Cabled PCI Express as a Standard Interface for Virtual and Synthetic Instruments

Overview

Cabled PCI Express is a cabled serial bus used for high-performance interconnect of system components. It is based on PCI Express and so provides a scalable, high-bandwidth, low-latency bus. In measurement and automation, cabled PCI Express is very appealing to high-performance applications using a host PC for measurement processing and analysis. For example, cabled PCI Express is currently used to connect a host PC to a PXI (PCI eXtensions for Instrumentation) chassis with sustained transfer rates of nearly 800 Mbytes/s. The high performance, low cost, and easy connectivity of cabled PCI Express makes it ideal for a number of measurement applications, and therefore, its applications is expected to expand to serve more applications in the future. This paper examines cabled PCI express technology and both its current and future application in measurement and automation systems.

What Is Cabled PCI Express?

Cabled PCI Express is the next generation peripheral bus for servers, desktops, and laptops. Cabled PCI Express will have the following advantages:
- Wide use in standard PCs means low implementation costs
- High bandwidth – 4 Gigabytes / second
- Low latency – 300-700 nanoseconds
- Application software and operating systems run without changes due to no software changes from PCI model
- At least 15 standardized form factors including cabled PCI Express
- Only standard that is designed for chip-to-chip, board-to-board, and box-to-box applications

Cabled PCI Express is being defined by the PCI-SIG standards body as an extension of the PCI Express Base specification. Extending PCI Express from box-to-box and over longer distances is the goal of cabled PCI Express. Cabled PCI Express provides a simple yet high-performance bus for expanding PC and measurement I/O. Some commercial applications of cabled PCI Express include interfaces on laptop or small form factor PC to connect peripherals to laptops and split-system desktop PCs that can move the CPU box under the desk while keeping user I/O easily accessible on top of it. The cabled PCI Express specification anticipates cables up to 7 meters long and still meet the PCI Express timing requirements. It is nearing completion with the final release expected in the fall of 2006.

Products Available

National Instruments, as a leading innovator in applying commercial technology to test and measurement applications, provides a line of remote controllers to connect VXI and PXI chassis to PCs, called MXI (Multiplatform eXtensions for Instrumentation). The first MXI product, MXI-1, was used to connect VXI mainframes to PCs in 1991. The latest products, MXI Express, use cabled PCI Express to connect a PXI chassis to a host PC. MXI Express remote controllers are available now in x1 to connect to a PXI chassis and x4 configurations provide up to nearly 800 MB/s of sustained throughput to PXI Express chassis. There is both a PCIe (see Figure 1) and ExpressCard (see Figure 2) host interface for use with desktops and laptops, respectively. The primary purpose of using cabled PCI Express in MXI Express was to take advantage of the higher performance, form factor options and lower costs of PCI Express.

Figure 1. NI MXI Express uses cabled PCI Express to connect a PC to PXI

The x1 MXI Express form factor shown above uses a PCI Express slot in a desktop PC to connect to a PXI chassis. The ExpressCard form factor shown below supports a x1 cabled PCI Express link to a PXI chassis using the same cables. Thus the PXI module and cables are common to both laptops and desktops allowing for higher reuse.

