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Subject: (TEE-404) Microprocessors & Its Application

Unit I – Introduction to Microprocessor

An Overview of Microprocessor.

- Let us start with a familiar term computer.
- Computers are of two types: digital & analog computers.
- A digital computer makes processing of numbers.
- An analog computer processes analog signals. An analog signal is a continuous quantity.
- Now-a-days computers which are commonly used are digital computers.
- 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 calculations.
- A digital computer is different from a general purpose calculator in that it 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.
- By the definition a programmable calculator is a computer.

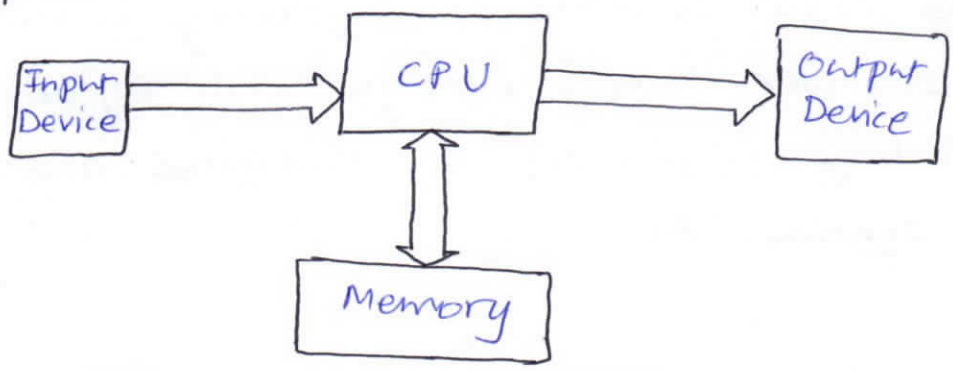

Fig. 1.1 Schematic digram of a digital computer.

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- Main components of a digital computer are:
  - I - CPU (Central Processing Unit) executes instructions
  - II - Memory is storing device (e.g. programs, data, results etc)
  - III - Input device used to feed programs and data
  - IV - Output Device display or prints (program, data, results etc)
- Historically, digital computers have been categorized according to the size using the words large, medium, minicomputer and microcomputer.

HISTORICAL BACK GRDUND

1947 : INVENTION OF TRANSISTOR

1959 : INVENTION OF INTEGRATED CIRCUIT

1965 : BIRTH OF MOORE'S LAW

1971 : DEVELOPMENT OF FIRST MICROPROCESSOR

1976 : INTRODUCTION OF FIRST MICROCONTROLLER

- Large and medium sized computers were designed to store complex scientific and engineering problems. These computers were accessible and affordable only to large corporations, big universities and government agencies.

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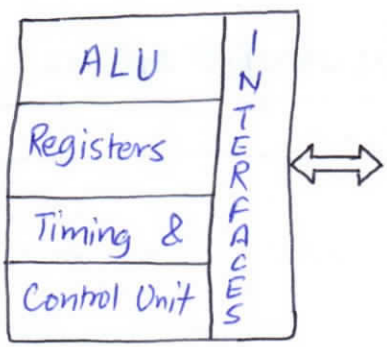
- With the invention of integrated circuit, In late 1960s minicomputers were available for use in a office, small Colleges, medium size business organization, small factory etc.
- As the technology has advanced from SSI to VLSI & SLSI (very large scale integration & super large scale integration) the face of the computer has changed.
- The central processing unit built on a single IC is called Microprocessor.
- A digital computer in which one microprocessor has been provided to act as a CPU, is called Microcomputer.
- So that complete CPU comprising all the components such ALU, Registers, Timing and control unit, interfaces etc. can be fabricated on a single IC is Microprocessor.



"CPU on a Chip"
Microprocessor.

Fig. 1.2. Schematic digram of a Microprocessor.

