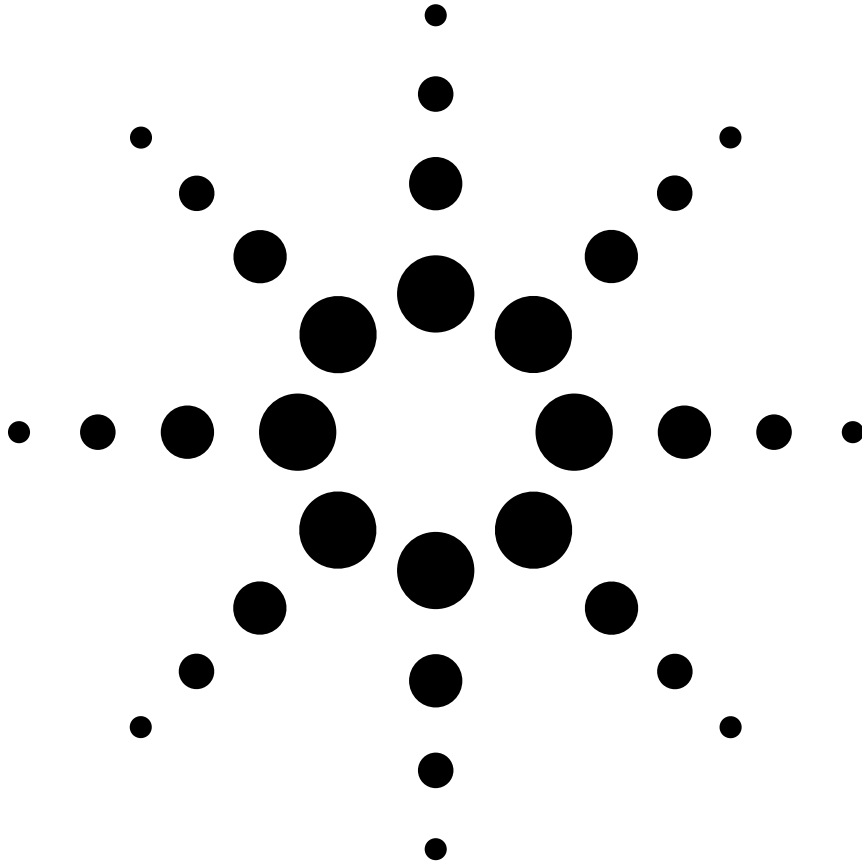


Agilent E4991A RF Impedance/ Material Analyzer

Technical Overview



The new standard in RF impedance
and material measurements.



Agilent Technologies

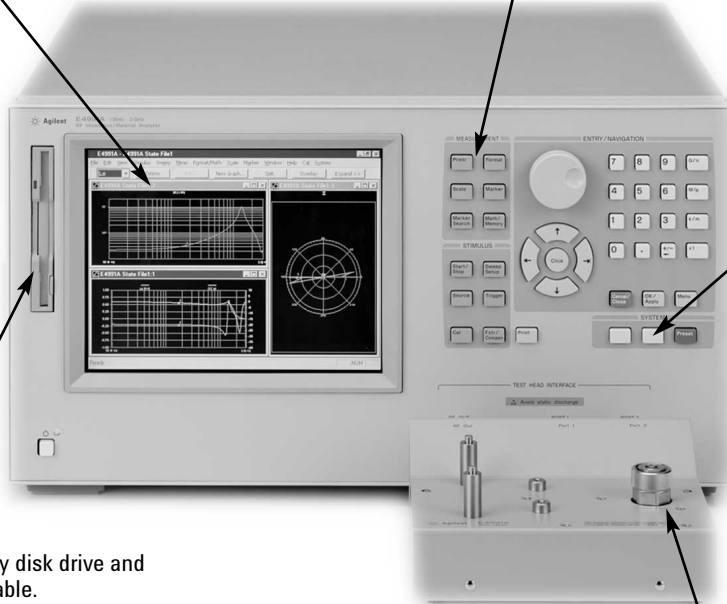
E4991A RF Impedance/ Material Analyzer

Windows®-based user interface

- Windows®-based graphical user interface (GUI) brings an intuitive view of measurement settings and results.
- 8.4-inch TFT color LCD can display up to 5 traces (3 scalar and 2 complex parameters), 9 markers (1 reference marker and 8 markers), and 801 sweep points.

Versatile analysis functions

- Marker analysis and marker limit functions reduce test time.
- Various test signals such as frequency, DC bias and AC signal level are available.
- Equivalent circuit analysis function enables easy modeling of components with 5 different multi-parameter models.



Built-in Visual Basic for Applications (VBA) programming function

- VBA offers easy programming for automation and further detailed analysis.

Data storage function

- Internal 3 1/2 - inch floppy disk drive and hard disk drive are available.
- Store VBA program, calibration data, and measurement data.
- CITIFILE format is supported for automation tool users.

High accuracy and adaptability

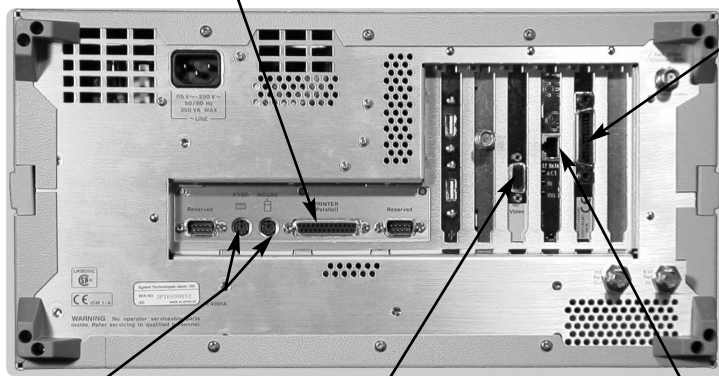
- Test head with 7 mm connector adapts easily to various test fixtures.
- RF I-V technique enables highly accurate measurements up to 3 GHz.

