STUDY MATERIALS ON COMPUTER ORGANIZATION

(As per the curriculum of Third semester B.Sc. Electronics of Mahatma Gandh Uniiversity)

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1. INTRODUCTION

1.1 GENERATION OF COMPUTERS

The first electronic computer was designed and built at the University of Pennsylvania based on vacuum tube technology. Vacuum tubes were used to perform logic operations and to store data. Generations of computers has been divided into five according to the development of technologies used to fabricate the processors, memories and I/O units.

I Generation : 1945 – 55
II Generation : 1955 – 65
III Generation : 1965 – 75
IV Generation : 1975 – 89
V Generation : 1989 to present

First Generation (ENIAC - Electronic Numerical Integrator And Calculator
EDSAC – Electronic Delay Storage Automatic Calculator
EDVAC – Electronic Discrete Variable Automatic Computer
UNIVAC – Universal Automatic Computer
IBM 701)

- Vacuum tubes were used – basic arithmetic operations took few milliseconds
- Bulky
- Consume more power with limited performance
- High cost
- Uses assembly language – to prepare programs. These were translated into machine level language for execution.
- Mercury delay line memories and Electrostatic memories were used
- Fixed point arithmetic was used
- 100 to 1000 fold increase in speed relative to the earlier mechanical and relay based electromechanical technology
- Punched cards and paper tape were invented to feed programs and data and to get results.
- Magnetic tape / magnetic drum were used as secondary memory
- Mainly used for scientific computations.

Second Generation (Manufacturers – IBM 7030, Digital Data Corporation's PDP 1/5/8 Honeywell 400)

- Transistors were used in place of vacuum tubes. (invented at AT&T Bell lab in 1947)
- Small in size
- Lesser power consumption and better performance

- Lower cost
- Magnetic ferrite core memories were used as main memory which is a random-access nonvolatile memory
- Magnetic tapes and magnetic disks were used as secondary memory
- Hardware for floating point arithmetic operations was developed.
- Index registers were introduced which increased flexibility of programming.
- High level languages such as FORTRAN, COBOL etc were used - Compilers were developed to translate the high-level program into corresponding assembly language program which was then translated into machine language.
- Separate input-output processors were developed that could operate in parallel with CPU.
- Punched cards continued during this period also.
- 1000 fold increase in speed.
- Increasingly used in business, industry and commercial organizations for preparation of payroll, inventory control, marketing, production planning, research, scientific & engineering analysis and design etc.

Third Generation (System 360 Mainframe from IBM, PDP-8 Mini Computer from Digital Equipment Corporation)

- ICs were used
- Small Scale Integration and Medium Scale Integration technology were implemented in CPU, I/O processors etc.
- Smaller & better performance
- Comparatively lesser cost
- Faster processors
- In the beginning magnetic core memories were used. Later they were replaced by semiconductor memories (RAM & ROM)
- Introduced microprogramming
- Microprogramming, parallel processing (pipelining, multiprocessor system etc), multiprogramming, multi-user system (time shared system) etc were introduced.
- Operating system software were introduced (efficient sharing of a computer system by several user programs)
- Cache and virtual memories were introduced (Cache memory makes the main memory appear faster than it really is. Virtual memory makes it appear larger)
- High level languages were standardized by ANSI eg. ANSI FORTRAN, ANSI COBOL etc
- Database management, multi-user application, online systems like closed loop process control, airline reservation, interactive query systems, automatic industrial control etc emerged during this period.

