Computers
Logic and CPU

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Computers

Logic: acting on information

The Central Processing Unit (CPU)

Elements of a Computer

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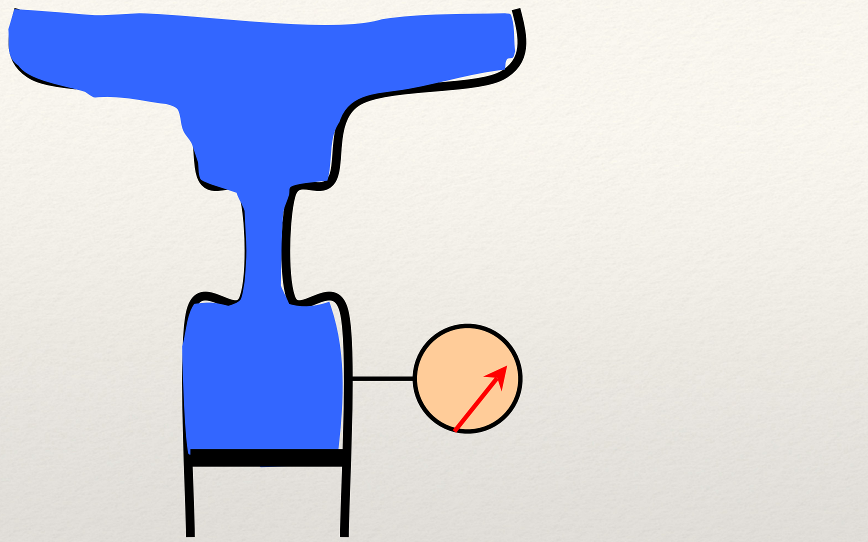
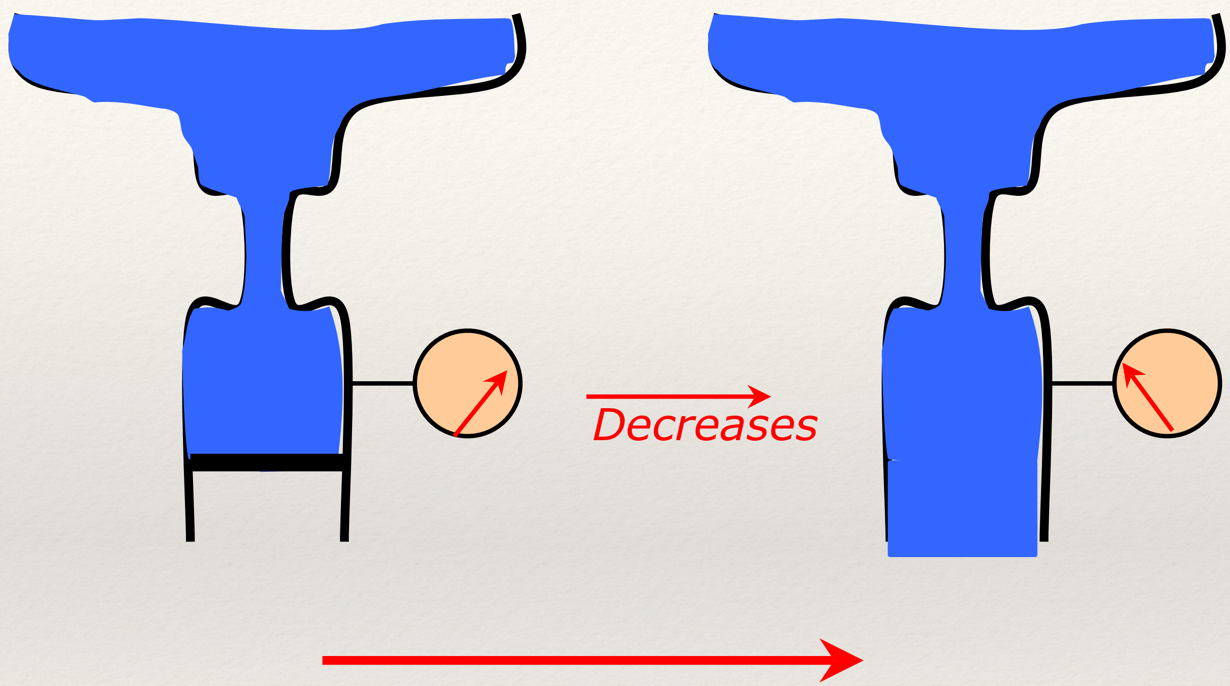
Elements of a Computer

The concept of pressure



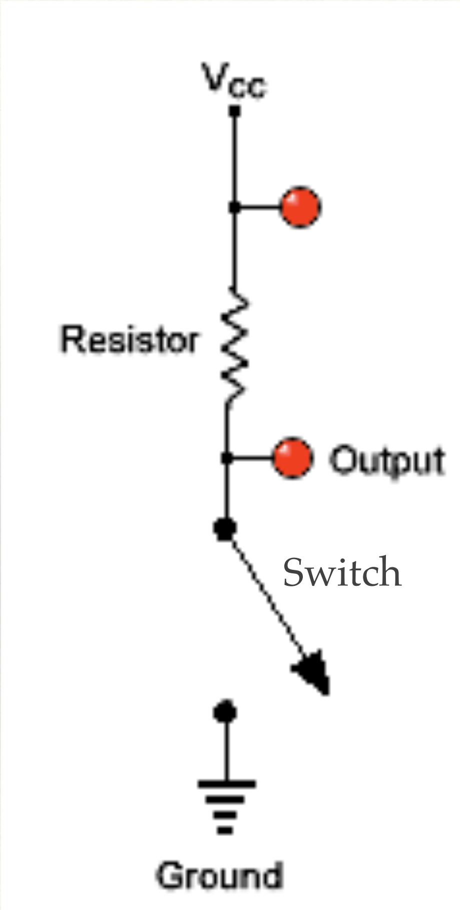
When we remove the block, what is the effect on pressure?

The concept of pressure



When we remove the block, what is the effect on pressure?

Electrical pressure: voltage



If switch is off (0) (equivalent to the presence of the block)

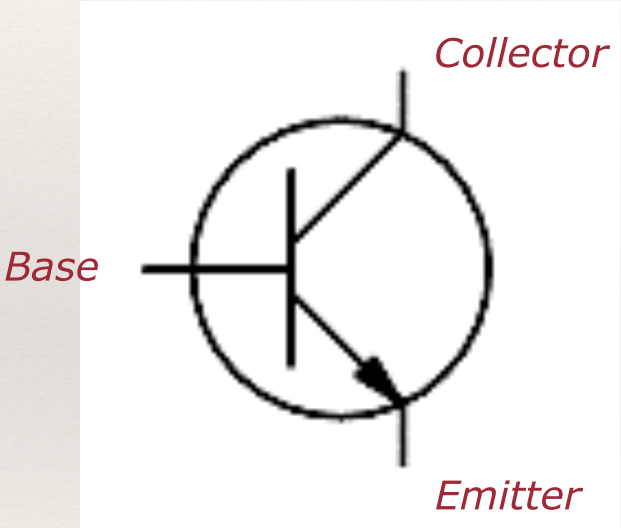
$V_{output}=V_{cc}$ high (i.e. 1)

If switch is on (1) (equivalent to the absence of the block)

$V_{output}<<V_{cc}$ low (i.e. 0)

"Inverter"

