

Lecture 1

Introduction to Computer Architecture

Course description

- Explores architectural characteristics of electronic computer systems
 - Internal organization, instruction sets, assemblers, datapaths, pipelining, caching, memory management, I/O and bus subsystems, multiprocessing, etc.

Basically, you'll learn ...

- How programs written in high-level languages (e.g. C, C++, Java) translated to a machine language understandable to the hardware. How the hardware execute the resulting program
- What's the interface b/w software & hardware and their interactions. How does software instruct hardware to perform specified functions

- Register-transfer level description of computer execution.
- Functional organization and elements of computer architecture.
- Memory hierarchy organization.
Interfacing and communication between processor and peripheral devices.

Introduction to Computers

What is Computer Architecture

- Just like an architect designs **buildings**, a computer architect designs computers.
- Computer architecture is the study of how computers are designed and why they are designed that way.
- We will also study the effect of different designs on the computer performance.



USER



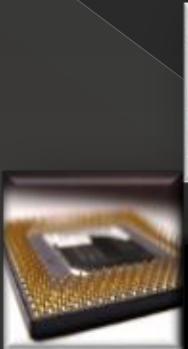
APPLICATION



OS



COMPUTER



INTEGRATED CIRCUITS



DIGITAL ELECTRONICS

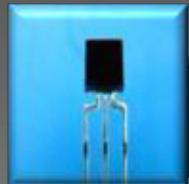


LOGIC GATE



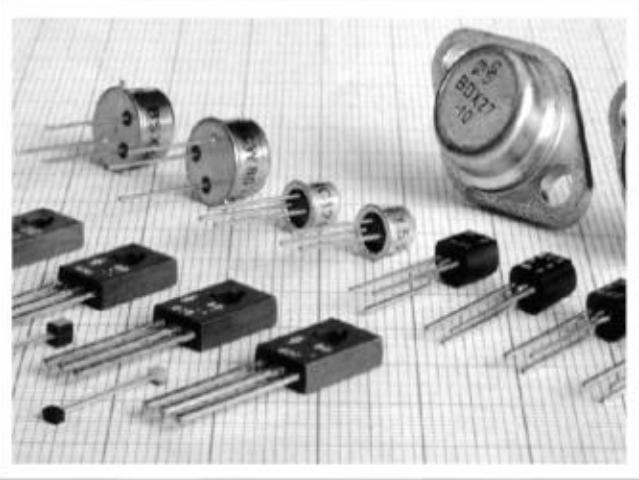
TRANSISTOR

How a computer works...



TRANSISTOR

Transistor

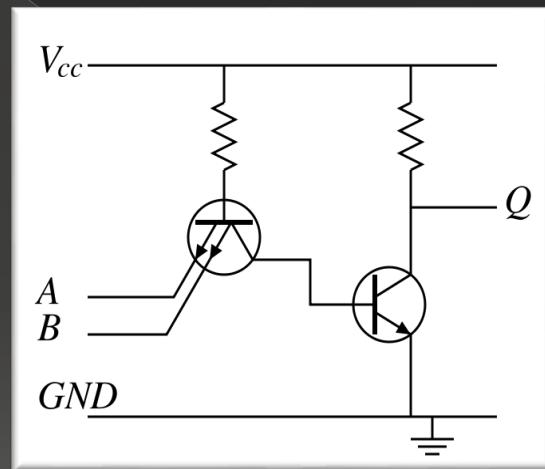


- A transistor is a semiconductor device, commonly used as an electrically controlled switch.
- The transistor is the fundamental building block of the circuitry that controls the operation of computers, cellular phones, and other electronics.

Transistor



- In analog circuits, transistors are used in amplifiers
 - direct current amplifiers, audio amplifiers, radio frequency amplifiers, and linear regulated power supplies.

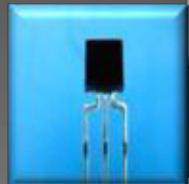


- In digital circuits, transistors function as electronic switches
 - Digital circuits include logic gates, random access memory (RAM), microprocessors, and digital signal processors (DSPs).

How a computer works...

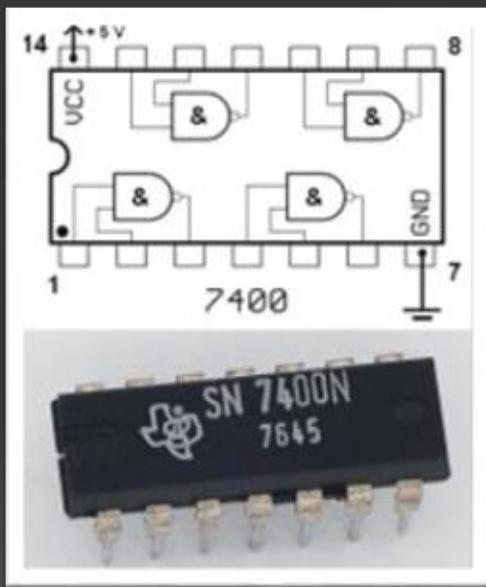
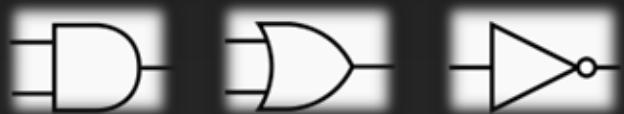


LOGIC GATE



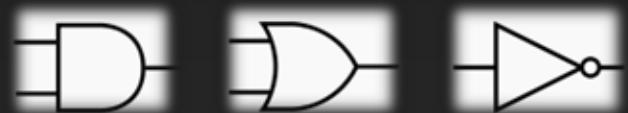
TRANSISTOR

Logic Gate



- A logic gate performs a logical operation on one or more logic inputs and produces a single logic output.
- The logic normally performed is **Boolean logic**.
- It is most commonly found in digital circuits.
- Logic gates are primarily implemented electronically using transistors.

Logic Gate



- The simplest form of electronic logic is diode logic.
- To build a complete logic system, transistors can be used.
- The simplest family of logic gates using bipolar transistors is called resistor-transistor logic, or RTL.



