How NAND Flash Threatens DRAM

Jim Handy
Outline

- Why even think about DRAM vs. NAND?
- The memory/storage hierarchy
- What benchmarks tell us
- What about 3D XPoint memory?
- The system of the future
- Questions
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Why Compare NAND to DRAM?

• IT managers started telling me:
  – You need less DRAM if you add an SSD
  – You can sometimes even eliminate servers!
    • Fewer servers means fewer software licenses
• Why shouldn’t that would work on PCs???
  – Why not on all computer types?
Right Way/Wrong Way
To View NAND Flash

Wrong Way
NAND is:

• NAND is storage
• NAND is expensive!

Right Way
NAND is part of the memory/storage hierarchy
• NAND is 1/15th DRAM’s cost
• NAND is cheap memory!
  – With awful specs!

OBJECTIVE ANALYSIS – www.OBJECTIVE-ANALYSIS.com
Outline

• Why even *think* about DRAM vs. NAND?
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The Memory/Storage Hierarchy

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

**Result:** A Growing Gap

Cheaper & Faster

Cheaper

Cheaper & Faster

Tape

HDD

DRAM

L3

L2

L1

From Objective Analysis: *Are Hybrid Drives Finally Coming of Age?*
NAND Fills the Gap

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

• Speed:
  – Flash is faster than HDDs
  – Flash is slower than DRAM

• Price ($/GB):
  – Flash is less expensive than DRAM
  – Flash is more expensive than HDD

• Bonus: It’s nonvolatile
Outline

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Benchmarking DRAM vs. NAND

From: How PC NAND Will Undermine DRAM

OBJECTIVE ANALYSIS – www.OBJECTIVE-ANALYSIS.com
What If Only DRAM Mattered?

From: How PC NAND Will Undermine DRAM

O B J E C T I V E A N A L Y S I S – w w w . O B J E C T I V E - A N A L Y S I S . c o m
What If Only Storage Mattered?

From: How PC NAND Will Undermine DRAM

OBJECTIONALY ANALYSIS – www.OBJECTIONALY-ANALYSIS.com
Let’s Look At That Data Again!

From: How PC NAND Will Undermine DRAM

OBJECTIVE ANALYSIS – www.OBJECTIVE-ANALYSIS.com
Speed/Price Advantage

From: How PC NAND Will Undermine DRAM
You **Do Need** Some DRAM!

• There is a certain minimum DRAM
  – In our benchmarks it wasn’t much:
    • 1GB for 8 benchmarks
    • 2GB for 5 benchmarks
    • 3GB for 1 benchmark
  – After that, NAND was cheaper
    • More “Boost for the Buck!”
Must Have: Automatic Data Placement

Source: IBM Corp. Used with Permission
You Can’t Do That!

• Flash is way too slow!
• Flash wears out!
• Flash memory is storage, not memory!
Is Flash Too Slow?

Share of Accesses vs. Address Range

OBJECTIVE ANALYSIS – www.OBJECTIVE-ANALYSIS.com
## Which Is Better?

<table>
<thead>
<tr>
<th>Storage Type</th>
<th>Latency</th>
<th>No SSD (%)</th>
<th>With SSD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRAM, Latency = 1</td>
<td>90%</td>
<td>55%</td>
<td></td>
</tr>
<tr>
<td>SSD, Latency = 10^3</td>
<td>0%</td>
<td>44%</td>
<td></td>
</tr>
<tr>
<td>HDD, Latency = 10^6</td>
<td>10%</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Ave. Latency</td>
<td>~10^5</td>
<td>~10^4</td>
<td></td>
</tr>
</tbody>
</table>
What About Wear?

Share of Writes vs. Amount of Memory
Flash Is Storage!

What if you pretend it isn’t?
Outline

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3D XPoint Memory
Better Than NAND

NAND
• Serial read
• Erase before write
• Block erase/page write
• Slow write
• Inherent bit errors
• Wear

3D XPoint
• Random read
• Overwrite
• Byte write
• Fast write
• Lower error rates
• Low wear

"Storage Class Memory"

OBJECTIVE ANALYSIS – www.OBJECTIVE-ANALYSIS.com
But Cost is More Important

• 3D XPoint won’t thrive until its cost falls below DRAM
• Technological strengths rarely offset cost
• This is a highly-competitive market
• Memories are a commodity
Cost Brought Flash Into Computing

Average Price per Gigabyte

$0 $1 $10 $100 $1,000 $10,000

2004: NAND Crossed DRAM

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

OBJECTIVE ANALYSIS – www.OBJECTIVE-ANALYSIS.com
3D XPoint’s Role

Source: A Close Look at the Intel/Micron 3D XPoint Memory, Objective Analysis 2015
How Much Does XPoint Help?
Getting Cheaper Than DRAM
10x as many bits in the same die area

-BUT-

• If the wafer is 2x as expensive then it is only 1/5\(^{th}\) the cost
• Even so, yield has to be equally good
  – This will take a lot of wafers
  – It’s a new technology – that makes it harder!
Outline

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The System of the Future

• Small DRAM
  – HMC? HBM?
  – Soldered down
  – Not upgradeable

• Upgradeable NVM
  – The new module
  – Could be either NAND or 3D XPoint
Outline

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Questions?
Other Information
Resources

• **A Close Look at the Intel/Micron 3D XPoint Memory**
  Objective Analysis, September 2015
  [http://Objective-Analysis.com/Reports.html#XPoint](http://Objective-Analysis.com/Reports.html#XPoint)

• **How PC NAND Will Undermine DRAM**
  Objective Analysis, 2011
  [http://Objective-Analysis.com/Reports.html#DRAM-NAND](http://Objective-Analysis.com/Reports.html#DRAM-NAND)

• Intel/Micron 3D XPoint introduction

• Intel Developer Forum (IDF) 2015 presentations
  [http://myeventagenda.com/sessions/0B9F4191-1C29-408A-8B61-65D7520025A8/7/5](http://myeventagenda.com/sessions/0B9F4191-1C29-408A-8B61-65D7520025A8/7/5)
Minimum DRAM Sizes

1GB
- SYSmark Productivity
- SYSmark 3D
- PCMark Memory
- PCMark Productivity
- PCMark Music
- PCMark Comms
- Photoshop
- Compressing

2GB
- SYSmark E-Learning
- SYSmark Video Creation
- PCMark TV
- PCMark Game
- Decompressing
Objective Analysis

Profound Analysts

Reports & Services

Custom Consulting

Objective Analysis – www.Objective-Analysis.com
## Objective Analysis

### Semiconductor Forecast Accuracy

<table>
<thead>
<tr>
<th>Year</th>
<th>Forecast</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>Zero growth at best.</td>
<td>-3%</td>
</tr>
<tr>
<td>2009</td>
<td>Growth in the mid teens</td>
<td>-9%</td>
</tr>
<tr>
<td>2010</td>
<td>Should approach 30%</td>
<td>32%</td>
</tr>
<tr>
<td>2011</td>
<td>Muted revenue growth: 5%</td>
<td>0%</td>
</tr>
<tr>
<td>2012</td>
<td>Revenues drop as much as -5%</td>
<td>-2.7%</td>
</tr>
<tr>
<td>2013</td>
<td>Revenues increase nearly 10%</td>
<td>4.9%</td>
</tr>
<tr>
<td>2014</td>
<td>Revenues up 20%+</td>
<td>9.9%</td>
</tr>
<tr>
<td>2015</td>
<td>Revenues up ~10%</td>
<td>TBD</td>
</tr>
</tbody>
</table>