HDDs and Flash Memory
A Marriage of Convenience

Tom Coughlin
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&

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Objective Analysis
Two may be Better than One: Why HDD and Flash Belong Together (http://www.snia.org/forums/sssi/knowledge/education)
Outline

- What this presentation is about
- Why flash belongs in computers
- Many ways to fit NAND into a PC
  - Hybrid Drives
  - Storage Pairing
  - NAND on the mother board
  - Other ideas
  - Manual vs. automatic data placement
- Outlook for NAND in computing
- Q & A
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NAND Plus HDD

- NAND is finding its way into PCs
  - Faster boot
  - Faster program launch
  - Longer battery life
- NAND is expensive compared to HDDs
  - SSDs 10-20 times the cost per GB of HDDs
- Ideal solution:
  - Performance advantages of flash memory
  - Low cost of HDDs
What PC Users Want

- HDD-like price
- HDD-like capacity
- SSD-like speed
A New Computer Memory/Storage Hierarchy

- Cache
- DRAM
- DRAM Read Cache
- NAND Write Cache
- Hard Disk Drive
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HDD and Flash Data Rates

From: *HDDs and Flash Memory: A Marriage of Convenience*
Today’s DRAMs: 6,000 Times HDDs’ Speed

From: *HDDs and Flash Memory: A Marriage of Convenience*
A Gap in the Storage Hierarchy

From Objective Analysis: Are Hybrid Drives Finally Coming of Age?

Result: A Growing Gap

Cheaper & Faster

Cheaper

Price per Gigabyte

Bandwidth (MB/s)
NAND Fills the Gap

From Objective Analysis: Are Hybrid Drives Finally Coming of Age?
Why Flash Fits

- Speed:
  - Faster than HDDs
  - Slower than DRAM
- Price ($/GB):
  - Less expensive than DRAM
  - More expensive than HDD
- Bonus: It’s nonvolatile
- Good cache or buffer for fast access of frequently used content
- Flash memory expands storage tiering options in computers
NAND Flash Cheaper than DRAM

From: *HDDs and Flash Memory: A Marriage of Convenience*
Computer Performance vs. NAND Capacity

From: *HDDs and Flash Memory: A Marriage of Convenience*
A Tale of 300 Benchmarks

From: *How PC NAND Will Undermine DRAM*
Speed/Price Advantage

From: How PC NAND Will Undermine DRAM

1GB DRAM + 20GB NAND + HDD = $80

8GB DRAM + 7GB NAND + HDD = $128
Battery Life Increases for NAND Flash

- Energy Consumption = 1 / Battery Life
- Energy is Power x Time
  - Short times at high power may be better than long times at low power
- “HUGI” = Hurry Up, Go Idle
  - Get platform into low-power states faster

Shahed Ameer, Intel, IDF 2010
Even Partial SSD Saves Power

SSD-based system consumes lowest energy

Two-drive system comes next
- Most common files loaded onto SSD
- All else on HDD
- HDD spun-down ~97% of time

HDD alone consumes most power
- Results from Intel, MobileMark* 2007 workload, Intel® 80GB SSD vs. 5,400rpm HDD
What this presentation is about

Why flash belongs in computers

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Outlook for NAND in computing

Q & A
From Objective Analysis: *Are Hybrid Drives Finally Coming of Age?*
Example Hybrid HDD
Seagate Momentus XT

Adaptive Memory™ Learns Quickly
PCMark Vantage – HDD Score

- Self-managed, independent of the OS
  - “Adaptive Memory™”
  - Algorithms monitor data access transactions
  - Qualified data is placed in the SSD
  - Maintains frequently used data
- Dynamically improves based on usage
- Customizes performance to the user
- Highest performance with least NAND

First user experience: "like 7200"
Second user experience: "the next level"

From Seagate Momentus XT Introduction Presentation, 2010
Dual-Drive PCs

• What is a Dual Drive?
  – Small SSD plus HDD
    – SSD for performance
    – HDD for capacity

• Software manually organized
  – SSD contains the operating system and some applications
  – HDD contains other applications and personal data
## Flash Capacity Required