AND gate

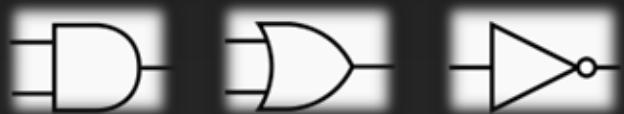


OR gate

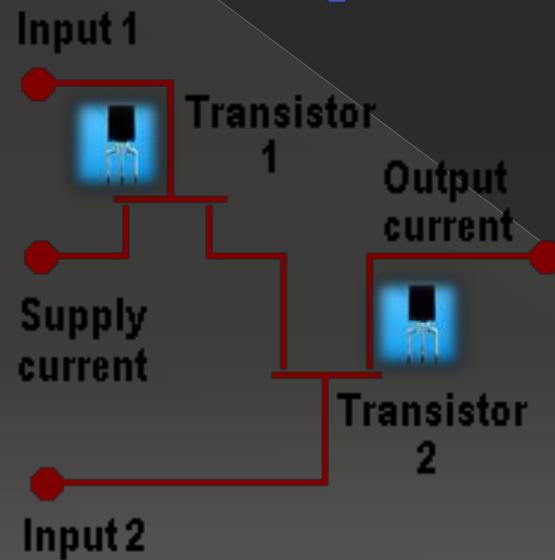


NOT gate

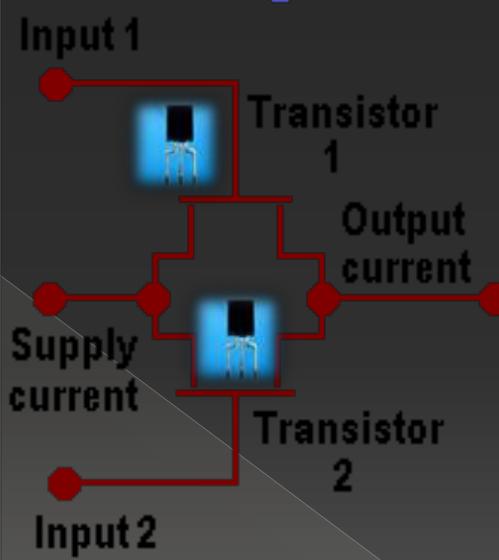
Logic Gate



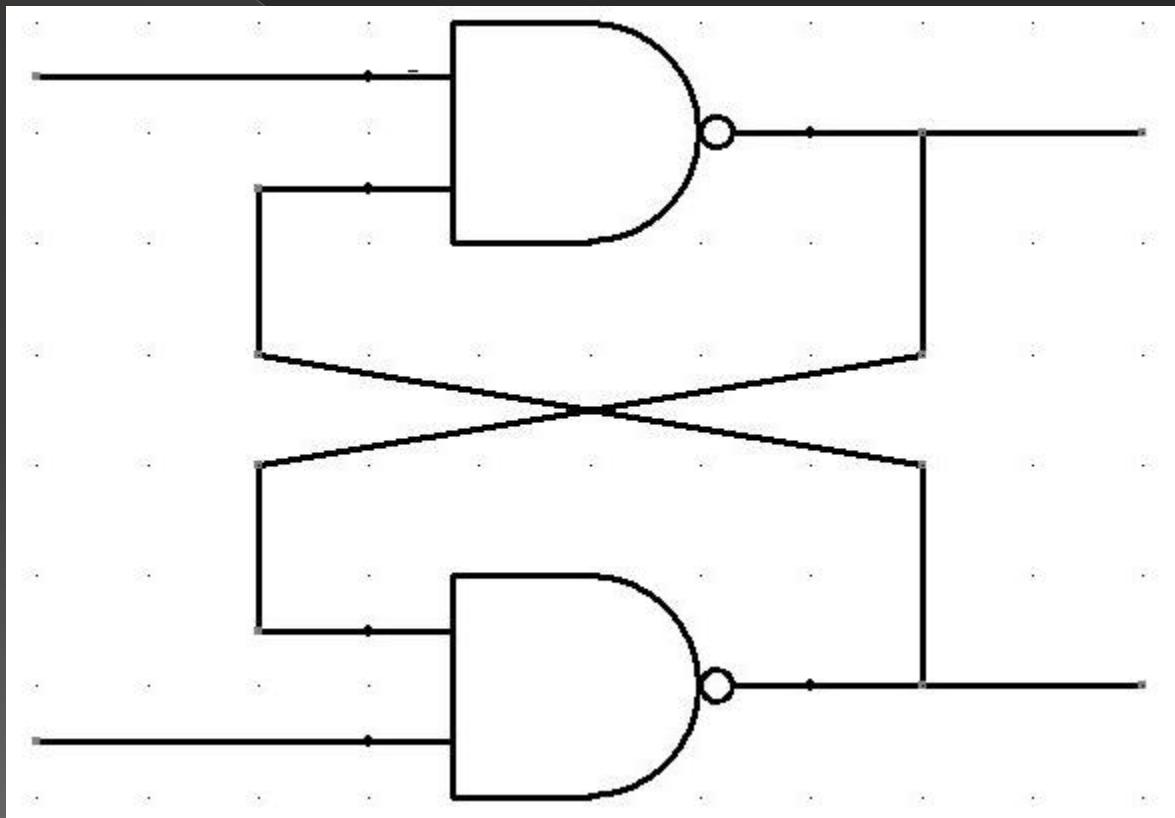
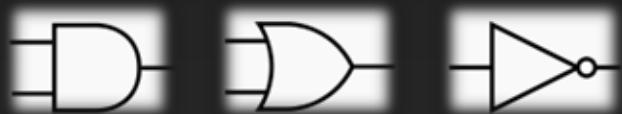
AND gate



OR gate



Logic Gate



How a computer works...



DIGITAL ELECTRONICS

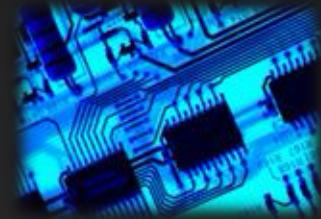


LOGIC GATE

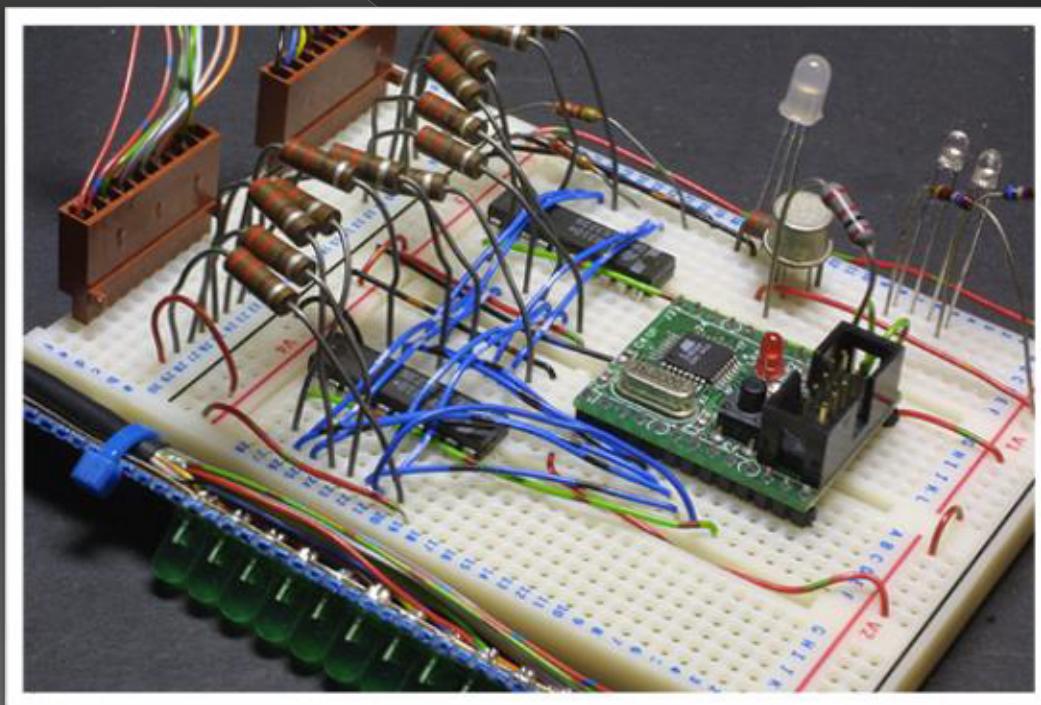


TRANSISTOR

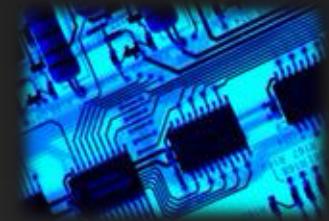
Digital Electronics



- Digital electronics are those electronics systems that use a digital signal **instead** of an analog signal.

