Chapter 4: Computer Hardware: RAM
In this chapter, you will learn how to

- Identify the different types of RAM packaging
- Explain the varieties of DRAM
Chapter 4: Computer Hardware: RAM

- **Primary storage or memory**: Is where the data and program that are currently in operation or being accessed are stored during use.
  - Two types:
    - **RAM** (non-permanent)
      - Programs and data can be stored here for the computer’s use.
      - Volatile: All information will be lost once the computer shuts down.
    - **ROM** (permanent)
      - Contents do not change.
Memory is a term for a device that enables the computer to retain (store) information.
RAM or Random Access Memory

“Waiting room” for computer’s CPU.

Holds instructions for processing data, processed data, and raw data.

Ram is measured by:

- Capacity (in Megabytes or Gigabytes)
- Speed (in Nanoseconds)
ROM is a type of memory circuitry that holds the computer’s startup routine
   – Permanent and non-volatile
The ROM BIOS tells the computer how to access the hard disk, find the operating system, and load it into RAM
Electrically Erasable Programmable Read-Only Memory

More permanent than RAM, and less permanent than ROM

Requires no power to hold data
Chapter 4: Computer Hardware : RAM

DRAM
DRAM

- DRAM (dynamic random access memory) is the most popular type of electronic memory
  - Special type of semiconductor that stores ones and zeroes using microscopic capacitors and transistors
  - Single chip can hold millions of these capacitor/transistor combinations
Chapter 4: Computer Hardware: RAM

Program Execution

- Program code is copied from your hard disk into RAM before it is executed.
Chapter 4: Computer Hardware : RAM

Organizing DRAM

- DRAM is considered the standard
  - Low cost, high speed, and able to store data in a relatively small package
  - Many varieties of DRAM

- DRAM stores programs and data in 8-bit (1-byte) chunks of memory

- Chips have historically been referenced with respect to their depth and width
  - 1 MB x 4
  - 256 K x 1

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Organizing DRAM

- The **depth** and **width** are measured in units of bits

- Not easy to determine based on what’s written on chips

- The physical size and the internal organization of the chip are not directly related
Chapter 4: Computer Hardware : RAM

Review : Memory controller chip

- The memory controller chip (MCC) device facilitates the flow of data from the RAM to the CPU.

- Data is placed on the external data bus.

- Width of data bus related to width or DRAM.
Chapter 4: Computer Hardware : RAM

Practical DRAM

- **8086 used 16-bit data bus**
  - Much more expensive at the time
  - At $12,000 per PC, would not have fueled the PC revolution

- **Original 8088 chip used 8-bit data bus**
  - Market was ready for this
  - Adapted to some commands needing 16 bits
Chapter 4: Computer Hardware : RAM

Bus Review

- **Address bus**
  - This addresses the RAM
  - Number of lines in address bus determines max RAM (32 lines = 4 GB, 36 lines = 64 GB)

- **External data bus**
  - This is where data is placed once addressed
  - MCC retrieves data from RAM on places on EDB
  - Width of data bus dictates width of RAM

- **Frontside bus**
  - Same as external data bus

- **Backside bus**
  - Used to access cache

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DRAM Sticks
Chapter 4: Computer Hardware: RAM

Memory Modules

- **Memory modules** are narrow printed circuit boards that hold memory chips.

- Three types of modules:
  - **Single Inline Memory Module (SIMM)**—30- or 72-pin connectors. Available in 1 MB, 4 MB, 16 MB, and 32 MB versions.
  - **Dual Inline Memory Module (DIMM)**—168- or 184-pin connector. Available in 8 MB, 16 MB, 32 MB, 64 MB, 128 MB, 256 MB, and 512 MB versions.
  - **Rambus Inline Memory Module (RIMM)**—Look like DIMMs but are not interchangeable with DIMMs.
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DRAM Sticks

- A better solution was needed

- 72-pin SIMMs
  - Modern CPUs have 64-bit external data buses
  - 72-pin SIMMs have a notch in the middle
  - Each 72-pin SIMM is 32 bits wide (two required)
Chapter 4: Computer Hardware: RAM

