LXI: Going Beyond GPIB, PXI and VXI

Overcoming the major challenges of testing

Application Note 1465-20

The challenges of product testing don't have to overload your budget or your team. You can lighten the load with a versatile architecture that enables your team to create test systems with less effort. That's the vision behind LAN eXtensions for Instrumentation (LXI), the test-system architecture that's based on proven, widely used standards such as Ethernet. By specifying the interaction of those standards, LXI enables fast, efficient and cost-effective creation—and reconfiguration—of test systems.

LXI: Going Beyond GPIB, PXI and VXI is the first in a series of application notes that will help you make the transition to LXI. This first note focuses on the major challenges in system development, the key attributes of the LXI standard, the ways in which LXI addresses the key challenges, and the new possibilities in testing enabled by LXI devices.

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Reviewing the challenges

Test managers across many industries face several of the same issues: shorter launch windows, reduced staffing, dwindling software expertise, smaller development budgets, and outsourced (or offshore) manufacturing. Most are looking for the same solution: a more cost-effective way to develop test systems.

Taking a broad view

In the big picture of system development, "cost-effective" goes far beyond lowering the cost of test instrumentation. Even if GPIB, PXI and VXI hardware were free, developers would still face five challenges that affect the cost-effectiveness of system creation: reuse, set-up time, system throughput, system size and future-proofing.

Reuse: Developers seldom have the luxury of building a test system with all-new hardware and software. As a result, many systems include a collection of instruments that use different I/O interfaces and command sets. It can be difficult to reuse existing instrumentation and test-system code without tools that simplify instrument connectivity and control in the PC environment.

Set-up time: System set-up can be time consuming, especially when you're trying to get the PC to communicate with the instruments or get the instruments to work with the system software. It's even more time consuming with systems that include multiple interfaces: GPIB, RS-232C, VXI, PXI, MXI, Firewire, USB or LAN. Add to that multiple I/O libraries and instrument drivers from multiple manufacturers, and it may take days or weeks to troubleshoot the system and get it to work as expected.

System throughput: In time-critical applications, every millisecond counts. However, improving overall system throughput requires more than just a fast backplane. Bottlenecks may occur in test routines, measurement algorithms, data transfers, the sequencing of system tasks and more.

System size: Whenever systems must be shipped elsewhere or deployed where floor space is at a premium, system size matters. Unfortunately, this may also mean sacrificing functionality, performance and accuracy as the system shrinks.

Future-proofing: With limited versatility, existing test architectures make it difficult to meet future needs—higher frequencies, greater accuracy, faster throughput and so on. As more systems are deployed to remote locations, they become increasingly difficult to manage and troubleshoot without onsite expertise.

Critiquing current approaches

Developers have highlighted additional issues that limit their ability to create, manage and maintain test systems in a cost-effective manner:

- **Overhead:** The overhead costs of current modular systems—cardcages, slot-0 controllers, proprietary interfaces—shrink the budget available for actual measurement hardware. Also, if the cardcage is filled, the addition of just one more device to the system requires an additional cardcage.
- **I/O:** Because most PCs now include USB and LAN interfaces, it seems wasteful to require the additional cost and complexity of a measurement-specific interface.
- **Software:** It's difficult to leverage software across the product lifecycle if different types of instruments are used in each phase. This is especially true if testing shifts from benchtop instruments in R&D to modular instruments in manufacturing.
- **Consistency:** In systems that require source, measure, power and RF/microwave capabilities, developers have to mix two or more of the current instrumentation standards. This type of inefficiency also affects cost effectiveness.

There are also a few issues specific to each of today's three major test-system architectures.

- **GPIB:** Although this remains the instrumentation standard, it has slower data transfer rates than other architectures, forces you to install an interface card in your PC, requires expensive cables, and allows only 14 devices on the bus.
- **VXI:** This architecture requires an expensive cardcage, a slot-0 controller and an expensive, proprietary interface (MXI).
- **PXI:** In addition to the VXI overhead costs mentioned above, PXI has issues with size, power and EMI that limit the range of solutions to those normally covered by PC plug-in cards.

All of these broad and specific challenges were factored in during the development of the LXI standard.

