HEWLETT PACKARD

4192A LF Impedance Analyzer

DESIGNED FOR HP-IB SYSTEMS

TECHNICAL DATA OCTOBER 1981

Complete Component and Network Analysis

- **Variable Measuring Frequency: 5.000 Hz to 13.000000 MHz**
- **Amplitude, Phase and Group Delay Measurements: Resolution 0.001 dB, 0.01°, 0.1 ns**
- **Direct Impedance Measurements: |Z| • |Y| • θ • R • X • G • B • L • C • D • Q • Δ • Δ%**
- **Test Grounded or Floating Devices**

...able Transmission Characteristics and Impedance Measurements From 5 Hz – 13 MHz

The Model 4192A LF Impedance Analyzer is Hewlett-Packard's newest microprocessor-controlled impedance measuring instrument. The 4192A uses a completely new measurement concept which enables it to measure a wide range of impedance parameters as well as gain, phase and group delay.

The 4192A improves efficiency and quality in the development and production of many types of complex components, semiconductors and materials. Complete network analysis of devices such as filters and audio/video equipment, plus evaluation of the impedance characteristics of their circuit components, can be performed. These tests can be performed using test signals equivalent to those found under actual operating conditions. Circuit operating characteristics can thus be precisely analyzed down to the component level.

The Model 4192A can accurately measure the gain/loss, phase, group delay and level of many types of circuits. All impedance parameters are displayed with 4½ digit resolution. The built-in frequency synthesizer can be set to any test frequency from 5.000 Hz to 13.000000 MHz, and can be swept within that frequency range with any desired frequency resolution.

Cost Efficient HP-IB Measurement System

Integrating the 4192A into a high-speed measurement system is possible with the standard Hewlett-Packard Interface Bus (HP-IB). Such a system reduces cost by improving DUT throughput, improving circuit design efficiency, and shortening the component development period.

Major applications with the HP-IB capability include: 1) configuration of a system to evaluate equivalent circuit constants and impedance characteristics of ceramic resonators, 2) configuration of an automatic production line test system for telecommunication filters and IFTs, and 3) configuration of R&D systems for automated circuit design.

Direct Reading of Fifteen Transmission and Impedance Parameters

The 4192A can measure four transmission parameters – gain/loss (B-A), Level (A, B), phase (θ), and group delay – plus eleven impedance parameters – |Z|, |Y|, θ, R, X, G, B, L, C, D, Q. These parameters can be measured over a wide range – |Z|: 0.1 mΩ – 1 MΩ, |Y|: 1 nS – 10 S.

Very good gain measuring resolution (0.001 dB) and accuracy (0.02 dB to 0.09 dB) plus good phase resolution (0.01°) and accuracy (0.1° to 0.2°) are worthy of special mention. These features make accurate measurement of transmission characteristics easier than ever before. For example, .001 dB changes in insertion loss and ripple in the pass band of a BPF, caused by temperature changes, can be resolved. Moreover, the ability of the 4192A to measure group delay of 0.1 ns to 10 s using an arbitrary frequency step and with a resolution of 4½ digits, helps in the design and construction of filters that must accurately transmit phase information. The 4192A is an excellent choice for improving the quality of hybrid IC's and filters, as well as circuit designs.

Variable Test Frequency, Test Level and DC Bias, Plus Automated Swept Measurements

Components and circuits can be measured using test signals equal to actual operating conditions. This makes it possible to accurately evaluate component characteristics and meet design target specifications in circuit development. Because the 4192A provides complete component and circuit characteristics, it can be used in the QA department to perform incoming inspection and in R&D for circuit design.

The built-in frequency synthesizer can be set to individual frequencies or swept within the range from 5.000 Hz to 13.000000 MHz. This allows stable measurement of high Q devices such as crystals. Test signal level is variable from 5 mV to 1.1 Vrms with 1 mV resolution (5 mV for levels higher than 100 mV) and the internal dc bias voltage source provides ±35 V at 10 mV increments. Thus, the 4192A can evaluate components and circuits under a wide variety of measurement conditions.

Test Fixtures Interface the 4192A to Your Component or Network

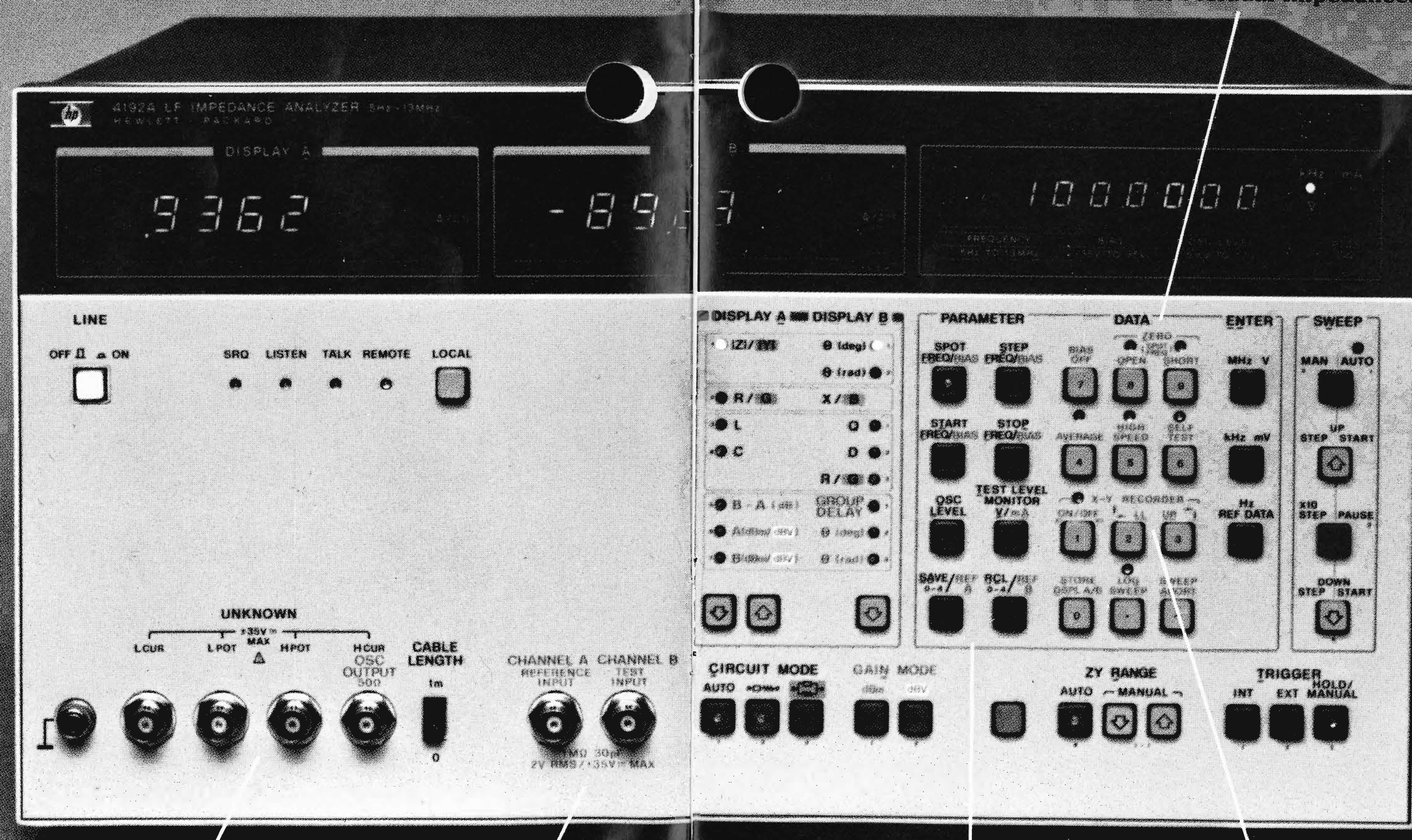
Because components and networks are not of uniform shape and size, the 4192A has several test fixtures that can be used to best meet different measurement requirements.

The HP 16095A Probe Fixture permits measurement of in-circuit, mounted components. Both grounded and floating measurements can be made. The 16096A Test Fixture provides quick and easy connection of four terminal devices, such as reed filters, and permits measurement of either transmission characteristics or input impedance.

The 16097A Accessory Kit contains several fixtures, loads and cables which can aid in circuit characterization.

Storage Registers for Five Measurement Conditions

Five completely different front panel settings, including both parameter selection and sweep controls, can be stored in memory and recalled at any time with the touch of a key. Frequently used front panel settings can be stored and recalled instead of having to reenter the measurement conditions each time. The standard memory of the 4192A keeps data stored even when the LINE switch is off. This feature improves efficiency in production applications where repetitive measurements are being made. This feature can also be used to measure the same parameter on one component under five different sets of test conditions.



