How do computers work ?

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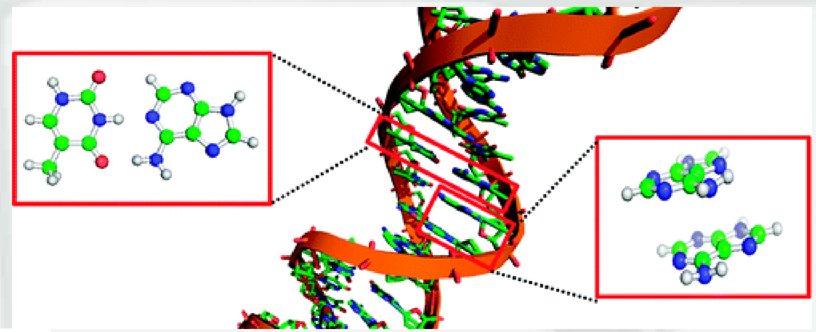
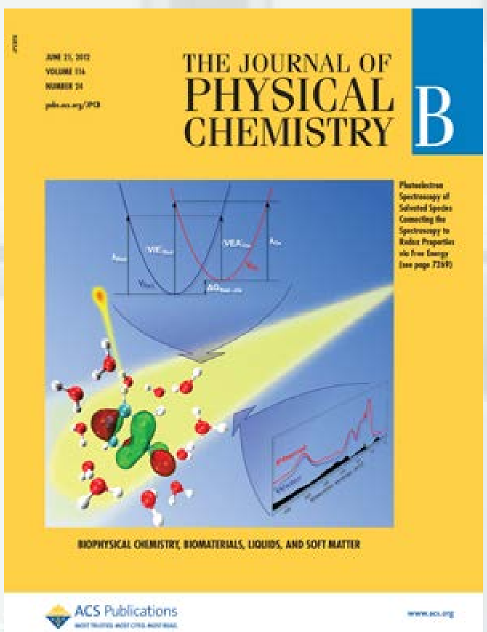
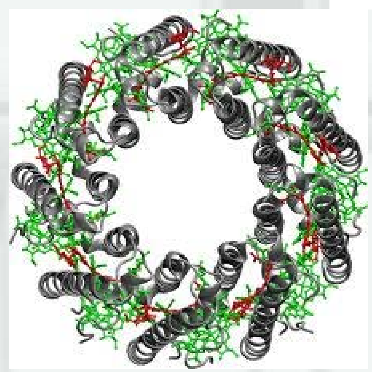
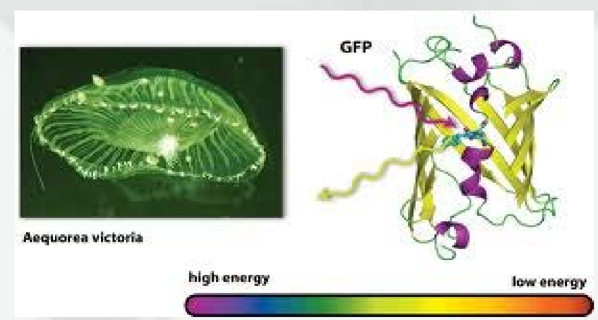
What do I do?

- I am a theoretical chemist.
- In silico experiments or computer experiments or simulations.







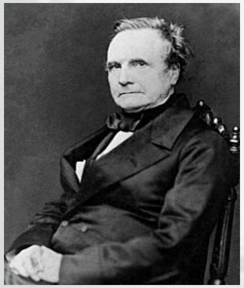


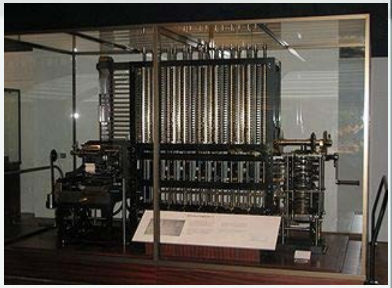
Some historical background

- 2400 B.C. - Abacus in Babylon.

- 1642 – Blaise Pascal created the mechanical or Pascal calculator.

- 17^{th} century AD – John Napier discovers log table and Charles Babbage designs “difference engine”.



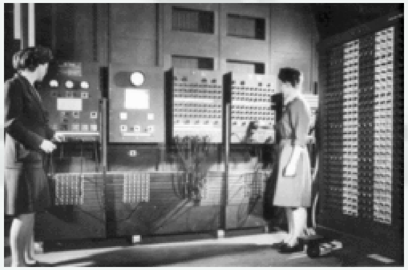


- Ada Lovelace – created first program to use this machine to calculate Bernouli's number.

