DRAM Module Market
Overview

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Vice President, DRAM Technology
SimpleTech
Many Applications,
Many Configurations
Agenda

- Terminology review
- DRAM Market Factors
- Market: Personal Computers
- Market: Servers & Workstations
  - FB-DIMM or RDIMM?
- Market: Routers & Communications
- Market: Peripherals
### DDR2 Speed Grading

<table>
<thead>
<tr>
<th>Clock Speed</th>
<th>Chip Bin</th>
<th>Data Rate</th>
<th>Module Bin</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 MHz</td>
<td>DDR2-400</td>
<td>400 MT/s</td>
<td>PC2-3200</td>
</tr>
<tr>
<td>266 MHz</td>
<td>DDR2-533</td>
<td>533 MT/s</td>
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<td>333 MHz</td>
<td>DDR2-667</td>
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<td>400 MHz</td>
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<td>800 MT/s</td>
<td>PC2-6400</td>
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</tbody>
</table>

X64/x72 bit data bus * chip speed
## DDR3 Speed Grading

<table>
<thead>
<tr>
<th>Clock Speed</th>
<th>Chip Bin</th>
<th>Data Rate</th>
<th>Module Bin</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 MHz</td>
<td>DDR3-800</td>
<td>800 MT/s</td>
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<tr>
<td>533 MHz</td>
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<td>PC3-8500</td>
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<td>667 MHz</td>
<td>DDR3-1333</td>
<td>1333 MT/s</td>
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<td>800 MHz</td>
<td>DDR3-1600</td>
<td>1600 MT/s</td>
<td>PC3-12800</td>
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</table>

X64/x72 bit data bus * chip speed
Terminology

DIMM = Dual Inline Memory Module

- **UDIMM = Unbuffered**: Address bus connected directly to DRAMs, limited to 18 chips per DIMM, 2 slots
- **RDIMM = Registered**: Address bus redriven to DRAMs, enables 72 DRAMs per DIMM, 2 slots
- **FB-DIMM = Fully Buffered**: Address and data buses packetized and redriven to DRAMs, enables 36 DRAMs per DIMM, 8 slots
Terminology

- ECC = Error Correction Code
- Chip Kill (also SDDC) = enhanced variant of ECC
- Rank = DRAMs sharing a select line

- 1 rank of x8 DRAMs = 8 chips for x64 bus
  9 chips for x72 bus (ECC)
- 1 rank of x4 DRAMs = 18 chips for x72 bus
- 2Rx4 = 36 DRAMs
- 4Rx4 = 72 DRAMs
English or Metric?

<table>
<thead>
<tr>
<th></th>
<th>SDRAM</th>
<th>DDR1</th>
<th>DDR2 &amp; DDR3</th>
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<tbody>
<tr>
<td>DIMM</td>
<td>5.25 x 1.7&quot;</td>
<td>5.25 x 1.2&quot;</td>
<td>133.35 x 30mm</td>
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<td>VLP</td>
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<td>5.25 x 0.72&quot;</td>
<td>133.35 x 18.3mm</td>
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<tr>
<td>SO-DIMM</td>
<td>2.66 x 1.25&quot;</td>
<td>67.6 x 31.75mm</td>
<td>67.6 x 30mm</td>
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</tbody>
</table>

*Metric conversion finally complete…*
## Module Configurations

| DDR1 | Registered DIMM (4 rank)  | Micro-DIMM  
|      | Unbuffered DIMM           | 32b-DIMM  
|      | SO-DIMM                   | 16b-SO-DIMM |
| DDR2 | Registered DIMM (4 rank)  | SO-DIMM  
|      | Mini-RDIMM (4 rank)       | Micro-DIMM |
|      | Unbuffered DIMM           | 16b/32b-SO-DIMM |
|      | FB-DIMM                   | 72b-SO-RDIMM (4 rank) |
| DDR3 | Registered DIMM           | SO-DIMM  
|      | Mini-RDIMM (4 rank)       | Micro-DIMM |
|      | Unbuffered DIMM           | 16b/32b-SO-DIMM |
DRAM Market Overview & Impact on Memory Modules
**DRAM Density**

