Microprocessor

Unit 1:
Introduction

Course Outline

- Introduction to Microprocessor and its application
- Evolution of Microprocessor
- Von Neumann and Harvard architecture
- Components of a Microprocessor
  - Registers,
  - ALU, and
  - Control And Timing
  - System Bus (data, address and control bus)
- System Bus: Data , Address and Control Bus
- Microprocessor system with bus organization

Microprocessor

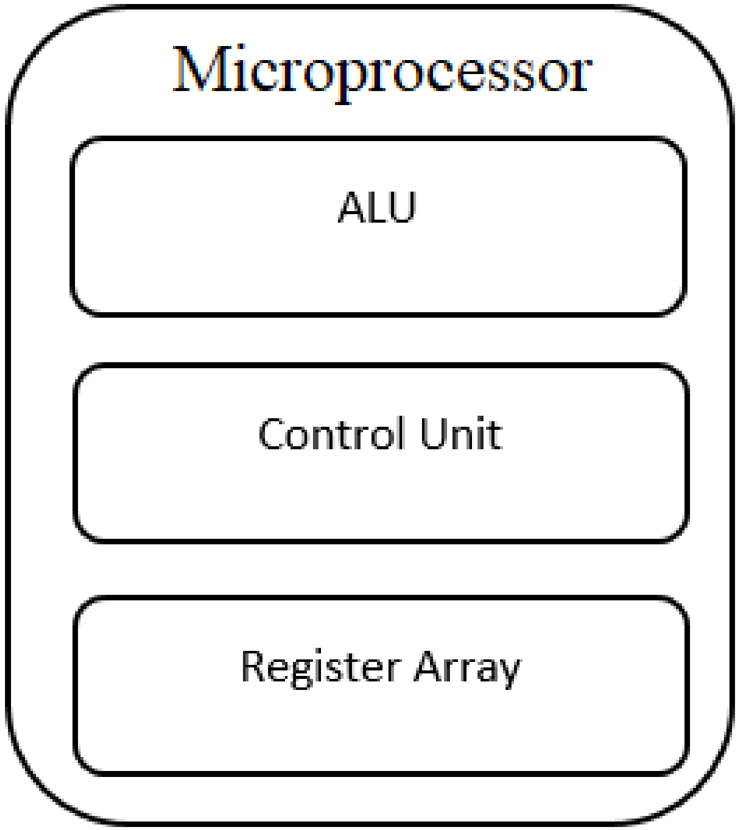
- CPU (central processing unit) on a single IC (integrated circuit).
- Microprocessor is also called as "CPU on a chip".
- It is a semiconductor device (Integrated Circuit) manufactured by the VLSI or LSI technique.
- The microprocessor contains millions of tiny components like transistors, registers, and diodes that work together.
- A system designed using a microprocessor as its CPU is called a microcomputer.

Microprocessor

- Defined in Webster
  - Integrated circuit that contains the entire central processing unit of a computer on a single chip.
- Another source
  - Microprocessor is a device that integrates the functions of the CPU in a computer onto the LC or semiconductor chip.

Microprocessor

- Basic Block Diagram



Inside the Microprocessor

- Internally, microprocessor is made up of 3 main units:
  - Arithmetic/Logic Unit (ALU)
    - ALU performs arithmetical and logical operations on the data received from the memory or an input device.
    - It performs such arithmetic operations as addition and subtraction, and such logic operations as AND, OR, and XOR.
    - Results are stored either in registers or in memory.
  - Control Unit
    - The control unit provides the necessary timing and control signals to all the operations in the microcomputer.
    - It controls the flow of data between the microprocessor and memory and peripherals
  - An array of register
    - These registers are used to store data and addresses temporarily during the execution of a program
    - consists of registers identified by letters like B, C, D, E, H, L and accumulator.

Control Unit

- The Control Unit is one of the most important parts of the microprocessor because it is in charge of the entire process.
- Based on instructions from the Decode Unit, it creates control signals that tell the Arithmetic Logic Unit (ALU) and the Registers
  - how to operate,
  - what to operate on, and
  - what to do with the result.
- The Control Unit makes sure everything happens in the right place at the right time.

