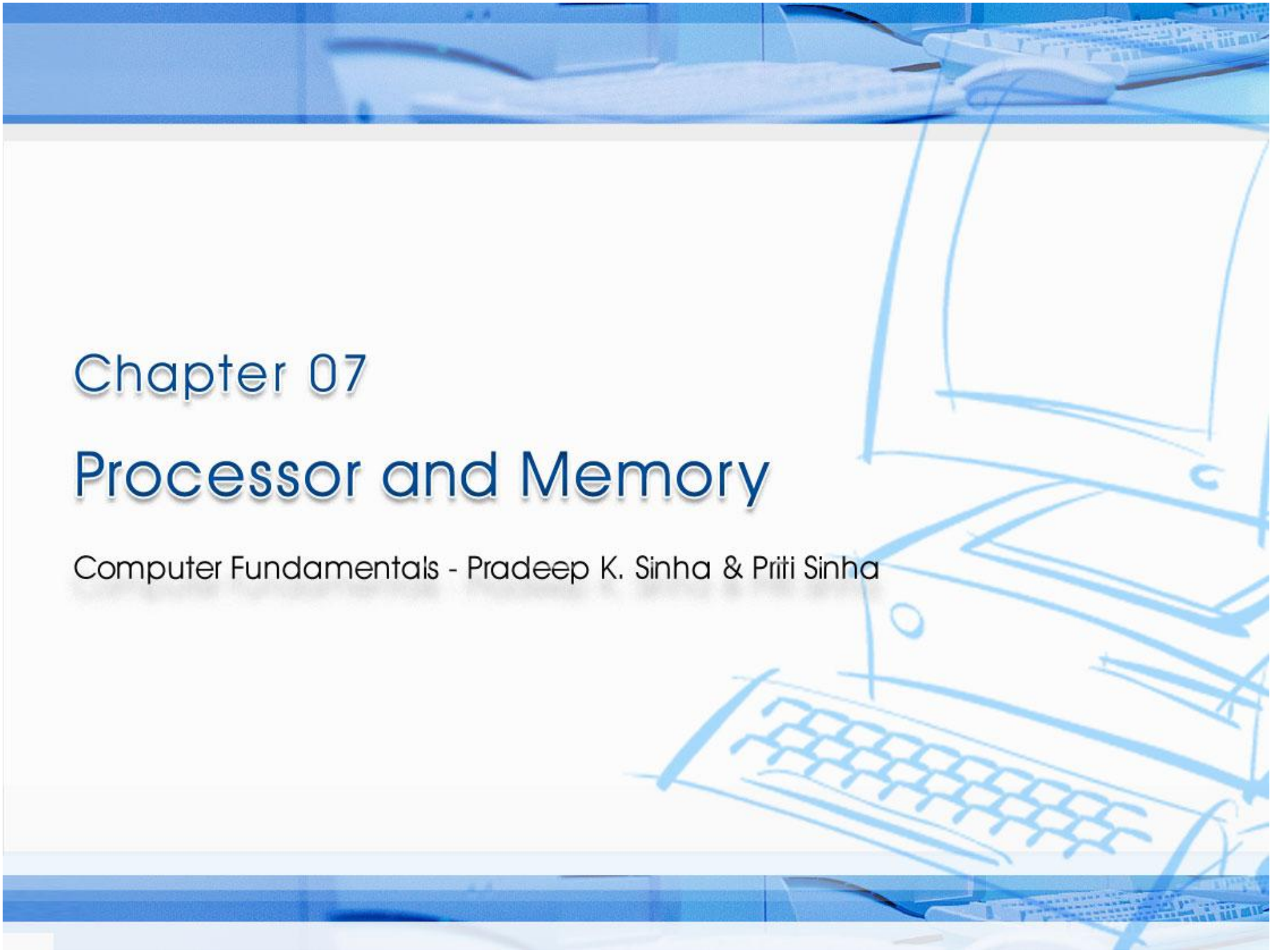


Chapter 07

Processor and Memory

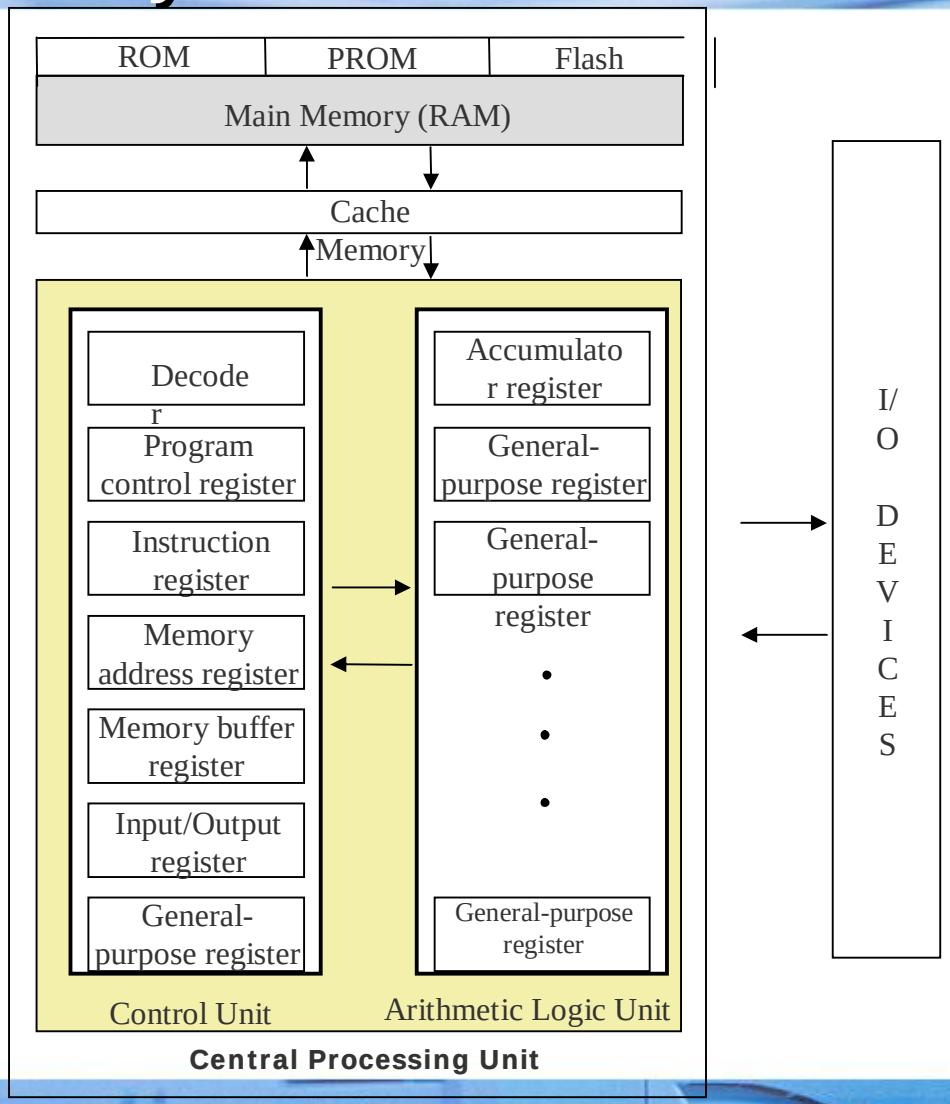
Computer Fundamentals - Pradeep K. Sinha & Priti Sinha

Learning Objectives

In this chapter you will learn about:

- Internal structure of processor
- Memory structure
- Determining the speed of a processor
- Different types of processors available
- Determining the capacity of a memory
- Different types of memory available
- Several other terms related to the processor and main memory of a computer system

Basic Processor & Memory Architecture of a Computer System



Central Processing Unit (CPU)

- The *brain* of a computer system
- Performs all major calculations and comparisons
- Activates and controls the operations of other units of a computer system
- Two basic components are
  - Control Unit (CU)
  - Arithmetic Logic Unit (ALU)
- No other single component of a computer determines its overall performance as much as the CPU

Control Unit (CU)

- One of the two basic components of CPU
- Acts as the central nervous system of a computer system
- Selects and interprets program instructions, and coordinates execution
- Has some special purpose registers and a decoder to perform these activities

Arithmetic Logic Unit (ALU)

