BCA - 2nd Year

3rd semester

Computer Architecture and Assembly language

Unit ⇒ 1

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★ **Introduction :-** Computer Architecture is a set of rules and method that describe the functionally, organisation and Implementation of Computer System. Some definitions of Architecture define it and describing the capabilities of programming model of a computer.

✓ Computer architecture involves instructions at architecture design, micro architecture design, logical design and Implementation.

M.Imp There are three categories of computer arch. :-

1- **System design :-** This includs all hardware components in the system, including data processor aside from the CPU such as graphics designing units and direct access memory.

2- **Instruction set Architecture (ISA) :-** This is the embedded programming language of the central Processing unit. ✓ It define the CPU's functions and capabilities

based on what programming it can perform or process. This include the word size, processor register type, memory addressing mode, data formate and the instruction set that programers use.

3- Micro Architecture :-
It known as Computer organisation. This type of architecture define the data path, data processing and storage elements, as well as how they should be implemented in the ISA.

* Basic Concepts of Component of Computer Architecture :-
The model of a computer can be described by four basic units in high level abstraction. These basic units are :-
1) Central Processing unit (CPU)
2) Input device
3) Output device.
4) Memory unit

1- Central Processing unit :-
Central Processing unit consist of two basic block.

i) The program control unit has a set of registers and control circuits to generate control signals.

ii) The execution unit or data processing unit contain a set of registers for storing data and an arithemetic and logic unit. ALU. For execution of arithematic and logical operations.

- In addition, CPU may have some additional registers for using temporary storage the data.

2- Input device :-
With the help of Input unit data from outside can be supplied to the computer. program or data is read by the Input unit.
ex :- keyboard, mouse,

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3- Output device :-
With the help of output unit computer results can be provided to the user or it can be stored in storage device permanently for the future use.
ex:- Printer, Monitor, plotter, Scanner.

4- Memory unit :- Memory unit is use to store the data and program. This memory is termed as primary memory or main memory.

i) Primary memory :-
Primary memory is a temporary memory which store the data only when the work on it. This memory data automatically storage destroyed. When your system will be shut-down.
ex:- RAM, ROM, EROM, PROM, EPROM, EEROM.

(ii) Secondary memory :-
Secondary memory is use to permanent storage of data and program.
ex:- Harddisk Hardisk, floppy disk, CDROM.

★ Program execution and Instruction execution

★ Instruction :- In computer architecture, an instruction is a single operation of a processor define by the processor instruction set. The size or length of a instruction is 4 bits.

★ Instruction code :- An Instruction code is a group of bits that instruct the computer to perform a specific operation. An Instructions must also include one or more oprands. Which indigate the registers and / or memory addresses from which data is taken or to which data is deposite.

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★ Instruction formate :-
An Instruction formate defines the layout of a bit of an Instruction. An Instruction formate must include an opcode and zero or more operands Implicitly and explicitly. Its explicit oprands is referenced using one of the addressing mode that is available in the machine.

★ OPcode :- An opcode is a single instruction that can be executed by the CPU. In machine language it is a binary no. or hexadecimal no. which is loaded into instructions registers.

★ Operand :- Operand are manuplated by opcode.

★ Execution :- It is a process to of the program into memory to decode. Instructions are perform functionality according the demand of program.

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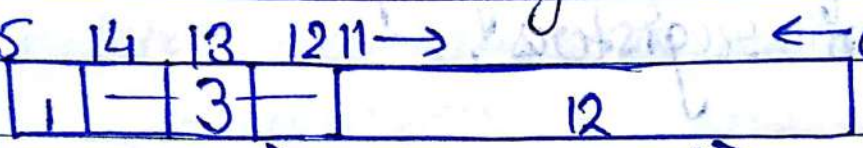
✱ Timed and control In CU (central unit).

IR (Instruction Register) (16 bits)



- It provides timing and control signals to the micro processor to perform the various operation. It has three control signals. It controls all external and internal circuits. It operates with reference of clock signals. It synchronizes or the data transfer.

1- ALE (arithmetic latch enable) :-

It provide control signals to synchronizes the component of micro processor.

