Chapter-1: Introduction to Microprocessor

1.1 Introduction

A Microprocessor is a multipurpose programmable, clock driven, register based electronic device that reads binary instructions from a storage device called memory, accepts binary data as input, processes data according to those instructions and provide result s as output. The microprocessor operates in binary 0 and 1 known as bits are represented in terms of electrical voltages in the machine that means 0 represents low voltage level and 1 represents high voltage level. Each microprocessor recognizes and processes a group of bits called the word and microprocessors are classified according to their word length such as 8 bits microprocessor with 8 bit word and 32 bit microprocessor with 32 bit word etc.

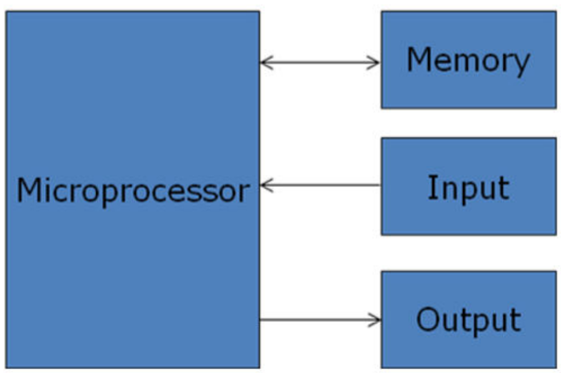

Fig 1.1: A Programmable Machine

Terms used

→ CPU: - Central processing unit which consists of ALU and control unit.

→Microprocessor: - Single chip containing all units of CPU.

→ Microcomputer: - Computer having microprocessor as CPU.

→ Microcontroller: single chip consisting of MPU, memory, I/O and interfacing circuits.

→ MPU: - Microprocessing unit – complete processing unit with the necessary control signals.

Applications of Microprocessors

Microcomputer: Microprocessor is the CPU of the microcomputer.

Embedded system: Used in microcontrollers

Measurements and testing equipment: Used in signal generators, oscilloscopes, counters, tal voltmeters, x-ray analyzer, blood group analyzers baby incubator, frequency Syathesizers, data acquisition systems, spectrum analyzers etc.

→Washing machine

→Microwave oven

→Scientific and Engineering research

→ Industry: used in data monitoring system, automatic weighting, batching systems etc.

→ Security systems: smart cameras, CCTV, smart doors, traffic light control etc

→Military Applications

Historical Background of the Development of Computers:

The most efficient and versatile electronic machine computer is basically a development of a calculator which leads to the development of the computer. The older computer were mechanical and newer are digital. The mechanical computer namely difference engine and analytical engine developed by Charles Babbage the father of the computer can be considered as the forerunners of modern digital computers.

The difference engine was a mechanical device that could add and subtract and could only run a single algorithm. Its output system was incompatible to write on punched cards and early optical disks. The 'analytical engine' provided more advanced features. It consisted mainly four components the store (memory), the mill (computation unit) , input section (punched card reader) and output section (punched and printed output). The store consisted of 1000s of words of 50 decimal digits used to hold variables and results. The mill could accept operands from the store, add, subtract, multiply or divide them and return a result to the store.

The evolution of the vacuum tubes led the development of computer into a new era. The world's first general purpose electronic digital computer was ENIAC (Electronic Numerical Integrator and Calculator) built by using vacuum tubes was enormous in size and consumed very high power. However it was faster than mechanical computers. The ENIAC was decimal machine and performed only decimal numbers. Its memory consisted of 20 'accumulators' each capable of holding 10 digits decimal numbers. Each digit was represented by a ring of 10 vacuum tubes. ENIAC had to be programmed manually by setting switches and plugging and unplug a cable which was the main drawback of it.

Automated calculator:

It is a data processing device that carries out logic and arithmetic operations but has limited programming capability for the user. It accepts data from a small keyboard one digit at a time performs required arithmetic and logical calculations and stores the result on visual display like LCD or LED. The calculator's programs are stored in ROM's while the data is stored in RAM.

