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HIGH-SPEED DATA STREAMING: WHEN AND HOW

Agenda

- **Applications for Data Streaming**
- Hard-Drive Performance
- Disk Formatting and File Placement
- PXI Streaming Architecture
 - Demo 1
- RAID
- File I/O Optimized for Streaming
- PXI Express and Data Streaming
 - Demo 2
- Summary

Streaming

The act of transferring data to or from an instrument at a rate high enough to sustain continuous acquisition or generation.

Motivation for Data Streaming

- Ever-increasing amounts of data
- Record “everything” and play it back later
- DAQ, DSA, vision, modular instruments
- Hard drives: faster, bigger, cheaper!
 - RAID hardware is ubiquitous and inexpensive
 - PCI Express, ExpressCard, USB, 1394, eSATA
- PCI Express provides higher, dedicated bandwidth



Applications Requiring Data Streaming

- RF Recording and Playback
- IF and Baseband Streaming
- Noise Mapping
- Digital Streaming

Spectral
Monitoring :
Chengdu Huari Tele-
communications
Company



RF Record and
playback:
B&B Technologies



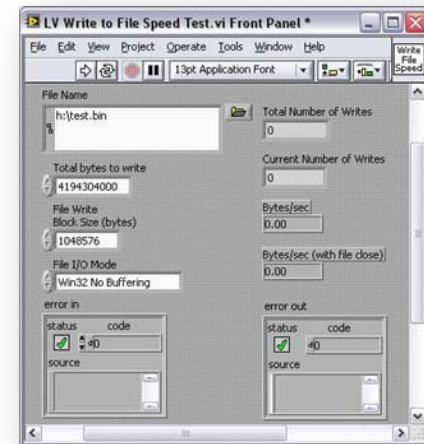
Noise
Mapping:
Boeing



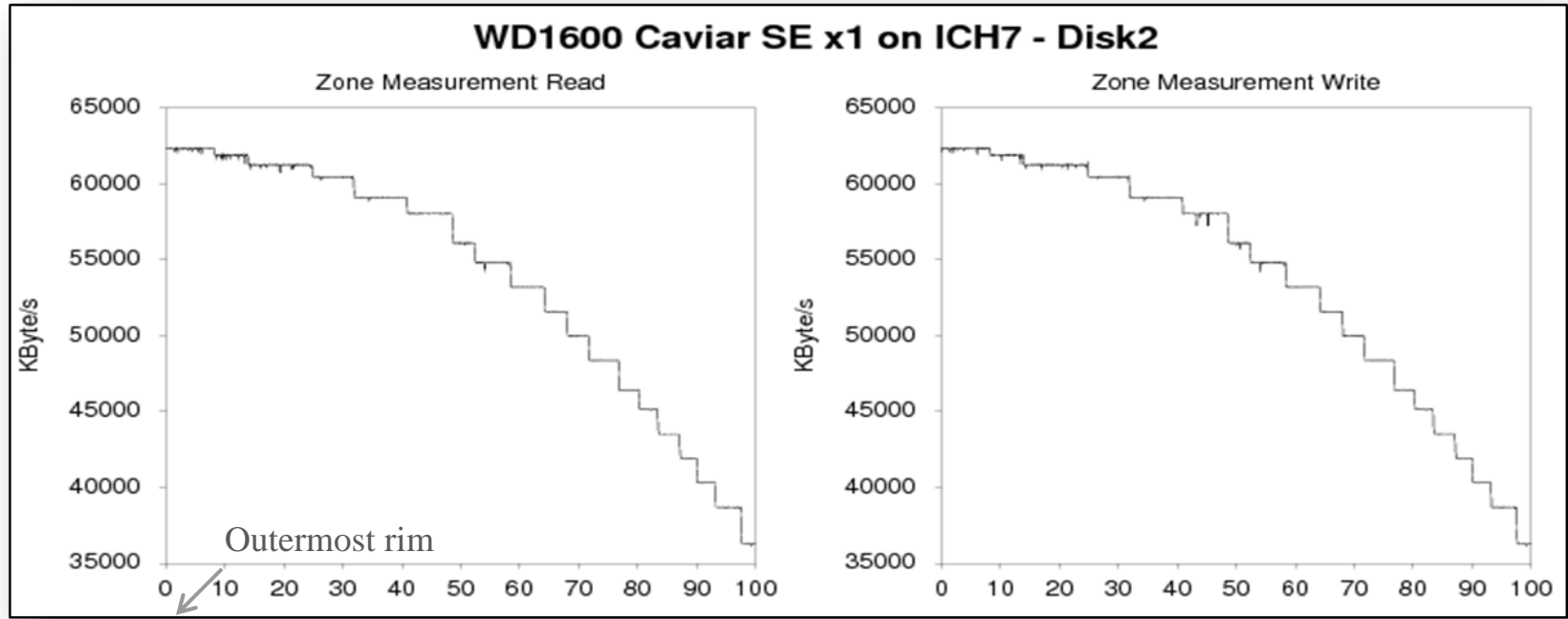
Stream to/from Disk Rates

Drive(s)	Max Rate: Write/Read (MB/Sec)
Laptop	30 (NI PXIe-8103 internal drive; 5400 RPM)
IDE	57 (Western Digital 160 GB; 7200 RPM)
SATA	62 (Western Digital 160 GB; 7200 RPM)
SATA	75 (Seagate Barracuda 7200.10; 250 GB)

- Most hard drive manufacturers do not specify streaming rates
- Specifications beyond the interface (SATA, PATA, IDE, and so on) dictate hard drive performance
 - Seek times (ms), Buffer size (MB), Rotational speed (RPM)
- Benchmarking is the only guarantee



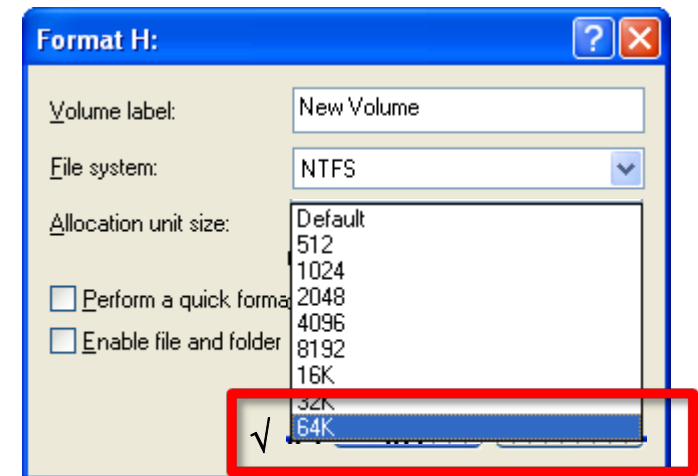
Disk Performance



- Outer rim faster, inner rim slower
- 62 MB/s at outer rim; 36 MB/s at inner rim
- Windows allocates file space from outer rim inwards

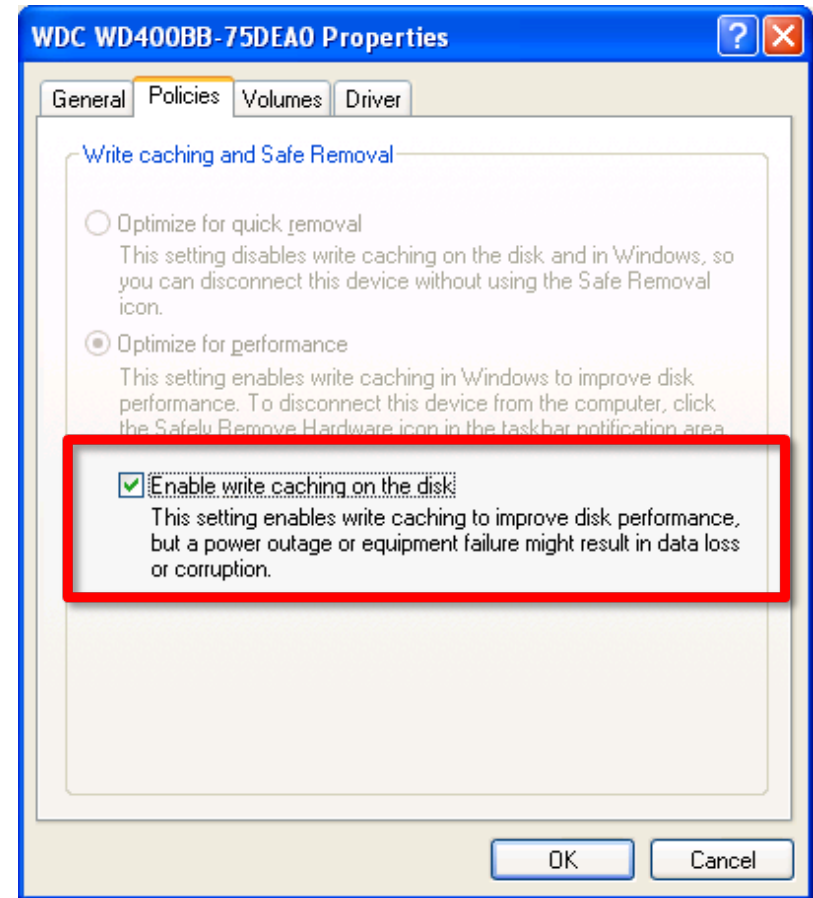
Formatting – Allocation Unit Size

- Computer Management » Disk Management
- Larger cluster sizes provide better streaming performance
 - “Allocation unit size” is the cluster size
- Example (8-drive Streaming Solution):
 - 512 byte clusters
 - 402 MB/s write, 306 MB/s read
 - 64k byte clusters:
 - 452 MB/s write, 445 MB/s read
- Use “quick format”



