Computer Organization

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Introduction to Computer

- **Definition**: Computer is an electronic data processing device which is used to read and write, compute and compare, store and process, large amount of data with high speed, accuracy and reliability.

Data Processing

- The activity of processing data using a computer is called *data processing*
- *Data: raw material used as input*
- *Information:* processed data obtained as output.

Need

- Education
- Commercial Offices and Banks
- Scientific Researches
- Military Services
- Engineering and Production
- Publication
- Hospitals

Google India

Characteristics

- High Speed: Computer can perform data processing jobs very fast, usually measured in **microseconds (10^{-6}), nanoseconds (10^{-9}), and picoseconds (10^{-12})**
- Accuracy: Accuracy of a computer is consistently high and the degree of its accuracy depends upon its design. Computer errors caused due to incorrect input data or unreliable programs are often referred to as *Garbage- In-Garbage-Out (GIGO)*

Characteristics

- Storage Capability: Computer can store and recall any amount of information because of its secondary storage capability. It forgets or looses certain information only when it is asked to do so.
- Diligence: Computer is free from monotony, tiredness, and lack of concentration. It can continuously work for hours without creating any error and without grumbling
- Versatility: Computer is capable of performing almost any task, if the task can be reduced to a finite series of logical steps

Characteristics

- Reliability
- Automation
- Reduction in Paper Work
- Reduction in Cost

Disadvantages

- No I.Q. : A computer does only what it is programmed to do. It cannot take its own *decision in this regard*
- No Feeling : Computers are devoid of emotions. Their judgement is based on the instructions given to them in the form of programs that are written by us (human beings)
- Dependency
- Environment

Evolution of Computers

- Blaise Pascal invented the first *mechanical adding machine in 1642*
- Baron Gottfried Wilhelm von Leibniz invented the first *calculator for multiplication in 1671*
- *Keyboard machines originated in the United States* around 1880
- Around 1880, Herman Hollerith came up with the concept of *punched cards that were extensively used as input* media until late 1970s

Evolution of Computer

- Charles Babbage:
  - father of modern digital computers
  - He designed “Difference Engine” in 1822
  - He designed a *fully automatic analytical engine in* 1842 for performing basic arithmetic functions
  - His efforts established a number of principles that are fundamental to the design of any digital computer

Evolution of Computer

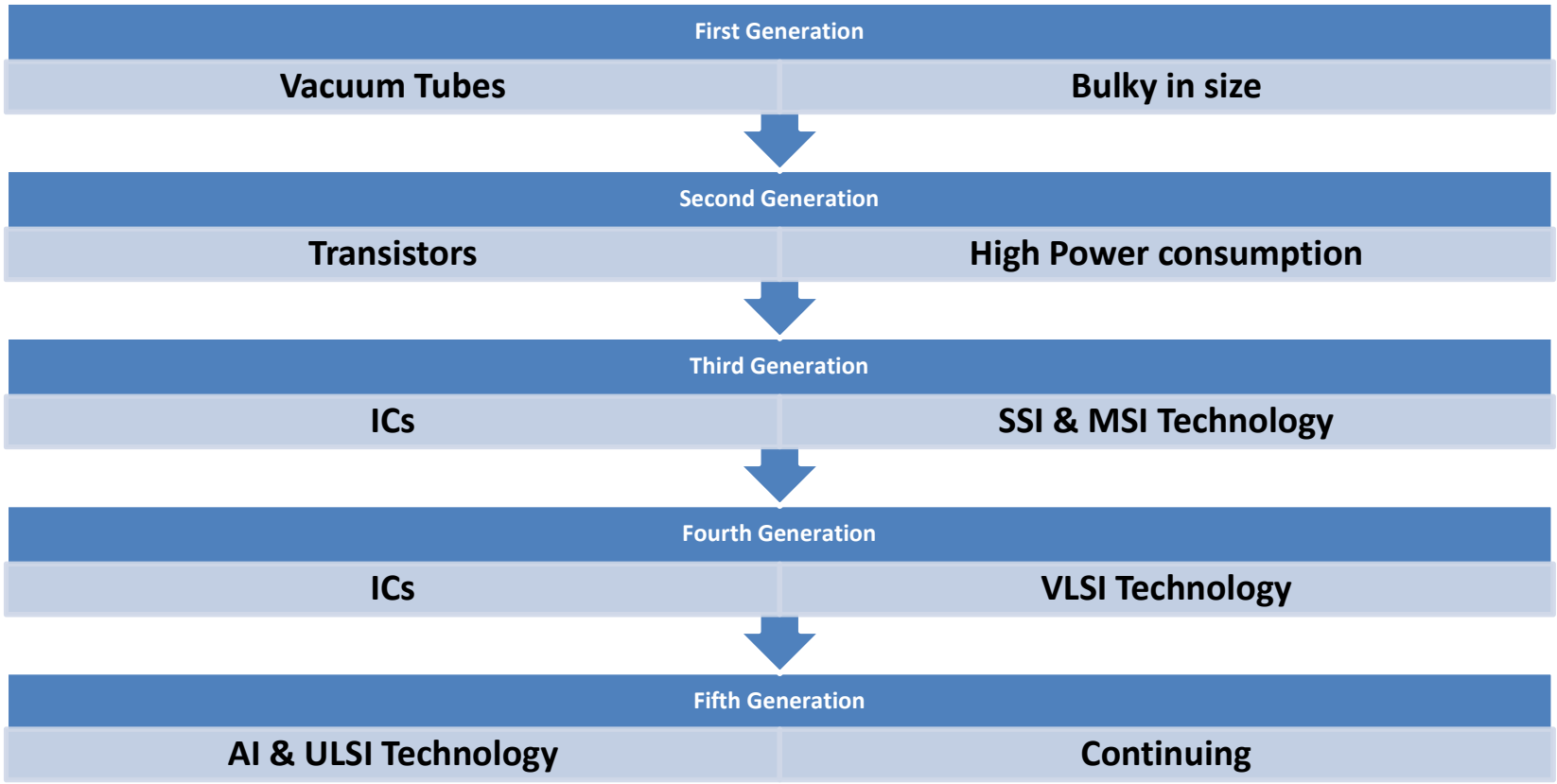
- COBOL: The first known computer language (1953)
- Jack Kilby and Robert Noyce: IC (1958), Noble Prize in Physics (2000)

