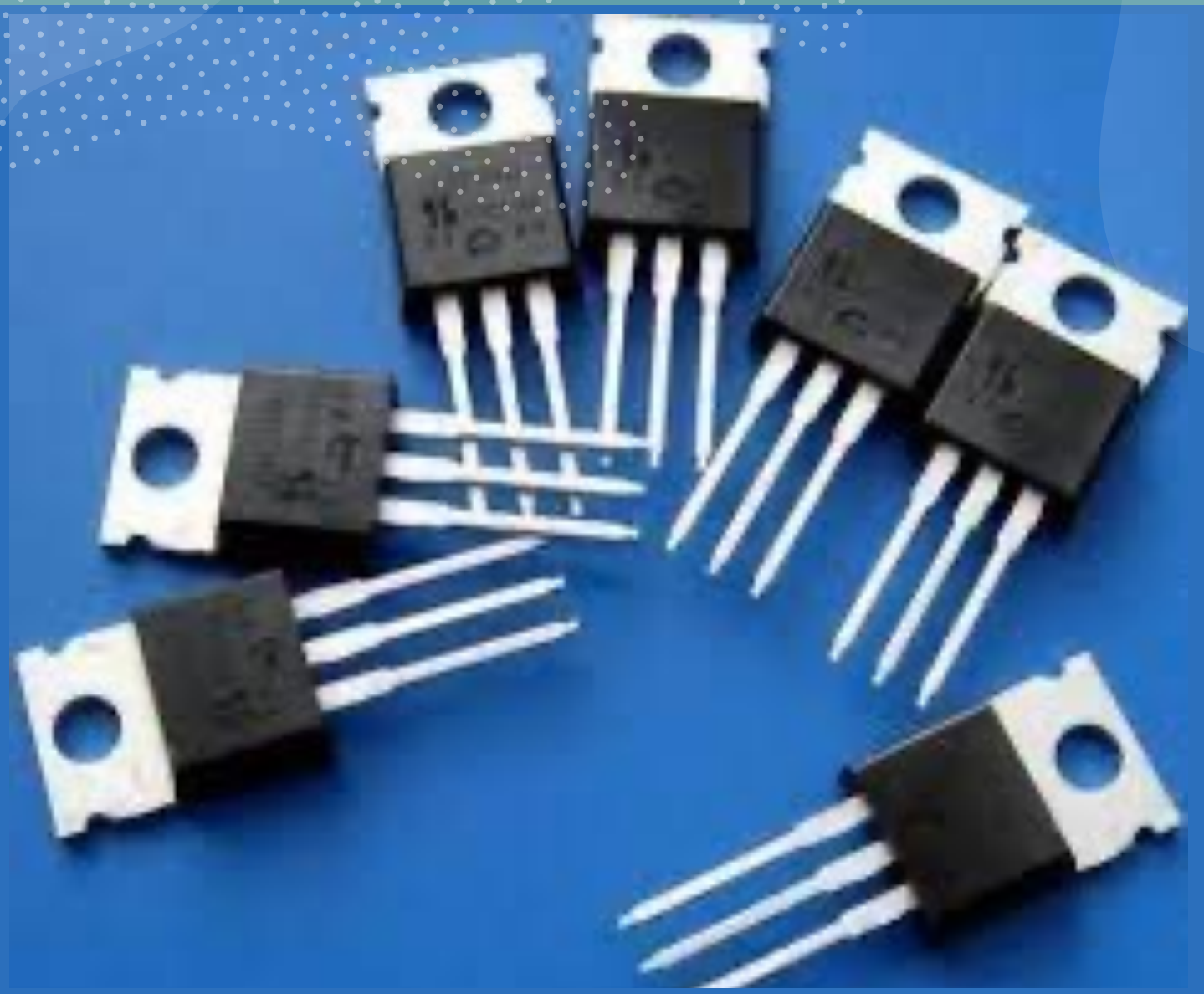
Chapter Two

COMS Logic Circuits

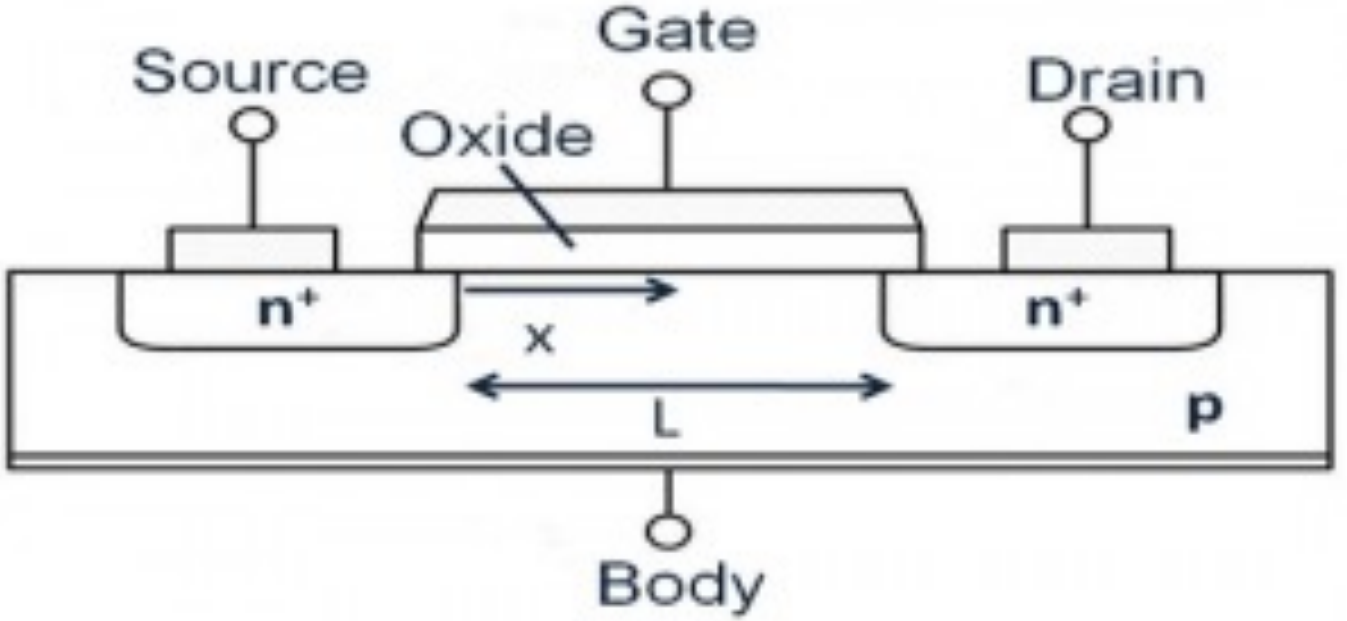


Metal Oxide Semiconductor Field Effect Transistor (MOSFET)

The MOSFET (Metal Oxide Semiconductor Field Effect Transistor) transistor is a semiconductor device that is widely used for switching purposes and for the amplification of electronic signals in electronic devices.