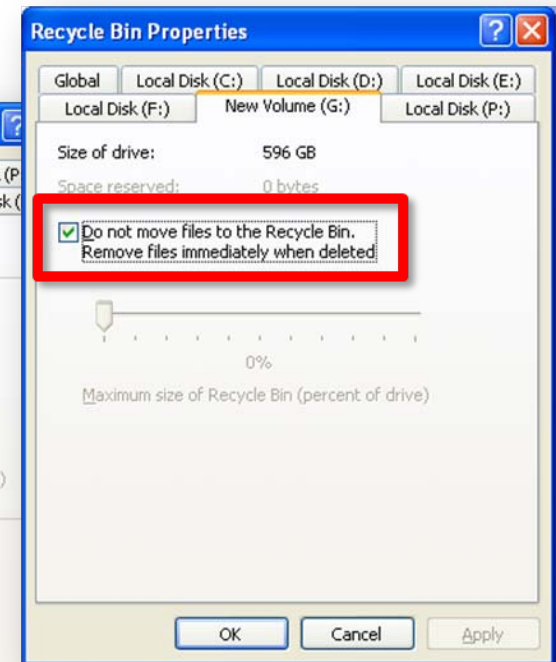
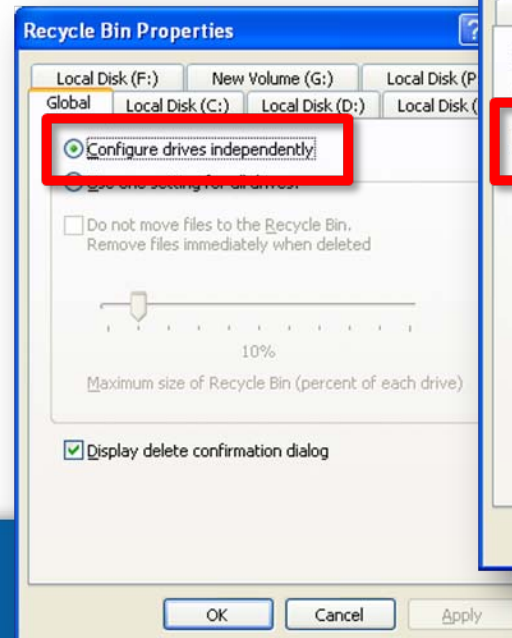
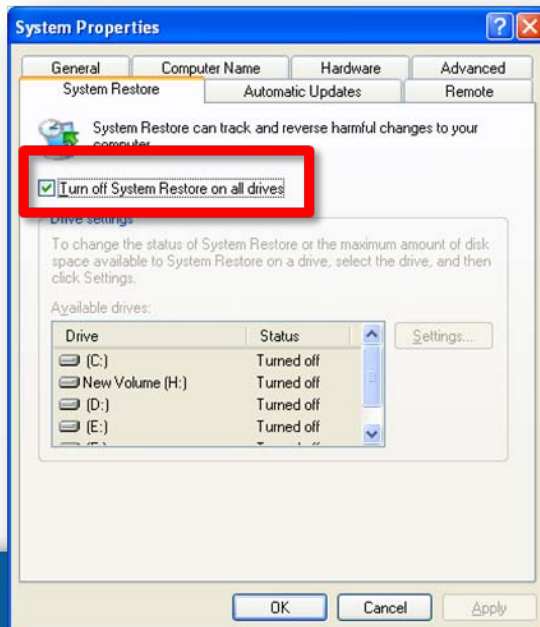
Hard Drive Properties

- Write caching **MUST** be turned on
- By default, it is usually turned on
- Write caching enables the use of the hard drive's onboard buffer



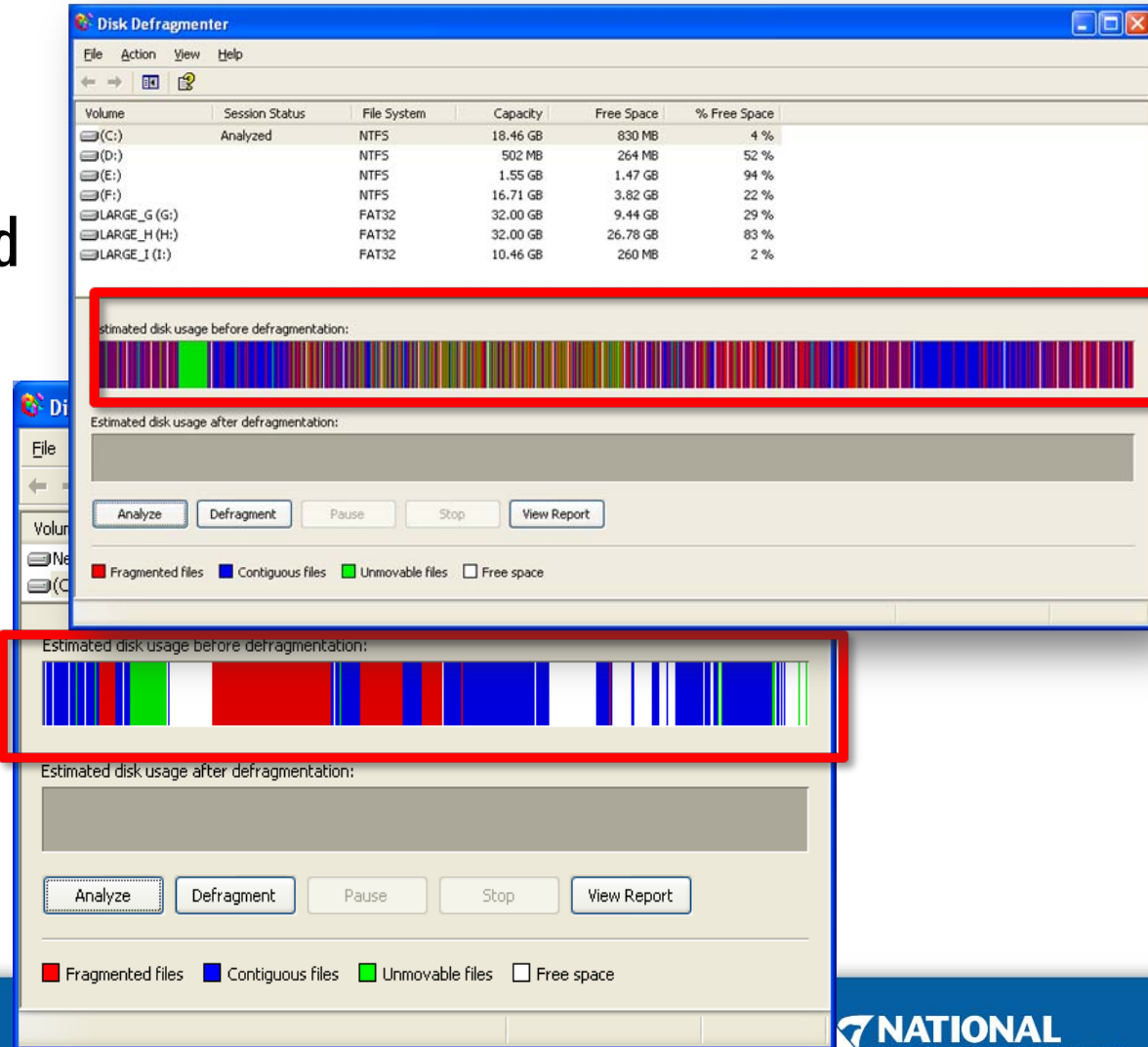
Hard Drive Properties

- Turn off System Restore and Recycle Bin
- These services access the hard drive without your knowledge, which decreases performance



Location on Disk and Fragmentation

- Ideally, the file is at the beginning of the disk and unfragmented
- Start » Programs » Accessories » System Tools » Disk Defragmenter

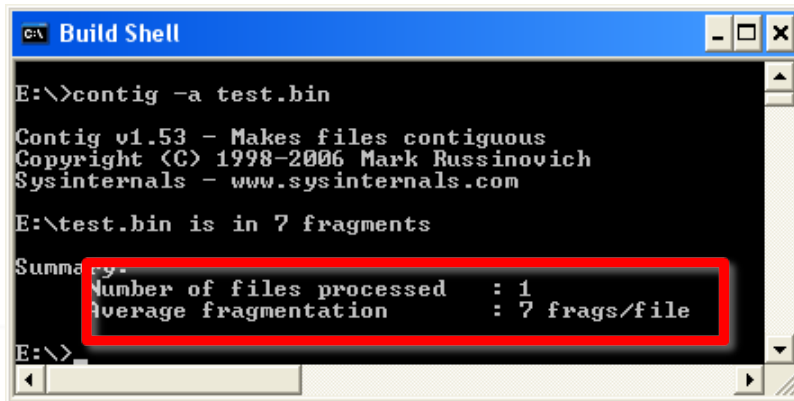


Read from disk

- File 1: 593 fragments
 - Many fragments near outer rim (good)
 - 47.4 MB/s
- File 2: 19 fragments
 - Fragments near inner rim (bad)
 - 57.4 MB/s
- Fragmentation effects can be much more pronounced
 - 18 MB/s → 35 MB/s on single disk after defrag

