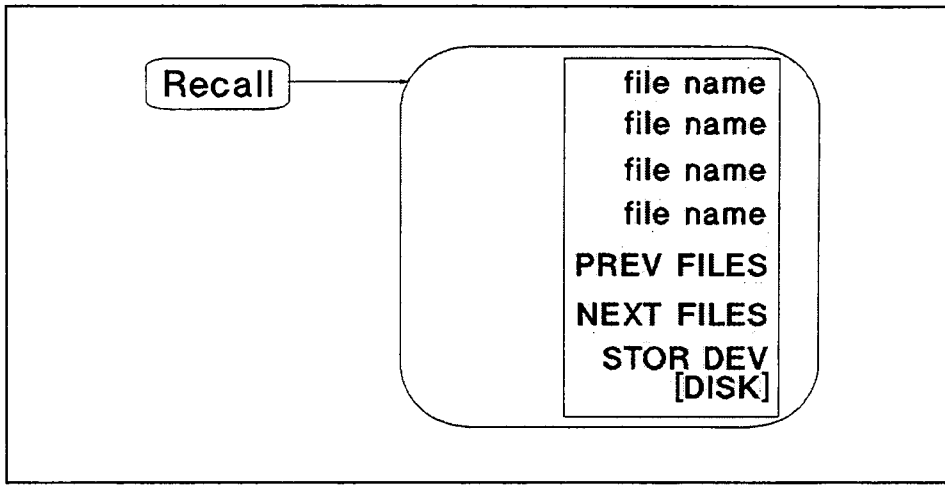
Save



C6008039

Figure B-25. Softkey Menus Accessed from the **Save** Key

Recall



0000029

Figure B-26. Softkey Menus Accessed from the Recall Key

Input Range and Default Setting

When the **Preset** key is pressed or the analyzer is turned ON, the analyzer 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 analyzer 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				
Ch1:Impedance meas.	$|Z|, \theta_z, R, X, |Y|, \theta_y, G, B, |\Gamma|, \theta_\gamma, \Gamma_x, \Gamma_y, C_p, C_s, L_p, L_s, R_p, R_s, D, Q$	$|Z|$	$|Z|$	
Ch2:Impedance meas.	$|Z|, \theta_z, R, X, |Y|, \theta_y, G, B, |\Gamma|, \theta_\gamma, \Gamma_x, \Gamma_y, C_p, C_s, L_p, L_s, R_p, R_s, D, Q$	θ_z	θ_z	
Ch1: ϵ meas.	$|\epsilon|, \tan \delta, \epsilon', \epsilon'', |Z|, \theta_z, R, X, |Y|, \theta_y, G, B, |\Gamma|, \theta_\gamma, \Gamma_x, \Gamma_y, C_p, C_s, L_p, L_s, R_p, R_s, D, Q$	ϵ'	ϵ'	
Ch2: ϵ meas.	$|\epsilon|, \tan \delta, \epsilon', \epsilon'', |Z|, \theta_z, R, X, |Y|, \theta_y, G, B, |\Gamma|, \theta_\gamma, \Gamma_x, \Gamma_y, C_p, C_s, L_p, L_s, R_p, R_s, D, Q$	ϵ''	ϵ''	
Ch1: μ meas.	$|\mu|, \tan \delta, \mu', \mu'', |Z|, \theta_z, R, X, |Y|, \theta_y, G, B, |\Gamma|, \theta_\gamma, \Gamma_x, \Gamma_y, C_p, C_s, L_p, L_s, R_p, R_s, D, Q$	μ'^1	μ'^1	
Ch2: μ meas.	$|\mu|, \tan \delta, \mu', \mu'', |Z|, \theta_z, R, X, |Y|, \theta_y, G, B, |\Gamma|, \theta_\gamma, \Gamma_x, \Gamma_y, C_p, C_s, L_p, L_s, R_p, R_s, D, Q$	μ''^1	μ''^1	
Test Fixture	HP 161191A, 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	

1 After setting material size

Format

Function	Range	Preset Value	Power ON default	Factory Setting
Format	Linear, Log, Polar, Smith, Admittance, Complex	Linear	Linear	
Expanded Phase	ON/OFF	OFF	OFF	
Phase Unit	Degree, Radian	Degree	Degree	

Display

Function	Range	Preset Value	Power ON default	Factory Setting
Dual Chan	ON/OFF	ON	ON	
Split Display	ON/OFF	OFF	OFF	
Define Trace	Data, Memory, Data and Memory	Data	Data	
Select memory trace	1 to 16 (Total NOP of memory traces < 801x3)	1	1	
Data math	Data, Data-Mem, Data+ Mem, Data/Mem	Data	Data	
Gain	-1×10^6 to 1×10^6	1	1	
Offset	-100×10^6 to 100×10^6	0	0	
AUX offset	-100×10^6 to 100×10^6	0	0	
Equivalent Circuit	Circuit A, B, C, D, E, F	A	A	
Equivalent Parameter R ₁	-1×10^{18} to 1×10^{18}	0	0	
Equivalent Parameter L ₁	-1×10^{18} to 1×10^{18}	0	0	
Equivalent Parameter C ₀	-1×10^{18} to 1×10^{18}	0	0	
Equivalent Parameter C ₁	-1×10^{18} to 1×10^{18}	0	0	
Disp EQV param	ON/OFF	OFF	OFF	
Title		null string	null string	
Text	Max 20 Labels	null string	null string	
X position	0 to 545	0		
Y position	0 to 399	0		
Graphic/Memory trace Selection	Graphic, Memory trace	No effect	No effect	Graphics
Frequency Blank	ON	OFF	OFF	
Display Allocation	All instrument, Half/Half, All BASIC, BASIC status	All Instrument	All Instrument	
Intensity	0 to 100 %	No effect	83 %	
Background Intensity	0 to 100 %	No effect	0	
User trace	ON/OFF	OFF	OFF	
User trace headline	Maximum 12 characters	USER TRACE (1-4)	USER TRACE (1-4)	
User trace footnote	Maximum 34 characters	(null string)	(null string)	
X-axis unit	Maximum 4 characters	U	U	
Y-axis unit	Maximum 4 characters	U	U	
X-axis left value	-8×10^9 to 8×10^9	1×10^6	1×10^6	
X-axis right value	-8×10^9 to 8×10^9	1.8×10^9	1.8×10^9	
Y-axis top value	-1×10^{12} to 1×10^{12}	100	100	
Y-axis bottom value	-1×10^{12} to 1×10^{12}	0	0	
X-axis Lin/Log	Linear, Logarithm	Linear	Linear	
Y-axis Lin/Log	Linear, Logarithm	Linear	Linear	
X/Y-axis couple	ON, OFF	ON	ON	

Scale Ref

Scale Ref

Function	Range	Preset Value	Power ON default	Factory Setting
Scale Coupling	Coupling, Uncoupling	Coupling	Coupling	
Reference Position	0 to 10	5	5	
Scale top value (linear scale)				
|Z|, R, R _p , R _s , X	-1×10 ⁹ to 1×10 ⁹	1 MΩ	1 MΩ	
|Y|, G, B	-1×10 ⁹ to 1×10 ⁹	1 S	1 S	
|Γ|, Γ _x	-1×10 ⁹ to 1×10 ⁹	1	1	
Γ _y	-1×10 ⁹ to 1×10 ⁹	5×10 ⁻⁶	5×10 ⁻⁶	
C _p , C _s	-1×10 ⁹ to 1×10 ⁹	1 mF	1 mF	
L _p , L _s	-1×10 ⁹ to 1×10 ⁹	10 H	10 H	
θ	-1×10 ⁹ to 1×10 ⁹	180°	180°	
D	-1×10 ⁹ to 1×10 ⁹	1	1	
Q	-1×10 ⁹ to 1×10 ⁹	1 k	1 k	
Scale bottom value (linear scale)				
|Z|, R, R _p , R _s , X	-500×10 ⁶ to 500×10 ⁶	0 Ω	0 Ω	
|Y|, G, B	-500×10 ⁶ to 500×10 ⁶	0 S	0 S	
|Γ|, Γ _x , Γ _y	-500×10 ⁶ to 500×10 ⁶	-1	-1	
C _p , C _s	-500×10 ⁶ to 500×10 ⁶	0 F	0 F	
L _p , L _s	-500×10 ⁶ to 500×10 ⁶	0 H	0 H	
θ	-500×10 ⁶ to 500×10 ⁶	-180°	-180°	
D	-500×10 ⁶ to 500×10 ⁶	0	0	
Q	-500×10 ⁶ to 500×10 ⁶	0	0	
Scale/Div				
|Z|, R, R _p , R _s , X	1×10 ⁻¹⁵ to 100×10 ⁶	100 kΩ	100 kΩ	
|Y|, G, B	1×10 ⁻¹⁵ to 100×10 ⁶	100 ms	100 ms	
|Γ|, Γ _x , Γ _y	1×10 ⁻¹⁵ to 100×10 ⁶	0.2	0.2	
C _p , C _s	1×10 ⁻¹⁵ to 100×10 ⁶	100 μF	100 μF	
L _p , L _s	1×10 ⁻¹⁵ to 100×10 ⁶	1 H	1 H	
θ	1×10 ⁻¹⁵ to 100×10 ⁶	36°	36°	
D	1×10 ⁻¹⁵ to 100×10 ⁶	0.1	0.1	
Q	1×10 ⁻¹⁵ to 100×10 ⁶	100	100	

Function	Range	Preset Value	Power ON default	Factory Setting
Reference value				
|Z|, R, R _p , R _s , X	-500×10 ⁶ to 500×10 ⁶	500 kΩ	500 kΩ	
|Y|, G, B	-500×10 ⁶ to 500×10 ⁶	500 ms	500 ms	
|Γ|, Γ _x , Γ _y	-500×10 ⁶ to 500×10 ⁶	0	0	
C _p , C _s	-500×10 ⁶ to 500×10 ⁶	500 μF	500 μF	
L _p , L _s	-500×10 ⁶ to 500×10 ⁶	5 H	5 H	
θ	-500×10 ⁶ to 500×10 ⁶	0°	0°	
D	-500×10 ⁶ to 500×10 ⁶	0.5	0.5	
Q	-500×10 ⁶ to 500×10 ⁶	500	500	
Scale top value (logarithm scale)				
|Z|, R, R _p , R _s , X	-1×10 ⁹ to 1×10 ⁹	1 MΩ	1 MΩ	
|Y|, G, B	-1×10 ⁹ to 1×10 ⁹	1 S	1 S	
|Γ|, Γ _x , Γ _y	-1×10 ⁹ to 1×10 ⁹	1	1	
C _p , C _s	-1×10 ⁹ to 1×10 ⁹	1 mF	1 mF	
L _p , L _s	-1×10 ⁹ to 1×10 ⁹	10 H	10 H	
θ	-1×10 ⁹ to 1×10 ⁹	100°	100°	
D	-1×10 ⁹ to 1×10 ⁹	1	1	
Q	-1×10 ⁹ to 1×10 ⁹	1 k	1 k	
Scale bottom value (logarithm scale)				
|Z|, R, R _p , R _s , X	-500×10 ⁶ to 500×10 ⁶	1 Ω	1 Ω	
|Y|, G, B	-500×10 ⁶ to 500×10 ⁶	1 μs	1 μs	
|Γ|, Γ _x , Γ _y	-500×10 ⁶ to 500×10 ⁶	1×10 ⁶	1×10 ⁶	
C _p , C _s	-500×10 ⁶ to 500×10 ⁶	1 μF	1 μF	
L _p , L _s	-500×10 ⁶ to 500×10 ⁶	10 pH	10 pH	
θ	-500×10 ⁶ to 500×10 ⁶	10 μ°	10 μ°	
D	-500×10 ⁶ to 500×10 ⁶	1 μ	1 μ	
Q	-500×10 ⁶ to 500×10 ⁶	1	1	
Reference Position	0 to 10	5	5	
Reference X Value	-500×10 ⁶ to 500×10 ⁶	0	0	
Reference Y Value	-500×10 ⁶ to 500×10 ⁶	0	0	
Scale for	Data, Memory 1 to 16	Data	Data	
Data & Memory Scale	Couple/Uncouple	Couple	Couple	

Bw/Avg Cal

Bw/Avg

Function	Range	Preset Value	Power ON default	Factory Setting
Sweep Averaging	ON/OFF	OFF	OFF	
Sweep Averaging Factor	1 to 999	16	16	
Point Averaging	ON/OFF	OFF	OFF	
Point Averaging Factor	1 to 999	1	1	

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 X	-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 X	-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.

Cal (ε)

Function	Range	Preset Value	Power ON default	Factory Setting
Material size - Thickness	1 μm to 4.8 mm	invalid	invalid	
LOAD ε _r '	-1×10 ⁶ to 1×10 ⁶	not effect	not effect	2.1
LOAD ε _r ''	-1×10 ⁶ to 1×10 ⁶	not effect	not effect	0
LOAD Thickness	0 to 1×10 ⁶ m	not effect	not effect	800×10 ⁻⁶ m

Cal (μ)

Function	Range	Preset Value	Power ON default	Factory Setting
Material size for HP 16454A small				
Inner diameter	3.04 mm to 9 mm	invalid	invalid	
Outer Diameter	3.04 mm to 9 mm	invalid	invalid	
Height	0.01 mm to 3.65 mm	invalid	invalid	
Material size for HP 16454A large				
Inner diameter	3 mm to 21 mm	invalid	invalid	
Outer Diameter	3 mm to 21 mm	invalid	invalid	
Height	0.01 mm to 11.6 mm	invalid	invalid	

Input Range and Default Setting

Sweep Source Trigger

Sweep

Function	Range	Preset Value	Power ON default	Factory Setting
Delay time	0 to 3600 s	0 ms	0 ms	
Trigger delay time	0 to 3600 s	0 ms	0 ms	
Number of points	2 to 801	201	201	
Coupled channel	ON/OFF	ON	ON	
Sweep source	Freq., OSC level, DC-V, DC-I	Frequency	Frequency	
Sweep type	Linear, Log, List	Linear	Linear	
List table		(empty)	(empty)	
List segment	0 to 15	0	0	
Sweep direction	UP/DOWN	UP	UP	

Source

Function	Range	Preset Value	Power ON default	Factory Setting
Osc level	0.2 mV to 1 V	0.5 V	0.5 V	
Osc level unit	Voltage, dBm, Ampere	Volt	Volt	
CW Frequency	1 MHz to 1.8 GHz	500 MHz	500 MHz	
DC BIAS	ON/OFF	OFF	OFF	
Voltage	-40 V to +40 V	0 V	0 V	
Current	-100 mA to 100 mA	2 μ A	2 μ A	
Voltage limit	1 V to 40 V	1 V	1 V	
Current limit	2 mA to 100 mA	2 mA	2 mA	
DC BIAS source	I-constant/V-constant	V-constant	V-constant	

Trigger

Function	Range	Preset Value	Power ON default	Factory Setting
Sweep	Hold, Single, Number of group, Continuous	Continuous	Continuous	
Number of Groups	1 to 999	-	-	
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	

Start, Stop, Center, Span

Function	Range	Preset Value	Power ON default	Factory Setting
Start				
Frequency	1 MHz to 1.8 GHz	1 MHz	1 MHz	
Osc level	0.2 mV to 1 V	200 μ V	200 μ V	
DC-V	-40 V to 40 V	0 V	0 V	
DC-I	-100 mA to 100 mA	0 A	0 A	
Stop				
Frequency	1 MHz to 1.8 GHz	1.8 GHz	1.8 GHz	
Osc level	0.2 V to 1 V	1 V	1 V	
DC-V	-40 V to 40 V	0 V	0 V	
DC-I	-100 mA to 100 mA	0 A	0 A	
Center				
Frequency	1 MHz to 1.8 GHz	900.5 MHz	900.5 MHz	
Osc level	0.2 mV to 1 V	500.1 mV	500.1 mV	
DC-V	-40 V to 40 V	0 V	0 V	
DC-I	-100 mA to 100 mA	0 A	0 A	
Span				
Frequency	0 to 1.799 GHz	1.799 GHz	1.799 GHz	
Osc level	0 to 999.8 mV	999.8 mV	999.8 mV	
DC-V	0 to 80 V	0 V	0 V	
DC-I	0 to 200 mA	0 A	0 A	

Input Range and Default Setting

Marker

Function	Range	Preset Value	Power ON default	Factory Setting
Trace using markers	Data, Memory 1 to 16, User trace 1 to 4	Data	Data	
Marker coupling	Coupling/Uncoupling	Coupling	Coupling	
Marker cont/discont	Continuous/Discontinuous	Continuous	Continuous	
Marker mode	ON/OFF	OFF	OFF	
Fixed Δ marker stimulus value	START to STOP	0	0	
Fixed Δ marker value	-1×10^9 to 1×10^9	0	0	
Fixed Δ marker AUX value	-1×10^9 to 1×10^9	0	0	

Marker→ Search Utility

Marker→

Function	Range	Preset Value	Power ON default	Factory Setting
Zooming aperture	0 to 100 %	10 % of span	10 % of span	
Cross channel	ON/OFF	OFF	OFF	

Search

Function	Range	Preset Value	Power ON default	Factory Setting
Width	ON/OFF	OFF	OFF	
Width value	Fixed, MKRVAL/ $\sqrt{2}$, MKRVAL* $\sqrt{2}$, MKRVAL/2	Fixed	Fixed	
Fixed width value	-100×10^6 to 100×10^6	-3	-3	
Threshold	ON/OFF	OFF	OFF	
Threshold value	-100×10^6 to 100×10^6	-100	-100	
Peak polarity	Positive, Negative	Positive	Positive	
Peak definition Δx				
Frequency	0 to 8×10^9	10 MHz	10 MHz	
OSC level	0 to 8	1	1	
DC-V	0 to 80	10	10	
DC-I	0 to 0.8	0.1	0.1	
Peak definition Δy	0 to 100×10^6	1	1	
Search tracking	ON/OFF	OFF	OFF	
Partial search	ON/OFF	OFF	OFF	
Target value	-100×10^6 to 100×10^6	-3	-3	

Utility

Function	Range	Preset Value	Power ON default	Factory Setting
Marker list	ON/OFF	OFF	OFF	
Statistics	ON/OFF	OFF	OFF	
Marker sweep parameter unit	Stimulus, Time, $1/2\pi f$	Stimulus	Stimulus	
Smith/polar marker	Real-imaginary, Lin magnitude-phase, Log magnitude-phase, $R + jX$, $G + jB$	Real-imaginary	Real-imaginary	

System

Function	Range	Preset Value	Power ON default	Factory Setting
Logging	ON/OFF	No effect	No effect	
Memory partition	64kRAM-448kBASIC, 128kRAM-334kBASIC, 256kRAM-256kBASIC, 284kRAM-128kBASIC, 448kRAM-64kBASIC	No effect	No effect	128kRAM- 334kBASIC
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	
Limit line	ON/OFF	OFF	OFF	
Limit test	ON/OFF	OFF	OFF	
Limit beep	OFF, Path, Fail	OFF	OFF	
Limit segment	1 to 18			
Upper limit	-1×10^9 to 1×10^9	0	0	
Lower limit	-1×10^9 to 1×10^9	0	0	
Delta limit	-1×10^9 to 1×10^9	0	0	
Middle value	-1×10^9 to 1×10^9	0	0	
Stimulus offset				
Frequency	-1.8 GHz to 1.8 GHz	0	0	
OSC level	-1 to 1 V	0	0	
DC-V	-40 to 40 V	0	0	
DC-I	-100×10^{-3} to 100×10^{-3} A	0	0	
Limit line amplitude offset	-1×10^9 to 1×10^9	0	0	

Local

Function	Range	Preset Value	Power ON default	Factory Setting
HP-IB controller mode	System controller/addressable	No effect	No effect	addressable
Address: 4291	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
Print mode	Standard/Color	Standard	Standard	
Copy time	ON/OFF	OFF	OFF	
Print color	Fixed/Variable	Fixed	Fixed	
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	
Limit table display mode	Upper&Lower/Middle&Delt	Upper&Lower	Upper&Lower	
List table display mode	Start&Stop/Center&Span	Start&Stop	Start&Stop	

Save

Function	Range	Preset Value	Power ON default	Factory Setting
Save data definition	Raw, Cal, Data, Memory, Data trace, Memory trace	Data trace, Memory trace	Data trace, Memory trace	
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

Error Messages

This section lists the error messages that are displayed on the analyzer 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).

