UiO : University of Oslo

FYS3240
PC-based instrumentation and microcontrollers

Data storage and high-speed streaming

Spring 2014 – Lecture #8

Bekkeng, 5.5.2014

Data streaming

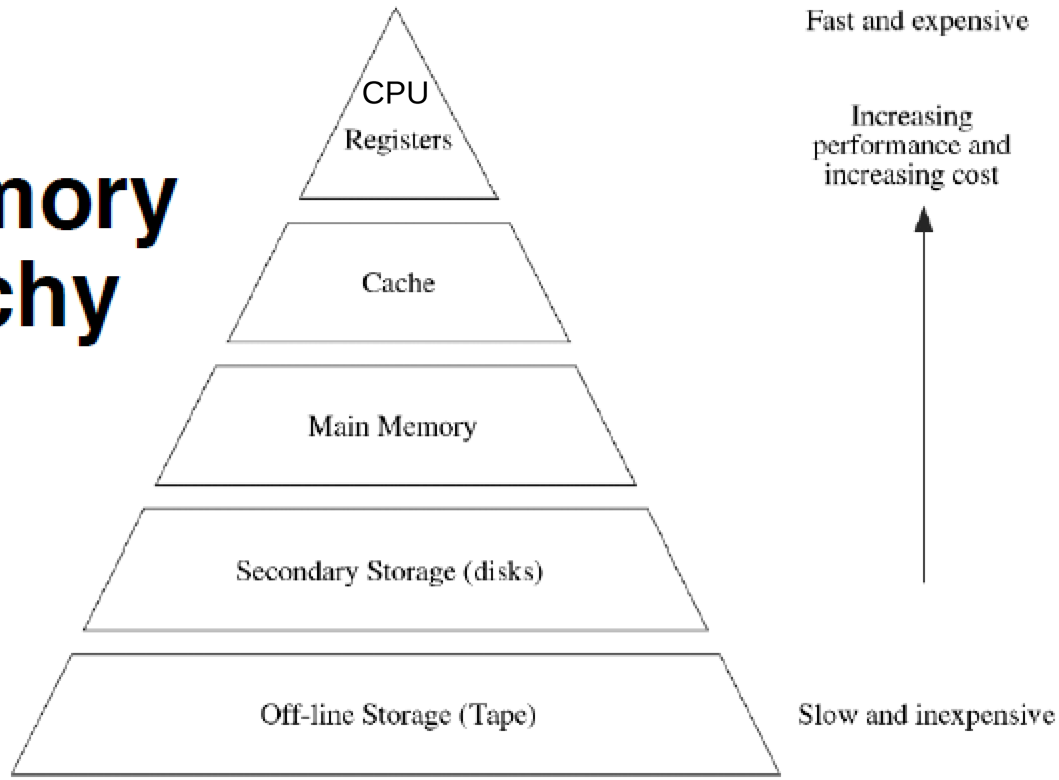
- Data written to or read from a storage device at a <u>sustained rate</u> is often referred to as **streaming**

- Trends in data storage
  - *Ever-increasing amounts of data (**Big Data**)*
  - *Record "everything" and play it back later*
  - *Hard drives: faster, bigger, and cheaper*
  - *Solid state drives*
  - *RAID hardware*
  - *PCI Express*
    - *PCI Express provides higher, dedicated bandwidth*

Overview

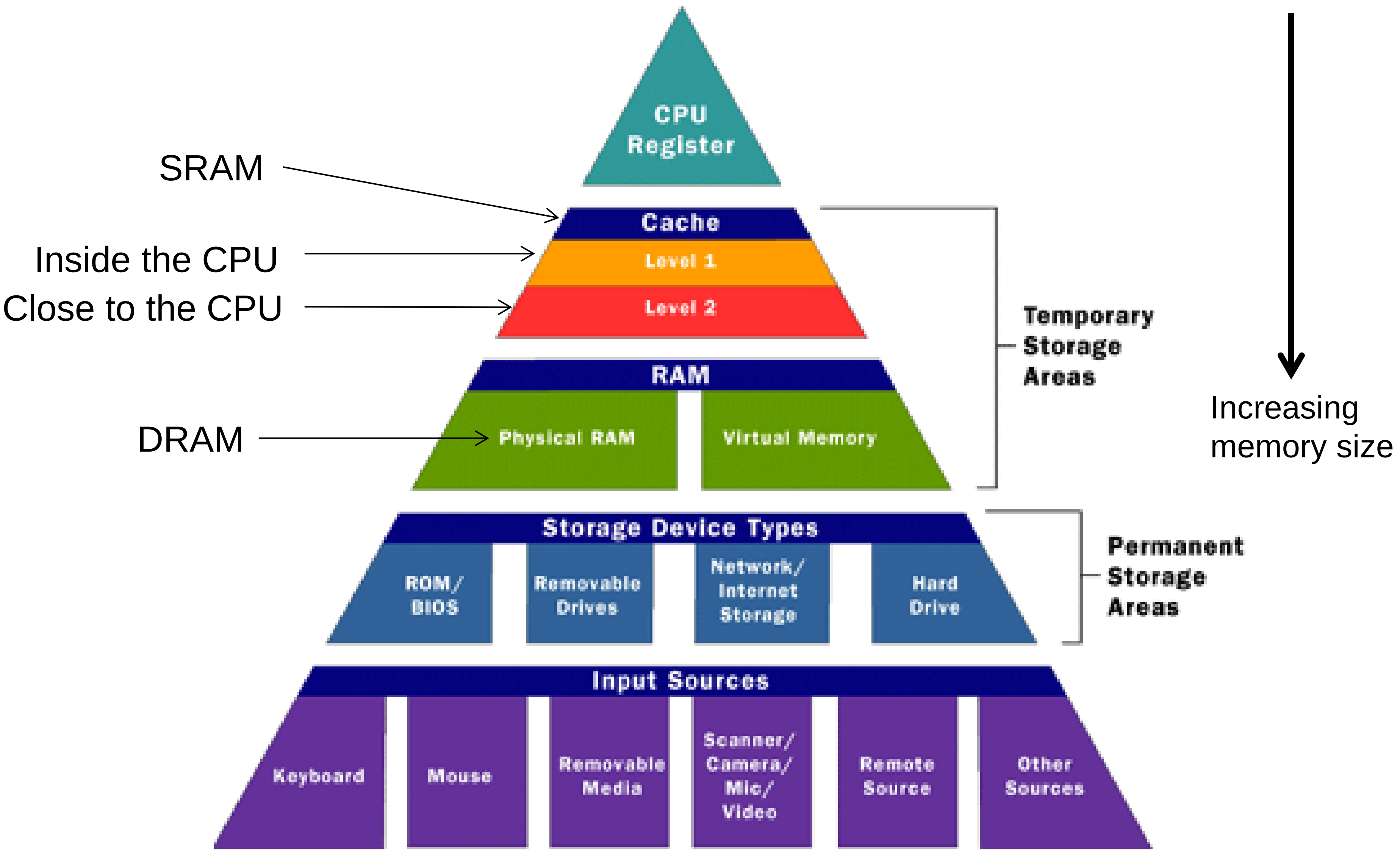
- Hard drive performance and alternatives
- File types
- RAID
- DAQ software design for high-speed acquisition and storage

The Memory Hierarchy



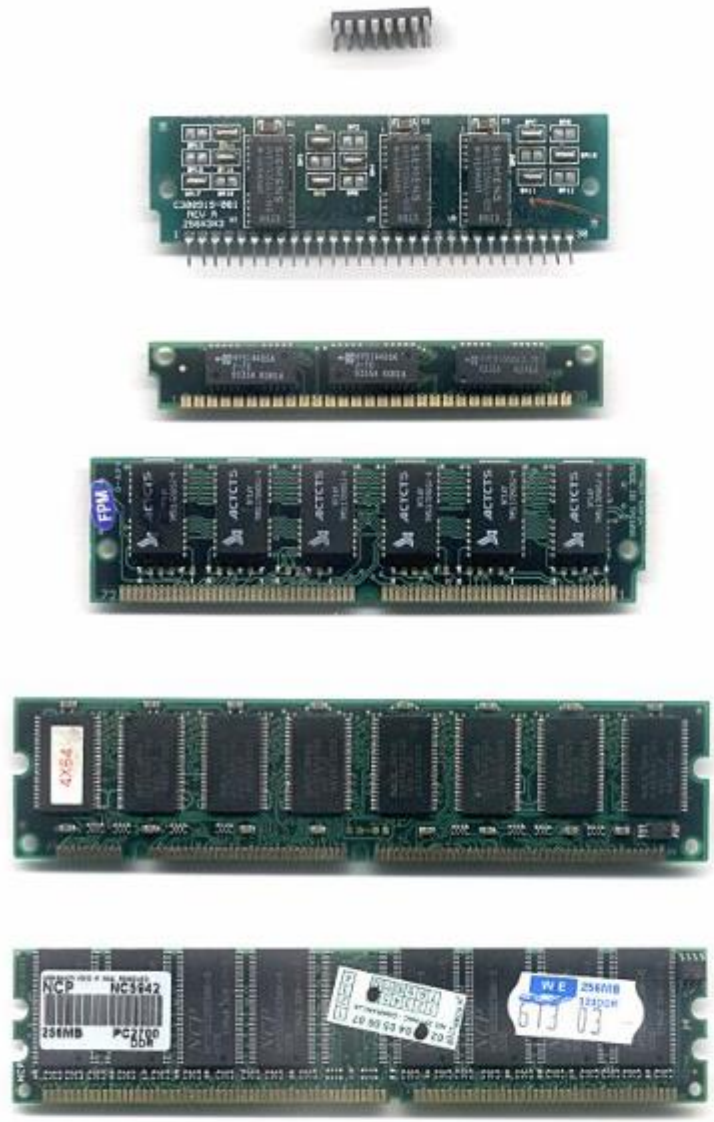
Memory type	Access time	Cost/MB	Typical amount used	Typical cost
Registers	0.5 ns	High	2 KB	–
Cache	5–20 ns	$80	2 MB	$160
Main memory	40–80ns	$0.40	512 MB	$205
Disk memory	5 ms	$0.005	40 GB	$200

Computer Memory



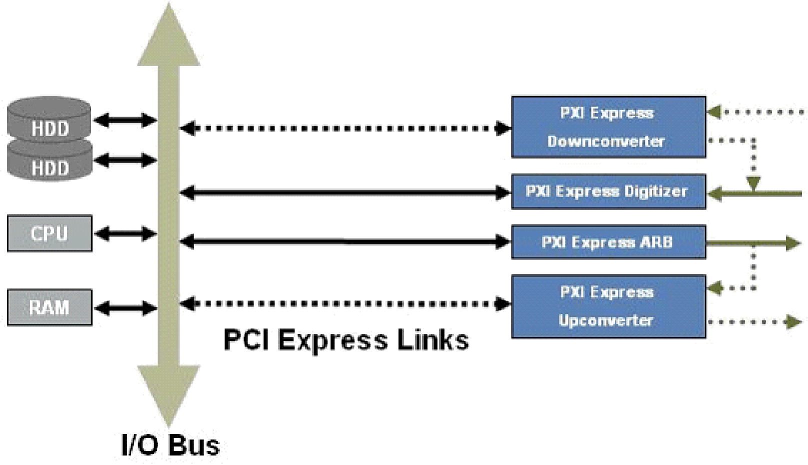
RAM – Random Access Memory

- **SRAM – Static RAM: Each bit stored in a flip-flop (4-6 transistors)**
- **DRAM – Dynamic RAM: Each bit stored in a capacitor (transistor). Has to be refreshed (e.g. each 15 ms)**
  - EDO DRAM – Extended Data Out DRAM.
    Data available while next bit is being set up
  - Dual-Ported DRAM (VRAM – Video RAM).
    Two locations can be accessed at the same time
  - SDRAM – Synchronous DRAM.
    Latched to the memory bus clock → read/write on one single clock cycle
  - Rambus (RDRAM) - Intel had to use RDRAM 1996-2002.
    Much more expensive than SDRAM
  - DDR SDRAM – Double Data Rate SDRAM (2.5 V).
    Data transferred on both rising and falling edge of clock.
  - DDR2 SDRAM (1.8 V)
    Same, but lower power consumption and higher clock frequency
  - DDR3 SDRAM (1.5 V)
    Came in 2007. Even less power and faster

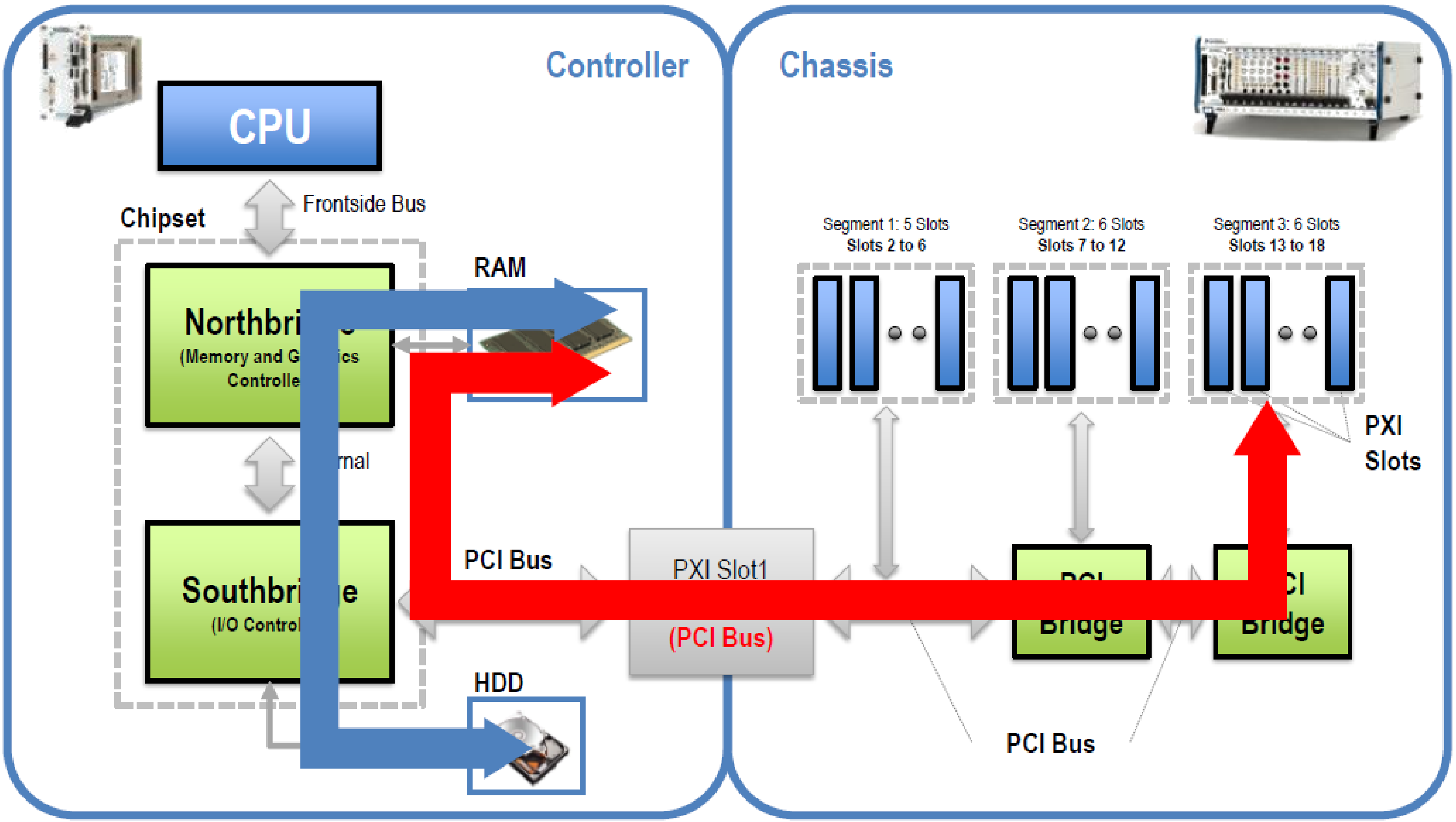


Streaming Data with the PCI Express Bus

- A PCI Express device receives dedicated bandwidth (250 MB/s or more).
- Data is transferred from onboard device memory (typically less than 512 MB), across a dedicated PCI Express link, across the I/O bus, and into system memory (RAM; 3 GB or more possible). It can then be transferred from system memory, across the I/O bus, onto hard drives (TB´s of data). The CPU/DMA-controller is responsible for managing this process.
- Peer-to-peer data streaming is also possible between two PCI Express devices.