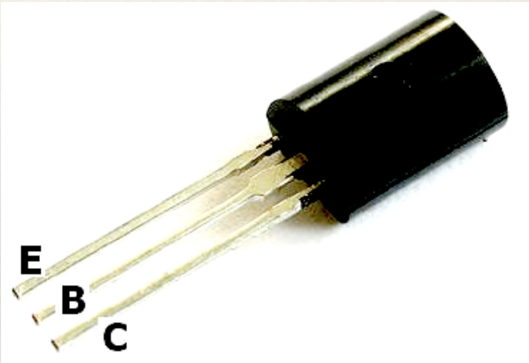
The transistor



A transistor can be used as an electronic switch:

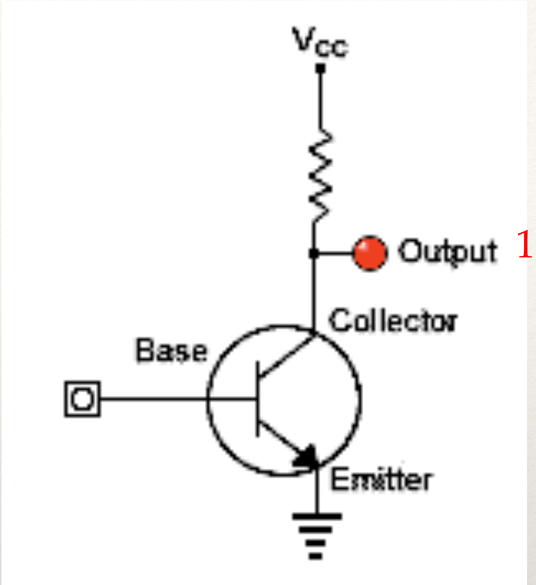
-if V_{base} is high, the current "flows" between the emitter and the collector (switch is on)

-If V_{base} is low, the current does not pass (switch is off)



