# CS301 Computer Architecture

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***Materials in these slides are borrowed from textbooks and existing Architecture courses***

# Course Details & Logistics

Tuesday – 3 to 3.55 PM

Wednesday – 2 to 2.55 PM

Thursday - 5 to 5.55 PM

**CS311– Computer Architecture Lab**

Monday – 10AM to 12.55 PM

Books:

**Text Book: Computer Organisation and Architecture, Smruti Ranjan Sarangi, McGrawHill 2015**

Reference Book : Computer Architecture A Quantitative Approach, Fifth edition, by David Patterson and John L. Hennesy, Morgan Kaufmann, 2017.

TA information:
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Omkar Shende – 212011004@iitdh.ac.in

# Tentative Grading Components

**CS 301 CA THEORY**

| EVALUATION COMPONENT | WEIGHTAGE |
|---|---|
| QUIZZES (2) | 25 |
| MID SEM | 25 |
| END SEM | 40 |
| VIVA | 10 |

**CS 311 CA LAB**

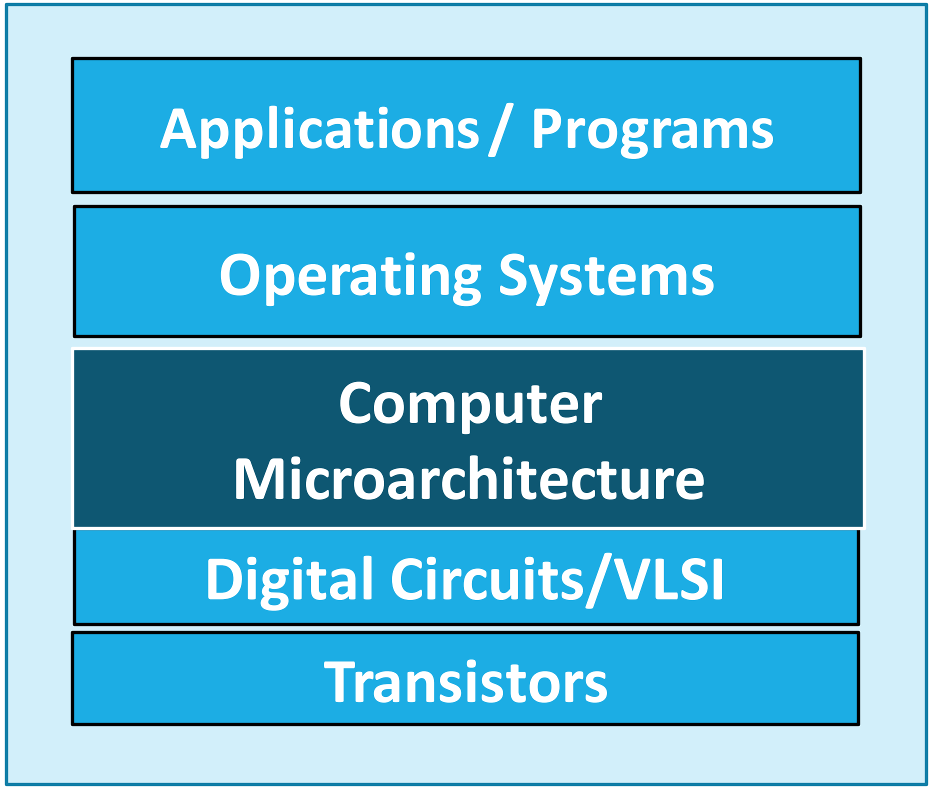
| EVALUATION COMPONENT | WEIGHTAGE |
|---|---|
| IN SEMESTER LABS | 80 |
| LAB EXAM | 20 |

- You will build a software model of a processor
- Programming will be in Java
- 6 Labs/Experiments in total (each of varying complexity)
- For each experiment, marks will be based on code, and report submitted, Demos & Viva

# Note

- **Academic honesty is expected from each student participating in the course.**
- **NO sharing (willing, unwilling, knowing, unknowing) of assignments/ codes between students is allowed.**
- **Academic violations will be handled as per the rules mentioned in Section** 5.9 of the B.Tech Rule book