2- WR (write) :-

This is used for writing operation in instruction register.

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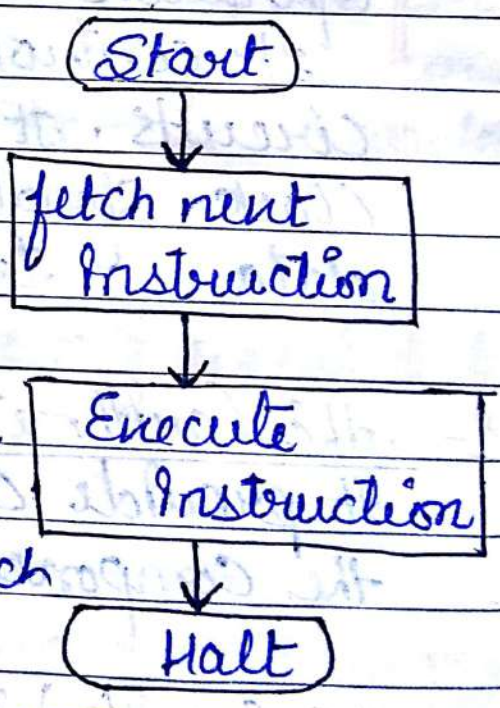
3- RD (Read) :-
It is used for reading operation in instruction registers.

- There are status signals use in micro processor. S0, S1 and I/O/m (memory). It changes its status. According the providing in put to the instruction registers.

4. Instruction Cycle :-



An instruction cycle (also known as the fetch-decode-Execute cycle or fetch execute cycle) is the basic operational process of a computer. It is the process by which a computer retrieves a program instruction from its memory, determines what actions the instruction dedicate and carry out these actions.

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• There are four step of Instruction cycle.

1- Fetch - Retrieve and Instruction from the memory.
2- Decode - Translate the retrieved Instruction into a series of computer command.
3- Execute - Execute the computer command.
4- Store - Send and write the results back In memory.

★ Program counter (PC) :-
An Intrementry counter that keeps track of the memory address of the Instruction that is to be executed next or hold the address of the Instruction to be executed next.

★ Memory address register (MAR) -
It hold the address of a block of memory for reading form or writing too.

★ Memory data register (MDR) -
A two Way register that hold data

fetched from memory (and ready for the CPU to process) or data writing to be stored in memory (this is also known as memory buffer register (MBR).

★ Instruction register (IR):-
A temporary holding ground for the instruction that has just we fetch from memory.

NOTE:- CIR (Current Instruction Register) -
An instruction register which process or called currently being executed or decoded that register is called CIR.

★ Control unit (CU) -
Decode the program instruction in IR selecting machine resources such as a data source register and a particular arithmetic operation and coordinate activation of those resources.