A MOSFET is a four-terminal device having source(S), gate (G), drain (D) and body (B) terminals. In general, The body of the MOSFET is in connection with the source terminal thus forming a three-terminal device such as a field-effect transistor

MOSFET structure

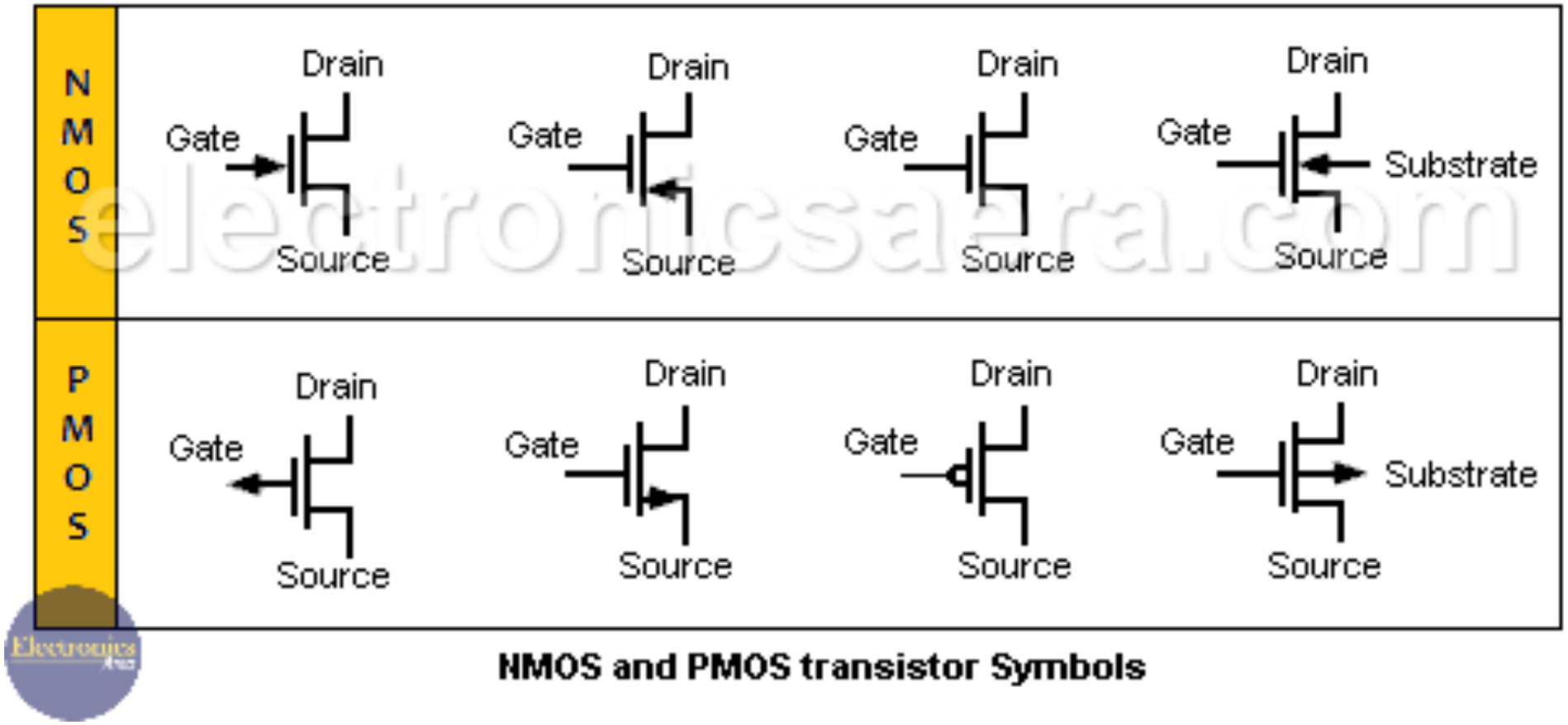


A MOSFET can function in two ways

Depletion Mode

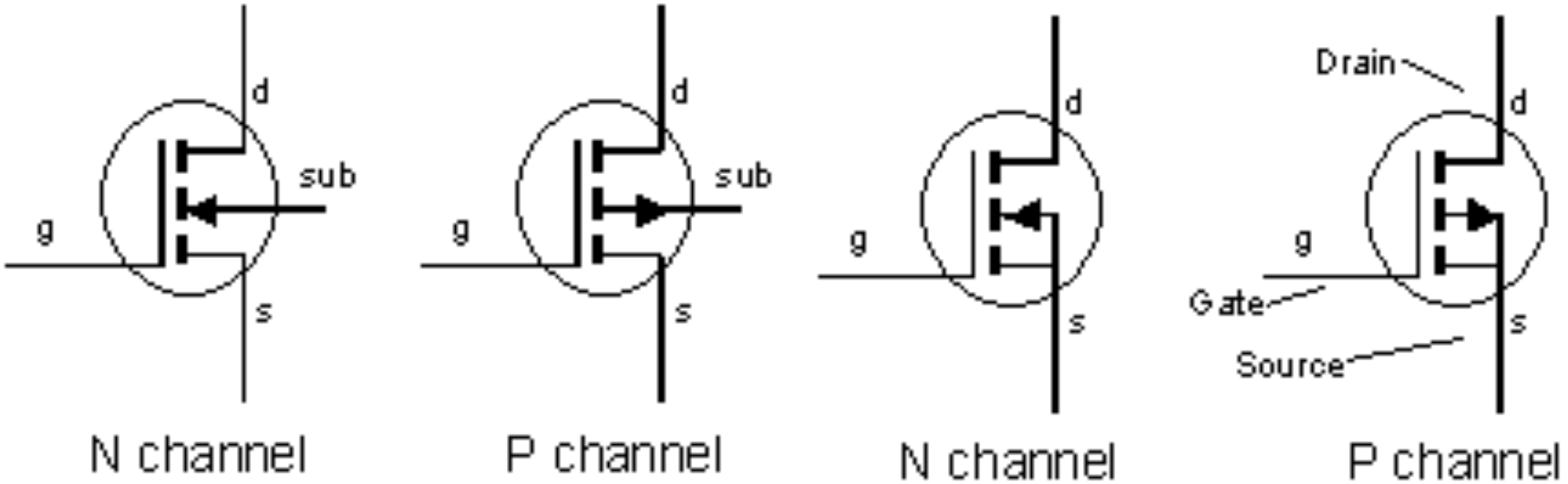
Enhancement Mode

Depletion Mode



NMOS and PMOS transistor Symbols

Enhancement Mode



PMOS and NMOS Transistors

Microprocessors are built of transistors. In particular, they are constructed out of MOS transistors. MOS is an acronym for (Metal-Oxide Semiconductor).

