The Basics of PXI Express

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PXI Express integrates PCI Express into the PXI backplane. We will first go over the advantages of PCI Express over PCI.

PCI Express was introduced to improve upon 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 between all devices on the bus, PCI Express provides each device with its own dedicated data pipeline. Data is sent serially in packets through pairs of transmit and receive signals called lanes, which enable 250 MBytes/s bandwidth per direction, per lane. Multiple lanes can be grouped together 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, users 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.

When considering the technical merits of alternative buses, bandwidth and latency are two of the most important bus characteristics. Bandwidth measures the rate at which data is sent across the bus, typically in MBytes/s, while latency measures the inherent delay in data transmission across the bus. A bus with high bandwidth would be able to transmit more data in a given period than a bus with low bandwidth. A bus with low, meaning good, latency would introduce less of a delay between the time data was transmitted on one end and processed on the other end. Most users recognize the importance of bandwidth since it affects whether data can be sent as fast as it is acquired and how much onboard memory their instruments will need. Latency, while less observable, has a direct impact on applications such as digital multimeter (DMM) measurements, switching, and instrument configuration, since it affects how quickly a command sent from one node on the bus, such as the PC controller, arrives at and is processed at another node, such as the instrument. PCI Express has excellent bandwidth and low latency compared to PCI.

The main advantages of PCI Express (PCIe) over PCI are the following:

- Software compatibility
- High throughput (up to > 4 GBytes/s)
- Scalable bandwidth
- Dedicated bandwidth per slot
- Peer-to-peer communication
- Long life (20+ years in mainstream market)

Nearly all architectures build upon PCI Express to get to other I/O. Other I/O built upon PCI Express can not be lower latency or higher bandwidth than PCI Express. Systems built on PCI Express give you the greatest flexibility to attach to other I/O.

The next step is to integrate the PCI Express bus into the PXI backplane. The PXI Express backplane integrates PCI Express while still preserving compatibility with current PXI modules, users benefit from increasing bandwidth while maintaining backward compatibility with existing systems.

PXI Express specifies 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 Express backplane, representing more than a 45X improvement in PXI backplane throughput.

By integrating PCIe into the PXI backplane, we can get up to 2 GBytes/sec/direction dedicated bandwidth per slot, up to 6 GBytes/sec/direction to the host, up to 18 GBytes/sec/direction system bandwidth; enhanced synchronization capabilities (100 MHz differential clock and differential triggering); and backwards compatibility.

The first PXI Express chassis will provide PXI peripheral slots. Additionally, 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, the hybrid slot allows you to install a PXI module that uses PCI signaling or a future high-performance PXI Express module that uses PCI Express signaling.

In addition to providing hardware compatibility through hybrid slots, PXI Express systems also provide software compatibility so that engineers can preserve their investment in existing software. PCI Express software compatibility is guaranteed through the PCI Special Interest Group (PCI-SIG) which includes companies like Intel and Dell. Because PCI Express uses the same driver and OS model as PCI, the specification guarantees that engineers 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.

The integration of PCI Express into PXI allows the platform to reach new applications. Examples include the following:

- High frequency, resolution IF / RF systems
- High speed digital interfaces
- High channel count data acquisition
- High speed imaging

However, many existing PXI applications do not benefit from the enhanced performance of PXIe. For example, hardware such as digital multimeters (DMMs), switches, industrial I/O, bus interfaces, and many mainstream generators and analyzers do 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, many instrument manufacturers continue to base PXI products on PCI signaling since the current PCI architecture serves the need and PCI signaling is provided to all slots.

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. 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 allowing engineers to improve the performance of the system, high-frequency clocks also match well with modern processes and allow lower cost products to remove clock multiplication circuits. With excellent synchronization and latency, PXI Express improves the measurement accuracy and test time of high bandwidth applications.

The PXI Express software specification adds system-level management software extensions, such as system-level geographical addressing, slot type / capability identification, and chassis monitoring (temperature, fan speed, etc). It also retains software compatibility with PXI, CompactPCI, and other PCI-based devices.

In summary, PXI Express integrates PCI Express into PXI yielding up to 18GBytes/s system bandwidth, up to 6 GBytes/s backplane to host bandwidth, and up to 2 GBytes/s slot bandwidth. PXI Express maintains backwards compatibility with PXI, both in software and in hardware with hybrid slots and hybrid systems. PXI Express opens new applications to the PXI platform. To view or download the PXI Express specifications, go to www.pxisa.org/Specifications.html.