Transitions: A Roadmap to Low-Power Memory

Kevin K. Yee
Oct 15, 2014
MemCon 2014
A Look at History
Last three decades – PC driven

- 1981 IBM PC
  - 16 kB base memory
- 1990 office standard
  - 640 kB memory
- 2000 gaming computer
  - 4 GB memory
- 2013 gaming laptop
  - 32 GB
What drives the market now...next?
The next 3 decades - ?

Source: ISH (iSuppli) for 2013
A Look at the Present…Future
New Applications, new systems…new challenges
## Shifting Memory Requirements

Mobile changes the priority

<table>
<thead>
<tr>
<th></th>
<th>Bandwidth</th>
<th>Power</th>
<th>Cost</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile</td>
<td>♦♦</td>
<td>♦♦♦</td>
<td>♦♦</td>
<td>♦♦♦</td>
</tr>
<tr>
<td>Consumer</td>
<td>♦</td>
<td>♦♦</td>
<td>♦♦♦♦</td>
<td>♦</td>
</tr>
<tr>
<td>Networking</td>
<td>♦♦♦♦</td>
<td>♦</td>
<td>♦</td>
<td>♦♦♦</td>
</tr>
<tr>
<td>PC/Server</td>
<td>♦♦♦♦</td>
<td>♦</td>
<td>♦♦</td>
<td>♦♦♦♦</td>
</tr>
</tbody>
</table>

*Mobile shifts focus from DDR to LPDDR!*

* Cadence assessments
Mobile and Low Power DDR
LPDDR3 vs. LPDDR4

- LPDDR4 is more power efficient than LPDDR3 for certain tasks
- For Mobile applications, this is everything
Proof in Point
Today’s Smartphones

- Xaiomi Mi4 16G
- Samsung Galaxy S5 32G
- Apple iPhone 6 128G
- Apple iPhone 5 32G
The DDR Memory Roadmap
Does JEDEC drive transitions?

- Not really
- JEDEC drives memory specifications
- Memory is a high volume manufacturing business
  - Driver 1: Price – low cost and volume
  - Driver 2: Need – power or performance
- What is the inflection point?
  - Price vs. need
  - Chicken & Egg – low price first or volume demand first (cost)
The DDR Memory Roadmap
Memory Specifications
What drives Memory Adoption?

Breaking the Cycle

- **Technology or Price?**
  - New technology hard to adopt
  - High initial price limits adoption or transition
  - Low initial volume keeps prices high
  - The vicious cycle

- **Breaking the cycle**
  - Mobile could be the thing that breaks the cycle
  - Need is great and the volumes high (quickly)
  - This means that prices can drop quickly leading to faster adoption
  - Economy of Scales
What drives Memory Adoption?

Need vs. Cost

• End Product Needs
  – Larger and higher resolution displays and cameras
  – Bigger and faster applications
  – Bragging rights

• Memory costs
  – Memory is traditionally driven by cost
  – If the need is not there it is all about costs
  – The lower the cost, the faster the adoption
What drives the mobile need?
Beyond Power: Density

- Screens are getting larger
- Smartphones going from 4 inch to 4.7 inch to 5.5 inch
- Tablets going from 7 inch to 8.0 inch to 10 inch

Flagship Smartphone Memory Density

<table>
<thead>
<tr>
<th>Year</th>
<th>Memory Density</th>
<th>Memory Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>256MB</td>
<td>LPDDR</td>
</tr>
<tr>
<td>2010</td>
<td>512MB</td>
<td>LPDDR</td>
</tr>
<tr>
<td>2011</td>
<td>1GB</td>
<td>LPDDR2</td>
</tr>
<tr>
<td>2012</td>
<td>2GB</td>
<td>LPDDR2</td>
</tr>
<tr>
<td>2013</td>
<td>2GB</td>
<td>LPDDR3</td>
</tr>
<tr>
<td>2014</td>
<td>3GB</td>
<td>LPDDR3</td>
</tr>
<tr>
<td>2015</td>
<td>4GB ?</td>
<td>LPDDR3/4 ?</td>
</tr>
</tbody>
</table>
More Bandwidth in Mobile
Higher resolution and screen size

- Resolution is getting higher
- From 1280x720 to 3840x2160 and beyond
- > size and resolution = > Memory