# Abstractions in a Computer System



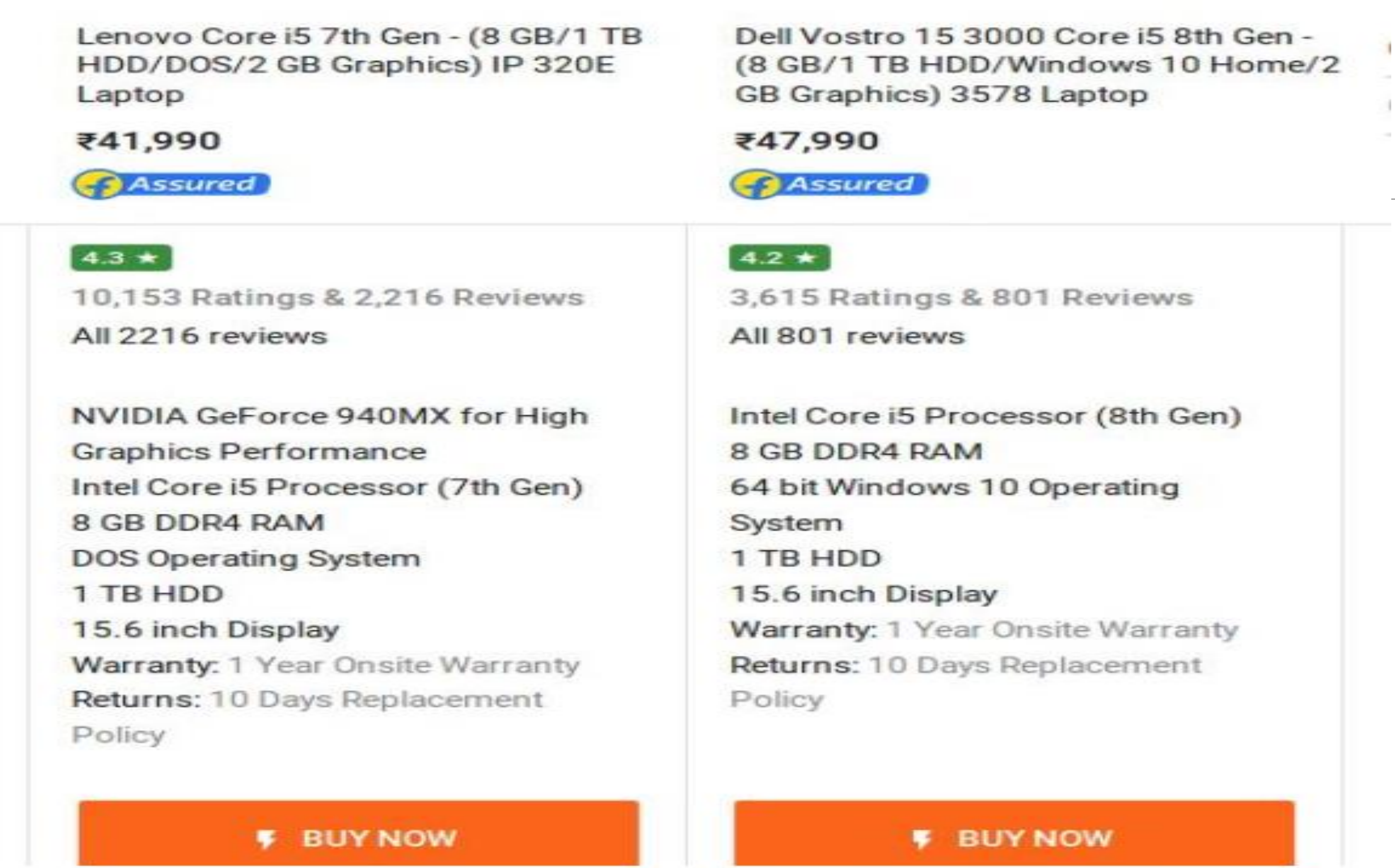
Applications / Programs

Operating Systems

Computer Microarchitecture

Digital Circuits/VLSI

Transistors



Lenovo Core i5 7th Gen - (8 GB/1 TB HDD/DOS/2 GB Graphics) IP 320E Laptop

₹41,990

4.3 ★

10,153 Ratings & 2,216 Reviews

All 2216 reviews

NVIDIA GeForce 940MX for High Graphics Performance
Intel Core i5 Processor (7th Gen)
8 GB DDR4 RAM
DOS Operating System
1 TB HDD
15.6 inch Display
**Warranty:** 1 Year Onsite Warranty
**Returns:** 10 Days Replacement Policy

Dell Vostro 15 3000 Core i5 8th Gen - (8 GB/1 TB HDD/Windows 10 Home/2 GB Graphics) 3578 Laptop

₹47,990

4.2 ★

3,615 Ratings & 801 Reviews

All 801 reviews

Intel Core i5 Processor (8th Gen)
8 GB DDR4 RAM
64 bit Windows 10 Operating System
1 TB HDD
15.6 inch Display
**Warranty:** 1 Year Onsite Warranty
**Returns:** 10 Days Replacement Policy

## i3 v/s i5 v/s i7

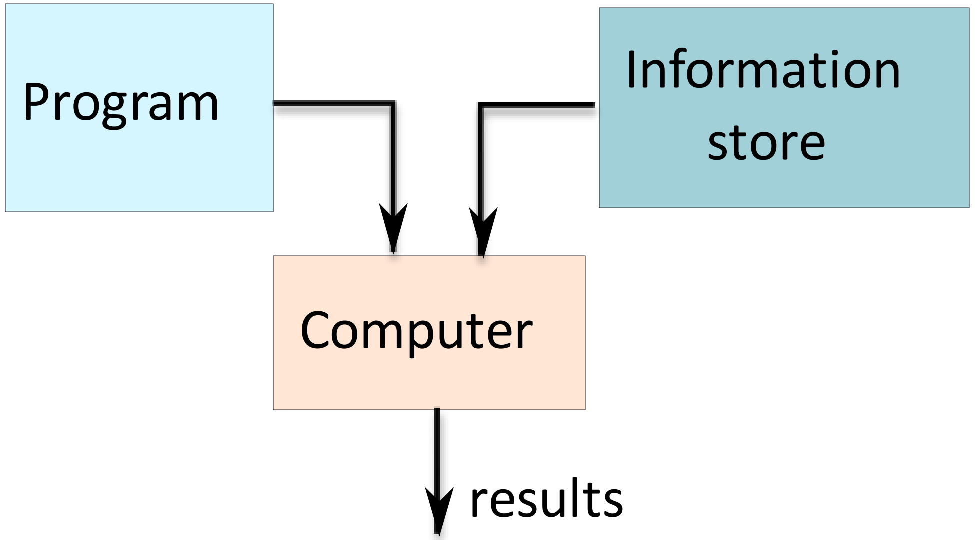
- Classification of manufactured chips based on maximum safe operating frequency

## Generations

- Reducing feature size
    - Transistors are smaller, switch faster, consume less energy
- Improved Computer Architecture

Based on the same principles

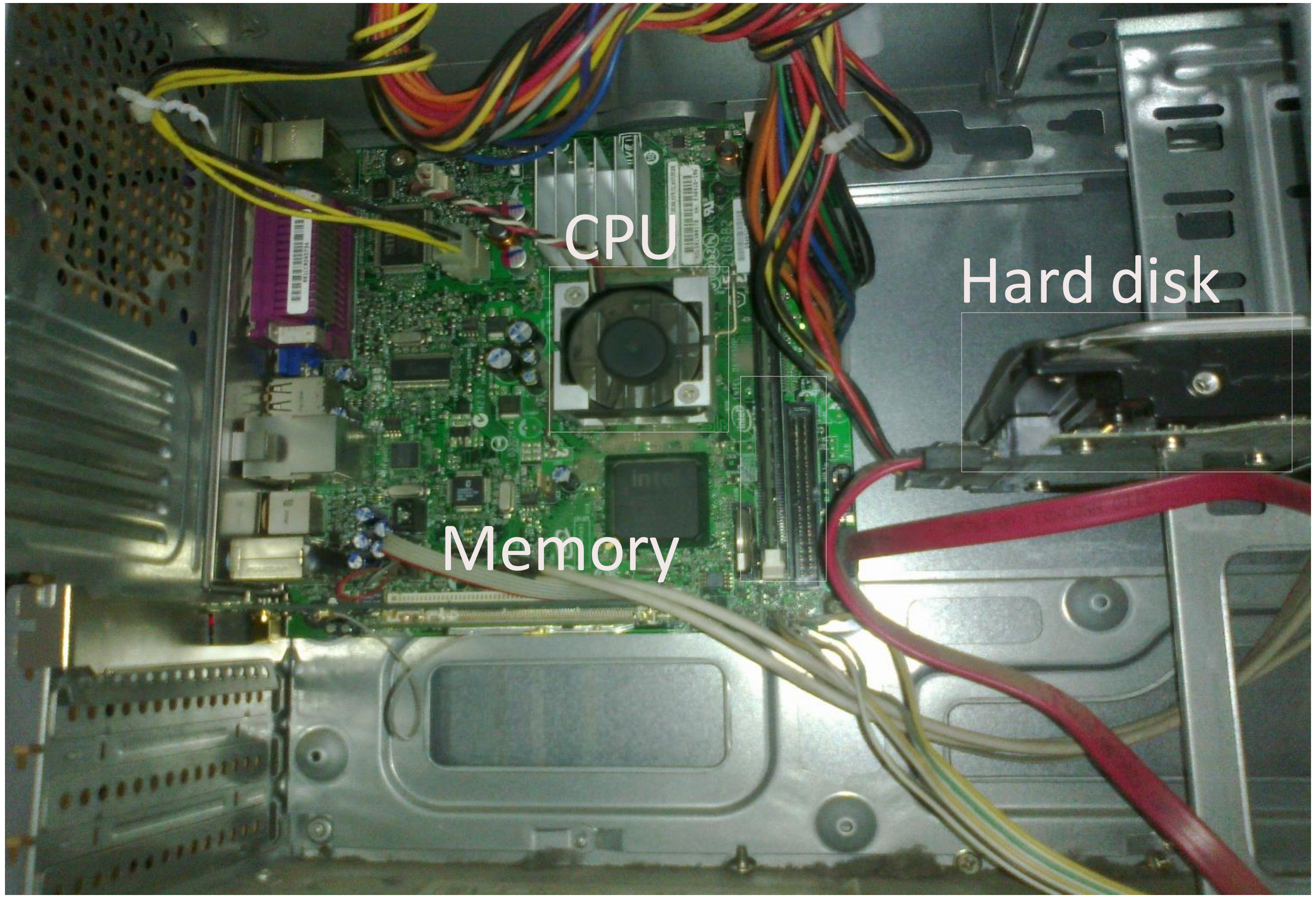
# How does it work ?