Parallel interface

- Support parallel interface printers.

GPIB interface

- Automatic measurement system is easily configured with external PC.
- Control external instruments.



External keyboard and mouse interface

- VBA programming made easy.
- Users can perform operations with a mouse for more comfortable operation.

External VGA output

- Display measurement results on a larger VGA monitor.

LAN interface (10 Base T/100 Base TX)

- Control other instruments or simplify test-data sharing.
- Connect to a PC through remote user interface software.

Powerful Analysis Functions to Meet Your Needs

The Agilent E4991A RF impedance/material analyzer provides a total solution for making highly accurate, repeatable and stable measurements of surface mount devices (SMD) and dielectric/magnetic materials.

Recent trends indicate that wireless communications and digital equipment operating frequencies are getting higher, while component sizes are getting smaller. Component and equipment manufacturing engineers need to evaluate components they will be using in their products under their projected operating conditions. The E4991A can evaluate passive component's characteristics up to 3 GHz. Additionally, engineers must measure SMDs as small as 0201(inch)/0603(mm).

Key specifications

Table 1. E4991A key specifications

E4991A RF Impedance/Material Analyzer	
Operating frequency	1 MHz to 3 GHz (1 mHz resolution)
Impedance parameters	$ Z , \theta_Z, Y , \theta_Y, R, X, G, B, C_S, C_P, L_S, L_P, R_P, R_S, D, Q, \Gamma , \theta_\Gamma, \Gamma_X, \Gamma_Y$
Material parameters*	$ \epsilon_r , \epsilon_r', \epsilon_r'', \mu_r , \mu_r', \mu_r'', \theta, \tan\delta$
Basic impedance accuracy	$\pm 0.8\%$
Test port	7mm connector
Sweep parameters	Frequency, AC signal level, DC bias level
Calibration	Open/short/50 Ω /low-loss capacitor
Fixture compensation	Open/short, fixture electrical length
Mass storage	3 1/2 -inch floppy disk drive (MS-DOS® format), hard disk drive
Other features	<ul style="list-style-type: none"> •Equivalent circuit analysis function •Built-in VBA for internal programming •Segment sweep
DC bias (Option.001)	
DC level	0 V ~ ± 40 V (1 mV resolution) 100 μ A ~ 50 mA, -100 μ A ~ -50 mA (10 μ A resolution)

*Option 002 is required

Advanced Solution for RF Impedance and Material Measurement

The E4991A provides a powerful tool for component manufacturing R&D engineers and circuit designers of wireless and digital equipment who want to evaluate components from various perspectives. The following are application examples:

Passive components

- RF impedance measurement of chip components such as ceramic capacitors, RF inductors, ferrite beads, and resistors

Semiconductors

- Capacitance-Voltage (C-V) characteristics and Equivalent Series Resistance (ESR) measurements of varactor diodes

Materials

- Permittivity and loss tangent evaluation of plastics, ceramics, printed circuit boards and other dielectric material
- Permeability and loss tangent evaluation of ferrite, amorphous and other magnetic materials

E4991A Provides New insights into RF Passive Component Behavior

The Agilent E4991A's enhanced frequency coverage up to 3 GHz is compatible with wireless communication applications such as W-CDMA, Bluetooth™, and Wireless LAN. The E4991A's wide impedance coverage and versatile measurement functions allow analysis of RF chip inductors and capacitors under actual operating conditions. A wide range of test fixturing solutions makes tiny chip device measurements even easier.

Quality Factor (Q) and Equivalent Series Resistance (ESR) are critical parameters for the components used in mobile communication equipment. Q and ESR measurements require high accuracy. Prior to the E4991A, there was not a good solution available over 2 GHz. The E4991A offers much improved Q and ESR accuracy over traditional network analyzers; due to the enhanced RF I-V technique that measures voltage and current at the device under test (DUT), along with the innovative low-loss capacitor calibration.

Table 3 provides a brief summary of the key differences between Agilent E4991A and network analyzers.

Low-loss capacitor calibration

The low-loss capacitor calibration of the E4991A improves phase measurement accuracy, which establishes a reference to the reactance axis (-90 degrees) in the impedance plane with its near-zero resistance. Capacitors and inductors are measured close to the reactance axis in the impedance plane, making low-loss capacitance calibration very effective for ESR and Q measurements. (See Figure 1)

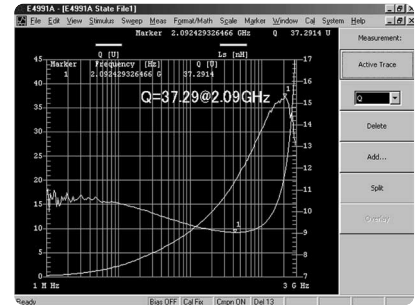


Figure 1. Ls-Q characteristics of a chip inductor

Table 2. Q measurement accuracy (Typical)

