PXI Developer Kit

Contents

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1.Introduction to PC-Based Architecture and Virtual Instrumentation

Virtual Instrumentation

With more than 6 million new measurement channels sold last year, National Instruments is a worldwide leader in virtual instrumentation. Engineers have used virtual instrumentation for more than 25 years to bring the power of flexible software and PC technology to test, control, and design applications making accurate analog and digital measurements from DC to 6.6 GHz RF. This document provides an excellent introduction to virtual instrumentation as well as additional resources for continued research.

Contents

What Is Virtual Instrumentation?

With virtual instrumentation, software based on user requirements defines general-purpose measurement and control hardware functionality. Virtual instrumentation combines mainstream commercial technologies, such as the PC, with flexible software and a wide variety of measurement and control hardware, so engineers and scientists can create user-defined systems that meet their exact application needs. With virtual instrumentation, engineers and scientists reduce development time, design higher-quality products, and lower their design costs.

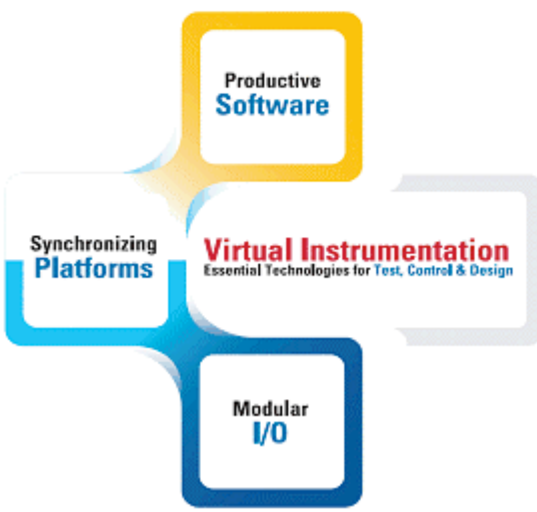

Figure 1. Virtual instrumentation combines productive software, modular I/O, and scalable platforms.

National Instruments introduced virtual instrumentation more than 25 years ago, changing the way engineers and scientists measure and automate the world around them. National Instruments sold more than 6 million channels of virtual instrumentation in 90 countries. Today, virtual instrumentation has reached mainstream acceptance and is used in thousands of applications around the world in industries from automotive to consumer electronics to oil and gas.

Why Is Virtual Instrumentation Necessary?

Virtual instrumentation is necessary because it delivers instrumentation with the rapid adaptability required for today's concept, product, and process design, development, and delivery. Only with virtual instrumentation can engineers and scientists create the user-defined instruments required to keep up with the world's demands.

To meet the ever-increasing demand to innovate and deliver ideas and products faster, engineers and scientists are turning to advanced electronics, processors, and software. Consider a modern cell phone. Most contain the latest features of the last generation, including audio, a phone book, and text messaging capabilities. New versions include a camera, MP3 player, and Bluetooth networking and Internet browsing.

The increased functionality of advanced electronics is possible because devices have become more software centric. Engineers and scientists can add new functions to a device without changing the hardware, resulting in improved concepts and products without costly hardware redevelopment. This extends product life and usefulness and reduces product delivery times. Engineers and scientists can improve functionality through software instead of developing further specific electronics to do a particular job.

However, this increase in functionality comes with a price. Upgraded functionality introduces the possibility of unforeseen interaction or error. So, just as device-level software helps rapidly develop and extend functionality, design and test instrumentation also must adapt to verify the improvements.

The only way to meet these demands is to use test and control architectures that are also software centric. Because virtual instrumentation uses highly productive software, modular I/O, and commercial platforms, it is uniquely positioned to keep pace with the required new idea and product development rate. National Instruments LabVIEW, a premier virtual instrumentation graphical development environment, uses symbolic or graphical representations to speed up development. The software symbolically represents functions. Consolidating functions within rapidly deployed graphical blocks further speeds development.

Another virtual instrumentation component is modular I/O, designed to be rapidly combined in any order or quantity to ensure that virtual instrumentation can both monitor and control any development aspect. Using well-designed software drivers for modular I/O, engineers and scientists quickly can access functions during concurrent operation.

The third virtual instrumentation element – using commercial platforms, often enhanced with accurate synchronization – ensures that virtual instrumentation takes advantage of the very latest computer capabilities and data transfer technologies. This element delivers virtual instrumentation on a long-term technology base that scales with the high investments made in processors, buses, and more.

In summary, as innovation mandates software use to accelerate new concept and product development, it also requires instrumentation to rapidly adapt to new functionality. Because virtual instrumentation applies software, modular I/O, and commercial platforms, it delivers instrumentation capabilities uniquely qualified to keep pace with today's concept and product development.

Why Has Virtual Instrumentation Been So Successful?

Virtual instrumentation achieved mainstream adoption by providing a new model for building measurement and automation systems. Keys to its success include rapid PC advancement; explosive low-cost, high-performance data converter (semiconductor) development; and system design software emergence. These factors make virtual instrumentation systems accessible to a very broad base of users.

PC performance, in particular, has increased more than 10,000X over the past 20 years. Virtual instrumentation takes advantage of this PC performance increase by helping you analyze measurements and solve new application challenges with each new-generation PC processor, hard drive, display, and I/O bus. These rapid advancements, combined with the general trend that technical and computer literacy starts early in school, contribute to successful computer-based virtual instrumentation adoption.

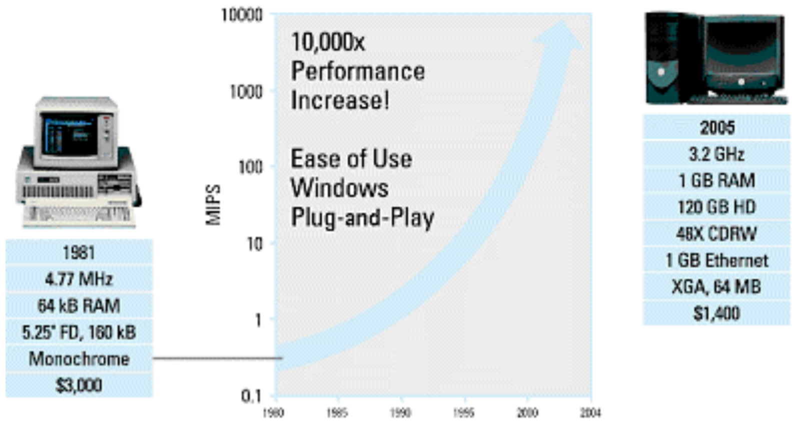

Figure 2. A 10,000X performance increase for PCs helps drive virtual instrumentation system performance.

Another virtual instrumentation driver is the proliferation of high-performance, low-cost analog-to-digital (ADC) and digital-to-analog (DAC) converters. Applications such as wireless communication and high-definition video impact these technologies relentlessly. While traditional proprietary converter technology tends to move slowly, commercial semiconductor technologies tend to follow Moore's law – doubling performance every 18 months. Virtual instrumentation hardware uses these widely available semiconductors to deliver high-performance measurement front ends.

Finally, system design software that provides an intuitive interface for designing custom instrumentation systems furthers virtual instrumentation. NI LabVIEW is an example of such software. The LabVIEW graphical development environment offers the performance and flexibility of a programming language, as well as high-level functionality and configuration utilities designed specifically for measurement and automation applications.

Additional Virtual Instrumentation Resources

To learn more about virtual instrumentation, refer to these resources:

- About Virtual Instrumentation
- Virtual Instrumentation versus Traditional Instruments
- Virtual Instrumentation for Test, Control, and Design
- Software's Role in Virtual Instrumentation
- Hardware's Role in Virtual Instrumentation
- Who Uses National Instruments Virtual Instrumentation

To learn more about virtual instrumentation products, refer to these resources:

- Test-Drive LabVIEW Online
- Online Product Catalog

Introduction to PXI: Standard for Measurement and Automation Systems

This tutorial provides an overview of PXI, including the PXI hardware and software architecture, benefits of PXI, and PXI in modular instrumentation.

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Introduction

PXI (PCI eXtensions for Instrumentation) is a rugged PC-based platform for measurement and automation systems. PXI combines PCI electrical-bus features with the rugged, modular, Eurocard packaging of CompactPCI, and then adds specialized synchronization buses and key software features. PXI is both a high-performance and low-cost deployment platform for measurement and automation systems. These systems serve applications such as manufacturing test, military and aerospace, machine monitoring, automotive, and industrial test.

Developed in 1997 and launched in 1998, PXI was introduced as an open industry standard to meet the increasing demands of complex instrumentation systems. Today, PXI is governed by the PXI Systems Alliance (PXISA), a group of more than 70 companies chartered to promote the PXI standard, ensure interoperability, and maintain the PXI specification. For more information on PXISA, including the PXI specification, refer to the PXISA Web site at www.pxisa.org.

Hardware Architecture

PXI systems are composed of three basic components – chassis, system controller, and peripheral modules.

Figure 1. A standard 8-slot PXI chassis contains an embedded system controller and seven peripheral modules.

PXI Chassis
PXI chassis provide the rugged and modular packaging for the system. You can obtain chassis, available in both 3U and 6U versions and generally ranging in size from 4 slots to 18 slots, with special features such as DC power supplies and integrated signal conditioning. The chassis contains the high-performance PXI backplane, which includes the PCI bus and timing and triggering buses. Using these timing and triggering buses, you can develop systems for applications requiring precise synchronization.

PXI Controllers
As defined by the PXI Hardware Specification, all PXI chassis contain a system controller slot located in the leftmost slot of the chassis (slot 1). Controller options include remote controllers from a desktop, workstation, server, or a laptop computer and high-performance embedded controllers with either a Microsoft OS (Windows 2000/XP) or a real-time OS (LabVIEW Real-Time).

PXI Remote Controllers
There are two types of PXI remote controllers:

- Laptop control of PXI
- PC control of PXI

Laptop Control of PXI
With ExpressCard MXI (Measurement eXtensions for Instrumentation) and PCMCIA CardBus interface kits, you can control PXI systems directly from laptop computers. During boot-up, the laptop computer recognizes all peripheral modules in the PXI system as PCI devices. Using ExpressCard MXI, you can control your PXI system with a sustained throughput of up to 214 MB/s.

ExpressCard MXI Interface Kit

PCMCIA CardBus Interface Kit

Figure 2. Laptop Control of PXI

You now have the advantage of mobile PXI systems for applications such as field tests, in-vehicle data logging, NVH (noise, vibration, and harshness), and NDT (non-destructive testing) with laptop control of PXI. You can purchase any ExpressCard MXI-compatible laptop or PCMCIA CardBus-compatible laptop to remotely control your PXI system. For more information, please refer to Laptop Control of PXI.

PC Control of PXI
With MXI-Express and MXI-4 interface kits, you can control PXI systems directly from desktops, workstations, or server computers. During boot-up, the computer recognizes all peripheral modules in the PXI system as PCI devices.

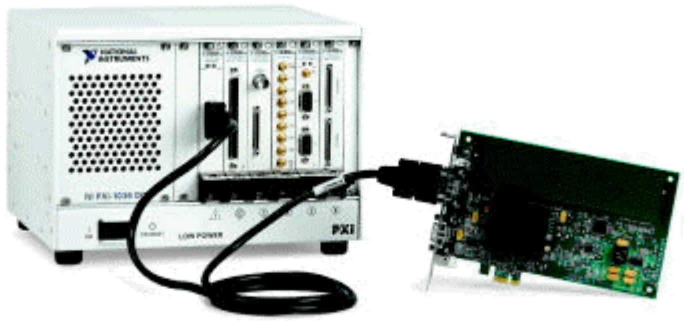

Figure 3. Remote control with 2-port MXI-Express provides simultaneous control of two PXI chassis with a combined throughput of 160 MB/s.

Using MXI-Express, you can control your PXI system with a sustained throughput of up to 832 MB/s. With the MXI-Express 2-port interface kit, you are able to control two PXI systems simultaneously from a single PC.

Figure 4. Remote control with MXI-4 provides PC control of PXI, as well as multichassis PXI systems.

The MXI-4 interface kit comes with low-cost copper links or fiber-optic links for both extended distances and electrical isolation. As shown in Figure 4, you can build multichassis PXI systems with MXI-4 for high-channel-count applications. Using a MXI-4 link, you can implement either a daisy-chain or a star topology to build multichassis systems. For more information on topologies for multichassis configurations, refer to the MXI-4 Series User Manual. You can purchase any desktop, workstation, or server computer, and then remotely control your PXI system using either MXI-Express or a copper/fiber-optic MXI-4 serial link. For more information, please refer to PC Control of PXI.

With PXI remote controllers, you can maximize processor performance and minimize cost by using a desktop computer or laptop to remotely control a PXI system. Because all remote control products are software transparent, no additional programming is required.

PXI Embedded Controllers

Embedded controllers eliminate the need for an external PC by providing a complete system contained in the PXI chassis. PXI embedded controllers are typically built using standard PC components in a small, PXI package. For example, the NI PXI-8105 controller has the 2.0 GHz Intel Core Duo T2500 dual-core processor, with up to 2 GB of DDR2 RAM, a hard drive, and standard PC peripherals such as ExpressCard, Hi-Speed USB, Ethernet, serial, parallel, and GPIB ports. There are two types of PXI embedded controllers:

- PXI Embedded Controllers with Windows
- PXI Embedded Real-Time Controllers

PXI Embedded Controllers with Windows

PXI embedded controllers with Windows come with standard PC features such as an integrated CPU, hard drive, RAM, Ethernet, video, keyboard/mouse, serial, USB, and other peripherals, as well as Microsoft Windows and all device drivers already installed. Because the controllers have Microsoft Windows, the user experience is no different than a PC or laptop computer. It has application software similar to that on your PC or laptop computer such as Microsoft Office Word, Excel, and PowerPoint.

PXI Embedded Real-Time Controllers

PXI embedded real-time controllers also come with standard PC features along with a real-time OS such as LabVIEW Real-Time or VxWorks to deliver real-time, deterministic, and reliable I/O for measurement, automation, and control. Because RT Series PXI controllers are configured and programmed over the Ethernet, you can distribute a real-time application across the network and remotely monitor it. These controllers are designed for applications requiring deterministic and reliable performance, and you can run them under headless operation (that is, no keyboard, mouse, or monitor).

Figure 5. In this photo of the National Instruments PXI-8105 2.0 GHz dual-core PXI embedded controller, notice the familiar PC peripherals such as keyboard/mouse and monitor connections, as well as the hard drive, Hi-Speed USB, Ethernet, serial, ExpressCard, and other standard PC peripherals.

Embedded controllers are ideal for portable systems and contained "single box" applications where you move the chassis from one location to the next. For more information, please refer to PXI controllers.

PXI Peripheral Modules

National Instruments offers more than 100 different PXI modules and, because PXI is an open industry standard, nearly 1,200 products are available from the more than 70 members of the PXI Systems Alliance.

- Analog Input and Output
- Bus Interface and Communication
- Digital Input and Output
- Functional Test and Diagnostics
- Prototyping Boards
- Motion Control
- Receiver Interconnect Devices
- Timing Input and Output
- Boundary Scan
- Carrier Products
- Digital Signal Processing
- Image Acquisition
- Instruments
- Power Supplies
- Switching
- RF and Communications

Because PXI is directly compatible with CompactPCI, you can use any 3U CompactPCI module in a PXI system. A categorized list of modules offered by National Instruments and PXI product collaborators is available at **ni.com/pxi**.