Some well known early computers

- The Mark I Computer (1937-44)
- The Atanasoff-Berry Computer (1939-42)
- The ENIAC (1943-46) : (Electronic Numerical Integrator and Calculator): Grand father of digital computers
- The EDVAC (1946-52)
- The EDSAC (1947-49)
- Manchester Mark I (1948)
- The UNIVAC I (1951) : The first commercial computer for business and govt.

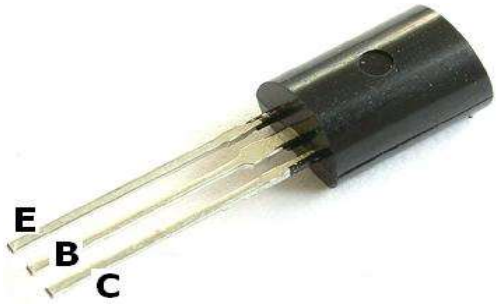
Generation of Computers

- The history of computer development is often referred to in reference to the different generations of computers.
- Each generation of computer is characterized by a major technological development that fundamentally changed the way computers operate.

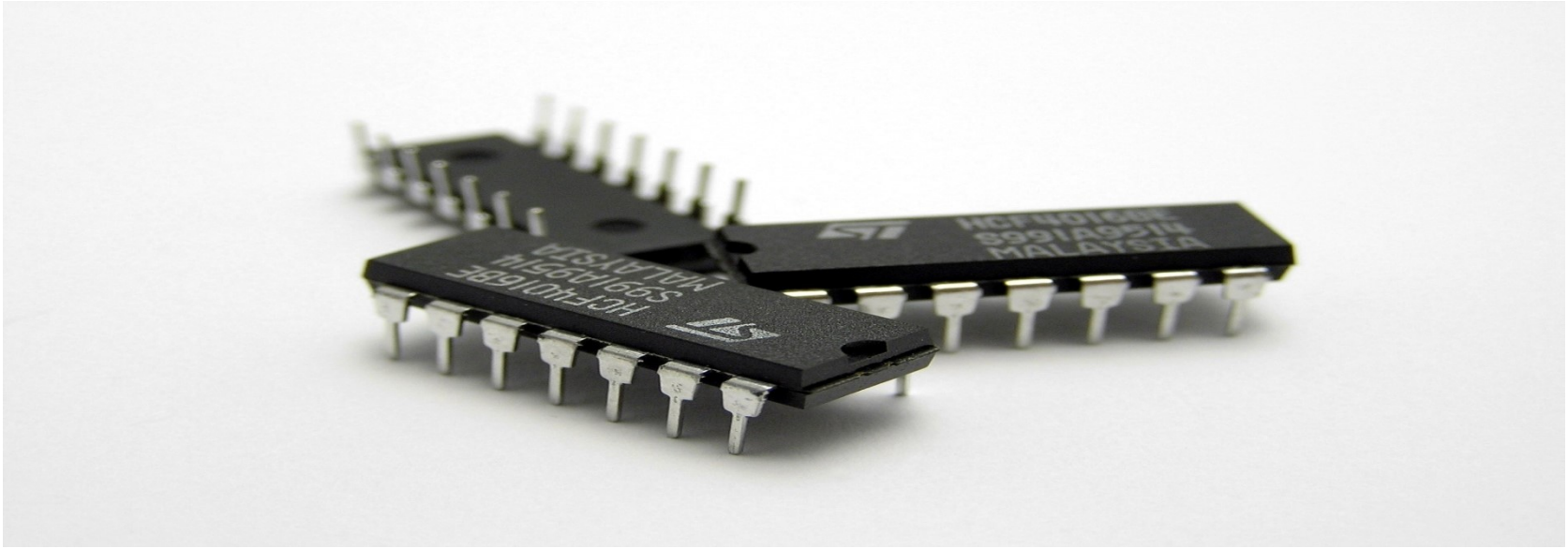


Components Used

(Vacuum tube)



(Transistor)



(ICs)