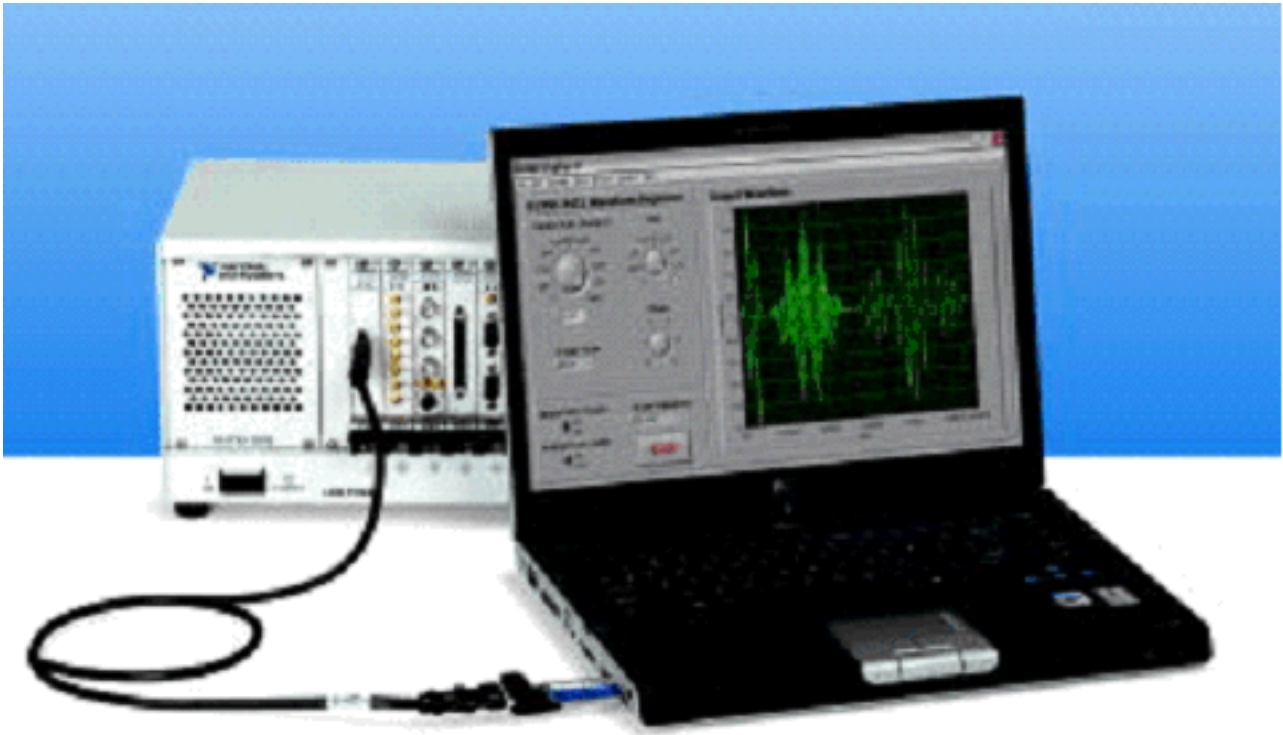# Cabled PCI Express as a Standard Interface for Virtual and Synthetic Instruments

Figure 2. NI MXI Express uses cabled PCI Express to connect a Laptop with ExpressCard to PXI

When MXI-1 first launched in 1991 it provided 10MB/s bandwidth. This was state-of-the-art and used commercial technologies available at that time (see Figure 3). By incorporating cabled PCI Express into the MXI product line can now sustain nearly 800 MB/s.
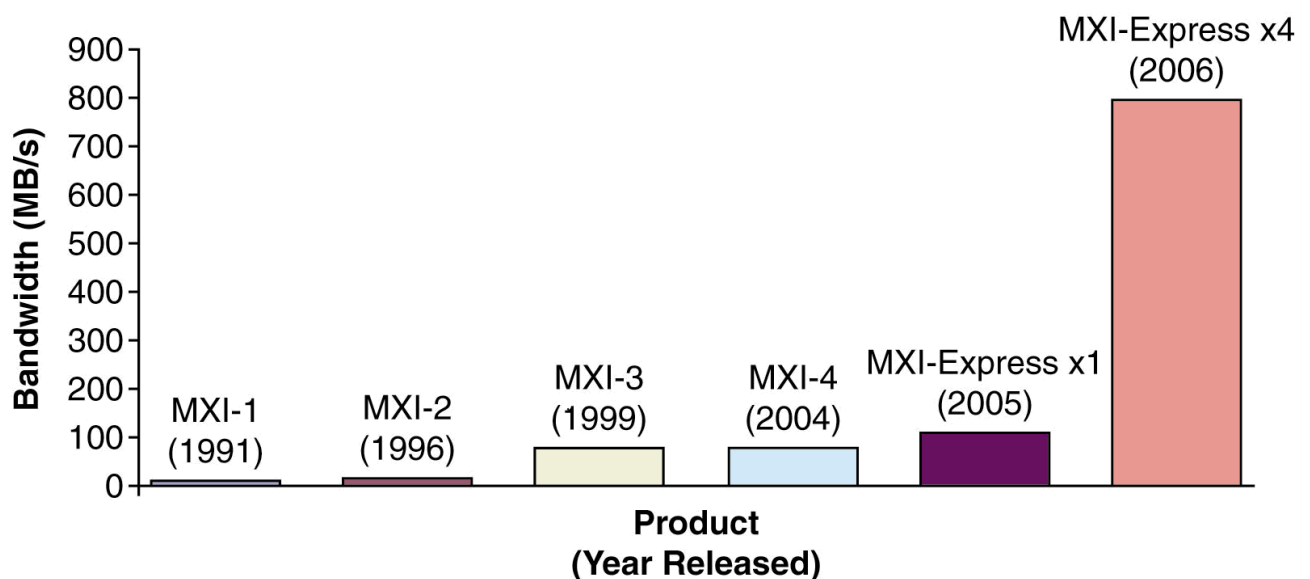
Figure 3. Cabled PCI Express makes MXI Express 80X higher bandwidth than MXI-1