Some historical background

- 1941 – Z3, electromachanical, Konrad Zuse : first working programmable, fully automatic digital computer, use of binary numbers, freq 5-10 Hz.
- 1937-1941 – Atanasoff-Berry computer : non-programmable.
- 1943 – Collosus computer : used to break German codes.
- 1946 – Electronic Numerical Integrator and Computer.

Second generation computers – used vacuum tubes.



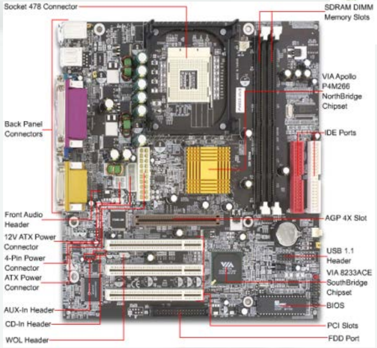
Some historical background

- IBM 7090 – started using transistors instead of vacuum tubes.

Third generation computers – used transistors.

What are computers made up of?

- Input unit – For entering data into your computer, e.g., keyboard, mouse, light pen....
- Storage unit – For storing data :: RAM (random access memory), hard drive, CD etc
- Output unit – Screen
- Processing – Task of performing arithmetic logic units (ALU) and control. - CPU (mother board)

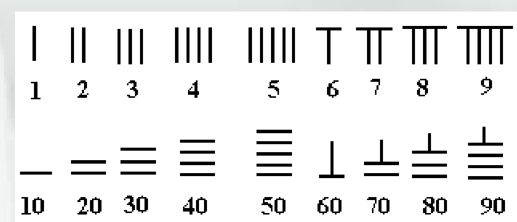


Storage

- Where ?

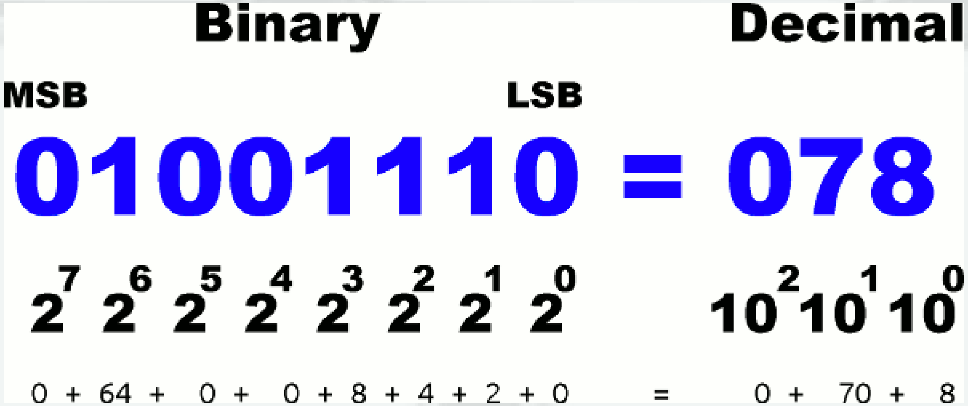


- How ?   As ON/OFF states. Like a light bulb!
- What is so great about decimal or 10?



- So we can use 2 as our base.