Registers

- Registers are the set of flip-flops that store data or instruction temporarily.
- The Registers are a mini-storage area for data used by the Arithmetic Logic Unit (ALU) to complete the tasks the Control Unit has requested.
  - The data can come from the memory or the control unit and are all stored at special locations within the Registers.
  - This makes retrieval for the ALU quick and efficient.
- Registers are made up of flip-flops.
- The number of flip-flops used in the registers determine the capacity of registers.

Types of Registers

- Special Purpose
  - Has specific task
  - Like PC, AC, MBR, MAR
- General Purpose
  - Used in general operation in the microprocessor
  - Like B, C, H, L

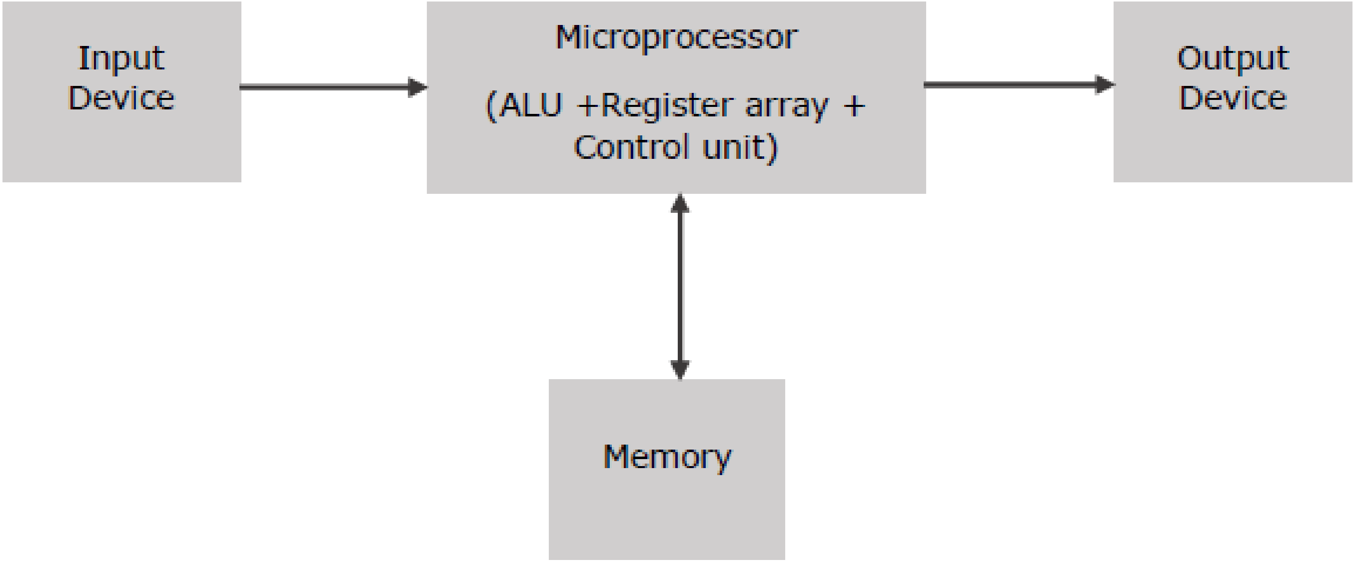
Types of Special Purpose Register

- MAR
  - stand for Memory Address Register
  - This register holds the memory addresses of data and instructions.
  - This register is used to access data and instructions from memory during the execution phase of an instruction.
  - Suppose microprocessor wants to store some data in the memory or to read the data from the memory. It places the address of the-required memory location in the MAR.
- Program Counter
  - The program counter (PC) is a processor register that keeps track of the next memory address of the instruction that is to be executed once the execution of the current instruction is completed.
  - In other words, it holds the address of the memory location of the next instruction when the current instruction is executed by the microprocessor.
- Accumulator Register
  - This Register is used for storing the Results those are produced by the System.
  - When the CPU will generate Some Results after the Processing then all the Results will be Stored into the AC Register.

Types of Special Purpose Register

- Memory Buffer Register
  - MBR stand for Memory Buffer Register.
  - This register holds the contents of data or instruction read from, or written in memory.
  - It means that this register is used to store data/instruction coming from the memory or going to the memory.
- Data Register
  - A register used in microcomputers to temporarily store data being transmitted to or from a peripheral device.
- Instruction Register
  - It is used to hold the current instruction being executed or decoded.