PXI: Streaming to/from Hard Disk Drives



Stream to/from disk rates

Peak, not sustained rate!

Note: old numbers - show the relative data rates

Drive(s)	Write/Read (MB/s)	Rate Types
Laptop	30 (NI PXIe-8103 internal drive; 5,400 RPM)	Peak
IDE	57 (Western Digital 160 GB; 7,200 RPM)	Peak
SATA	62 (Western Digital 160 GB; 7,200 RPM)	Peak
SATA	75 (Seagate Barracuda 7,200.10; 250 GB)	Peak

- Important parameters for streaming
  - Seek times
  - Rotational speed (RPM)
    - 7200, 10000, 15000
  - Buffer size

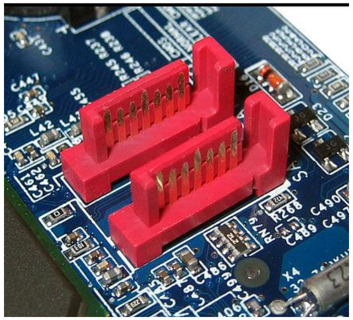
- Sustained streaming rates is most affected by the **rotational speed**

Typical "Memory" speed 2011

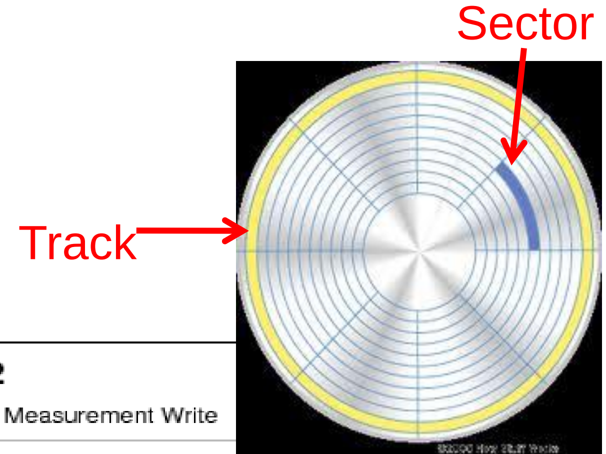
- Cache (CPU cache, Disk cache)
  - Caches are normally made from static RAM chips (SRAM), unlike main system memory which is made from dynamic RAM (DRAM)
  - Much faster then DRAM
- RAM
  - DDR3 SDRAM: **6400 MB/s**
- HDDs
  - Data rate: ~ **100 - 150 MB/s**
  - Note: Peak vs. Sustained data rate
- SATA
  - Serial ATA (SATA or Serial Advanced Technology Attachment)
  - Capacity: **1.5, 3.0, 6.0 Gbit/s**

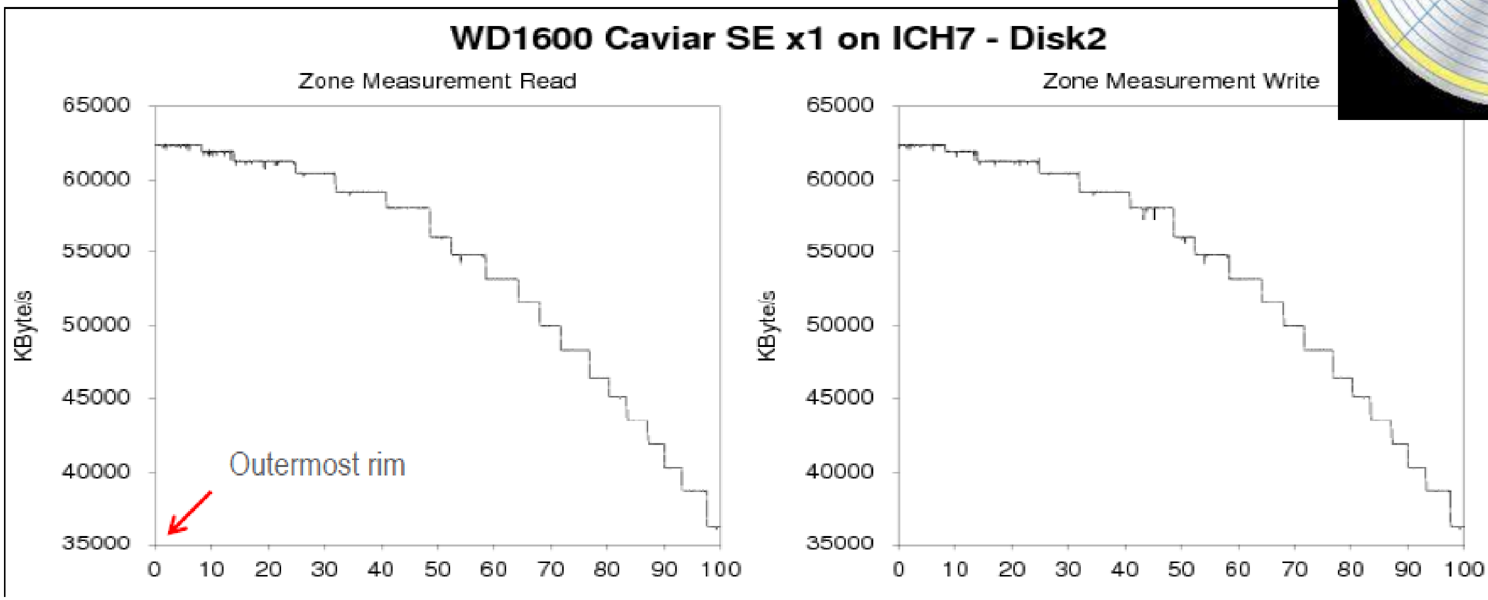
Seagate Barracuda 7200.12 Specifications

Available capacities	250, 500, 750GB, 1TB
Maximum external transfer rate	300MB/s
Maximum sustained data rate	125MB/s
Cache size	32MB (750GB, 1TB) 16MB (500GB) 8MB (250GB)
Spindle speed	7,200 RPM



HDD Performance





- HDD's Internal Data Rate (IDR) = density * RPM * disk diameter
- **Outer HDD track is faster, inner track is slower**
  - more data sectors on outer tracks, fewer data sectors on inner tracks
- Example above: 62 MB/s at outer track, 36 MB/s at inner track
- **Windows OS allocates file space from outer track and inward**

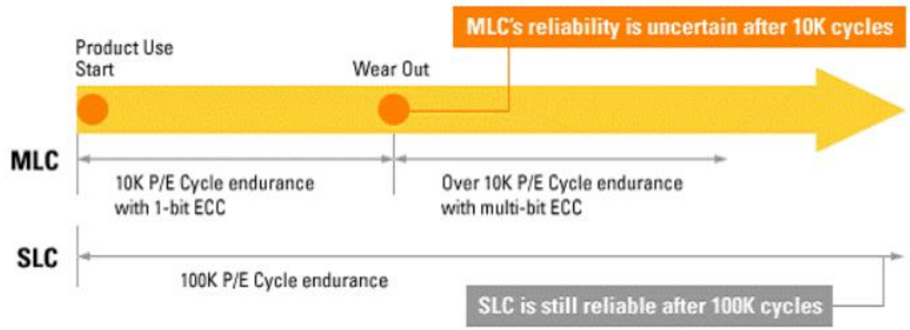
SSD (Solid-State drive)

- A data storage device that uses solid-state (Flash) memory to store data.
- SSDs are distinguished from traditional hard disk drives (HDDs), which are electromechanical devices containing spinning disks and movable read/write heads.
- SSDs, in contrast, use microchips which retain data in non-volatile memory chips and contain no moving parts.
- SSDs use the same interface as HDDs, thus easily replacing them in most applications

SSD (Flash Chip) Types (TLC, MLC, SLC)

SLC- Single Layer Cell

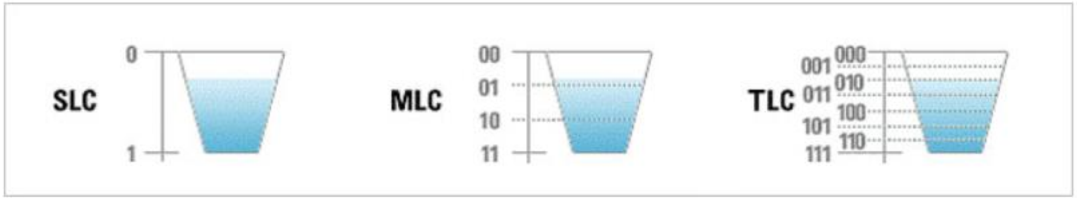
- High performance
- Lower power consumption
- Faster write speeds
- 100,000 program/erase cycles per cell
- Higher cost
- A good fit for industrial grade devices, embedded systems, critical applications.



MLC- Multi Layer Cell

- Lower endurance limit than SLC
- 10,000 program/erase cycles per cell
- Lower cost
- A good fit for consumer products. Not suggested for applications which require frequent update of data.

TLC- Three Layer Cell

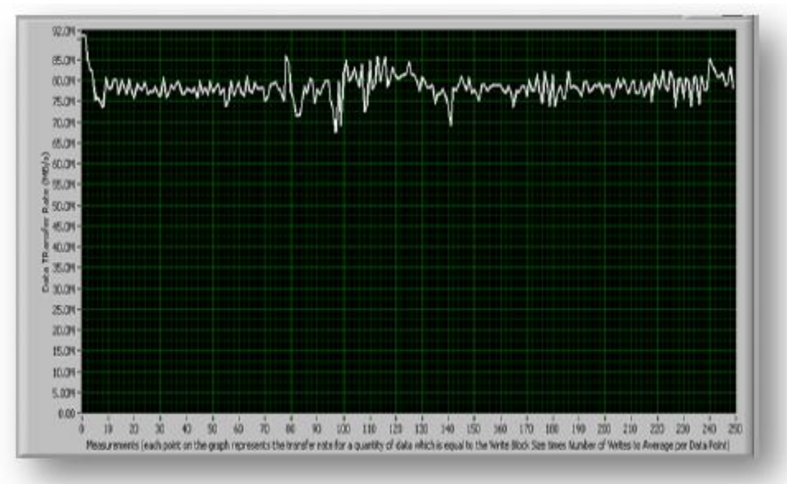


- Higher density
- Lower endurance limit than MLC and SLC
- TLC has slower read and write speeds than conventional MLC
- 5,000 program/erase cycles per cell
- Best price point
- A good fit for low-end basic products. Not suggested for critical or important applications at this time which require frequent updating of data.

From: http://www.centon.com/flash-products/chiptype

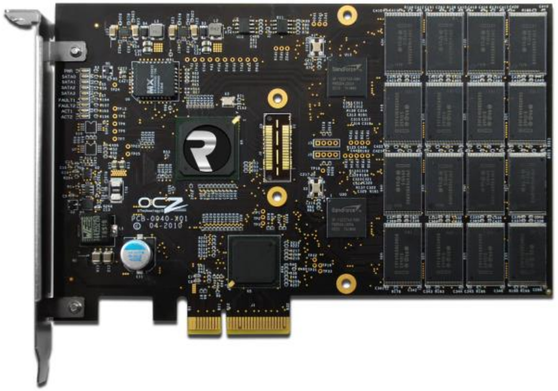
SSDs pros and cons

- Pros
  - Robustness (Less susceptible to vibrations and shock)
  - Increased write/read speeds (low access time and latency)
  - Not a drop in write speed when the memory fills up (as for HDDs)
  - Low power consumption (reduced heat generation)
  - Low boot-up time (for OS) and quicker application-launches
- Cons
  - High cost (in price/GB)
  - Low capacity (in # GB)
  - Great quality variations have been experienced
  - Reduced write speed experienced over time (for some suppliers)



[SSD - NI tutorial]

SSD example: OCZ RevoDrive



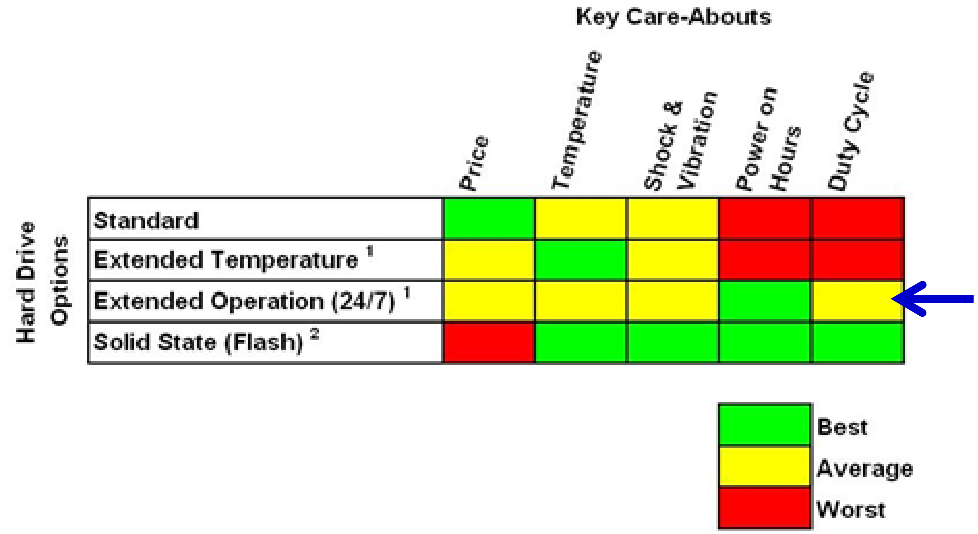
- PCI express card with flash memory and RAID-controller (RAID-0)
- Up to 480/960 GB capacities
- PCI-Express interface (x4)
- For use as primary boot drive or data storage
- **OCZ RevoDrive**
  - Read: Up to 540 MB/s
  - Write: Up to 480 MB/s
  - <u>Sustained Write: Up to 400 MB/s</u>
- **OCZ RevoDrive 3**
  - Read: Up to 1900 MB/s
  - Write: Up to 1700 MB/s

Sequential read/write

Selecting hard drives for DAQ systems

- A standard HDD is a 8/5 drive
  - Designed for power on for 8 hours, 5 days a week

- **Select Enterprise/Extended operations/ES version HDDs (when available)**
  - They are 24/7 drives, meaning that they are designed for continuous operation and high sustained throughput
  - Used in servers!