- One of the two basic components of CPU.
- Actual execution of instructions takes place in ALU
- Has some special purpose registers
- Has necessary circuitry to carry out all the arithmetic and logic operations included in the CPU instruction set

Instruction Set

- CPU has built-in ability to execute a particular set of machine instructions, called its *instruction set*
- Most CPUs have 200 or more instructions (such as add, subtract, compare, etc.) in their instruction set
- CPUs made by different manufacturers have different instruction sets
- Manufacturers tend to group their CPUs into “families” having similar instruction sets
- New CPU whose instruction set includes instruction set of its predecessor CPU is said to be *backward compatible* with its predecessor

Registers

- Special memory units, called registers, are used to hold information on a temporary basis as the instructions are interpreted and executed by the CPU
- Registers are part of the CPU (not main memory) of a computer
- The length of a register, sometimes called its *word size*, equals the number of bits it can store
- With all other parameters being the same, a CPU with 32-bit registers can process data twice larger than one with 16-bit registers

Functions of Commonly Used Registers

Sr. No.	Name of Register	Function
1	Memory Address (MAR)	Holds address of the active memory location
2	Memory Buffer (MBR)	Holds contents of the accessed (read/written) memory word
3	Program Control (PC)	Holds address of the next instruction to be executed
4	Accumulator (A)	Holds data to be operated upon, intermediate results, and the results
5	Instruction (I)	Holds an instruction while it is being executed
6	Input/Output (I/O)	Used to communicate with the I/O devices

Processor Speed

- Computer has a built-in *system clock* that emits millions of regularly spaced electric pulses per second (known as *clock cycles)*
- It takes one cycle to perform a basic operation, such as moving a byte of data from one memory location to another
- Normally, several clock cycles are required to fetch, decode, and execute a single program instruction
- Hence, shorter the clock cycle, faster the processor
- Clock speed (number of clock cycles per second) is measured in Megahertz (10^6 cycles/sec) or Gigahertz (10^9 cycles/sec)

Types of Processor

Type of Architecture	Features	Usage
CISC (Complex Instruction Set Computer)	§ Large instruction set § Variable-length instructions § Variety of addressing modes § Complex & expensive to produce	Mostly used in personal computers
RISC (Reduced Instruction Set Computer)	§ Small instruction set § Fixed-length instructions § Reduced references to memory to retrieve operands	Mostly used in workstations

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Types of Processor

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Type of Architecture	Features	Usage
EPIC (Explicitly Parallel Instruction Computing)	§ Allows software to communicate explicitly to the processor when operations are parallel § Uses tighter coupling between the compiler and the processor § Enables compiler to extract maximum parallelism in the original code, and explicitly describe it to the processor	Mostly used in high-end servers and workstations

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Types of Processor

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Type of Architecture	Features	Usage
Multi-Core Processor	§ Processor chip has multiple cooler-running, more energy-efficient processing cores § Improve overall performance by handling more work in parallel § can share architectural components, such as memory elements and memory management	Mostly used in high-end servers and workstations