Fourth Generation (Intel's 8088,80286,80386,80486 .., Motorola's 68000, 68030, 68040, Apple II, CRAY I/2/X/MP etc)

- Microprocessors were introduced as CPU– Complete processors and large section of main memory could be implemented in a single chip
- Tens of thousands of transistors can be placed in a single chip (VLSI design implemented)
- CRT screen, laser & ink jet printers, scanners etc were developed.
- Semiconductor memory chips were used as the main memory.
- Secondary memory was composed of hard disks – Floppy disks & magnetic tapes were used for backup memory
- Parallelism, pipelining cache memory and virtual memory were applied in a better way
- LAN and WANS were developed (where desktop work stations interconnected)
- Introduced C language and Unix OS
- Introduced Graphical User Interface

- Less power consumption
- High performance, lower cost and very compact
- Much increase in the speed of operation

Fifth Generation (IBM notebooks, Pentium PCs-Pentium 1/2/3/4/Dual core/Quad core.. SUN work stations, Origin 2000, PARAM 10000, IBM SP/2)

- Generation number beyond IV, have been used occasionally to describe some current computer system that have a dominant organizational or application driven feature.
- Computers based on artificial intelligence are available
- Computers use extensive parallel processing, multiple pipelines, multiple processors etc
- Massive parallel machines and extensively distributed system connected by communication networks fall in this category.
- Introduced ULSI (Ultra Large Scale Integration) technology – Intel's Pentium 4 microprocessor contains 55 million transistors millions of components on a single IC chip.
- Superscalar processors, Vector processors, SIMD processors, 32 bit micro controllers and embedded processors, Digital Signal Processors (DSP) etc have been developed.
- Memory chips up to 1 GB, hard disk drives up to 180 GB and optical disks up to 27 GB are available (still the capacity is increasing)
- Object oriented language like JAVA suitable for internet programming has been developed.
- Portable note book computers introduced
- Storage technology advanced – large main memory and disk storage available
- Introduced World Wide Web. (and other existing applications like e-mail, e Commerce, Virtual libraries/Classrooms, multimedia applications etc.)
- New operating systems developed – Windows 95/98/XP/…, LINUX, etc.
- Got hot pluggable features – which enable a failed component to be replaced with a new one without the need to shutdown the system, allowing the uptime of the system to be very high.
- The recent development in the application of internet is the Grid technology which is still in its upcoming stage.
- Quantum mechanism and nanotechnology will radically change the phase of computers.

1.2 TYPES OF COMPUTERS

1. **Super Computers**
2. **Main Frame Computers**
3. **Mini Computers**
4. **Micro Computers**

1. Super Computers E.g.:- CRAY Research :- CRAY-1 & CRAY-2, Fujitsu (VP2000), Hitachi (S820), NEC (SX20), PARAM 10000 by C-DAC, Anupam by BARC, PACE Series by DRDO

- Most powerful Computer system - needs a large room
- Minimum world length is 64 bits
- CPU speed: 100 MIPS
- Equivalent to 4000 computers
- High cost: 4 – 5 millions
- Able to handle large amount of data
- High power consumption
- High precision

- Large and fast memory (Primary and Secondary)
- Uses multiprocessing and parallel processing
- Supports multiprogramming

