

ONFI: Leading the Way to Higher NAND Performance

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Agenda

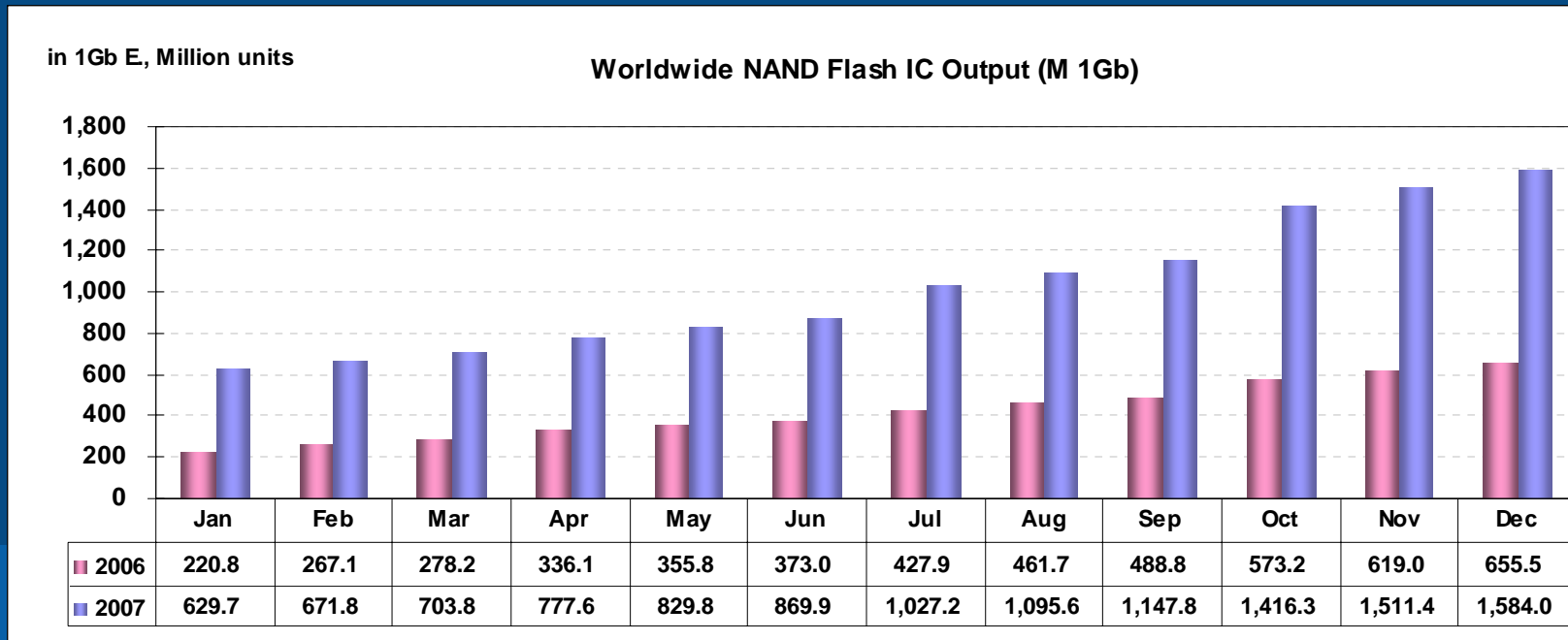
- PC platform and need for a standard
- High speed and PC opportunity
- Other key ingredients for PC use of NAND

The PC is a Key Component of NAND Growth

- NAND growth is projected to be 140% YoY for 06/07
- Largest growth area is "Others"
 - More than 50% projected QoQ growth for Q3/Q4
- A key component of the "Others" category is PC uses

Unit: in 1Gb E., Million units

	Q307F		Q407F	
	Shipment	Demand	Shipment	Demand
Digital Still Cameras	26.8	697.9	31.5	884.6
	13.7%	32.0%	17.4%	27.0%
Cell phones	271.7	880.2	309.7	1,271.5
	7.0%	38.0%	14.0%	44.0%
USB Drives	35.1	615.2	38.9	734.5
	14.8%	29.0%	10.7%	19.0%
Flash-based MP3/PMP	32.6	779.7	46.7	1,223.4
	9.5%	32.0%	43.3%	57.0%
Other (DVs , Game		250.6		578.2
		54.0%		61.0%
Total NAND Flash Demand		3,309.0		4,692.2
		33.0%		42.0%

