Analog Electronics II (CMOS)

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Question: What is Integrated Circuit (IC)?

Ans: An integrated circuit (IC) is a set of electronic circuits on one small flat piece (chip) of semiconductor material (silicon).

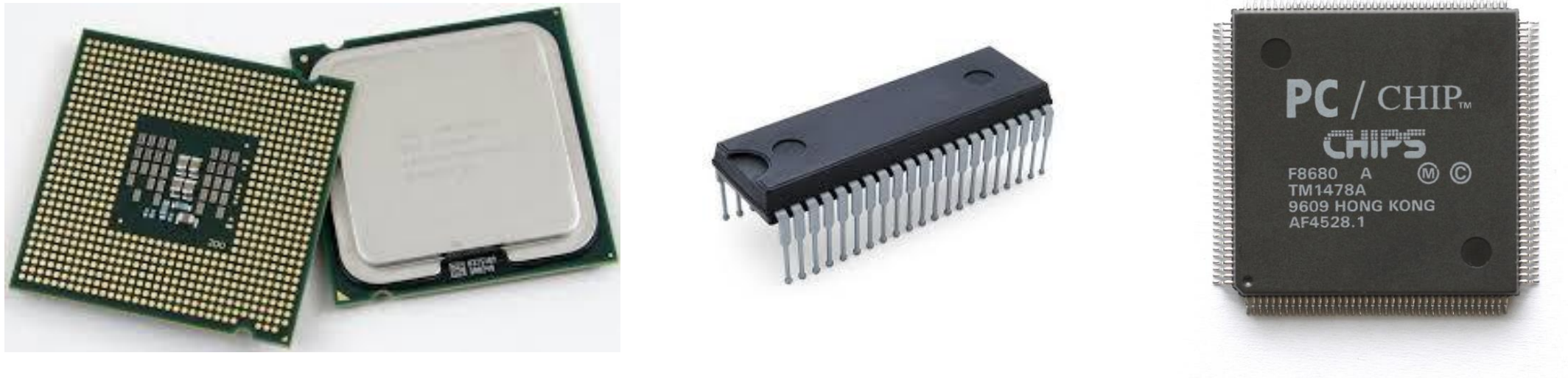


Figure: Integrated Circuit (IC) Chip

Question: What is Very Large Scale Integration (VLSI)?

Ans: Very large-scale integration (VLSI) is the process of creating an integrated circuit (IC) by combining millions of MOS transistors onto a single chip.