- First Microprocessor is 4-bit "4004" was intended for making a calculator and it was found that it has the

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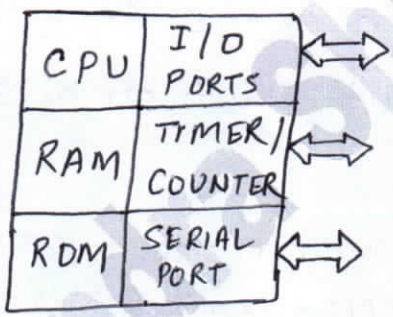
of a general purpose building block of any intelligent electronic device.

- Very soon first microcontroller was also invented.
- Microcontroller is not only comprises CPU but it is also comprising RAM, ROM, Input and output Port, Timer Counter, serial ports on a single IC.



"Computer on a single chip" Microcontroller.

Fig 1.3 Schematic Diagram of a Micro controller.

- First Microcontroller developed by INTEL known as "8048".
- Because of the evolution of IC Technology the history of the microprocessor development is very interesting.

Table 1.1 EVOLUTION OF IC TECHNOLOGY

YEAR	TECHNOLOGY		TYPICAL PRODUCTS
1947	Invention of Transistor	1	–
1950-1960	Discrete Components	1	Junction Diode, Transistors
1961-1965	SSI	10 -100	Planner devices, Logic Gates Flipflops etc.
1966-1970	MSI	100-1000	Counters, MUX, DECODERS ADDERS etc.
1971-1979	LSI	1000 -20000	8 Bit uP, RAM, ROM etc.
1980-1984	VLSI	20000 -50000	DSP ICs, RISC Processors 16 bits & 32 bits uP
1985 –	ULSI	>50000	64 bits uP etc.

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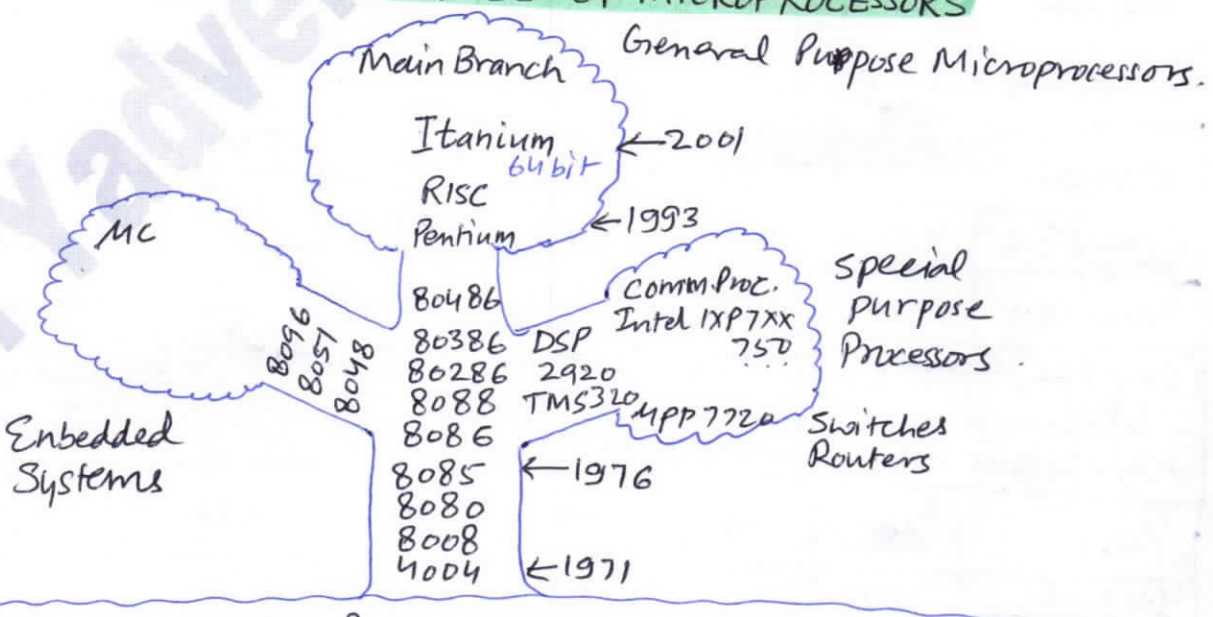
Word Length of A Computer or Microprocessor

- The word length of a computer or microprocessor is given as n-bit, where n may be 4, 8, 16, 32, 64 ... 2^n.
- An 8-bit microprocessor (or computer) can process 8-bit data at a time. If data consists of more than 8-bits of data, the processor takes up 8 bits of data first and makes its processing, then the next group of 8-bit data are taken up one by one for processing.
- A processor of longer word Length is more powerful and can process data at faster speed as compared to a processor of shorter word length.