- 1Gb transition hindered by the Perfect Storm
  - DDR1/DDR2 split on suppliers & designs
  - 110 → 90nm transition difficulties
  - 10% die penalty for 8 banks
- 512Mb DRAM will be the sweet spot through 2006!
- Implications include 2GB/slot for 2Rx4

- 4 Rank Modules will increase market share
- Stacking will be the lowest cost path to 4GB
SimpleTech
Postage Stamp BGA Stack
Postage Stamp Features

- 2 DRAMs (one under cavity)
- Cavity Substrate
- High Reliability Ball-less Vertical Interconnect
- Decoupling Capacitors
- Probe Points on All Signals and Voltages
Thermal path to all ground planes then to surface copper flood – entire DIMM becomes a heat spreader
Designing for Performance

SimpleTech Postage Stamp stack

Planar single sided

Unequal Trace Lengths

Equal Trace Lengths

Planar double sided

Transmission line stack
Module Markets: Desktop & Mobile
## PC Market: Unified View

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
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</thead>
<tbody>
<tr>
<td><strong>Desktop PC</strong></td>
<td>DDR2-667 UDIMM 2 Rank</td>
<td>DDR2-800 UDIMM 2 Rank</td>
<td>DDR3-1066 UDIMM 2 Rank</td>
</tr>
<tr>
<td><strong>Notebook PC</strong></td>
<td>DDR2-667 SO-DIMM 2 or 4 Rank</td>
<td>DDR2-800 SO-DIMM 2 or 4 Rank</td>
<td>DDR3-1066 SO-DIMM 2 or 4 Rank</td>
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<tr>
<td><strong>Subnotebook PC</strong></td>
<td>DDR2-667 Micro-DIMM 2 or 4 Rank</td>
<td>DDR2-800 Micro-DIMM 2 or 4 Rank</td>
<td>DDR3-1066 Micro-DIMM 2 or 4 Rank</td>
</tr>
</tbody>
</table>

*DDR3 Transition*
Why SO- and Micro-DIMM?

**DDR2 SO-DIMM with Edge Connector Socket**

- Thickness = 5.2 mm
- 2D Layout efficiency = 1654 / 2489 = 66%
- 1GB → 79KB/mm³

**DDR2 Micro-DIMM with Mezzanine Connector**

- Thickness = 5.65 mm
- 2D Layout efficiency = 1318 / 1620 = 81%
- 1GB → 112KB/mm³

142% cubic density ratio advantage using Micro-DIMM versus SO-DIMM
Module Markets:
Servers & Workstations
Fragmentation

Diverging views in server segment

1. RDIMM → FB-DIMM in all segments; DDR2 FB-DIMM a huge success

2. DDR2 → DDR3 RDIMM; FB-DIMM not “real” until DDR3 if at all

JEDEC roadmaps support either path
## Server Market View #1

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
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</thead>
<tbody>
<tr>
<td>HE Server</td>
<td>DDR2-400 RDIMM 2 Rank</td>
<td>DDR2-533 FB-DIMM</td>
<td>DDR2-667 FB-DIMM</td>
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<tr>
<td>Mid Server</td>
<td>DDR2-400 RDIMM 2 Rank</td>
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<tr>
<td>LE Server</td>
<td>DDR2-400 RDIMM 2 Rank</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HPC</td>
<td>DDR2-533 UDIMM 2 Rank</td>
<td>DDR2-667 UDIMM 2 Rank</td>
<td>DDR3-1333 UDIMM 2 Rank</td>
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</table>