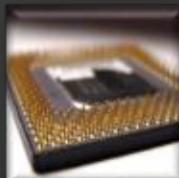


Digital Electronics



- Digital electronics are the most common representation of Boolean algebra.
- They are the basis of all digital circuits for computers, mobile phones, and numerous other consumer products.
- The most fundamental unit of digital electronics is the logic gate.
- By combining numerous logic gates, more complex systems can be created. The complex system of digital electronics is collectively referred to as a digital circuit.

How a computer works...



INTEGRATED CIRCUITS



DIGITAL ELECTRONICS



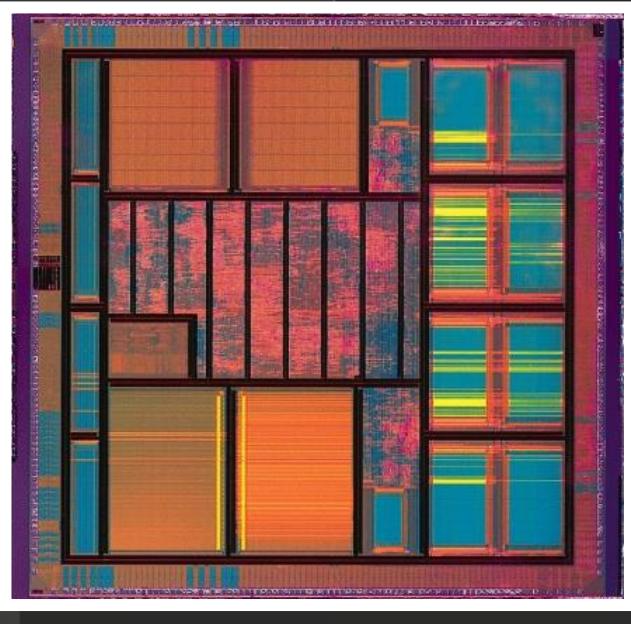
LOGIC GATE



TRANSISTOR

IC

Integrated Circuits



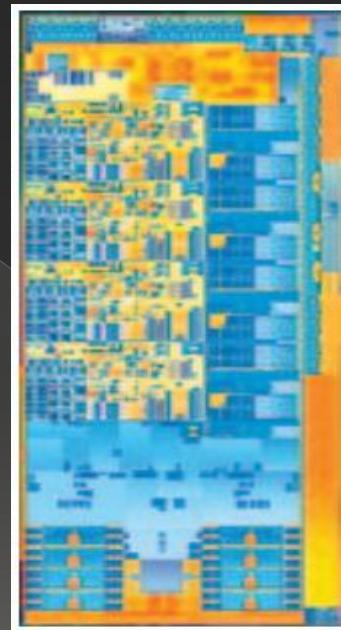
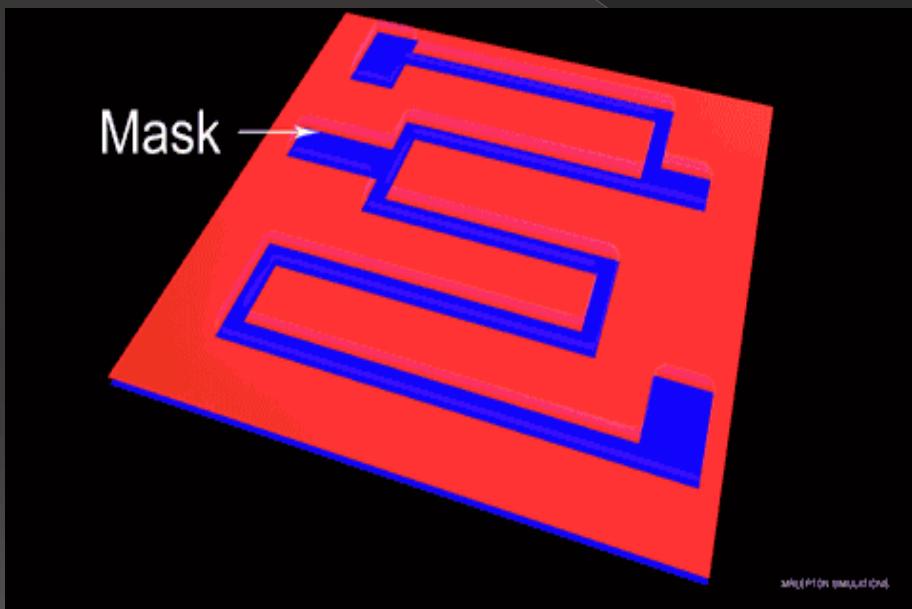
- IC is the integration of large numbers of tiny transistors into a small chip
- It was an enormous improvement over the manual assembly of circuits using discrete electronic components.
- The integrated circuit's mass production capability, reliability, and building-block approach to circuit design.
- They are ensured the rapid adoption of standardized ICs in place of designs using discrete transistors.



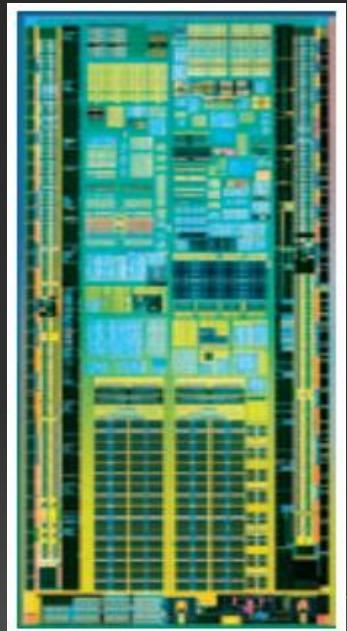
Discrete electronic components

Etching silicon wafer

Etching is used in micro-fabrication to chemically remove layers from the surface of a wafer during chip manufacturing.

