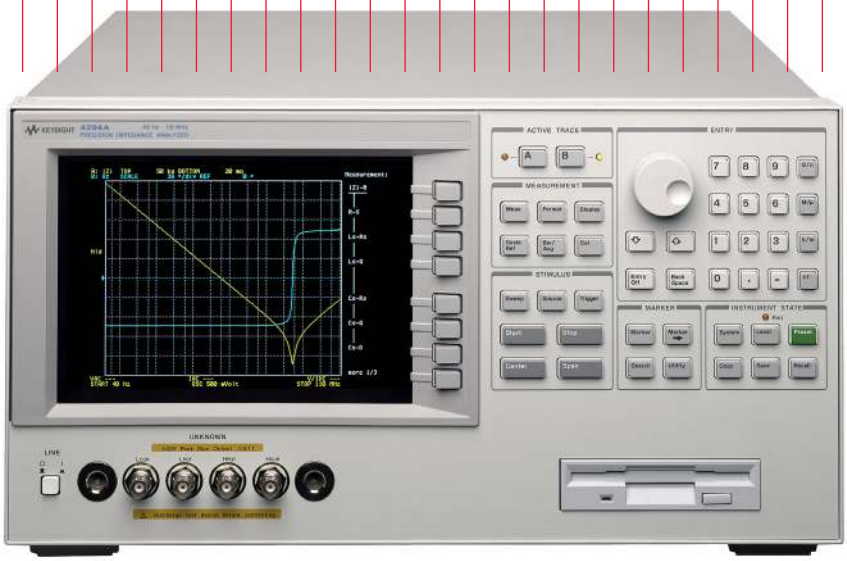
Keysight Technologies
Paving the Way for Research and Innovation



KEYSIGHT TECHNOLOGIES

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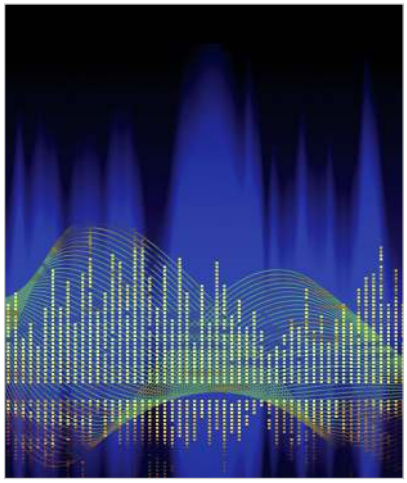
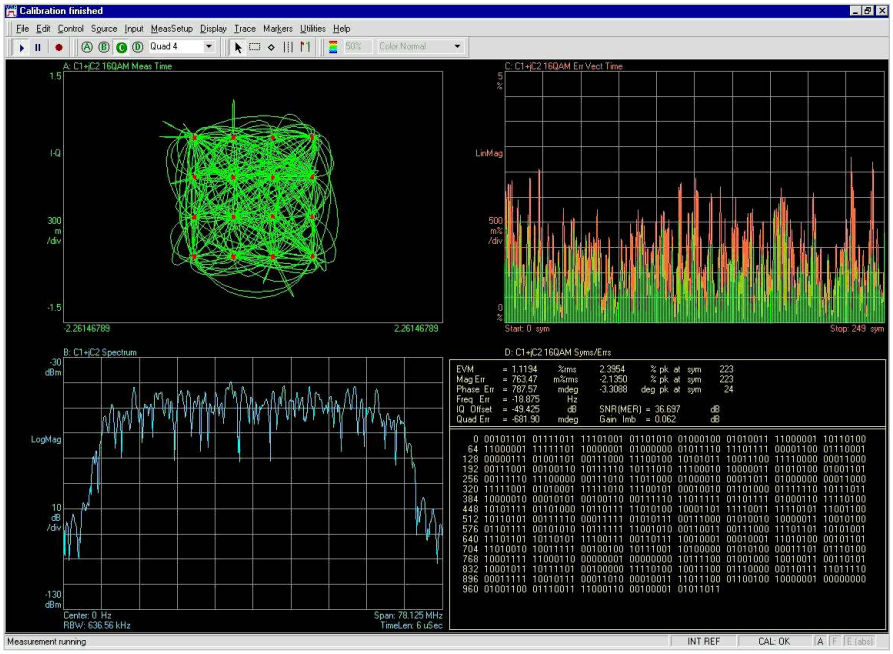


Research often goes beyond scientific discovery to become the discovery of new sciences. As you develop hypotheses, new theorems and theories to expand the world's knowledge, confidence in measurements is paramount. In research laboratories around the world, Keysight Technologies, Inc. instrumentation and partnership has become an integral part of advanced experimental systems.