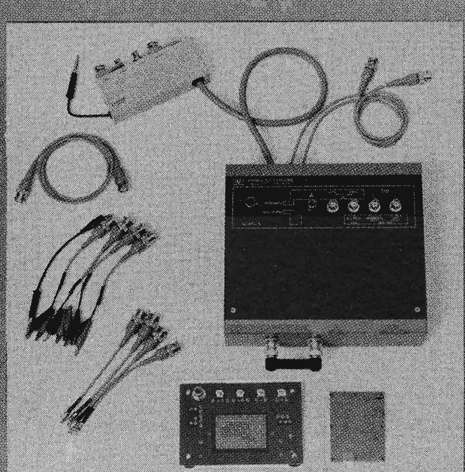
Automatic Zero Adjustment cancels residual impedances

4-Terminal Pair Configuration measures floating or grounded devices

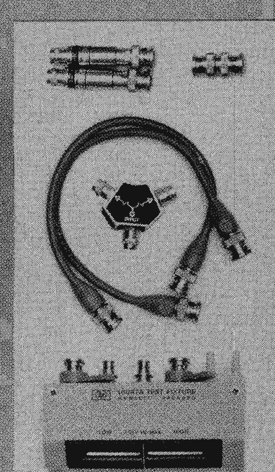
Transmission Characteristics measuring input terminals

Deviation Measurement detects changes from a stored value

Recorder Output allows low-cost hard copies



16096A Test Fixture is an accessory available for measurement of 4-terminal devices



Furnished Accessories Include 16047A Test Fixture

4192A Key Features

Test Signal	Frequency: 5.000 Hz to 13.000000 MHz Sweep: Manual and automatic Signal Level: 5 mV to 1.1 Vrms Output Impedance: 50 Ω (gain/phase measurements) and 100 Ω (impedance measurements)
Amplitude and Phase Measurement	B – A: 0 to ±100 dB*; resolution 0.001 dB (0 to ±20 dB) and 0.01 dB (±20 dB to ±100 dB*) θ: −180° to +180°, resolution 0.01° A, B: +0.8 to −100 dBV*, and +13.8 dBm to −87 dBm*; resolution 0.001 dB (+0.8 to −20 dB) and 0.01 dB (−20 to −100 dB*) Group Delay Time: 0.1 ns – 10 s
Impedance Measurement	|Z|•R•X: 0.1 mΩ to 1 MΩ |Y|•G•B: 1 nS to 10 S L**: 0.01 nH to 1 kH*, C**: 0.1 fF to 100 mF* D: 0.0001 to 10.000 Q: 0.1 to 1000 θ: −180.00° to +180.00°
Basic Accuracy	Amplitude and Phase Measurement: 0.02 to 0.09 dB; 0.1° to 0.2° Impedance Measurement: 0.1% reading
Display	4½ digit (maximum)**
DC Bias	0 to ±35 V, 10 mV step, sweep capability

*Accuracy not specified over entire range.
**Varies with test frequency and test signal level.

DESIGNED FOR HP-IB SYSTEMS

HP-IB: Not just IEEE-488, but the hardware, documentation and support that delivers the shortest path to a measurement system.

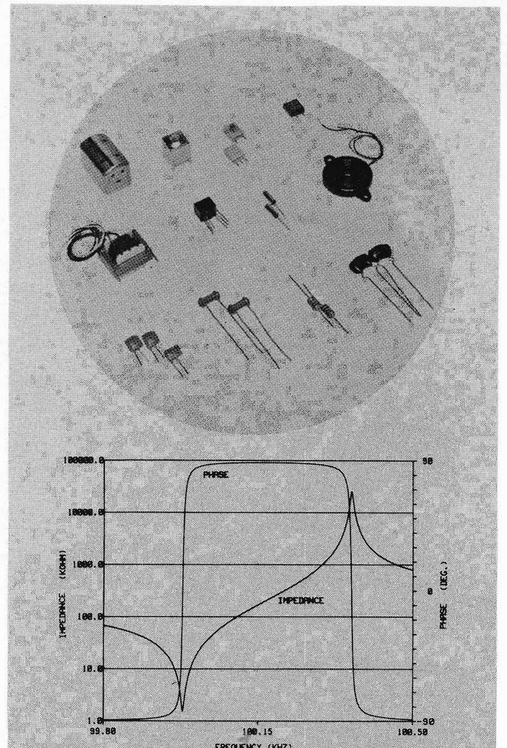
4192A Applications – The Complete Solution

Complex Component Measurements

Measuring frequencies can be set from 5.000 Hz to 13.000000 Hz with 0.005% accuracy. In addition, most impedance parameters can be measured over a wide range (|Z|: 0.1 mΩ to 1 MΩ, |Y|: 1 nS to 10 S). This allows the intrinsic characteristics of a crystal, which vary widely with small frequency changes, to be measured with a basic accuracy of 0.1%. These features provide an effective means to accurately evaluate design performance, to improve QA inspection, and to increase component quality.

Major Applications:
- Impedance vs. frequency characteristics of resonators
- Resonating frequency and impedance detection
- Calculation of equivalent circuit constants for resonators

Devices:
- Resonators (crystal, ceramic, supersonic)
- Magnetic head (audio, video), delay lines
- Transformers (audio, RF, IF, iron resonating)
- Capacitors (electrolytic, ceramic, film)
- Piezoelectric buzzers, communication cables



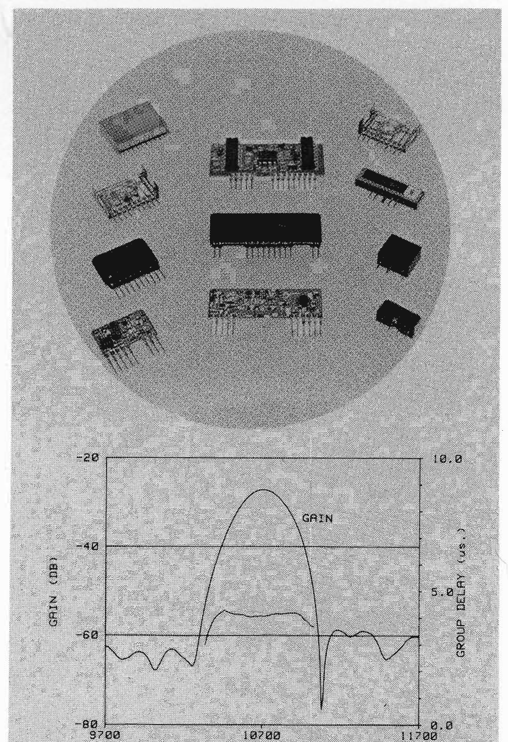
Impedance Characteristics of 100 kHz Crystal

Filter/Hybrid IC Design and Evaluation

The 4192A can easily evaluate most of the transmission characteristics and input/output impedance of filters and hybrid IC's. Also, the individual components used in these networks can be evaluated. Gain and loss can be measured with 0.001 dB resolution and 0.02 to 0.09 dB accuracy. Group delay measurements are displayed with 4½ digits resolution over a range of 0.1 ns to 10 s. These features can help improve the design and manufacture of devices, thus improving the quality and performance of end products such as televisions, VTR's, and telecommunication equipment.

Major Applications:
- Accurate evaluation of filter insertion loss and ripple
- Determine filter bandwidth, center frequency, and spurious gain by measuring amplitude vs. frequency response, gain/loss and phase
- Group delay and delay distortion of filter passbands
- Input/Output impedance measurement

Devices:
- Filters (ceramic, crystal, mechanical, active, LC)
- Hybrid IC's (thick film, thin film)
- Crystal oscillators, power supplies, operational amplifiers
- Attenuators, antennas



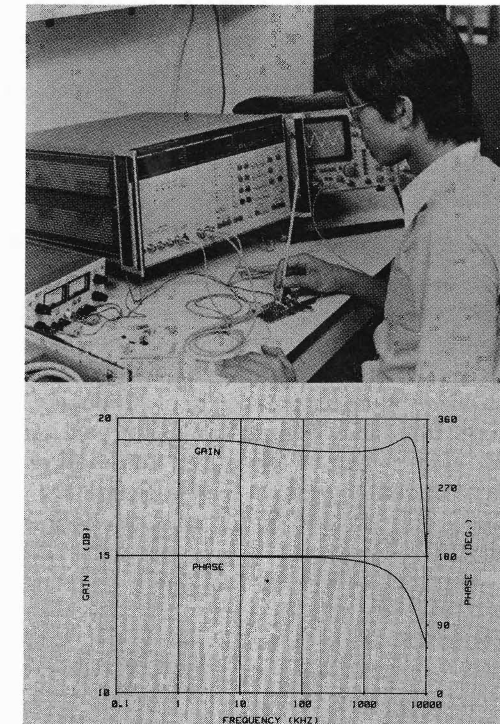
Transmission Characteristics of SAW Filter

Use as an Electronic-Circuit Design Tool

The 4192A can be used at every step of circuit design, from parts selection to complete characteristics evaluation of entire circuits. With the 4192A, design engineers can test in-circuit components under actual operating conditions, measure input/output impedance of grounded in-circuit devices using a unique probe fixture, and measure transmission characteristics over a display range of − 100 dB to + 100 dB. The 16097A accessory kit contains test fixtures with different impedance values for use on components and circuits of odd shapes and sizes. This feature can help improve design efficiency and make the 4192A a valuable tool in the design of consumer electronic equipment.

