Digital System

Week 2: Number Systems and Boolean Algebra
Part III

Fenerbahce University

Course 3 Content

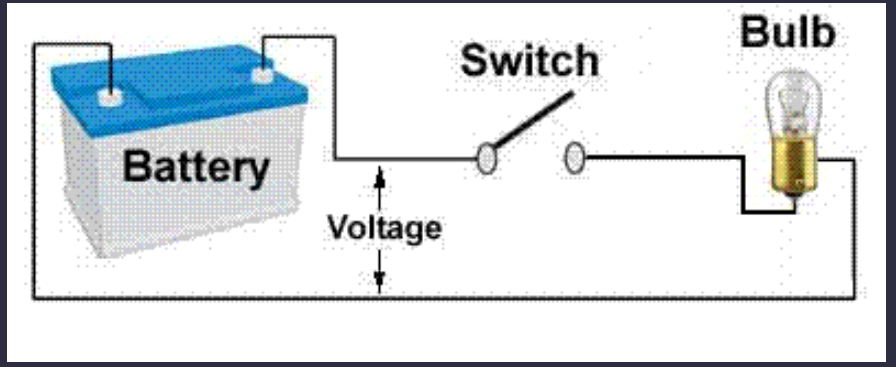
- Transistors
- Logic Gates
  - Not
  - Or, Nor
  - And, Nand
  - De Morgan's Law
  - Multi-input Logic Gates

Design of Processor Blocks with

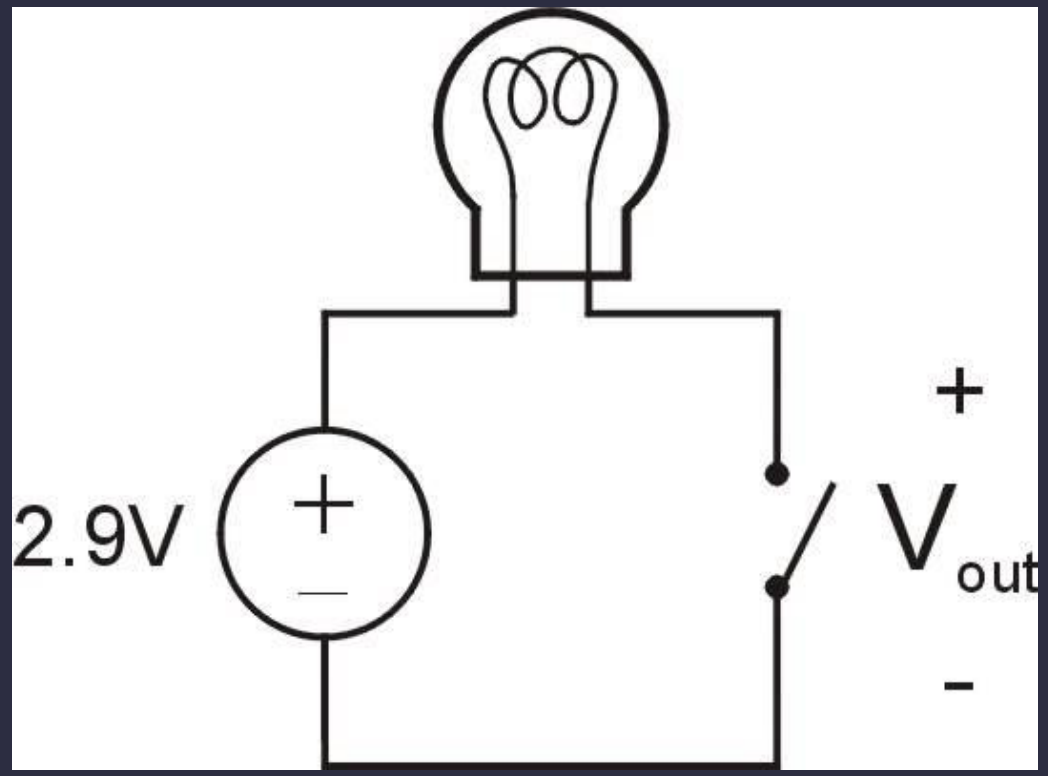
- Number of Transistors in Processors
  - Intel 4004 (1971): 2250
  - Intel 8088 (1979): 29k
  - AMD K6 (1997): 7.5 million
  - Intel Pentium 4 (2006): 184 Million
  - Intel I7 Haswell -E (2014): 2.6 Billion
  - AMD Epyc Rome (2019): 32 Billion

Design of Processor Blocks with

- Transistors work like switches.
- They form the control mechanisms in the circuit.
- Multiple transistors come together to form logic circuits.
  - And , Or , Not
- With the combination of logic gates
  - Structures such as adders, multipliers can be created.
- A processor can be made with adder, multiplier and store structures.

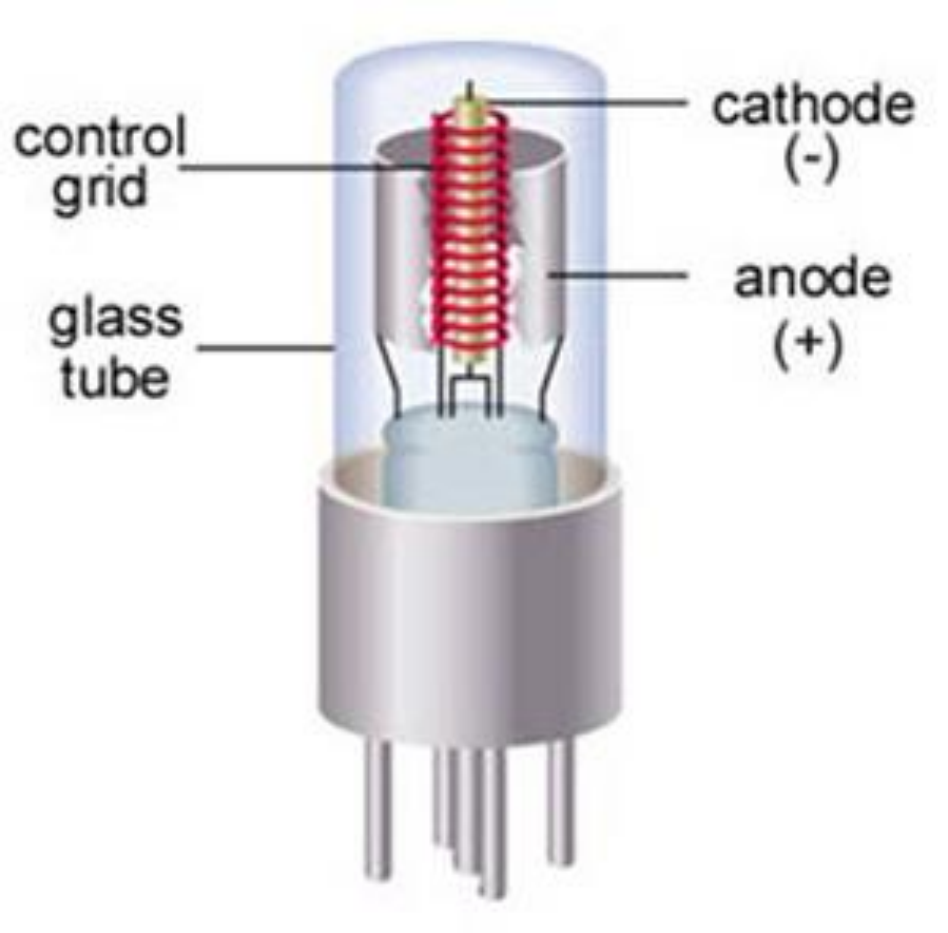


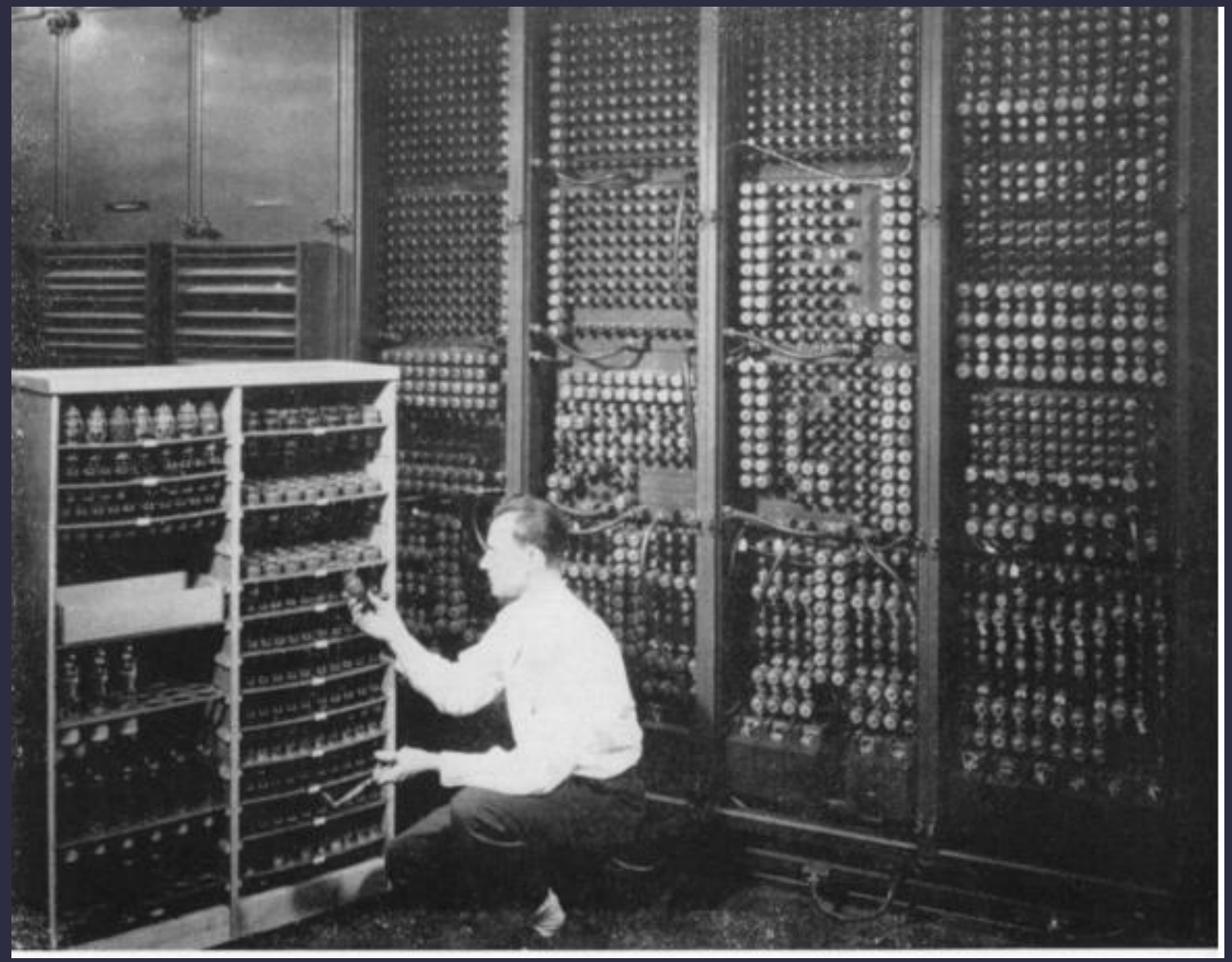
Simple Switch Circuit



- Switch On:
  - There is no current flow.
  - lamp off
  - V_{out} +2.9V (There is potential difference)
- Switch Off :
  - There is current flow in the circuit.
  - lamp on
  - V_{out} 0V (No potential difference)