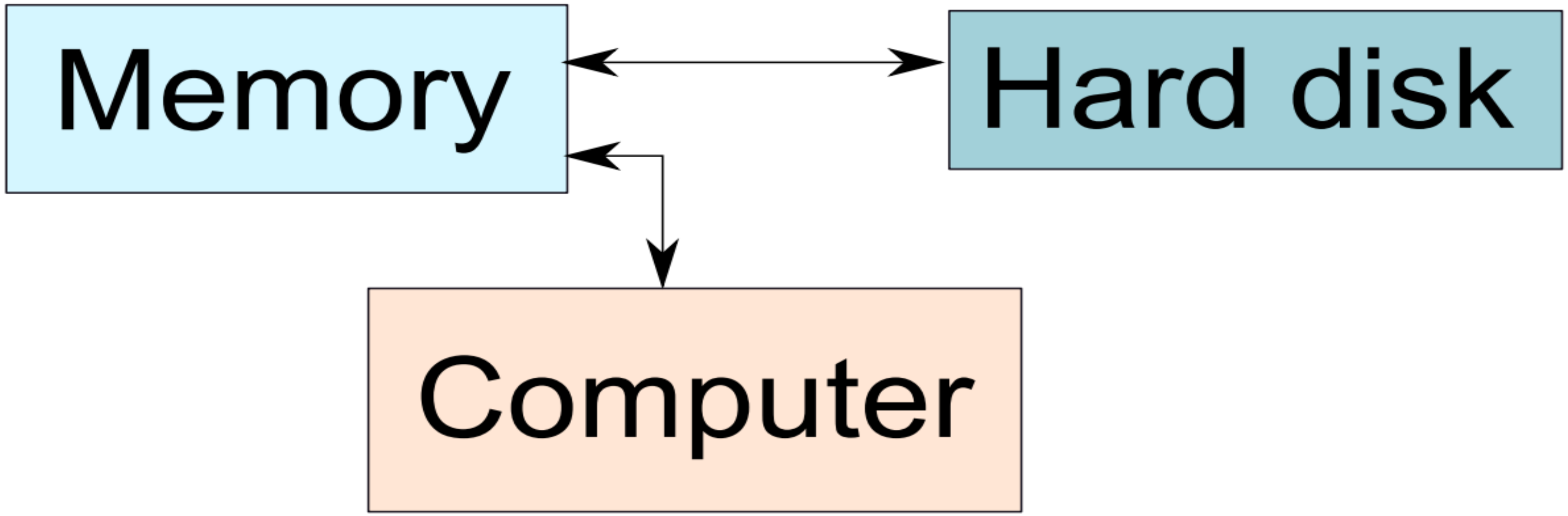


- Program – List of instructions given to the computer
- Information store – data, images, files, videos
- Computer – Process the information store according to the instructions in the program

# What does a computer look like ?

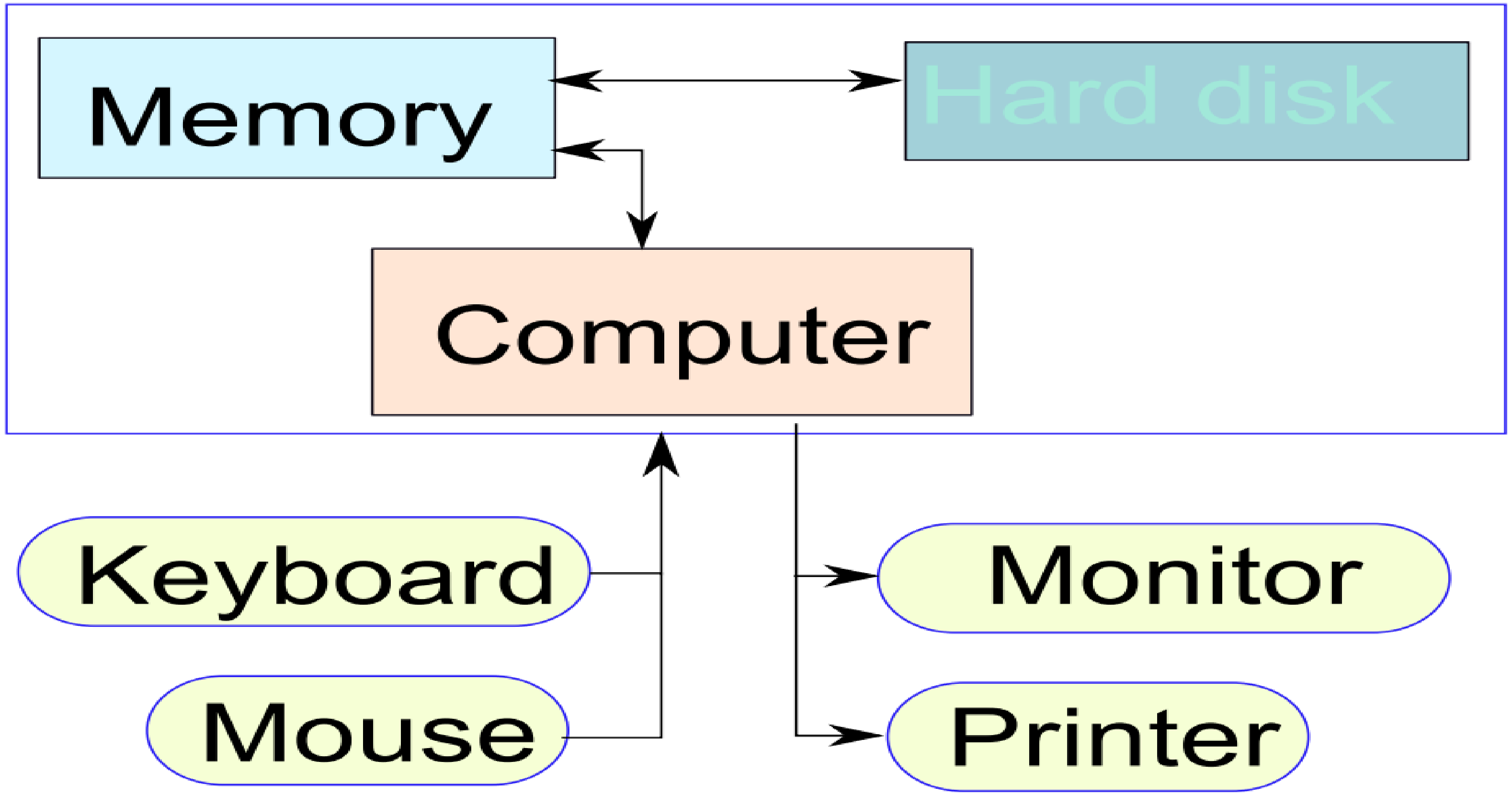
- Let us take the lid off a desktop computer