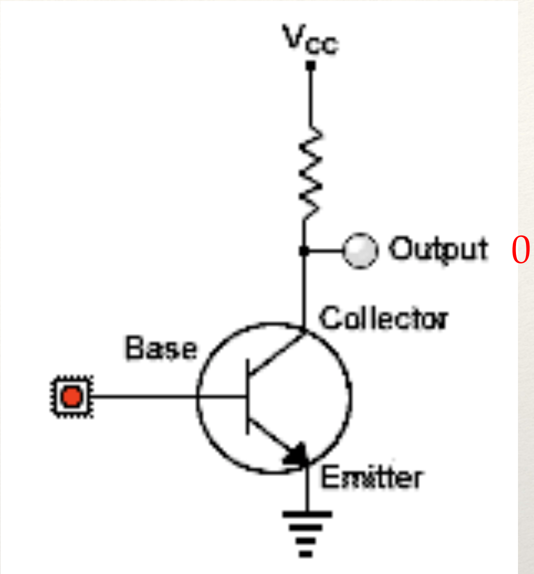
The not gate

Input: 0



1

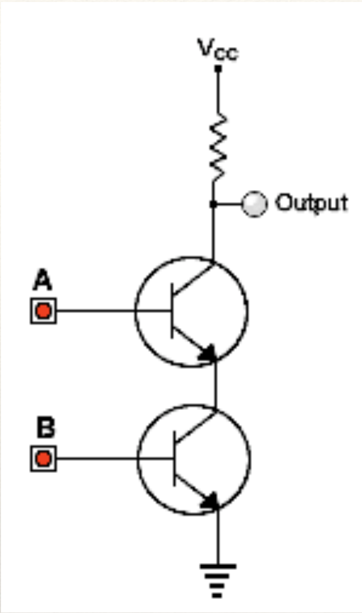
Input: 1

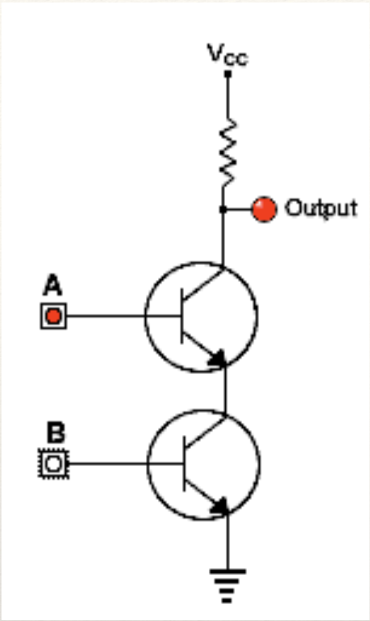


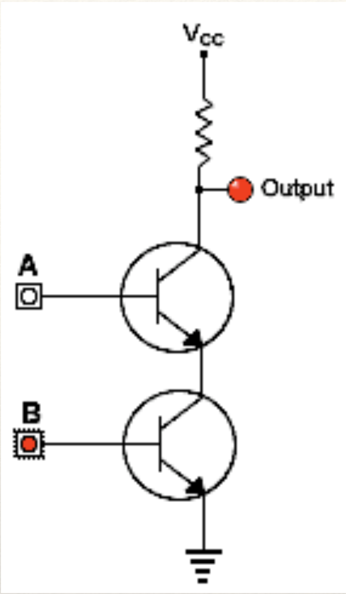
0

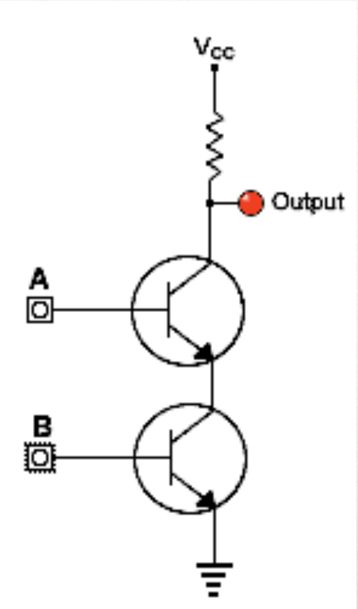
Input	Output
0	1
1	0

The not-and (NAND) gate



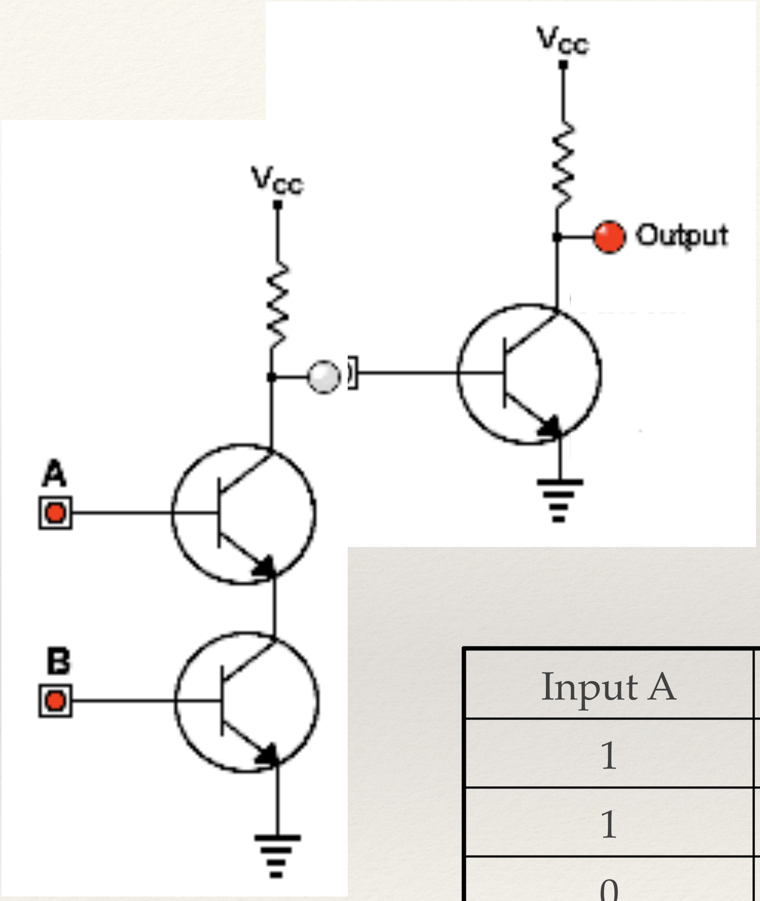






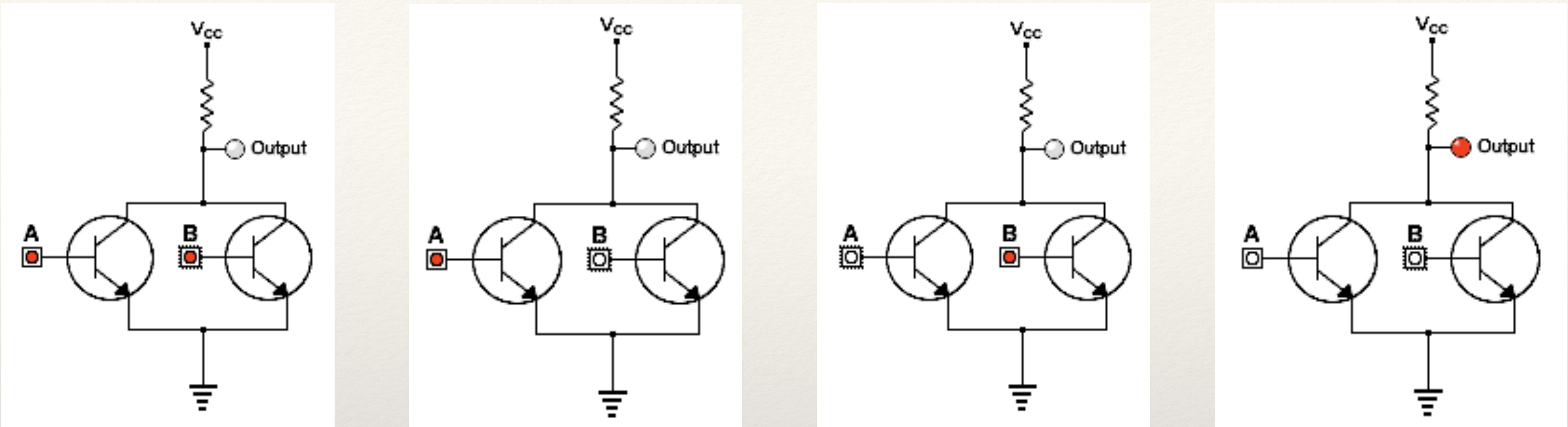
Input A	Input B	Output
1	1	0
1	0	1
0	1	1
0	0	1

The AND gate



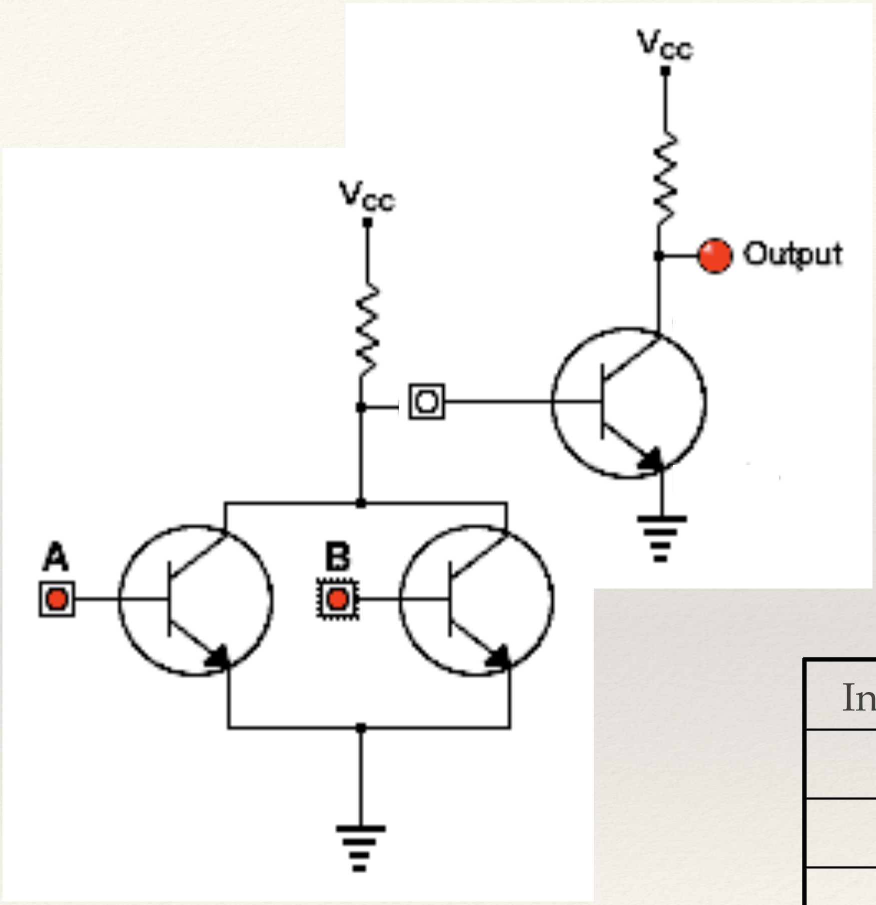
Input A	Input B	Output
1	1	1
1	0	0
0	1	0
0	0	0

The not-or (NOR) gate

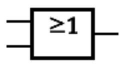
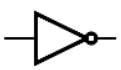
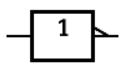
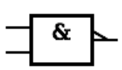
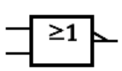


Input A	Input B	Output
1	1	0
1	0	0
0	1	0
0	0	1

The OR gate



Input A	Input B	Output
1	1	1
1	0	1
0	1	1
0	0	0

Type	Distinctive shape	Rectangular shape	Boolean algebra between A & B	Truth table
AND			$A \cdot B$	INPUT / OUTPUT A | B | A AND B 0 | 0 | 0 0 | 1 | 0 1 | 0 | 0 1 | 1 | 1
OR			$A + B$	INPUT / OUTPUT A | B | A OR B 0 | 0 | 0 0 | 1 | 1 1 | 0 | 1 1 | 1 | 1
NOT			$\overline{A}$	INPUT / OUTPUT A | NOT A 0 | 1 1 | 0
NAND			$\overline{A \cdot B}$	INPUT / OUTPUT A | B | A NAND B 0 | 0 | 1 0 | 1 | 1 1 | 0 | 1 1 | 1 | 0
NOR			$\overline{A + B}$	INPUT / OUTPUT A | B | A NOR B 0 | 0 | 1 0 | 1 | 0 1 | 0 | 0 1 | 1 | 0