EVOLUTION TREE OF MICROPROCESSORS



Main Branch : General Purpose Microprocessors.

Features Added in the evolution: 4bit → 8bit → 16bit → 32bit → 64bit
Pipelining, Superscalars, Cache Memory and various other features.
RISC → Reduced Instruction Set computer. (simplified Inst. set)

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Table 1.2 Evolution of Major Microprocessor's Characteristics

	4004	8008	8085A	8086	80386	Pentium
Data	71	71	77	78	85	
Lass	4 bit	8-bit	8-bit	16-bit	32-bit	32 bits
Technology	PMOS	PMOS	NMOS	HMOS	CHMOS	
Record size data / must	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	
Add time	10.8 μs	20 μs	1.3 μs	0.375 μs	0.125 μs	
Internal reg. all/gp	1/16	1/6	1/6	1/8	1/8	
Tale size	3*12	7*14	RWM	RWM	RWM	
Records / bits	150–10 ,5*					
Voltages		−9.5V	+5V	+5V	+5V	
Package Size introduction	45	48	74	83	135	
Transition	2300	2000	6200	29000	275000	
Chip size (mil)	117*159	125*170	164*222	225*230	390*390	
Manufactures	Intel	Intel	Intel	Intel	Intel	Intel
Pins	16	18	40	40	132	
Year of Introduction	1971		1976	1978		1993
Remarks.	1st MP		Popular 8-bit MP	Popular 16bit MP		2ALUs, 2caches FPU, 1.2 Million Transistors

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APPLICATIONS

General Purpose Microprocessors

- Desktop, PCs, Laptops, workstations, Servers, supercomputers etc.

Microcontrollers - (Embedded Systems)

- Embedded Systems is a combination of hardware and software designed for some specific function.
- Consumer Electronics – Toys, Cameras, Camcorders, Robots etc.
- Consumer Products – Washing Machine, Microwave Oven etc.
- Instrumentation - Oscilloscope, various Medical Instruments / Equipments.
- Process Control - Data acquisition and control various industries.
- Communication – Telephone sets, Answering Machines Cordless phones.
- Office Equipments - FAX machines, Printers, PABx
- Emerging Multimedia Application - PDAs, Cellphone Teleconferencing Equipments

Special Purpose Microprocessors

- DSP Processors, Switches, Routers, Intsurion Detections. etc.

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COMPUTER GENERATIONS

- The division of generations is decided primarily by the major changes in hardware technology and software.

First Generation (1946-1954)
- Used vacuum tubes as CPU components.
- High cost of vacuum tubes prevented their use for main memory, less costly but slower devices such as mercury delay lines were used for memory.
- Used machine language or assembly language for programming.
- Magnetic taps/ Magnetic drum were used as secondary memory.
- Subroutine linkage was not developed.
- No concept of operating System.
- Punched cards and paper tape were invented to feed programs and data, into the computer, and get results from the computer.
- Printers were used to get printed output.
- The first electronic digital computer ENIAC was completed in 1946. (ENIAC – Electronic Numerical Integrator and Calculator)
- EDVAC (Electronic Discrete Variable Computer, 1957)
- UNIVAC (Universal Automatic Computer, 1957)
- IBM 704 (1955), IBM 709 etc.

Second Generation (1955-1964)
- Transistors were used
- Magnetic ferrite core memory as main memory, Magnetic disk memory and Magnetic tapes were used as secondary memory.
- High level languages like FORTRON, COBOL and ALGOL were used as programming languages.

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Second Generation (contd. ...)