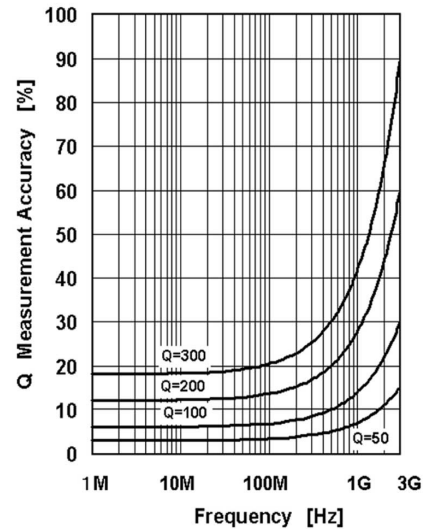


Table 3. Comparison of key characteristics of E4991A and network analyzers

	E4991A	Network analyzers
Device type	1 port devices such as inductors, capacitors, and others.	2 port devices such as filters, amplifiers, and others.
Measurement parameters	$ Z $, $ Y $, θ , R, X, G, B, C, L, R, D, Q, Γ	S-parameters, Γ , θ
Sweep parameter setting	<ul style="list-style-type: none"> • Frequency • Test signal level • DC bias voltage • DC bias current 	<ul style="list-style-type: none"> • Frequency • Test signal level
Fixturing	<ul style="list-style-type: none"> • Selection from various Agilent test fixtures • Built-in fixture compensation function (Accuracy enhancement at DUT connection) 	* Prepare custom test fixture or use Agilent channel partner solution
Impedance measurement accuracy	<ul style="list-style-type: none"> • Accurate high Q device measurement due to low loss capacitor calibration • Accurate measurement over non-50 Ω impedance 	• Accurate impedance measurement around 50 Ω
Other	Equivalent circuit analysis function	

In-depth Device Characterization

Intuitive graphical user interface

The 8.4-inch color LCD with Windows-based GUI brings an intuitive view of measurement settings and results. The E4991A can display up to 3 scalar and 2 complex parameters simultaneously.

Figure 2 shows a measurement result of a chip bead. You can observe the $|Z|$, R and X parameters on the display at same time. You can also assign each measurement trace in a separate window.

Windows-styled GUI brings the added benefits of mouse operation to the E4991A. Simply drag the mouse over the area you are interested in and you can zoom in quickly and easily. (See Figure 3)

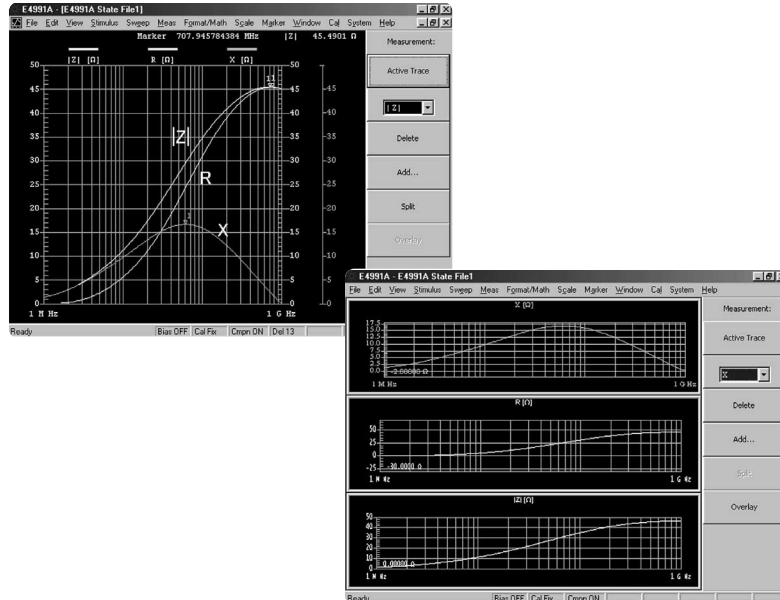


Figure 2. Flexible measurement trace assignment

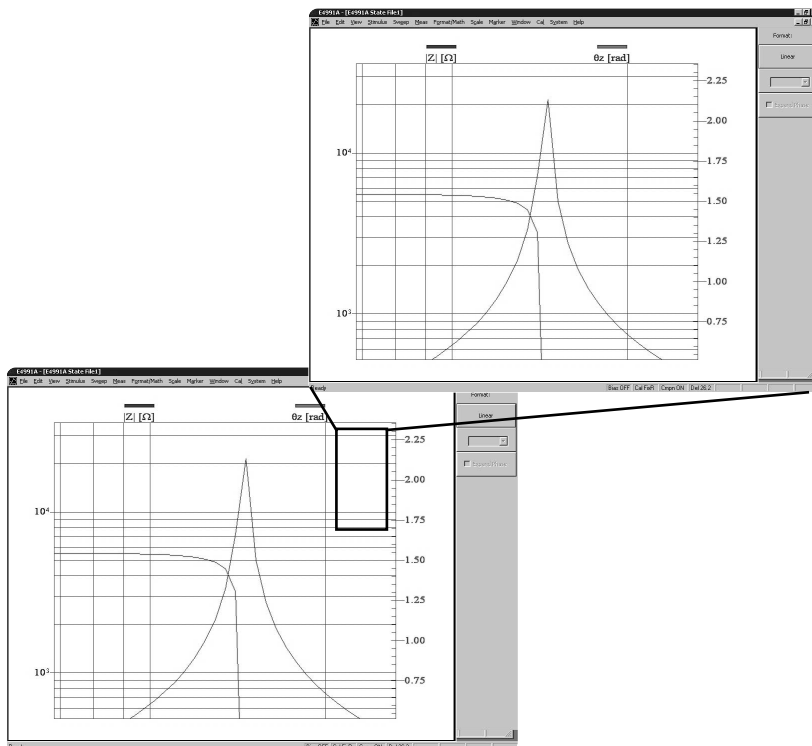


Figure 3. Mouse operation example

DC bias function— Option 001

For components with voltage and current dependency, such as RF inductors or ceramic capacitors, the DC bias function (Opt. 001) supplies DC voltage (± 40 V) and current bias (± 50 mA) across the device. You can easily observe your device behavior under various DC bias conditions without using an external DC bias source.