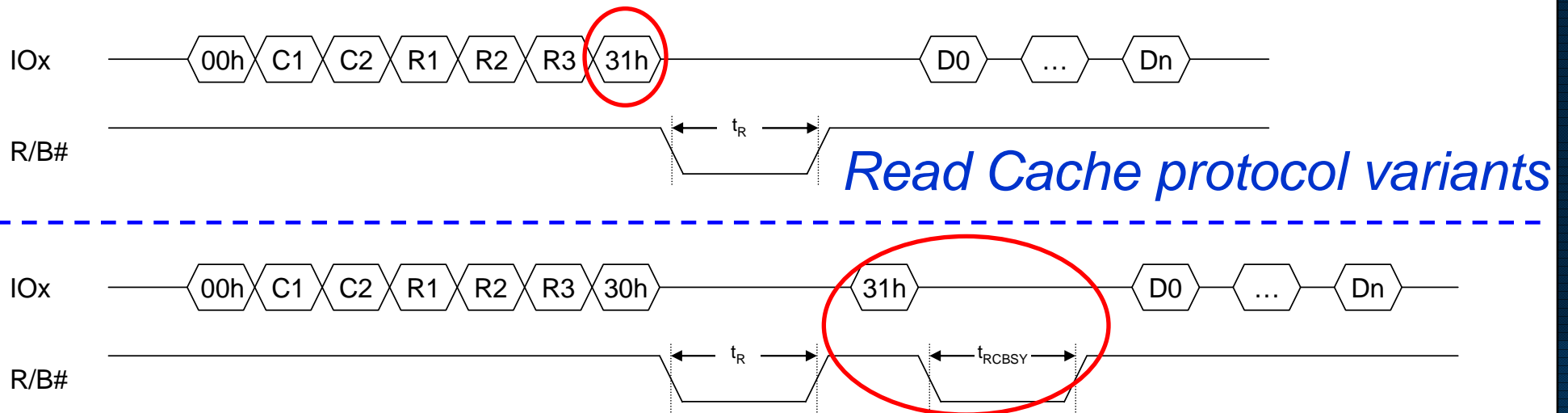


Source: DRAMeXchange, 4/2007



NAND Interoperability Impacts Adoption in PC Platforms

- NAND has been the only commodity memory with no standard
 - Command set, timings, and pin-out are similar among vendors
- Intel® Turbo Memory highlights the increasing role of NAND
 - Platforms have longevity (3+ years) and address many market segments
 - Platforms need to conveniently support new NAND components without silicon or even software changes (due to WHQL recertification)
- Lacking a standard, NAND is ill-suited to the realities of the PC



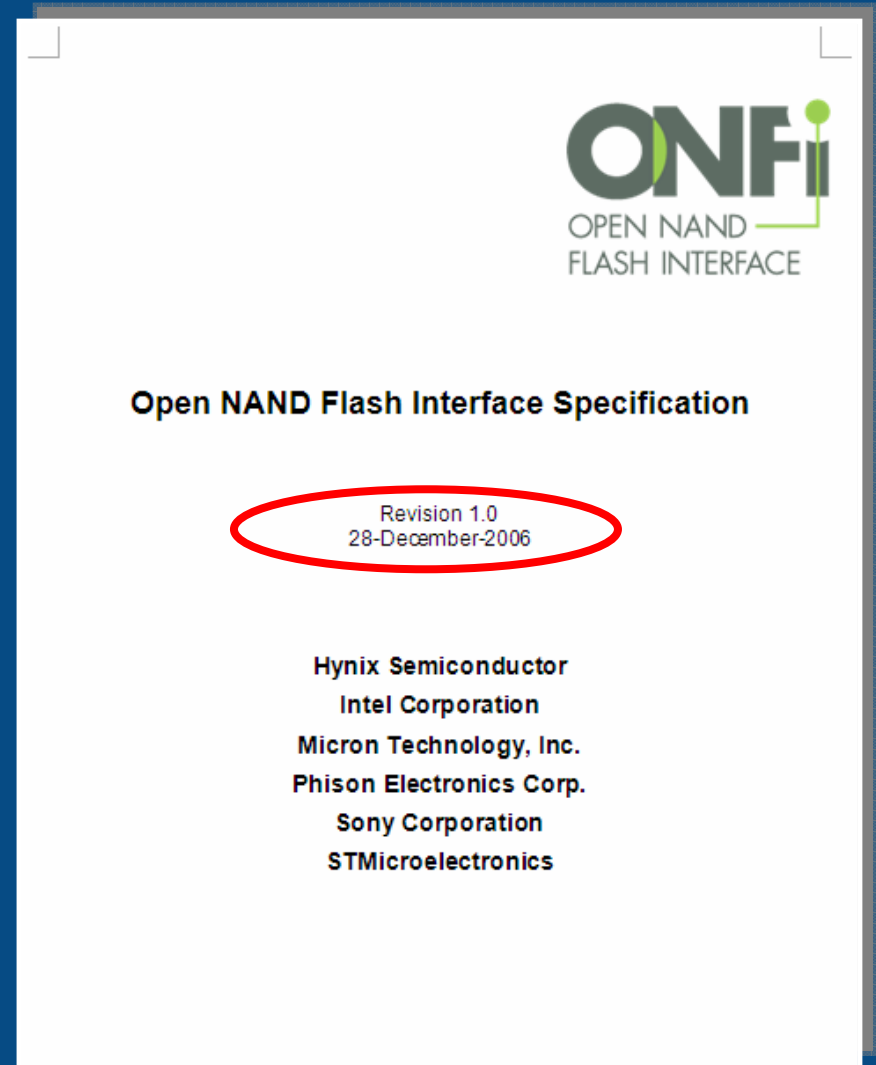
Open NAND Flash Interface (ONFI)

ONFI 1.0 defines:

- Uniform NAND electrical and protocol interface
 - Raw NAND component interface for embedded use
 - Includes timings, electricals, protocol
 - Standardized base command set
- Uniform mechanism for device to report its capabilities to the host