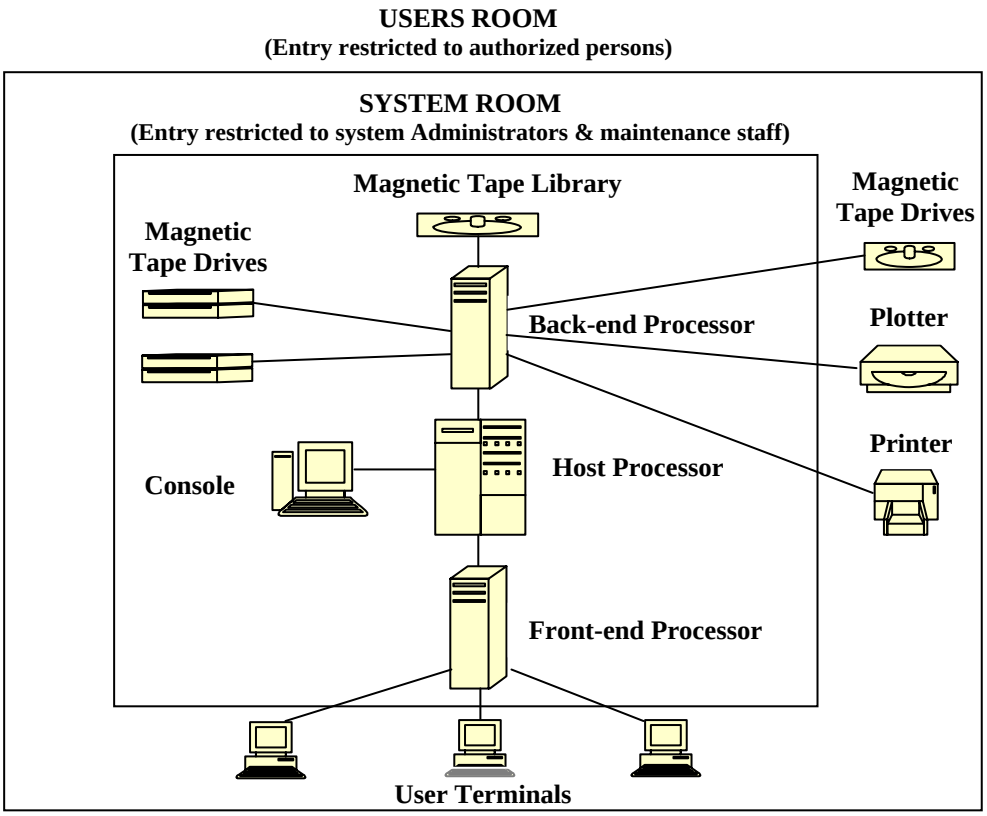
Applications

- In petroleum industry - to analyze volumes of seismic data which are gathered during oil seeking explorations to identify areas where there is possibility of getting petroleum products inside the earth
- In Aerospace industry - to simulate airflow around an aircraft at different speeds and altitude. This helps in producing an effective aerodynamic design for superior performance
- In Automobile industry – to do crash simulation of the design of an automobile before it is released for manufacturing – for better automobile design
- In structural mechanics – to solve complex structural engineering problems to ensure safety, reliability and cost effectiveness. Eg. Designer of a large bridge has to ensure that the bridge must be proper in various atmospheric conditions and pressures from wind, velocity etc and under load conditions.
- Meteorological centers use super computers for weather forecasting
- In Biomedical research – atomic nuclear and plasma analysis – to study the structure of viruses such as that causing AIDS
- For weapons research and development, sending rockets to space etc

2. Main Frame Computers

E.g.**:-** IBM 3000 series, Burroughs B7900, Univac 1180, DEC

- Able to process large amount of data at very high speed
- Supports multi-user facility
- Number of processors varies from one to six.
- Cost: 3500 to many million dollars
- Kept in air conditioned room to keep them cool
- Supports many I/O and auxiliary storage devices
- Supports network of terminals



Applications

- Used to process large amount of data at very high speed such as in the case of Banks/ Insurance Companies/ Hospitals/ Railways…which need online processing of large number of transactions and requires massive data storage and processing capabilities
- Used as controlling nodes in WANs (Wide Area Networks)
- Used to mange large centralized databases

3. Mini Computers

E.g.:- Digital Equipments PDP 11/45 and VAX 11)

- Perform better than micros
- Large in size and costlier than micros
- Designed to support more than one user at a time
- Posses large storage capacities and operates at higher speed
- Support faster peripheral devices like high speed printers
- Can also communicate with main frames

Applications

- These computers are used when the volume of processing is large for e.g. Data processing for a medium sized organization
- Used to control and monitor production processes
- To analyze results of experiments in laboratories
- Used as servers in LANs (Local Area Networks)