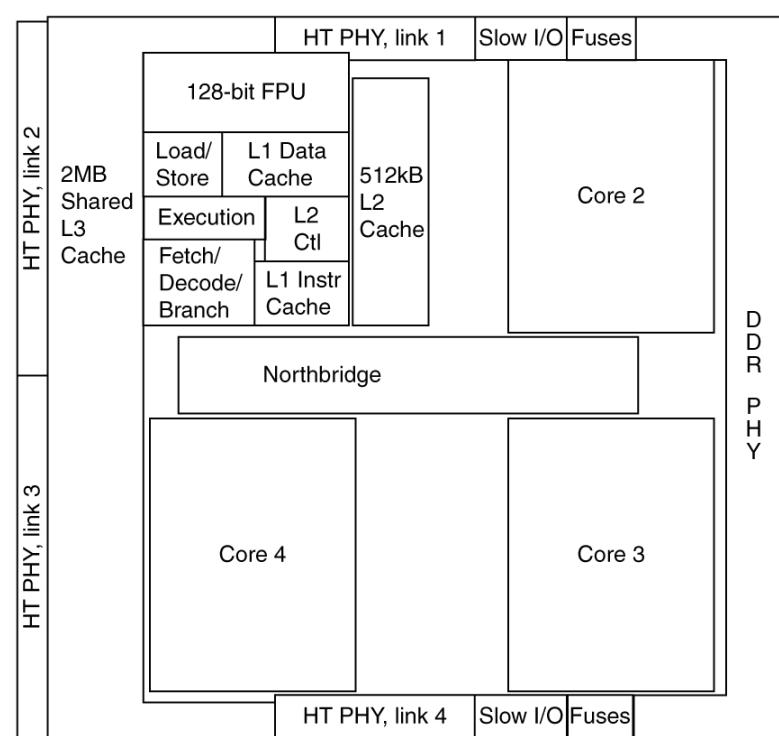
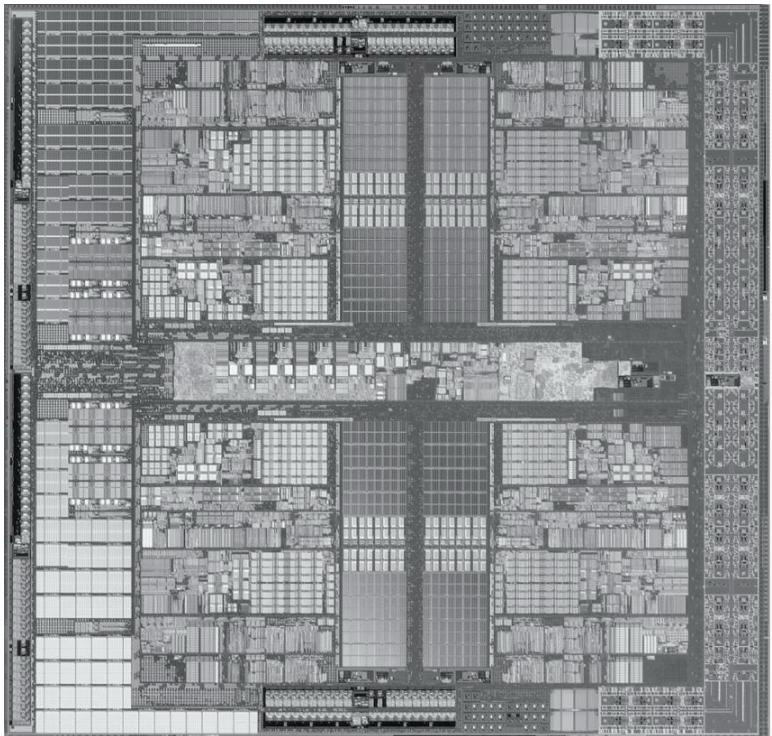


Core
Proc.

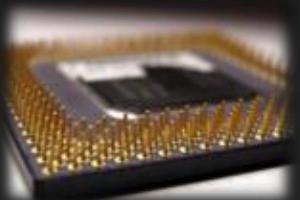


Atom





Integrated Circuits



- There are two main advantages of ICs over discrete circuits.
 - > Cost is low
 - > Performance is high
- Cost is low because the chips with all their components, are printed as a unit and not constructed a transistor at a time.
- Performance is high. The components switch quickly and consume little power, because the components are tiny and close together .
- Chip areas range from a few square mm to several hundreds mm², with up to several millions of transistors per mm².
- Moore's law states that the number of transistors in an integrated circuit doubles every two years.

Integrated Circuits



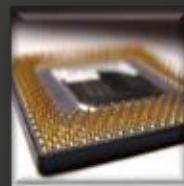
● IC's new generations:

- VLSI or "very large-scale integration" started with hundreds of thousands of transistors (1980s), and continues beyond several billion transistors
- WSI or “Wafer-scale integration” uses an entire silicon wafer to produce a single "super-chip", often used in massively parallel supercomputers.
- SoC or “System on a Chip” integrates all the components needed for a system on a single chip (complex and costly).
- 3D-IC or “3-dimensional Integrated Circuit has two or more layers of active electronic components that are integrated both vertically and horizontally into a single circuit.

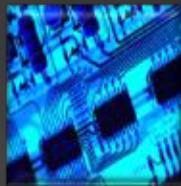
How a computer works...



COMPUTER



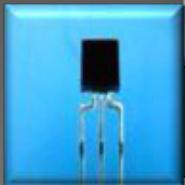
INTEGRATED CIRCUITS



DIGITAL ELECTRONICS

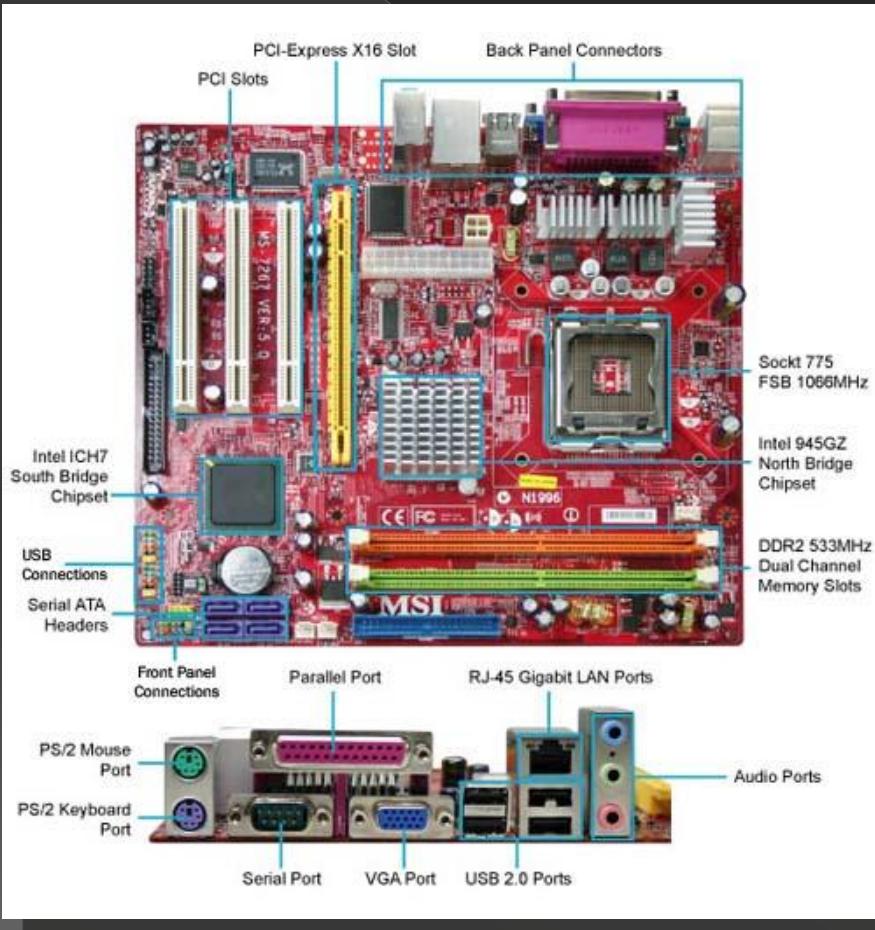


LOGIC GATE



TRANSISTOR

Computer



- Computer is a general-purposed, fast electronic computing machine
- Computer program is a list of stored instructions
- Memory is an internal storage of a computer system