Computer Generations

Generation (Period)	Key hardware technologies	Key software technologies	Key characteristics	Some representative systems
First (1942-1955)	▪ Vacuum tubes ▪ Electromagnetic relay memory ▪ Punched cards secondary storage	▪ Machine and assembly languages ▪ Stored program concept ▪ Mostly scientific applications	▪ Bulky in size ▪ Highly unreliable ▪ Limited commercial use and costly ▪ Difficult commercial production ▪ Difficult to use	▪ ENIAC ▪ EDVAC ▪ EDSAC ▪ UNIVAC I
Second (1955-1964)	▪ Transistors ▪ Magnetic cores memory ▪ Magnetic tapes	▪ Batch operating system ▪ High-level programming languages	▪ Faster, smaller, more reliable and easier to program than previous generation systems ▪ Commercial production	

Computer Generations

Generation (Period)	Key hardware technologies	Key software technologies	Key characteristics	Some rep. systems
Third (1964-1975)	▪ ICs with SSI and MSI technologies ▪ Larger magnetic cores memory ▪ Larger capacity disks and magnetic tapes secondary storage ▪ Minicomputers;	▪ Timesharing operating system ▪ Standardization of high-level programming languages ▪ Unbundling of software from hardware	▪ Faster, smaller, more reliable, easier and cheaper to produce ▪ Commercially, easier to use, and easier to upgrade than previous generation systems ▪ Scientific, commercia and interactive on-line applications	▪ IBM 360/370 ▪ PDP-8 ▪ PDP-11 ▪ CDC 6600

Computer Generations

Generation (Period)	Key hardware Technologies	Key software technologies	Key characteristics	Some rep. systems
Fourth (1975-1989)	▪ ICs with VLSI technology ▪ Microprocessors; semiconductor memory ▪ Larger capacity hard disks as in-built secondary storage ▪ Magnetic tapes and floppy disks as portable storage media ▪ Personal computers ▪ Supercomputers based on parallel vector processing and symmetric	▪ Operating systems for PCs with GUI and multiple windows on a single terminal screen ▪ Multiprocessing OS with concurrent programming languages ▪ UNIX operating system with C programming language ▪ Object-oriented design and programming ▪ PC, Network-based, and supercomputing	▪ Small, affordable, reliable, and easy to use PCs ▪ More powerful and reliable mainframe systems and supercomputer ▪ Totally gene purpose machi ▪ Easier to prod commercially ▪ Easier to upgra ▪ Rapid softw development	▪ IBM PC and its clones ▪ Apple II ▪ TRS-80 ▪ VAX 9000 ▪ CRAY-1

Computer Generations

Generation (Period)	Key hardware technologies	Key software technologies	Key characteristics	Some rep. systems
Fifth (1989-Present)	▪ ICs with ULSI technology ▪ Larger capacity main memory, hard disks with RAID support ▪ Optical disks as portable read-only storage media ▪ Notebooks, powerful desktop PCs and workstations ▪ Powerful servers, supercomputers	▪ Micro-kernel based, multithreading, distributed OS ▪ Parallel programming libraries like MPI & PVM ▪ JAVA ▪ World Wide Web ▪ Multimedia, Internet applications ▪ More complex supercomputing applications	▪ Portable computers ▪ Powerful, cheaper, reliable, and easier to use desktop machines ▪ Powerful supercomputers ▪ High uptime due to hot-pluggable components ▪ Totally general purpose machines ▪ Easier to produce commercially, easier to upgrade	▪ IBM notebooks ▪ Pentium PCs ▪ SUN Workstations ▪ IBM SP/2 ▪ SGI Origin 2000

