Computer architecure

Turing machine, von Neumann computer, Flynn classification

Data processing

Data processing is the activity that has a goal of processing available dana to produce the desired result.

Dana processing consists of:

- Storing data
- Processing large volumes of data
- Sending data to a recepient or storing it to a particular place

Data processing

- While talking about data processing, we can distinguish three main components of it:
  - Data
  - Algorithm
  - Executor or processor

Data processing

- Data is the target of our processing and should be presented in a machine readable format
- Algorithm are instructions, a „recipe” or „guide” that describes how to transform input data into the data we requested
- Processor can be a person or a machine

Basic computer models

- We are dealing with processing – talking about computer based on a *von Neumann model*
- *Computer model* is an abstraction above computer architecture and computer or programming languages
- Model consists of three things:
  - Basic elements that are used in computing
  - Model that describes the problem
  - Execution model

Instruction flow control

Order in which the instructions are executed or execution flow can be:

- *control-driven*
- *data-driven*
- *demand-driven*

Turing machine

- Turing machine is a theoretical computing machine designed and introduced in 1936. by Alan M. Turing, English mathematician. Turing initially designed its machine to be able to distinguish between mathematical statements that are true or false but that cannot be proven as such using axiomatic structure available at the time.
- Turing proved that there is no universal algorithm that can prove those statements.

Encyclopedia Britannica

Turing machine

- The Turing machine is not a machine in the ordinary sense but rather an idealized mathematical model that reduces the logical structure of any computing device to its essentials.
  As envisaged by Turing, the machine performs its functions in a sequence of discrete steps and assumes only one of a finite list of internal states at any given moment. The machine itself consists of an infinitely extensible tape, a tape head that is capable of performing various operations on the tape, and a modifiable control mechanism in the head that can store directions from a finite set of instructions.

Britannica

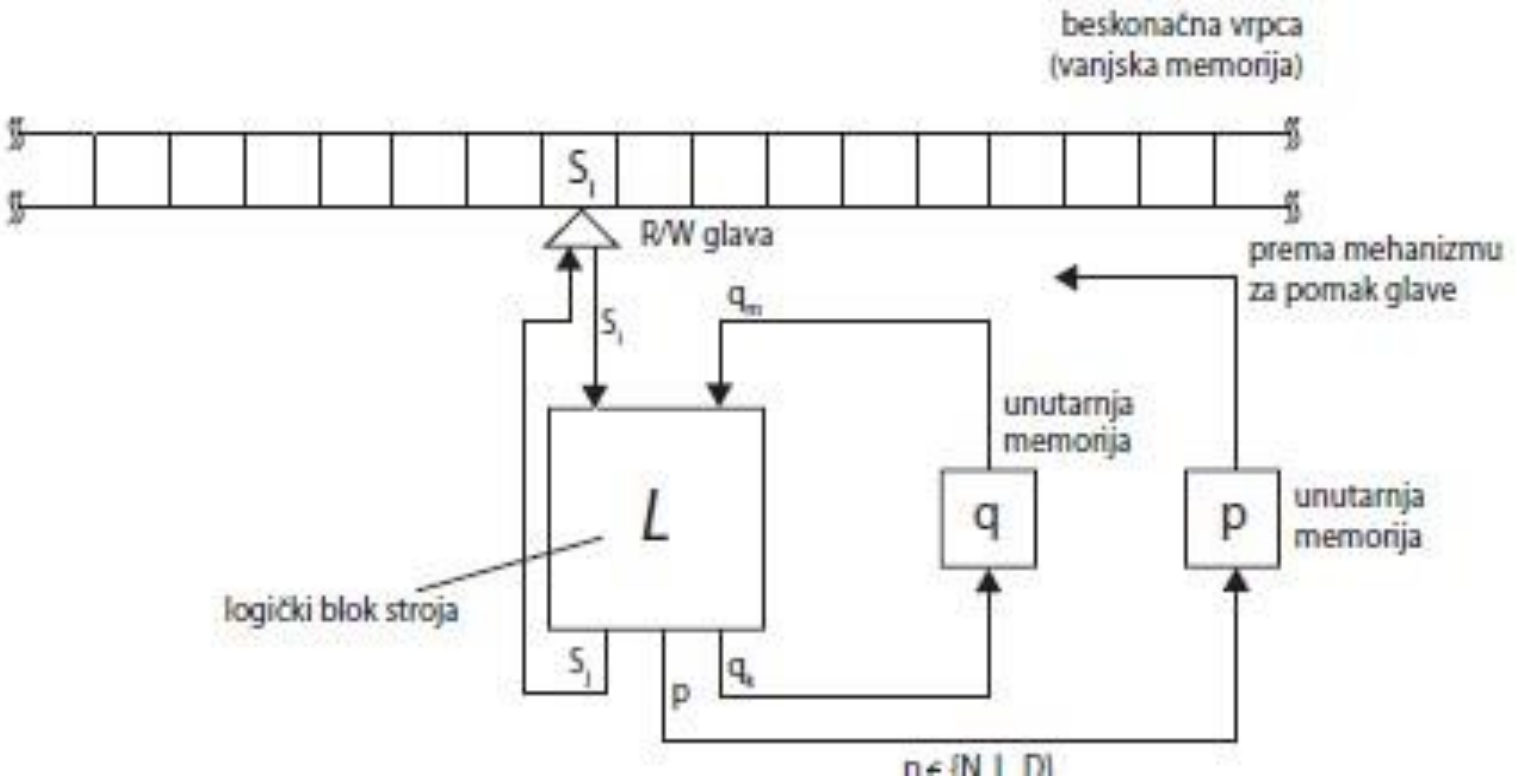
Where is the interest in Turing machine?