Major Applications:
- Simultaneous gain/loss and phase measurements (Bode plot)
- Circuit component testing under actual operating conditions
- Direct input/output impedance measurement for impedance matching requirements

Devices:
- Video circuits in VTR's, TV's
- Transmission circuits in telephone equipment
- Audio circuits in Hi-Fi amplifiers
- Oscillator circuits, power supply circuits
- Amplifiers, I-V converters



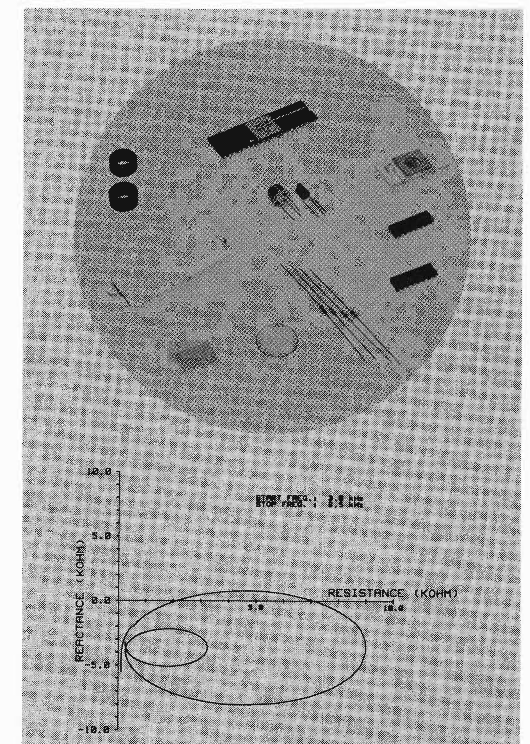
Gain-Phase Curve of Wideband Amplifier

Design and Evaluation of Semiconductors/Electronic Materials

To make evaluation of semiconductor and electronic materials easy to perform, the 4192A provides a dc bias voltage source that is adjustable from 0 to ± 35 V with 10 mV resolution and a variable frequency synthesizer for test frequencies from 5.000 Hz to 13.000000 MHz. Parameters important in evaluating semiconductors and electronic materials can be measured directly and with high resolution: C (max. 0.1 fF), G•|Y| (max. resolution 1 nS), and R•X• |Z| (max. resolution 0.1 mΩ). Low cost and accurate hard copies can also be obtained using the X-Y recorder output. The 4192A is useful in the development of high performance devices, improving production yield and providing valuable characteristics analysis of new electronic materials.

Major Applications:
- AC conductance (G/ω-ω) characteristics
- High frequency C-V characteristics
- Transfer-impedance frequency dependency (R-X display)

Devices:
- Amorphous semiconductor devices
- III-V compound semiconductors and EL semiconductor devices
- MOS and bipolar IC's, transistors, and diodes
- Magnetic materials (ferrite, etc.)

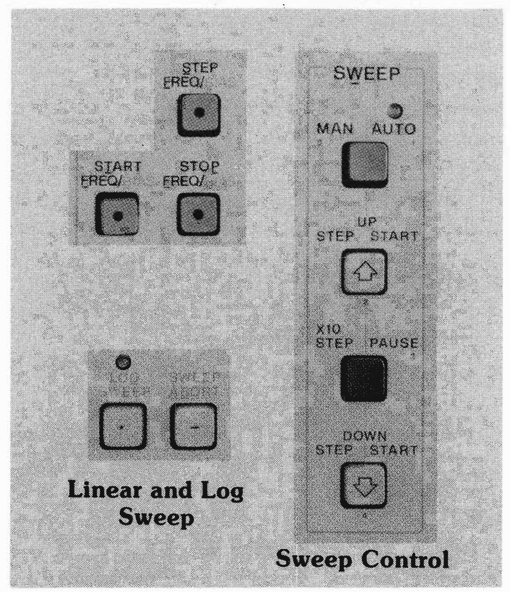


R-X Display of Ceramic Material

4192A Unique Features Widen Its Application Range and Help To Improve Measurement Efficiency and Product Quality

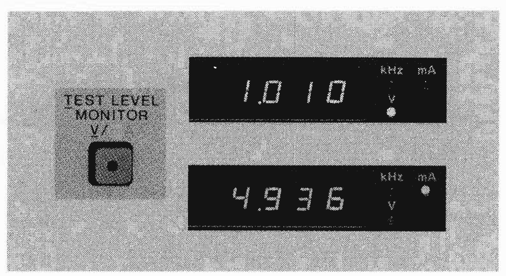
Flexible Sweep Control for Frequency and DC Bias

Sweep capability of the built-in frequency synthesizer and dc bias voltage source permits quick and accurate DUT measurements. The sweep capability can be controlled either automatically or manually. Therefore, frequency characteristics for parameters like C, L, R, and |Z| can be measured automatically. The range and increment values for the sweep are set via the START, STOP, and STEP keys on the front panel. Either linear or log sweep can be selected. The sweep can be temporarily stopped to change sweep conditions and restarted from the same point. Other sweep related capabilities include a X10 STEP frequency key for use in manual sweep mode plus a SWEEP ABORT key for sweep cancellation.



Variable Test Signal Level Using HP-IB Remote Control

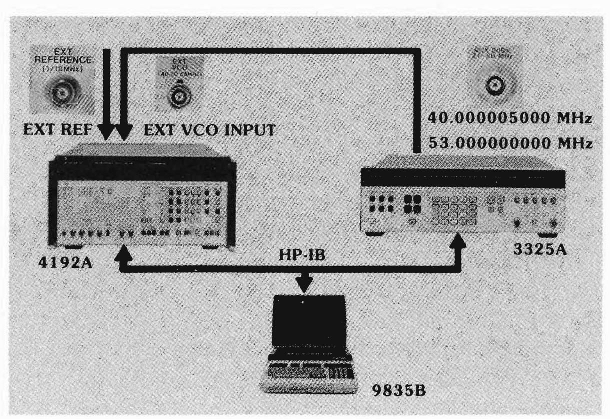
Test signal current through the DUT or test voltage across the DUT is displayed on the front panel. Desired source levels can be set remotely and the test level across the DUT can be read via the HP-IB. Using this kind of HP-IB system, for example, the current characteristics of a ferrite core inductor can be automatically obtained.



Evaluation of High-Q Devices Using the 4192A EXTERNAL VCO Input

The 4192A's built-in frequency synthesizer permits stable measurements of the intrinsic characteristics of high Q devices. Such devices include crystals whose impedance can change drastically with changes in frequency of only a few hertz.

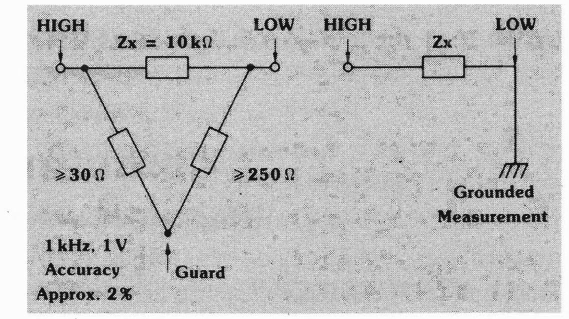
For measurements on high Q devices or for impedance measurements that require a test signal that is more stable than that provided by the 4192A, an external frequency synthesizer can be connected to the 4192A Ext VCO Input. Using this technique, a frequency resolution of 1 mHz over the full frequency range, from 5 Hz to 13 MHz, can be obtained. In addition, a high stability reference (1 MHz or 10 MHz) can be connected to a 4192A rear panel input so that even more stable test signals are obtained.



Direct Impedance Measurements of Grounded Devices

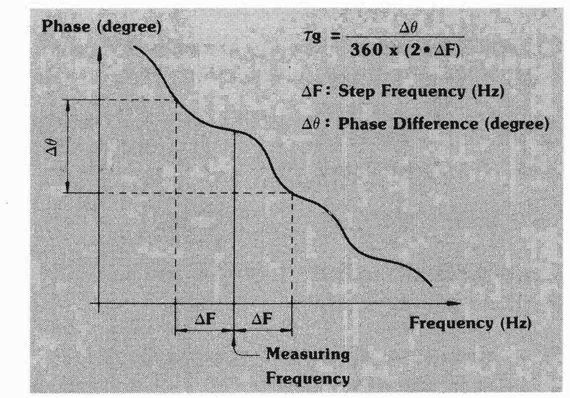
The unique measuring circuitry of the 4192A provides direct and accurate impedance measurements of both grounded and floated devices. Stray capacitance and residual impedance of the test fixture can be cancelled at any test frequency by using the automatic zero adjust capability. This can be accomplished regardless of the values of the residual components and even when the low terminal is grounded. Accuracy degradation is limited to <0.2% of reading (|Z|: 1 Ω to 10 kΩ range, |Y|: 1 mS to 10 S range). Also, guard ratio must be 100 or less and measuring frequency 100 kHz or less for reliable grounded device measurements.

PC board mounted components also can be accurately evaluated.