[1] Hard drives are available that are both extended-temperature and extended-operation.
[2] Care must be taken when selecting a solid-state hard drive in order to ensure that it will meet the requirements of your application. Additional details are provided in this white paper.

Example – Desktop HDD from WD

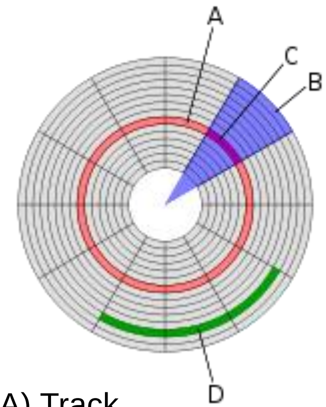
Desktop/Workstation Hard Drives	 WD Blue	 WD Green	 WD Black	 WD Red	 WD VelociRaptor
Product Selector »	Solid performance and reliability for everyday computing.	Cool, quiet operation with massive capacity.	Maximum performance for power computing.	Designed and tested for RAID environments.	High-performance storage for power users.
Designed For	Desktop	Desktop	Desktop	Desktop RAID	Workstation
Capacity	80 GB – 1 TB	500 GB – 4 TB	500 GB – 4 TB	750 GB – 4 TB	250 GB – 1 TB
Interface	SATA 6 Gb/s PATA 100 MB/s	SATA 6 Gb/s	SATA 6 Gb/s	SATA 6 Gb/s	SATA 6 Gb/s
Form Factor	3.5-inch	3.5-inch	3.5-inch	3.5-inch 2.5-inch	3.5-inch 2.5-inch
Cache	8 MB – 64 MB	64 MB	64 MB	16 MB – 64 MB	64 MB
Limited Warranty	2-year	2-year	5-year	3-year	5-year

Factors that affect streaming performance

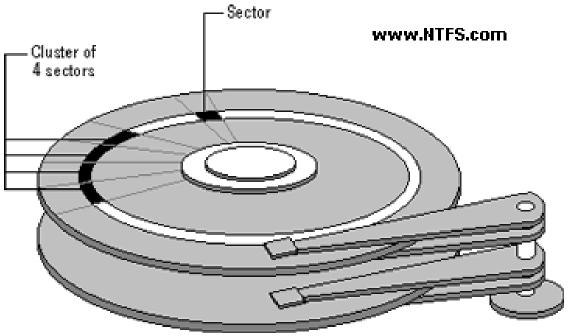
- Beyond overall application architecture, stream-to-disk or stream-from-disk rates can be affected by some of the following factors
  - Running background programs such as virus scan
    - Recommended to disable the scheduled scans and updates for the entire duration of data streaming
  - How the hard drive is formatted to group data
  - Location of the file on the hard drive(s)
    - Locate the OS on a separate HDD (to free the fastest outer tracks for data storage)

HDD Sectors and Clusters

- The smallest unit of space on the hard disk that any software program can access is a ***sector***, which usually consists of 512 bytes
- Traditional formatting provides space for 512 bytes per sector. Newer hard drives use 4096 byte (4k)
- Sectors are grouped into larger blocks that are called ***clusters*** *(or allocation units)*

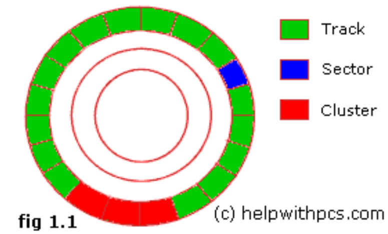


(A) Track
(B) *Geometrical* **sector**
(C) Track sector
(D) Cluster

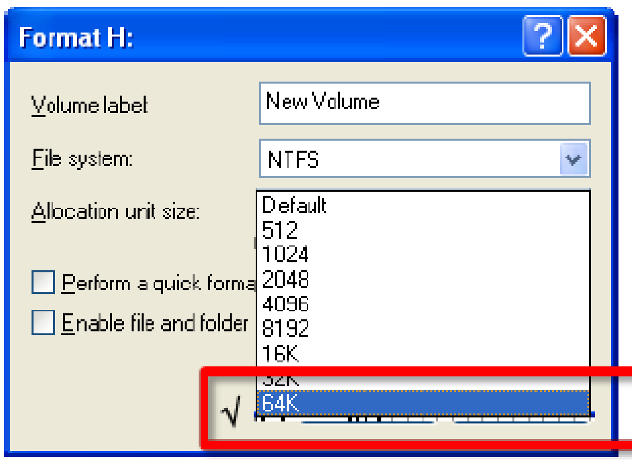


Hard Drive Streaming Performance

Formatting – Allocation Unit Size

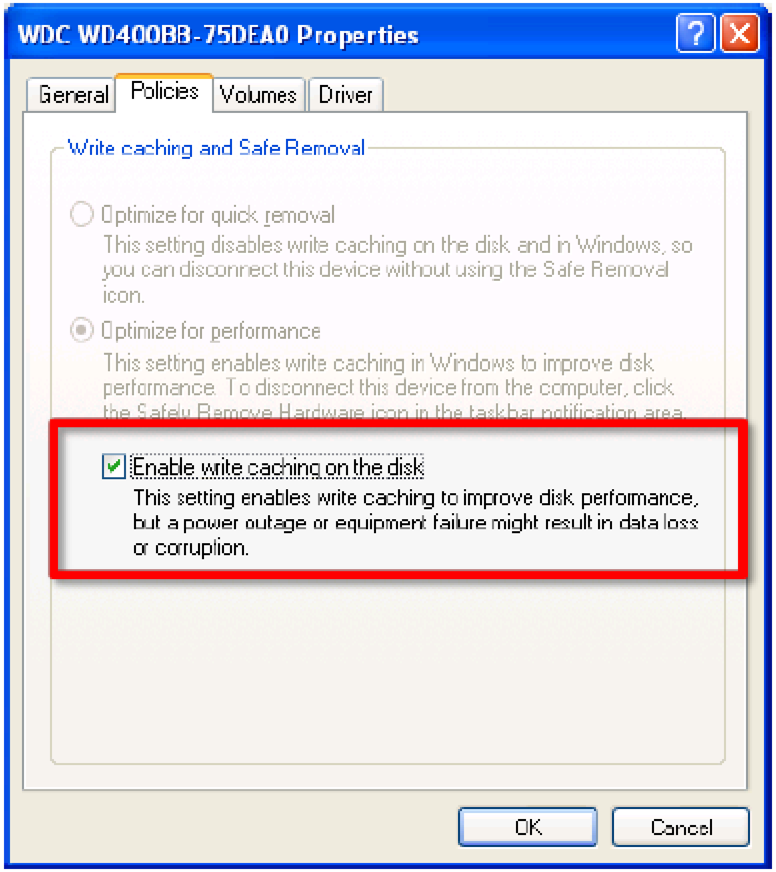


- Computer Management » Disk Management
- Larger cluster sizes provide better streaming performance
  - "Allocation unit size" is the cluster size
- Example (8-drive Streaming Solution):
  - 512 byte clusters
    - 402 MB/s write, 306 MB/s read
  - 64k byte clusters:
    - 452 MB/s write, 445 MB/s read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



Hard Drive Properties

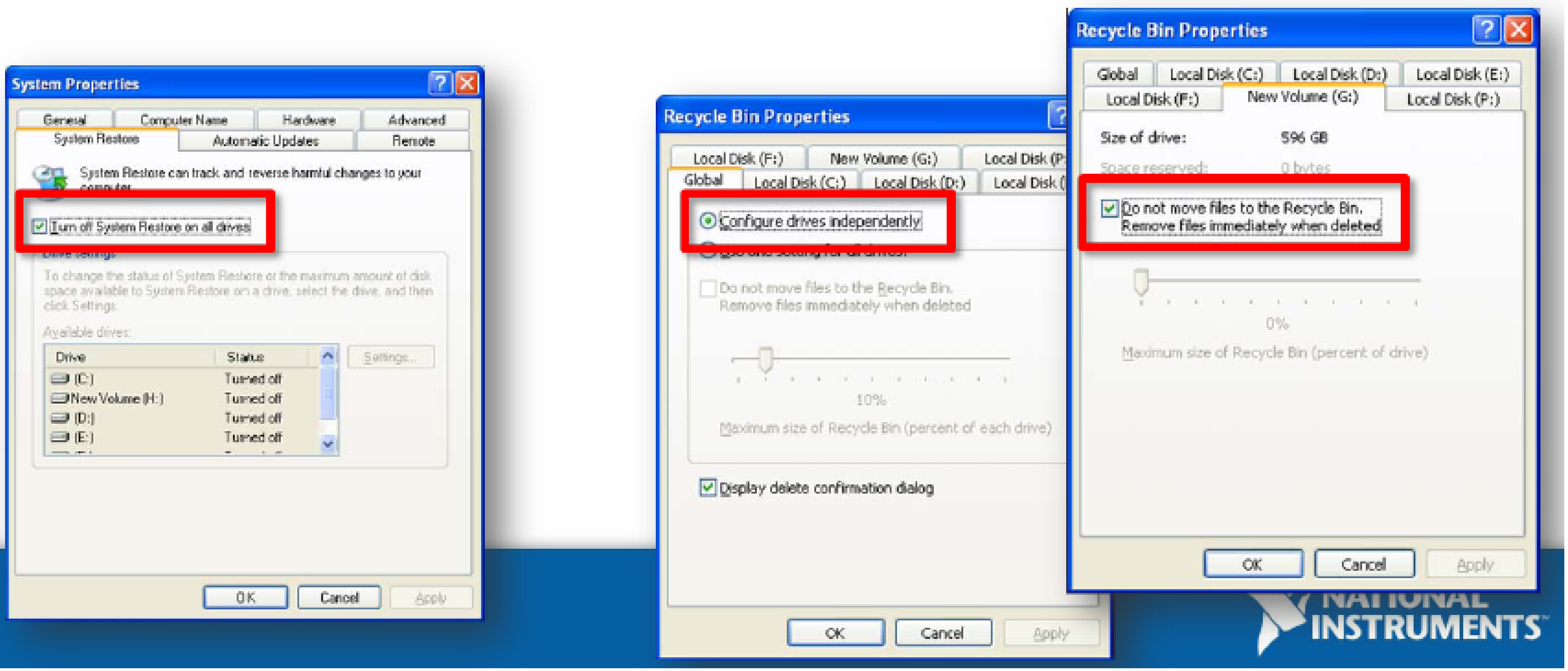
- Write caching MUST be turned on
- By default, it is usually turned on
- Write caching enables the use of the hard drive's onboard buffer



Hard Drive Streaming Performance

Hard Drive Properties

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



Determining Storage Format

When determining the appropriate storage format for the data, consider the following:

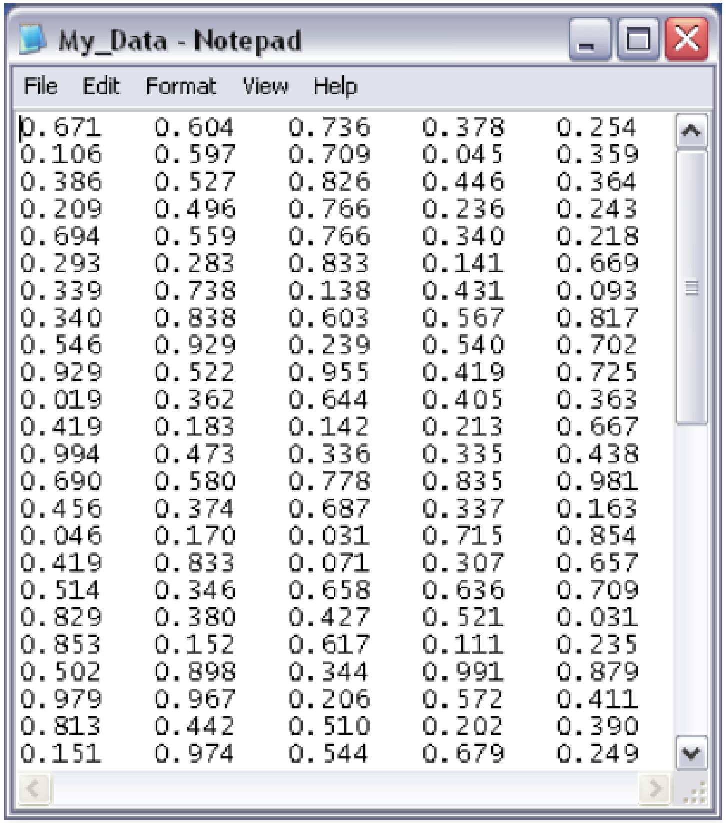
- What will you do with your data once you have acquire them?
- Will you write and read data with the same application?
- How much data will you acquire?
- At what rate will you acquire data?
- Will you need to exchange data with another program?
- Will you need to search your data files?