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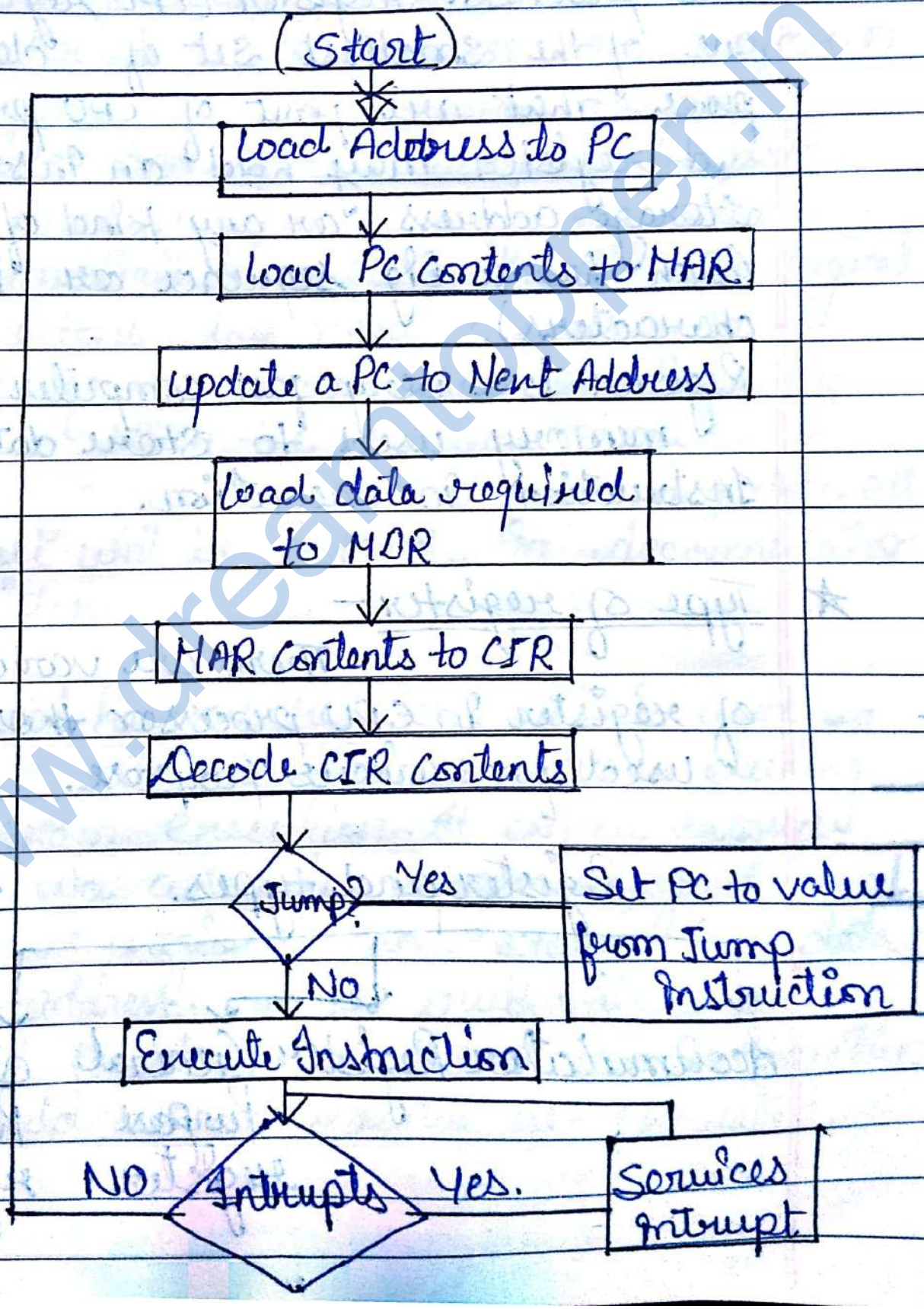
★. Block diagram of Instruction Cycle-



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★ Registers and Its types –

A processor register (CPU register) is one of the smallest set of data holding place that are part of CPU processor.
A register may hold an instruction, storage address or any kind of data (such has a big sequence or individual characters).
Register is a very fast computer primary memory used to store data/ instruction in execution.

★ Type of register –

There are various type of register in CPU processor those are used for various purpose.

Register and types.

- Accumulator Register
- General Purpose register
- Special Purpose register

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1- Accumulator Register :- In computer central processing unit (CPU) an accumulator register is a register which perform connection b/w general purpose register and special purpose register.
Accumulator register perform intermediate b/w arithmetic and logical operations. This register is used to storing the results those produce by CPU. When the CPU with generates some results after the processing then all result will be stored in Accumulator register.

2- General Purpose register :- This is used to store data intermediate results during program execution. It can be excessed via assembly programming. General purpose register can store both data and address. It so truth value often used to determined the some instructions should or should not be executed.

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★ Special purpose Register –
Users do not access these registers. These registers reserved for computer System. There are many types of special purpose register according to their purpose.

1- MAR- Memory Address register
2- PC- Program counter.
3- MBR- Memory buffer register.
4- MDR- Memory data register
5- IR – Instruction register.
6- CIR – Current Instruction register.
7- Index register.

• MBR:-
Memory buffer register store Instruction and data received from the memory and sent from the memory.
This register hold the content of data or Instructions read from or write in memory. It means that register is used to stored data / Instructions. Coming from the memory or going to the memory.