Group Delay Measurements Using Arbitrary Split Frequencies

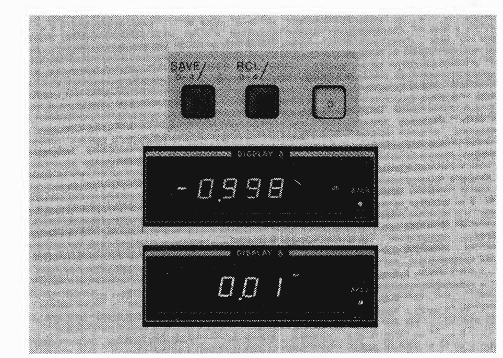
Group delay is an important parameter in determining the transmission quality of filters. The 4192A has delay sensitivity and resolution which is adequate in the most demanding application. Group delay can be measured at individual spot frequencies as well as when frequency is being swept. Delay is automatically calculated from the phase readings at two frequencies located on either side of the measuring frequency. Delay readings from 0.1 ns to 10 s are output in analog and digital format with a maximum resolution of 4½ digits.



Single Keystroke Deviation (Δ) and Deviation Percent (Δ%) Measurements

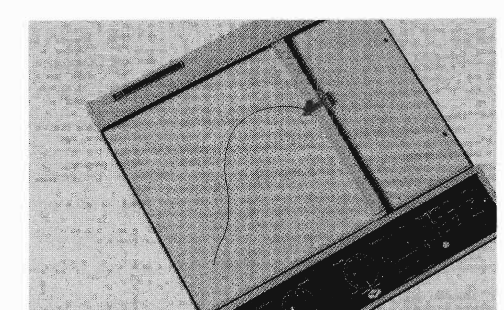
The 4192A provides two methods of inputting reference values for deviation measurements: 1) input the reference value using front panel numerical keys, or 2) single keystroke input of measured values of the reference device. Deviation is displayed as either the deviation (Δ) from the reference value or the percent deviation (Δ%).

Deviation measurement can be performed on all measuring parameters. This feature is useful for environmental tests such as temperature characteristics measurement for filter loss, and gain vs. frequency for amplifiers.



Standard X-Y Recorder Output for Inexpensive Hard Copy

Because the 4192A provides calibration output for the X-Y gain controls on the recorder and furnishes a pen lift signal, clear and accurate hard copies can be made with ease. Use of the X-Y recorder outputs does not require an external HP-IB controller.



specifications

(Divided into three parts: Amplitude-Phase Measurement, Impedance Measurement, and Items Common to both measurements)

common specifications

(Amplitude-Phase and Impedance Measurements)

INTERNAL SYNTHESIZER: Output from OSC OUTPUT (H_{CUR}) terminal

Frequency Range: 5 Hz to 13 MHz

Frequency Resolution: 1 mHz (5 Hz to 10 kHz), 10 mHz (10 kHz to 100 kHz), 100 mHz (100 kHz to 1 MHz), 1 Hz (1 MHz to 13 MHz)

Frequency Accuracy: ±50 ppm (23 ±5°C)

OSC Level Accuracy (H_{CUR} terminal open): (5 + 10/f)% of setting + 2 mV* (5 Hz to 1 MHz), (4 + 1.5•F)% of setting + 2 mV* (1 MHz to 13 MHz) where f is measuring frequency in Hz, and F is measuring frequency in MHz

*10 mV when OSC level is > 100 mV.

OSC Level Resolution: 1 mV (5 mV to 100 mV), 5 mV (100 mV to 1.1 V)

Output Resistance (direct coupled): 50 Ω (amplitude-phase measurements), 100 Ω (impedance measurements, ⩾ 38 kHz), 100 Ω to 10 kΩ (impedance measurements, < 38 kHz, depends on measuring range)

Level Monitor (impedance measurement): Measures and displays voltage across or current through device under test

Frequency and Level Control: Via front panel numeric keys or HP-IB, auto sweep (except for level) and manual sweep

EXTERNAL SYNTHESIZER: Can be connected to VCO INPUT connector on rear panel (HP 3325A Synthesizer or equivalent is recommended)

Frequency Range: 40.000005 MHz to 53 MHz (measuring frequency is equal to frequency of the external synthesizer minus 40 MHz)

Required Signal Level: 0 dBm to 3 dBm

NOTE: In an HP-IB system, frequency of internal synthesizer should be set to the frequency of the external synthesizer minus 40 MHz, and the 4192A and external synthesizer system should be phase-locked.

EXT REFERENCE INPUT CONNECTOR: Can be connected to a 1 MHz/10 MHz high stability reference signal (−1 dBm to +5 dBm) to improve the internal synthesizer stability. Input resistance is approximately 50 Ω.

MEASURING MODE:

Spot Measurement: At specific frequency (or dc bias*)

Swept Measurement: Between START and STOP frequencies (or dc bias*). Sweep can be automatic or manual.

Sweep Mode: Linear sweep mode (sweeps at specified step) and logarithmic sweep mode (20 points measurement per decade frequency range)

X10 STEP Key (Linear manual sweep): Multiplies the specified frequency/dc bias* step by 10.

PAUSE (temporary sweep stop) and SWEEP ABORT (sweep cancellation) functions are provided for auto sweep.

*dc bias can be used only during impedance measurements.

RECORDER OUTPUT: DC output proportional to measured values of DISPLAY A, DISPLAY B, and measuring frequency or dc bias

Maximum Output: ±1 V

Output Voltage Accuracy: ±(0.5% of output voltage +20 mV)

PEN LIFT output and X-Y recorder scaling outputs are provided.

FIVE NONVOLATILE STORAGE REGISTERS: Memorize five complete instrument measurement configurations. A measurement configuration can be set from the front panel, from the HP-IB, or both. Also, a configuration can contain measurement functions which require single keystroke setup, multiple keystroke setup, or both.

HP-IB DATA OUTPUT AND REMOTE CONTROL: Based on IEEE-std-488 and ANSI-MC1•1

Remote Control Function: All front panel functions except for LINE switch and X10 STEP key

Data Output: Measured values of DISPLAY A, DISPLAY B, and measuring frequency or dc bias

SELF TEST: Checks 4192A basic operation

TRIGGER: Internal, External, Hold/Manual, or HP-IB remote control

amplitude-phase measurements

PARAMETERS MEASURED: Amplitude ratio B-A (dB), θ (degrees or radians), group delay (s), absolute amplitude A, B (dBV or dBm). Deviation (Δ and Δ%) measurement for all the above parameters.

Parameter Combinations: B-A and θ, B-A and group delay, A and B are single display

REFERENCE AMPLITUDE: 0 dBV = 1 Vrms, 0 dBm = 1 mW (into 50 Ω)

OSCILLATOR OUTPUT RESISTANCE (Direct Coupled): 50 Ω +5% −8% (50 Hz to 5 MHz) 50 Ω ±10% (< 50 Hz and > 5 MHz)

CHANNEL A AND B INPUT IMPEDANCE: 1 MΩ ±2%, shunt capacitance 25 pF ±5 pF, maximum input voltage: ±35 Vp

DISPLAY RANGE AND RESOLUTION (Normal or Average Test Speed Mode):

B-A: 0 to ±100 dB, 0.001 dB (< 20 dB), 0.01 dB (⩾ 20 dB)

θ: 0 to ±180° (0 to ±π radian), 0.01°

A, B: +0.8 to −100 dBV, +13.8 to −87 dBm, 0.001 dB (>−20 dB), 0.01 dB (⩽−20 dB)

Measuring resolution decreases one digit in high speed mode.

Group Delay (t_g): 1 μs to 10 s, 8 ranges 0.1 ns maximum resolution

MEASURING ACCURACY*: Specified at measuring terminals when the following conditions are satisfied:

(1) Warmup Time: ⩾ 30 min

(2) Ambient Temperature: 23 ±5°C (error limits double for 0°C to 55°C temperature range)

(3) Measuring Speed: Normal or Average mode

*NOTE: Additional errors due to power splitter, feed-through termination, etc., are to be added to specification given here.

Group Delay (t_g) Measurements: Accuracy is derived from the following equation (phase accuracy ΔθA and ΔθB are read from the table below):

$$\text{group delay accuracy} = \frac{\Delta\theta A + \Delta\theta B}{720 \times \Delta F} \text{ (s)}$$

where ΔθA and ΔθB are channel A and B phase accuracy (deg.) and ΔF is step frequency (Hz).

Example Calculation for Group Delay Accuracy:

(1) Measurement conditions:
- measurement frequency = 1 kHz
- step frequency (ΔF) = 16.67 Hz
- channel A input level = −15 dBV
- channel B input level = −25 dBV

(2) Phase accuracy in Channel A (ΔθA) is given in the table below as ±0.05°. Phase accuracy in Channel B (ΔθB) is ±0.15°.