  - ASCII (text)
  - Binary
  - TDMS
  - INI
  - Spreadsheet
  - AVI
  - XML

Configuration files

ASCII Files

- **Pros**
  - Human-readable
  - Easily portable to other applications such as Microsoft Excel
  - Can easily add text information (first line) for each data column
- **Cons**
  - Large file size
  - Slow read and write



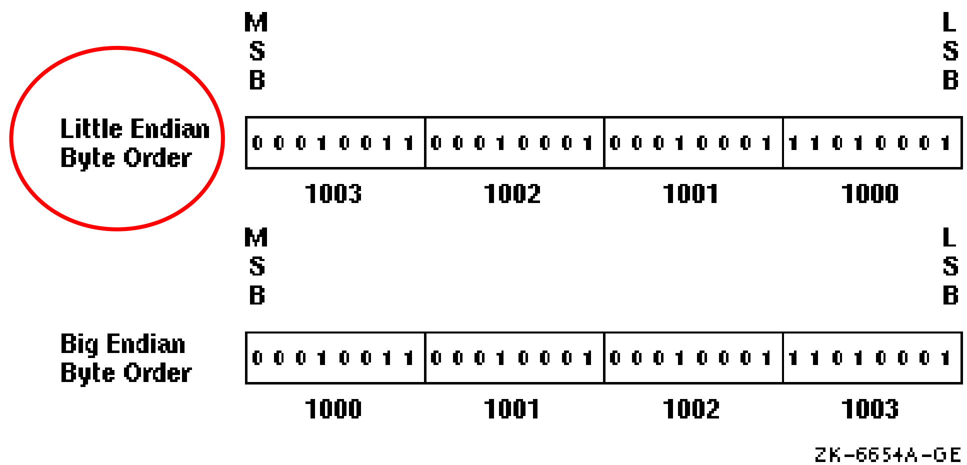
0.671	0.604	0.736	0.378	0.254
0.106	0.597	0.709	0.045	0.359
0.386	0.527	0.826	0.446	0.364
0.209	0.496	0.766	0.236	0.243
0.694	0.559	0.766	0.340	0.218
0.293	0.283	0.833	0.141	0.669
0.339	0.738	0.138	0.431	0.093
0.340	0.838	0.603	0.567	0.817
0.546	0.929	0.239	0.540	0.702
0.929	0.522	0.955	0.419	0.725
0.019	0.362	0.644	0.405	0.363
0.419	0.183	0.142	0.213	0.667
0.994	0.473	0.336	0.335	0.438
0.690	0.580	0.778	0.835	0.981
0.456	0.374	0.687	0.337	0.163
0.046	0.170	0.031	0.715	0.854
0.419	0.833	0.071	0.307	0.657
0.514	0.346	0.658	0.636	0.709
0.829	0.380	0.427	0.521	0.031
0.853	0.152	0.617	0.111	0.235
0.502	0.898	0.344	0.991	0.879
0.979	0.967	0.206	0.572	0.411
0.813	0.442	0.510	0.202	0.390
0.151	0.974	0.544	0.679	0.249

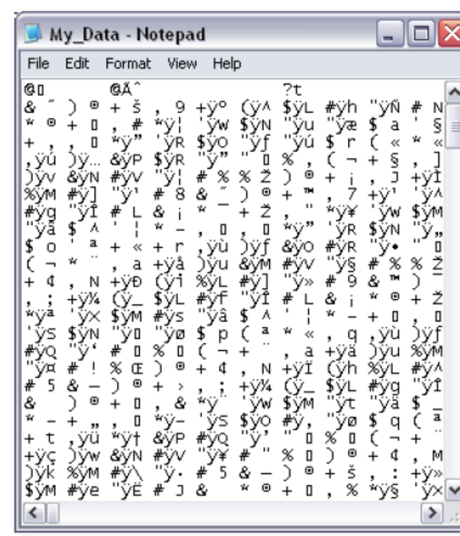
Binary Files

- **Pros**
  - Compact file size
  - Fast streaming

- **Cons**
  - Not human-readable
  - Less easily exchangeable

Two different architectures for handling memory storage:





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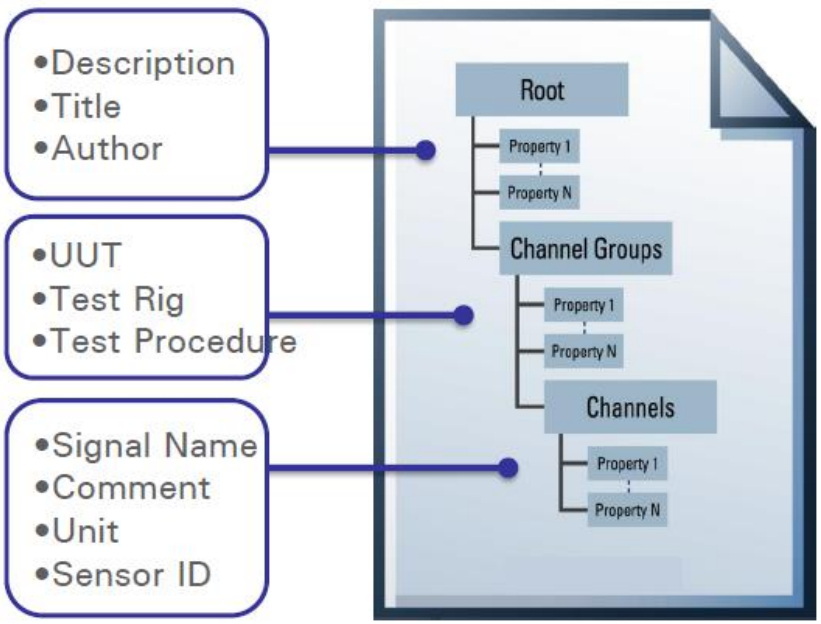
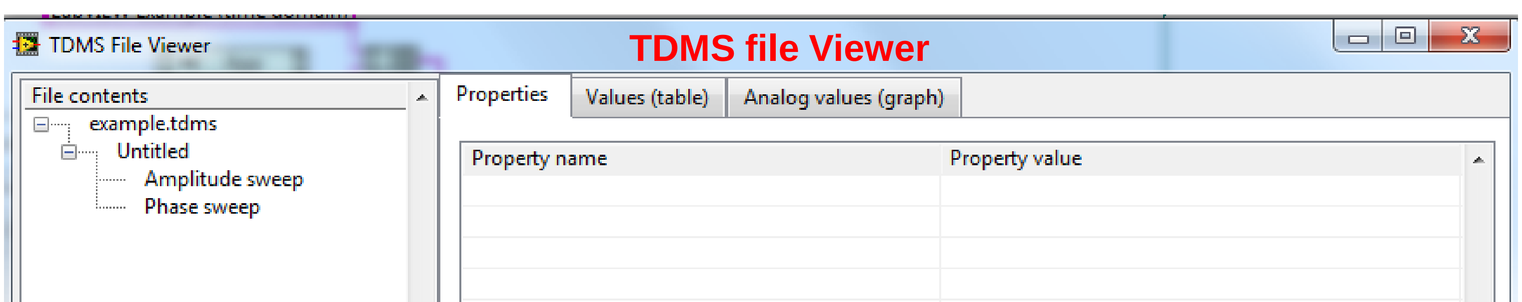
TDM and TDMS

- A file format from National Instruments
- TDMS = Technical Data Management Streaming
- Three levels of hierarchy



- **TDMS**
  - *Optimized for high-speed streaming*
  - *Binary-based header*
  - *Binary bulk data*
  - *Single file for both header information and bulk data*
  - *Supported on real-time software platforms*
- **TDM**
  - *XML-based header file*
  - *Separate binary bulk data file*

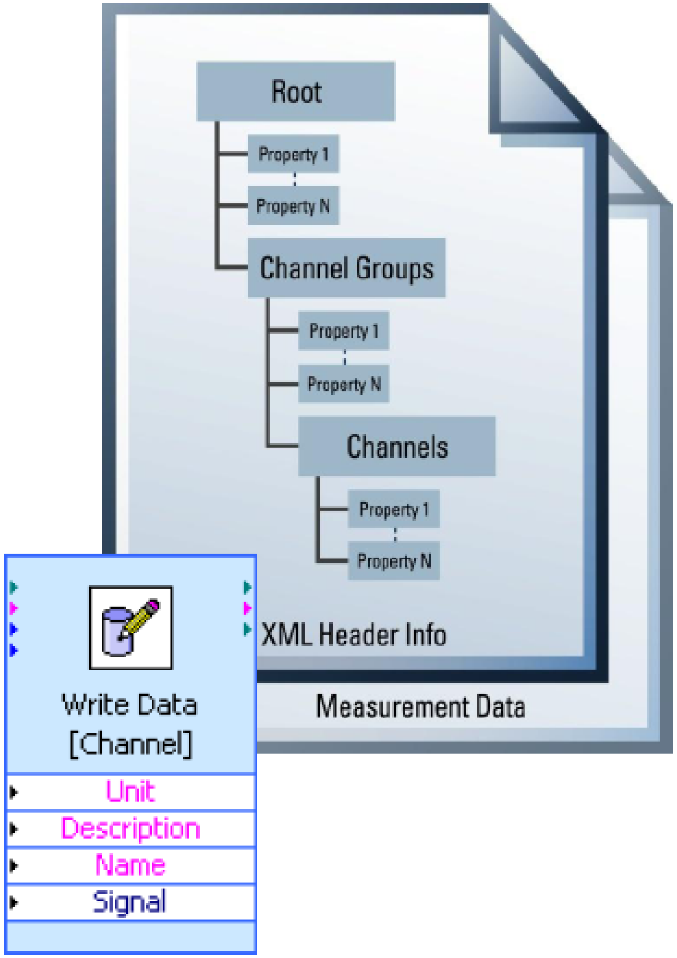
ni.com/tdm



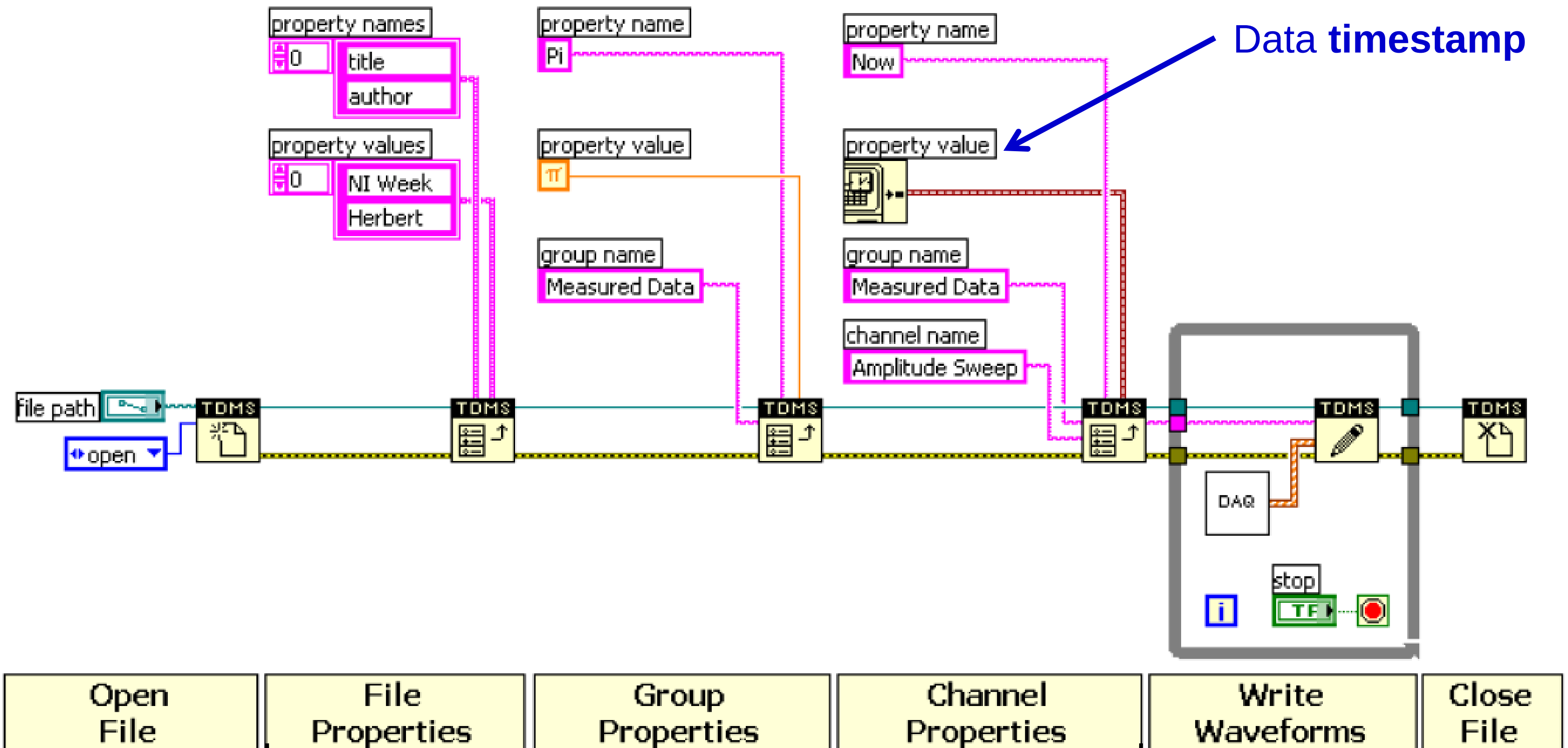
TDMS File Format: Optimized for Data Storage and Search

- **Simple:** Easiest approach for storing measurement data in NI software
- **Flexible:** Add custom attributes to every file, channel group, and channel
- **Fast:** TDMS is the TDM file for streaming applications
- **Open:**
  - – Microsoft Excel and OpenOffice add-in
  - – Public documentation
  - – C DLL for creating files in third-party applications

