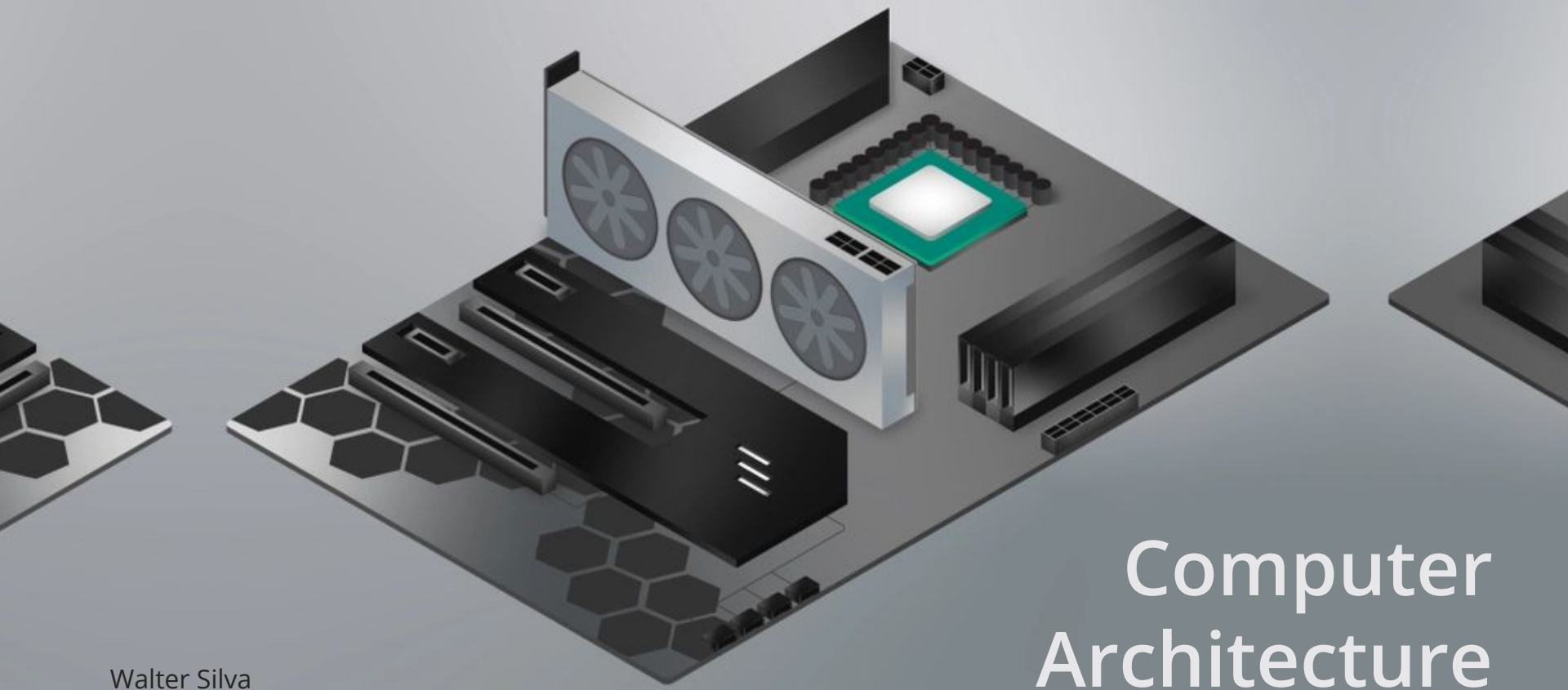


Computer Architecture

Walter Silva

Summary

1. CPU (Central processing unit)
    a. Electronic circuit
    b. Components
        i. CU (Control Unit)
        ii. ALU (Arithmetic logic unit)
        iii. Registers
2. Von Neumann
    a. Memory
    b. CPU
        i. Clock
        ii. Cycle (fetch-decode-execute)
    c. I/O (Input and output devices)
3. Turing Machine
4. Thanks

CPU

What is it ?

The CPU is an electronic circuit that executes software instruction in memory, along with data

CPU

What is it ?

The CPU is an **electronic circuit** that executes software instruction in memory, along with data

CPU - Electronic circuit

What is it ?

Individual electronic components connected by conductive wires or circuit boards (also known as integrated circuits, IC), made of silicon or gallium arsenide, through electric current can flow. E.g:

- Resistors

CPU - Electronic circuit

What is it ?

Individual electronic components connected by conductive wires or circuit boards (also known as integrated circuits, IC), made of silicon or gallium arsenide, through electric current can flow. E.g:

- Transistors

CPU - Electronic circuit

What is it ?

Individual electronic components connected by conductive wires or circuit boards (also known as integrated circuits, IC), made of silicon or gallium arsenide, through electric current can flow. E.g:

- Capacitors

CPU - Electronic circuit

What is it ?

Individual electronic components connected by conductive wires or circuit boards (also known as integrated circuits, IC), made of silicon or gallium arsenide, through electric current can flow. E.g:

- Inductors

CPU - Electronic circuit

What are the types ?