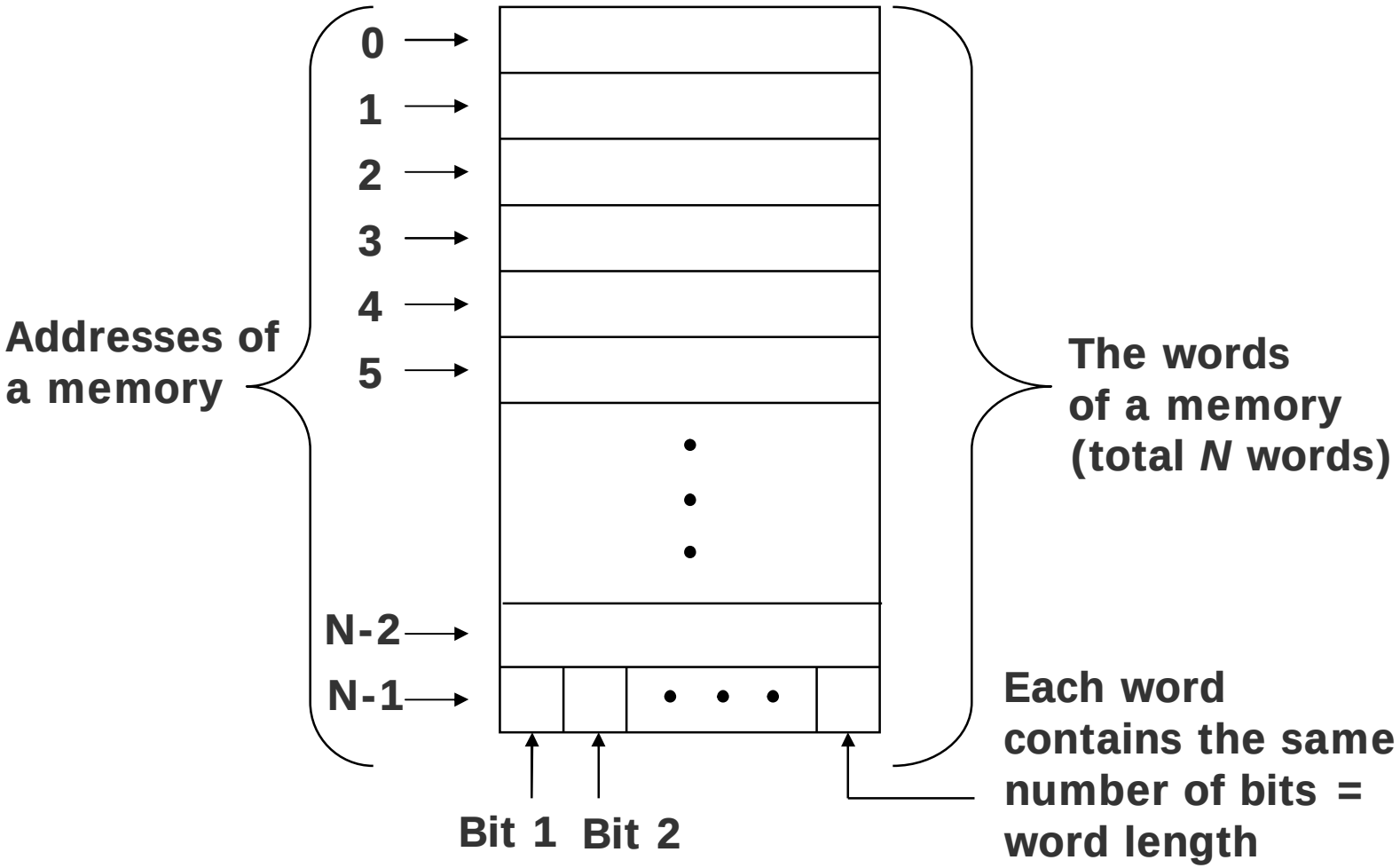
Main Memory

- Every computer has a temporary storage built into the computer hardware
- It stores instructions and data of a program mainly when the program is being executed by the CPU.
- This temporary storage is known as main memory, primary storage, or simply *memory*.
- Physically, it consists of some chips either on the motherboard or on a small circuit board attached to the motherboard of a computer
- It has random access property.
- It is volatile.

Storage Evaluation Criteria

Property	Desirable	Primary storage	Secondary storage
Storage capacity	Large storage capacity	Small	Large
Access Time	Fast access time	Fast	Slow
Cost per bit of storage	Lower cost per bit	High	Low
Volatility	Non-volatile	Volatile	Non-volatile
Access	Random access	Random access	Pseudo-random access or sequential access