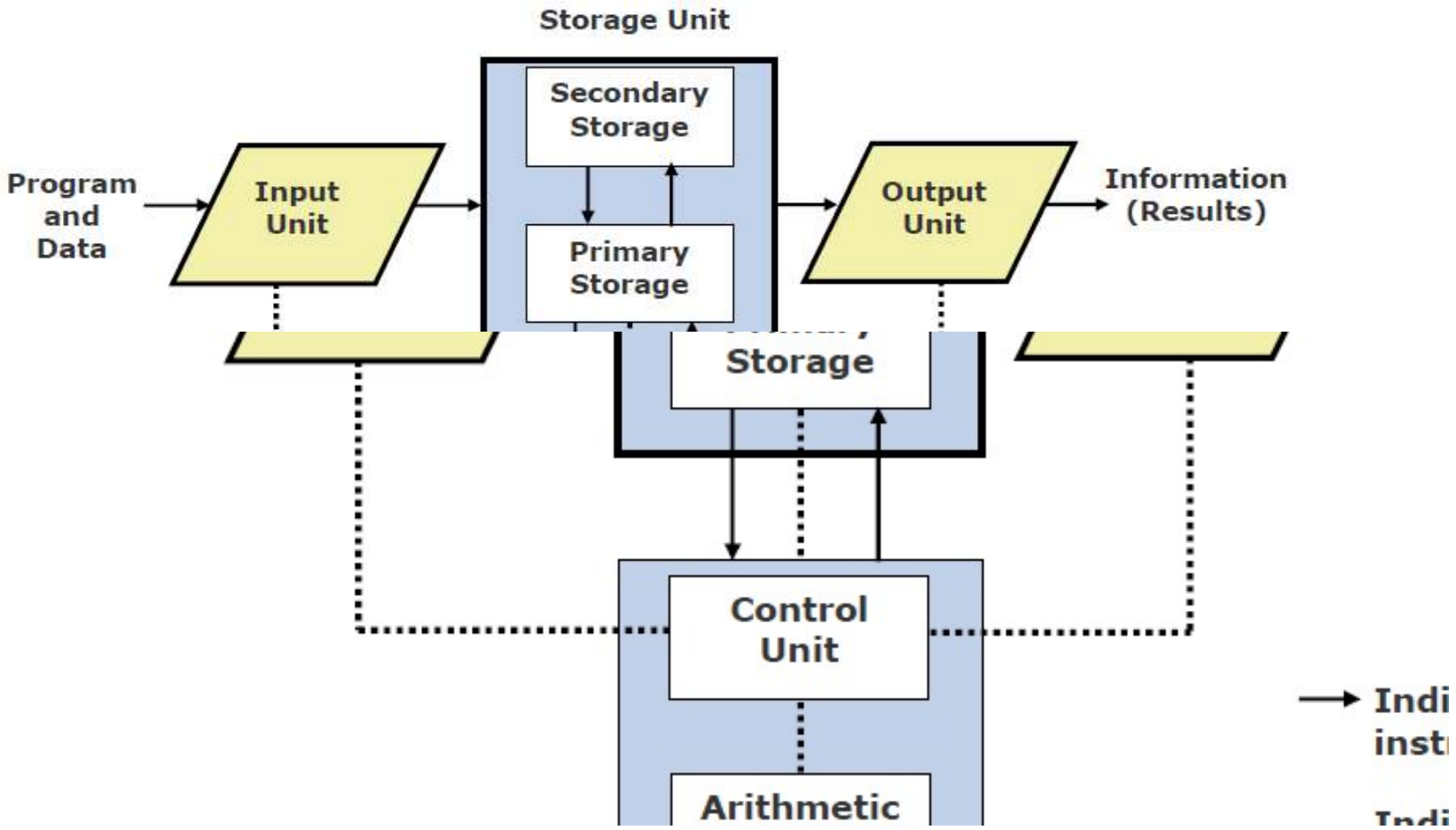
Basic Operations of a Computer

- **Inputting. The process of entering data and instructions** into the computer system
- **Storing. Saving data and instructions to make them** readily available for initial or additional processing whenever required
- **Processing. Performing arithmetic operations (add,** subtract, multiply, divide, etc.) or logical operations (comparisons like equal to, less than, greater than, etc.) on data to convert them into useful information

Basic Operations of a Computer

- **Outputting. The process of producing useful information** or results for the user such as a printed report or visual display
- **Controlling. Directing the manner and sequence in which** all of the above operations are performed

Basic Organisation of Computer (Functional Block diagram)



Input Unit

- Helps to accept data & read instructions from outside world.
- Input interface converts the user language to computer understandable form.