Binary to Decimal



Binary

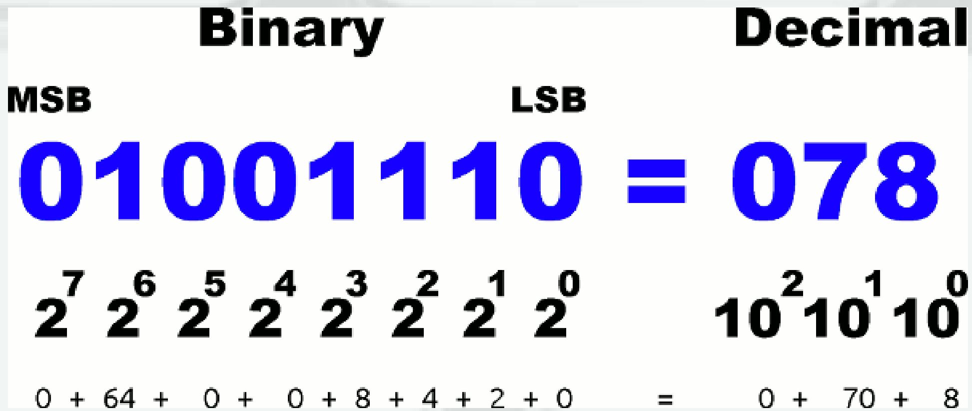
- When we have only 2 numbers instead of 9 – 0 & 1 (off and on).
- Let us consider any number, 9563 – 3 in units place, 6 in tens place, 5 in hundreds place and 9 in thousands place
  = $9_3 5_2 6_1 3_0$ = $3*10^0 + 6*10^1 + 5*10^2 + 9*10^3$
  = 3*1 + 6*10 + 5*100 + 9*1000 = 3 + 60 + 500 + 9000
- Similarly if we make a number from 0 & 1, say 11011
  = $(1_4 1_3 0_2 1_1 1_0)$ = $1*2^0 + 1*2^1 + 0*2^2 + 1*2^3 + 1*2^4$
  = 1*1 + 1*2 + 0*4 + 1*8 + 1*16 = $(1+2+0+8+16)_{10}$ = $(27)_{10}$
- So we can write any number in decimal or binary or for that matter any number system.

Storing numbers

- Registers – space to store numbers – similar to a bunch of bulbs which are either on/off . (In reality diodes)
- Let us convert decimal to binary – $(57)_{10}$ Same as when we try to understand what we mean by the decimal number – 57/10 → 5 as quotient and 7 as remainder.
- 57/2 → Q=28, R=1; 28/2 → Q=14, R=0;14/2 → Q=7, R=0 ; 7/2 → Q=3, R=1; 3/2 → Q=1, R=1.
- Thus the binary equivalent in $(111001)_2$ = 1+8+16+32 = $(57)_{10}$ 
- 5.7 = $57*10^{-1}$ 