Main Memory Organization



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Main Memory Organization

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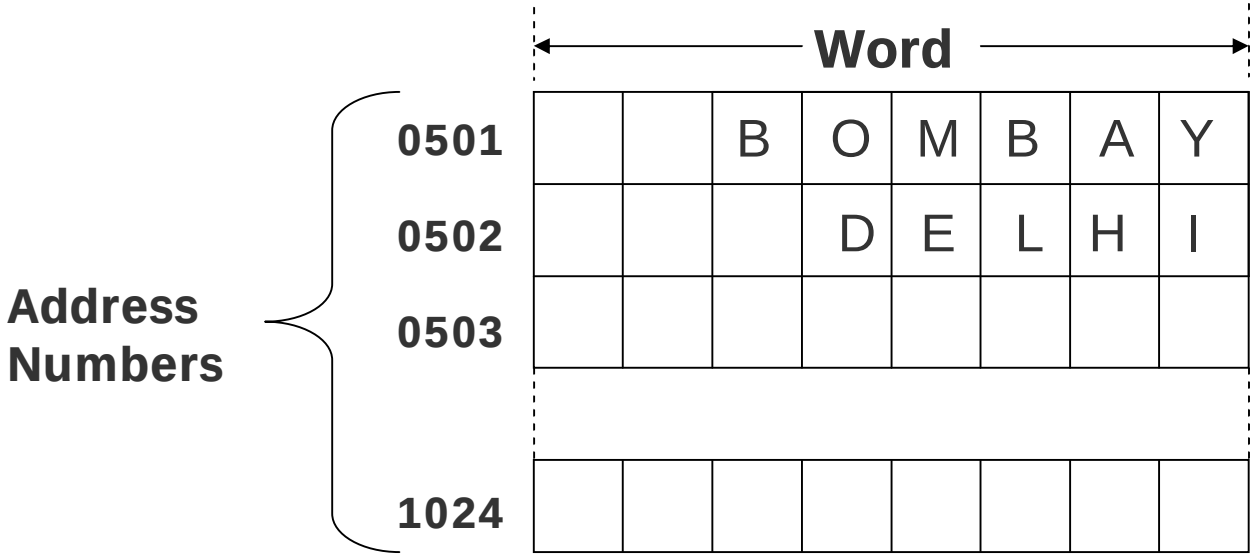
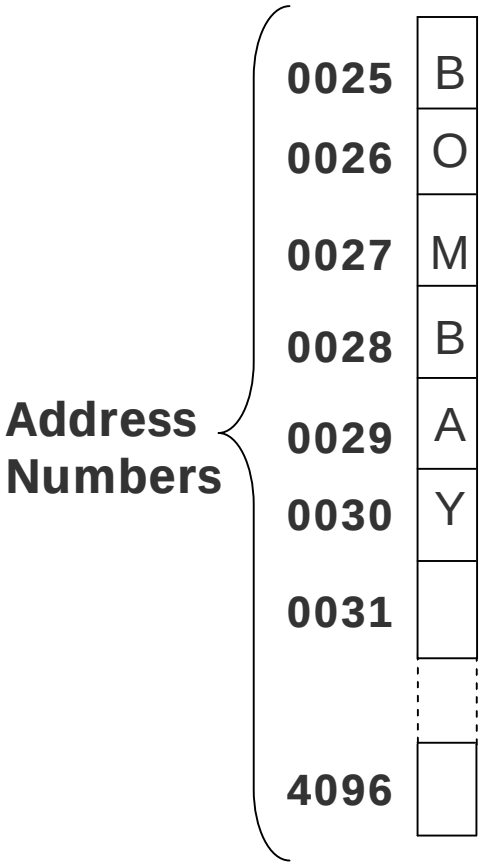
- Machines having smaller word-length are slower in operation than machines having larger word-length
- A *write* to a memory location is destructive to its previous contents
- A *read* from a memory location is non-destructive to its previous contents

