Memory Devices (Part-1)

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Modules

A. Module-1: Introduction
B. Module-2: Memory Terminology
C. Module-3: General Memory Operations
D. Module-4: CPU-Memory Connections

Module-1

Introduction

Introduction

- **Flip-flops**, also called as registers, are commonly used types of memory devices and systems
- Digital data can also be stored as charges on **capacitors**
- The principle is to obtain **high density storage** at **low power-requirement levels**

Main Memory

- **Semiconductor memories** are used as the main memory of a computer
- It's used where **fast operation** is important
- It's also called **working memory**
- It is in constant **communication with the central processing unit (CPU)** as a program of instructions is being executed.
- It works with **a program and any data** used by the program
- **RAM and ROM** make up main memory.

Auxiliary Memory

- Another form of storage in a computer is performed by **auxiliary memory**
- It is also called **mass storage** – has the capacity to store **massive amounts of data** without the need for **electrical power**
- Auxiliary memory operates at a **much slower speed** than main memory
- It stores programs and data that **are not currently being used** by the CPU
- This information is **transferred to the main memory** when the computer needs it
- Common auxiliary memory devices are **magnetic disk** and **compact disk (CD)**

Computer Memories

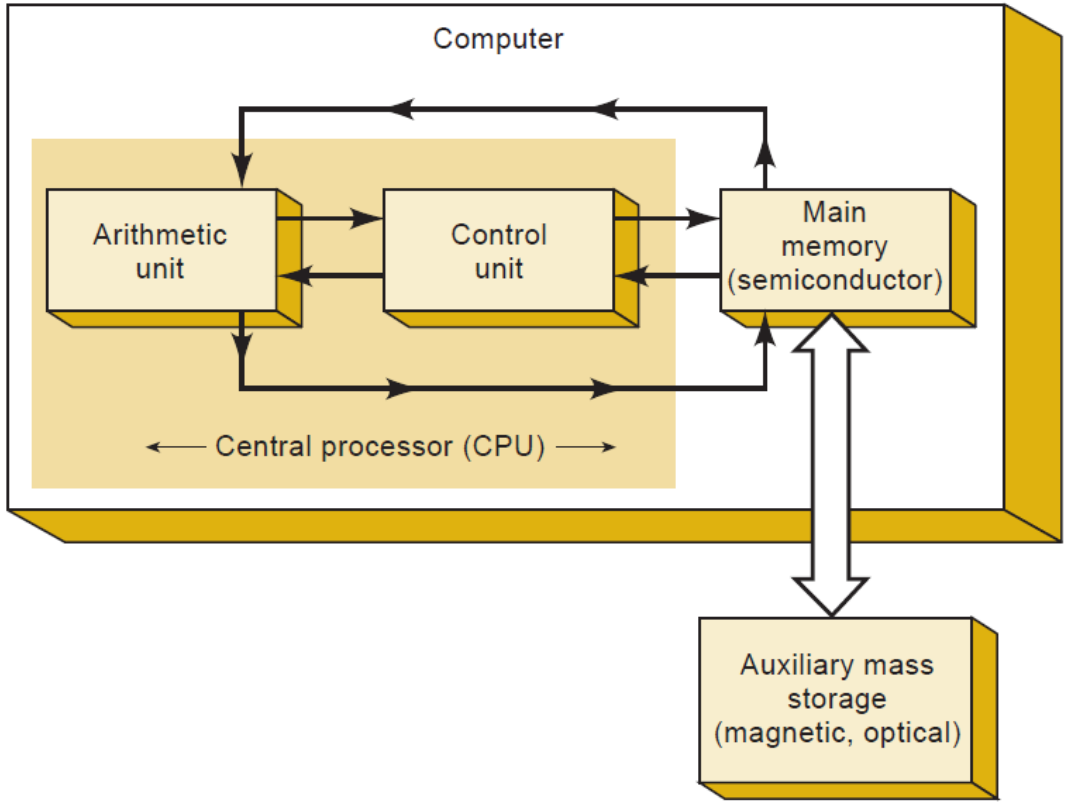

Fig. 1.1: A computer system normally uses highspeed main memory and slower external auxiliary memory.

Module-2

Memory Terminology

Memory Cell

- A device or an electrical circuit used to **store a single bit (0 or 1)**
- Examples of memory cells include **a flip-flop, a charged capacitor, and a single spot on magnetic tape or disk**

Fig. 2.1: Memory Cell Representation

Memory Word

- A group of bits (cells) in a memory that represents **instructions or data of some type**.
- For example, a register consisting of **eight FFs** can be considered to be a memory that is storing an **eight-bit word**.
- Word sizes in modern computers typically **range from 8 to 64 bits**, depending on the size of the computer.