Fragmentation – Contig Utility

- Contig can be used to:
 - View a specific file's fragmentation
 - Defragment a file or files
 - Preallocate a file for writing to later (avoids on-the-fly file creation)
- SysInternals (www.sysinternals.com)
- Defragments a file but cannot tell you where it is on disk (DiskView)



```
C:\> Build Shell

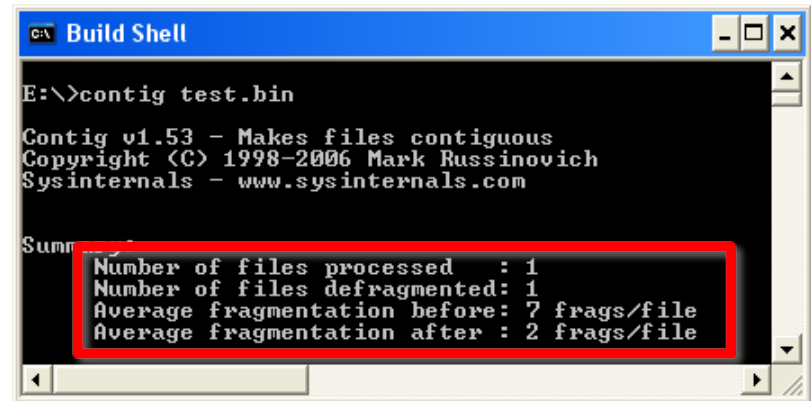
E:\>contig -a test.bin

Contig v1.53 - Makes files contiguous
Copyright (C) 1998-2006 Mark Russinovich
Sysinternals - www.sysinternals.com

E:\test.bin is in 7 fragments

Summary-
Number of files processed      : 1
Average fragmentation         : 7 frags/file

E:\>
```



```
C:\> Build Shell

E:\>contig test.bin

Contig v1.53 - Makes files contiguous
Copyright (C) 1998-2006 Mark Russinovich
Sysinternals - www.sysinternals.com

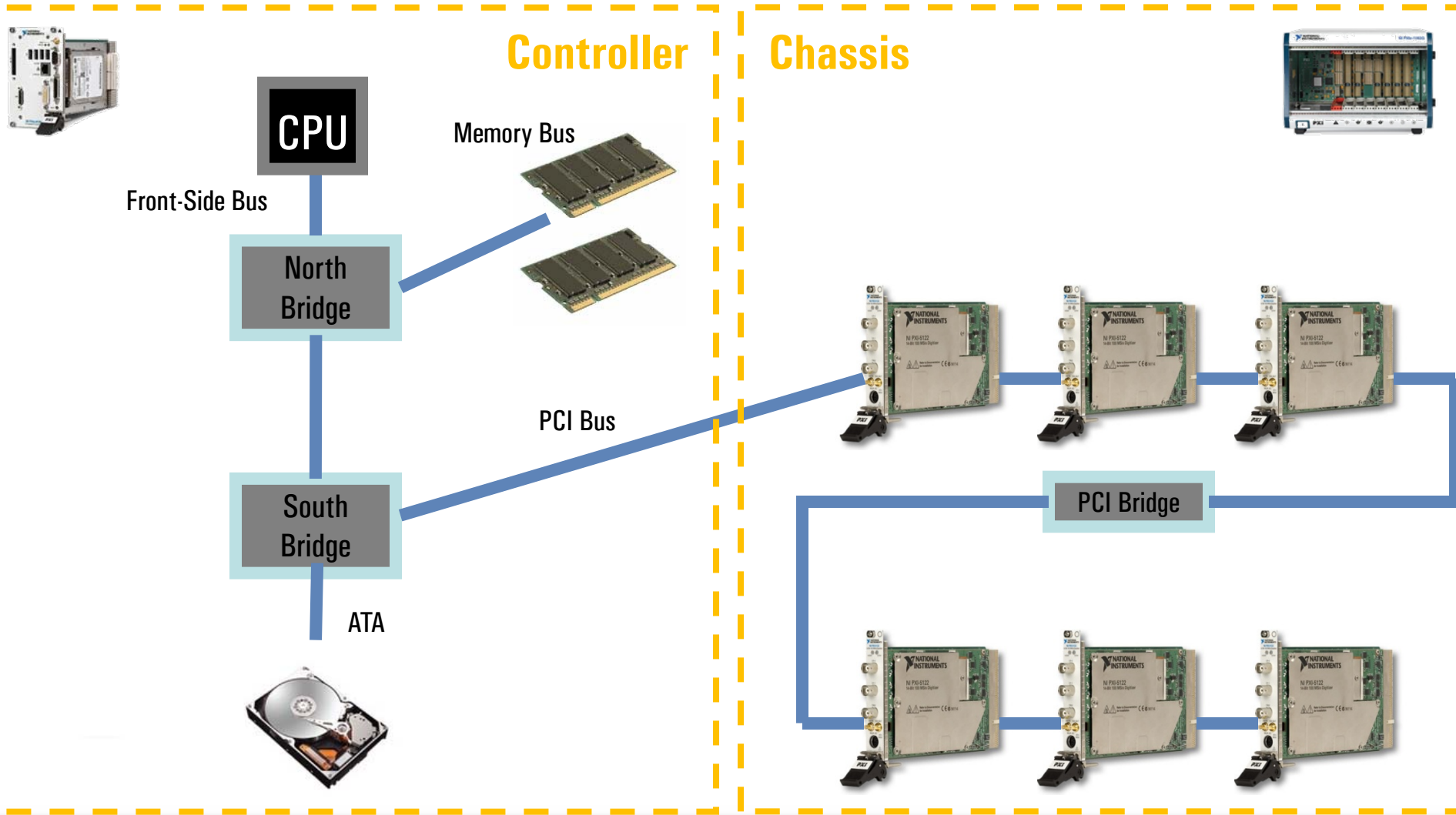
Summary-
Number of files processed      : 1
Number of files defragmented  : 1
Average fragmentation before   : 7 frags/file
Average fragmentation after    : 2 frags/file

E:\>
```

Hard Drive Streaming Performance

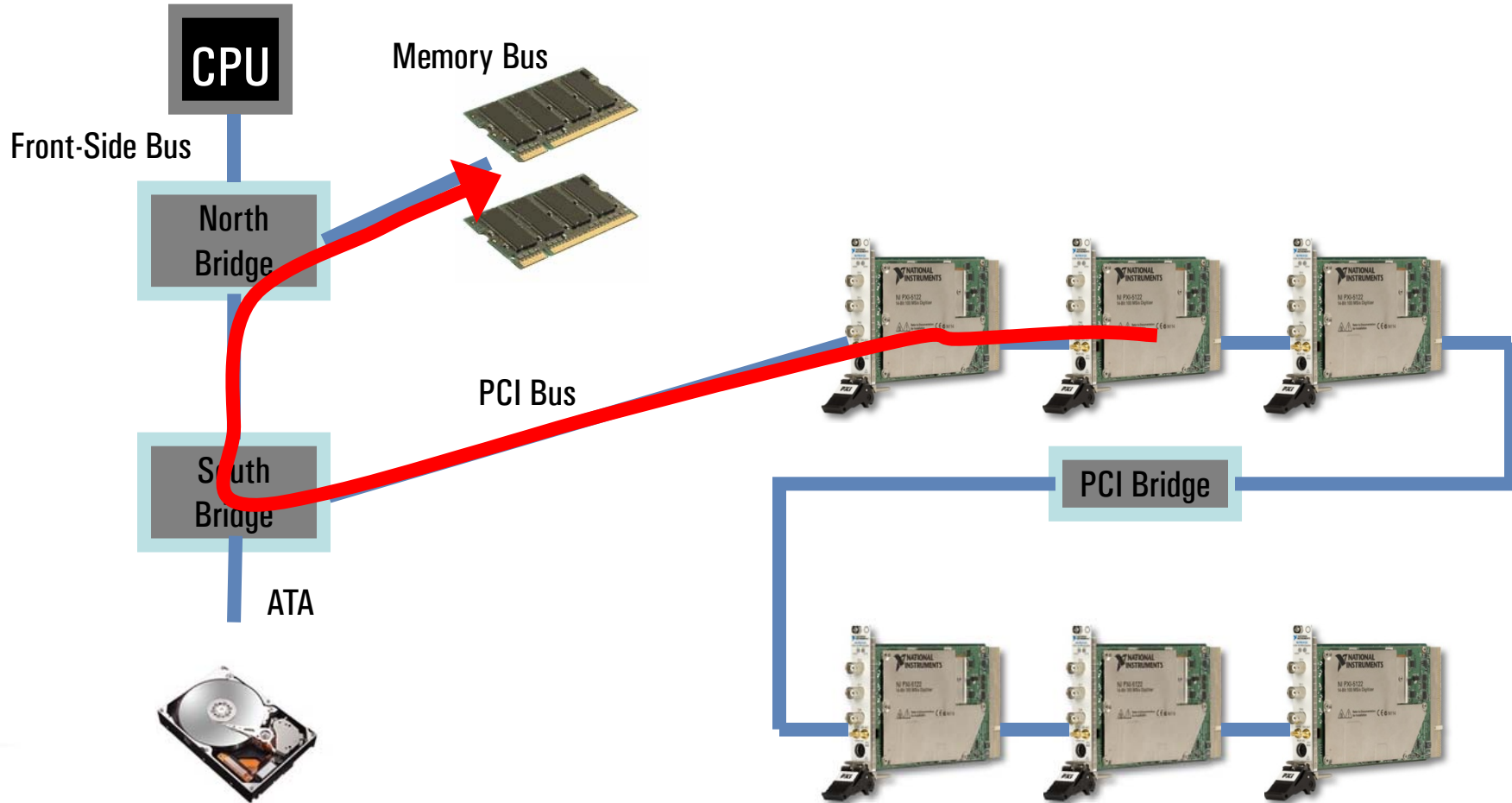
- Dedicate a separate hard drive for data
- Create a partition at the beginning of the hard drive if you do not have another hard drive
 - Reinstall Windows
 - Use a commercial tool (Partition Magic)
- Reformat at will
- Avoid other simultaneous file I/O to this hard drive
- Configure large cluster sizes
 - Allocation unit size
- Preallocate files for writing
 - Contig utility
- Defragment drives and files