PXI also preserves investments in stand-alone instruments or VXI systems by providing standard hardware and software for communication to these systems. For example, interfacing a PXI system to GPIB-based instrumentation is no different with a PXI-GPIB module than it is with a PCI-GPIB board. The software is identical. Additionally, a number of methods are available to build hybrid systems interfacing PXI, USB, LAN/LXI, VXI, and stand-alone instruments. For more information, refer to Integrating LXI, USB, PXI Express, and Other Standards into a Hybrid Test System.

Software Architecture

Because PXI hardware is based on standard PC technologies, such as the PCI bus, as well as standard CPUs and peripherals, the standard Windows software architecture is familiar to users as well. Development and operation of Windows-based PXI systems is the same as that of a standard Windows-based PC. Additionally, because the PXI backplane uses the industry-standard PCI/PCI Express bus, writing software to communicate with PXI modules is, in most cases, identical to that of PCI boards. For example, software to communicate to an NI PXI-6251 multifunction data acquisition module is identical to that of an NI PCI-6251 board in a PC. Therefore, existing application software, example code, and programming techniques do not have to be rewritten when moving software between PC-based and PXI-based systems.

Figure 6. These two different packages work with one software standard. In software, communication with a PXI module (bottom) is identical to that with a PCI board (top).

As an alternative to Windows-based systems, you can use a real-time software architecture for time-critical applications requiring deterministic loop rates and headless operation (no keyboard, mouse, or monitor). Additional information on using LabVIEW Real-Time with PXI systems is available at **ni.com/realtime**.

PXI – Industry Standard for Modular Instrumentation

Every bus is unique and has its advantages. For example, USB is excellent for easy desktop connectivity; LAN/Ethernet is well-suited for distributed systems; and PCI and PCI Express provide high performance for ATE. For applications demanding a modular solution, you can achieve reduced cost and size through a shared chassis, backplane, and processor; faster throughput through a high-speed connection to the host processor; and greater flexibility and longevity through user-defined software.

PXI, based on PCI and next-generation PCI Express, is the fastest-growing test and measurement standard since GPIB. PXI best meets modular instrumentation demands now and in the future, with more than 70 vendors in the PXI Systems Alliance, more than 1,200 products available today, and a projected 25 percent annual growth rate through

2011 (Frost & Sullivan, 2005). Primarily, all instruments in a PXI system share the same power supply, chassis, and controller. Alternative approaches duplicate the power supply, chassis, and/or controller for every instrument, adding cost and size and decreasing reliability. With PXI, the controller can be a high-performance slot 0 embedded controller, desktop PC, laptop, or server-class machine. When you require faster processing, you can easily upgrade the controller of a PXI system. To reuse existing equipment, you can use PXI to control USB, GPIB, LAN/LXI, serial, and VXI instruments.

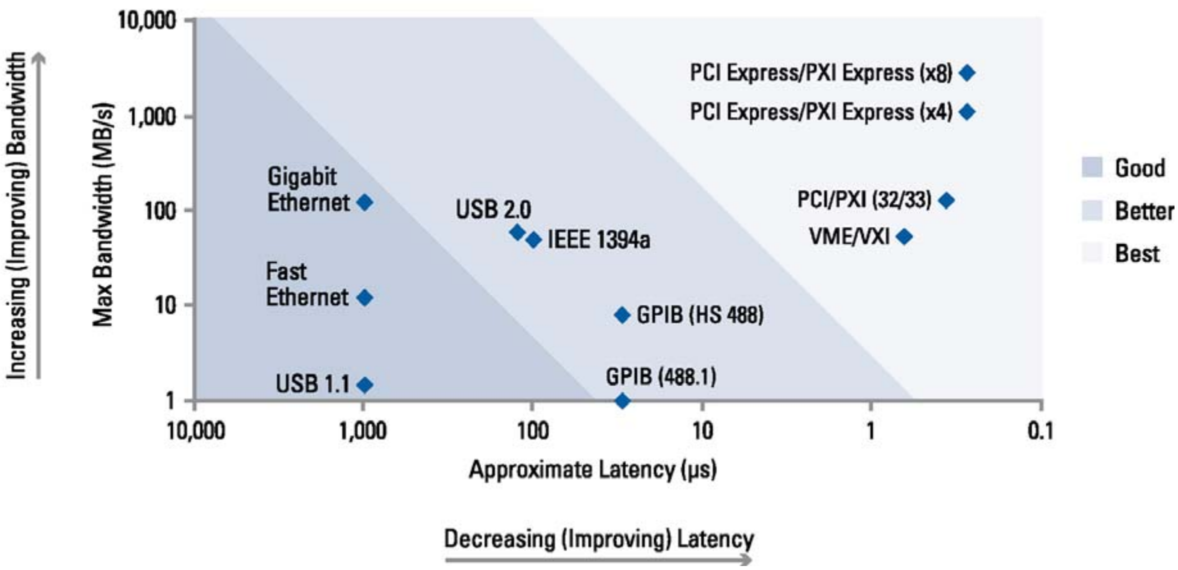

Figure 7. PCI and PCI Express provide the highest bandwidth and lowest latency, decreasing test time and delivering flexibility and longevity through user-defined software.

Modular instruments require a high-bandwidth, low-latency bus to connect instrument modules to the shared processor for performing user-defined measurements. PXI meets these needs with bandwidth up to 2 GB/s for each slot. Take a modular RF acquisition system for example. PXI can stream two channels of 100 MS/s, 16-bit IF data directly to a processor for computation. Neither LAN nor USB can meet these requirements, so these instruments always include an embedded, vendor-defined processor. Hence high-bandwidth standards such as PXI provide a truly software-defined approach required for modular instrumentation.

Why Customers Choose PXI

Higher Throughput
Every application is unique and has very specific needs. However, bandwidth and latency are two important attributes of a platform for many applications. Latency tends to dominate single-point operations, such as digital multimeter/switch scanning, and bandwidth tends to dominate data streaming applications, such as waveform stimulus/response. PXI provides high speed for a wide range of applications with both high bandwidth and low latency via the PCI/PCI Express bus, as shown in Figure 7.

Timing and Synchronization
Many measurement and automation applications require advanced timing and synchronization capabilities that you cannot implement directly across PC standard I/O

buses such as PCI/PCI Express, Ethernet/LAN, USB, and so on. PXI offers advanced timing and synchronization features to meet your application needs:

- 100 MHz differential system reference clock
- 10 MHz reference clock signal
- Differential star trigger
- Star trigger bus with matched-length trigger traces to minimize intermodule delay and skew
- Trigger bus to send and receive high-speed timing and triggering signals
- Differential signals for multichassis synchronization

System Reliability
The PXI specification defines requirements that make PXI systems well-suited for harsh environments. PXI features the high-performance IEC (International Electrotechnical Commission) connectors and rugged Eurocard packaging system used by CompactPCI. The PXI specification also defines specific cooling and environmental requirements to ensure operation in industrial environments. Modularity makes it easy to configure, reconfigure, and repair your PXI systems, resulting in very low mean time to repair (MTTR). Because PXI is modular, you can update individual modules and components without replacing the entire system.

Lower System Costs
Because PXI is a PC-based platform, it delivers high-precision instrumentation, synchronization, and timing features at an affordable price. The low cost of PC components is only the beginning of the savings you gain from using PXI. With PXI, you use the same OS and application software such as Microsoft Excel and Word in your office and on the production floor. The familiarity of the software eliminates training costs and the need to retrain personnel every time you implement a new system. Because the foundation of PXI is PC technology, you benefit from low component costs, familiar software, and system reuse.

Expansion of the PXI Platform: PXI Express

PXI Express technology is the latest addition to the PXI platform. The PXI Express specification integrates PCI Express signaling into the PXI standard, which increases backplane bandwidth from 132 MB/s to 6 GB/s, a 45 times improvement. It also enhances PXI timing and synchronization features by incorporating a 100 MHz differential reference clock and differential triggers.

The PXI Express specification adds the following features to PXI while maintaining backward compatibility.

- **Software –** PCI Express uses the same operating system and driver model as PCI, resulting in complete software compatibility between PCI-based systems (such as PXI) and PCI Express-based systems (such as PXI Express). This software compatibility is ensured by the PCI Special Interest Group (PCI-SIG), a group composed of member companies, such as Intel, who are committed to the development and enhancement of the PCI and PCI Express standards.
- **Hardware –** PXI Express chassis provide hybrid peripheral slots that accept both PXI Express peripheral modules and hybrid slot-compatible PXI peripheral modules. These peripheral slots deliver signaling for both PCI and PCI Express.

You can use code you have written for previous PXI systems with PXI Express systems because PXI Express maintains complete software compatibility with PXI. Software compatibility includes operating systems such as Windows XP and Linux®, application software such as Microsoft Office, and user code such as LabVIEW VIs and C++ projects. For more information, please refer to PXI Express.

Summary

PXI modular instrumentation defines a rugged computing platform for measurement and automation users that clearly takes advantage of the technology advancements of the mainstream PC industry. By using the standard PCI/PCI Express bus, PXI modular instrumentation systems can benefit from widely available software and hardware components. The software applications and OSs that run on PXI systems are already familiar because they are used on common desktop computers. PXI meets your needs by adding rugged industrial packaging, plentiful slots for I/O, and features that provide advanced timing and triggering capabilities.

Visit **ni.com/pxi** for more information on PXI, including links to product pages, pricing, data sheets, and specifications.

If you have any questions, you can contact a technical sales representative by phone at (888) 280-7645 or e-mail.

Related Links

For more information on:

- The functionality of the PXI timing and triggering buses, refer to the PXI Hardware Specification at www.pxisa.org/specs.htm
- Timing and synchronization in PXI, refer to Building a multi-client single server distributed architecture, PXI Reference Clock Synchronization and NI T-Clk Synchronization
- PXI in modular instrumentation, refer to PXI, PCI Express, and PXI Express

Introduction to PCI Express

This paper offers a brief introduction to the PCI Express bus and shows how National Instruments leads the way in the adoption of PCI Express for PC-based measurement and automation hardware and software. For more information on the PCI Express standard, please refer to PCI Express – An Overview of the PCI Express Standard.

Contents

Introduction

The rate of innovation in desktop computers is mind-boggling. Following Moore's Law, processing speeds have doubled every 18 months since the invention of the integrated circuit. Software makers create new products and versions to support the latest advances in processing speeds, memory size, and hard disk capacity, while hardware vendors release new devices and technologies to keep up with the demands of the latest software. This rapid innovation is also evident with PC-based measurement hardware and software, as plug-in devices now provide 16-bit measurements at up to 15 MHz.

As data acquisition rates increase with advances in silicon technologies, larger amounts of data must be transferred to the PC for processing. These transfers are handled by the data bus connecting the device to PC memory. The bus is analogous to the transmission in a car – without it there is no way to get horsepower from the engine to the road. Like the transmission, the importance of the data bus is often overshadowed by the horsepower of the engine (processing and A/D rates). However, the rate at which data transfers occur is often the bottleneck in measurements, and is the primary reason that many instruments have incorporated expensive onboard memory.

To address the growing appetite for bandwidth, a new bus technology called PCI Express was recently introduced. Originally designed to enable high-speed audio and video streaming, PCI Express is also being used to improve the data rate from measurement devices to PC memory by up to 30 times versus the traditional PCI bus used on desktops for the past 10 years.

The PCI Express Standard

PCI Express was introduced to overcome the limitations of the original PCI bus. Developed and released by Intel over a decade ago, the original PCI bus operated at 33 MHz and 32 bits with a peak theoretical bandwidth of 132 MB/s. It used a shared bus topology – bus bandwidth is shared among multiple devices – to enable communication among the different devices on the bus. As devices evolved, new bandwidth-hungry devices began starving other devices on the same shared bus. Gigabit LAN cards, for example, can monopolize up to 95 percent of available PCI bus bandwidth.

To provide the bandwidth required by these modern devices, PCI Express was developed by an industry consortium of PC and peripheral vendors and began shipping in standard desktop PCs in 2004. Already, most desktop machines from the leading suppliers include at least one PCI Express slot. The most notable PCI Express advancement over PCI is its point-to-point bus topology. The shared bus used for PCI is replaced with a shared switch, which provides each device its own direct access to the bus. And unlike PCI, which divides bandwidth among all devices on the bus, PCI Express offers each device its own dedicated data pipeline. Data is sent serially in packets through pairs of transmit and receive signals called lanes, which enable 250 MB/s bandwidth per direction, per lane. You can group multiple lanes together into x1 ("by one"), x2, x4, x8, x12, x16, and x32 lane widths to increase bandwidth to the slot.

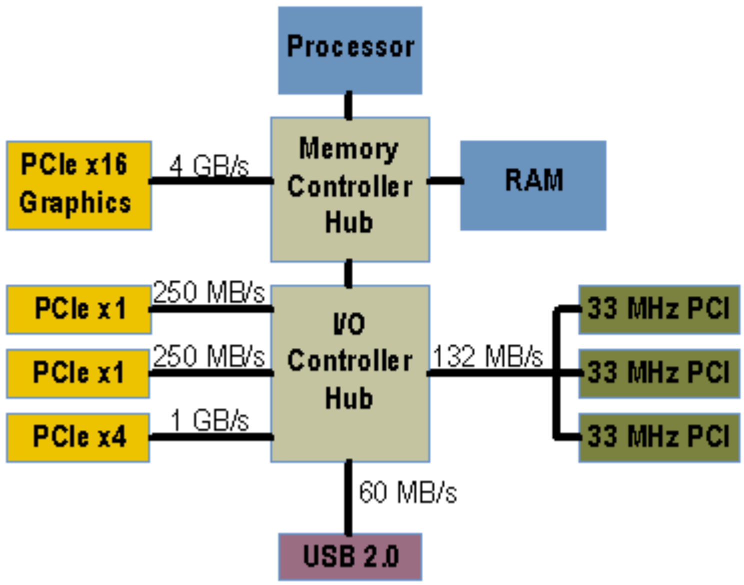

Figure 1. Each PCI Express slot has dedicated bandwidth to PC memory, unlike PCI, which shares bandwidth.

Applications such as data acquisition and waveform generation require sufficient bandwidth to ensure that data can be transferred to memory fast enough without being lost or overwritten. PCI Express dramatically improves data bandwidth compared to legacy buses, minimizing the need for onboard memory and enabling faster data streaming. The initial signaling frequency provided by the specification of 2.5 Gb/s provides 30 times (with a x16 slot) the usable bandwidth of 32-bit, 33 MHz PCI, and this signaling frequency is expected to increase with advances in silicon technology to 10 Gb/s – the practical limit for signals in copper. And because of the scalable lane topology of PCI Express, data acquisition vendors can implement a PCI Express connector with the number of lanes suitable to the requirements of the device.