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 analyzer cannot detect a more specific error.

-168 **Block data not allowed**

A legal block data element was encountered but was not allowed by the analyzer 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.

31 CAN'T CALCULATE EQUIVALENT PARAMETERS

Data is not match to the equivalent circuit and cannot calculate the parameters.

120 CAN'T CHANGE IN LIST SWEEP

When list sweep is selected, the following parameters are not allowed to be changed:

- Stimulus center, span, start, stop
- Number of Point
- OSC level

Modify the list table to change these parameters in the list sweep.

93 CAN'T CHANGE WHILE DUAL CHAN OFF

The cross channel (CALCulate:EVALuate:EFFect:ON 1) cannot be turned on when dual channel is off. Turn on the dual channel before the cross channel is turned on.

74 CAN'T CHANGE- ANOTHER CONTROLLER ON BUS

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

16 CAN'T CHANGE-HIGH TEMP TEST HEAD CONNECTED

You cannot execute CAL POINTS [FIXED] (SENSe:CORRection1:COLLect:FPOints FIXed) or COMP POINT [FIXED] (SENSe:CORRection2:COLLect:FPOints FIXed) when the high temperature test head is connected.

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 analyzer cannot detect a more specific error.

-148 Character data not allowed

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

- 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 analyzer 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 analyzer 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 analyzer received is ignored, because the segment is editing. Send CALCulate:LIMit:SEGMent: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 analyzer 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 analyzer (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.

- 229 **DC BIAS TEST FAILED**
- An “internal test 16: DC BIAS” fails. See the *Service Manual* for troubleshooting.
- 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 [] — MMEemory: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 analyzer 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) chip 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.

95 FREQUENCY SWEEP ONLY

Cannot select MKR X AXIS $[1/(2\pi F)]$ in OSC level sweep, or DC-V/DC-I sweep.

- 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 analyzer. Definition of what constitutes a hardware problem is completely device-specific. This error message is used when the analyzer 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 analyzer 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.
- 248 **HIGH TMP HIGH Z HEAD TEST FAILED**
An "external test 32: HIGH TMP HIGH Z HEAD TEST FAILED" fails. See the *Service Manual* for troubleshooting.
- 249 **HIGH TMP LOW Z HEAD TEST FAILED**
An "external test 33: HIGH TMP LOW Z HEAD TEST FAILED" fails. See the *Service Manual* for troubleshooting.
- 237 **HIGH Z HEAD TEST FAILED**
An "external test 30: HIGH Z HEAD" fails. See the *Service Manual* for troubleshooting.
- 114 **Header Suffix out of range**
The value of a numeric suffix attached to a program mnemonic makes the header invalid.

- 237 **HI Z HEAD TEST FAILED**
An “external test 30: HIGH Z HEAD” fails. See the *Service Manual* for troubleshooting.
- 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 MME~~Mo~~ry:DELe~~te~~ command must have a “_D” or “_S” extension for LIF format, or “STA” or “.DTA” for DOS format.
- 77 **INVALID MATERIAL SIZE**
(For the permeability measurement) The material size definition is wrong. The outer diameter must be larger than the inner.
- 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 analyzer.
- 160 **INVALID X-AXIS VALUE FOR LOG**
User trace cannot be displayed in log scale, because,
■ The right value and left value of the X-axis is same.
■ The X-axis range is defined from – value to + value.
Change the X-axis right/left value.
- 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.

118 LIST TABLE EMPTY OR INSUFFICIENT TABLE

The frequency list is empty. To implement the list frequency mode, add segments to the list table.

238 LO Z HEAD TEST FAILED

An "external test 31: LOW Z HEAD" fails. See the *Service Manual* for troubleshooting.

238 LOW Z HEAD TEST FAILED

An "external test 31: LOW Z HEAD" fails. See the *Service Manual* for troubleshooting.

-250 Mass storage error

A mass storage error occurred. This error message is used when the analyzer cannot detect the more specific errors described for errors -251 through -259.

78 MATERIAL SIZE UNDEFINED

(For the permittivity and permeability measurement) The DONE (MODIFIED key (under **Meas**) MATERIAL SIZE) is pressed or it is attempt to select the measurement parameter key when the material sizes are empty. Define the material size before press these keys.

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.

33 MEM-TRACE MEMORY FULL

Another memory trace cannot be saved because the total NOP of memory traces exceeds (801 × 3).

-311 Memory error

An error was detected in the analyzer'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.

32 **MUST BE MORE THAN 2 POINTS FOR ANALYSIS**

CALCULATE EQV PARAMS (CALCulate:EVALuate:EPARameters) is pressed when the NOP (number of points) is 2. Set the number of measurement points to the number larger than 2.

92 **NO ACTIVE MARKER**

(*HP-IB only*) The marker→ command cannot be execute when no marker is displayed on the screen. Turn on the marker before executing the marker→ commands.

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* .

87 **NO DATA TRACE**

The **MARKER ON [DATA]** (CALCulate:EVALuate:ON1 "TR1") is selected when the data trace is not displayed.

113 **NO DATA TRACE DISPLAYED**

The **SCALE FOR [DATA]** (DISPlay[:WINDow]:TRACe1:Y[:SCALE]) is selected when the data trace is not displayed.

+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.

94 **NO FIXED DELTA MARKER**

The Δ marker cannot move (**AMKR STIMULUS** , **FIXED Δ MKR VALUE** or **FIXED Δ AUX VALUE** —CALCulate:EVALuate:REFErence:{X|Y1|Y2} <numeric> cause the error) because,

- The Δ marker is not turned on. → Turn the Δ marker ON (DISPlay[:WINDow]:TRACe:MARKer:RELative ON).
- The only fixed Δ marker can move by **FIXED Δ MKR VALUE** or **FIXED Δ AUX VALUE** . → Press **FIXED Δ MKR** (DISPlay[:WINDow]:TRACe:MARKer:RELative:REFErence FIXed).

90 NO MARKER DELTA - RANGE NOT SET

The MKRA→SEARCH RNG softkey (CALCulate:EVALuate:BAND:SPAN DMARker) requires that Δmarker is turned ON.

89 NO MARKER DELTA - SPAN NOT SET

The MKRA→SPAN softkey (SENSe:FREQuency:SPAN DMARker, or SOURce{1|2}:{VOLTage|CURRent}:SPAN DMARker') requires that the Δmarker mode be turned ON.

88 NO MEMORY TRACE

The MARKER ON [MEMORY] (CALCulate:EVALuate:ON1 "TR{2-17}") is selected when the memory trace is not displayed.

114 NO MEMORY TRACE DISPLAYED

The SCALE FOR [MEMORY] (DISPlay[:WINDow]:TRACe{2-17}:Y[:SCALE]) is selected when the memory trace is not displayed.

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.

30 NO VALID MEMORY TRACE

If memory traces are to be displayed or otherwise used, a data trace must first be stored to memory.

159 NO VALID USER TRACE

The marker cannot be used in user trace because the selected user trace is OFF.

- 14 **NOT ALLOWED IN DC BIAS SWEEP**
- The calibration **CAL POINTS [USER]** (**SENSe:CORRection1:COLLect:FPOints USER**) or compensation in **COMP POINT [USER]** (**SENSe:CORRection2:COLLect:FPOints USER**) cannot be executed in the DC-V/DC-I sweep.
- 121 **NOT ALLOWED IN FREQUENCY SWEEP**
- SWEEP DIR []** (**SOURce{1|2}:SWEep:DIRection DOWN**) is pressed in frequency sweep. Sweep direction down is only available for OSC level sweep, DC-V, or DC-I sweep.
- 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.
- 79 **NOT AVAILABLE FOR THIS FORMAT**
- (For the permittivity and permeability measurement)
You cannot execute **POLAR CHART**, **SMITH CHART**, and **ADMITTANCE CHART (DISPlay[:WINDow]:TRACe1:GRATicule:FORMat {POLar|SMITH|ADMittance})**.
- 47 **NOT ENOUGH DATA**
- (*HP-IB only*) The amount of data sent to the analyzer 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 analyzer cannot detect a more specific error.
- 128 **Numeric data not allowed**
- A legal numeric data element was received, but the analyzer does not accept it in this position for a header.
- 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 analyzer is not installed the option. Please confirm options installed to the analyzer using *OPT? command (see Chapter 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 analyzer 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 analyzer and the plotter. Ensure that the plotter address recognized by the analyzer 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.

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- 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.
- 231 **POWER SWEEP LINEARITY TEST FAILED**
An "external test 19: POWER SWEEP LINEARITY" fails. 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 analyzer and the printer. Ensure that the printer address recognized by the analyzer 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 analyzer 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 analyzer cannot continue.
- 400 **Query errors**
This is the generic query error that the analyzer 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 analyzer 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 analyzer 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.

- 68 **SEGMENT START/STOP OVERLAPPED**
Segments are not allowed to be overlapped. Reenter appropriate value for start or stop value of segments to avoid that segment is not overlapped.
- 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 analyzer cannot detect a more specific error.
- 158 **String data not allowed**
A string data element was encountered but was not allowed by the analyzer 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 analyzer 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 analyzer was not expecting to receive a string.
- 310 **System error**
Some error, termed "system error" by the analyzer, 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 line table is 18.
- 69 **TOO MANY SEGMENTS OR POINTS**
Frequency list mode is limited to 15 segments or 801 points.
- 223 **Too much data**
A legal program data element of block, expression, or string type was received that contained more data than the analyzer 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 analyzer when the data transfer format is binary, or the amount of data is greater than the number of points.
- 70 **TOO SMALL POINTS OR TOO LARGE STOP**
STOP + SPAN / (NOP - 1) is out of sweep range. Increase NOP or change STOP value to lower frequency to avoid this error.
- 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 analyzer 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 analyzer but was ignored because of analyzer timing considerations. For example, the analyzer was not ready to respond.
- 113 **Undefined header**
The header is syntactically correct, but it is undefined for the analyzer. For example, *XYZ is not defined for the analyzer.
- 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.

Index

Special characters

$\Delta L.F$, 7-23
 $\Delta R.F$, 7-23
 $\Delta mode$, 7-22
 ΔX , 7-27
 ΔY , 7-27
* , 2-7
⏴ , 4-2
⏵ , 4-2
-0 , 2-7
↑ , 2-7
x1 , 4-2

A active channel, 3-2
active channel , 2-4
active channel block, 1-4
active channel block , 3-1
active entry area , 2-8
AD converter, 9-3
addressable , 8-44
addressable only , 8-16
address setting , 8-16
adjust display , 5-42
ADJUST DISPLAY , 5-35
Admittance, 11-4
APC-7 , 2-17
ascii save , 8-30
AUTOREC , 8-37, 8-49
auto recall , 8-37, 8-49
auto scaling , 5-49
aux offset , 5-39
averaging , 5-52, 9-4
averaging factor , 5-52
averaging ON Avg , 2-7
Avg , 2-7

- B** B, 11-4
background intensity , 5-42
Back Space , 4-3
BACK SPACE , 5-46
BASIC , 8-4
BASIC draw , 5-36
BASIC screen , 5-36
battery backup, C-1
beeper , 8-4
block , 1-1
block diagram , 9-1
brightness , 5-44
Bus , 2-7
bus trigger , 6-12
BW, 7-23
Bw/Avg , 1-5
- C** C, 11-4
C! , 2-7
C+ , 2-7
C+ , 2-7
C+! , 2-7
C+? , 2-7
C? , 2-7
Cal , 1-5
calibration , 5-55
calibration coefficient arrays , 9-4
calibration coefficients arrays , 8-47
cal kit , 1-2
calkit , 5-60
cal points , 5-55
Capacitance, 11-4
cent, 7-23
Center , 1-5
center value , 2-6
Ch 1 , 3-2
Ch 2 , 3-2
channel coupling , 6-4
circuit model, 11-6
clear markers, 7-5
clock , 8-4
Cm! , 2-7
Cm? , 2-7
Cmp, 2-7
CMP, 2-7
CD+ , 2-7
color , 5-44
color printer , 8-20
color reset , 5-44
compen kit , 5-62
compensation coefficient arrays , 9-5
compensation points , 5-57
complex permeability , 11-30
complex permittivity , 11-26

complex plane , 5-30
Conductance, 11-4
connectors , 2-9
continuous marker, 7-5
continuous mode, 7-22
controller , 8-43
controller address , 8-16
Copy , 1-6, 8-19
copy abort , 8-28
copy time ON OFF , 8-28
Cor , 2-7
COR , 2-7
coupling channel , 6-4
coupling channels , 3-2
Cpl, 2-5
cross channel, 7-10
CROSS CHAN on OFF , 7-10
crt , 2-4
cw freq , 6-10
cw frequency , 2-6

D D*M , 2-7
data arrays , 8-47, 9-5
data math , 5-34, 5-38, 9-6
data math gain ON G* , 2-7
data math offset ON -0 , 2-7
data math ON D-M, D+M, D/M, Hld , 2-7
DATA & MEMORY , 5-33
data only, 8-47
data processing , 9-2
DATA→MEMORY , 5-33
Data-Trace arrays , 8-47
data trace arrays , 9-6
dc bias , 6-10
dc bias option , 10-1
D (Dissipation Factor), 11-4
default color, 5-44
default colors , 5-43
default gain offset , 5-39
delay time , 6-4
 Δ marker , 7-6
 Δ marker, 7-6
 Δ marker→funciton , 7-10
 Δ MKR SWP PARAM , 7-7
 Δ mode , 7-22
delta mode ON OFF, 7-7
digital filter, 9-3
disc, 10-5
discrete marker, 7-5
discrete mode, 7-22
disk capacity , 8-46
disk format , 8-46
display , 2-4, 5-33
Display , 1-5

display adjustment , 5-42
display allocation , 5-33, 5-36
DATA MATH , 5-35
DISPLAY: DATA , 5-33
display limit table , 8-27
display list sweep table , 8-27
D+M , 2-7
D/M , 2-7
D-M, 2-7
dual channel , 5-33
dual parameter setting , 5-12

E edge effect , 11-27
entry block , 4-1
Entry Off , 4-3
equivalent circuit , 5-40
equivalent circuit model, 11-6
ERASE TITLE , 5-46
error message, Messages-1
expanded phase ON OFF , 5-30
Ext , 2-7
external program run/cont input , 2-10
external reference, 2-7
external reference input , 2-9
external trigger , 6-12
external trigger input , 2-10

F factory setting, C-1
fast sweep indicator ↑ , 2-7
file name , 8-48
fixed cal points , 5-55
fixed compensation points , 5-57
fixed delta marker , 7-7
FIXED ΔMKR AUX VALUE , 7-7
FIXED ΔMKR VALUE , 7-7
fixed Δmarker, 7-7
fixture compensation , 5-57, 5-58, 5-59
fixture compensation coefficient arrays , 9-5
fixture setting , 5-14
fixture stand , 1-3
flexible disk drive , 2-3
footnote , 5-48
format , 5-30, 9-6
Format , 1-4
frequency base , 6-8
frequency blank , 5-35
front panel , 2-1

- G**
 - G, 11-4
 - gain, 5-39
 - gain , 5-38
 - G* , 2-7
 - G+jB , 7-20
 - $\frac{G}{n}$, 4-2
 - G&0 , 2-7
 - graphics, 8-47
 - graphics , 5-36
 - graphics save , 8-30
 - graticule on off , 5-35

- H**
 - handle kit option , 10-2
 - headline , 5-48
 - heat sink , 2-14
 - height , 5-29
 - high impedance test head , 1-2
 - high impedance test head delete option , 10-1
 - high stability frequency reference add option , 10-2
 - high temperature high impedance test head , 1-3
 - high temperature high impedance test head add option , 10-1
 - high temperature low impedance test head , 1-3
 - high temperature low impedance test head add option , 10-1
 - H1d , 2-7
 - HP 10833A hp-ib cable(1 m), 10-5
 - HP 10833B hp-ib cable(2 m), 10-5
 - HP 10833C hp-ib cable(3 m), 10-5
 - HP 10833D hp-ib cable(0.5 m), 10-5
 - HP 16091A coaxial termination fixture set , 10-3
 - HP 16092A spring clip test fixture , 10-3
 - HP 16093A/B binding post test fixtures , 10-4
 - HP 16094A probe test fixture , 10-4
 - HP 16191A Component test fixture , 1-2
 - HP 16191A side electrode SMD test fixture , 10-3
 - HP 16192A Component test fixture , 1-2
 - HP 16192A parallel electrode SMD test fixture , 10-3
 - HP 16193A Component test fixture , 1-2
 - HP 16193A small side electrode SMD test fixture , 10-3
 - HP 16194A high temperature component fixture , 10-3
 - HP 16194A High temperature component test fixture , 1-3
 - HP 16453A dielectric material test fixture , 10-3
 - HP 16453A Dielectric material test fixture , 1-3
 - HP 16454A Magnetic material test fixture , 1-3, 10-3
 - HP 2227B QuietJet printer, 10-4
 - HP 3630A Paint Jet color printer , 10-4
 - HP 4291U upgrade kit, 10-2
 - HP 7440A ColorPro color graphics plotter, 10-4
 - HP 7475A graphics plotter, 10-4
 - HP 7550B graphics plotter, 10-4
 - HP 85043B system rack , 10-4
 - HP 92192A micro flexible disks, 10-5
 - HP 92192X micro flexible disks, 10-5
 - HP-IB , 8-42
 - HP-IB address , 8-16, 8-45

hp ibasic add option , 10-2
hp-ib cable, 10-5
HP-IB interface , 2-10

I IBASIC , 5-43
I↓, 2-7
Impedance, 11-3
 Parameters, 11-3
impedance measurement , 5-9, 5-12
initialize, C-1
inner diameter , 5-29
instrument BASIC , 8-4
Instrument data arrays , 8-47
instrument state block , 1-6
Instrument states and internal data arrays , 8-47
intensity , 5-42
internal reference output , 2-10
introduction , 1-1
i/o port , 2-10, 2-11
i/o port pin assignment , 2-11
I-V method , 11-12

K key
 Back Space , 4-3
 ↓, 4-2
 ↑, 4-2
 Ch 1 , 3-2
 Ch 2 , 3-2
 Entry Off , 4-3
 G/n , 4-2
 k/m , 4-2
 M/μ , 4-2
 terminator key , 4-2
 x1 , 4-2
keyboard connector , 2-10
k/m , 4-2
knob , 4-2