- Halting problem – theoretical problem proving that a certain algorithm can be performed in a given amount of finitive time
- Example (Python) (reads input, if not empty loops in infinity)

```
x = input()
while x:
    pass
```

- Halting problem in a primitive form
- Any problem that may have a finite solution, but we need to prove it
- Turing machine uses infinite time and infinite storage, so it can prove this kinds of problems
- More on this https://brilliant.org/wiki/halting-problem/
- Turin machine is an elegant way of learning *assembly*

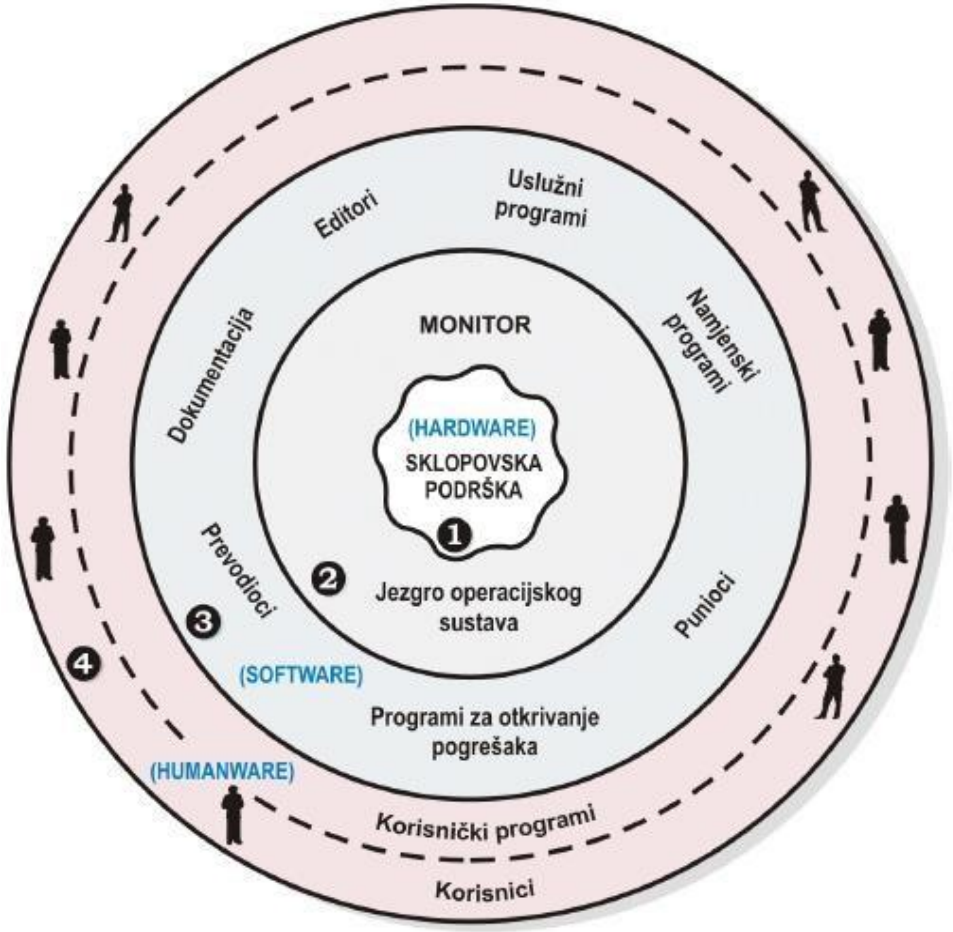
Turing machine



Turing machine

- Basic idea: - dividing computation into simple easly understadable atomic instructions
- Parts of the machine
  - External memory in the form of an infinite tape
  - Tape is divided into cells that can contain only one character from set S
  - Read-write head that can be moved along the tape
  - Internal memory: q stores internal state of the machine and p to store information about the movement of the head
- Logical block L performs computations.

Hierarchical model



Architecture Classification

By mean of running instructions

- control-flow
- data-flow
- demand driven

Control flow

- Architecture of interest for us
- Uses conventional von Neumann model

Basics:

- Adressable memory containg both data and instructions
- Program counter (PC) containing address of the next instruction
- Instructions are performed sequentially