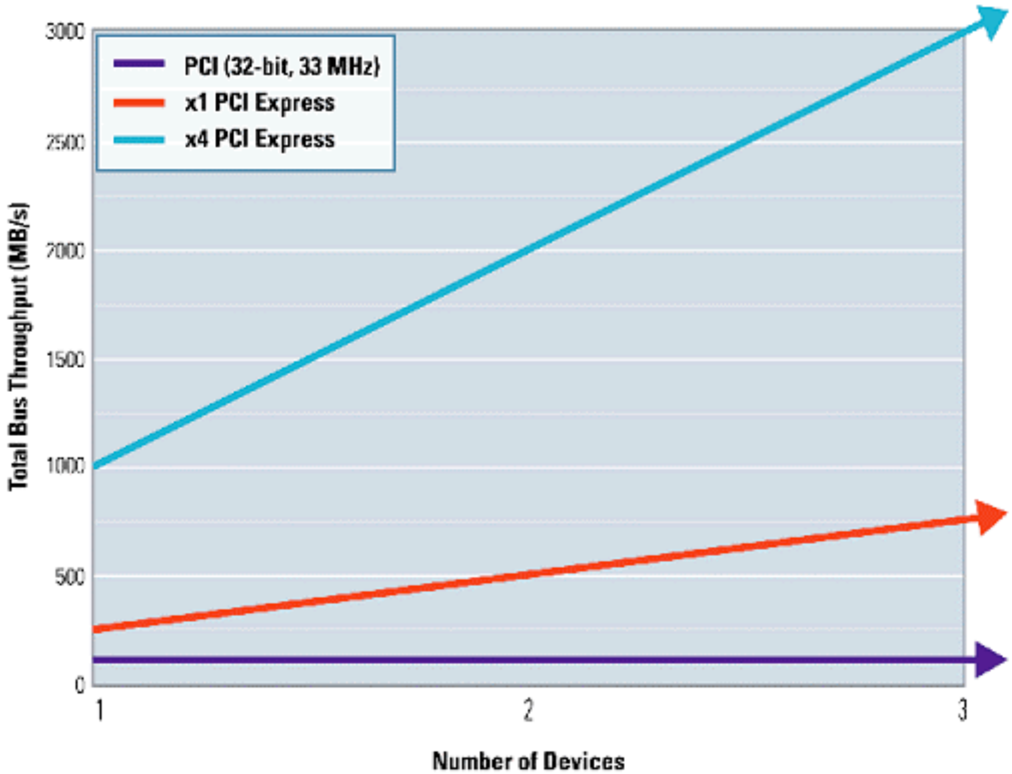

Figure 2. PCI Express provides dedicated, scalable bandwidth with up to 30 times the bandwidth of traditional PCI.

Hardware and Software Compatibilities

PCI Express maintains software compatibility with traditional PCI but replaces the physical bus with a high-speed (2.5 Gb/s) serial bus. Because of this architecture change, the connectors themselves are not compatible. However, for the transition from PCI to PCI Express, most computer motherboards offer a combination of PCI and PCI Express connectors. Devices with smaller connectors can be “up-plugged” into larger host connectors on the motherboard, improving hardware compatibility and flexibility. However, “down-plugging” into smaller-sized connectors is not supported.

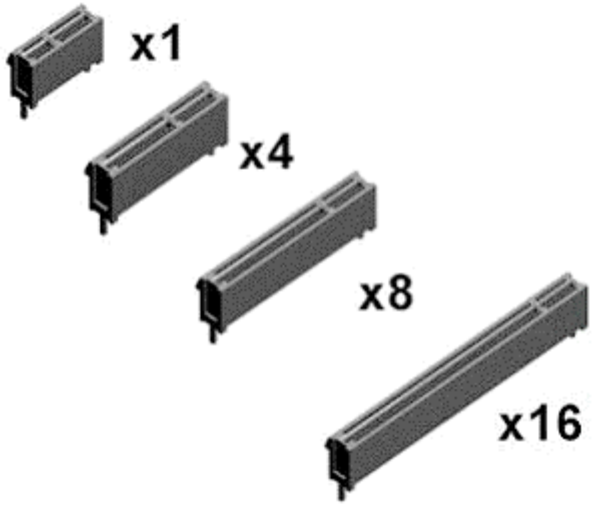

Figure 3. The standard PCI Express slot sizes on computers today are x1, x4, x8 and x16.

Software compatibility is also ensured by the PCI Express specification. The configuration space and programmability of PCI Express boards are unchanged from the traditional PCI methodology. In fact, all operating systems are able to boot without modification on a PCI Express architecture. At boot time, the operating system can discover all of the PCI Express devices present and then allocate system resources such as memory, I/O space, and interrupts to create an optimal system environment. And because the PCI Express physical layer is transparent to application software, programs originally written for PCI devices can run unchanged on PCI Express boards that have the same functionality, and you can use PCI and PCI Express boards together in the same system. This backward compatibility of PCI Express software with traditional PCI is critical in preserving the software investments of both vendors and users.

Related Links

PCI Express – An Overview of the PCI Express Standard

PXI Integrates PCI Express

This document provides answers to frequently asked questions about PXI Express. It assumes a basic familiarity with the PXI platform.

Contents

General

What is PXI Express?
PXI Express technology is the latest addition to the PXI platform. The PXI Express specification integrates PCI Express signaling into the PXI standard, which increases backplane bandwidth from 132 MB/s to 6 GB/s, a 45 times improvement. It also enhances PXI timing and synchronization features by incorporating a 100 MHz differential reference clock and differential triggers. The PXI Express specification adds these features to PXI while maintaining backward compatibility.

How does PXI Express compare to other buses in bandwidth and latency?

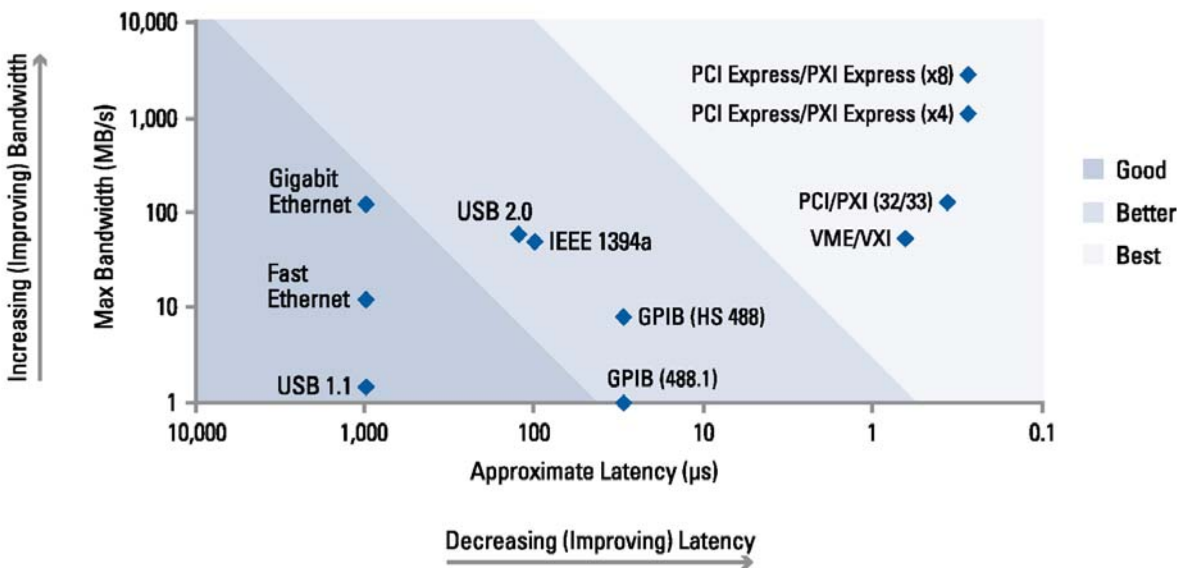

Figure 1. PCI and PCI Express provide the highest bandwidth and lowest latency, decreasing test time and delivering flexibility and longevity through user-defined software.

Bandwidth measures the rate at which data is sent across a bus, typically in megabytes per second, while latency measures the delay in transmission of data across a bus. With PXI Express, you can achieve a maximum 6 GB/s controller-to-backplane bandwidth, the highest bandwidth available in the test and measurement industry. Additionally, you can dedicate up to 2 GB/s of bandwidth to each peripheral slot, depending on the system specifics.

PXI Express offers the lowest (best) latency of all mainstream commercial test and measurement bus technologies, delivering latency comparable to – and in some cases, better than – PCI-based PXI. PXI Express latency is several orders of magnitude better than the latencies of external buses such as USB or Ethernet.

Does PXI Express replace PXI?

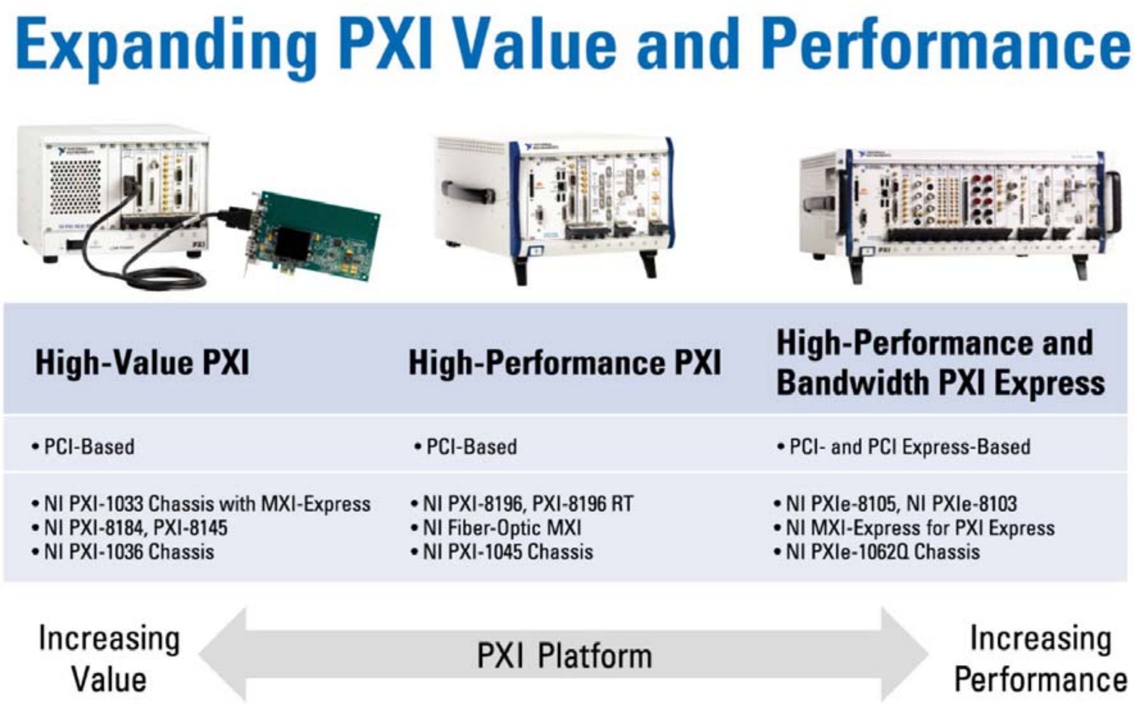

Figure 2. Expanding the PXI Platform with PXI Express

No. PXI Express is part of the PXI platform, and National Instruments and others continue to invest in that platform by developing products that are based on both PCI signaling and PCI Express signaling. Many applications, including general data acquisition and motion control, do not require the increased bandwidth of PXI Express, so users need to choose which specification within the PXI platform is right for them. PXI systems already serve a large installed base of applications, and PXI systems based on PCI signaling will be deployed in large numbers for many years to come. Additionally, because PXI Express chassis from NI include both PXI peripheral slots and PXI Express hybrid peripheral slots, you can use both existing PXI peripheral modules and PXI Express peripheral modules together in the same chassis and systems. See What Is PXI?

Compatibility

Is PXI Express backward compatible with PXI?
Yes. PXI Express maintains both software and hardware compatibility with PXI peripheral modules.

- **Software –** PCI Express uses the same operating system and driver model as PCI, resulting in complete software compatibility between PCI-based systems (such as PXI) and PCI Express-based systems (such as PXI Express). This software compatibility is ensured by the PCI Special Interest Group (PCI-SIG), a group composed of member companies, such as Intel, who are committed to the development and enhancement of the PCI and PCI Express standards.
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Can I use my existing code written for previous PXI systems?
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What are the different types of slots in a PXI Express chassis?
A PXI Express chassis can include:

- A system slot, which accepts an embedded or remote PXI Express controller
- PXI peripheral slots, which accept PXI modules
- PXI Express hybrid peripheral slots, which accept PXI Express peripheral modules, 32-bit CompactPCI peripheral modules, and hybrid-compatible PXI peripheral modules
- A system timing slot, which accepts both PXI Express peripheral modules and PXI Express system timing modules

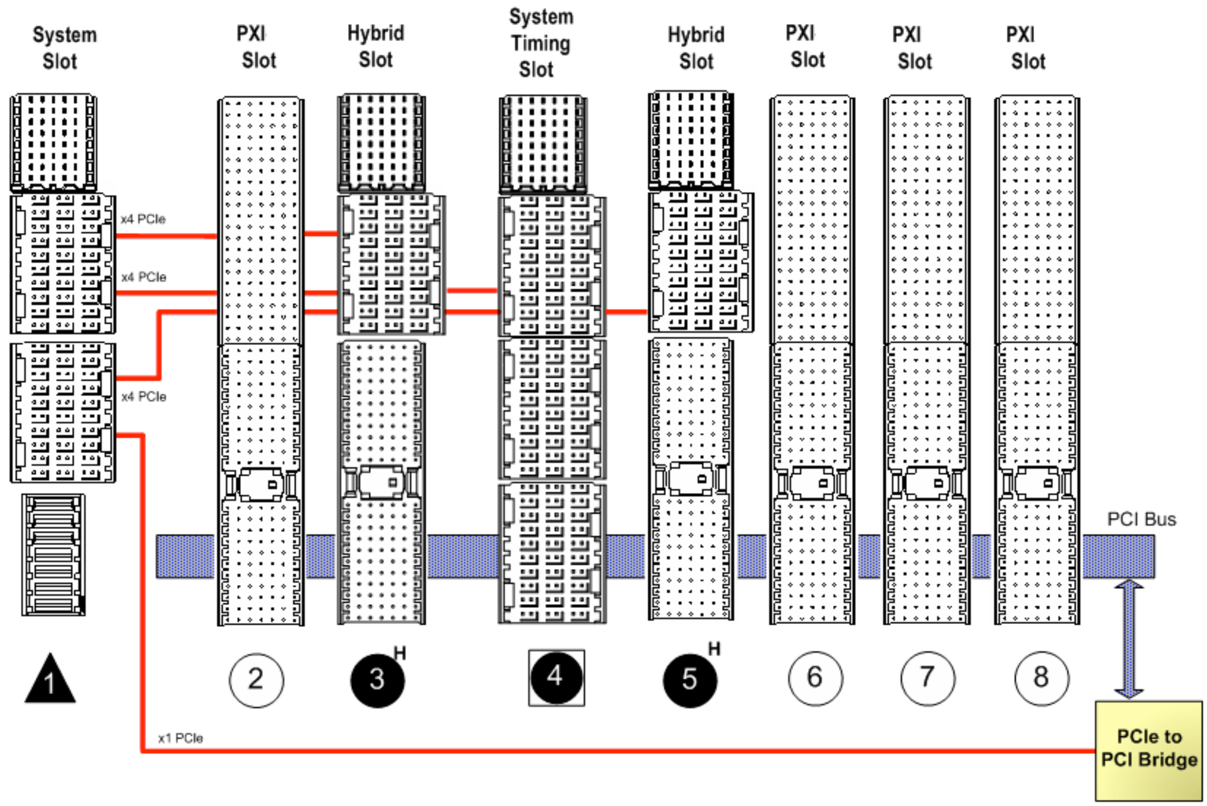

Figure 3. The Backplane Layout for a National Instruments PXI Express Chassis

What is a PXI Express hybrid slot?
PXI Express chassis have two kinds of peripheral slots – PXI peripheral slots and PXI Express hybrid peripheral slots. The PXI hybrid peripheral slots, shown below, can accept either PXI Express peripheral modules, 32-bit CompactPCI boards, or hybrid slot-compatible PXI modules.