L L, 11-4
label , 5-35, 5-45
left peak, 7-15
level monitor , 2-5, 6-11
LIF (logical inter change format) , 8-46
limit line concept , 8-38
limit test , 8-11
linear sweep , 6-5
line switch , 2-3
listener , 8-43
list sweep , 6-5
list values , 8-21
Local , 1-6, 8-16
logging ON OFF , 8-6
log sweep , 6-5

loss, 7-23
low impedance test head , 1-2
low impedance test head add option , 10-1
low-loss air-capacitor calibration , 11-12

M main frame , 1-2
man , 2-7
manual changes, A-1
manual trigger , 6-12
marker, 7-21
 coupled maker , 3-2
marker , 7-4
 Marker , 1-5, 7-3
marker block , 1-5
marker coupling, 7-5
marker data readout , 2-5
marker list, 7-20
marker→ , 7-8
marker search, 7-23
marker statistics , 2-5
marker time mode , 7-21
 Marker→ , 1-5
material measurement firmware option , 10-1
material size , 5-22, 5-29
Max, 2-5
MAX , 7-12
max search, 7-12
 Meas , 1-4
 Meas , 5-3
measured input , 2-5
measurement block, 1-4
measurement block , 5-1
measurement circuit , 11-12
measure restart , 6-13
memory arrays , 8-47, 9-5
memory partition , 8-4
memory trace , 5-33, 5-36
memory trace arrays , 8-47, 9-6
memory trace number , 5-34
menu , 2-2
message area, 2-8
Min, 2-5
MIN , 7-12
min search, 7-12
MKRA→CENTER , 7-10
MKRA→SEARCH RNG , 7-16
MKRA→SPAN , 7-10
MKR→REFERENCE , 7-10
MKR→CENTER , 7-10
MKR→LEFT RNG , 7-16
MKR→PEAK DELTA , 7-14

MKR→RIGHT RNG , 7-16
MKR→START , 7-10
MKR→STOP , 7-10
MKR→THRESHOLD , 7-14
MKR ZOOM , 7-10
(M/μ), 4-2
modify colors , 5-42
modify compen kit , 5-62, 5-64
mounting post , 2-13
mounting screw, 2-13

N next peak, 7-15
NEXT PEAK (SEANPK), 7-15
NEXT PEAK LEFT (SEANPKL), 7-15
NEXT PEAK RIGHT (SEANPKR), 7-15
non-volatile memory, C-1
nop , 6-4
notations , 2-7
number of points , 6-4
numeric keypad , 4-2

O offset , 5-38
option 001 add dc bias , 10-1
option 002 add material measurement firmware , 10-1
option 011 delete high impedance test head , 10-1
option 012 add low impedance test head , 10-1
option 013 add high temperature high impedance test head , 10-1
option 014 add high temperature low impedance test head , 10-1
option 0BW add service manual , 10-2
option 1C2 , 2-10
option 1C2 add hp ibasic , 10-2
option 1D5 , 2-9, 2-10
option 1D5 add high stability frequency reference , 10-2
options available , 10-1
order base , 6-8
osc level , 6-10
outer diameter , 5-29

P parallel circuit model, 11-6
Parallel Resistance, 11-4
PART SRCH on OFF , 7-16
pass/fail , 2-5
Peak, 2-5
PEAK (SEAM PEAK), 7-15
PEAK→CENTER , 7-10
peak definition, 7-27
PEAK DEF MENU , 7-12
peak delta, 7-14
PEAK DELTA: ΔX , 7-14

PEAK DELTA: ΔY , 7-14
Peak menu , 7-14
PEAK PLRTY POS neg , 7-14
peak polarity, 7-14
peak polarity , 7-27
PEN , 5-43
pen color , 5-43
permeability measurement , 5-23, 11-29
permittivity measurement , 5-17, 11-26
phase unit , 5-30
plotter, 10-4
plotter address , 8-16
POINT AVG FACTOR , 5-52
POINT AVG on OFF , 5-52
port extension , 5-66, 9-5, 11-16
power , 2-10
power level , 2-6
Preset , 1-6, 2-3, 8-18
preset marker , 7-5
preset state, C-1
printer, 10-4
printer address , 8-16
print standard , 8-23

Q Q, 7-23
Q (Quality Factor), 11-4
quadrant , 8-21

R R, 11-3
rack mount and handle kit option , 10-2
rack mount kit option , 10-2
RAM disk , 8-46
raw data arrays , 8-47, 9-4
Reactance, 11-3
rear panel , 2-9
Recall , 1-6, 8-37
recall color , 5-43
recall file , 8-37
recharge time, C-1
reference level , 2-5
reference oven output , 2-10
reference position , 5-49
reference value , 5-49
relaxation time , 7-20
REMOTE indicator , 2-3
Resistance, 11-3
right peak, 7-15
 $R+jX$, 7-20
 R_p , 11-4
 R_s , 11-3
run/cont input , 2-10

S **Save** , 1-6, 8-29
 save color , 5-43
SAVE COLORS , 5-43
 scale coupling , 5-50
 scale/div , 2-5
 scale for data , 5-50
 scale for memory , 5-50
 scale per div , 5-49
Scale Ref , 1-5
 scale reference , 5-49
 scaling , 9-6
 screen display , 2-4
 search, 7-23
Search , 1-5
SEARCH LEFT (SEAL), 7-13
 search menu , 7-12
SEARCH: PEAK , 7-12
 search range, 7-16
SEARCH RANGE MENU , 7-12
 search range menu , 7-16
SEARCH RIGHT (SEAR), 7-13
SEARCH TRK on OFF , 7-12
 segment , 6-7, 8-38
SEL'D UTRC ON off , 5-47
SELECT LETTER , 5-46
 serial number, A-2
 series circuit model, 11-6
 service manual add option, 10-2
 service menu , 8-4
 Smith polar marker , 7-20
 smth/polar menu , 7-20
Source , 1-5, 6-10
SPACE , 5-46
Span , 1-5
 span value , 2-6
 split display , 5-33
 standard model , 5-61
Start , 1-5, 6-14
 start value , 2-6
 state, 8-47
 statistics ON OFF , 7-20
 status notations , 2-7
 step key , 4-2
 stimulus block , 1-5
Stop , 1-5
 stop value , 2-6
 storage devices , 8-46
 sub marker , 7-5
SUB MKR , 7-13
 Susceptance, 11-4
 Svc, 2-7
Sweep , 1-5, 6-3

SWEEP AVG FACTOR , 5-52
SWEEP AVG ON off , 5-52
SWEEP AVG RESTART , 5-52
sweep direction , 6-5
sweep hold , 6-12
sweep time , 6-4
sweep type , 6-5
System , 1-6
System , 8-3
system accessory, 10-4
system controller , 8-16, 8-43, 8-44
system overview , 1-2, 9-1
system rack, 10-4

T talker , 8-42
Targ, 2-5
TARGET , 7-12
TARGET (SEATARG), 7-13
target menu , 7-13
target search, 7-12
teflon , 5-64
terminator key , 4-2
test head , 2-15
test station , 1-2, 2-13, 2-14
test station connector , 2-3
TEXT MARKER , 5-43
 θ , 11-3
thickness , 5-22
threshold , 7-14
THRESHOLD on OFF , 7-14
threshold value, 7-27
THRESHOLD VALUE , 7-14
time stamp , 8-28
tint , 5-44
title , 2-8, 5-35, 5-46
tracking delta marker , 7-6
TRACKING Δ MKR , 7-7
Trigger , 1-5, 6-12
trigger event , 6-13
trigger input , 2-10
trigger signal polarity , 6-13

U upgrade kit, 10-2
user defined cal points , 5-55
user defined compensation points , 5-57
user kit , 5-64
user trace , 5-47
user trace format , 5-31
user trace scale , 5-51
Utility , 1-5
utility menu , 7-19

V $V\downarrow$, 2-7

W width function, 7-17
width search, 7-23
width value , 2-5

X X, 11-3

Y |Y|, 11-4
 \dot{Y} , 11-4

Z |Z|, 11-3
 \dot{Z} , 11-3
ZOOMING APERTURE , 7-10

Temperature Coefficient Measurement

Introduction

Hewlett-Packard provides a high temperature test head, a high temperature fixture, and temperature coefficient measurement software to achieve an efficient and highly reliable method for evaluating temperature characteristics.

The temperature coefficient measurement software can control a temperature chamber through HP-IB, and measures the temperature characteristic and the time characteristic under constant temperature conditions. After the measurement, HP 4291A can display the measurement results on the screen. Further more, because the measurement results are saved as ASCII text, they are easy to read using the spreadsheet software or the editor software of a personal computer.

The other features are as follows:

- *High Temperature Test Head* that can be used within the range of $-55\text{ }^{\circ}\text{C}$ to $200\text{ }^{\circ}\text{C}$, maintaining high accuracy.
- *High Temperature Test Fixture* that simplify DUT connection.

Tabai Espec Temperature Chamber SU-240-Y is designed to integrated easily with HP 4291A.

- *HP-IB* as standard
- *Measuring Port* eliminating the needs to create additional measurement cables access hole.
- *Thermocouple* for measurement of temperature around the DUT

You can use a chamber other than the Tabai Espec SU-240-Y by modifying this program for that temperature chamber. Refer to "Using Another Chamber" for that modification.

Warning



The high temperature test head, HP 16194A, HP 16453A, and HP 16454A has the capability for $-55\text{ }^{\circ}\text{C}$ to $200\text{ }^{\circ}\text{C}$ temperature measurement in environmental testing. Use globes to prevent scalding when handling heated parts.

Setup and Installation Guide

This section provides the information necessary to set up your analyzer and temperature chamber.

Required Equipment

To perform all the steps in this quick start, the following equipment is required:

- HP 4291A RF Impedance/Material Analyzer with option 1C2
- HP-HIL Keyboard (Included with option 1C2)
- Test Head
 - High Temperature High-impedance Test Head (option 013), or
 - High Temperature Low-impedance Test Head (option 014)
- Fixture Stand (HP PN 04291-60121, included with option 013 or 014)
- Pad (HP PN 04291-09001, included with option 013 or 014)
- Temperature Coefficient Measurement Program Disk (HP PN 04291-61003, included with option 013 or 014)
- Calibration Kit (included with HP 4291A)
- Test Fixture
 - HP 16194A High Temperature SMD Fixture, or
 - HP 16453A Dielectric Material Test Fixture, or
 - HP 16454A Magnetic Material Test Fixture
- Chamber (Tabai Espec Chamber SU-240-Y)
- Test Station Stand (Tabai Espec TSS4291A)
- Blank Diskette (2HD is recommended, HP PN 9164-0299)

Note



Copy the files in the furnished Temperature Coefficient Program disk to a blank diskette. Use the copied diskette for daily use and keep the original disk in a safe place.

Equipment Setup Figure 1-1 shows the equipment setup.

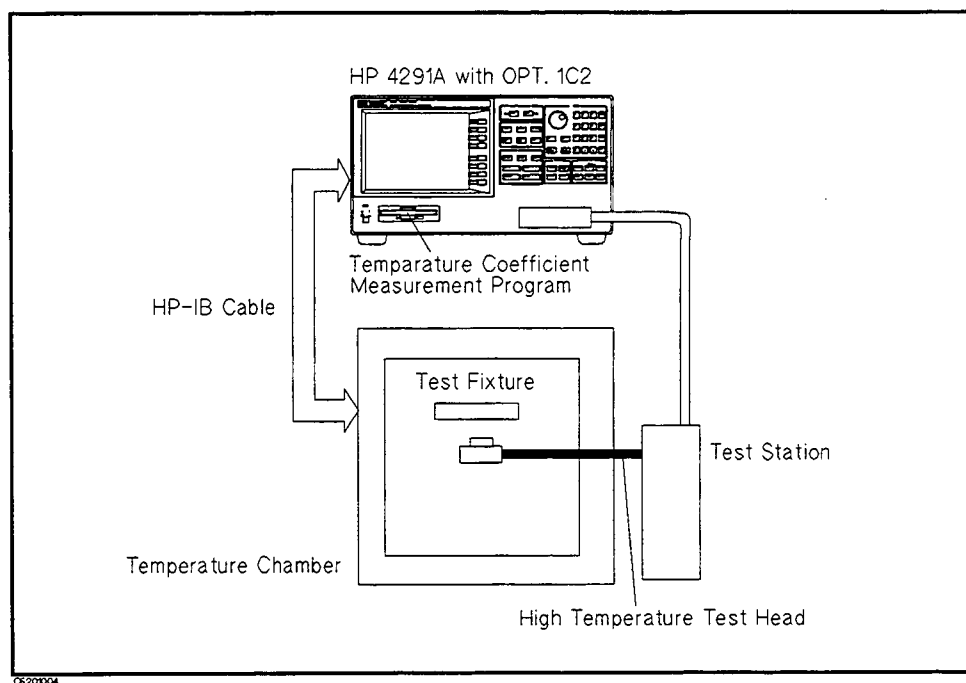


Figure 1-1. Equipment Setup

Figure 1-2 shows the test head and test stand setup.

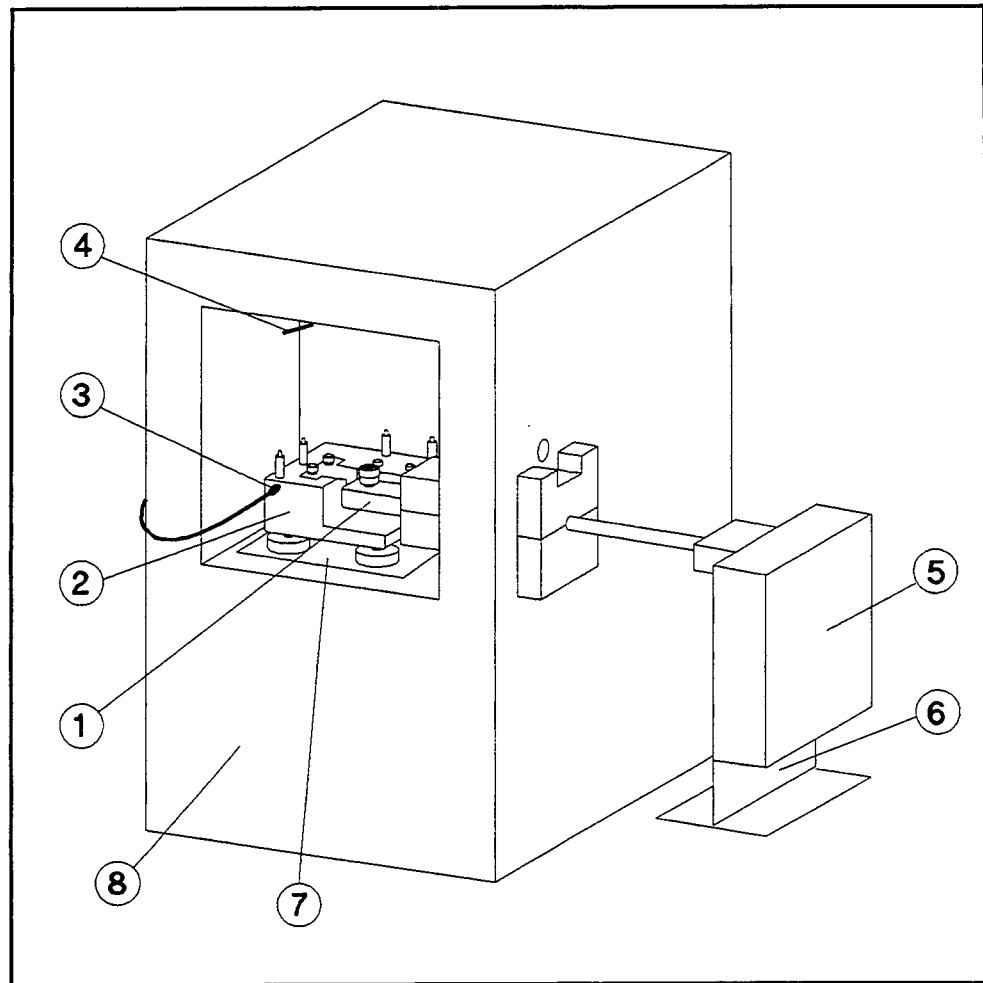


Figure 1-2. Test Head and Test Stand Setup

- ① High Temperature Test Head
- ② Fixture Stand
- ③ Specimen Temperature Sensor
- ④ Chamber Temperature Sensor
- ⑤ Test Station
- ⑥ Test Station Stand
- ⑦ Pad
- ⑧ Temperature Chamber

The Tabai Espec temperature chamber SU-240-Y has two kinds of temperature sensor, a chamber temperature sensor and a specimen temperature sensor. The specimen temperature sensor should be placed near the DUT. The temperature/humidity in the chamber is controlled by monitoring the chamber temperature sensor. The data

saved to the diskette as measurement results is monitored by the specimen temperature sensor.

Put the pad under the fixture stand to prevent the fixture stand from sliding.

Quick Start

This section provides a quick start guide for the temperature coefficient measurement. After performing this quick start, you can read the impedance and capacitance measurement results at the selected frequency/OSC level points for several temperature/humidity settings.

The analyzer and temperature setups are shown in Table 1-1 and Table 1-2.

The Tabai Espec temperature chamber (SU-240-Y) does not have the capability of humidity control, however, the program can control the chamber which has the capability of humidity control. If a chamber does not have the capability of humidity control, the program recognizes it automatically and ignores the humidity settings. When you use the SU-240-Y, skip the humidity setting in this quick start.

Table 1-1. Analyzer Setup Example

	Setup A	Setup B
Measurement Parameter	$|Z| - \theta$	Cp - D
Sweep Parameter	Frequency	OSC Level
Measurement Point	120 MHz, 200 MHz	300, 350, 400, 450 mV
OSC/CW Frequency	300 mV	200 MHz
Point Averaging	5	OFF

Table 1-2. Temperature Chamber Setup Example

Measurement Temp. Point (Humidity)	10 (30), 20 (35), 30 (40), 40 (45), 50 °C (50 %)
Waiting Time ¹	5 min.
Repeat Type	A
Number of Repeat	2

¹ The program pauses the measurement for the required waiting time after the temperature reaches the specified value.

Figure 1-3 shows the graph in the format of temperature/humidity vs. time for the temperature chamber setup (Table 1-2).

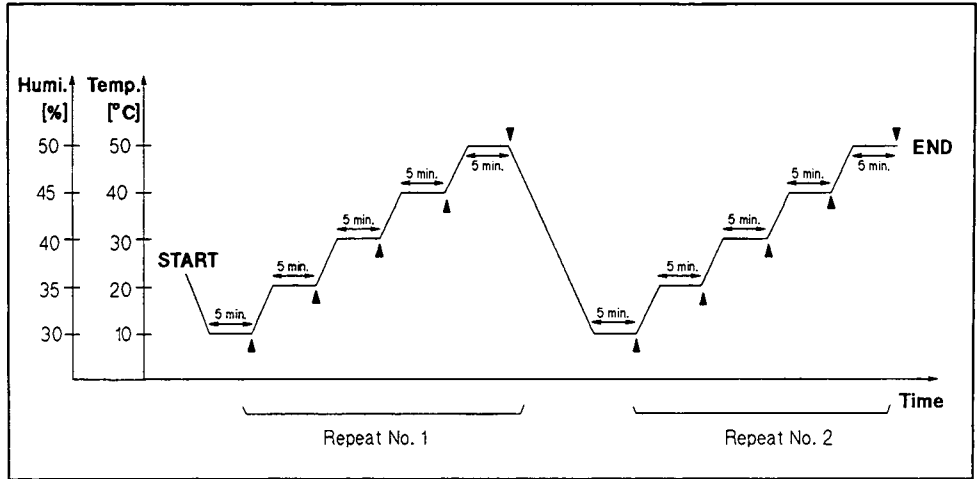


Figure 1-3. Chamber Setup Example

This program provides two kind of repeat type, A and B as shown in Figure 1-4.