- Can download reader for Matlab



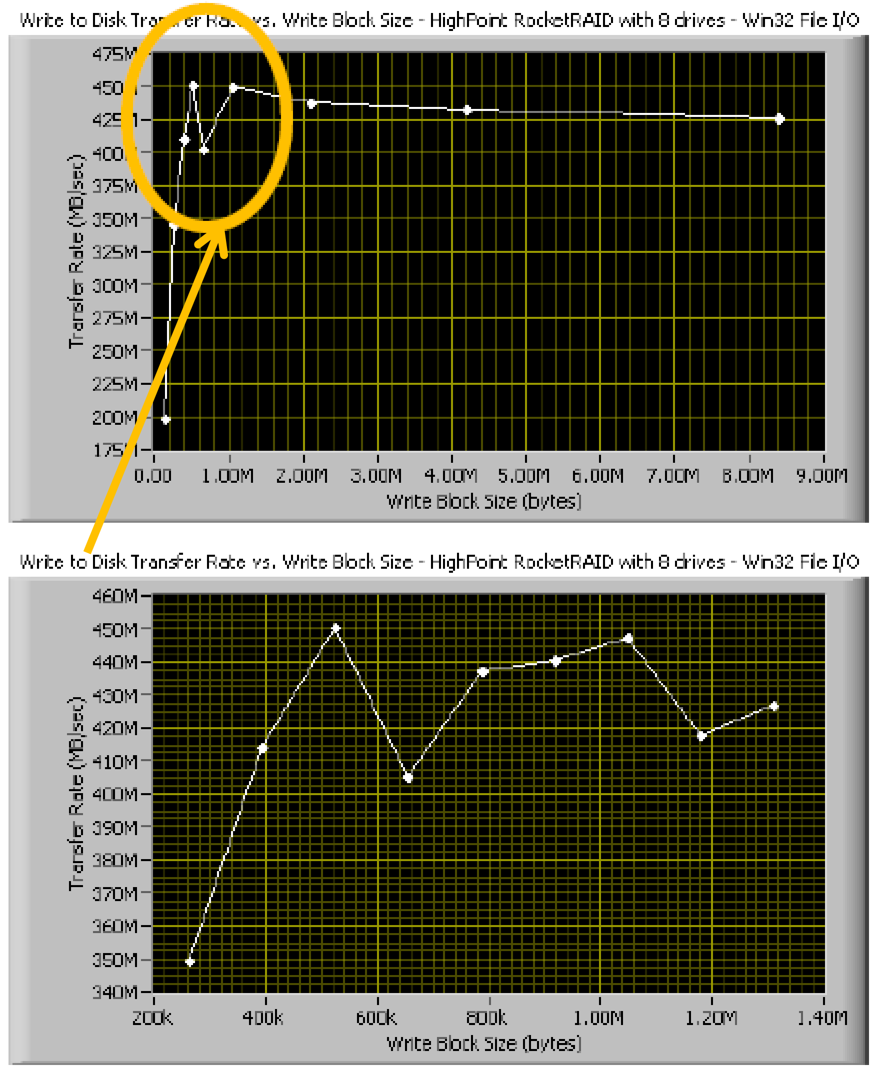
TDMS –Write Data and Set Properties



E.g. sample rate, UUT/sensor names, channel names

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



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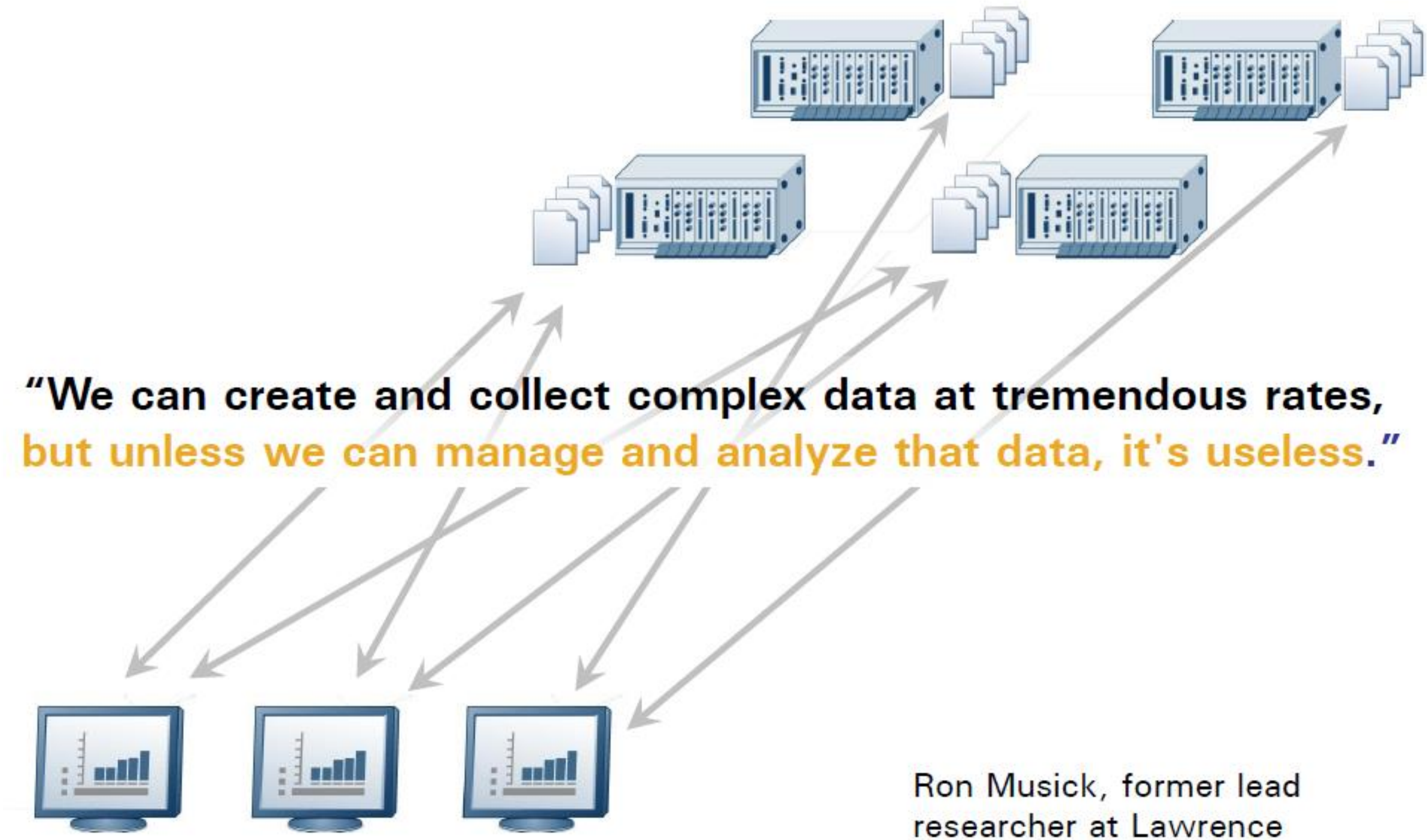
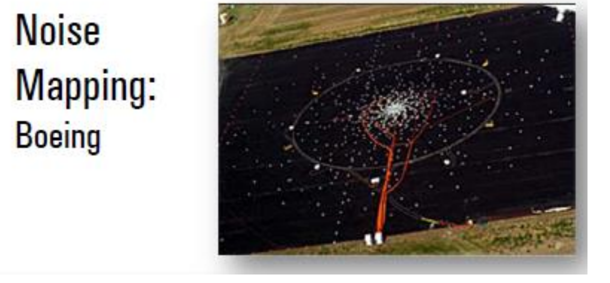
The data challenge



"We can create and collect complex data at tremendous rates, but unless we can manage and analyze that data, it's useless."

Ron Musick, former lead researcher at Lawrence Livermore National Laboratory

Applications Requiring high-speed Data Streaming (examples)

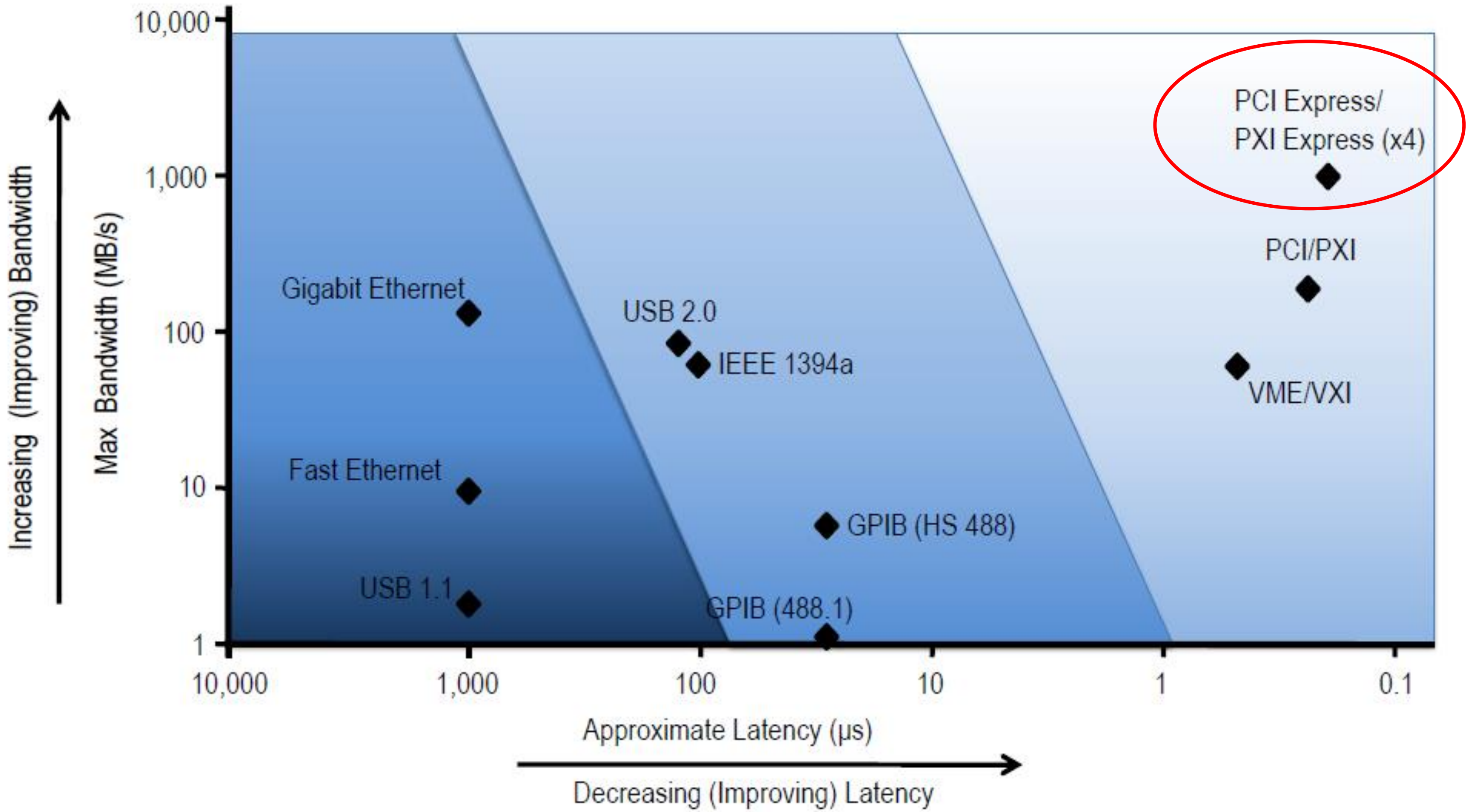


- High speed data acquisition
  - Combined with many DAQ channels
- Radar (Giga-samples/s)
  - RF recording and playback
- High resolution and/or high speed video
  - Digital video recording and playback

Key system components for high-speed streaming

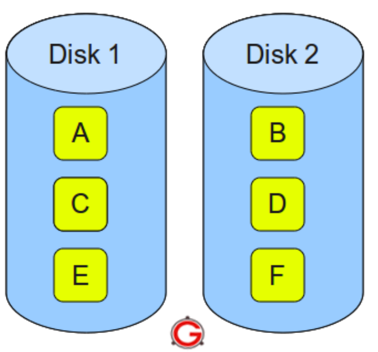
- Hardware Platform with High-Throughput and Low-Latency
  - PXI/PCI Express bus
- High-Speed Data Storage
  - Hard Disk Drives (HDDs) in RAID
  - Solid-State Drives (SSDs)
- Software for Streaming to Disk at High Rates

Bandwidth versus Latency

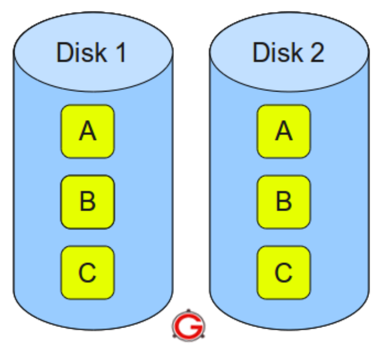


RAID introduction

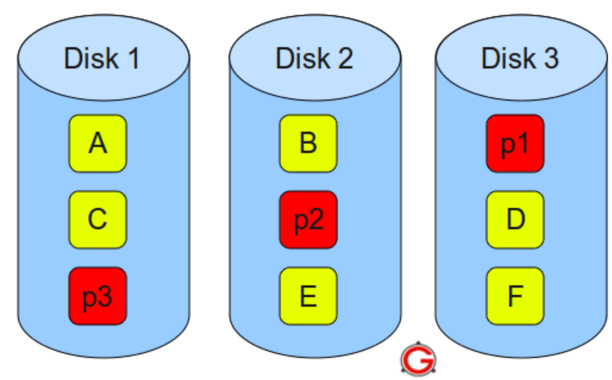
- RAID = Redundant Array of Independent Drives.
- RAID is a general term for mass storage schemes that split or replicate data across multiple hard drives.
  - **To increase write/read performance and/or increase safety (redundancy)**



RAID 0 – Blocks Striped. No Mirror. No Parity.



RAID 1 – Blocks Mirrored. No Stripe. No parity.



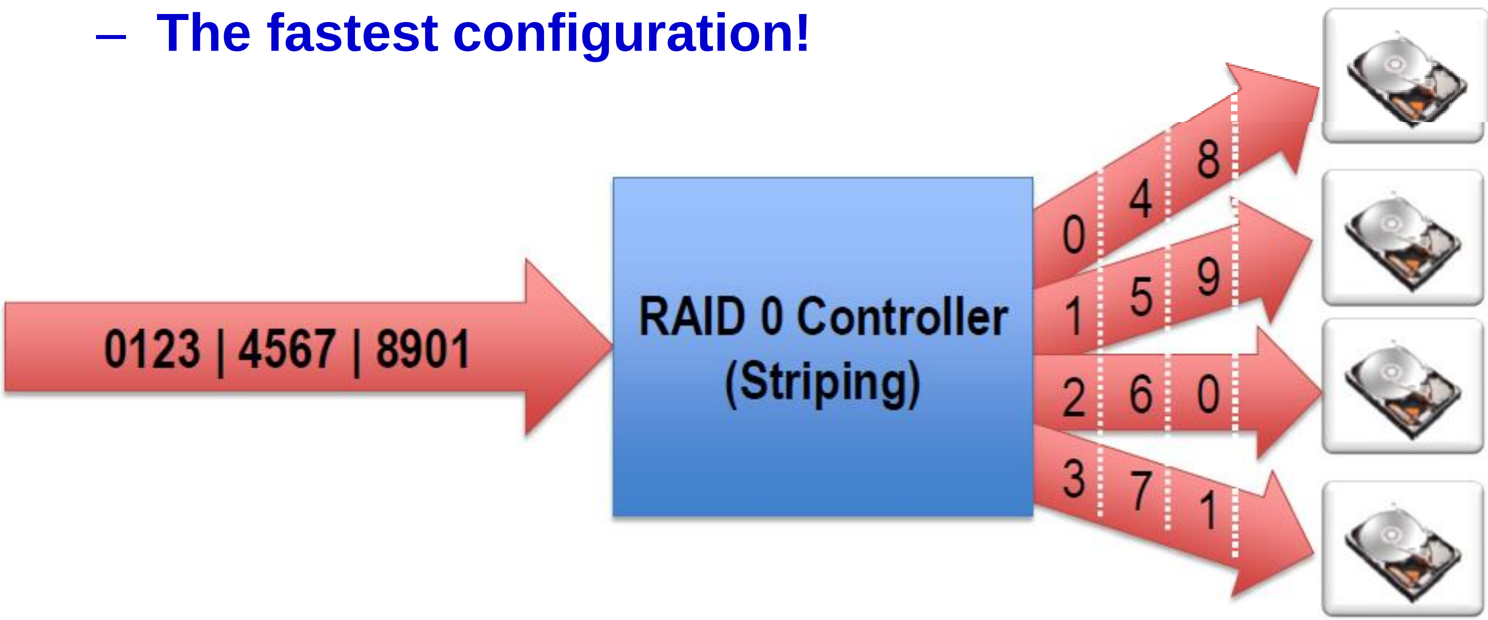
RAID 5 – Blocks Striped. Distributed Parity.