Flynn’s taxonomy

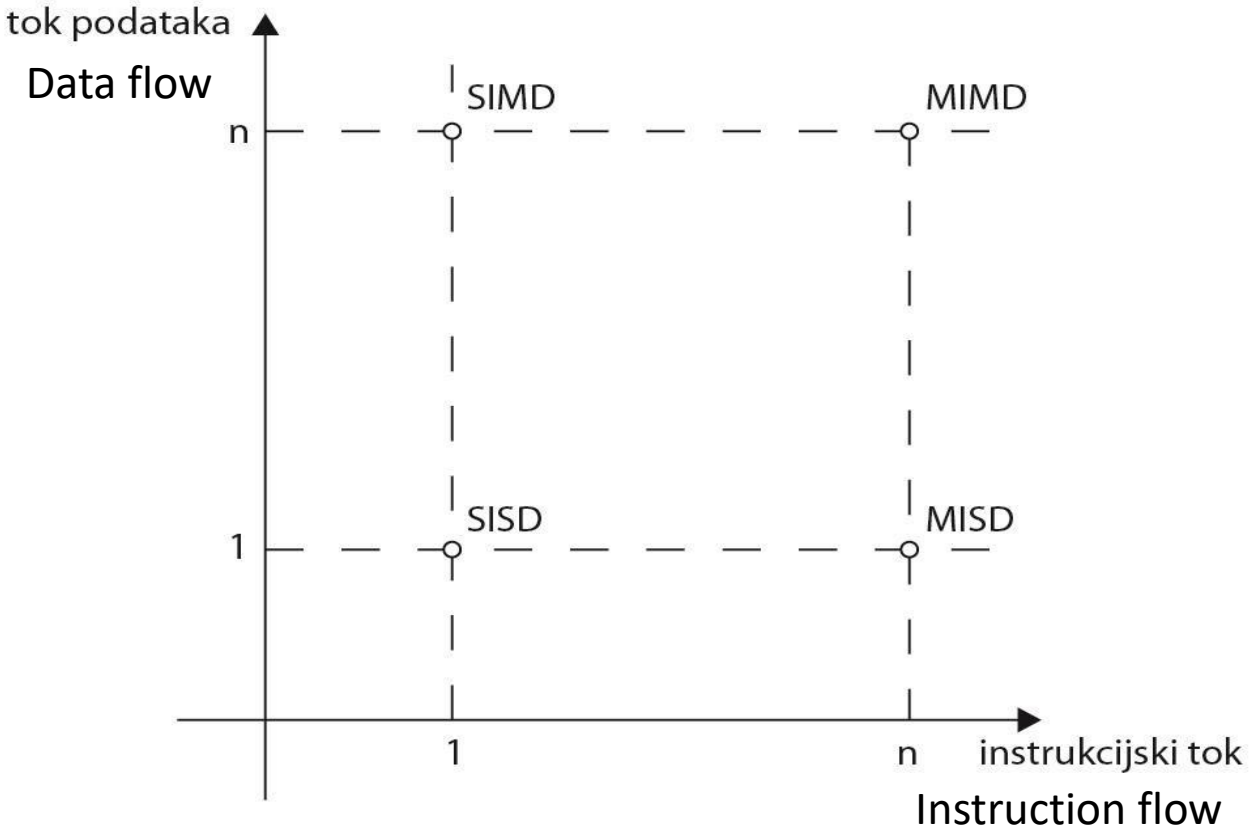
Based on

- Instruction flow
- Data flow

Four basic types

- SISD (von Neumann)
- MISD (pipeline)
- SIMD (vector computing, parallel computing)
- MIMD (multi computers multi processors)

Flynn


tok podataka
Data flow
SIMD
MIMD
n
SISD
MISD
1
1
n
instrukcijski tok
Instruction flow

SISD

Let’s explain this architecture by using:

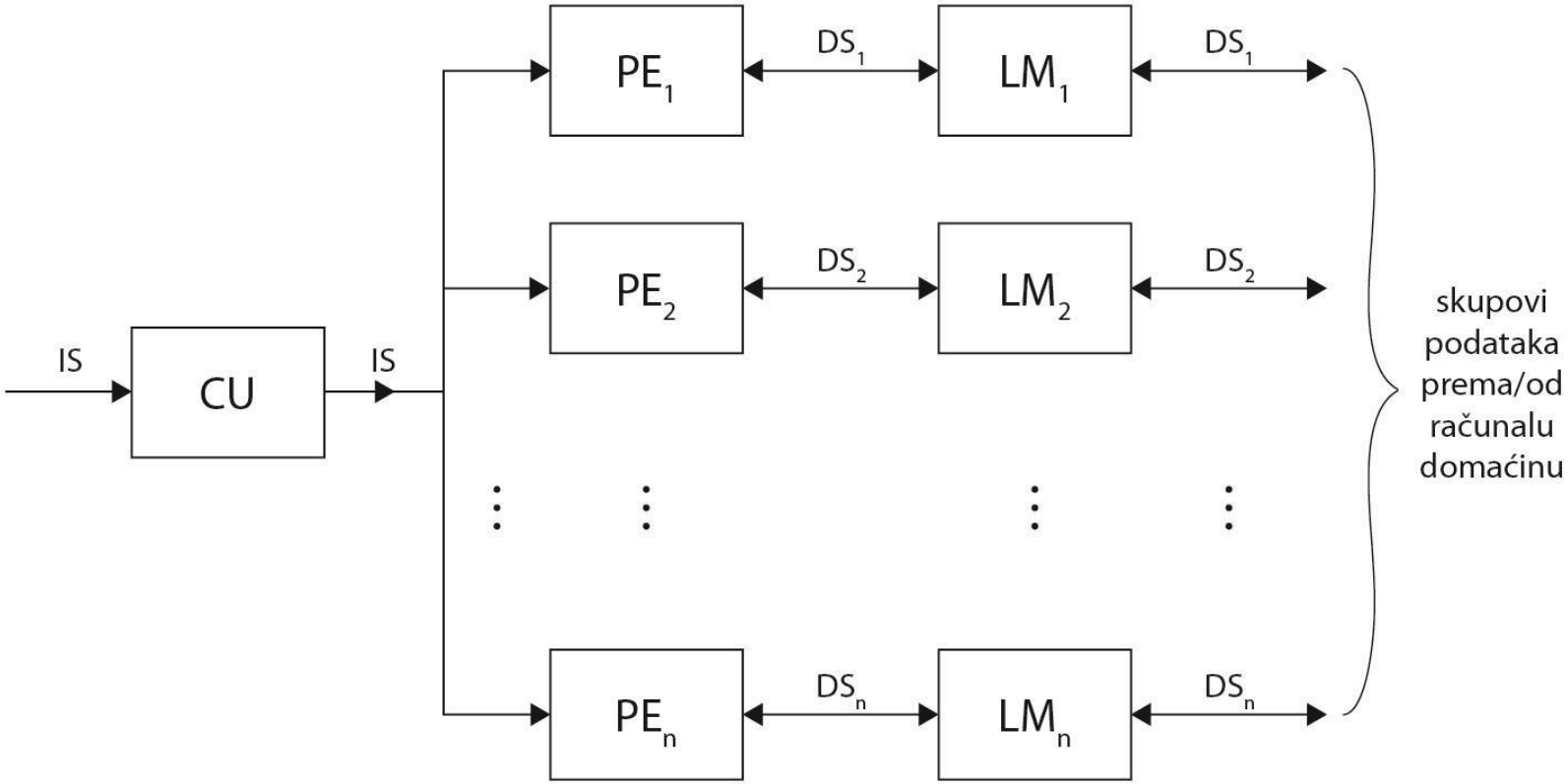
- memory (MU – memory unit)
- CU (control unit)
- PU – processing unit or PE – processing element

