Agilent
E4991A RF Impedance/ Material Analyzer

Product Overview

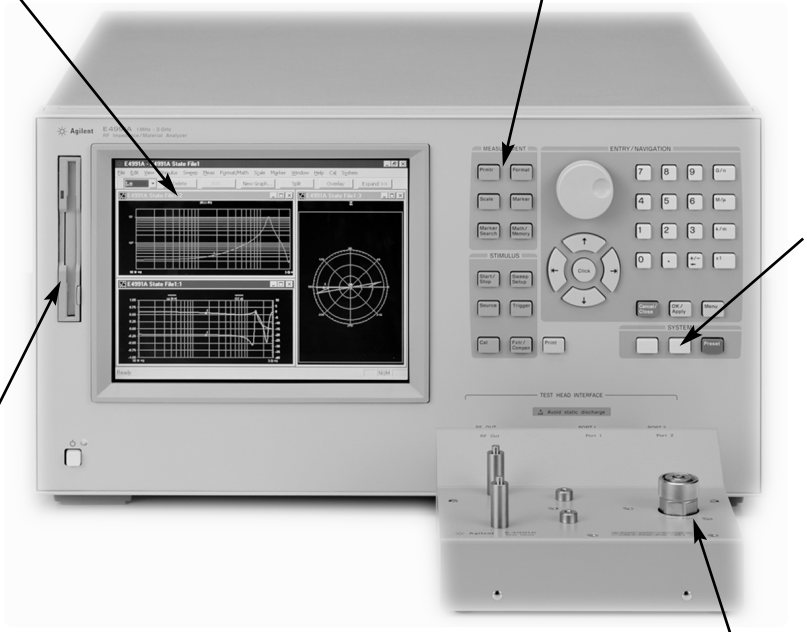
The new standard in RF impedance and material measurements.

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.



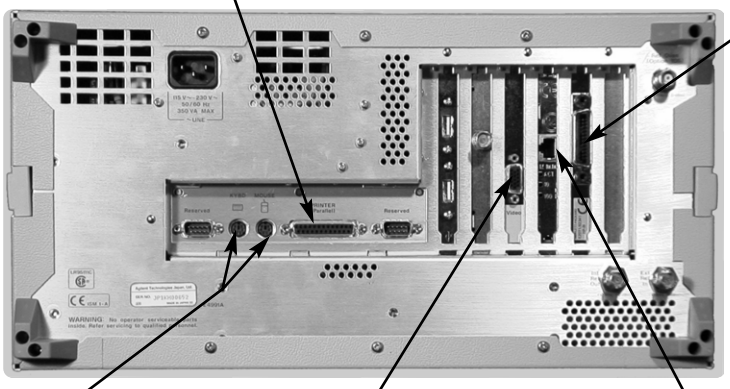
Built-in Visual Basic for Applications (VBA) programming function
- VBA offers easy programming for automation and further detailed analysis.

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).

Agilent provides various test fixtures for SMDs, designed to help you obtain the impedance parameters with high repeatability. The E4991A offers impedance measurement capabilities for your needs today and into the future.

- Accurate and versatile 3 GHz impedance measurement solution
- Analyze passive component behavior
- Wide range of test fixtures available
- PC connectivity features with Windows®-based technology

Key specifications

Table 1. E4991A key specifications

E4991A RF Impedance/Material Analyzer	
Operating frequency	1 MHz to 3 GHz (1 mHz resolution)
Impedance parameters	$\|Z\|$, θ_Z, $\|Y\|$, θ_Y, R, X, G, B, C_S, C_P, L_S, L_P, R_P, R_S, D, Q, $\|\Gamma\|$, θ_Γ, Γ_X, Γ_Y
Material parameters*	$\|\varepsilon_r\|$, ε_r', ε_r'', $\|\mu_r\|$, μ_r', μ_r'', θ, $\tan\delta$
Basic impedance accuracy	±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	•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 μA ~ 50 mA, –100 μA ~ –50 mA (10 μA 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 no 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. It 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)