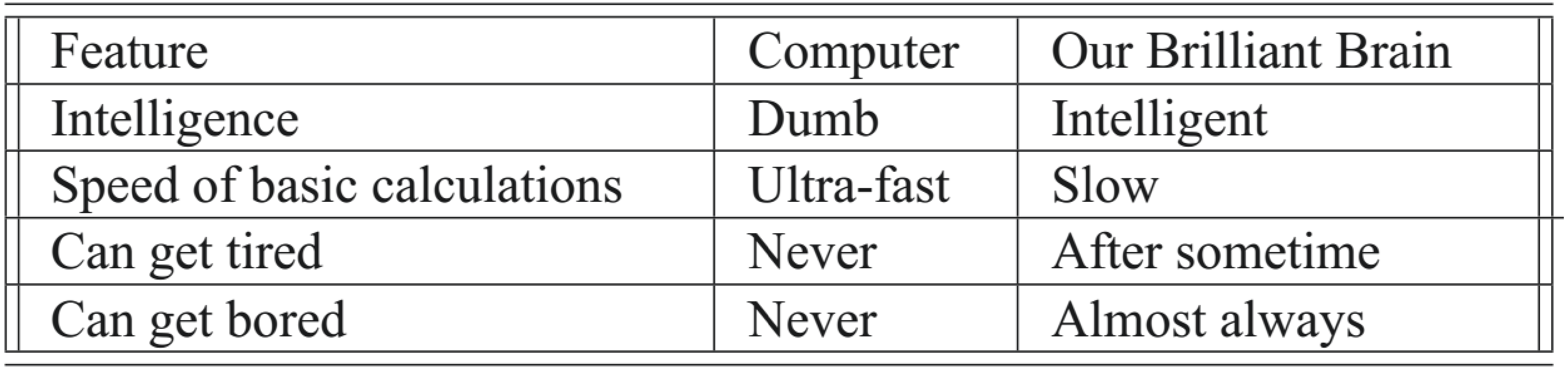


- Memory – Stores programs and data. Gets destroyed when the computer is powered off
- Hard disk – stores programs/data permanently

# Lets Make a Full System !



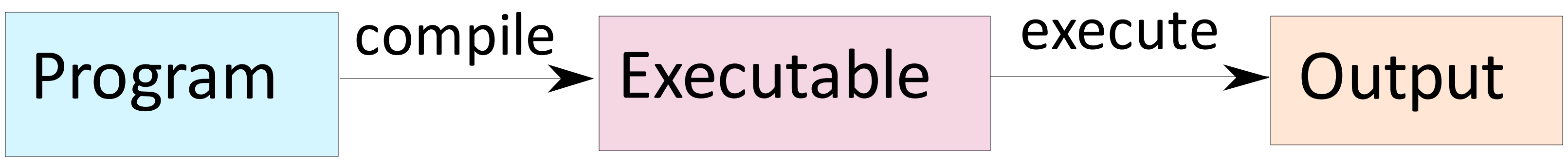
# What does a computer look like ?



| Feature | Computer | Our Brilliant Brain |
|---|---|---|
| Intelligence | Dumb | Intelligent |
| Speed of basic calculations | Ultra-fast | Slow |
| Can get tired | Never | After sometime |
| Can get bored | Never | Almost always |

- Computers are ultra-fast and ultra-dumb

# How to Instruct a Computer ?



- Write a program in a high level language – C, C++, Java
- **Compile** it into a format that the computer understands
- Execute the program

# What Can a Computer Understand ?

- Computer can clearly NOT understand instructions of the form
  - Multiply two matrices
  - Compute the determinant of a matrix
  - Find the shortest path between Mumbai and Delhi
- They understand :
  - Add $a + b$ to get $c$
  - Multiply $a * b$ to get $c$