Electronic circuits can be categorized in three different types:

1 - Analog

Analog circuits are those in which current or voltage (force required to move the electrons) may vary continuously with time to correspond to the information being represented. This type of circuit can be built of two different ways:

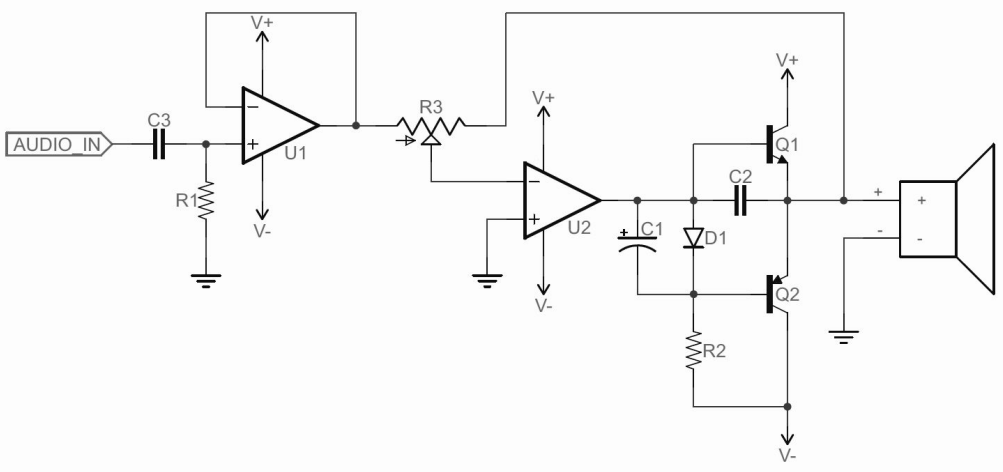
- Serie, the same current passes through a serie of components
- Parallel, all the components are connected to the same voltage, and the current divides between the various components according to their resistance

CPU - Electronic circuit

What are the types ?

Electronic circuits can be categorized in three different types:

1 - Analog



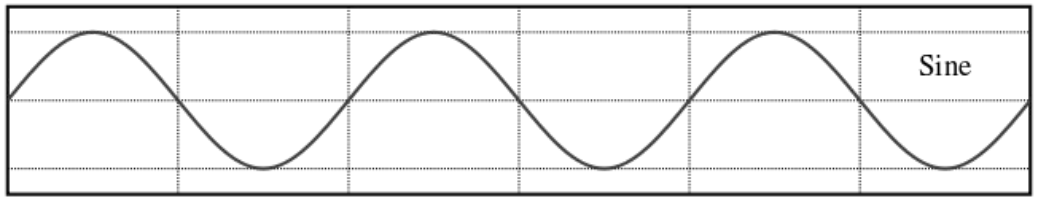
CPU - Electronic circuit

What are the types ?

Electronic circuits can be categorized in three different types:

1 - Analog

The signal has the form of a senoidal function:



CPU - Electronic circuit

What are the types ?

Electronic circuits can be categorized in three different types:

2 - Digital

Digital circuits are those that take on discrete values (specific numeric value or categorical, normally in this context binary), to represent logical and numeric values. These values represent the information that is being processed.

CPU - Electronic circuit

What are the types ?

Electronic circuits can be categorized in three different types:

2 - Digital

The key characteristics of Digital electronic circuits are:

- Digital circuits make extensive use of transistors, interconnected to create logic gates that provide the functions of Boolean logic: NOT, OR, AND, XOR, NAD, etc
- Transistors are interconnected so as to provide positive feedback are used as latches and flip flops, circuits that have two or more metastable states, and remain in one of these states until changed by an external input
    - Memory based on flip-flop circuit (logical digital circuits): static random-access memory (SRAM)

CPU - Electronic circuit

What are the types ?

Electronic circuits can be categorized in three different types:

2 - Digital

The key characteristics of Digital electronic circuits are:

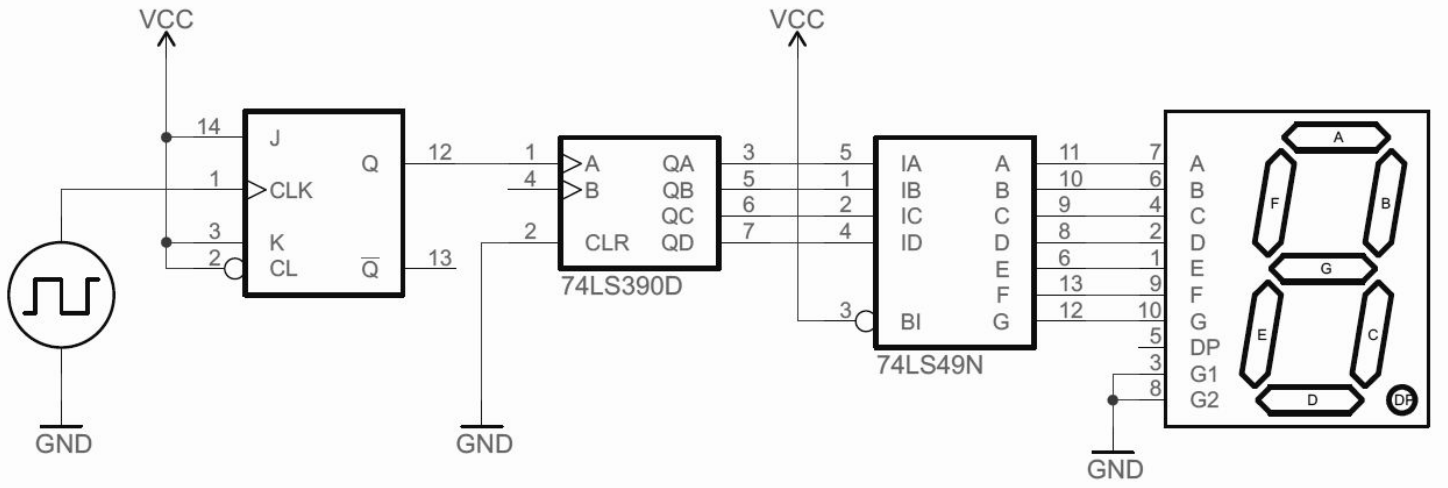
Memory based on the storage of charge in a capacitor: dynamic random-access memory (DRAM)

CPU - Electronic circuit

What are the types ?

Electronic circuits can be categorized in three different types:

2 - Digital



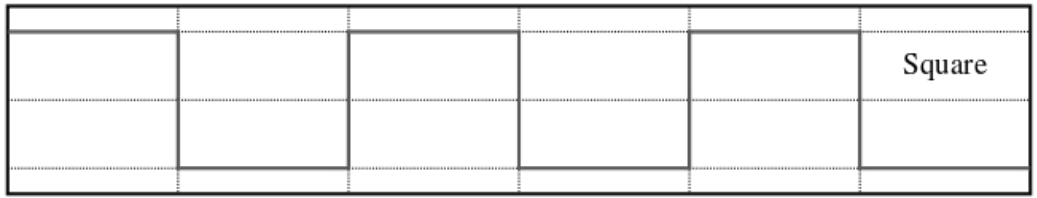
CPU - Electronic circuit

What are the types ?

Electronic circuits can be categorized in three different types:

2 - Digital

The signal has the form of a quadratic function:



CPU - Electronic circuit

What are the types ?

Electronic circuits can be categorized in three different types:

3 - Mixed-signal

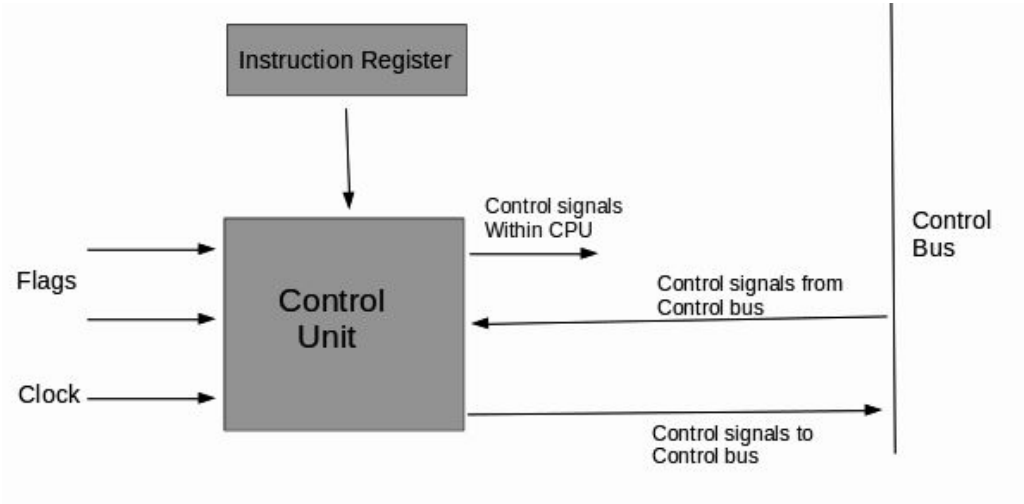
Mixed-signal or hybrid circuits contain elements of both analog and digital circuits. The most common usage is:

- Convert frequencies
- Amplify frequency signals

CPU - Components - CU

What does this do ?

The CU is a component of the CPU that controls the memory, ULA and I/O devices. This component controls how to respond to the instructions that the processor had received from different devices.



CPU - Components - CU

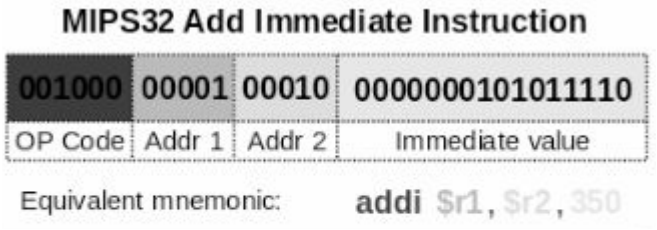
What does this do ?