Some important features of automated calculations:

- The ability to interface easily with keyboards and displays.
- The ability to handle decimal digits, the device is able to handle more than 4 bits at a time.
- Ability to execute the standard programs stored in read only memory.

- Extendibility, so that mathematical functions such as %, √, trigonometric, statistical etc. can be easily executed.
- Flexibility so it can be used in engineering business or programming without a complete new design.
- Low cost, small size and low power consumptions

Von-Neumann and Harvard Architecture

There are two types of digital computer architectures that describe the functionality and implementation of computer systems. One is the Von Neumann architecture that was designed by the renowned physicist and mathematician John Von Neumann in the late 1940s, and the other one is the Harvard architecture which was based on the original Harvard Mark I relay-based computer which employed separate memory systems to store data and instructions.

Von Neumann Architecture

Storing the data and instructions in a same memory is called as stored program concept. This approach concept' was first adopted by John Von Neumann and such architecture is named as von-Neumann architecture. The idea behind the Von Neumann architectures is the ability to store instructions in the memory along with the data on which the instructions operate.

The Von Neumann architecture consists of three distinct components: a central processing unit, memory unit and input/output (I/O) interfaces.

CPU consists of control unit and arithmetic and logic unit (ALU). ALU is responsible for carrying out all arithmetic and logical operations on data where as control unit determines the order of flow of instructions that need to be executed in programs by issuing control signals to the hardware.

The memory unit consists of RAM (Read/Write memory), which is the main memory used to store program data and instructions. The I/O interfaces allows the users to communicate with the outside world such as storage devices.

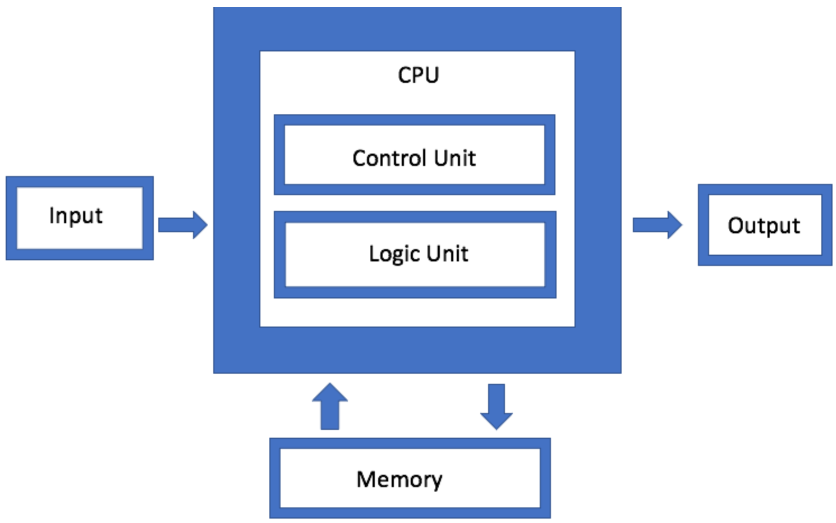

Fig: Von Neumann Architecture

Harvard Architecture:

In von-Neumann architecture, the same memory is used for storing instructions and data. Similarly, a single bus called data bus or address bus is used for reading data and instructions from or writing to memory. It also had limited the processing speed for computers.

The Harvard architecture based computer consists of separate memory spaces for the programs (instructions) and data. Each space has its own address and data buses. So instructions and data can be fetched from memory concurrently and provides significance processing speed improvement.