- Hardware for floating point arithmetic operations was developed.
- Index registers (which increased flexibility in programming), I/O processors (to supervise and control input/output operation) were introduced.
- Primitive supervisory programs such as batch monitors were introduced.
- Software like compilers, subroutine libraries, etc. were also supplied by computer manufacturers.
- Punched cards continued during this period.
- Examples: IBM 1626 (1960), IBM 7090 (1960), IBM 7094 (1962) Digital Data Corporation's (DEC's) PDP1 (1957), PDP5 (1963), PDP 8 (1965), Control Data Corporation's CDC 1604 etc. (PDP – Programmed Data Transfer)

Third Generation (1965–1974)

- used ICs (SSI and MSI) in CPU, I/O processors and other electronic components.
- Improved magnetic core memory as main memory (upto 4M bytes) and magnetic disks were used as secondary memory. Magnetic tapes were used as back-up memory.
- Later on semiconductor memories (RAMs and ROMs) (upto 100 M bytes' disk drives) replaced magnetic core type main memory.

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Third Generation (Contd...)

- Cache memory was also introduced.
- Microprogramming, parallel processing (pipelining, multiprocessor system etc.), multiprogramming, multiuser system (time-shared system), etc. were introduced.
- When a CPU contains more than one functional units and each functional unit performs a part of the task independently, this technique is called pipelining.

Examples: IBM/370 series (1970), CDC 7600 (1969), PDP 11 (1970 16bit computer), CDC's CYBER-175 and STAR-100 etc.

Fourth Generation (1973-1990)

- used microprocessor(s) as CPU.
- Memory supporting chips, I/O processors, controllers etc. also use ICs (LSI/VLSI chips).
- With the development of VLSI technology, all components alongwith the CPU on a single IC i.e the microprocessor's chip.
- Multifunctional peripheral chips providing functions of interrupt controller, DMA controller timer/counters, bus controller etc on a single IC were developed.
- Single chip microcomputer were developed.
- CRT screen, Laser printers, inkjet printers, scanners etc. were developed.
- Semiconductor memory chips (upto 4Mbits on a single chip) constitute the main memory.

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Fourth Generation (contd...)

- Floppy disk and magnetic tapes were used for back up memory.
- Desktop, portable notebook and workstations were available.
- High speed LANs and WANs were developed.
- The operating system MS-DOS, Apple's Macintosh with GUI (Graphic User Interface), an object oriented language C++ etc were developed.
- Examples: Intel's 8088, 80286, 80386 and 80486, Motorola's 68000, 68020, 68030 and 68040 CRAY-1, CRAY-2, CRAY X-MP, CRAY Y-MP supercomputers. IBM 3090, VAX 9000 etc.

Fifth Generation (1991-Present)

- Use VLSI and ULSI chips.
- Superscalar processors, vector processors, SIMD processors, 32-bit micro-controllers, embedded processors, DSP (Digital Signal Processors), symbolic processors etc. have been developed.
- They can accept spoken commands besides text commands.
- Image commands also accepted.
- System based on artificial Intelligence are available.
- Use parallel processing, multiple pipelines, multiple processors etc.
- Memory chips upto 1Gbits, hard drives upto 4 Terabytes and Optical disk upto 50 GB are available.

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Fifth Generation (Contd...)

- Hetrogeneous processing has been developed.
- Internet connects the whole world.
- Video conferencing has been developed.
- Programming is become very easy to understand.
- Object oriented language JAVA, suitable for Internet programming has been developed.
- Operating systems developed during fifth generation periods are: WINDOWS-95, 98, XP, Windows2000, 2003; WINDOWS-7, WINDOWS-8, Apple's MAC OS-8, 9 and X, SUN's Solaris, LINUX, Google's Android etc.
- Examples of processors are: Intel's Pentium
  Intel's Pentium II, Pentium III
  Intel's Pentinm 4,
  Itanium
  Intel's Core i7, i5, i3
  and other multiprocessors.,
  AMD's Athlon 64 and Opteron
  SUN's UltraSPARC III and 4++
  Motorola's Power PC compaq's Alpha
  MIPS processors etc
- Processing time is in nanoseconds.

