The Inevitable Rise of NVM in Computing

Jim Handy

Nonvolatile Memory Seminar
Hot Chips Conference
August 22, 2010
Memorial Auditorium
Stanford University
Objective Analysis
Semiconductor Market Research

- Market consulting/research firm
  - Market analysis, strategies, white papers
- Highly-respected lead analysts
  - Jim Handy: Memories
  - Tom Starnes: Processors
- Industry experience & 25+ years in field
- Reports, Competitive Analysis, Consulting
Agenda

• SSDs: Why now?
• Where do they fit?
• How will flash penetrate the PC?
• What challenges does flash present?
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The DRAM/HDD Speed Gap

From: **Solid State Drives in the Enterprise**

**OBJECTIVE ANALYSIS** – www.OBJECTIVE-ANALYSIS.com
NAND Shot Past DRAM’s Price per GB

From: *Hybrid Drives: How, Why, & When?*
Now NAND Fits in Computers

From: *Solid State Drives in the Enterprise*

**OBJECTIVE ANALYSIS** – www.OBJECTIVE-ANALYSIS.com
NAND Unlikely to Match HDD $/GB

From: Understanding the NAND Market

OBJECTIVE ANALYSIS – www.OBJECTIVE-ANALYSIS.com
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SSDs in the Enterprise

100 Enterprise HDDs
- Capacity: 30TB
- Performance: 30K IOPS
- Cap/Op-X: $55,000 - 1.75kWh

Hybrid Storage Pool
- 1 SSD
- 30 High Capacity HDDs
- Capacity: 30TB
- Performance: 30K IOPS
- Cap/Op-X: $6,040 - 0.392kWh

Source: Sun Microsystems, August 2008
Enterprise SSD Forecast

- $3.8 Billion in 2015
- 89% Unit CAGR
- 55% Revenue CAGR

Millions of Units

0 1 2 3 4 5

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Flash in Enterprise Storage

- DRAM
- SSD
- Capacity HDDs
Many Alternatives Coming

- Intel Braidwood
  - NAND on the motherboard
    - Managed by chipset & firmware
    - Preceded by Robson/Turbo Memory
- Seagate Momentus XT Hybrid HDD
  - Uses internal NAND management
- NVELO (formerly Denali) Dataplex
  - NAND management for SSD/HDD combo
- Others coming soon
Why Early Attempts Failed

• Robson/Turbo Memory
  – Small size (4MB)
  – Poor Windows Vista Support
    • Invoking support sometimes degraded performance

• Hybrid HDD
  – As above: Small size and Vista problems
  – Weak industry support: Samsung & Seagate
Taking Control of the Flash

• Intel’s Braidwood
  – Firmware, chipset, drivers
  – NAND on ONFi DIMMs

• Seagate Momentus XT
  – HDD controller manages flash
  – Flash sits inside HDD

• NVELO’s Dataplex
  – Just sell the control software
  – OEM decides whose HDD & flash to use
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Problem 1: HDD Interfaces

- HDD interfaces designed around HDDs
  - Slow I/O needs queuing
  - Single internal data path
  - Overwrite old data at any time
- SSDs are really different:
  - Very fast reads
  - Erase before write
  - Multiple internal data paths
  - Wear-out mechanism
Why the Interface Matters

32 NAND Chips

Many Potential Data Paths

Controller

DRAM

I/O Bus

1GB NAND

1GB NAND
Problem 2: Erase & Write Timing

• Erase required before write
  – HDD simply overwrites data
  – Requires erase strategy
• Slower write than read
  – Page read ~25μs setup, then 50ns/byte
  – Page write ~1ms
  – Block erase ~5ms
• Today’s software expects balanced R/W
How Software Can Help

• Frequent reads/infrequent writes
• Cues for housekeeping
  – “Trim” command today
• Understanding the hierarchy
  – Fast things onto flash
  – HDD stores other stuff
  – Just like cache memory, virtual memory, etc.
Problem 3: NAND Scaling Limit

• NAND will reach a limit
  – Too few electrons per gate
  – Needs constant shrinks for cost reductions
  – 4-bit/cell hard to make
    • This may be the maximum possible

• Other technologies will scale past NAND
  – PCM, MRAM, RRAM, FRAM…. 
    • Not yet clear which will win
Too Few Electrons per Gate

Electrons per Gate

- NAND
- NOR

Process Node

150nm 90nm 65nm 45nm 32nm

OBJECTIVE ANALYSIS – www.OBJECTIVE-ANALYSIS.com
How to Maintain this Inertia?

Average Price per Gigabyte

From: Hybrid Drives: How, Why, & When?

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How Alternatives will Emerge

![Graph showing the relative cost per bit for Flash and New Tech processes over time. The x-axis represents process nodes (180nm, 65nm, 23nm, 8nm) and the y-axis represents relative cost per bit. The graph compares Flash with New Tech, showing a decrease in cost as process nodes decrease.]
Summary

• Flash belongs in **all** computers
  – So does HDD
• Many changes will result
  – Interface
  – Software
  – Even the memory technology!
Thank You!

Jim Handy