Using PXI for Complex Data Acquisition Systems

Philip Ehlers
Field Sales Engineer
What Is a Complex Data Acquisition System?

- Unique synchronization needs
- Mixture of different sensor types
- Inline signal processing
- High-speed streaming
PCI eXtensions for Instrumentation

- PCI electrical bus with the rugged, modular, Eurocard mechanical packaging of CompactPCI
- PC-based platform optimised for test, measurement, and control
- Advanced timing and synchronization features
- Support for real-time multicore processors

Real-Time Processor Controller

More Than 1,500 PXI Products Available
Embedded PXI System Controllers

Windows-Based Embedded Controllers
- High-performance
- Integrated peripherals
- Entire system in one chassis

Real-Time Embedded Controllers
- Determinism and reliability with LabVIEW Real-Time
- Select high-performance or low-cost/low-power
- Headless operation

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Remote PXI System Controllers

PC Control of PXI
• Use latest high-performance PCs
  • PCI Express with MXI-Express
  • PCI with MXI-4
• High-speed, software transparent links
  • Up to 110 MB/s sustained throughput
• Build multi-chassis PXI systems
• Copper and fiber-optic cabling options

Laptop Control of PXI
• Use latest high-performance laptop computers
  • ExpressCard with ExpressCard MXI
  • PCMCIA CardBus
• High-speed, software transparent links
  • Up to 110 MB/s sustained throughput
• PXI controllers for portable applications
• Use with DC-powered chassis for mobile systems
PXI Chassis

Chassis Offering

- 4, 6, 8, 14, and 18-slot
- Portable, benchtop, and rack-mount
- AC and DC options
- PXI/SCXI combination chassis with integrated signal conditioning
PXI Products. . . More Than 1,500 and Counting

Data Acquisition and Control
- Multifunction I/O
- Analog I/O
- Digital I/O
- Counter/Timer
- FPGA/Reconfigurable I/O
- Machine Vision
- Motion Control
- Signal Conditioning
- Temperature
- Strain/Pressure/Force/Load
- Synchro/Resolver
- LVDT/RVDT
- Many More. . .

Modular Instrumentation
- Digital Waveform Generator
- Digital Waveform Analyzer
- Digital Multimeter
- LCR Meter
- Oscilloscope/Digitizer
- Source/Signal Generator
- Switching
- RF Signal Generator
- RF Signal Analyzer
- RF Power Meter
- Frequency Counter
- Programmable Power Supply
- Many More. . .

Bus Interfaces
- Ethernet, USB, IEEE 1394
- SATA, ATA/IDE, SCSI
- GPIB
- CAN, DeviceNet
- Serial RS232, RS485
- VXI/VME
- Boundary Scan/JTAG
- MIL-STD-1553, ARINC
- PCMCIA/CardBus
- PMC
- PROFIBUS
- LIN
- Many More. . .

Others
- IRIG-B, GPS
- Direct-to-Disk
- Reflective Memory
- DSP
- Optical
- Resistance Simulator
- Fault Insertion
- Prototyping/Breadboard
- Graphics
- Audio
- Many More. . .

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PXI Adopted by Wide Range of Industries

Consumer Electronics  
Military & Aerospace  
Automotive

Communications  
Semiconductor  
Medical

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Multichassis Synchronization
You Can Achieve Synchronization on PXI in Many Ways

Considerations

• Matched cable lengths
• 2 to 3 cables required
• Limited distance

*For a reference example, search “Structural Test Reference Architecture” on ni.com
You Can Achieve Synchronization on PXI in Many Ways

Signal-Based

Share Physical Clocks/Triggers

Time-Referenced

Share Time

Generate Signals

Clock Discipline

Clock Discipline
PXI Express Clock Discipline Bundle

Timing and Synchronization Module
Clock Discipline

Considerations
• Multiple modules
• Synchronization accuracy

NI PXIe-6674T
NI PXI-6682H
GPS, 1588, IRIG-B
Time Reference

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Large-Channel-Count DAQ Reference Architectures

- NI LabVIEW software templates
- Acquire and log data
- Synchronize chassis
- Support variety of I/O
- Scale to thousands of channels

Diagram showing a master and multiple slave units connected.
EtherCAT Distributed Synchronization