- **Index Register:-** An Index register in a CPU is a processor register used for modifying operand addresses during the run of program an execute the program.
it hardware element which hold a no. that can be added to (In case of subtract form). the address portion of a computer instruction to form an effective address. Index register also known as base register.

Imp ★ **Micro-operation:-** Micro-operation In computer CPU micro-operation (also known as micro-ops), are the functional or atomic operation of a processor. Micro-ops are low level instructions. Micro-ops perform basic ops. on data (which is stored in registers) and also transfer the data between registers and buses.

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Types of micro-operation -

1. Arithmetic micro-operation
2. Logic micro-operation
3. Shift micro-operation
4. Register transfer.

1. Arithmetic micro-operation -

This micro operation performs the basic arithmetic operations like - addition, subtraction, Increment, decrement.

Example -

$R_3 \leftarrow R_1 + R_2$ Content of R_1 plus R_2 transfered to R_3
$R_3 \leftarrow R_1 - R_2$ Contents of R_1 minus R_2 transfered to R_3
$R_2 \leftarrow R_2'$ Complement the contents of R_2
$R_2 \leftarrow R_2' + 1$ 2's complement the contents of R_2 (Negate)
$R_1 \leftarrow R_1 + 1$ Increment
$R_1 \leftarrow R_1 + -1$ Decrement.

2. Logic micro-operation -

Logic micro-operation are bitwise operation, they work on the individual bits of data.

Logical micro operation perform these logic operations -

1. AND ($\wedge$)
2. OR ($\vee$)
3. XOR ($\oplus$)
4. Complement / Not

Example -

x 0011 y 0101	Boolean function	Micro-operation	Name
0000	$f_0 = 0$	$f \leftarrow 0$	Clear
0001	$f_1 = xy$	$f \leftarrow A \wedge B$	AND
0010	$f_2 = xy'$	$f \leftarrow A \wedge B'$	Complement AND (B)
0011	$f_3 = x$	$f \leftarrow A$	Transfer A
0100	$f_4 = x'y$	$f \leftarrow A' \wedge B$	Complement AND (A')
0101	$f_5 = y$	$f \leftarrow B$	Transfer B
0110	$f_6 = x \oplus y$	$f \leftarrow A \oplus B$	Exclusive OR
0111	$f_7 = x + y$	$f \leftarrow A \vee B$	OR
1000	$f_8 = (x \oplus y)'$	$f \leftarrow (A \oplus B)'$	Exclusive NOR
1001	$f_9 = (x + y)'$	$f \leftarrow (A \vee B)'$	NOR
1010	$f_{10} = y'$	$f \leftarrow B'$	Complement B
1011	$f_{11} = x + y'$	$f \leftarrow A + B'$	Complement OR (B')
1100	$f_{12} = x'$	$f \leftarrow A'$	Complement A
1101	$f_{13} = x' + y$	$f \leftarrow A' \vee B$	Complement OR (A')
1110	$f_{14} = (xy)'$	$f \leftarrow (A \wedge B)'$	NAND
1111	$f_{15} = 1$	$f \leftarrow$ All 1's	Start on 1's