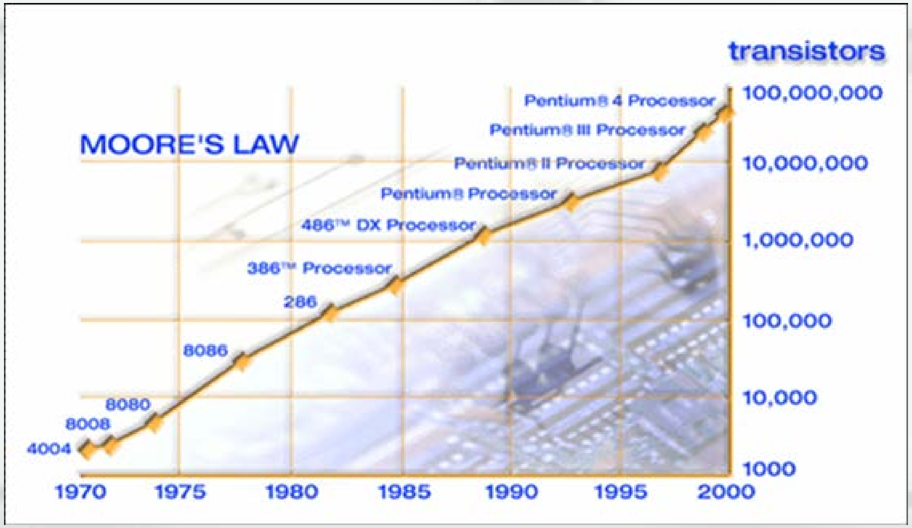
http://www.binaryconvert.com/

Binary to Decimal



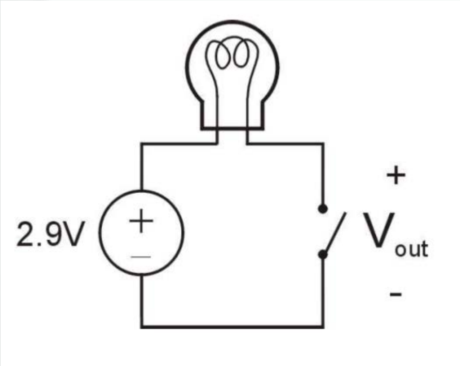
Processing

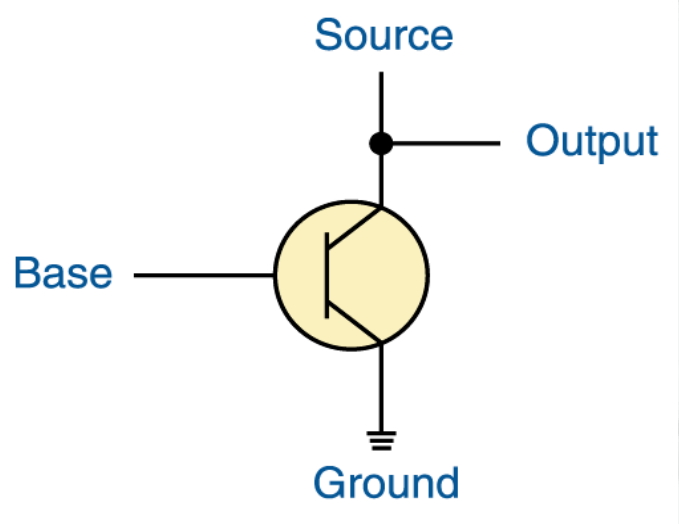
- Similar to the central nervous system in a human.
- Made of transistors.
- Faster and smaller.

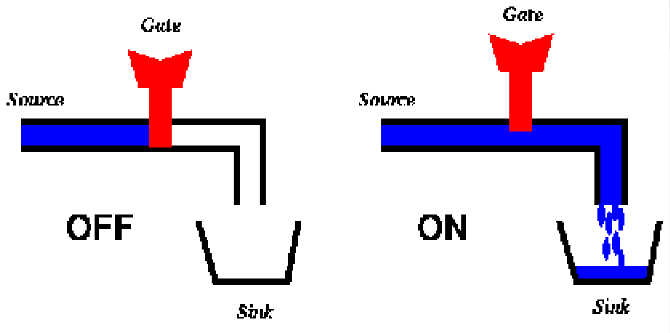


Transistors

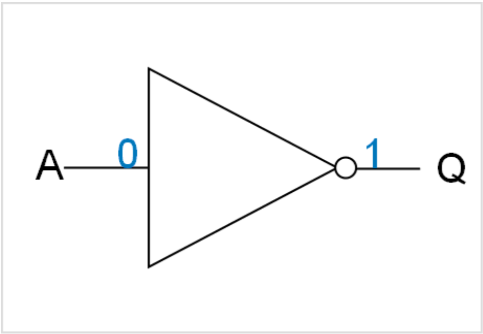
- Similar to faucets.
- Used to amplify and switch electronic signals, made of semiconductors.



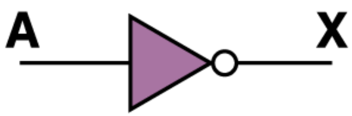




Logic gates - NOT



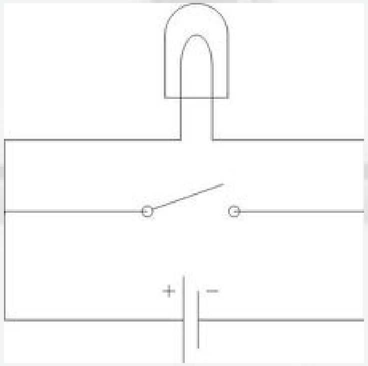
Logic Diagram Symbol



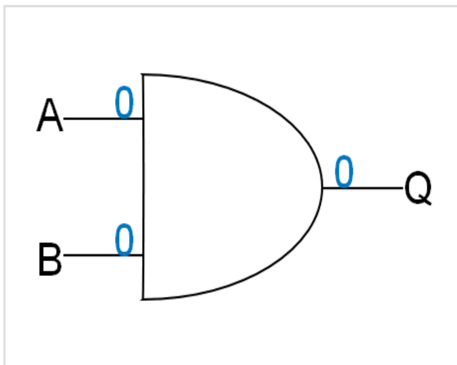
Truth Table

A	X
0	1
1	0

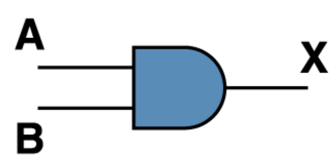
Use : Inverter. When the power is down, the inverter takes over and supplies power.