As the world's premier measurement company, Keysight works in close collaboration with engineers, scientists, and researchers around the globe to meet the communications, electronics, life sciences, material sciences and chemical analysis challenges of today and tomorrow. Keysight is committed to providing innovative measurement solutions that enable our electronics and bio-analytical customers and partners deliver the products and services that make a measurable difference in the lives of people everywhere.

This brochure highlights key research areas in which Keysight is involved such as; materials measurement, device characterization, millimeter-wave, nanotechnology, RF and communications and renewable energy, and the solutions that can help you meet your research and development objectives. Keysight offers a full breath of electronic equipment for both teaching and research labs and also provides solutions for your specific research needs.



Materials Measurement

University of Washington's Applied Physics Laboratory and Center for Process Analytical Chemistry, are working on new sensors to monitor carbon nano-tube sonication. Utilizing Keysight's PNA Series Network analyzer and the 85070E Dielectric Probe Kit for complex permittivity measurements, researchers have developed a principle component analysis to categorize single and double walled carbon nano-tubes in a solution.

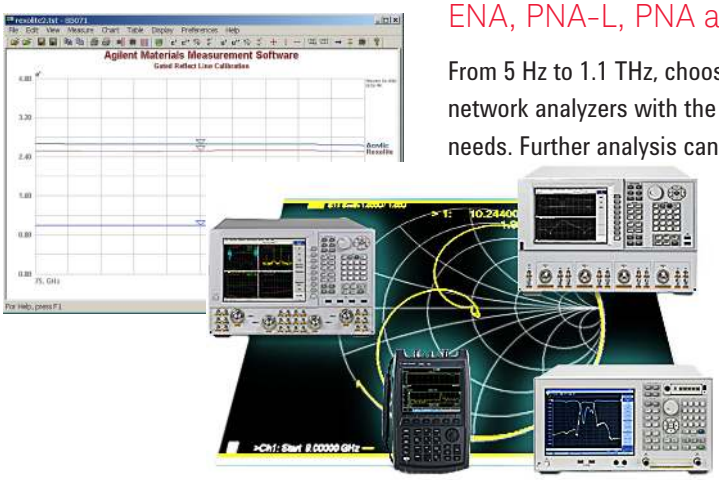
From meta-materials to dielectric substrates, microwave food products to bio-fuels, accurate characterization of electromagnetic properties at RF, microwave and mm-wave frequencies provide scientists with critical information needed for material and circuit design, modeling, research, manufacturing and quality control. Keysight offers a wide variety of instruments and fixtures to meet the most demanding needs.

4294A Precision Impedance Analyzer, 40 Hz to 110 MHz

This is an integrated solution for the measurement and analysis of components and circuits as well as dielectric, magnetic and semiconductor materials. Its equivalent circuit function automatically extracts a circuit model from measured data, letting you analyze the characteristics of your device or material. Additional test fixtures allows for dielectric constant and impedance measurements of liquids.

E4991A Impedance/Material Analyzer, 1MHz to 3GHz

This instrument offers ultimate impedance measurement performance and powerful built in analysis function. The optional 16453A Dielectric Material Test Fixture enables measurements of dielectric constant and loss tangent of solid materials, while the 16454A Magnetic Material Test fixture offers accurate permeability measurements of toroidal — shaped magnetic materials.



ENA, PNA-L, PNA and PNA-X series Network Analyzers

From 5 Hz to 1.1 THz, choose from a growing selection of RF and Microwave network analyzers with the appropriate accessories for your materials measurement needs. Further analysis can be done by adding the 85070E Dielectric Probe Kit to measure complex permittivity of liquids, conformable solids, or smooth flat hard solids. High Temperature, Slim Form and Performance Probes are available and Waveguide, FreeSpace and NRL Arch methods are supported. Add the 85071E Materials Measurement Software with appropriate sample holders and test fixtures to measure electromagnetic properties of dielectric and magnetic materials over a broad frequency range.