Some characteristics of CU are:

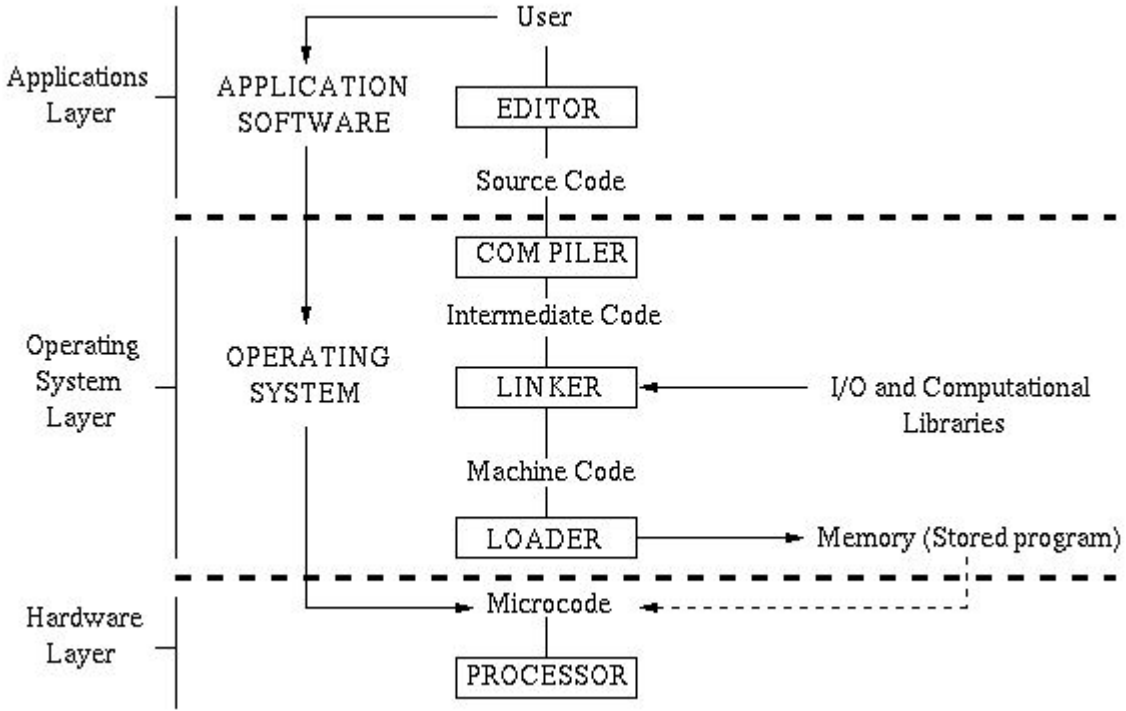
- Control data flow inside the processor
- Provides several external control signals (carry-out, zero, negative, overflow, parity…) to the rest of the computer, while executing instructions
- Convert external instructions into a sequence of control signals, that the CU applies to the data path to implement a sequence of register-transfer level operations
- The CU decodes individual instructions into several sequential steps that controls and coordinates the CPU's inner works to properly manipulate the data

CPU - Components - CU

Instruction



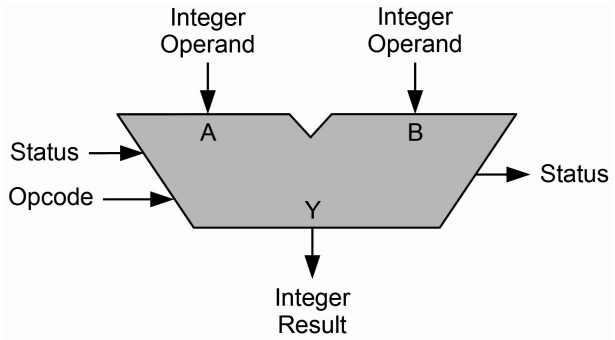
CPU - Components - CU



CPU - Components - ALU

What does this do ?

- ALU process instructions
- Arithmetic and bitwise operations (integer binary numbers)
- FPU (Floating-point unit) Arithmetic and bitwise operations (float point)
- The input to an ALU are the data to be operated on, called operands, and a code indicating the operation to be performed



CPU - Components - Registers

What does this do ?

