

Computer Organization and Architecture

Architecture → abstract → Logical things → What to do

Ex: 2×3 (it's not said to be requirement change
Hardware and Software)

Organization → How to do (concerned with structure and behaviour)

Assembly language

It is a low-level programming language.

It helps in understanding the programming language to machine code. In a computer, there is an assembler that helps in converting the assembly code into machine code executable. Assembly language is designed to understand instruction and provide it to machine language for further processing.

Assembly language helps programmers to write human-readable code that is similar almost similar to machine language.

Advantages

- It allows complex jobs to run in a simpler way.
- It is memory efficient, as it requires less memory.
- It is faster in speed, as its execution time is less.
- It is a low-level embedded system.

Disadvantages

- It takes a lot of time and effort to write the code for the same.
- It is very complex and difficult to understand.
- It needs more size or memory.

Instruction Set Architecture

It is a collection of machine language instructions that a particular processor understands and executes.

Instruction can take different formats:-

The instruction length

The type

length and position of operation codes in an instruction

Two major of Instruction

Opcode:- An operation code field termed as opcode that specified operations to be performed

Operands:- An address operand is the second part of an instruction, which tells the computer where to find or store the data or instructions

Example:

ADD - Adds two numbers together

COMPARE - Compare numbers

LOAD - Load information from RAM to CPU.

The operand address can be :-

→ The memory address

→ CPU Register Address (high speed)

→ I/O Device Address

Addressing Modes

The term addressing modes refers to the way in which the operand of an instruction is specified. The addressing mode specifies a rule for modifying the address field of the instruction before the operand is actually executed.

Mostly used Addressing mode is Indirect Addressing mode.
The various Addressing modes are.

1. Immediate Addressing Mode
2. Direct Addressing Mode
3. Indirect Addressing Mode
4. Register Addressing Mode
5. Indexed Addressing Mode
6. Auto Increment Addressing Mode
7. Displacement Addressing Mode.

Operand specification can be done by

- Part of the instruction
- Reference to the memory location
- Address of CPU register

1. Immediate Addressing Mode

- Initializing a variable
- No additional memory
- Operand is mentioned explicitly.

Ex: ADD 7, which says Add 7 to accumulator
MVI A, 33H

2. Direct Addressing Modes

- address of memory location is given explicitly
- contents at the memory location is provided.

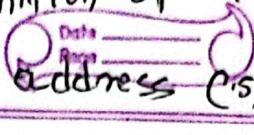
Ex: STA 3050H

Memory location

Op register \rightarrow memory location [content: 10]

3. Register Addressing Modes

- Operand is present in the register
- Register No. is written in Instruction.
- Ex: MOV A, B

Implied Addressing mode (INC A) (CR C) 
- operand is specified implicitly in definition of instruction
- used for zero address (stack organization) and one address (single Address indicator)

Indirect Addressing Modes

Used to implement pointers and passing parameters

2 memory access required

Ex: $MOV A, 2000H$.

It moves the data from memory location specified by the location 2000 to A.

Indexed Addressing Mode

Array elements are accessed.

If $A[7]$ is array.

Then $A[i] = \text{Base Address} + \text{Offset}$

Starting Address positions to skip

Eg.: $MOV R1, [B + 5]$

CPU Register Base address of array

Offset (index)

Auto Increment Addressing Mode.

Contents are incremented by register increment.

Denoted by $(R) +$

Ex. $MOV R1, 1010$

Displacement Addressing mode

Powerful Addressing mode.