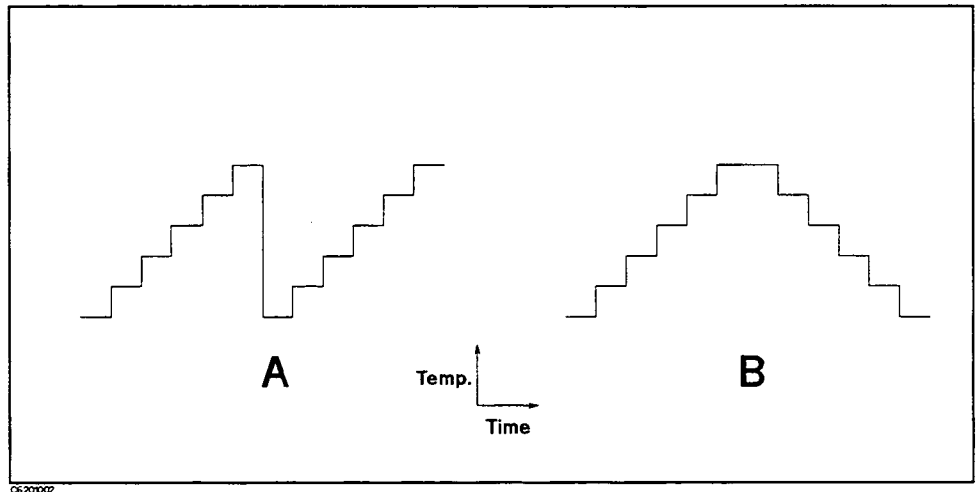


Figure 1-4. Repeat Type A and B

Measurement Flow

Figure 1-5 shows the basic measurement flow of the temperature coefficient measurement. The tasks of measurement set up, measurement, and displaying results are performed using the program named "MAIN".

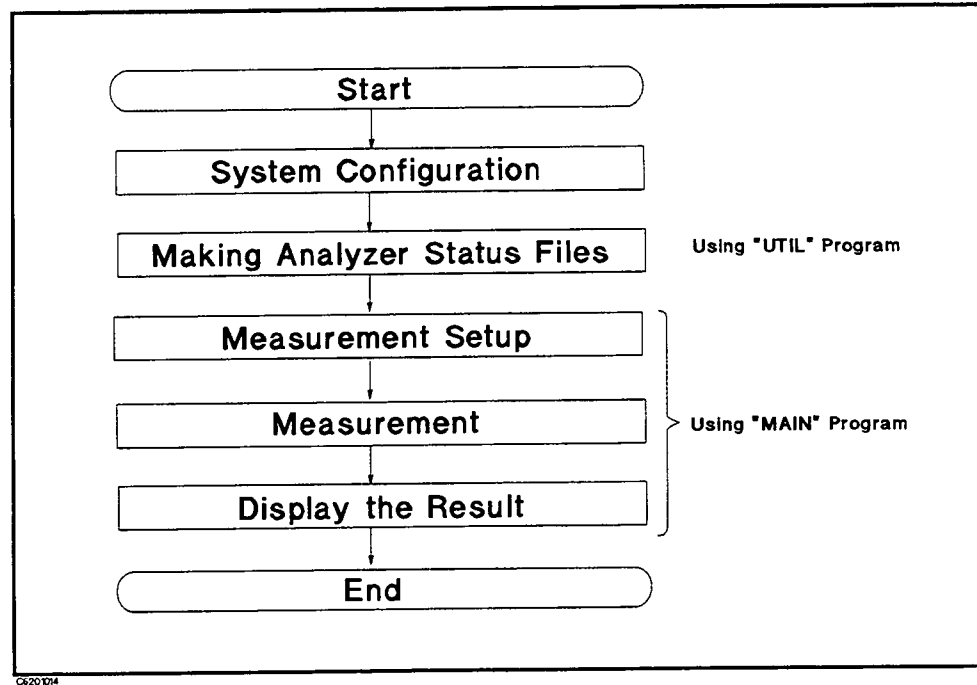


Figure 1-5. Measurement Flow

System Configuration

1. Set your chamber HP-IB (GP-IB) address to 1.

When you want to change the address, edit the sub-program `System_init` in "MAIN" program and the sub-program `ProgramStart` in "UTIL" program.

Procedure for Main Program:

- a. Load the Main program.
 - b. Type `EDIT SYSTEM_INIT` and then press `(Return)`.
 - c. Modify the address number in `ASSIGN @Chamber TO 701`.
 - d. Re-save the program.
2. Press `(Local) SYSTEM CONTROLLER` on the analyzer.

Making a Data Diskette

The test program requires a diskette in which the analyzer status files and results can be saved. The data diskette must be in the DOS format. To format for DOS, use the following procedures:

1. Insert the temperature coefficient measurement program diskette into the slot.
2. Press `(Display) DISPLAY ALLOCATION BASIC STATUS`.
3. Type `"GET "UTIL" ,` then press `(Return)`.

4. The light on the disk drive is ON while the file is being loaded.
5. After the light turns OFF, type "RUN" and then press **Return**.
6. The main menu is displayed as shown in Figure 1-6.

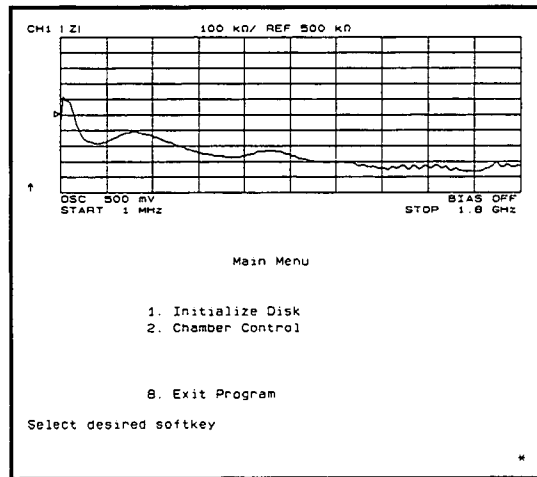


Figure 1-6. Main Menu of UTIL Program

7. Insert an unformatted diskette into the floppy disk drive.
8. Press **Initialize disk Yes**.

Making Analyzer Status File

Before you make the temperature coefficient measurement, save the analyzer setup and calibration/compensation data as the status files.

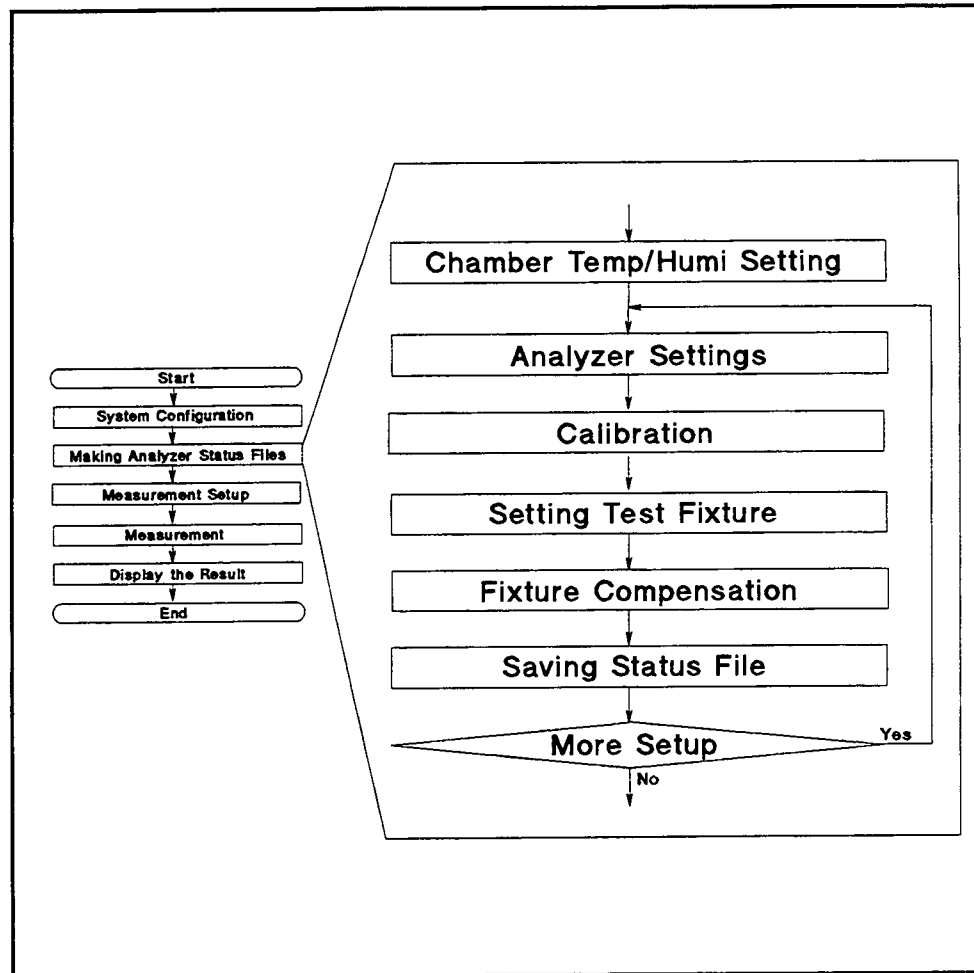


Figure 1-7. Measurement Flow of Making Analyzer Status File Chamber Temperature/Humidity Settings

Before performing calibration and compensation, the chamber should be set to the reference environment (temperature and humidity). Usually the reference environment is 23 ± 5 °C. Set your chamber to the reference environment. The program named "UTIL" can control the chamber temperature and humidity, and can monitor the temperature of the chamber sensor/specimen sensor and the humidity. The procedure is described below:

1. Press **Chamber Control**.
2. Press **Set Temp.** and enter the reference temperature. Then press **Return**.
3. Press **Set Humidity** and enter the required reference humidity.
4. Press **Start Chamber**.

- The graticule is displayed the above half-screen, and the temperature/humidity are displayed the under half-screen under as shown in Figure 1-8.

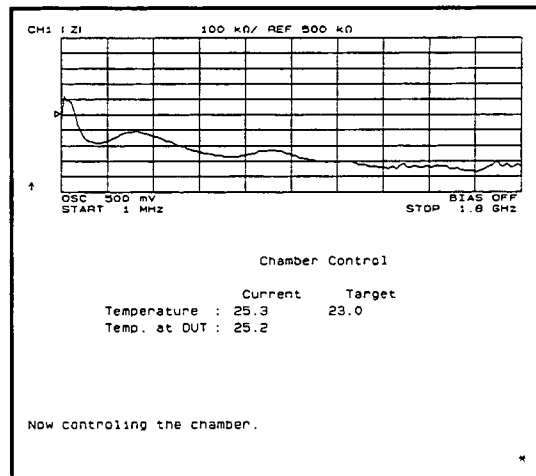


Figure 1-8. Temperature/Humidity Monitor

Analyzer Settings

Set each parameter to your required setting while the program is running. In this quick start, the following settings are used as an example:

Table 1-3. Analyzer Settings Example For Setup A

Measurement Parameter	Z - θ
Sweep Parameter	Frequency
Measurement Frequency Point	120 MHz, 200 MHz
OSC Level	300 mV
Point Averaging	5

Key Sequence

- Press **Meas** **Ch 1** IMPEDANCE: MAG ($|Z|$).
- Press **Meas** **Ch 2** PHASE: (θ_z).
- Press **Sweep** SWEEP MENU SWP SRC: FREQ.
- Press **Sweep** SWEEP MENU SWP TYPE: LIN.
- Press **Sweep** NUMBER of POINTS **2** **x1**.
- Press **Start** **1** **2** **0** **M/μ**.
- Press **Stop** **2** **0** **0** **M/μ**.
- Press **Source** OSC LEVEL **3** **0** **0** **k/m**.
- Press **Bw/Avg** POINT AVG FACTOR **5** **x1**.
- Toggle POINT AVG on OFF to ON off.

The measurement frequency points are determined by the start/stop frequencies and the number of points. If the **NUMBER of POINTS** is set to 3, the measurement frequency points are 120, 160 and 200 MHz. If **SWEEP MENU SWP TYPE: LOG** is also selected, the measurement frequency points are 120, 154.919333848, and 200 MHz. When you want to verify the measurement frequency points, press **Copy MORE LIST VALUES**.

Calibration

When the temperature/humidity becomes the reference values, perform calibration at the high temperature test head APC-7 connector. This calibration procedure is the same as the one for the impedance/dielectric/magnetic measurements. The **USER DEFINED** calibration is required when the high temperature test head is connected. The analyzer is set to the **USER DEFINED** calibration automatically.

Setting the Test Fixture

The test fixture should be set on the test head after calibration. The setup for the HP 16194A is shown in Figure 1-9.

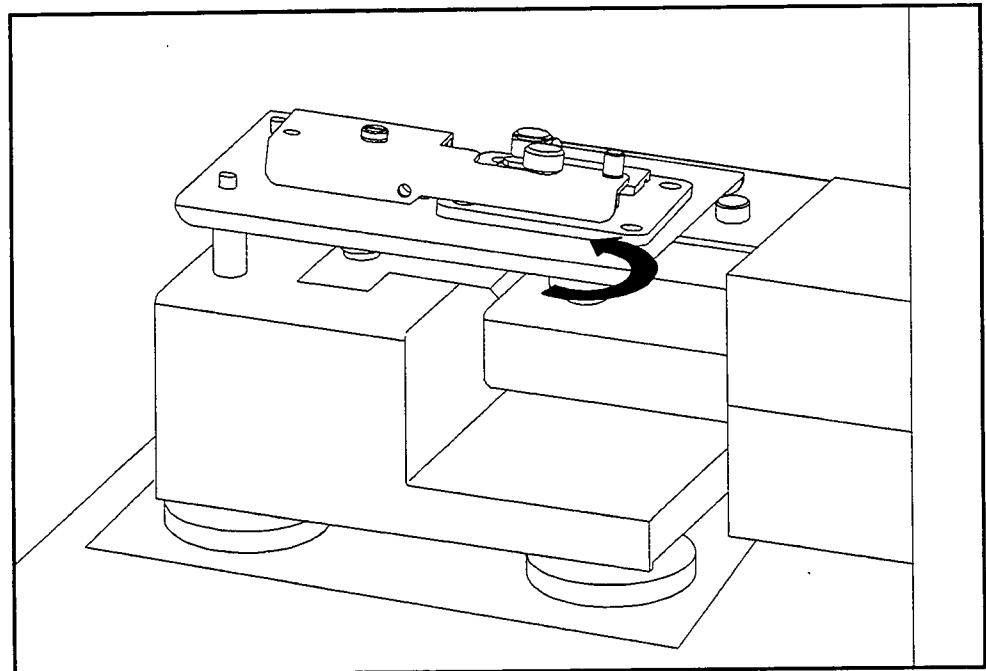


Figure 1-9. HP 16194A Connection

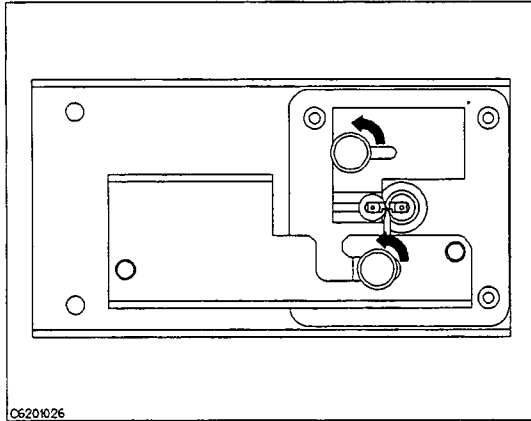
Select your test fixture model number using the **Meas** hardkey.

Fixture Compensation

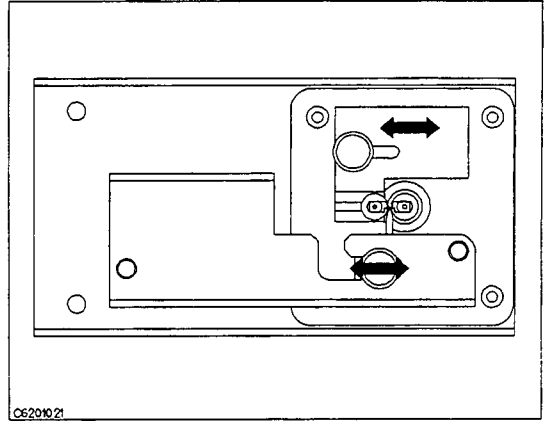
How to perform fixture compensation for the HP 16194A is shown below. For a basic measurement, the Open and Short compensations are required. However, if you use both the HP 16194A and the High Temperature Test Head for High Impedance, or the measurement

frequency is above 500 MHz, the Load compensation is also required. The procedures for the HP 16453A and HP 16454A are shown in the applicable *Fixture Compensation* section in each quick start.

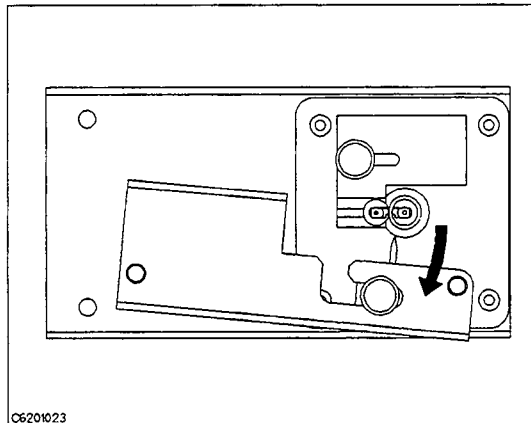
Short Compensation



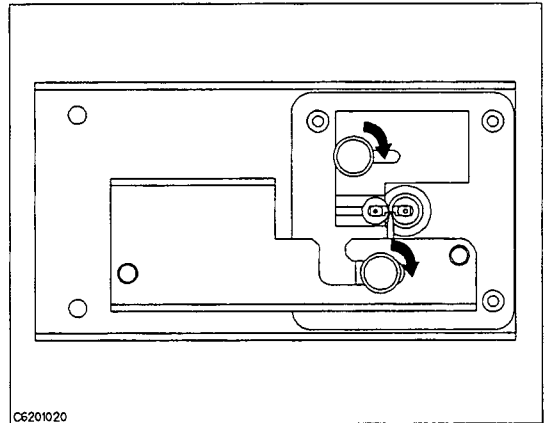
1. Loosen the two knobs.