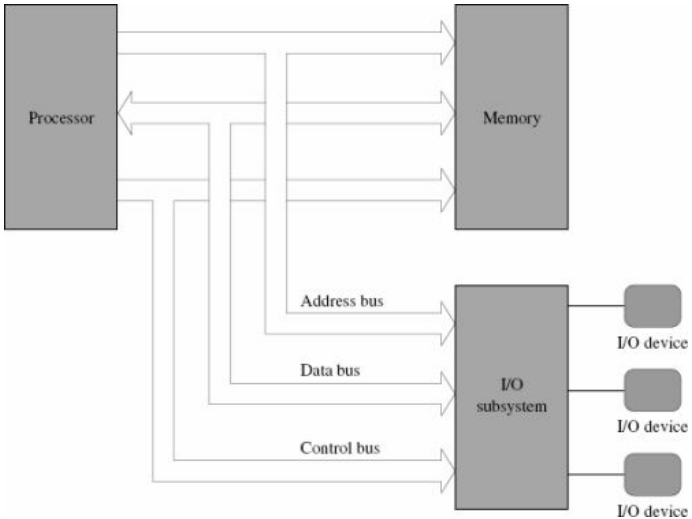
- Quickly accessible location available to a computer's CPU
- Small size
- Optimization: Locality of reference hold frequently used values, made by the compiler

MAR	Memory Address Register	Holds the memory location of data that needs to be accessed
MDR	Memory Data Register	Holds data that is being transferred to or from memory
AC	Accumulator	Where intermediate arithmetic and logic results are stored
PC	Program Counter	Contains the address of the next instruction to be executed
CIR	Current Instruction Register	Contains the current instruction during processing

Von Neumann

What is this architecture ?

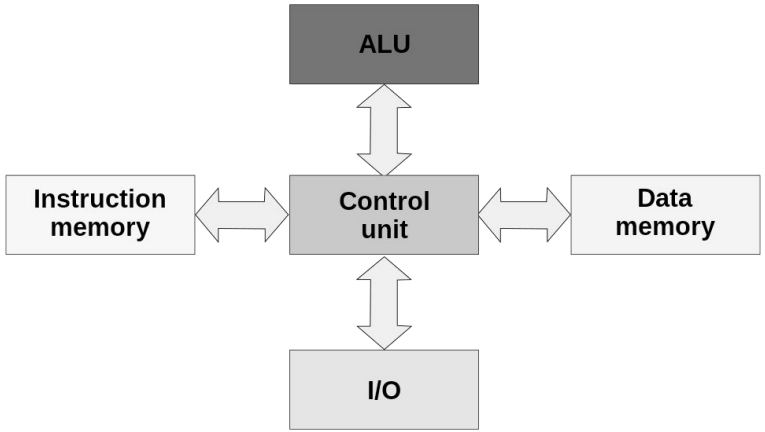
Von Neumann architecture is a design of computer system where there essentially three different entities, a CPU, memory and I/O devices. The units are connected over buses.



Von Neumann

What came similar and applicable ?

Harvard Architecture



Von Neumann

Von Neumann Vs Harvard Architecture

It is a theoretical design based on the stored-program computer concept.	It is a modern computer architecture based on the Harvard Mark I relay-based computer model.
It uses same physical memory address for instructions and data.	It uses separate memory addresses for instructions and data.
Processor needs two clock cycles to execute an instruction.	Processor needs one cycle to complete an instruction.
Simpler control unit design and development of one is cheaper and faster.	Control unit for two buses is more complicated which adds to the development cost.
Data transfers and instruction fetches cannot be performed simultaneously.	Data transfers and instruction fetches can be performed at the same time.
Used in personal computers, laptops, and workstations.	Used in microcontrollers and signal processing.

Von Neumann - Memory

What is it ?

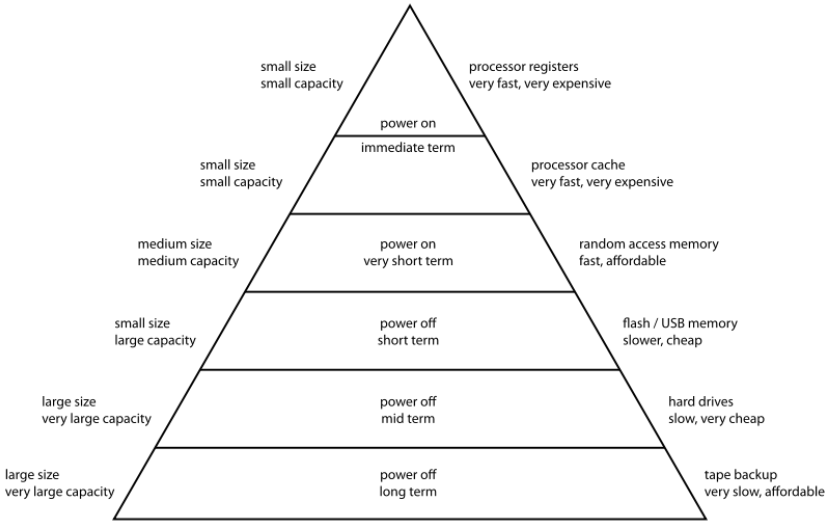
Memory refers to physical memory that is internal or external to the computer. The computer can manipulate only data that is in main memory: static or dynamic.

The data is sent to CPU, then the CU load the data from memory to CPU registers that is then processed by the ALU and stored in the memory.