Device Characterization in TeraHertz

Interest in terahertz is accelerating since many materials exhibit unique terahertz frequency-range properties that provide high contrast for imaging and spectroscopic materials identification. There also is a need for measurement equipment to be expanded into the terahertz region not only to support these applications but also to measure devices that, due to Moore's law, are rapidly pushing up toward 1 THz and beyond. From detecting cancer tumors to inspecting semiconductors, terahertz measurements are gradually increasing.

For many years, the University of Leeds Photonics Laboratory has performed some of the world's best research in terahertz. In the past five years its program has expanded to include involvement with most aspects of the terahertz research going on around the world. As a leading provider of microwave, millimeter wave and IR/optical measurement equipment, Keysight Technologies is supporting some of this research with an eye toward expanding our measurement coverage into this area — and exploring new possibilities in measurement, imaging and spectroscopy.

Directly Connected PNA-X Based Solutions

These solutions connect directly to the front panel of a dual source PNA-X Network Analyzer and do not require a millimeter-wave test set controller. This configuration with allows full S-Parameter measurements up to 1.1 THz, and is a fully integrated solution that provides stable and repeatable measurements in the THz frequencies using a PNA-X.

The Key features of this solution are:

- Does not require a test set controller
- Supports full S-parameter measurements within a waveguide band with a dual source PNA-X network analyzer with either 2- or 4-ports
- Uses external power supplies that come with the recommended frequency extenders from Virginia Diodes Inc
- Frequency offset mode of the PNA-X is utilized to drive the frequency extenders
- Currently support power calibration and power sweep with all of Keysight's recommended frequency extenders
- Allows use of a higher IF frequency for the test and reference signals and can be driven with either a 26.5, 44, 50 or 67 GHz PNA-X Network Analyzer
- A downloadable macro is available from Keysight that simplifies the setup of the frequency offset mode

Millimeter-wave Measurements

Keysight Technologies and the University of Texas at Dallas established a leading millimeter-wave and sub-millimeter-wave electronics characterization facility at the Texas Analog Center of Excellence (TxACE). The facility will be available to industrial and government institutions using an open, collaborative framework. "With a facility of this type in a university environment, critical barriers will be removed for research in this challenging measurement area." Ken O - Director of TxACE and holder of the Texas Instruments Distinguished Chair at UT Dallas.

Millimeter-wave is becoming more common as measurement needs are pushed beyond 110 GHz, to 220 GHz, 325 GHz, and even 1 THz. Applications include on-wafer device characterizations as well as various types of materials measurements. High performance equipment is the essential part for all R&D activity in millimeter wave industry. Keysight provides the following test instruments needed for your millimeter wave labs.

N5251A PNA Based Single Sweep Solution (10 MHz to 110 GHz)

This configuration of the millimeter network analyzer is based on the N5227A PNA network analyzer. It allows both a single sweep measurement solution that starts at 10 MHz and goes to 110 GHz. This solution is intended as a replacement for the HP 8510XF solution and has improved performance capability. In particular it adds the capability to control and use receiver leveling to set the power accurately at the 1.0 mm test port. Architecturally very similar to the existing N5250C but allows for the configuration of either a 2- or 4- port 10 MHz to110 GHz measurements. Refer to the configuration information at the end of this section.

Key features

- Provides 2- and 4-port S-Parameter measurements from 10 MHz to 110 GHz in a single sweep
- Full source power control across the 10 MHz to 110 GHz with receiver leveling down to –50 dBm
- Utilizes Keysight's patented weight least squares calibration method in 1.0 mm for industry leading accuracy at 110 GHz
- Industry leading measurement applications

Millimeter-Wave Controllers N5261/62A

The N5261/62A millimeter-wave Controller provides the interface between the millimeter-wave modules and PNA-X series network analyzer. The controller, when used in conjunction with the millimeter-wave modules and the PNA-X, provides all of the features and functions of a millimeter-wave vector network analyzer with the frequency range of the millimeter-wave modules used.

X-Series Signal Analyzers (PXA and EXA)

The PXA and EXA X-Series signal analyzers measure signals from 3 Hz up to 1.1 THz with external frequency extenders. Advanced performance, flexibility, capability and expandability address demanding applications in research, commercial communications and more.

Microwave Analog and Vector Signal Generators

Keysight offers a broad selection of microwave signal generators with basic to advanced functionality, each delivering benchmark performance in its class. Vector models offer modulation bandwidths > 2 GHz.