Vacuum Tubes

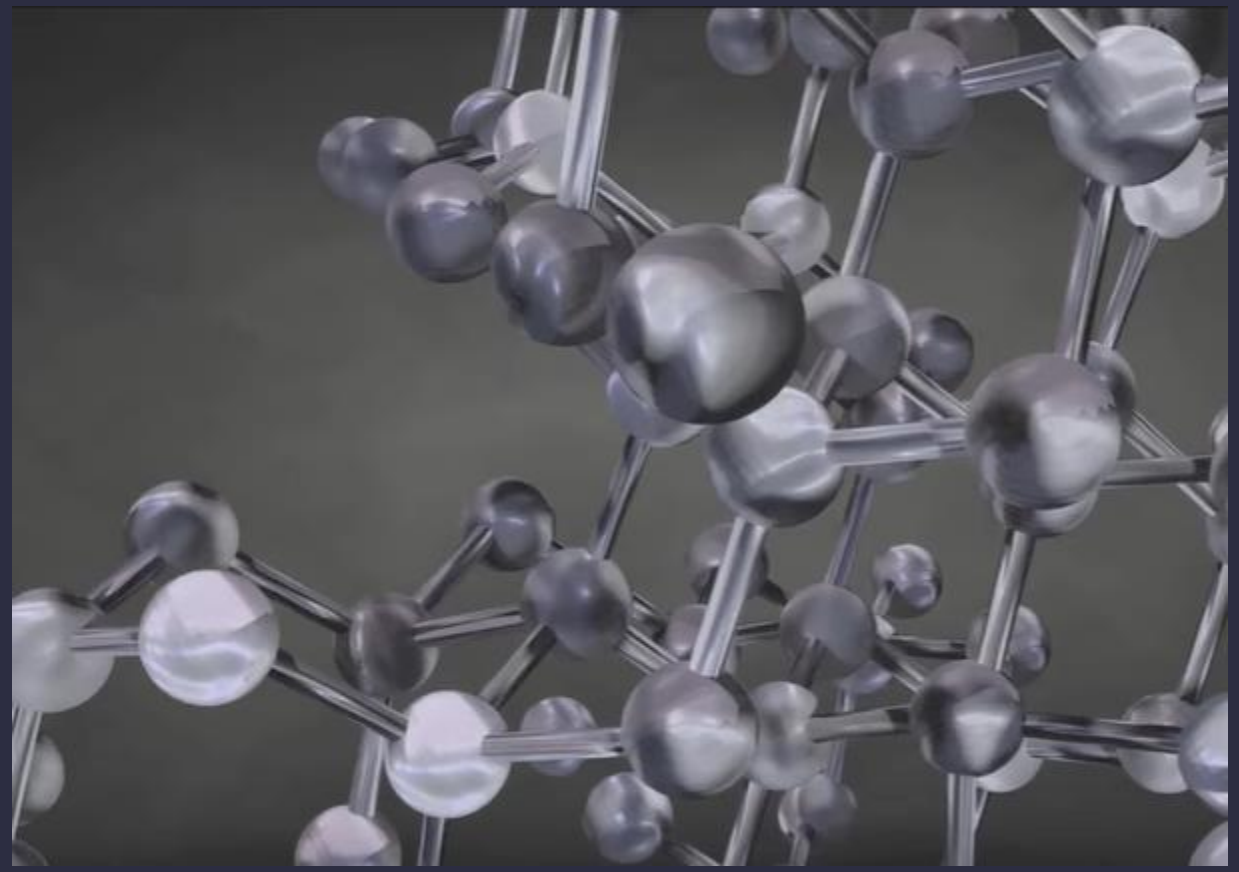




Transistors

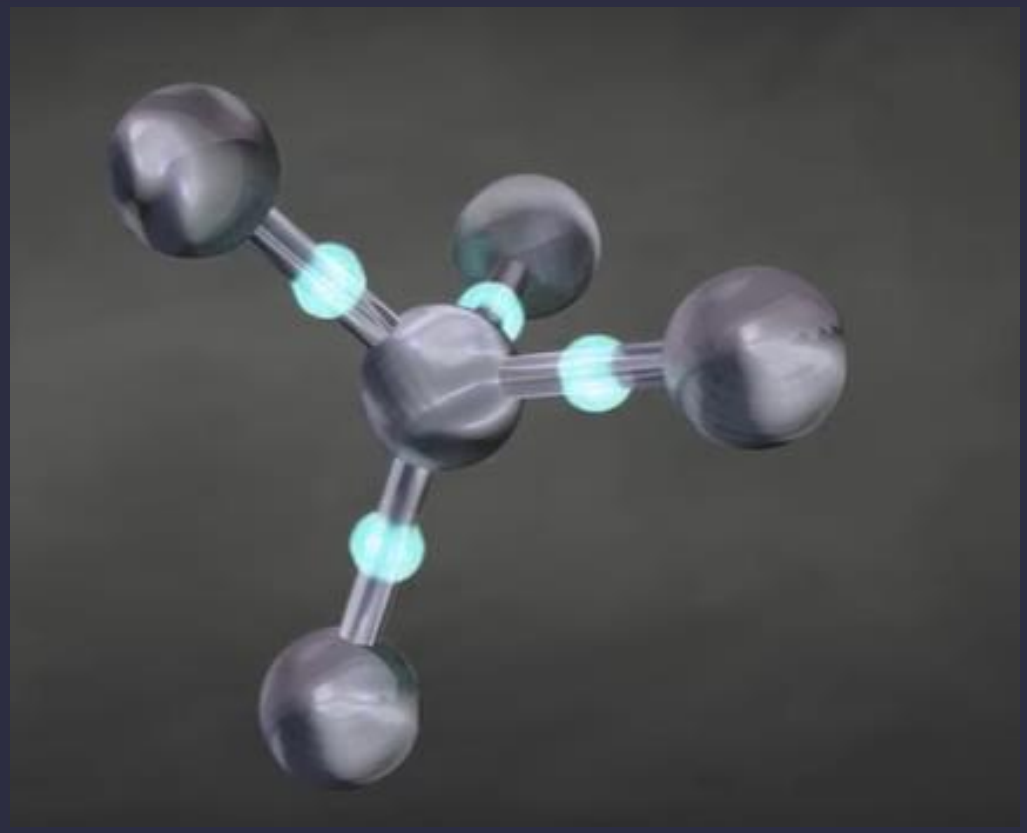
Silicon Element

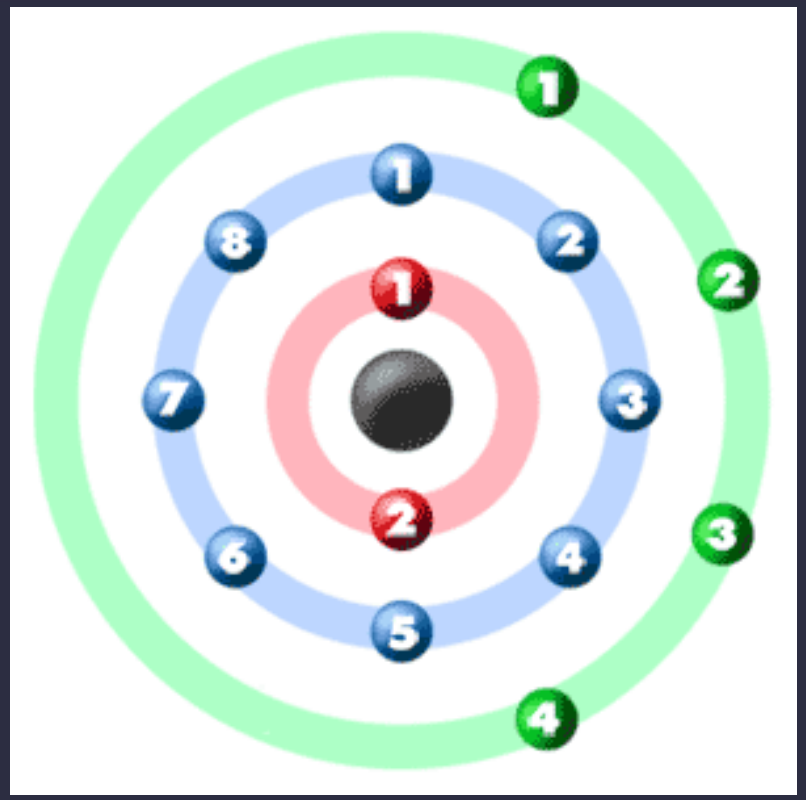
Transistors



Each silicon atom forms a covalent bond with 4 surrounding silicon atoms.

