Flash Technology: Annual Update

Jim Handy
## Objective Analysis

### Semiconductor Forecast Accuracy

<table>
<thead>
<tr>
<th>Year</th>
<th>Forecast</th>
<th>Actual</th>
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</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>
Outline

• NAND Market
  – 3D NAND
• SSDs
• NOR Market
• 3D XPoint
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NAND Prices In Slow Decline
What Drives the Next Downturn?

• Pricing stable into 2017
  – No collapse until 3D is competitive with planar
  – Will drive continuing profitability
  – Should attract new participants

• Historic collapse at the end
  – Organic overcapacity, plus…
  – Externally-funded additions
  – Largest-ever price-cost gap
Tech Challenges
Extend Market Cycles

DRAM Examples

Price per GB

1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013

1993-1995 x4 to x16 Transition

2005 90nm Difficulties

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Extension is Hard to Predict

• When will 3D be mastered?
  – Samsung is shipping at a loss
  – We have found no evidence of a data sheet
• Other vendors are sampling
  – This indicates some confidence
• Vendors say the big ramp will be in 2017
  – Such projections are usually optimistic
• We say 2017, but may push that out
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Enterprise SSD Outlook

• Penetration still only about 50% of installations
  – Huge upside potential
  – Message is not reaching many corners

• HDD makers are feeling the impact
  – Enterprise HDD market falling
  – Overall HDD market soft
Client SSD Outlook

• PC market has had many failures
  – SSD-based PCs don’t sell
  – Ultrabook hasn’t driven high SSD sales
  – Apple stands alone in SSD success
    • Apple users have no other option
  – Upgrade market doing very well

• Other markets doing well
  – Difference is the level of understanding
Demand Softens Temporarily

• PC market still in flux
  – Are tablets reducing PC consumption?
  – Could it be the fault of SSDs?
    • Older PCs are in use longer
  – When will growth resume?

• Enterprise demand still strong
  – Cloud consumption is healthy
  – HDD to SSD conversion impacting HDD makers
SSDs Impacting Coffee Prices?
HDD Legacy Hard to Overcome

• Pre Fusion-io: “Put NAND into an HDD format.”
• Fusion-io: “Put NAND into a RAID format.”
• Violin, TMS: “Put NAND in a big box.”
• Intel: “Give NAND its own bus (ONFi on Braidwood).”
• Diablo: “Put NAND on the DRAM bus.”
Form Factors Finding Their Way

- **Client:** 2.5” → mSATA → m.2
- **Data Center:** FC → PCIe → SATA
  - SATA “Fast enough” & cheap
  - High read environment OK with low DWPD
- **Enterprise:**
  - 3.5” → 2.5”
  - DAS → SAN → DAS
  - FC → PCIe → SATA
  - SAN → Flash Array + JBOD/Cloud
PCIe Moving Into Prominence

• Increased PCIe sockets in client
• NVMe unleashes PCIe’s performance
  – Not an “Either/Or”
• Slow recent growth impacts NVMe
  – Ties back to users’ lack of understanding of their workloads
• Market’s in a strange place
  – Enterprise: SATA’s cheap & good enough
  – Client: m.2 PCIe costs the same as SATA
Drive Wear (DWPD/TBW)

User Requests
- 2006: Don’t care
- 2008: Real issue
- 2012: Enterprise
- 2013: Even more
- 2015: Less important

Manufacturers Make
- Glorified CF cards
- Low Write Amp.
- 3 DWPD
- 10 DWPD
- Some 1 DWPD

End-User Sophistication is Growing
m.2 PCIe
Where does m.2 Fit?

• “It’s a replacement for mSATA”
  – This appears to be catching on
• “It’s a performance PCIe format”
  – Low chip count works against this
  – Too early to tell if it’s a market driver
• “It’s a boot drive for servers”
  – First market seems to be here
  – This is a highly-competitive space
2.5” PCIe Conundrum

• Where did this come from?
  – “Flash is storage”
    • “Storage is unreliable and must be hot-swappable”
  – Removing PCIe cards goes against this

• Existing sockets created a market
  – Few new sockets are being developed
  – We expect it to have a relatively short life
  – It’s like FC SSDs all over again
PCIe Price Drivers

• Single-chip PCIe controllers are coming
  – PCIe SSD costs/prices will drop

• NAND types
  – Today: SLC and MLC, highly overprovisioned
  – Tomorrow: MLC (non-client) and TLC (client) with less overprovisioning

• NAND pricing changes
  – Prices relatively flat until 2017
The Migration to MLC & Beyond

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<tr>
<th>Year</th>
<th>SLC</th>
<th>MLC</th>
<th>TLC</th>
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<tbody>
<tr>
<td>2005</td>
<td>Stock</td>
<td>Never</td>
<td>Never</td>
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<tr>
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NOR Revenues 2006-2015

Annual Revenues ($Billions)

- 2006: $9
- 2007: $8
- 2008: $7
- 2009: $6
- 2010: $5
- 2011: $4
- 2012: $3
- 2013: $2
- 2014: $1

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NOR Market Leaders

• Spansion
  – Now a part of Cypress

• Numonyx
  – Was Intel & ST
  – Acquired by Micron in 2010

• Samsung
  – Exited a dying market

• Others: Macronix, Microchip/SST, etc.
What Happened To NOR?

• Cell phones were a key market
  – Smart phones have taken over
  – When you have lots of NAND & DRAM, you don’t need NOR

• This created an oversupply
  – Prices came down to cost
  – Vendors either exited or consolidated

• No demand growth x price erosion = revenue erosion!
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It’s A New Memory Layer

• It fits the memory/storage hierarchy well:
  – Faster than NAND, slower than DRAM
  – Costlier than NAND, cheaper than DRAM

• It’s nonvolatile
  – Opens the door to in-memory storage

• This could bring new performance to computing
A New Memory Layer Needs A Lot Of Support

• Will require a new bus
  – DDR doesn’t support variable access times

• Will require new O/S support
  – Cache management?
  – Memory management?

• Persistence will require application support
  – SNIA and others working on this
  – Some instruction support now in Intel specs
A Chicken & Egg Problem

• 3D XPoint will be sell in volume once it’s priced lower than DRAM
• 3D XPoint prices will fall below DRAM once the volume is high enough
Summary

• NAND poised for continuing growth
  – 3D will cause shortages
  – Big collapse in 2017 or 2018
• SSDs have much room to grow
• NOR flash will remain slow
• 3D XPoint is tomorrow’s technology
  – Or, perhaps, the day after tomorrow
Thank You!

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