I. EIGHT RECENT IDEAS IN COMPUTER ARCHITECTURE

These great eight ideas enhance the performance of the system with enhanced pipelining operation; guess the task by prediction method and also provide the memory hierarchy and dependability of the system to improve the 100% efficiency.

1. Design for MOORE'S LAW:

* Moore's law states that integrated circuit resources double every 18-24 months.

* According to Moore's law computer architects must know where the technology is going and when the design has to finish.

* We use an "up and to the right" moore's law graph to represent designing for rapid change.

2. Use Abstraction to Simplify Design:

* Abstraction is used to represent the design at different levels of representation for hardware and software.

* It helps to reduce the design time of both computer architecture and programmes.

* In abstraction lower level details are hidden to offer a simpler model at higher levels.

3. Make the Common Case fast:

* Any system can have 2 kinds of functions such as common case and rare case.

* The common case fast will enhance performance better than optimizing the rare case.

* Common case is simpler than the rare case so it is easier to enhance.

4. Performance via Parallelism:

* Performance of computer can be increased by parallelism. Because parallel processing will increase the speed of performance execution

* Computer architecture design has more performance by performing operations in parallel.

5. Performance via Pipelining:

* Parallelism can be performed in many ways. A particular pattern of parallelism performed in computer architecture is named as "pipelining".

* Pipelining process will improve the performance of computer system.

* A substantial improvement in performance can be achieved by overlapping the execution of successive instructions using a technique called pipelining.

6. Performance via Prediction:

* Prediction is the great idea to increase the performance.

* Improve system performance by proper prediction about future events and it must be relatively accurate.

7. Hierarchy of Memories:

* Memory is most important functional component in computer system.

* Performance of computer directly depends on the memory speed and its size.

* Programmers want memory to be fast, large and cheap.

* Memory speed will increase the performance and its capacity, limits the size of problems that can be solved.

8. Dependability via Redundancy:

Computers not only need to be fast, they need to be dependable, because computer contains collection of physical devices. So any physical devices get fail it can identify using dependable by including redundant componenty.

Amdahl's Law: (2 marks)