(3) $$\text{Group delay accuracy} = \left(\frac{0.05° + 0.15°}{720 \times 16.67 \text{ Hz}}\right) \text{ (s)}$$

Group delay accuracy = ±16.67 microseconds

B-A and θ Accuracy: (f in Hz, F in MHz)

Input Absolute Level of Each Channel (dBV) \ Measuring Frequency (Hz)	5 – 100 (dB)	5 – 100 (°)	100 – 10k (dB)	100 – 10k (°)	10k – 1M (dB)	10k – 1M (°)	1M – 13M (dB)	1M – 13M (°)
+0.8 to −20	0.008 + 0.2/f dB	(0.04 + 1/f)°	0.01 dB	0.05°	0.045 dB	0.08°	(0.025 + 0.02F) dB	0.08F°
−20 to −30	0.047 + 0.3/f	(0.13 + 2/f)°	0.05	0.15°	0.08	0.25°	(0.04 + 0.04F)	(0.05 + 0.2F)°
−30 to −40	0.05 + 1/f	(0.14 + 6/f)°	0.06	0.2°	0.12	0.3°	(0.06 + 0.06F)	(0.05 + 0.25F)°
−40 to −50	0.05 + 3/f	(0.15 + 15/f)°	0.08	0.3°	0.14	0.6°	(0.07 + 0.07F)	(0.3 + 0.3F)°
−50 to −60	0.1 + 10/f	(1 + 50/f)°	0.2 dB	1.5°			(0.1 + 0.1F)	(1 + 0.5F)°
−60 to −70	0.45 + 25/f	(4 + 100/f)°	0.7	5°			(0.4 + 0.3F)	(4 + F)°
−70 to −80	1.5 + 50/f	(12 + 300/f)°	2	15°			(1 + F)	(13 + 2F)°
−80 to −90			7	–				
−90 to −100								

A, B Accuracy (+0.8 to −80 dBV):

0.8 dBV to −50 dBV \ Measuring Frequency (Hz)	5 – 100	100 – 1M	1M – 13M
	0.4 + 1/f dB	0.4 dB	0.4 + 0.08F dB

- The measuring accuracy of each parameter is given above: The accuracy depends on input absolute level of each channel and measuring frequency.
- B-A and θ accuracies are the sum of each channel accuracy given in the tables above: For example, when the frequency is 1 kHz, A channel is −15 dBV and B channel is −25 dBV; the uncertainty contributed by each channel to the B-A error is 0.01 dB/0.05° and 0.05 dB/0.15°, respectively. Therefore, the final accuracy of 0.06 dB/0.2° is given by adding the accuracy of both channels.
- Accuracy is not specified for shaded areas.
- Absolute amplitude accuracy (A, B) for the range of −50 to −80 dBV is the sum of the accuracy for 0.8 to −50 dBV plus the accuracy of the absolute input level of each channel. For example, when channel A is −55 dBV at 1 kHz, accuracy is 0.6 dB; the sum of 0.4 dB and 0.2 dB.
- In the table above f is in Hz and F is in MHz.

impedance measurements

MEASURED PARAMETER: |Z| (impedance), |Y| (admittance), θ (phase angle), R (resistance), X (reactance), G (conductance), B (susceptance), L (inductance), C (capacitance), D (dissipation factor), and Q (= 1/D).

Deviation (Δ and Δ%) measurement for all the above parameters.

Floating measurements and low-grounded measurements are possible.

Parameter Combinations: $|Z|-\theta$, $|Y|-\theta$, R−X, G−B, L−Q•D•R•G, C−Q•D•R•G

EQUIVALENT CIRCUIT MODE: Auto, (Series) and (Parallel). |Z|, R and X are measured in (Series) mode, and |Y|, G and B in (Parallel) mode.

DISPLAY (NORMAL OR AVERAGE MODE): Maximum 4½ digits, maximum display 19999 (L•C measurements) or 12999 (other parameter measurements). Number of display digits depends on OSC LEVEL and measuring range.

RANGING: Auto or manual for impedance/admittance measured values

MEASUREMENT TERMINAL: 4-terminal pair configuration

AUTOMATED ZERO ADJUSTMENT: Unwanted residual impedances (L, C, R and G) are measured at a frequency selected by the operator. The residual values are stored and used as offsets for subsequent measurements. The stored residual values are applied directly at all frequencies and on all functions except R. The R offset value is calculated from the following equation:

$$R \bullet \frac{1 + \sqrt{\text{measuring frequency}}}{1 + \sqrt{\text{zero offset frequency}}}$$

DC BIAS: Standard furnished (valid for impedance measurements)

Voltage Range: −35 V to +35 V, 10 mV step

Setting Accuracy: (23 ±5°C); ±(0.5% of setting + 5 mV)

Output Resistance: 110 Ω to 11 kΩ ±10% (depends on measuring range)

Maximum Output Current: Maximum Output Current (varies with measuring frequency and range): 20 mA max. (floating measurement), 5 mA max. (low-grounded measurement).

Control: Front panel numeric keys and HP-IB remote control.

MEASURING RANGE, ACCURACY AND RESOLUTION: Accuracy is specified at UNKNOWN terminals under the following conditions:

(1) Warmup Time: ⩾ 30 min.

(2) OSC Level: ⩾ 100 mVrms (accuracy varies for level below 100 mV)

(3) Floating Measurement: (see GENERAL for low-grounded measurement)

(4) Measuring Frequency: zero offset adjustment is to be done

(5) Ambient Temperature: 23 ±5°C (error limits double for temperature range of 0°C to 55°C)

(6) Measuring Speed: Normal or Average mode

(7) How to interpret the graphs on the following pages: The following graphs give range, accuracy and maximum resolution for each parameter measured by the 4192A. When using the graphs, use these guidelines:

(A) Accuracies given for |Z|, |Y|, R, X, G, B and θ are for full scale readings.

(B) Accuracy for D and θ is given as ±(number of counts). Accuracy for all other parameters is given as ±(% of reading + number of counts).

(C) In the tables, f is measuring frequency in Hz and F is measuring frequency in MHz.

(D) Textured areas in the tables (shaded box) indicate that measurements can be obtained but accuracy is not guaranteed.

(E) The number of display digits varies with 1) measuring frequency, 2) test level and 3) measuring speed.
In general, the number of diplay digits will increase when measuring frequency is above 400 Hz, at high test levels and slow measuring speeds.

|Z| − θ and R − X Measurements:

	Measuring Range	Maximum Resolution
|Z|•R•X	1.0000 Ω to 1.0000 MΩ	0.1 mΩ
θ	−180.00° to +180.00°	0.01°

|Z| •R•X*& θ Accuracy: (f in Hz, F in MHz)

Range	5–400 Hz		400 Hz–1 MHz		1M–13 MHz (1 MΩ: 1M–2 MHz)	
1 MΩ	(1.44 + 125/f)% + 1	(0.72 + 75/f)°	1.44% + 1	0.72°	(1.2 + 0.24F)% + 1	(0.6 + 0.15F)°
100 kΩ	(0.36 + 21.5/f)% + 1	(0.18 + 12.9/f)°	0.36% + 1	0.18°	(0.24 + 0.24F)% + 1	(0.12 + 0.15F)°
10 kΩ	(0.36 + 16/f)% + 1	(0.18 + 9.6/f)°	0.36% + 1	0.18°	(0.24 + 0.18F)% + 1	(0.12 + 0.11F)°
1 kΩ	(0.36 + 19/f)% + 1	(0.18 + 11.4/f)°	0.36% + 1	0.18°	(0.36 + 0.024F + 0.029F²)% + 1	(0.18 + 0.012F + 0.017F²)°
100 Ω	(0.12 + 7.4/f)% + 3	(0.08 + 4.5/f)°	0.12% + 3	0.08°	(0.12 + 0.024F + 0.029F²)% + 3	(0.08 + 0.012F + 0.017F²)°
10 Ω	(0.24 + 11/f)% + 5	(0.15 + 6.6/f)°	0.24% + 5	0.15°	(0.24 + 0.036F + 0.037F²)% + 5	(0.15 + 0.022F + 0.023F²)°
1 Ω	(0.6 + 47/f)% + 5 (shaded)	(0.48 + (28.2/f)° (shaded)	0.6% + 5	0.48°		

5 — 400 — 1M — 2M — 13M
Measuring Frequency (Hz)

|Y| − θ and G − B Measurements:

	Measuring Range	Maximum Resolution
|Y|•G•B	10.000 μS to 10.00 S	0.001 μS
θ	−180.00° to +180.00°	0.01°

|Y| •G•B†& θ Accuracy: (f in Hz, F in MHz)

Range	5–400 Hz		400 Hz–1 MHz		1M–13 MHz (10 μS: 1M–2 MHz)	
10 μS	(0.24 + 17/f)% + 3	(0.18 + 10.2/f)°	0.24% + 3	0.18°	0.24F% + 3	(0.06 + 0.15F)°
100 μS	(0.12 + 8/f)% + 3	(0.08 + 4.8/f)°	0.12% + 3	0.08°	0.24F% + 3	(0.12 + 0.15F)°
1 mS	(0.12 + 7/f)% + 3	(0.08 + 4.2/f)°	0.12% + 3	0.08°	0.18F% + 3	(0.12 + 0.15F)°
10 mS	(0.12 + 8.2/f)% + 3	(0.08 + 4.92/f)°	0.12% + 3	0.08°	(0.12 + 0.024F + 0.029F²)% + 3	(0.08 + 0.012F + 0.017F²)°
100 mS	(0.36 + 11/f)% + 1	(0.18 + 6.6/f)°	0.36% + 1	0.18°	(0.36 + 0.024F + 0.029F²)% + 1	(0.18 + 0.012F + 0.017F²)°
1 S	(0.84 + 47/f)% + 1	(0.36 + 28.2/f)°	0.84% + 1	0.36°	(shaded)	
10 S	(shaded)		3% + 1 (shaded above 16k)	1.56°	(shaded, to 2M)	

5 — 400 — 16k — 1M — 2M — 13M
Measuring Frequency (Hz)

***R and X accuracy depends on the value of D as follows: (Refer to R-X table above).**

	D<1	1⩽D<10	10⩽D
R	Accuracy of R is equal to the accuracy of X, in number of counts, as calculated from the table above. For example, if X is 1000 counts, R is 500 counts, and the test frequency is 100 Hz, the accuracy of R is: $\left(\frac{19}{100\text{ Hz}}\% + 0.36\%\right) \bullet 1000 + 1 = 6.5$ counts	Two times % error given in the table above	table above
X	table above	Accuracy of X is equal to the accuracy of R, in number of counts, as calculated from the table above.	