PXI Streaming Architecture



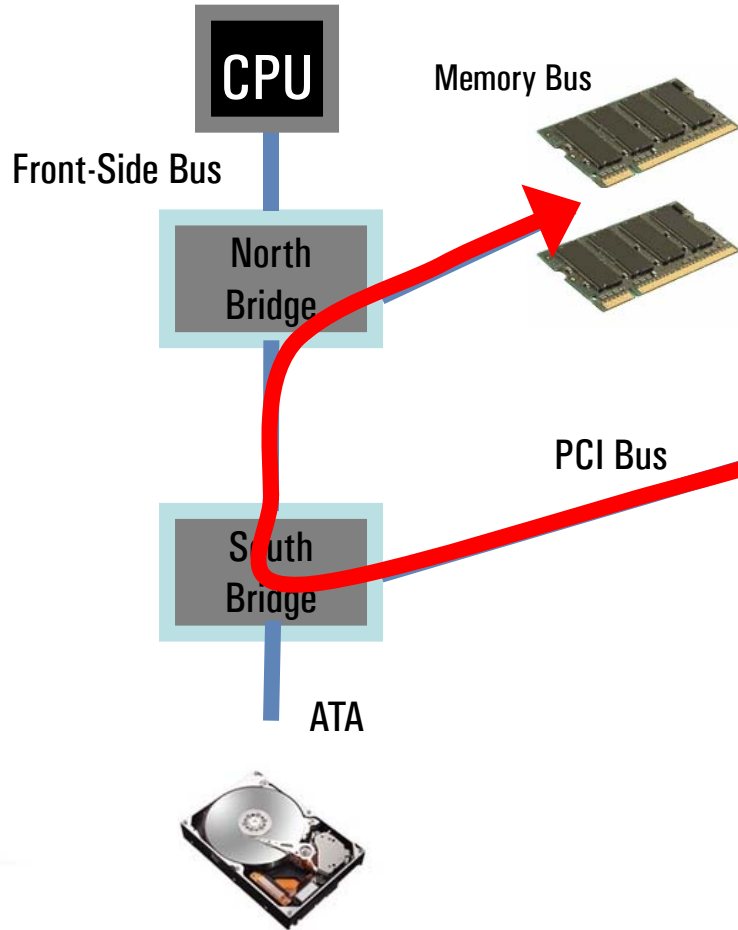
Streaming to/from Controller Memory

Highest controller streaming rates

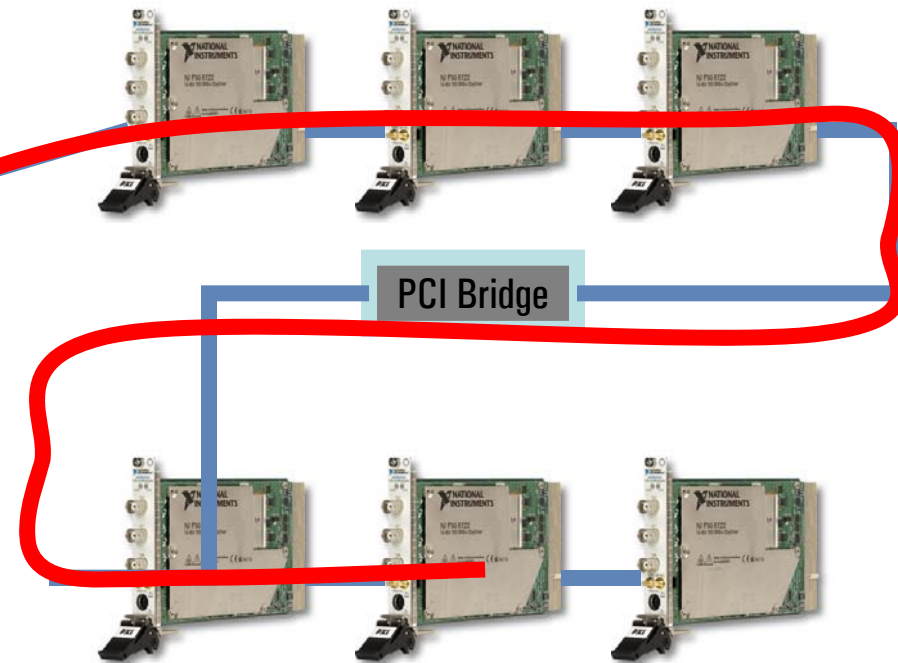


Streaming across PCI Bridges

Reduces streaming rates

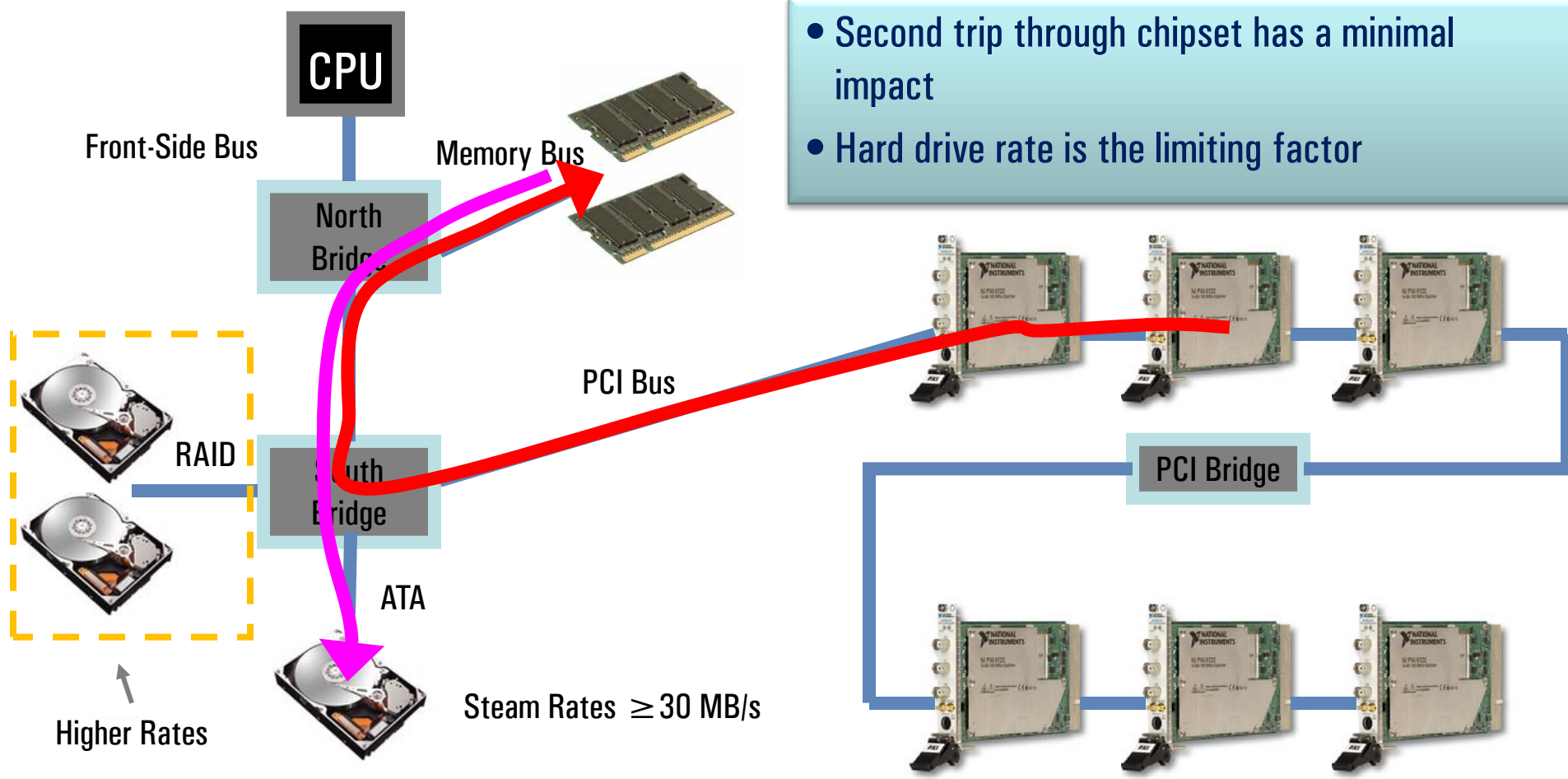


- PXI-1044/5 → 2 bridges (3 segments)
- MXI-Express → 1 bridge
- Input sees a minimal impact
- Output rates drop 20 and 40% per bridge

