A Multivendor Test System

BY ROB PURSER, THE MATHWORKS

When the LXI Consortium elected to develop a system featuring LXI devices in 2006, the plan involved creating a multivendor demonstration system (MVDS) to show the capabilities of LXI-compliant instruments as well as how to incorporate equipment from multiple vendors into a real-world system. The project's goals included the following:

- Create a system that integrated hardware and software from several of the member companies.
- Demonstrate the variety of LXI-compliant equipment.
- Experience the scenarios end users might encounter when building an LXI-based test system.
- Validate the interoperability of as-built LXI-compliant equipment and that the LXI- 1.1 standard meets its objectives.
- Complete the demo for the 2006 AUTOTESTCON and Electronica shows.

The Multivendor Team

The MVDS brought together people from Agilent Technologies, Data Translation, Elgar Electronics, Keithley Instruments, The MathWorks, Measurement Computing, Rohde & Schwarz, and VXI Technology. We met three times in person and weekly by conference call.

Getting such a diverse team to work together is a significant challenge. Many of the members represented companies that are direct competitors, which occasionally led to some contentious situations. However, everyone recognized that LXI represents a key step forward for customers and that successfully demonstrating the capabilities of LXI was critical. This shared commitment allowed us to find solutions when issues arose.

At the June 2006 meeting in Loveland, CO, we decided to focus on the following aspects:

- Show how to perform setup and discovery of an LXI device.
- Demonstrate that LXI matches the capabilities of GPIB and surpasses it in many areas.
- Show how to integrate LXI into existing systems and how to create hybrid systems containing LXI, GPIB, VXI, and PXI elements.
- Show how to migrate a system from GPIB to LXI.
- Compare LXI performance to GPIB.
- Feature hardware and software that is available today to help build LXI-based test systems.
- Demonstrate the triggering capabilities of Class A and Class B devices.

Along with these goals, tight time limits were set for executing the demos to ensure that we maintained our audience's interest. Most demos were executed in less than 60 seconds.

Getting-Started Video

To demonstrate how to get started with LXI, we created a 90-second video that illustrated the three steps required to communicate with an LXI instrument: connecting power and Ethernet to the instrument, discovering the instrument on the network, and accessing the instrument using a browser and its Web page. This video was interleaved with the Class C demo that introduced LXI.

Class C Capabilities Demonstration

The Class C demonstration focused on how a user can transition from GPIB-based test systems to LXI systems based on Ethernet. Every LXI instrument must implement the Class C capabilities including:

- A Web page hosted by the instrument that provides access to basic configuration and setup functions from any Web browser. In addition, it may provide more in-depth Web applications.
- Instrument discovery via the VXI-11 protocol.
- An IVI driver that provides access to the instrument from various programming languages and applications.
- A TCP/IP-based Ethernet hardware and software inter-

face making the instrument a good network citizen.

To demonstrate the various software environments available for supporting LXI equipment, each demo was created as a Windows 32-b .EXE and implemented using four different software packages: the C# programming language, Measure Foundry from Data Translation, MATLAB and Instrument Control Toolbox from The MathWorks, and LabVIEW from National Instruments.

Figure 1. Class C Demo

The development environments were not installed on the systems running the demo. Additional software included Agilent I/O libraries and NI-VISA from National Instruments.

Figure 1 shows the Class C system as built. It consisted of a number of devices that were connected via GPIB or LXI. Several devices supported both interfaces with no reconfiguration, allowing for straightforward benchmark performance comparisons of GPIB and LXI.

Most systems with LXI have other instrument control interfaces as well. As part of the demo, a Rohde & Schwarz FSQ Signal Analyzer (GPIB and LXI), a Keithley 2910 RF Vector Signal Generator (LXI), and VXI instruments using a VXI Technology EX2500 LXI-VXI Bridge were incorporated to demonstrate a hybrid system implementation. This collection of instruments, in conjunction with software I/O libraries, demonstrated the ease with which a test system could be implemented with multiple instrument control interfaces.

To illustrate the minimal software changes needed to switch from GPIB to LXI, the demo included the use of two Sorensen DLM 20-30 Power Supplies, one controlled via GPIB and the other by LXI. By using the same programming code, it was possible to demonstrate that, by simply changing the resource string, either device could be controlled.

For example, for the GPIB device, the VISA resource string "GPIB0::22::INSTR" was used. For LXI, the VISA resource string "TCPIP0::192.168.1.105::INSTR" was used. No other changes were needed to move the test program from GPIB to LXI.

Performance of new technologies always is a concern. To show how LXI and Ethernet stacked up against GPIB, two scenarios were created.