Microprocessor based Computer



Name	Year of Invention	Clock speed	Number of transistors	Inst. per sec
INTEL 4004/4040	1971 by Ted Hoff and Stanley Mazor	740 KHz	2300	60,000
8008	1972	500 KHz	3500	50,000
8080	1974	2 MHz	6000	10 times faster than 8008
8085	1976 (16 bit address bus)	3 MHz	6500	769230
8086	1978 (multiply and divide instruction, 16 bit data bus and 20 bit address bus)	4.77 MHz, 8 MHz, 10 MHz	29000	2.5 Million
8088	1979 (cheaper version of 8086 and 8 bit external bus)			2.5 Million
80186/80188	1982 (80188 cheaper version of 80186, and additional components like interrupt controller, clock generator, local bus controller,counters)	6 MHz		
80286	1982 (data bus 16bit and address bus 24 bit)	8 MHz	134000	4 Million
INTEL 80386	1986 (other versions 80386DX, 80386SX, 80386SL and data bus 32 bit address bus 32 bit)	16 MHz – 33 MHz	275000	
INTEL 80486	1986 (other versions 80486DX, 80486SX, 80486DX2, 80486DX4)	16 MHz – 100 MHz	1.2 Million transistors	8 KB of cache memory
PENTIUM	1993	66 MHz		Cache memory 8 bit for instructions 8 bit for data
INTEL core 2	2006 (other versions core2 duo, core2 quad, core2 extreme)	1.2 GHz to 3 GHz	291 Million transistors	64 KB of L1 cache per core 4 MB of L2 cache
i3, i5, i7	2007, 2009, 2010	2.2GHz – 3.3GHz, 2.4GHz – 3.6GHz, 2.93GHz – 3.33GHz		

Evolution of Microprocessor

- **First Generation 4-bit Microprocessor**
  - This is the first microprocessor invented by Intel in **1971**. They named it Intel **4004** because it was a 4-bit microprocessor
- **Second Generation 8-bit Microprocessor**
  - The Second generation processor was an 8-bit microprocessor developed by Intel in the year **1973**. It was named Intel **8008** because it was 8 bit.
- **Third Generation 16-bit Microprocessor**
  - The third generation microprocessors were 16-bit microprocessors introduced in **1978** by Intel. **8086 / 80186 / 80286 , Motorola 68000, 68010** is a 3rd generation microprocessor.
- **Fourth Generation 32-bit Microprocessor**
  - The Fourth generation microprocessors were introduced in **1985** and they were 32 bit. 80386 or also known as **i386** or just 386 is the most renowned 4th generation microprocessor.
- **Fifth Generation 64-bit Microprocessor**
  - The fifth-generation microprocessor or 64-bit microprocessors were introduced in **1995** and they are being used till now. The Intel Pentium processors were based on 64-bit architecture. The recent 64-bit microprocessor use super scaling to offer high speed and high performance such as Intel dual, quad, octa-core microprocessors.

Application of Microprocessor

- Use as a single board micro computer
- In embedded system like firm alarm system,, washing machine, microwave, etc
- Special purpose microprocessor are used in switch, router, etc
- Traffic light controlling system
- Computers and electronics
- It is also used in mobile phones and television.

How does microprocessor works?

- The microprocessor works according to the pattern:
  - Fetch -> Decode -> Execute
- The instruction are stored sequentially in the memory.
- Then microprocessor fetches the data/instruction from its memory, decodes it, and executes that instruction.
- This process is continued until the microprocessor comes across an instruction to stop.
- During this entire process, microprocessor uses the system bus to fetch the binary instructions and data from the memory.
- It uses registers from the register section to store data temporarily, and it performs the computing function in the ALU section.
- Finally, it sends out the result in binary, using the same bus-lines to output ports.

Fetch – Decode - Execute

- **Fetch**
  - The Fetch Operation is used for taking the instructions those are given by the user and the Instructions those are stored into the Main Memory will be fetch by using Registers.
- **Decode**
  - The Decode Operation is used for interpreting the Instructions means the Instructions are decoded means the CPU will find out which Operation is to be performed on the Instructions.
- **Execute**
  - The Execute Operation is performed by the CPU. And Results those are produced by the CPU are then Stored into the Memory and after that they are displayed on the user Screen.

