

ENHANCING VXIBUS SYSTEMS THROUGH THE POWER OF ETHERNET

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Abstract - The VXIbus architecture has proven to be an ideal solution for high channel count applications that require extremely tight synchronization between multiple instruments and mainframes. Additionally, VXIbus products have historically integrated quite easily with other open-instrumentation platforms and communication buses such as IEEE-488, IEEE-1394 and USB 2.0, providing a very stable platform, independent of rapidly changing PC bus architectures. The recent introduction of LAN-based instrumentation based upon the LXI standard provides yet another opportunity for VXIbus devices to leverage advances in interface technology. High-speed Ethernet serial communication presents many benefits across a wide range of applications, and leveraging these benefits continues to make VXIbus solutions viable well into the 21st century.

INTRODUCTION

When the first VXIbus products began to hit the market shortly after the introduction of the specification in 1987, there were limited options available to test system designers with regards to communicating between a remote computer and the instruments in the VXI mainframe. Many of the first remote (slot 0) interfaces were released with GPIB providing the primary link to the VXI instruments. However, the next fifteen years saw the ATE industry take advantage of the fact that the VXIbus can adapt to advancements in bus architecture, and system designers were presented with a range of options that included proprietary buses such as MXI and MXI2, as well as industry standards such as IEEE-1394 and USB. Now that Ethernet is gaining enormous

popularity as an instrumentation bus, and with the emergence of LXI which defines a standard for Ethernet-based instruments, the VXI community has another opportunity to show its strength in computer platform independence and long-term viability with the introduction of the industry's first LAN-based slot 0 interface.

Ethernet has inherent benefits that have resulted in it becoming the interface of choice for system architects and instrumentation suppliers as outlined below:

- Established high-speed bus that continues to evolve
- Stable architecture that provides backward compatibility with previous implementations
- Computer platform and OS independence
- Low-cost interface, cabling and accessories
- Up to 10 km separation between host and target device

The LXI community has embraced Ethernet as the backbone for its standard for many of these reasons and has added instrumentation critical definitions to the specification, such as timing and device synchronization. Integrating LXI features into a VXIbus mainframe through a slot 0 interface is a logical step to ensure that VXI systems can be seamlessly bridged to an LXI instrument network, and also adds the power of Ethernet into the world of VXI, allowing the platform to address new application spaces and markets.

THE VALUE OF UBIQUITY

Webster defines ubiquitous as "constantly encountered" or "widespread". This is certainly an apt description of Ethernet and is the basis for its

immense popularity among ATE system integrators. It is safe to say that virtually every company, small or large, has Ethernet as part of its core technology, providing external web access, and/or internal networking. This vast installed base ensures that the platform will be around for years and years into the future. This is particularly important for instrumentation suppliers and mil/aero system engineers alike who are designing systems that will be in place and must be kept viable for ten years or more. Additionally, the byproduct of designing systems around such a common bus is the reduced cost of the system infrastructure, that is, all that is required to build a system independent of the instrumentation.

It is practically impossible to find a PC that does not integrate Ethernet into its motherboard as a standard component. Unlike other buses that remotely connect to a PC, this means that additional PC interface hardware is not necessary (e.g. a GPIB interface board that plugs into a PC). It is immune to obsolescence of PC bus structure (e.g. ISA or PCI). Furthermore, the LXI specification dictates that an instrument must minimally connect to a test LAN with standard CAT5e copper which results in very little cost required for system cabling. Again, compare this to GPIB cables that are available from significantly fewer manufacturers and at orders of magnitude higher cost.

MERGING TWO STABLE PLATFORMS

The VXIbus is based on the VME architecture which was introduced in 1981 and, like VXI, is still going strong. Both platforms have evolved over the years, yet still have maintained compatibility with product that was released during the initial release of the specifications. Contrasting this to products released on the various iterations of the PCbus which has never been designed for longevity and it is easy to see why system designs that depend on the combination of long-term support and the latest technology have historically used the VXIbus.

Similarly, Ethernet has a proven track record extending for more than 25 years. Subsequent implementations over time have extended the bandwidth from 10 Mb/s to 1 Gb/s with 10 Gb/s performance on the horizon. While the LXI standard defines that instruments can be capable of transmitting data at 1 Gb/s, it further mandates that such devices must be capable of operating on

slower networks thus ensuring compatibility of legacy and newer devices.

Figure 1 illustrates the long-term stability of both Ethernet and VXI platforms as compared to the fast-changing PC industry which does not demand interoperability across architectures.