- PSG models offer metrology-grade performance to 67 GHz, with frequency extenders to 1.1 THz
- MXG and EXG X-Series microwave models offer attractive size, speed and cost alternatives with frequency ranges to 40 GHz

Frequency Extension Source Modules

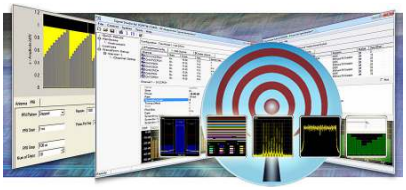
Millimeter wave sources are essential instruments for developing almost all millimeter wave systems and for extending the range of microwave systems. The E8257DSxx and DVxx series of external, high power, frequency banded mm-wave source modules, when paired with the high performance PSG, provide synthesized frequency performance, mm-wave test signals for waveguide bands from 50 to 1.1 THz.

RF and Communications

Enabling the development of devices and networks is the creation of new wireless communication standards and waves of continuous improvement to existing standards. As such, Keysight actively participates in the development of test processes and measurement methods in many of the wireless connectivity standards. We are determined never to let test equipment needs stand in your way of developing innovative products and technology for evolving wireless standards.

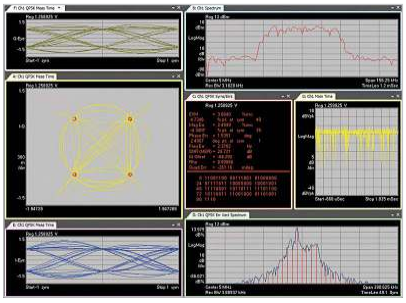
X-Series measurement applications

- Library of more than 27 measurement applications; transportable between X-Series signal analyzers
- Install during instrument purchase or as an upgrade to existing instruments
- Run applications such as 89600 VSA software and MATLAB for more detailed analysis



Signal Studio software with vector signal generators

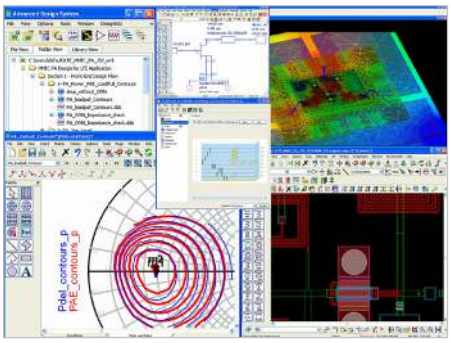
- Create Keysight validated and performance optimized reference signals
- Configure signals in an easy-to-use, application-specific graphical interface
- Over 37 applications offer broad coverage
- Scale the capability and performance to meet your specific test needs



89600 VSA and WLA software

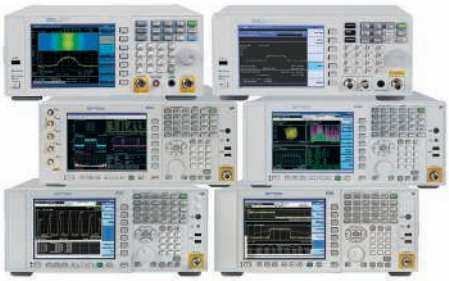
- Verify signal performance quickly with multiple simultaneous views in time, frequency and modulation domains
- Pinpoint answers to signal problems with advanced troubleshooting tools including trace-to-trace coupling, triggering, and record and playback
- Accelerate development with consistent measurements at any stage of design — from baseband to RF, simulation to design validation
- Supports more than 75 signal standards and modulation types
- Wireless Link Analysis constructs dynamic bidirectional decodes of MAC and PHY layer messaging for insight and troubleshooting

Electronic Design Automation (EDA) software



- Advanced Design System (ADS) is the industry's leading RF, microwave and high speed digital electronic design automation software with integrated MoM-, FEM- and FDTD-based EM simulation
- SystemVue enables system architects and algorithm developers to innovate the physical layer (PHY) of next-generation communications systems
- Keysight's Device Modeling tools provide complete end-to-end modeling solutions, from automated measurements, accurate device model extraction, comprehensive qualification to final process design kit (PDK) validation

Spectrum and signal analyzers



- X-Series signal analyzers (PXA/MXA/EXA/CXA)
  - From high-performance to low-cost, with frequency coverage up to 50 GHz and beyond with external mixing
  - Up to 160 MHz analysis and real-time bandwidth
  - Broadest set of measurement applications to cover evolving standards and test needs
  - Upgradable features and functions to extend instrument longevity
- Basic spectrum analyzers (N9322C and N9320B)
  - General-purpose spectrum analysis for R&D, universities and polytechnic education to address primary frequency domain measurement needs
  - Easy-to-use one-button PowerSuite measurements
- Modular PXIe VSA (M9391A) provides multi-channel design validation for 802.11ac and LTE based on Keysight's 89600 VSA software. See page 16 for more details