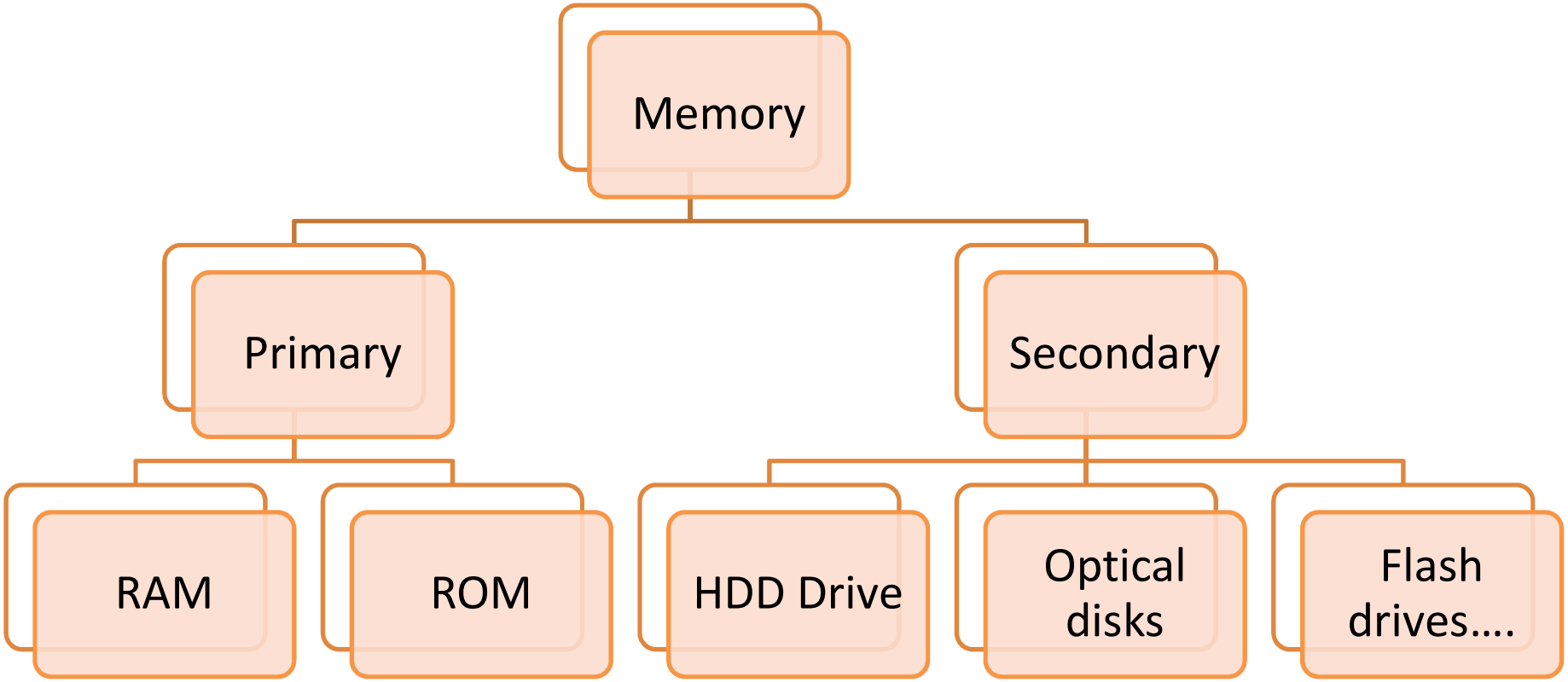
Output Unit

- Helps to accept the processed data from the system.
- Output interface converts the machine language to user understandable form.

Storage Unit

- **The storage unit of a computer system holds (or stores) the following**
  - Data and instructions required for processing (received from input devices)
  - Intermediate results of processing
  - Final results of processing, before they are released to an output device

Classification of Memory



Two types of Memory

- Primary
  - Used to hold running program instructions
  - Used to hold data, intermediate results, and
  - results of ongoing processing of job(s)
  - Fast in operation
  - Small Capacity
  - Expensive
  - Volatile (looses data on power dissipation)
- Secondary
  - Used to hold stored program instructions
  - Used to hold data and information of stored jobs
  - Slower than primary storage
  - Large Capacity
  - Lot cheaper that primary storage
  - Retains data even without power

Primary Memory

- RAM (Random Access Memory)
  - Volatile Memory
  - Contents will be erased when the power is OFF.
- ROM (Read Only Memory)
  - Not a Volatile Memory
  - The System start-up programs and System date and time information will be stored in ROM.

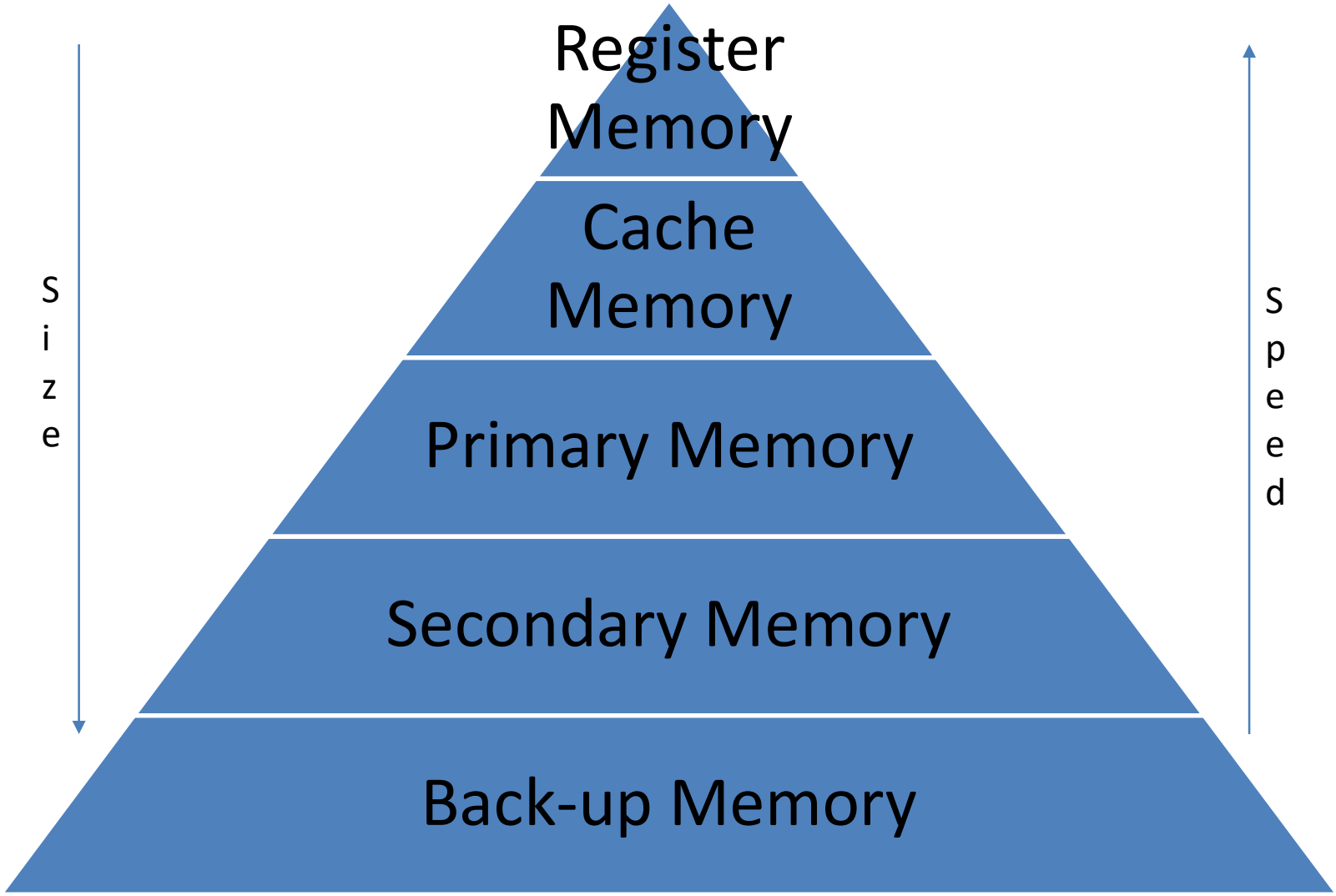
Secondary Memory

- Permanent Memory
- Contents will remain constant even though the power is OFF.