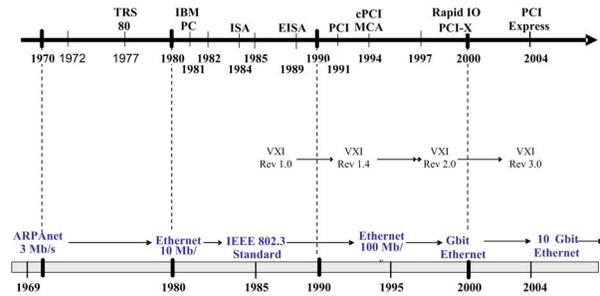


Figure 1: Comparison of Bus Longevity

By merging LXI instruments and VXI devices via an LXI-VXI slot 0 interface, system architects are in a position to take advantage of the strengths of each platform to form a powerful instrumentation network capable of addressing nearly every functional test and data acquisition application.

A BRIDGE FROM VXI TO LXI

The initial LXI specification was released in September, 2005 and was quickly adopted by over 40 suppliers to make it the fastest growing instrumentation standard in the last 30 years. However, there remains a significant installed base of VXIbus products, and the desire of many system engineers is to maintain the investment in VXI moving forward for higher channel count requirements, while integrating LXI-based products as they become available. This means that LXI and VXI products must seamlessly work together in hybrid systems for years to come. By designing the LXI-VXI slot 0 to be a class A compliant bridge device, VXI instruments can be tightly integrated with instruments residing on an LXI instrument network.

IEEE-1588, Precision Time Protocol (PTP) required for LXI Class B compliance, defines a precision clock synchronization method for distributed networked devices. A VXI system can become time synchronous with other LXI devices on the test LAN, if the slot 0 interface incorporates IEEE-1588 into its fabric. For more deterministic synchronization and handshaking between networked devices in close proximity, the

hardware triggering required by LXI Class A compliance devices should be utilized. A separate eight-line LVDS trigger bus is incorporated into the LXI specification and can map directly to the VXIbus TTLTrigger bus. To accomplish this bridge between trigger buses, the VXI slot 0 must integrate not only an LXI-compliant trigger bus connector, but also level translators and drivers to accommodate the disparate logic levels of each bus. A front panel implementation present on the EX2500 LXI-VXI slot 0 interface is shown in Figure 2:

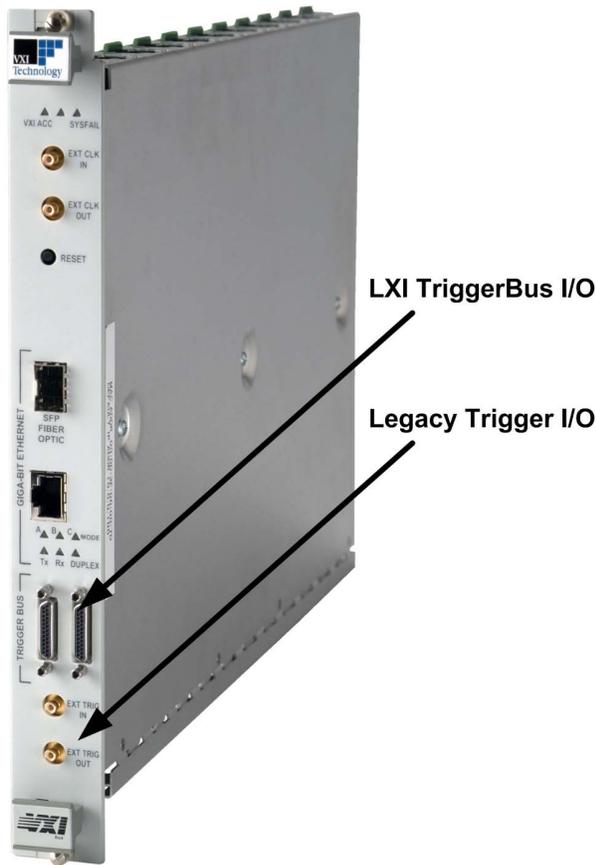


Figure 2: EX2500 LXI-VXI slot 0 interface

In addition to melding the VXI and LXI trigger buses together, the front panel LVDS trigger extension also provides a means for bridging the VXI trigger bus across multiple mainframes that was not previously possible with existing serial slot 0 interfaces.