4. Micro Computers

E.g.:- IBM PC, PS/2 and Apple Macintosh

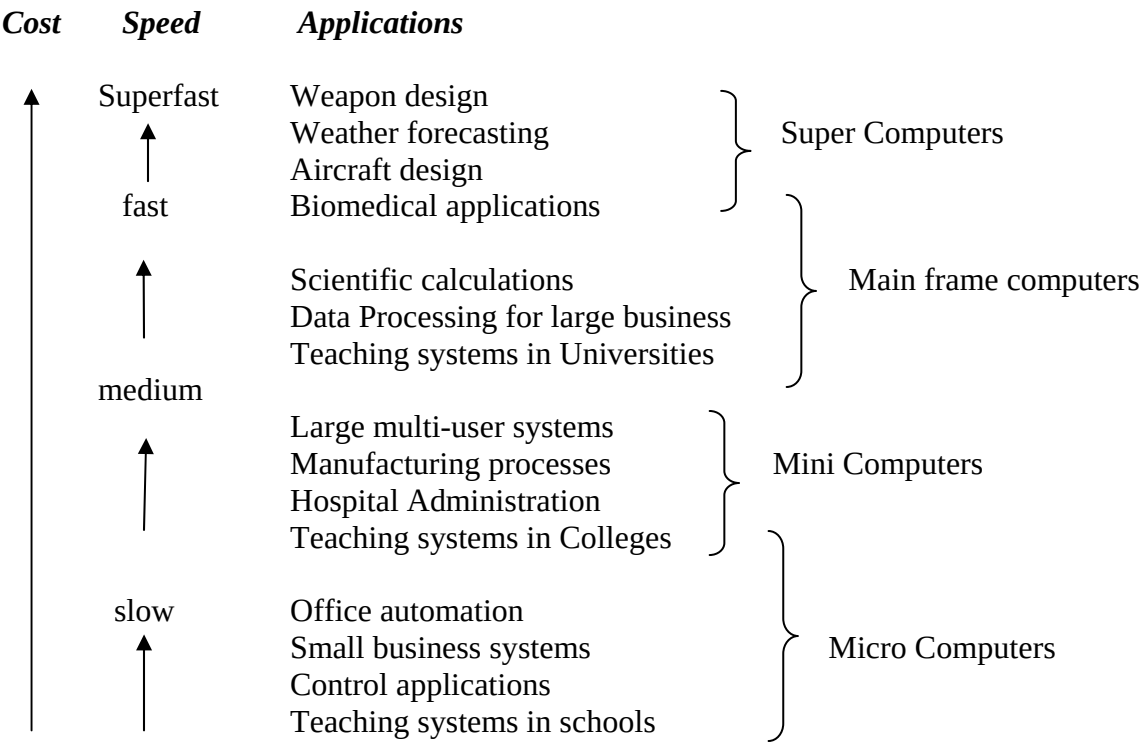
- A microcomputer uses a microprocessor as its central Processing Unit. Microcomputers are tiny computers that can vary in size from a single chip to the size of a desktop model
- They are designed to be used by only one person at a time
- Small to medium data storage capacities 500MB – 2GB
- The common examples of microcomputers are chips used in washing machines, TVs, Cars and Note book/Personal computers.

Applications

Used in the field of desktop publishing, accounting, statistical analysis, graphic designing, investment analysis, project management, teaching, entertainment etc

