Memory Technology and Solutions Roadmap

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Vice President
Semiconductor Business
Samsung Electronics Co., Ltd.
Contents

Overview
DRAM
Flash Memory
Mobile Solution
Emerging Technology
Summary
Memory Market Trend (Revenue Based)

(Source: Dataquest, Semico, iSuppli, Samsung)
Healthy Growth of Digital Electronics

CAGR '04-'09 = 8.4%

(Millions of Sets)

(Source: iSuppli, Sep, '05)
Memory Technology Driver

- DRAM: Used to be the Technology Driver
- Today: NAND Flash is Leading the Memory Density

![Graph showing the evolution of memory technology density from 1990 to 2005. The graph compares DRAM, NAND, NOR, and SRAM technologies. DRAM shows a technology driver with approximately 4x increase in density every 3 years.](image-url)
DRAM
Desktop PC has been driving DRAM technology evolution

<table>
<thead>
<tr>
<th>Year</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Tech. Launch</td>
<td>SDR</td>
<td>DDR</td>
<td>DDR</td>
<td>DDR2</td>
<td>DDR2</td>
<td>DDR3</td>
<td>DDR2</td>
<td>DDR3</td>
<td>DDR3</td>
<td>DDR3</td>
</tr>
<tr>
<td>Volume Transition</td>
<td>~3.5%</td>
<td>5%</td>
<td>~10%</td>
<td>29%</td>
<td>56%</td>
<td>10%</td>
<td>&gt;DDR3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DRAM Density Crossover

Source: Gartner Dataquest (May'05)
Industry First 2Gb DDR2 DRAM (Samsung ’04)

- First & Highest Density with 80nm Design Rule
- High Density Modules for Server & Notebook Possible

< 80nm 2Gb DDR2 Chip >

( Released in IEDM 2004 )
- Industry 1\textsuperscript{st} DDR3 SDRAM with 80nm technology
- Higher Speed, Lower Power than DDR2
- DDR3 SDRAM System launch in 2007

<table>
<thead>
<tr>
<th></th>
<th>DDR3</th>
<th>DDR2</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDD/VDDQ</td>
<td>1.5V</td>
<td>1.8V</td>
</tr>
<tr>
<td>Data Rates (Gbps)</td>
<td>0.8\textasciitilde1.6</td>
<td>0.4\textasciitilde0.8</td>
</tr>
</tbody>
</table>

512M DDR3 DRAM (Feb, ’05) (Published in VLSI Symposium 2005)
Samsung DRAM Technology Roadmap

- **Technology**: 90nm (Now), 80nm (2006)
- **Density**: 512Mb, 1Gb (Now), 2Gb (2006)

<table>
<thead>
<tr>
<th>Year</th>
<th>Design Rule</th>
<th>Density</th>
<th>Speed</th>
<th>Voltage</th>
<th>Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>100nm</td>
<td>256Mb</td>
<td>400 Mbps</td>
<td>2.5V</td>
<td>DDR</td>
</tr>
<tr>
<td>2005</td>
<td>90nm</td>
<td>512Mb</td>
<td>533Mbps</td>
<td>1.8V</td>
<td>DDR2</td>
</tr>
<tr>
<td>2006</td>
<td>80nm</td>
<td>1Gb</td>
<td>667Mbps</td>
<td>1.5V</td>
<td>DDR3</td>
</tr>
<tr>
<td>2007</td>
<td>70nm</td>
<td>2Gb</td>
<td>800Mbps</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DRAM Industry Environment

1990
- Windows 3.0
- 16Bit O/S

1995
- Windows 3.1
- Windows 95
- Pentium 1993
- Pentium Pro 1995
- 32Bit O/S

2000
- Windows 98
- Pentium III 1999
- Pentium IV 2000

2005
- Windows XP
- Pentium D 2005
- Dual Core Xeon 2005
- 64Bit O/S

2010
- Windows Vista
- 64Bit / Dual Core

486DX 1989
- 16Bit
- 32Bit
### DRAM Requirement of Windows Vista

- **Higher DRAM Requirement for New Features**
  - 3D GUI (Graphic User Interface), High Speed Searching
- **More than 128MByte Graphic DRAM Recommendation**
  - Direct X9 (Graphic Library)