Some other terms used in Memory

- **Virtual Memory** : A part of Secondary storage used as temporary storage, when the main memory is not sufficient enough to hold the current program in execution.
- **Buffer**: It is the temporary memory in the input or output device which holds small amount of data (some KB) for small time interval.
- **Cache**: It is the memory available in CPU(processor) to load the program and execute in a faster manner.

Memory Hierarchy



Central Processing Unit

- ALU + CU = CPU
- It is the brain of a computer system.
- Performs all major calculations and comparisons
- It is responsible for activating and controlling the operations of all other units of a computer system.
- No other single component of a computer determines
- its overall performance as much as the CPU
- ALU: Arithmetic Logic Unit of a computer system is the place where the actual executions of instructions takes place during processing operation.
- CU: Control Unit of a computer system manages and coordinates the operations of all other components of the computer system.

Control Unit

- 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

- 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

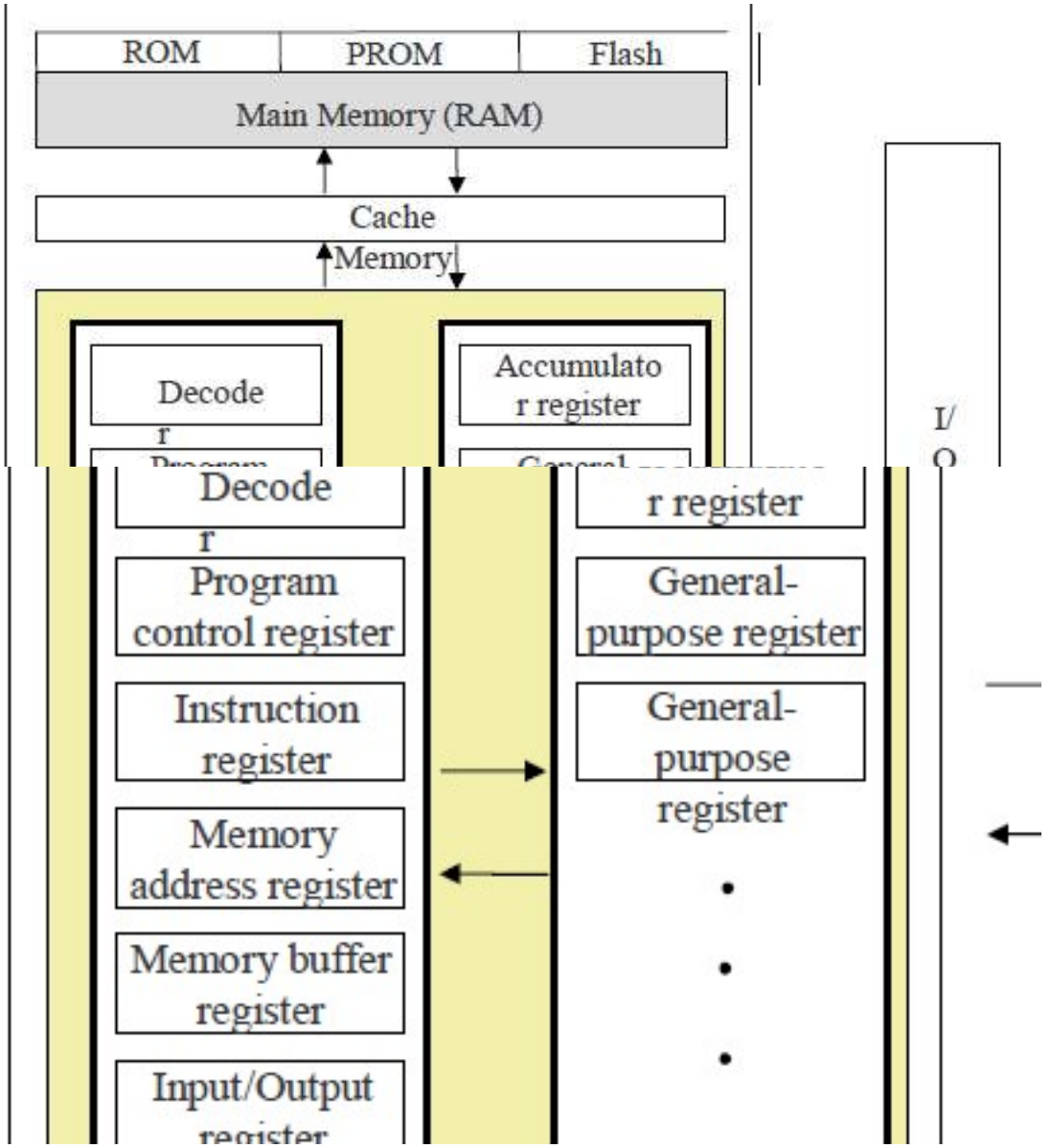
Instruction set

- 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

Basic Processor Memory Architecture



Functions of Commonly Used Registers

- Memory Address (MAR): Holds address of the active memory location
- Memory Buffer (MBR): Holds contents of the accessed (read/written) memory word
- Program Control (PC): Holds address of the next instruction to be executed
- Accumulator (A): Holds data to be operated upon, intermediate results, and the results
- Instruction (I): Holds an instruction while it is being executed
- 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 (106 cycles/sec) or Gigahertz (109 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