While bandwidth has dramatically increased, the costs of these links have decreased. Figure 4 shows how the price per bandwidth has dropped significantly over the last 15 years.
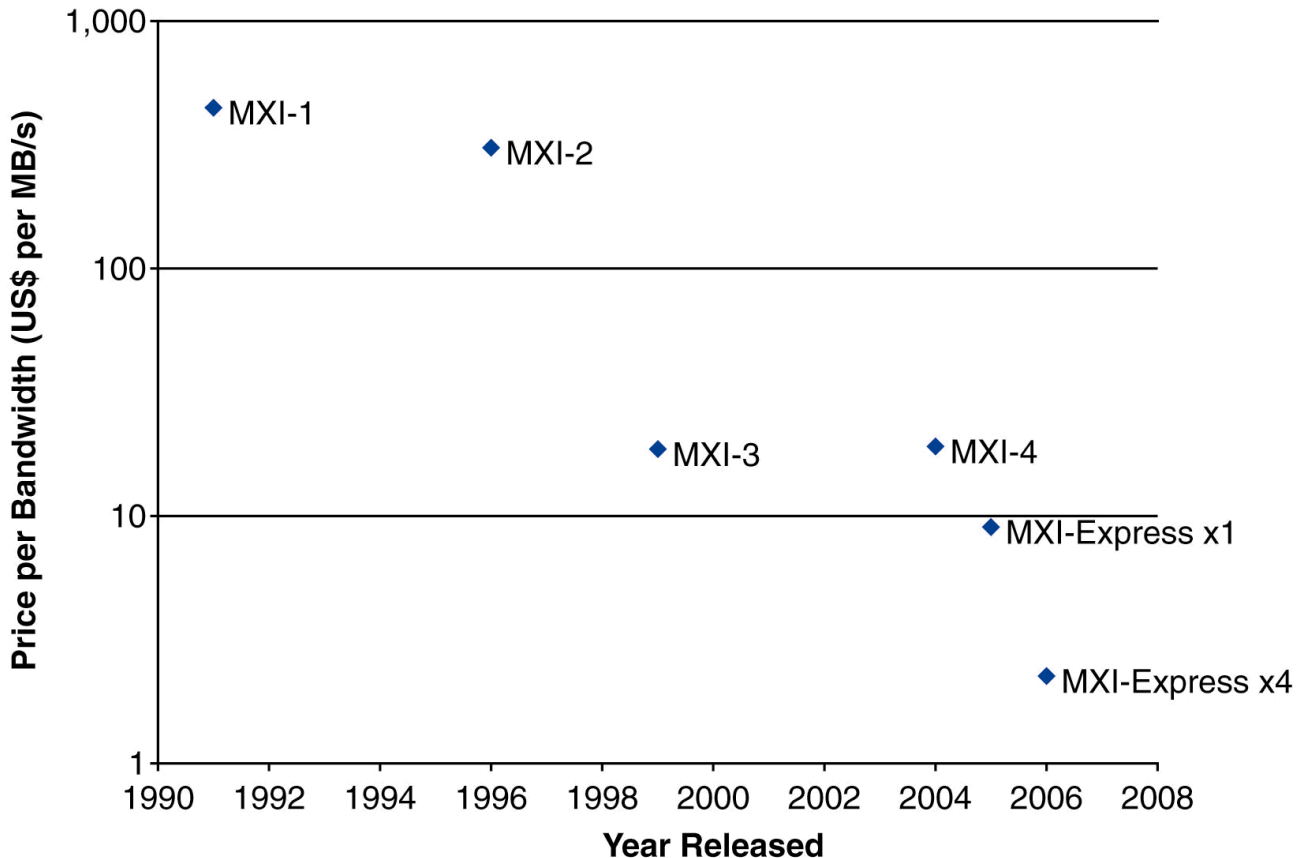

Figure 4: From $450/MB/s to $2.25/MB/s – Cabled PCI Express Helps Decrease Price per Bandwidth

MXI Express x1 for PXI chassis cut the cost per MB/s in half from $19/MB/s to $9/MB/s. MXI Express x4 for PXI Express chassis cut that further to $2.25/MB/s. The cost reductions show the power of adopting commercial technologies and ensure that PXI-based virtual instrumentation will continue to grow into more price sensitive applications.