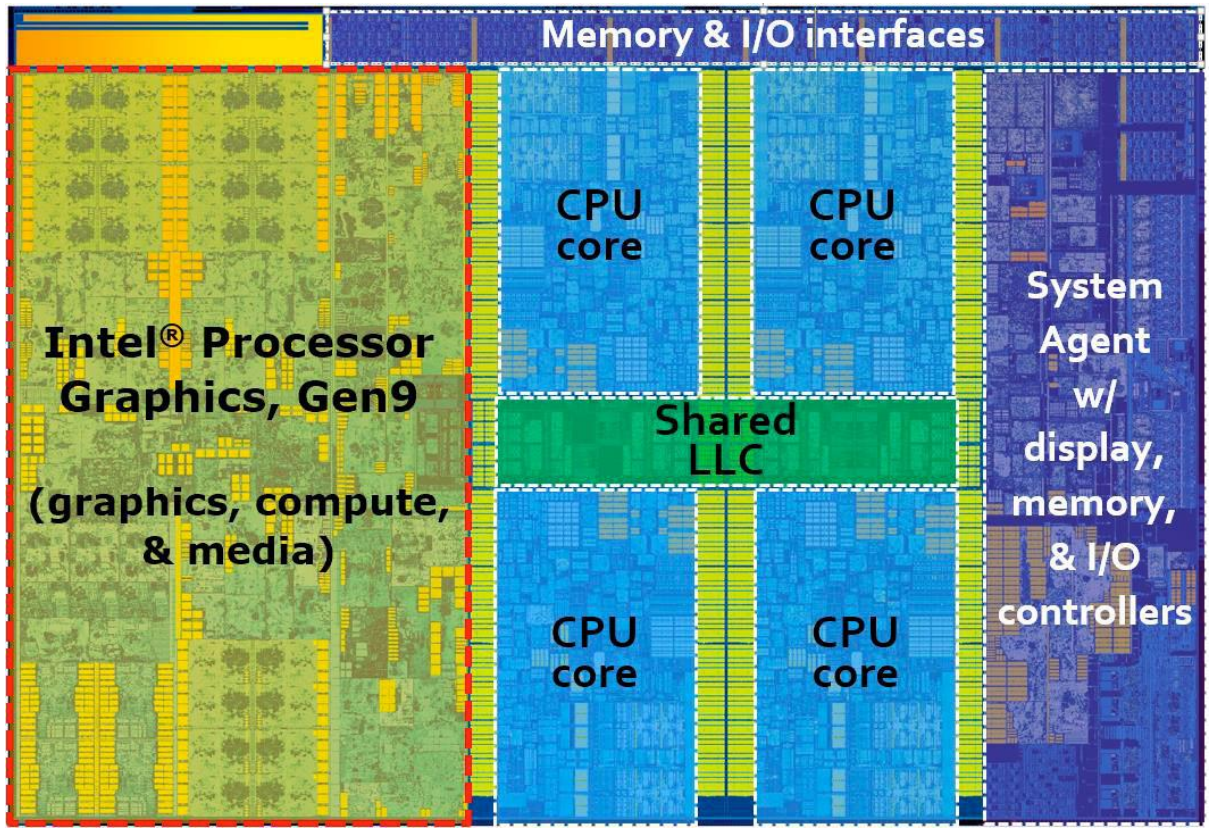


Figure: Intel CPU (IC) die which is made of billions of MOS transistors and VLSI is used to create this IC.

Question: What are the factors that need to be considered when designing IC?

Ans: Factors are-

1. Space
2. Power Dissipation (Heat Generation/Power Loss)

Question: Why is FET transistor used in IC design instead of BJT transistor?

Ans: Because

1. FET transistor requires less space than BJT transistor.
2. FET transistor consumes less power than BJT transistor.

Question: What are the differences between BJT and FET?

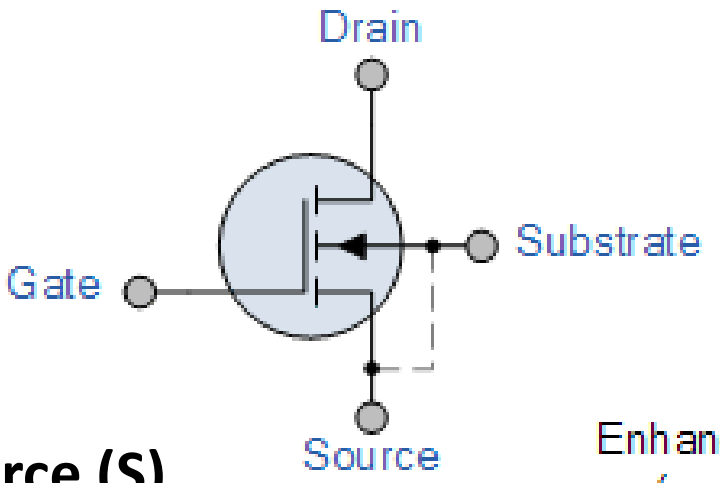
Ans:

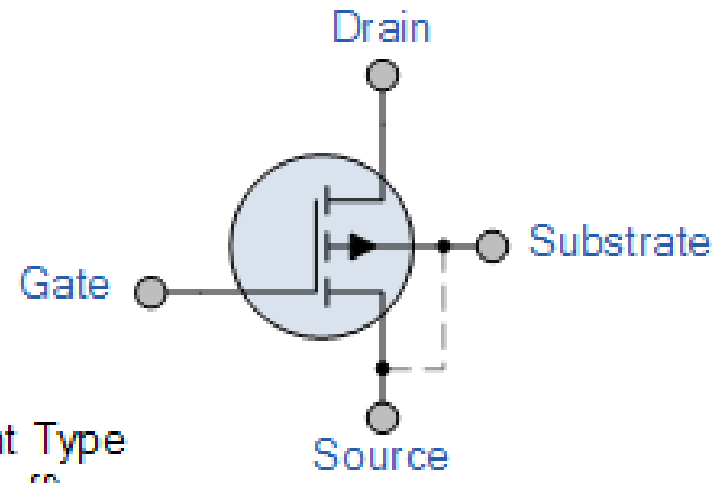
BJT	FET
1. Bipolar (Hole and Electron).	1. Unipolar (Hole/Electron).
2. Current Controlled.	2. Voltage Controlled.
3. Size is bigger.	3. Size is smaller.
4. High Power Dissipation.	4. Low Power Dissipation.
5. Low input Impedance.	5. High Input Impedance.