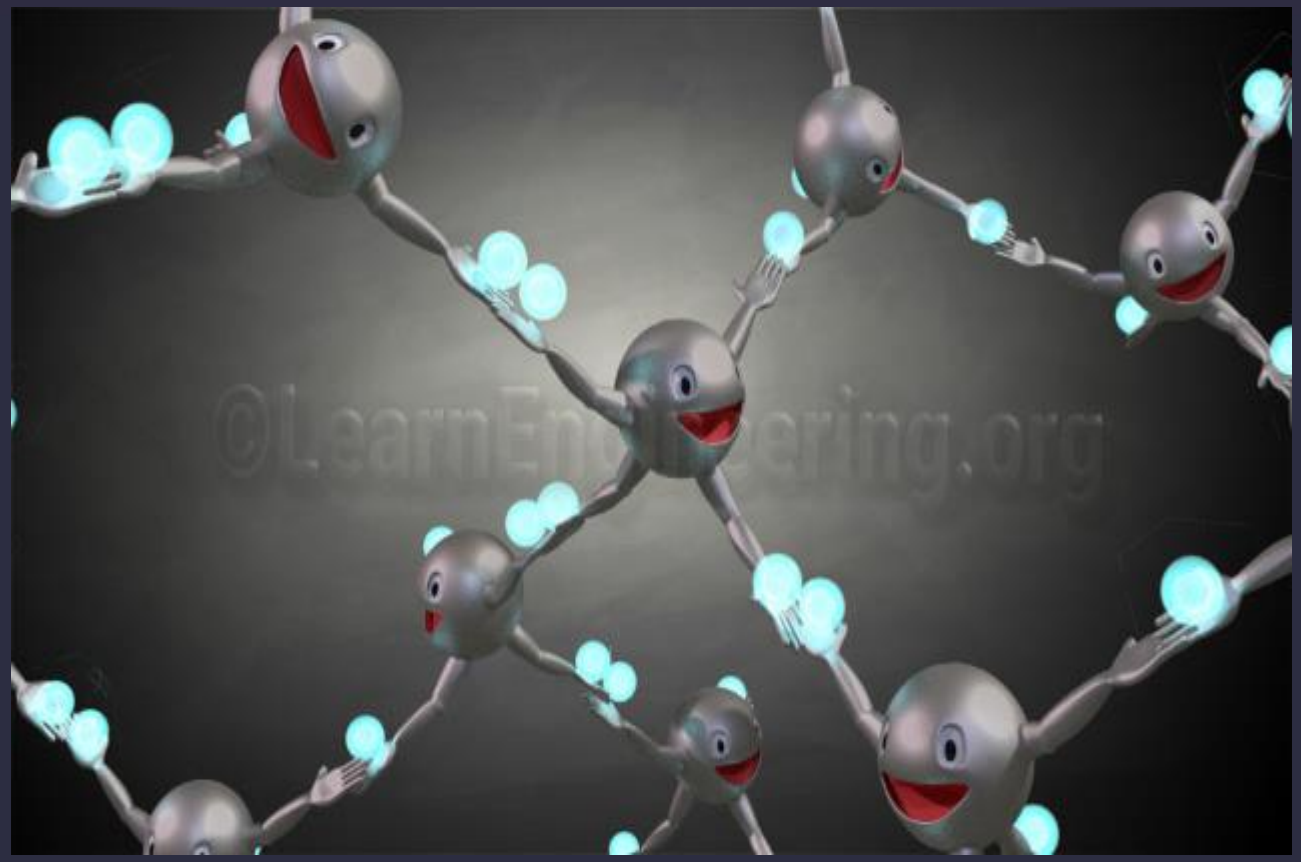
Transistors





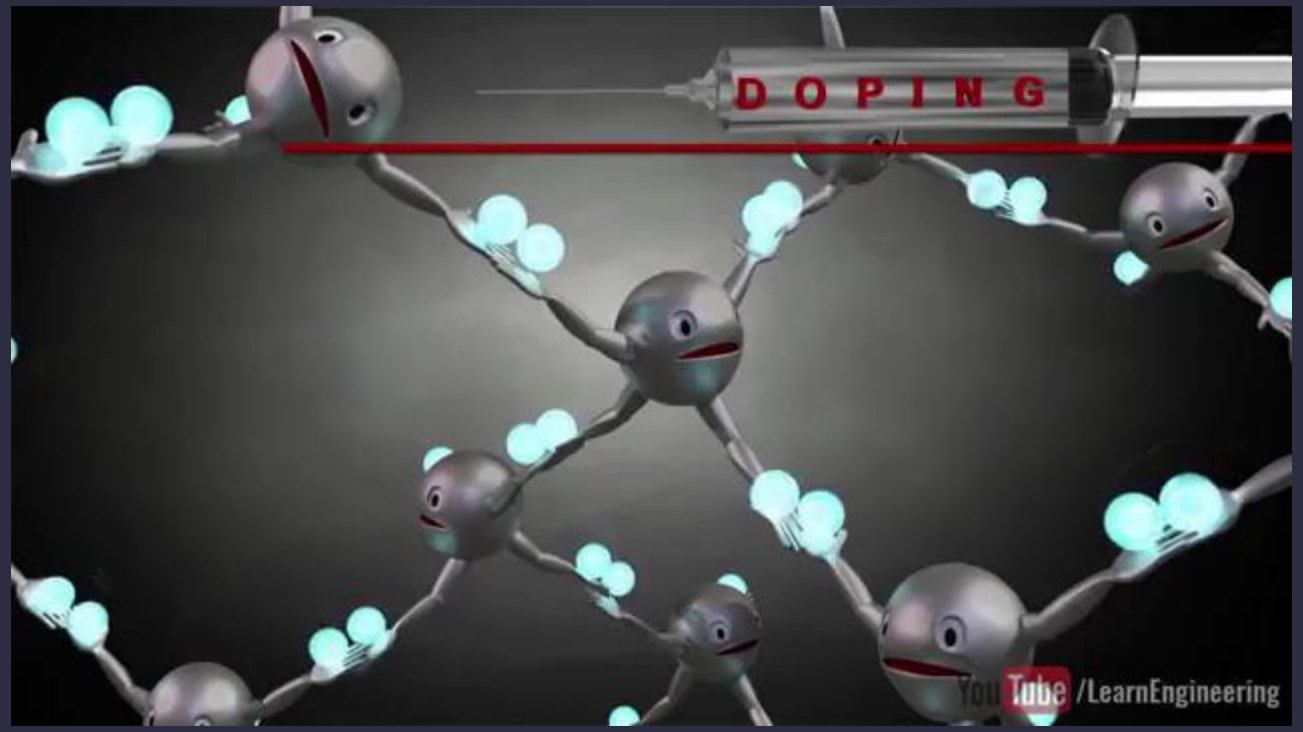
4 electrons

Transistors



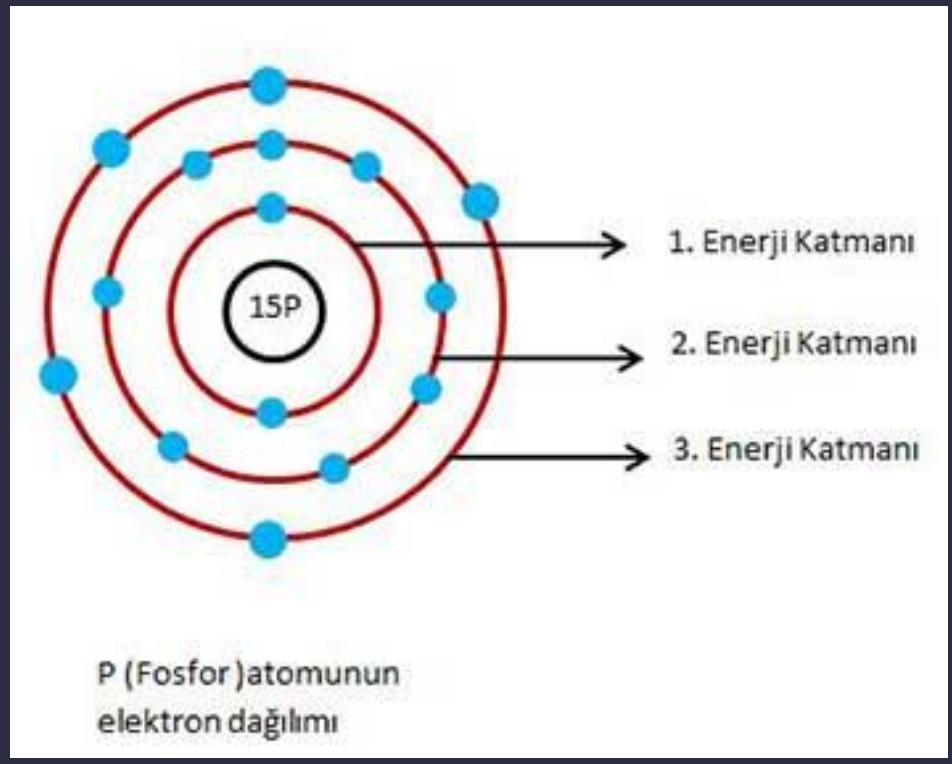
4 electrons in its last orbital .
It is semiconductor but has low conductivity.

Transistor Doping Process



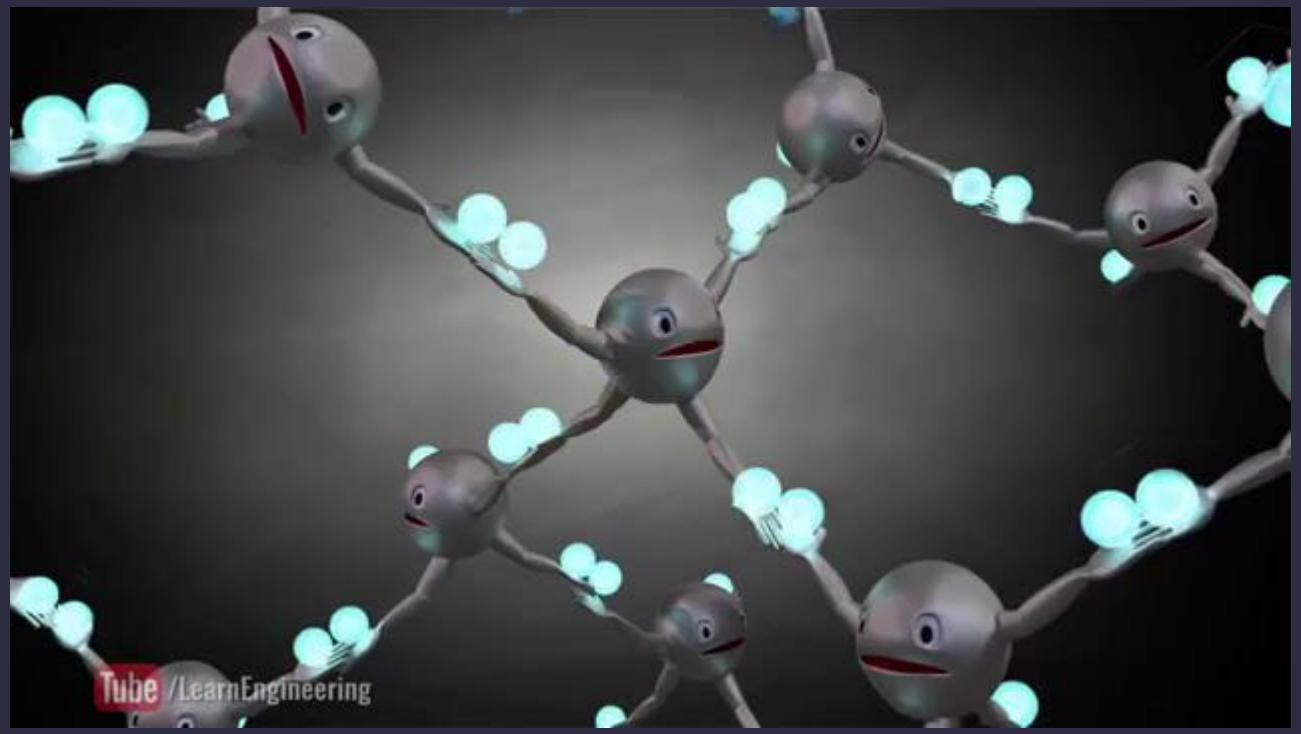
"Doping" technique, which is used to increase the conductivity of semiconductors, is applied.