- The different models of microcomputers are given below:-

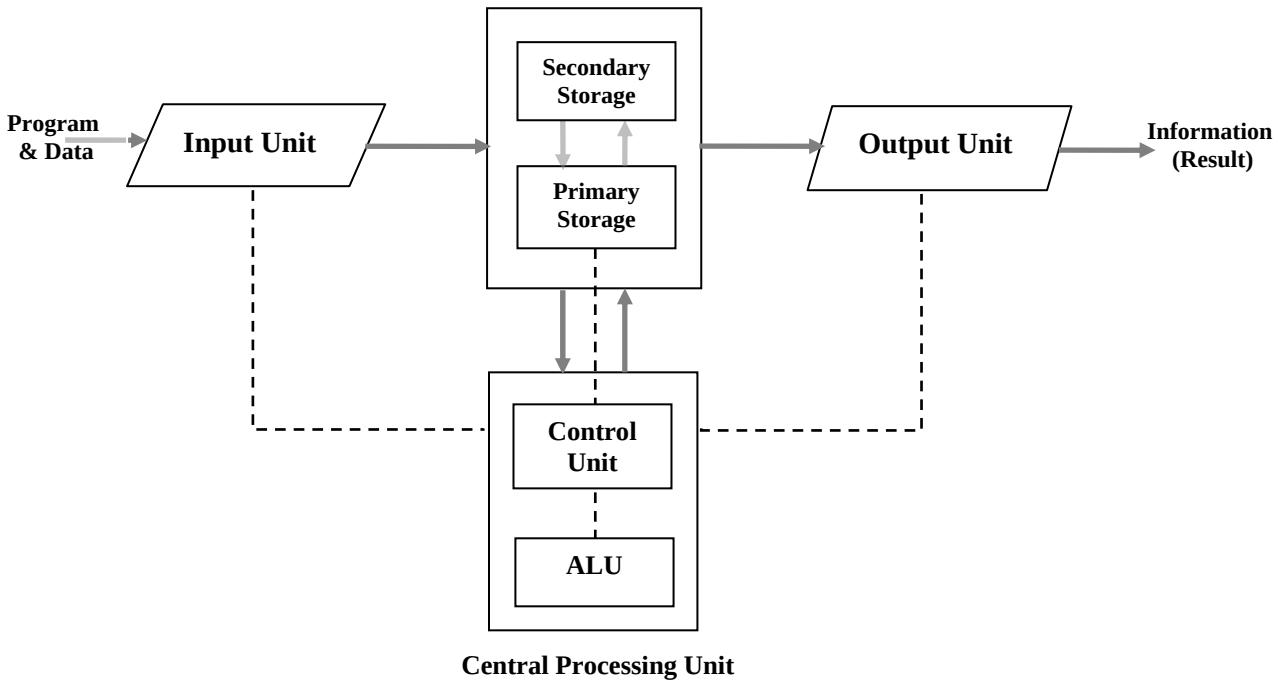
a) **Personal computers**:- The name PC was given by the IBM for its microcomputers. PCs are used for word processing, spreadsheet calculations, database management etc.
b) **Note book or Lap Top**:- Very small in terms of size – can be folded and carried around – Monitor is made up of LCD and the keyboard and system units are contained in a single box. Got all the facilities of a personal computer (HDD, CDD, Sound card, N/W card, Modem etc) and a special connection to connect to the desktop PC which can be used to transfer data.
c) **Palm Top**:- Smaller model of the microcomputer- size is similar to that of a calculator – pocket size- It has a processor and memory and a special connection to connect to the desktop PC which can be used to transfer data.
d) **Wrist PC**:- Smallest type of microcomputer – can be worn on our wrist like a watch- It has a processor and memory and a wireless modem



FUNCTIONAL UNITS OF A COMPUTER

Computer is a device that operates upon information or data. It is an electronic device which accepts input data, stores the data, does arithmetic and logic operation and outputs the information in desired format.

Even though the size, shape, performance, reliability and cost of computers have been changing over the years, the basic logical structure proposed by Von Neumann has not change. The internal architecture of computers differs from one system model to another. A block diagram of the basic computer organization specifying different functional units is shown below. Here the solid lines indicate the flow of instruction and data and the dotted lines represent the control exercised by the control unit.



INPUT UNIT

Input unit accepts coded information from human operators through electromechanical devices such as the keyboard or from other computers over digital communication lines. The information received is either stored in the memory for later reference or immediately used by the Arithmetic and Logic circuitry to perform the desired operation. Finally the result is sent back to the outside through the output unit.

The keyboard is wired so that whenever a key is pressed, the corresponding letter or digit is automatically translated into its corresponding code and sent directly to either the memory or the processor.

Other kinds of input devices: Joy stick, track ball, mouse (pointing devices), scanner etc.