Von Neumann - Memory

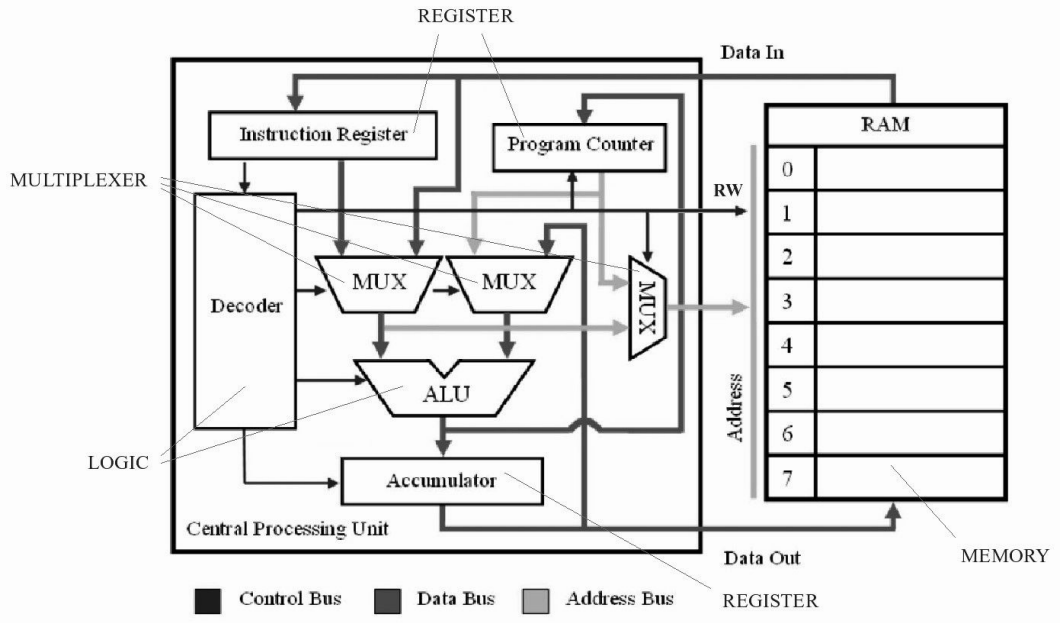
Different types of memory

The different types of memory are separated in hierarchy, where memory hierarchy separates computer storage based on response time, complexity and capacity:



Von Neumann - CPU

- Previous presented
- If the bus is slow, it can be possible that data and instruction can’t be processed at the same time

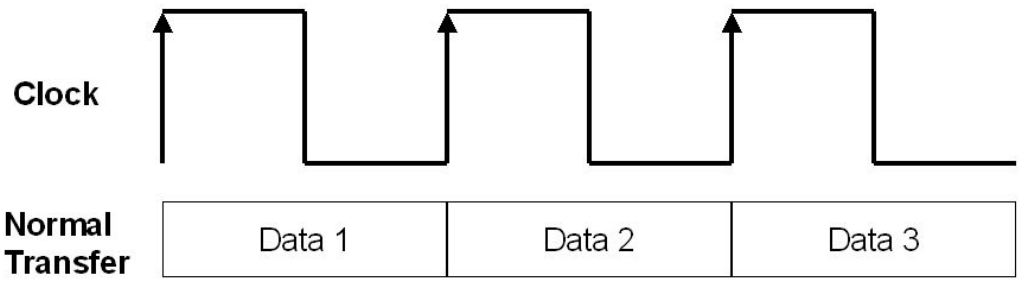


Von Neumann - CPU

Clock

Computers use a clock system, which proves timing signals to synchronize circuits. These signals are quadratic waves (digital circuits).

E.g to send data when the clock state is active



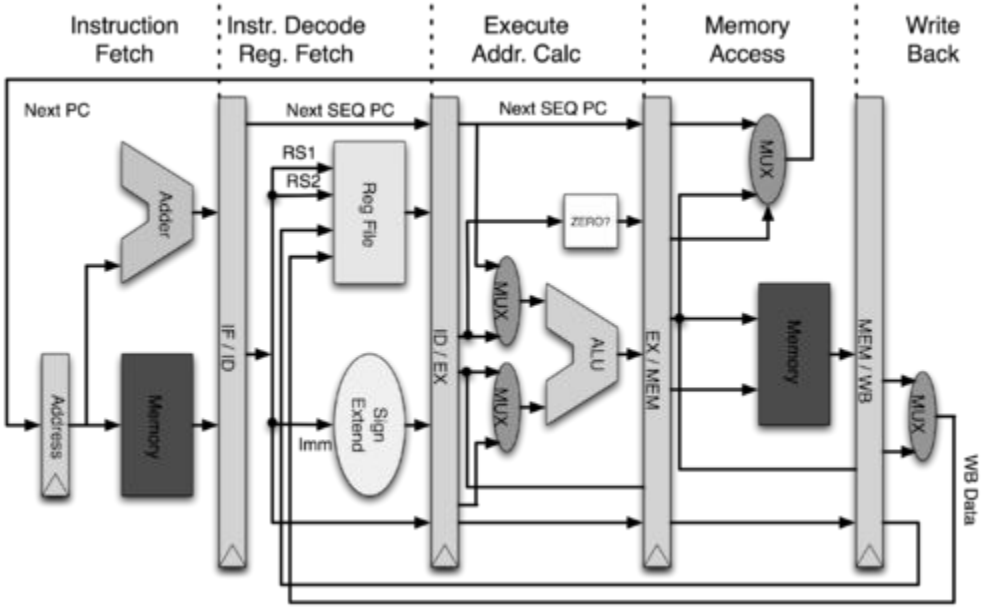
Von Neumann - CPU

Clock

CPUs are projected to run in a specific frequency. The CPUs increase the clock rate to determine a specific amount of cycles / moments that is required to run a instruction