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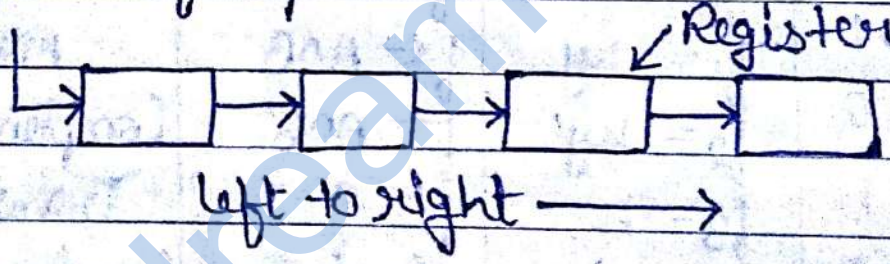
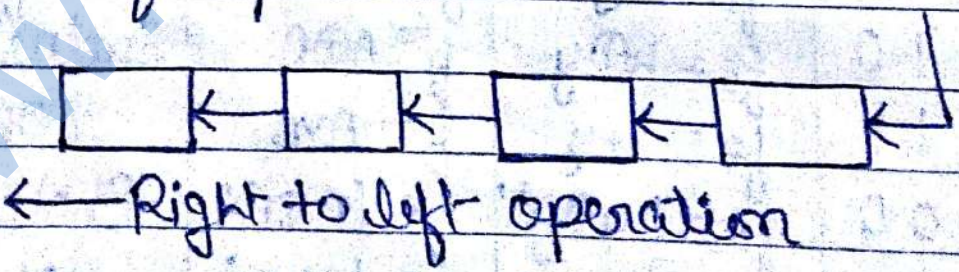
3. Shift micro-operation -
Shift micro operation are the operation in which the content of the register can be shifted left to right or right to left. Shift micro-operation are used for serial transfer of data. They can also used in arithmetic, logic and other data processing operations.

(i) A right shift operation.



(ii) A left shift operation



4. Register transfer micro-operation -
Information transferred from one register to another register (or one resource to another resource)

is designed in symbolic form by means of replacement operator.

★ Interrupts :-

What is it?

It is a mechanism by which modules like I/O or memory may interrupt the normal processing of CPU.

Why required?

To improve the processing efficiency of CPU.

How?

Most external devices are slower than C.P.U. If no interrupts → the CPU would waste a lot of time waiting for these external devices to match up with C.P.U's speed.

1- Wastage of C.P.U time.
2- Wastage of instruction cycles.
3- Continuous checking to find the task completion.

Without Interrupts –

1)- CPU instructs printer to print.
2)- While printer does its task, CPU waits for task completion.
3)- User program stopped.
4)- Repeated checking by CPU.
5)- When task done, CPU proceeds.

With Interrupt –

1- CPU instructs printer to print.
2- While printer does its task, CPU engaged in executing other instructions.
3- User program proceeds concurrently with printing.
4- When task done, printer tells CPU.

Types of Interrupts

1- Program Interrupt – It occur when some instruction within the program creates a condition that leads to an interrupt. Eg: Divide by 0, arithmetic overflow, attempt to access an illegal memory location.

2- Timer Interrupt-
- Generated by the timer present within the processor.
- OS set the timer to perform certain operation on regular basis.

3- I/O Interrupt-
- Generated by I/O devices.
- Signal successful task completion or error conditions.

4- Hardware Interrupt -
Cause: failure related to hardware.
eg:- Memory Parity Error.

★. Interrupt Request and Interrupt Handler:-
CPU executing some task
⇓
User uses the keyboard to issue a high-priority command.
⇓
This issues an interrupt request to the CPU
⇓