Question: Which type of FET transistor is best for IC design?

Ans: MOSFET (Metal Oxide Semiconductor FET)

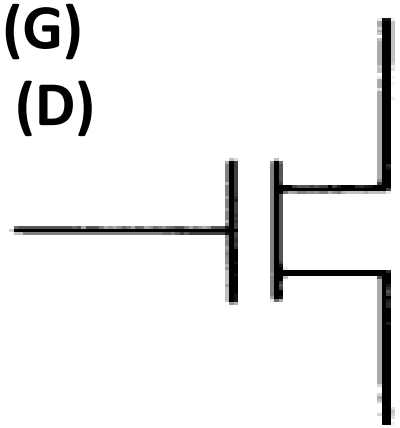
MOSFET Symbol



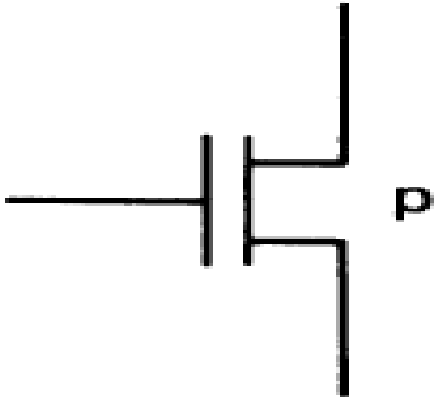


Enhancement Type
(normally-off)

Emitter (E) -> Source (S)
Base (B) -> Gate (G)
Collector (C) -> Drain (D)



NMOS transistor



PMOS transistor

Link: https://www.electronics-tutorials.ws/transistor/tran_6.html

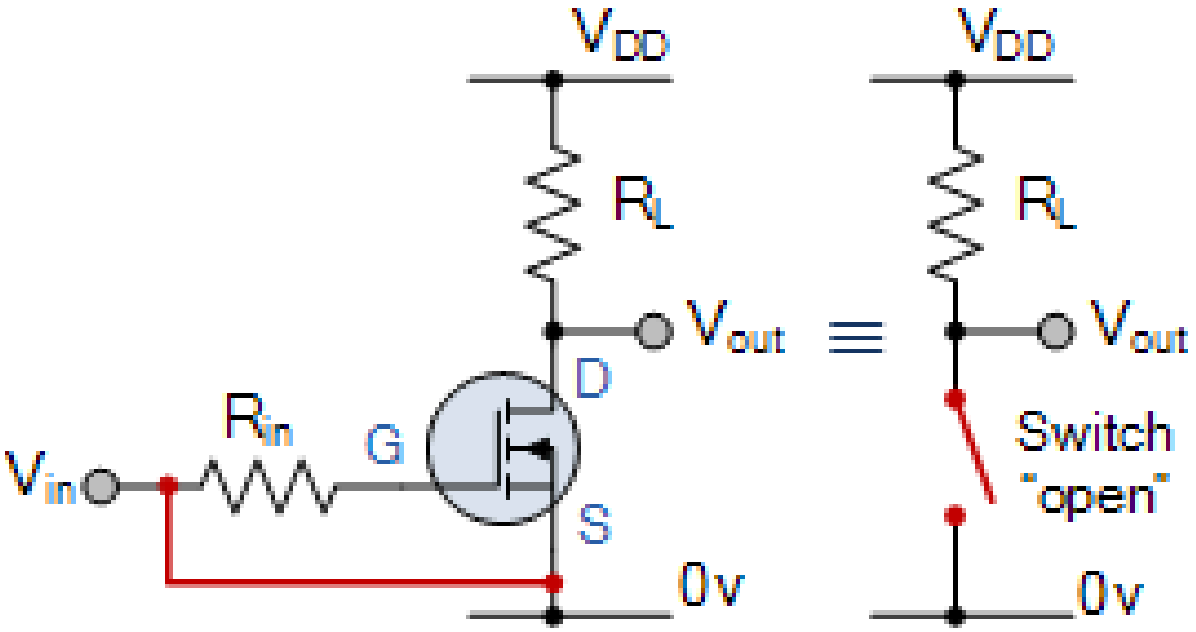
Question: How does MOSFET work as switch?