Banking

- Combining the widths of DRAM to match the width of the external data bus is called **banking**

- The number of sticks that make up a bank depends on the chipset, which in turn depends on the CPU’s external data bus size

  - EDB of 64 bits = 2 SIMMS 32 bits wide
  - EDB of 64 bits = 1 DIMM 64 bits wide
Chapter 4: Computer Hardware : RAM

Consumer RAM

- RAM has widths larger than bytes
  - 8 bits wide = byte
  - 16 bits wide = word
  - 32 bits wide = double word

- However, still referred to in bytes
  - 256 MB, 512 MB, 1 GB sticks
Chapter 4: Computer Hardware : RAM

Types of RAM
• The 168-pin DIMM is the most popular DRAM package in use today
  - Extra pins to handle functions such as buffering and ECC
  - 144-pin SO-DIMMs (small outline) are used in laptops


- **SDRAM** (synchronous dynamic RAM) are tied to the system clocks
  - Synchronized with system clock
  - SDRAM is always a DIMM, but a DIMM isn’t always SDRAM
  - Wide number of pins
  - Small-outline DIMM (SO-DIIMM) used on laptops
  - Faster than DRAMs
• **RDRAM (Rambus DRAM)** is a new type of RAM
  - Speeds of up to 800 MHz
  - Comes on sticks called RIMMs
  - 184-pin for desktops and 160-pin SO-RIMM for laptops
  - All slots must be populated: unused slots must have a CRIMM (continuity RIMM)
Chapter 4: Computer Hardware : RAM

DDR SDRAM : Double Data Rate

• DDR SDRAM doubles the throughput of SDRAM
  - 184-pin DIMM packages (desktops)
  - 172-, 200-pin DIMM packages (laptops)
  - Wide range of speeds
  - Considered a standard today
  - Dual slots are blue, third slot is black

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## DDR Speed

<table>
<thead>
<tr>
<th>Clock Speed</th>
<th>DDR Speed Rating</th>
<th>PC Speed Rating</th>
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<tbody>
<tr>
<td>100 MHz</td>
<td>DDR200</td>
<td>PC1600</td>
</tr>
<tr>
<td>133 MHz</td>
<td>DDR266</td>
<td>PC2100</td>
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<tr>
<td>166 MHz</td>
<td>DDR333</td>
<td>PC2700</td>
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<tr>
<td>200 MHz</td>
<td>DDR400</td>
<td>PC3200</td>
</tr>
<tr>
<td>217 MHz</td>
<td>DDR433</td>
<td>PC3500</td>
</tr>
<tr>
<td>233 MHz</td>
<td>DDR466</td>
<td>PC3700</td>
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<tr>
<td>250 MHz</td>
<td>DDR500</td>
<td>PC4000</td>
</tr>
<tr>
<td>275 MHz</td>
<td>DDR550</td>
<td>PC4400</td>
</tr>
<tr>
<td>300 MHz</td>
<td>DDR600</td>
<td>PC4800</td>
</tr>
</tbody>
</table>

**PC Speed Rating =**  
Clock speed \times 2 \times 8

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Dual channel architecture

- Dual-channel architectures use two sticks of RAM together to increase throughput
  - Similar to RAMBUS

- Works only if two sticks
  - Dual slots often blue
  - Third one often black
**DDR SDRAM**

- Doubled the clock, increasing buffering
- Does not speed up core RAM, but just the I/O
- 240-pin DIMM (not compatible with DDR)
## Chapter 4: Computer Hardware: RAM