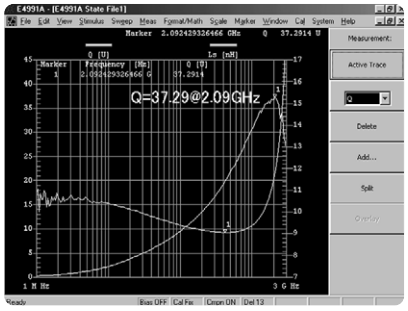


Figure 1. Ls-Q characteristics of a chip inductor

Table 2. Q measurement accuracy (Typical)

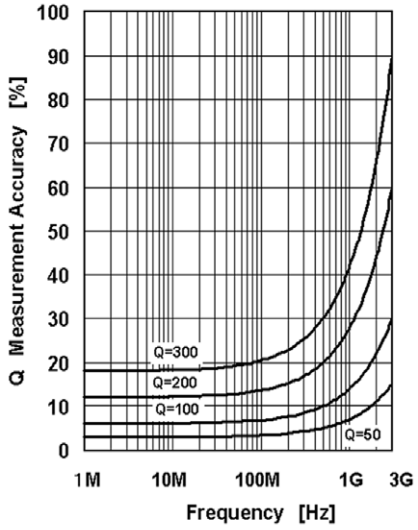


Table 3. Comparison of key characteristics of E4991A and network analyzers

	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	• Frequency • Test signal level • DC bias voltage • DC bias current	• Frequency • Test signal level
Fixturing	• 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	• 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)