http://en.wikipedia.org/wiki/Logic_gate

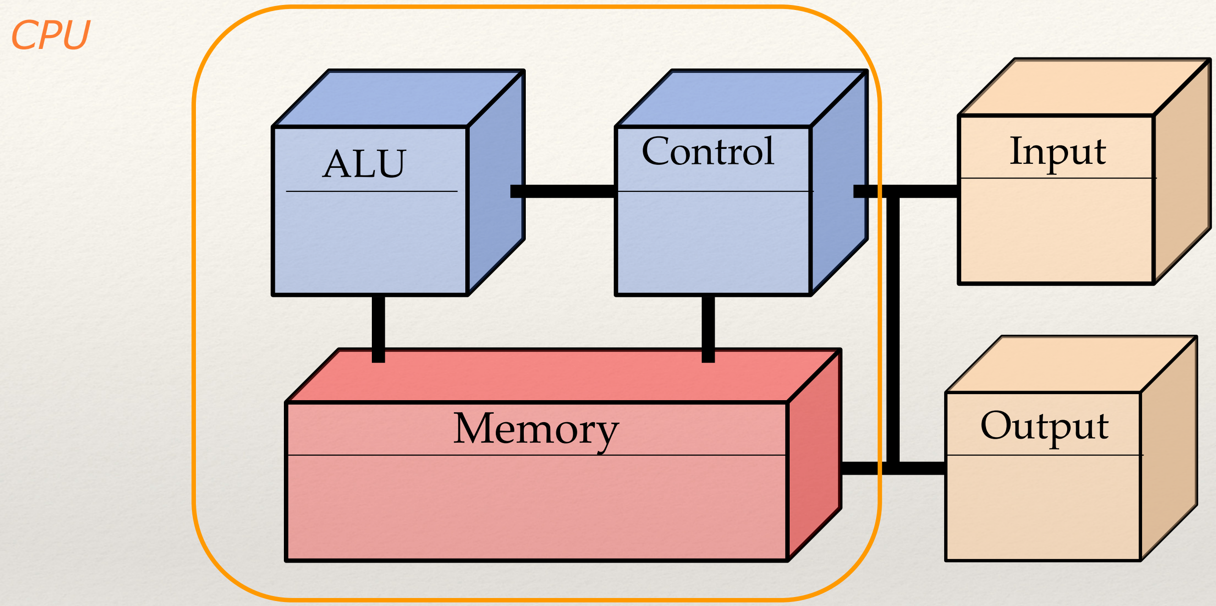
Computers

Logic: acting on information

The Central Processing Unit (CPU)

Elements of a Computer

The Central Process Unit (CPU)



The CPU consists of three parts:

the Arithmetic Logic Unit (ALU)

The Control Unit

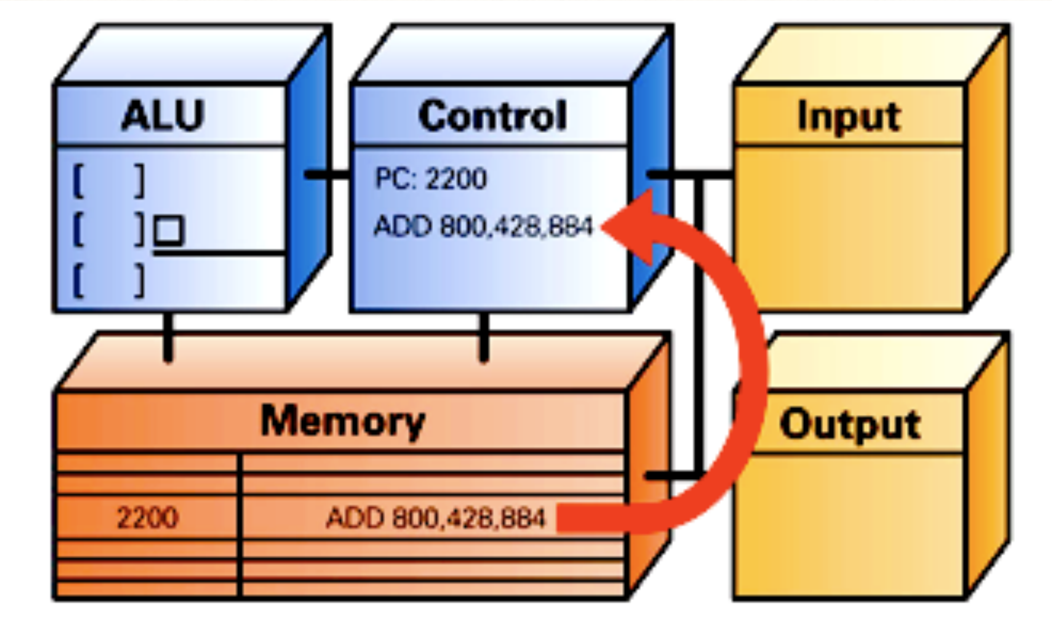
Memory

The Fetch/Execute Cycle

The CPU cycles through a series of operations or instructions, organized in a cycle, the Fetch/Execute cycle:

1. Instruction Fetch (IF)
2. Instruction Decode (DP)
3. Data Fetch (DF)
4. Instruction Execute (IE)
5. Result Return

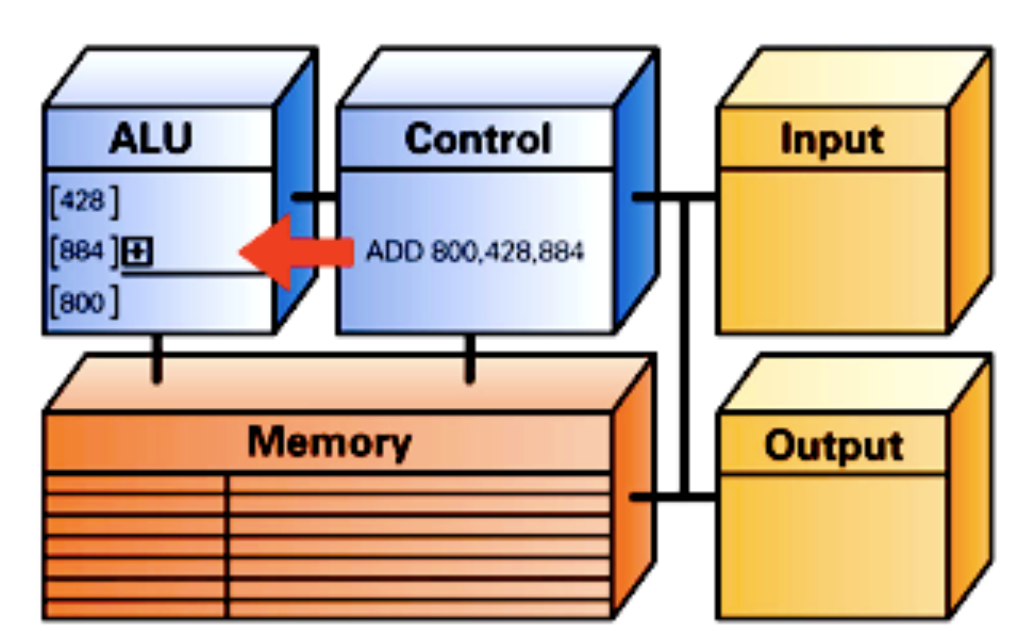
Step 1: Instruction Fetch



Fetch instruction from memory position 2200:

Add numbers in memory positions 884 and 428, and store results at position 800

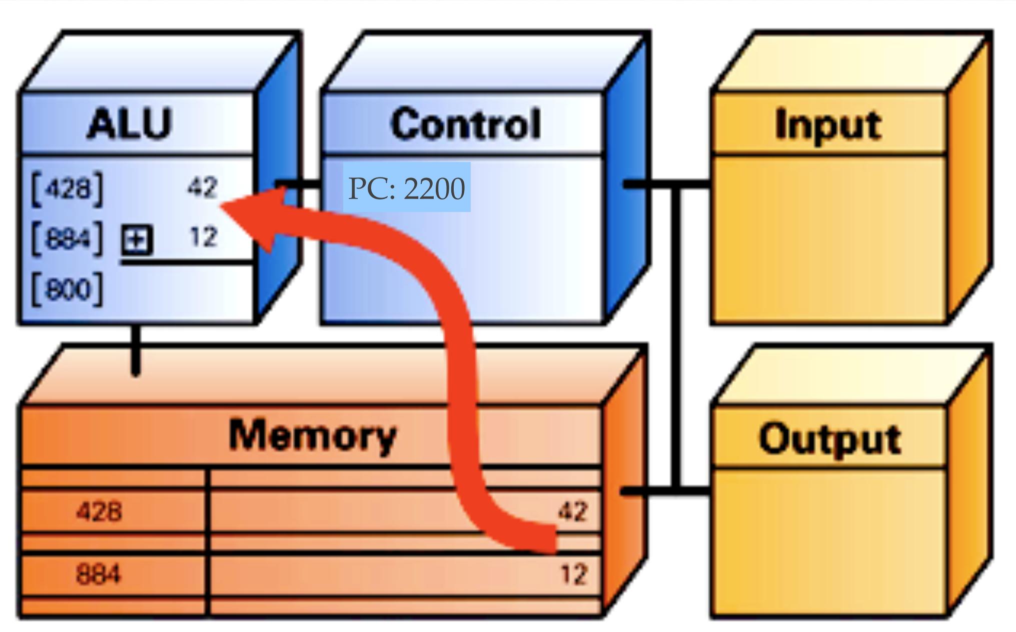
Step 2: Instruction Decode



Decode instruction:

Defines operation (+), and set memory pointers in ALU

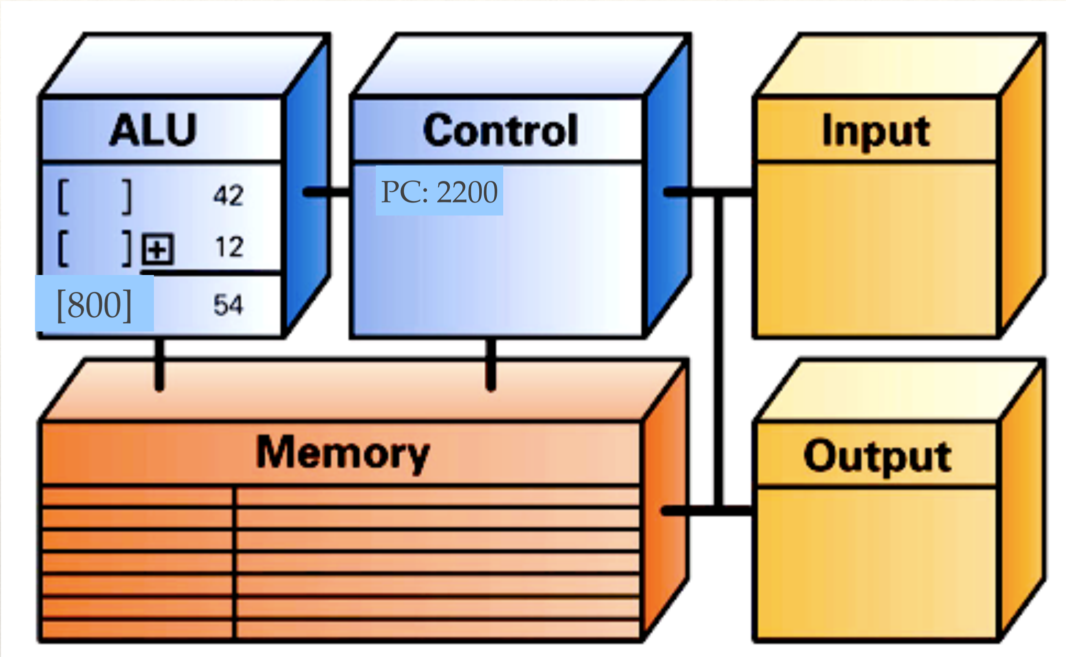
Step 3: Data Fetch



Fetch data:

Get numbers at memory positions 428 and 884: 42 and 12
and put in ALU

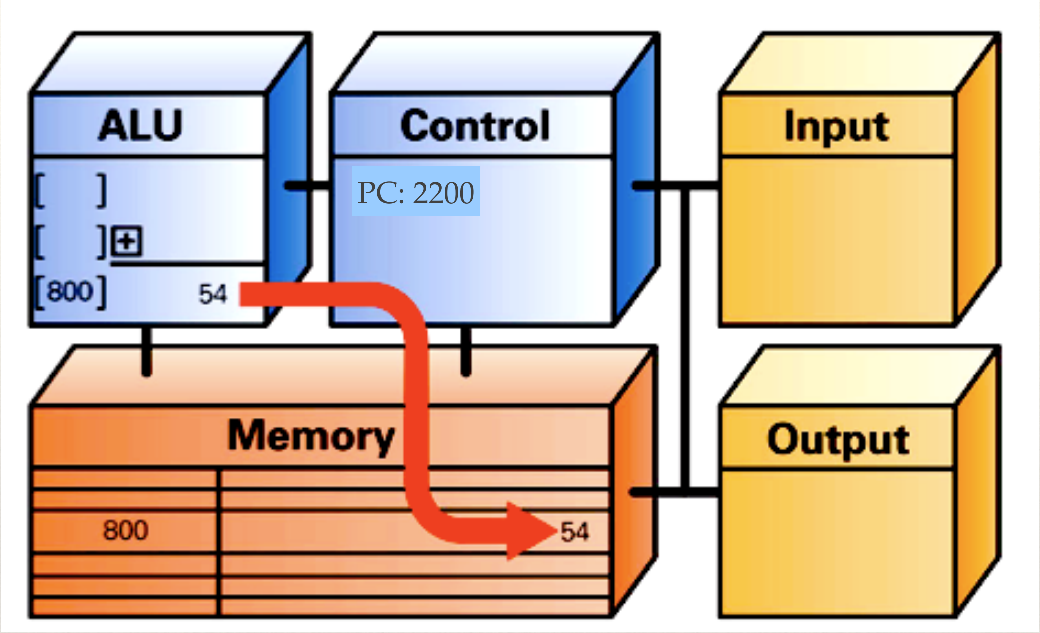
Step 4: Instruction Execution



Execute:

Add numbers 42 and 12 in ALU: 54

Step 5: Return Result



Return:

Put results (54) in position 800 in memory

Possible operations

Computers can only perform about 100 different types of operations; all other operations must be broken down into simpler operations among these 100.

Some of these operations:

-Add, Mult, Div
-AND, OR, NAND, NOR, …
-Bit shifts
-Test if a bit is 0 or 1
-Move information in memory
-…

Repeating the F/E cycle

Computers get their impressive capabilities by performing many of these F/E cycles per second.