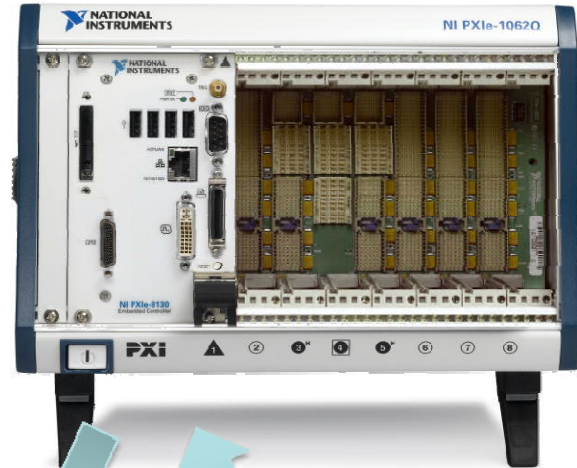


Streaming to/from Controller Hard Drives

High capacities, lower streaming rates



Demo!



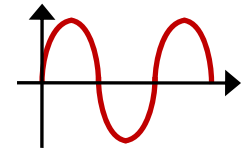
NI 8264 and 8262
3 TB RAID and x4 Cabled PCI
Express



NI PXIe-5122
100 MS, 14-Bit Digitizer

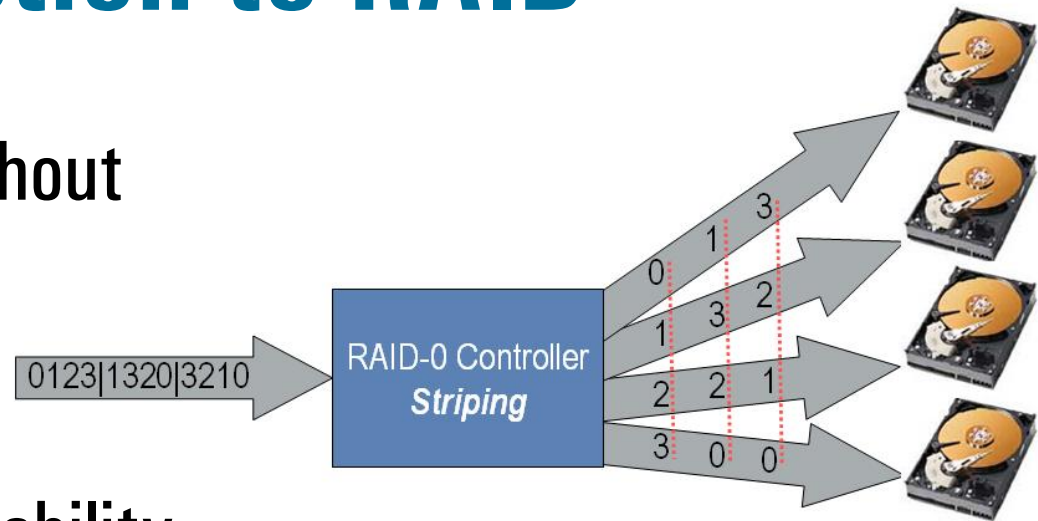


NI PXIe-5442
100 MS, 16-Bit Arbitrary
Waveform Generator



Introduction to RAID*

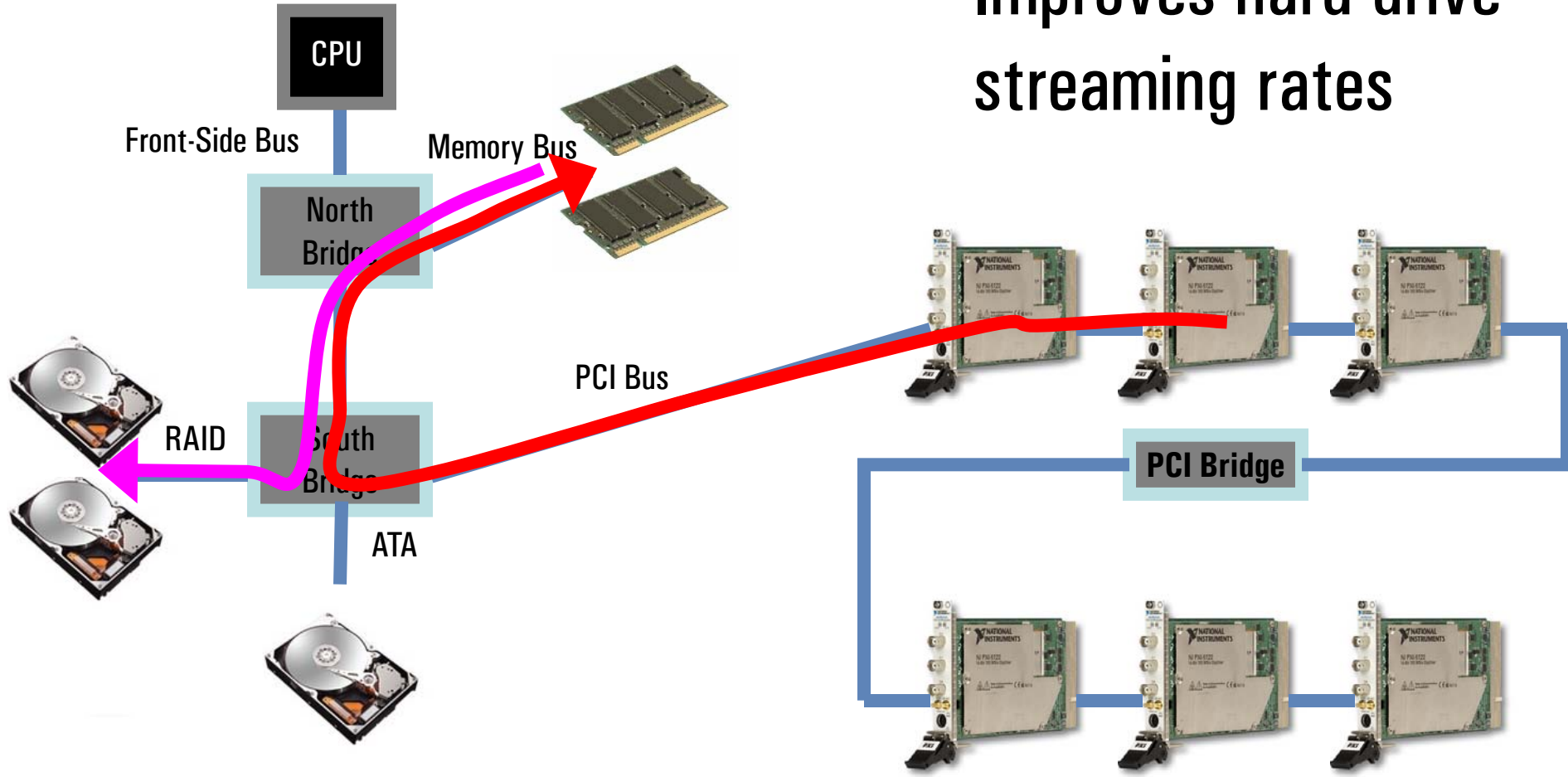
- RAID-0 → Striping without redundancy
- Improved speed
- Unimproved system reliability
- Transparently supported by Windows
- Make RAID-0 stripe size as large as possible



*Redundant Array of Inexpensive Disks

Streaming to/from RAID 0 Hard Drives

Improves hard drive streaming rates



RAID Levels

- RAID 0 – striped (performance)
- RAID 1 – mirrored (redundancy)
- RAID 5 – striped with parity (performance, redundancy)
 - Capacity is $(n-1) \times \text{capacity}$ (minimum 3 drives)
 - Writes are slower than reads
- RAID 6 – striped with 2D parity
 - Capacity is $(n-2) \times \text{capacity}$
 - Very poor write performance
- RAID 2, 3, 4, 7, 10, 53, 0+1
 - <http://linux.cudeso.be/raid.php> (good descriptions)

Stream to/from Disk Rates

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IDE	57 (Western Digital 160 GB; 7200 RPM)
SATA	62 (Western Digital 160 GB; 7200 RPM)
SATA	75 (Seagate Barracuda 7200.10; 250 GB)
2 RAID	114/127 (NI PXI-8351 1U Rack-Mount Controller)
4 RAID	243/240 (PCI Express x4 HighPoint 2320 RAID Controller)
8 RAID	448/439 (PCI Express x4 HighPoint 2320 RAID Controller)
8 RAID	370/374 (PCI Express x4 Promise)
12 RAID	600 + / 700 + (NI 8262 RAID Controller)

Outer rim rates. Cannot be sustained across the whole drive.

