Logic and Digital Logic CPUs

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Basic Concepts (part II)

- ***Logic***
  - Proposition
  - Operation on propositions
- ***Digital Logic***
  - The transistor
  - Gates
- ***CPU***
  - Order of operations
  - Speed

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Logic: proposition

Definition: A proposition is a declarative sentence that is either true (T, or 1) or false (F, or 0). We refer to 1 or 0 as the truth value of the proposition.

Examples:

Sentence	Proposition?	Truth value
1+1=4	Yes	0
Today is Friday	Yes	1
It will rain tomorrow	Yes	We will know tomorrow…
X+1=2	No	
I am lying now	No	

Logic: compound propositions

Negation:
Let p be a proposition. The sentence "it is not the case that p" is another proposition, called the negation of p, denoted ¬p or ~p. It is also read as "not p".

Truth table

p	¬ p
1	0
0	1

"inverter"

Logic: compound propositions

Conjunction:
The conjunction of two propositions p and q is the proposition p ∧q (read "p and q") that is true if and only if both p and q are true.

Truth table:

p	q	p∧q
0	0	0
0	1	0
1	0	0
1	1	1

"Multiplication"

Logic: compound propositions

Disjunction:
The disjunction of two propositions p and q is the proposition p ∨q (read "p or q") that is true if and only if p or q, or both are true.

Truth table:

p	q	p∨q
0	0	0
0	1	1
1	0	1
1	1	1

"Addition"

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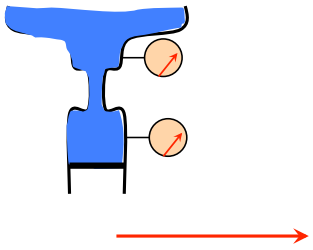
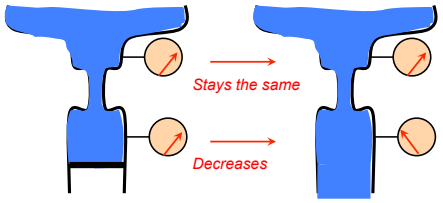
The concept of pressure

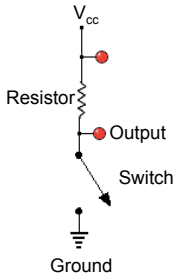


When we remove the block, what is the effect on pressure?

The concept of pressure



Electrical pressure: voltage



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

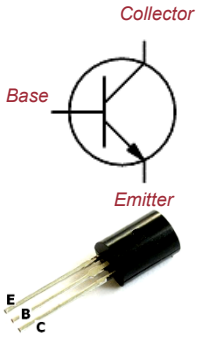
$V_{output}=V_{cc}$ high (i.e. 1)

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

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

"Inverter"

The transistor

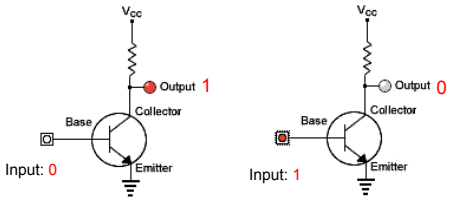


A transistor can be used as an electronic switch:

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

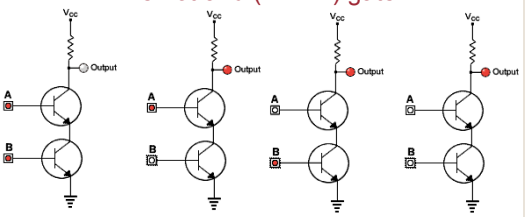
-If V_{base} is low, the current does not pass (switch is off)

The not gate



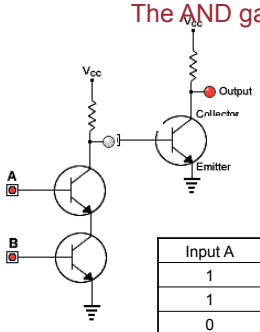
Input	Output
0	1
1	0

The not-and (NAND) gate



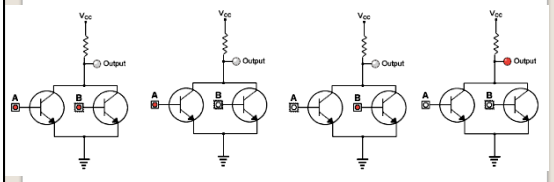
Input A	Input B	Output
1	1	0
1	0	1
0	1	1
0	0	1

The AND gate



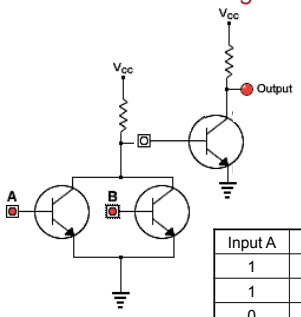
Input A	Input B	Output
1	1	1
1	0	0
0	1	0
0	0	0

The not-or (NOR) gate

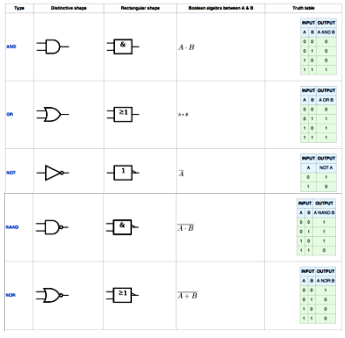


Input A	Input B	Output
1	1	0
1	0	0
0	1	0
0	0	1

The OR gate



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



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

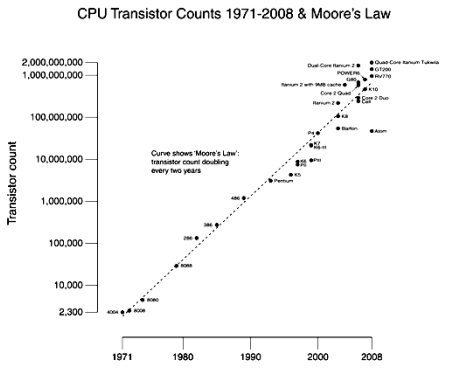
Integrated Circuit

- A computer central processing unit (CPU) is an electronic circuit combining millions of these logical digital gates and other electronic components.