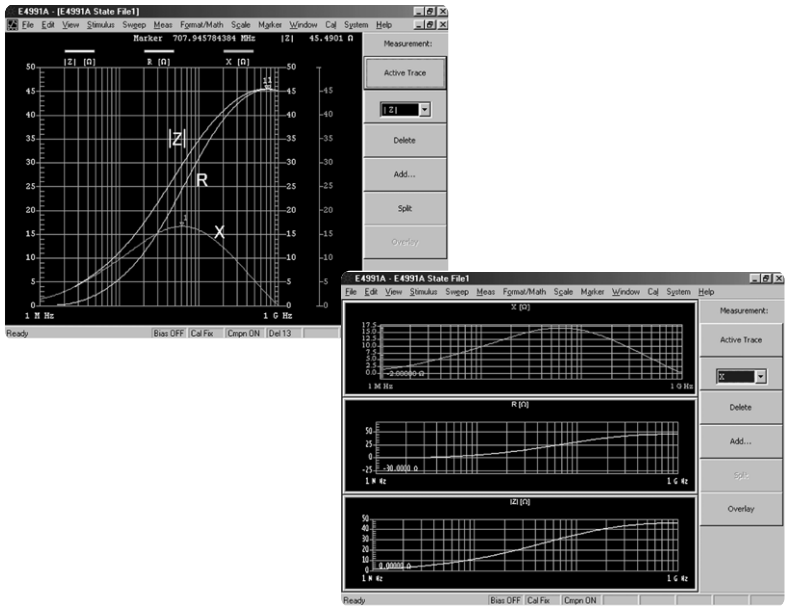


Figure 2. Flexible measurement trace assignment

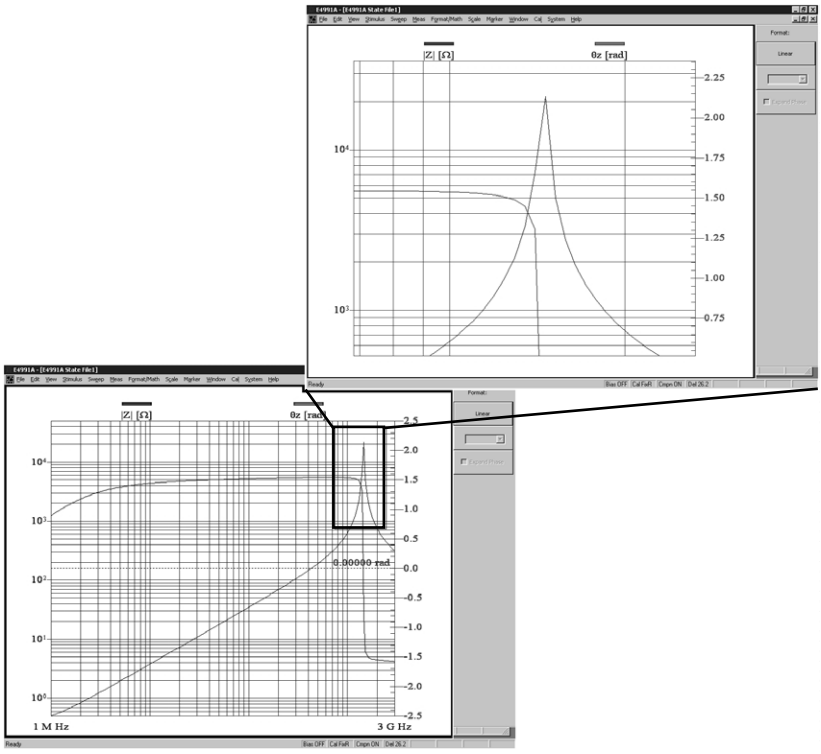


Figure 3. Mouse operation example

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

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.

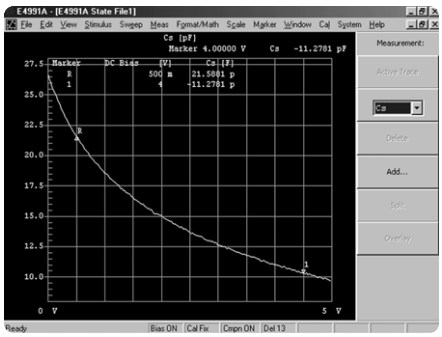


Figure 4. Varactor diode capacitance vs. DC voltage characteristics

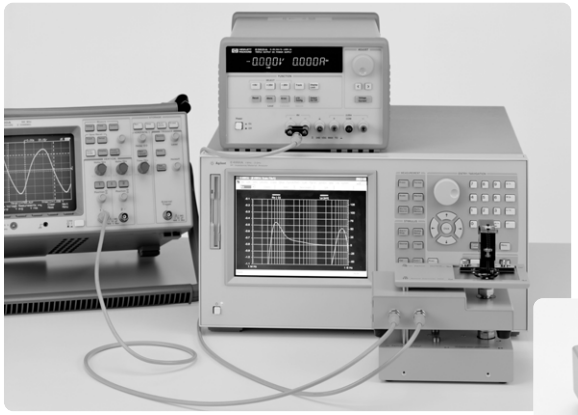


Figure 5. 16200B DC bias adapter connected to the E4991A

Figure 5-1. 16200B

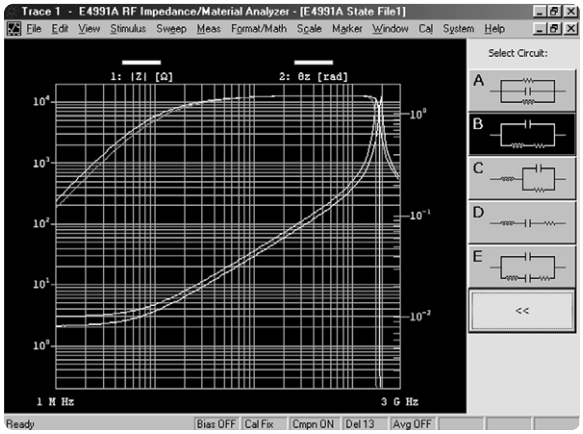


Figure 6. Equivalent circuit analysis models

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)