External DC bias adapter

If you require even higher DC current bias, the Agilent 16200B external DC bias adapter allows you to apply larger DC bias across the device of up to ± 5 A through a 7 mm test port by using an external DC current source. E4991A operating frequency is limited to 1 GHz with the 16200B.

Extracting the equivalent circuit parameters

The equivalent circuit analysis function offers more detailed circuit models over the standard 2-parameter model. Five different multi-parameter models accommodate different types of devices, such as ceramic capacitors or crystal resonators. You can simulate the impedance trace of your own equivalent parameter values and then compare it with actual measurement traces. The extracted parameters can also be used with electronic design automation (EDA) tools to improve modeling accuracy.

Figure 4 shows the C-V characteristic measurement of a varactor diode. Sweeping DC voltage from 0.5V to 4.5V, you can easily read capacitance change (11.27pF) using the delta marker function. Evaluate DC bias voltage dependency on components easily. DC current bias measurement is also available so that you can evaluate characteristics of inductors, such as, saturation or hysteresis.

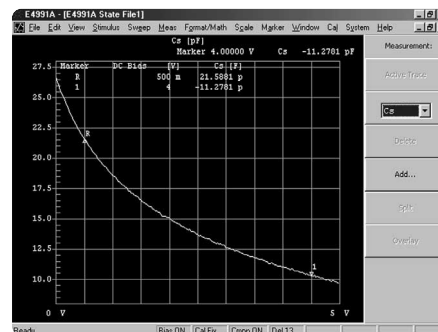


Figure 4. Varactor diode capacitance vs. DC voltage characteristics

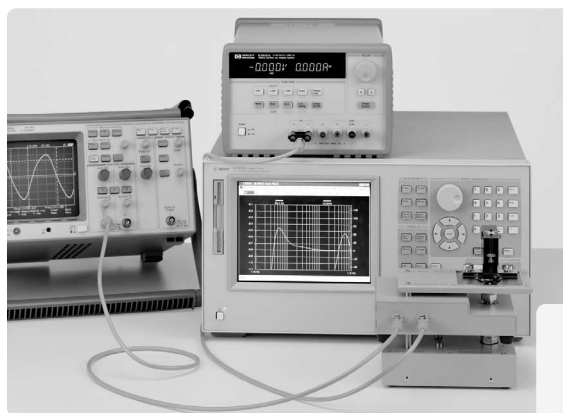


Figure 5. 16200B DC bias adapter connected to the E4991A



Figure 5-1. 16200B

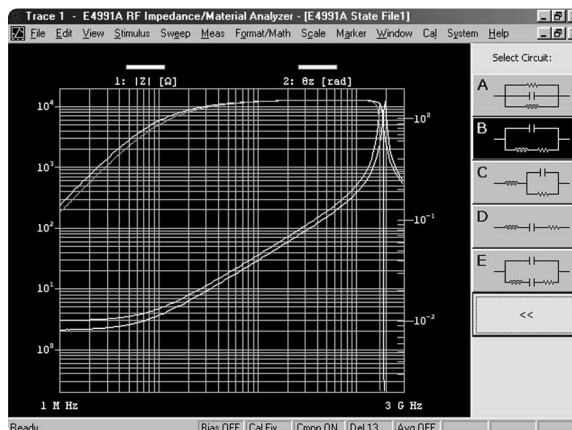


Figure 6. Equivalent circuit analysis models

Increase Productivity with Segment Sweep Function

The segment sweep function enables different measurement setups in a single sweep by dividing the sweep range into segments. Each segment, including the frequency range, number of points, averaging factor, DC bias level (V or I), and test signal level can be set independently. (See Figure 7) Segment sweep function can drastically reduce your test time when you need specific data in a wide frequency range. With segment sweep, you can avoid repeatedly changing instrument setups. (See Figure 7-1)

No.	Start [Hz]	Stop [Hz]	Hop [Hz]	Avg	Occ (dBm)	Bias V/I	Bias Lev [dB]	Segm No.
1	1 M	500 M	100	1	-10.000	0.0000	2.0000 m	
2	1 G	1.4 G	40	8	-10.000	0.0000	2.0000 m	
3	1.7 G	1.9 G	100	16	-5.0000	0.0000	2.0000 m	
4	1.93 G	2 G	80	16	-5.0000	0.0000	2.0000 m	

Figure 7. Segment list table

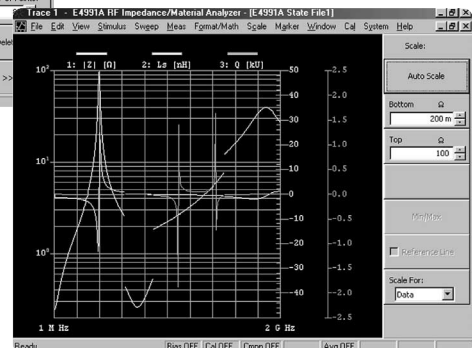


Figure 7-1. Segment sweep measurement example

Various Text Fixtures are Ready to Use

The 16197A and 16196A/B/C are test fixtures that accommodate passive surface mount devices (SMD) and have high repeatability and stable frequency characteristics up to 3 GHz.