- One stream each IS, DS out if MU
- Control unit decodes instructions - CU
- PU – processing unit combines these into a computation

SISD (Single Instruction Stream Single Data Stream)

- von Neumannovom model

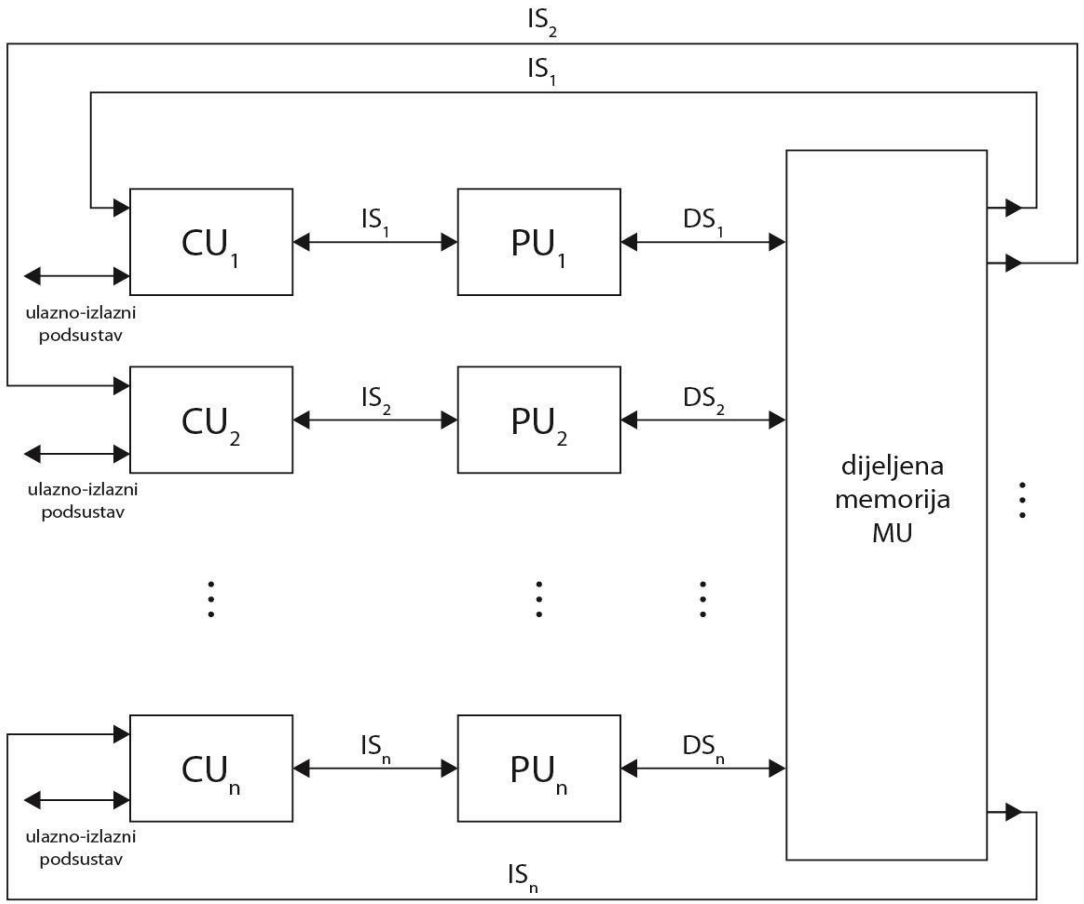
SIMD


IS
CU
IS
PE1
PE2
PEn
DS1
DS2
DSn
LM1
LM2
LMn
DS1
DS2
DSn
skupovi
podataka
prema/od
računalu
domaćinu

SIMD (Single Instruction Stream Multiple Data Stream)

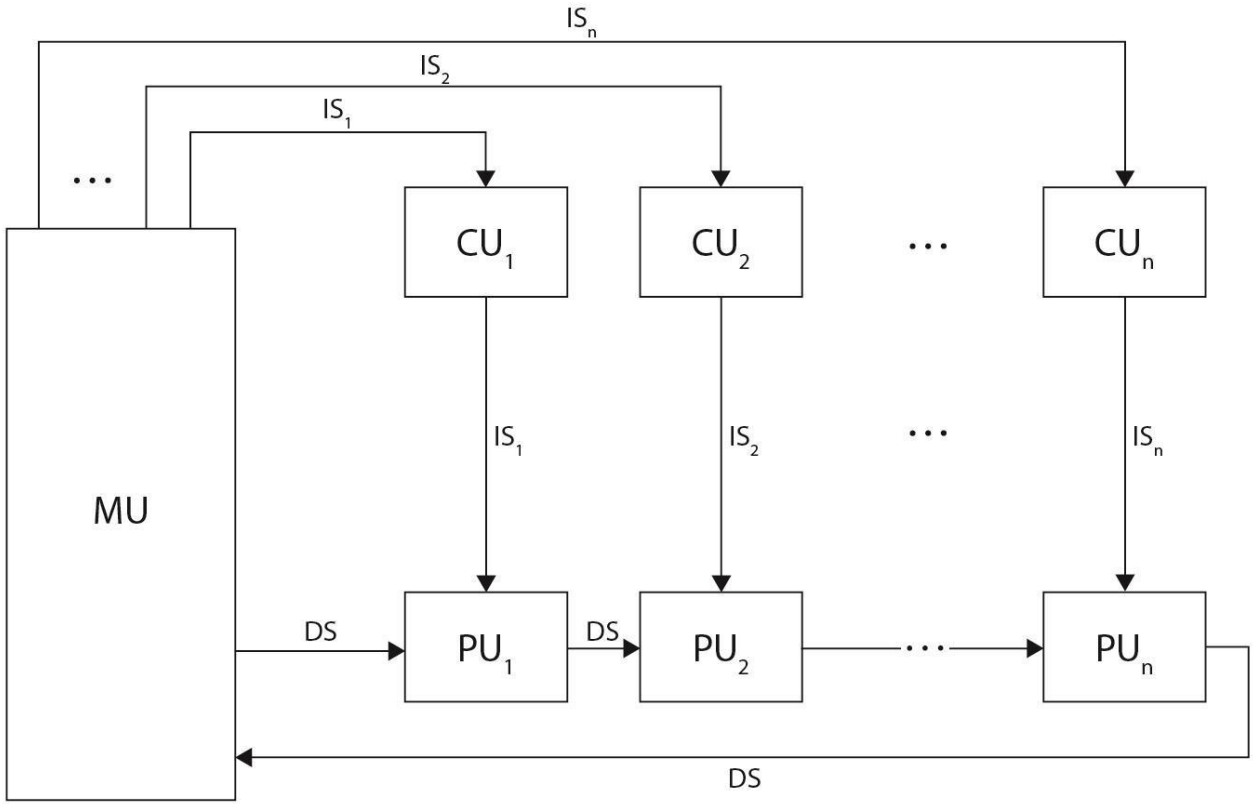
- Parallel computing or matrix computing
- Multi processor running one instruction on multiple data