Addressing the challenges with LXI

By specifying the interaction of proven, widely used standards such as Ethernet, Web browsers and IVI drivers, LXI enables fast, efficient and cost-effective creation and reconfiguration of test systems.

Although many current-generation instruments include LAN ports, LXI is the next logical step in the evolution of LAN-based instrumentation. It includes classic "box" instruments, faceless modular instruments, and functional building-block modules (synthetic instruments). Even when space is at a premium, you don't have to sacrifice functionality, accuracy or performance. Best of all, you can use the same instruments–and leverage the same test-system software–across R&D, design validation, manufacturing and service.

The promise of system longevity has inspired over 40 test-and-measurement companies to join the LXI Consortium. Agilent and others introduced the first wave of LXI-compliant products in September 2005. As the number of available LXI devices continues to grow, you will be well-equipped to take the next step beyond GPIB, PXI and VXI.

The LXI Consortium

The consortium is a not-for-profit corporation initially established by Agilent Technologies and VXI Technology, Inc. Its primary purpose is to promote the development and adoption of the LXI standard as an open, accessible standard that identifies specifications and solutions relating to the functional test, measurement and data acquisition industries. The Consortium is open to all test and measurement companies—over 40 are now members—as well as industry professionals, system integrators and government representatives. For more information about the consortium, please visit **www.lxistandard.org.**

Introducing the basics of LXI

LAN is at the heart of LXI. However, instead of modifying existing standards, LXI clearly specifies the interaction of proven standards in five areas: physical, Ethernet, programmatic interface, instrument pages and synchronization.

Physical

To achieve physical consistency, the LXI standard begins with IEC-standard rack dimensions. To help simplify system integration and implementation, it also recommends the placement of various connections (Figure 1). For example, compliant instruments use the front panel for signal inputs and outputs plus indicator lights for LAN, power and IEEE 1588 (synchronization). The rear panel is used for hardware triggering, power input and Ethernet communication. Each LXI module must meet worldwide standard EMI shielding and cooling specifications.

Form factor: To serve a wide range of requirements, LXI devices can be implemented in a variety of form factors. At present, the most common form will be classic benchtop instruments that include a front-panel display and user interface. For computer-controlled systems in manufacturing or aerospace/defense applications, there is a compact, faceless form-factor that enables small, cost-effective systems well-suited to local or remote deployment. These modules will typically be 1U to 4U high and half- or full-rack wide. The LXI standard also makes provisions for devices such as sensors, amplifiers, filters and attenuators in compact enclosures that can be deployed inside test fixtures and in remote locations.

Leverage: Although not mentioned in the standard, LXI enables leverage from classic instruments into faceless modular instruments and synthetic instruments (SIs). Agilent is already moving in this direction with the introduction of SIs based on popular benchtop RF and microwave products. By using the same measurement hardware in both classic and modular instruments, we're boosting your ability to leverage test software as the system evolves.

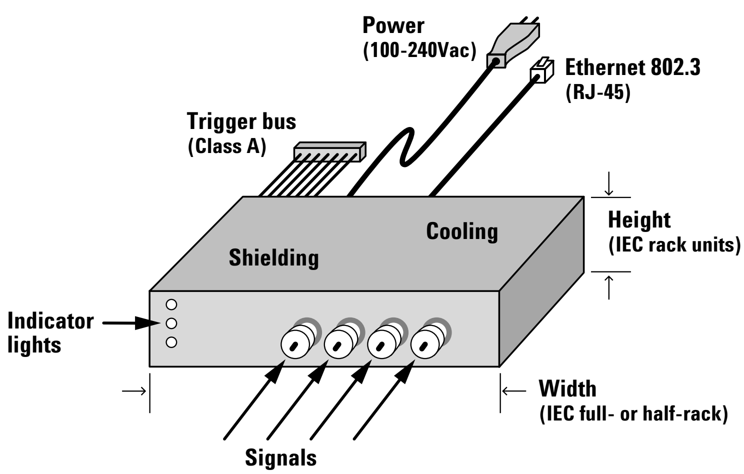

Figure 1. The LXI standard strives for physical consistency that simplifies system integration and implementation

Ethernet

LXI uses the IEEE 802.3 networking standard to define the appropriate connections, protocols, speeds, addresses, configuration and default conditions that must be implemented to ensure a consistent—yet easy-to-use—test system.