Types of Processor

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
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

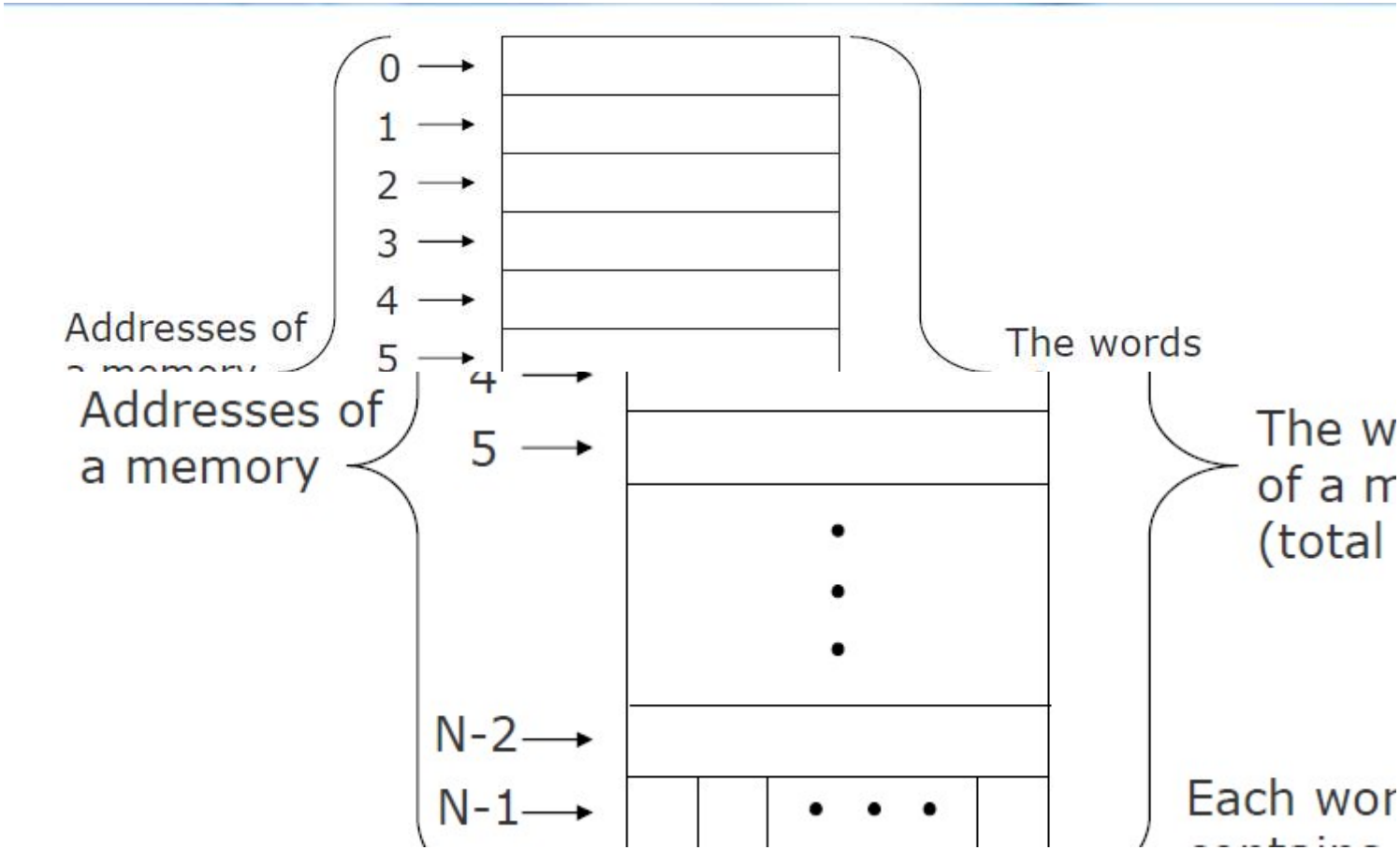
Main Memory

- 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
Access Time	Fast access time	Fast	
Cost per bit of storage	Lower cost per bit	High	
Volatility	Non-volatile	Volatile	
		Random	