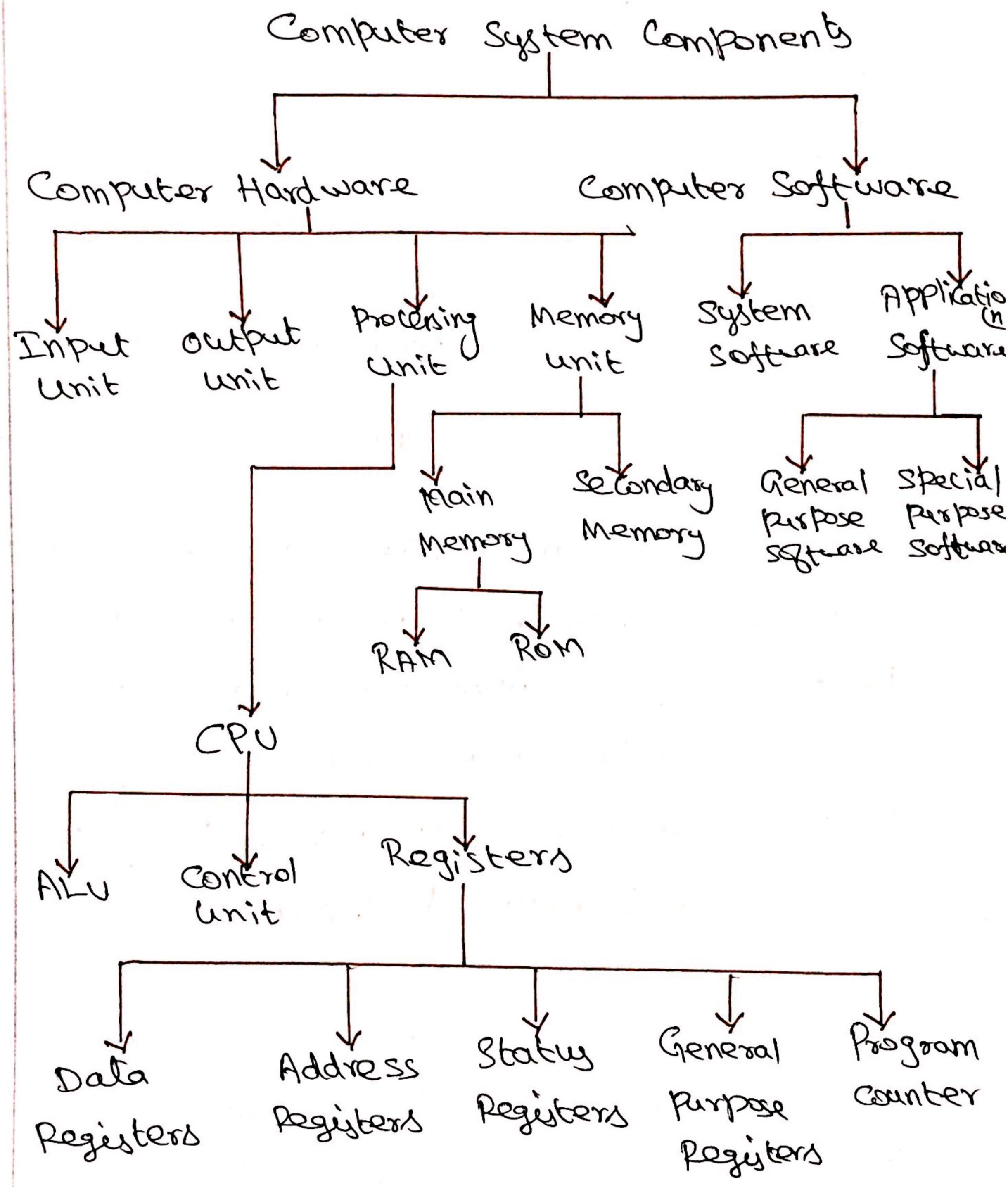
Amdahl's law is used to find the execution time of a program after making the improvement. It can be represented in an equation as follows:

$$\text{Execution time after improvement} = \text{Execution time affected by improvement} + \frac{\text{Execution time of unaffected}}{\text{Amount of improvement}}$$

Amdahl's law can be used to estimate performance improvements. Amdahl's law, together with the CPU performance equation, is a handy tool for evaluating potential enhancements. Amdahl's law is also used to access practical limits to the number of parallel processors.

II/ COMPONENTS OF COMPUTER SYSTEM: (N/D 2015) (N/D 2014) (NOV/DEC 2016) (May/June 2016)

Computer system contains many kinds of components.



Functional units:

Computer hardware can be classified into many units such as follows:

1. Input unit
2. Output unit
3. Processing unit (ALU)
4. Memory unit
5. Control unit

1. Input Devices:

"How to tell it what to do"

Different kind of input devices are

1.1. Mouse

It used to drive microsoft windows.

1.2. Keyboard

Entering information into a computer.

1.3. Tracker ball

Alternative to the traditional mouse and used by graphic designers.

1.4. Scanners

1.5. Touch pads

1.6. Light pens

1.7. Joy sticks.

2. Output Unit or Devices:

"How it shows you what it is doing"

To get the result of task performed by the Computer. Different kinds of output devices used for different purpose.

2.1 VDU or Monitor

2.2 Printers

- Impact
  - Dot Matrix Printer
- Non-Impact
  - Inkjet Printer
  - Laser Printer

2.3 Plotters

2.4 Speakers

2.5 Speech Synthesizers

3. Processing unit:

Processing unit is the brain of any Computer System. It contains the following functional units.