- **Connections:** LXI devices use standard RJ-45 connectors and implement Auto-MDIX to sense the polarity of LAN cables (through or crossover).
- **Protocols:** Compliant devices are required to implement TCP (transmission control protocol), UDP (user datagram protocol) and IPv4 (Internet protocol version 4). TCP is the standard Internet protocol that will be used most often in peer-to-peer messaging while UDP is a low-overhead protocol that will be typically used for multicast messaging when high speed delivery is critical.
- **Speeds:** The standard recommends use of 1-Gb Ethernet (and permits 100-Mb) with auto-negotiation to ensure that devices use their optimum speed.
- **Addresses:** LXI devices must support IP addresses (assigned by the server), MAC addresses (assigned by the manufacturer) and hostnames (assigned by the user).
- **Configuration:** Compliant devices must support ICMP (ping server), DHCP-based assignment of IP addresses, manual Domain Name Server (DNS) and Dynamic DNS. Because DNS can translate domain names into IP addresses, it can contribute to the longevity of system software: IP addresses may change but domain names will not.
- **Default conditions:** As a safeguard, LXI defines a set of default LAN conditions and requires a "LAN configuration initialize" (LCI) switch that will reset a device to this set of known conditions.

Programmatic interface

Because the LXI standard requires that all devices have an Interchangeable Virtual Instrument (IVI) driver, it allows you to use whichever programming language or development environment you prefer. IVI-COM and IVI-C are well-established industry standard drivers that instrument makers supply with their products.

LAN discovery: The LXI standard also mandates that compliant devices implement LAN discovery, which enables the host PC to identify connected instruments. Currently, the LXI standard requires use of the VXI-11 protocol, which defines LAN-based connectivity for all types of test equipment, not just VXI. Going forward, future revisions to the LXI standard may include other proven discovery mechanisms such as Universal Plug&Play (UPnP).

Instrument pages

Every LXI-compliant device must be able to serve its own Web page. This page provides key information about the device, including its manufacturer, model number, serial number, description, hostname, MAC address and IP address (Figure 2). The standard also requires a browser-accessible configuration page that allows the user to change parameters such as hostname, description, IP address, subnet mask and TCP/IP configuration mode. Accessing these Web pages is as simple as typing the instrument IP address into the address line of any W3C browser.

Many of Agilent's LXI-compliant instruments go beyond the LXI requirements, providing monitor and control capabilities. For example, you can set up a DMM, command it to start making measurements and then read the results. Some of our LXI devices even allow you to download complete measurement personalities—CDMA, GSM, Wi-Fi—into the instrument and perform specific measurements with one command. The ability to control an instrument through its browser interface opens up a realm of new possibilities for test engineers who need a simple way to access test systems from virtually anywhere in the world.

Synchronization

One especially intriguing aspect of LXI is its triggering and synchronization capabilities. By harnessing the capabilities of LAN and the IEEE 1588 time-synchronization protocol, LXI provides a variety of triggering modes that are not available in GPIB, PXI or VXI. The three classes of LXI devices—Class C, B and A—implement these capabilities to an increasing degree.

- **Class C** is the base class and it includes all of the requirements for the LAN interface and protocols, LAN discovery, IVI driver interface and instrument pages plus recommendations for power, cooling, size, indicators and a reset button. All LXI instruments must adhere to Class C requirements.
- **Class B** includes all Class C requirements and adds IEEE 1588 time synchronization. This makes it possible to achieve sub-microsecond synchronization of LXI devices located anywhere on a network—local or remote. Class B also adds peer-to-peer and multicast LAN messaging (required in Class B and A, permitted in Class C).
- **Class A** includes Class C and B requirements and adds a hardware trigger bus that enables triggering of LXI instruments in close proximity. The trigger bus is similar to the backplane bus of VXI: it is an eight-line, differential-voltage bus that enables 5-nsec/meter timing accuracy for co-located instruments. Synthetic instruments are expected to be Class A compliant.