Fig. 2.2: Memory Word Representation for 8 bits computer

Fig. 2.3: Memory Word Representation for 16 bits computer

Byte

- A byte always consists of **eight bits**
- Word sizes can be **expressed in bytes** as well as in bits
- For example, a **word size of eight bits** is also a **word size of one byte**, a **word size of 16 bits** is **two bytes**, and so on

Fig. 2.3: Representation of a byte (8 bits)

Capacity

- A way of specifying **how many bits can be stored** in a particular memory device or complete memory system.
- To illustrate, suppose that we have a memory that can store **4096 20-bit words**. This represents a **total capacity of 81,920 bits**.
- It is common to use the designation **“1K” to represent 1024**

Example 2.1

Question: A certain semiconductor memory chip is specified as $2K \times 8$. How many words can be stored on this chip? What is the word size? How many total bits can this chip store?

Solution:

$$2K = 2 \times 1024 = 2048 \text{ words}$$

Each word is eight bits (one byte). The total number of bits is therefore

$$2048 \times 8 = 16{,}384 \text{ bits}$$

Example 2.2

Question: Which memory stores the most bits: a $5M \times 8$ memory or a memory that stores 1M words at a word size of 16 bits?

Solution:

$$5M \times 8 = 5 \times 1{,}048{,}576 \times 8 = 41{,}943{,}040 \text{ bits}$$

$$1M \times 16 = 1{,}048{,}576 \times 16 = 16{,}777{,}216 \text{ bits}$$

The $5M \times 8$ memory stores more bits.

Density

- **Another term** for capacity.
- When we say that one memory device has a greater density than another, we mean that it can store **more bits in the same amount of space**.

Address

- A number that identifies the **location of a word in memory**.
- Each word stored in a memory device or system has **a unique address**.
- Addresses always exist in a digital system as a **binary number**, although octal, hexadecimal, and decimal numbers are often used to represent the address for convenience.

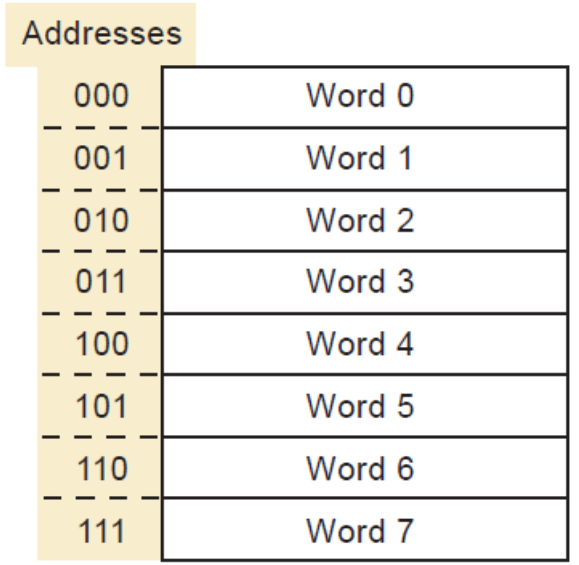

Fig 2.4: Each word location has a specific binary address.

Read Operation

- The operation whereby the binary word stored in a specific memory location (address) is **sensed and then transferred** to another device.
- The read operation is often called a **fetch operation** because a word is being fetched from memory.

Write Operation

- The operation whereby a new word is **placed into a particular memory location**.
- It is also referred to as a **store operation**.
- Whenever a new word is written into a memory location, it **replaces the word** that was previously stored there.

Access Time

- A measure of a memory device's **operating speed**.
- It is the **amount of time required** to perform a read operation.
- More specifically, it is the time **between the memory receiving a new address input and the data becoming available at the memory output**.
- The symbol $\boldsymbol{t_{ACC}}$ is used for access time.

Volatile and Non-volatile Memories

- Any type of memory that requires the application of **electrical power in order to store** information.
- If the electrical power is **removed,** all information stored in the **memory will be lost**.
- Many **semiconductor memories are volatile**, while all **magnetic memories are nonvolatile**, which means that they can store information without electrical power.

Random-Access Memory (RAM)

- Memory in which the actual physical location of a memory word **has no effect on how long it takes** to read from or write into that location.
- In other words, the **access time is the same** for any address in memory.
- Most **semiconductor memories are RAMs**.