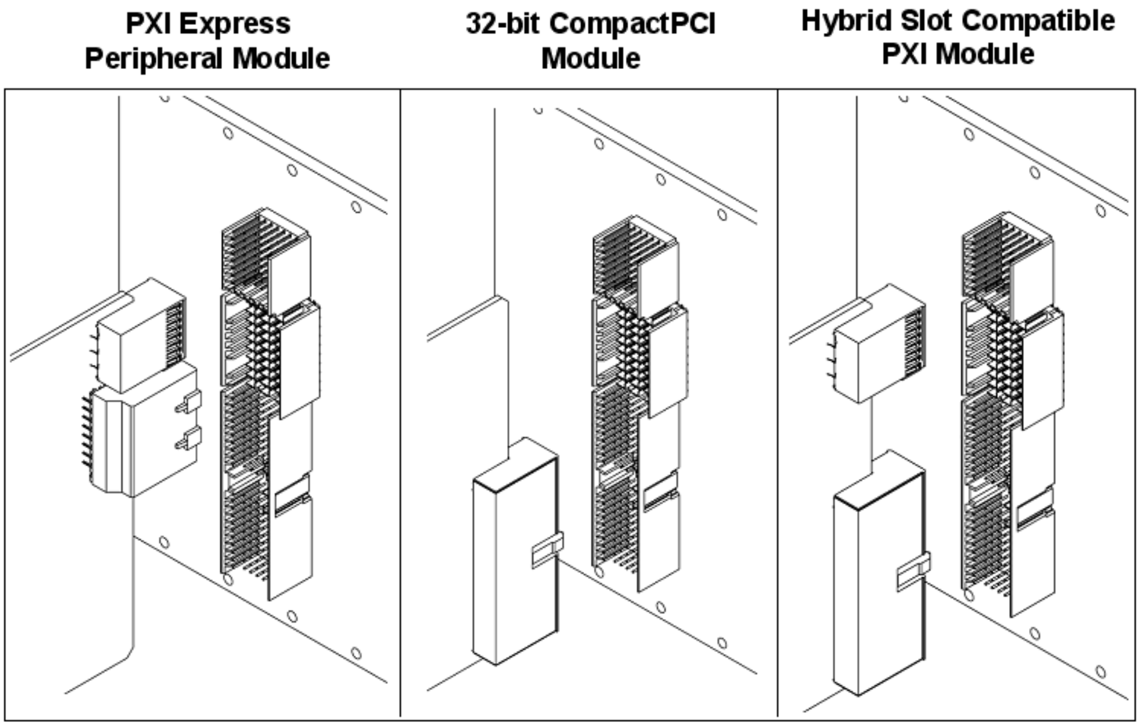

Figure 4. A PXI Express hybrid slot accepts PXI Express peripheral modules, 32-bit CompactPCI boards, and hybrid slot-compatible PXI modules.

What is a hybrid slot-compatible PXI module?
National Instruments PXI modules that do not include a J2 connector are already hybrid slot-compatible. For NI modules that do include the J2 connector, you must replace that physical connector to achieve compatibility with PXI Express hybrid peripheral slots. As shown below, the J2 connector is removed and replaced with the smaller eHM connector. You can still use the resulting hybrid slot-compatible module in existing PXI peripheral slots.

For NI modules that are modified, only the backplane connectors are replaced; the rest of the module remains unchanged. This modification takes advantage of the fact that the lower portion of the J2 connector is largely unused in 32-bit PXI modules, with the exception of its use in the local bus.

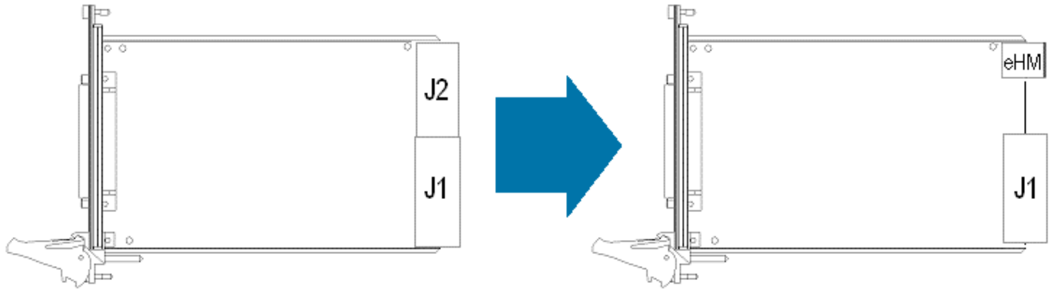

Figure 3. Connector Modification of a PCI-Based PXI Module for Hybrid Slot Compatibility

What is going to happen to my existing PXI equipment?
You can use existing PXI peripheral modules in both PXI Express chassis that have hybrid slots and in PXI chassis. Because the PXI Express specification offers a feature set enhancement and not a replacement for PXI, National Instruments and others will continue to develop and sell PXI controllers, chassis, and modules based on PCI signaling.

To use existing PXI peripheral modules in a National Instruments PXI Express chassis, simply insert the module into one of the several PXI peripheral slots available. If the existing equipment does not have a J2 connector, you also can place the module in a hybrid slot. If there are more existing PXI modules that have J2 connectors than there are PXI slots available, you can send the remaining PXI modules to National Instruments to be made hybrid slot-compatible for a nominal fee.

Can I send in my National Instruments PXI modules to make them hybrid slot-compatible?
National Instruments modifies existing NI PXI modules for hybrid slot compatibility for a nominal fee, but, in most cases, this is not necessary. PXI Express chassis from NI include both PXI slots and PXI Express hybrid slots, so you can use your existing (unmodified) modules with the new chassis. For PXI modules sent to National Instruments, NI achieves compatibility by removing the J2 connector and replacing it with the smaller eHM connector. It should be noted that not all existing modules can be made hybrid slot-compatible. For example, legacy products such as E Series PXI data acquisition modules are not modified.

Will future PXI modules from NI be natively hybrid slot-compatible?
Yes. National Instruments now incorporates the smaller eHM connector on most of its PXI modules that previously used the J2 connector. As a result, you may use these modules in either existing PXI peripheral slots or PXI Express hybrid peripheral slots. Again, not all existing modules are made hybrid slot-compatible. For example, legacy products such as E Series data acquisition modules cannot transition to the new connector.

Technical

Is there a comparable specification for CompactPCI based on PCI Express signaling?
Yes. The CompactPCI Express specification, upon which PXI Express was built, was released in June 2005. The specification is owned and maintained by the PCI Industrial Computer Manufacturers Group (PICMG).

What does x1, x4, and x16 mean?
With PCI Express, data is sent serially through pairs of transmit and receive connections called lanes, which enable data transfer at 250 MB/s per direction. You can group together multiple lanes into x1 ("by one"), x2, x4, x8, x12, x16, and x32 links to increase bandwidth to the slot. For example, a x16 slot would have bandwidth of 4 GB/s per direction (250 MB/s * 16). Though different lane widths correspond to different physical slot sizes in PCI Express, PXI Express slots and connections do not differ physically based on the lane width of the link.

Does every PXI Express slot necessarily have its own dedicated bandwidth?
The answer depends on the implementation of the PCI Express bus in the chassis and controller. If the PCI Express lanes for the slot are directly linked to the controller chipset, then the slot has its own dedicated bandwidth. But if the controller and/or chassis uses a PCI Express switch to split the link so that it fans out to several slots, those slots share the bandwidth. Controllers and chassis that fall into both the *directly linked* and *switched* categories will be available. The first 8-slot PXI Express chassis and the first PXI Express embedded controller will provide dedicated (x1) bandwidth to each PXI Express-enabled slot.

How is the local bus affected?
The PXI local bus provides a daisy-chained connection between each PXI peripheral slot and the adjacent PXI peripheral slots to its left and right. With the exception of a single local bus pin, the local bus is not available in the PXI Express hybrid slots or on PXI Express modules. The physical connector space previously used by the local bus is occupied now by a connector for PCI Express signaling. The local bus, however, is still available between adjacent PXI slots in the PXI Express chassis, and will, of course, continue to be available in the future PCI-based PXI chassis.

What is the relationship between MXI Express and PXI Express?
With MXI Express technology, you can achieve transparent remote control of a PXI or PXI Express chassis from a PCI Express slot in a PC or an ExpressCard slot in a laptop. "Express" in MXI Express refers to the interface on the PC/laptop side rather than the chassis to which the interface is connected.

Related Links

PXI Specification Tutorial
PXI Express Specification Tutorial
PCI Express Fuels Virtual Instrumentation
PCI Express – An Overview of the PCI Express Standard

2. Market Opportunity

Benefits of the PXI Standard for Measurement and Automation Systems

Modular instrumentation systems based on the open industry-standard PXI (PCI eXtensions for Instrumentation) architecture deliver high-performance, PC-based measurement and automation systems at an affordable price. With PXI modular instrumentation, you automatically benefit from the low cost, ease of use, and flexibility of PC technology. PXI also delivers significant performance improvements over other architectures by combining the high-speed, industry-standard PCI/PCI Express bus with a modular, chassis-based architecture. PXI then adds timing and synchronization to provide a high level of integration among modules designed specifically for measurement and automation applications.

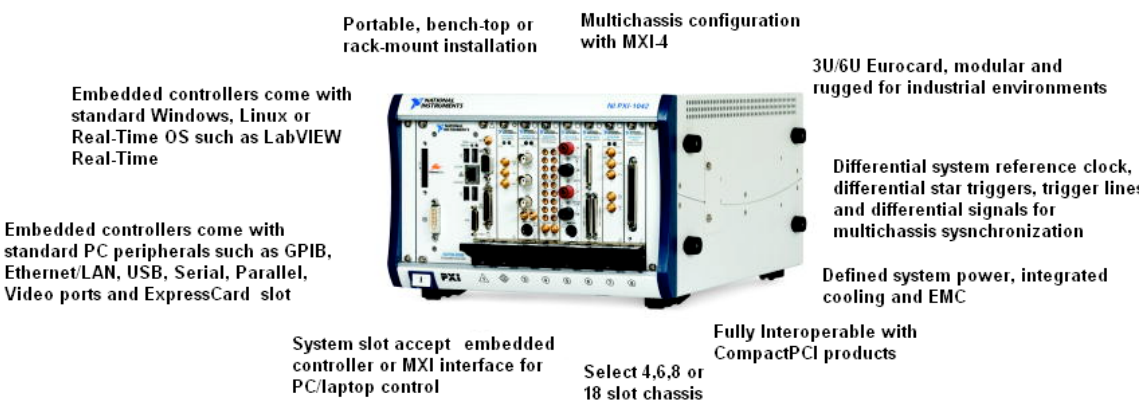

Figure 1. PXI/PC-Based Platform Ruggedized for Industrial Environments

History

PXI was introduced in 1997 as an open industry standard to meet the increasing demands of complex instrumentation systems. The PXI Systems Alliance (PXISA), a group of more than 70 companies providing more than 1,200 PXI products, governs the standard. PXISA was chartered to promote the PXI standard, ensure interoperability, and maintain the PXI specification. For more information on PXISA, visit www.pxisa.org.

PXI Features

The PC-based architecture and advanced synchronization features, which are the heart of PXI modular instrumentation, combine to deliver a high-performance architecture. With the large number of cutting-edge measurement modules available from National Instruments and PXISA, you can use PXI to implement a variety of applications, from advanced data acquisition to automated manufacturing test.

- With more than 1,200 PXI products available in this growing market, you can find the measurement hardware you need

- With the PC-based architecture, you can incorporate the latest PC technologies, such as high-performance processors for analysis-intensive applications, as they become available
- You can take advantage of the PCI Express bandwidth, which increases backplane bandwidth from 132 MB/s to 6 GB/s, a 45 times improvement.
- With advanced timing and synchronization features, you can achieve tighter integration among modules for higher overall measurement accuracy, as well as scalable synchronized high-channel-count systems
- You can handle up to 17 modules per system with the modular chassis architecture
- You can simplify your system integration with the familiar PC software model, which requires no learning curve

System Reliability

The PXI specification defines requirements that make PXI systems well-suited for harsh environments. PXI features the high-performance IEC (International Electrotechnical Commission) connectors and rugged Eurocard packaging system used by CompactPCI. The PXI specification also defines specific cooling and environmental requirements to ensure operation in industrial environments. Modularity makes it easy to configure, reconfigure, and repair your PXI systems, resulting in very low mean time to repair (MTTR). Because PXI is modular, you can update individual modules and components without replacing the entire system.

Higher Throughput

Every application is unique and has very specific needs. However, bandwidth and latency are two important attributes of a platform for many applications. Latency tends to dominate single-point operations, such as digital multimeter/switch scanning, and bandwidth tends to dominate data streaming applications, such as waveform stimulus/response. PXI provides high speed for a wide range of applications with both high bandwidth and low latency via the PCI/PCI Express bus as shown in Figure 2.

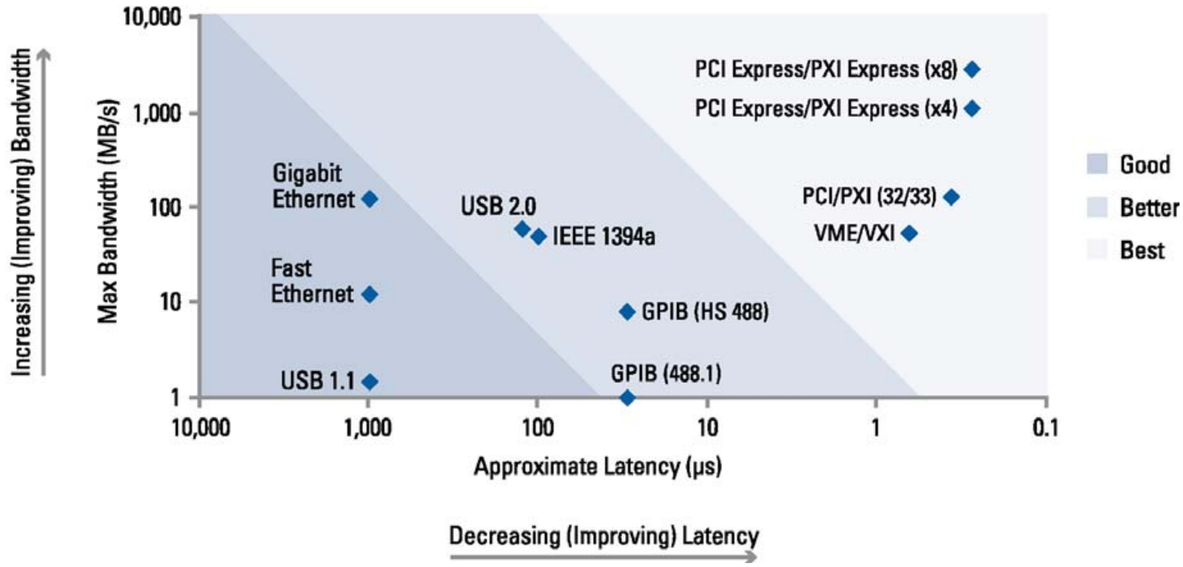

Figure 2. PCI and PCI Express provide the highest bandwidth and lowest latency, decreasing test time and delivering flexibility and longevity through user-defined software.

Timing and Synchronization

Many measurement and automation applications require advanced timing and synchronization capabilities that you cannot implement directly across PC standard I/O buses like PCI/PCI Express, Ethernet/LAN, USB, and so on. PXI offers advanced timing and synchronization features to meet your application needs:

- 100 MHz differential system reference clock
- 10 MHz reference clock signal
- Differential star trigger
- Star trigger bus with matched-length trigger traces to minimize intermodule delay and skew
- Trigger bus to send and receive high-speed timing and triggering signals
- Differential signals for multichassis synchronization

Lower System Costs

Because PXI is a PC-based platform, it delivers high-precision instrumentation, synchronization, and timing features at an affordable price. The low cost of PC components is only the beginning of the savings you gain from using PXI. With PXI, you use the same OS and application software such as Microsoft Excel and Word in your office and on the production floor. The familiarity of the software eliminates training costs and the need to retrain personnel every time you implement a new system. Because the foundation of PXI is PC technology, you benefit from low component costs, familiar software, and system reuse.