Ultra-high performance Infiniium Oscilloscopes – 90000A, X, and Q-Series

- Capture wide bandwidth of WiMAX with 63 GHz of available bandwidth
- Capture MIMO signals with up to four channel inputs
- Use built in FFT capability to seamlessly tie frequency and time domains together
- Superior Dynamic Range, up to 2 GPts memory and Microwave Probe Amplifiers for Scientific applications

Network analyzers – ENA or PNA-X Series

- Perform comprehensive network analysis for WiMAX component needs
- Integrate measurements for active devices with minimum iterations
- Attain accurate measurements with fast sweep speeds, wide dynamic range and low trace noise

Signal generators (signal sources)

- Widest selection of baseband, RF and microwave models with basic to advanced functionality, from baseband to 67 GHz
- PSG Series offer the lowest phase noise and highest bandwidth
- MXG and EXG X-Series offer best-in-class performance and low cost of ownership
- Generate LTE, 802.11ac, GNSS signals and more
- Modular PXIe VSG (M9381A) provides multi-channel design validation for 802.11ac and LTE supported by Keysight's Signal Studio software. See page 16 for more details

FieldFox Handheld RF and Microwave Analyzers

- Ten-instruments-in-one to save you money
- Easy to share and carry from class to lab
- Save time with ready-made lesson plans and teaching aids
- Carry precision with you

Nanotechnology

When your next discovery is within reach, getting there first — and getting a glimpse of what others haven't seen — depends on accurate, efficient nanotech measurement tools. Keysight's nanotech portfolio lets you image, manipulate and characterize a wide variety of nano-scale behaviors — electrical, chemical, biological, molecular, atomic and more. Our growing collection of instruments, accessories, software, services and consumables can reveal the clues you need to understand the nanoscale world.

The Blackett Laboratory, Department of Physics, Imperial College London utilizes the Keysight AFM to facilitate research into organic and hybrid semiconductor systems and opto-electronics devices. "We are very excited about the possibilities that the Keysight AFM system will enable, especially in our research for novel high-performance semiconducting materials and devices," said Dr. Thomas Anthopoulos, a reader in Experimental Solid-State Physics. "The high-spatial-resolution Kelvin force microscopy and current sensing capabilities of the system combined with its excellent environmental control will allow study of the electronic and structural properties of these novel material systems and devices down to nanometer scale."

Keysight 7500 Atomic Force Microscope

The Keysight 7500 AFM/SPM establishes new performance, versatility, and ease-of-use benchmarks for nanoscale measurement, characterization, and manipulation. The 90 µm AFM closed scanner achieves outstanding low noise performance, enabling atomic-resolution imaging. The 7500 is ideal for materials science, life science, polymer science, electrochemistry, electrical characterization, and nanolithography applications.

The 7500 offers excellent closed-loop resolution, leading environmental and temperature control, and an wide- range of electrochemistry capabilities. The 7500 scanner's standard nose cone permits many AFM techniques, including Keysight's patented MAC Mode. Easy-to-load nose cones for additional AFM techniques can be interchanged quickly and conveniently. Single-pass nanoscale electrical characterization is achievable using MAC Mode III. For ultimate experimental control, the 7500 automatically identifies connected accessories via hot plug technology.

U9320A 8500 Field Emission Scanning Electron Microscope (FE-SEM)

A compact system that has been optimized for low-voltage imaging, extremely high surface contrast, and resolution typically found only in much larger and more expensive field emission microscopes. Applications include polymers, thin films, biomaterials and energy sensitive materials.

U9820A G200 Nano-Indenter

Most accurate, flexible, user-friendly instrument for nanomechanical testing. Electromagnetic actuation allows unparalleled dynamic range in force and displacement and measurement of deformation over six orders of magnitude (from nanometers to millimeters). Applications include semiconductor, thin films, and MEMs (wafer applications); hard coatings and DLC films; composite materials, fibres, and polymers; metals and ceramics; and biomaterials and biology.