NI PXI Express Data Streaming Solutions

NI 8263

4-drive RAID



NI 8264

12-drive RAID



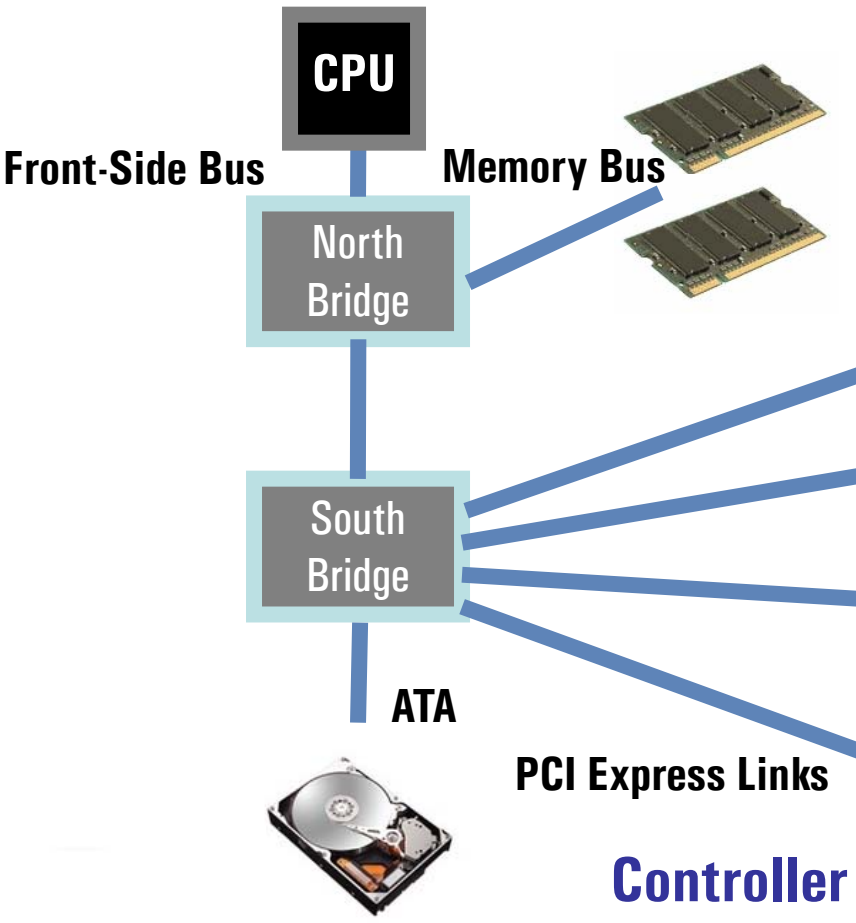
- High-performance RAID controllers
- Rates up to 600 MB/s (sustainable for 2 TB, NI 8264)
- Enterprise class hard drives
- Active antivibration technology

NI 8262

x4 Cabled PCI Express

PXI Express RAID Streaming

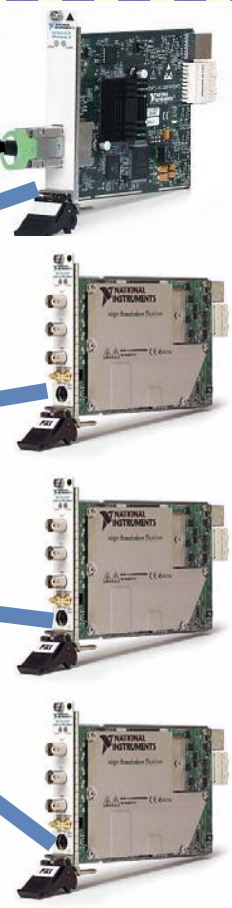
Hard Drive Array



Cabled PCI Express

PCIe Switch

PCIe to PCI Bridge

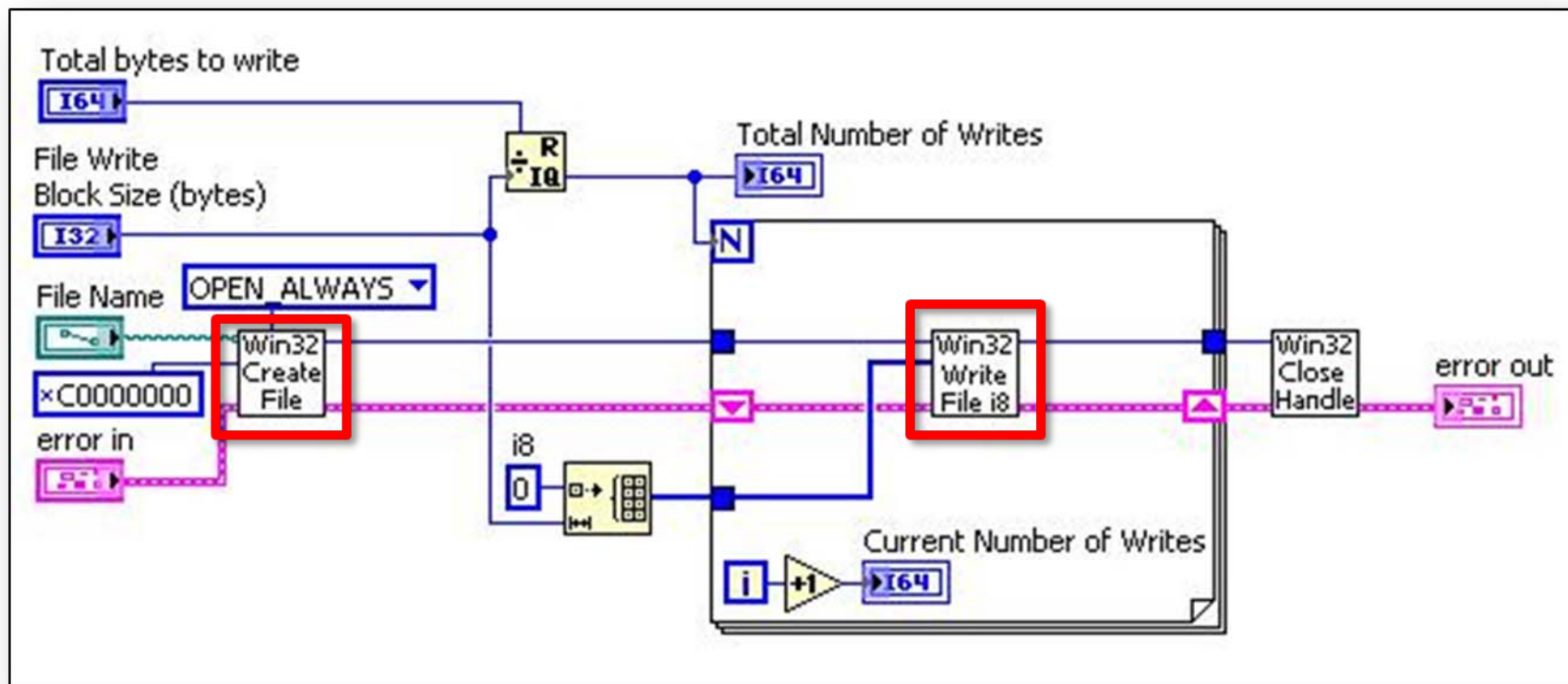


Chassis

LabVIEW Binary File I/O Not Optimized for Streaming

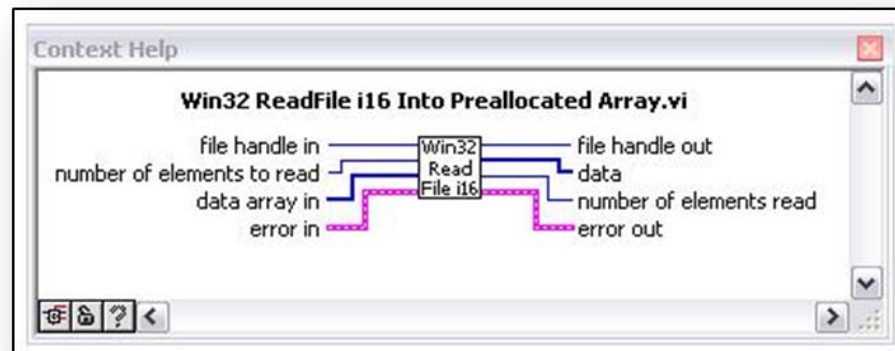
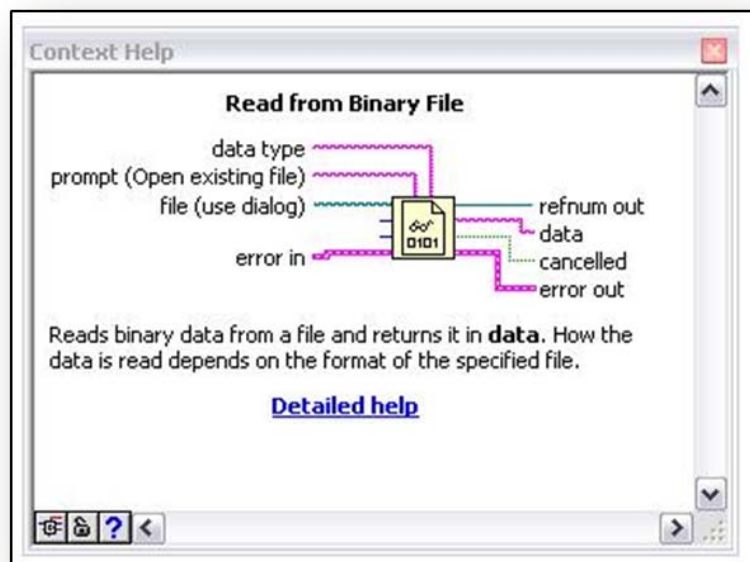
- x4 PCI Express 8-drive RAID 0
- 448 MB/s write benchmark
- Stream to disk from a digitizer
- LabVIEW binary file I/O → 105 MB/s
- Nonbuffered Win32 file I/O → 440 MB/s