Logic gates - AND

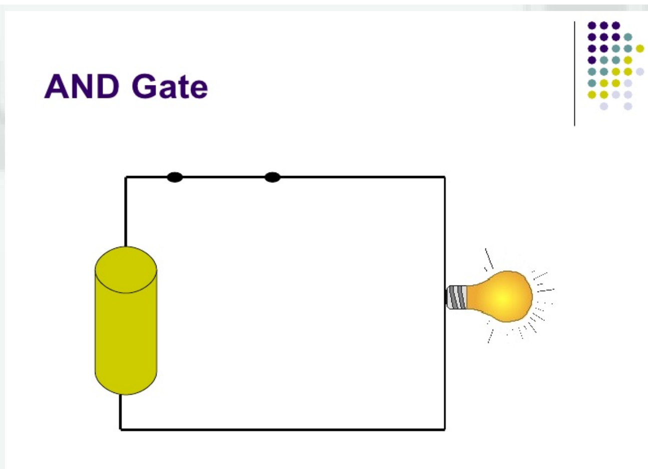


Logic Diagram Symbol



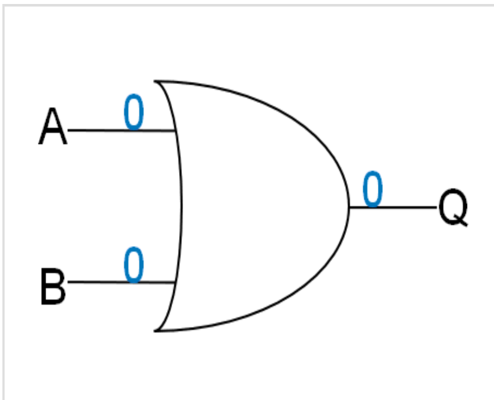
Truth Table

A	B	X
0	0	0
0	1	0
1	0	0
1	1	1

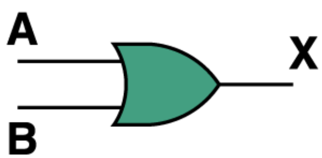


Use : As a safety feature in machines. The machine works only when both the buttons are pressed by both the hands.

Logic gates - OR

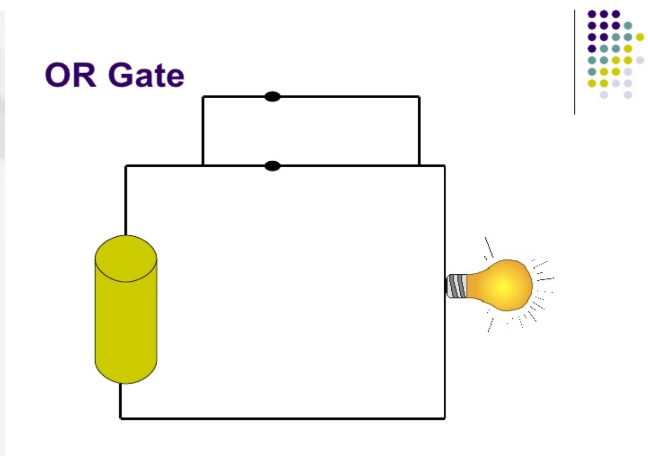


Logic Diagram Symbol



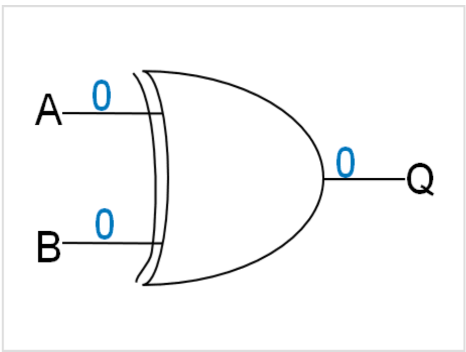
Truth Table

A	B	X
0	0	0
0	1	1
1	0	1
1	1	1

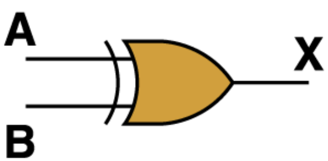


Use : Door bell for 2 doors – either one is pressed, the bell rings.