# The Language of Instructions

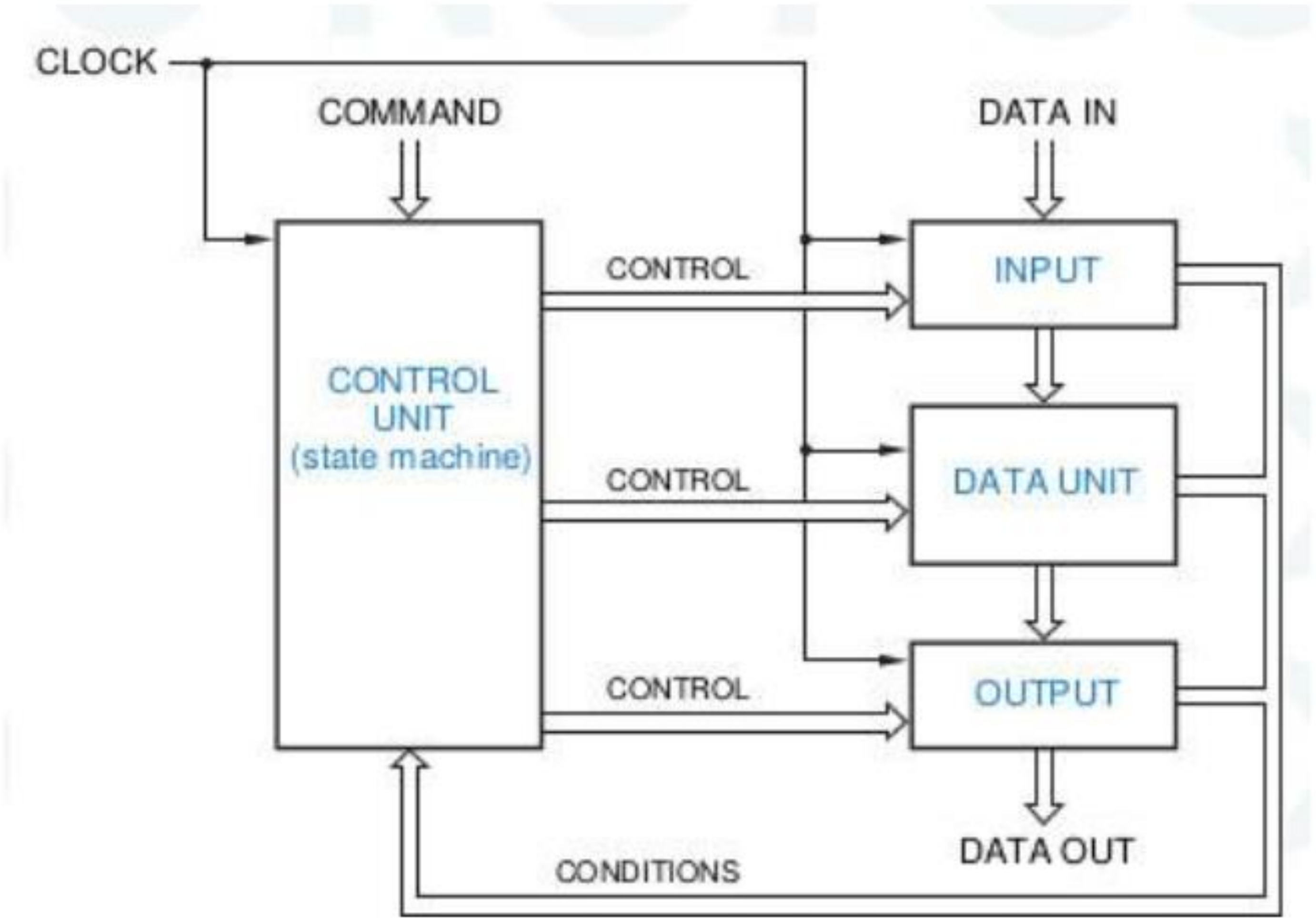
- Humans can understand
  - Complicated sentences
    - English, French, Spanish
- Computers can understand
  - Very simple instructions

The semantics of all the instructions supported by a processor is known as its instruction set architecture (ISA). This includes the semantics of the instructions themselves, along with their operands, and interfaces with peripheral devices.

# Relation with Theory of Computation

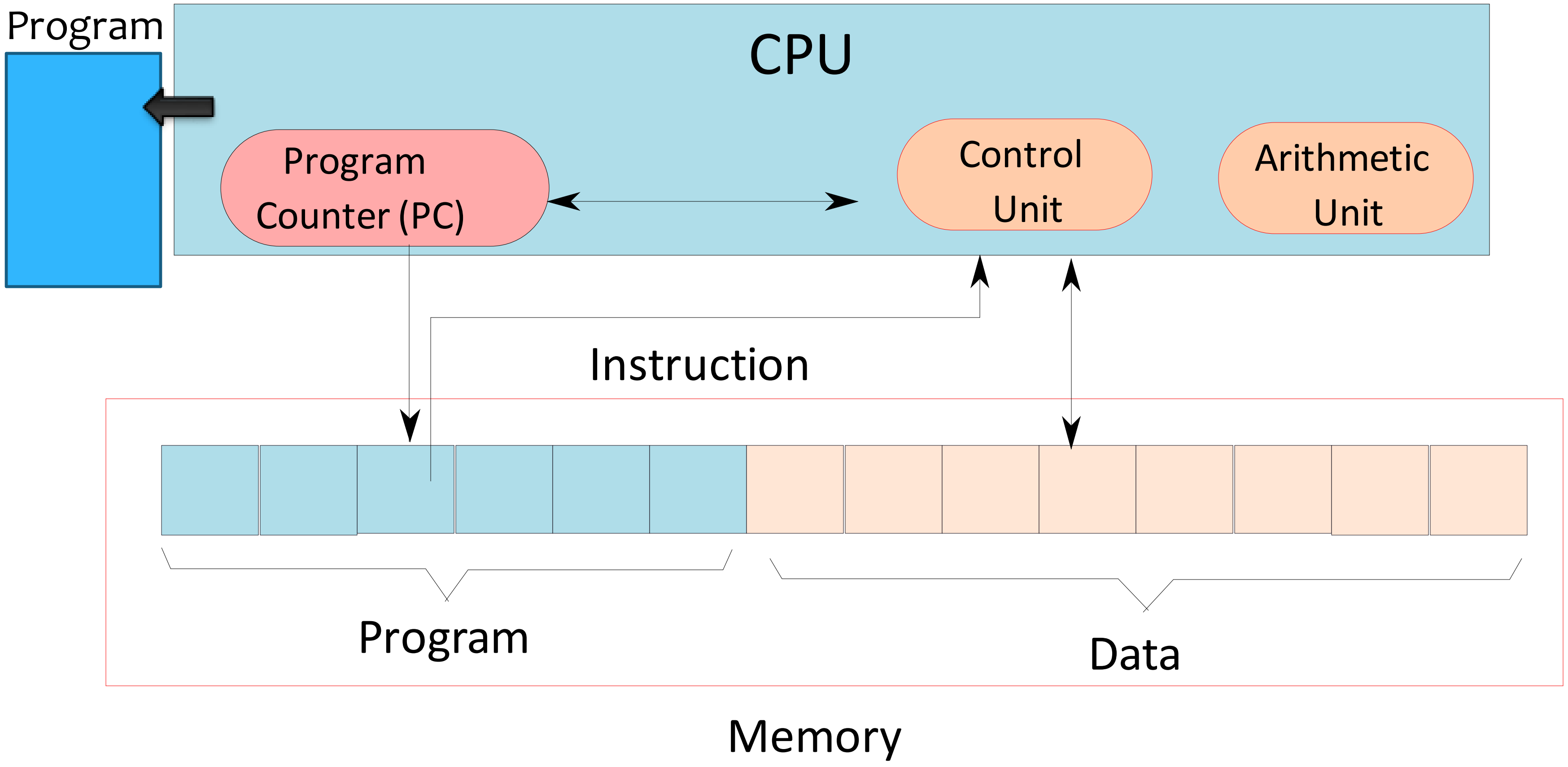
- A modern computer is a practical Turing Machine
  - The memory refers to the tape
    - Both program instructions and data reside in memory
  - Program counter refers to the state
    - Program counter indicates which instruction is to be executed next
  - The processor itself refers to the transition table
    - Based on the instruction, it performs some modifications on data

# Relation with Synchronous Digital Systems



- “Control” can be a hardwired circuit. This makes it “application specific”.
- Alternatively, “control” can be “programmable”. This allows it to do a lot more.