System Bus

- System bus is set of signal lines that connects various parts of microprocessor with I/O devices and memory.
- Through this bus, various pars of microprocessor, I/O devices and memory communicate with each other.

Control Bus

- A control bus is a computer bus that is used to carries control signals from the microprocessor to other components.
- It also carries the clock's pulses which are used by the microprocessor to communicate with devices that are contained within the computer.
- The microprocessor transmits a variety of control signals to components and devices.
- This occurs through physical connections such as cables or printed circuits.

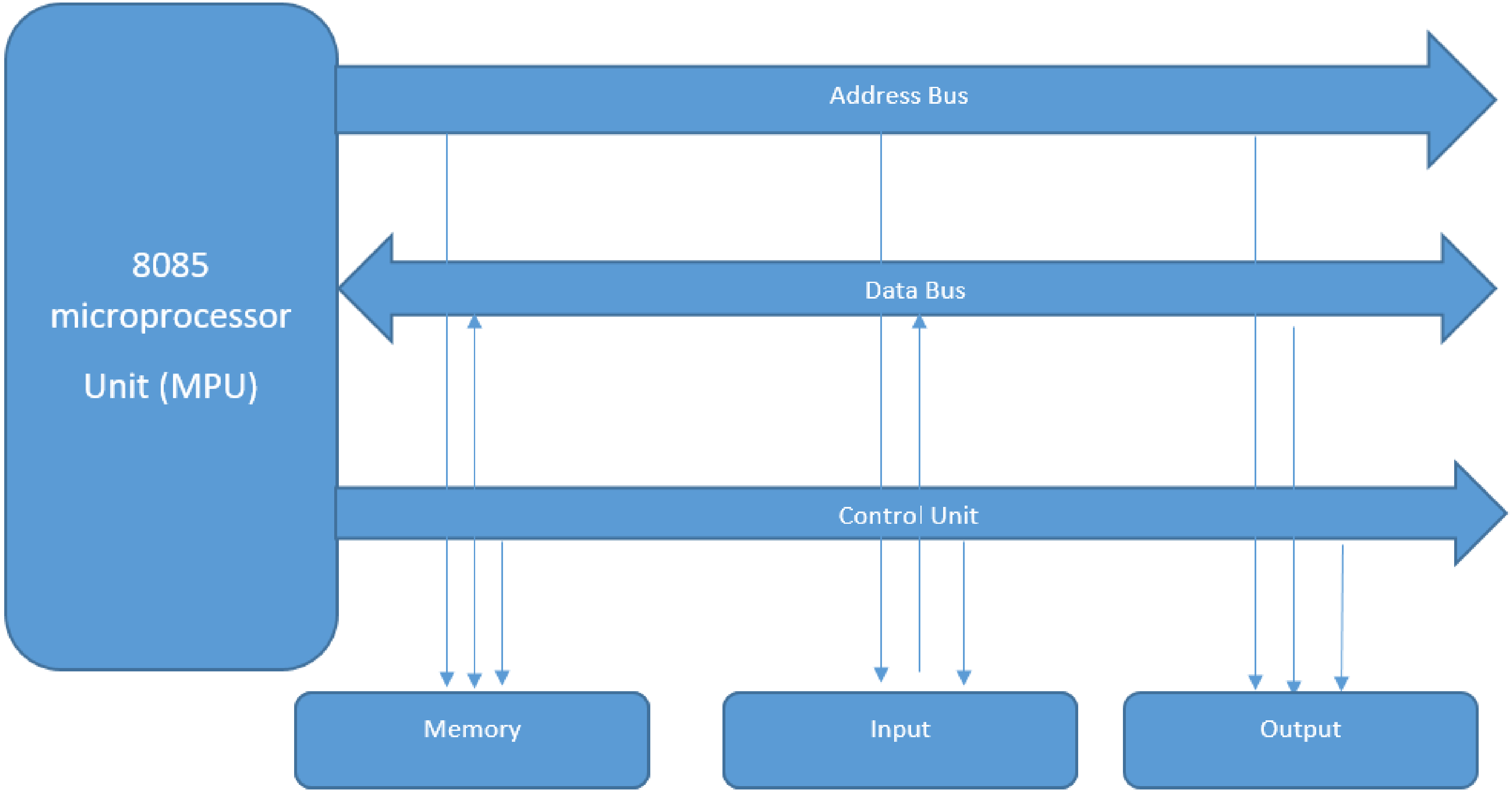
Address Bus

- Address bus carries the memory the address within the device allows the CPU to reference memory locations within the device.
- It connects the CPU and another peripheral and carries only the memory address.
- The address bus contains the connections between the processor and memory that carry the signals relating to the addresses which the microprocessor is processing at that time, such as the locations that it is reading from or writing to.
- It address but could carry 8 bit at a time, the CPU could address only. (2^8) 256 bytes of RAM.

Data Bus

- A data bus is a computer subsystem that carries the data between the processor and other components.
  - between memory and processor **or** between I/O device and processor
- The data bus is bidirectional that allows for the transferring of data from one component to another within a computer system or between two computers.
- This can include transferring data to and from the memory, or from the central processing unit (CPU) to other components.
- Each one is designed to handle so many bits of data at a time.
- It is the main part of a system bus that allows the actual transmission of data.