To illustrate the performance of LXI when transmitting large blocks of data, a Rohde & Schwarz FSQ Signal Analyzer was used which has both an LXI and a GPIB interface. This unit can return raw spectrum data to the PC in 256-kB blocks. Our test acquired and transmitted 100 of these blocks back to the PC over LXI and then repeated the test using GPIB. Typically, an improvement of four to five times in the throughput was observed when using the LXI interface.

To test small packet transfers where GPIB has lower overhead, 1,000 readings were acquired from a high-speed Agilent 34410 Digital Multimeter with both LXI and GPIB interfaces. Each of these readings was 16 B. In this case, GPIB and LXI offered similar performance.

These scenarios were implemented using all four software packages and coordinated by using Microsoft PowerPoint running in a continuous kiosk mode. To provide equal time to all the packages, they were sequenced so that the viewer saw demo 1 from vendor A, demo 2 from vendor B, and so on. In addition, each demo from each vendor was atomic, meaning setup, execution, and exit were self-contained, allowing the next demo to proceed without relying on pre-existing or previous conditions.

Despite these complexities and multiple software packages running side by side, the reliability of the demo was very high; it never had to be rebooted while running at AUTOTESTCON and Electronica.

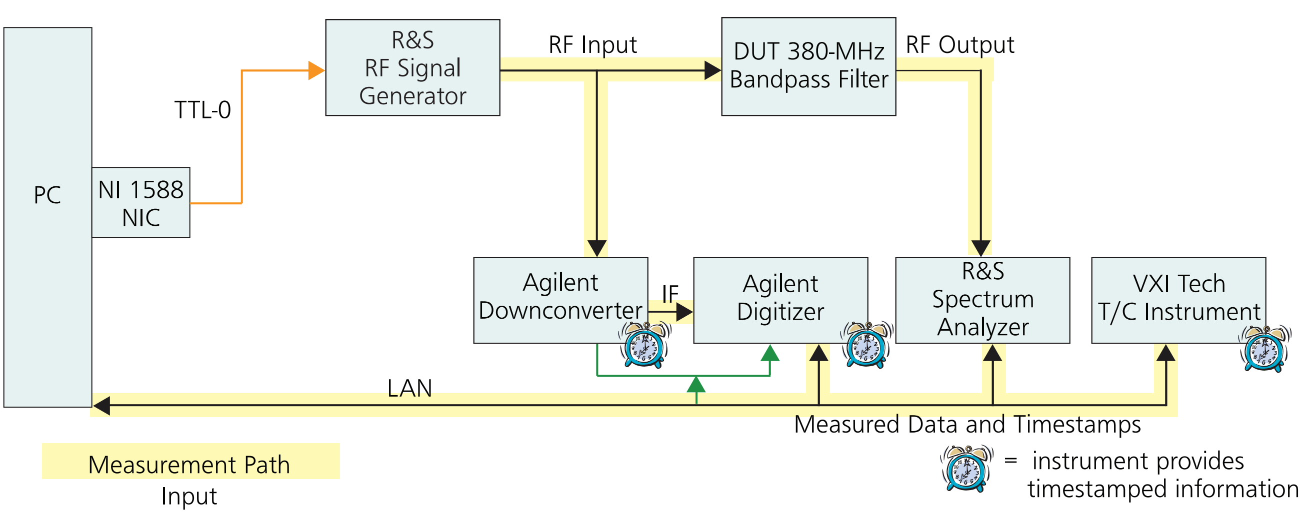

Figure 2. Class B Schematic

This is a credit to the skills of the team members, the stability of the various software packages, and the instruments used in the demo.

Class B Triggering Demonstration

The Class A and B demonstrations focused on the new capabilities that the LXI standard created for triggering and synchronization of instruments in the test system. Class B devices have all the Class C capabilities plus the IEEE 1588 network-based protocol that allows instruments to precisely synchronize their internal clocks. This enables multiple instruments to trigger at the same moment, time-stamp all their readings, and even use pretriggering techniques to retroactively collect data on past events. To learn more about IEEE 1588 and Class B capabilities, see "Time Scales and IEEE 1588" by John Eidson and Dan Pleasant in the July and October 2006 issues of *LXI ConneXion*.

The demos were implemented in both the C# programming language and LabVIEW. The system alternated between the two software packages and between demos, showing the capabilities of both the Class B and Class A triggering and synchronization mechanisms.

The Class B demo used IEEE 1588 to synchronize the internal clocks of the instruments. Although traditional networking hardware can be used, we chose a Hirschmann high-precision boundary clock to align the instrument clocks to within 100 ns of each other. No user intervention is required for synchronization.