MIMD


IS2
IS1
CU1
IS1
PU1
DS1
ulazno-izlazni podsustav
CU2
IS2
PU2
DS2
ulazno-izlazni podsustav
dijeljena memorija MU
CUn
ISn
PUn
DSn
ulazno-izlazni podsustav
ISn

MIMD (Multiple Instruction Stream Multiple Data Stream)

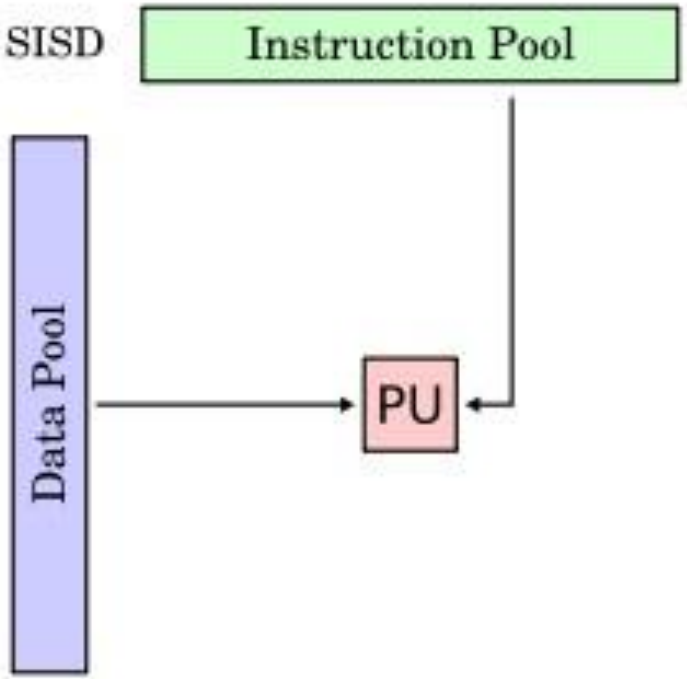
MISD

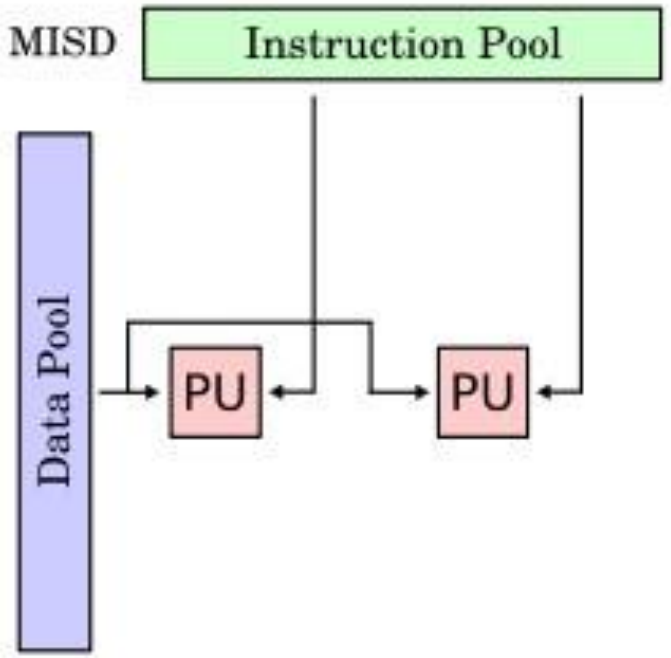


MISD (Multiple Instruction Stream Single Data Stream)