Software-centric Synthetic and Virtual Instrumentation

Because cabled PCI Express was designed for box-to-box applications it can connect a PC to traditional instruments. As the trend for more software-centric instrumentation increases, the need for a high-speed connection to a host processor is even more important. The US Department of Defense, for example, has coined a term called *synthetic instrumentation*, to describe these software-centric systems. The DoD has created a forum called the Synthetic Instrument Working Group (SIWG) who's role is to define standards for interoperability of synthetic instrument systems. The SIWG defines synthetic instruments (SI) as:

A reconfigurable system that links a series of elemental hardware and software components with standardized interfaces to generate signals or make measurements using numeric processing techniques.

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The focus of the SIWG has been primarily on the SI concepts as applied to RF stimulus and measurement systems. Data intensive applications, like RF testing, require a high-bandwidth, low-latency bus to connect the IF digitizers to the processor (see Figure 5).
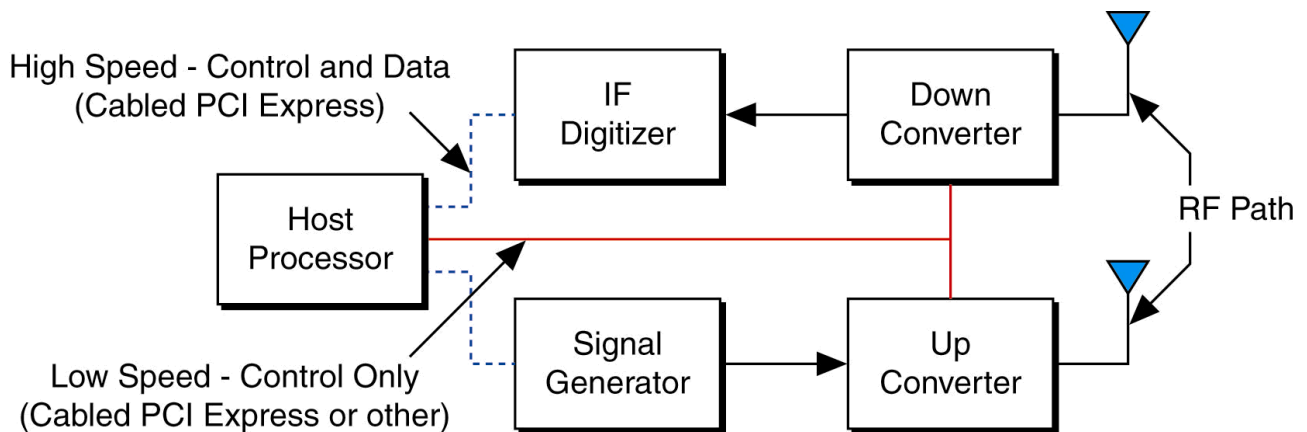

Figure 5. Synthetic Instrument RF Block Diagram

For example, to digitize a 50 MHz wide RF signal requires 100 Mbytes/s of bandwidth (at 2 bytes of resolution per sample). For an input and output channel, this grows to 200 MB/s. And for increasingly common multi-channel, or MIMO (Multi Input, Multi Output) applications, the bandwidth required can quickly scale to multiply gigabytes per second. PCI Express, and cabled PCI Express in particular, is a leading contender for this high speed link because of its excellent technical capabilities, wide commercial adoption, and low-cost infrastructure.

Cabled PCI Express is based on PCI Express and so provides a scalable, high-bandwidth, low-latency bus for chip-to-chip, board-to-board, and box-to-box applications. In the past some data intensive applications couldn't transfer the data fast enough to the host PC and so the data was processed in the box instrument using vendor-defined software and hardware. Cabled PCI Express opens up a new larger and faster pipe to the host PC so more applications can take advantage of user-defined software and hardware for measurement processing and analysis. Today NI uses cabled PCI Express to connect host PCs to PXI chassis with MXI Express. It currently sustains transfer rates of 110 MB/s for a x1 link and 798 MB/s for a x4 link. In the future, cabled PCI Express may offer a compelling bus solution for synthetic instrumentation.

Relevant NI Products and Whitepapers

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Software:
*   NI TestStand Test Management Framework
*   LabVIEW Graphical Programming Environment
*   Signal Express Interactive Measurement Software

Hardware:
*   Modular Instruments (Oscilloscopes, Multimeters, RF, Switching, and more)
*   Multi-function Data Acquisition
*   PXI System Components (Chassis and Controllers)
*   Instrument Control (GPIB, USB, and LAN)

Whitepapers

NI offers a Designing Next Generation Test Systems Developers Guide. This guide is collection of whitepapers designed to help you develop test systems that lower your cost, increase your test throughput, and can scale with future requirements. To read the entire developers guide, you can: Download the PDF (90+ page) version or view the web-version of the Designing Next Generation Test Systems Developers Guide.