MEMORY UNIT

The memory unit stores program and data. There are two classes of memory devices :- Primary memory and Secondary memory.

Primary memory (Main memory)

- Contains a large number of semiconductor cells each capable of storing one bit of information
- These cells are processed in group of fixed size called words containing 'n' bits. The main memory is organized such that the contents of one word can be stored or retrieved in one basic operation.
- For accessing data, a distinct address is associated with each word location.
- Data and programs must be in the primary memory for execution.
- Number of bits in each word is called the word length and it may vary from 16 to 64 bits.
- Fast memory
- Expensive
- Time required to access one word is called Memory Access Time - 10nS to 100nS. This time is fixed and independent of the location.

E g. Random Access Memory (RAM)

Secondary storage

- They are used when large amount of data have to be stored (also when frequent access is not necessary)

E.g. Hard Disk, Compact Disk, Floppy Disk, Magnetic Tapes etc.

PROCESSOR UNIT

- The heart of the computer system is the Processor unit.
- It consists of Arithmetic and Logic Unit and Control Unit.

Arithmetic and Logic Unit (ALU)

- Most computer operations (Arithmetical and logical) are executed in ALU of the processor.
- For example: Suppose two numbers (operands) located in the main memory are to be added. These operands are brought into arithmetic unit – actual addition is carried. The result is then stored in the memory or retained in the processor itself for immediate use.
- Note that all operands may not reside in the main memory. Processor contains a number of high speed storage elements called Registers, which may be used for temporary storage of frequently used operands. Each register can store one word of data.
- Access times to registers are 5 to 10 times faster than access time to memory.

Control Unit

- The operations of all the units are coordinated by the control unity (act as the nerve centre that sends control signal to other units)
- Timing signal that governs the I/O transfers are generated by the Control Unit.
- Synchronization signals are also generated by the Control Unit
- By selecting, interpreting and executing the program instructions the program instructions the control unit is able to maintain order and direct the operation of the entire system.

The control unit and ALU's are usually many times faster than other devices connected to a computer system. This enabled a single processor to control a number of external devices such as video terminals, magnetic taped, disk memories, sensors, displays and mechanical controllers which are much slower than the processor.

OUTPUT UNIT

- Counter part of input unit
- Output devices accept binary data from the computer - decodes it into original form and supplies this result to the outside world.

E.g. Printer, Video terminals (provides both input & output functions), graphic displays etc

Basic Operational Concepts:-

- Activity in a computer is governed by instructions
- To perform a given task, a set of instructions called program must be there in the main memory
- Individual instructions are brought from the memory into the processor which executes the specific operation.
- Data to be used as operands are also stored in the memory.

E.g. **Add LOCA, R_0**

This instruction adds the operand at the memory location LOCA to the operand in the Processor R_0 and places the sum into the register R_0. Here the original contents of LOCA are preserved whereas those of R_0 are overwritten.

Steps:-

1. Instruction is fetched from the main memory into the processor
2. Operand at LOCA is fetched

} ***Memory access operation***

3. Add the contents to the contents of R_0
4. Finally store the result in R_0

} ***ALU operation***

Note: Data transfer between the main memory and the processor are started by sending the address of the memory location to be accessed to the memory unit and issuing the appropriate control signal by the control unit.

INTERNAL ORGANIZATION OF PROCESSOR

Processor contains a number of registers used for temporary storage of data other than ALU and Control circuitry

Instruction Register (IR) – holds the instruction that is currently being executed – its output is available to the control circuits which generate the timing signals that control the various processing elements involved in executing the instruction.

Program Counter (PC) – It contains the address of the instruction currently being executed. During the execution of an instruction, the contents of the program counter are updated to hold the address of the next instruction to be executed. *i.e.* PC points to the next instruction that is to be fetched from the memory.

n General Purpose Registers (R_0 to R_{n-1}) – Facilitates communication with the main memory. Access to data in these registers is much faster than to data stored in memory locations because the registers are inside the processor. Most modern computers have 8 to 32 general purpose registers.