RAID examples

- Internal RAID of the workstation/PC
- Network attached storage (NAS) with RAID
- Server RAID
- Externally connected RAID (e.g. to the PXIe chassis)
- In-chassis PXI RAID
- SSDs (FLASH circuits) on a PCIe card

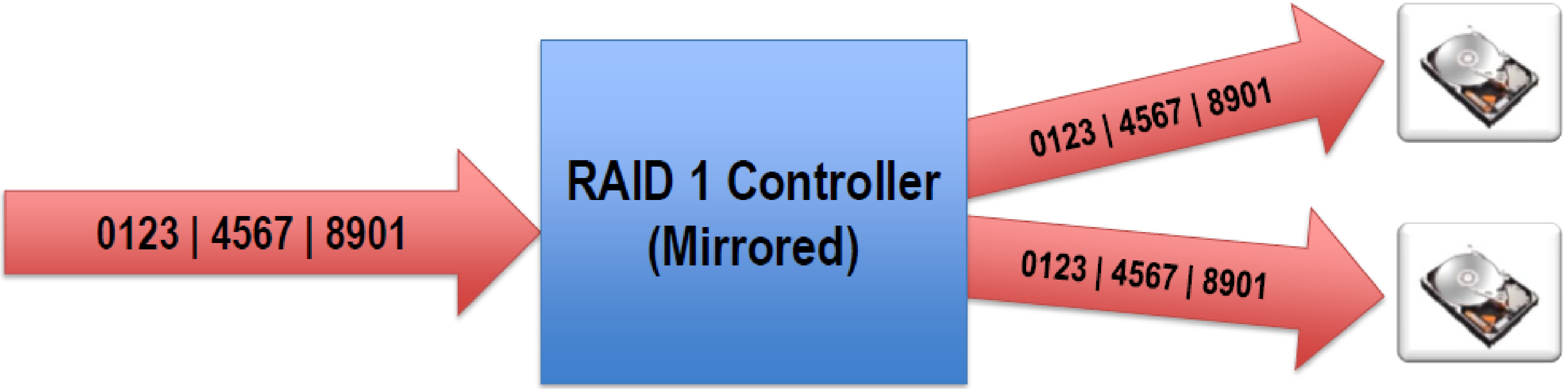
RAID-0

- **Striping without redundancy**
  - Improved speed over streaming to a single hard drive
  - Unimproved system reliability
  - Transparently supported by Windows OS
  - **The fastest configuration!**



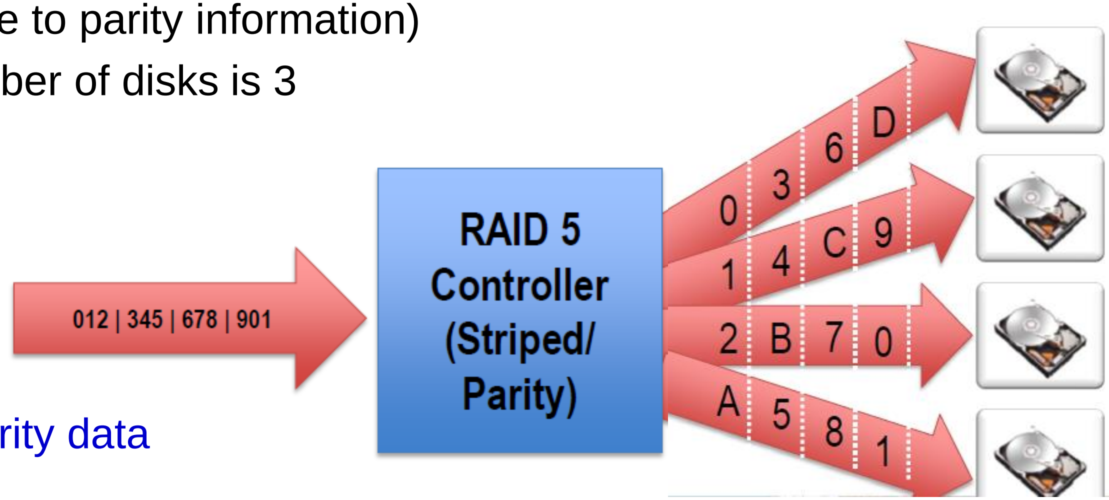
RAID-1

- **Mirrored (redundancy)**
  - 100% data redundancy
    - Each piece of data is written to **two** (or more) hard drives
  - No write speed increase over single disk
  - Highest overhead of all raid configurations
  - Often used for the operating system (OS) disks



RAID-5

- **Distributed parity (single parity)**
  - Parity data distributed on all disks
  - Can only tolerate <u>one drive failure (</u>array continues to operate with one failed drive)
  - Single-parity RAID levels are as vulnerable to data loss as a RAID-0 array until the failed drive is replaced and its data rebuilt
  - More write overhead than RAID-1 because of the additional parity data that has to be created and written to the disk array
  - Poor performance with small files
  - Gives less space for measurement data (due to parity)
    - Reduces the amount of storage space available by the size <u>of one hard drive (</u>due to parity information)
    - Minimum number of disks is 3



Note: A, B, C and D are parity data

```
0 XOR 0 = 0
0 XOR 1 = 1
1 XOR 0 = 1
1 XOR 1 = 0
```

Parity: XOR method

- Parity is used both for the protection of data, as well as for the recovery of missing data.
- To calculate the parity for a RAID the bitwise XOR of each drive's data is calculated.
- The parity data is written to the dedicated parity drive.
  - Note: distributed parity is used in the common RAID configurations!
- In order to restore the contents of a failed drive, the same bitwise XOR calculation is performed against all the remaining drives, substituting the parity value (here 11100110) in place of the missing/dead drive:

```
Drive #1: 00101010 (Data)
Drive #2: 10001110 (Data)
Drive #3: 11110111 (Data)
Drive #4: 10110101 (Data)
Drive #5: -------- (Hot Spare)
Drive #6: 11100110 (Parity)
```

```
Drive #1: 00101010 (Data)
Drive #2: 10001110 (Data)
Drive #3: --Dead-- (Data)
Drive #4: 10110101 (Data)
Drive #5: 11110111 (Hot Spare)
Drive #6: 11100110 (Parity)
```

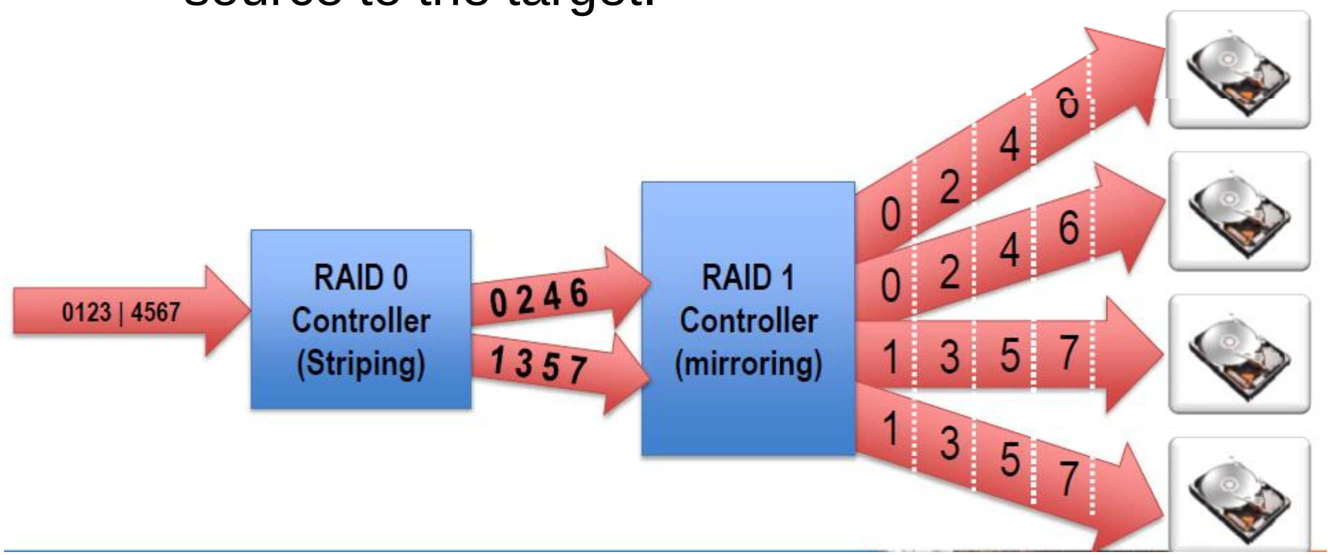
00101010 XOR 10001110 XOR 11110111 XOR 10110101 = 11100110

RAID-6

- **Double distributed parity**
  - Extends RAID 5 by adding an additional parity block
  - Provides fault tolerance from <u>two drive failures (</u>array continues to operate with up to two failed drives)
  - This becomes increasingly important as large-capacity drives lengthen the time needed to recover from the failure of a single drive
  - Double parity gives time to rebuild the array without the data being at risk if a single additional drive fails before the rebuild is complete.
  - <u>Very slow write</u>
    - – because of the overhead associated with parity calculations

RAID-10 (1+0)

- **Striping and mirroring**
  - Both increased speed and redundancy compared to single drive
  - Can sustain <u>multiple drive failures</u>
  - Configuration requires <u>twice the number of hard drives</u>
  - Fast **rebuild** as data is copied block for block from the source to the target.



Kilobyte – kB vs. KB (from Wikipedia)

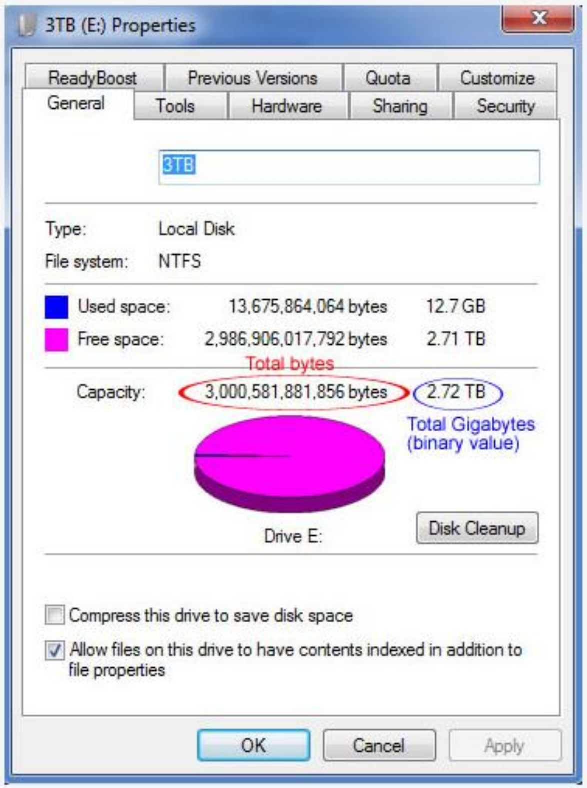
- The **kilobyte** (symbol **KB**)[1] is a multiple of the unit byte for digital information. Historically and in common usage, a kilobyte refers to 1024 (2^{10}) bytes in most fields of computer science and information technology.[2][3][4] However, hard disk drives measure capacity in strict accordance with the rule of the International System of Units' *unit prefixes* (prefixes like *kilo-* and *mega-*) that are based on decimal math.[5][6] In such mass storage contexts, *megabyte* equals precisely 1,000,000 bytes and *gigabyte* is precisely 1,000 times greater than a megabyte. This association suggests that *kilobyte* can also denote 1,000 bytes in the context of mass storage. Thus, "kilobyte" and its symbol "KB" can be ambiguous, their exact value (1,024 or 1,000) dependent upon context.
- In December 1998, an international standards organization attempted to address these dual definitions of the conventional prefixes by proposing unique binary prefixes and prefix symbols to denote multiples of 1024, such as "kibibyte (KiB)", which exclusively denotes 2^{10} or 1024 bytes.[7] Had this proposal been widely and consistently adopted, it would have liberated the standard unit prefixes to unambiguously refer only to their strict decimal definitions wherein *kilobyte* would be understood to represent only 1000 bytes. However, in the over-12 years that have since elapsed, the proposal has seen little adoption by the computer industry.[8][9][10][11]

kB vs. KB

Two Different Measurements Systems

Name	Abbreviation	Binary Power	Binary Value (in Decimal)	Decimal Power	Decimal (Equivalent)
kilobyte	KB	2^10	1,024	10^3	1,000
megabyte	MB	2^20	1,048,576	10^6	1,000,000
gigabyte	GB	2^30	1,073,741,824	10^9	1,000,000,000
terabyte	TB	2^40	1,099,511,627,776	10^12	1,000,000,000,000

How Operating Systems Report Drive Capacity



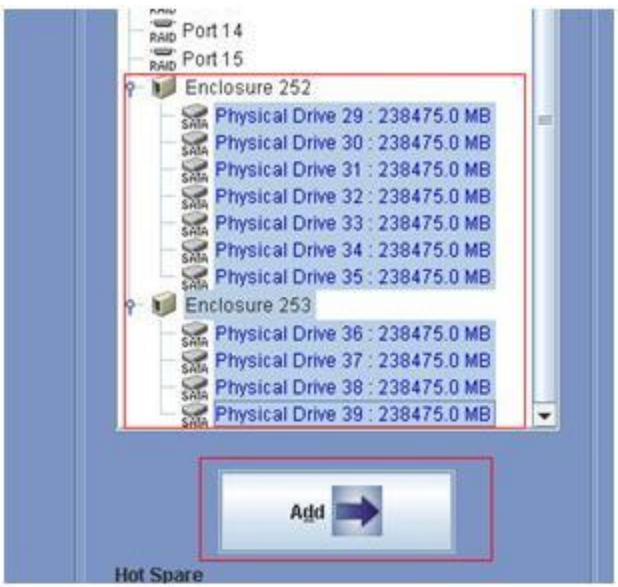
k = 1000 (decimal)
K = 1024 (binary)

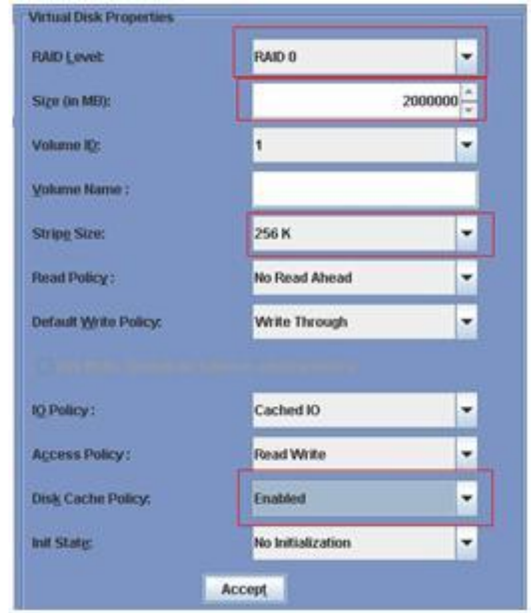
$GB_{binary} = 1024^3$ byte
$TB_{binary} = 1024^4$ byte

(GB_{binary} ~= $GB_{desimal}$*0.93)
(TB_{binary} ~= $TB_{desimal}$*0.90)

RAID configuration

- Use the RAID management software to configure you RAID system





- Do not create any single partition larger than **2 TB** when using Windows XP (32-bit OS). Windows XP and the original release of Windows Server 2003 <u>have a limit of 2 TB per physical disk, including all partitions</u>

Drive Partition - 2.2 TB limitation

- A partition is a contiguous space of storage
- Partitions are visible to the system firmware and the installed operating systems.
- This 2.2 TB limitation dates back to the 1980s and the original IBM PC. This introduced the **master boot record (MBR)** partitioning scheme to describe hard disk partitions.
- MBR consists of a sequence of 512 bytes located at the first sector of a data storage device such as a hard disk
- BIOS systems with MBR disks use **32-bit values** to describe the starting offset and length of a partition. Due to this size limit, MBR allows a maximum disk size of approximately 2.2 TB
  - 2^32 -1 sectors * 512 bytes/sector = 2.199TB

- This limitation applies for Windows XP 32 bit !