ONFI 1.0 status:

- ONFI Workgroup formed in May '06
- Ratified specification in Dec '06



ONFI Establishes the First Standard NAND Interface



SONY

hynix



Members

A-Data
 Arasan Chip Systems
 BitMicro
 DataFab Systems
 FCI
 Genesys Logic
 HiperSem
 ITE Tech
 Marvell
 Orient Semiconductor
 Qimonda
 Sigmatel
 SimpleTech
 Solid State System
 Telechips
 Transcend Information
 USBest Technology

Alcor Micro
 ATI
 Biwin Technology
 DataIO
 Foxconn
 Hagiwara Sys-Com
 InComm
 Jinvani Systech
 Molex
 Powerchip Semi.
 Seagate
 Silicon Storage Tech
 Skymedi
 Spansion
 Teradyne, Inc.
 Tyco
 WinBond

Aleph One
 Avid Electronics
 Cypress
 Denali
 Fusion Media Tech
 Hitachi GST
 Intelliprop
 Kingston Technology
 NVidia
 PQI
 Shenzhen Netcom
 Silicon Motion
 Smart Modular Tech.
 Super Talent Elec.
 Testmetrix
 UCA Technology

ONFi Membership Continues to Grow

*Other names and brands may be claimed as the property of others



NAND Changes for ONFI Support

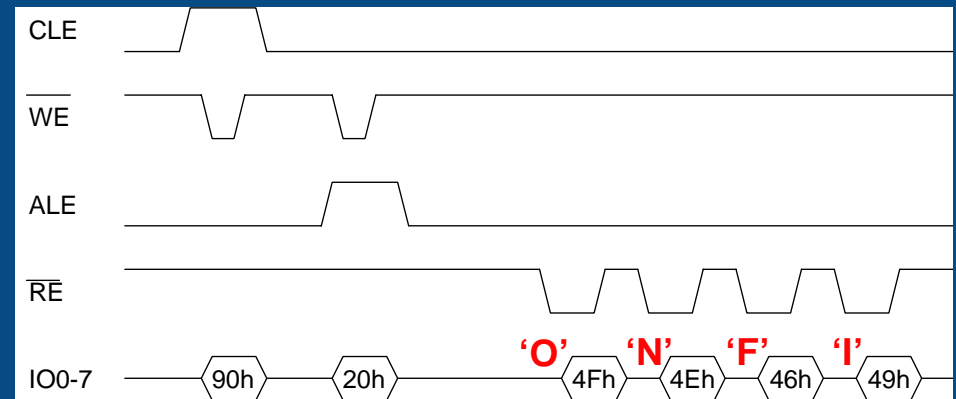
- ONFI 1.0 standardizes similar behavior of industry NAND
- Two NAND changes are needed to comply with ONFI 1.0

Modification 1

- Read ID indicates ONFI compliance

Modification 2

- Read Parameter Page describes NAND capabilities
 - Allows new NAND to be used in older hosts
- The host may choose whether or not to use these capabilities



Memory Organization Block of Parameter Page

- Number of data bytes per page
- Number of redundant bytes per page
- Number of pages per block
- Number of blocks per logical unit (LUN)
- Number of logical units
- Number of address cycles
- Number of bits per cell
- Block endurance
- Number of programs per page
- Recommended bits of ECC correction

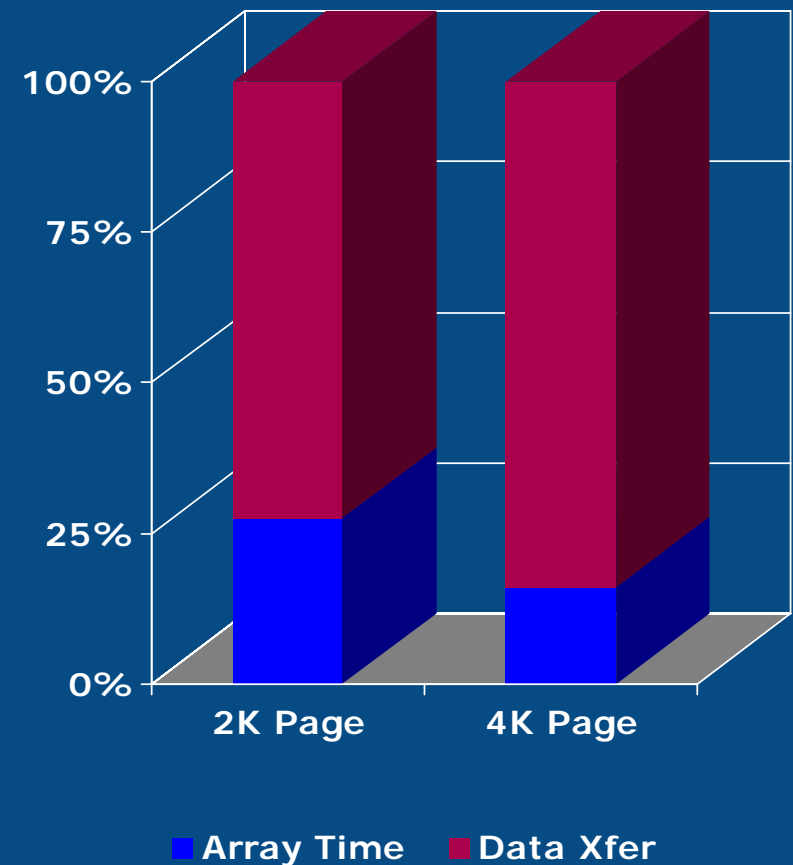
ONFI 1.0 is Easy for the Industry to Adopt