Basic Operational Concepts:-

1. Central Processing Unit (CPU)

2. Arithmetic and Logical Unit (ALU)

3. Control Unit

4. Registers.

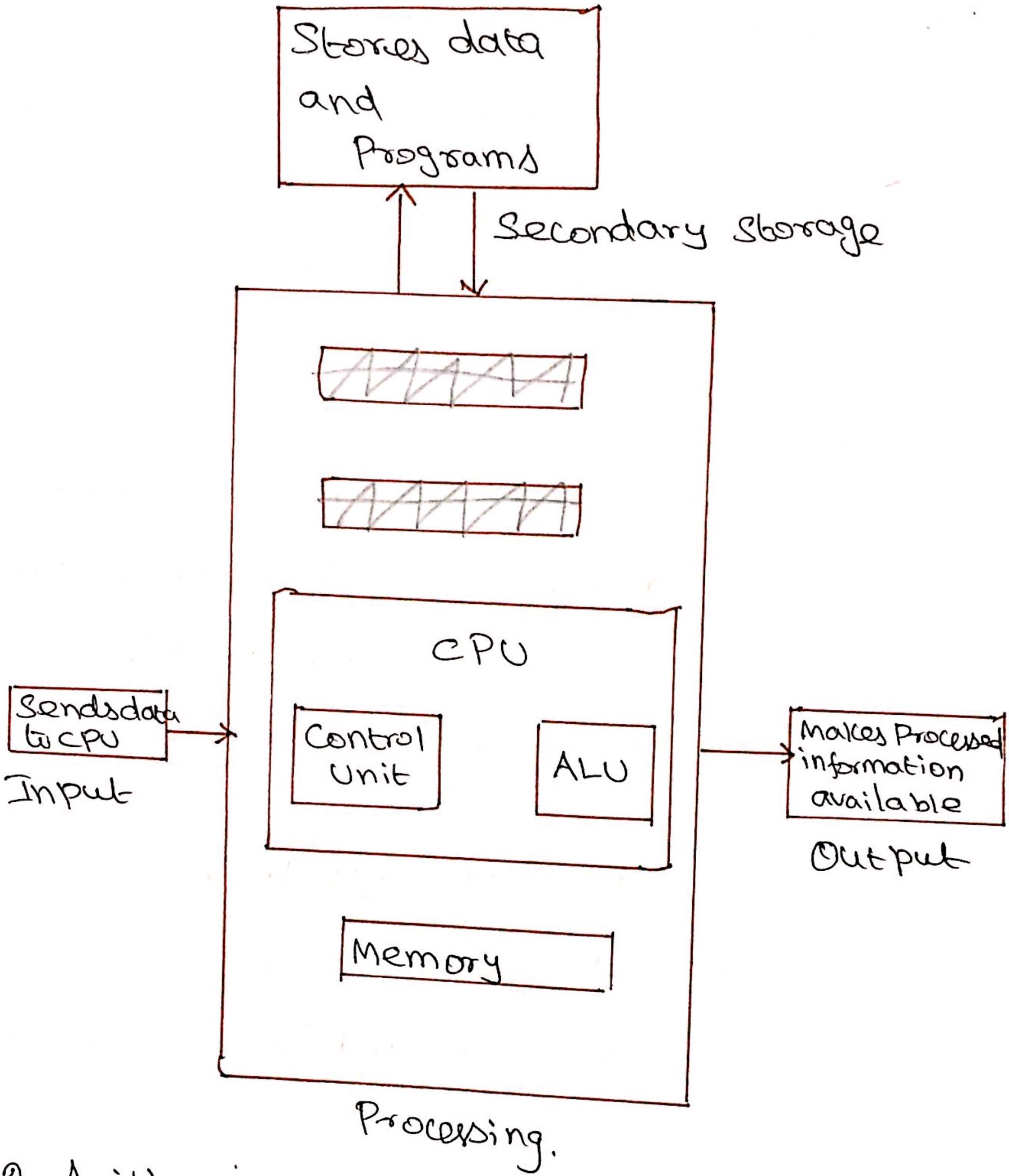
1. Central Processing Unit: (CPU)

* CPU is a complex set of electronic circuit which acts as a control central for the system.