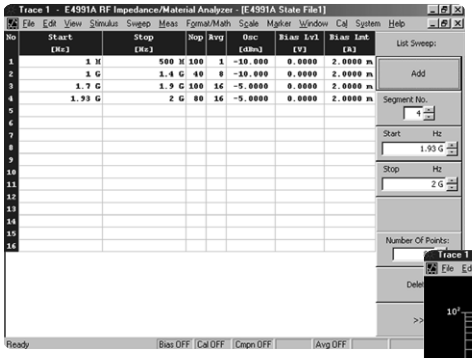


Figure 7. Segment list table

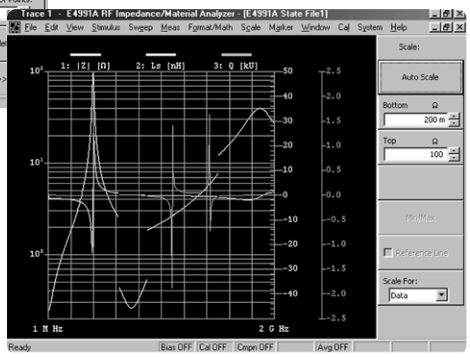


Figure 7-1. Segment sweep measurement example

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 recently introduced 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)

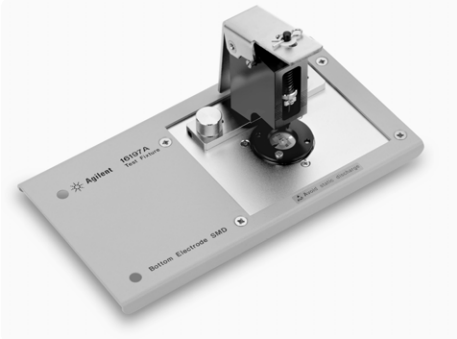


Figure 8. Agilent 16197A bottom electrode SMD test fixture

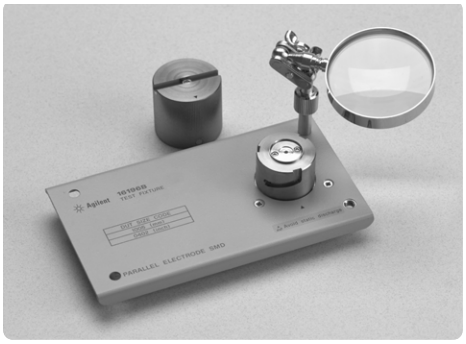


Figure 9. Agilent 16196B parallel electrode SMD test fixture

***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.

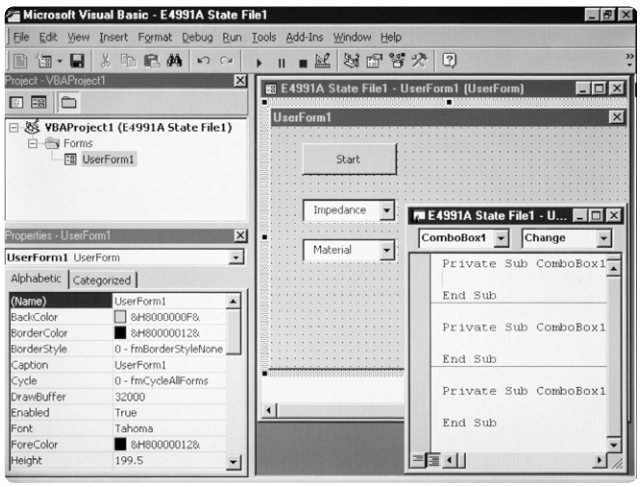


Figure 10. VBA

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.)

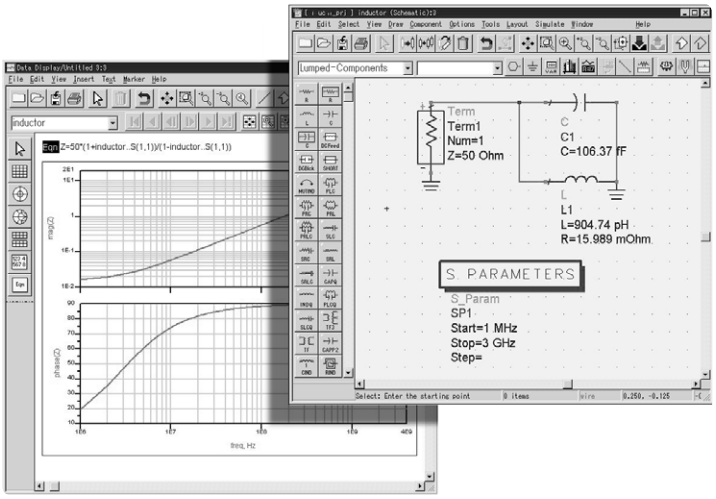


Figure 11. ADS figure

LAN interface enable seamless connectivity with PC environment

Using 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.