Combination of direct addressing mode and register indirect addressing mode.

a. Relative Addressing Mode

PC \rightarrow Program Counter

- Effective Address = $PC + \text{Offset (index)}$

b. Base Addressing Mode

BR \rightarrow Base Register

Effective Address (EA) = $BR + \text{Displacement offset}$

RISC

CISC

1. Reduced Instruction Set Computer. Complex Instruction Set Computer.
2. Large no. of Instructions. Less number of Instructions.
3. Fixed length Instruction format. Variable Length Instruction format.
4. Few no. of Addressing Modes. Large no. of Addressing Modes.
5. Less cost. Cost is High.
6. Less Powerful. More Powerful.
7. Single Cycle Instructions. Several Cycle Instructions.
8. Only in Registers. Manipulation directly in Memory.
9. Hardwired Control Unit. Microprogrammed Control Unit.
10. Ex: MIPS, SPARC, etc. Ex: Mainframes, Intel 8080;

Pipelining Processing

→ Set of data processing elements connected in series
Here, output of one instruction is the input of the next instruction.

processing: The five phases are:-

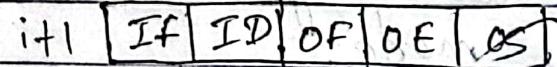
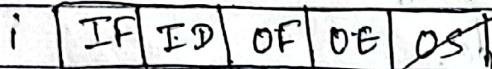
IF - Instruction fetch

ID - Instruction Decode

OF - Operand fetch

OE - Operand Execute

OS - Operand Store



→ Total time taken will be reduced in this process.

→ If execute faster.

→ System performance increase.

TOPOLogy

The physical arrangement of the computer system which is connected to each other via communication medium is called topology.

Interrupts

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

Interrupt is required to improve the processing efficiency of CPU.

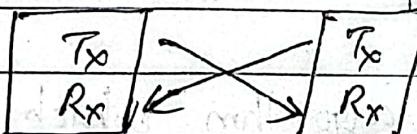
UART Communication

It is Universal Asynchronous Receiver Transmitter.

No clock is necessary.

A physical circuit in micro-controller, with the main purpose to Transmit / Receive serial data.

2 wires



WALLACE Tree Multipliers

A fast way to multiply two binary integers.

Any multiplier has three stages:

1. Partial Products

2. Partial Products Addition

3. Final Addition

This advantage becomes more pronounced for multipliers of bigger than 16 bits.

It requires more hardware.

Pipelining Hazards

Anythings that breaks the continue flow of executions in pipelining is known as Pipelining Hazards.

Three types! 1) Structural Hazard

When two or more instruction are going to be use same resource (Ex: memory, register file, etc) at the same time these will cause structural hazard.

2) Data Hazard.

When two or more instruction are going to act upon same data (File, data stats for register) then it causes data hazard.

3) Control Hazard

- mainly occurs in branch instruction (unconditional branch, conditional branch, function call and return).

Booth's Algorithm

- Booth's Algorithm is an algorithm which multiplies 2 signed or unsigned number integers in 2's complement.

- This approach uses fewer additions and subtraction than more straight-forward algorithms.

- # Signed Numbers use sign flag or can be distinguish between negative values and positive values.

- # Unsigned number stores only positive numbers but not negative numbers.

Asynchronous Data Transfer

- A data can be transfer at a irregular interval
- is known as asynchronous.
- In this, the transmitter transmits data bytes at any instant of time.
- Only 1 byte is sent at a time.
- There is ideal time between 2 bytes, data types.
- Transmitter and Receiver op can operate at diff clock frequencies.
- To help receiver start and stop bits are used along with data in middle.

Flynn's taxonomy

- It is a "specific classification of parallel computer architectures".
- Classification are based on number of (single or multiple) instructions and data streams (single or multiple) available in the architecture.
- The sequence of instructions read from memory is called instruction stream.
- The operations performed on the data in the processor is called data stream.