N Type



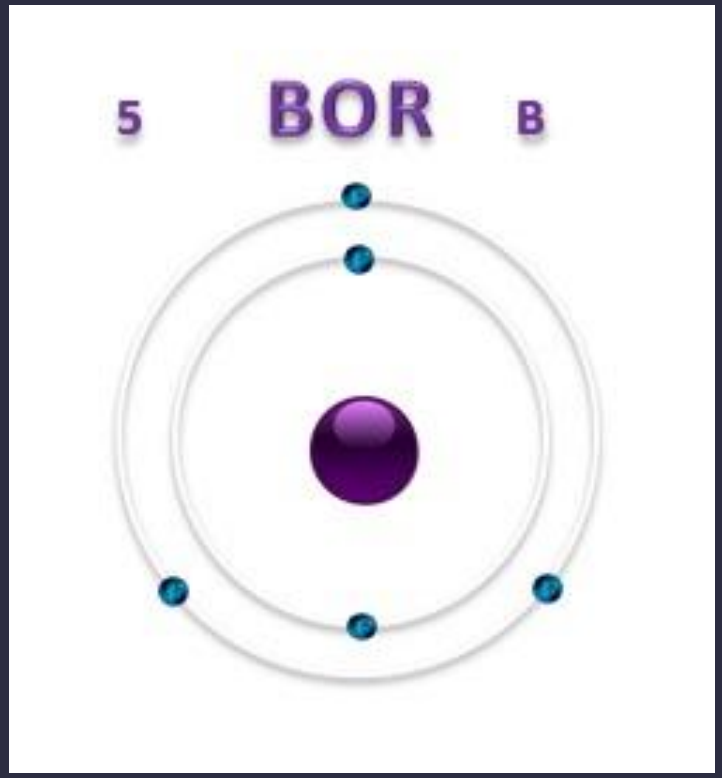
Phosphorus Atom

Transistor Doping Process



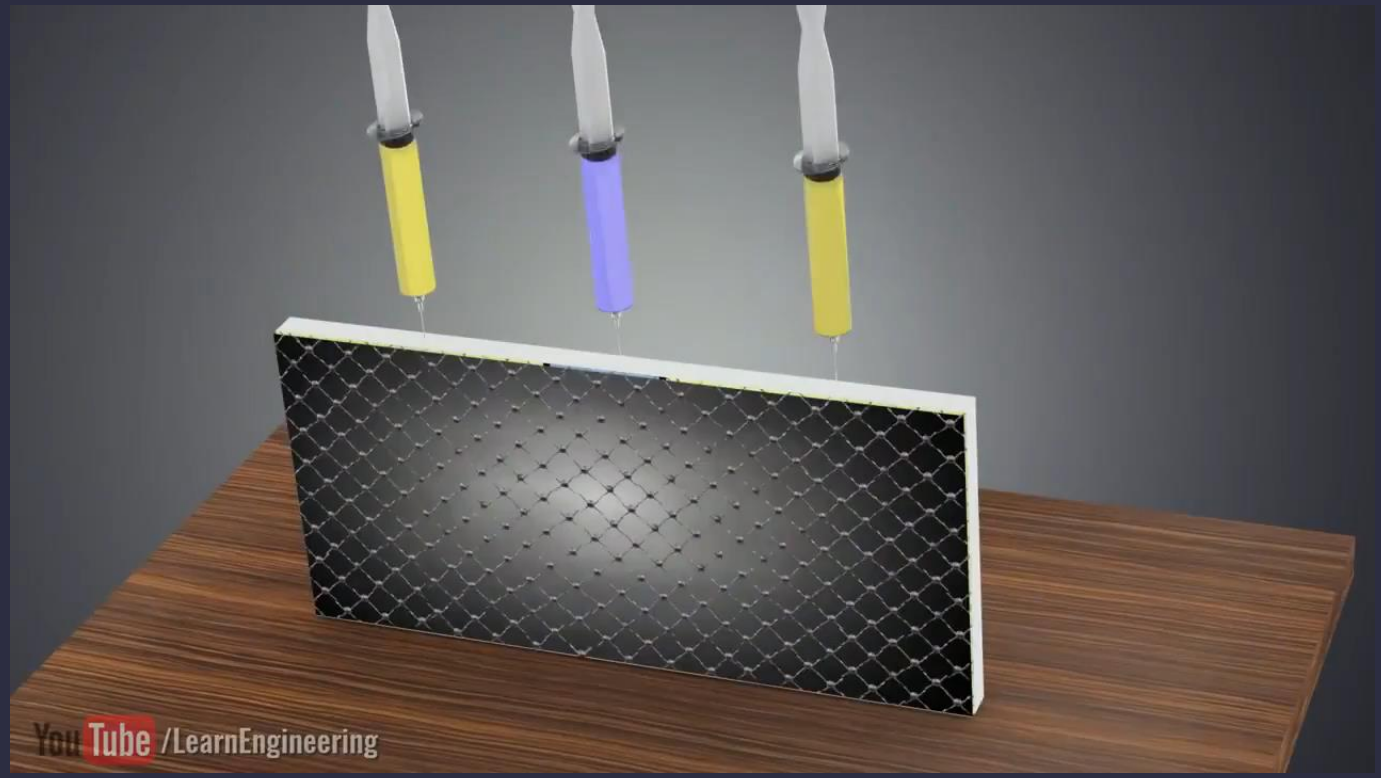
"Doping" technique, which is used to increase the conductivity of semiconductors, is applied.