2. Distributed Hardware and Synchronization

Master Time Reference

IEEE 1588

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GPS Distributed Synchronization

2. Distributed Hardware and Synchronization

Master Time Reference

GPS

southerni.com/tetchsym
Hybrid Distributed Synchronization

2. Distributed Hardware and Synchronization

Master Time Reference

GPS

Shared Clocks and Triggers
Multidevice PXI_Clk10

Disciplining: Software

Just three VIs...
Signal Processing

Filter
- error in (no error)
- Lower Cut-Off
- Signal
- error out
- Filtered Signal
You Can Achieve Any Channel Mix With PXI Modularity

Component Durability Testing
You Can Achieve Any Channel Mix With PXI Modularity

Aerodynamic Wind Tunnel Testing

Strain

Vibration

Pressure

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## Signal Conditioning for Common Measurement Types

<table>
<thead>
<tr>
<th></th>
<th>Filtering</th>
<th>Amplification</th>
<th>Excitation</th>
<th>Shunt Calibration</th>
<th>Bridge Completion</th>
<th>Isolation</th>
<th>Cold-Junction Compensation (CJC)</th>
<th>Attenuation</th>
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</thead>
<tbody>
<tr>
<td>Strain Gage</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Force, Pressure, Torque Sensors</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermocouple</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>High Voltage</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>
High-Performance I/O—SC Express

NI PXIe-4844  Optical Interrogator
NI PXIe-449x  Dynamic Signal Analyzers
NI PXIe-433x  Bridge Input Modules
NI PXIe-4353  TC Input Module
NI PXIe-430x  HV Input Module

Strain
Load
Pressure
Temperature
Torque
HV Isolated AI

Acceleration
Temperature
Strain
Load
Pressure
Temperature
Torque
HV Isolated AI

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NI SC Express Key Features

1. Increased Accuracy
   - Up to 24-bit resolution
   - Delta-Sigma A/D converters
   - Anti-aliasing filters per channel

2. High Bandwidth
   - PXI Express – Dedicated bandwidth/device
   - Dynamic strain measurements
   - ADC per channel

3. Best-in-Class Synchronization
   - 100 MHz reference clock built-in chassis
   - ns synchronization with NI-DAQmx multidevice task
   - Automatic synchronization with DSA & NI X Series

4. Easy to Use
   - Same NI-DAQmx driver as DAQ and DSA
   - New bridge channel types in NI-DAQmx
   - Modules & terminal blocks auto-recognized
NI-DAQmx Simplifies the Scaling for a Wide Variety of Sensors

NI LabVIEW

ANSI C

DAQmxCreateAIVoltageChan
DAQmxCreateAIVoltageRMSChan
DAQmxCreateAIThrmcp1Chan
DAQmxCreateAIRTDChan
DAQmxCreateAIThrmstrChanIex
DAQmxCreateAIThrmstrChanVex
Data Streaming

- Hard-Drive Interface
- CPU
- Physical Layer Interface
- ADC/DAC
With Flexibility and High Channel Counts Comes High Data Rates

Architecture of a Typical Data Streaming System

System/Host Computer
- Hard-Drive Interface
- CPU
- Physical Layer Interface
- ADC/DAC

Instrument
- Custom Serial or Parallel ADC/DAC Interface
- Physical Interface to Signal Source/Sink

SATA/SAS
Either Custom or Standard Data Bus
PCI/PCI Express, Ethernet, USB, and So On
Custom Serial or Parallel ADC/DAC Interface
Physical Interface to Signal Source/Sink

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NI PXIe-8133 with NI PXIe-1075 = 5.6 GB/s total system bandwidth (2.8 GB/s Streaming to/from Disk)

RAID allows:
- 12 TB storage
- 800 MB/s read/write

P2P streaming options:
- NI FlexRIO
- Digitizers and Arbs
- RF VSA
The PXI platform is an ideal platform to create large data streaming solutions.