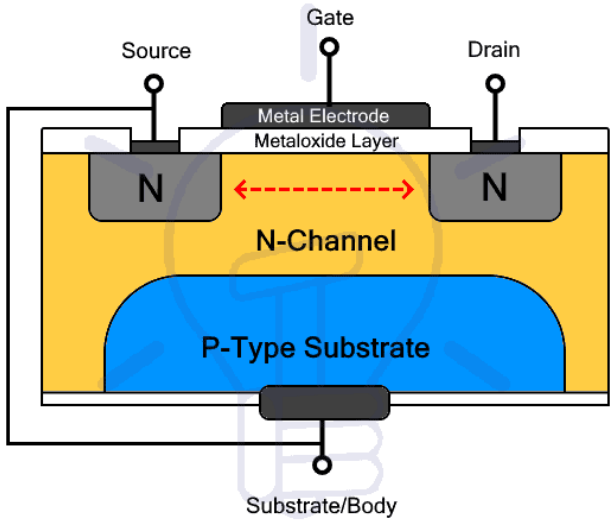
There are two types of MOS transistors:

- **NMOS (negative-MOS).**
- **PMOS (positive-MOS).**

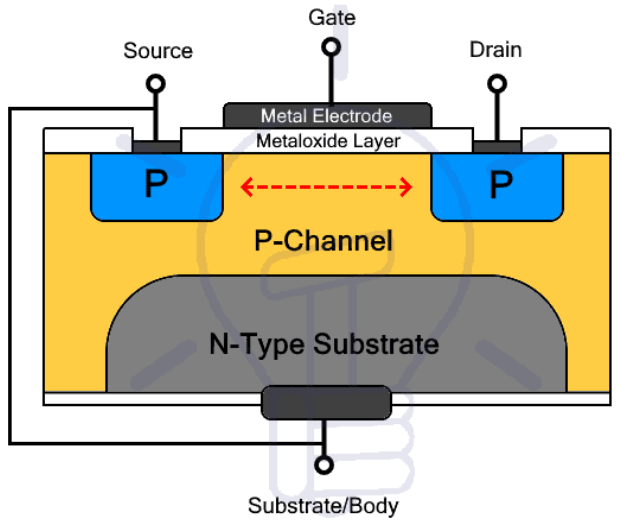
Every PMOS and NMOS comes equipped with three main components:

- **Gate**
- **Source**
- **Drain.**

D-MOSFET

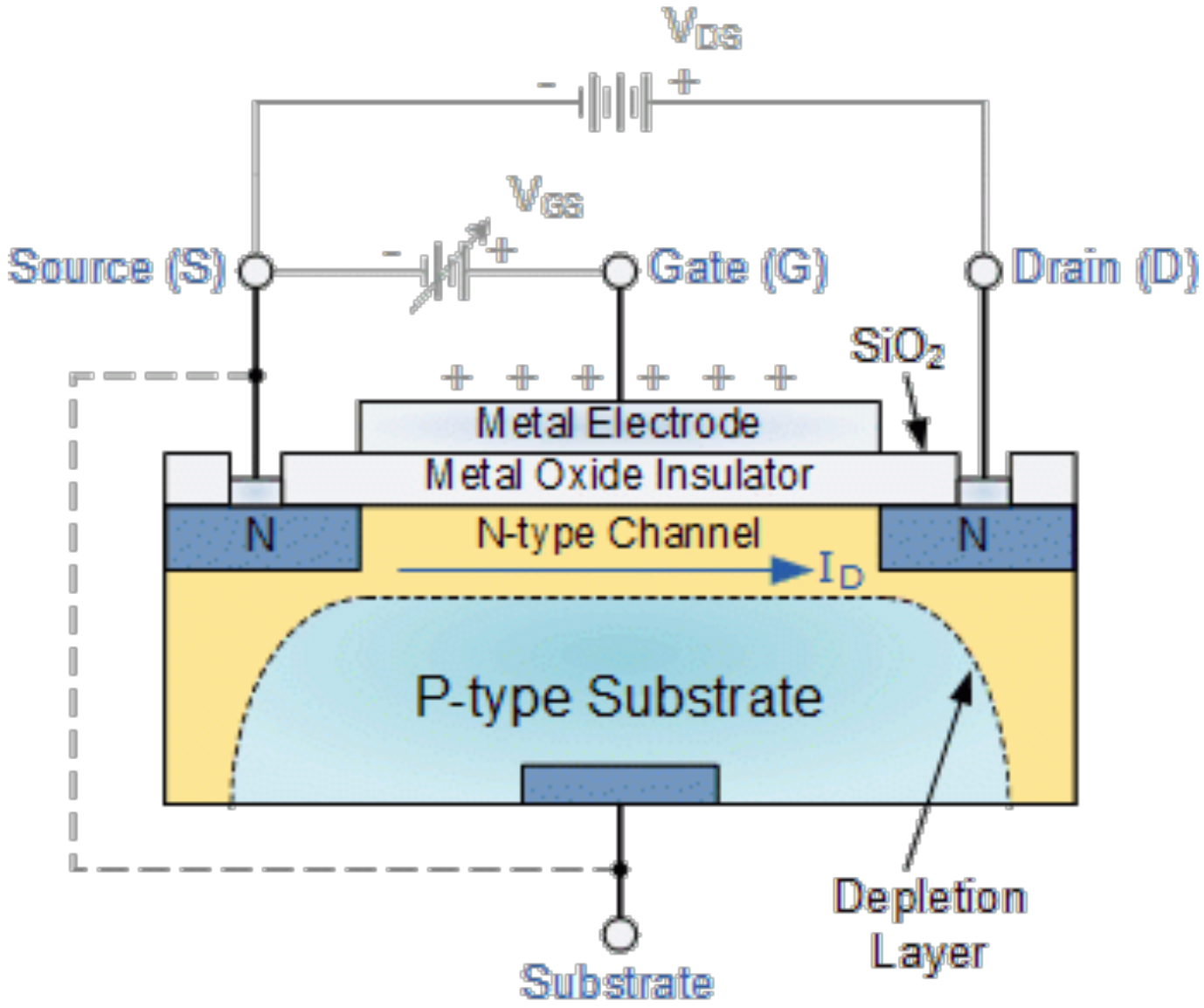


N-Channel D-MOSFET

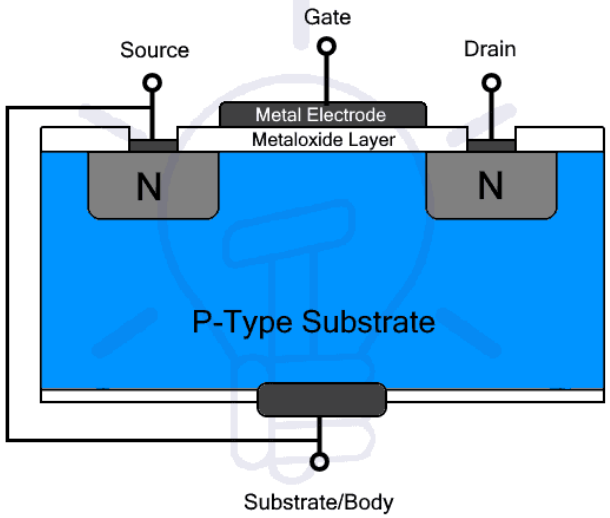


P-Channel D-MOSFET

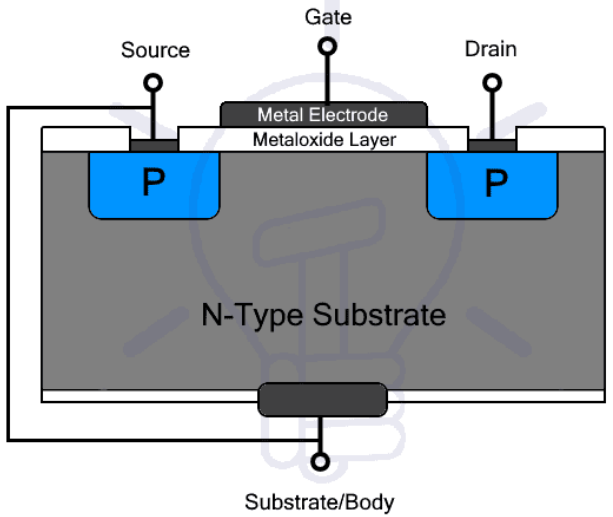
NMOS


V_{DS}
V_{GS}
Source (S)
Gate (G)
Drain (D)
SiO_2
Metal Electrode
Metal Oxide Insulator
N
N-type Channel
N
I_D
P-type Substrate
Substrate
Depletion Layer