* Set of electronic circuit used to execute stored program instructions.

CPU contains two major parts:

1. Control unit (CU)
2. Arithmetic and Logic unit (ALU)



2. Arithmetic and Logical Unit (ALU):

* An ALU is a digital circuit used to perform arithmetic and logic operations.
* An ALU represents the fundamental building block of the CPU of a Computer.

3. Control Unit (CU):

* Control unit is a part of the hardware
* It directs the computer system to execute stored program instructions and tells the ALU what operation.
* Control unit must communicate with memory and ALU.
* It sends data and instructions from secondary storage to memory as needed.

4. Registers:

A register is one of a small set of data holding places that are part of a computer processor.

A register may hold a computer instruction, a storage address or any kind of data.

Ex: 32 bit instruction computer, a register must be 32 bits in length.

Registers

- Data registers
- Address registers
- Status registers
- Program counter
- General purpose registers

4. Memory Unit:

Memory – "How the processor stores and uses immediate data".

The function of the memory unit is to store programs and data. There are 2 classes of memory.

1. Main memory (or) primary memory
2. Secondary memory.

1. Main memory:-

Main memory is a fast memory that operates at electronic speeds. Programs must be stored in the memory while they are being executed. The memory contains a large number of semiconductor storage cells, each capable of storing one bit of information.

Main memory classified into 2 types

1. RAM – Random Access memory
2. ROM – Read only Memory.

2. Secondary Memory:

Main memory is so expensive, we need additional cheaper memory is called Secondary memory.

Secondary memory is used when large amounts of data, and many Programs have to be stored.

Secondary memory has many classification such as:

1. Hard disk
2. Floppy disk
3. CD-Rom or optical disk
4. magnetic disks
5. Tape drive
6. Flash memory.

2. Computer software:

Software is a set of Programs, which is designed to perform a well-defined function. A program is a sequence of instruction written to solve a particular Problem.

Types of software: 1. system software
2. Application software.

III TECHNOLOGIES FOR BUILDING PROCESSORS AND MEMORY.

Technology shapes what computers will be able to do and how quickly they will evolve.

Year	Technology used in computer	Relative Performance Unit/cost
1951	Vacuum Tube	1
1965	Transistor	35
1975	Integrated circuit	900
1995	very large scale integrated Circuit	24,00,000
2013	Ultra large scale integrated circuit	250,000,000,000

Transistor:

A transistor is simply an on/off switch Controlled by electric signal.

Integrated circuit (IC):

The IC combined dozens to hundreds transistors into a single chip.

Vacuum Tubes:-

* The first electronic computer, ENIAC
* It was designed and constructed by Eckert and Mauchly.
* It was made up of more than 18000 vacuum tubes and 1500 relays.
* It was able to perform nearly 5000 addition or subtractions per second.
* It was a decimal rather than a binary machine.
* Its data memory consists of 20 accumulators, each capable of storing a ten digit decimal number.
* Features:- weight - 30 tons, Power consumption - 140 KW. area - 15000 sq. ft

Draw back:-

* It was wired in for specific computations.
* John Von Neumamn introduced concept of stored program to design computer - EDVAC.
* The stored program concept in EDVAC facilitated the user to enter and alter various programs and do variety of computations.
* The programs and their data were located in the same memory.

Very Large Scale Integrated Circuits (VLSI):

* VLSI technology made it possible to fabricate an entire CPU, main memory or similar devices with a single IC that can be mass produced at very low cost.
* Has resulted in new classes of machines such as personal computers and high-performance parallel processors.

* The organizational concepts such as concurrency, pipelining, caches and virtual memories evolved to produce the high performance computing system.