Sequential-Access Memory (SAM)

- A type of memory in which the access time is not constant but varies **depending on the address location**.
- A particular stored word is found **by sequencing through all address** locations until the desired address is reached.
- This produces access times that are **much longer** than those of random-access memories.
- An example of a sequential-access memory device is **a magnetic tape backup**.

Read/Write Memory (RWM)

- Any memory that can be **read from or written into with equal ease**.
- Has both functionality of **reading and writing**.

Read-Only Memory (ROM)

- A broad class of semiconductor memories designed for applications where the **ratio of read operations to write operations is very high**.
- Technically, a ROM can be written into (programmed) only once, and this operation is normally **performed at the factory**.
- Thereafter, information can only be **read from the memory**.
- Other types of ROM are actually **read-mostly memories (RMM),** which can be written into more than once; but the write operation is more complicated than the read operation, and it is not performed very often.
- All ROM is **nonvolatile** and will store data when electrical power is removed.

Static Memory Devices

- Semiconductor memory devices in which the stored data will remain permanently **stored as long as power is applied**,
- without the need for **periodically rewriting the data** into memory.

Dynamic Memory Devices

- Semiconductor memory devices in which the stored data **will not remain permanently stored**, even with power applied, unless the data are **periodically rewritten** into memory.
- The latter operation is called a **refresh operation**.

Review Questions

- **Define the following terms**

  (a) Memory cell, (b) Memory word, (c) Address, (d) Byte, (e) Access time

- A certain memory has a capacity of $\boldsymbol{8K \times 16}$. How many bits are in each word? How many words are being stored? How many memory cells does this memory contain?
- Explain the difference between **the read (fetch) and write (store)** operations.
- **True or false:** A volatile memory will lose its stored data when electrical power is interrupted.
- Explain the difference between **SAM and RAM**.
- Explain the difference between **RWM and ROM**.
- **True or false:** A dynamic memory will hold its data as long as electrical power is applied.