P Type



Boron Atom

Transistor Doping Process

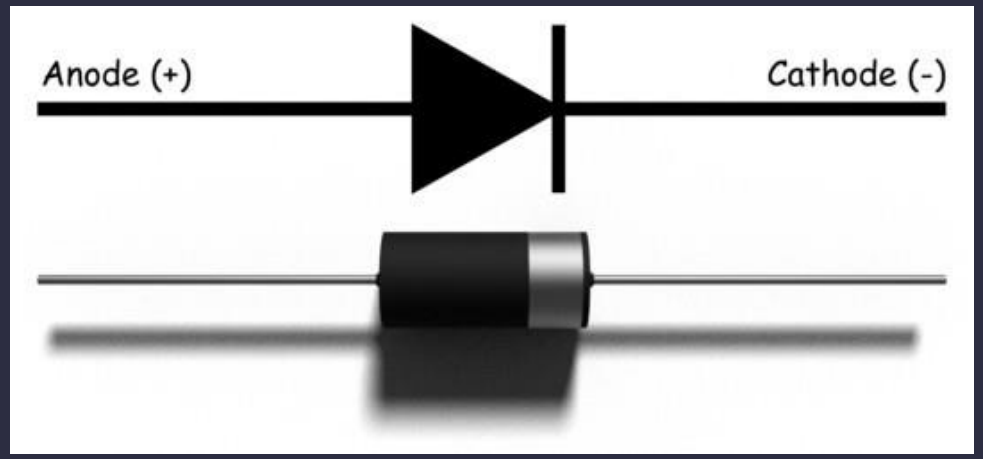


Structure of Transistor

NPN Transistor

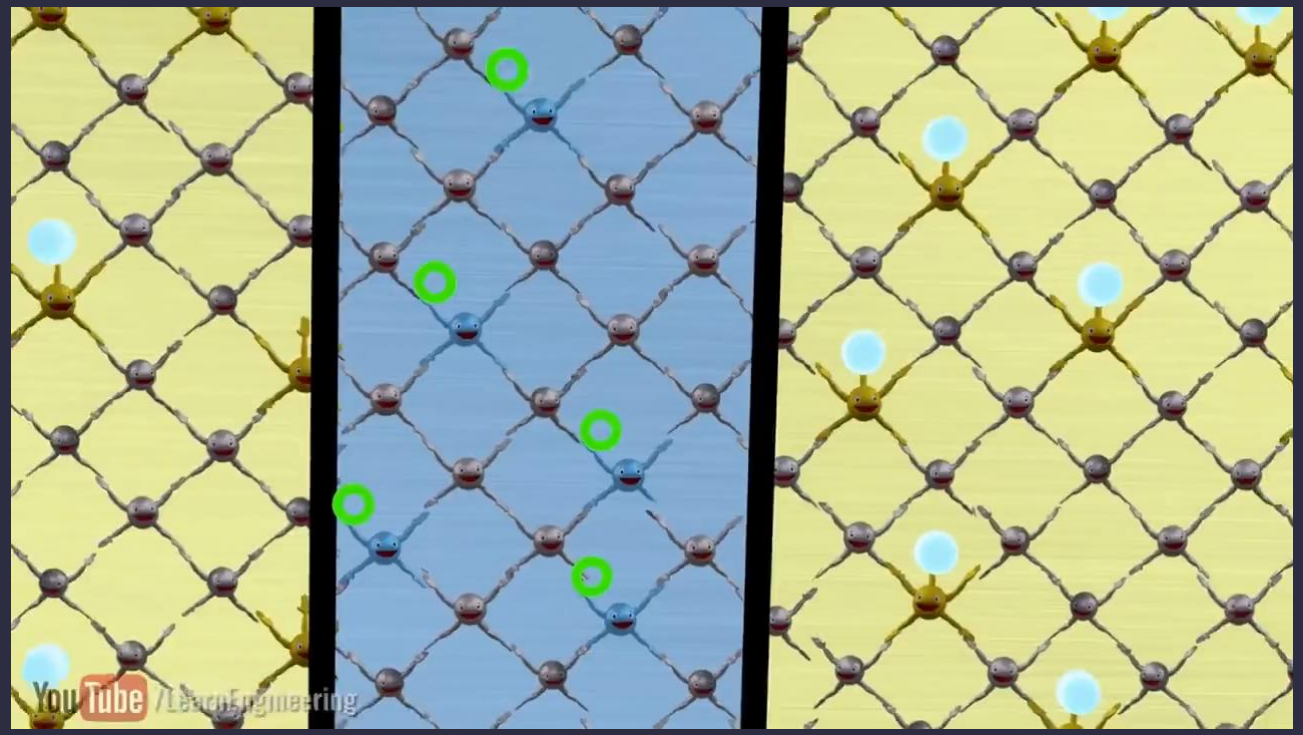
Transistor Doping Process

Diode Structure



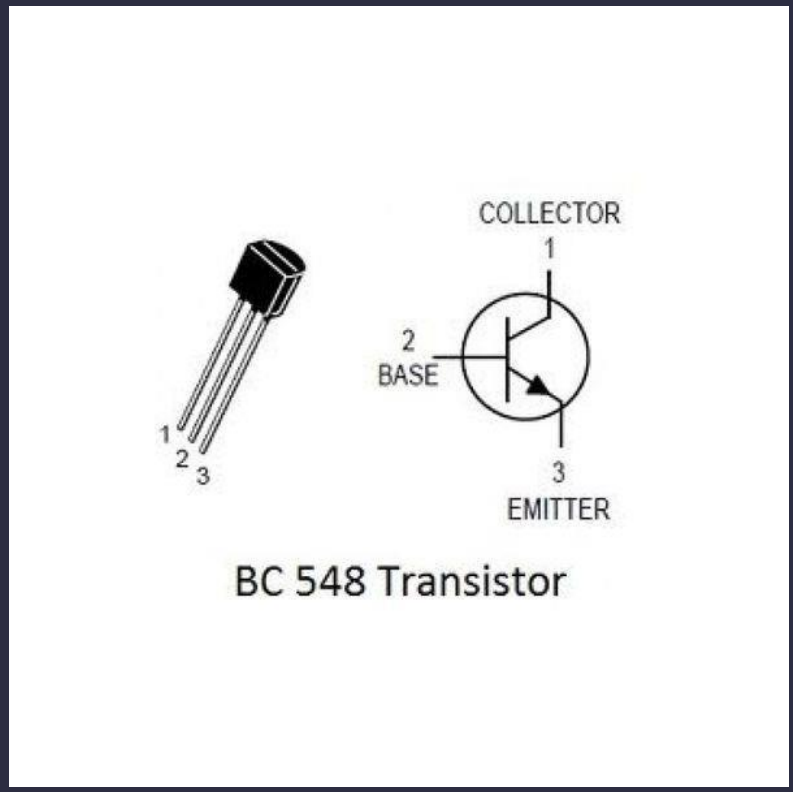
Diode

Transistor Doping Process



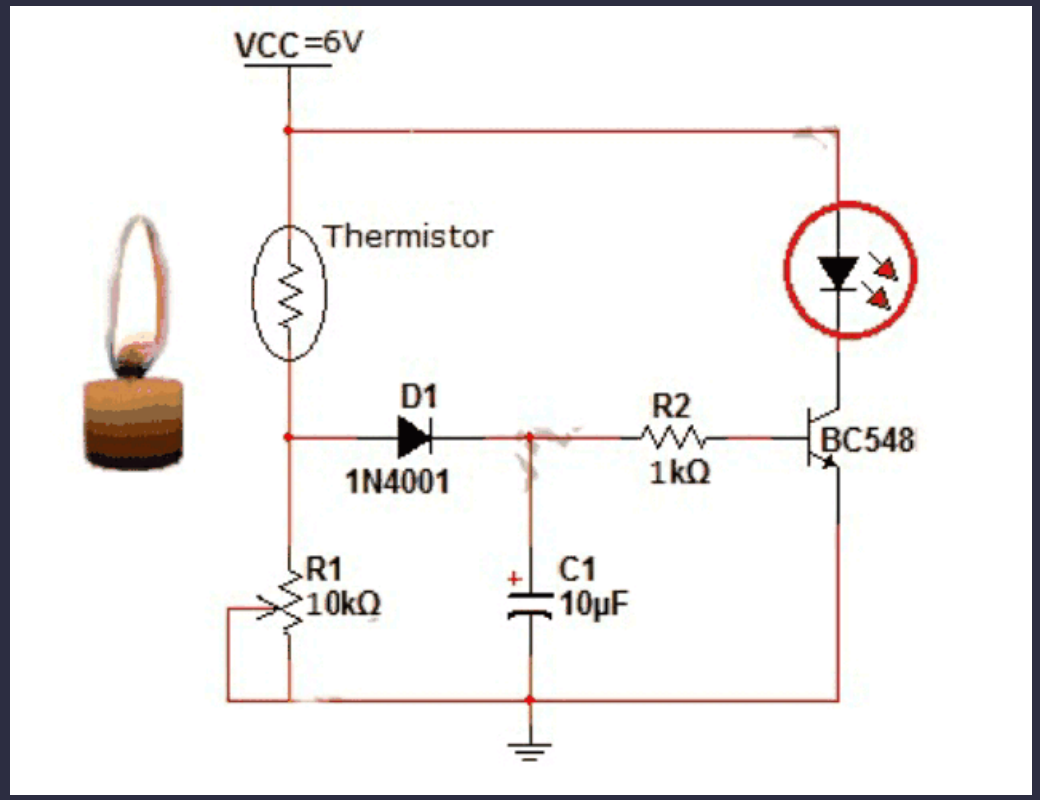
NPN Transistor

Electrons cannot advance unless voltage is applied to the base input.



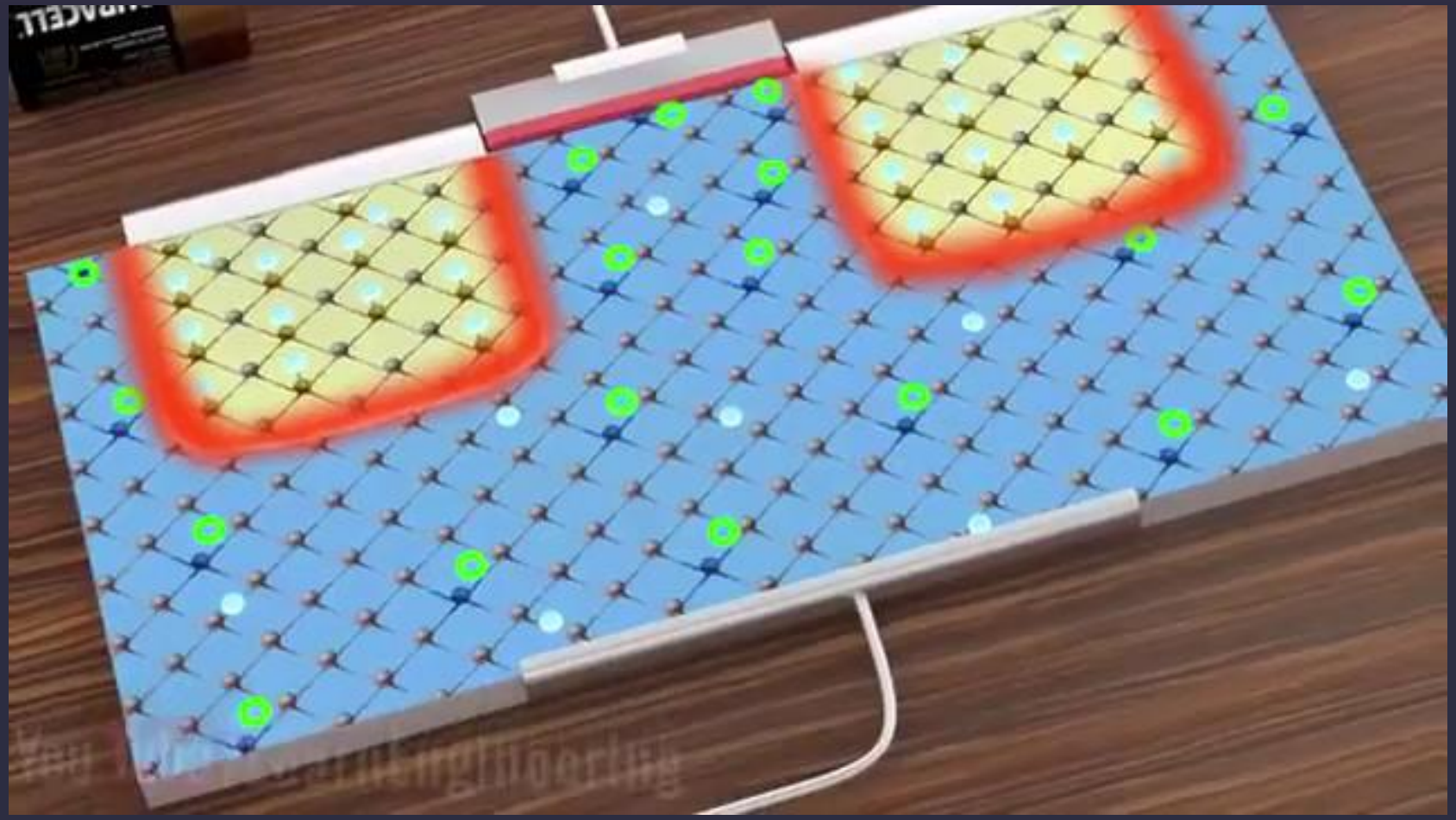
NPN Transistor

Transistor Doping Process



A Simple Fire Alarm Circuit with a Transistor

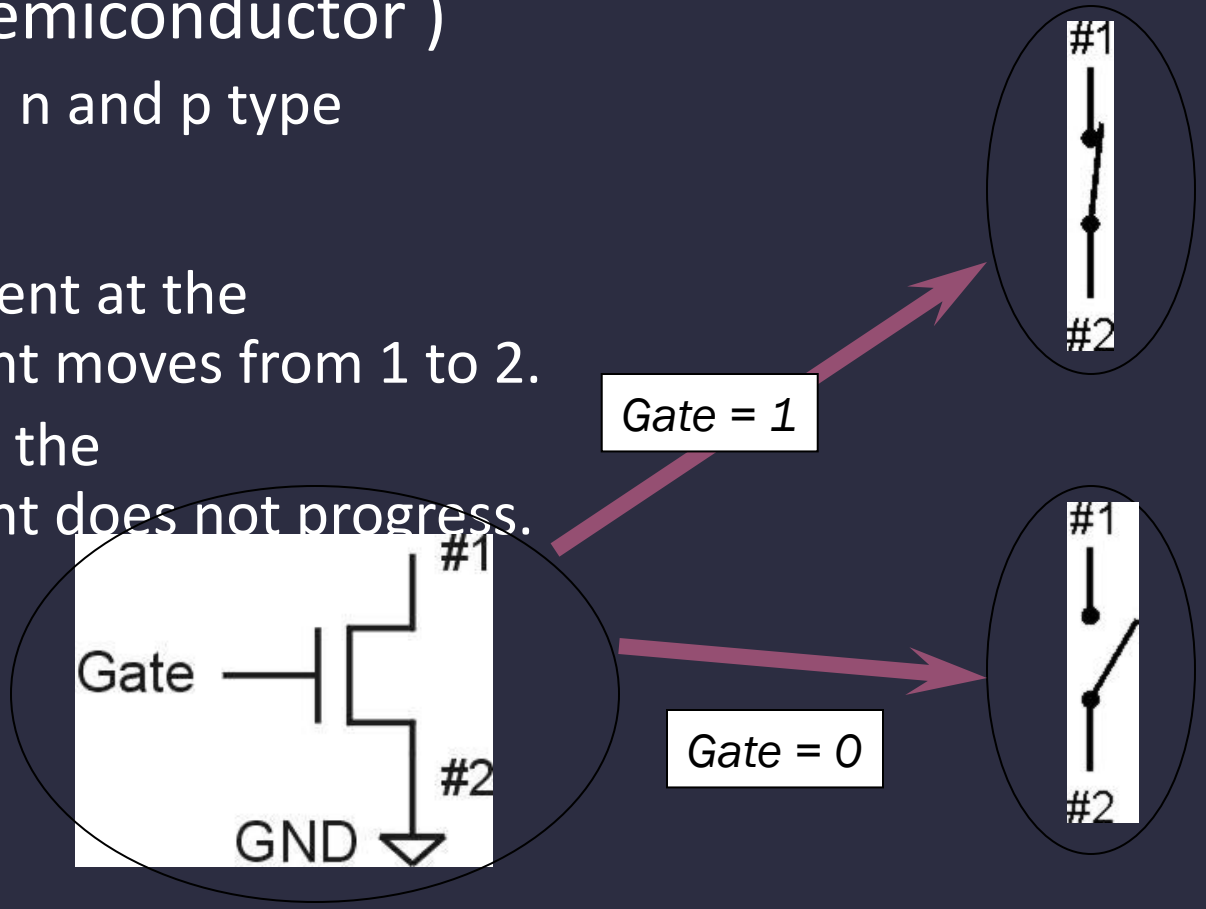
MOS Transistors , Also known as MOSFET (Metal Oxide Semi-conductor Field Effect Transistor)