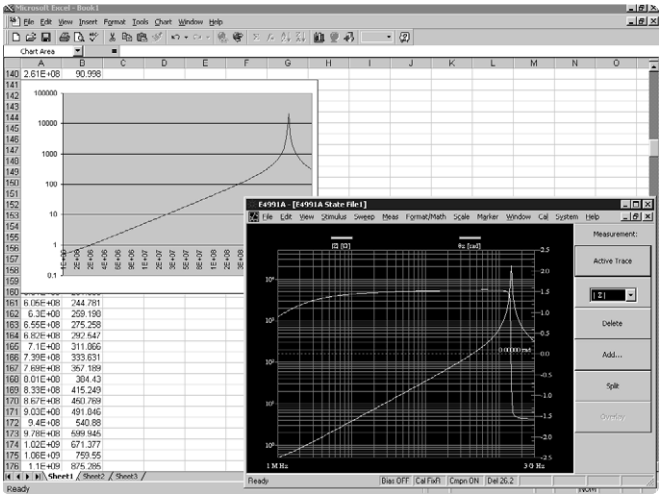


Figure 12. Remote user interface

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.

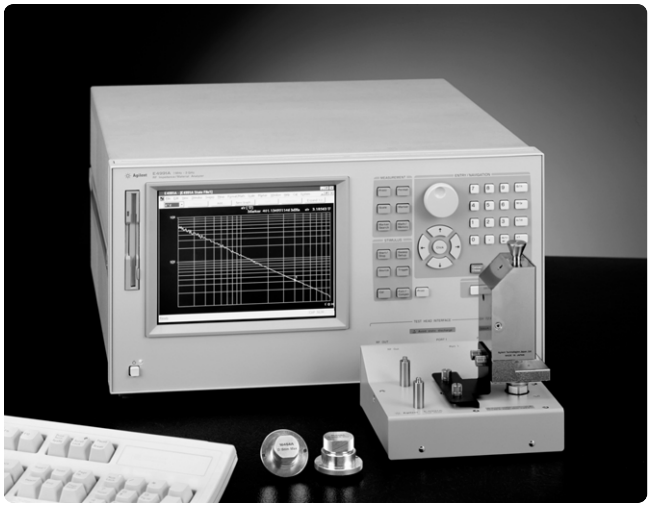


Figure 13. E4991A with material test fixtures

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 ≥ 15mm
Thickness ≤ 3mm

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. You need E4991A option 002, material measurement function, to use the 16454A.

Figure 15. 16454A Magnetic material fixture

Material size requirements

Small size:

Outer diameter ≤ 8mm
Inner diameter ≥ 3.1mm
Thickness ≤ 3mm

Large size:

Outer diameter ≤ 20mm
Inner diameter ≥ 5mm
Thickness ≤ 8.5mm

Accurate impedance measurement with probe station

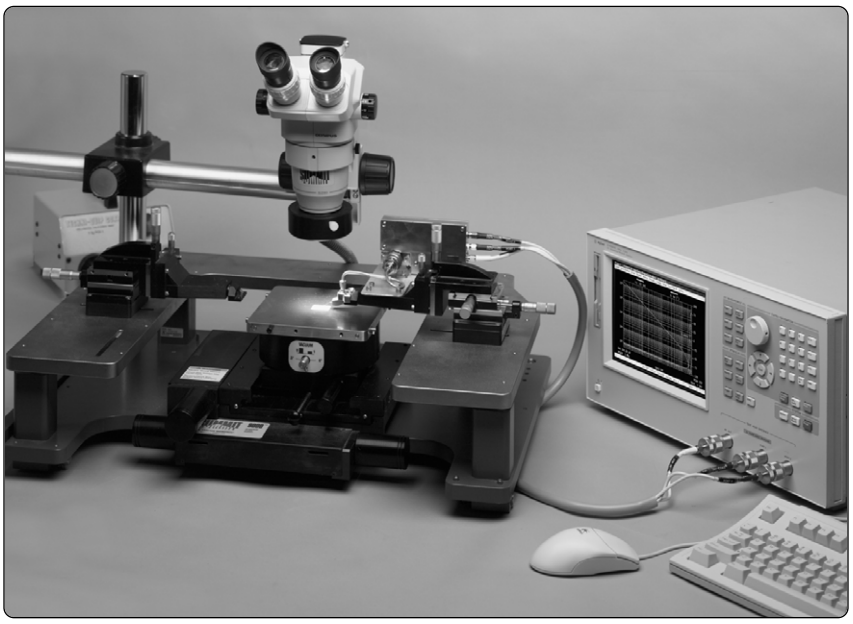


Figure 16. Agilent E4991A with probe station

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 new option 010 Probe Station Connection Kit, offers an accurate on-wafer or micro-component impedance measurement solution up to 3 GHz.

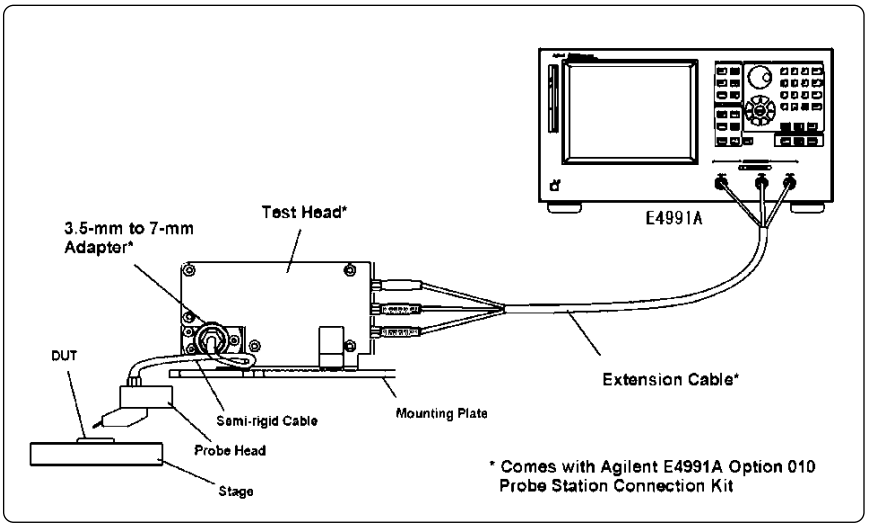


Figure 17. Probe measurement configuration using E4991A option 010

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 them, 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 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 50 Ω, but the accuracy gets worse for impedance away from 50 Ω. The E4991A is designed to measure non-50 Ω 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 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. Followings 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 from Cascade Microtech, Inc. For more information, contact Cascade Microtech, Inc. directly (URL http://www.cmicro.com/).

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.

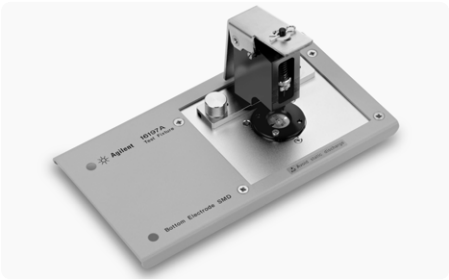


Figure 19. 16197A

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.

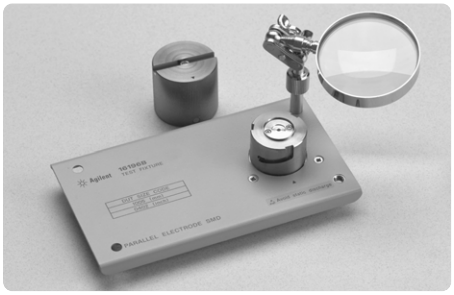


Figure 20. 16196A/B/C

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.