-While the transistor was key to the development of computers, another major step was the possibility to miniaturized to the extreme the design of these electronic circuits: this was made possible by the invention of the Integrated Circuit (or IC, microcircuits, microchips, silicon chips or chips).

There has been several generations of IC:
-SSI: small scale integration
-MSI: medium scale integration
-LSI: large scale integration
-VLSI: very large scale integration

-Moore's law (1965):
"The complexity for minimum component costs has increased at a rate of roughly a factor of two per year. Certainly over the short term this rate can be expected to continue"



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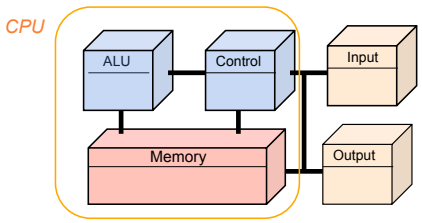
The Central Process Unit (CPU)



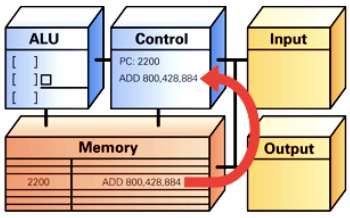
The CPU consists of three parts:
-the Arithmetic Logic Unit (ALU)
-The Control Unit
-Memory

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

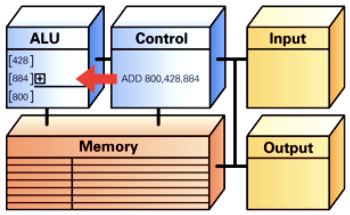
Step 1: Instruction Fetch



Fetch instruction from memory position 2200:

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

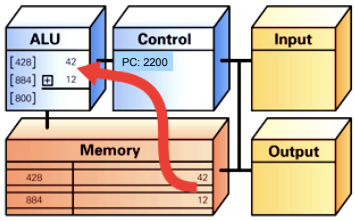
Step 2: Instruction Decode



Decode instruction:

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

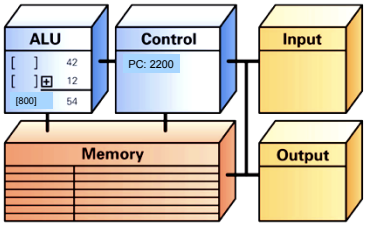
Step 3: Data Fetch



Fetch data:

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

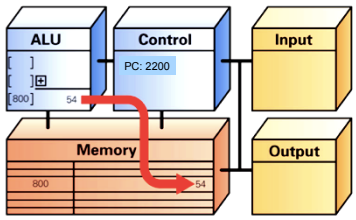
Step 4: Instruction Execution



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

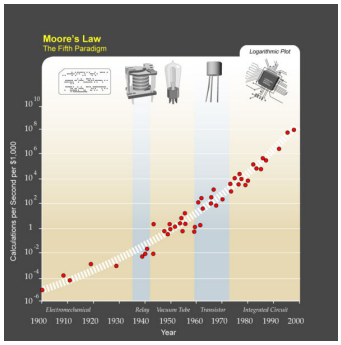
Computers get their impressive capabilities by performing many of these F/E cycles per second.

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!

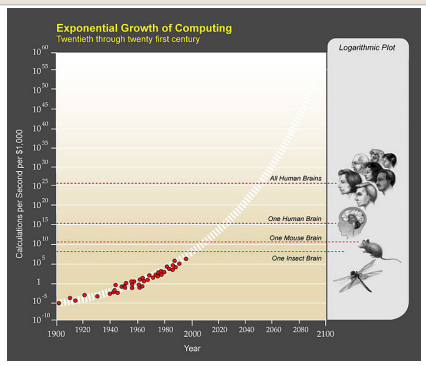
Note that the rate given is not an exact measurement.

Indicative numbers

Name	Date	Transistors	Microns	Clock speed	Data width	MIPS
8080	1974	6,000	6	2 MHz	8 bits	0.64
8088	1979	29,000	3	5 MHz	16 bits 8-bit bus	0.33
80286	1982	134,000	1.5	6 MHz	16 bits	1
80386	1985	275,000	1.5	16 MHz	32 bits	5
80486	1989	1,200,000	1	25 MHz	32 bits	20
Pentium	1993	3,100,000	0.8	60 MHz	32 bits 64-bit bus	100
Pentium II	1997	7,500,000	0.35	233 MHz	32 bits 64-bit bus	~300
Pentium III	1999	9,500,000	0.25	450 MHz	32 bits 64-bit bus	~510
Pentium 4	2000	42,000,000	0.18	1.5 GHz	32 bits 64-bit bus	~1,700
Pentium 4 "Prescott"	2004	125,000,000	0.09	3.6 GHz	32 bits 64-bit bus	~7,000



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



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