BIOS (basic input/output system)

- The BIOS software is built into the PC, and is the first code run by a PC when powered on ('boot firmware'). When the PC starts up, the first job for the BIOS is to initialize and identify system devices such as the video display card, keyboard and mouse, hard disk drive, optical disc drive and other hardware. The BIOS then locates boot loader software held on a peripheral device (designated as a 'boot device'), such as a hard disk or a CD/DVD, and loads and executes that software, giving it control of the PC.[2] This process is known as *booting*, or booting up, which is short for bootstrapping.
- BIOS software is stored on a non-volatile ROM chip on the motherboard. It is specifically designed to work with each particular model of computer, interfacing with various devices that make up the complementary chipset of the system. In modern computer systems the BIOS chip's contents can be rewritten without removing it from the motherboard, allowing BIOS software to be upgraded in place.

From Wikipedia

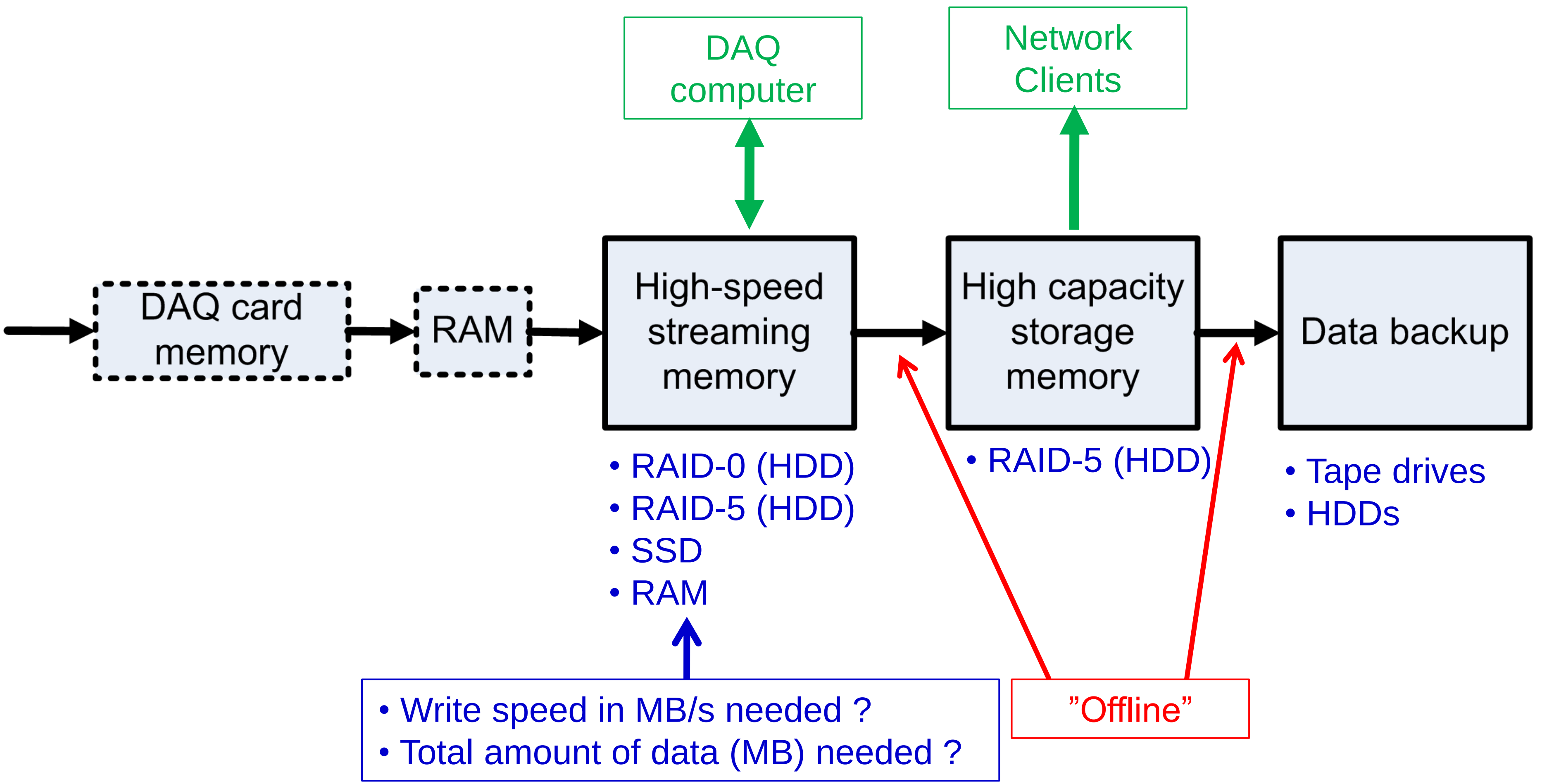
Avoiding 2.2 TB limit : GPT and UEFI

- **GUID Partition Table** (GPT)
  - Provides a more flexible mechanism for partitioning disks than the older Master Boot Record (MBR) partitioning scheme
  - Supported by Windows 7, XP 64-bit, Windows Server 2008 etc.
  - 64-bit values to describe partitions
  - GPT can handle disks of up to 9.4 x 10^{21} bytes (2^64 -1 sectors * 512 bytes/sector)
  - Windows file systems currently are limited to 256 terabytes each
  - <u>Windows only support booting to GPT partitions on systems with EFI firmware.</u>
- Unified **Extensible Firmware Interface** (UEFI)
  - A more secure replacement for the older BIOS firmware interface
  - But, BIOS remains in widespread use since EFI booting has only been supported in Microsoft's operating system products supporting GPT and Linux kernels 2.6.1 and greater builds.

RAID configuration II

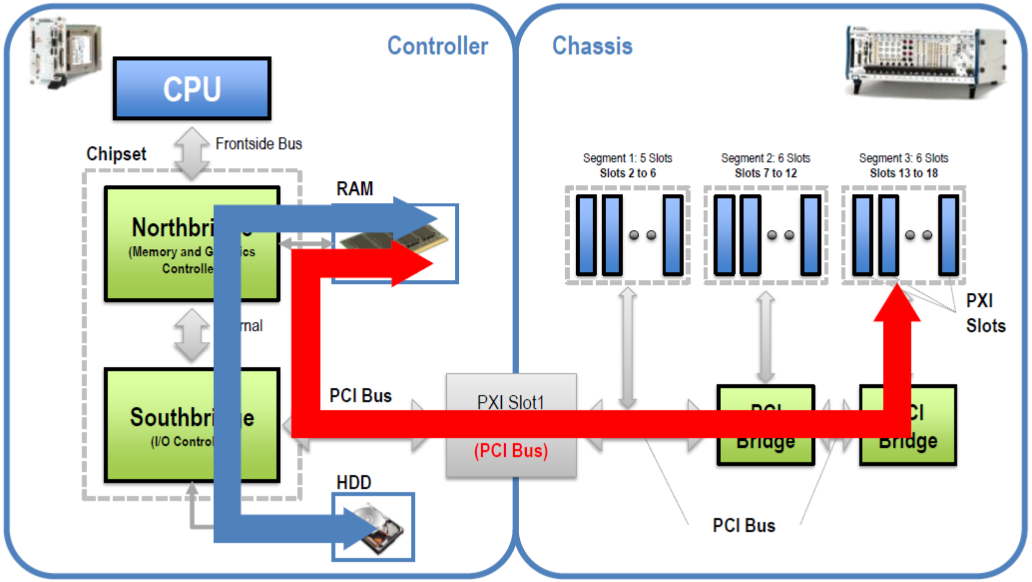
- In order to speed up the write of multiple (simultaneous) files it is recommended to write these files to separate RAID volumes
  - The RAID must be reconfigured with a suitable number of RAID volumes of a suitable size
  - If for example three equally fast high-speed digital video streams are to be stored on a 12 disk RAID, the RAID could be configured with 3 separate RAID volumes of 4 drives each

Memory – Example of a Storage Chain for a large DAQ system



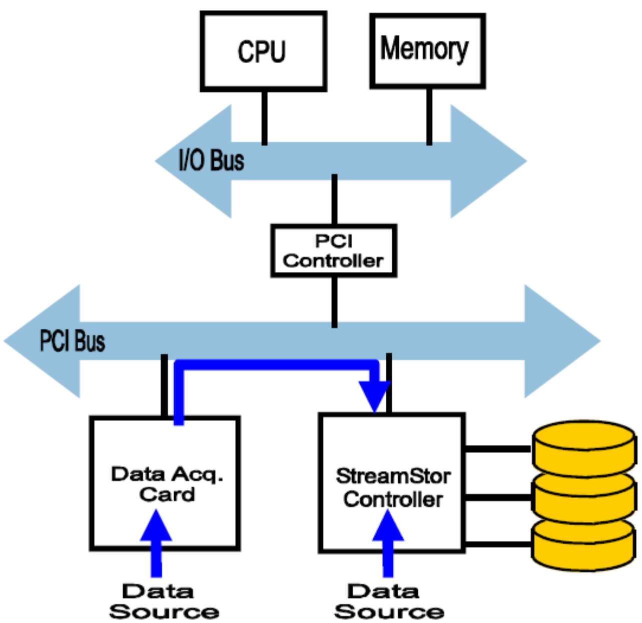
Drawbacks of traditional streaming

- When streaming to or from controller memory or hard drives, the PCI controller (in the case of PCI), I/O bus, controller memory, and processor are <u>shared data paths</u>, <u>which divides down data streaming bandwidth.</u>
- Additionally, the operating system, drivers, and application software managing data flow <u>introduce latencies</u>.



Direct-to-Disk controller

- With a PCI Express direct-to-disk controller module, data is streamed directly from the device memory onboard a DAQ-card, across the PCI or PCI Express bus, to the direct-to-disk controller for acquisition
- This gives a minimum use of the PCI-buss and the CPU



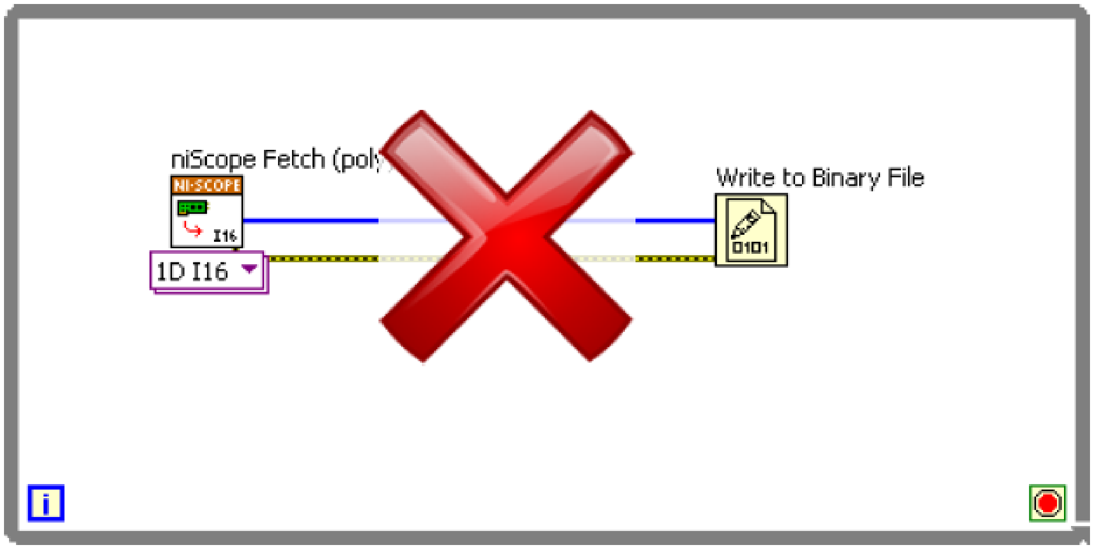
http://www.conduant.com/

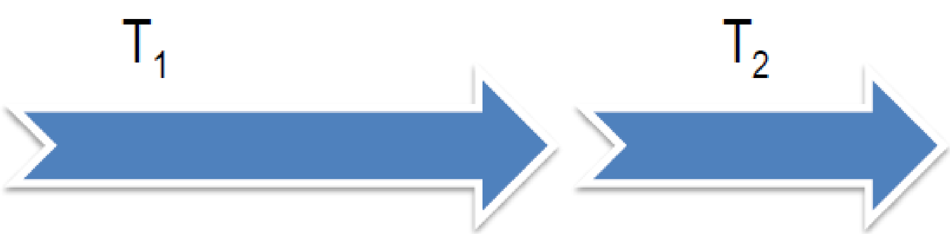
Streamstor Amazon Express Controller (using PCI Express)

32-Bit vs. 64-Bit OS for DAQ applications

- A 32-bit processor can reference 2^{32} bytes, or 4 GB of memory
- A 64-bit processor are theoretically capable of referencing 2^{64} locations in memory. However, all 64-bit versions of Microsoft operating systems currently impose a 16 TB limit on address space
- Note: 64-bit versions of operating systems and application programs are note necessarily faster than their 32-bit counterparts. They can be slower!
- The main benefits of 64-bits for DAQ applications is the large amounts of RAM possible.
- Other applications that can benefit from 64-bits are those working with very large numbers.