E- MOSFET

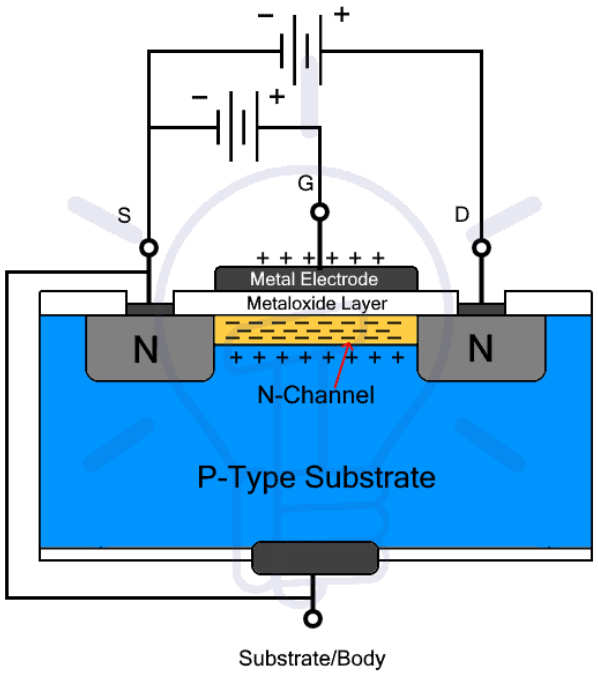


N-Channel E-MOSFET

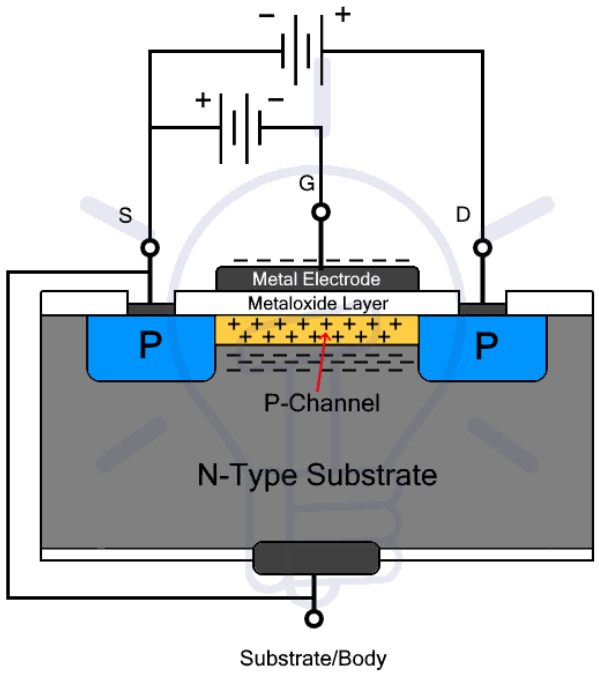


P-Channel E-MOSFET

E- MOSFET



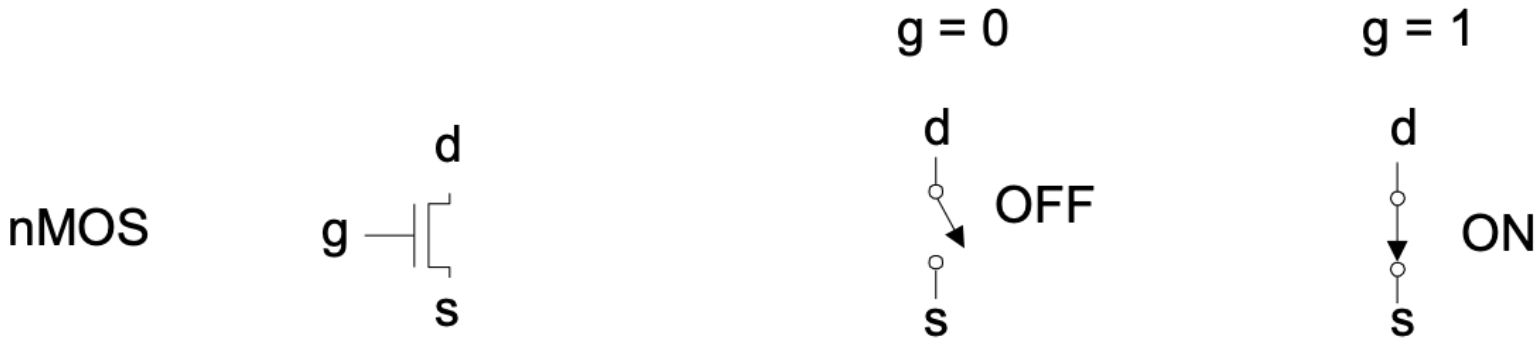
Channel Induced in N-Channel E-MOSFET



Channel Induced in P-Channel E-MOSFET

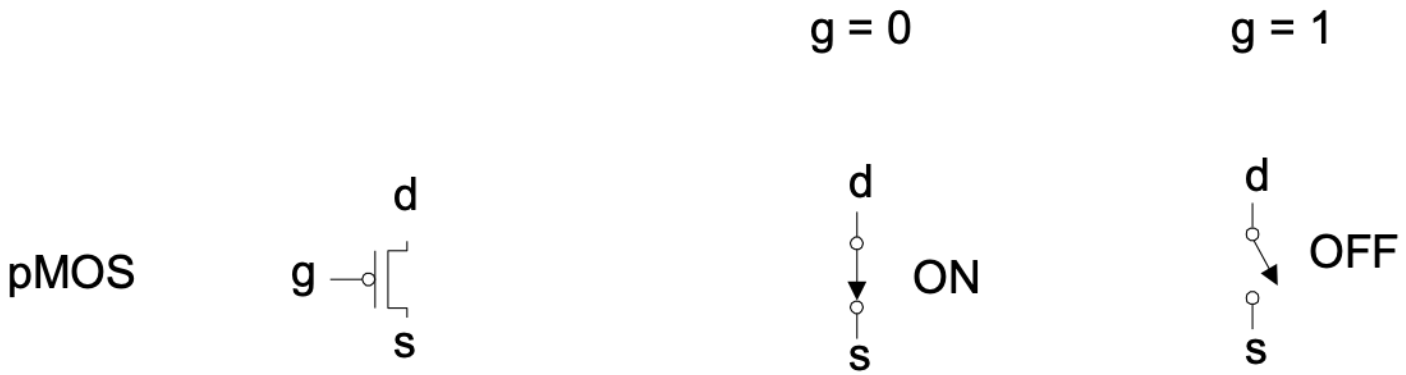
N-MOS as a switch

A N-type MOSFET can be modeled as a switch that is closed when the input voltage is high (5 V) and open when the input voltage is low (0 V)



P-MOS as a switch

A P-type MOSFET can be modeled as a switch that is closed when the input voltage is low (0 V) and open when the input voltage is high (5 V)



Complementary Metal Oxide Semiconductor (CMOS)

The term CMOS stands for “Complementary Metal Oxide Semiconductor”. This is one of the most popular technology in the computer chip design industry and it is broadly used today to form integrated circuits in numerous and varied applications.