Agenda

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NAND Performance is Limited by the Legacy Interface

- NAND performance is determined by two elements:
 - Array access time
 - Time to transfer data to/from the data buffer in the NAND
- For reads, the dominant factor is the transfer to the data buffer
 - Limits performance to 40 MB/s
 - Could achieve over 150 MB/s with interface improvements
- As page size increases, the interface bottleneck gets even larger



ONFI 2.0 is Solving the Interface Bottleneck

ONFI is Delivering Higher Speed

- ONFI is following a straight forward path to higher speed

Step 1: Source synchronous

- Add source synchronous data strobes

Step 2: Learn from DRAM

- Follow the lessons of DDR

Step 3: Easy transition

- Avoid change for change's sake

ONFI Interface Rate Roadmap

Legacy	40 MB/s
Gen1	~ 133 MB/s
Gen2	~ 266 MB/s
Gen3	400 MB/s +

ONFI is Leading the Way to 10x Higher Performance

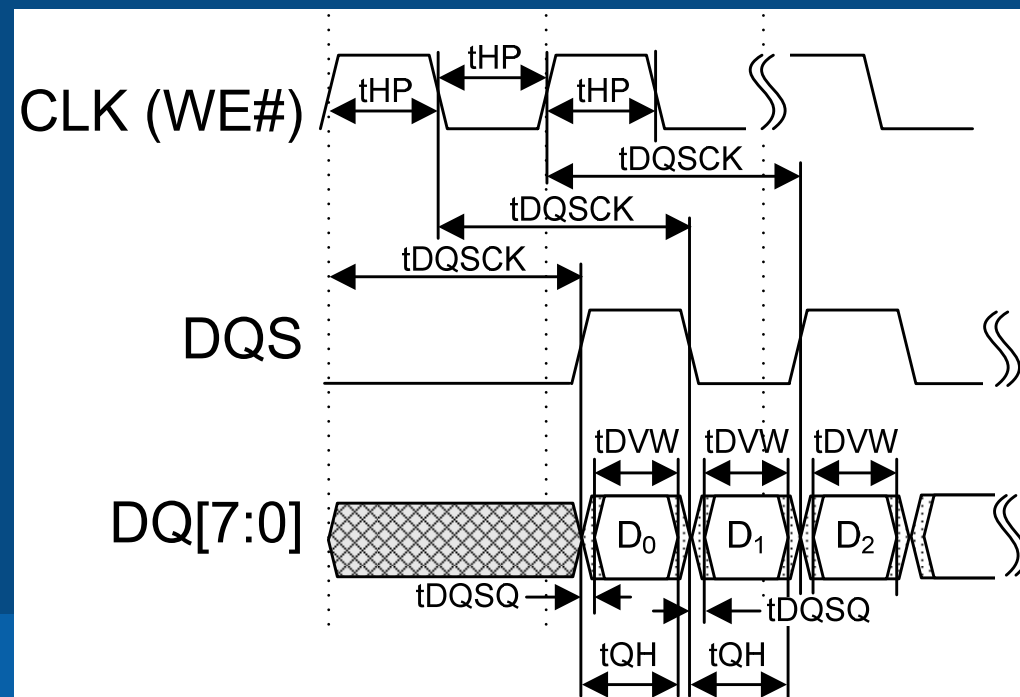
Going Source Synchronous

- A source synchronous data strobe is added to indicate where data should be latched
 - ONFI adds one new signal for the first generation
- The write and read enable signals are re-purposed for high speed
 - Write enable is used as a clock for all data input, output
 - Read enable is used to indicate the direction of data transfer