The 16197A is a test fixture that can hold chip devices that have electrodes at the bottom. Various sizes and shapes of devices are supported. The 16197A supports the following EIA/EIAJ standard sizes:

- 0201(inch)/0603(mm)*
- 0402(inch)/1005(mm)
- 0603(inch)/1608(mm)
- 0805(inch)/2012(mm)
- 1208(inch)/3216(mm)
- 1210(inch)/3225(mm)
- Non-standard shape (requires modification of the holder part)

The 16196A/B/C series are coaxial-structured high performance test fixtures, which achieve high repeatability and stability up to 3 GHz. The 16196 series simplifies operation significantly and eliminates operation-related errors. The 16196 series supports chip devices as small as 0201 (inch)/0603 (mm) size. Each test fixture model supports respectively shaped devices as follows:

Model	Device size supported
16196A	0603 (inch)/1608 (mm)
16196B	0402 (inch)/1005 (mm)
16196C	0201 (inch)/0603 (mm)

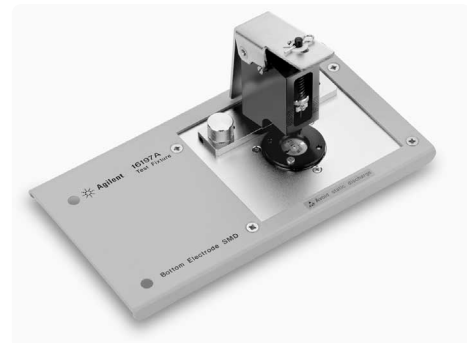


Figure 8. Agilent 16197A bottom electrode SMD test fixture



Figure 9. Agilent 16196B parallel electrode SMD test fixture

*Option 001 is required

Connectivity Advances with PC and Windows-based Technology

Visual Basic for Applications (VBA) helps automate tasks

The built-in VBA is available for customization and automation of complex measurement procedures. You can create macro programs in the Integrated Development Environment (IDE) of VBA in a similar manner to Visual Basic® operation.

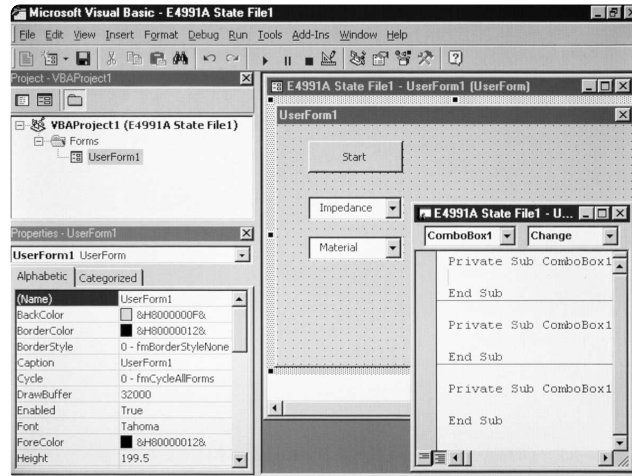


Figure 10. VBA

Link to EDA tools

Using electronic design applications such as Agilent's Advanced Design System (ADS), in conjunction with the E4991A, can help you optimize and verify the performance of your device with simulated circuit modeling. You can easily store measured data in CITIFILE format and import to EDA software tools. (Agilent's ADS software may be purchased separately from the E4991A.)

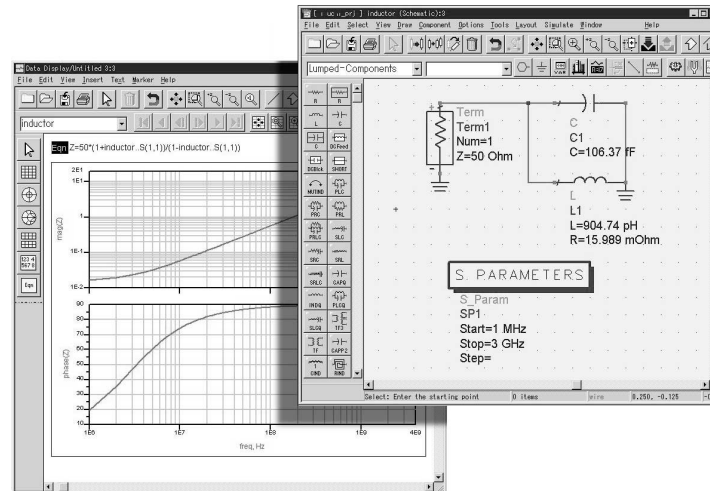


Figure 11. ADS figure

LAN interface enables seamless connectivity with PC environment

Using the remote user interface software provided with the E4991A, you can easily correct data and troubleshoot over the LAN interface. The remote user interface brings the instrument control panel to the PC display via LAN. You can gain control of instruments in physically separate locations. Easily share your measurement data with other applications, such as spreadsheets, through a file or via the clipboard.