Today’s computer memories, CPUs, and cell phones make use of this technology due to several key advantages. This technology makes use of both P channel and N channel semiconductor devices

CMOS Working Principle

In CMOS technology, both N-type and P-type transistors are used to design logic functions. The same signal which turns ON a transistor of one type is used to turn OFF a transistor of the other type.

Pull up and Pull-Down Networks

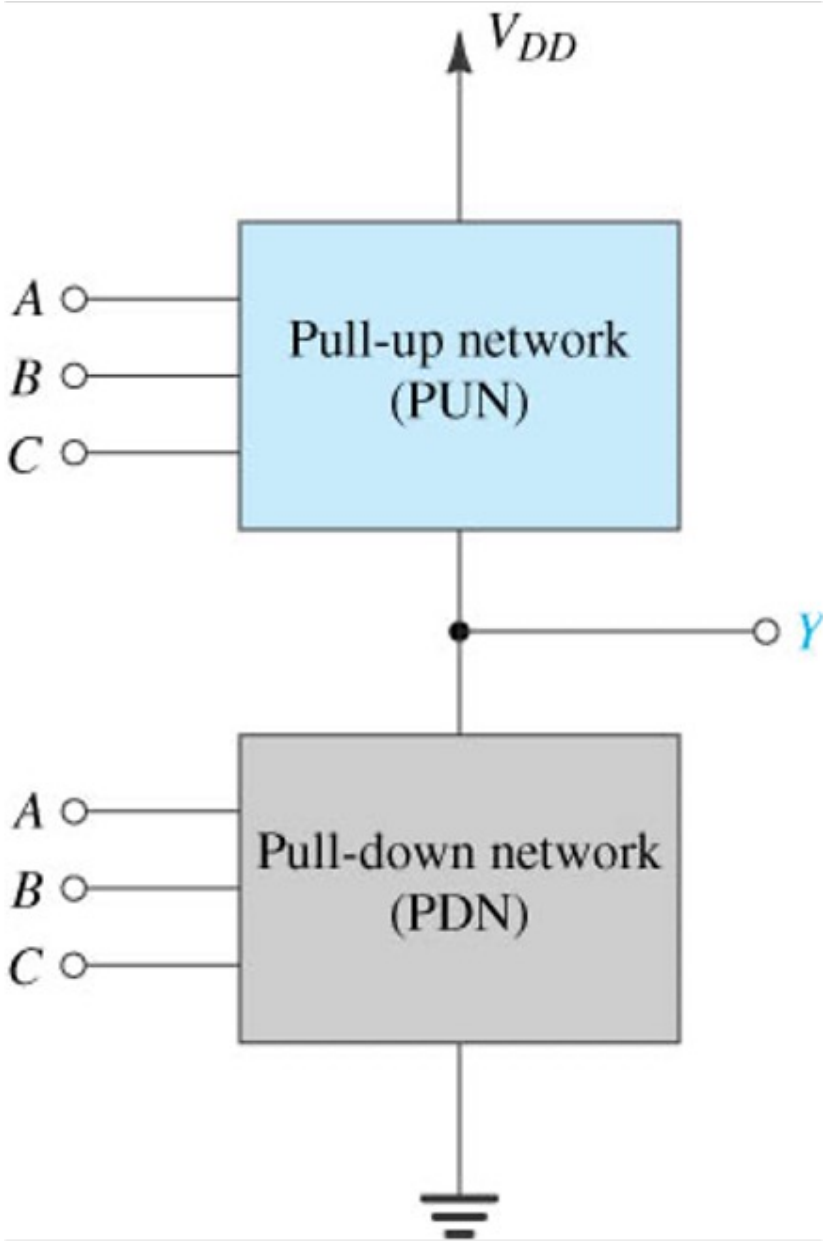
A complementary MOS gate is a combination of two networks the Pull Up Network **(PUN)** and the Pull-Down Network **(PDN).** Figure below shows the 'N' input logic gate where all inputs are distributed to both the PUN and PDN.

The function of **PUN** is to provide a connection between VDD and Vout to pull Vout to logic '1' whereas the function of **PDN** is to provide connection between GND and Vout to pull Vout to logic '0'.

The PUN and PDN are complementary to each other

Normally the PDN is consisting of NMOS devices whereas PUN is consisting of PMOS devices

CMOS Logic Gates



Baisce Rules

Baiscally there are two main oprations

- ❖ AND Oparation (.)
- ❖ OR Oparation (+)

AND Oparatiopn (.)