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Unit I - Introduction to Microprocessor

EDUCATIONAL NEED

- Hard ware Designer
- Soft ware Designer
- System Integrator

Three-In-One
So that low cost equipments can be develope.

COURSE OUTLINE

- Architecture and Organization of Microprocessor.
- Instruction Set Architecture
- Assembly Language Programming
- Interfacing of Memory Devices
- Data Transfer Techniques
- I/o Ports
- Interfacing of I/o Devices
- Building Complete Microprocessor based systems.

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Unit I - Introduction to Microprocessor

REVIEW QUESTIONS

- When did the invention of Transistor took place and where?
- What is an Integrated circuit?
- When was Microprocessor's first introduced?
- What is Moore's Law?
- What are consequences of Moore's Law?
- What is Microcontroller? How does it differ from a Microprocessor?

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Unit I - Introduction to Microprocessor

MICROCOMPUTER ORGANIZATION

- The basic components of a microcomputer are:
  1- CPU (Central Processing Unit)
  2- Program Memory
  3- Data Memory
  4- Output Ports
  5- Input Ports
  6- Clock Generator
- These components are shown in figure below:

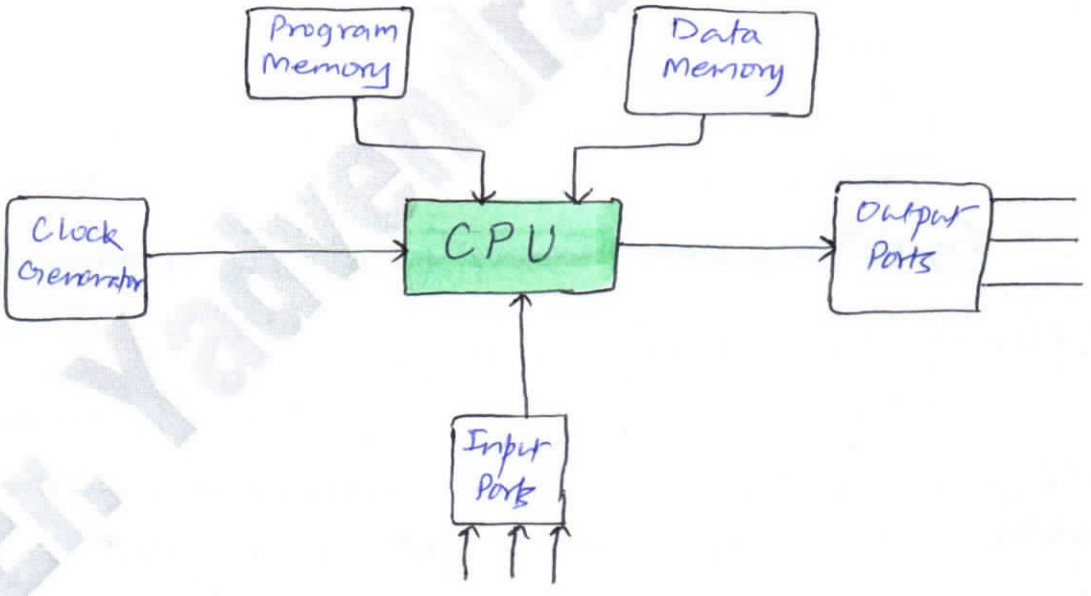

Fig 1.4 Microcomputer Organization.

CPU (Central Processing Unit)

- The CPU is the brain of a computer.
- It executes users programs.

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Unit I - Introduction to Microprocessor

CPU (Contd...)

- The CPU consists of ALU (Arithmetic and Logic Unit), Register unit and control unit.
- The CPU retrieves stored instructions and data word from memory.
- It deposits processed data in memory.