Each clock identifies how accurate it is, and the devices negotiate to determine who has the best clock, with all clocks then aligning to that one. Once the clocks are aligned, they can be used to trigger based on wall-clock time with a reasonable level of accuracy and no additional wiring.

In addition, Class B instruments are required to timestamp their data. Consequently, when these instruments send their data to the system controller, data can be readily correlated from multiple instruments, knowing that the internal clocks are aligned.

As shown in **Figure 2**, the Class B demonstration involved the characterization of an RF filter using a Rohde & Schwarz SMATE RF Generator to provide the test signals. A pair of Agilent synthetic instruments, a downconverter and digitizer, monitored the signal input into the filter. On the output side, a Rohde & Schwarz FSU Spectrum Analyzer was used. Ambient temperature was monitored using the VXI Technology EX1048 Thermocouple System.

With the exception of the SMATE, all are Class A LXI devices. The SMATE is Class C so it does not support LAN synchronization and triggering. Consequently, to synchronize this unit, a National Instruments' NI-1588 NIC was used in the PC to provide synchronization triggers to the SMATE.

Once the instruments had synchronized their clocks, all were configured to acquire continuously. The SMATE then iterated through the various frequencies used to test the filter. Although each instrument was free running, the data was timestamped so when the data was uploaded to the PC, it was easy to post-process to evaluate the characteristics of the DUT.

On the whole, the Class B demo was fairly reliable. Many of the instruments in this demo still were prototypes and as such required an occasional reset to get them working correctly. In addition, when using the Hirschmann clock as the master clock, some configuration was required to boot up and stabilize the unit, which made it impractical to use it as part of the demo on the show floor. Consequently, to simplify the process of starting up the demo system, we forced the system to use the NI-1588 Card as the master.

Class A Triggering Demonstration

The Class A demo used the same hardware as the Class B demo but rather than the IEEE 1588 LAN synchronization, it relied on the LXI Class A high-performance wired trigger bus (WTB) to synchronize instrument operations. Class A devices have all the Class C and Class B capabilities and incorporate a WTB, which provides low-latency triggering and synchronization between devices. This low-voltage differential signal system has eight triggering channels to coordinate instruments using traditional hardware triggering and wired-or modes. For more information, see "Introducing the Wired Trigger Bus" by David Owen in the October 2006 issue of *LXI ConneXion*.

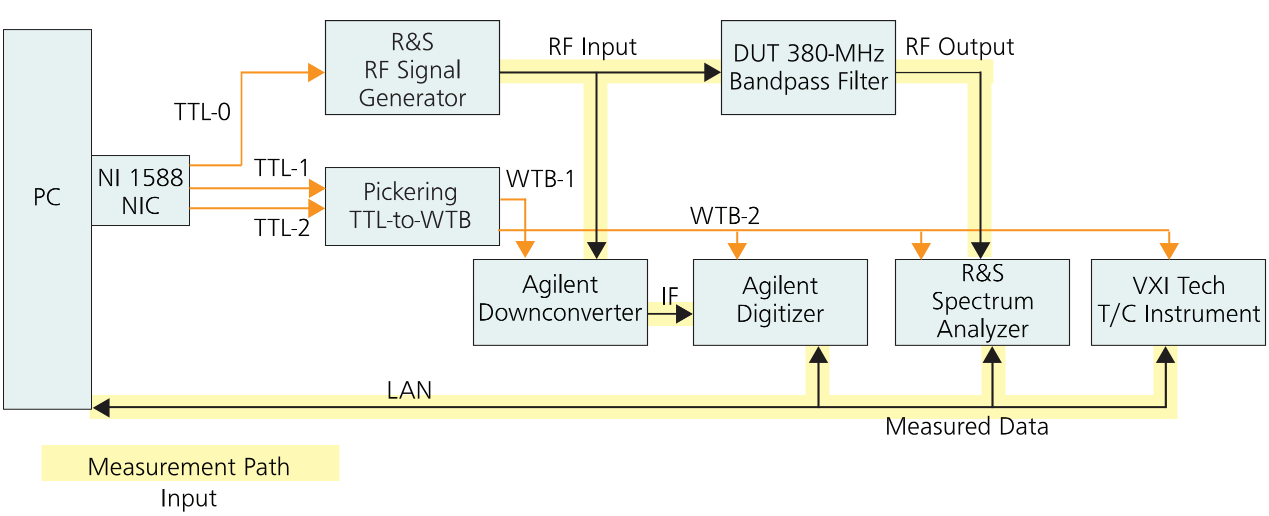

Figure 3. Class A Schematic

As shown in **Figure 3**, the Class A demo used the same set of hardware as the Class B demo but synchronized the instruments very differently. It was implemented in both the C# programming language and LabVIEW.