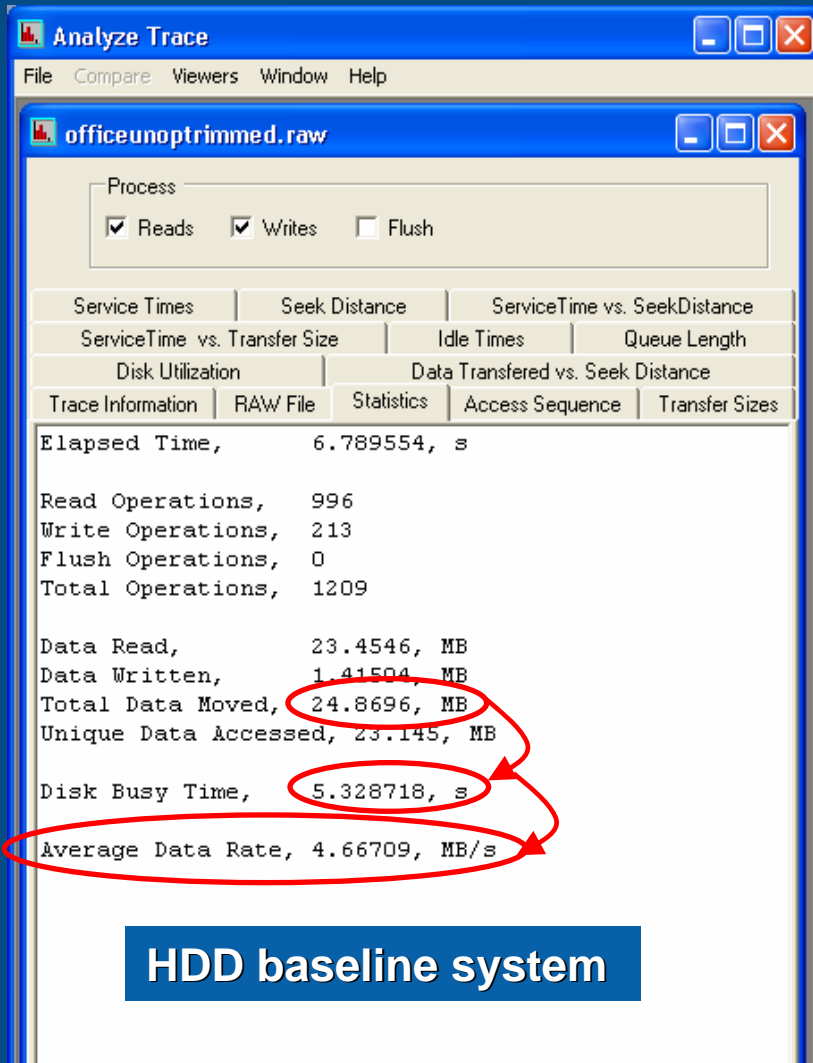
Symbol		Type	Description
Traditional	Source synchronous		
I/O[7:0]	DQ[7:0]	I/O	Data inputs/outputs
—	DQS	I/O	Data strobe
WE#	CLK	Input	Write enable => Clock
RE#	W/R#	Input	Read enable => Write / Read# direction

Learning from DRAM

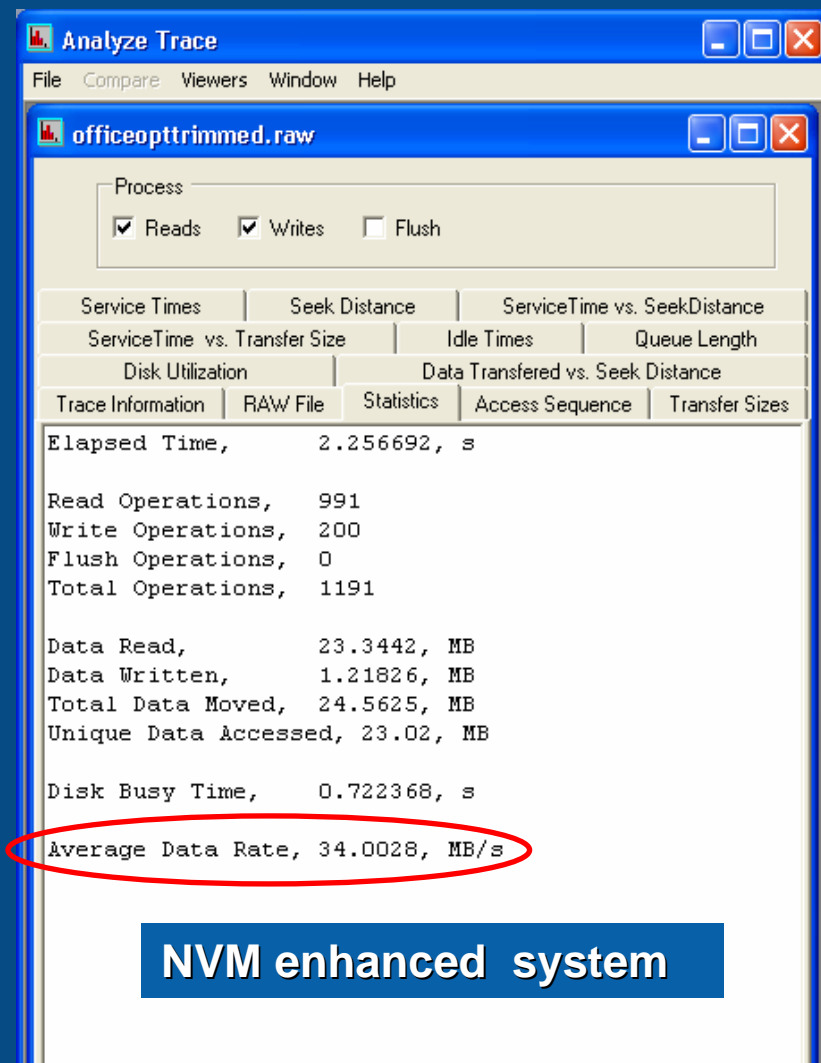
- High speed NAND uses a DDR protocol
 - DDR balances performance and power
- DQS identifies the start of a data byte on the DQ bus
 - Data is latched on each edge of DQS (rising and falling)