Logic gates - XOR



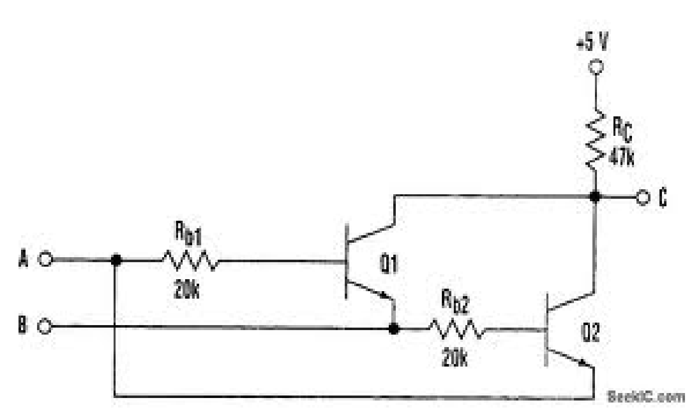
Logic Diagram Symbol



Truth Table

A	B	X
0	0	0
0	1	1
1	0	1
1	1	0

Use : Two way switches. A light bulb that can be operated by two switches on the top and bottom of stairs.

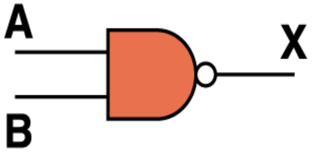


Logic gates - NAND

Boolean Expression

$X = (A \cdot B)'$

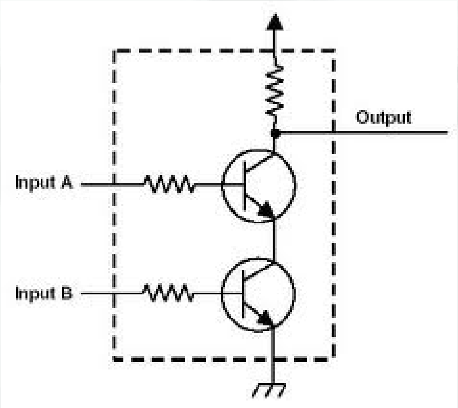
Logic Diagram Symbol

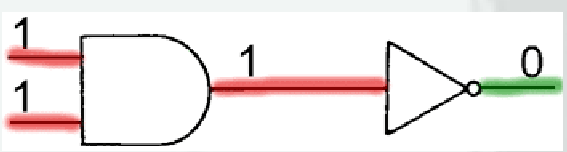


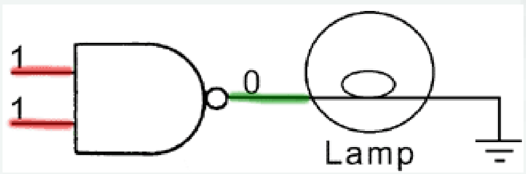
Truth Table

A	B	X
0	0	1
0	1	1
1	0	1
1	1	0

Use : Car door warning. It warns if any (one or more) of the car doors are open.





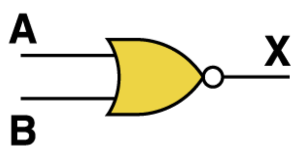


Logic gates - NOR

Boolean Expression

X = (A + B)'