Related Links

PXI Tutorial, PXI Systems Alliance, and PXI Brochure

PXI Industry Adoption

PXI Industry Adoption

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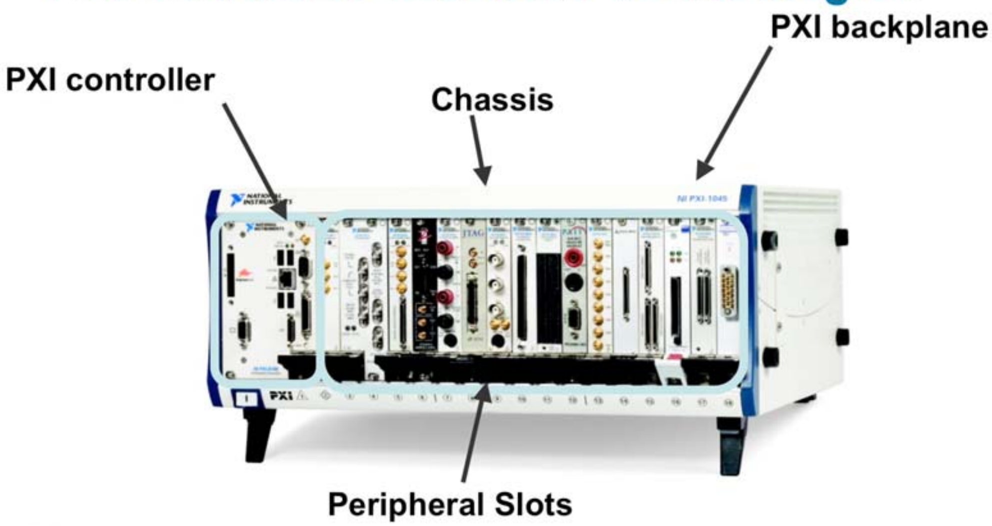
NATIONAL INSTRUMENTS

PXI Combines Standard Technologies



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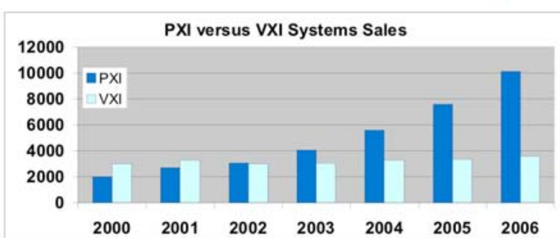
NATIONAL INSTRUMENTS

PXI Advantages

- Broad multi-vendor support
- Increased test throughput
- Decreased system size
- Lower cost

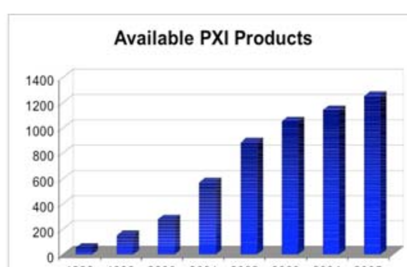
PXI – The Fastest Growing Standard Since GPIB



Source: World VXI & PXI Test Equipment Markets
Frost & Sullivan, April 2005

25% projected growth through 2011

More than 1,200 PXI Products



Source: PXI Systems Alliance

PXI Industry Acceptance

"With PXI on the scene, you'll need to evaluate your options. The odder the job you face or the wider range of chores you must contend with, the more likely **you'll want the flexibility to reconfigure hardware and software test resources that modular systems provide**." *-Rick Nelson, Test and Measurement World, 2/1/2006*

"The **fastest growing segment of the T&M industry** over the next several years will be PXI-based systems, according to research by Madhan Dhandayutham, a senior research analyst at Frost & Sullivan"

"With PCI Express' quick adoption rate, **its impact on T&M systems may rival that of the GPIB** from 30 years ago." *-Electronic Design 2006 Technology Forecast, 1/12/2006*

PXI – High Performance Instrumentation

- Industry's highest resolution digitizer
  - NI PXI-5922 Flexible Resolution Digitizer – 170 dBFS/Hz noise density

- Industry's highest performance AWG
  - Agilent 6030A, 15 bits, 500MHz BW

- Industry's fastest, most accurate 7 ½ Digit DMM
  - NI PXI 4071 7 ½ Digit FlexDMM

- Highest channel count and best synchronization
  - 5000 dynamic signal channels to .01 degree
  - Mixed signal synchronization under 100 ps

- Largest matrix density switch
  - 512 cross-points in single 3U slot
  - 4x2176 1-wire matrix in a single PXI chassis

Photo courtesy of Agilent

Major PXI Vendors
National Instruments

- Instrumentation from DC to RF – DMMs, digitizers, signal generators, power supplies, digital I/O, audio, video, RF
- Over 100 general purpose, multiplexer, matrix, and RF switch topologies
- Data acquisition, vision, motion control, vibration/acoustical monitoring

Major PXI Vendors
Agilent

Agilent Technologies N6030A

- 15-bit, 500 MHz Wideband Arbitrary Waveform Generator
- 1.25 MSamples/s Sampling Rate
- Radar, Satellite, and Frequency Agile System Test

Photo courtesy of Agilent

Major PXI Vendors
Aeroflex

PXI-based In-circuit Tester

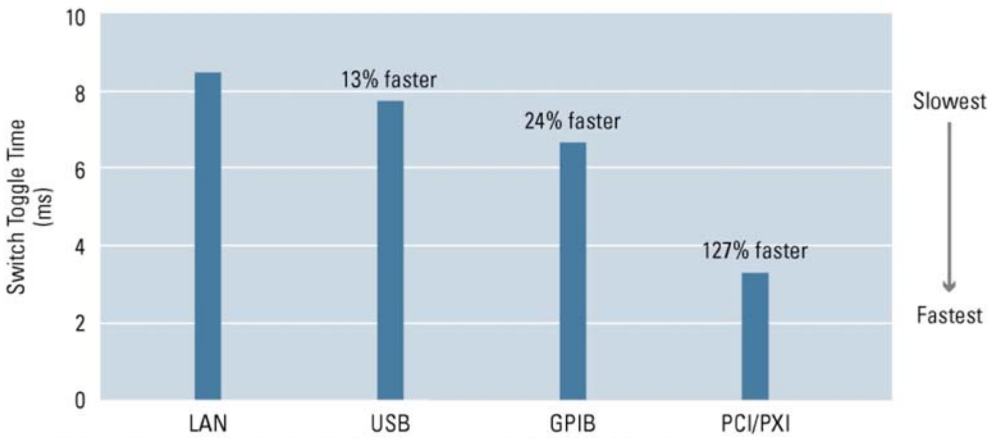
RF Stimulus and Measurement Instruments

Major PXI Vendors
Advantest

Fig 2 Demo of Mixed-Signal IC Tester Using the PXI Carrier Module (the board in the central transparent case).

CertiMAX – complete IC tester built on PXI

PCI/PXI Improves Measurement Time



LAN, USB, GPIB performed on Agilent 34980A, PXI performed on NI PXI 4070, NI PXI 2532
Benchmark: Toggle and readback of armature relay

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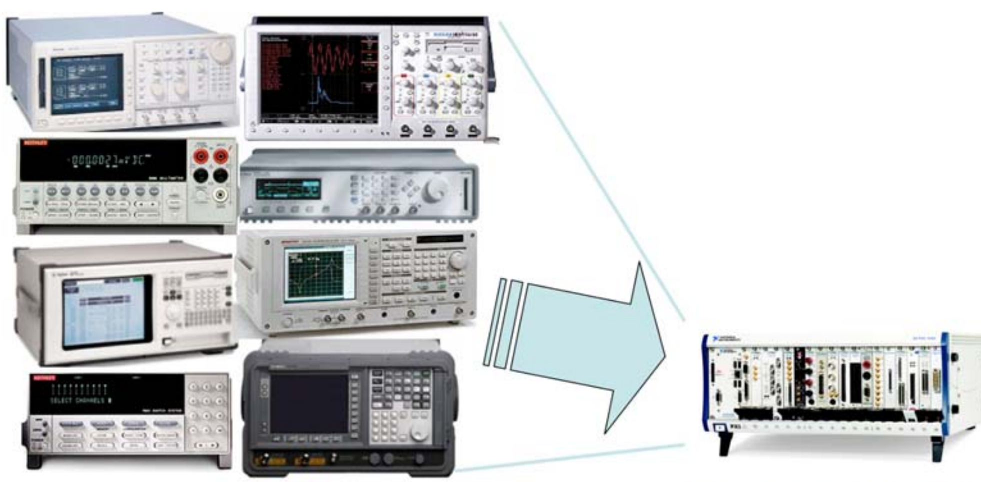
PXI Decreases Size and Lowers Cost



Traditional Solution: $82,972
6.12 ft³ (.1734 m³)

PXI Solution: $39,545
.67 ft³ (.019 m³)

ni.com

Photos courtesy of Agilent, Keithley, Advantest, Nicolet, and Tektronix

PXI is Adopted by a Wide Range of Industries

Consumer Electronics

Military & Aerospace

Automotive

Communications

Semiconductor

Medical

PXI Express Solves New Applications

- High bandwidth communications systems test (multichannel, streaming IF)
- High-speed digital interfacing and test
- Large channel count data acquisition systems for structural and acoustic test
- High-speed image acquisition

Source: PXISA Whitepaper: *Enabling New Applications with PXI Express: 6 GByte/s of Backplane Bandwidth with Backwards Compatibility*

PXI-Industry Standard for Measurement and Automation

- PXI is a well established and growing standard for modular instrumentation
- PXI systems benefit from the wide industry adoption
- PXI Express expands PXI value and performance

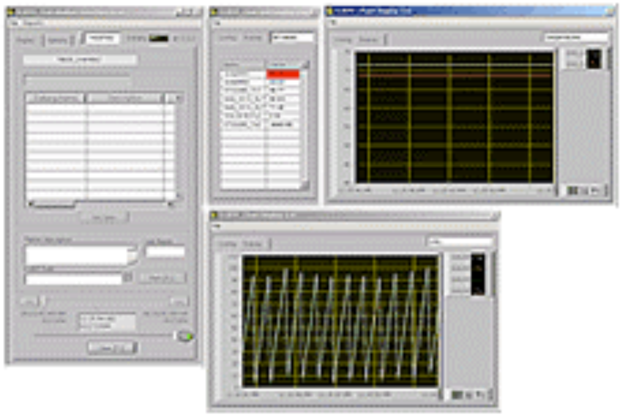
Customer Testimonials

1. Boeing Measures Reduced Aircraft Noise Emissions with NI PXI and LabVIEW

"Using NI software and hardware, we were able to create a high-end, low-cost system that could distribute the acquisition system across multiple chassis, tightly synchronize all channels, provide high channel count with full bandwidth on all channels simultaneously, and allow virtually unlimited channel-count expansion. With this new system, not only were we able to improve capabilities of the individual acquisition channels, but we also achieved a 5:1 reduction in the amount of cable required and cut the cost of microphone systems by 30:1 for flyover test applications."
- James R. Underbrink, The Boeing Company

Read entire customer solution.

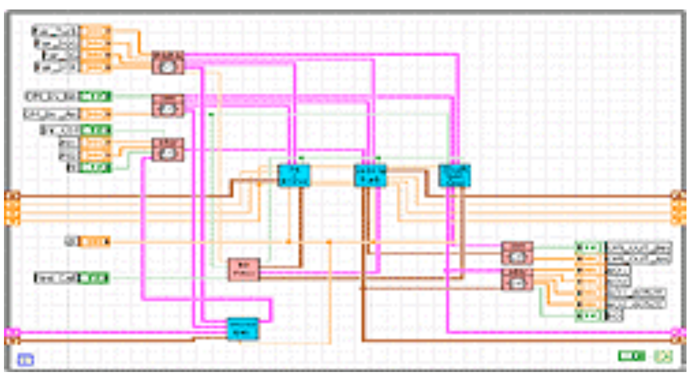
2. **Honeywell Implements Distributed, High-Channel-Count Data Acquisition System with NI PXI**



“We based our software on the LabVIEW platform for its ease of use and tight integration with the hardware. In addition, using LabVIEW Real-Time, we ran the control and acquisition program on the PXI controller as an embedded process without operating system overhead. Using NI products, we completed our project in seven months, reducing development time by more than 40 percent.”
- Sorin Grama, Cal-Bay Systems, Inc.

Read entire customer solution.

3. **Siemens Develops a Dynamic Turbine Simulator for Steam Turbine Controller Examination with NI PXI**



“Because of the high demand for this dynamic turbine simulator system, we decided to develop an additional simulator system for different turbine controller testing at the same time. For the new system, we again used a PXI system with real-time controllers.”
- Eckart Brackenhammer, Siemens

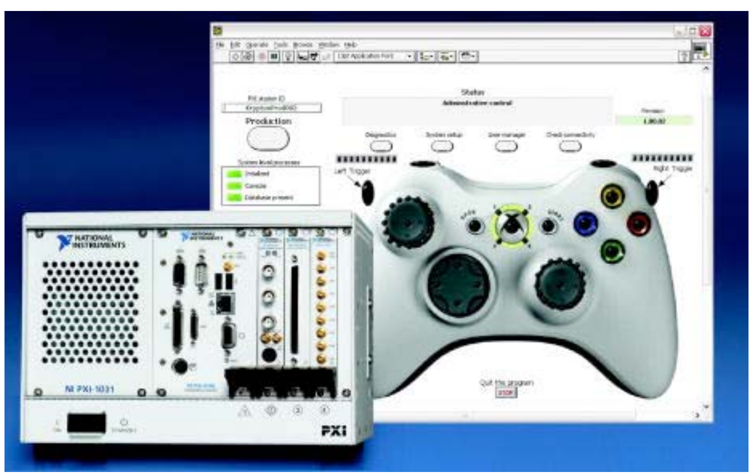
Read entire customer solution.

4. Lockheed Martin Uses NI LabVIEW Interface Toolkit and PXI for Flight Simulation Model Development

"The project presented various technical problems and multiple changes in requirements. The LabVIEW graphical development environment and supporting applications helped our team solve the problems and ultimately deliver a robust and versatile product."
- Jesse Hopkins, Lockheed Martin Space Systems Company

Read entire customer solution.

5. Microsoft Uses NI LabVIEW and PXI Modular Instruments to Develop Production Test System for Xbox 360 Controllers



"With the PXI-based system, we can achieve reliable production line testing and store all parameters to our Microsoft SQL Server. Using the high-resolution input and high sampling rate of the PXI-5124 digitizer, we acquire our test signals with 12 bits of resolution at data rates up to 200 MS/s, which provides a low-cost automated test system."
- D.J. Mathias, Microsoft

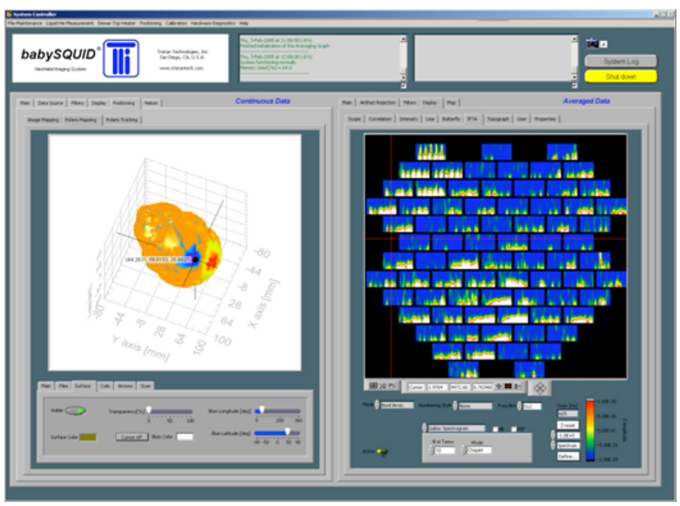
Read entire customer solution.