# Computer Inspired from the Turing Machine

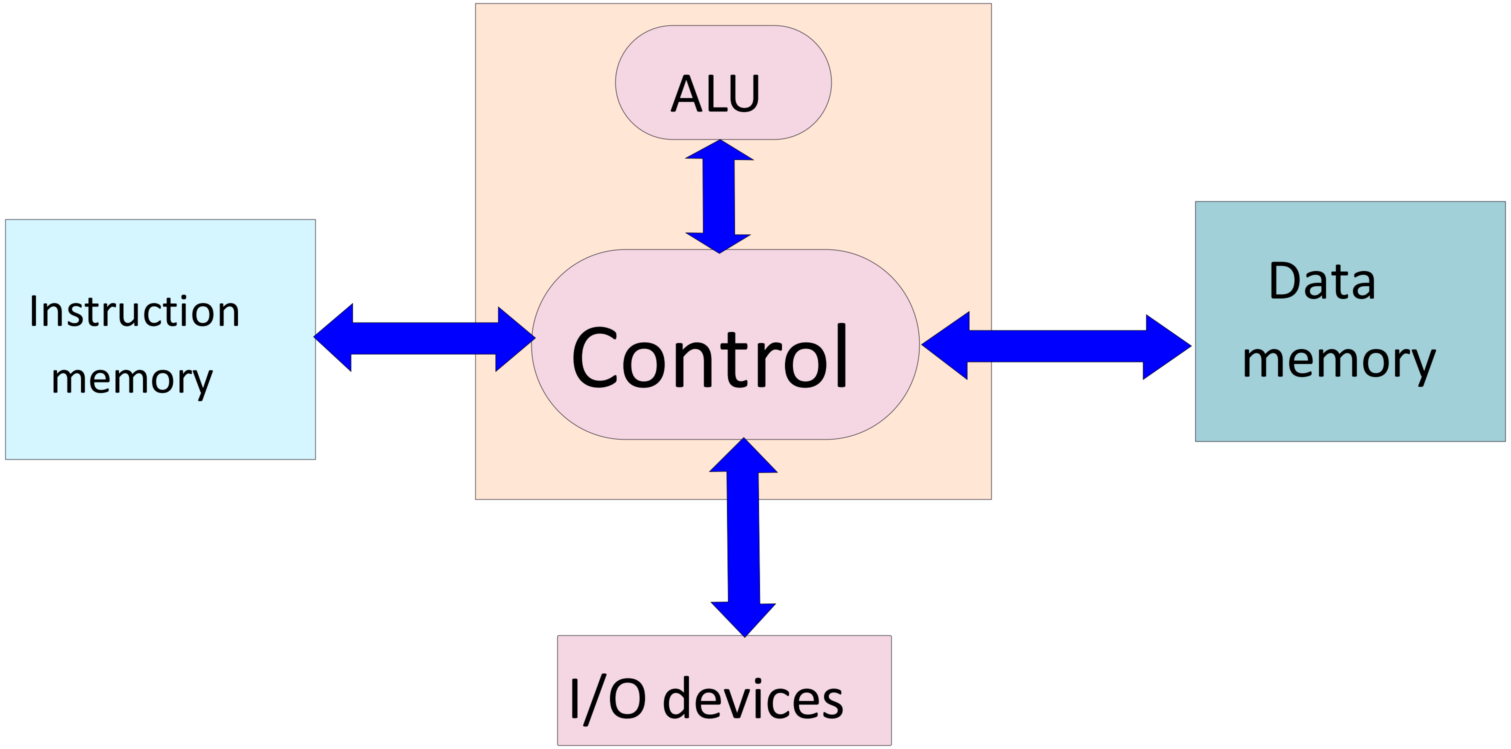


# Elements of a Computer

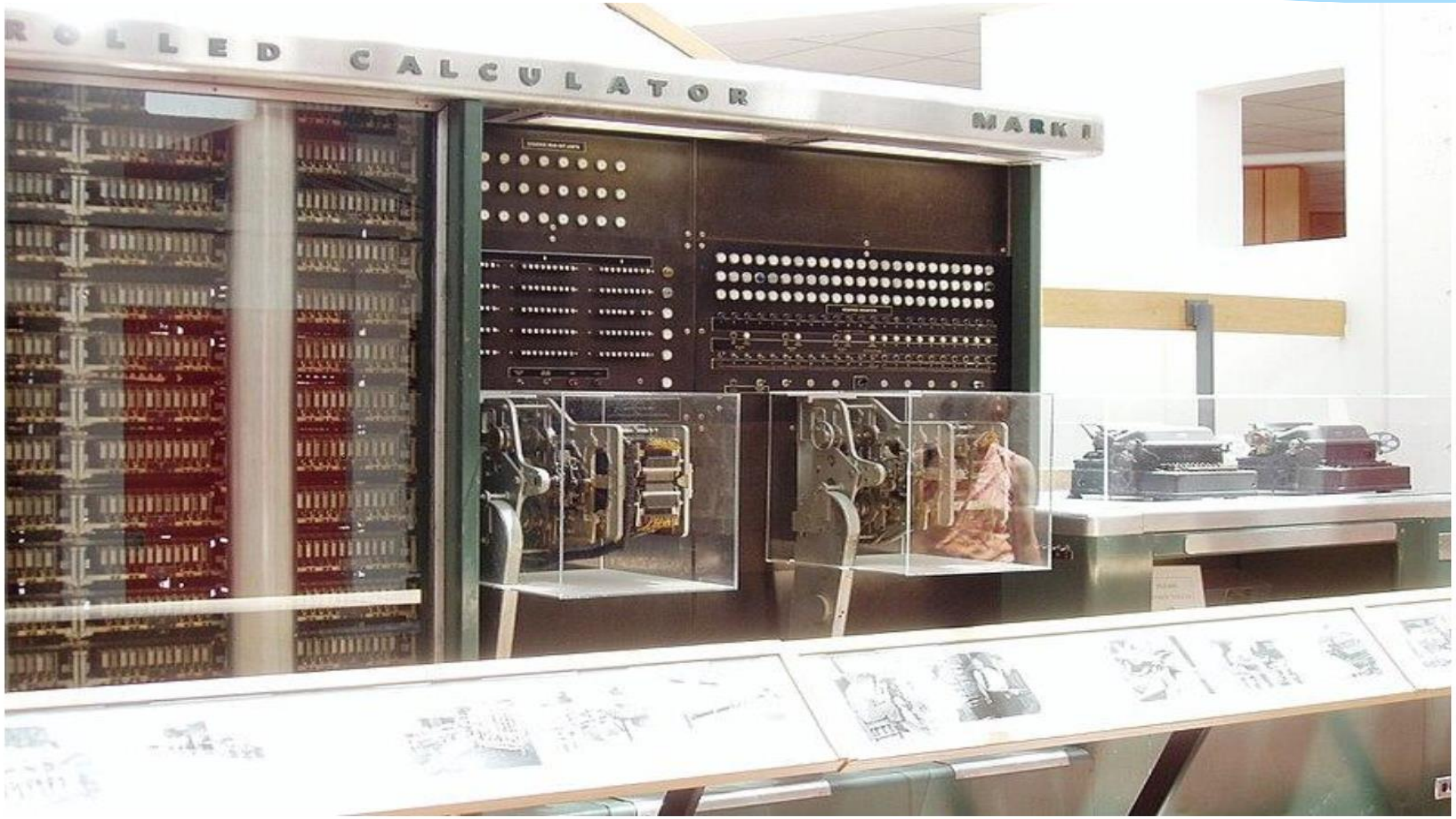
- Memory (array of bytes) contains
  - The program, which is a sequence of instructions
  - The program data → variables, and constants
- The program counter(PC) points to an instruction in a program
  - After executing an instruction, it points to the next instruction by default
  - A branch instruction makes the PC point to another instruction (not in sequence)
- CPU (Central Processing Unit) contains the
  - Program counter, instruction execution units