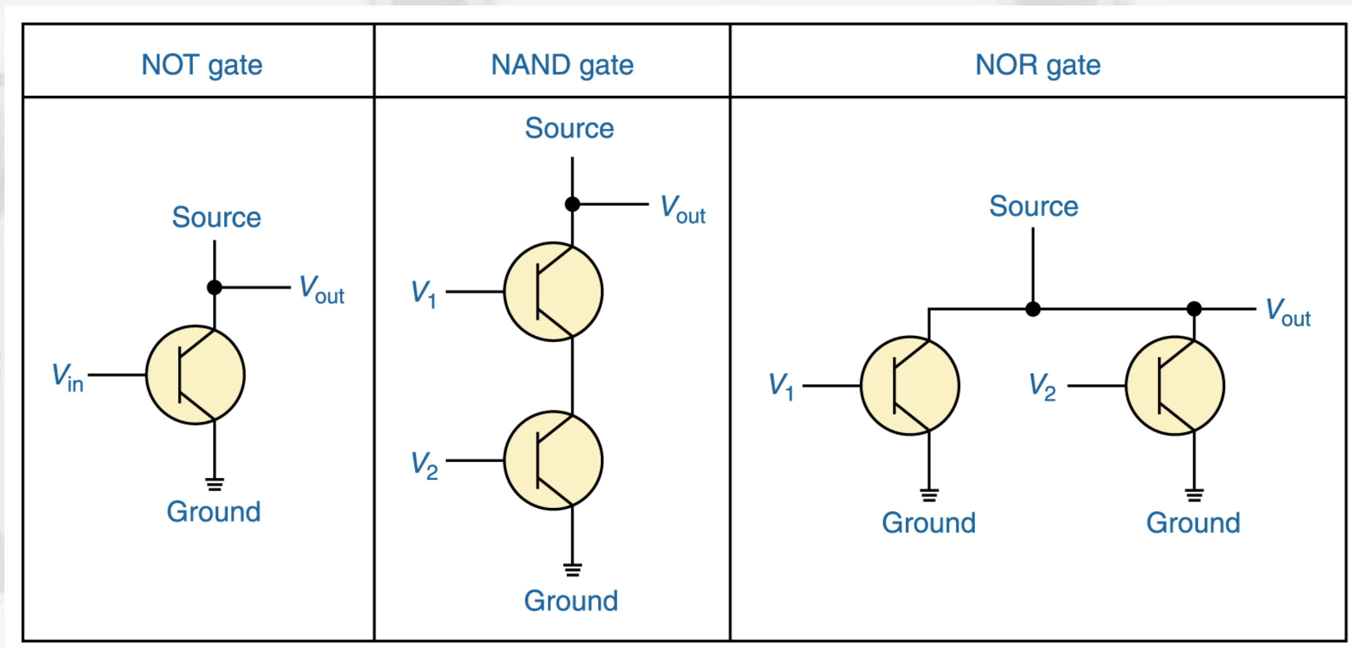
Logic Diagram Symbol



Truth Table

A	B	X
0	0	1
0	1	0
1	0	0
1	1	0

Constructing gates with transistors



Addition

The result of adding two binary digits could produce a carry value.

1+1 = 10 in binary

Our aim : A circuit that calculates the sum of two bits and produces the correct carry bit.

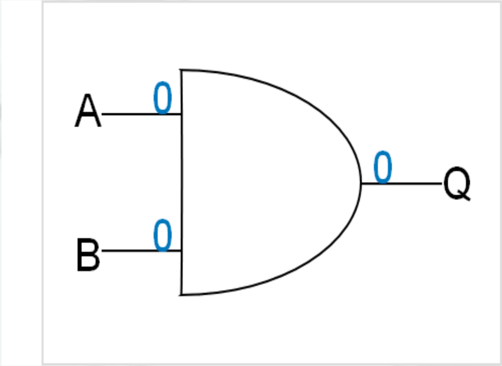
A	B	Carry	Sum
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition

```
    175        10101111
+   165     +  10100101
_______     ___________
```

Addition

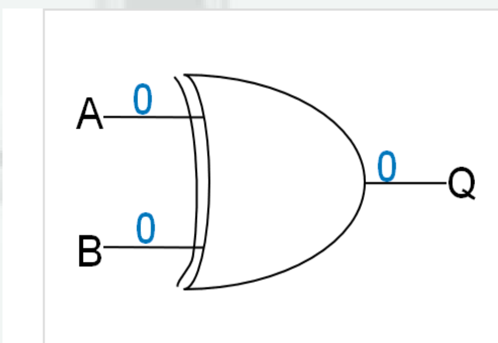
The carry part looks like a AND gate.



A	B	Carry	Sum
0	0	0	[redacted]
0	1	0	[redacted]
1	0	0	[redacted]
1	1	1	[redacted]

Addition

The sum part looks like a XOR gate.

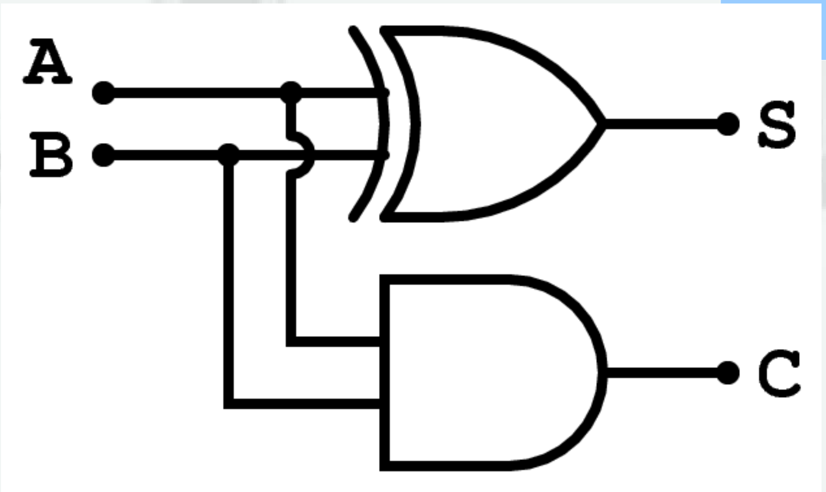


A	B	Carry	Sum
0	0	[redacted]	0
0	1	[redacted]	1
1	0	[redacted]	1
1	1	[redacted]	0

Addition

The addition of 2 binary bits – AND gate + XOR gate.