Memory Address Register (MAR) – holds the address of the location to or from which data are to be transferred
Memory Data Register (MDR) – contains the data to be written into or read out of the address location.

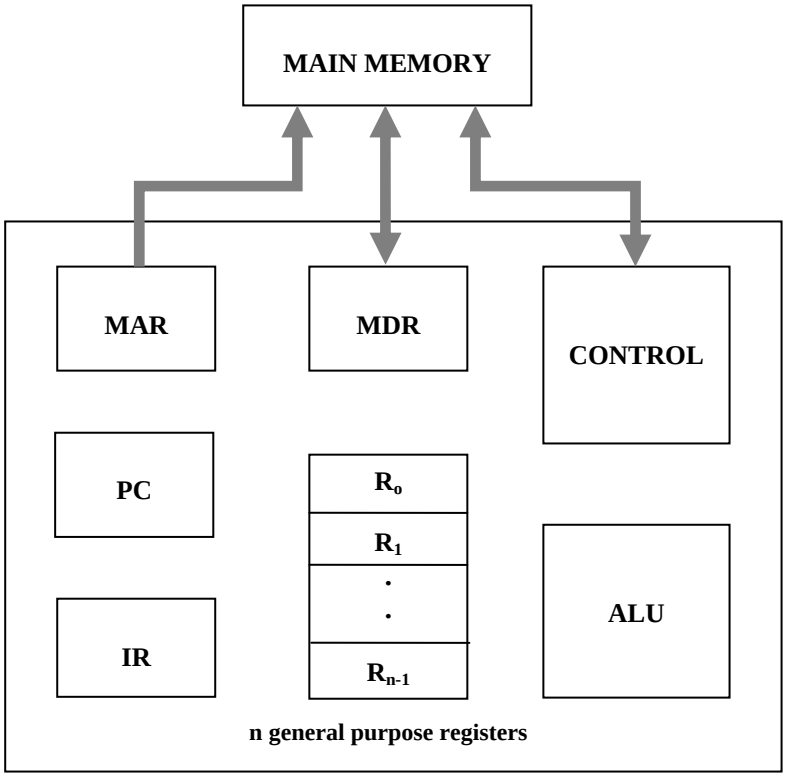


Fig: Processor

Steps involved during operation:-

1. Program is stored in the main memory
2. PC is set to point to the first instruction of the program
3. Contents of the PC are transferred to the MAR and a Read Control signal sent to the memory
4. After the access time, the addressed word (in this case the first instruction) is read out of the memory and is loaded into the MDR
5. Contents of the MDR are transferred to the IR. Now the instruction is ready to be decoded and executed.
6. If the instruction involves an operation to be performed by the ALU, the required operands are to be fetched from the memory (or CPU registers). This is done by sending its address to the MAR and initiating a Read cycle.

7. Operands are read from the memory into the MDR and are transferred from MDR to the ALU.
8. ALU will perform the desired operation.
9. If the result is to be stored in the memory, then it is sent to the MDR.
10. The address of the location where the result is to be stored is sent to the MAR and a Write cycle is initiated.
11. At some point during the execution of the current instruction, the contents of the PC are incremented so that the PC now points to the next instruction to be executed.
12. As soon as the execution of the current instruction is completed, a new instruction fetch may be started.

NOTE:- In addition to transferring data between the memory and the processor, the computer accepts data from input devices and sends data to output devices. For example, a sensing device in a computer controlled industrial process may detect a dangerous condition. Here the device raises an interrupt signal. An interrupt is a request from an I/O device for service by the processor. Now the processor provides the requested service by executing an appropriate interrupt-service routine. The internal state of the processor at such moments (like the contents of the PC, the general registers, and some control information) are saved in memory locations. When the interrupt-service routine is completed, the state of the processor is restored so that the normal program may be continued.