As an example of what is possible with LXI, all Class B and A LXI instruments (optional in Class C) can utilize triggers embedded in LAN packets that can originate from any device on the network—a PC or another instrument. One device can send a multicast message that triggers all instruments on the network without the need for a real-time computer. Peer-to-peer messages can enable measurement scripts or cause data to be passed from one LXI device to another without involving the system's host computer (a potential communication bottleneck).

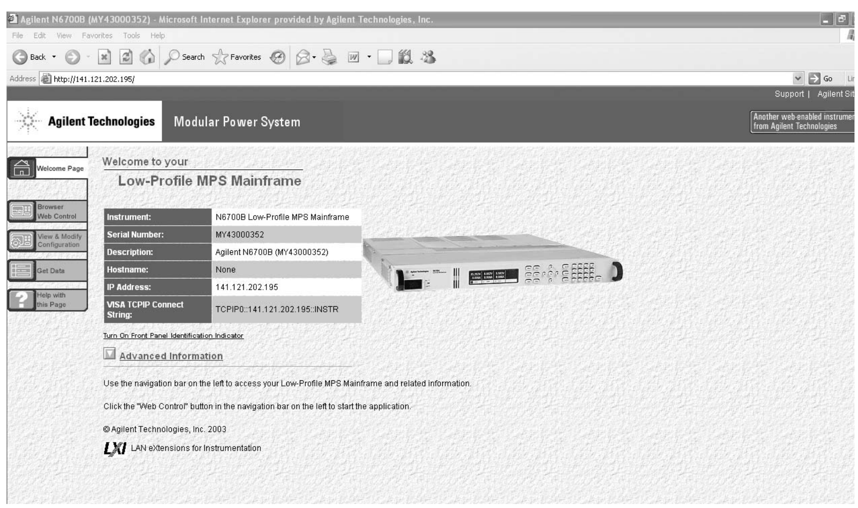

Figure 2. LXI specifies an informative instrument page that can be accessed with a standard Web browser

Simplifying system creation with LXI

Compared to other architectures, LXI does more to help you reduce the expense and effort required to create cost-effective test systems. It does this by addressing all six of the key challenges outlined earlier.

Reduce overall system cost

Whichever form suits your application, LXI-compliant instrumentation can help reduce system costs. Modular devices—faceless or synthetic instruments—don't require the overhead costs of a cardcage, slot-0 controller or proprietary interface. SI modules can be arranged via software control to emulate a wide variety of measurement instruments, and it will be possible to insert updated or upgraded technology to replace discontinued modules and accommodate future requirements.

LXI-based remote devices provide a low-cost, portable way to deploy sensors, cameras, microphones and more. Benchtop implementations provide accurate, cost-effective instruments with built-in LAN connections (Figure 3). Intelligent instruments can receive new measurement capabilities and personalities via download, enabling reuse for a variety of applications.

Reuse existing instruments and software

The various forms of LXI devices make it easier for you to test your product across its entire lifecycle. In some cases, a classic instrument can be used on the bench or in a rack to develop and refine test routines that can then be used with an equivalent faceless instrument in the final test system. This concept can be extended with synthetic instruments: through the necessary SI software modules, a few functional building blocks can do the work of multiple RF/microwave instruments.

Agilent also offers a range of I/O gateways and converters that make it easy to create hybrid systems that include LXI-based devices and your existing test assets. Bringing your system software forward to work with LAN requires nothing more than simple address changes.

Reduce set-up time

Through proven standards such as Ethernet and IVI drivers, LXI ensures that everything is compatible—and setup will take less time. With Web pages built into every LXI instrument, a standard Web browser is all you need to view device information, change its configuration and even monitor results and control measurements (in many Agilent LXI devices). You can also use proven tools such as LAN hardware, LAN cables and ping servers to communicate via LAN and troubleshoot local or remote systems.

Improve system throughput

LXI makes it possible to build high-speed distributed systems that utilize intelligent instruments communicating with each other—without PC intervention—and operating in parallel. Everything will stay synchronized through the use of IEEE 1588, LAN-based triggers, peer-to-peer and multicast messaging, and the hardware trigger bus. These capabilities offer new ways to build highly efficient test systems that deliver dramatic improvements in overall system throughput.