<table>
<thead>
<tr>
<th>Windows Operating System</th>
<th>Min.</th>
<th>Recommend</th>
<th>Graphic</th>
<th>Launch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows 95</td>
<td>8MB</td>
<td>16MB</td>
<td>N/A</td>
<td>1996</td>
</tr>
<tr>
<td>Windows 98</td>
<td>16MB</td>
<td>32MB</td>
<td>N/A</td>
<td>1998</td>
</tr>
<tr>
<td>Windows Me</td>
<td>32MB</td>
<td>64MB</td>
<td>N/A</td>
<td>2000</td>
</tr>
<tr>
<td>Windows 2000(Pro)</td>
<td>64MB</td>
<td>128MB</td>
<td>N/A</td>
<td>2000</td>
</tr>
<tr>
<td>Windows XP</td>
<td>64MB</td>
<td>256MB</td>
<td>N/A</td>
<td>2001</td>
</tr>
<tr>
<td>Windows Vista</td>
<td>64MB</td>
<td>512MB</td>
<td>128MB</td>
<td>2006</td>
</tr>
</tbody>
</table>

* Source: Microsoft Website

Desirable Graphic DRAM Requirement for New Features:
- More than 128MByte Graphic DRAM Recommendation
- Direct X9 (Graphic Library)
FBDI MM: Next Generation Server Module

- **Current DRAM Module Structure**
  - Direct connection between DRAM and chipset

- **FBDI MM* Structure**
  - AMB* placed between DRAM and Chipset
  - More number of memory slots possible

---

**Note 1.** FB-DI MM: Fully Buffered DI MM
**2. AMB:** Advanced Memory Buffer
<table>
<thead>
<tr>
<th>Type</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FBDIMM</strong></td>
<td></td>
<td><strong>AMB1</strong></td>
<td><strong>AMB1</strong></td>
<td><strong>AMB2</strong></td>
</tr>
<tr>
<td></td>
<td>DDR2-533</td>
<td>DDR2-667</td>
<td>DDR2-800</td>
<td>DDR3-1066</td>
</tr>
<tr>
<td></td>
<td>DDR2-667</td>
<td>DDR2-800</td>
<td>DDR3-1333</td>
<td>DDR3-1333</td>
</tr>
<tr>
<td><strong>RDIMM</strong></td>
<td>DDR2-400</td>
<td>DDR2-667</td>
<td>DDR2-800</td>
<td>DDR3-1066</td>
</tr>
<tr>
<td></td>
<td>DDR2-533</td>
<td>DDR2-800</td>
<td>DDR3-1333</td>
<td>DDR3-1600</td>
</tr>
<tr>
<td><strong>UDIMM</strong></td>
<td>DDR2-533</td>
<td>DDR2-800</td>
<td>DDR3-1066</td>
<td>DDR3-1600</td>
</tr>
<tr>
<td></td>
<td>DDR2-667</td>
<td>DDR3-1333</td>
<td>DDR3-1333</td>
<td>DDR3-1600</td>
</tr>
<tr>
<td><strong>SODIMM</strong></td>
<td>DDR2-533</td>
<td>DDR2-667</td>
<td>DDR3-800</td>
<td>DDR3-1066</td>
</tr>
<tr>
<td></td>
<td>DDR2-667</td>
<td>DDR3-1333</td>
<td>DDR3-800</td>
<td>DDR3-1066</td>
</tr>
</tbody>
</table>
Paradigm Shift in DRAM Demand

- Expansion of DRAM market for Mobile and Digital Consumer

**High Density**
- 2G DDR2
- 1G DDR3
- 16GB Module

**High Speed**
- 800MHz ('06)
- 1GHz ('07)
- Graphic Application

**Legacy**
- 512M DDR
- 256M Sync
- Consumer Application

**Specialty**
- XDR™ (Trademark of Rambus)
- GDDR3
- Mobile DRAM
DRAM by Application (2004)

2004 Megabyte Based:

- Desktop (35.1%)
- Note PC (18.7%)
- Server (12.1%)
- PC Others (10.7%)
- Mobile (3.2%)
- Consumer (5.0%)
- Game (1.1%)
- Others (1.2%)

PC & Server 78.8%

2004 Revenue Based:

- Desktop (35.1%)
- Note PC (12.1%)
- Server (13.0%)
- PC Others (18.7%)
- Mobile (1.2%)
- Consumer (5.0%)
- Game (3.2%)
- Others (10.7%)

PC & Server 74.7%

(Source: DQ, Samsung)
DRAM by Application (2010, est.)