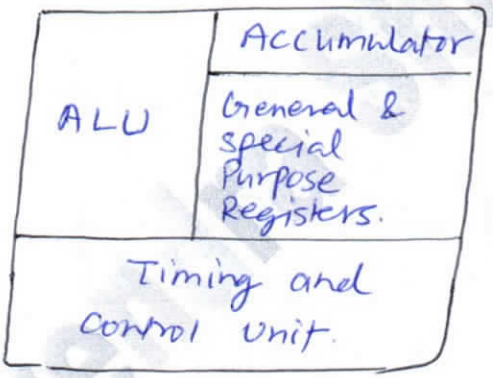

Fig 1.5 Schematic digram of a CPU (or Microprocessor)

ALU (Arithmetic and Logic Control)

- This section performs computing function on data.
- These functions are arithmetic operations such as additions, subtraction, multiplication* and division* and logical operation such as AND, OR rotate etc.
- Results are stored either in registers or in memory or sent to output devices.

* Simple less powerful microprocessor such as Intel 8085 does not have these instructions.

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Unit I – Introduction to Microprocessor

Timing and Control Unit- (Clock Generator & Control Unit)

- Operations inside the microprocessor as well as in other parts of microcontroller, are usually synchronous by nature.
- The clock generator generates the appropriate clock periods during which instruction executions are carried out by the microprocessor.
- Some of the microprocessors have an internal clock generator circuit to generate a clock signal.
- These microprocessors require an external crystal or RC network to be connected at the appropriate pins for deciding the operating frequency.
- Some microprocessors require an external clock generator. These microprocessors also provide an output clock signal which can be used by other devices.
- It provides necessary timing and control signals necessary to all the operations in the microcomputer.
- It control the flow of data between the microprocessor and peripherals (input, output & memory).
- The CPU has three basic functions.
  1- It fetches an instructions word stored in memory.
  2- It determines what the instruction is telling it to do. (decodes the instruction)
  3- It executes the instruction. Executing the instruction may include some of following major tasks.

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Unit I - Introduction to Microprocessor

Timing and Control Unit (Contd...)

i- Transfer of data from reg. to reg. in the CPU itself.
ii- Transfer of data between a CPU reg. and specific memory location.
iii- Performing arithmetic and logical operations on data from a specific memory location or a designated CPU register.
iv- Directing the CPU to change a seqnence of fetching instruction, if processing the data created aspecific condition.
v- Performing housekeeping function within the CPU itself in order to establish desired condition at certain registers.

4- It looks for control signal such as interrupts and provides appropriate responses.
5- It provides states, control, and timing signals that the memory and input-/output section can use.

Register Unit

- It contain various registers.
- The registers are used primarily to store data temporarily during the execution of a program.
- Some of the registers are accessible to uses through instructions.

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MEMORY

- Memory is an essential component of a digital computer.
- It is needed to store programs, data and results.
- A computer uses a number of memory and optical memory.
- The speed of memory should also be very high and it must match the speed of the CPU.
- To match the speed of the CPU a very high speed semiconductor memory called cache memory is directly connected to the CPU. (speed about 10ns)
- The next level of memory which is used in a computer system is the main or primary or (DRAM) memory. It is also a fast semiconductor memory. (speed about 50ns). It is cheaper than cachememory.
- The memory which stores information permanently is called secondary or auxiliary or (ROM) memory. e.g. magnetic and optical disks.
- The terms program and data memory are used with single chip microcomputers (micro controllers) which are used for industrial control, instrumentation appliances control and other dedicated application
- The memory of the microcontroller which stores fixed program is known as program memory.
- The memory of the microcontroller which stores data during processing is called data memory.

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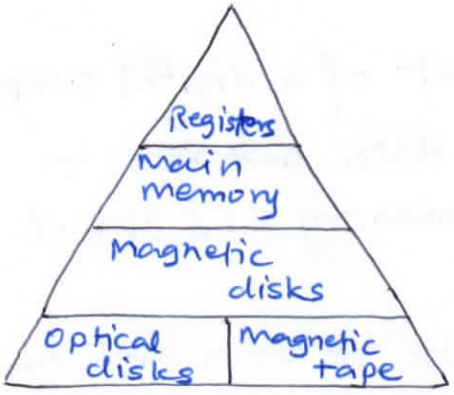