Screen size progression for smartphone and tablets
More Performance in Mobile
From 400 to over 3200

Memory Speed in Mbps

- LPDDR2
- LPDDR3
- LPDDR4

PC-DDR4 Bandwidth

Bandwidth (Mbps):
- 400
- 800
- 1066
- 1600
- 2133
- 3200
- 4266
Case Study: Apple iPhone and iPad
Volume and ramp rates

iPhone Unit Sales

<table>
<thead>
<tr>
<th>Year</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>2010</th>
<th>2011</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>2012</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>8700</td>
<td>8752</td>
<td>8398</td>
<td>14102</td>
<td>16235</td>
<td>18647</td>
<td>20338</td>
<td>17073</td>
<td>37044</td>
<td>35064</td>
<td>26028</td>
<td>26910</td>
<td>47789</td>
</tr>
</tbody>
</table>

iPad Unit Sales

<table>
<thead>
<tr>
<th>Year</th>
<th>Q3</th>
<th>Q4</th>
<th>2011</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>2012</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>8700</td>
<td>4188</td>
<td>7331</td>
<td>4694</td>
<td>9246</td>
<td>11123</td>
<td>15434</td>
<td>11798</td>
<td>17042</td>
<td>17042</td>
<td>14036</td>
</tr>
</tbody>
</table>

Data from Macworld
Case Study: Apple iPhone
Apple iPhone volume and ramp rates!

A Game Changer:
5 Million phones in a weekend
20 Million phones in a month
LPDDR transitions in Apple iPhone Models

**iPhone Memory Size/Type**

<table>
<thead>
<tr>
<th>Year</th>
<th>Model</th>
<th>Memory Size/Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>iPhone</td>
<td>128MB LPDDR</td>
</tr>
<tr>
<td>2008</td>
<td>iPhone 3G</td>
<td>256MB LPDDR</td>
</tr>
<tr>
<td>2009</td>
<td>iPhone 3GS</td>
<td>512MB LPDDR2</td>
</tr>
<tr>
<td>2010</td>
<td>iPhone 4</td>
<td>1 GB LPDDR2</td>
</tr>
<tr>
<td>2011</td>
<td>iPhone 4S</td>
<td>1 GB LPDDR2</td>
</tr>
<tr>
<td>2012</td>
<td>iPhone 5</td>
<td>1 GB LPDDR3</td>
</tr>
<tr>
<td>2013</td>
<td>iPhone 5C</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>iPhone 5S</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>iPhone 6</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td>1 GB LPDDR3</td>
</tr>
</tbody>
</table>

Case Study: Xiaomi Smartphone
Record Shipment in 2014

Xiaomi sells 26 million smartphones in first half of 2014
Xiaomi bucks a reportedly slowing Chinese market with 26.1 million smartphones sold in the first half of 2014, a 271 percent increase compared with the year before.

by Francis Bea @francisybea / July 2, 2014 4:26 AM PDT

Source: Xiaomi web site, 10/2014
WW smartphone shipments (2009-2018)

Units in Millions

Mobile Volumes will impact the Low-Power Memory Transition!

Smartphone shipments in China
2011~2013

Units in Millions

LPDDR Exceed DDR in Performance
Mobile moves into PC space

LPDDR Performance is converging!
LPDDR & DDR Price converging
Little to No Premium for Low Power

- 1Q 2012 Pricing
  - 4Gb LPDDR -> $6.80
  - 4Gb DDR3L -> $4.20
  - LP Premium = 62%

- Mid 2013 Avg. Forecast
  - 4Gb LPDDR2 -> $4.75
  - 4Gb DDR3L -> $3.60
  - LP Premium = 32%

- Mid 2013 Avg. Forecast
  - 4Gb LPDDR3 -> $6.40
  - 4Gb DDR3L -> $3.60
  - LP Premium = 78%

4Gb Equivalent prices of DRAM Alternatives

Convergence
Mobile Market Transition
Low Power High B/W Memory

LPDDR Roadmap Transition is happening!
The Low-Power Memory Roadmap Transition
Summary

• Factors Driving Transition
  – Lower power
  – Greater bandwidth
  – Higher volume/lower cost

• Transition is happening NOW!
  – From DDR to LPDDR
  – From LPDDR3 to LPDDR4