2010 Megabyte Based

- Desktop: 27.8%
- Note PC: 17.9%
- Server: 9.6%
- PC Others: 20.2%
- Mobile: 9.5%
- Game: 0.8%
- Consumer: 3.7%
- Communi.: 1.8%
- Others: 8.7%

2010 Revenue Based

- Desktop: 75.5%
- Note PC: 69.8%
- Server: 69.8%
- PC Others: 69.8%
- Mobile: 69.8%
- Game: 69.8%
- Consumer: 69.8%
- Communi.: 69.8%

(Source: DQ, Samsung)
Flash Memory
Two fold increase every year in density

- 256M('99) → 512M('00) → 1G('01)
- 1G('02) → 4G('03) → 8G('04) → 16G('05)

World’s First Commercialization of 50nm technology

256Mb 512Mb 1Gb 2Gb 4Gb 8Gb 16Gb
220nm 150nm 120nm 90nm 70nm 60nm 50nm

64Gb 32Gb 16Gb 8Gb 4Gb 2Gb 1Gb
3xnm 4xnm 50nm 70nm 90nm 120nm 220nm

New Memory Growth Model
Industry First 16Gb NAND (Samsung, ’05)

- World’s highest capacity
- Advanced technology (50nm)
- Leads revolution in digital consumer and storage devices
- 32GByte Memory Card by 16Gb
  - 8,000 MP3 audio files (680 hrs),
  - 20 DVD-quality movies (32 hrs),
  - 200 yrs of average daily newspaper
Samsung keeps the memory density up in incomparable speed

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design Rule</strong></td>
<td>90nm</td>
<td>70nm</td>
<td>60nm</td>
<td>50nm</td>
</tr>
<tr>
<td><strong>NAND(SLC)</strong></td>
<td>2Gb</td>
<td>4Gb</td>
<td>4Gb</td>
<td>8Gb</td>
</tr>
<tr>
<td><strong>NAND(MLC)</strong></td>
<td></td>
<td>4Gb</td>
<td>8Gb</td>
<td>16Gb</td>
</tr>
<tr>
<td><strong>NOR(SLC)</strong></td>
<td>256Mb</td>
<td></td>
<td></td>
<td>512Mb</td>
</tr>
<tr>
<td><strong>NOR(MLC)</strong></td>
<td></td>
<td>256Mb</td>
<td>512Mb</td>
<td>1Gb</td>
</tr>
</tbody>
</table>
Worldwide NAND Flash Application

(Source: Samsung Marketing)
High Speed (133Mhz) for Handset Performance Enhancement

- Operating Voltage : 1.8V
- Sync-Burst : 133Mhz
- Continuous Burst (Wrap/ No Wrap)
- 32 Words Acc. Buffered Program (4us/ word)

<90nm, 256Mb MLC NOR Flash> (Released in VLSI TSA 2005, SSDM 2005)
Samsung MMC (Multi-Media Card) Roadmap

- **Density**: 1GB (Now), 16GB (2007)
- **Performance**: Dual Voltage (MMCmobile & MMCmicro)

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MMCplus</strong></td>
<td></td>
<td>512MB</td>
<td>1GB</td>
<td>2GB</td>
</tr>
<tr>
<td><strong>MMCmobile</strong></td>
<td>256MB</td>
<td>512MB</td>
<td>1GB</td>
<td>2GB</td>
</tr>
<tr>
<td><strong>MMCmicro</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>Normal(x1)</td>
<td>High Speed(x1, x4, x8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Voltage</strong></td>
<td>3.3V</td>
<td>3.3V/1.8V (Dual) – Except MMCplus</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Demonstration Result at Digital Camera

- Maximum Moving Picture Recording Time
  (Micro SD vs. MMC\textit{micro})

<table>
<thead>
<tr>
<th>128MB Micro SD</th>
<th>128MB MMC\textit{micro}</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Recording halts after 18&quot;)</td>
<td>(Records until Card is full)</td>
</tr>
</tbody>
</table>

Test Conditions @ 64MB Free Space => Maximum Recording Time (32")
Mobile Solution
(Fusion Memory)
Memory for Mobile Phone

Memory Consumption Trend in 3G Phone

- Bluetooth Music Phone: Total 256MB Memory embedded
- DMB Phone: Total 210MB Memory embedded
- 7M Pixel Camera Phone: Total 432MB Memory embedded

- NOR Flash: CAGR: 7%
- NAND Flash: CAGR: 88%
- Mobile DRAM: CAGR: 56%
Before, mobile memory was simple (NOR+SRAM)

Today, mobile memory is diversified due to various requirements.
Samsung provides various RAM solutions (M-DRAM, PSRAM/UtRAM, SRAM)