“RDIMM is obsolete next year”
## Server Market View #2

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<td>DDR1-266 RDIMM</td>
<td>DDR2-533 RDIMM</td>
<td>FB-DIMM</td>
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<tr>
<td></td>
<td>4 Rank</td>
<td>4 Rank</td>
<td>in 2008?</td>
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<tr>
<td><strong>Mid Server</strong></td>
<td>DDR1-333 RDIMM</td>
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<td>DDR3-1333</td>
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<tr>
<td></td>
<td>4 Rank</td>
<td>4 Rank</td>
<td>RDIMM</td>
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<tr>
<td><strong>LE Server</strong></td>
<td>DDR1-400 RDIMM</td>
<td>DDR2-667 RDIMM</td>
<td>DDR3-1333</td>
</tr>
<tr>
<td></td>
<td>4 Rank</td>
<td>4 Rank</td>
<td>RDIMM</td>
</tr>
<tr>
<td><strong>HPC</strong></td>
<td>DDR1-400 UDIMM</td>
<td>DDR2-667 UDIMM</td>
<td>DDR3-1333</td>
</tr>
<tr>
<td></td>
<td>2 Rank</td>
<td>2 Rank</td>
<td>UDIMM</td>
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</tbody>
</table>
Form Factor Wars

- 1.2” (30mm) standard chosen in 1999 based on 1U server market projections

- But, market fragmenting
  - Blade needs 18.3mm (VLP)
  - 1U needs 30mm (LP)
  - 2U can use 38mm or taller

- OEMs “demand” one size fits all … but …
Blade Server, 1.2” Module

Cool Air

Heated Air

Angled Socket

CPU

CPU

Blade Server

Top View

17,700 mm²

30 mm DIMM
The VLP Form Factor

133.35 mm (5.25”)

18.3 mm (0.72”)

14.3 mm (0.56”)
Usable Layout Area

4 mm (0.158”)
4 Rank RDIMM

Requires 2 extra rank select signals routed on motherboard

BIOS updated to detect SPD byte 5 = ‘4’

DDR1 & DDR2 4 rank specs approved
Fully Buffered DIMM
Motivation for FB-DIMM

As speeds increase, the number of RDIMMs per channel decrease.

FB-DIMM supports 8 slots per channel at any speed.
Fully Buffered DIMM

- Solves stub bus timing challenges
- 16GB per channel (8 DIMMs per channel)
- Eases DDR2 → DDR3 transition
- Cost and thermal issues may limit use
- Single DIMM failure can cause channel failure
- Intellectual property questions delay approval
FB-DIMM Design

4.8GHz → 9.6GHz
5-7W of power
Center of module – no good direction for cooling
Constantly draining power through termination

Expensive 655 ball BGA package
Requires heat sink

Very tricky thermal design challenge
Under Consideration

- VLP FB-DIMM
  - Repackaging the AMB to 14mm for VLP
- 4 Rank support
  - 4GB per slot → 8GB per slot
- Spare bit lane
  - Increased reliability for non-stop mission critical systems
Unbuffered & Registered DIMMs
Typical System Configuration

- Two slots per channel
- Dual channel memory controller
  - Unbuffered: 2 ranks per slot, 8GB
  - Registered: 4 ranks per slot, 16GB
DDR3 Unbuffered Modules

VLP Form Factor Impractical!!!
DDR3 RDIMM Fly-By

Support for 2 ranks (36 DRAMs) and 4 ranks (72 DRAMs) – VLP enabled
Registering Clock Driver

<table>
<thead>
<tr>
<th>Registers/Redrivers</th>
<th>Control Registers</th>
<th>Address Command</th>
<th>Parity Logic</th>
<th>Phase Locked Loop</th>
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</thead>
<tbody>
<tr>
<td>Input</td>
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<tr>
<td>CK#</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Input: ...
Output: ...
Err_Out#: ...
CKn/CKn#: ...

SimpleTech
DDR3 RDIMM

Register/PLL ballout defined for clean routing
Address Bus Routing

So clean it’s beautiful!
DDR3 RDIMM Summary

• Compatible with UDIMM controller
  – Eases adoption for existing controllers
• Single low pin count register/PLL
  – Lower cost
  – Simpler layout
  – Size enables VLP (18.3mm) RDIMM
• Integrated PLL with only 4 output pairs
  – Lower power
• 4 rank support designed in
## Industry Wide Support

<table>
<thead>
<tr>
<th>Raw card A: 1Rx8 (1-4 GB)</th>
<th>Micron</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw card B: 2Rx8 (2-8 GB)</td>
<td>Samsung</td>
</tr>
<tr>
<td>Raw card C: 1Rx4 (2-8 GB)</td>
<td>Elpida</td>
</tr>
<tr>
<td>Raw card D: 2Rx4 (4-16 GB) – Stacked</td>
<td>SimpleTech</td>
</tr>
<tr>
<td>Raw card E: 2Rx4 (4-16 GB) – Planar</td>
<td>Infineon</td>
</tr>
</tbody>
</table>
What Happens in Server & Workstation Market?
FB-DIMM or RDIMM?