Shrink the system

In applications such as depot test and contract manufacturing, the smaller the system the better. Unlike cardcage-based systems that limit the size and power of the measurement hardware, LXI's modular and synthetic instruments let you reduce the size, weight and footprint of the system—without sacrificing the quality of the measurements.

Figure 3. Classic instruments such as the Agilent 34980A multifunction switch/measure unit can be enhanced to achieve LXI Class C compliance.

Address future needs

Two key ideas extend the life of LXI systems: the ability to download new capabilities or personalities into intelligent instruments and the possibility of injecting updated or upgraded technology into SI-based systems. These capabilities simplify the task—and reduce the cost—of keeping pace with evolving measurement standards, wider frequency ranges and tighter accuracy requirements. Taking a wider view, LXI enables new levels of versatility by making it possible to configure or reconfigure a system through software changes to IEEE 1588 clocking and LAN triggering.

LXI also helps you address future organizational needs. Test-system experts are becoming scarce in many organizations and can't be everywhere at once—onsite, offshore or anywhere in between. With LXI, you can place test systems virtually anywhere on your intranet, enabling your team to perform centralized troubleshooting, remote monitoring and more.

Exploring new possibilities with LXI

LXI-compliant devices open up a number of useful new possibilities that are difficult—and in some cases impossible—to implement with traditional rack-and-stack or cardcage systems. The following examples are not meant to define the complete set of possibilities: they are simply an initial set of concepts that will grow as the use of LXI spreads.

Distributed testing

Current-generation systems use a PC-centric approach in which the computer controls basic instruments and "dumb" devices. The PC sends commands and uses wait statements or queries to determine when an operation is complete—and all data returns to the PC through a dedicated I/O port. This is fine for small systems but can become slow and inefficient in larger systems that use 10 or more instruments. While the speed of the I/O connection plays a role, successful operation requires a skillful programmer who can manage the flow of both control and data.

Next-generation systems, as embodied in LXI, make it possible to apply a distributed approach that utilizes the intelligence of the instruments. Much of the analysis and synchronization can be performed in the measurement hardware, offloading these chores from the PC. Data flow is reduced because only the results of the analysis are sent to the PC. Timing is simplified with LXI Class B and A devices that can start their activities at a specific time or based on messages from other instruments. Instruments also can exchange information using peer-to-peer and multicast messaging. With this architecture, the PC and its I/O path are less likely to become bottlenecks in large, complex systems.

Long-distance operations

Through the LAN interface, LXI makes it possible to place instruments far from the PC and from each other. As an example, instruments can be placed near the devices or processes they are monitoring or controlling—and be connected to existing LAN ports in a test lab or near a manufacturing line. LXI devices can even be placed inside a text fixture, minimizing cable runs and enhancing measurement results.

Expert troubleshooting

Whether a system is located in the next room, the building next door or a site halfway around the world, your system developer (or product expert) can check its operation and troubleshoot problems. No travel is required: simply type an instrument's URL or IP address into a standard Web browser and the instrument page will appear.

Intelligent instruments

Without the size restrictions of VXI and PXI, LXI enables use of intelligent instruments within a system. You can download measurement personalities into a spectrum analyzer, sophisticated signals into an arbitrary waveform generator or complex power sequences into a programmable dc supply—and let the instrument handle the details.

The capabilities built into these instruments help you save time, too. You can reduce programming time by taking advantage of the software (and firmware) developed by the vendor rather than writing it yourself. Instrument set-up time can be reduced by creating configurations in advance and recalling them as needed. Data transfers take less time because the instrument can make measurements, perform the required analysis and then send results—not large data blocks—to the host PC.

Synthetic instruments

In addition to the attributes mentioned earlier, SIs create two additional possibilities. SI hardware and software modules can be used to emulate obsolete instruments, removing the burden (and cost) of supporting outdated equipment in long-lived systems. SIs also make it possible to create and perform totally unique measurements that are not currently possible with traditional instruments.

Peer-to-peer triggering

By making it possible for one instrument or device to send triggers and information to another, LXI frees up the PC to perform other, higher-level tasks. Peer-to-peer triggering also eliminates the need for an expensive real-time controller to issue precise triggers to the instruments in a system. Ultimately, overall test time can be reduced because techniques such as wait states and status queries will be used less often in system software.