Main Memory Organization

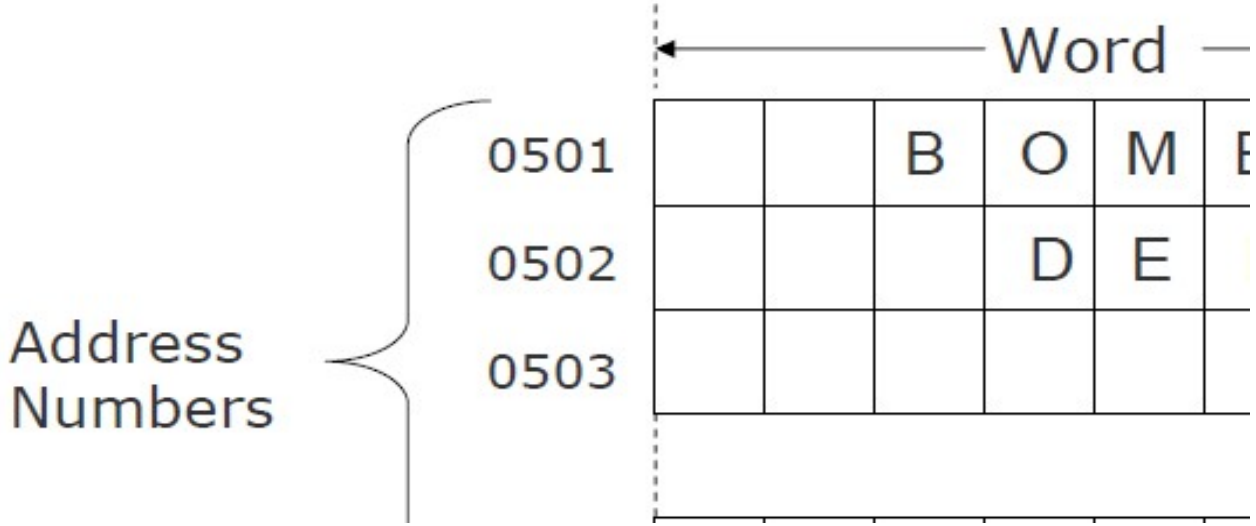


Main Memory Organization

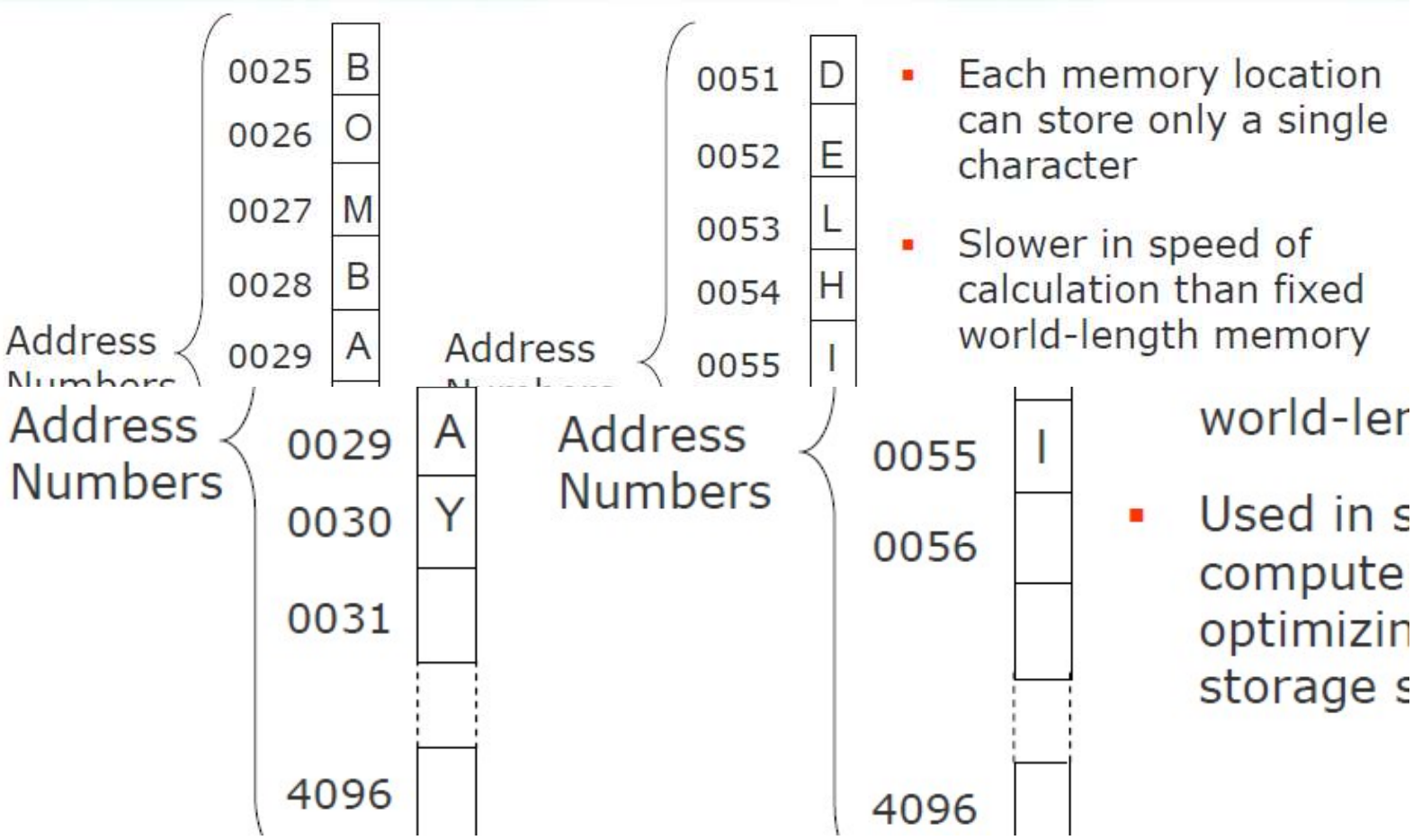
- Machines having smaller word-length are slower in operation than machines having larger word-length
- A *write to a memory location is destructive to its previous* contents
- A *read from a memory location is non-destructive to its* previous contents

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



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
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
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”*