* The fourth generation products are portable notebook computers, desktop computers and workstations, interconnected by local area networks, wide area network and the Internet.

ULSI :- (Ultra Large-Scale Integration)

* ULSI is the process of Integrating or embedding millions of transistors on a single silicon semiconductor microchip.

* It is a successor to LSI and VLSI technologies.

* ULSI was designed to provide the greatest possible computational power from the smallest form factor of microchip or microprocessor dye.

* microchip with more than one million transistors is considered a ULSI implementation.

PERFORMANCE :- [AU : M - 17, 18 D - 14, 18]

The performance is an important attribute of a computer. It is an important criteria for selection of a computer.

There are number of ways by which performance of a computer can be measured.

Defining Performance :-

* One computer is faster than another, we compare their speeds and observes that the faster computer runs a program in less time than other computers.

* The computer user is always interested in reducing the time between the start and the completion of the program or event, i.e. reducing the execution time

* The execution time is also referred to as response time. Reduction in response time increases the throughput. The performance of the computer is directly related to throughput and hence it is reciprocal of execution time.

$$\boxed{Performance_A = \frac{1}{Execution\ time_A}}$$

* Two computers A & B if the performance of A is greater than the performance of B, we have

$$\boxed{Performance_A > Performance_B}$$

$$\boxed{\begin{gathered}\frac{1}{Execution\ time_A} > \frac{1}{Execution\ time_B} \\ Execution\ time_B > Execution\ time_A\end{gathered}}$$

* The execution time on B is longer than that on A, if A is faster than B.

Example:- [AU 2019 Dec]

If computer A runs a program in 10 seconds and Computer B runs the same program in 25 seconds, how much faster is A than B?

Solution:-

$$\frac{Performance_A}{Performance_B} = \frac{Execution\ time_B}{Execution\ time_A} = n$$

∴ the performance ratio is

$$\frac{25}{10} = \boxed{2.5}$$

and A is therefore 2.5 times faster than B.

Measuring Performance:

* Program execution time is measured in seconds per program. However, time can be defined in different ways depending on what it measures.

CPU Time:-

* CPU time is the time the CPU spends computing for particular task and does not include time spend waiting for I/O or running other programs

* CPU time can be divided into the CPU time spent in the program, called user CPU time. and the CPU time spent in the operating system performance tasks on behalf of the program called system CPU time.

Performance Metrics:-

* Users and designers often examine performance using different metrics.

$$\text{CPU execution time for a program} = \text{CPU clock cycles for a Program} \times \text{Clock cycle time}$$

inverse

$$\text{CPU execution time for a program} = \frac{\text{CPU clock cycles for a Program}}{\text{Clock rate}}$$

Scanned with CamScanner

Example: -

Computer A runs a program in 12 seconds with a 3 GHz clock. We have to design a computer B such that it can run the same program with in 9 seconds. Determine the clock rate for computer B. Assume that due to increase in clock rate, CPU design of computer B is affected and it requires 1.2 times as many clock cycles as computer A for execution this program.

Solution:

Given: $\text{clock rate}_A = 3 \times 10^9$ cycles/sec

$\text{CPU time}_A = 12$ seconds

$\text{CPU time}_B = 9$ seconds.

We have,

$$\text{CPU time}_A = \frac{\text{CPU clock cycles}_A}{\text{Clock rate}_A}$$

$$12 \text{ sec} = \frac{\text{CPU clock cycles}_A}{3 \times 10^9 \text{ cycles/sec}}$$

$$\therefore \text{CPU clock cycles}_A = 12 \text{ seconds} \times 3 \times 10^9 \text{ cycles/sec}$$

$$= \boxed{36 \times 10^9 \text{ cycles.}}$$

The CPU time for computer B can be given as

$$\text{CPU time}_B = \frac{\text{CPU clock cycles}_B}{\text{Clock rate}_B} = \frac{1.2 \times \text{CPU clock cycles}_A}{\text{Clock rate}_B}$$

$$\therefore 9 \text{ sec} = \frac{1.2 \times 36 \times 10^9 \text{ cycles}}{\text{Clock rate}_B}$$

$$\therefore \text{Clock rate}_B = \frac{1.2 \times 36 \times 10^9 \text{ cycles}}{9 \text{ sec}} = 4.8 \text{ cycles/sec} = \boxed{4.8 \text{ GHz}}$$