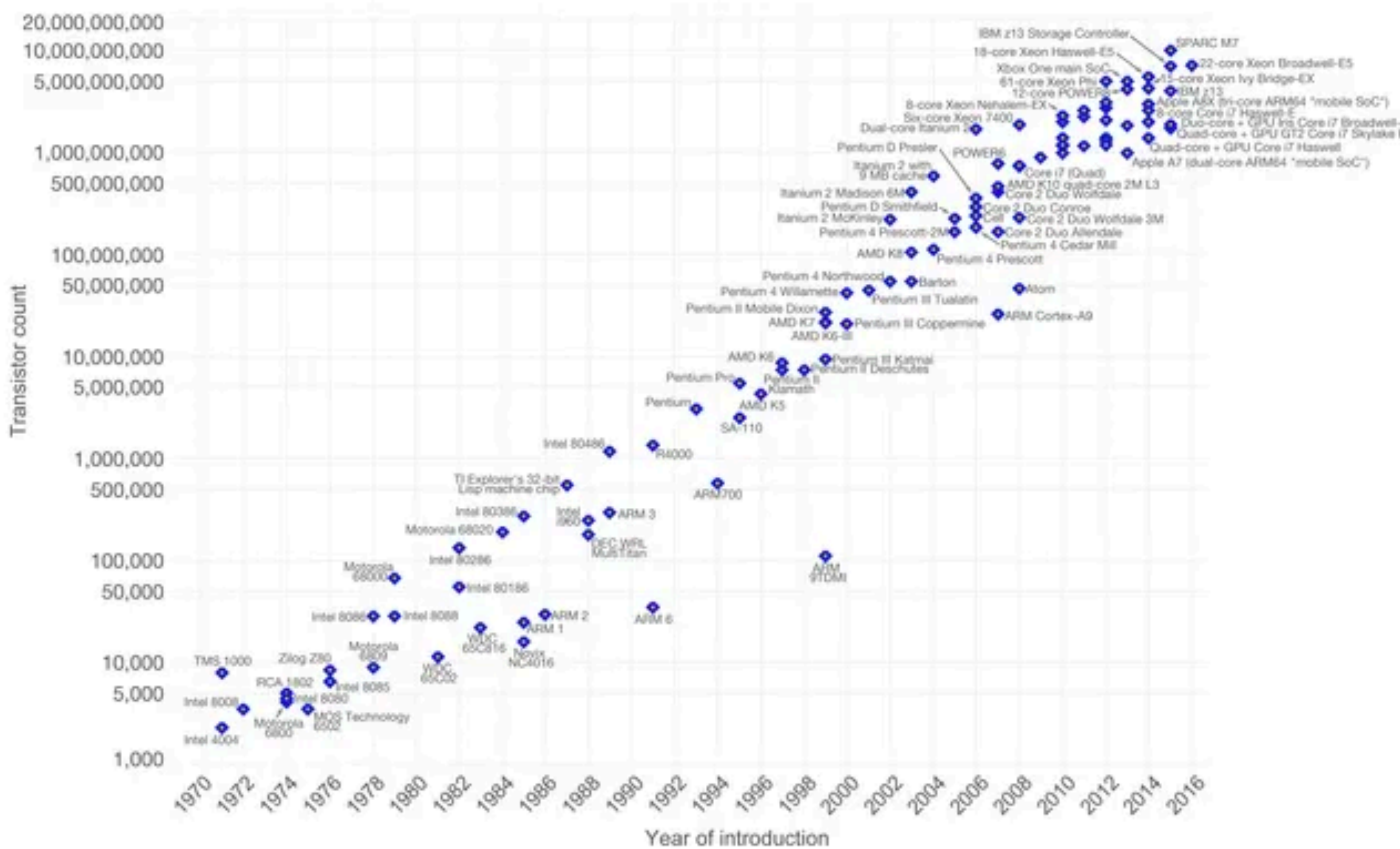
The computer clock determines the rate of F/E cycles per second; it is now expressed in GHz, i.e. in billions of cycles per seconds!

Note that the rate given is not an exact measurement.

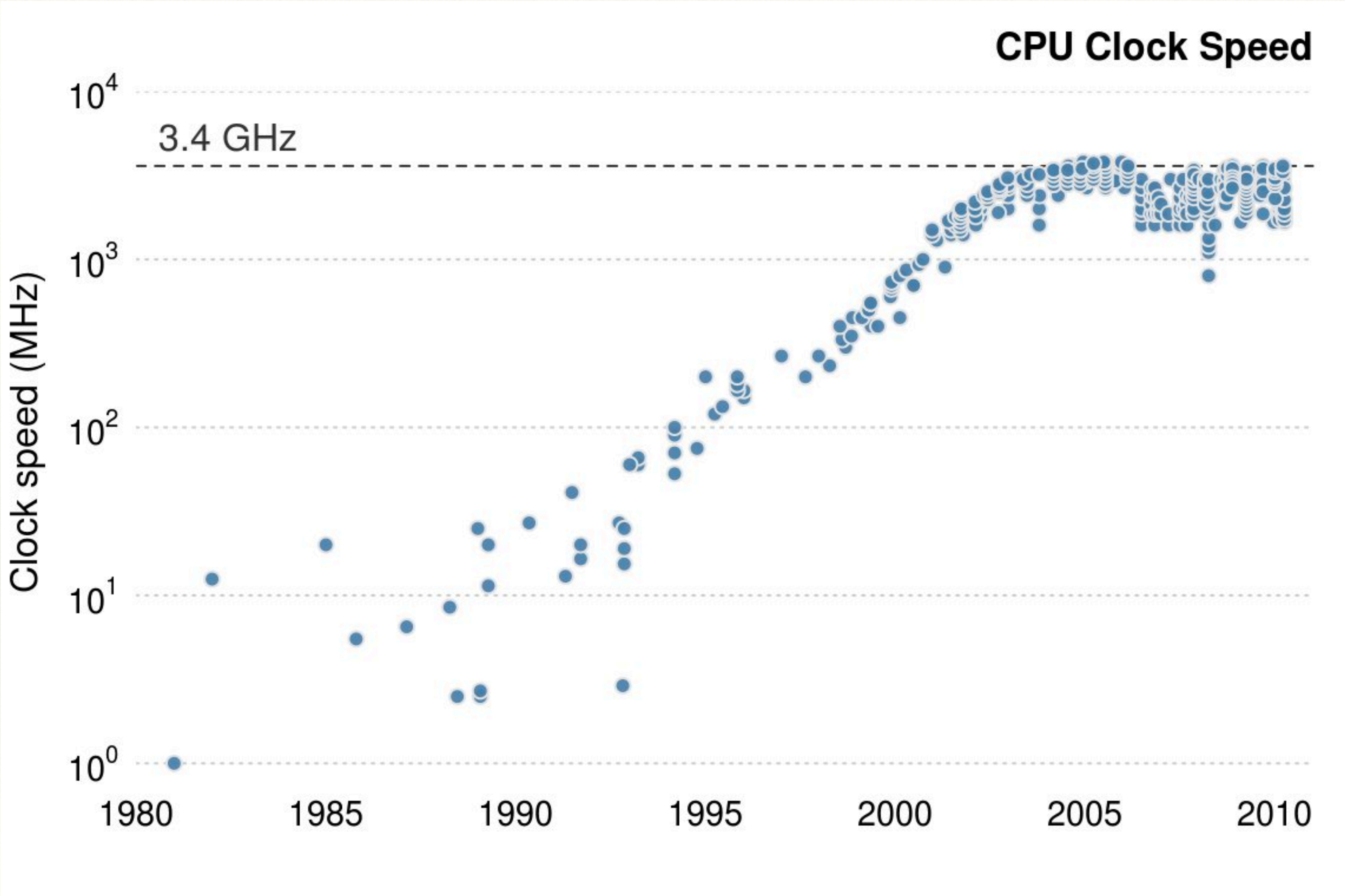
Moore's Law – The number of transistors on integrated circuit chips (1971-2016)