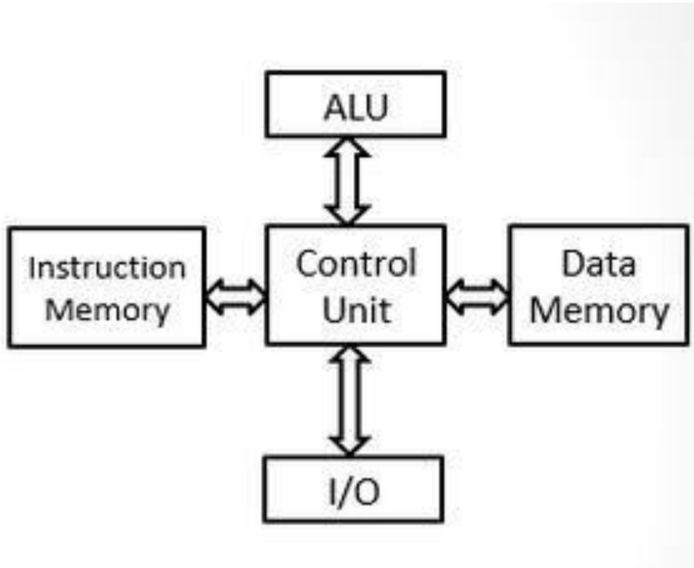

Fig: Harvard architecture

Difference between Von Neumann and Harvard Architecture

Basics of Von Neumann and Harvard Architecture

The Von Neumann architecture is a theoretical computer design based on the concept of stored- program where programs and data are stored in the same memory. The concept was designed by a mathematician John Von Neumann in 1945 and which presently serves as the basis of almost all modern computers. The Harvard architecture was based on the original Harvard Mark I relay-based computer model which employed separate buses for data and instructions.

Memory System of Von Neumann and Harvard Architecture

The Von Neumann architecture has only one bus that is used for both instruction fetches and data transfers, and the operations must be scheduled because they cannot be performed at the same time. The Harvard architecture, on the other hand, has separate memory space for instructions and data, which physically separate signals and storage for code and data memory, which in turn makes it possible to access each of the memory system simultaneously.

Instruction Processing of Von Neumann and Harvard Architecture

In Von Neumann architecture, the processing unit would need two clock cycles to complete an instruction. The processor fetches the instruction from memory in the first cycle and decodes it, and then the data is taken from memory in the second cycle. In the Harvard architecture, the processing unit can complete an instruction in one cycle if appropriate pipelining strategies are in place.

Cost of Von Neumann and Harvard Architecture

As instructions and data use the same bus system in the Von Neumann architecture, it simplifies design and development of the control unit, which eventually brings down the production cost to minimal. Development of control unit in the Harvard architecture is more expensive than the former because of the complex architecture that employs two buses for instructions and data.

Use of Von Neumann and Harvard Architecture

Von Neumann architecture is mainly used in every machine you see from desktop computers and notebooks to high performance computers and workstations. Harvard architecture is a fairly new concept used primarily in microcontrollers and digital signal processing (DSP).

Von Neumann Architecture	**Harvard Architecture**
It is a theoretical design based on stored program concept.	It is a modern computer architecture based on the Harvard Mark I computer model
It uses same physical memory address for instructions and data.	It uses separate memory addresses for instruction and data.
Processor needs two clock cycles to execute an instruction.	Processor needs one cycle to complete an instruction.
Data transfers and instruction fetches cannot be performed simultaneously.	Data transfer and instruction fetches can be performed at the same time.
Used in personal computers, laptops and workstations.	Used in microcontrollers and signal processing.

Organization of a microprocessor based system

Microprocessor based system includes there components microprocessor, input/output and memory (read only and read/write). These components are organized around a common communication path called a bus.