- 8 DIMMs per channel
  - X 2GB per DIMM
  - = 16GB per channel
  - Low pin count
  - High cost
  - High heat

- 2 DIMMs per channel
  - X 4GB per DIMM
  - = 8GB per channel
  - High pin count
  - Low cost
  - Low heat

Biggest volume is 4-8 slots total

Too early to determine which will be the next mainstream server memory.
Router/Networking Markets
### Router & Networking

<table>
<thead>
<tr>
<th>Year</th>
<th>High End Routers</th>
<th>Low End Routers</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>DDR1 RDIMM</td>
<td>DDR1 SO-DIMM</td>
</tr>
<tr>
<td>2006</td>
<td>DDR2 Mini-RDIMM</td>
<td>DDR2 SO-DIMM</td>
</tr>
<tr>
<td>2007</td>
<td>DDR3 Mini-RDIMM</td>
<td>DDR3 SO-DIMM</td>
</tr>
</tbody>
</table>

- Split between those that need ECC and those that don’t need ECC
- FB-DIMM not a fit for this market

72b-SO-RDIMM (4 rank)
Mini-RDIMM Form Factor

- JEDEC ballot in process to add:
  - Support for address/command parity
  - Support for 4 ranks of memory
- Task group for DDR3 Mini-RDIMM

82mm versus 133mm = 40% reduction in size versus full size RDIMM
New! 72b-SO-RDIMM

- SO-DIMM sized module with 72 bit bus
- Reuse existing mobile sockets (right angle) with no voltage key change
- Performance to DDR2-667
- 512MB/1GB sweet spot, 2GB capable
72b-SO-RDIMM Pinout

<table>
<thead>
<tr>
<th>Pin #</th>
<th>Front Side</th>
<th>Pin #</th>
<th>Back Side</th>
<th>Pin #</th>
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<th>Pin #</th>
<th>Back Side</th>
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<tbody>
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Mini-RDIMM vs 72b-SO-RDIMM

- Module = 82 x 30mm
- Component area = 78 x 26mm
- 244 pins, 0.6 mm pitch

- Module = 67.6 x 30mm
- Component area = 63.6 x 26mm
- 200 pins, 0.6 mm pitch
# Key Differences

<table>
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<tr>
<th>Mini-RDIMM</th>
<th>72b-SO-RDIMM</th>
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<tr>
<td>• X4 DRAM supported</td>
<td>• X4 DRAM not supported</td>
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<td>• 4 rank supported (proposed)</td>
<td>• 4 rank supported</td>
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<tr>
<td>• 8GB max</td>
<td>• 4GB max</td>
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<tr>
<td>• 3 clock pairs → unbuffered supported</td>
<td>• One clock pair → PLL needed</td>
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<tr>
<td>• Address/command parity supported (proposed)</td>
<td>• Address/command parity not possible (no pins)</td>
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Peripheral Markets
Peripherals

- Devices that need smaller granularity
  - A single 512Mb chip contains 64MB of data!
- Small footprint is desirable
  - 1 to 4 DRAMs typical
- Reuses SDRAM 144-pin SO-DIMM form
- Common pinout for DDR1/2/3 and 16/32 bits
Modules for Peripherals

Raw Card A, Front View

Raw Card B, Front View

Raw Card A, Rear View

Raw Card B, Rear View
Memory Module Summary

- DDR2 transition under way, DDR3 coming
- PC market form factors fairly stable
  - UDIMM, SO-DIMM, Micro-DIMM
  - DDR1 → DDR2 → DDR3
- Server market fragmenting
  - RDIMM → FB-DIMM or RDIMM → RDIMM?
  - Module height = 30mm? 18.3mm?
- Networking: Mini-RDIMM
- Peripherals: 16b-SO-DIMM 72b-SO-RDIMM (4 rank)
Thank You

Questions?