Computer



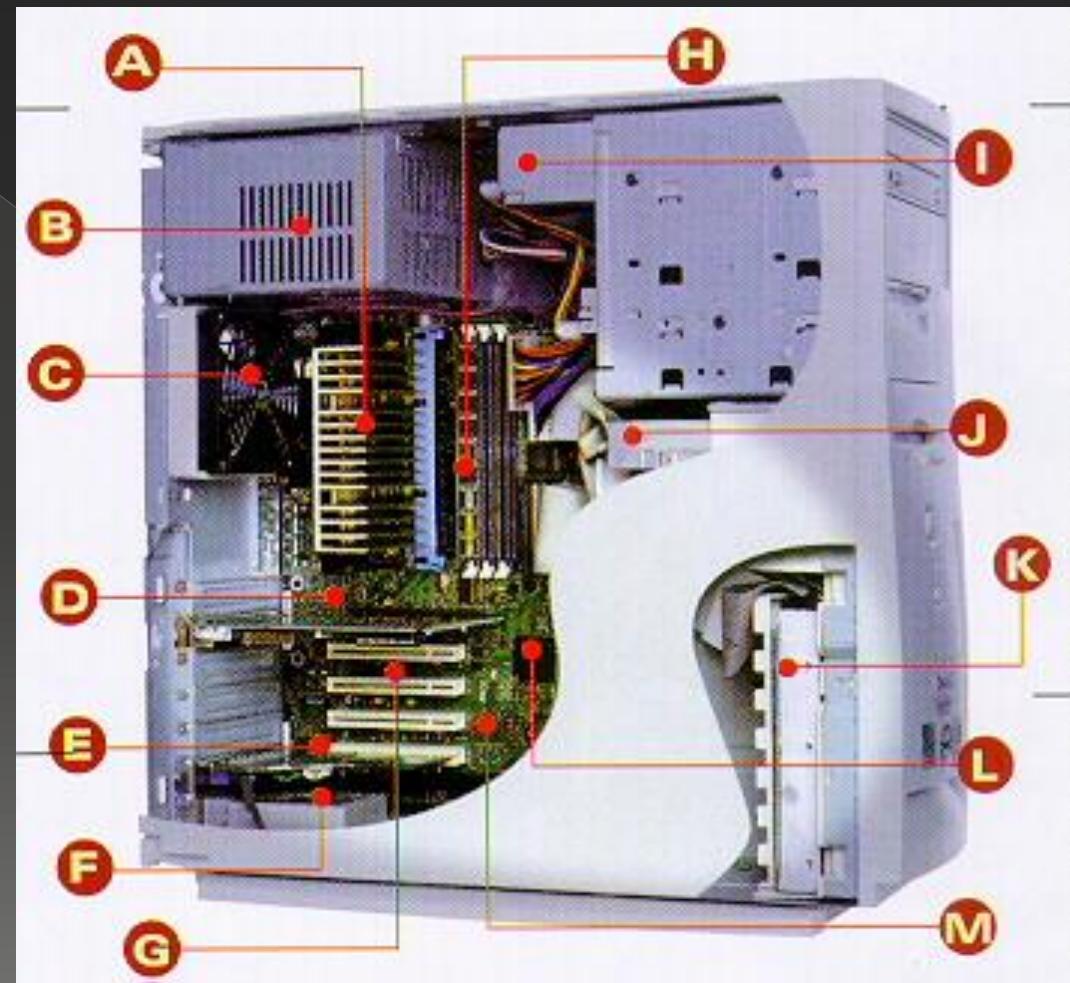
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L



Computer



Basic functional units

Input

Output

I/O

Memory

Arithmetic
and
logic

Control

Processor

Computer



Basic functional units

Input : accept coded information from operators or other computers (keyboard, mouse, communication lines)

Memory : store information for later references

ALU : perform digital operations defined in programs

Output : device that present results to outside worlds

Control unit : coordinates all the actions of all units

Instructions and Data

- An instruction is fetched one after another into memory to be executed.
- Desire operations consist of a series of instructions, which are operated on data.
- Data are encoded characters used as operands by the instructions.
- An example instruction:

Add R1,R2 => instruction

Add => operator

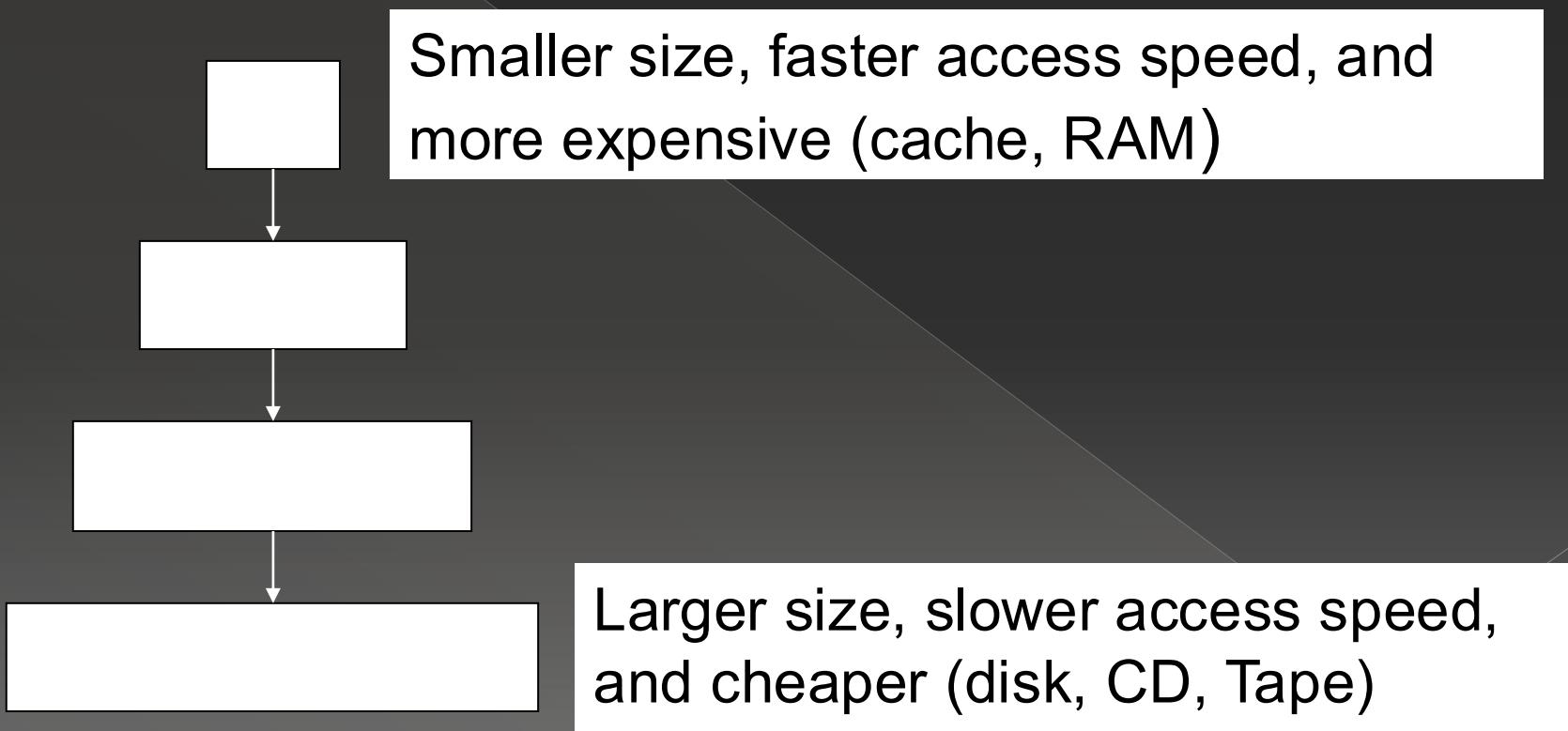
R1,R2 => operand

Concept of Memory

- Primary storage : fast memory that is used to store a program Ex. cache, RAM.
- When executed, memory is organized so that a word (n -bit) can be stored and retrieved in one basic operation.
- Ram (random access memory) is a memory where any word can be reached in a short fixed amount of time

Concept of Memory

- Memory is usually arranged in a hierarchy format, where each level has a different speed and size.



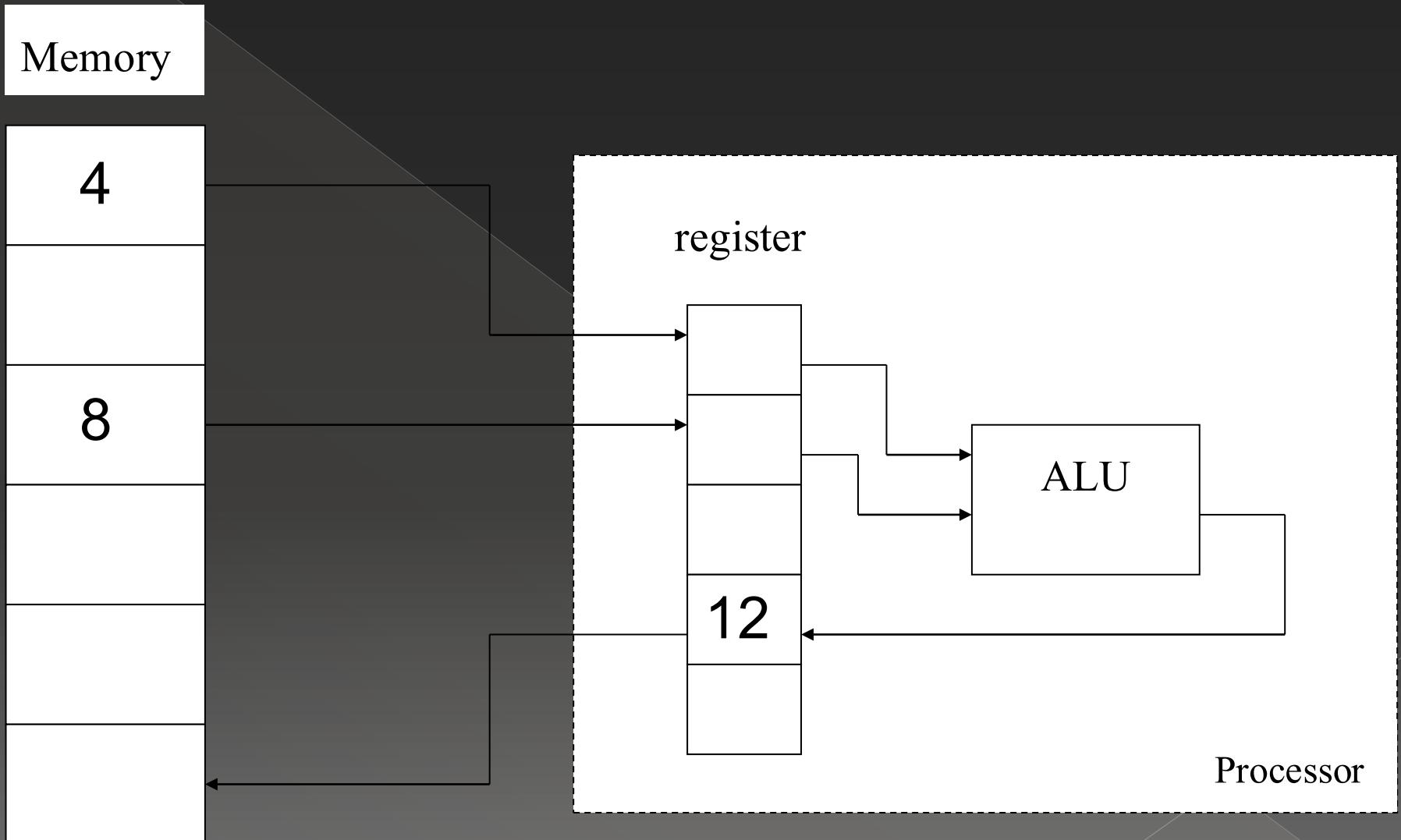
Concept of Memory

- Secondary storage : a cheap memory that can store a lot of data Ex. Disk, CD-Rom and tape
- When data on a secondary unit is accessed, the computer has to transfer the data to a primary unit before use.

Arithmetic and logic unit (ALU)

- ALU : a part of a processor that is used to execute operations/instructions
- Operators : +, -, *, /, % , compare
- Operands : any type of arithmetic data
- Registers : high speed storage elements that are built onboard a processor. The ALU can access the data from registers which is faster than a cache.