Once again, to integrate the Rohde & Schwarz SMATE, we used the NI-1588 NIC along with a Pickering TTL-to-WTB converter. This device provides eight TTL lines that correspond to the eight channels of the LXI WTB. WTB channel 1 triggered the Agilent downconverter, and channel 2 coordinated the readings of the Agilent digitizer and the Rohde & Schwarz FSU Analyzer. As in the Class B demo, the VXI Technology thermocouple system monitored ambient temperature when triggered over the WTB.

While creating the Class A demo, it was difficult to diagnose exactly what was occurring on the WTB. Debugging tools onboard the instruments that offer insight into the status of the bus were rudimentary, and we found an oscilloscope to be a requirement while wringing out bus issues in the demo. Here, the Pickering TTL-WTB interface made debugging much simpler.

Both the Class A and Class B demos executed a similar test and gave results similar to **Figure 4** but each used very different techniques to control the instruments' measurements. This highlighted one of the advantages of LXI: its measurement flexibility.

If you need high-performance triggering and synchronization, you can use the additional connections of the WTB. However, if submicrosecond jitter in trigger signals is acceptable in your system, you can take advantage of the simplicity of a Class B pure LAN configuration.

AUTOTESTCON & Electronica

The demos were completed and final testing took place in August 2006. The systems worked within two hours of being rolled out of the box at AUTOTESTCON in September and ran well. The Class C demo operated essentially continuously for three days. The Class A and Class B demos did require occasional reboots, but given the prototype nature of some of the equipment in the demo, some instability was inevitable.

One instance at AUTOTESTCON underlines a great strength of LXI. We had planned to give away yellow Ethernet cables to demonstrate how inexpensive the interconnect cables are because they leverage the economies of scale of the telecommunications industry. But, unfortunately, the cables were stolen during shipment to the show. Had these been GPIB cables, the loss one day before the show opened would have been a catastrophe. However, we were able to find a vendor in Anaheim who delivered 200 cables in the right length and color directly from their stock—for less than we'd paid originally.

After AUTOTESTCON, the systems were shipped to Munich, Germany, for Electronica in November. There they essentially worked out of the box even with the switch from 120 V to 220 V, a requirement for all LXI devices.

Lessons Learned

Our goal was to create a system that integrated hardware and software from several of the member companies and demonstrated a variety of LXI-compliant equipment. We found that it is straightforward to create an LXI-based system made up of equipment from multiple vendors. We have validated that real-world LXI-compliant equipment does interoperate and that the LXI 1.1 standard meets its objectives.

Along the way, we learned that assignment and configuration of the Ethernet network could be easier. Our early demos used dynamic addressing, which is how LXI is configured out of the box. However, to coordinate the dozen or so software and hardware vendors, we needed the instrument addresses to be consistent and reliable. Consequently, we found it necessary to use fixed IP addresses.

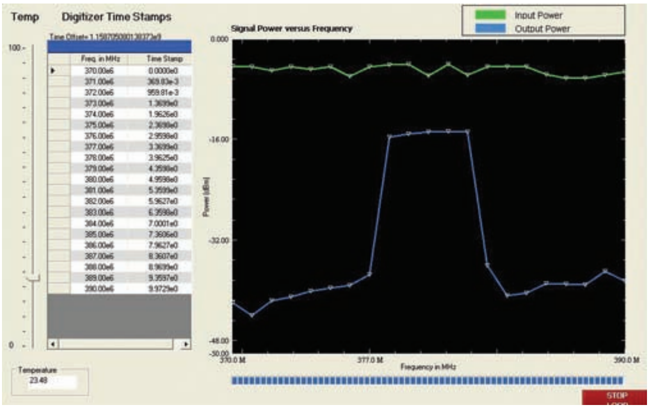

Figure 4. Filter Characterization Result

Multivendor System Demo 2007

We are in the early stages of planning the Multivendor System Demo for 2007. This time, we will focus on ease of use. We plan to enhance and refine the demos to address issues that we found, show how wireless Ethernet technologies can be used with LXI, and provide concrete examples of a hybrid system where LXI, VXI, and PXI work together. We're currently recruiting hardware and software products for incorporation into a demo system that will show how these products can be used together to produce powerful solutions to a user's problems.

About the Author

Rob Purser is the senior team lead for connectivity products at The MathWorks and leads the Multivendor System Demo Group for the LXI Consortium. Previously, he founded Owl Control Systems, LLC. He is a member of the IEEE and has held positions at PictureTel and Microsoft. Mr. Purser holds a B.S.C.S. from Rensselaer Polytechnic Institute. The MathWorks, 3 Apple Hill Dr., Natick, MA 01760, e-mail: rob.purser@mathworks.com

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