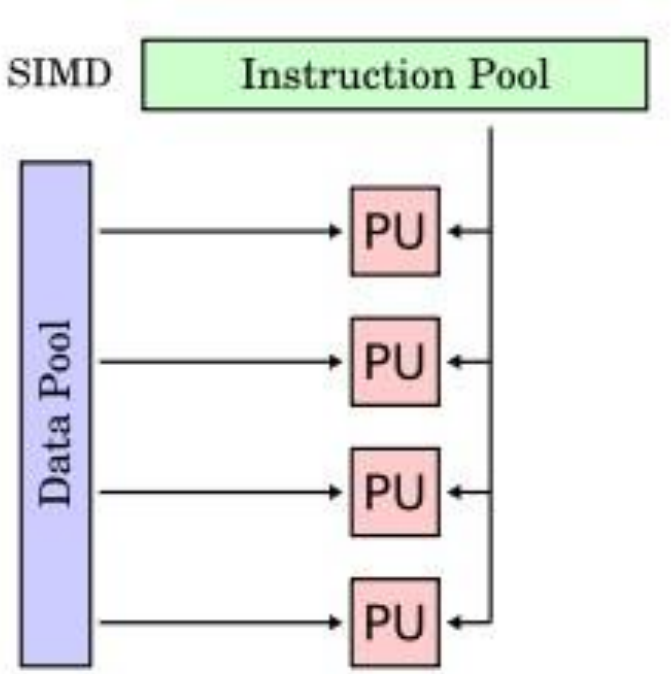
- Cannot be made practically
- A similar concept as the one that makes us unable to be at two places at the same time
- Pipeline computers

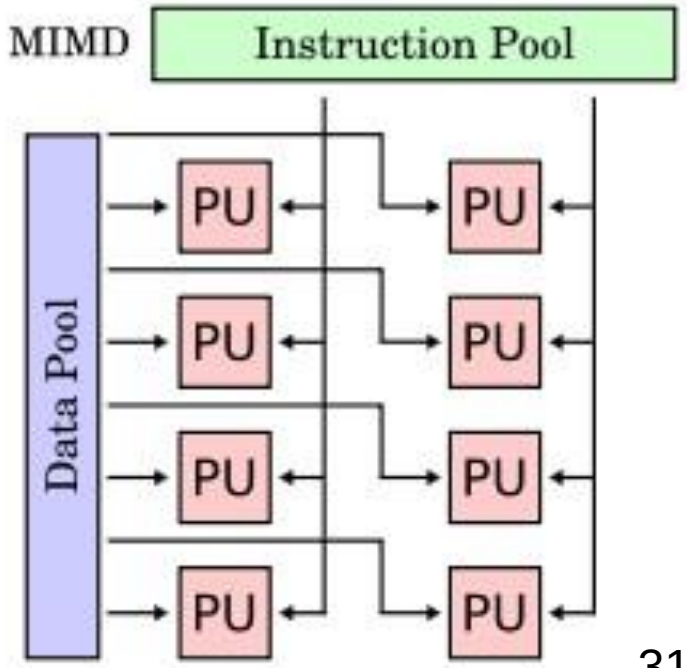
Schematics


SISD
Instruction Pool
Data Pool
PU


MISD
Instruction Pool
Data Pool
PU
PU

Scehmatics


SIMD
Instruction Pool
Data Pool
PU
PU
PU
PU


MIMD
Instruction Pool
Data Pool
PU
PU
PU
PU
PU
PU
PU
PU

Determining computer architecture

Requirements for the platform

- General purpose computer
- Data storage
- Instruction storage

General purpose computer

Main characteristics:

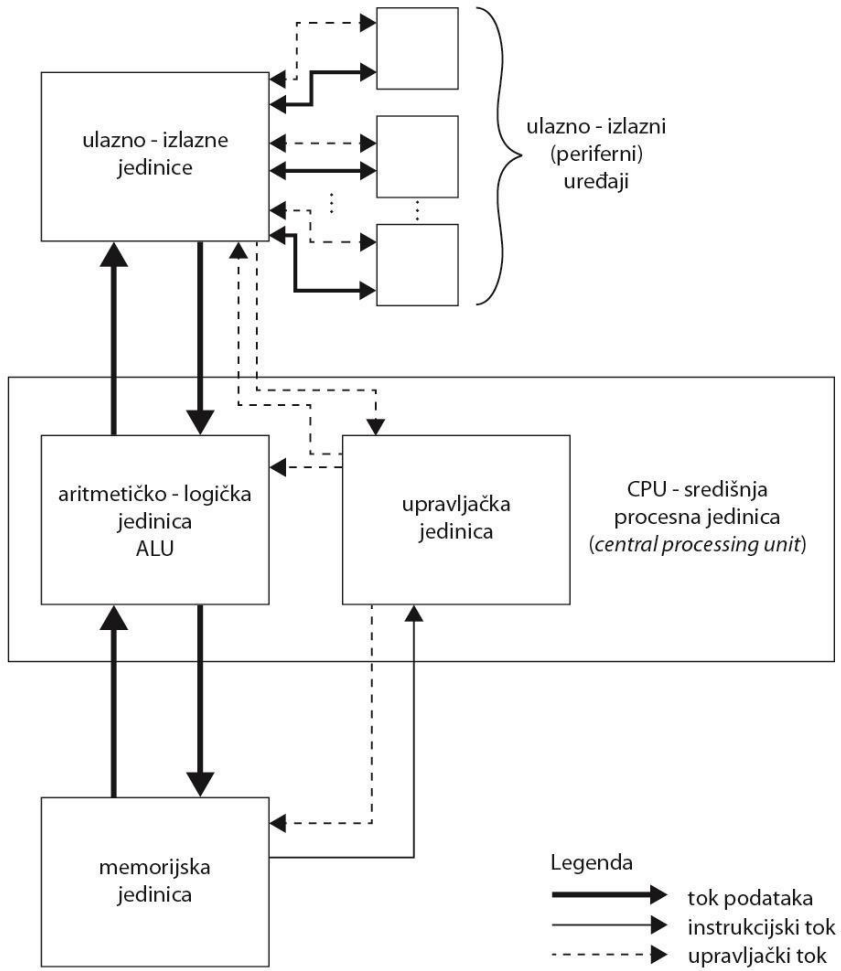
- Data and instructions in one memory
- AU
- Logical unit
- IO unit