Types : (On the basis of instruction stream & data stream)

- 1) SISD (Single Instruction Single Data) (Ex: IBM630)
- 2) SIMD (Single Instruction Multiple Data) (Ex: ab, ac, ad)
- 3) MISD (Multiple Instruction Single Data)
- 4) MIMO (Multiple Instruction Multiple Data).
(Ex: a+b, c+d, e/f, b-f)

RTL

- It stands for "Register Transfer Language".
- The symbolic notation used to describe the micro-operation transfer among registers is called RTL.
- It is a language that represents the movement and processing of data stored in registers.
- The operations performed on registers are known as micro-operations
- ex: $R_1 \leftarrow R_2$ (move data from R_2 into R_1)

RTL Shift Operation

- 1) Circular Shift
- 2) Logical Shift
- 3) Arithmetic Shift

HDL

- It stands for "Hardware Description Language" which describes the hardware of digital system in formal form.
- Digital systems can be represented in the form of documentation, which can be understood by human and also computers.
- Logic diagrams, digital circuits, Boolean expressions can be represented by HDL.
- It must describes the hardware structures and behaviour.

Microcode

- It is the lowest specified level of processor and machine instructions sets. Microcode performs short, multiple micro instructions, each of which performs one or more operations.

Micro code deals with lower-level or circuit based operation, because microcode is usually embedded in hardware, it cannot be altered.

Virtual Memory

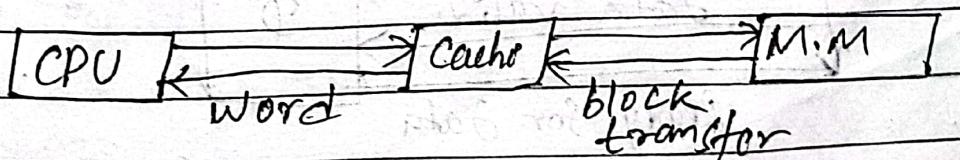
- It is a valuable concept in computer architecture that allows you to run large, sophisticated programs on a computer even if it has a relatively small amount of RAM.
sophisticated \rightarrow high degree of complexity.
- It is a memory management technique where secondary memory can be used as if it were a part of the main memory.
- It is a very common technique used in OS of computers.

Cache Memory

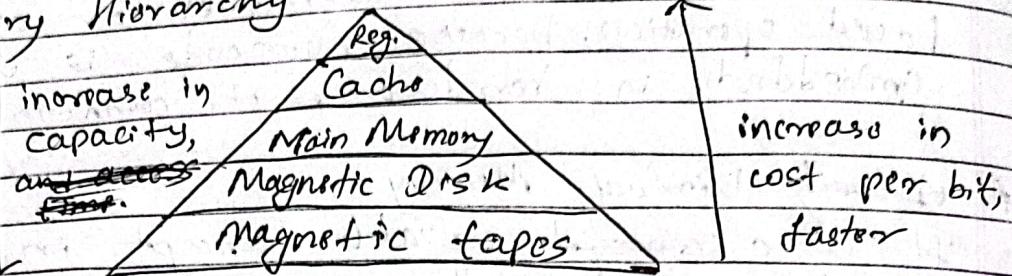
- It is the memory which is very nearest to the CPU, all recent instructions are stored into cache memory.

Cache memory is attached for storing the input which is given by the user and which is necessary for the CPU to perform a task.

It is faster than main memory.



Memory Hierarchy



Main Memory

It stores data and program during computer operation.

It uses semiconductor technology.

L Types

L volatile and Non-Volatile

L RAM ROM L flash

#

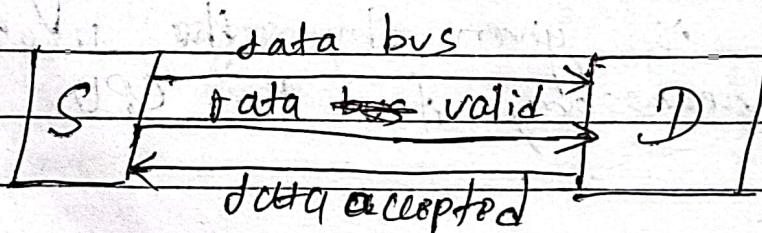
Handshaking

A communication link is established between two computers different components of a computer. This communication is through frames for transfer of data.