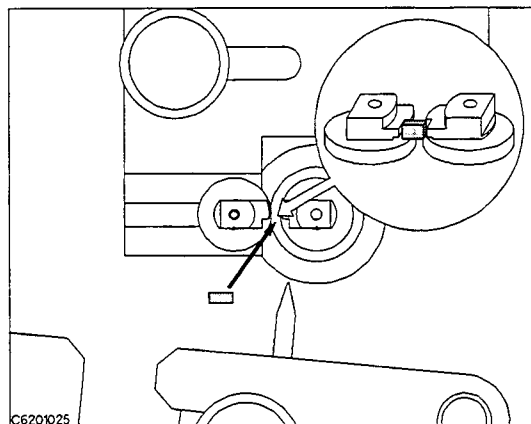
2. Adjust the stage and the pressure arm to fit your shorting device.



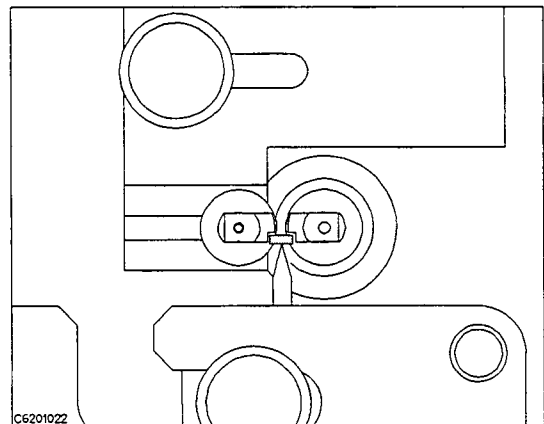
3. Move the pressure arm to the outside.



4. Tighten the two knobs.



5. Place the shorting device so that it contacts both electrodes.



6. Release the pressure arm so that the shorting device is held by the pressure arm.

Note



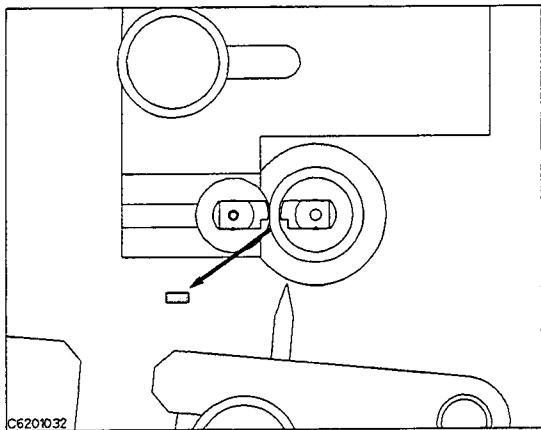
When it is difficult to connect the device to the test fixture that is in the chamber, remove the test fixture from the test fixture stand. Then connect the device outside the chamber and set the fixture on the test fixture stand again.

When the test fixture is ready for the SHORT compensation sequence, press the following front panel keys:

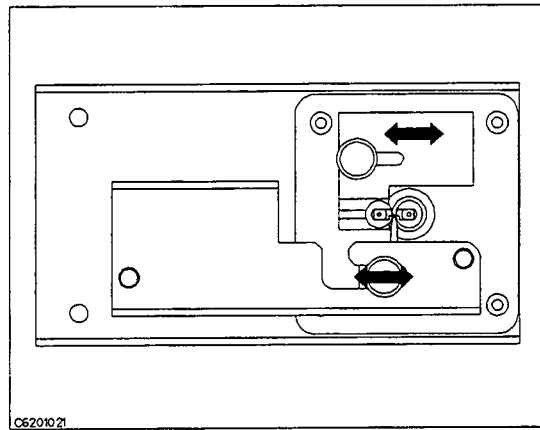
1. Press **Cal** **FIXTURE COMPEN COMPEN MENU**.
2. Press **SHORT**.

After the SHORT compensation sequence is done, the **SHORT** softkey label is underlined.

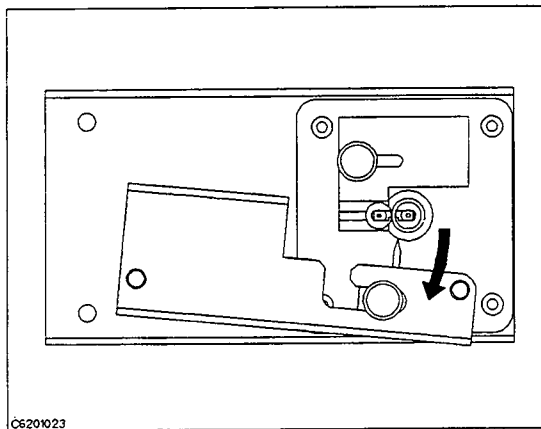
Open Compensation



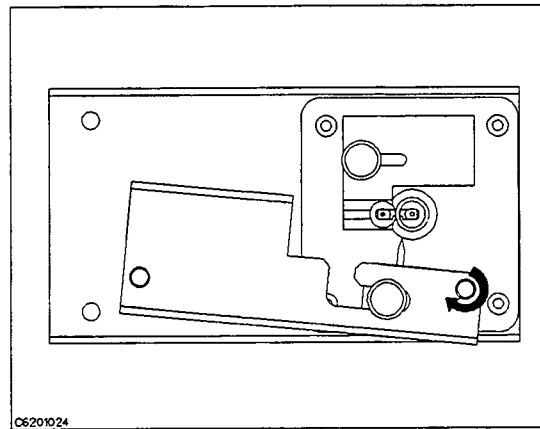
1. Remove the shorting device.



2. Adjust the stage and the pressure arm to fit your DUT.



3. Move the pressure arm to the outside.



4. Turn the latch knob and insert it into the hole so that the pressure is locked.

When the test fixture is ready for the Open compensation sequence, perform the following procedure:

1. Press **OPEN** .

After the OPEN compensation sequence is done, the **OPEN** softkey label is underlined.

2. Press **DONE: COMPEN** if you do not intend to perform the Load compensation.

If you use both the HP 16194A and High Temperature Test Head for High Impedance, or the measurement frequency is above 500 MHz, the Load compensation is required.

Load Compensation

Connect the Load to the HP 16194A just as you connected the shorting device in the Short compensation. The Load device is included with HP 16194A.

When the test fixture is ready for the Load compensation sequence, perform the following procedure:

1. Press **LOAD** .

After the Load compensation sequence is done, the **LOAD** softkey label is underlined.

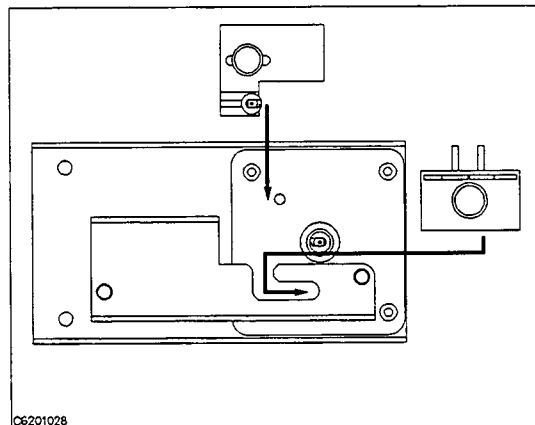
2. Press **DONE: COMPEN** .

Note



When your DUT is leaded type, the compensation procedure is as follows:

1. Perform the Short Compensation using the biggest shorting device (HP P/N 16191-29004).
2. Perform the Load Compensation using the furnished load device.
3. Replace the pressure arm pin for SMD with one for a leaded component.



4. Adjust the stage to fit your DUT.
5. Perform the Open Compensation.

If you use both the HP 16194A and High Temperature Test Head for Low Impedance, and the measurement frequency is below 500 MHz, the Load compensation is not required.

Saving Status File

After performing calibration/fixture compensation at your required settings, save the settings with the calibration/fixture compensation data to the status file. In this example, setup A is saved using the name "ZTF".

1. Insert the data diskette (DOS formatted) into the floppy disk drive slot.
2. Press **(Save) STATE**.
3. Enter the file name "ZTF" and press **(Return)**.
4. The message of "SAVING "ZTF.STA" TO DISK" is displayed. The analyzer saves a status file with a ".STA" extension.

When You Need More Setups

This program has the capability of saving 5 measurement setups (SETUP A to E) for one temperature/time characteristic measurement sequence. This means you can analyze different parameters and sweep parameters using one measurement sequence.

As in the first example, the second setup can be saved using the name "CDO". After the analyzer is set to the following setting, the calibration and compensation must be performed again, and then saved to the status file.

Table 1-4. Analyzer Setting For Example B

Measurement Parameter	Cp - D
Sweep Parameter	OSC Level
Measurement OSC Level Point	300, 350, 400, 450 mV
CW frequency	200 MHz

1. Press **(Meas) (Ch 1) CAPCITNCE: PRL (Cp)**.
2. Press **(Meas) (Ch 2) D FACTOR (D)**.
3. Press **(Sweep) SWEEP MENU OSC LEVEL**.
4. Press **(Sweep) SWEEP MENU SWP TYPE:LIN**.
5. Press **(Sweep) NUMBER of POINTS (4) (x1)**.
6. Press **(Start) (3) (0) (0) (k/m)**.
7. Press **(Stop) (4) (5) (0) (k/m)**.
8. Press **(Source) CW FREQ (2) (0) (0) (M/μ)**.

After you save all of the analyzer status files you require, quit the "UTIL" program by pressing **(System)** **IBASIC MORE ON KEY LABELS QUIT**.

Loading the Main Program

After you save all of the analyzer status files you require, load the main program.

1. Insert the temperature coefficient measurement program diskette into the slot.
2. Type "GET "MAIN"" and then press **(Return)**.
3. The light on the disk drive is ON while the file is being loaded.
4. After the light turns OFF, type "RUN" and then press **(Return)**.
5. Insert the data diskette in which the state files are saved into the floppy disk drive.
6. The Main Menu (shown in Figure 1-10) is displayed.

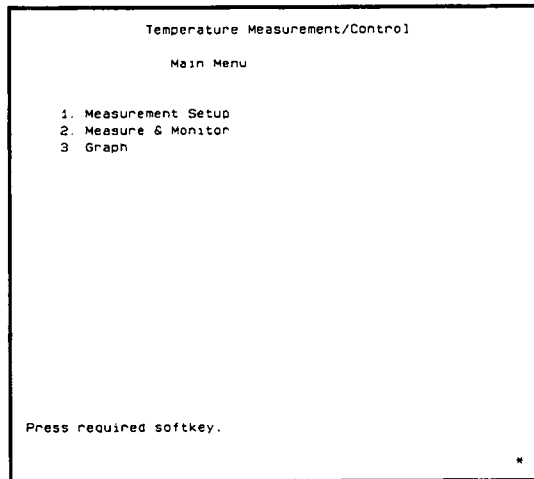


Figure 1-10. Main Menu

The main program flow is shown in Figure 1-11.

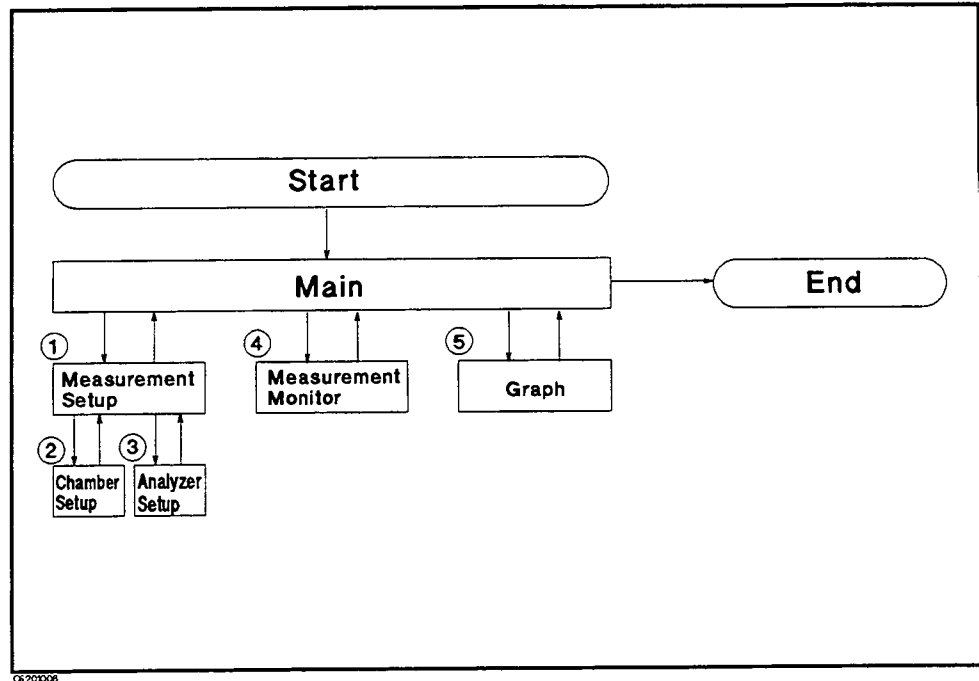


Figure 1-11. Main Program Flow

Note



If you press any hardkey on front panel while the program is running, the softkey label is changed to the softkey label that corresponds with that hardkey. Pressing **(System) IBASIC MORE ON KEY LABELS** returns to the softkey that was displayed while the program is running.

① **Measurement Setup**

1. Press **Setup Menu**.
2. The Menu (shown in Figure 1-10) is displayed.

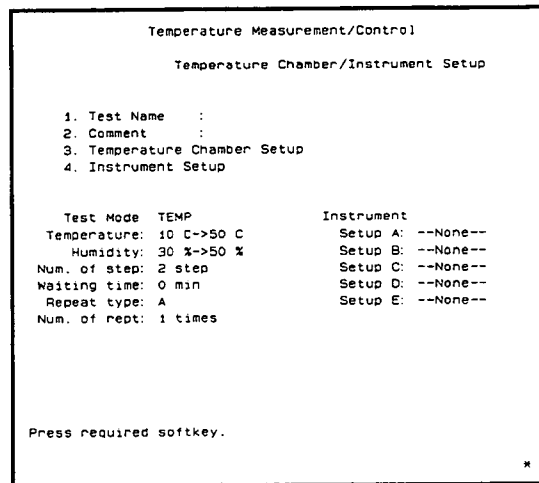


Figure 1-12.
Temperature Chamber/Instrument Setup Menu

② Setting the Chamber Control Parameters

Table 1-5. Chamber Settings

Measurement Temp. Point (Humidity)	10 (30), 20 (35), 30 (40), 40 (45), 50 °C (50 %)
Waiting Time	5 min.
Repeat Type	A
Number of Repeat	2

1. Press **Setup Menu** to display the “Temperature Chamber Setup” menu.
2. Toggle **Test Mode** to **Test Mode [TEMP]** .
3. Press **Temp. Start temp.** 10 **(Return)**.
4. Press **Stop temp** 50 **(Return)** Done .
5. Press **Humidity Start humidity** 30 **(Return)**.
6. Press **Stop humidity** 50 **(Return)** Done .
7. Press **Number of Step** 5 **(Return)**.
8. Press **Wait time** 5 **(Return)**.
9. Press **Repeat type** A .
10. Press **Number of Repeat** 2 **(Return)**.
11. Press **Done** to return back to “Temperature Chamber/Instrument Setup” menu.

③ Selecting the Analyzer Status File

1. Press **Instrument Setup** to display the “Instrument Setup” menu.
2. Press **Setup A** .
3. The status files in the diskette are displayed in the softkey label area.
4. Press **ZTF** .
5. Press **Setup B CDO** .
6. Press **Done** to return to the “Temperature Chamber/Instrument Setup” menu.

Saving the Test Setup

1. Press **Test name** .
2. Enter the test setup name as required (in this example, “EXAM1”).

3. Press **Comment** and enter your comments (in this example, "TEMP. TEST").
4. Verify that the menu is as shown in Figure 1-13.
5. Press **Save setting**.
6. Press **Goback main menu**.

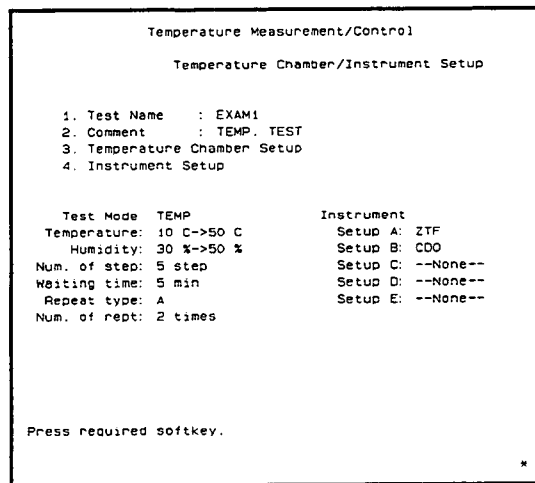


Figure 1-13.
Temperature Chamber/Instrument Setup Menu

④ Measurement

Setting the DUT on the Test Fixture

Set your DUT on the test fixture. When your device is leaded type, the connection is shown as Figure 1-14.

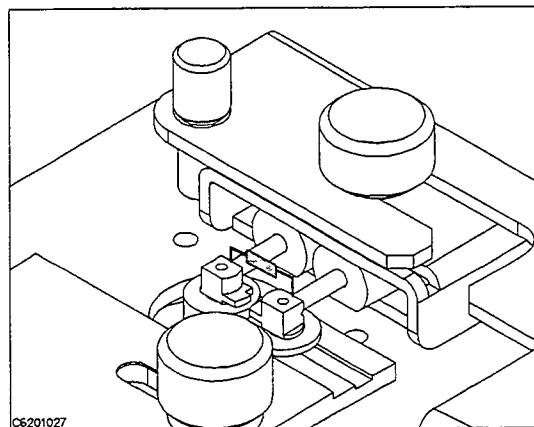


Figure 1-14. Setting the Leaded Type DUT

Starting the measurement

1. Press **Measure & Monitor**.
2. Press **Test Name**.

3. The test files in the diskette are displayed in the softkey label area.
4. Press **EXAM1**.
5. Press **Start Measure** to start the measurement.

The program controls the chamber as specified in the chamber setup. After the environment in the chamber reaches the specified temperature/humidity point, the analyzer measures your device. It repeats this measurement for all the measurement points specified in the analyzer setup.

While the program running, Figure 1-15 is displayed.

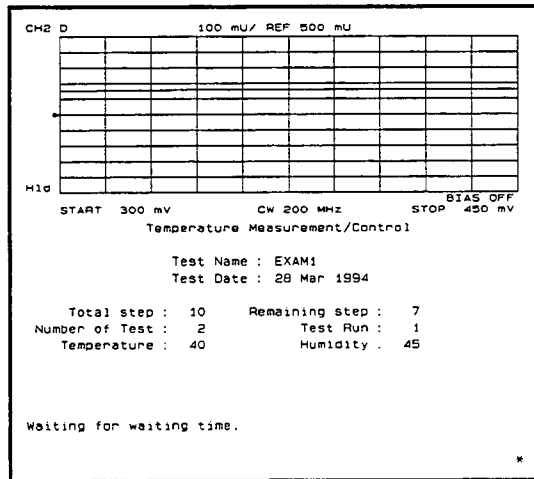


Figure 1-15. Display under Measurement

Total Step	Total Temperature Measurement Step
Remaining Step	Remaining Step
Number of Test	Number of Repeat
Test Run	Repeat No.
Temperature	Chamber Temperature Setting Value
Humidity	Chamber Humidity Setting Value
Current Temp.	Temperature of Specimen Temperature Sensor
Current Humi.	Humidity

⑤ Displaying the Result

The program allows you to see the temperature characteristic results on the display.