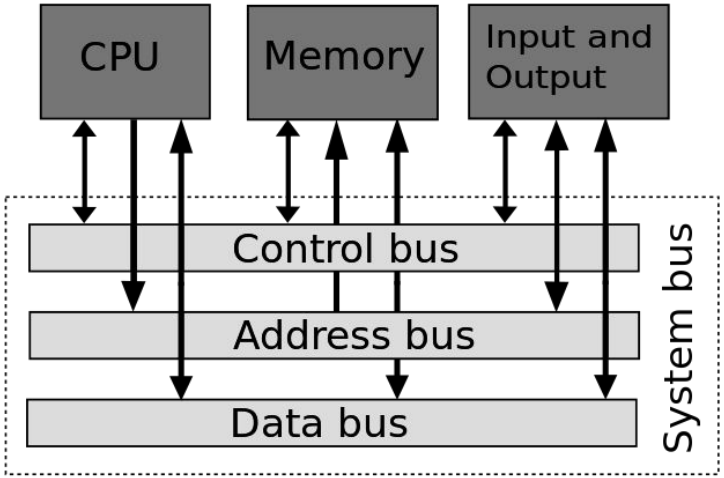
Von Neumann - CPU

Cycle - Pipeline



Von Neumann - I/O

- CPU -> Memória: Address bus
- CPU <-> Memória: Data bus
- CPU <-> I/O devices: Control bus



Turing Machine

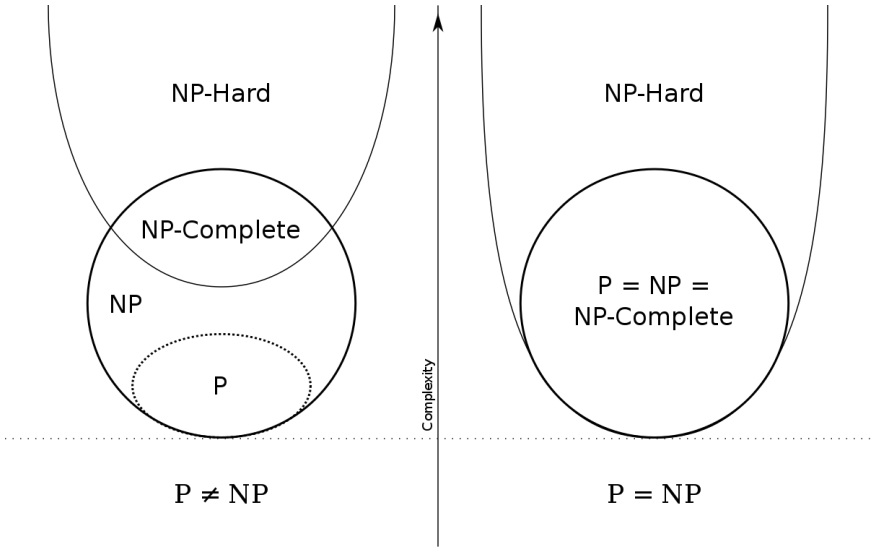
Theoretical machine. A Turing Machine has the following components:

- Infinite tape
- Header (read and write / move to right or left)
- State register
- Transition table, that indicates which symbol to write, how to move the header and what is the new state, based on the current symbol and state

Everything that computers can do, can, theoretically, be done in a Turing Machine. Quantum computing is a special case.

Turing Machine

Classes of problems



Turing Machine

Classes of algorithms

- Deterministic algorithm is an algorithm which, given a particular input, will always produce the same output, with the underlying machine always passing through the same sequence of states.
- Nondeterministic algorithm is an algorithm that, even for the same input, can exhibit different behaviors on different runs. A concurrent algorithm can perform differently on different runs due to a race condition. An algorithm that solves a problem in nondeterministic polynomial time can run in polynomial time or exponential time depending on the choices it makes during execution.