81150A and 81160A Pulse Function Arbitrary Noise Generators

Accurate and repeatable measurements, small voltages for fully characterizing nanotech materials and devices. The combination of pulse and function arbitrary generator allows special stress tests like pulse width modulation. The modulation of the duty cycle allows for control of the amount of power, which is critical for this type of device. Short pulses and bursts of pulses avoid heat generation, and short pulse width avoids leakage through gate oxide.

B1500A Semiconductor Device Analyzer

Provides accurate, flexible current-voltage (IV) and capacitance-voltage (CV) measurements of devices such as carbon nano-tube transistors and single electron transistors. Its task-oriented interface lets you make a few quick selections regarding the device — and it then chooses the appropriate settings, makes measurements, analyzes the data and displays the results.

4294A Precision Impedance Analyzer, 40 Hz to 110 MHz

An integrated solution for the measurement and analysis of components and circuits as well as dielectric, magnetic and semiconductor materials. Its equivalent circuit function automatically extracts a circuit model from measured data, letting you analyze the characteristics of your device or material.

Energy Research

Keysight offers tools to easily characterize new emerging high-power semi-conductors and a wide variety of power, measurement, and switching products — ideal building blocks to characterize electrical properties of solar cells, modules, arrays and new battery technology. Tools that help decrease your test costs, without sacrificing performance, and increase test flexibility in your rapidly changing test environments.

B1505A Power Device Analyzer/Curve Tracer

The B1505A Power Device Analyzer/Curve Tracer is an all-in-one solution with next-generation curve tracer functionality that can accurately evaluate and characterize power devices at up to 10 kV and 1500 amps. The B1505A is capable of handling all types of power device evaluation, with features that include a wide voltage and current range, fast pulsing capability (10 microseconds), micro-Ohm level on-resistance measurement resolution and sub-pA level current measurement capability. In addition, an oscilloscope view permits visual verification of both current and voltage pulsed waveforms right on the front panel of the B1505A.

When testing DUTs used in power storage applications, such as battery packs, battery management systems, bi-directional, and satellite power conditioning units, you ideally need test hardware that can provide continuous current sourcing and loading. Keysight's Advance Power System offers full two-quadrant glitch-free operation.

N6900A & N7900A 1000W & 2000W APS DC Power Supplies

The Advanced Power System (APS) family consists of 1 kW and 2 kW single output DC power supplies that deliver a new level in power supply performance enabled by Keysight's exclusive VersaPower architecture. The APS family was designed to help you overcome your toughest power test challenges by delivering industry-leading specifications and innovative features in an integrated solution. VersaPower architecture is designed to accurately capture current profiles, increase measurement speed and reduce development time with integrated features. Keysight's 14585A software now supports the N6900 & N7900 series.

N8900A 5, 10, and 15 kW Autoranging DC Power Supplies

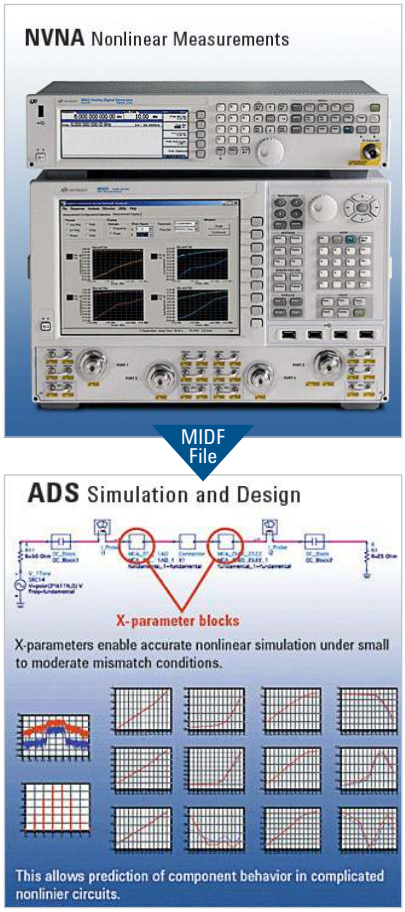
The Keysight N8900 Series provides 5 kW, 10 kW, and 15 kW autoranging, single-output programmable DC power for high power applications that require just the right amount of performance at just the right price. The N8900 Series power supplies' autoranging output characteristic enables unprecedented flexibility by offering a wide range of voltage and current combinations at full power. Choose the right voltage/current combination up to 1500 V and up to 510 A of current. Units can be paralleled to deliver of 100 KW while acting as a single supply.