NAND Impact for a PC Application Launch Workload



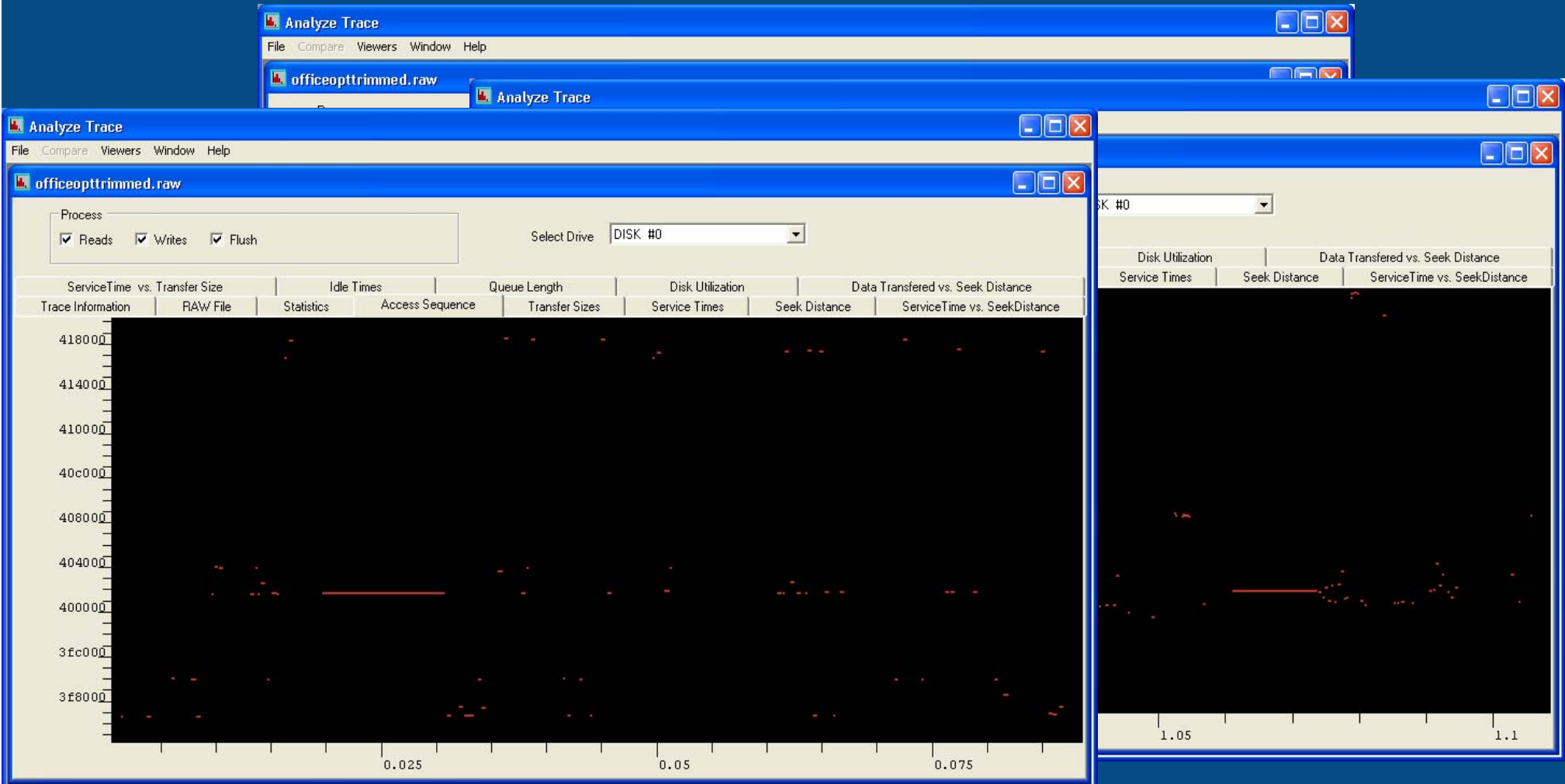
HDD baseline system



NVM enhanced system

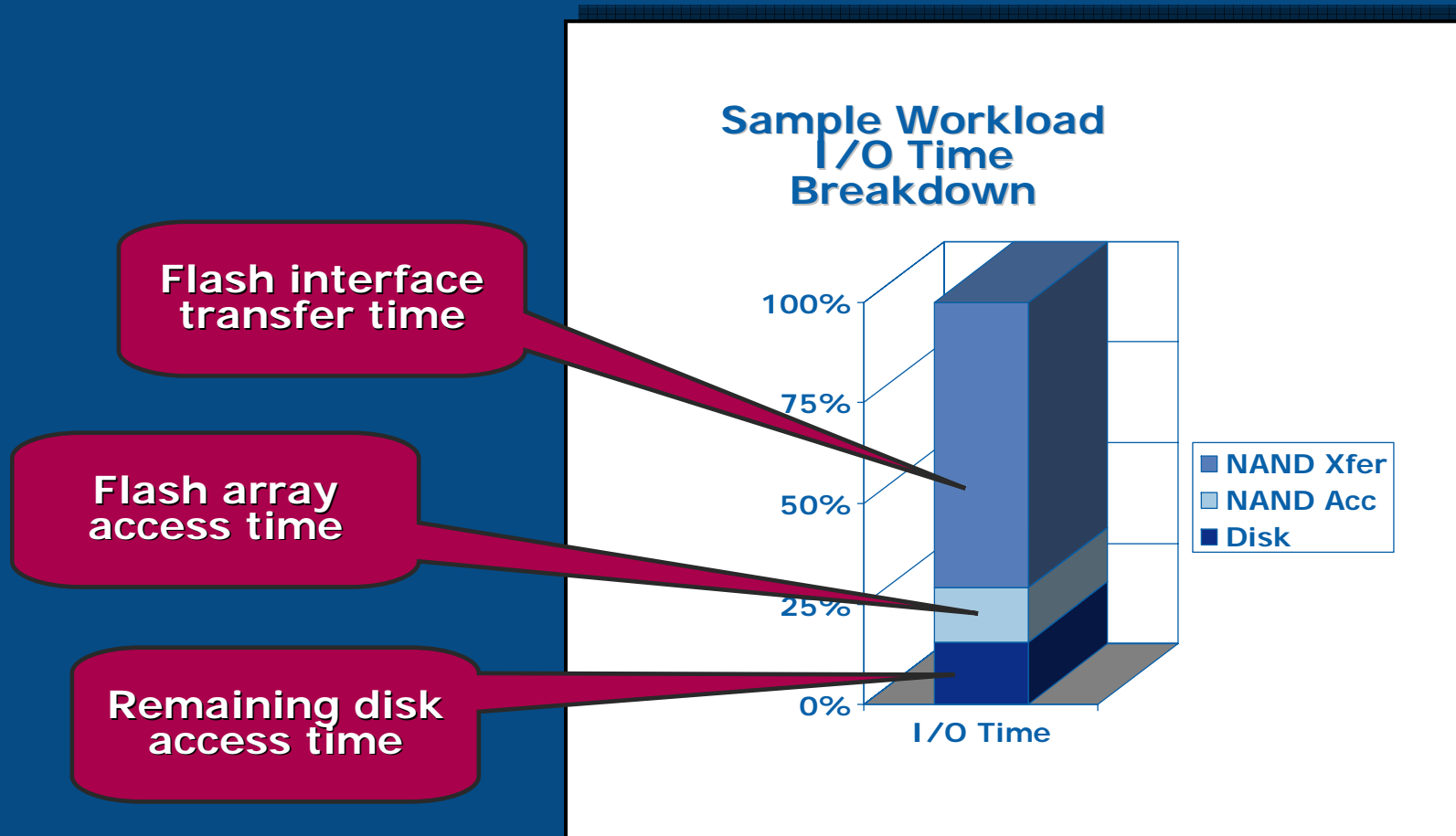
Effective Data Rate for Flash Solution 7x Higher

Workload Analysis: High Hit Rate