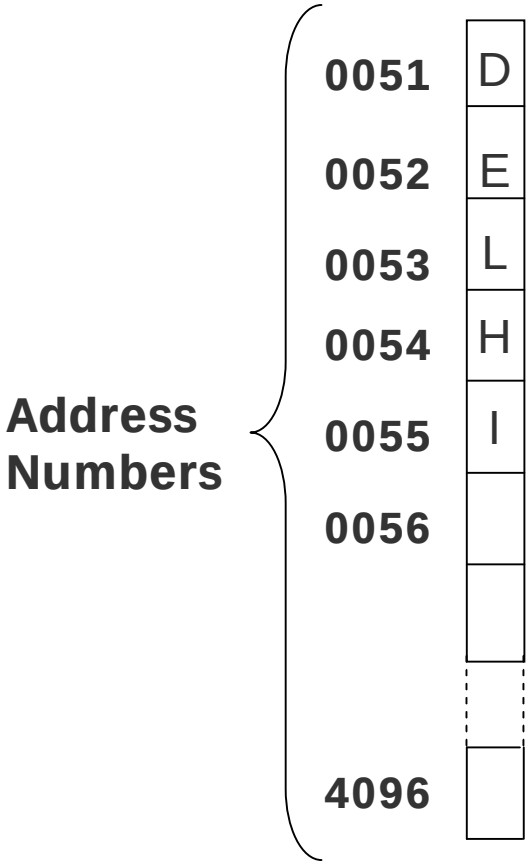
Fixed Word-length Memory



- Storage space is always allocated in multiples of word-length
- Faster in speed of calculation than variable word-length memory
- Normally used in large scientific computers for gaining speed of calculation

Variable Word-length Memory





- Each memory location can store only a single character
- Slower in speed of calculation than fixed world-length memory
- Used in small business computers for optimizing the use of storage space

Note: With memory becoming cheaper and larger day-by-day, most modern computers employ fixed-word-length memory organization

Memory Capacity

- Memory capacity of a computer is equal to the number of bytes that can be stored in its primary storage
- Its units are:

Kilobytes (KB)	:	1024 (2^{10}) bytes
Megabytes (MB)	:	1,048,576 (2^{20}) bytes
Gigabytes (GB)	:	1,073,741824 (2^{30}) bytes

Random Access Memory (RAM)

- Primary storage of a computer is often referred to as RAM because of its random access capability
- RAM chips are volatile memory
- A computer's motherboard is designed in a manner that the memory capacity can be enhanced by adding more memory chips
- The additional RAM chips, which plug into special sockets on the motherboard, are known as *single-in-line memory modules (SIMMs)*

Read Only Memory (ROM)

- ROM a non-volatile memory chip
- Data stored in a ROM can only be read and used – they cannot be changed
- ROMs are mainly used to store programs and data, which do not change and are frequently used. For example, system boot program

Types of ROMs

Type	Usage
Manufacturer-programmed ROM	Data is burnt by the manufacturer of the electronic equipment in which it is used.
User-programmed ROM or Programmable ROM (PROM)	The user can load and store "read-only" programs and data in it
Erasable PROM (EPROM)	The user can erase information stored in it and the chip can be reprogrammed to store new information

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Types of ROMs

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Type	Usage
Ultra Violet EPROM (UVEPROM)	A type of EPROM chip in which the stored information is erased by exposing the chip for some time to ultra-violet light
Electrically EPROM (EEPROM) or Flash memory	A type of EPROM chip in which the stored information is erased by using high voltage electric pulses

Cache Memory

- It is commonly used for minimizing the memory-processor speed mismatch.
- It is an extremely fast, small memory between CPU and main memory whose access time is closer to the processing speed of the CPU.
- It is used to temporarily store very active data and instructions during processing.

Cache is pronounced as "cash"

Key Words / Phrases

- Accumulator Register (AR)
- Address
- Arithmetic Logic Unit (ALU)
- Branch Instruction
- Cache Memory
- Central Processing Unit (CPU)
- CISC (Complex Instruction Set Computer) architecture
- Clock cycles
- Clock speed
- Control Unit
- Electrically EPROM (EEPROM)
- Erasable Programmable Read-Only Memory (EPROM)
- Explicitly Parallel Instruction Computing (EPIC)
- Fixed-word-length memory
- Flash Memory
- Input/Output Register (I/O)
- Instruction Register (I)
- Instruction set
- Kilobytes (KB)
- Main Memory
- Manufacturer-Programmed ROM
- Megabytes (MB)
- Memory
- Memory Address Register (MAR)
- Memory Buffer Register (MBR)
- Microprogram
- Multi-core processor
- Non-Volatile storage Processor
- Program Control Register (PC)
- Programmable Read-Only Memory (PROM)
- Random Access Memory (RAM)

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Key Words / Phrases

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- Read-Only Memory (ROM)
- Register
- RISC (Reduced Instruction Set Computer) architecture
- Single In-line Memory Module (SIMM)
- Ultra Violet EPROM (UVEPROM)
- Upward compatible
- User-Programmed ROM
- Variable-word-length memory
- Volatile Storage
- Word length
- Word size