Lecture-1

An Overview of Microprocessor

The first question that comes in one's mind is "What is a microprocessor?". Let us start with a more familiar term computer. A digital computer is an electronic machine capable of quickly performing a wide variety of tasks. They can be used to compile, correlate, sort, merge and store data as well as perform complex calculations at much faster rate than human being by means of stored instructions.

A digital computer is different from a general purpose calculator in a sense that digital computer is capable of operating according to the instructions that are stored within the computer whereas a calculator must be given instructions on a step by step basis to perform calculations. By this definition a programmable calculator can be considered a computer.

Historically, digital computers have been categorized according to the size using the words large, medium, minicomputer and microcomputer. In the early years of development, the emphasis was on large and more powerful computers. Large and medium sized computers were designed to solve complex scientific and engineering problems. In early stage of development these computers were accessible and affordable only to large corporations, big universities and government agencies. Later on, minicomputers were made available for use in office, small collage, medium size business organization, small factory etc. As the technology has advanced from SSI to VLSI & SLSI, the face of the computer has changed gradually and it became possible to build the entire central processing unit (CPU) on a single-chip known as microprocessor.

A control processing unit (CPU) with its related timing functions on a single chip known as microprocessor. A microprocessor combined with memory and input/output devices forms a microcomputer.

The microcomputer is making an impact on every activity of mankind. It is being used in almost all control applications. For example analytical and scientific instruments, data communication, character recognition, musical instruments, household items, defence equipments, medical equipments etc.

Microcomputers or, in general, computers communicate and operate in binary numbers ‘0’ and ‘1’ also known as bits. A bit is the abbreviation for the term **b**inary dig**it**. The bit size of a microprocessor refers to the number of bit which can be processed simultaneously by the arithmetic circuit of the microprocessor. A number of bits taken as a group in this manner is called word. For example, the first commercial microprocessor the Intel 4004 which was introduced in 1971 is a 4-bit machine and is said to process a 4-bit word. A 4-bit word is commonly known as nibble and an 8-bit word is commonly known as byte. Intel 8085A is an 8-bit microprocessor whereas Intel 8086 is a 16-bit microprocessor. It should be noted that a processor can perform calculations involving more than its bit size but through program and takes more time to complete the operation. For example, multi-byte data can be added byte by byte in 8085A processor which is an 8-bit processor. The short word length requires few circuitry and interconnection in the CPU.

Microcomputers:

In a very general sense, a microcomputer is best regarded as a system incorporating a CPU and associated hardware whose purpose is to manipulate data in some fashion. This is exactly what any digital circuit designed using SSI’s and MSI’s does. Therefore, microcomputer should be regard as a general purpose logic device. In contrast to standard SSI’s and MSI’s where the manufacturer decides what the device will do, with microcomputer it is the user who decides what the device should do by asking it to execute a proper set of instructions. A microcomputer, from this point of view is merely an assembly of devices whose sole task is to ensure that the instruction desired are indeed carried out properly and to allow the microprocessor to communicate with the real world, i.e. the user environment. The power of the microcomputer lies in the fact that if the application changes, the same system can be used by appropriately modifying the instructions to be executed and, if necessary, some changes in the hardware. In contrast, a digit circuit designed using SSI’s and MSI’s for some application will need to be completely redesigned if the application changes significantly.

The objective of a microcomputer (μc) is to manipulate data in a certain fashion specified by the system designer. A typical microcomputer achieves their objective by getting its CPU to execute a number of instructions in the proper sequence. This sequence of instruction comprises the program that is executed by the microcomputer. A microcomputer which does nothing other than manipulate data present within itself, will not be of much use to anyone. In order to do something meaningful, data being manipulated should depend on inputs provided to the microprocessor by the user. Similarly, the data manipulations being carried out by the microprocessor would be completely meaningless unless the results of these manipulations affect things outside the microcomputer itself. Therefore, the µc should provide outputs which in some way depend on its inputs, the way inputs and outputs are related is decided by the program that gets executed.

Therefore, a microcomputer is an assembly of devices including a CPU, which manipulate data depending on one or more inputs and according to a program, in order to generate one or more output.

Microcontrollers

A µP does not have enough memory for program and data storage, neither does it has any input and output devices. Thus when a µP is used to design a system, several other chips, such as memory chips and input/output ports, are also used to make up a complete microcomputer system. For many applications, these extra chips imply additional cost and increased size of the product and may not be suitable for the application. For example, when used inside a toy, a designer would like to minimize the size and cost of the electronic equipment inside the toy. Therefore, in such applications a microcontroller is used more often than a microprocessor.

A microcontroller is a chip consisting of a microprocessor, memory and input/output ports.

Evolution of the Microprocessors

The first µP was introduced in 1971 by Intel Corporation. This was the Intel 4004, a processor on a single chip. It had the capability of performing simple arithmetic and logical operations. For example, addition, subtraction, comparison, logical AND and OR operations. It also had a control unit which could perform various control functions like fetching an instruction from the memory, decoding it and generating control signals to execute it. It was a 4 bit µP operating on 4 bits of data at a time. The processor was the central component in the chip set, which was called the MCS-4. The other components in the set were a 4001 ROM, 4002 ROM and a 4003 shift register.