Time-based triggering

With IEEE 1588, time-based triggering may prove to be a revolutionary way to synchronize measurements within systems and between instruments. For example, this method eliminates the need for trigger-specific external cabling so is not limited by the distance between instruments. All measured data can be time stamped, making post-test analysis easier, more efficient and more meaningful. System throughput also increases because each instrument can start at a specific time rather than waiting for a trigger or command.

Transitioning to the future of test

LXI solves the key problems faced by system developers like you: it cuts costs, reduces system size, simplifies integration, accelerates throughput and provides more opportunities for reuse of both hardware and software. These benefits make LXI a test architecture for both today and the future.

To help you fully realize those benefits, we've adopted LXI as part of the Agilent Open concept. The strength of Agilent Open is in more than just instruments—it's in the way we help you simplify the entire testing process with PC-standard I/O and open software tools (Figure 4). As technology moves forward, our reliance on widely used standards makes it easy to extend system longevity and incorporate new developments such as LXI.

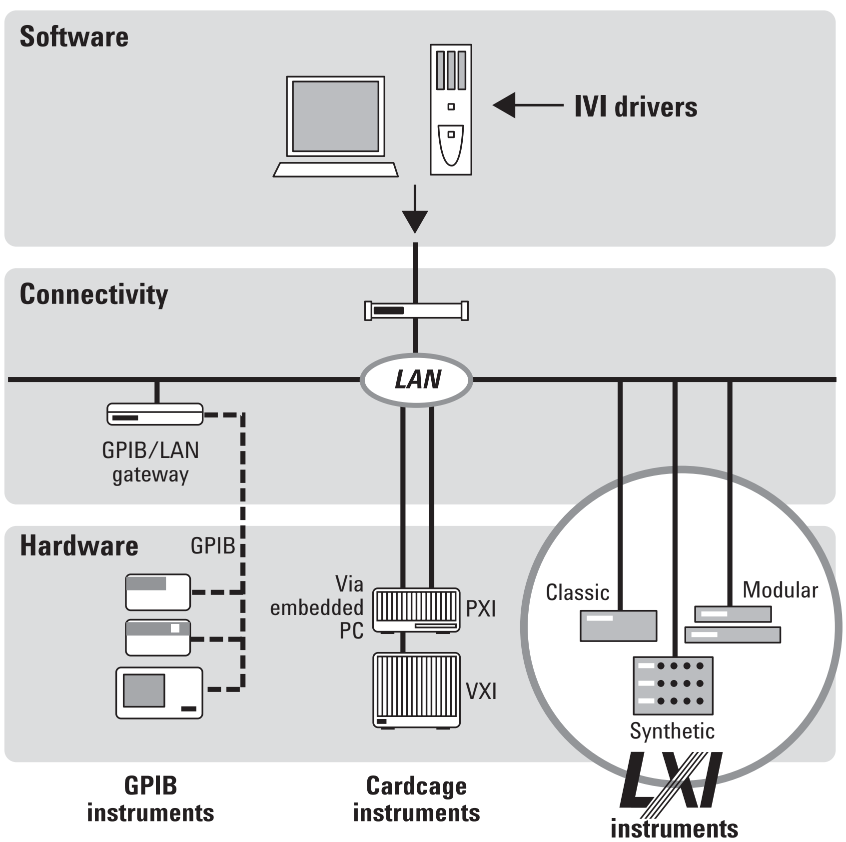

Figure 4. With Agilent Open and LXI, LAN becomes the backbone of test systems that easily incorporate present and future test assets

Simplify system communication and connectivity with PC-standard I/O

System I/O no longer means costly, proprietary interfaces and cables. Today you can choose the I/O connection that fits your test requirements: most Agilent Open instruments are available with GPIB, LAN and USB ports. This flexibility lets you select the interface that works best with your system now—and switch to another one in the future. We also make it easy to incorporate GPIB instruments into LAN- and USB-based systems by offering a variety of interface gateways and converters.