Turing Machine

Classes of problems

- NP: NP is the set of all decision problems (question with yes-or-no answer) for which the 'yes'-answers can be verified in polynomial time (O(n^k) where n is the problem size, and k is a constant) by a deterministic Turing machine. Polynomial time is sometimes used as the definition of fast or quickly.
- P: P is the set of all decision problems which can be solved in polynomial time by a deterministic Turing machine. Since it can solve in polynomial time, it can also be verified in polynomial time. Therefore P is a subset of NP. Algorithms that run in linear time (O(n)),quadratic time (O(n^2)),exponential time (O(2^n)), or even logarithmic time (O(log n)) are polynomial time algorithms.
- NP-Complete: If you have a solution to a (typically decision) problem and the solution can be verified in polynomial time, but you can NOT come up with a solution in polynomial time, then the problem is said to be NP-complete.

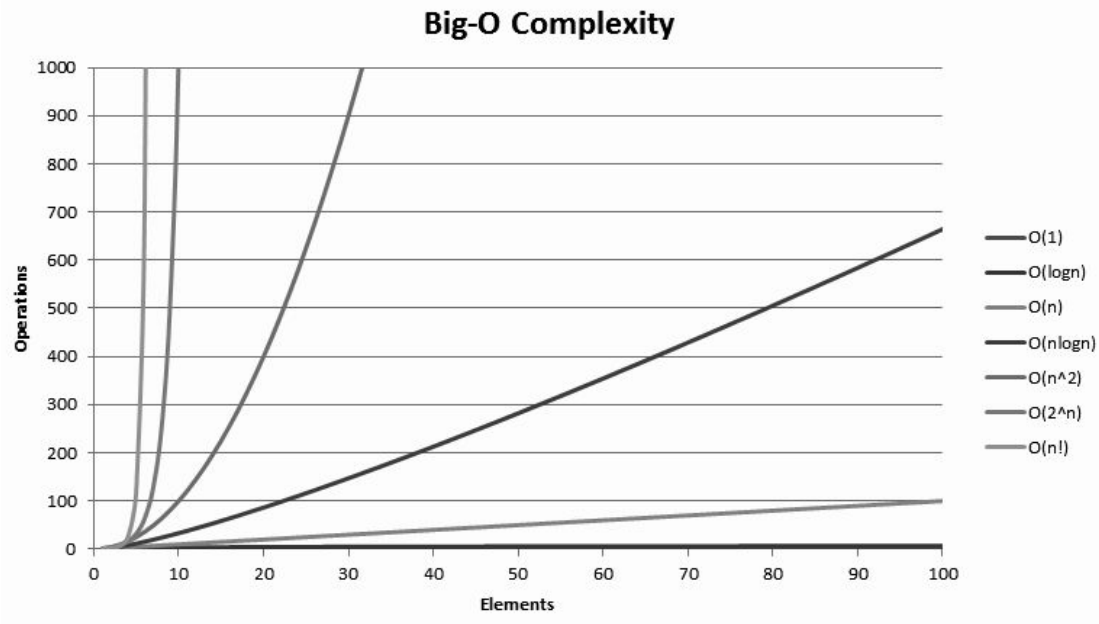
Turing Machine

Classes of problems

- NP-Hard: If you have a solution to a problem and the solution can not even be verified in polynomial time , then the problem is said to be NP-hard.

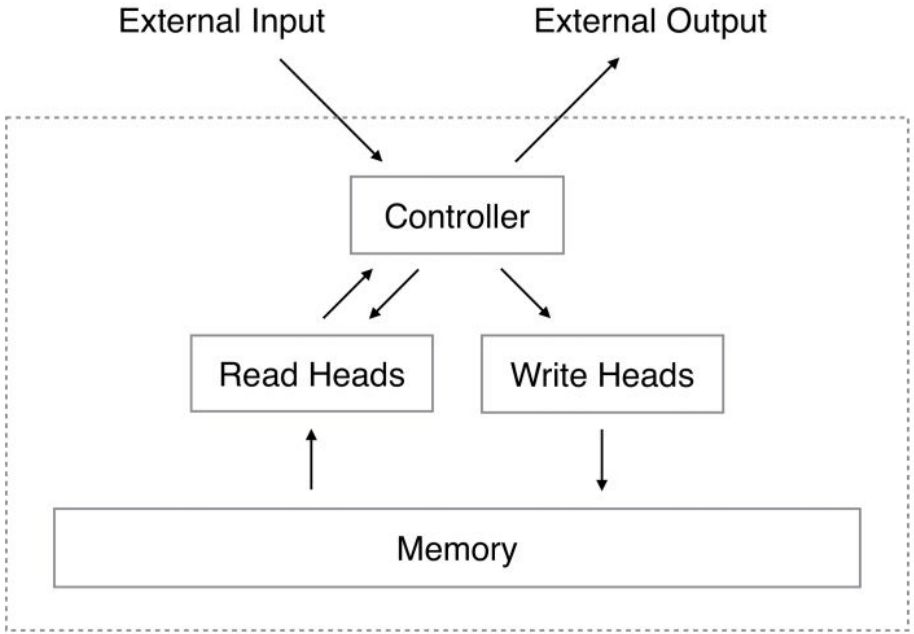
Turing Machine

Classes of problems - Time



Turing Machine

- Theoretical machine



Different machines

- Lisp Machine
- Lambda calculus

Thanks