A	B	Carry	Sum
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

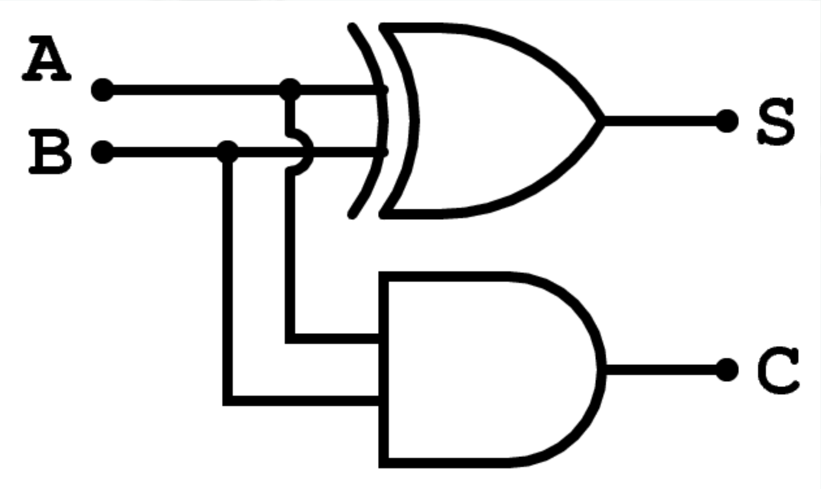


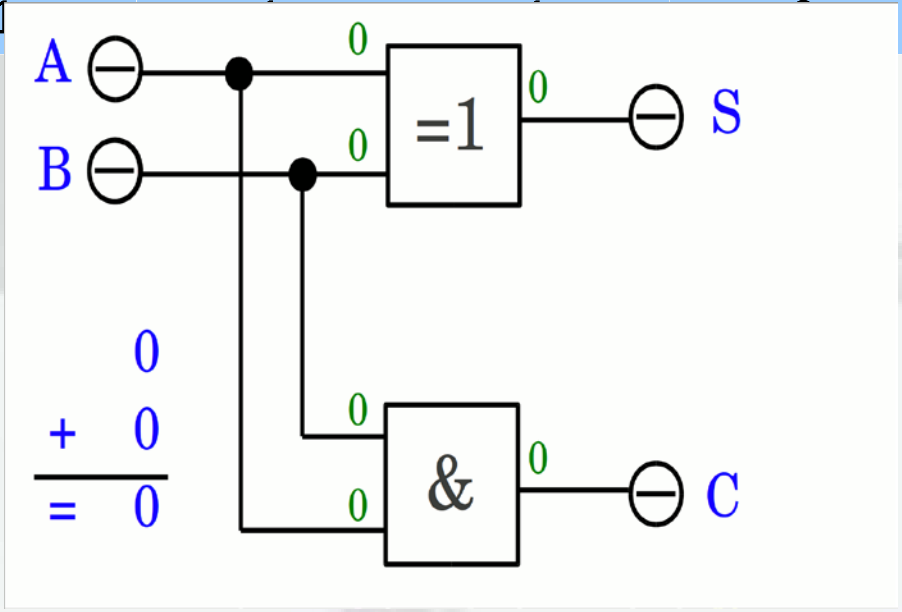
Addition

The addition of 2 binary bits – AND gate + XOR gate.

Decimal value of sum = $2^1*C + 2^0*S$

A	B	Carry	Sum
0	0	0	0
0	1	0	1
1	0	0	1
1	[illegible]	[illegible]	[illegible]





Addition

```
  175      10101111
+ 165    + 10100101
```

Conclusion

- Computers stores numbers and operates on them using seemingly simple electronic components.
- The amazing part is in the technology that can enable so many components in so little space.

- Computers only are as smart as the user.
- They have to be given very precise orders in precise order.

Computers are incredibly fast, accurate, and stupid. Human beings are incredibly slow, inaccurate, and brilliant. Together they are powerful beyond imagination. -- Albert Einstein