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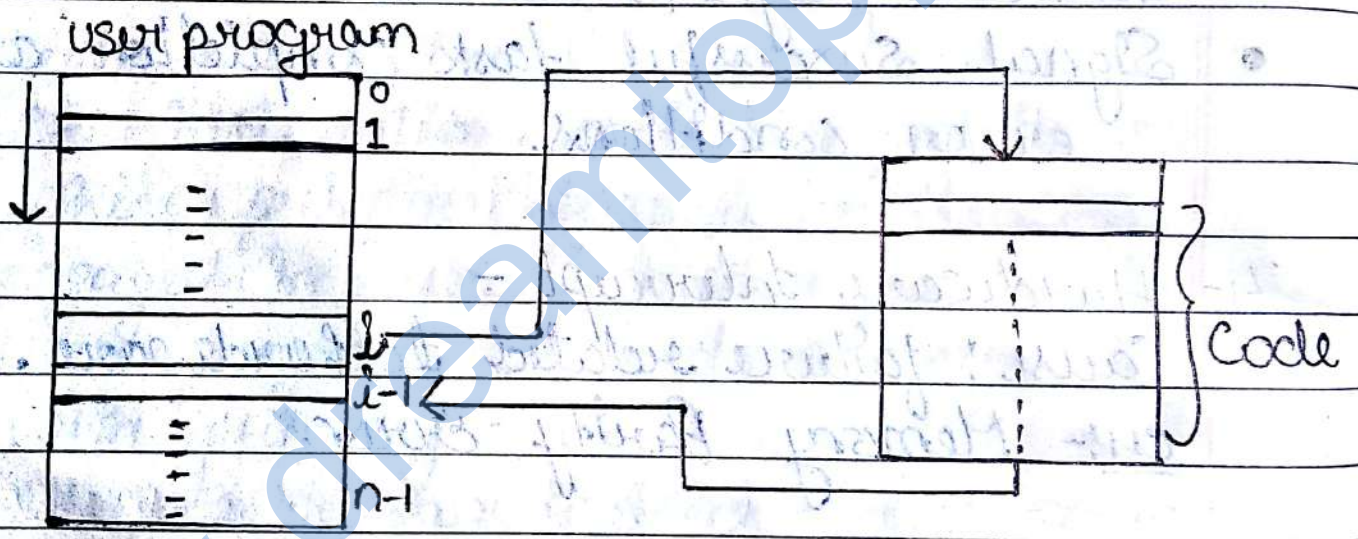
CPU suspends the current execution of the task.

⇓

CPU executes the (code) ← Interrupt handler written to handle Implement this command.

⇓

CPU resumes its previous execution.



Control Transfers In case of Interrupt

Advantage - Efficiency of CPU improves.

Disadvantage - Overhead required to service the Interrupt request.

- Saving Current Content
- Decoding of the code to handle Interrupt
- Switch back

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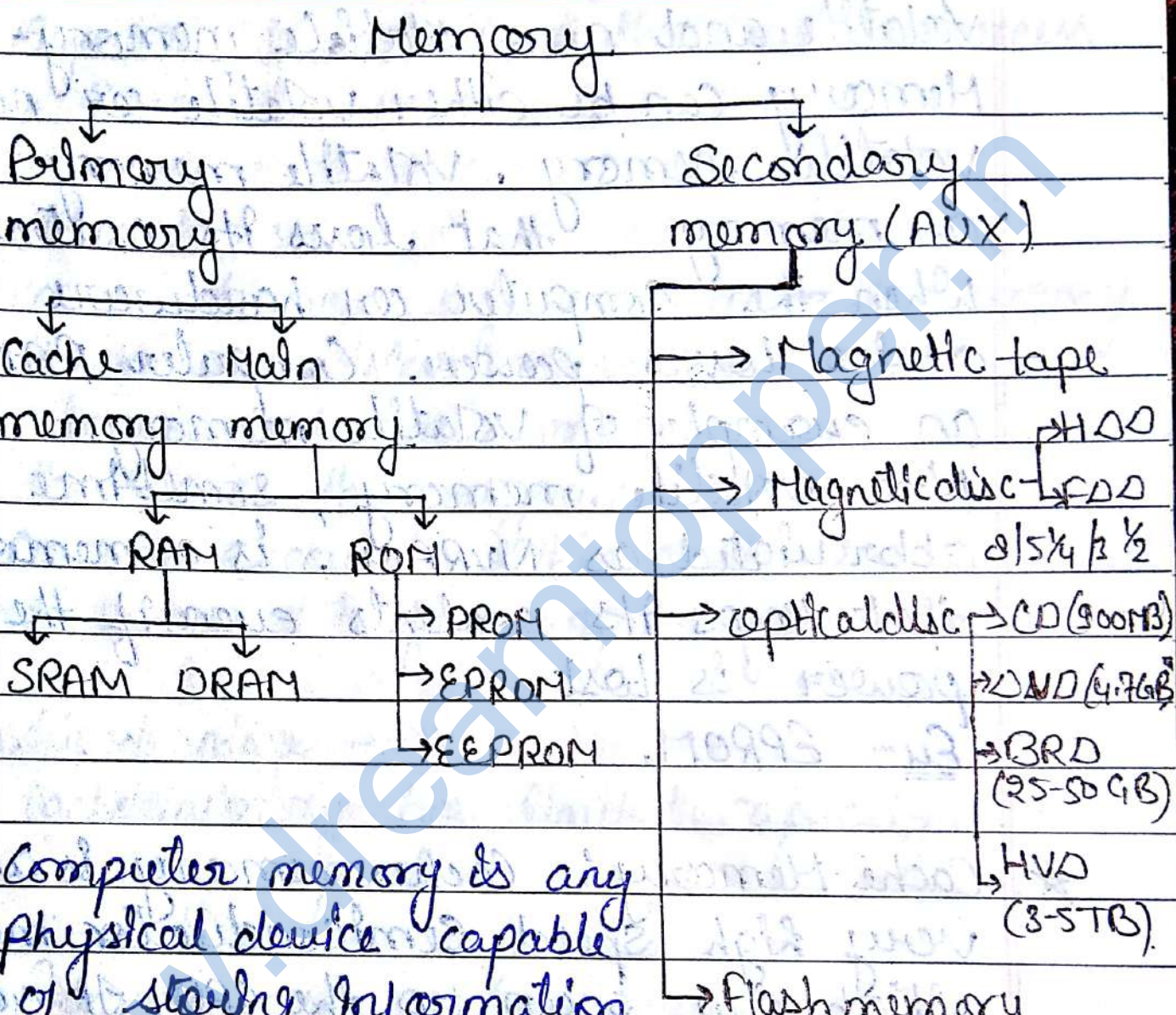
★ Memory