THE POWER OF THE WEB PAGE

HTML and JAVA driven web pages have been enormously popular for Internet users world-wide as web page designers focused on elaborate, yet user-friendly interfaces which can be used for all aspects of a company's business from initial introduction, through the sales ordering cycle. Test instrumentation vendors have been able to apply this technology to their LAN-based products, providing a soft-front panel (GUI) that allows a user to control a device through common browser applications such as Internet Explorer or Firefox. The LXI specification requires that all LXI class instruments include an embedded web page for direct communication to instruments through a browser. This is a powerful tool that is now made available to VXI system users. An example of an LXI-VXI slot 0 interface web page is depicted Figure 3:

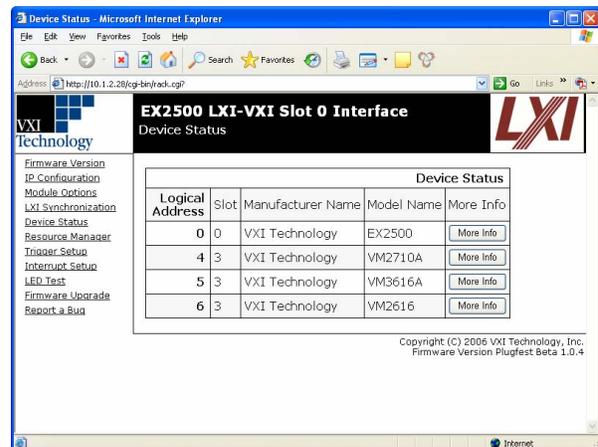


Figure 3: Embedded Web Interface (VXIbus)

Many VXI slot 0 interfaces do not embed the VXI resource manager on the module; rather, it is hosted on the remote PC and must be executed prior to opening any communication to devices on the backplane. By embedding the resource manager utility on the module and automatically executing it at power up, the need for a separate software utility on the host is eliminated. More importantly, an HTML driven interface like the one shown above, can be designed to act as an interactive control panel, which normally resides on the host controller and permits register or message-based communication to take place through the web browser. In essence, this provides 'out-of-the-box' operation for VXI for first-level support engineers, removing the complexity of software installation and setup.

VXI IN DISTRIBUTED APPLICATIONS

The VXIbus architecture was initially designed to address large channel count or high mix functional test and data acquisition systems requirements. Applications that required the distribution of measurement channels across significant distances were typically left to small, low-performance modules linked together via proprietary buses. When higher channel counts or measurement quality demanded the performance that could only be effectively delivered by VXI devices, the options were limited to costly embedded controllers or bus extenders that did not always prove reliable. A LAN-based slot 0 device allows multiple mainframes to be connected to a single host controller up to 100 m away using standard copper cable and an Ethernet switch and up to 10 km using fiberoptic cables and switches. If the slot 0 implements LXI Class B synchronization techniques, measurements can be synchronized to a high degree of resolution (tens of nanoseconds) across the instrumentation network.

CASE STUDY – DISTRIBUTED STRAIN GAGES

An existing system installation is constructed to acquire data from six groups of 192 channels strain gages each distributed across 1 km of pavement. The pavement is subjected to the repeated load of a test article that emulates the landing of large commercial aircraft and the strain gages measure the stress that is incurred. The VXIbus architecture was selected because of the high channel count and integrated signal conditioning and six mainframes with six embedded controllers are in the configuration. Each controller independently manages the acquisition of the channels in its mainframe and passes the data back to a separate remote PC via Ethernet where a complex program post-processes and synchronizes the data.

The system designers found this architecture to be susceptible to faults due to the number of independent processors involved. The introduction of an LXI-VXI slot 0 interface provided them with an opportunity to change their test paradigm and consolidate the control and data processing onto a single host, greatly reducing the complexity of the test setup. Further, since the LXI-VXI slot 0 implements LXI class B

synchronization techniques, channel to channel skew is considerably reduced and data samples acquired across mainframes (and distances) have tight time correlation. Figure 4 illustrates the topology of the new implementation.

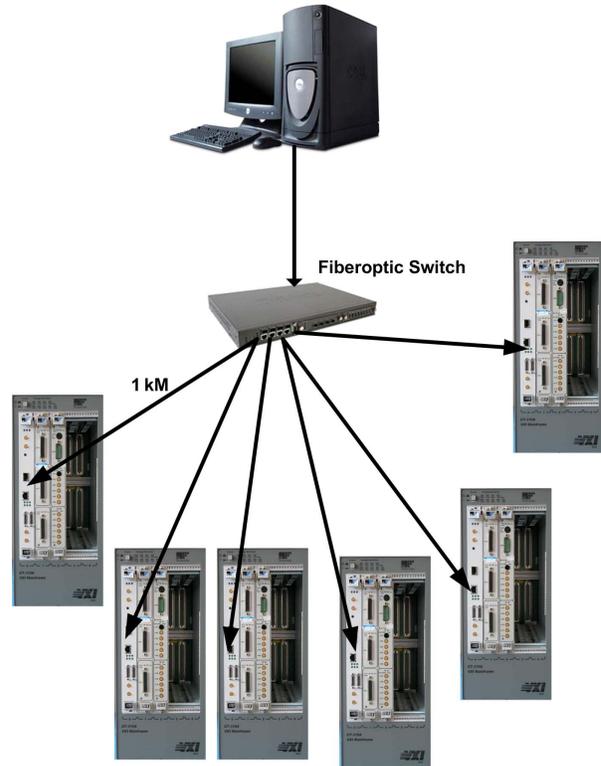


Figure 4: Each mainframe contains a VXI-LXI slot 0 interface, roughly 1/3 cost of and embedded slot 0