†G and B accuracy depends on the value of D as follows: (Refer to G-B table above).

	D⩽0.1	0.1 D⩽1	1<D
G	Accuracy of G is equal to the accuracy of B, in number of counts, as calculated from the table above.		table above
B	table above	two times % error given in table above	Accuracy of B is equal to the accuracy of G, number of counts, as calculated from the table above.

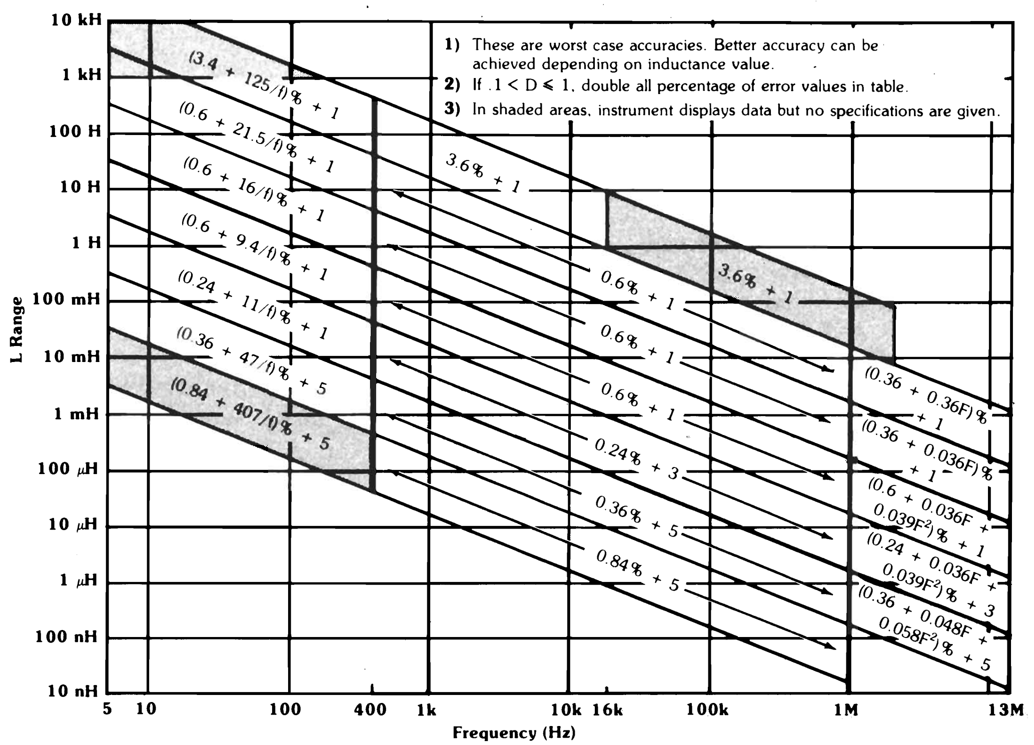
L–Q•D•R•G MEASUREMENTS: (f in Hz, F in MHz)

Refer to R–X or G–B Measurements for R and G Accuracy.

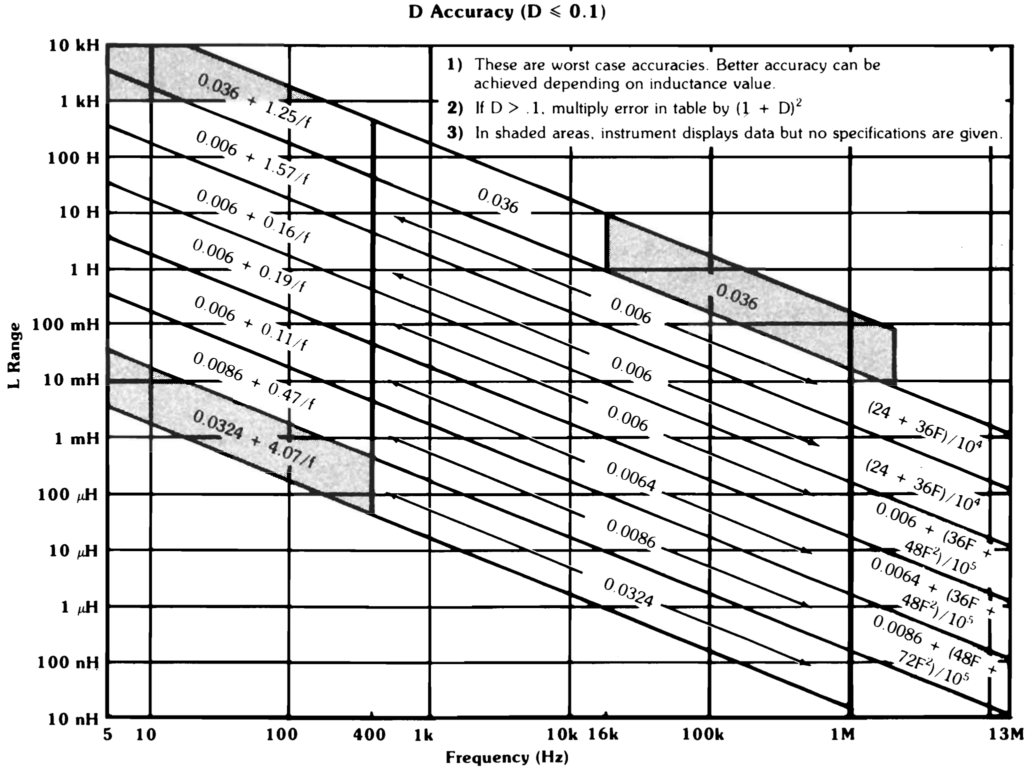
	Measuring Range*	Maximum Resolution*
L	100.00 nH to 1000 H	0.01 nH
D	1.0000 to 10.000	0.0001
Q	1000.0	0.1

*Depends on measuring frequency

L Accuracy (D ≤ 0.1)



D Accuracy (D ≤ 0.1)



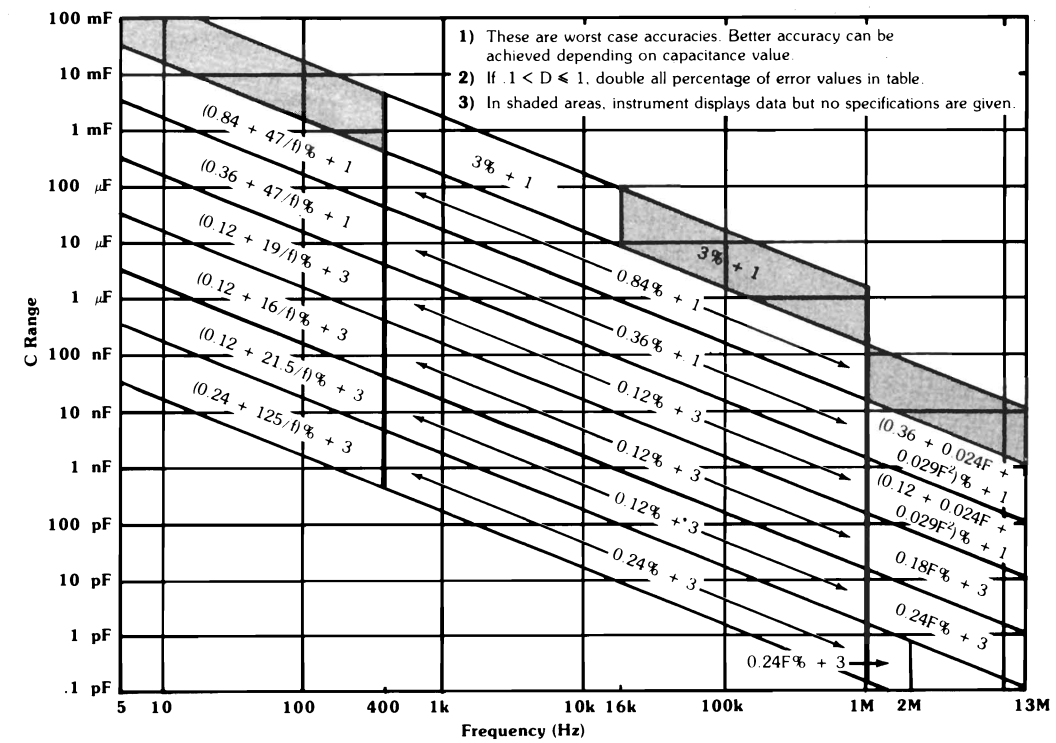
C–Q•D•R•G MEASUREMENTS: (f in Hz, F in MHz)

Refer to R–X or G–B Measurements for R and G Accuracy.