MOSFETs

N Type MOS Transistors

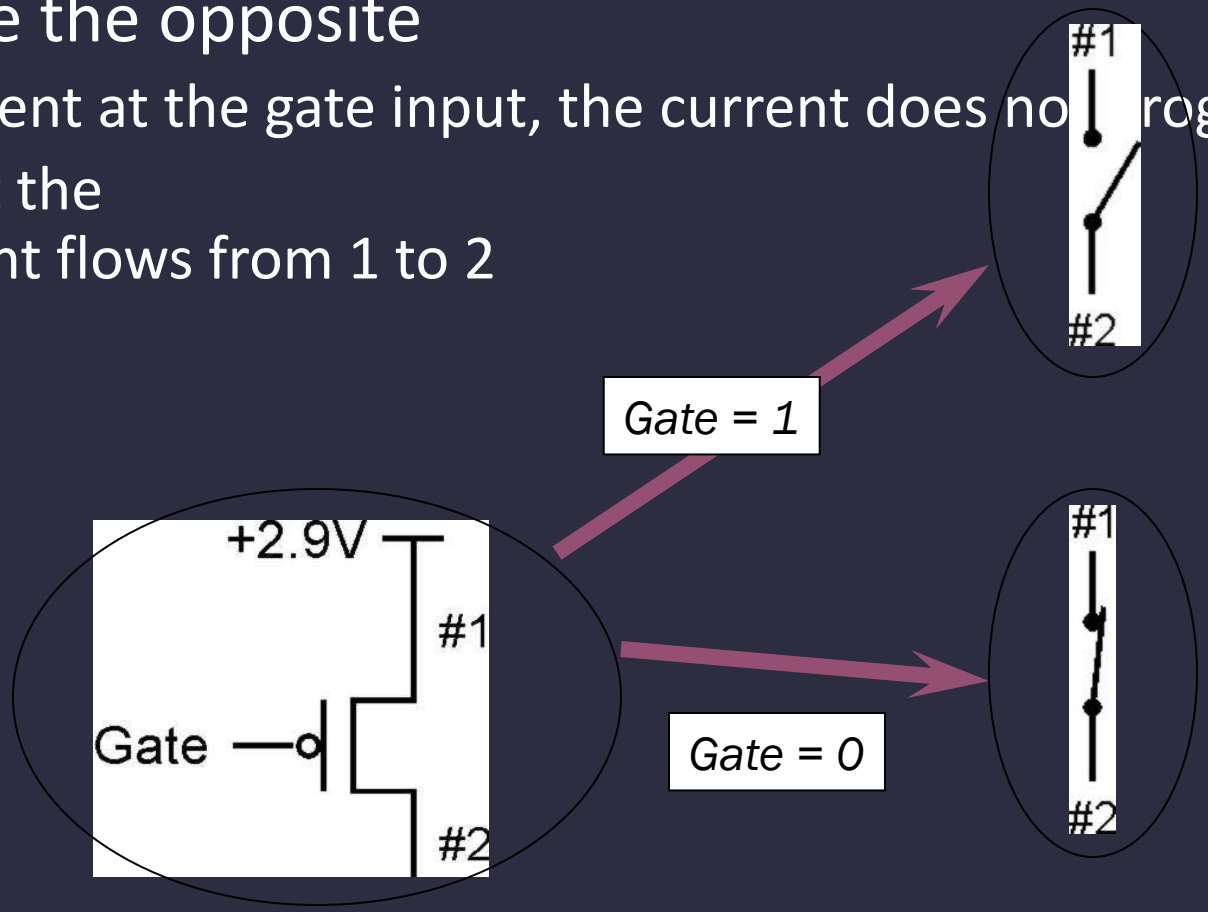
- MOS (Metal Oxide Semiconductor)
  - There are two types : n and p type
- N Type
  - When voltage is present at the gate input, the current moves from 1 to 2.
  - there is no voltage at the gate input, the current does not progress.



Terminal #2 must be connected to GND (0V).

P Type MOS Transistors

- P- type transistors are the opposite
  - When voltage is present at the gate input, the current does no rogress.
  - there is no voltage at the
    gate input, the current flows from 1 to 2



Logic Gates

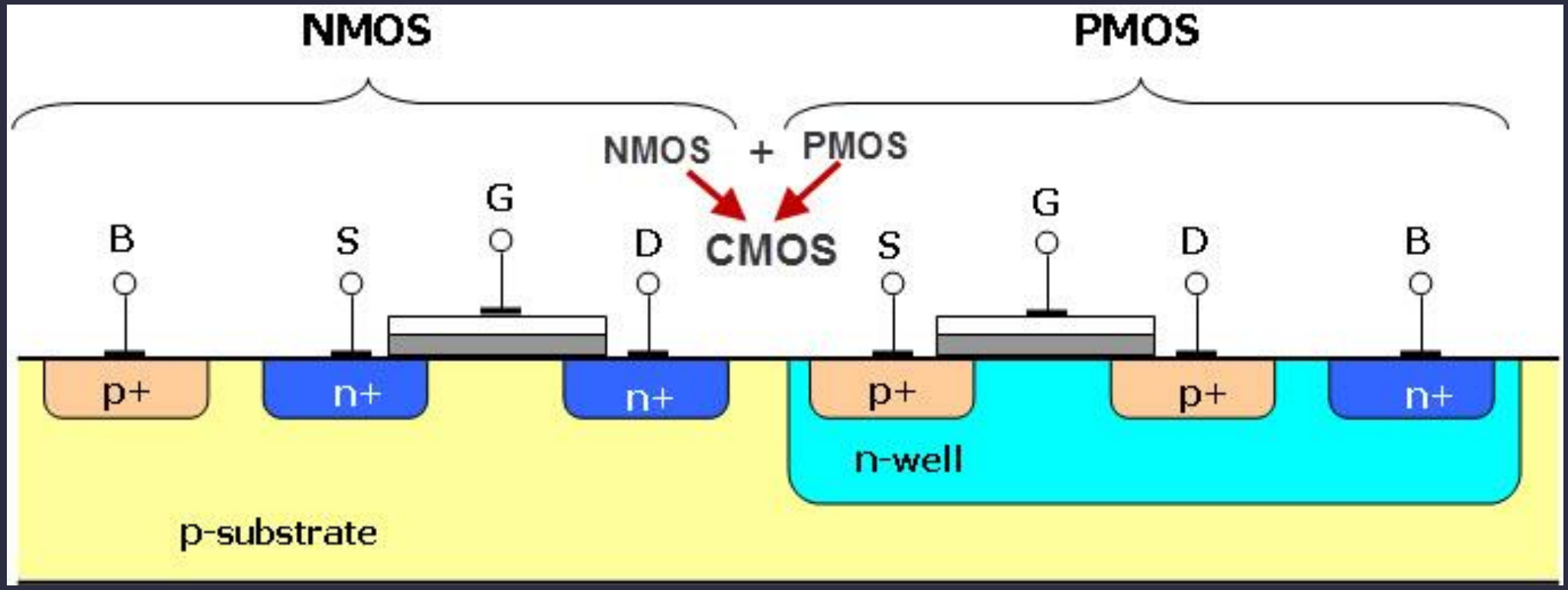
- Many logic gates can be implemented with MOSFETs . Examples of these are

- Digital Symbols :

  - A wide variety of voltage values are used in the electronics world.
    - Usually Yes – for 1 : +5V, +3.3V, +2.9V values
    - For None, 0V value is used.

CMOS (Complementary MOS) Circuit

- Both NMOS and PMOS transistors .

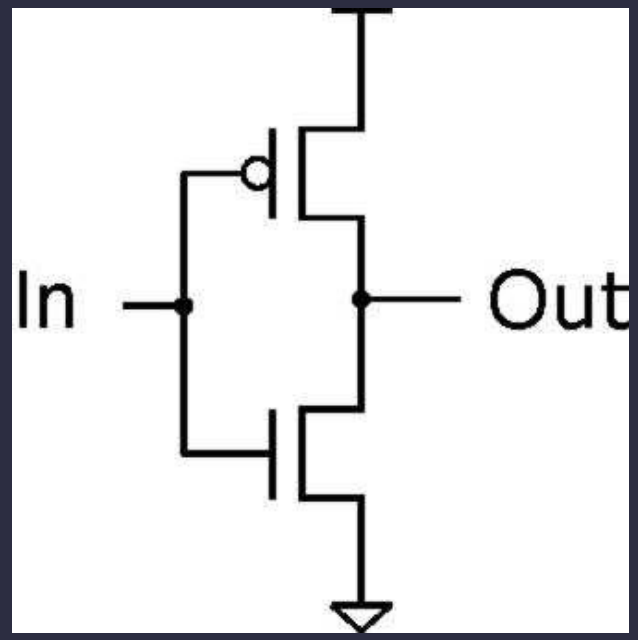


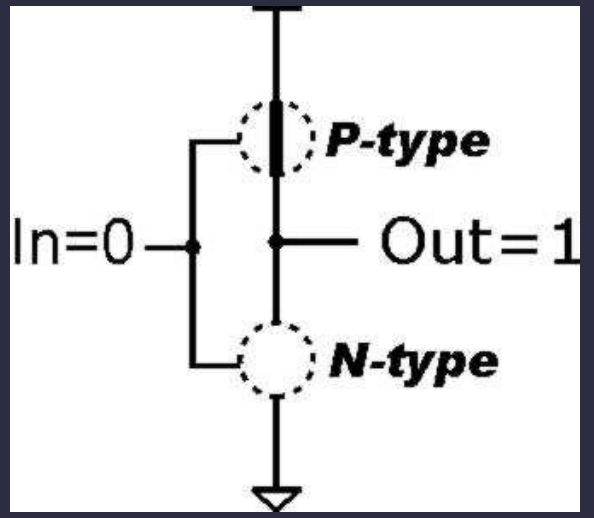
CMOS (Complementary MOS) Circuit

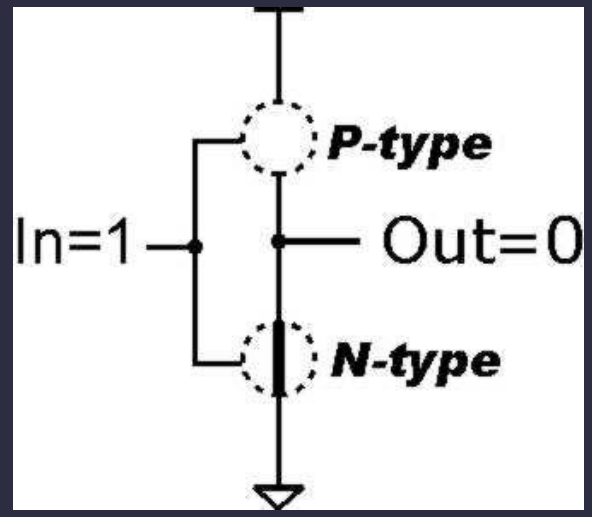
Has several advantages over NMOS and PMOS.