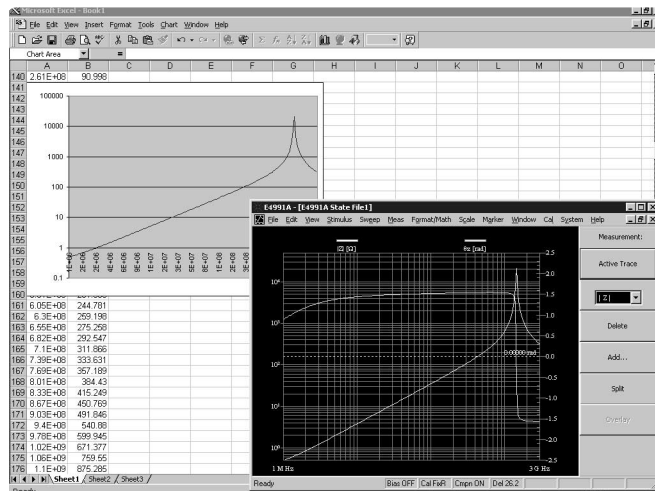


Figure 12. Remote user interface

Material Analysis Made Easy

The dielectric and magnetic measurement software (Option 002) provides direct readout of material parameters such as permeability and permittivity up to 1 GHz. The dielectric material test fixture, 16453A, and the magnetic material test fixture, 16454A, eliminate designing time-consuming custom test fixtures.



Figure 13. E4991A with material test fixtures

Dielectric material testing

The 16453A employs the parallel plate method for dielectric constant and loss tangent measurements up to 1 GHz. It is well-suited for measuring a sheet of solid substrate material, such as PC board, ceramic or polymer. Simple measurements are possible by inserting the material between the electrodes. With E4991A Option 002, material measurement function, you can display permittivity parameters directly on the analyzer's display.



Figure 14. 16453A Dielectric material fixture

Material size requirements

- Diameter $\geq 15\text{mm}$
- Thickness $\leq 3\text{mm}$

Magnetic material testing

The 16454A is used for permeability measurements up to 1 GHz on the E4991A. This single-wound, coil-structured test fixture holds toroidal-shaped magnetic materials such as soft-ferrite and magnetic cores. It is possible to accommodate different sizes of toroidal cores by exchanging small (smaller than 8mm diameter) and large adapters. To use the 16454A, you need the material measurement function (E4991A Option 002).



Figure 15. 16454A Magnetic material fixture

Material size requirements

Small size:

- Outer diameter $\leq 8\text{mm}$
- Inner diameter $\geq 3.1\text{mm}$
- Thickness $\leq 3\text{mm}$

Large size:

- Outer diameter $\leq 20\text{mm}$
- Inner diameter $\geq 5\text{mm}$
- Thickness $\leq 8.5\text{mm}$

Accurate impedance measurement with probe station



Figure 16. Agilent E4991A with probe station

More ICs or circuit modules are used in electronic circuits to save spaces, more capacitors or inductors, such as thin dielectric layers and pattern inductors, tend to be developed on wafer or substrate. These devices usually have a small capacitance or inductance like pF, nH. The Agilent E4991A RF Impedance/Material Analyzer, with Option 010 Probe Station Connection Kit, offers an accurate on-wafer or micro-component impedance measurement solution up to 3 GHz.

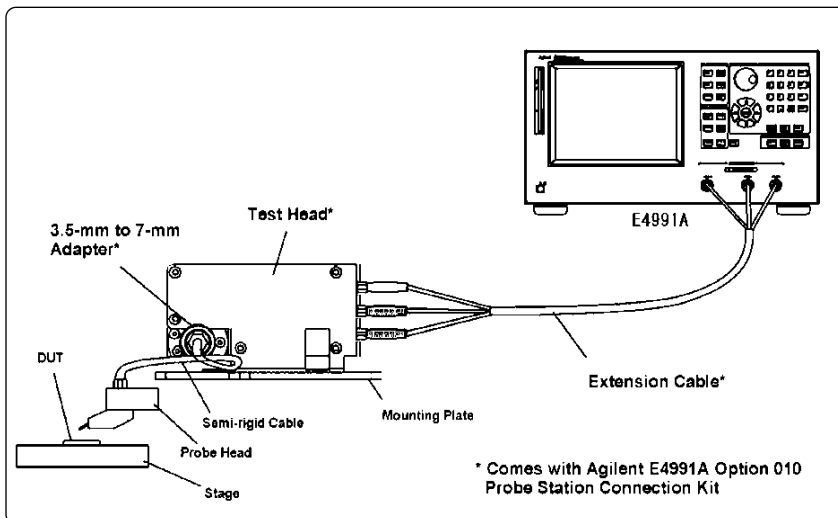


Figure 17. Probe measurement configuration using E4991A Option 010

Easy installation

When connecting the E4991A to probe stations, the accuracy degradation, caused by port extension and improper calibration, always becomes a big issue. The Option 010 probe station connection kit, for E4991A provides all necessary parts as one option and solves this problem. This option includes a smaller test head, extension cables, adapters, a connecting plate and detailed installation procedures. Probe stations are provided from Cascade Microtech, Inc. With this kit, you can easily establish a reliable measurement system in the short time.

Impedance measurement specification at the extended test head port

The E4991A's Option 010 has a guaranteed impedance measurement specification at the end of the extended 7-mm test head port. This is an important element for accurate measurement, because the port extension usually degrades the measurement accuracy. The situation becomes even worse if the cable used has an improper characteristic. Agilent solved this issue by preparing reliable extension cables and making a special test head. This test head is small enough to be brought closer to probe stations, so that the measurement error caused by this extra length is also minimized.