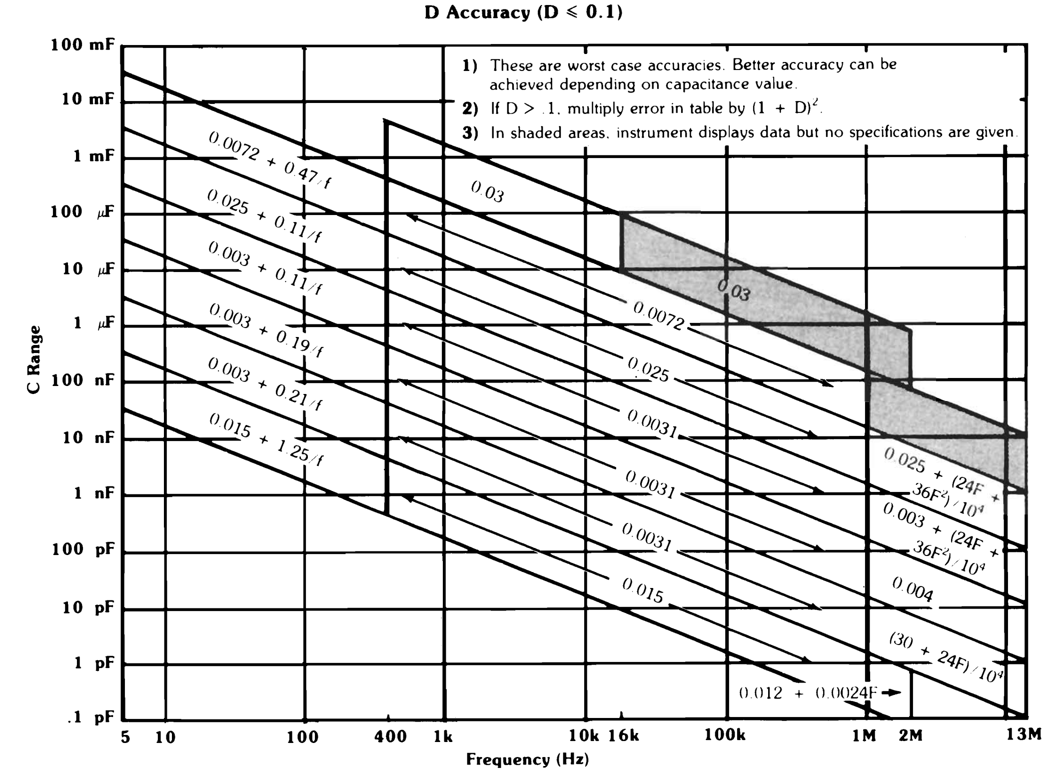
	Measuring Range*	Maximum Resolution*
C	1.0000 pF to 100.0 mF	0.1 fF
D	1.0000 to 10.000	0.0001
Q	1000.0	0.1

*Depends on measuring frequency

C Accuracy (D ≤ 0.1)



D Accuracy (D ≤ 0.1)



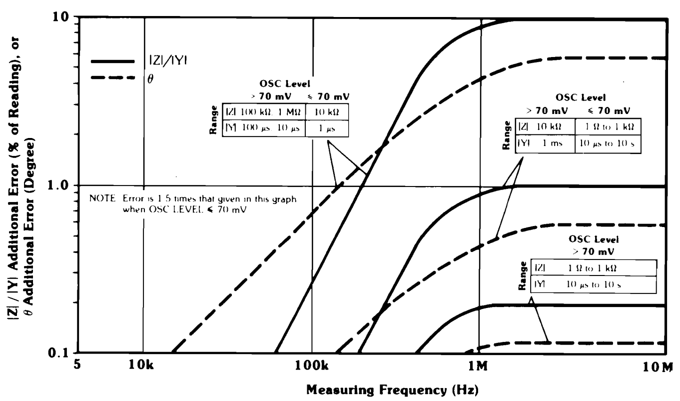
general information

(The following information is reference data and not guaranteed specifications)

LOW GROUNDED IMPEDANCE MEASUREMENT ACCURACY: To obtain low-grounded measurement accuracy, add 1) accuracy given for floating measurements found on pages 11 – 13 plus 2) Zero Offset Errors given below plus 3) Additional Errors given in the graph below.

Zero Offset Errors: When reading is full scale and OSC LEVEL is greater than 100 mV
Parallel Admittance: 0 to ± 60 nS
Phase Offset Error: 0 to ± 0.36°

Additional Errors Graph for Low Grounded Measurements:



Example Calculation for Low Grounded Measurement Accuracy: Assume 4192A readings of |Z| = 1.0000 kΩ and θ = −45.00°

1. Measurement conditions:
   - measuring |Z| − θ on 1 kΩ range
   - test frequency = 500 kHz
   - test level = 500 mV
   - normal measuring speed
2. Accuracy calculation:
   - From top graph on page 11
     |Z| accuracy = ±(.36% + 1 count)
     = ±(.36% + 0.1 Ω)
     θ accuracy = ±0.18°
   - From Zero Offset Errors above
     Parallel G ≤ 60 nS
     θ error ≤ 0.36°
   - From Additional Errors graph below
     |Z| additional = 0.1% of reading
     θ additional = 0.1°
   - TOTAL ACCURACY

$$|Z| = 1.0000\ k\Omega \pm [(0.36\% \times 1\ k\Omega + 0.1\ \Omega) + \left(1.0000\ k\Omega - \frac{1\ k\Omega \times \frac{1}{60 \times 10^{9} S}}{1\ k\Omega + \frac{1}{60 \times 10^{9} S}}\right) + (1\ k\Omega \times 0.1\%)]$$

|Z| = 1.0000 kΩ ±[(3.7 Ω) + (0.06 Ω) + (1 Ω)]
|Z| = 1.0000 kΩ ± 4.8 Ω
θ = −45.00° ±[(0.18°) + (0.36°) + (0.1°)]
θ = −45.00° ± 0.64°

3. This accuracy calculation assumes that residual impedance was compensated at the test frequency (in this case, 500 kHz). Residual compensation is done using the OPEN and SHORT front panel controls.

FLOATING IMPEDANCE MEASUREMENT ACCURACY:

Accuracy when CABLE LENGTH is 1m: 2.5 times percent error for frequencies above 1 MHz.

L•C Accuracy for D > 1: (1 + D^2) times accuracy specifications.

LEVEL MONITOR RANGE AND ACCURACY (23 ± 5°C):

	Range	Accuracy (% of reading + 1 count)
Voltage	5 mV − 1.1 V	(4 + 10/f*)% + 1 (≤ 100 Hz) 4% + 1 (100 Hz to 1 MHz) (4 + 0.8F*)% + 1 (≥ 1 MHz)
Current	1 μA − 11 mA	

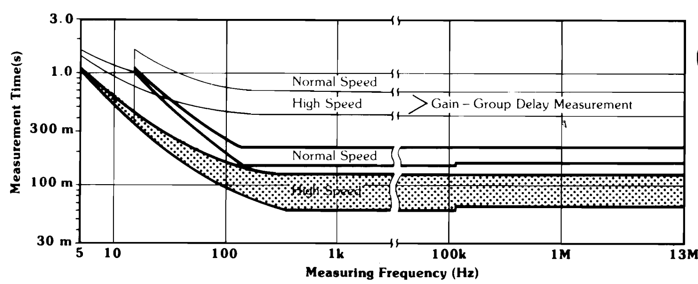
***f:** Measuring frequency in Hz, **F:** Measuring frequency in MHz

Time Required for Level Monitor: Approximately 120 ms

1 MHZ REFERENCE OUTPUT: Square wave, ≥ 1.6 Vpp, Output resistance: Approximately 50 Ω

MEASURING SPEED: At fixed frequency, measurement range and OSC level.

Speed in Average mode is approximately 7 times that for Normal speed mode.



Frequency Switching Time: Approximately 50 to 65 ms

|Z|/|Y| Range Switching Time: Approximately 35 to 50 ms/range (> 400 Hz)

OSC Level Switching Time: Approximately 65 ms

DC Bias Voltage Settling Time: Approximately (0.4 x ΔV + 10) ms where ΔV is voltage change in volts.