Microprocessor with Bus Organization



Von Neumann architecture

- Von Neumann architecture was first published by John von Neumann in 1945.
- Von Neumann architecture is based on the stored-program computer concept, where instruction data and program data are stored in the same memory.
- This design is still used in most computers produced today.
- His computer architecture design consists of a Control Unit, Arithmetic and Logic Unit (ALU), Memory Unit, Registers and Inputs/Outputs.

Von Neumann Bottleneck

- Whatever we do to enhance performance, we cannot get away from the fact that
  - instructions can only be done one at a time, and
  - can only be carried out sequentially.
- Both of these factors hold back the competence of the processing unit.
- This is commonly referred to as the 'Von Neumann bottleneck'.
- We can provide a Von Neumann processor with more cache, more RAM, or faster components but if original gains are to be made in CPU performance then
  - an influential inspection needs to take place of CPU configuration.
- This architecture is very important and is used in our PCs and even in Super Computers.

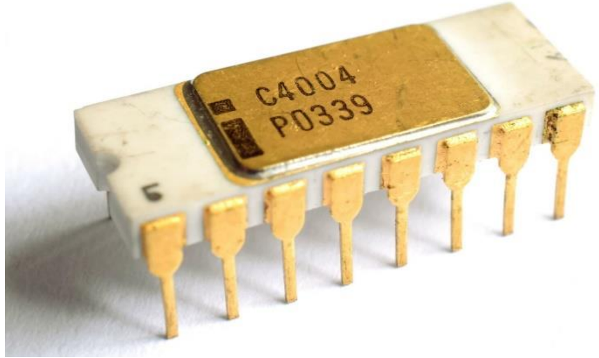
Harvard Architecture

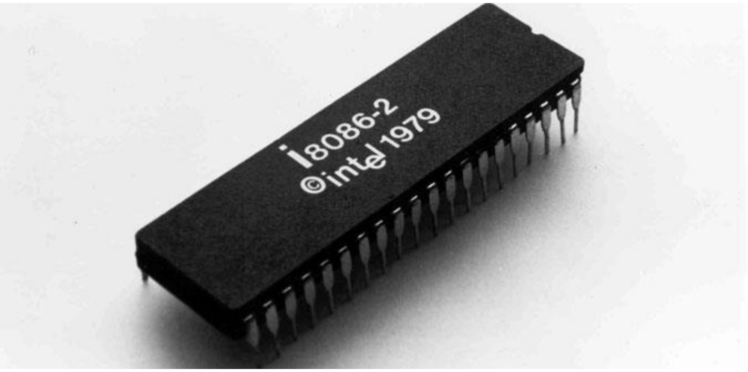
- The Harvard architecture is a computer architecture with separate storage and signal pathways for instructions and data.
- It contrasts with the von Neumann architecture, where program instructions and data share the same memory and pathways.
- Computers designed with the Harvard architecture are able to run a program and access data independently, and therefore simultaneously.
- Harvard architecture has a strict separation between data and code.
- Thus, Harvard architecture is more complicated but separate pipelines remove the bottleneck that Von Neumann creates.