6. **BAE Systems Uses PXI and NI LabVIEW to Develop an Efficient RF Cable Test Suite for the Eurofighter Aircraft**

"We saved more time than originally anticipated, and the operation of the final product is so simple that the operators need only minimal training. This method of testing has proven to be so successful that other BAE Systems departments are considering using this solution to RF testing requirements for high-performance coaxial cables."
- Alastair Kane, TBG Solutions, Inc.

Read entire customer solution.

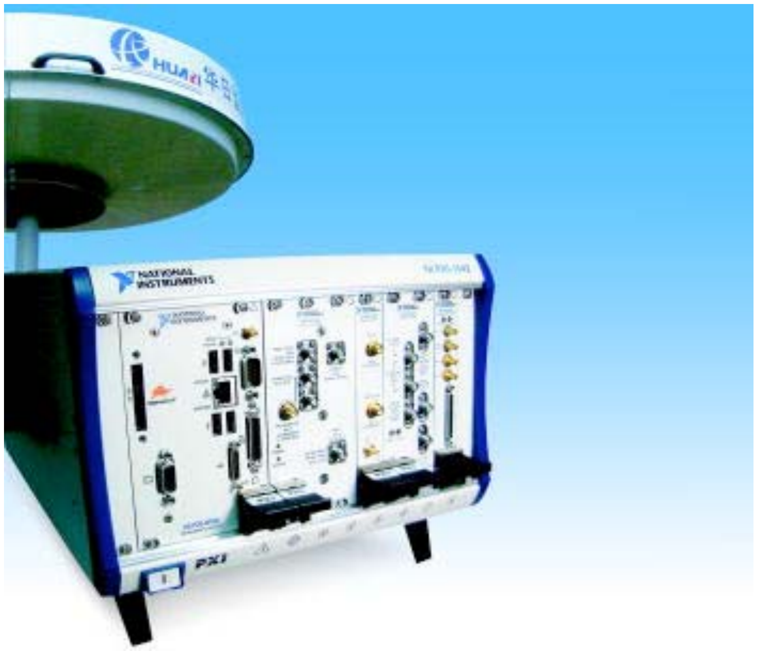
7. **Creating a Magnetic Imaging System for Diagnosing Infant Brain Activity Based on NI PXI and LabVIEW**



"Using NI PXI hardware, we can expand and reduce the channel count as needed. With LabVIEW, we can freely move the software to other operating systems and easily swap the national language of the displays for foreign clients."
- Christopher Atwood, Tristan Technologies, Inc.

Read entire customer solution.

8. Using NI PXI for Improved Spectral Monitoring in China



"By using commercial PXI technology and the PXI-5660 modular vector signal analyzer, we now offer our customers a cost-effective, scalable, and faster spectrum-monitoring system."
- Daotian Yang, Huari Telecom

Read entire customer solution.

9. Monitoring the Structural Health of the Rion-Antirion Bridge Using PXI and LabVIEW Real-Time

"Given the large number of input channels and the adverse operational environment, we chose the National Instruments PXI/SCXI chassis housing National Instruments LabVIEW Real-Time software to perform the task. The resulting system houses and performs tasks with a high degree of reliability."
- Bernard Basile, Advitam

Read entire customer solution.

Related Links

ni.com/success

3. PXI Specifications

PXI Specification Tutorial

Contents

Introduction

The PCI eXtensions for Instrumentation (PXI) specification defines a rugged PC-based platform for measurement and automation systems. PXI uses the high-speed peripheral component interconnect (PCI) bus, which is the de facto standard driving today's desktop computer software and hardware designs.

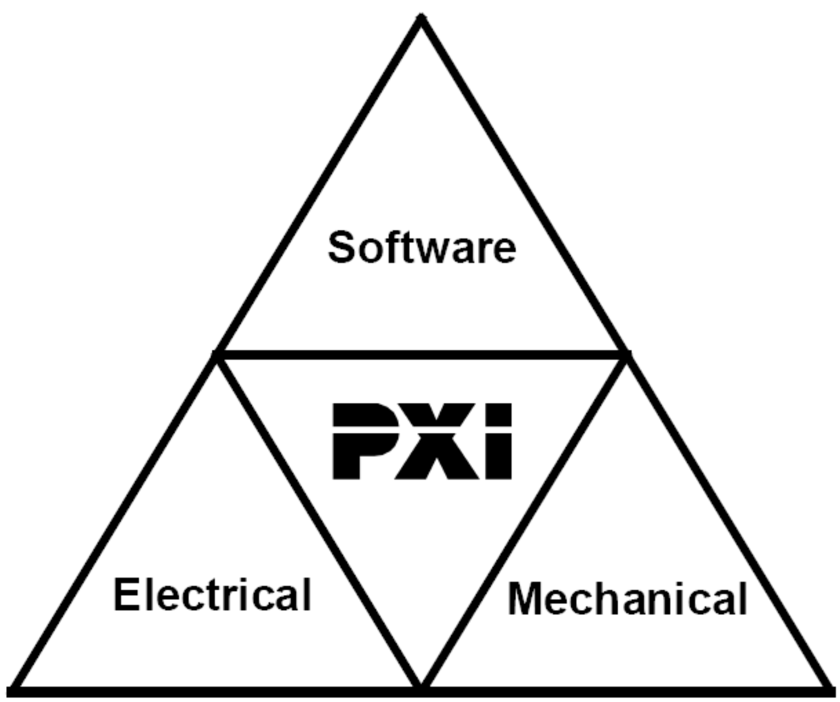


Figure 1. PXI Adds Timing and Triggering Capabilities to CompactPCI

PXI combines the PCI electrical bus with the rugged modular Eurocard mechanical packaging of CompactPCI. PXI then adds mechanical, electrical, and software features that define complete systems for test and measurement, data acquisition, and manufacturing applications. National Instruments developed and announced the PXI specification in 1997 as an open industry specification. Today, the PXI specification is managed by the PXI Systems Alliance – a group of more than 70 company members. Because PXI is an open specification, any vendor can build PXI products. CompactPCI, the standard regulated by PICMG, and PXI modules can reside in the same system without any conflict because interoperability between CompactPCI and PXI is a key feature of the PXI specification. To download a free copy of the full PXI specification, see www.pxisa.org.

Mechanical Features

The PXI specification defines requirements that make PXI systems well-suited for harsh environments. The high-performance IEC connectors and rugged Eurocard packaging system used by CompactPCI are used in PXI. PXI also adds specific cooling and environmental requirements to ensure operation in industrial environments.

High-Performance Connector System
PXI employs the same advanced pin-in-socket connector system used by CompactPCI. These highly dense (2 mm pitch) impedance-matched connectors are defined by the International Electrotechnical Commission (IEC-1076) and offer the best possible electrical performance under all conditions. These connectors have seen widespread use in high-performance applications, particularly in the telecommunications field. Because of the electrical characteristics of these IEC connectors, PXI systems offer more slots on a single bus segment than desktop PCs.

Eurocard Mechanical Packaging
The mechanical aspects of PXI and CompactPCI are governed by Eurocard specifications (ANSI 310-C, IEC-297, IEEE 1101.1, IEEE 1101.10, and P1101.11), which have a long history of application in industrial environments (for example, VME and VXI). These electronics packaging standards define compact, rugged systems that can withstand harsh industrial environments in rack-mount installations.

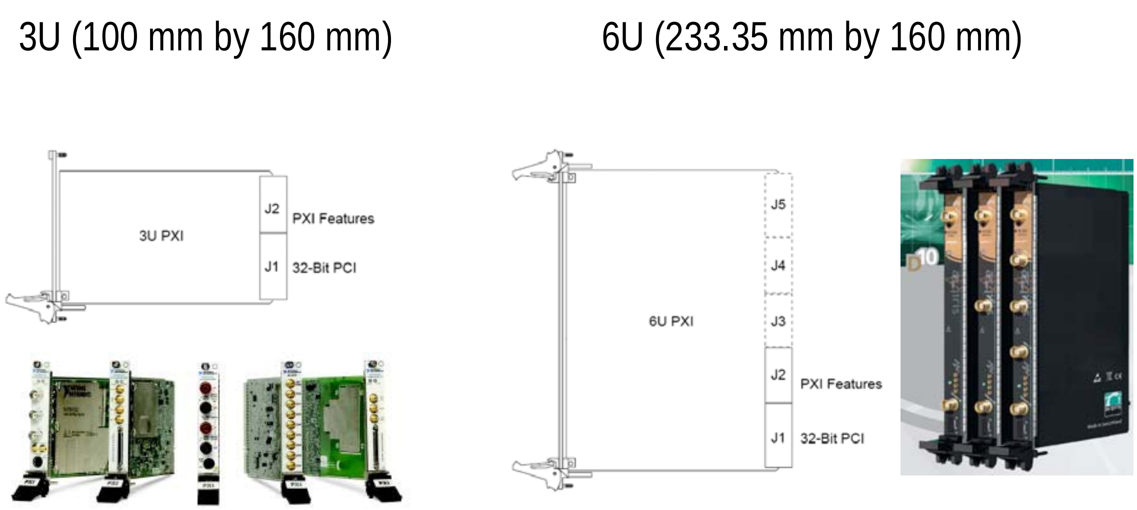


Figure 2. PXI specifies two module sizes – 3U and 6U.

PXI specifies two module sizes – a small (3U = 10 by 16 cm) and large (6U = 23.335 by 16 cm). The 3U size is the most popular size for PXI systems. Because of the small size, you benefit from the miniaturization of high-performance electronics. You can use all 3U size modules in 6U systems with an adapter. PXI defines the system slot, the system controller location, on the far left end of the bus segment. This defined arrangement is a subset of the numerous possible configurations with CompactPCI. Defining a single location for the system slot simplifies integration and increases the degree of compatibility between controllers and chassis from different vendors.

Additional Electronic Packaging Specifications
All mechanical specifications defined in the CompactPCI specification apply directly to PXI systems; however, PXI does include additional requirements that simplify systems integration. The PXI specification requires forced-air cooling of all chassis and recommends complete environmental testing, including temperature, humidity, vibration, and shock. All PXI products are required to have documentation of these test results. Operating and storage temperature ratings are required for all PXI products. The PXI specification also requires electromagnetic emissions and susceptibility testing to ensure compliance with international standards.

Electrical Features

Many instrumentation applications require system timing capabilities that cannot be implemented directly across standard ISA, PCI, or CompactPCI backplanes. PXI modular instrumentation adds a dedicated system reference clock, PXI trigger bus, star trigger bus, and slot-to-slot local bus to address the need for advanced timing, synchronization, and side-band communication. PXI adds these instrumentation features while maintaining all PCI bus advantages.

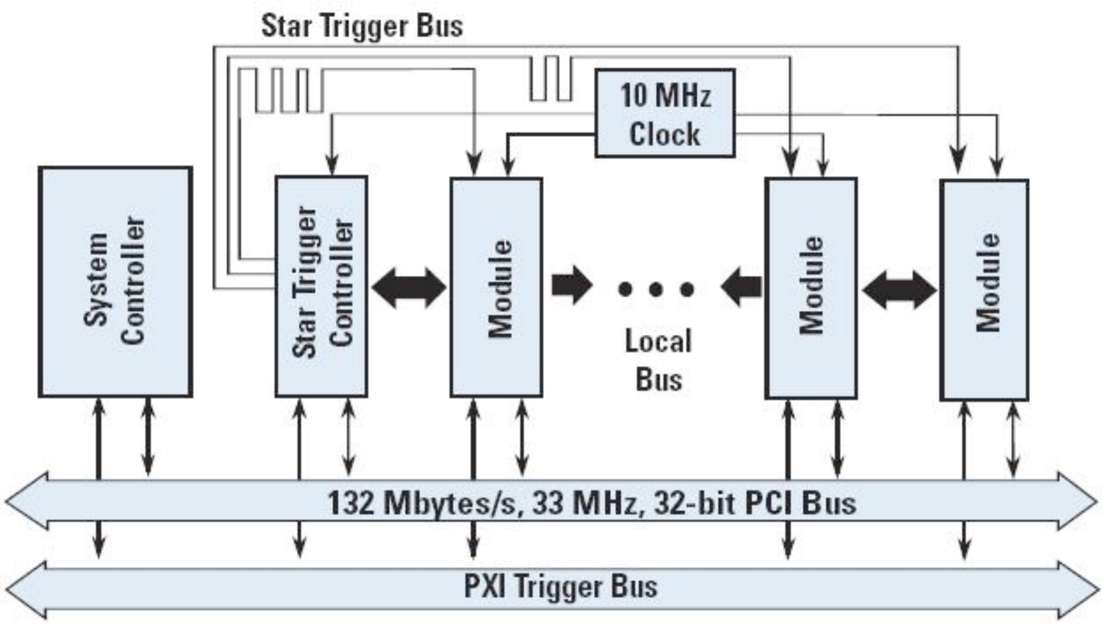


Figure 3. PXI Timing and Triggering Buses

System Reference Clock
The PXI backplane provides a built-in common reference clock for synchronization of multiple modules in a measurement or control system. Each peripheral slot features a 10 MHz TTL clock, transmitted on equal-length traces, providing skew of <1 ns between slots. The accuracy of the 10 MHz clock is chassis specific, but it is typically less than 25 parts per million (ppm), making it a reliable clock for synchronization based on phase-locked looping (PLL) methods. For example, multiple 100 MHz digitizers are easily synchronized by phase-locked loop of their individual voltage-controlled crystal oscillator (VCXO) 100 MHz clocks to the 10 MHz system reference clock. You can improve the accuracy of the 10 MHz clock by

installing a capable board into the star trigger slot (slot 2) of the chassis. For example, placing an NI PXI-6608 into slot 2 reduces the clock error to less than 75 parts per billion (ppb) by driving a high-accuracy 10 MHz clock to the backplane.

PXI Trigger Bus
PXI defines eight trigger bus lines for synchronization and communication between modules. You can share trigger, clock, and handshaking signals using the trigger bus lines. You can pass triggers from one module to any number of modules, so you can distribute digital trigger signals from master to slave measurement devices. The trigger bus allows transmission of variable frequency sampling clocks, so multiple modules can directly share a sample clock or variable frequency time base. For example, four data acquisition modules using a 44.1 kS/s CD audio sampling rate can directly share a clock that is a multiple of 44.1 KHz over the trigger bus. However, for clock frequencies of approximately 20 MHz or greater, direct transmission of a clock with the trigger bus is not recommended because of signal degradation, and you should use a system reference clock instead.

Star Trigger Bus
The star trigger bus has an independent trigger line for each slot oriented in a star configuration from a special star trigger slot (defined as slot 2 in any PXI chassis). The PXI star line lengths are matched in propagation delay to within 1 ns from the star trigger slot. This feature addresses high-speed synchronization where you can distribute start/stop trigger signals from the master measurement module in the star trigger slot with low delay and skew. Alternately, you can transmit a variable-frequency clock signal to modules over the star trigger bus with <1 ns skew.

Local Bus
The PXI local bus is a daisy-chained bus that connects each peripheral slot with its adjacent peripheral slots to the left and right. Thus, a given peripheral slot’s right local bus connects to the adjacent slot’s left local bus, and so on. Each local bus, which is 13 lines wide, can pass analog signals as high as 42 V between cards or provide a high-speed side-band communication path that does not affect the PCI bandwidth.