OPERATING TEMPERATURE: 0 to 55°C, relative humidity ≤ 95% at 40°C

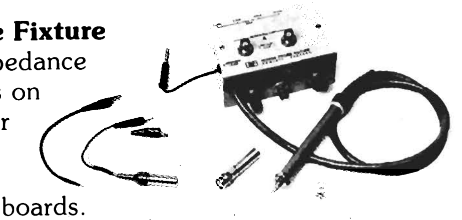
POWER: 100, 120, 220 V ± 10%, 240 V + 5% − 10%, 48 to 66 Hz, power consumption 100 VA maximum

DIMENSION: 425.5 mm (W) x 247 mm (H) x 574 mm (D) (16.75" x 9" x 22.6")

WEIGHT: Approximately 19 kg

accessories (available)

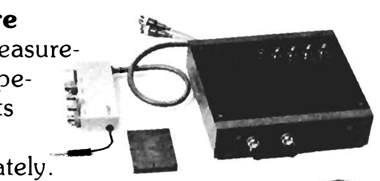
16095A Probe Fixture



For probe impedance measurements on components or entire circuits mounted on printed-circuit boards.
Low lead can be floated or grounded.
OSC OUTPUT connector provided for amplitude-phase measurements. BNC adapter and clip adapter furnished. Terminals for an external blocking capacitor are part of the 16095A. An external blocking capacitor can be attached to block direct current from the circuit under test.

During low grounded measurements, the 16095A ground lead should be connected to 4192A GND terminal to reduce noise.
Stray Capacitance: ≤ 150 pF
Residual Inductance: ≤ 40 nH
Residual Resistance: ≤ 100 mΩ (when BNC adapter is used)

16096A Test Fixture



Amplitude-phase measurements and input impedance measurements on two-port devices can be made alternately.
Furnished with the 16096A are BNC to clip connector, BNC to SMA cable and lock type socket kit for components with 2.5 mm (.1") terminal spacing. Residual impedances (at BNC connector after zero offset):

Capacitance: ≤ 0.01 pF
Inductance: ≤ (100 + 0.5 F^2) nH − where F is measuring frequency in MHz
Resistance: ≤ (50 + 5 F^2) mΩ − where F is measuring frequency in MHz

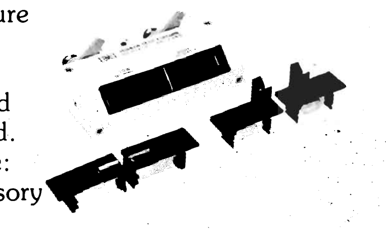
Error in amplitude/phase measurement (after cable compensation):
B-A error: ±0.1 dB
Phase error: ±0.1 degree
A,B error: ±(0.1 + 0.06 F^2) dB − where F is measuring frequency in MHz

Input impedance for channel A and B: 1 MΩ shunted by less than 15 pF

16097A Accessory Kit

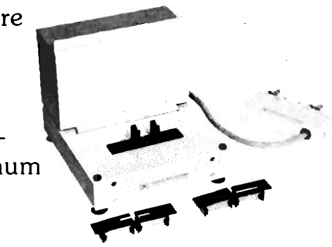
Contains various fixtures for circuit measurements in a carrying case. The contents are 16095A, 16047C/16048C Test Fixtures, 75 Ω/600 Ω Feedthrough terminations, 10:1/1:1 Scope probes and BNC cables (60 cm and 120 cm).

16047A: Direct Coupled Test Fixture



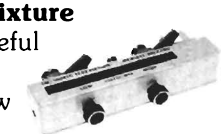
General purpose test fixture for the 4192A. Contacts for axial lead, radial lead, and short radial lead components are furnished. Maximum dc bias voltage: ±35 V. Furnished accessory with the 4192A.

16047B: Test Fixture With Safe Guard



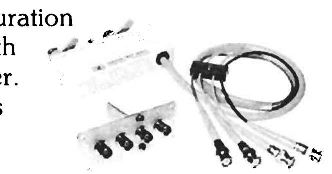
General purpose test fixture with safe guard cover for dc bias applications. Contacts for radial, axial, and short lead radial components furnished. Maximum dc bias voltage: ±200 V.

16047C: High Frequency Test Fixture



This direct attachment fixture is useful for high frequency measurements requiring high accuracy. Two screw knobs insure optimum contact of electrodes and sample leads. Maximum applied dc bias is ±35 V.

16048A: Test Leads With BNC Connector



Four-terminal pair configuration test leads for interface with user test fixture or handler. Maximum applied dc bias voltage: ±300 V.

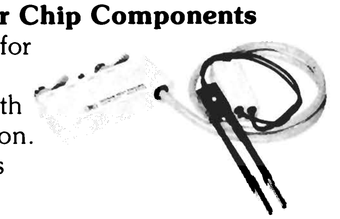
16048B: Test Leads With RF Miniature Connector

Four-terminal pair configuration test leads for interface with user test fixture or prober. Maximum applied dc bias voltage: ±300 V.

16048C: Test Leads With Alligator Clips

Four-terminal test leads convert to two clip-on probes for ease of operation. Ideal for various shapes and sizes of components. Recommended for frequencies below 100 kHz. Maximum applied dc bias voltage: ±35 V.

16034B: Test Fixture for Chip Components



Tweezer type test fixture for chip components. Components are measured with three-terminal configuration. Maximum applied dc bias voltage: ±35 V.

related accessories / parts (available)

HP-IB Interface Cable: 10631A (approx. 1m), 10631B (approx. 2m), 10631C (approx. 4m), 10631D (approx. 0.5m)

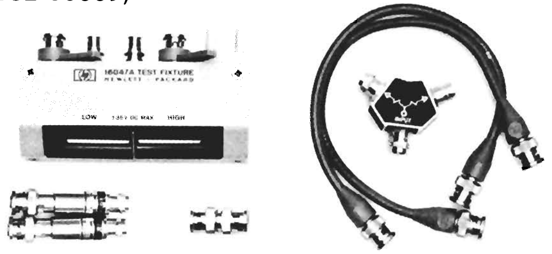
Line Fuse: hp P/N: 2110-0007 (100/120 V)
hp P/N: 2110-0202 (220/240 V)

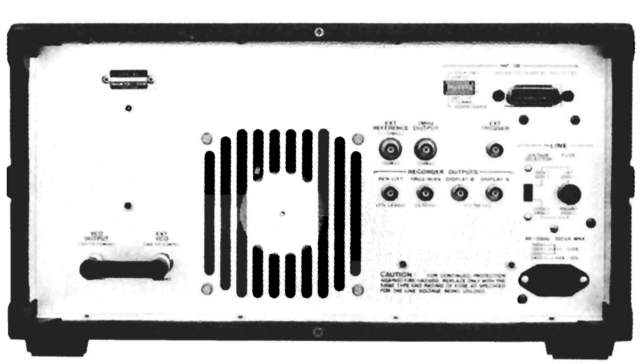
16095A Related Parts:
Probe Tips: hp P/N 16095-60012
Earth Pins: hp P/N 16095-65001
Earth Lead: hp P/N 16095-61611
BNC Adapter: hp P/N 16095-60011
Clip Adapter: hp P/N 16095-61612

16096A Related Parts:
Textool® Test Board Assembly:
hp P/N 16096-65001
BNC to Dual Clip Connector:
hp P/N 16096-61614
BNC to SMA connector: hp P/N 16096-61611
Banana to Clip Connector: hp P/N 16096-61613

accessories (furnished)

Furnished Accessories and Parts: 16047A Test Fixture, 11048C 50 Ω Feedthrough Termination (2 ea.), 11170A BNC Cable (2 ea.), BNC Adapter (hp P/N: 1250-0216) and Power Splitter (hp P/N: 11652-60009)





4192A Rear Panel

ordering information

OPTIONS

(Use part number listed when ordering separately)

Option 907: Front Handle Kit (hp P/N 5061-0091)

Option 908: Rack Flange Kit (hp P/N 5061-0079)

Option 909: Rack and Handle Kit (hp P/N 5061-0085)

Option 910: Extra Manual (hp P/N 04192-90000)

ACCESSORIES AVAILABLE

16047A: Test Fixture, Direct Coupled (One 16047A Test Fixture is supplied with each 4192A)

16047B: Test Fixture, safeguard

16047C: Test Fixture, high frequency

16048A: Test Leads, BNC

16048B: Test Leads, RF min.

16048C: Test Leads, alligator clips

16034B: Test Fixture, chip

16095A: Probe Fixture

16096A: Test Fixture

16097A: Accessory Kit

STANDARD INSTRUMENT

4192A LF Impedance Analyzer

Manufactured by Yokogawa-Hewlett Packard LTD., Tokyo

For more information, call your local HP Sales Office or nearest Regional Office: • Eastern (201) 265-5000; • Midwestern (312) 255-9800; • Southern (404) 955-1500; • Western (213) 970-7500; • Canadian (416) 678-9430. Ask the operator for instrument sales. Or write Hewlett-Packard, 1501 Page Mill Road, Palo Alto, CA 94304. **In Europe:** Hewlett-Packard S.A., 7, rue du Bois-du-Lan, P.O. Box, CH 1217 Meyrin 2, Geneva, Switzerland. **In Japan:** Yokogawa-Hewlett-Packard Ltd., 29-21, Takaido-Higashi 3-chome, Suginami-ku, Tokyo 168.

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