The N6781A and the 14585A allow you to visualize dynamic current of your design in real time. You can optimize your hardware and software making tradeoffs between low power modes in real time.

N6781A 2-Quadrant SMU for Battery Drain Analysis

The Keysight N6781A is a source/measure unit (SMU) designed specifically for the task of battery drain analysis. Whether the device-under-test (DUT) is a mobile phone, medical device, or wireless sensor, the N6781A's seamless measurement ranging, programmable output resistance, and auxiliary DVM combine to be the best set of advanced features on the market for battery drain analysis. When used with the 14585A Control and Analysis software, the N6781A becomes an even more powerful battery drain analysis solution, offering additional insights into your measurements.

Non-linear Waveform Measurements



Testing today's high-power devices demands an alternate solution—one that quickly and accurately measures and displays the device's nonlinear behavior under large signal conditions, and provides an accurate behavioral model that can be used for linear and nonlinear circuit simulations.

Since S-parameters assume that all elements in the system are linear, this approach does not work well when attempting to simulate performance when the amplifier is in compression or saturation, as real-world HPAs often are. The errors are particularly apparent when simulating the combined performance of two cascaded devices that exhibit nonlinear behavior. While engineers may live with this inaccuracy, it invariably results in extensive and costly empirical-based iterations of the design, adding substantial time and cost to the design and verification process.

Nonlinear Vector Network Analyzer

- Efficiently and accurately analyze and design active devices and systems under real-world operating conditions, to reduce design cycles by as much as 50%
- Gain valuable insight into device behavior with full nonlinear component characterization
- Display calibrated time-domain waveforms of incident, reflected, and transmitted waves of the DUT in coaxial, in-fixture, or on-wafer environments
- Show the amplitude and phase of all harmonic and distortion spectral products to design optimal matching circuits
- Create user-defined displays such as dynamic load lines
- Measure with full traceability to the National Institute of Science and Technology (NIST)

Modular Solutions

M9703A 12-bit High-Speed Digitizer

The Keysight AXIe high-speed digitizer provides the ideal solution for advanced experiments in hydrodynamics, plasma fusion, and particle physics. With this module you can build a large number of synchronous acquisition channels with unprecedented measurement fidelity in the smallest footprint. Advanced IP design, state-of-the art technology, and on-board real-time data processing are combined to achieve outstanding performance.

M9391A PXIe Vector Signal Analyzer, 1 MHz to 3 GHz or 6 GHz and M9381A PXIe Vector Signal Generator, 1 MHz to 3 GHz or 6 GHz

The M9391A PXI VSA is a modular vector signal analyzer designed for fast data interfaces and high-speed automated test systems.

The M9381A PXI VSG is a modular vector signal generator that accelerates throughput by delivering new levels of speed in signal generation fast RF tuning, Keysight proprietary innovative baseband tuning and versatile list mode.

The M9391A PXI VSA, combined with the M9381A PXIe VSG provides a complete solution for fast, high quality measurements optimized for RF manufacturing test environments. Keysight also provides software which can be used with benchtop and modular equipment for measurement consistency: X-Series measurement applications, 89600 VSA software, Signal Studio, Waveform Creator and SystemVue.

M8190A 12 GSa/s Arbitrary Waveform Generator

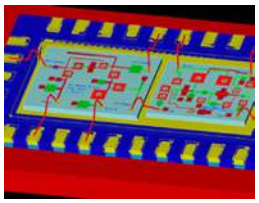
Keysight AXIe Arbitrary Waveform Generators are the source of greater fidelity, delivering high resolution and wide bandwidth – simultaneously. This unique combination lets you create signal scenarios that push your design to the limit and bring new insight to your analysis. Applicable for physics, radar, satellite and cable communication and current and emerging wireless standards like wireless backhaul and 5G mobile networks.

- 12- or 14-bit vertical resolution
- SFDR up to 90 dBc
- 2 GSa arbitrary waveform memory per channel with advanced sequencing
- Bandwidth of 5 GHz

Design and Simulation Software

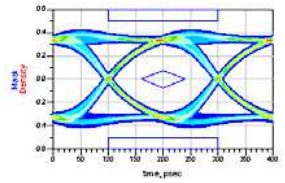
Keysight is the leading supplier of Electronic Design Automation (EDA) software for communications product design. Microwave and RF circuit, high-speed, device modeling, and signal-processing design engineers accelerate the development of better products using design flows built on our device modeling, electro-thermal, electromagnetic, circuit and system design and simulation tools.