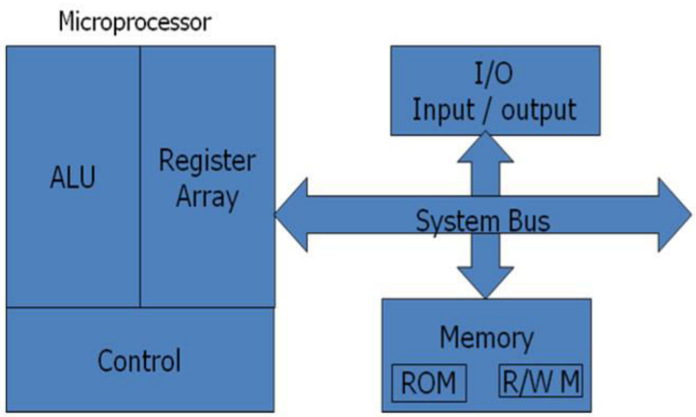

Fig 1.3: Microprocessor Based System with Bus Architecture

Microprocessor:

It is clock driven semiconductor device consisting of electronic logic circuits manufactured by using either a large scale integration (LSI) or very large scale integration (VLSI) technique. It is capable of performing various computing functions and making decisions to change the sequence of program execution. It can be divided in to three segments.

A. Arithmetic/Logic unit: It performs arithmetic operations as addition and subtraction and logic operations as AND, OR & XOR.

B. Register Array: The registers are primarily used to store data temporarily during the execution of a program and are accessible to the user through instruction. The registers can be identified by letters such as B, C, D, E, H and L.

C. Control Unit: It 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 & peripherals.

Memory:

Memory stores binary information such as instructions and data, and provides that information to the up whenever necessary. To execute programs, the microprocessor reads instructions and data from memory and performs the computing operations in its ALU. Results are either transferred to the output section for display or stored in memory for later use. Memory has two sections.

A. Read only Memory (ROM): Used to store programs that do not need alterations and can only read.

B. Read/Write Memory (RAM): Also known as user memory which is used to store user programs and data. The information stored in this memory can be easily read and altered.

Input/output:

- It communicates with the outside world using two devices input and output which are also Known as peripherals.
- The input device such as keyboard, switches, and analog to digital converter transfer binary information from outside world to the microprocessor.
- The output devices transfer data from the microprocessor to the outside world. They include the devices such as LED, CRT, digital to analog converter, printer etc.

System Bus:

It is a communication path between the microprocessor and peripherals; it is nothing but a group of wires to carry bits.

Bus organization

Bus is a common channel through which bits from any sources can be transferred to the destination. A typical digital computer has many registers and paths must be provided to transfer instructions from one register to another. The number of wires will be excessive if separate lines are used between each register and all other registers in the system. A more efficient scheme for transferring information between registers in a multiple register configuration is a common bus system. A bus structure consists of a set of common lines, one for each bit of a register, through which binary information is transferred one at a time. Control signals determine which register is selected by the bus during each particular register transfer.

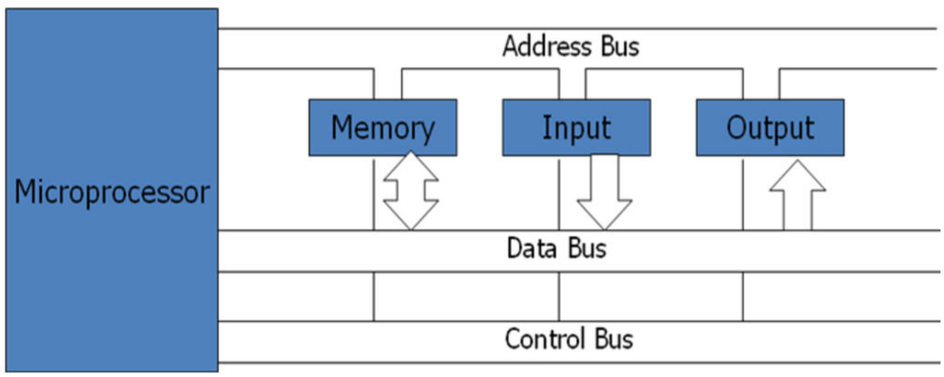

Fig: Bus Organization

A very easy way of constructing a common bus system is with multiplexers. The multiplexers select the source register whose binary information is then pleased on the bus.