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ES</strong></td>
<td>100nm</td>
<td>90nm</td>
<td>80nm</td>
<td>70nm</td>
</tr>
<tr>
<td><strong>Design Rule</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>M-SDR</strong></td>
<td>256Mb</td>
<td>512Mb</td>
<td>512Mb</td>
<td>512Mb</td>
</tr>
<tr>
<td><strong>M-DDR</strong></td>
<td>256Mb</td>
<td>512Mb</td>
<td>512Mb</td>
<td>1Gb</td>
</tr>
<tr>
<td><strong>UtRAM</strong></td>
<td>64Mb</td>
<td>128Mb</td>
<td>256Mb</td>
<td>512Mb</td>
</tr>
<tr>
<td><strong>SRAM</strong></td>
<td>16Mb</td>
<td></td>
<td>64Mb</td>
<td>128Mb</td>
</tr>
</tbody>
</table>
MCP (Multi-Chip PKG) & SIP (System In PKG) are conventional.
Size, Cost, Performance Limitations push set makers to adopt the next Gen. PKG solutions.
High Density MCP Usage by Mobile Phone

- 2.3G/3G and Feature Phones requires high density MCP (Multi-Chip Package)

[Total Density]

<table>
<thead>
<tr>
<th>Year</th>
<th>8Gb</th>
<th>4Gb</th>
<th>2Gb</th>
<th>1Gb</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>NNDD1G512</td>
<td>NDD1G256</td>
<td>NDD2G512</td>
<td>ROO256512</td>
</tr>
<tr>
<td>2005</td>
<td>(W)CDMA</td>
<td>NDD1G512</td>
<td>RRRO768512</td>
<td>ROU2566G12</td>
</tr>
<tr>
<td>2006</td>
<td>NNDD2G1G</td>
<td>RROD512512512</td>
<td>NDD1G512</td>
<td>OD1G512</td>
</tr>
<tr>
<td>2007</td>
<td>NNDD4G1G</td>
<td>ROO5122G</td>
<td>OOD2G1G</td>
<td>NDD2G1G</td>
</tr>
<tr>
<td></td>
<td>NNDD8G1G</td>
<td>ROU5121G512</td>
<td>ROU5126G256</td>
<td></td>
</tr>
</tbody>
</table>

* D(DRAM), R(NOR), N(NAND), O(OneNAND), U(UtRAM)
10-Chip MCP is developed in one package
- Total 11Gb (4Gb NAND 2pcs, 512Mb M-DRAM 4pcs, 256Mb NOR 4pcs)
- Package size 11x18mm, thickness is below 1.6mm
- 4-Chip('02) → 6-Chip('03) → 8-Chip('04) → 10-Chip ('05)

* MCP : Multi-Chip Package
POP (PKG on PKG) Structure & Image

- Package on Package (POP) for Space Saving & Performance
- Package Combination of POP: Chipset + Memory (MCP)

20~40% Space Gain

POP-MCP
Phone PCB Board
OneNAND = NAND Core + SRAM + Logic + NOR Interface

4 times NAND’s reading speed
67 times NOR’s writing speed

1Gb X 4 Stack
= 4Gb OneNAND™
# OneNAND™ vs. NAND Benchmark

<table>
<thead>
<tr>
<th></th>
<th>NAND</th>
<th>OneNAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read</td>
<td>2.6MB/s</td>
<td>15MB/s</td>
</tr>
<tr>
<td>Write</td>
<td>180KB/s</td>
<td>3MB/s</td>
</tr>
<tr>
<td>CPU</td>
<td>Same CPU</td>
<td></td>
</tr>
<tr>
<td>Booting Time*1</td>
<td>22 sec (Code Shadowing: ~5MB/s)</td>
<td>17 sec (Code Shadowing: ~18MB/s)</td>
</tr>
<tr>
<td></td>
<td>∆ = 5 sec</td>
<td></td>
</tr>
<tr>
<td>24MB Image</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shadowing</td>
<td>+ Code Execution</td>
<td></td>
</tr>
</tbody>
</table>

Note *1: Booting Time = From power button push to Antenna Appearance at LCD
<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design Rule</strong></td>
<td>0.12um</td>
<td>90nm</td>
<td>70nm</td>
<td>60nm</td>
</tr>
<tr>
<td><strong>Density</strong></td>
<td>512Mb</td>
<td>1Gb</td>
<td>2Gb</td>
<td>4Gb</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>66MHz(68MB/s)</td>
<td>83MHz (108MB/s)</td>
<td>83MHz (133MB/s)</td>
<td></td>
</tr>
<tr>
<td><strong>Cell Type</strong></td>
<td>SLC</td>
<td></td>
<td></td>
<td>MLC</td>
</tr>
<tr>
<td><strong>Interface</strong></td>
<td>Asynch. Page, Synch. Burst, Muxed I/O Option</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Emerging Tech. 1: New Memory