Figure 18. Agilent E4991A Option 010 probe station connection kit

Wide and repeatable impedance measurement

Agilent E4991A can cover wider impedance range than network analyzers. In general, network analyzers are good at measuring impedance near 50Ω , but the accuracy gets worse for impedance away from 50Ω . The E4991A is designed to measure non- 50Ω impedance as well, so it can give much better accuracy especially when you measure small capacitance and inductance like 1pF and 1nH . The E4991A is repeatable over time and temperature, too. This is another benefit of dedicated impedance analyzers.

What is E4991A Option 010?

The E4991A Option 010 includes following items:

- Smaller E4991A test head
- Extension cables
- 7mm-3.5mm (f) adapter x 1 ea.
- N (m)-SMA(f) adapter x 3 ea.
- Installation manual

What else do you need for a system?

Besides the E4991A with Option 010, a probe station and probe heads need to be purchased separately. This option works with any probe stations, but we recommend Cascade Microtech probe stations, because this combination was carefully checked to work well. The following are product examples:

- Summit 9000, 11000, or 12000 series probe station
- ACP-series or HPC-series probe head
- Impedance Standard Substrate (ISS)
- Adjustable mounting plate for the E4991A test head.
- Semi-rigid cable for the probe head connection

These products are provided by Cascade Microtech, Inc.

Integrated Temperature Characteristic Testing

A temperature characteristic test solution is now available

The temperature characteristic test kit, E4991A Option 007, is a new solution of temperature characteristic measurement for components and materials. This solution provides highly accurate temperature characteristic analysis capability within the wide temperature range from -55°C to +150°C with a powerful temperature drift compensation function.

Figure 19 shows the typical 10% measurement accuracy range of the E4991A compared to the 4291B. The 4291B requires both low and high impedance test heads for obtaining the wide impedance measurement range. On the other hand, the E4991A covers the wider impedance measurement range with a single test head.

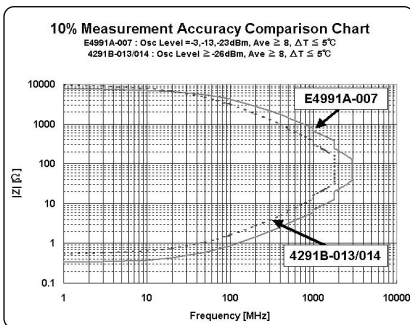


Figure 19. Typical 10% measurement accuracy comparison chart

The temperature drift compensation function is a new technology that is adopted in the E4991A. Unlike the 4291B, open/short compensation can be performed at pre-defined temperature points so that temperature drift errors can be drastically reduced as shown in Figure 20.

Easy integration with the ESPEC* temperature chamber

ESPEC supplies a temperature chamber, while Agilent provides all other necessary accessories and a sample program for creating an automated temperature characteristic test system. Figure 21 shows the contents of the E4991A Option 007.

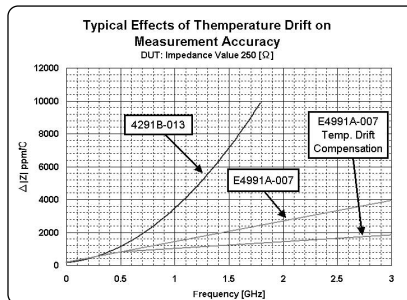


Figure 20. Effect of the temperature drift compensation function

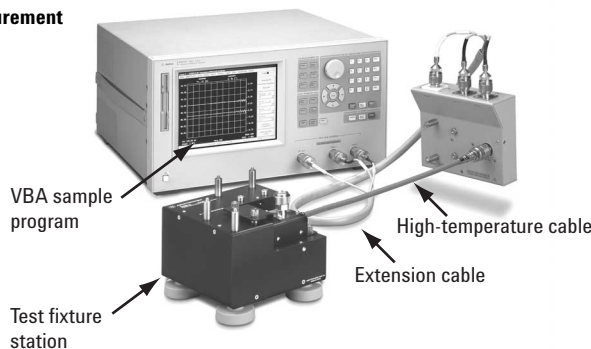


Figure 21. Contents of the E4991A Option 007 RF Impedance/Material Analyzer

A VBA sample program is compatible with the ESPEC bench-top temperature chamber, SU-261, so that you can easily integrate an automated temperature characteristic test system Figure 22. The SU-261 provides a wide temperature range from -60°C to +150°C; which covers the entire temperature range of Option 007. Also, this sample program can be modified to fit other companies' temperature chambers. In addition, the VBA sample program provides an intuitive GUI interface; which provides the temperature chamber control, measurement parameter setup, and temperature profile setup with easy operation.



Figure 22. The E4991A Option 007 with the ESPEC bench-top temperature chamber (SU-261)

*ESPEC is an Agilent Channel Partner

Test Fixture Accessories

16197A Bottom electrode SMD test fixture

Designed for bottom electrode SMDs up to 3 GHz. Adjustable electrodes accommodate a wide array of sizes. This fixture is designed to evaluate SMDs between 0.6 mm* and 3.2 mm in length.



Figure 23. 16197A

16196A/B/C Parallel electrode SMD test fixture

Designed for SMDs with electrodes on both sides up to 3 GHz. Dedicated design for specific shape of the devices eliminates repeatability errors and significantly improves usability. 0603 inch/1608 mm (16196A), 0402 inch/1005 mm (16196B) and 0201 inch/0603 mm (16196C) are supported.