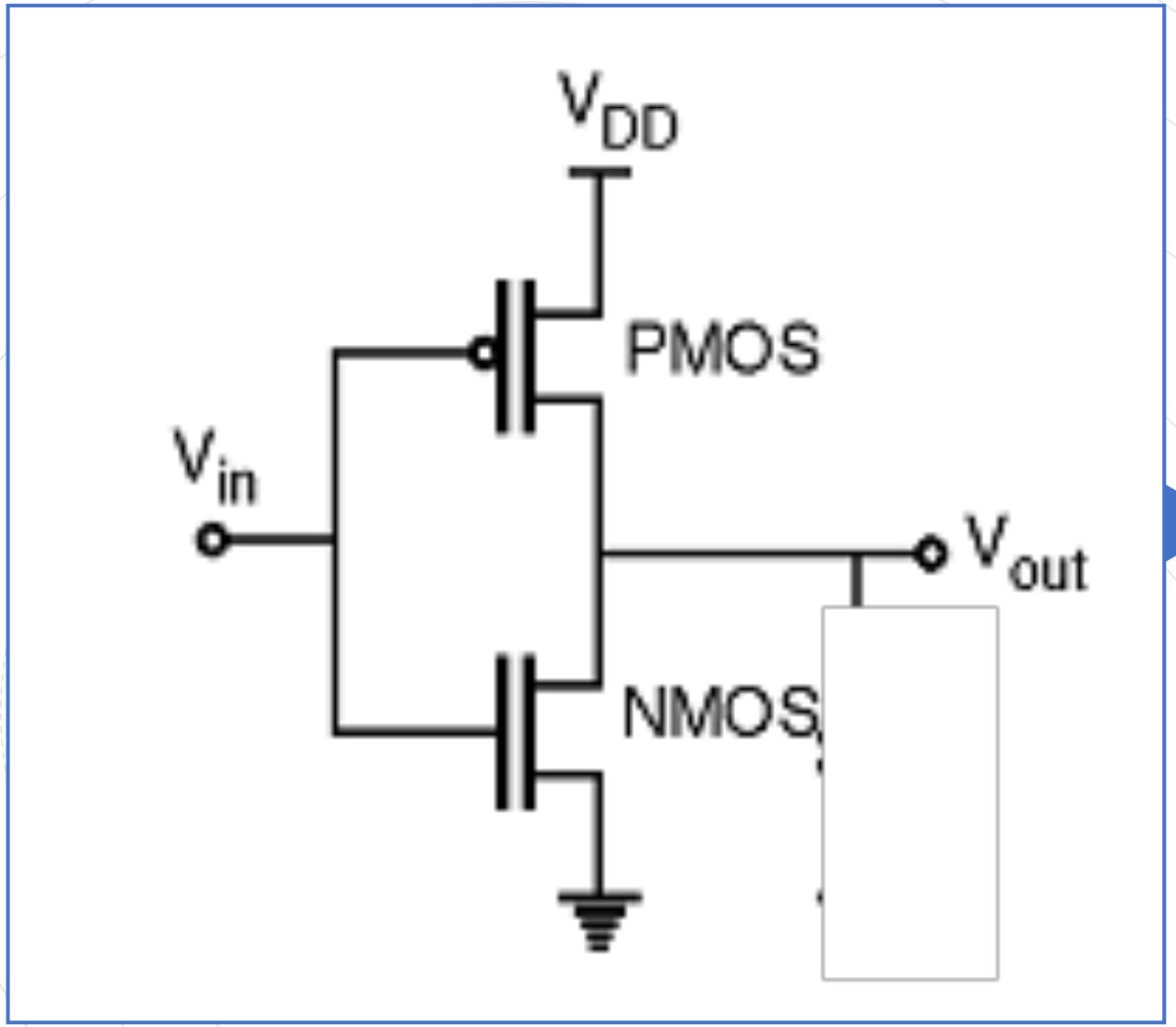
PMOS --------- Parallel

NMOS ---------Series

OR Oparation (+)