Write to Disk



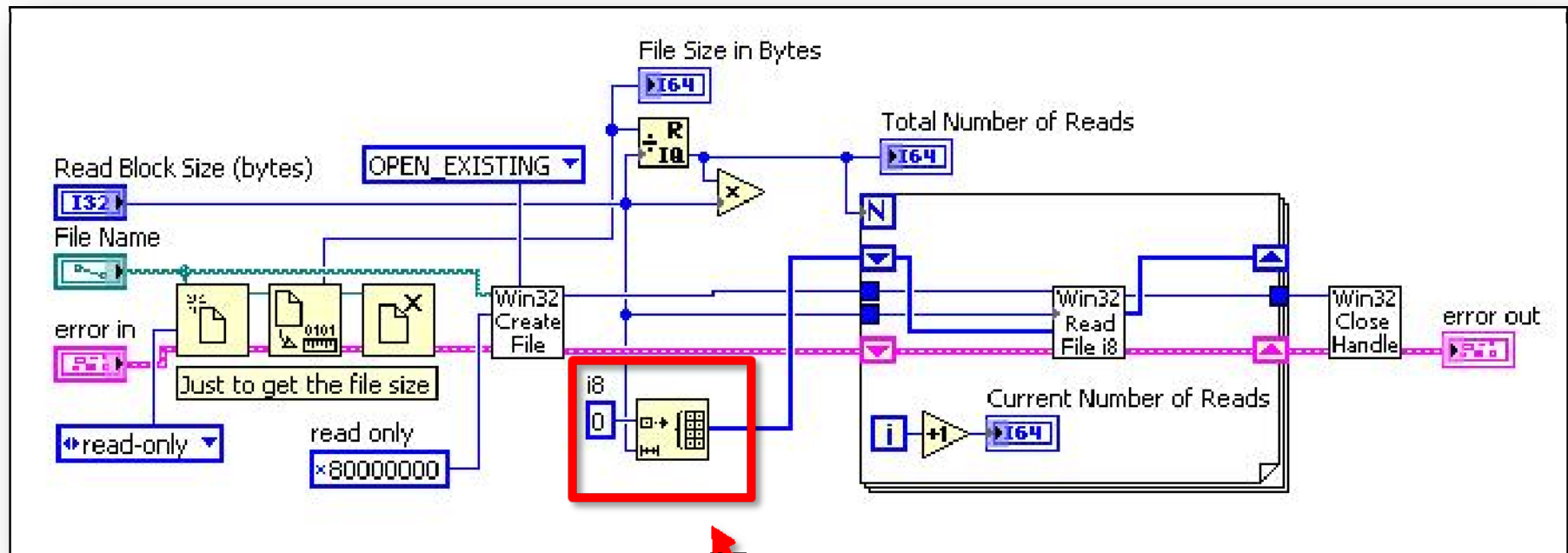
- Special file I/O VIs

Read from Disk



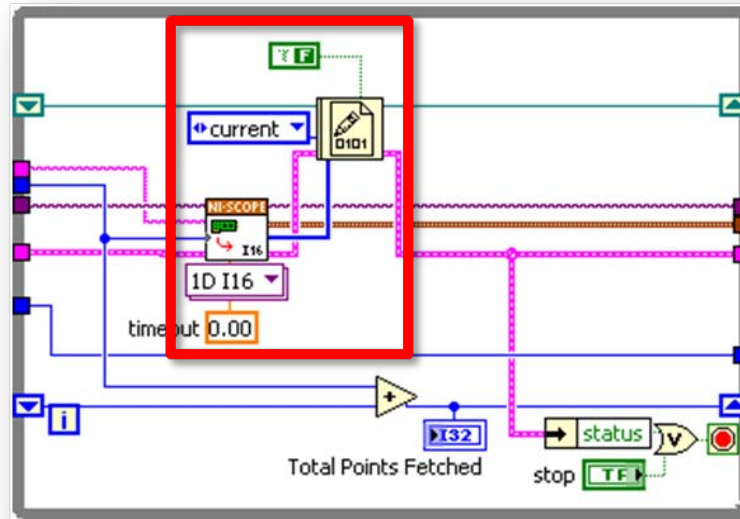
- Array creation degrades performance
- Must read into a preallocated array
- Requires the Win32 file I/O VIs to be used for reading from disk

Read from Disk



- Special file I/O VIs
 - Read into a preallocated array
- Pre-allocated Array

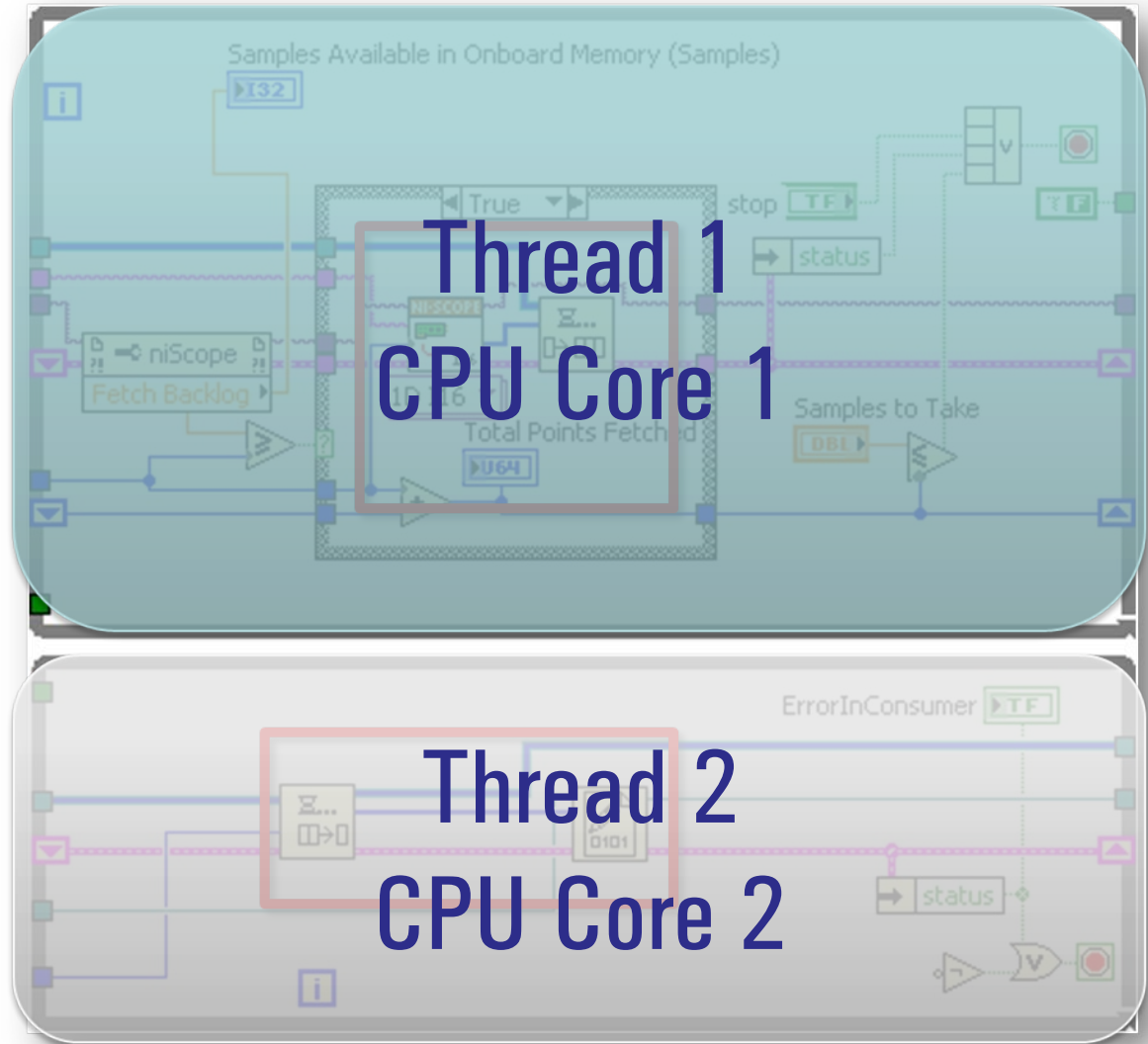
LabVIEW Programming Structure



- Typical code written to do a serial fetch from hardware and then write to binary file
- Does not take full advantage of the hardware

Streaming to/from RAID 0 Hard Drives

- Parallelize fetch and write functions
- Take full advantage of I/O, hard drives, and multicore processors



Where Can I Find the Win32 VIs and Examples?