- Power consumption is low
- Circuit complexity is low
- It has high noise resistance

CMOS NOT Gate

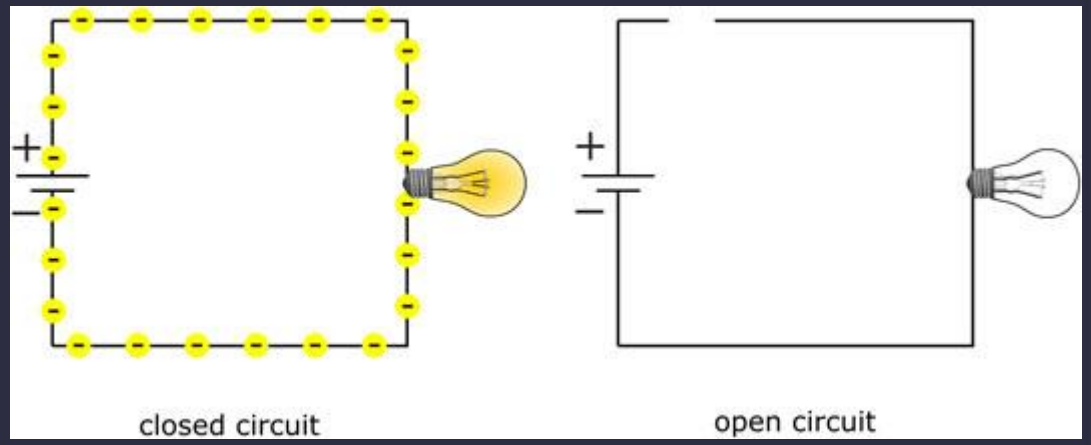




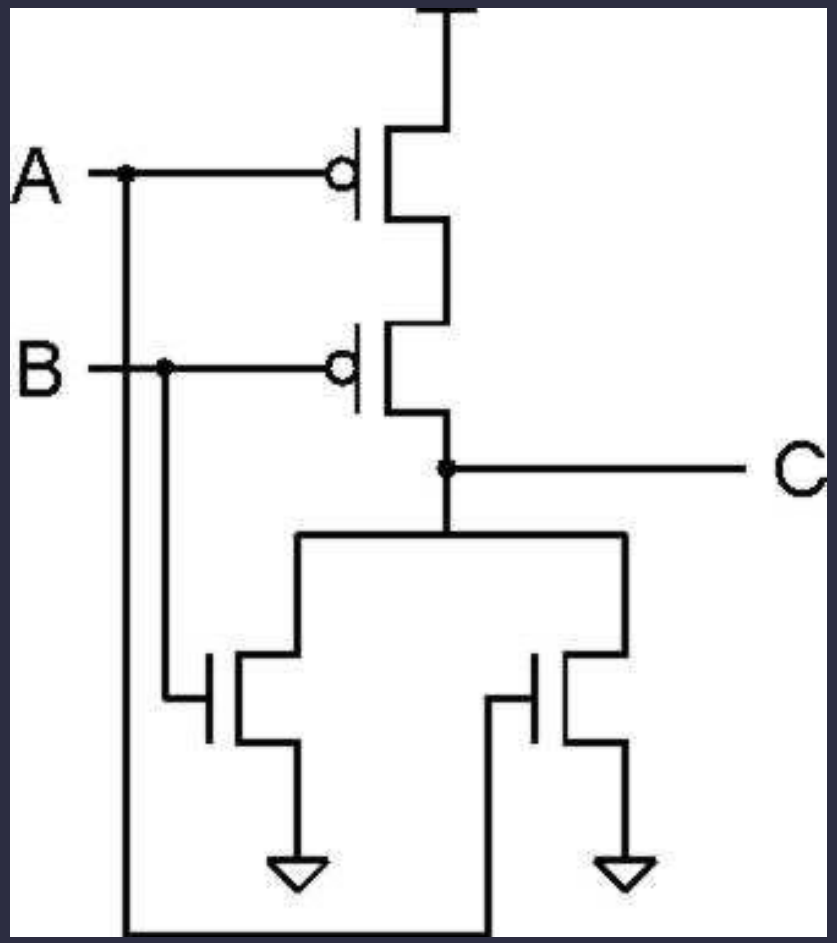


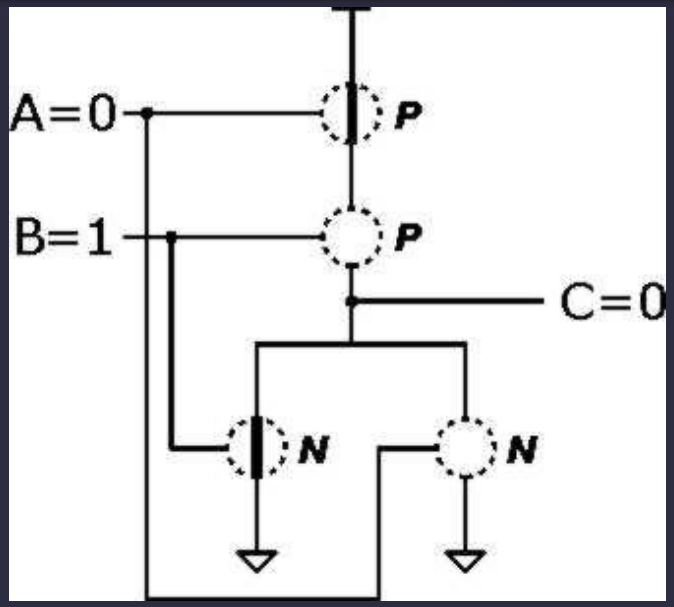
Truth Table

Logic	Out	Logic	Out
0V	2.9V	0	1
2.9V	0V	1	0



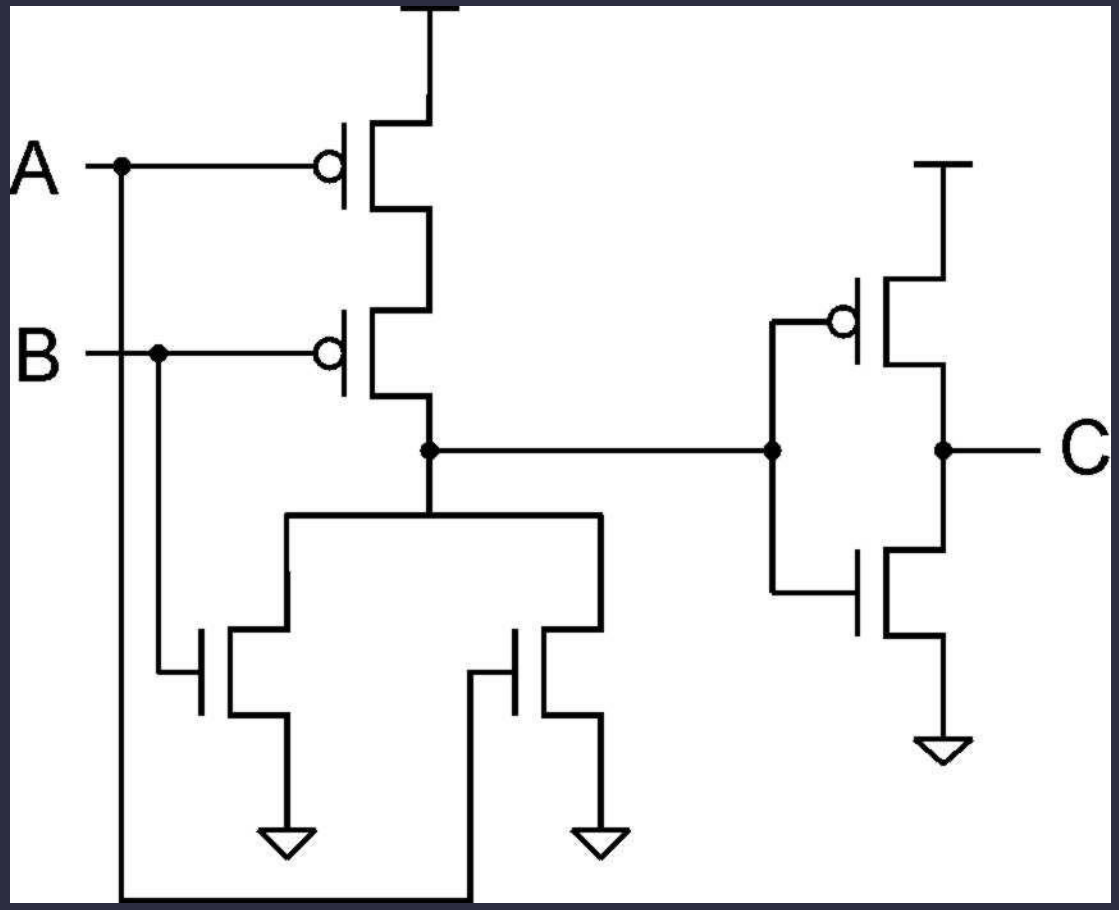
NOR gate





A	B	C
0	0	1
0	1	0
1	0	0
1	1	0

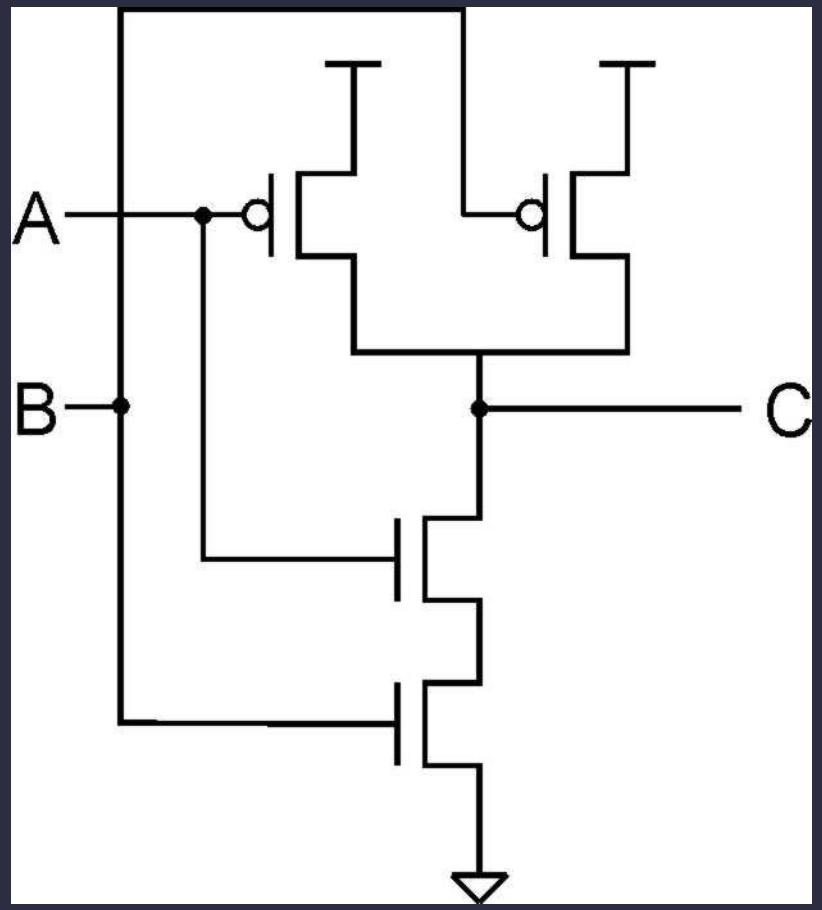
Or gate

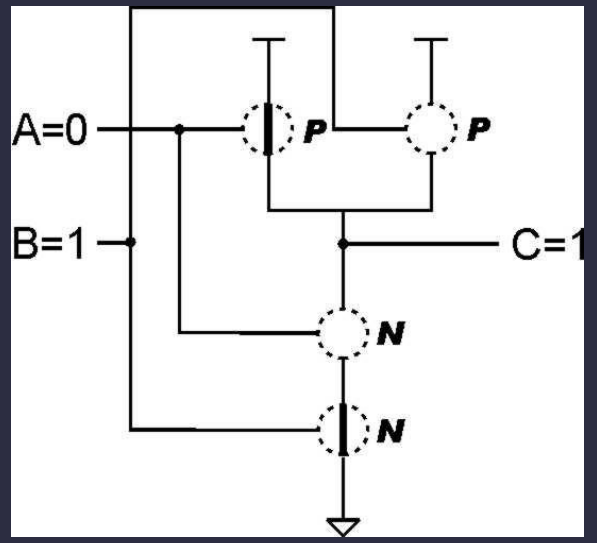


A	B	C
0	0	0
0	1	1
1	0	1
1	1	1

NOR gate but not gate added

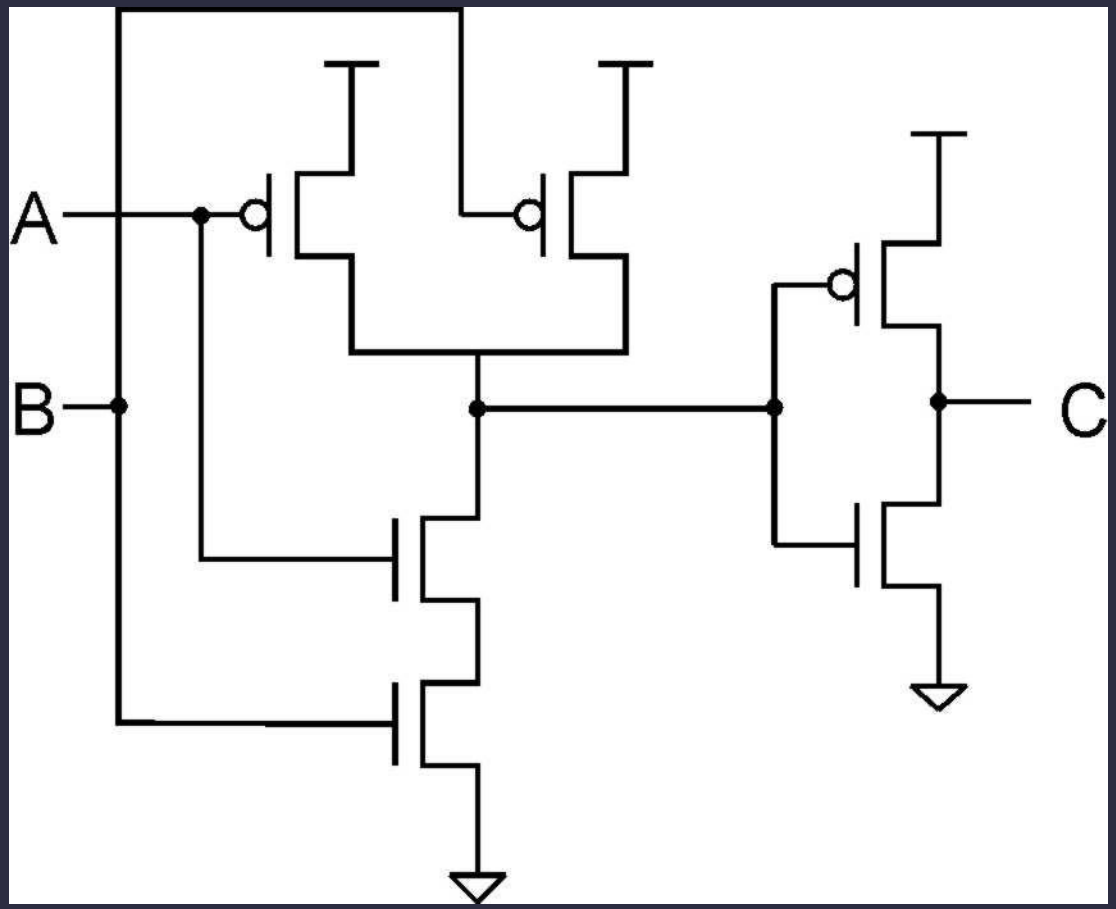
NAND gate





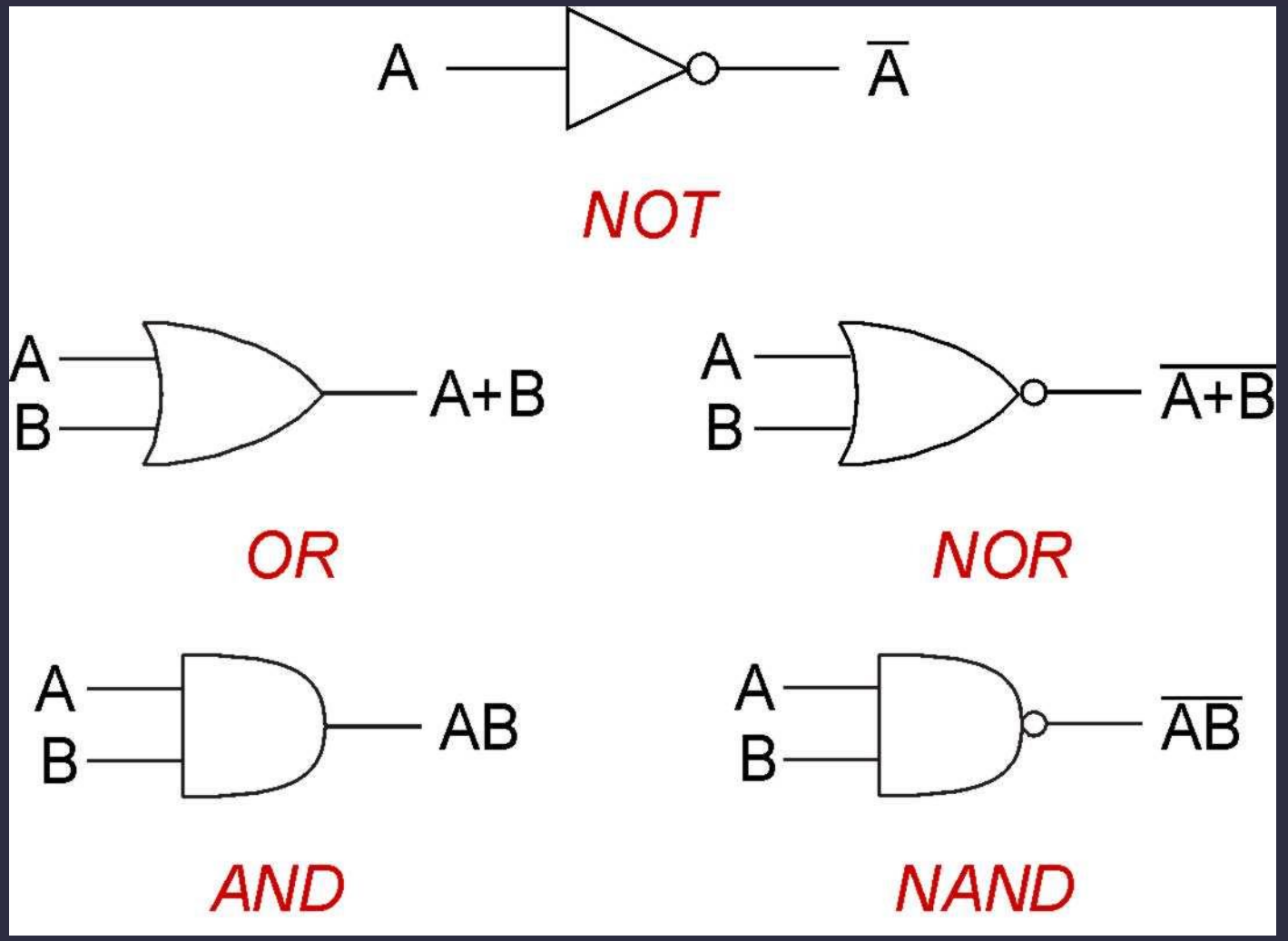
A	B	C
0	0	1
0	1	1
1	0	1
1	1	0

and (AND) gate



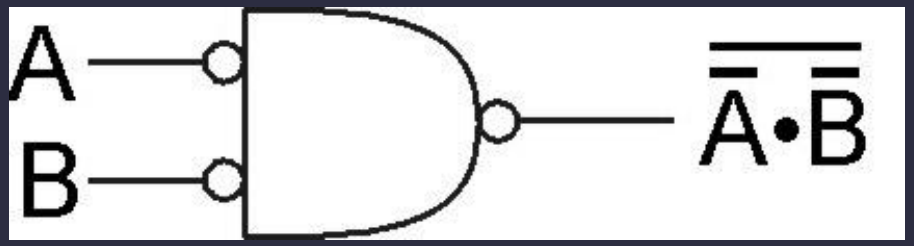
A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

Simple Logic Gates