Our World in Data

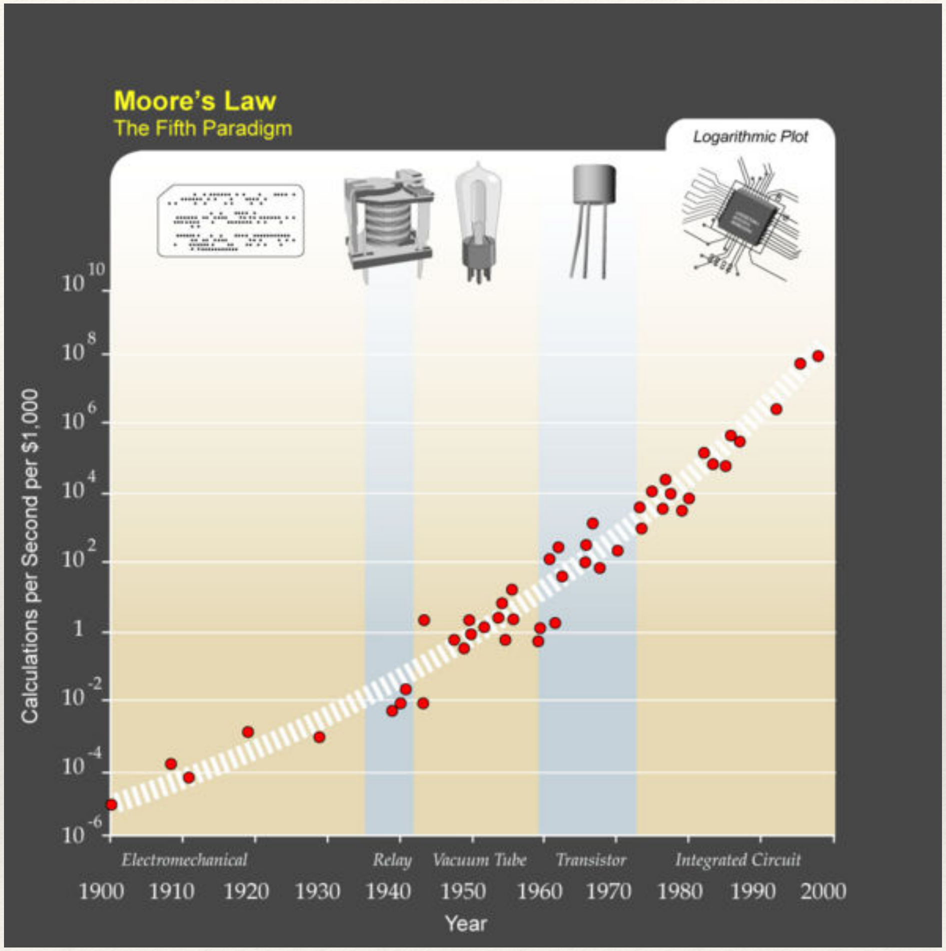
Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important as other aspects of technological progress – such as processing speed or the price of electronic products – are strongly linked to Moore's law.



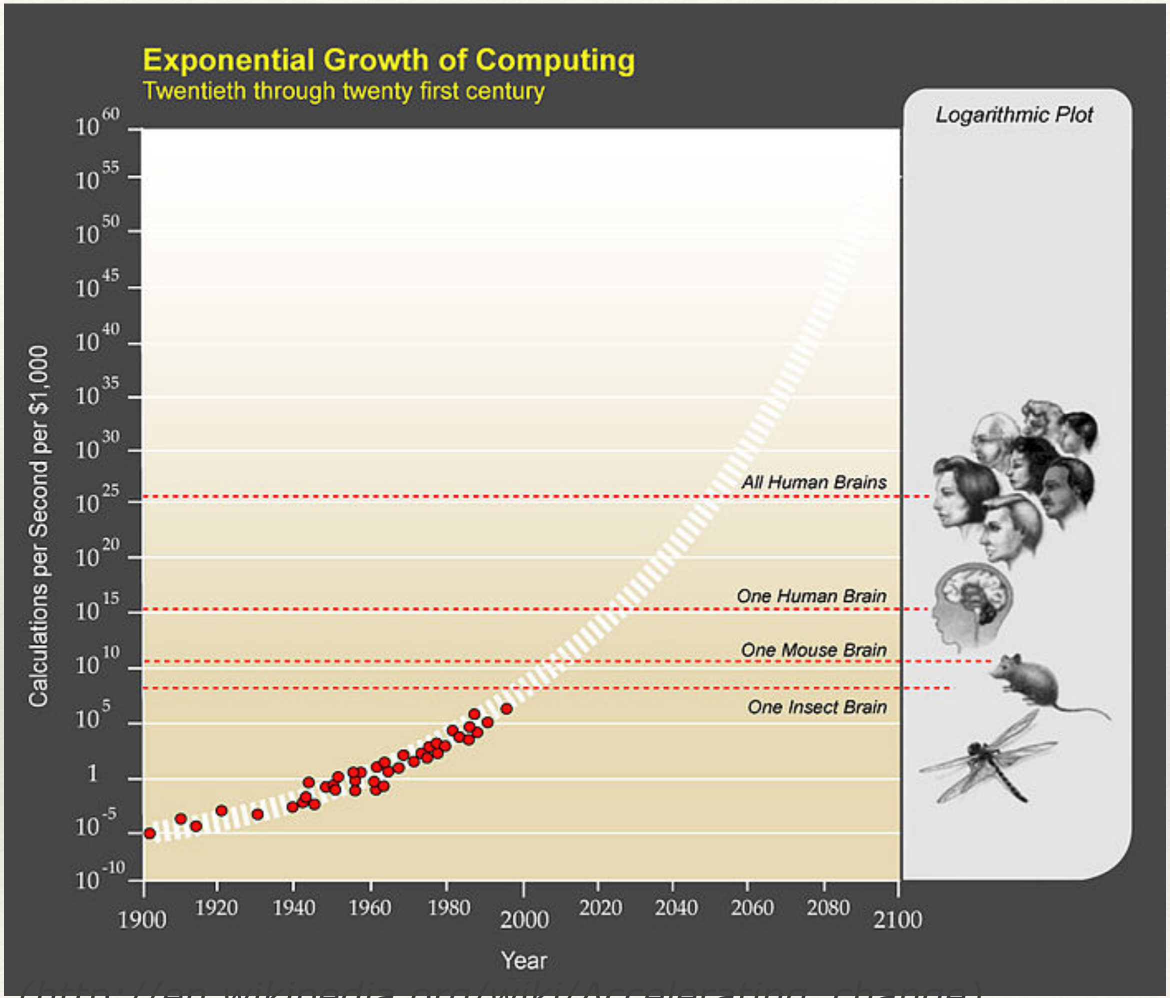
Data source: Wikipedia (https://en.wikipedia.org/wiki/Transistor_count)
The data visualization is available at OurWorldinData.org. There you find more visualizations and research on this topic.