- The Win32 file I/O VIs are available on ni.com/streaming
- Includes examples, tutorials
 - High-speed digitizers
 - Arbitrary waveform generators
 - RF analyzers
 - RF generators
 - High-speed digital

NI Home > Solutions > Industries and Applications > Data Streaming

Data Streaming

Questions? [Get real-time assistance now!](#)

High-speed data streaming is the act of transferring data between an instrument and memory, either on a host PC or on a hard disk drive. National Instruments offers data-streaming solutions that can sustain transfers at 600 MB/s for up to 3 terabytes of data. Individual modular instruments from NI are capable of:

- 100 MS/s (200 MB/s) time-domain acquisition
- 100 MS/s (200 MB/s) arbitrary waveform generation
- 20 MHz bandwidth (100 MB/s) radio frequency (RF) recording and playback
- 50 MHz (200 MB/s) digital pattern acquisition and generation

Featured Data-Streaming Applications

RF Recording and Playback


Learn about real-time streaming of radio frequency (RF) signals to and from disk. Related applications include spectral (spectrum) monitoring and signal intelligence.

IF/Baseband Streaming

Obtain information on intermediate frequency (IF) and baseband time domain signal streaming to and from disk.

Noise Mapping

Learn about high-channel-count sensor arrays that spatially locate sources of noise and vibration. This application is also



Introducing Streaming
Read a white paper on streaming from disk

Key Resources

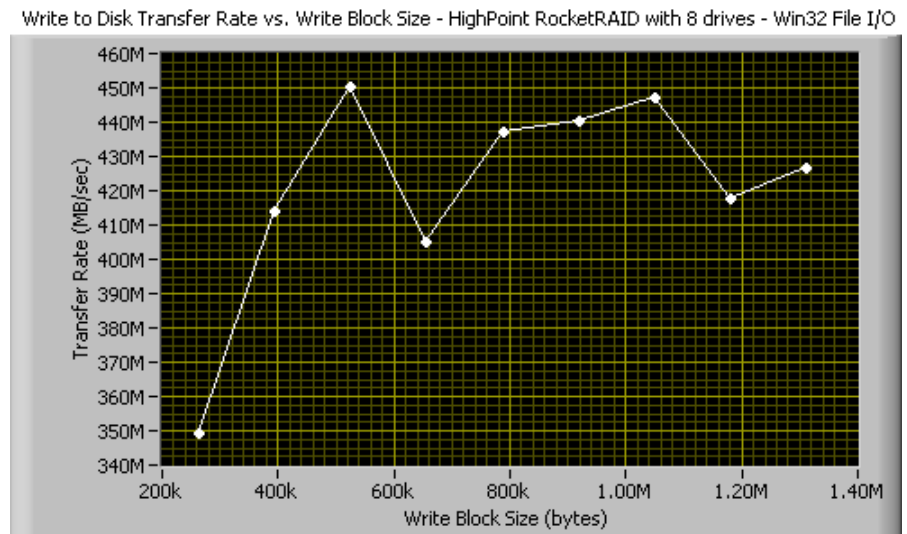
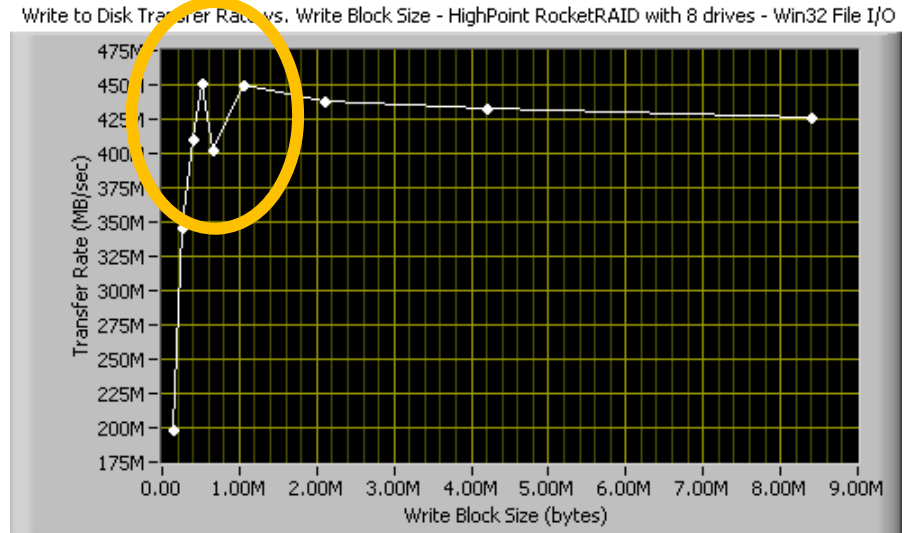
- Mixed-Signal Data Streaming
- New Product Streaming
- LabVIEW

More about Streaming

- Benchmarks
- Selecting
- PXI Systems

File I/O Block Size

- Different file I/O block sizes can impact performance
- Specifically relevant to RAID controllers
- Ideal file I/O block size may not line up with ideal measurement I/O block size
- LabVIEW utilities available



PXI Module Streaming Rates

Modular Instrument	Rate
Digitizer	~ 400 MB/s
Arbitrary Waveform Generator	~ 200 MB/s
High-Speed Digital Input / Output	~ 200 MB/s
High-channel-count DAQ	> 90 MB/s *
RF analyzer (w/ OSP)	20 MHz RTB *
RF generator (w/ OSP)	6.6 MHz RTB *

*** All rates are subject to certain conditions and restrictions**

PCI Express – The Enabling Technology

- Serial interconnect at 2.5 Gb/s
 - Multiple lanes can be grouped together to form links
 - x1 (by 1) has bandwidth of 250 MB/s/direction
 - x16 (by 16) has bandwidth of 4 GB/s/direction
 - Dedicated bandwidth per link
- Uses same software model as PCI
 - Ensures software compatibility
- Roadmap to 5 Gb/s clocking (Gen-2)



PXI Modules in PXI Express Systems

- PXI Express is the industry's premier streaming platform!
- However, lower streaming performance for PXI modules in PXI Express systems due to an extra PCI Express to PCI bridge
- Example (NI PXI-5122):
 - NI PXI-1042 and NI PXI-8105 → 115 MB/s
 - NI PXIe-1062Q and NI PXIe-8105 → 102 MB/s
- Use a PXI chassis and controller for maximum streaming performance with PXI modules

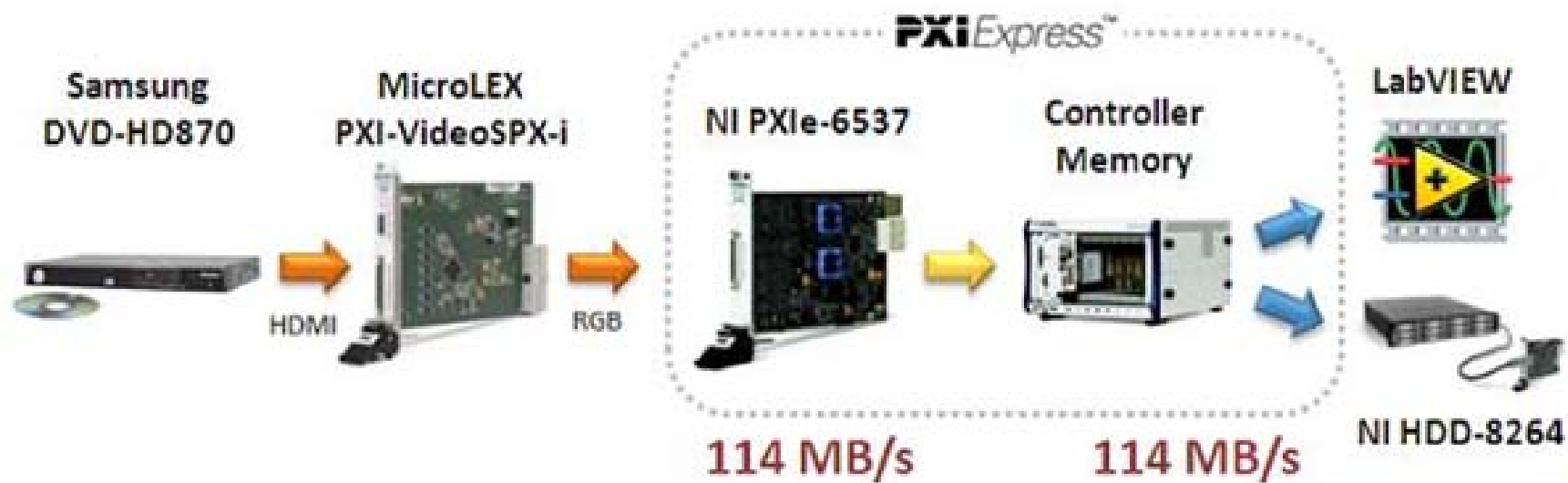


Conduant StreamStor PXIe-416

- > 600 MB/s sustained recording for up to 3.5 hours
- > 12 TB of disk storage capacity
- 3U PXI Express controller card with 4-lane endpoint connectivity
- Records simultaneous streams from multiple data sources and plays back to multiple destinations



Demo



Summary

- Hard drive-based recording and playback with PXI solves most current applications
- Maximum streaming performance requires planning during system development
- PXI Express enables new recording and playback capabilities and opportunities