A system bus consists of about 50 to 100 of separate lines each assigned a particular meaning or function. Although there are many different bus designers, on any bus, the lines can be classified into three functional groups; data, address and control lines. In addition, there may be power distribution lines as well.

Address Bus

It is a group of conducting wires which carries address only. Address bus is unidirectional because data flow in one direction, from microprocessor to memory or from microprocessor to Input/output devices (That is, Out of Microprocessor).

Length of Address Bus of 8085 microprocessor is 16 Bit (That is, Four Hexadecimal Digits), ranging from 0000 H to FFFF H (H denotes Hexadecimal). The microprocessor 8085 can transfer maximum 16 bit address which means it can address 65,536 different memory location.

The Length of the address bus determines the amount of memory a system can address. Such as a system with a 32-bit address bus can address 2^{32} memory locations. If each memory location holds one byte, the addressable memory space is 4 GB. However, the actual amount of memory that can be accessed is usually much less than this theoretical limit due to chipset and motherboard limitations.

Data Bus

It is a group of conducting wires which carries data only. Data bus is bidirectional because data flow in both directions from microprocessor to memory or Input/Output devices and from memory or Input/Output devices to microprocessor.

Length of Data Bus of 8085 microprocessor is 8 Bit (That is, two Hexadecimal Digits), ranging from 00 H to FF H. (H denotes Hexadecimal).

When it is write operation, the processor will put the data (to be written) on the data bus, when it is read operation, the memory controller will get the data from specific memory block and put it into the data bus.

The width of the data bus is directly related to the largest number that the bus can carry, such as an 8 bit bus can represent 2^8 unique values, this equates to the number 0 to 255. A 16 bit bus can carry 0 to 65535.

Control Bus

It is a group of conducting wires, which is used to generate timing and control signals to control all the associated peripherals. The control lines are used to control the access to and the use of the data and address lines. Because data and address lines are shared by all components, there must be a means of controlling their use. Some control signals are:

→Memory read → I/O read

→I/O Write →Memory write

→ Opcode fetch

Evolution of Microprocessors (Intel series)

The CPU of a computer consists of ALU, CU and memory. If all these components can be organized on a single chip by means of SSI, MSI, LSI, VLSI, ULSI, ELSI technology, then such chip is called microprocessor. It can fetch instructions from memory, decode and execute them, perform logical and arithmetic functions, accept data from input devices and send results to the output devices. The evolution of microprocessor is dependent on the development of integrated circuit technology from single scale integration (SSI) to giga scale integration (GSI).

Date	Microprocessor	Data bus	Address Bus	Memory
1971	4004	4-bit	10-bit	640 Bytes
1972	8008	8-bit	14-bit	16k
1974	8080	8bit	16bit	64k
1976	8085	8bit	16b it	64k
1978	8086	16bit	20bit	1M
1979	8088	8bit	20bit	1M
1982	80286	16bit	24bit	16M
1985	80386	32bit	32bit	4G
1989	80486	32bit	32bit	4G
1993	Pentium	32/64bit	32bit	4G
1995	Pentium pro	32/64bit	36bit	64G
1997	Pentium II	64bit	36bit	64G
1998	Celeron	64bit	36bit	64G
1999	Pentium III	64bit	36bit	64G
2000	Pentium IV	64bit	36bit	64G
2001	Itanium	128 bit	64bit	64G
2002	Itanium 2	128 bit	64bit	64G
2003	Pentium M/Centrino (wireless capability) for Mobile version e.g. Laptop			
	Core 2: X86 – 64 Architecture			

Assignment:

1. What do you mean by microprocessor? List out its application areas?
2. Explain Stored Program Concept and Von Neumann Architecture?
3. Draw the block diagram of basic microprocessor and explain its operation.
4. What is system bus? Explain its types.
5. Differentiate between Von Neumann and Harvard Architecture.