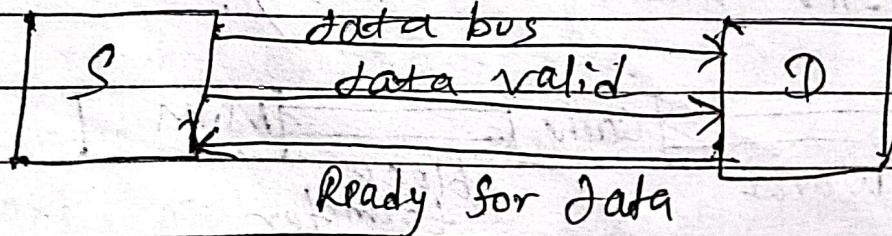
Types:-

1. source to destination

2. Handshaking signals are used to synchronize the bus activities



2. Destination to Source



Programmed I/O

- Programmed I/O operations are result of I/O instructions written in computer program.
- Each data transfer is initiated by an I/O instruction in the program (to access register or memory on a device)
- Transforming data under program control requires constant monitoring of the I/O devices by the CPU.

Program Counter

It is a register in a computer processor that contains the address of the instruction being executed at the current time.

Segmentation

Paging

In paging logical address space is divided into fixed size of pages.

(1) It is invisible for programmer. It is visible for program.

(2) It does not support user views. It supports user views.

(3) It doesn't support protection. It supports protection of application component.

(4) Logical Address generated by CPU consists of page number, segment number and offset.

(5) Hardware decides the page size. The segment size is specified by the user.

(6) Swapping is easier. (Same page size) Comparing is difficult.

Vector Interrupt.

A vector interrupt is where the CPU actually knows the address of the ~~input~~ interrupt service routine in advance. Ex: RST 7.5, RST 65, RST .5.5, TRAP.

Non-Vector Interrupt.

A non-vector interrupt is where the interrupting device never sends an interrupt vector. Ex: INT.

Microprogrammed Control Unit

uses
- Sequence of micro instruction in microprogramming language.

- It is act as a mid-way between hardware and software.
- It generates a set of control signals.
- It is easy to design, test and implement.
- It is flexible to modify.
- It consists of:-

control signals, control variable, control word, control memory, micro-instructions and micro programs.

Hardwired Control Unit.

In hardwired control unit, the control logic is implemented with gates, flip-flops, decoders and other digital circuits.

The hardwired control unit ~~generates~~ generates the control ~~unit~~ signal to execute the instructions in a proper sequence and at a correct time.

It is designed for RISC style instruction set.

register, control signal, control bus, flags, clock signal, etc.



A Control Unit

To execute an instruction, the control unit of the CPU must generate the required control signal in the proper sequence.

2 approaches used for generating control signals:

1. Hardwired Control Unit

2. Micro-programmed Control Unit.

RS 232

- It supports the serial communication.

- It transfers the data ~~bytes~~ bit by bit from transmitter to receiver.

- Used to connect PC to modems.

- full duplex manner.

- It has 9 pins. (Ex: VGA cable)

DMA

- Stands for Direct Memory Access.

- Enables data transfer between I/O and memory without CPU intervention.

- Need a hardware DMA controller.

- DMA transfers the data in three modes:

1. Burst Mode

2. Cycle Stealing Mode

3. Transparent Mode.

VHDL

- It stands for "Very High Speed Integrated Circuit Hardware Description Language".

- Various model of VHDL

- Behavioural (nature of input given and output nature)

- Data flow (How the data flow from one component to other)

- Structural (No. of component entire system. Ex: flip-flop, counters, etc.)

- VHDL describes the behaviour of electronic circuit or system, from which the physical system or circuit can be implemented.