<table>
<thead>
<tr>
<th>Approximate Latency (μs)</th>
<th>Max Bandwidth (MB/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USB 1.1</td>
<td>10</td>
</tr>
<tr>
<td>Fast Ethernet</td>
<td>100</td>
</tr>
<tr>
<td>Gigabit Ethernet</td>
<td>1,000</td>
</tr>
<tr>
<td>USB 2.0</td>
<td>100</td>
</tr>
<tr>
<td>IEEE 1394a</td>
<td>10</td>
</tr>
<tr>
<td>GPIB (HS 488)</td>
<td>10</td>
</tr>
<tr>
<td>GPIB (488.1)</td>
<td>1</td>
</tr>
<tr>
<td>PCI/PXI</td>
<td>0.1</td>
</tr>
<tr>
<td>PCI Express/</td>
<td></td>
</tr>
<tr>
<td>PXI Express (x4)</td>
<td></td>
</tr>
</tbody>
</table>
PCI Express Signaling

- A link is a group of lanes
- Point-to-point high-speed serial
  - 2.5 Gbit/s per lane for Gen 1
- PCI Express provides longevity with Gen 2 and Gen 3
### PCI Express

**The Progression From PCI**

<table>
<thead>
<tr>
<th>PCI Express Feature</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>Significant increase over PCI</td>
</tr>
<tr>
<td>PCI Transparency</td>
<td>PCI software reuse</td>
</tr>
<tr>
<td>Point-to-Point</td>
<td>Not a shared bus, more efficient error correction and detection</td>
</tr>
<tr>
<td>Scalable</td>
<td>Can increase bandwidth by adding more lanes; slots can be unequal—only pay for what you need</td>
</tr>
<tr>
<td>Fewer Pins</td>
<td>Reduces board area and layers; easier PCB routing</td>
</tr>
<tr>
<td>Lower Power</td>
<td>Lower cost and heat</td>
</tr>
</tbody>
</table>
## PCI Express Transfer Rates

<table>
<thead>
<tr>
<th>PCI Express Link</th>
<th>Generation</th>
<th>Theoretical Unidirectional Transfer Rates</th>
<th>Theoretical Bidirectional Transfer Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>x4</td>
<td>Gen 1</td>
<td>1 GB/s</td>
<td>1 GB/s x2</td>
</tr>
<tr>
<td>x16</td>
<td>Gen 1</td>
<td>4 GB/s</td>
<td>4 GB/s x2</td>
</tr>
<tr>
<td>x4</td>
<td>Gen 2</td>
<td>2 GB/s</td>
<td>2 GB/s x2</td>
</tr>
<tr>
<td>x16</td>
<td>Gen 2</td>
<td>8 GB/s</td>
<td>8 GB/s x2</td>
</tr>
</tbody>
</table>
PXI Express for High-Speed Streaming

PXI Express System

NI PXIe-88093

PCIe Bus
8.32 GB/s

NI PXIe-1045

1082

Four x4 PCI Express Links

Total system Slot bandwidth depends on controller/chassis combination.
Data Throughput

- x4 PCI Express
- x1 PCI Express
- PCI (32-bit, 33 MHz)

Total Bus Throughput (MB/s) vs Number of Devices
Inline Signal Processing Software That Takes Advantage of Multicore Technology
“The PXI platform from National Instruments enabled the high-channel-count acquisition because of its synchronisation capabilities, small size and modularity. As the platform adds capabilities with higher-performance instruments and faster data transfer speeds with PXI Express, we can meet future requirements and continue to advance our research.”

Dr. Kohji Ohbayashi - Kitasato University of Japan, Center for Fundamental Sciences
A Wide Variety of Real-World Measurements Require Ever More Data

- Acoustic Holography
- Large-Scale Fatigue Testing
- Noise Mapping
- Design Validation
- Algorithm Prototyping

Acoustic Holography of Maglev Trains in Korea: SM Instruments

Structural Aircraft Testing: SITEM
With Piaggio Aero Industries S.p.A

Noise Mapping: Boeing
Conclusion

1 TO 10,000 SENSORS

USB Single-Channel DAQ
NI C Series
   Wi-Fi, Ethernet, USB
NI CompactDAQ
SCXI
PXI

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Demo
Hardware Setup

• NI PXIe-8133 1.73 GHz Quad-Core PXI Express Controller

• NI PXIe-1062Q PXI Express Hybrid Chassis

• NI PXI-4472 8-Channel Dynamic Signal Acquisition Module

• NI PXIe-4330 8 Ch, 24-Bit, 25 kS/s Bridge Input Module

• NI PXIe-6251 16-Bit, 1.25 MS/s (Max), 1 MS/s (Scanning), 16 Analog Inputs
Questions?