Computer memory is any physical device capable of storing information temporarily or permanently. Ferer - RAM is a volatile memory that stores information on an integrated circuit used by the operating system, software and hardware.

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Volatile and non-volatile memory- Memory can be either volatile or non-volatile memory. Volatile memory is a memory that loses its contents when the computer or hardware device loses power. Computer RAM is an example of volatile memory. Non-volatile memory, sometime abbreviated as NVRAM, is a memory that keeps its contents even if the power is lost.

Eg- EPROM.

★ Cache Memory :- Cache memory is a very high speed semiconductor memory which can speep up the CPU. It acts as a buffer between the CPU and the main memory. It is used to hold those parts of data and program which are most frequently used by the CPU. The parts of data and programs are transferred from the disk to Cache memory by the operating.

System, from where the CPU can access them.

Advantages -

1- Cache memory is faster than main memory.
2- It consumes less access time as compared to main memory.
3- It stores the program that ~~prded~~ can be executed within a short time period.
4- It stores data for temporary use.

Disadvantages -

1- Cache memory has limited capacity. It is very expensive.

☆ Primary memory (Main memory):-
Primary memory holds only those data and instructions on which the computer currently working. It has a limited capacity and data is lost when power is switched off.
These are semiconductor memories. It is known as the main memory.

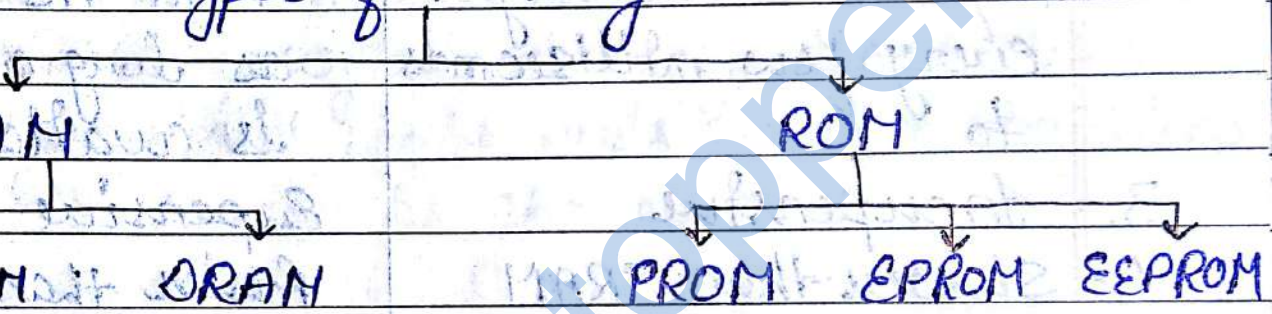
usually volatile memory.
Data is lost in case power is switched off.
It is the working memory of the computer.
Faster than secondary memories.
A computer cannot run without the primary memory.