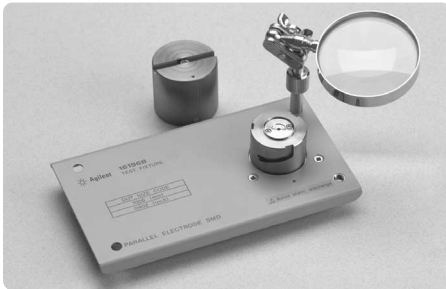


Figure 24. 16196A/B/C

16191A Bottom electrode SMD test fixture

Designed for bottom electrode SMDs up to 2 GHz. Adjustable electrodes accommodate a wide array of sizes. This fixture is designed to evaluate SMDs between 2.0 mm and 12.0 mm in length.



Figure 25. 16191A

*Option 001 is required

16192A Parallel electrode SMD test fixture

Holds chip devices with electrodes on both sides up to 2 GHz. Adjustable electrodes can accommodate a wide array of sizes. This fixture is adapted to evaluate SMDs between 1.0 mm and 20.0 mm in length.

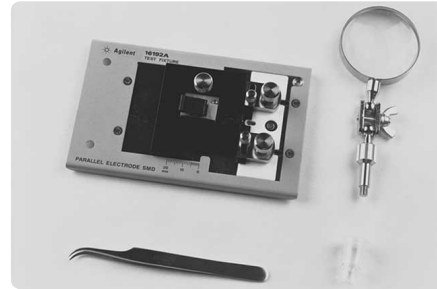


Figure 26. 16192A

16194A Parallel electrode SMD test fixture

Holds both lead devices and SMDs up to 2 GHz. It is furnished with two device holders that can be easily attached to measure either type of DUT.



Figure 27. 16194A

SMD test fixture selection guide

DUT Size	Parallel Electrodes SMD	Bottom Electrode SMD
0201 (inch)/0603 (mm)	16196C	16197A ²
0402 (inch)/1005 (mm)	16196B	16197A
0603 (inch)/1608 (mm)	16196A	16197A
0805 (inch)/2012 (mm)	16192A ¹	16197A
1206 (inch)/3216 (mm)	16192A ¹	16197A
1210 (inch)/3225 (mm)	16192A ¹	16197A
Over 1210 (inch)/3225 (mm)	16192A ¹	16191A ¹

1. Frequency is limited to 2 GHz.
2. 16197A Option 001

E4991A

Configuration and Accessory Guide

Ordering information

Agilent E4991A RF Impedance/ Material Analyzer includes: Impedance test head, calibration kit (50 Ω load, open, short, low loss capacitor, torque wrench), PS/2 keyboard and mouse, operational manual, and power cable.

Options

001	Add DC Bias ($\pm 40V$, $\pm 50mA$)
002	Add material measurement firmware
007	Temperature characteristic test kit
010	Probe station connection kit
1D5	Add high-stability frequency reference
0B0	Delete manual set
0B1	Add manual set
1A2	Delete keyboard
1CS	Delete mouse
ABA	US-English localization
ABJ	Japan-Japanese localization
1CM	Rack mount kit
1CN	Front handle kit
1CP	Handle/rack mount kit
A6J	ANSI Z540 compliant calibration

New accessories¹

16197A	Bottom electrode SMD test fixture (up to 3 GHz)
<i>Option 001</i>	Device guide set for 0201(inch)/0603(mm) size
16196A/B/C	Parallel electrode SMD test fixture (up to 3 GHz)
<i>Option 001</i>	Option 001 Delete magnifying lens and tweezers
16196U	Maintenance kits for 16196X.
<i>Option 010</i>	Upper Electrode Set (5ea)
<i>Option 100</i>	1608(mm) Short Plate Set (5ea)
<i>Option 110</i>	1608(mm) Lower Electrode Set (5ea)
<i>Option 200</i>	1005(mm) Short Plate Set (5ea)
<i>Option 210</i>	1005(mm) Lower Electrode Set (5ea)
<i>Option 300</i>	0603(mm) Short Plate Set (5ea)
<i>Option 310</i>	0603(mm) Lower Electrode Set (5ea)
16200B	External DC bias adapter (up to 1 GHz)

Existing accessories¹

16190B	Performance kit
16195B	7mm coaxial calibration kit
16092A	SMD test fixture (up to 500 MHz)
16191A	Side (Bottom) electrode SMD test fixture (up to 2 GHz)
<i>Option 001</i>	Delete magnifying lens and tweezers
<i>Option 010</i>	Add industry standard size short bar set
<i>Option 011</i>	Delete furnished short bar set
16192A	Parallel electrode SMD test fixture (up to 2 GHz)
<i>Option 001</i>	Delete magnifying lens and tweezers
<i>Option 010</i>	Add industry standard size short bar set
<i>Option 011</i>	Delete furnished short bar set
16094A	Probe test fixture (up to 125 MHz)
16453A	Dielectric material test fixture (up to 1 GHz)
16454A	Magnetic material test fixture (up to 1 GHz)

1. Additional accessory details can be found in the *Accessories Selection Guide for Impedance Measurements*, publication #5965-4792E.

Key web resources

Please visit our component manufacturer industry area at:
www.agilent.com/find/component_test

Please visit our impedance solutions area at:
www.agilent.com/find/impedance



Agilent Email Updates

www.agilent.com/find/emailupdates
Get the latest information on the products and applications you select.

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Visual Basic® for Applications is a U.S. registered trademark of Microsoft Corporation.

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For Cascade Microtech products, contact Cascade Microtech, Inc.

Cascade Microtech
2430 NW 206th Avenue
Beaverton, Oregon 97006, U.S.A.
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www.espec.co.jp

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