POWER WALL: (2 marks / 4 marks)

* Running a processor at high clock speeds allows for better performance. However, when processor runs at a higher speed, it generates more heat and consumes more power. Thus when there is an increase clock rate, there is increase in power consumed.

* The dominant technology used for integrated circuits is CMOS. For CMOS, the dynamic power depends on the capacitive loading of each transistor, the voltage applied and the frequency that the transistor is switched.

$$\boxed{\begin{aligned}\text{Power} &= \text{capacitive load} \times \text{Voltage}^2 \times \text{Frequency switched} \\ &= CV^2f\end{aligned}}$$

* The f is the function of clock rate. The C is function of both the number of transistors connected to an output and the technology.

Example:-

If a new processor has 85% of the capacitive load of old processor, its supply voltage is reduced by 20% and new processor results in a 25% shrink in frequency. What is the impact on power consumption?

Solution:-

$$\frac{\text{Power (new processor)}}{\text{Power (old processor)}} = \frac{(C \times 0.85) \times (V \times 0.8)^2 \times (f \times 0.75)}{CV^2f}$$

$$= (0.85) \times (0.8)^2 \times (0.75)$$

$$= \boxed{0.408}$$

Example:- write a program to evaluate the arithmetic statement $Y = (A+B) * (C+D)$ using three-address, two-address, one-address and zero address instructions.

Solutions:- Using three address instructions

```
ADD R1, A, B   : R1 ← M[A] + M[B]
ADD R2, C, D   : R2 ← M[C] + M[D]
MUL Y, R1, R2  : M[Y] ← R1 * R2.
```

Using two address instructions :-

```
MOV R1, A     : R1 ← M[A]
ADD R1, B     : R1 ← R1 + M[B]
MOV R2, C     : R2 ← M[C]
ADD R2, D     : R2 ← R2 + M[D]
MUL R1, R2    : R1 ← R1 * R2
MOV Y, R1     : M[Y] ← R1
```

Using zero address

```
PUSH A   : TOS ← A
PUSH B   : TOS ← B
ADD      : TOS ← (A+B)
PUSH C   : TOS ← C
PUSH D   : TOS ← D
ADD      : TOS ← (C+D)
MUL      : TOS ← (C+D)*(A+B)
POP Y    = M[Y] ← TOS
```

Using One address instruction

```
LOAD A    : AC ← M[A]
ADD B     : AC ← AC + M[B]
STORE T   : M[T] ← AC
LOAD C    : AC ← M[C]
ADD D     : AC ← AC + M[D]
MUL T     : AC ← AC * M[T]
STORE Y   : M[Y] ← AC
```

Types of Operands:

* Instruction is divided into 2 parts

1. Opcode (operation Code)
2. Operands

* The operands may appear in different forms:
  * Addresses : The addresses are in fact a form of data.
  * Numbers : numeric data types
  * Characters : text or character strings.
  * Logical data: bit, byte, word or double word.

Types of operations:-

* Arithmetic
* Data transfer
* Logical
* Conditional branch
* unconditional jump.

Representing Instructions:-

Translating a MIPS Assembly instruction into a machine instruction.

R-Format Instruction:- MIP instruction is divided into segments called fields.