Arithmetic and logic unit (ALU)



Control unit

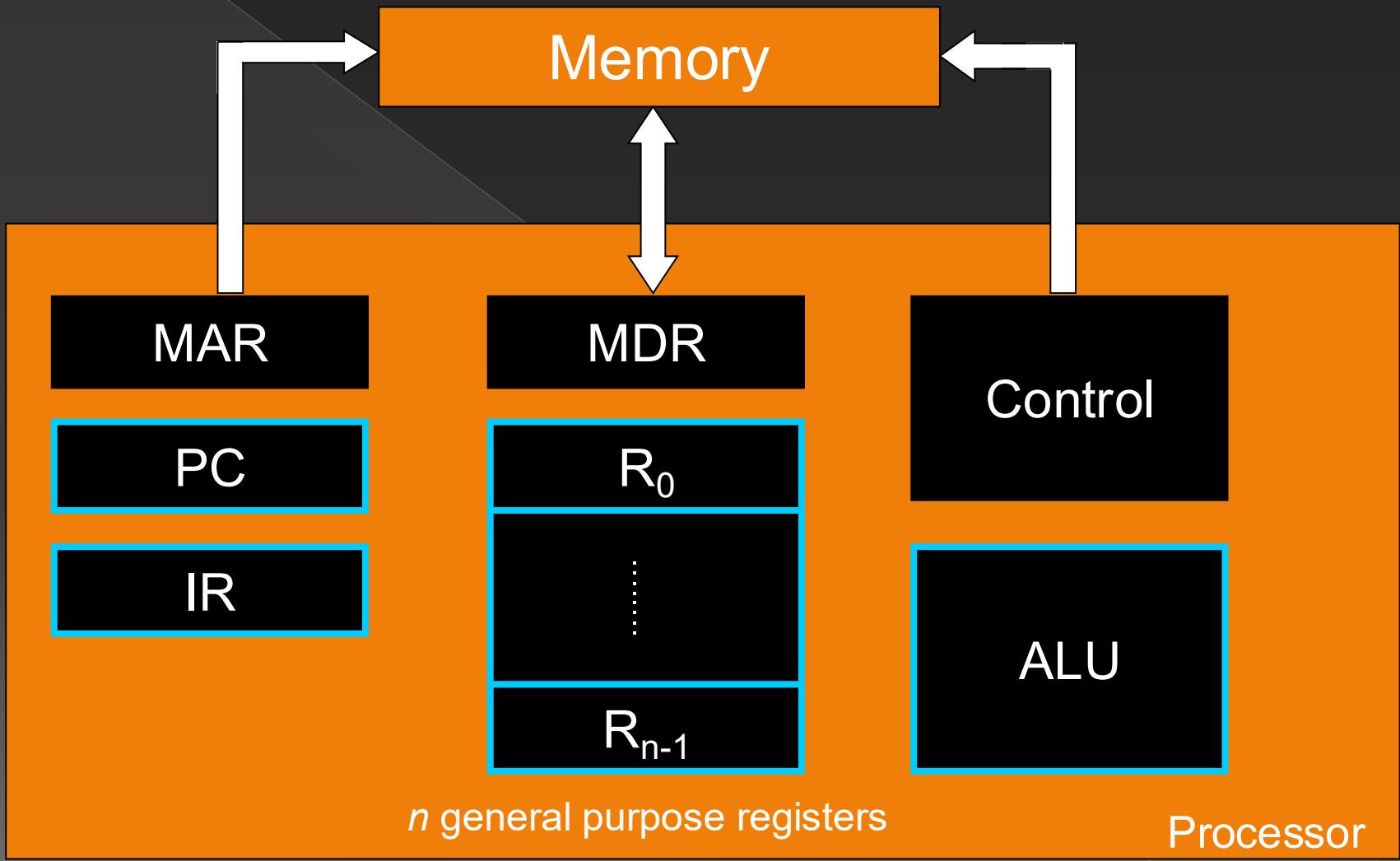
- Control unit : governs all activities inside the machine
- The basic operations that the control unit coordinates :
 - Accept input from an input unit and store in a memory
 - Fetch instruction from a memory for the ALU to process
 - Bring the processed information to an output unit

Basic Operation Concepts

Example Operation : Add LOCA , R0

- | | |
|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Event | <ol style="list-style-type: none">1. An instruction is fetched from a memory2. An operand in location A (of a memory) are fetched from a memory to a processor's register3. An operand is added to the content of R04. The result is put into R0 |
|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

General Architecture of a Processor



General Architecture of a Processor

- IR (Instruction register) : holds a current instruction
- PC (program counter) : holds a memory address of the next instruction
- MAR (memory address register) : holds an address of a location in a memory to be accessed
- MDR (memory data register) : holds the data that will be sent or received to or from a memory
- General purpose registers : use to store information, operand, instruction and/or anything else

Basic Operation Concepts

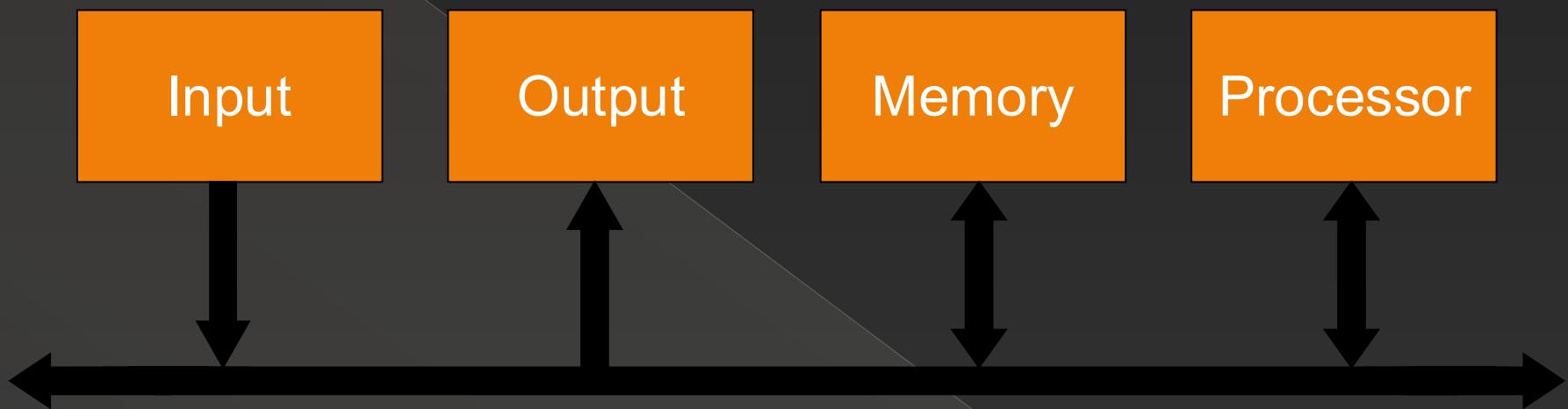
When program are executed :

- 1) The PC is set to the first instruction
- 2) The content of the PC is sent to the MAR
- 3) The control unit sends a read signal
- 4) The instruction is fetched from a memory to the MDR
- 5) The content of the MDR is sent to the IR
- 6) If an operand is needed, repeats the fetch cycle to fetch an operand

Basic Operation Concepts

- 7) Transfers an operand from the MDR to the ALU
- 8) The ALU performs an operation
- 9) If the data is needed to be written back, a memory write cycle is started
- During the execution sequence, the PC will keep incrementing (to the address of the next instruction).