- The two main application of VHDL is

1. FPGA (Field Programmable Gate Array)

2. CPLD (Complex Programmable Logical Device)

Interleaved Memory

- Memory Interleaving is a technique to increase the throughput.
- Here, the system is divided into number of independent memory modules, which answers read or write requests independently in parallel.
- Memory interleaving technique helps to improve the performance of DMA.
- It is done by spreading memory address evenly across memory modules.
- System performance is enhanced because read and write activity occurs simultaneously across the multiple modules in a similar fashion.

Ex: Chai 4 bit to upto 15 samma

0	0000	10	MM00 (1st 4E)	MM01
1	0001	20		
2	0010	30		
3	0011	40		
4	0100	50	MM00	MM01
5	0101	60	00 10	00 50
6	0110	70	01 20	01 60
7	0111	80	10 30	10 70
			11 40	11 80

Fig: ~~Memory~~ Interleaved memory.

24-way

II High Order Interleaving

In high-order interleaving, the most significant bits of the address select memory chip. The least significant bits are sent as address chip to each chip. One problem is that consecutive address tend to be in the same chip. The maximum rate of data transfer is limited by the memory cycle time.

III Low-Order Interleaving

In low-order interleaving, the least significant bits select the memory bank (module). The most significant bits select the address in the module.

In this, consecutive memory addresses are in different memory module. This allows memory access at much faster rates than allowed by the cycle time.

0	4	8	12	0	4	1	2	3
1	5	9	13	4	5	6	7	
2	6	10	14	8	9	10	11	
3	7	11	15	12	13	14	15	

fig: High-Order Interleaving

fig: Low Order Interleaving

Instruction Cycle

The total process of fetching an instruction from the memory, decoding the opcode to understand the operation and finally executing the instruction is called an instruction cycle.
(Fetch-decode-execute cycle.)

Stack Pointer

It is a special purpose 16-bit register that stores the address of the "top of the stack".

GPRs | General Purpose Register

These are registers present inside the processor. They are available to the programmer for storing operands and getting results in a program.

Compiler

A compiler is a program that converts a higher language code (C, C++, ...) into machine language that can be executed by the processor.

Microoperation

Operations performed on the data stored in registers. e.g. shift, count, clear, load.

Types of microoperations

a) Register transfer microoperation

→ transfer binary information from one register to another.

b) Arithmetic Transfer Microoperation

→ performs arithmetic operation on numeric data stored in register.

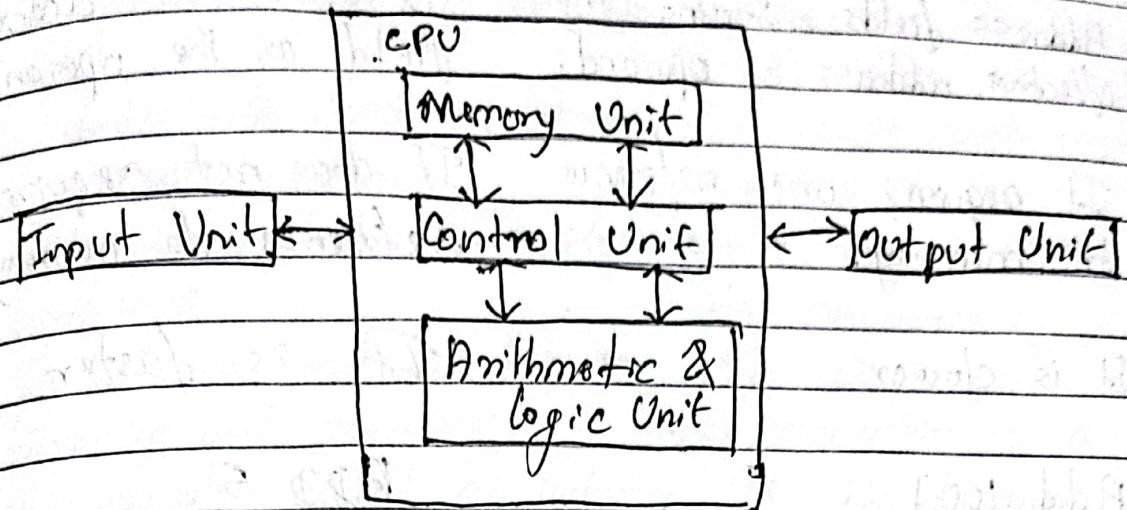
c) Logic Microoperation

→ perform bit manipulation.

d) Shift Microoperation

→ perform shift operation on data stored in register.