CPU Clock Speed
3.4 GHz
Clock speed (MHz)
10^4
10^3
10^2
10^1
10^0
1980
1985
1990
1995
2000
2005
2010



(http://en.wikipedia.org/wiki/Accelerating_change)



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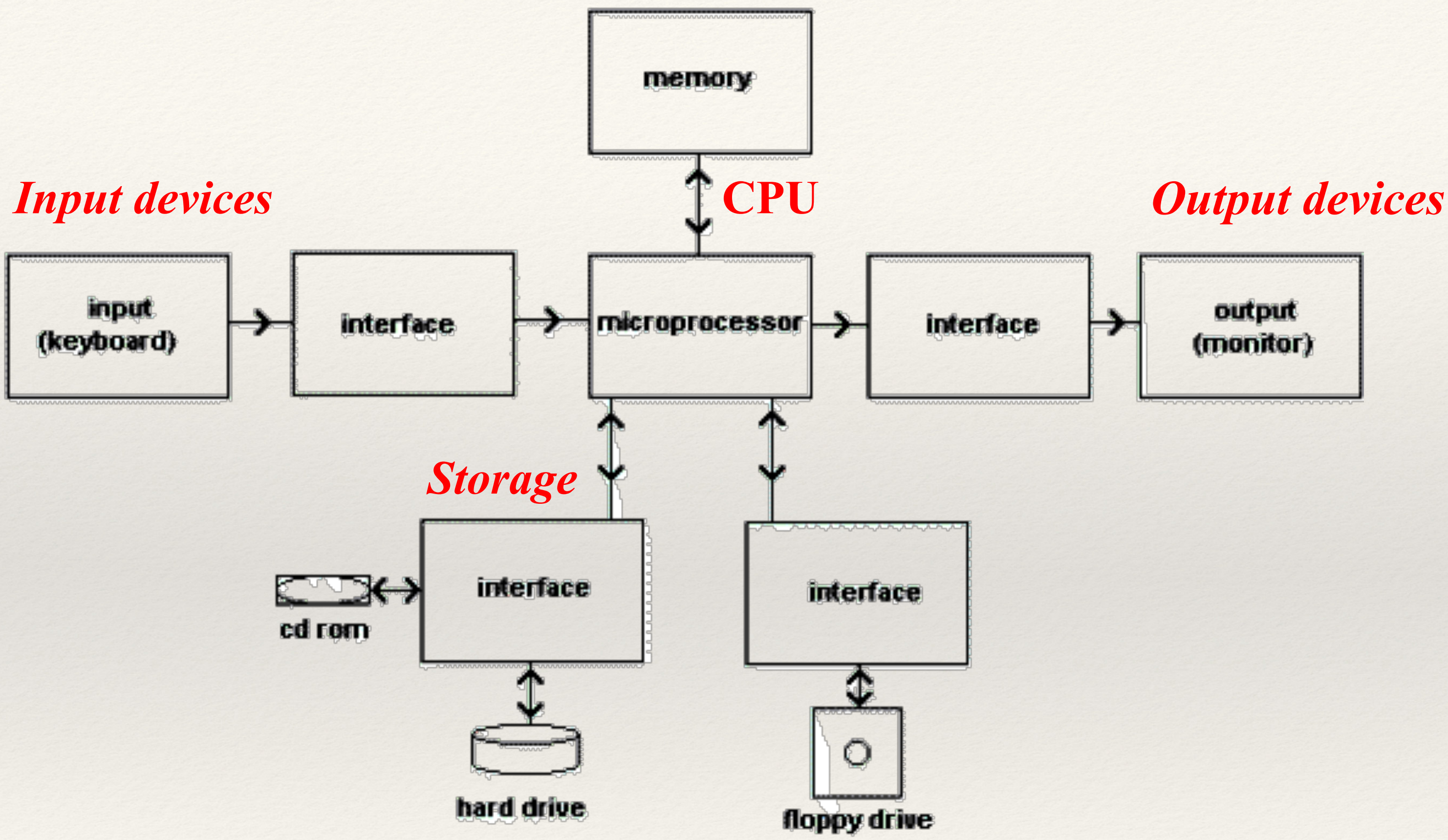
Computer: basic scheme



The Central Process Unit (CPU)

CPUs are getting smaller, and can include more than one "core" (or processors).

CPUs get hot, as their internal components dissipate heat: it is important to add a heat sink and fans to keep them cool.

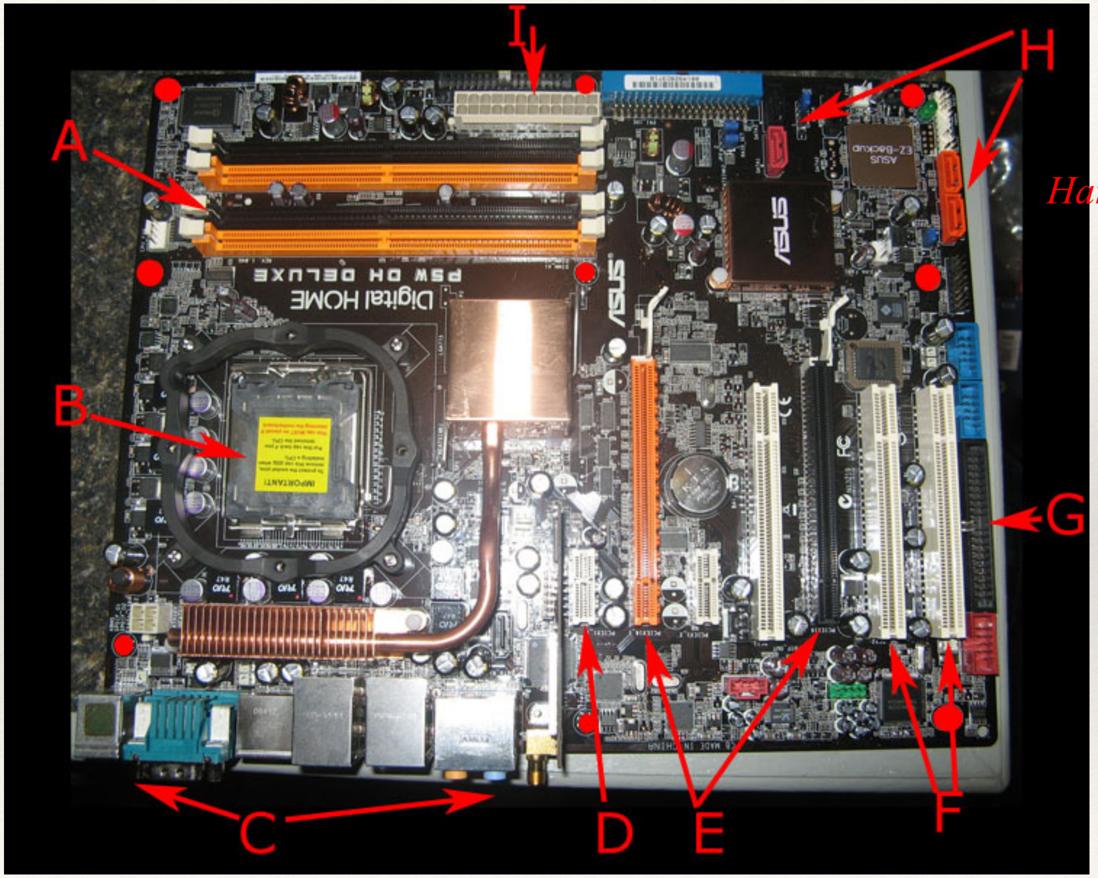
The motherboard: backbone of the computer

Power supply connector

Slot for memory: RAM

Slot for CPU

Hard drive connectors



Input/Output: Keyboard, Mouse,…

Extension cards: Video, sound, internet…

Communications on the mother board