Module-3

General Memory Operations

Sample Memory Illustration

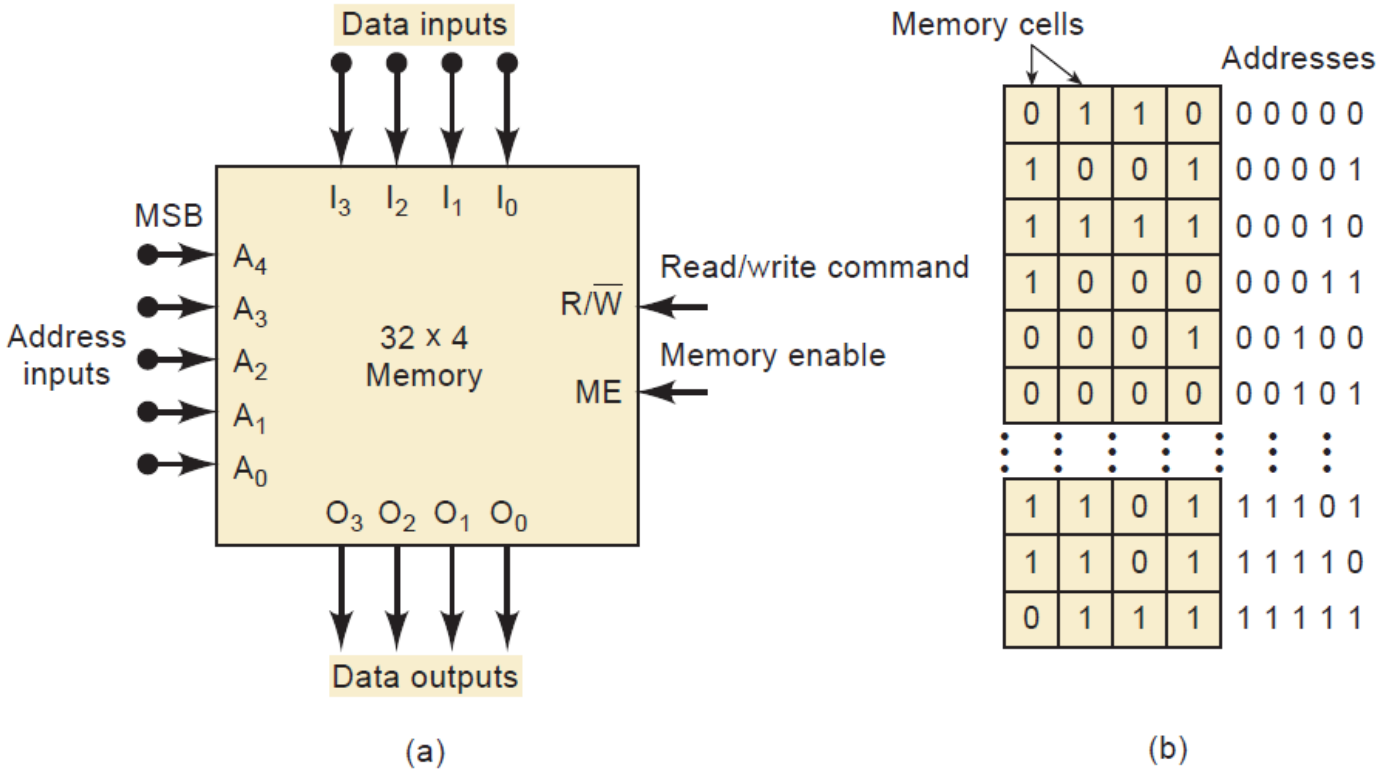

Fig 3.1: (a) Diagram of a 32 × 4 Memory, (b) virtual arrangement of memory cells into 32 four-bit words.

Simplified Reading-Writing Operations

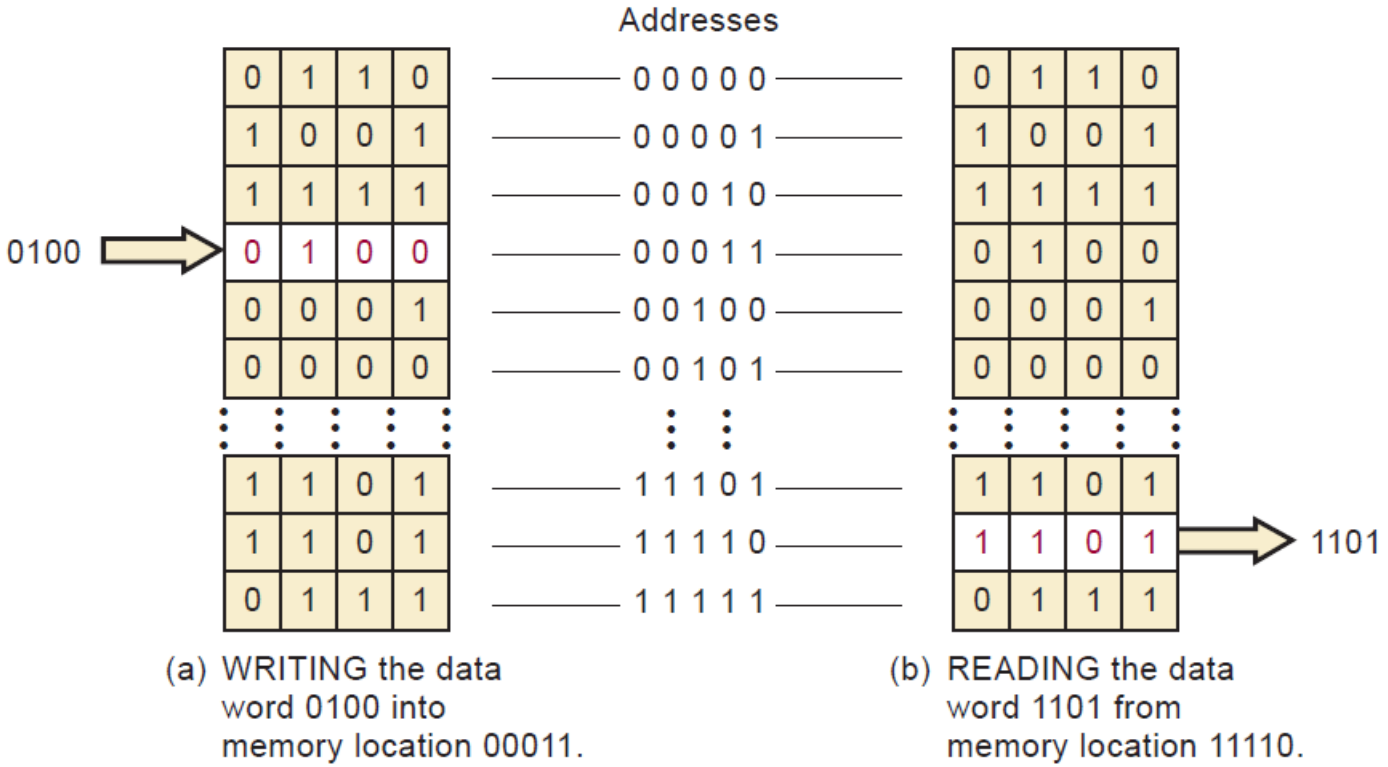

Fig 3.2: Simplified Reading-Writing Operations

Example 3.1

Question: A certain memory has a capacity of $\mathbf{4}\boldsymbol{K} \times \mathbf{8}$

(a) How many **data input and data output** lines does it have?