DeMorgan's rule

- Allows conversion between And – Or gates



$$\overline{(xy)} = \overline{x} + \overline{y}$$

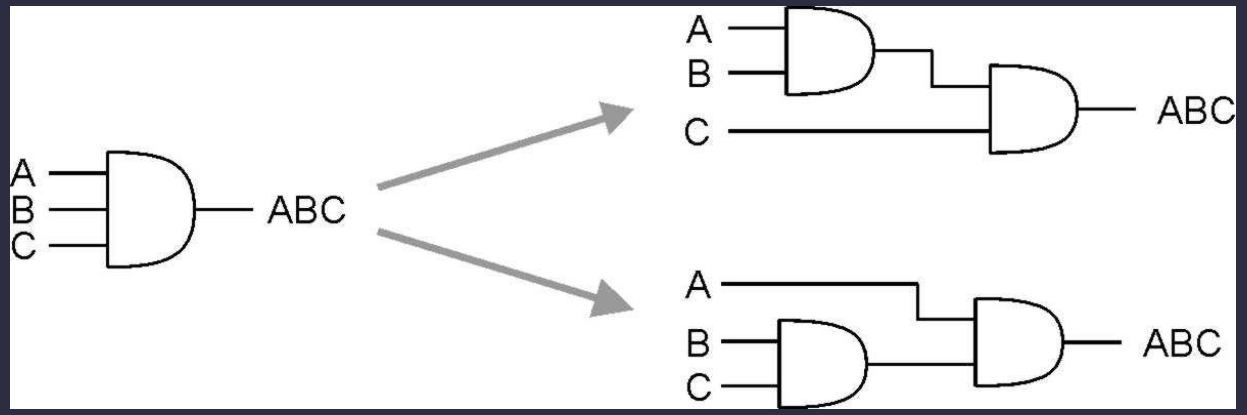
$$\overline{(x+y)} = \overline{x}\,\overline{y}$$

A	B	$\overline{A}$	$\overline{B}$	$\overline{A} \cdot \overline{B}$	$\overline{\overline{A} \cdot \overline{B}}$
0	0	1	1	1	0
0	1	1	0	0	1
1	0	0	1	0	1
1	1	0	0	0	1

Situations With More Than Two Inputs – Complex Doors

- And/or operations can take multiple inputs.
  - And which infers 1 when all inputs are 1
  - Or which infers 1 when any input is 1

- Two-input gates or with a single cmos circuit can be used.



Source Videos

You can access the source videos from the addresses below.

Transistor
https://www.youtube.com/watch?v=7ukDKVHnac4

What is MOSFET?
https://www.youtube.com/watch?v=stM8dgcY1CA