<table>
<thead>
<tr>
<th></th>
<th>Dual-Drive</th>
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<th>Single-Drive</th>
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<tbody>
<tr>
<td></td>
<td>C: SSD</td>
<td>D: HDD</td>
<td>C: SSD</td>
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<td><strong>Microsoft Windows® 7 64-bit (Ultimate)</strong></td>
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<td><strong>Page file</strong></td>
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<td>4GB (4GB DRAM)</td>
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<td><strong>iTunes®</strong></td>
<td>0.8</td>
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<td>0.8</td>
</tr>
<tr>
<td><strong>Total Disk Space used</strong></td>
<td>25.4–29.9 GB</td>
<td>1.9 GB</td>
<td>27.3-31.8 GB</td>
</tr>
</tbody>
</table>

40GB is the minimum size for dual drive software and DRAM scalability.

Shahed Ameer, Intel, IDF 2010
Flash on the Motherboard

- Past Failed Attempts
  - Intel TurboMemory
  - Intel Braidwood
    - NAND on the motherboard
    - Managed by chipset & firmware
    - SSD speeds with HDD capacities
    - Low-priced option

- This approach will resurface!
  - The fundamental concept is very good
Other Paired Storage Products

- Marvell HyperDrive
- LSI CacheCade
- Intel Smart Response
- Other SSDs from Samsung, many others
- PCIe products

Caching is very popular in enterprise applications
Hitachi-LG HyDrive
(Another “Hybrid” Drive)

- ODD/flash combo
- Flash caches ODD content
  - ODD powered down saving power
- Future plans:
  - Make it thinner
  - Ship in a netbook, set-top box or tablet

Source: EnGadget at Computex 2010
Hitachi-LG Hybrid ODD Roadmap

Flash Capacity Data Points

- Seagate Momentus XT Hybrid HDD
  - 4GB
  - Automatic data placement
- NVELO recommendation
  - 16GB
  - Automatic data placement
- Intel
  - Manual data placement (prior slide) 40GB
  - Automatic data placement (Smart Response Technology) 20GB
Manual vs. Automatic Data Placement

Source: IBM Corp. Used with Permission
Automatic Data Placement

- Fast or slow devices managed by:
  - Software on the host, or
  - Firmware in the components (i.e. RAID controller).
- Software examples:
  - NVELO
  - FlashSoft
- Firmware examples:
  - Marvell HyperDuo
  - LSI CacheCade
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NAND Fits in Computers

- NAND is a layer between HDD and DRAM
  - It does not replace HDD
- It is necessary for speed
  - A key component in the memory/storage hierarchy
- All computers will have NAND soon
  - Hybrid HDDs
  - Boot drives
  - NAND on the motherboard
  - Other places?
- Result: Strong NAND growth in Data Processing
Non-HDD SSD Formats

- Flash fits into smaller spaces than HDDs—leading to new SSD formats
  - mSATA
  - iSSD
- New formats simplify pairing in a tight layouts
Paired Storage in Tablets?

- Will tablets go to HDD or paired storage?
  - Archos already has an HDD tablet
  - Thin HDDs can fit into tablets

- Is paired storage the future for tablet PCs?
Mobile Device Storage Expansion

- WiFi tablet PCs (like the iPad) rely on storage over a network
  - This could be in the “cloud”
  - A new crop of HDD and flash based external storage devices can provide local wireless storage
- A new type of paired storage?
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Your Presenters

Tom Coughlin, President, Coughlin Associates is a highly-respected storage analyst and consultant with over 30 years in the data storage industry in engineering and management at high profile companies.

Jim Handy is a widely recognized semiconductor analyst, has over 30 years in the electronics industry. His background includes marketing and design positions at market-leading suppliers.
Source Material

- How PC NAND will undermine DRAM, Objective Analysis, 2011
- Two may be Better than One: Why HDD and Flash Belong Together, Tom Coughlin and Jim Handy, SNIA SSSI White Paper, 2010
- Are Hybrid Drives Finally coming of Age?, Objective Analysis, 2010