CPU Organization



memory unit = stores all data and instructions.

control unit = Controls the operation of all parts of the computer but does not carry out any actual data processing.

ALU = does arithmetic operation.

Mnemonic

A mnemonic is a term, symbol or name used to define or specify a computing function.

Assembly language also uses a mnemonics to represent machine operation, or opcode.

Computer Architecture

Computer Organization

- It is concerned with the way hardware components are connected together to form a computer system as seen by the user.
- It acts as a interface b/w hardware and software.
- It is considered first while designing.
- It deals with the components of connection in a system.
- If is done on the basis of architecture.

- # Direct Addressing Mode
 - Address fields contains the effective address of operand.

Immediate Addressing Mode
 There is no address field as the operand.

- It requires one reference to memory.
 If does not require any reference to memory.

- It is slower
 It is faster

- Add 1001 ADD 5

- # Computer Architecture Computer Organization
 - It describes what the comp. It describes how it works.

- It deals with functional behavior of computer system. It deals with structure & behavior of computer sys.

- It is considered first while designing. It is done on the basis of Architecture.

- If deals with high level design issue. If deals with low-level design issue.

- It involves instruction sets, Addressing Mode, Data types. It involves circuit design, Adders, signals.

- It acts interface between hardware & software. It deals with connection components of connection in a system.

Computer Architecture

It describes what the computer organization describes how it does it.

It deals with functional behavior of computer system. It deals with structural relationship.

Architecture indicates its hardware. While, organization indicates its performance.

It acts as interface between hardware and software. It deals with components of connection in a system.

It is also called as Instruction set architecture. It is frequently called micro architecture.

It is considered first while designing. It is done on the basis of architecture.

Compiler

Interpreter

It scans the entire programs first and translate it into machine code. It scans line by line programs and converts into machine code.

Debugging is slow. Debugging is faster.

Execution time is less. Execution time is more.

The compiler is best suited for the production environment. An interpreter is best suited for a software development environment.

The compiler is used by programming language such as C, C++, C#, Scala, ~~Java~~, Python, PHP, Perl, Ruby, etc. An interpreter is used by programming language such as Python, PHP, Perl, Ruby, Etc., Java

Memory

A memory is just like a human brain. It is used to store data and instructions. Computer memory is the storage space in the computer, where data to be processed and instruction required for processing are stored.