In this example, the result of $|Z|$ at 120 MHz at repeat No. 1 is displayed as trace 1 and the result of θ at 120 MHz at repeat No. 1 is displayed as trace 2.

1. Press **Graph**
2. Press **Temp. TRACE 1**.

3. Press **Data File** .
4. The data files in the diskette are displayed.
5. Press **EXAM.A11** .
6. Press **Stimulus Value** **1** **2** **0** **M/μ** **x1** .
7. Press **Return** .
8. Press **TRACE 2 Data File** .
9. Press **EXAM.A21** .
10. Press **Stimulus Value** **1** **2** **0** **M/μ** **x1** .
11. Press **Return** .
12. Press **Display Graph** .
13. The trace for **EXAM.A11** is displayed as the user trace 1 and one for **EXAM.A21** is displayed as the user trace 2.

These files, example **EXAM.A11**, are data files in which the measurement results are saved. The extension is defined as follows:

The first letter defines the setup files.

The second digit defines the measurement channel of the analyzer.

The third digit defines the repeat No.

.A21 defines the data file of channel 2 for setup A at repeat No. 1. For more information, see "File Configuration".

Note



What's the User Trace:

The analyzer has a user definable trace feature. If you want to display data using custom formats or parameters that are not provided in the analyzer, you can display any x-axis or y-axis format that you specify. This program displays the temperature coefficient result using the user trace function.

The user trace function of the analyzer has the following features:


1. You can display up to 4 arbitrary traces.
2. You can independently define x-axis and y-axis units, labels, and scale for each trace.
3. Marker functions can be used on the user traces.

You cannot display the user trace and the normal measurement display simultaneously. To switch the user trace to the measurement trace, toggle **TRACE [USER]** to **[DATA&MEM]** under **Display MORE** .

Using the Marker

The marker function allows you to read a value at the marker.

1. Press **Marker** .
2. Move the Marker by turning the rotary knob or entering the target value.

3. When you want to move the marker on other trace, press **Display**
DEFINE TRACE SELECT UTRC  and select the user trace
number.

Press **System** **IBASIC MORE ON KEY LABELS DONE** to return to the
menu.

Other Display Format

Next example, the stimulus characteristic result (120 MHz, 200 MHz)
of |Z| at 20 °C at repeat No. 1 is displayed as trace 1.

1. Press **Graph**.
2. Press **Stimulus TRACE 1**.
3. Press **Data File**.
4. The data files in the diskette are displayed.
5. Press **EXAM.A11**.
6. Press **Temp. Value** **2** **0** **x1**.
7. Press **Return**.
8. Press **Display Graph**.
9. The stimulus characteristic result for EXAM.A11 at 20 °C is
displayed as the user trace 1.

Note



The displayed temperature results may be different from the
temperature that you set. Because, it is monitored by not the
chamber temperature sensor but the specimen temperature sensor.

Other Measurement Modes

In the quick start section, the temperature characteristics measurement is demonstrated. The program also provides the time characteristics measurement under constant temperature/humidity condition, and the temperature characteristics measurement using the programmed temperature/humidity operations.

Time Characteristic Measurement

Table 1-6 is an example of the time characteristic measurement.

Table 1-6.
Temperature Chamber Setup for Time Characteristic Measurement

Measurement Time Point	0, 20, 40, 60, 80, 100, 120 min.
Waiting Time	5 min.
Temperature	50 °C
Humidity	50 %

Figure 1-16 shows the graph in the format of temperature/humidity vs. time for the temperature chamber setup (Table 1-6).

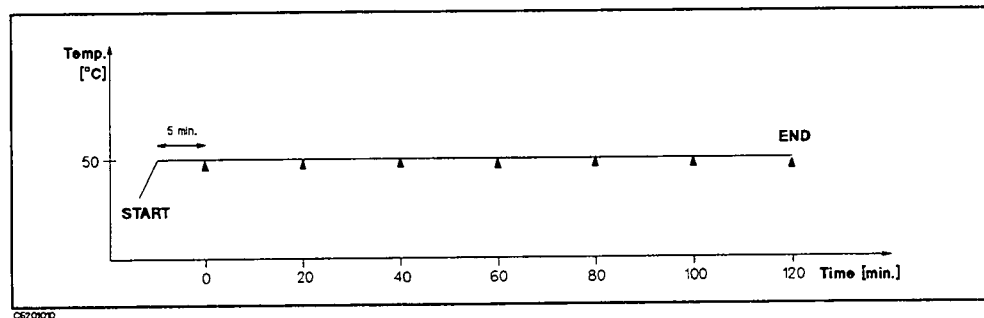


Figure 1-16. Chamber Setup Example

Figure 1-17 shows the setup menu in the case of the example setup above.

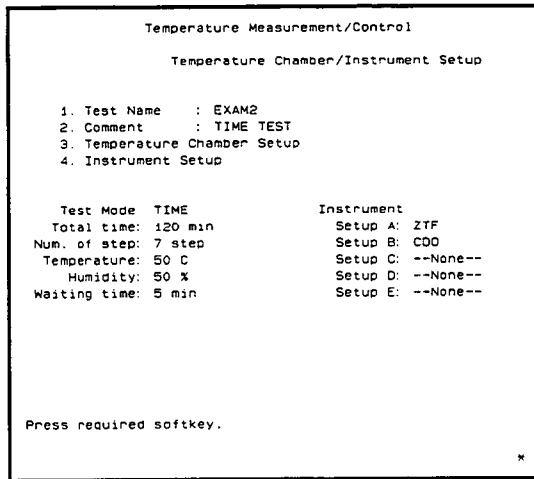


Figure 1-17.
Temperature Chamber/Instrument Setup Menu

**Programmed
Temperature/Humidity
Operation**

You can program the temperature/humidity operation. Save the temperature/humidity operation pattern to a file whose extension is ".SUR". Table 1-7 shows an example of the temperature/humidity operation pattern file. Save this file as "EX1.SUR" in ASCII format.

Table 1-7. Example of "EX1.SUR"

Format	{Temperature}, {Humidity}, {Waiting Time},
Example	10, 20, 3, 15, 25, 5, 20, 30, 5, 50, 30, 10,

Figure 1-18 shows the graph in the format of temperature/humidity vs. time for the EX1.SUR Setup.

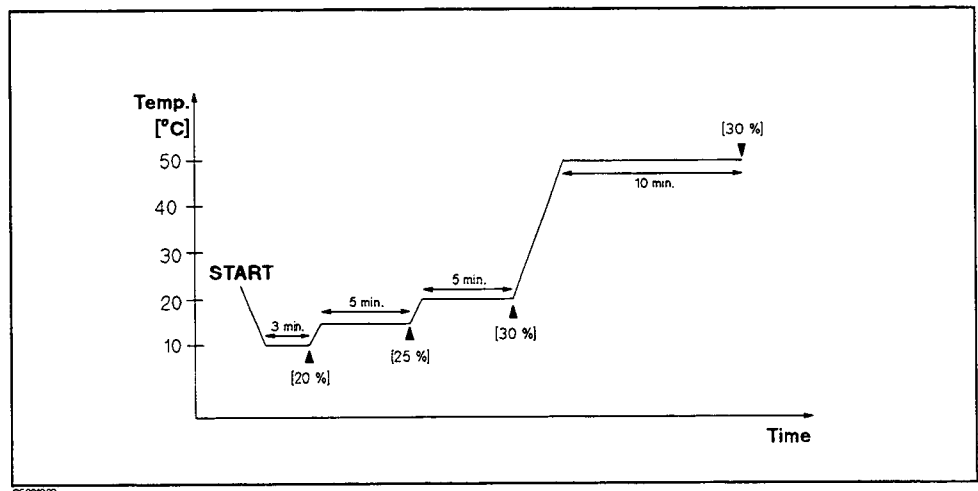


Figure 1-18. Temp/Humi Operation Pattern

Temperature Coefficient Measurement

Figure 1-19 shows the setup menu in the case of the example setup above.

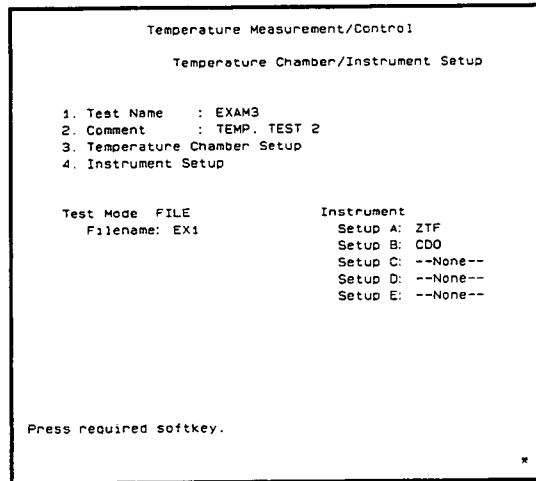


Figure 1-19.
Temperature Chamber/Instrument Setup Menu

File Configuration

The program creates several files to store measurement setups and results. This section describes the information in each of these files. Because these files are saved as ASCII text, they are easy to read using the spreadsheet software or the editor software of a personal computer.

The files that the program creates are shown in Table 1-8.

Table 1-8. File Name and Extension

File Name	Extension Example
Measurement Setup File	.HED
Measurement/Sweep Parameters File	.LA1, .LB2
Measurement Stimulus Points File	.SA1, .SB2
Time/Temperature/Humidity File	.SR1, .SR2
Measurement Result File	.A11, .B21

The extension for each file is defined in Figure 1-20.

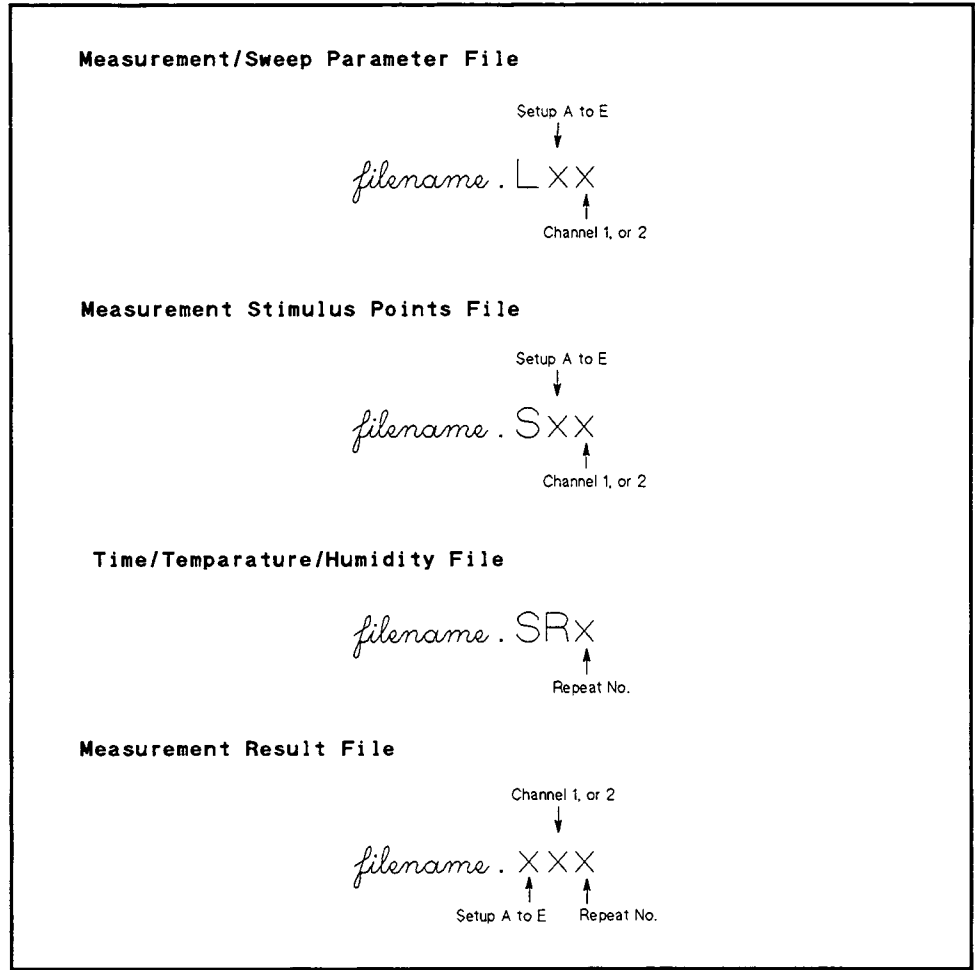


Figure 1-20. File Extension Definitions

File Example

Measurement Setup File

The measurement setup file includes information on the chamber setup, analyzer status file setups, comments, and measured date. The file extension is HED. Table 1-9 shows the example file that is created by this quick start procedure.

Table 1-9. Example of "EXAM1.HED"

Contents	Explanation
COMMENT : TEMP. TEST	comment
DATE : 15 Apr 1993	measured date
SETUP A : ZTF	status file name for setup A
SETUP B : CDO	status file name for setup B
SETUP C :	status file name for setup C
SETUP D :	status file name for setup D
SETUP E :	status file name for setup E
MODE : TEMP	measurement mode
START TEMP : 10	start temperature
STOP TEMP : 50	stop temperature
START HUMI : 30	start humidity
STOP HUMI : 50	stop humidity
NOS : 5	number of step
WAIT : 5	waiting time
REPT : A	repeat type
NOR : 2	number of repeat

Measurement/Sweep Parameter File

This file provides the measurement parameter and sweep parameter information for each analyzer status file. Table 1-10 shows the example file that is created in this quick start procedure

Table 1-10. Example of "EXAM1.LA1" file

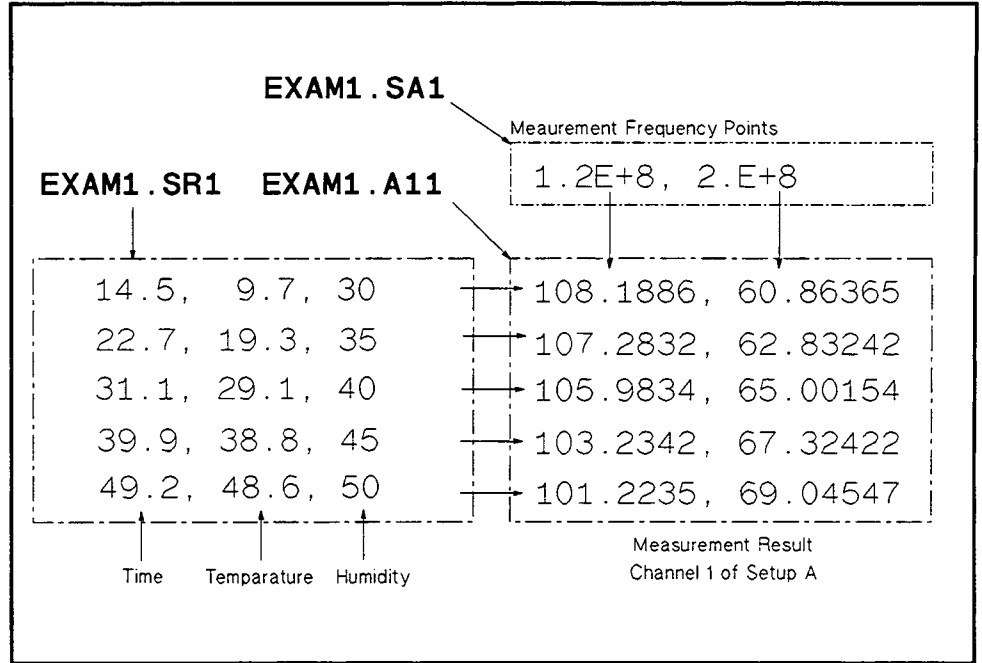
Contents	Explanation
2	number of points for ch 1 of setup A
FREQ	sweep parameter for ch 1 of setup A
Hz	sweep parameter unit
|Z|	measurement parameter for ch 1 of setup A
Ohm	measurement parameter unit

Other File Examples

The extension ".SA1" is used for the measurement stimulus file. The measurement stimulus points are determined by the analyzer status file and are saved in this file.

The extension ".SR1" is used for the time/temperature/humidity file. The time, temperature, and humidity at each measurement point are saved into this file.

The extension ".A11" is used for the measurement results file. The measurement results are saved into this file. Figure 1-21 shows an example file that is created in this quick start procedure.



06201006

Figure 1-21. Example of "EXAM.SA1, .SR1, .A11" files

The temperature/humidity in the chamber is controlled by monitoring the chamber temperature sensor. The data saved into the diskette as measurement results are monitored by the specimen temperature sensor. This means that the temperature results in an .SR1 file may be different from the temperature that you set.

Using Another Chamber

You can use a chamber other than the Tabai Espec SU-240-Y by modifying this program for that temperature chamber. This section provides the information needed for that modification.

Modifying the Program

You need to modify the following sub-programs:

- MAIN
 - CheckChamber
 - SetChamber
 - GetEnvData
- UTIL
 - Checkchamber
 - Setchamber
 - Getenvdata

Modify the sub-programs in UTIL referring ones of MAIN because the sub-programs of UTIL program are similar to ones of MAIN program.

The CheckChamber sub-program in MAIN program checks whether the chamber has humidity control capability. It also gets the lower limit and upper limit of the temperature and humidity of the chamber. Table 1-11 is a list of the sub-program. You need to modify the steps that are underlined.

Table 1-11.

```

CheckChamber:SUB CheckChamber
COM /Cham/ @Chamber,HumFlag,TempMax,TempMin,HumiMax,HumiMin,SelCham
!
Message("Checking chamber type.")
!
! This part verify whether the chamber has a capability of humidity
! control. If yes, set HumFlag= 1
!
ON TIMEOUT SelCham,30.0 GOTO Tout
OUTPUT @Chamber;"01,HUMI?"
ENTER @Chamber;Buf$ ! Buf$ is dummy
OUTPUT @Chamber;"_"
ENTER @Chamber;Buf$
IF Buf$[1,2] = "OK" THEN
HumFlag= 1
ELSE
HumFlag= 0
END IF
!
! This part checks the upper and the lower limits of temperature.
! Te and Ts are not used in this sub-program.
!
OUTPUT @Chamber;"01,TEMP?"
ENTER @Chamber;Te,Ts,TempMax,TempMin
!
! If the chamber has a humidity control capability,
! check the upper and the lower limits of humidity.
! He and Hs are not used in this sub-program.
!
IF HumFlag THEN
OUTPUT @Chamber;"01,HUMI?"
ENTER @Chamber;He,Hs,HumiMax,HumiMin
END IF
SUBEXIT
Tout:!
Message("HPIB time out.")
STOP
!
SUBEND

```


The SetChamber sub-program in the MAIN program sets the temperature and humidity and waits for them to become the target values. Table 1-12 is a list of the sub-program. You need to modify the steps that are underlined.