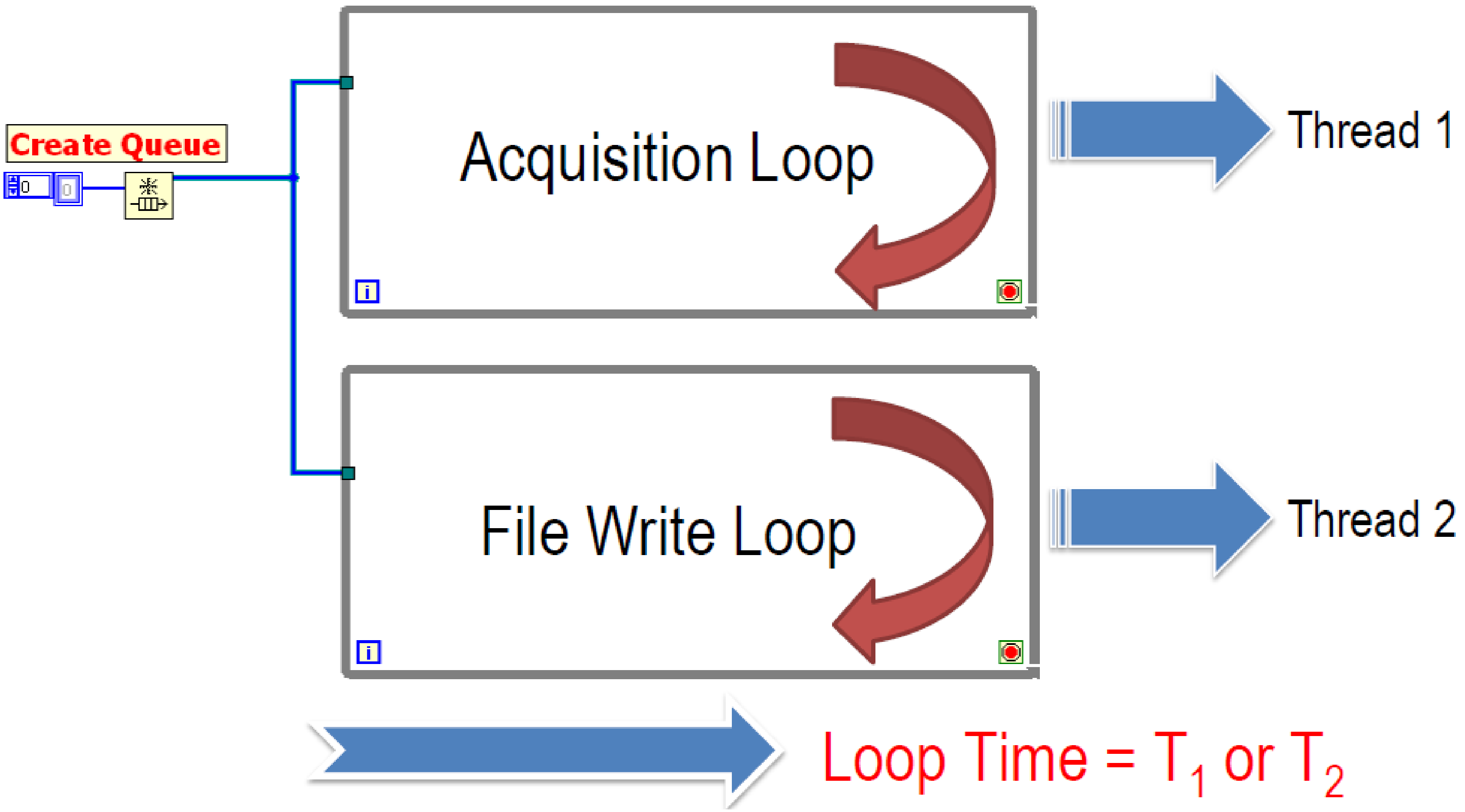
LabVIEW: Bad Programming Structure for High-speed acquisition and storage





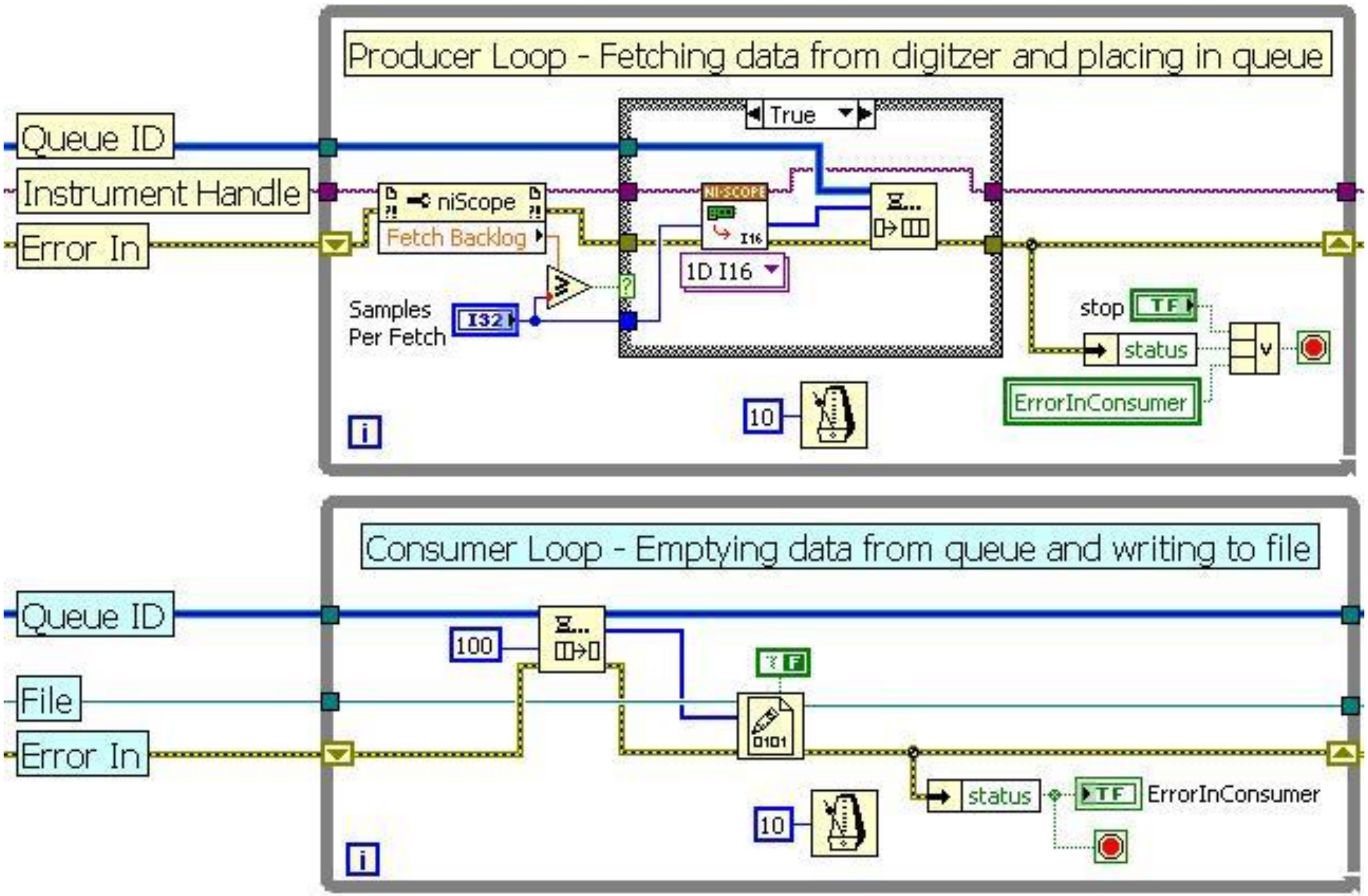
Loop Time = $T_1 + T_2$

Solution: Use Multithreading!



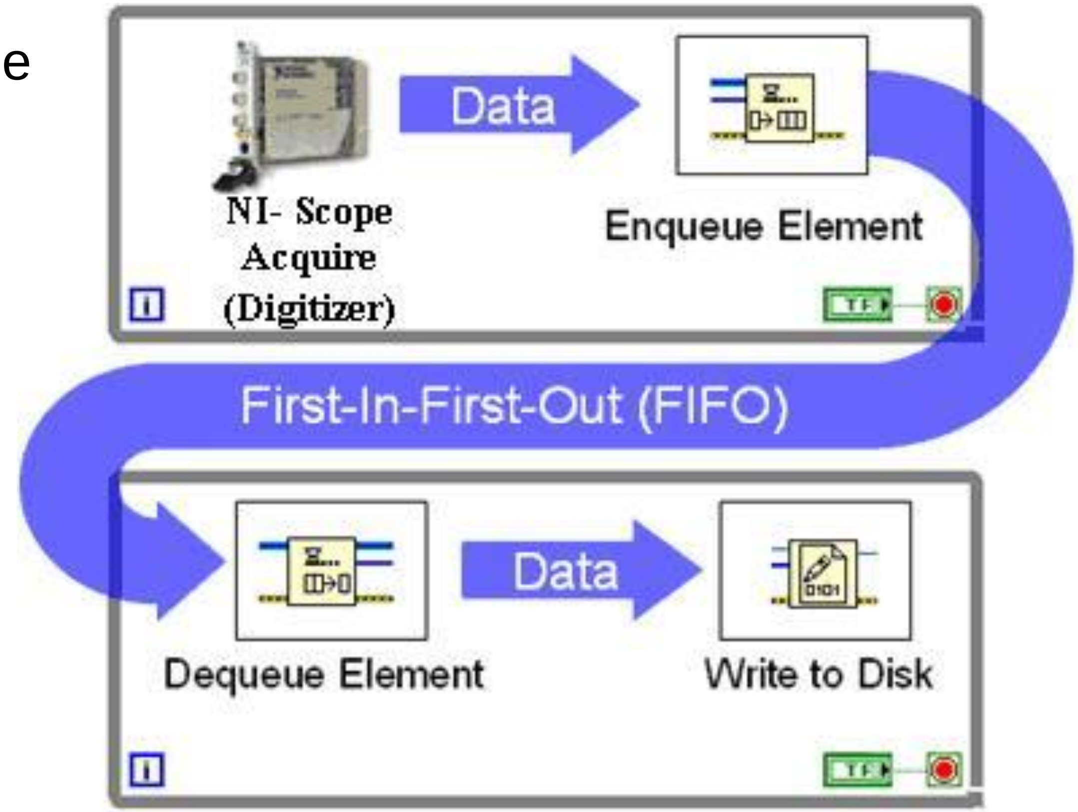
Loop Time = T_1 or T_2

Producer-Consumer loops



- LabVIEW handles the queue as a block of allocated PC memory.

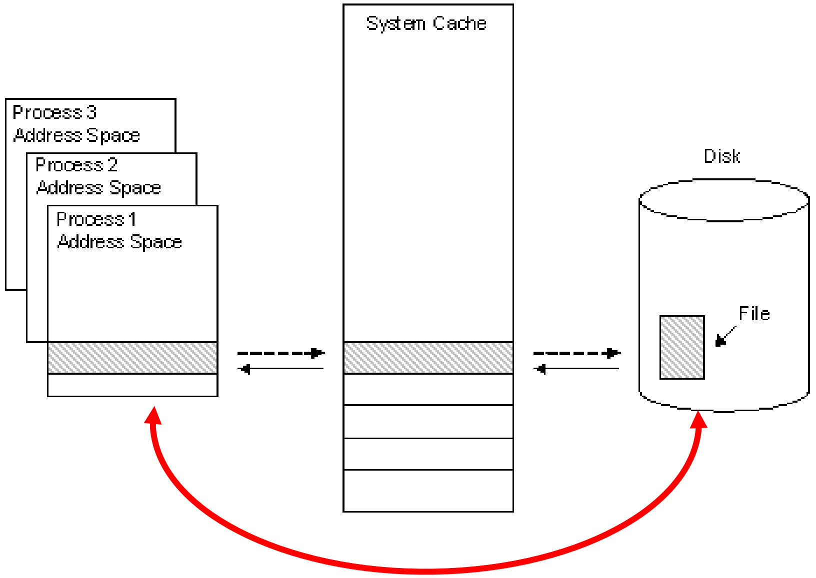
- This memory block is utilized as a temporary storage **FIFO** for data passing between two loops



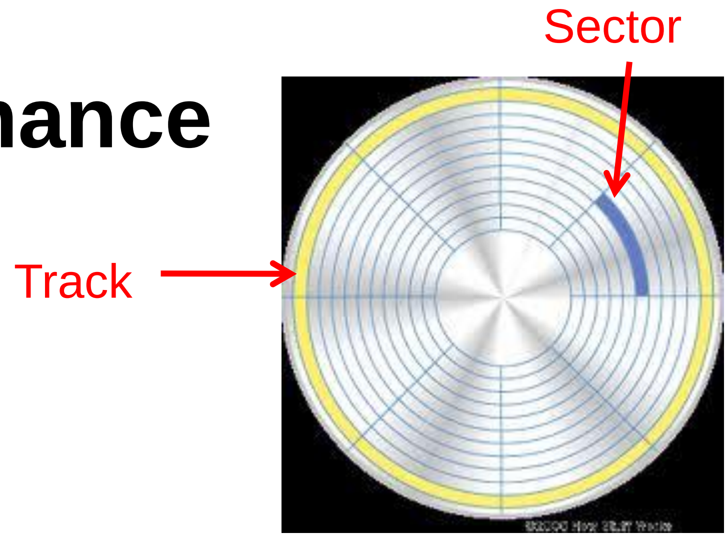
Unbuffered File I/O

- Can use unbuffered file I/O to increase write/read speed for RAID systems

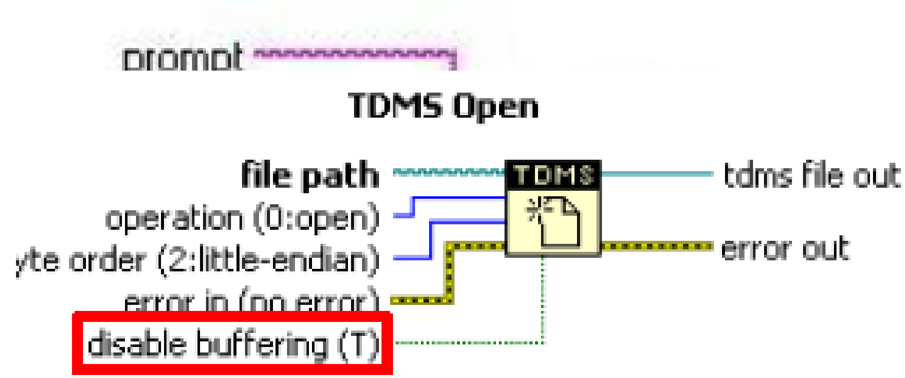
Link to Microsoft - File Buffering



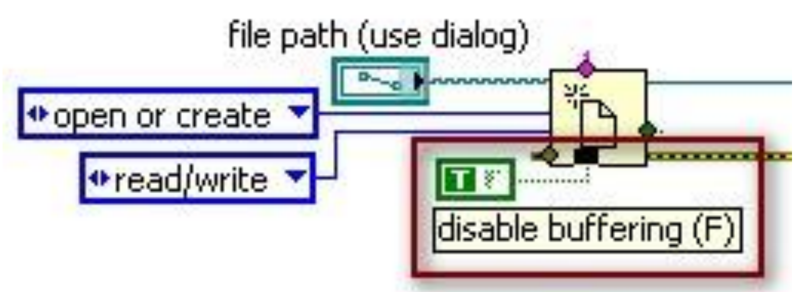
Increase DAQ I/O Performance



- Use the option to **disable buffering (unbuffered I/O**) in Win API
  - Optimizes streaming applications
  - Important for RAID systems



- Note that you must <u>read from or write to the file in **integer multiples of the disk sector size**</u> (usually 512 bytes)
- The data can span multiple sectors but must fill each sector completely
- If the data is not a multiple of the sector size, you must pad the data with filler data and delete the filler data before the data is used



Data Types – file size

- Reduce file size
  - 1 I16 sample = 16 bits = 2 bytes
  - 1 DBL sample = **64 bits = 8 bytes = 4X increase in bandwidth**