Fig 1.6 Memory Hierarchy

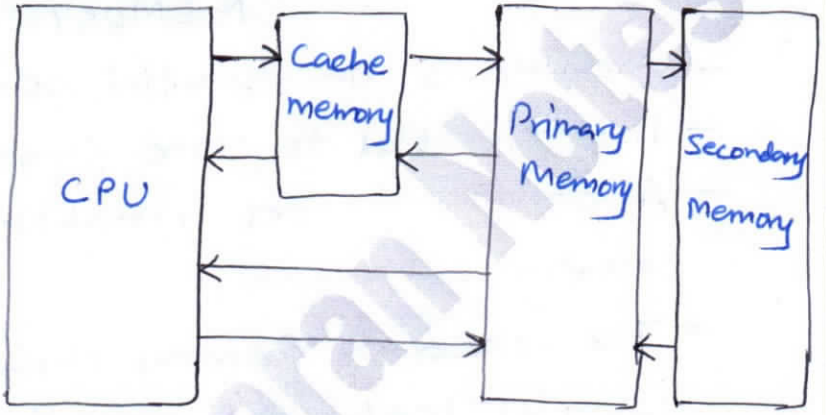

Fig 1.7 Connection of different types of memory.

Program Memory

- The instruction sequence is stored in the program memory on initialization - usually a power up and manual reset the processor starts by executing the instruction in a predetermined location in the program memory.
- The first instruction of the program should therefore be in this location in typical up basic system, the program to be executed is fixed one which does not change. Therefore up program are store on ROM, or PROM, EPROM, EEPROM (internally or externally)

Data Memory

- Apart from intermediate storage, the data memory may also be used to provide data needed by the program, to store some of the results and for all storage purposes other than storage of program.
- RAM is used as a data memory in a microcontroller.

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SEMICONDUCTOR MEMORY

- There are two types of semiconductor memory.
- RAM (Random Access Memory) used as Reed / write memory
  - In RAM any memory location can be accessed in a random way without going through any other location.
  - Access time is same for every memory location.
  - RAM is not the correct name because ROM has also random access property. The correct name should be reed/write memory.
  - RAM is a volatile memory. It stores information as long as power is supplied to it.
  - There are two types of RAM:

    Static RAM (SRAM) retains the stored information as long as power supply is on. It uses conventional flip-flop circuit consisting of two cross-coupled inverters, to store binary bits.
    A RAM memory cell must be associated with reed and write facility. Six transistors are needed to form a memory cell of SRAM. Hence, its packing density is low. It consume more power. It is faster than DRAM.

    Dynamic RAM (DRAM) loses its stored information in a few milliseconds even though its power supply is on. It stores information in the form of charge on a capacitor, which leaks away in very short time. It is manufactured in smaller sizes. (upto 1 Gbits on a single chip)

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SDRAM (Synchronous DRAM) uses the same clock rate as the CPU. As a result the memory chips remain ready to transfer data when the CPU expects them to be ready. They run at the processor memory bus without imposing wait states. On the other hand, DRAM is an asynchronous device.

SGRAM (Synchronous Graphics RAM) It is synchronous RAM suitable for graphics applications.

DDR SDRAM (Double Data Rate SDRAM) has an evolutionary advancement over SDRAM as it doubles the data transfer rate.

The standard SDRAM does all actions on the rising edge of the clock signal. On the other hand DDR SDRAM transfer data on both edges of the clock for burst data transfer. To achieve double data rate, the memory cell array is arranged in two banks. Each bank can be accessed separately.

DDR2 and DDR3 are later versions of DDR.

Data transfer rates of DDR, DDR2 and DDR3 are 0.4, 0.8 and 1.6 Gbps respectively. DDR3 operates at 1.5 volts, whereas DDR2 operates at 1.8 volts

GDDR3 and GDDR4 memory are used is graphics cards GDDR5 is later version

- After the unsuccessful incorporation of RDRAM of RAMbus company has developed an improved RAM called XDR DRAM. It uses Octal Data Rate (8 bits of data per clock cycle i.e. 6.4 Gbps) which is higher than that of DDR2 or DDR3. Its operating frequency is 400 MHz.