31 – 26	25 – 21	20 – 16	15 – 11	10 – 6	5 – 0
Opcode	rs	rt	rd	Shift amount	Function
6 bits	5 bits	5 bits	5 bits	5 bits	6 bits

I-Format Instruction: I-format and is used by the immediate and data transfer instructions. The fields of I-format are:-

31 – 26	25 – 21	20 – 16	15 – 0
Opcode	rs	rt	Constant or Address
6 bits	5 bits	5 bits	16 bits

J-format Instructions :-

J-Type is short for "Jump type". The format of an J-type instructions

31 26	25 0
Opcode	Target
6 bits	26 bits

Logical Operations :-

Logical operations	C Operators	Java Operators	MIPS instructions
Shift Left	<<	<<	sll
Shift Right	>>	>>>	srl
Bit-by-bit AND	&	&	and, andi
Bit-by-bit OR	|	|	or, ori
Bit-by-bit NOT	~	~	nor

Control Operations - Making Decisions and Loops :-

* MIPS assembly language includes two decision-making instructions, similar to an if statement with a goto.

beq register1, register2, L1 : This instruction means go to the statement labeled L1 if the value in register1 equals the value in register2. The beq stands for branch if equal.

bne register1, register2, L1 : if the value in register1 does not equal the value in register2. The bne stands for branch not equal. These two instructions are called Conditional branches.

MIPS Addressing Modes:-

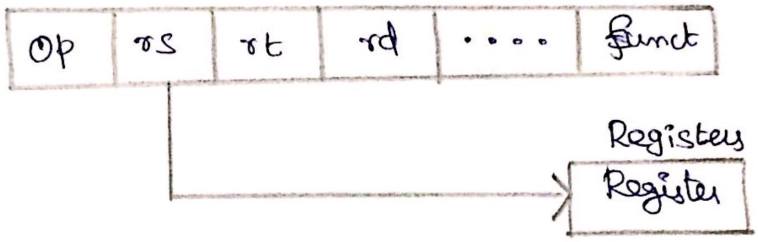
MIPS has the following addressing modes.

1. Immediate Addressing 2. Register Addressing
3. Base or displacement 4. PC-relative addressing
5. Pseudo-direct Addressing

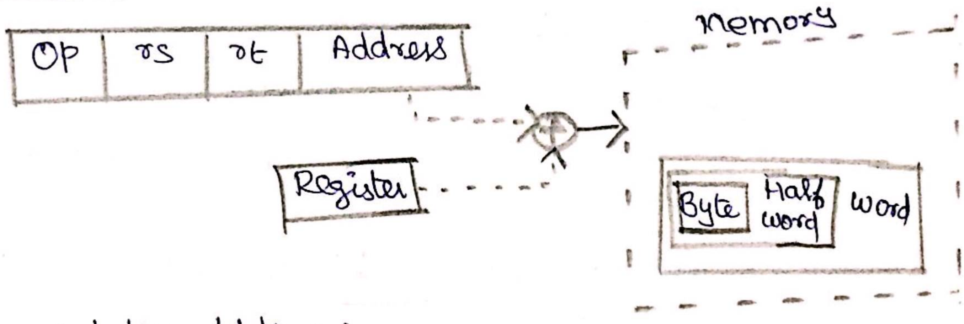
1. **Immediate Addressing**:- where the operand is a constant within the instruction itself.

op	rs	rt	immediate

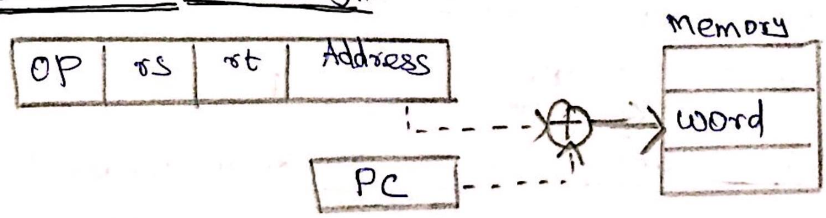
2. **Register Addressing**:- where the operand is a register



3. **Base or Displacement Addressing**:



4. **PC-Relative Addressing**:-



5. **Pseudo-direct Addressing**:-