Table 1-12.

```

SetChamber:DEF FNSetChamber( Temp, Hum )
COM /Cham/ @Chamber,HumFlag,TempMax,TempMin,HumiMax,HumiMin,SeICham
DIM Mess$[120]
!
Temp = PROUND(Temp,-1)
Hum = PROUND(Hum,0)
!
!
OUTPUT @Chamber;"01,TEMP,S";VAL$(Temp)
IF FNHumCheck THEN
OUTPUT @Chamber;"01,HUMI,S";VAL$(Hum)
END IF
LOOP
OUTPUT @Chamber;"01,TEMP?"
ENTER @Chamber;Te,T1,T2,T3
!
! If your chamber has no specimen temperature sensor, modify here.
! Example:
! OUTPUT @Chamber; "01,RX,TEMP?,DUT" -> delete
! ENTER @Chamber "Adr,Temp"-----> delete
! &VAL$(Tdut)-----> &VAL$(Te)
!
OUTPUT @Chamber;"01,RX,TEMP?,DUT"
ENTER @Chamber;Adr,Tdut
Mess$ = "Controlling chamber. Current temp.: "&VAL$(Tdut)
!
IF FNHumCheck THEN
OUTPUT @Chamber;"01,HUMI?"
ENTER @Chamber;Hu,H1,H2,H3
Mess$ = Mess$&"Current humi.: "&VAL$(Hu)
END IF
Message(Mess$)
EXIT IF (Te = T1 AND (Hu = H1 OR NOT FNHumCheck))
END LOOP
!
RETURN 1
FNEND

```

The GetEnvData sub-program in MAIN program observes the temperature of the thermocouple and humidity. Table 1-13 is a list of the sub-program. You need to modify the steps that are underlined.

Table 1-13.

```

GetEnvData:SUB GetEnvData( Temp, Hum )
COM /Cham/ @Chamber,HumFlag,TempMax,TempMin,HumiMax,HumiMin,SelCham
!
! If your chamber has no specimen temperature sensor, modify here.
! Example:
! "01,RX,TEMP?,DUT"—> "01,TEMP?"
! "Adr,Temp"-----> "Temp,T1,T2,T3"
!
OUTPUT @Chamber;"01,RX,TEMP?,DUT"
ENTER @Chamber;Adr,Temp
!
!
IF FNHumCheck THEN
OUTPUT @Chamber;"01,HUMI?"
ENTER @Chamber;Hum,H1,H2,H3
ELSE
Hum = 0
END IF
SUBEND

```

Table 1-14 and Table 1-15 show the command references of the Tabai Espec Chamber. These references help you to understand the above programs.

Table 1-14.
Tabai Espec Chamber Command Reference

Command
01,TEMP,S{Set Temperature}
01,HUMI,S{Set Humidity}

Table 1-15. Tabai Espec Chamber Command Reference (Query)

Command	Response data
01,TEMP?	{Measured Temperature}, {Set Temperature}, {Upper Temperature Limit}, {Lower Temperature Limit}
01,HUMI?	{Measured Humidity}, {Set Humidity}, {Upper Humidity Limit}, {Lower Humidity Limit}
01,RX,TEMP?,DUT	{1}, {Measured Temperature at a specimen sensor}

Index

CR : HP-IB Command Reference
FR : Function Reference
PG : Programming Guide
UG : User's Guide

Special characters

Δ L.F , FR 7-23
 Δ R.F , FR 7-23
 Δ mode , FR 7-22
 Δ X , FR 7-27
 Δ Y , FR 7-27
 * , FR 2-7
 \Downarrow , FR 4-2
 \Uparrow , FR 4-2
 -0 , FR 2-7
 ↑ , FR 2-7
 $\times 1$, FR 4-2

8

8 bit I/O, CR 3-107, CR B-34

A

ABOR , PG 5-2
 ABORT , PG 1-4
 accessing calibration coefficient arrays ,
 PG 3-4
 accessing compensation coefficient arrays ,
 PG 3-4
 ACI program , UG 6-12
 active channel, FR 3-2
 active channel , FR 2-4, PG 2-3
 active channel block, FR 1-4
 active channel block , FR 3-1
 active controller , PG 1-4, PG 8-5
 active entry area , FR 2-8
 active marker , UG 6-16
 AD converter, FR 9-3
 ADDRESS , UG 6-21
 addressable , FR 8-44
 addressable only , FR 8-16
 address setting , FR 8-16
 adjust display , FR 5-42
 ADJUST DISPLAY , FR 5-35
 Admittance, FR 11-4
 admittance , PG 2-9

admittance chart , PG 2-10
 ALC , UG 6-11
 APC-7 , FR 2-17
 ASCII data transfer , PG 3-7
 ascii save , FR 8-30
 ASCII save , UG 6-20
 automating the measurement procedure
 impedance , PG 2-3
 AUTOREC , FR 8-37, FR 8-49, UG 6-20
 auto recall , FR 8-37, FR 8-49
 auto scale , PG 2-13
 auto scaling , FR 5-49
 aux offset , FR 5-39
 averaging , FR 5-52, FR 9-4, UG 6-3, PG 5-5
 averaging factor, CR 3-73
 averaging factor , FR 5-52
 averaging ON Avg , FR 2-7
 Avg , FR 2-7

B

B, FR 11-4
 background intensity , FR 5-42
 \square Back Space , FR 4-3
 BACK SPACE , FR 5-46
 bandwidth center value, CR 3-11
 bandwidth parameter, CR 3-11, CR B-34
 bandwidth peak value, CR 3-11
 bandwidth value, CR 3-11
 BASIC , FR 8-4
 BASIC draw , FR 5-36
 BASIC screen , FR 5-36
 battery backup, FR C-1
 beeper, CR 3-105
 beeper , FR 8-4
 binary data transfer , PG 3-8
 BIN sorting , PG 6-3
 block , FR 1-1
 <block>, CR 1-6
 block diagram , FR 9-1
 brightness , FR 5-44
 Bus , FR 2-7
 bus trigger , FR 6-12, PG 5-2
 BW, FR 7-23
 \square Bw/Avg , FR 1-5

C

C, FR 11-4
C! , FR 2-7
C+ , FR 2-7
C+ , FR 2-7
C+! , FR 2-7
C+? , FR 2-7
C? , FR 2-7
Cal , FR 1-5
calibration
 fixed , UG 6-2
 user defined, UG 6-2
calibration , FR 5-55, PG 2-6
calibration coefficient , PG 3-3
calibration coefficient array, CR 3-27, CR B-32
calibration coefficient arrays , FR 9-4
calibration coefficients arrays , FR 8-47
calibration state , PG 2-6
cal kit , FR 1-2
calkit , FR 5-60
cal points , FR 5-55
CAL POINTS [USER] , UG 6-2
Capacitance, FR 11-4
cent, FR 7-23
Center , FR 1-5
center value , FR 2-6
Ch 1 , FR 3-2
Ch 2 , FR 3-2
channel coupling , FR 6-4
circuit model, FR 11-6
clearing register , PG 4-9
clear marker , PG 2-13
clear markers, FR 7-5
CLEAR SUB MKR , UG 6-16
clock , FR 8-4
*CLS , PG 4-9
Cm! , FR 2-7
Cm? , FR 2-7
Cmp, FR 2-7
CMP, FR 2-7
CO+ , FR 2-7
Cole-Cole plot , PG 2-18
color , FR 5-44
color printer , FR 8-20
color reset , FR 5-44
command abbreviation, CR 1-4
common command, CR 1-3
compen kit , FR 5-62
COMPEN POINTS [USER] , UG 6-3
compensation coefficient array, CR 3-27,
 CR B-32
compensation coefficient array , PG 3-4
compensation coefficient arrays , FR 9-5
compensation points , FR 5-57

complex permeability , FR 11-30
complex permittivity , FR 11-26
complex plane , FR 5-30, PG 2-10
condition register , PG 4-3
Conductance, FR 11-4
connectors , FR 2-9
continuous marker, FR 7-5
continuous mode, FR 7-22
controller , FR 8-43, PG 1-4
controller address , FR 8-16
convention, CR 3-2
conversion, CR 3-23, CR D-1
conversion mode , PG 2-9
Copy , FR 1-6, FR 8-19
copy abort , FR 8-28
copy time ON OFF , FR 8-28
Cor , FR 2-7
COR , FR 2-7
coupling channel , FR 6-4
coupling channels , FR 3-2
Cp1, FR 2-5
cross channel, FR 7-10
CROSS CHAN on OFF , FR 7-10
crt , FR 2-4
cw freq , FR 6-10
cw frequency , FR 2-6

D

D*M , FR 2-7
data array, CR 3-27, CR B-32
data array , PG 3-2
data arrays , FR 8-47, FR 9-5, PG 3-1
data header , PG 3-9
data math, CR 3-25, CR B-34
data math , FR 5-34, FR 5-38, FR 9-6
DATA MATH [DATA] , UG 6-19
data math gain ON G* , FR 2-7
data math offset ON -0 , FR 2-7
data math ON D-M, D+M, D/M, H1d , FR 2-7
DATA & MEMORY , FR 5-33
data only, FR 8-47
data processing , FR 9-2
data processing flow , PG 3-1
DATA→MEMORY , FR 5-33
data trace, CR 3-112, CR B-32
data trace , PG 3-2
Data-Trace arrays , FR 8-47
data trace arrays , FR 9-6
data transfer format, CR 3-50, CR B-33
data transfer methods , PG 3-7
dc bias, CR 3-97
 monitor , UG 6-7
dc bias , FR 6-10, PG 2-11
dc bias option , FR 10-1

dc current bias, CR 3-97
 dc current sweep , PG 2-5
 dc voltage bias, CR 3-97
 dc voltage sweep , PG 2-5
 D (Dissipation Factor), FR 11-4
 debugging program , PG 8-11
 default color, FR 5-44
 default colors , FR 5-43
 default gain offset , FR 5-39
 delay , UG 6-5
 delay time , FR 6-4
 Δ marker , FR 7-6
 Δ marker, FR 7-6
 Δ marker \rightarrow funciton , FR 7-10
 Δ MKR SWP PARAM , FR 7-7
 Δ mode , FR 7-22
 delta mode ON OFF, FR 7-7
 device selector , PG 1-3, **PG 1-5**
 digital filter, FR 9-3
 disc, FR 10-5
 discrete marker, FR 7-5
 discrete mode, FR 7-22
 disk capacity , FR 8-46
 disk format , FR 8-46
 disk to variable , PG 8-2
 display , FR 2-4, FR 5-33
Display , FR 1-5
 display adjustment , FR 5-42
 display allocation , FR 5-33, FR 5-36, PG 1-6
 DATA MATH , FR 5-35
 DISPLAY: DATA , FR 5-33
 display format, CR 3-16
 display format , PG 2-10
 display limit table , FR 8-27
 display list sweep table , FR 8-27
 D+M , FR 2-7
 D/M , FR 2-7
 D-M, FR 2-7
 DOS , PG 1-8
 dual channel, CR 3-59, CR 3-121, CR B-5,
 CR B-9
 dual channel , FR 5-33
 dual parameter setting , FR 5-12
E
 edge effect , FR 11-27
 electrical length, CR 3-108
 electrical length , PG 2-7
 enable register , PG 4-2
 entry block , FR 4-1
Entry Off , FR 4-3
 equivalent circuit, CR 3-28
 equivalent circuit , FR 5-40
 Equivalent Circuit Analysis , UG 3-23

equivalent circuit model, FR 11-6
ERASE TITLE , FR 5-46
 error, CR 3-108, CR B-33
 error corrected data , PG 3-2
 error message, FR Messages-1, CR Messages-1
 error queue , PG 8-11
 event register , PG 4-2
 expanded phase ON OFF , FR 5-30
 Ext , FR 2-7
 external controller , PG 1-7
 external program run/cont input , FR 2-10
 external reference, FR 2-7, CR 3-31
 external reference input , FR 2-9
 external trigger , FR 6-12
 external trigger input , FR 2-10

F

factory setting, FR C-1
 fast sweep indicator \uparrow , FR 2-7
 file
 purge , UG 6-21
 file format
 DOS , UG 6-21
 LIF , UG 6-21
 file name , FR 8-48
 firmware revision, CR 3-31
 fixed cal points , FR 5-55
 fixed compensation points , FR 5-57
 fixed delta marker , FR 7-7
FIXED Δ MKR AUX VALUE , FR 7-7
FIXED Δ MKR VALUE , FR 7-7
 fixed Δ marker, FR 7-7
 fixture compensation
 fixed , UG 6-3
 user defined, UG 6-3
 fixture compensation , FR 5-57, FR 5-58,
 FR 5-59, PG 2-7, PG 3-4
 fixture compensation coefficient arrays ,
 FR 9-5
 fixture compensation load standard array,
 CR 3-27, CR B-32
 fixture compensation open standard array,
 CR 3-27, CR B-32
 fixture compensation short standard array,
 CR 3-27, CR B-32
 fixture setting , FR 5-14
 fixture stand , FR 1-3
 flexible disk drive , FR 2-3
 footnote , FR 5-48
 format , FR 5-30, FR 9-6
Format , FR 1-4
 frequency base , FR 6-8
 frequency blank , FR 5-35
 frequency sweep , PG 2-4

front panel , FR 2-1

G

G, FR 11-4

gain, FR 5-39

gain , FR 5-38

G* , FR 2-7

general status register model , PG 4-1

getting data from analyzer , PG 3-10

getting measured data to controller , PG 2-13

G+jB , FR 7-20

$\frac{G}{n}$, FR 4-2

G&O , FR 2-7

go/no-go test , UG 6-8

graphics, FR 8-47

graphics , FR 5-36

graphics save , FR 8-30

graticule on off , FR 5-35

H

handle kit option , FR 10-2

headline , FR 5-48

heat sink , FR 2-14

height , FR 5-29

high impedance test head , FR 1-2

high impedance test head delete option ,
FR 10-1

high stability frequency reference add option
, FR 10-2

high temperature high impedance test head
, FR 1-3

high temperature high impedance test head
add option , FR 10-1

high temperature low impedance test head
, FR 1-3

high temperature low impedance test head
add option , FR 10-1

H1d , FR 2-7

HP 10833A hp-ib cable(1 m), FR 10-5

HP 10833B hp-ib cable(2 m), FR 10-5

HP 10833C hp-ib cable(3 m), FR 10-5

HP 10833D hp-ib cable(0.5 m), FR 10-5

HP 16091A coaxial termination fixture set ,
FR 10-3

HP 16092A spring clip test fixture , FR 10-3

HP 16093A/B binding post test fixtures ,
FR 10-4

HP 16094A probe test fixture , FR 10-4

HP 16191A Component test fixture , FR 1-2

HP 16191A side electrode SMD test fixture
, FR 10-3

HP 16192A Component test fixture , FR 1-2

HP 16192A parallel electrode SMD test fixture
, FR 10-3

HP 16193A Component test fixture , FR 1-2

HP 16193A small side electrode SMD test
fixture , FR 10-3

HP 16194A high temperature component
fixture , FR 10-3

HP 16194A High temperature component
test fixture , FR 1-3

HP 16453A dielectric material test fixture ,
FR 10-3

HP 16453A Dielectric material test fixture ,
FR 1-3

HP 16454A Magnetic material test fixture ,
FR 1-3, FR 10-3

HP 2227B QuietJet printer, FR 10-4

HP 3630A Paint Jet color printer , FR 10-4

HP 4291U upgrade kit, FR 10-2

HP 7440A ColorPro color graphics plotter,
FR 10-4

HP 7475A graphics plotter, FR 10-4

HP 7550B graphics plotter, FR 10-4

HP 85043B system rack , FR 10-4

HP 92192A micro flexible disks, FR 10-5

HP 92192X micro flexible disks, FR 10-5

HP BASIC , PG 1-8

HP CITIfile , PG 8-3

HP-GL , UG 6-20

HP-IB , FR 8-42, PG 1-4, PG 1-8

HP-IB address

setting , PG 1-6, PG 1-7

HP-IB address , FR 8-16, FR 8-45, UG 6-21,
PG 1-5

hp ibasic add option , FR 10-2

hp-ib cable, FR 10-5

HP-IB cable , PG 1-7

HP-IB command , PG 2-1

HP-IB control , PG 2-1

HP-IB error , PG 8-11

HP-IB interface , FR 2-10

HP Instrument BASIC, CR 3-66, CR B-33

HP Instrument BASIC , PG 1-5

HP Instrument BASIC graphic function,
CR 3-36

I

IBASIC , FR 5-43

idle state , PG 5-2

I↓ , FR 2-7

IEEE 32-bit floating point format , PG 3-8

IEEE 488 bus , PG 1-4

IEEE 64-bit floating point format , PG 3-8

Impedance, FR 11-3

Parameters, FR 11-3

impedance , PG 2-9

impedance measurement , FR 5-9, FR 5-12

INIT:CONT , PG 5-2

initialize, FR C-1

initialize , UG 6-21
 initializing module , PG 1-2
 inner diameter , FR 5-29
 Instrument BASIC
 controlling , PG 8-6
 preparing , PG 1-6
 instrument BASIC , FR 8-4
 Instrument BASIC , PG 1-6
 Instrument BASIC editor , PG 1-8
 Instrument BASIC Execution Status
 Controlling , PG 8-8
 Determining , PG 8-8
 instrument control command, CR 1-3
 Instrument data arrays , FR 8-47
 Instrument Event Status Enable register,
 CR 3-101
 instrument event status register , PG 4-5
 instrument state block , FR 1-6
 Instrument states and internal data arrays ,
 FR 8-47
 Instrument Status Register, CR 3-101
 intensity , FR 5-42
 internal disk drive , PG 8-1
 internal reference output , FR 2-10
 internal trigger , PG 5-4
 Interrupt , PG 4-9
 introduction , FR 1-1
 I/O port. *See* 8 bit I/O
 accessing from external controller , PG 6-2
 pin assignment , PG 6-1
 reading data , PG 6-2
 writing data , PG 6-2
 i/o port , FR 2-10, FR 2-11
 i/o port pin assignment , FR 2-11
 I-V method , FR 11-12

K

key
 Back Space , FR 4-3
 ↓ , FR 4-2
 ↑ , FR 4-2
 Ch 1 , FR 3-2
 Ch 2 , FR 3-2
 Entry Off , FR 4-3
 G/n , FR 4-2
 k/m , FR 4-2
 M/μ , FR 4-2
 terminator key , FR 4-2
 x1 , FR 4-2
 keyboard connector , FR 2-10
 key code, CR 3-109, CR C-1
 k/m , FR 4-2
 knob , FR 4-2

L

L, FR 11-4
 label , FR 5-35, FR 5-45
 label function , UG 6-13
 LABEL MENU , UG 6-13
 left peak, FR 7-15
 LEVEL MON , UG 6-7
 level monitor, CR 3-7, CR B-24, CR B-32
 level monitor , FR 2-5, FR 6-11, UG 6-7,
 PG 3-5
 level monitor array, CR 3-27, CR B-32
 LIF , PG 1-8
 LIF (logical inter change format) , FR 8-46
 limit line concept , FR 8-38
 limit line/testing , UG 6-8
 limit test, CR 3-28, CR B-33
 limit test , FR 8-11
 linear format , PG 2-10
 linear sweep
 frequency , PG 2-4, PG 2-5
 linear sweep , FR 6-5
 line switch , FR 2-3
 listener , FR 8-43
 list sweep , FR 6-5, UG 6-10
 list values , FR 8-21
 Local , FR 1-6, FR 8-16
 log
 program , UG 6-22
 log format , PG 2-10
 LOGGING , PG 8-13
 logging ON OFF , FR 8-6
 log sweep
 dc bias , PG 2-5
 frequency , PG 2-4
 OSC level , PG 2-5
 log sweep , FR 6-5
 loss, FR 7-23
 low impedance test head , FR 1-2
 low impedance test head add option , FR 10-1
 low-loss air-capacitor calibration , FR 11-12