PMOS ---------- Series

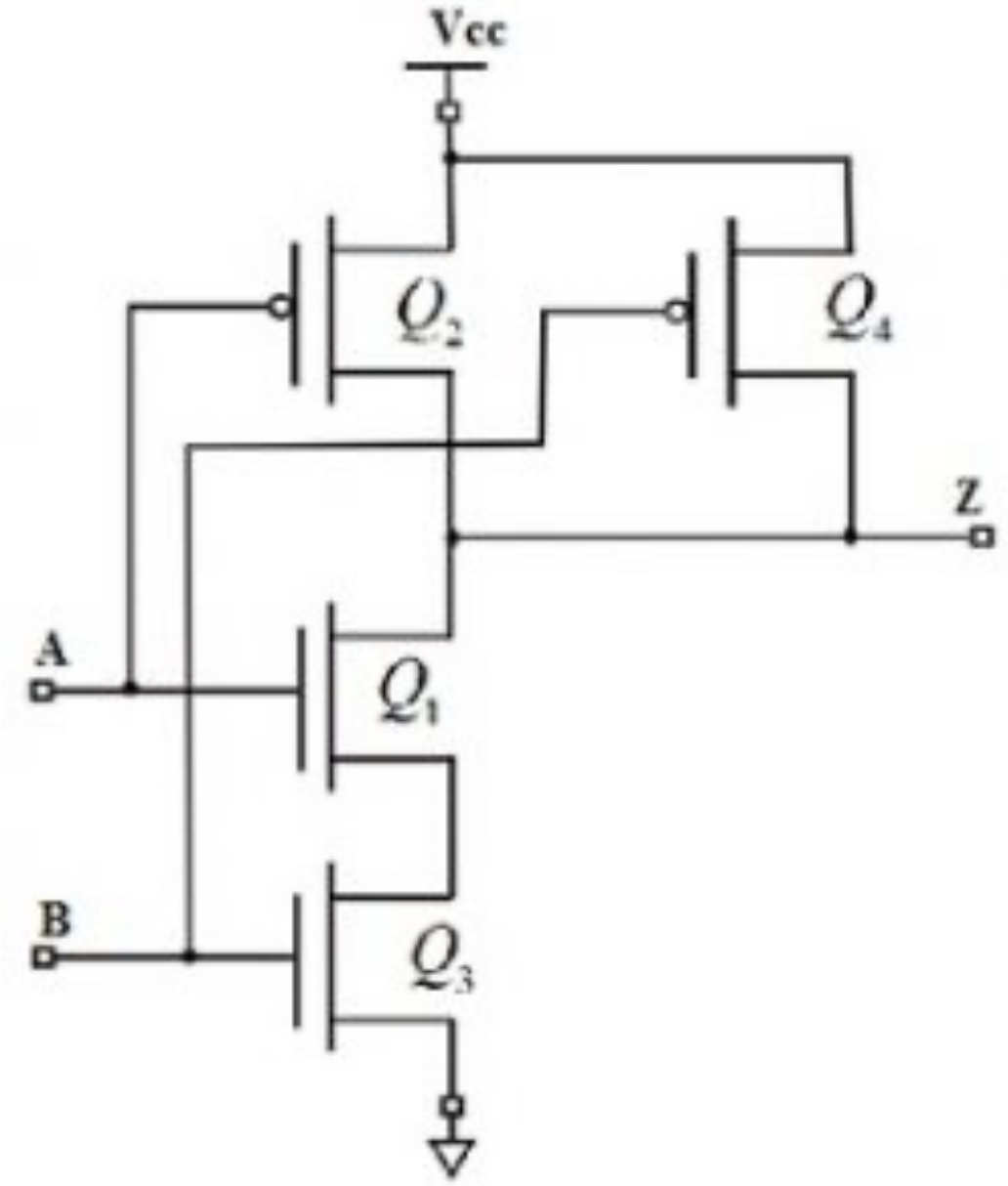
NMOS ---------- Parallel



CMOS Logic Gates

CMOS inverter

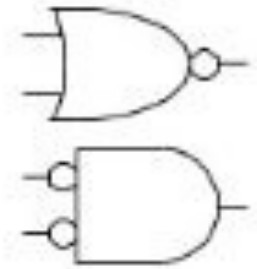
CMOS NAND Gate

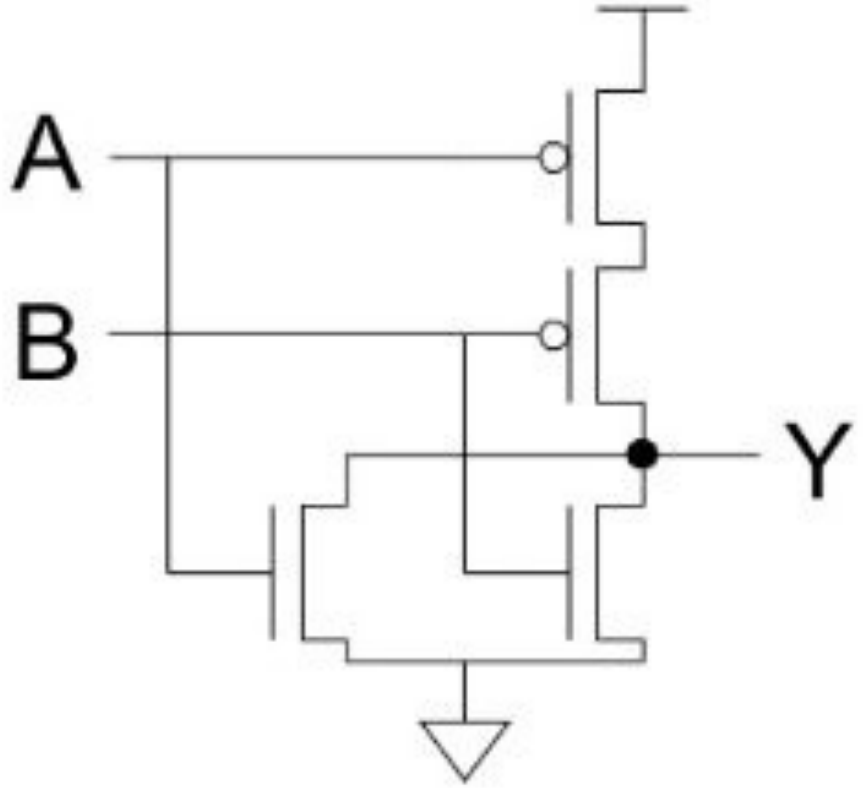


CMOS NOR Gate

CMOS NOR Gate

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0





Boolean Function Implement

Example

Mnimize the following boolean function ,implement using Cmos transistor .