Can higher speed NAND improve performance of this workload further?

Opportunity for High Speed Impact



Over 75% of Workload Time in NAND Data Transfer

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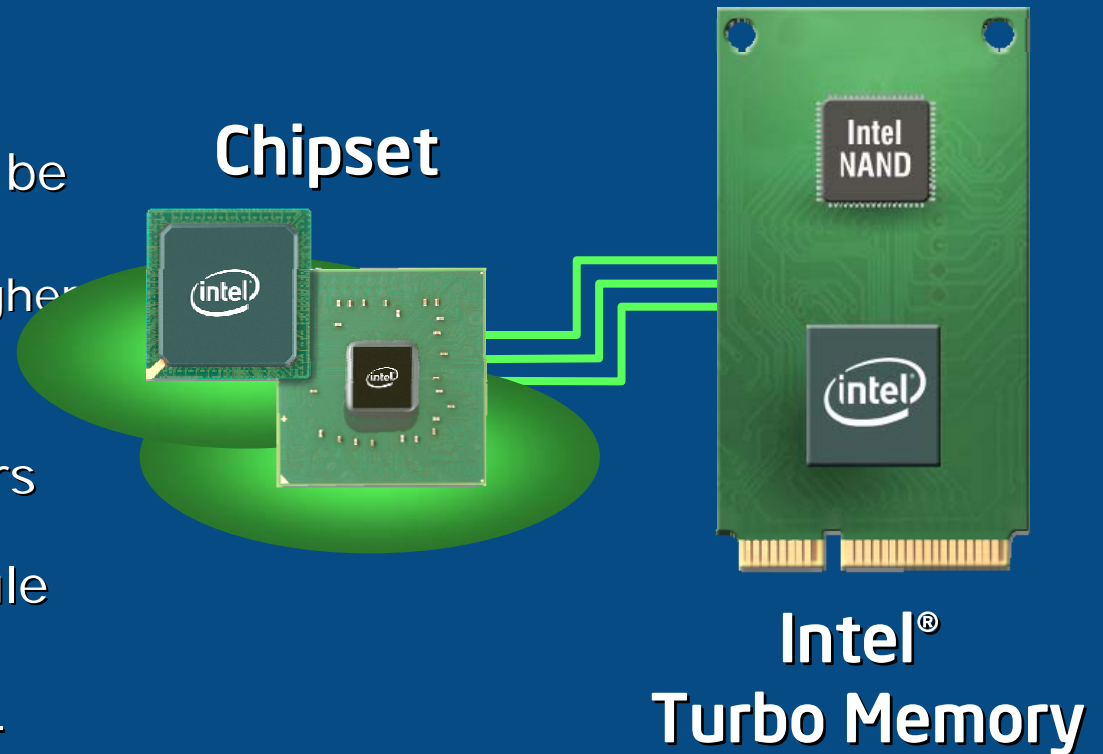
Non-Volatile Memory Host Controller Interface