Von Neumann Vs Harvard

- In a normal computer that follows **Von Neumann architecture**,
  - instructions and data both are stored in same memory.
- So same buses are used to fetch instructions and data.
- This means CPU cannot do both things together (read a instruction and read/write data).
- **Harvard Architecture** is the computer architecture that contains separate storage and separate buses (signal path) for instruction and data.
- It was basically developed to overcome the bottleneck of Von Neumann Architecture.
- The main advantage of having separate buses for instruction and data is that CPU can access instructions and read/write data at the same time.

Different Microprocessors & Processors





Clock and Timers

- Microprocessors have internal timers
  - Under the control of the user
  - Used for various functions requiring counting/timing
  - At least one counter is available
  - Larger microprocessor can have 4 or more timers
  - Some are 8 bit timers and some are 16 bit timers
  - A watchdog timer is available for the purpose of resetting the processor should it be “stuck” in an inoperative mode.

Some More

Programming Language

- Machine Language
  - Machine Language is the lowest level programming language.
  - It is the language intended to be understood by the microprocessor(machine) only.
  - In this language, every instruction is described by binary patterns.
    - E.g. 110101011
  - This is the form in which instructions are stored in memory.
  - This is the only form that the microprocessor understands.

Programming Language

- Assembly Language
  - An assembly language implements a symbolic representation of the machine code needed to program a given CPU architecture.
  - An assembly language is a type of low-level programming language that is intended to communicate directly with a computer’s hardware.
  - Assembly language is designed to understand the instruction and provide it to machine language for further processing.
  - It mainly depends on the architecture of the system, whether it is the operating system or computer architecture.
  - Assembly Language mainly consists of mnemonic processor instructions or data and other statements or instructions.

```
mov eax, 3
mov ebx, 4
add eax, ebx, ecx
```

Programming Language

- High Level Language
  - A high-level language is any programming language that enables development of a program in a much more user-friendly programming context and
    - is generally independent of the computer's hardware architecture.
  - Such languages are considered high-level because they are closer to human languages and further from machine languages.
  - A high-level language has a higher level of abstraction from the computer, and
    - focuses more on the programming logic rather than the underlying hardware components such as memory addressing and register utilization.
  - High-level languages are designed to be used by the human operator or the programmer.

Some Terminologies

Semiconductor

- A solid-state substance with conductive properties that can be altered with electricity.
- Silicon performs as a semiconductor when chemically combined with other elements.
- A semiconductor is also halfway between a conductor and an insulator.
- When charged with electricity or light, semiconductors change their state from non-conductive to conductive or vice versa.
- The most significant product built from a semiconductor is the transistor.

Transistor

- A device used to amplify a signal or open and close a circuit.
- In a computer, it functions as an electronic switch, or bridge.
- The transistor contains a semiconductor material that can change its electrical state when pulsed.
- Invented in 1947 at Bell Labs
- Transistors have become the key ingredient of all digital circuits, including computers.

Logic Gate

- A collection of transistors and resistors that implement Boolean logic operations on a circuit board.
- Transistors make up logic gates.
- Logic gates make up circuits.
- Circuits make up electronic systems.

IC

- Integrated Circuit
- a tiny complex of electronic components and their connections that is produced in or on a small slice of material (such as silicon).
- Its name results from the integration of previously separate transistors, resistors and capacitors – all on a single chip.

IPC

- Instructions Per Clock
- a measure of how many instructions a CPU is capable of executing in a single clock.
- Since different processor architectures have different IPCs, clock frequency x IPC is a much truer measure of processor performance than clock frequency alone.

VLSI, LSI, ULSI

- LSI
  - Large Scale Integration
  - refers to the placement of thousands (between 3,000 and 100,000) of electronic components on a single integrated circuit.
- VLSI
  - Very Large Scale Integration: the process of placing hundreds of thousands (between 100,000 and one million) of electronic components on a single chip.
- ULSI
  - Ultra Large Scale Integration: more than one million transistors on a chip.
- Nearly all modern chips employ VLSI architectures, or ULSI (ultra large scale integration).

- Superscalar
  - A CPU architecture that allows more than one instruction to be executed in one clock cycle. Processors can do this by fetching multiple instructions in one cycle, deciding which instructions are independent of other instructions, and executing them.