(b) How many **address lines** does it have?

(c) What is its **capacity in bytes**?

Solution:

(a) **Eight** of each because the word size is eight.

(b) The memory stores $4K = 4 \times 1024 = 4096$ words. Thus, there are 4096 memory addresses. Because $4096 = 2^{12}$, it requires a **12-bit address code** to specify one of 4096 addresses.

(c) A byte is eight bits. This memory has a capacity of **4096 bytes**.

Review Questions

- How many address inputs, data inputs, and data outputs are required for a **$16K \times 12$ memory**?
- What is the function of the **$R/\overline{W}$ input**?
- What is the function of the **MEMORY ENABLE input**?

Module-4

CPU-Memory Connections

Bus Connections

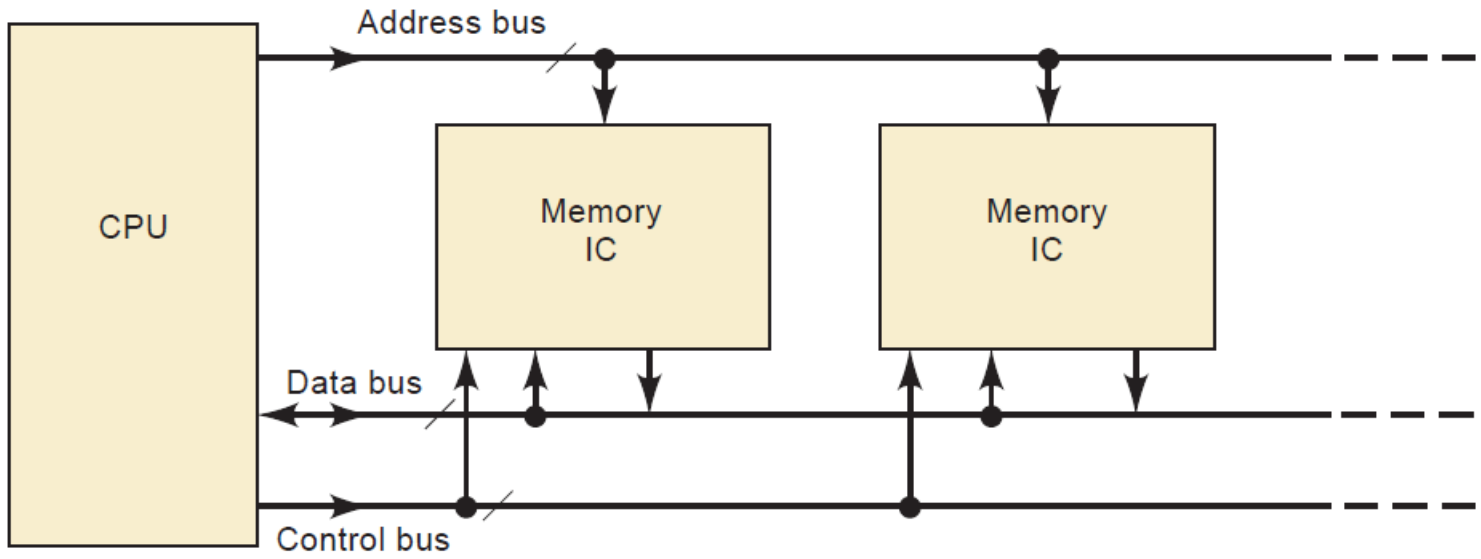

Fig 4.1: Three groups of lines (buses) connect the main memory ICs to the CPU.

Different Buses

- **Address Bus:** This unidirectional bus carries the binary address outputs from the CPU to the memory ICs to select one memory location.
- **Data Bus:** This bidirectional bus carries data between the CPU and the memory ICs.
- **Control Bus:** This bus carries control signals (such as the signal Read or Write signal) from the CPU to the memory ICs.

Review Questions

- Name the **three groups of lines** that connect the CPU and the internal memory.
- Outline the steps that take place when the **CPU reads from memory**.
- Outline the steps that occur when the **CPU writes to memory**.

References

Digital Systems by Tocci, Widmer, Moss

Chapter 12: Memory Devices (12.1-12.3)

Pages: 785-794

Thank You

Next Topics

Read-Only Memory