RF & Microwave Design



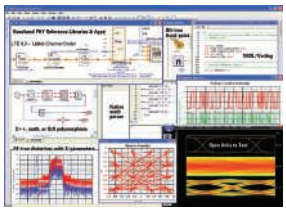
Keysight's RF and Microwave design and simulation tools provide the most complete solution for creating robust designs with first pass success and high yield in MMIC, RF-Mixed Signal IC, RF board, RF SiP and RF Module technologies.

High-Speed Digital Design



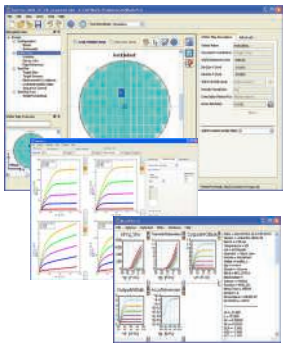
Keysight's high-speed digital design & simulation tools, such as ADS, EMPro & SystemVue, provide the most complete solution for multigigabit/s chip-to-chip links such as PCI Express®, DDR3, HDMI, USB 3.0, SAS, and 10G Ethernet.

Electronic System-Level (ESL) Design



ESL design tools enable designers of high performance PHY's in emerging wireless communications systems, LTE, LTE-A, MIMO, DPD, satellite & radar systems, and SDR to make optimum use of the latest RF/Analog and DSP techniques.

Device Modeling and Characterization



Keysight provides premier solutions for modeling and characterization of CMOS and III-V devices, including automated measurements, accurate device model extraction, comprehensive model qualification, PDK validation and comprehensive modeling services.

Over 850 Universities are enrolled in the Keysight EEsof University Educational Support Program. There is no better way for students to prepare for the real world than building skills on industry tools that will be in demand wherever their talent and interests lead. That's why over 850 universities worldwide participate in our program. The program is available to qualifying institutions offering academic instruction in electrical engineering, RF and communications system design, electromagnetic analysis, high-speed digital design, and device modeling.

Resources, Partnerships and Collaboration

Educator's Corner Website

Student Resources	Lab Equipment	Experiments	Teaching Materials	Researcher's Corner
– Cartoons, posters and screen-savers – Basics about engineering – Education sites – Career center – Tutorials	– Used test equipment – Keysight new equipment – Discount/ promo for education	– Java animations – Interactive experiments	– Application notes – Reference tables – Computer based training – Slide presentations	– Researcher's resources – Grant resources

Free resources from Educator's Corner Web portal

Educator's Corner is a dedicated Web site that provides a one-stop education resource to lecturers, researchers and students looking to enhance their higher education curriculum and research capabilities. Various tools and resources can be downloaded for free.

- iOS mobile apps
- Teaching tools
- Lab experiments
- Java animations
- Computer based training
- Application notes
- Webcast seminars
- Journal articles
- Engineering cartoons
- Student resources
- Information on education, discounts and promotions

www.keysight.com/find/edu

Research partnerships and collaboration

As the world's premier measurement company and a committed global citizen, Keysight takes an active role in supporting higher education and research.

We are committed to furthering science and technology by developing strategic partnerships with universities and research labs worldwide. We work with these universities to develop technology in areas of mutual interest.

www.keysight.com/find/research

Special programs, promotions and discounts

Keysight collaborates with universities and creates special programs to meet their needs: assistance with laboratory openings, mutual positive exposure through communications, and industry networking opportunities.

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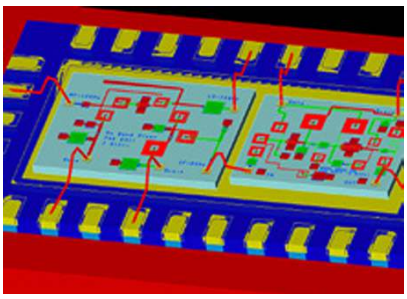

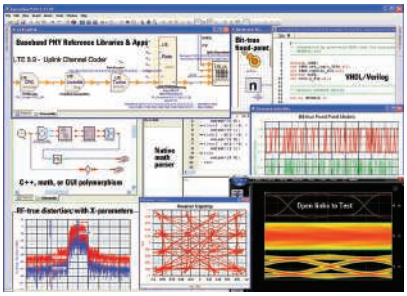

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