INCREASING DATA THROUGHPUT

Perhaps one of the most intriguing and valuable aspects of adding Ethernet capability to the VXI framework is the ability to increase overall data throughput by making use of the speed of the bus coupled with the fundamental nature of an Ethernet switch. Large channel count high-speed acquisition systems can push the limits of the even the fastest slot 0 interfaces on the market. This is because there is a single pipeline back to the host that is bandwidth limited. Further, the acquisition device often becomes the bottleneck if the device's cycle times (i.e., the speed at which a block of data can be placed on the bus) are constrained by on-board processing or other factors.

This is best illustrated with the following example. A 16 channel, 16-bit acquisition device is capable of sampling data on all channels simultaneously at a maximum rate of 100 kSa/s. There is an on-board digital signal processor (DSP) that operates runs the data through intense algorithms prior to putting a block on the bus for retrieval, and a single module is limited to approximately 12 MB/s throughput to the backplane. If the slot 0 interface is capable of supporting > 12 MB/s transfer rates from the backplane to the host, the instrument has the potential to become the bottleneck. If the slot 0 interface cannot support 12 MB/s transfer rates, then it has the potential to become the bottleneck. In either case, the instrument faces the prospect of overflowing its buffer because it cannot be emptied fast enough to keep up with the amount of data be acquired.

In a recent application, 240 channels of data were to be simultaneously and continuously sampled at a rate of 64,000 samples/second using this module. The amount of data to be processed by the entire system can be calculated using the following formula:

Sample Rate * bytes/sample * # of channels

Data In Rate = $64,000 * 2 * 240 = 30.7 \text{ MB/s}$

Because the data input rate exceeded the 12 MB/s rate at which a module could be emptied, an overflow condition was certain to occur and significant amounts of data would be lost. Further, even the fastest slot 0 interfaces could not alleviate this problem since the data transfers occurred across a single bus connection back to the host. A gigabit LXI-VXI slot 0 interface for example, supports block transfers in excess of 40 MB/s. However, this would not increase the aggregate data rate through a single pipeline. The only acceptable mechanism for addressing this application was to split the acquisition modules across three 6-slot VXI mainframes (five modules per mainframe) and interface back to the host controller using a gigabit slot 0 interface and a multi-port gigabit Ethernet switch as shown in Figure 5.

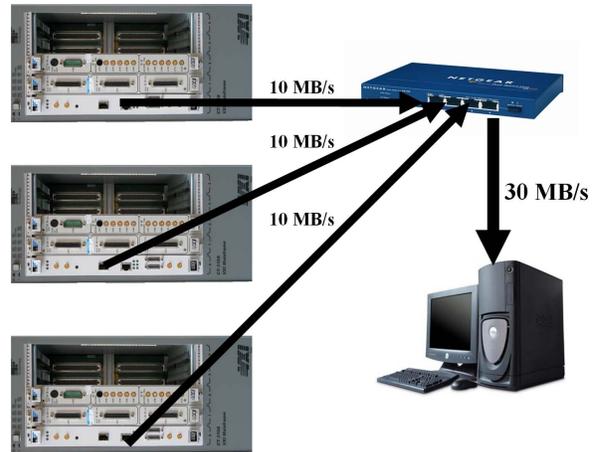


Figure 5: Data aggregation via gigabit switch

While the path from the switch to the host PC is across a single connection, the keys to successfully meeting this challenging requirement revolved around the bandwidth of the bus (gigabit Ethernet is roughly 100 MB/s) coupled with the intrinsic ability of the switch to manage and buffer the large amount of data that is being passed through each of the three ports.

SUMMARY

There has been wide acceptance of Ethernet by the test and measurement community through the adoption of the LXI standard. While LXI appears to be poised to address small to medium channel count applications, there continues to be a demand for the combination of density and performance that can be achieved with VXI. VXI has a significant installed base and the systems that utilize it depend on its sustainability into the future, yet there is also interest in combining the strengths of LXI and VXI platforms into integrated test systems. Integrating LXI into VXI systems through a LAN-based Class A compliant slot 0 interface ensures that VXIbus systems can keep pace with advances in technology and leverage the inherent power of Ethernet.