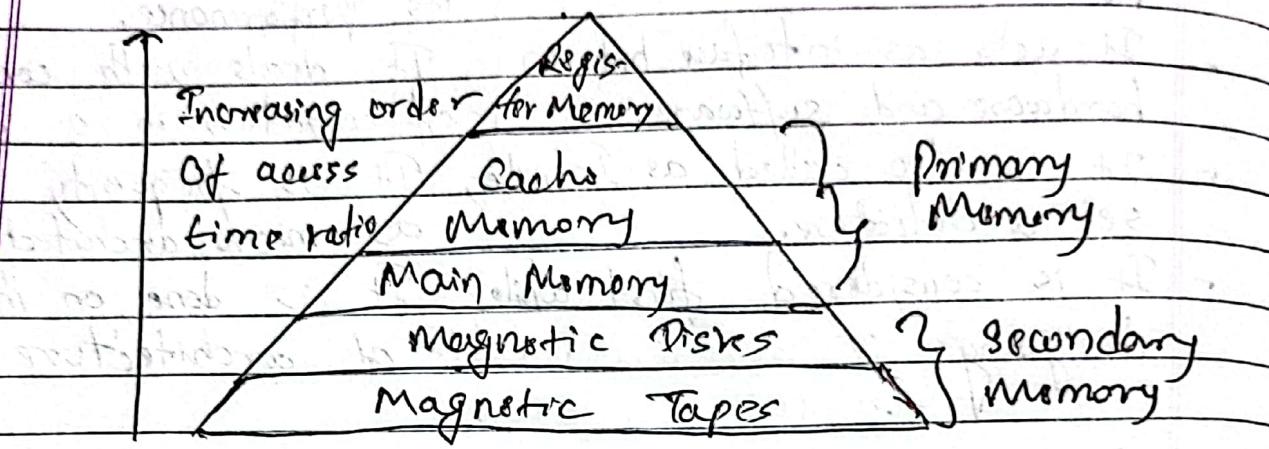


Fig: Showing Memory Hierarchy Design

Register Memory

It is the smallest and fastest memory in a computer. It is part of the main memory and is located in the CPU in the form of registers, which are the smallest data holding elements. A register temporarily holds frequently used data, instructions, and memory address that are to be used by CPU. It holds a small amount of data around 32 bits to 64 bits.

Accumulator register, program counter, instruction register, Address register, etc.

Cache Memory

Cache memory is a very high speed semiconductor memory which can speed up the CPU. It is inserted 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 operating system, from where the CPU can access them.

Advantages

- faster than main memory.
- consumes less access time as compared to main memory.
- It stores the program can be executed within a short period of time.
- It stores data for temporary use.

Disadvantages

- 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 is currently working. It has limited capacity and data is lost when power is cut off. It is generally made up of semiconductor device. These memories are not as fast as registers. The data and instruction required to processed resides in the main memory. It is divided into

Interrupt

The interrupt is usually initiated by an external or internal signal rather than from ~~exec~~ execution instruction. The address of the interrupt service program is determined by the hardware rather than from the address field of an instruction.

The difference between RISC and CISC Architectures is given below:

RISC

- Reduced Instruction Set Computer
- Large no. of instruction
- Simple instruction taking only one cycle.
- Heavily Pipelined
- Multiple register sets.
- Instructions executed by hardware.
- fixed format instructions
- Less cost
- Less powerful
- Hardwired Control Unit.

CISC

- Complex Instruction Set Computer
- Less number of instruction.
- complex instructions taking multiple cycles.
- Not/less pipelined
- Single register sets.
- Instructions interpreted by micro programming.
- variable format instructions
- more cost
- More powerful
- Microprogramming Control Unit

Shift Operation

Shift micro-operations are those micro-operations that are used for serial transfer of information. There are three types:-

1. Logical

In transfer, the 0 'zero' through the serial input. We use the symbols `shl` for logical shift-left and `shr` for shift-right.

2. Arithmetic

This micro-operations shifts ~~out~~ a signed binary number to the left or to the right position. In an arithmetic shift-left, it multiplies a signed binary number by 2 and in an arithmetic shift-right, it divides the number by 2.

~~or~~ 3. Circular

The circular shift calculates, circulates the bits in the sequence of the register around the both ends without any loss of information.

Data Conflicts

Data conflict occur when the pipeline causes an incorrect data value to be used.

When the current instruction changes a register that the next one needed, data conflicts happen.

- Software fixes

- No-op insertion
- instruction reordering

- Hardware fix

- stall insertion
- Data forwarding

Block \rightarrow A collection of words.



Branch Conflicts

When the current instruction makes a jump, branch conflicts happens.

Mapping function

The transformation of data from main memory to cache memory is referred to as a memory mapping process. There are three types:

1. Direct Mapping

The simplest technique, known as direct mapping, maps each block of main memory into only one possible cache line.