Create versatile measurement solutions with system-ready instrumentation

Selecting an Agilent Open instrument for your test system is an easy choice because it's designed for faster throughput as well as easy integration into your test software and your system rack. Whether you choose traditional, modular or building-block instruments, you can connect them quickly and correctly with our IO Libraries Suite. In minutes, its Agilent Connection Expert installs automatically, configures the interfaces, discovers connected instruments from hundreds of manufacturers, and verifies communication.

Achieve efficient development with open software tools

You shouldn't have to spend time struggling with an unfamiliar programming language just to set up a test. Agilent Open lets you work in the test-software development environment you already know. The key is open software tools such as standard instrument drivers and links to Microsoft” Excel or popular programming languages such as Visual Basic, C, LabVIEW, Agilent VEE Pro, Visual Basic.NET, Visual C++, Visual C# and others. Work where you prefer—and focus on your product, not the code you need to test it.

Through the combined capabilities of Agilent Open and LXI, Agilent can help you and your team open the door to simplified system creation—and new possibilities in testing.

Related literature

The 1465 series of application notes provides a wealth of information about the creation of test systems, the successful use of LAN, WLAN and USB in those systems, and the optimization and enhancement of RF/microwave test systems:

- *Introduction to Test System Design,*
  AN 1465-1 (pub no. 5988-9747EN)
  http://cp.literature.agilent.com/litweb/pdf/5988-9747EN.pdf
- *Computer I/O Considerations,*
  AN 1465-2 (pub no. 5988-9818EN)
  http://cp.literature.agilent.com/litweb/pdf/5988-9818EN.pdf
- *Understanding Drivers and Direct I/O,*
  AN 1465-3 (pub no. 5989-0110EN)
  http://cp.literature.agilent.com/litweb/pdf/5989-0110EN.pdf
- *Choosing Your Test-System Software Architecture,*
  AN 1465-4 (pub no. 5988-9819EN)
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- *Maximizing System Throughput and Optimizing System Deployment,*
  AN 1465-7 (pub no. 5988-9822EN)
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- *Operational Maintenance,*
  AN 1465-8 (pub no. 5988-9823EN)
  http://cp.literature.agilent.com/litweb/pdf/5988-9823EN
- *Using LAN in Test Systems: The Basics,*
  AN 1465-9 (pub no. 5989-1412EN)
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- *Using LAN in Test Systems: Network Configuration,*
  AN 1465-10 (pub no. 5989-1413EN)
  http://cp.literature.agilent.com/litweb/pdf/5989-1413EN.pdf
- *Using LAN in Test Systems: PC Configuration,*
  AN 1465-11 (pub no. 5989-1415EN)
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- *Using USB in the Test and Measurement Environment,*
  AN 1465-12 (pub no. 5989-1417EN)
  http://cp.literature.agilent.com/litweb/pdf/5989-1417EN.pdf
- *Using SCPI and Direct IO vs. Drivers,*
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- *Using LAN in Test Systems: Applications,*
  AN 1465-14 (pub no. 5989-1416EN)
  http://cp.literature.agilent.com/litweb/pdf/5989-1416EN.pdf
- *Using LAN in Test Systems: Setting Up System I/O,*
  AN 1465-15 (pub no. 5989-2409)
  http://cp.literature.agilent.com/litweb/pdf/5989-2409EN.pdf
- *Next-Generation Test Systems: Advancing the Vision with LXI,*
  AN 1465-16 (pub no. 5989-2802)
  http://cp.literature.agilent.com/litweb/pdf/5989-2802EN.pdf
- *Optimizing the Elements of an RF/Microwave Test System,*
  AN 1465-17 (pub no. 5989-3321)
  http://cp.literature.agilent.com/litweb/pdf/5989-3321EN.pdf
- *6 Hints for Enhancing Measurement Integrity in RF/Microwave Test Systems,*
  AN 1465-18 (pub no. 5989-3322)
  http://cp.literature.agilent.com/litweb/pdf/5989-3322EN.pdf
- *Calibrating Signal Paths in RF/Microwave Test Systems,*
  AN 1465-19 (pub no. 5989-3323)
  http://cp.literature.agilent.com/litweb/pdf/5989-3323EN.pdf

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