Computer functional units

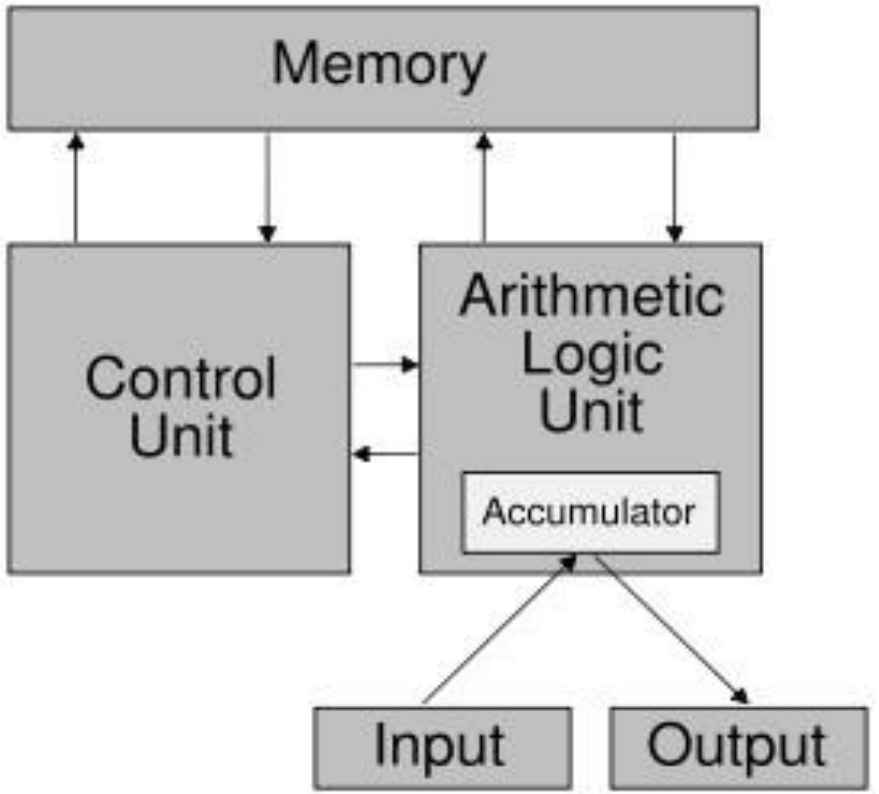
Main functional units of a computer are:

- Arithmetical unit
- Control unit
- Memory
- Input unit
- Output unit

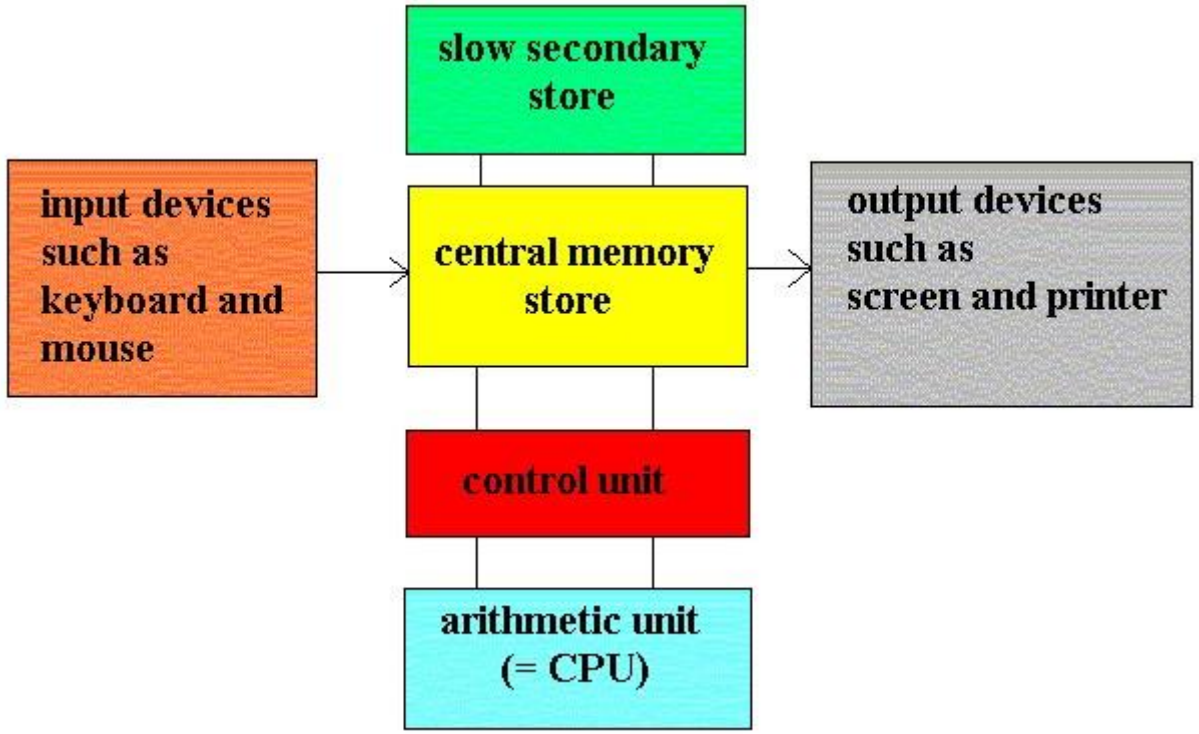
Functional units, (von Neumann)



von Neumann model



von Neumann model



Flows in a computer

Functional units in a computer are connected with:

- Data flow
- Instruction flow and
- Control flow

Most of the control commands are generated by the control unit when decoding the instruction used

von Neumann, ALU

Aritchemitc – logic unit of the von Neumann computer by the IAS (Institute of Advanced Study) had:

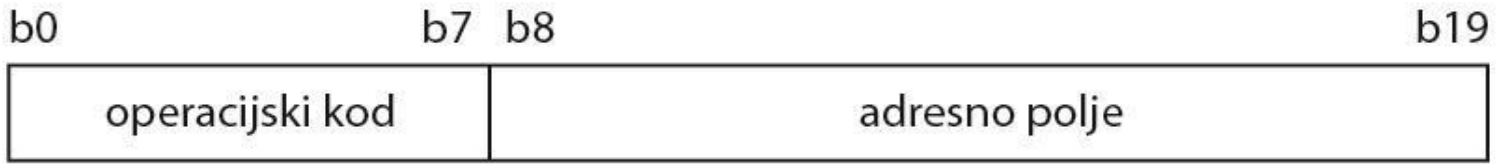
- Adding circuit (adder)
- Shifter used to shift bits in the registers either left or right
- two 40-bit registers used for temporarily storig operrands and data: AC (alčso named accumulator) and MQ (accumulator extension)

von Neumann, control unit

- After decoding the instruction opcode, control unit generates all the neccesary signals for timing and scheduling actual tasks that need to get done in the hardware
- Control unit is in charge of all the automation in a given program

Instruction format of the IAS computer

- opcode – operation code defines which instruction is to be executed
- Adress field –Contains the address of the parameter for the instruction (operand)
- Program is executed by fetching instruction in the coded form from the memory and decoding it



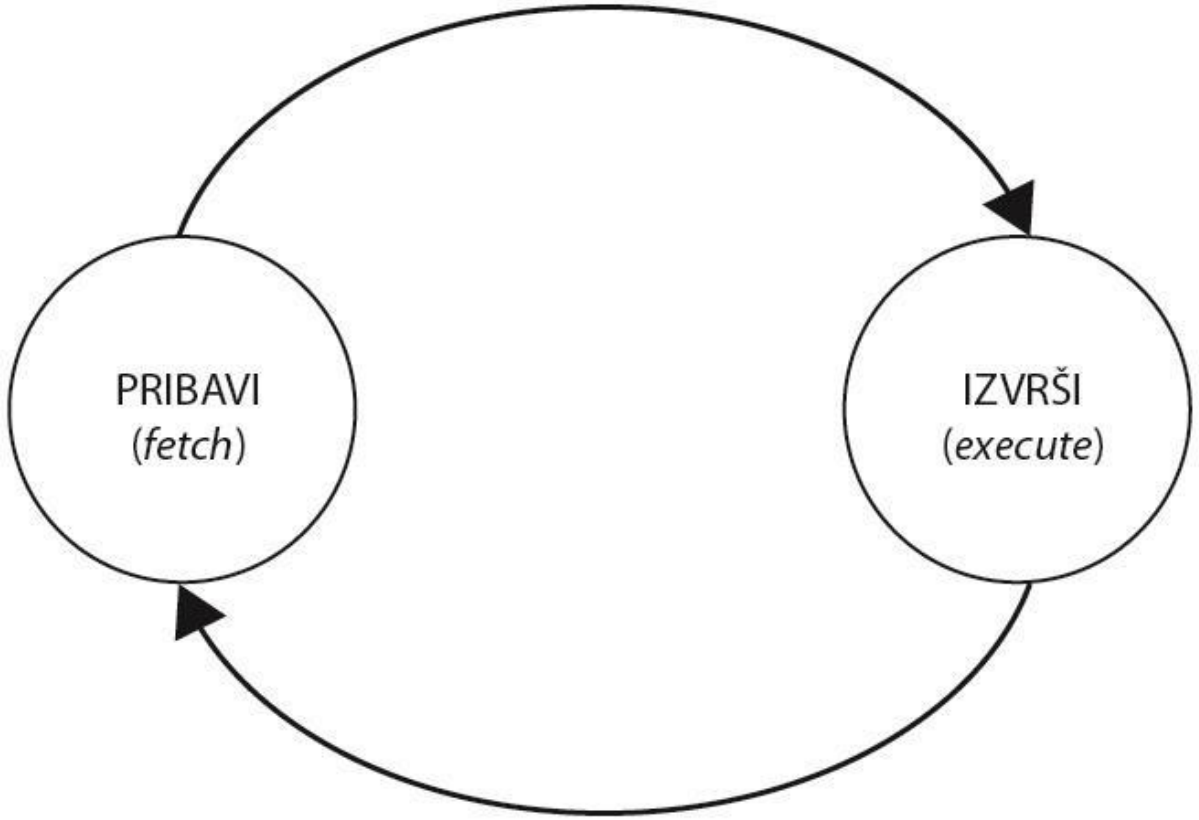
Executing instructions

- Program counter PC contains the address of the next instruction to be executed
- Instruction is executed in two phases that are sometimes called instruction cycle
  - fetch
  - execute

During FETCH phase control unit fetches the opcode from the memory and decodes it

EXECUTE phase, depending on the decoded instruction in the previous FETCH phase results in the control signals being generated. Control signals are meant to control all the circuits and operations that can be done in hardware

von Neumann model state diagram



Memory unit

- Not capable of processing data
- Responsible for two very important tasks:
  - Data storage
  - Retrieval of stored data
- Retrieval of data is called a Read
- Data storage is called a Write
- Memory is organized in tiers:
  - Primary or main memory
  - Secondary memory
  - Third tier or non – active memory

Input output unit

- IAS was a single-user oriented computer
- Only one user could be using it a time
- Exchanging data with the outside world was done under direct control of the processing unit
- Graphic display and a teleprinter with magnetic wire, later exchanged for a punched card unit
- Graphic unit was realised from Selectron tubes that were lighted on the positions that represented active signals or ones, and dark pattern in the place of zeroes.

von Neumann computer - SISD

- SISD (Single Instruction Stream Single Data Stream)
- Data and instruction share the same bus, dana and instruction stream are mixed together.
- As a result processing is sequential since data and instructions cannot be read simultaneously.

Thank you for your attention!