Bus Structure



Single-bus structure

Bus Structure

- A bus is a routing device that connects all other devices in a computer together.
- A single bus only allows a pair of devices to occupy the bus at any giving time.
- When a word is transferred between units, all bits are transferred in parallel (1 bit / 1 line)

Bus Structure

- A group of lines that creates a path in a bus consist of:
 - Data bus : for transferring data
 - Address bus : for sending addresses
 - Control bus : for sending the control signals

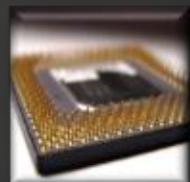
How a computer works...



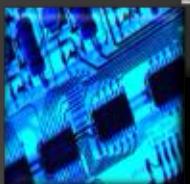
OS



COMPUTER



INTEGRATED CIRCUITS



DIGITAL ELECTRONICS

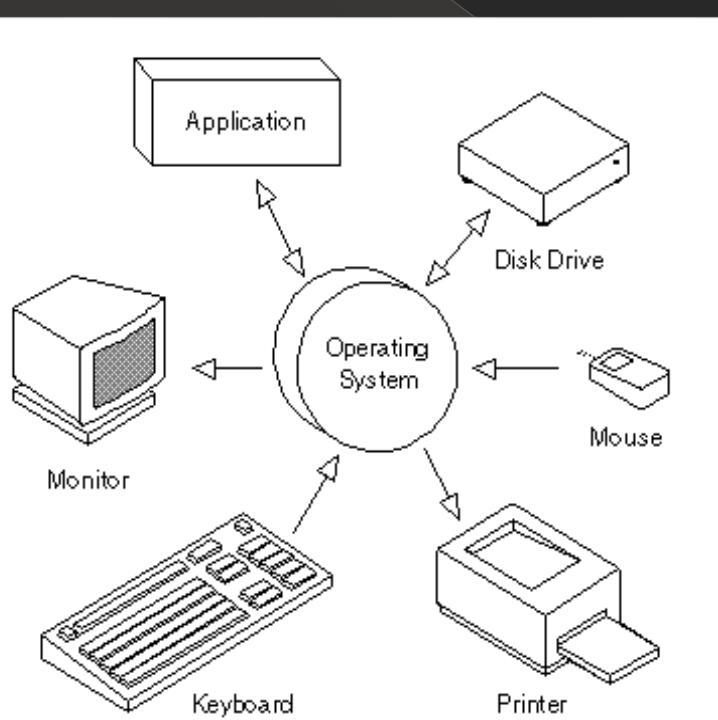


LOGIC GATE



TRANSISTOR

Operating Systems



- An operating system (OS) is a set of computer programs that manage the hardware and software resources of a computer.
- An operating system processes raw system and user input.
- It responds input requests by allocating and managing tasks and internal system resources as a service to users and programs of the system.

Operating Systems



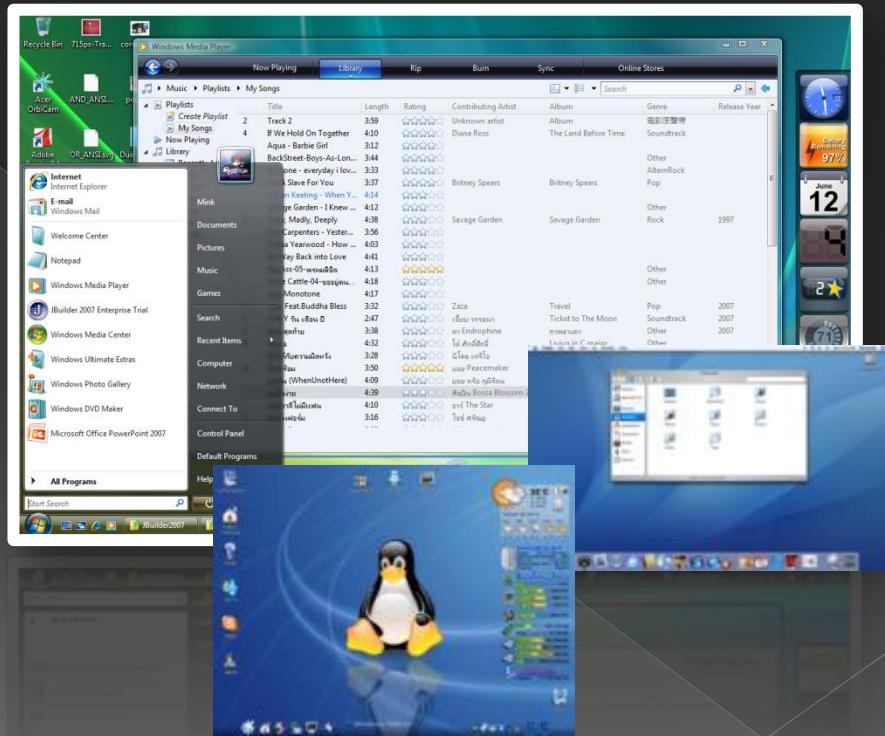
- An operating system performs basic tasks such as controlling and allocating memory, prioritizing system requests, controlling input and output devices, facilitating networking and managing file systems.
- Most operating systems come with an application that provides an interface to the OS managed resources.
- Operating Systems have had command line interpreters as a basic user interface.
- But....now everyone has a graphical user interface (GUI) for ease of operation.
- Windows, Android, Linux, and Mac OS are some of the most popular OS's.

Operating Systems



Desktop OS: Market Share for 2020/2024

- Windows 76.56%/72.72%
- MacOS 17.1%/16.38%
- Linux 1.93%/3.83%
- ChromeOS 1.72%/2.24%
- Other 2.68%/4.83%



Operating Systems



Mobile OS: Market Share for 2020/2024

- iOS 26.91%/29.89%
- Android 72.48%/69.44%
- Other 0.61%/0.67%



How a computer works...



APPLICATION



OS



COMPUTER

INTEGRATED CIRCUITS



DIGITAL ELECTRONICS



LOGIC GATE



TRANSISTOR

Application Software



- Application software allows end users to accomplish one or more specific tasks.
- Typical applications include industrial automation, business software, educational software, medical software, databases, and computer games.

Application Software



- The exact delineation between the operating system and application software is not precise, however, and is occasionally subject to controversy.
 - Microsoft's Internet Explorer web browser was part of its Windows operating system or a separable piece of application software
- Multiple applications bundled together as a package are sometimes referred to as an application suite.
 - Microsoft Office and OpenOffice.org, which bundle together a word processor, a spreadsheet, and others



USER



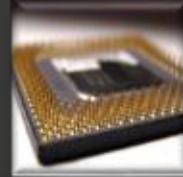
APPLICATION



OS



COMPUTER



INTEGRATED CIRCUITS



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LOGIC GATE



TRANSISTOR

How a computer works...

Computer User



YOU

- **User is one who uses a computer system.**
- **Users may need to identify themselves for the purposes of accounting, security, logging and resource management.**
- **In order to identify oneself, a user has an account (a user account) and a username (a screen name), and in most cases also a password.**