- $f(A,B,C) = \sum m(3,4,6,7)$

- $f(A,B,C) = \prod M(1,3,5,6,7)$

Example

$$f(A, B, C, D) = \sum m(0,1,5,15)$$

Examle

Mnimize the following boolean function ,implement using Cmos transistor

$$f(A,B,C,D) = (x+a)^n = \sum m(0,1,7,8,13,15)$$

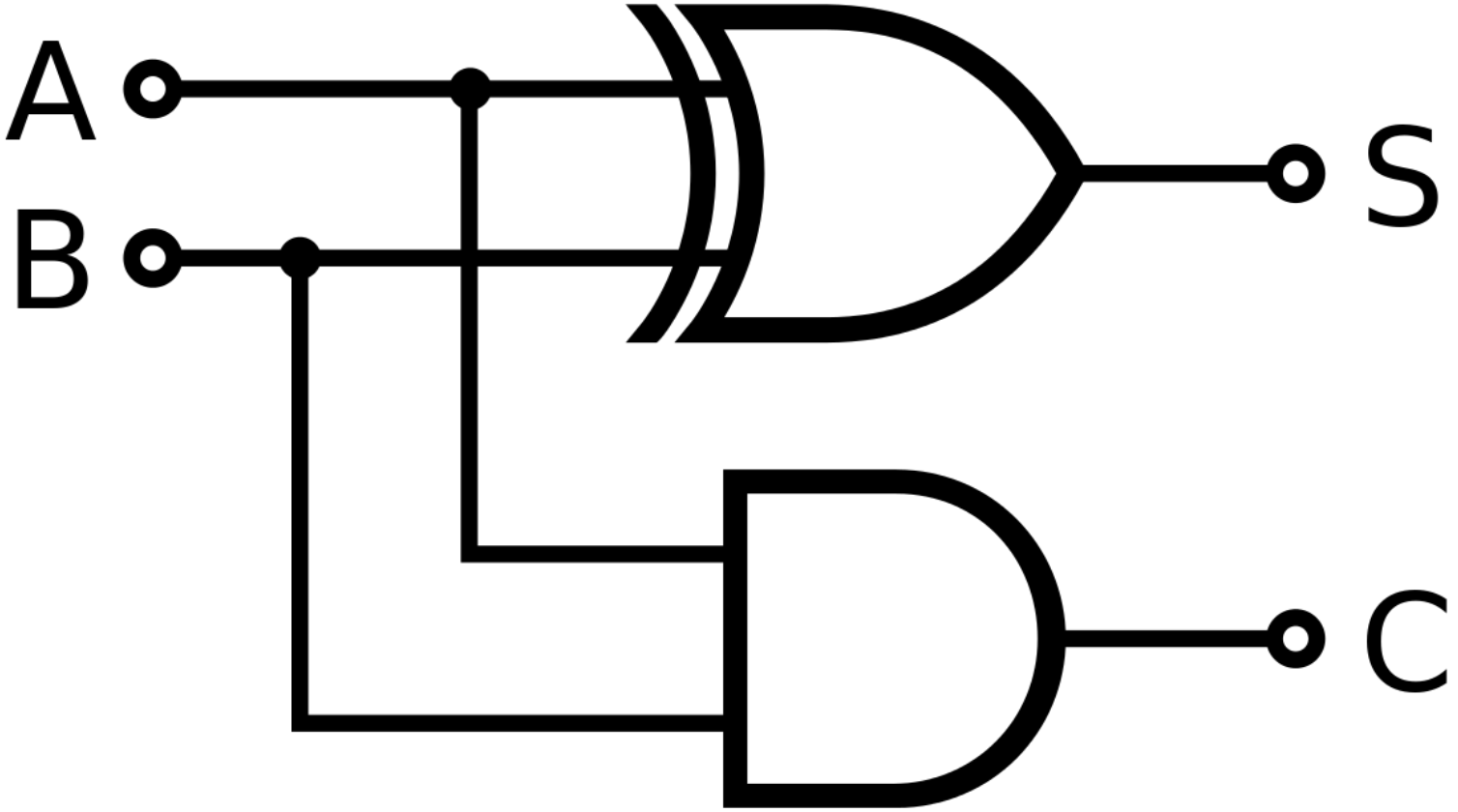
Example

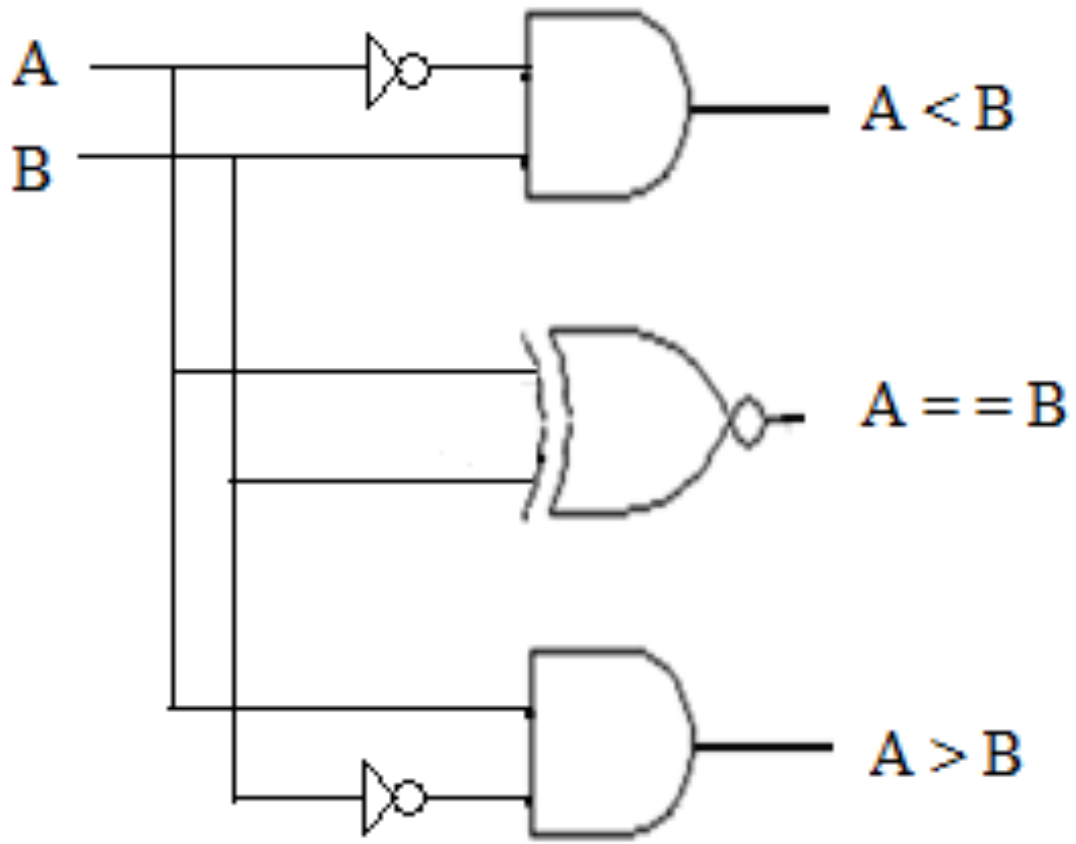
Minimize the following Boolean functions, implement your minimize function using the fewest number of MOS transistors

- $f(A,B,C,D) = \sum m(0,1,8,10,14,15)$
- $f(A,B,C) \prod M(2,3,5,7)$

Combinational logic circuit

Half Adder circuit



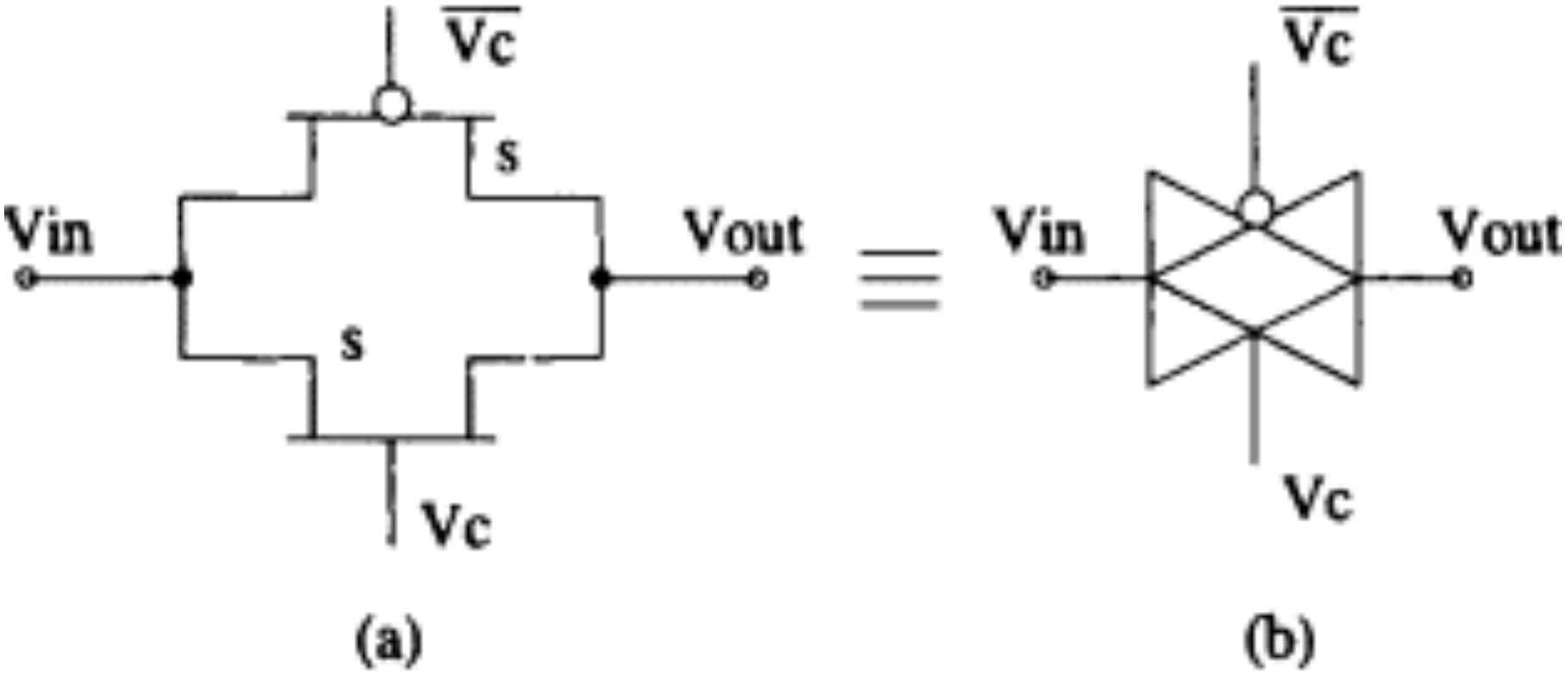


1-bit magnitude comparator

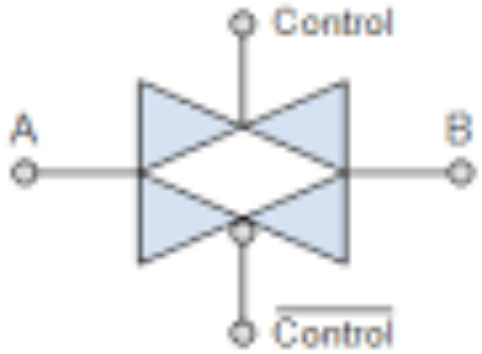
1 bit Copmarator

Transmission Gate

Connecting PMOS and NMOS devices together in parallel we can create a basic bilateral CMOS switch, known commonly as a “Transmission Gate”. Note that transmission gates are quite different from conventional CMOS logic gates as the transmission gate is symmetrical, or bilateral, that is, the input and output are interchangeable. This bilateral operation is shown in the transmission gate symbol below which shows two superimposed triangles pointing in opposite directions to indicate the two signal directions


$\overline{Vc}$
s
Vin
Vout
s
Vc
(a)
≡
$\overline{Vc}$
Vin
Vout
Vc
(b)

Transmission Gate Truth Table

Symbol	Truth Table		
 Transmission Gate	Control	A	B
	1	0	0
	1	1	1
	0	0	Hi-Z
	0	1	Hi-Z
Boolean Expression **B = A.Control**	Read as A **AND** Cont. gives B		

Example

Implement 4:1 multiplexer using C-Mos transsmision gate

Example

- Implement 8:1 multiplexer using C-Mos transsmision gate

Example

Implement 1:4 demultiplexer using C-Mos transsmision gate

Design 1 bit comparator . Implement your design using C-mos transistor