# Designing Practical Machines

CPU

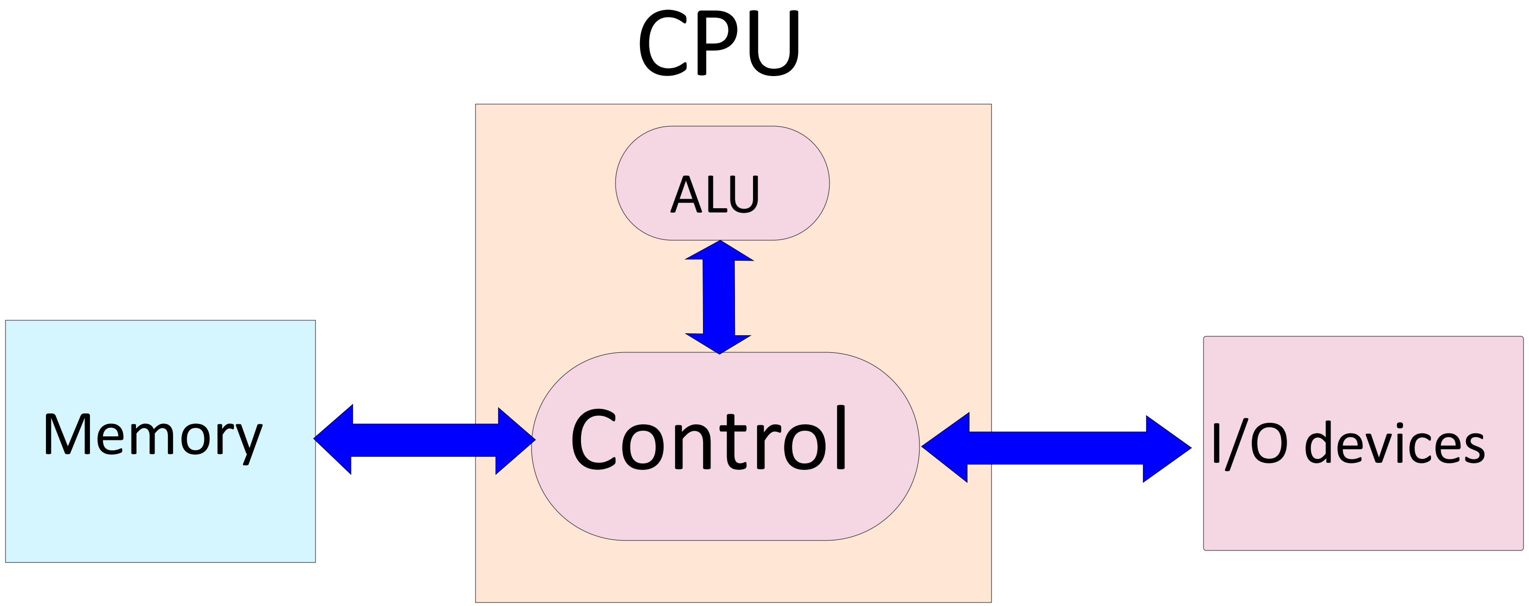


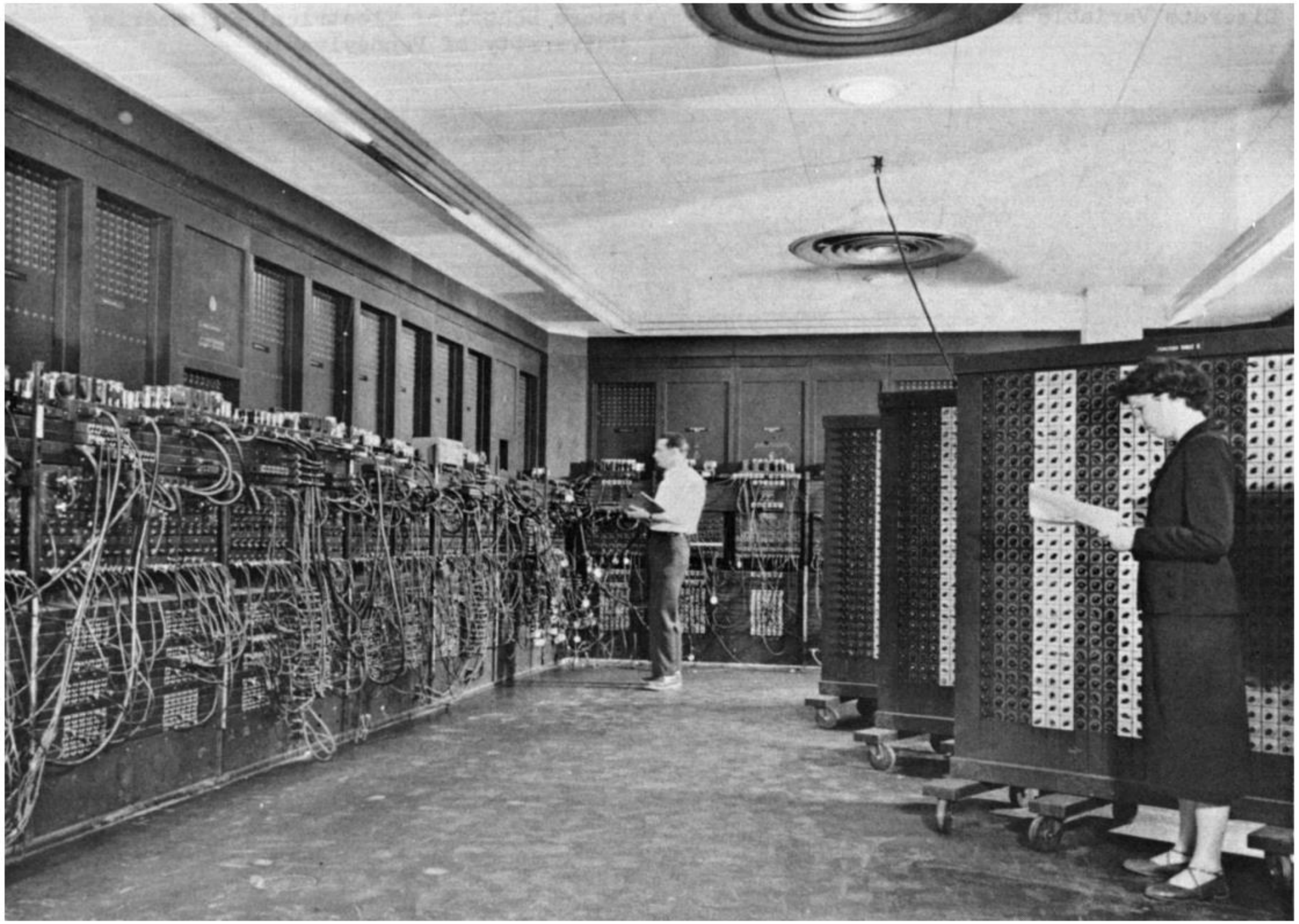
Harvard Architecture



The Harvard Mark I

# Von-Neumann Architecture





The ENIAC

# Problems with Harvard/ Von-Neumann Architectures

- The memory is assumed to be one large array of bytes
  - It is very very slow

**General Rule: Larger is a structure, slower it is**

  - Solution:
    - Have a small array of named locations **(registers)** that can be used by instructions
    - This small array is very fast

**Insight: Accesses exhibit locality (tend to use the same variables frequently in the same window of time)**

McGraw Hill Education