PCI Features
PXI offers the same performance features defined by the desktop PCI specification, with one notable exception. PXI and CompactPCI systems can have up to seven peripheral slots per bus segment, whereas most desktop PCI systems offer only three. Otherwise, all PCI features apply to PXI/CompactPCI:

- 33 MHz performance
- 32 and 64-bit data transfers
- 132 MB/s (32-bit) and 264 MB/s (64-bit) peak data rates
- System expansion via PCI-to-PCI bridges
- 3.3 V migration
- Plug-and-play capability

Software Features

PXI defines software requirements in addition to electrical requirements to further simplify systems integration. These requirements include the use of standard operating system frameworks. Appropriate configuration information and software drivers for all peripheral devices are also required.

Common Software Requirements
The PXI specification presents software frameworks for PXI systems based on Microsoft Windows operating systems. As a result, the controller can use industry-standard application programming interfaces, such as NI LabVIEW, NI Measurement Studio and Microsoft Visual Basic and Visual C/C++. PXI also requires certain software components to be made available by module and chassis vendors. Initialization files that define system configuration and system capabilities are required for PXI components. Finally, implementation of the Virtual Instrument Software Architecture (VISA), which has been widely adopted in the instrumentation field, is specified by PXI for configuration and control of VXI, GPIB, serial, and PXI instruments.

Summary

PXI modular instrumentation defines an industrial computing platform for measurement and automation users that clearly takes advantage of the technology advancements of the mainstream PC industry. By using the de facto standard PCI bus, PXI modular instrumentation systems can benefit from widely available software and hardware components. The software applications and operating systems that run on PXI systems are already familiar to users because they are used on common desktop computers. PXI meets your needs by adding rugged industrial packaging, plentiful slots for I/O, and features that provide advanced timing and triggering capabilities.

For more information on the PXI hardware architecture, software architecture, and an introduction to configuring PXI systems, see the PXI Tutorial.

Related Links

PXI Tutorial
PXI Systems Alliance – PXI Specifications

PXI Express Specification Tutorial

Contents

Introduction

The PXI industry standard has quickly gained adoption and grown in prevalence in automated test systems since its release in 1998. PXI is the platform of choice for thousands of applications, from areas such as military and aerospace, consumer electronics, and communications to process control and industrial automation. One of the key elements driving the rapid adoption of PXI is its use of PCI in the communication backplane. Now, as the commercial PC industry drastically improves the available bus bandwidth by evolving PCI to PCI Express, PXI has the ability to meet even more application needs by integrating PCI Express into the PXI standard. Ensuring the successful integration of PCI Express technology into the PXI and CompactPCI backplanes, engineers within the PCI Industrial Manufacturers Group (PICMG), which governs CompactPCI, and the PXI Systems Alliance (PXISA), which governs PXI, have worked to ensure that the PCI Express technology can be integrated into the backplane while still preserving compatibility with the large installed base of existing systems. With PXI Express, you will benefit from significantly increased bandwidth, ensured backward compatibility, and additional timing and synchronization features, improving on an already established platform.

Enabling New Applications

By taking advantage of PCI Express technology in the backplane, PXI Express increases the available PXI bandwidth from 132 MB/s to 6 GB/s for a more than 45 times improvement in bandwidth while still maintaining software and hardware compatibility with PXI modules. With this enhanced performance, PXI can reach into many new application areas, many of which were previously only served by expensive and proprietary hardware. For example, with PCI Express, a digitizer achieves a direct path to the CPU module through either an embedded controller or a MXI controller to a PC, with a bandwidth of 1 GB/s. This is approximately an 8 times improvement over the throughput offered by the 32-bit, 33 MHz PCI bus. Thus, with PCI Express technology, a high-resolution, 16-bit IF digitizer or generator can potentially stream continuously to the CPU at bandwidths up to 500 MHz without bus limits or sharing bandwidth with adjacent modules. Specifically, in automated tests for the military and aerospace industry, the higher bandwidth available in PXI Express provides new solutions for many applications:

- High-bandwidth IF instruments for communications systems test

- Interface to high-speed digital protocols including LVDS-based proprietary protocols, IEEE 1394, Fibre Channel, and others
- Large-channel-count data acquisition systems for structural and acoustic test
- High-speed image acquisition

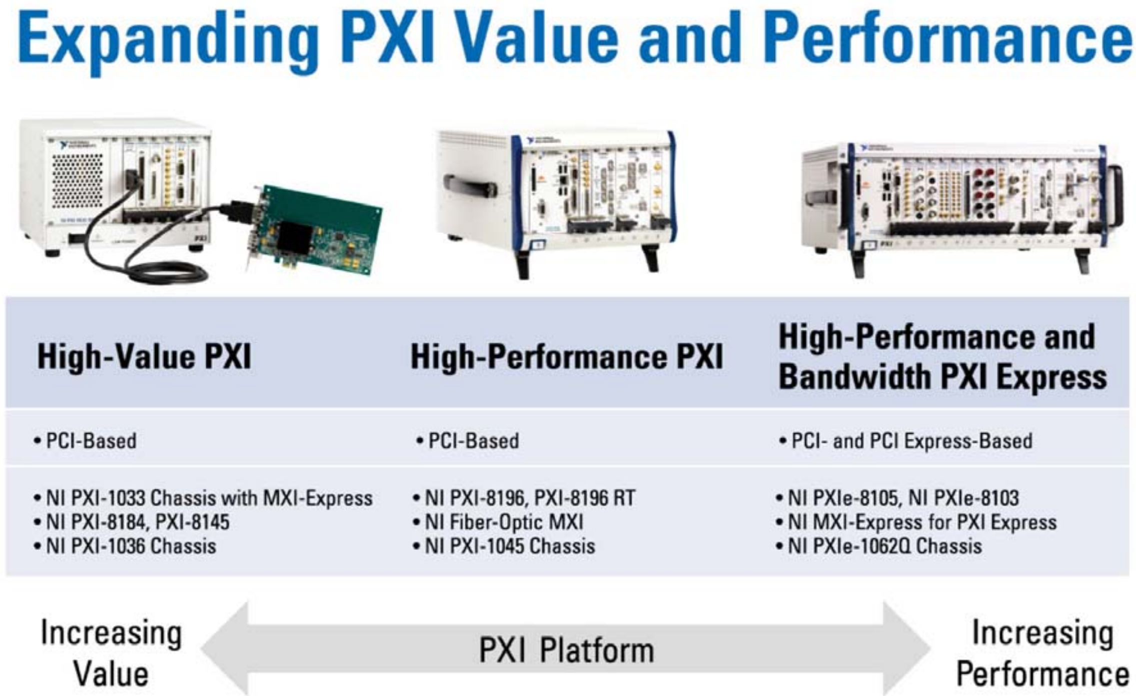


Figure 1. With PXI Express, you will be able to enter new application areas such as high-frequency applications, high-speed digital interfaces, and high-speed imaging.

Bringing PCI Express Technology to CompactPCI and PXI

PCI Express was introduced to improve on the PCI bus platform. The most notable PCI Express advancement over PCI is its point-to-point bus topology. The shared bus used for PCI is replaced with a shared switch, which provides each device its own direct access to the bus. Unlike PCI, which divides bandwidth among all devices on the bus, PCI Express offers each device its own dedicated data pipeline. Data is sent serially in packets through pairs of transmit and receive signals called lanes, which enable 250 MB/s bandwidth per direction, per lane. You can group together multiple lanes into x1 (“by one”), x2, x4, x8, x12, x16, and x32 lane widths to increase bandwidth to the slot. PCI Express dramatically improves data bandwidth compared to PCI buses, minimizing the need for onboard memory and enabling faster data streaming. For instance, with a x16 slot, you can achieve up to 4 GB/s of dedicated bandwidth as opposed to the 132 MB/s shared across all devices of the 32-bit, 33 MHz PCI.

To successfully integrate PCI Express into CompactPCI and PXI and still maintain backward compatibility, the PICMG (www.picmg.org) and the PXISA (www.pxisa.org) executed coordinated plans to ensure a smooth transition. Because PXI is based on the CompactPCI specification, these efforts to integrate PCI Express first began with CompactPCI Express in early 2004. Defining the fundamental mechanical and electrical features of CompactPCI Express systems, the CompactPCI Express specification in turn defines the mechanical and electrical features of PXI Express systems. Released June 27, 2005, the CompactPCI Express specification includes the selection of connectors to support PCI Express, definitions of slots and board mechanicals, definitions of slots and board electrical signals, and compliance-testing requirements. In May 2005, work on the PXI Express specification began, and in September 2005 the PXI Express specification passed. The PXI Express specification takes the CompactPCI Express technology and adds specifications for PXI compatibility, timing and synchronization, and system software frameworks.

Because the CompactPCI/PXI Express backplane, shown in Figure 2 below, integrates PCI Express while preserving compatibility with current PXI modules, you benefit from increasing bandwidth while maintaining backward compatibility with existing systems. PXI Express specifies PXI Express hybrid slots to deliver signals for both PCI and PCI Express. With PCI Express electrical lines connecting the system slot controller to the hybrid slots of the backplane, PXI Express provides a high-bandwidth path from the controller to backplane slots. Using an inexpensive PCI Express-to-PCI bridge, PXI Express provides PCI signaling to all PXI and PXI Express slots to ensure compatibility with PXI modules on the backplane. With the ability to support up to a x16 PCI Express link in addition to a x8 link, the system controller slot provides a total of 6 GB/s bandwidth to the PXI backplane, representing more than a 45 times improvement in PXI backplane throughput.

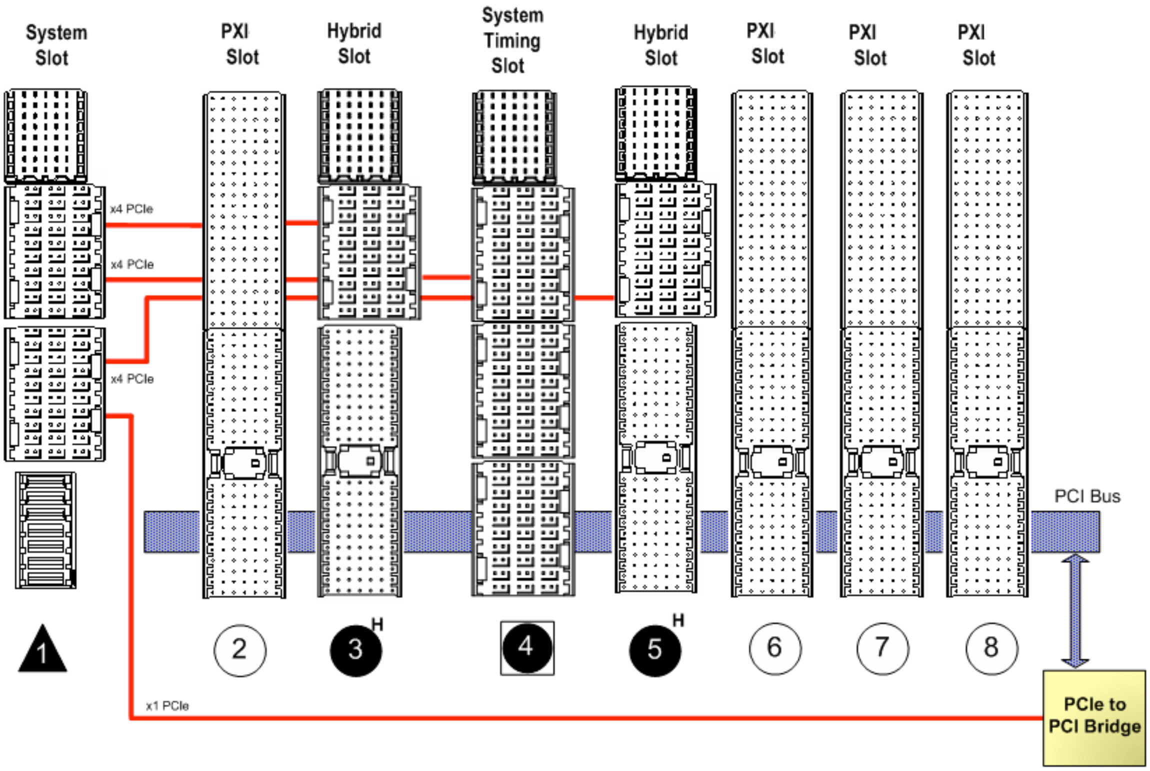


Figure 2. While preserving compatibility with existing PXI modules, this 8-slot backplane adds 3 new high-performance slots at 1 GB/s dedicated bandwidth each.

By taking advantage of the available pins on the high-density PXI backplane, the PXI Express hybrid slots are capable of delivering signals for both PCI and PCI Express. In doing so, these PXI Express hybrid slots provide backward compatibility that is not available with desktop PC card-edge connectors, where a single slot cannot support both

PCI and PCI Express signaling. Thus, you can use the hybrid slot to install a PXI module that uses PCI signaling or a future high-performance PXI Express module that uses PCI Express signaling.

In Figure 3, the diagram of the PXI Express hybrid slot demonstrates how it provides compatibility to both PXI and PXI Express. The P1 and XP4 connectors retain the PCI signaling and PXI timing and synchronization signals of PXI today. Using the new XP3 connector, the hybrid slot provides connectivity for x8 PCI Express as well as pins for additional timing and synchronization.

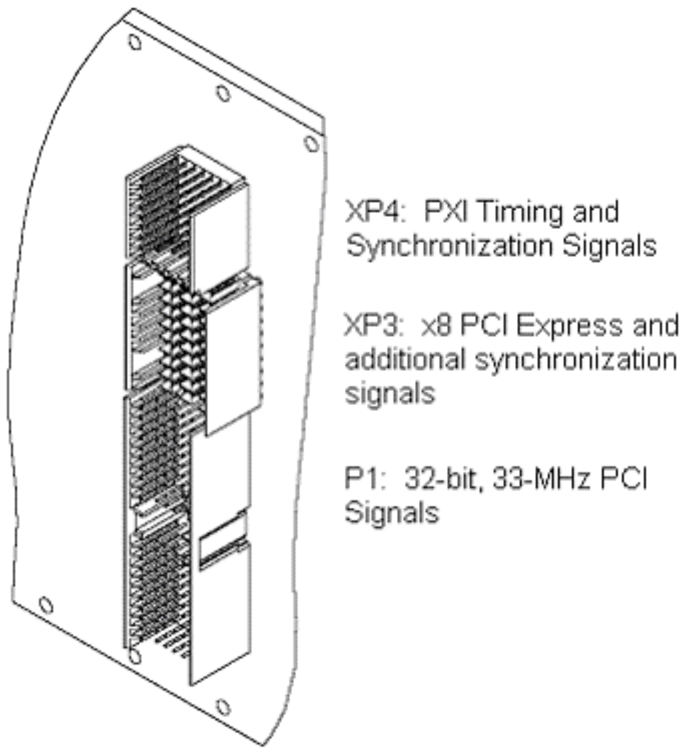


Figure 3. Unlike slots in desktop PCs, the new PXI Express hybrid peripheral slot offers hardware compatibility by using the extra area for pins on the backplane to install modules with either PCI or PCI Express signaling in a single slot.

Maintaining Software Compatibility

In addition to providing hardware compatibility through hybrid slots, PXI Express systems offer software compatibility so you can preserve your investment in existing software. PCI Express software compatibility is guaranteed through the PCI Special Interest Group (PCI-SIG), which includes companies such as Intel and Dell. Because PCI Express uses the same driver and OS model as PCI, the specification guarantees that you have complete software compatibility among PCI-based systems, for example PXI, and PCI Express-based systems, such as PXI Express. As a result, both vendors and customers do not need to change driver or application software for PCI Express-based systems.