- An impediment to enabling NAND benefits broadly in the PC is the lack of a standard register programming interface
 - There is no standard driver interface that allows OS vendors to provide a base support for platform NAND solutions
- Industry leaders have formed the NVMHCI Workgroup to define a standard host controller interface
 - NVMHCI heavily leverages the Serial ATA AHCI interface for fast time to market, and to enable a single driver to manage SATA and a platform NVM device

The screenshot shows a Microsoft PressPass page. At the top, there is a search bar for Microsoft.com and a navigation menu with links like 'PressPass Home', 'PR Contacts', and 'Fast Facts About Microsoft'. The main content area features a news article titled 'Dell, Intel and Microsoft Join Forces to Increase Adoption of NAND-Based Flash Memory in PC Platforms'. The article text states: 'Newly formed group to provide standard interface for nonvolatile memory subsystems.' Below the article, there is a 'Related Links' section with external resources: 'Dell Web site' and 'Intel Web site'. The Microsoft logo is visible in the top left corner of the page.

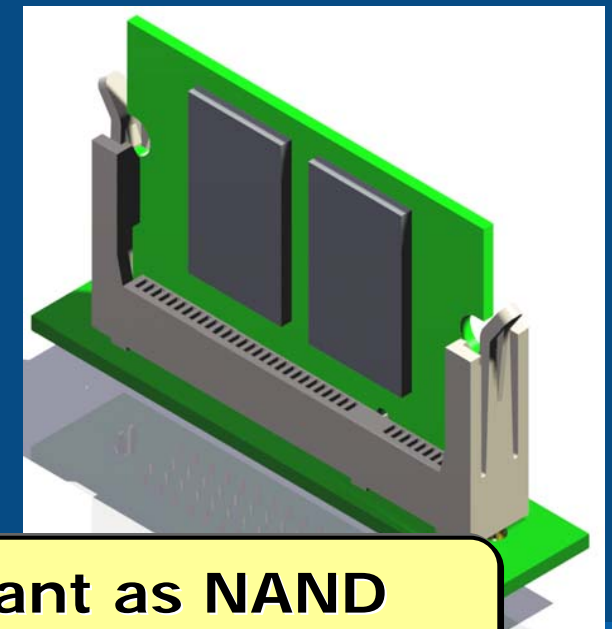
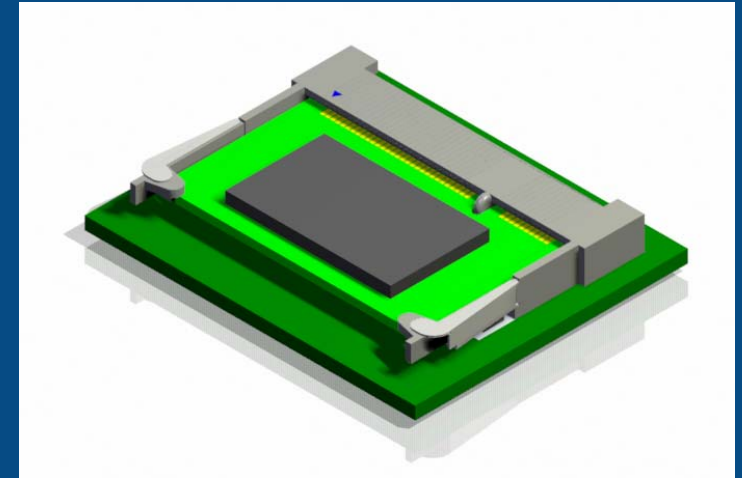
NAND in the Platform

- NAND in the platform has started with modules plugged in on PCIe
- As NAND becomes more prevalent, the controller will be integrated with the platform
 - Down on motherboard or higher levels of integration
- OEMs want to offer customers capacity/feature choice, so NAND will remain on a module
- **Issue:** How to plug a NAND-only module into a PC platform?
 - NAND does not talk PCIe*



Connector for NAND-only Modules

- To offer capacity choice, ONFI is defining a standard connector
 - Enables OEMs to sell NAND on a module
 - Like an unbuffered/unregistered DIMM
- The ONFI connector effort is leveraging existing DRAM standards
 - Avoids major connector tooling costs
 - Re-uses electrical verification
 - Ensures low cost with quick time to market
- Both right-angle and vertical entry form factors are being delivered



Standard NAND-only Module Important as NAND Becomes a Critical Component of PC Platforms

Summary

- ONFI 1.0 defines a standard interface for NAND
 - More details at www.onfi.org
- ONFI 2.0 is defining a higher speed interface NAND
 - Multi-generation roadmap delivering up to 10x in performance
 - Performance delivers significant benefits in PC platform workloads
- Other key pieces for PC platform use of NAND include:
 - NVMHCI standard register programming interface
 - NAND-only module for continued up-sell and customer choice

**ONFI is Leading the Way to Higher Performance –
New Features Critical for PC Platform Use of NAND**