Secondary memory :- This type of memory is also known as external memory or non-volatile. It is slower than the main memory. Ex- disk, CD-ROM, DVD etc.

1- These are magnetic and optical memories.
2- It is known as the back-up memory.
3- It is a non-volatile memory.
4- Data is permanently stored even if power is switched off.
5- It is used for storage of data in a computer.
6- Computer may run without the secondary memory.

7- Slower than primary memories.

★ Types of Computer memory :-



1- Random Access Memory (RAM) -

(i) It is also called as read write memory or the main or primary memory.

(ii) The programs and data that the CPU requires during execution of a program are stored in this memory.

(iii) It is a volatile memory as the data loses when the power is turned off.

(iv) RAM is further classified into two types - SRAM and DRAM.

	DRAM	SRAM
1-	Constructed of tiny capacitors that leak electricity.	Constructed of circuits similar to D flip-flops.
2-	Requires a recharge every few milliseconds to	Hold its contents as long as power is available.
3-	Inexpensive	Expensive
4-	Slower than SRAM	Faster than DRAM.
5-	Can store many bits per chip	Cannot store many bits per chip.
6-	Uses less power	Uses more power.
7-	Generates less heat	Generates more heat.
8-	Used for main memory	Used for cache.

2- Read only memory (ROM) -

(i) Stores crucial information essential to operate the system, like the program essential to boot the computer.

(ii) It is non-volatile.

(iii) Always retains its data.

(iv) Used in embedded systems or where the programming needs no change.

(v). Used in calculators and peripheral devices.

Types of ROM -

1- PROM (Programmable read-only memory) - It can be programmed by user. Once programmed, the data and instructions in it cannot be changed.

2- EPROM (Erasable programmable read-only memory) - It can be reprogrammed. To erase data from it, expose it to ultra violet light. To reprogram it, erase all the previous data.

3- EEPROM (Electrically erasable programmable read only memory) - The data can be erased by applying electric field, no need of ultra violet light. We can erase only portions of the chip.

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	RAM	ROM.
1.-	Temporary storage Store data in MBs volatile	Permanent storage Store data in GBs Non-volatile.
2.-	Used in normal operations writing data is faster.	used for startup process of computer. Writing data is slower.

★ Buses:- components communicate with each other using buses. A bus is a set of parallel wires connecting different components. The processor is connected to the main memory by three seperate buses. The three types of buses -

1. address bus - address bus is apathway or a set of parallel wires that carries the location of the data to be read from or written to. An address bus is one directional only - from the processor to the memory or an I/O controller.

The number of lines for the address bus determines the maximum number of bits it can carry, and in turn determines the maximum possible memory capacity of the computer. Ex- Think if the postal office only allows 3 digits for house numbers, the the maximum addressable houses will be 999. So, if the computer has a 32-bit bus, the maximum addressable memory locations will be 2^{32}, which is 4GB, assuming each memory location stores one byte of data.

2.- Data Bus:- Data bus is a bi-directional pathway or wires that carries data or instructions between computer components. The width of data bus is a key factor in determining the overall computer performance. Typical data bus is 8, 16, 32 or 64 bits wide. If a computer has a word size of 32 but with a 16-bit data bus, then the data bus has to fetch the

word twice from the main memory.

3:- Control Bus - Control bus is a bi-directional pathway that carries command, timing and specific status information among components. The following are the some of the control information a control bus may carry -
Write to memory
read to from memory
Write to I/O port
read from I/O port
request for data bus
grant for data bus
Sync clock
reset all components.

I/O controllers :- An I/O controller is a device (an electronic circuit board) that manages the communication between the processor and the I/O device.

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Each Input/O device has a seperate controller which connects to the control bus.
I/o controllers receive input and output request from the processor, then send device specific control signals to the device.
I/o controllers manage the data flow from and to the device.