### DDR2 Speed

<table>
<thead>
<tr>
<th>Clock Speed</th>
<th>DDR I/O Speed</th>
<th>DDR Speed Rating</th>
<th>PC Speed Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 MHz</td>
<td>200 MHz</td>
<td>DDR2-400</td>
<td>PC2-3200</td>
</tr>
<tr>
<td>133 MHz</td>
<td>266 MHz</td>
<td>DDR2-533</td>
<td>PC2-4200</td>
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<tr>
<td>166 MHz</td>
<td>333 MHz</td>
<td>DDR2-667</td>
<td>PC2-5300</td>
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<tr>
<td>200 MHz</td>
<td>400 MHz</td>
<td>DDR2-800</td>
<td>PC2-6400</td>
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<tr>
<td>250 MHz</td>
<td>500 MHz</td>
<td>DDR2-1000</td>
<td>PC2-8000</td>
</tr>
</tbody>
</table>

**PC Speed Rating =**

\[ \text{Clock speed} \times 2 \times 2 \times 8 \]
Chapter 4: Computer Hardware: RAM

Double sided DIMMs

- Almost all sticks come as single-sided or double-sided

- Beware of double-sided sticks
  - Some are thicker, which prevents populating all slots in some motherboards
  - Your motherboard may or may not be able to accept them.
Chapter 4: Computer Hardware: RAM

Memory Modules

- DIMM
- RIMM
- NOTEBOOK DIMM
- SIMM
Chapter 4: Computer Hardware: RAM

Latency

- Latency
  - Measure of how slow RAM may be.
  
  - CL2 refers to low latency. Faster. It takes two clock cycles to get data.
  
  - CL3 refers to high latency. Slower. It takes three clock cycles to get data.
  
  - Often listed as CAS (column address strobe).
Chapter 4: Computer Hardware : RAM

Parity and ECC

- **Parity** is a rudimentary method of checking the data to see if errors exist
  - No error correction, just detection

- **ECC (error correction code)** is a special type of RAM used by high-end systems
  - Major advance in error checking on DRAM
  - Can also correct many errors
  - RAM sticks of any size can use the ECC DRAM, but it is most common as 168-pin DIMMs
  - A motherboard must be designed to use ECC to take advantage of the ECC RAM
Chapter 4: Computer Hardware: RAM

Buffered/Registered DRAM

- Most motherboards support only four sticks of RAM
  - More sticks present unique challenges

- To overcome output problems, sticks add a buffering chip
  - Acts as intermediary between RAM and MCC
Do you need RAM?

- Two symptoms point to needing more RAM
  - General system sluggishness, especially as more programs are opened
  - Disk thrashing or excessive hard drive accessing, caused by excessive paging

Note: Disk thrashing can also be caused by disk fragmentation.
Data can be moved between physical RAM and virtual RAM

- Data swapped in 64-K page blocks
- Too much too often causes disk thrashing
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System RAM Recommendations

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Reasonable Minimum</th>
<th>Solid Performance</th>
<th>Power User</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows 2000</td>
<td>128 MB</td>
<td>256 MB</td>
<td>512 MB</td>
</tr>
<tr>
<td>Windows XP</td>
<td>256 MB</td>
<td>512 MB</td>
<td>1 GB</td>
</tr>
<tr>
<td>Windows Vista</td>
<td>512 MB</td>
<td>1 GB</td>
<td>2 GB</td>
</tr>
</tbody>
</table>

- Actual minimum requirements are much lower
  - Usually leads to slower computer and unhappy user
Chapter 4: Computer Hardware : RAM

Determining Current RAM

- **My Computer Properties**
  - Windows key-Pause/Break key

- **Task Manager**
  - Ctrl-Shift-Esc
Chapter 4: Computer Hardware: RAM

Getting the right RAM

- **Identify capacity**
  - What can the motherboard handle (look at the manual)

- **Identify empty slots**
  - If all slots filled, you’ll have to pull some out
  - For example, pull out 256-MB sticks to add 512-MB sticks

- **CPU-Z is a great tool to determine what you have**
  - Also shows latency
Chapter 4: Computer Hardware : RAM

Mixing and Matching

• Mixing DRAM speeds can cause the system to lock up, leading to data corruption

• You can use faster DRAM than the motherboard recommends, but you won’t see an increase in performance

• You can put different speeds of DRAM in different banks as long as they are both faster than the speed specified