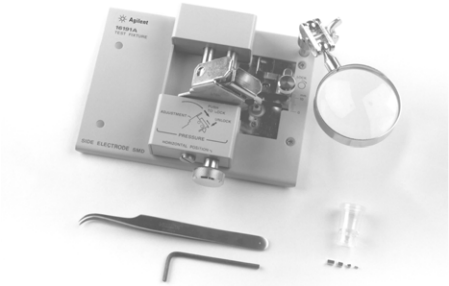


Figure 21. 16191A

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.

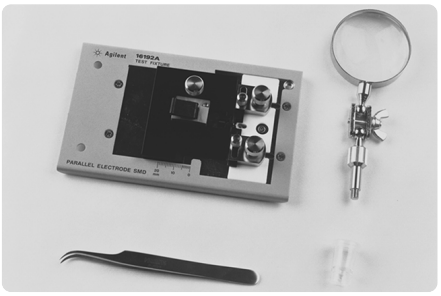


Figure 22. 16192A

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.

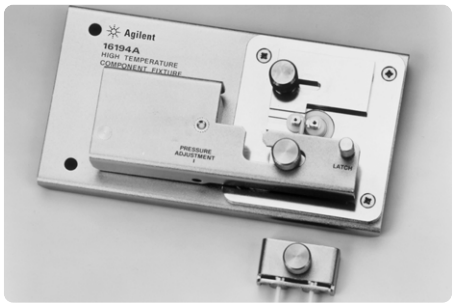


Figure 23. 16194A

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

***Option 001 is required**

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 (±40V, ±50mA)
002	Add material measurement firmware
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 accessories[1]

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

Existing accessories[1]

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)
Option 001	Delete magnifying lens and tweezers
Option 010	Add industry standard size short bar set
Option 011	Delete furnished short bar set
16192A	Parallel electrode SMD test fixture (up to 2 GHz)
Option 001	Delete magnifying lens and tweezers
Option 010	Add industry standard size short bar set
Option 011	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 Technologies' Test and Measurement Support, Services, and Assistance

Agilent Technologies aims to maximize the value you receive, while minimizing your risk and problems. We strive to ensure that you get the test and measurement capabilities you paid for and obtain the support you need. Our extensive support resources and services can help you choose the right Agilent products for your applications and apply them successfully. Every instrument and system we sell has a global warranty. Support is available for at least five years beyond the production life of the product. Two concepts underlie Agilent's overall support policy: "Our Promise" and "Your Advantage."

Our Promise

Our Promise means your Agilent test and measurement equipment will meet its advertised performance and functionality. When you are choosing new equipment, we will help you with product information, including realistic performance specifications and practical recommendations from experienced test engineers. When you use Agilent equipment, we can verify that it works properly, help with product operation, and provide basic measurement assistance for the use of specified capabilities, at no extra cost upon request. Many self-help tools are available.

Your Advantage

Your Advantage means that Agilent offers a wide range of additional expert test and measurement services, which you can purchase according to your unique technical and business needs. Solve problems efficiently and gain a competitive edge by contracting with us for calibration, extra-cost upgrades, out-of-warranty repairs, and on-site education and training, as well as design, system integration, project management, and other professional engineering services. Experienced Agilent engineers and technicians worldwide can help you maximize your productivity, optimize the return on investment of your Agilent instruments and systems, and obtain dependable measurement accuracy for the life of those products.

By internet, phone or fax, get assistance with all your test & measurement needs

Online assistance:
www.agilent.com/find/assist

Or contact the test and measurement experts at Agilent Technologies

United States:
(tel) 1 800 452 4844

Canada:
(tel) 1 877 894 4414
(fax) (905) 282 6495

Europe:
(tel) (31 20) 547 2323
(fax) (31 20) 547 2390

Japan:
(tel) (81) 426 56 7832
(fax) (81) 426 56 7840

Latin America:
(tel) (305) 269 7500
(fax) (305) 269 7599

Australia:
(tel) 1 800 629 485
(fax) (61 3) 9210 5947

New Zealand:
(tel) 0 800 738 378
(fax) 64 4 495 8950

Asia Pacific:
(tel) (852) 3197 7777
(fax) (852) 2506 9284

Product specifications and descriptions in this document subject to change without notice.

Printed in USA June 14, 2001
5980-1234E

Agilent Technologies