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- Samsung and some other companies are manufacturing XDR, XDR2 will be later version, with 16 Gbps peak bandwidth.

FPRAM is Fast Page Dynamic RAM

Quad Data Rate RAM (a form of static RAM) is used in switches and routers.

- Error Detection and Correction in RAMs are used. (e.g. Parity checking for single bit errors and Hamming code for multibit errors.

SIMM (Single In Line Memory Module)

→ SIMM is small circuit board on which DRAM memory chips are placed. This board vertically plugs into a single socket on the main system board of computer (motherboard)
→ Contacts are placed on only one edge of the PCB
→ For Example, 1MX8, 4MX8 and 16MX8 bit SIMM all the same 30pins socket.
→ 1MX32 or 1MX36 for 72 pins SIMMS
→ other sizes 2MX32, 4MX32 or 8MX32
→ The capacity of 4MX36 SIMM is 16 M bytes.

DIMM (Double In-Line Memory Module)

→ Contacts are placed on both sides of the PCB.
→ DDR2 RAM has been widely used in server.
→ Now FB-DIMM has arrived it has more memory bandwidth than DDR2 and DDR3. It includes an advanced memory buffer (AMB) between the memory controller and memory module.

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ROM (Read Only Memory)

- ROM is non volatile memory. It stores information permanently
- Its contents are not lost when its power supply is switched off.
- It is not accessible to user, and hence he can not write anything into it.
- It is used to store initializing programs of a computer, microcodes of a CISC processor, supervisory programs of a up kit, fixed programs in MC etc.
- Its contents are written at the time of its IC fabrication
- It is simple, cheap and dense. It uses one transistor memory cell.

PROM (Programmable ROM)

- The user can write a program, data or any other kind of information permanently into a PROM.
- PROMs are only once programmable by PROM programmer.
- Universal PROM programmer is also available which is more powerful and provide greater facilities, and accepts a variety of PROMs.

EPROM (Erasable PROM)

- Its contents can be erased and it can be reprogrammed more than once.
- To erase its contents it is exposed to high intensity short wave ultraviolet light for about 20 minutes. (wavelength of 2537 Å)
- The entire contents are erased in this process.
- It is cheap and reliable.

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EEPROM or E^2PROM (Electrically erasable PROMs) or EAROM
- It is also called EAROM (Electrically Alterable ROM)
- It is not required to be removed from the mother board for erasure.
- EEPROM is byte erasable. So, selective erasure of its contents is possible.
- Its disadvantage is that different voltages are required for erasing, writing and reading the stored information. (pulse of 21 volts for writing or erasing and 5V for read)
- It has low density, high cost and lower reliability.

Flash Memory
- It is electrically erasable and reprogrammable.
- It is inherently non volatile memory.
- Unlike EEPROM, flash memory uses one transistor memory cell resulting in high packing density, lower cost and higher reliability. (Less power consumption)
- Its one transistor memory cell is controlled by trapped charge. It uses floating gate transistor contain two gates
  - a control gate and a floating gate
- Whereas a metal oxide semiconductor field Effect transistor (MOSFET) uses only one gate.
- In flash memory device, it is possible to read and write the content of a single cell, but it is not possible to write to a single cell. It allows to write entire block.
- Before writing to a block, its previous contents are erased.
- It has blocks (e.g. 128 MB chip has 8192 blocks of 16 KB each)

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Input-/Output Ports

- The input and output ports provide the µC the capability to communicate with outside world.
- The user can enter instruction and data in memory through input devices (e.g. keyboard, simple switches CRT, disk devices, tape or card readers.
- Computers are also used to measure and control physical quantities like temperature, pressure, speed etc. For these purposes, transducers are used to convert physical quantise into proportional electrical signals.
- The computer sends the results of the computation to the output devices e.g. LED, CRT, D/A converters, printers etc.
- These Input/output (I/O) devices are called peripherals.