- Major Candidates are PRAM, MRAM, FRAM
  (PRAM = Phase Change RAM, MRAM = Magnetic RAM, FRAM = Ferro RAM)
Flash: Multiple steps to change data with complex software

PRAM: Just “one step” to change data with simple software
New Memory Means Fast Data Storage

- 200M Pixel Picture Storage Time (VGA, 640x480, 420KB)

- NOR Flash: Block Erase → Program: 7000ms
- NAND Flash: 245ms, 35x faster
- New Memory: 7ms, 1,000x faster

New Memory reduces data storage time drastically → Possibility of saving high quality motion picture!
Samsung PRAM Development Roadmap

Long Term PRAM Roadmap

- 64Mb (0.12um)
- 256Mb (0.10um)
- 512Mb
- 1Gb
- 2Gb

Technology:
- 6X nm
- 4X nm
Industry 1st 256M PRAM

Better Performance
- Short Data Programming Time
- High Reliability

Can Provide High Performance Solution for Mobile Handsets

(Published in 2005 VLSI Symposium)
Emerging Tech. 2: Hybrid Hard Disk

- Hybrid-HDD is one of “Windows Vista” Key Features
- System Benefits:
  - Reduce Power Consumption, Faster Boot and Resume time and Better Reliability

Source: Microsoft WinHEC in April, ’05
World’s First Hybrid-HDD (Proto-type)

- Microsoft - Samsung collaboration for proto Hybrid-HDD
- Microsoft’s Window Vista to support Hybrid-HDD (’06 2H)

Hybrid-HDD demonstration at WinHEC in April, ’05
※ WinHEC : Windows Hardware Engineering Conference
Hybrid-HDD Prototype Demo

Hybrid HDD
(Arm is almost in parking state)
(Average Power = 0.28W)

Conventional HDD
(Arm is keep moving on disk)
(Average Power=1.52W)
Better performance than HDD
- Saves 95% of power consumption, 50% of weight
- 2x Writing Speed, 4x Reading Speed
Creation of new market → Next generation mobile PC

<table>
<thead>
<tr>
<th>1.8” SSD</th>
<th>1.8” HDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>32GB/ 16GB</td>
<td>30GB/ 20GB</td>
</tr>
<tr>
<td>Density</td>
<td>Weight</td>
</tr>
<tr>
<td>15 g</td>
<td>61 g</td>
</tr>
<tr>
<td>Read speed: 57MB/ s</td>
<td>Speed</td>
</tr>
<tr>
<td>Write speed: 32MB/ s</td>
<td>Read/ Write speed: 15MB/ s</td>
</tr>
<tr>
<td>On: 0.1 W, Off: 0.5 W</td>
<td>Power Consumption</td>
</tr>
<tr>
<td>-20 ~ 80 (°C)</td>
<td>Endurance Temperature</td>
</tr>
<tr>
<td></td>
<td>0 ~ 60 (°C)</td>
</tr>
</tbody>
</table>
SSD (Solid State Disk) Booting Time Demo

SSD (Solid State Disk)

Conventional HDD

18 s  40% Time Saving  30 s

SSD: Solid State Disk
HDD: Hard Disk Drive
Other Application Example: Navigation

- Problems of current system for Car Navigation
  - Optical Media system (~4.7GB): No rewritable
  - HDD: Weak Reliability, Limited Performance
- Flash Premium of Reliability with Performance
  - High Reliability, and High speed searching function
- Flash capacity is enough for Most In-Car Entertainment
  - Visual and Audio capacity for Games, Music Videos, and Entertainment (4GB ~ 16GB)

Telematics  Navigation  In-Car Entertainment
New Memory Growth Model

Paradigm Shift: Semiconductor Consumption Divergence

ISSCC (International Solid State Circuit Conf.) Keynote Speech
Five Axes of Memory Technology Evolution

- High Density
- High Performance
- Fusion
- Low Power
- New Memory

IT Phases:
- IT Phase 1
- IT Phase 2
- IT Phase 3
- IT Phase 4

Eras:
- IT Infra Era
- PC Era
- Mobile Era
- Consumer + Mobile Era
Samsung’s Value Proposition

Leadership in All 5 Axes of Memory Technology

High Density
High Performance (HW, SW)
Low Power
New Memory

Product Portfolio & Solutions
Various R&D Capability
Timely Investment
Production Capacity
Thank You!