2. Associative Mapping

In this type of mapping, the associative memory is used to store content and addresses of the memory word. Any block can go into any line of the cache. It is considered to be the fastest and most flexible mapping form.

3. Set Associative Mapping

This form of mapping is an enhanced form of direct mapping where the drawbacks of direct mapping method. In this we can store two or more words of memory under the same index address.

Block: The main memory comprises of blocks, each with same no. of words.

Line: The cache memory is made up of multiple lines, each having an equal no. of words.

No. of words in MM Block = No. of words in Cache Line

flip flop

A flip flop is an electronic circuit with two stable states can be used to stored binary data. The stored data can be changed by applying varying inputs.

Latches

Latches are basic storage elements that operate with signal. Latches controlled by a clock transition are flip-flops. Latches are level-sensitive devices. Latches are useful for design of the asynchronous sequential circuit.

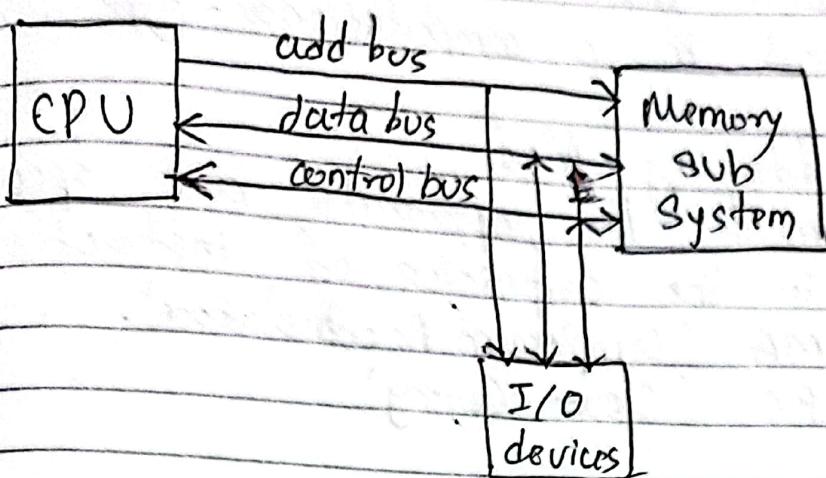
Components of CPU

- ALU
- Register
- Memory Unit & I/O Interface
- Control Unit
- Clock
- Bus

function of CPU

- It controls the system
- It performs the data movement
- It's having data processing capability
- It's having data storage functionality.

Generic Computer Organization



CPU Internal Organization

I. Control units

- It controls the operation of CPU, memory and I/O
- It controls the execution of CPU instructions which are stored in the memory.

2. ALU

- It is used for data processing.
- It manipulates and calculates the data values.

3. Registers

- It is used to stores the data values in CPU temporarily.

Advantage of Register Addressing Mode

- It helps to reduce no. of bits in the address field of the instruction.
- It is used to modify address field of instruction.
- It is flexible to access data as per the user's requirements.

Effective Address (EA)
 → The effective address is the address of the operand in a computational-type instruction.

Implied Addressing Mode

In this mode the operands are specified implicitly in the definition of instruction.
 for ex: CMA 'complement Accumulator'.
 CRC 'Clear Carry'

Types of Micro-Operation

- Transfer data between registers
- Transfer data from register to external interface
- Transfer data from external interface to register
- Perform Arithmetic & Logical operation with register for i/p, o/p.

#	Hardwired Control Unit	Microprogrammed Control Unit
-	It is fast.	It is slow.
-	more cost	less cost.
-	Uses sequential circuit containing logic gates.	Uses Microprogramming having micro instruction
-	Modification is complex.	Modification is flexible
-	It contains less instruction set.	It contains more instruction set.
-	It is used in RISC mp.	It is used in CISC mp
-	Decoding is complex.	Decoding is easy.

ROM ~~Registers~~ are made from

- Basic gates
- ~~Mult.~~ Decoders