M

main frame , FR 1-2
 man , FR 2-7
 manual changes, FR A-1, CR A-1
 manual changes , PG A-1
 manual overview , PG 1-1
 manual trigger , FR 6-12, PG 5-2, PG 5-5
 marker, FR 7-21, CR 3-4, CR B-33
 coupled maker , FR 3-2
 marker list , UG 6-16
 max point , UG 6-17
 min point , UG 6-17
 target , UG 6-17

marker , FR 7-4, UG 6-16, PG 2-13
Marker , FR 1-5, FR 7-3
marker block , FR 1-5
marker coupling, FR 7-5
marker data readout , FR 2-5
marker list, FR 7-20
marker→ , FR 7-8
marker search, FR 7-23
marker search , PG 2-13
marker statistics, CR 3-6
marker statistics , FR 2-5
marker time mode , FR 7-21
Marker→ , FR 1-5
material measurement firmware option ,
FR 10-1
material size , FR 5-22, FR 5-29
MAV , PG 4-4
Max, FR 2-5
MAX , FR 7-12
maximum , PG 2-13
max search, FR 7-12
Meas , FR 1-4
Meas , FR 5-3
measured input , FR 2-5
measurement block, FR 1-4
measurement block , FR 5-1
measurement circuit , FR 11-12
measurement parameter , PG 2-9
measurement state , PG 5-3
measure restart , FR 6-13
memory array, CR 3-29, CR B-32
memory arrays , FR 8-47, FR 9-5
memory partition , FR 8-4
memory trace, CR 3-112, CR B-32
memory trace , FR 5-33, FR 5-36, UG 6-17,
PG 3-6
memory trace arrays , FR 8-47, FR 9-6
memory trace number , FR 5-34
menu , FR 2-2
message area, FR 2-8
Min, FR 2-5
MIN , FR 7-12
minimum , PG 2-13
min search, FR 7-12
MKRA→CENTER , FR 7-10
MKRA→SEARCH RNG , FR 7-16
MKRA→SPAN , FR 7-10
MKR LIST , UG 6-16
MKR→REFERENCE , FR 7-10
MKR→CENTER , FR 7-10
MKR→LEFT RNG , FR 7-16
MKR→PEAK DELTA , FR 7-14

MKR→RIGHT RNG , FR 7-16
MKR→START , FR 7-10
MKR→STOP , FR 7-10
MKR→THRESHOLD , FR 7-14
MKR ZOOM , FR 7-10
M/μ , FR 4-2
modify colors , FR 5-42
modify compen kit , FR 5-62, FR 5-64
module , PG 1-2
monitor array , PG 3-5
mounting post , FR 2-13
mounting screw, FR 2-13
MS-DOS format , PG 3-9
MSS , PG 4-2, PG 4-4

N

next peak, FR 7-15
NEXT PEAK (SEANPK), FR 7-15
NEXT PEAK LEFT (SEANPKL), FR 7-15
NEXT PEAK RIGHT (SEANPKR), FR 7-15
non-volatile memory, FR C-1
nop , FR 6-4
notations , FR 2-7
number of groups , PG 5-4
number of points , FR 6-4, UG 6-6
<numeric>, CR 1-5
numeric keypad , FR 4-2

O

offset , FR 5-38
offset value, CR 3-26
Operation Status Register, CR 3-102
operation status register , PG 4-7
option 001 add dc bias , FR 10-1
option 002 add material measurement
firmware , FR 10-1
option 011 delete high impedance test head
, FR 10-1
option 012 add low impedance test head ,
FR 10-1
option 013 add high temperature high
impedance test head , FR 10-1
option 014 add high temperature low
impedance test head , FR 10-1
option 0BW add service manual , FR 10-2
option 1C2 , FR 2-10, PG 1-6
option 1C2 add hp ibasic , FR 10-2
option 1D5 , FR 2-9, FR 2-10
option 1D5 add high stability frequency
reference , FR 10-2
options available , FR 10-1
order base , FR 6-8

- OSC level
 frequency sweep , PG 2-4
 monitor , UG 6-7
 osc level , FR 6-10
 OSC level sweep, CR 3-94
 OSC level sweep , PG 2-4
 outer diameter , FR 5-29
 OUTPUT , PG 2-1
- P**
- parallel circuit model, FR 11-6
 Parallel Resistance, FR 11-4
 PART SRCH on OFF , FR 7-16
 PASS CONTROL , PG 1-4
 pass/fail , FR 2-5
 Peak, FR 2-5
 PEAK (SEAM PEAK), FR 7-15
 peak , PG 2-13
 PEAK→CENTER , FR 7-10
 peak definition, FR 7-27
 PEAK DEF MENU , FR 7-12
 peak delta, FR 7-14
 PEAK DELTA: ΔX , FR 7-14
 PEAK DELTA: ΔY , FR 7-14
 Peak menu , FR 7-14
 PEAK PLRTY POS neg , FR 7-14
 peak polarity, FR 7-14
 peak polarity , FR 7-27
 PEN , FR 5-43
 pen color , FR 5-43
 permeability , PG 2-20
 permeability measurement , FR 5-23,
 FR 11-29
 permittivity measurement , FR 5-17, FR 11-26
 phase unit , FR 5-30
 plot
 display image , UG 6-21
 plotter, FR 10-4
 plotter address , FR 8-16
 point averaging , UG 6-3, PG 2-12, PG 5-6
 point averaging factor, CR 3-72
 POINT AVG FACTOR , FR 5-52
 POINT AVG on OFF , FR 5-52
 point data
 retrieving , PG 5-6
 point delay , UG 6-5, PG 2-12, PG 5-6
 point measure complete bit , PG 5-5
 polar chart , PG 2-10
 port extension, CR 3-77
 port extension , FR 5-66, FR 9-5, FR 11-16,
 PG 2-7
 power , FR 2-10
 power level , FR 2-6
 power-on test, CR 3-31
 preparation for operation , PG 1-6
 preset, CR 3-110, CR B-34
Preset , FR 1-6, FR 2-3, FR 8-18
 preset marker , FR 7-5
 preset state, FR C-1
 print
 display image , UG 6-21
 PRINT , UG 6-21
 printer, FR 10-4
 printer address , FR 8-16
 printing , PG 8-5
 print standard , FR 8-23
 processing time measurement , PG 8-12
 program
 log , UG 6-22
- Program Module*
- adding complex arrays, PG B-1
 auto scale for user trace , PG 7-3
 checking calibration mode , PG 2-7
 checking calibration state , PG 2-6
 checking HP-IB error , PG 8-11
 controlling Instrument BASIC execution
 status , PG 8-8
 detecting sweep end using SRQ and
 interrupt , PG 4-9
 determining Instrument BASIC execution
 state , PG 8-8
 displaying Cole-Cole plot , PG 2-18
 dividing complex arrays, PG B-2
 downloading , PG 8-10
 entering data-trace data from disk into
 variable , PG 8-2
 generating SRQ on PAUSED , PG 8-8
 getting data from analyzer using binary
 transfer , PG 3-10
 getting data trace array , PG 3-3
 getting level monitor data , PG 3-5
 getting marker measurement data , PG 2-13
 getting memory array data , PG 3-6
 getting raw data array , PG 3-2
 getting stimulus array , PG 3-5
 initialize for the external controller ,
 PG 1-3
 initialize module for Instrument BASIC ,
 PG 1-2
 making a single sweep measurement ,
 PG 2-12
 making hard copy from external controller
 , PG 8-5
 measuring processing time , PG 8-12
 modifying permittivity compensation kit
 , PG 2-16
 multiplying complex arrays, PG B-1

performing compensation (permeability) ,
PG 2-19
performing compensation (permittivity) ,
PG 2-16
performing fixture compensation , PG 2-8
presetting the analyzer , PG 2-1
putting numerical data into array , PG 8-6
putting numerical data into variable ,
PG 8-6
putting string variable (1) , PG 8-7
putting string variable (2) , PG 8-7
querying active channel setting , PG 2-2
reading an event register , PG 4-8
Reading data from I/O port , PG 6-2
reading data from I/O port to an external
controller , PG 6-2
reading numerical array , PG 8-6
reading numerical variable , PG 8-6
reading string variable , PG 8-7
retrieving data from the analyzer using
ASCII transfer , PG 3-8
saving the analyzer status , PG 8-1
selecting the connected fixture , PG 2-7,
PG 2-19
selecting the connected fixture :
permittivity , PG 2-16
send data to I/O port , PG 6-2
send data to I/O port from an external
controller , PG 6-2
sending data to analyzer by ASCII transfer
, PG 3-8
sending data to analyze using binary
transfer , PG 3-10
sending multiple commands in a line ,
PG 2-1
setting a log format , PG 2-10
Setting data array data , PG 3-2
setting data train for x- and y-axis for user
trace , PG 7-3
setting dc bias , PG 2-11
setting dc current sweep , PG 2-5
setting dc voltage sweep , PG 2-5
setting frequency sweep , PG 2-4
setting grid for x-axis of user trace , PG 7-3
setting grid for y-axis of user trace , PG 7-3
setting measurement parameter , PG 2-9
setting measurement parameter
(permeability) , PG 2-20
setting measurement parameter
(permittivity) , PG 2-18
setting memory trace array data , PG 3-6
setting MUT size , PG 2-20
setting MUT thickness , PG 2-17
setting OSC level , PG 2-4
setting OSC level sweep , PG 2-4

setting the active channel , PG 2-3
setting the user fixture , PG 2-7
subtracting complex arrays, PG B-1
sweeping a specified number of times ,
PG 5-5
sweeping once using the HP-IB trigger ,
PG 5-4
triggering on each point using the manual
trigger , PG 5-6
turning off and clearing the user trace ,
PG 7-4
turning on the user trace , PG 7-4
uploading , PG 8-10
using marker on the user trace , PG 7-4
using PROG:WAIT? HP-IB query , PG 8-9
program module , PG 1-2
Program Running bit , PG 8-8
PROGram subsystem , PG 8-6
purge file , UG 6-21
putting numeric variable , PG 8-6
putting string variable , PG 8-7

Q

Q, FR 7-23
Q (Quality Factor), FR 11-4
quadrant , FR 8-21
query , PG 2-2
query response , PG 2-2
Questionable Status Register, CR 3-104
Q value, CR 3-11

R

R, FR 11-3
rack mount and handle kit option , FR 10-2
rack mount kit option , FR 10-2
RAM disk , FR 8-46
RAM disk memory , PG 8-1
raw data , PG 3-2
raw data array, CR 3-27, CR B-32
raw data arrays , FR 8-47, FR 9-4
Reactance, FR 11-3
reading an event register directly , PG 4-8
reading numeric variable , PG 8-6
reading string variable , PG 8-7
READIO , PG 6-2
real-time clock , PG 8-12
rear panel , FR 2-9
recall
 analyzer setting , UG 6-20
 automatically , UG 6-20
 measurement trace , UG 6-20
Recall , FR 1-6, FR 8-37
recall color , FR 5-43
recall file , FR 8-37
recharge time, FR C-1

reference , PG 2-13
 reference level , FR 2-5
 reference oven output , FR 2-10
 reference position , FR 5-49
 reference value , FR 5-49
 reflection coefficients , PG 2-9
 related documentation , PG 1-8
 relaxation time , FR 7-20
 REMOTE indicator , FR 2-3
 remote mode , PG 1-7
 required instrument , PG 1-1
 Resistance, FR 11-3
 right peak, FR 7-15
 R+jX , FR 7-20
 rotary knob, CR 3-14
 R_p, FR 11-4
 RQS , PG 4-2, PG 4-4, PG 4-9
 R_s, FR 11-3
 *RST , PG 5-2
 run/cont input , FR 2-10

S

sample program

loading , PG 1-8
 reading on PC , PG 1-8

Sample Program

basic impedance measurement program ,
 PG 2-14
 BIN sorting using the I/O port , PG 6-3
 loading compensation data from disk ,
 PG 3-13
 performing calibration , PG 4-11
 storing compensation data to disk , PG 3-11
 time characteristic measurement using
 user trace , PG 7-5
 using complex operation sub program ,
 PG B-2

sample program disk , UG 6-11, UG 6-12,
 PG 1-8

save

analyzer setting , UG 6-19
 display image , UG 6-20
 measurement trace , UG 6-19

Save , FR 1-6, FR 8-29

save color , FR 5-43

SAVE COLORS , FR 5-43

scale , PG 2-13

scale coupling , FR 5-50

scale/div , FR 2-5

scale for data , FR 5-50

scale for memory , FR 5-50

scale per div , FR 5-49

Scale Ref , FR 1-5

scale reference , FR 5-49

scaling , FR 9-6

SCPI, CR 1-2, CR 1-3

SCPI , PG 1-8, PG 5-1

SCPI command , PG 2-2

screen display , FR 2-4

search, FR 7-23

Search , FR 1-5

SEARCH LEFT (SEAL), FR 7-13

search menu , FR 7-12

SEARCH: PEAK , FR 7-12

search range, FR 7-16

SEARCH RANGE MENU , FR 7-12

search range menu , FR 7-16

SEARCH RIGHT (SEAR), FR 7-13

SEARCH TRK on OFF , FR 7-12

segment , FR 6-7, FR 8-38

SEL 'D UTRC ON off , FR 5-47

select code , PG 1-3

SELECT LETTER , FR 5-46

serial number, FR A-2, CR A-2

serial number , PG A-2

serial poll , PG 4-2

series circuit model, FR 11-6

service manual add option, FR 10-2

service menu , FR 8-4

service request , PG 4-2

simple command, CR 1-3

single sweep , PG 5-4

stimulus array, CR 3-29

Smith chart , PG 2-10

Smith polar marker , FR 7-20

smth/polar menu , FR 7-20

Source , FR 1-5, FR 6-10

SPACE , FR 5-46

span, CR 3-127

Span , FR 1-5

span value , FR 2-6

split display , FR 5-33

Split Display , UG 6-15

SPOLL , PG 4-2

spreadsheet , UG 6-20

SRQ , PG 2-8, PG 2-12, PG 4-2, **PG 4-9**

SRQ generation , PG 4-10

standard event status register , PG 4-6

standard model , FR 5-61

Start , FR 1-5, FR 6-14

start value , FR 2-6

state, FR 8-47

statistics ON OFF , FR 7-20

status byte, CR 3-118, CR B-34

status byte register , PG 4-2, PG 4-4

status notations , FR 2-7

status register

using , PG 4-8

status register structure , PG 4-4
 status reporting system , PG 4-1
 *STB , PG 4-2
 step key , FR 4-2
 stimulus, CR 3-95
 stimulus , PG 2-4
 stimulus array , PG 3-5
 stimulus block , FR 1-5
Stop , FR 1-5
 stop value , FR 2-6
 storage devices , FR 8-46
 <string>, CR 1-6
 sub-marker
 using , UG 6-16
 sub marker , FR 7-5
 SUB MKR , FR 7-13
 SUB MKR , UG 6-16
 subsystem , PG 2-2
 suffix, CR 1-6
 Susceptance, FR 11-4
 Svc, FR 2-7
 sweep
 list , UG 6-10
Sweep , FR 1-5, FR 6-3
 sweep averaging, CR 3-72
 sweep averaging , UG 6-4
 SWEEP AVG FACTOR , FR 5-52
 SWEEP AVG ON off , FR 5-52
 SWEEP AVG RESTART , FR 5-52
 sweep delay , UG 6-5
 sweep direction
 dc bias , PG 2-5
 OSC level , PG 2-5
 sweep direction , FR 6-5
 sweep hold , FR 6-12
 sweeping a specified number of times ,
 PG 5-4
 sweeping once using the HP-IB trigger ,
 PG 5-4
 sweep source, CR 3-95
 sweep time , FR 6-4
 sweep type, CR 3-45
 sweep type , FR 6-5
System , FR 1-6
System , FR 8-3
 system accessory, FR 10-4
 system controller , FR 8-16, FR 8-43, FR 8-44,
 PG 1-4
 system overview , FR 1-2, FR 9-1
 system rack, FR 10-4

T

talker , FR 8-42
 Targ, FR 2-5
 TARGET , FR 7-12
 TARGET (SEATARG), FR 7-13
 target menu , FR 7-13
 target search, FR 7-12
 teflon , FR 5-64
 terminator key , FR 4-2
 test fixture
 selecting , PG 2-7
 test head , FR 2-15
 test station , FR 1-2, FR 2-13, FR 2-14
 test station connector , FR 2-3
 TEXT MARKER , FR 5-43
 text with tab delimiter , UG 6-20
 θ , FR 11-3
 thickness , FR 5-22
 threshold , FR 7-14
 THRESHOLD on OFF , FR 7-14
 threshold value, FR 7-27
 THRESHOLD VALUE , FR 7-14
 TIMEDATE , PG 8-12
 time stamp , FR 8-28
 tint , FR 5-44
 title , FR 2-8, FR 5-35, FR 5-46
 trace
 memory , UG 6-17
 trace math function , UG 6-19
 tracking delta marker , FR 7-6
 TRACKING Δ MKR , FR 7-7
 transferring program source , PG 8-10
 transition filter , PG 4-3, PG 8-8
 trigger, CR 3-56, CR 3-115, CR B-34
 trigger , PG 2-12
Trigger , FR 1-5, FR 6-12
 TRIGGER , PG 5-3
 trigger event , FR 6-13
 triggering on each point using the manual
 trigger , PG 5-5
 trigger input , FR 2-10
 trigger on point
 using , PG 5-5
 trigger on point , PG 5-3, PG 5-6
 trigger on sweep
 using , PG 5-4
 trigger on sweep , PG 5-3, PG 5-6
 trigger signal polarity , FR 6-13
 trigger source , PG 5-2
 trigger system , PG 5-2

U

ΔL value, CR 3-11
 ΔR value, CR 3-11
 uncoupled channel , UG 6-15
 upgrade kit, FR 10-2
 uploading a program , PG 8-10
 user defined calibration , UG 6-2
 user defined cal points , FR 5-55
 user defined compensation points , FR 5-57
 user defined fixture compensation , UG 6-3
 user kit , FR 5-64
 user trace, CR 3-44, CR 3-114, CR B-34
 clearing , PG 7-4
 HP-IB command , PG 7-2
 log scale , PG 7-3
 setting a grid , PG 7-3
 setting data train , PG 7-3
 turning on , PG 7-4
 using marker , PG 7-4
 user trace , FR 5-47, **PG 7-1**
 user trace format , FR 5-31
 user trace scale , FR 5-51
 using disks , PG 8-1
Utility , FR 1-5
 utility menu , FR 7-19

V

V↓, FR 2-7

W

WAIT , PG 6-2
 wait for trigger state , PG 5-2
 width. *See* bandwidth
 width function, FR 7-17
 width search, FR 7-23
 width value , FR 2-5
 WRITEIO , PG 6-2

X

X, FR 11-3

Y

|Y|, FR 11-4
 Ÿ, FR 11-4

Z

|Z|, FR 11-3
 Ž, FR 11-3
 zooming aperture, CR 3-26
ZOOMING APERTURE , FR 7-10

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