By maintaining software compatibility between PCI and PCI Express technology, the specification drastically reduces cost for vendors and integrators to insert new PCI

Express technology into existing test systems. With hardware compatibility provided by the hybrid slot and software compatibility, the cost of adding PXI Express technology is minimal.

Providing Additional Timing and Synchronization Features

PXI Express not only retains the timing and synchronization features of PXI, but it also adds several new synchronization features by taking advantage of the existing differential connectors required in PXI and technological advances that provide higher-performance, low-cost differential signaling. Building on these existing capabilities in PXI, PXI Express provides the additional timing and synchronization features of a differential system clock, differential signaling, and differential star triggers, as shown in Figure 4. By using differential clocking and synchronization, PXI Express systems benefit from increased noise immunity for instrumentation clocks and the ability to transmit at higher-frequency clocks. In addition to helping you improve system performance, high-frequency clocks also match well with modern processes and allow lower-cost products to remove clock multiplication circuits. With the industry's best synchronization and latency, PXI Express improves the measurement accuracy and test time of high-bandwidth applications.

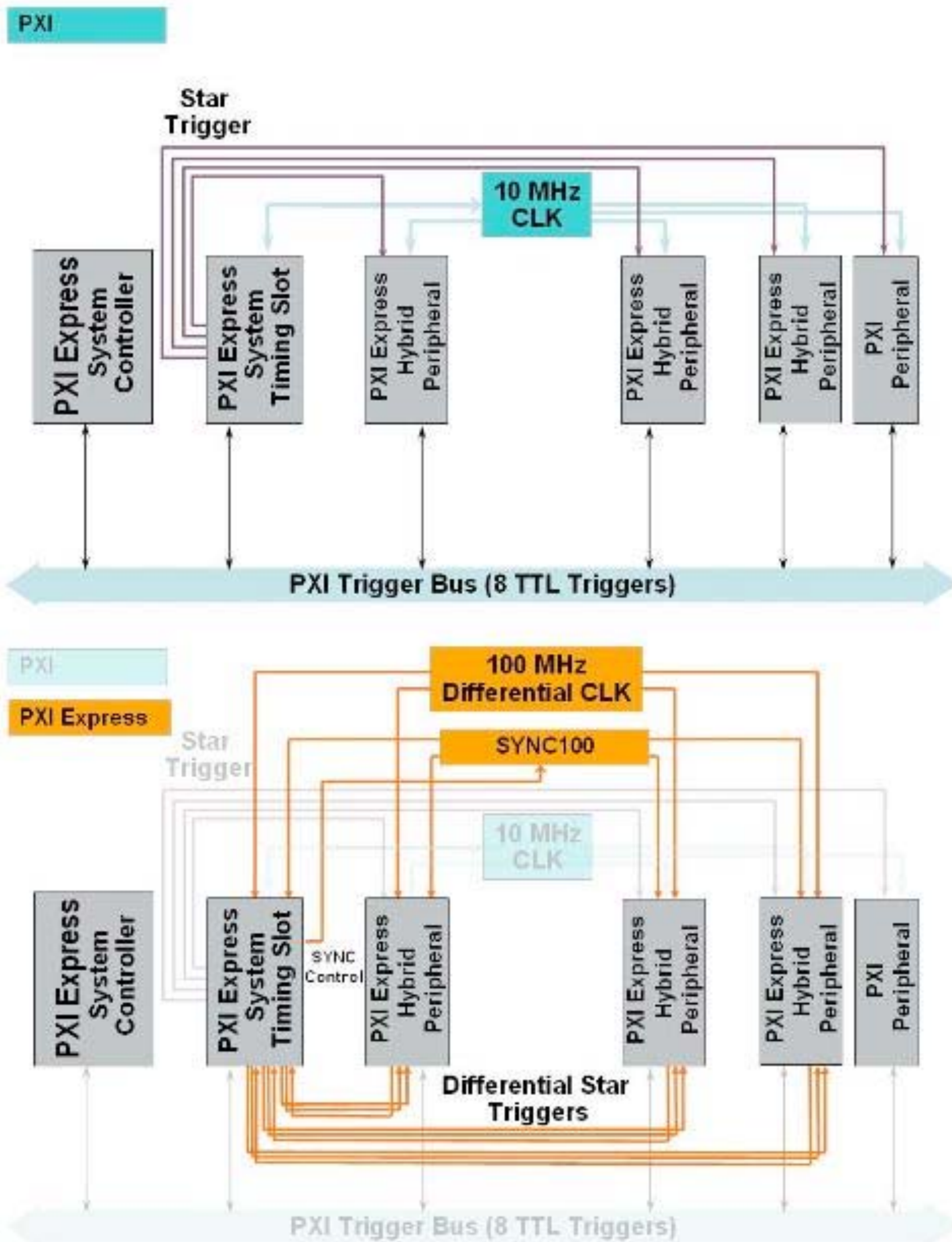


Figure 4. By building on the existing capabilities of the PXI platform, PXI Express provides additional timing and synchronization features to achieve better measurement accuracy.

The Future of PXI

While the integration of PCI Express technology into PXI will allow PXI Express to reach new applications, many existing PXI applications will not benefit from the enhanced performance of PXI Express. For example, hardware such as digital multimeters, switches, industrial I/O, bus interfaces, and many mainstream generators and analyzers will not benefit from the additional backplane bandwidth. Thus, one of the most valuable aspects of the PXI Express specification is its ability to route both PCI and PCI Express signaling to new slots. As a result, you should not expect instrument manufacturers to redesign all current boards for PXI Express; rather, many instrument manufacturers will continue to base PXI products on PCI signaling because the current PCI architecture serves the need and PCI signaling is provided to all slots.

Expected Timeline for PXI Express

The PXI Express specification passed in September 2005. As a result, you can expect to see the first PXI Express chassis, controllers, and modules featuring hybrid peripheral slots to enter the market in 2006. With these new high-performance PXI Express products, you can benefit from solutions for many new applications including high-frequency tests, high-speed digital interfaces, and high-speed imaging applications. At the same time, the compatibility of PXI Express also guarantees the growth of the current PXI architecture with new product releases to ensure the future success of the PXI platform.

References

[1] *CompactPCI Express PICMG EXP.0 R1.0 Specification*, PCI Industrial Manufacturers Group, July 27, 2005.

[2] *PXI-5 PXI Express Hardware Specification Revision 0.5*, PXI Systems Alliance, July 15, 2005.

[3] G Caesar, *PXI Embraces New Commercial Standards*, Instrumentation Newsletter, Q2 2005. http://ni.com/news/inst_news_q2_05.htm

[4] J Titus, *PXI gets the Express Treatment,* ECN, July 1, 2005. http://www.ecnmag.com/article/CA623714.html

[5] L Gutterman, *PXI Express?,* PXI Technology Review, Spring 2005. http://www.pxionline.com/columns/PXISA/

[6] *Introduction to PCI Express,* National Instruments. http://zone.ni.com/devzone/conceptd.nsf/webmain/605EFE8126ED4DB686257014006BC124

4. Developing a PXI/PXI Express Module

Step 1: Depending on whether you are developing a PXI or PXI Express module, collect the necessary specifications.

Step 2: Specifications

PXI Required Reading

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PXI Systems Alliance (www.pxisa.org)
PXI Software Specification (Latest Revision)
PXI Hardware Specification (Latest Revision)

PCI/PCI Express Specifications (www.pcisig.org)
PCI Local Bus Specification, Rev. 2.3

CompactPCI/PCI Express Specifications (www.picmg.org)
PICMG 2.0 R3.0 CompactPCI Specification

System Software (www.vxibus.org)
VXI*plug&play* Specifications (VPP-3.x and VPP-7)

Environmental/Regulatory Specifications (www.iec.ch)
IEC 61326-1:1997, Electrical equipment for measurement, control, and laboratory use—EMC requirements—Part I, General requirements, International Electrotechnical Commission
IEC 1010-1:1990 + A1:1992, Safety requirements for electrical equipment for measurement, control, and laboratory use—Part 1, General requirements, International Electrotechnical Commission
IEC 60068-1, Environmental testing, International Electrotechnical Commission

The above readings may refer to several documents with which you may need to become familiar. Please refer to the latest revision for all specifications

PXI Express Required Reading

PXI Systems Alliance (www.pxisa.org)
PXI Express Specification (Latest Revision)
PXI Software Specification (Latest Revision)
PXI Hardware Specification (Latest Revision)

PCI/PCI Express Specifications (www.pcisig.org)
PCI Local Bus Specification, Rev. 2.3
PCI Express Base Specification 1.1
PCI Express Card Electromechanical (CEM) Specification 1.1

Compact PCI/PCI Express Specifications (www.picmg.org)
PICMG 2.0 R3.0 CompactPCI Specification
PICMG EXP.0 CompactPCI Express Specification

System Management Bus Specification (www.smbus.org)
System Management Bus (SMBus) Specification, Version 2.0

System Software (www.vxibus.org)

VXI*plug&play* Specifications (VPP-3.x and VPP-7)

Environmental/Regulatory Specifications (www.iec.ch)
IEC 61326-1:1998, Electrical equipment for measurement, control, and laboratory use—EMC requirements—Part I, General requirements, International Electrotechnical Commission
IEC 1010-1:1990 + A1:1992, Safety requirements for electrical equipment for measurement, control, and laboratory use—Part 1, General requirements, International Electrotechnical Commission
IEC 60068-1, Environmental testing, International Electrotechnical Commission

The above readings may refer to several documents that the user may need to become familiar. Please refer to the latest revision for all specifications.

Step 3: Interfacing with the PCI/PCI Express bus.

The PXI/PXI Express Developer Kit is available through PLDA and PLX.

PLDA PXI and PXI Express Products

PXIe XpressLite CY2 Development Kit: A Complete Production-Ready or System Prototyping Solution

For 10 years, PLDA has designed and sold a wide range of ASIC and FPGA interfacing solutions (IP controllers and prototyping boards) for PXI, PXI Express, PCI Express, and derivative protocols. The company, which has more than 1,000 satisfied customers, was recently named "The largest provider of IP cores for the logical and transport layers of PCI, PCI-X, and PCI Express," according to *A Guide to High-Speed Interconnects*, published by The Linley Group Inc. in 2006. Visit PLDA at www.plda.com.

The PXIe XpressLite CY2, a PXI Express x1 endpoint add-in module based on Altera's Cyclone II FPGA, is designed for direct system implementation as well as prototyping. You can easily and quickly integrate PXIe XpressLite CY2 into a production environment. *Getting Started: A Case Study* (www.plda.com/download/pxi/getting_started_case_study.doc) explores a typical integration, including an assessment of needs and resources, the development of an application-specific daughter card that extends the PXIe XpressLite CY2, adaptation of the furnished Reference Design for a specific task, and the development of a LabVIEW environment. Depending on the complexity of your needs, you can adapt the PXIe XpressLite CY2 to a particular task within weeks in such fields as high-speed imaging, streaming communication, real-time signal processing, data acquisition, and module instruments.

The PXIe XpressLite CY2 is a complete and low-cost solution. The module, which includes a free PXI Express IP controller and testbench, features the Philips PX1012A-EL1 PHY. Additional deliverables include a Software Development Kit, complete technical documentation, and technical support provided directly by the design team.

The module is based on Altera's low-cost Cyclone II (EP2C50 standard configuration) and includes a x1 PXI Express male connector, a Mictor connector for probing, and a prototyping matrix for daughter card extensions (Santa Cruz). It also has LEDs and switches, to simplify development, and is programmable via a JTAG connector or the EPCS16 (AS configuration).

The market-proven PCI-SIG-compliant IP controller includes embedded processing and memory resources, but it still maintains up to 90 percent of FPGA resources for the client design. The IP implements a PCI-like back end, offering the strengths of the PCI Express technology while hiding the complexity of the protocol. Configuration of the IP controller is simple with the included IP wizard.

The XpressLite family of modules, which has shipped more than 20 times since Q1 2006, is proven PCI-SIG-compliant, as is the integrated PXI Express IP controller. The PXIe XpressLite CY2 has undergone extensive testing, and the Philips PHY is proven interoperable.

The PXIe XpressLite CY2 is shipping now. For more information, please visit: www.plda.com/products/board_pxie_cy2.php or www.plda.com/sales/niweek2006.php, or contact sales@plda.com.

PXI Development Boards: **CPCI SYS** and **CPCI10K-PROD**

PLDA offers two PXI-based development boards; the CPCI SYS and the CPCI10K-PROD, both based on Altera's FLEX FPGA. Please visit
www.plda.com/products/board_compactpci.php
for technical details and a comparison of the two boards.

The CPCI SYS and CPCI10K-PROD are shipping now. For more information, please contact sales@plda.com.

PLX PCI Express Products

PLX PEX 8311 CompactPCI Express/PXI Express Development Kit: A CompactPCI Express/PXI Express RDK for Easy Migration from CompactPCI/PXI to PCI Express

PLX Technology Inc. (www.plxtech.com), based in Sunnyvale, Calif., is a leading supplier of PCI Express and other standard I/O interconnect silicon to the communications, server, storage, embedded-control, and consumer industries. The PLX solution provides a competitive edge to customers through an integrated combination of partnerships and high-performance silicon, hardware, and software design tools. With these innovative solutions, PLX customers can develop equipment with industry-leading performance, scalability, and reliability. Furthermore, the combination of PLX product features and supporting infrastructure help customers deliver their designs to market faster. PLX PCI, PCI-X, PCI Express, and USB devices are designed into a wide variety of applications across multiple industries. In addition to its headquarters in the United States, PLX has offices in China, Japan, Taiwan, and the United Kingdom, while also supporting customers through distributors, sales representatives, and an on-demand customer-relationship-management system.

The PLX PEX 8311 PXIe Development Kit uses the PEX 8311 local bus-to-PCI Express bridge device. The PEX 8311 is the newest bridge in the PLX ExpressLane family, the most complete line of PCI Express switching and bridging devices available. The PEX 8311 is the industry's only bridging device dedicated to upgrading standard local-bus embedded designs and providing a smooth migration path from PCI to PCI Express. The feature-rich bridge offers the power and flexibility of PCI Express to embedded designs spanning the video, imaging, communications, and industrial control markets. The PEX 8311 provides efficient conversion between a parallel, low-overhead local bus and a serial, packed-based PCI Express interconnect, so customers can add a scalable, high-bandwidth interconnect to a wide variety of root complex- or endpoint-based applications.

The PLX PEX 8311 PXIe RDK provides a comprehensive array of tools to begin new CompactPCI Express/PXI Express designs or migrate existing CompactPCI/PXI devices. In addition to the PEX 8311 reference board, the kit includes schematics, layout files, bill of materials, and Gerber files.

The PEX 8311 is ideal for applications such as medical, industrial, automated equipment, video surveillance, image editing, communication, data acquisition, and instrumentation. Find details on the PEX 8311 at www.plxtech.com/products/expresslane/pex8311.asp.

In addition to being in volume production, the PEX 8311 is listed on the PCI-SIG integrators list at
www.pcisig.com/developers/compliance_program/integrators_list/pcie#components

For more information on PLX PCI Express products, visit
www.plxtech.com/products/expresslane/ or contact your local sales person at www.plxtech.com/about/contacts/.

Step 4: Device-Specific Development

Complete your device-specific development complying with the software, electrical, and mechanical specifications. Both PLDA and PLX provide prototyping areas for device development or you can use daughter cards that connect with bus interface modules for device development.

Step 5: Driver Development

You can develop your device driver using customized processes or you can use NI-VISA and the VISA Driver Development Wizard (DDW) to develop a low-level driver for a PXI module. For more information, read Using the VISA Driver Development Wizard and NI-VISA to Register-Level Program a PXI/PCI Device under Windows.

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