# Uses of Registers

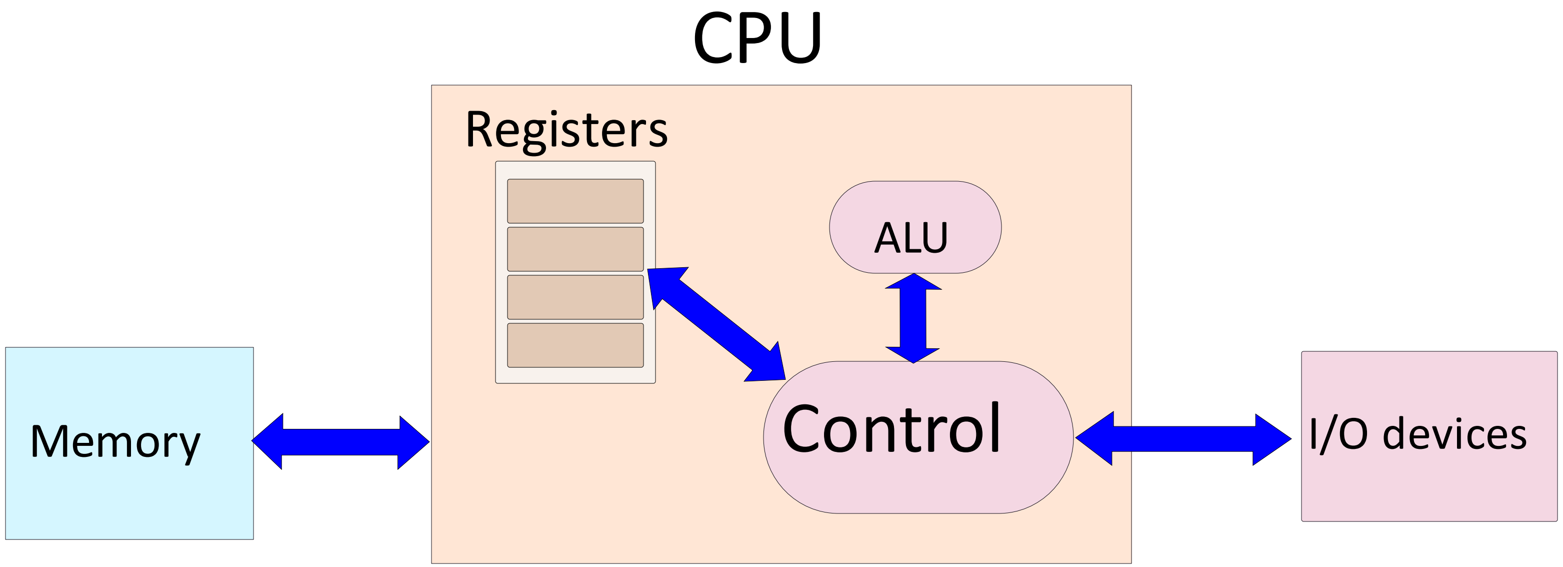
- A CPU (Processor) contains set of registers (16-64)
- These are named storage locations.
- Typically values are loaded from memory to registers.
- Arithmetic/logical instructions use registers as input operands
- Finally, data is stored back into their memory locations.

# Example of a Program in Machine Language with Registers

```
1: r1 = mem[b] // load b
2: r2 = mem[c] // load c
3: r3 = r1 + r2 // add b and c
4: mem[a] = r3 // save the result
```

- r1, r2, and r3, are registers
- mem → array of bytes representing memory

# Machine with Registers


CPU
Registers
ALU
Control
Memory
I/O devices