Shortly after the 4004 appeared in the commercial market place, three other general purpose microprocessors were introduced. These devices were the Rockwell International 4-bit PPS-4, the Intel 8-bit 8008 and the National Semiconductor 16-bit IMP-16. Other companies had also contributed in the development of µP.

The first 8 bit µP, which would perform arithmetic and logic operations on 8 bit words, was introduced in 1973, by Intel. This was 8008 that was followed by an improved version- the 8080 from the same company. The µPs introduced between 1971and 1972 were the first generation systems. They were designed using the PMOS technology. This technology provided low cost, slow speed and low output currents and was compatible with TTL.

After 1973, the second generation µPs such as Motorola 6800 and 6809, Intel 8085 and Zilog Z80 evolved. These µPs were fabricated using NMOS technology. The NMOS process offered faster speed and higher density than PMOS and was TTL compatible.

The distinction between the 1^{st} & 2^{nd} generation devices was primarily the use of new a semiconductor technology to fabricate the chips. This new technology resulted in a significant increase in instruction execution speed & higher chip densities.

After 1978, the 3^{rd} generation microprocessors were introduced. Typical µPs were Intel 8086/ 80186/ 80286 and Motorola 68000/ 68010. These µPs were designed using HMOS technology. HMOS provides the following advantages over NMOS.

1) Speed power produced (SSP) of HMOS is 4 times better than that of NMOS. That is for NMOS, SSP is 4 picojoules (PJ) and for HMOS, SSP is 1 picojoules (PJ).

   Speed power product = speed * power
   = nanoseconds * mill watt
   = picojoules

2) Circuit densities provided by HMOS are approximately twice those of NMOS. That is for NMOS, it is 4128 μm^2/gate and for HMOS it is 1052.5 μm^2/gate.

Later, Intel introduced a high speed version of the 8085A called 8085AH using HMOS technology to fabricate the 8085A.

The third generation introduced in 1978 was typically separated by the Intel 8086 iAPX8086, iAPX80186, iAPX80286, Zilog 8000, and the Motorola 68000 which are 16- bit µPs with minicomputer like performance. One of the most popular 16-bit µP introduced by Intel was 8088. The 8088 has the same introduction set as the 8086. However, it has only an 8 bit data bus. The 8088 is the µP used in the

IBM PC and its clones. A precursor to these microprocessors was the 16-bit Texas Instruments 9900 microprocessor introduced in 1976.

Table: Evaluation of major µP **characteristics from Intel**

	4004	**8008**	**8085A**	**8086**	**80386**
Year of Introduction	1971	1971	1977	1978	1985
Data Bus	4-bit	8-bit	8-bit	16-bit	32-bit
Technology	PMOS	PMOS	NMOS	HMOS	CHMOS
Word size data/ instr.	4/8	8/8	8/8	16/16	32/32
Address capacity	4K	16K	64K	1M	4G
Clock kHz/phase	740/2	800/2	6250/2	8000/2	16000/2
Addition time	10.8 µs	20 µs	1.3 µs	0.375 µs	0.125 µs
ALU/General Purpose Reg.	1/16	1/6	1/6	1/8	1/8
Stack size	3x12	7x14	RWM	RWM	RWM
Voltages	15-10,5*	-9.5v	+5V	+5V	+5V
Package size	16pin	18pin	40pin	40pin	132pin
Instructions	45	48	74	133	135
Transistors	2,300	2,000	6,200	29,000	2,75,000
Chip size(mil)	117x159	125x170	164x222	225x230	390x390

In 1980, the fourth generation µPs were evolved. Intel introduced the first commercial 32 bit microprocessor, Intel 432. Since 1985, more 32-bit µPs have been introduced. These include

Intel iAPX80386, Intel 80486, Motorola MC68020/68030/68040, National semiconductor NS 32032. These processors were fabricated using the low power version of HMOS technology called HCMOS, and they include an on-chip RAM called the cache memory to speed up program execution. The characteristics for few microprocessors introduced by Intel are given in the Table.

This shows that power of microprocessors has increased tremendously with advancement in integrated circuit technology & microprocessor systems architecture. Very large scale integration, VLSI, allows extremely complex system consisting of as many as a million of transistors on a single chip to be realized.

The performance offered by a 32-bit µP is more comparable to that of supercomputers such as VAX 11. Extensive research is being carried out for implementation of more on chip functions and for improvement of the speed of the memory and I/O devices.

Applications of Microprocessors:

The application of microprocessors is increasing day by day. Some of the applications are:

1) Analytical scientific instruments
2) Smart terminals
3) Stacker crane controls
4) Conveyor controls
5) Word processor
6) Point of scale systems
7) Standalone electronics cash system
8) Electronic games

9) Vending and dispensing machines

10) Market scales

11) Traffic light controls

12) Home heating and lighting controls

13) Security & fire alarm system

14) Home appliances

15) Computer aided instruction

16) On line control of lab instrumentation

17) Desktop computers

18) Check processor

19) Payroll system

20) Inventory control

21) Automatic type setting

22) Compact business machines

23) Medical instrumentation

24) Automobile diagnostics

25) Data communication processing

26) Optical character recognition

27) I/O terminal for computers.