Ans: MOSFET as switch

MOSFET Type	$V_{GS} \ll 0$	$V_{GS} = 0$	$V_{GS} \gg 0$
N-channel Enhancement	OFF	OFF	ON
P-channel Enhancement	ON	OFF	OFF

Link: https://www.electronics-tutorials.ws/transistor/tran_7.html

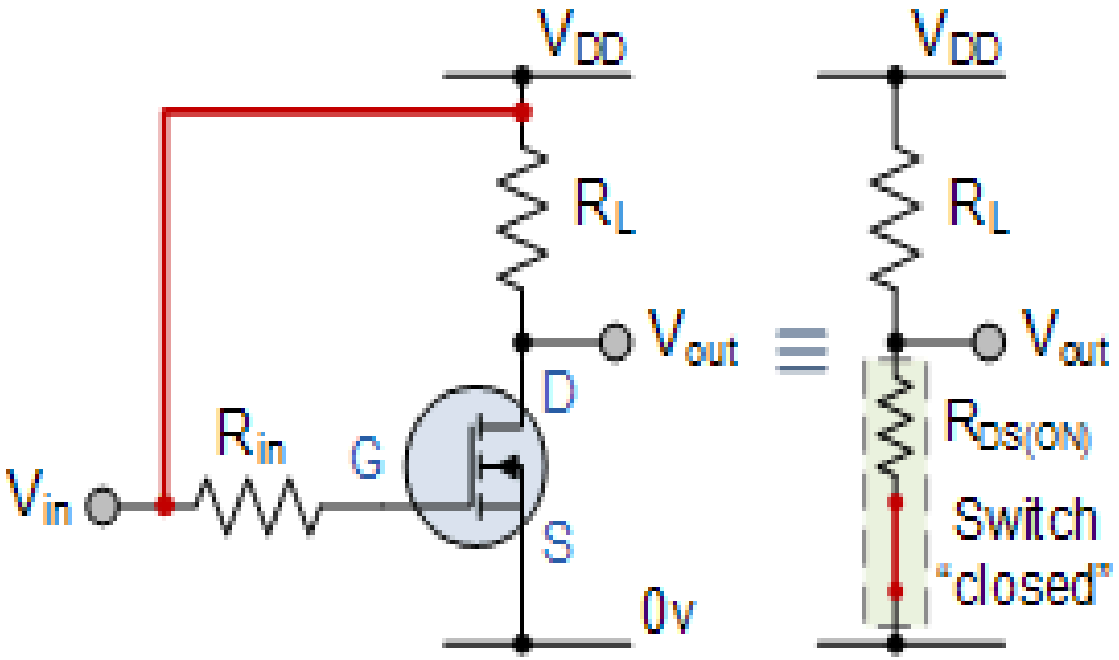
NMOS as switch



- **The input and Gate are grounded (0V)**
- **$V_{GS} < V_{TH}$**
- **MOSFET is "OFF" (Open switch)**

Link: https://www.electronics-tutorials.ws/transistor/tran_7.html

NMOS as switch



- The input and Gate are connected to V_{DD}
- $V_{GS} > V_{TH}$
- MOSFET is "ON" (Closed switch)

Link: https://www.electronics-tutorials.ws/transistor/tran_7.html

Question: Which is preferred between PMOS and NMOS for IC Design?

Ans: NMOS is preferred. Because-

1. Size of NMOS < Size of PMOS
2. Carrier of NMOS is electron but Carrier of PMOS is hole. It means NMOS is faster than PMOS.

Question: Implement NOT gate (Inverter) using NMOS.

Answer:

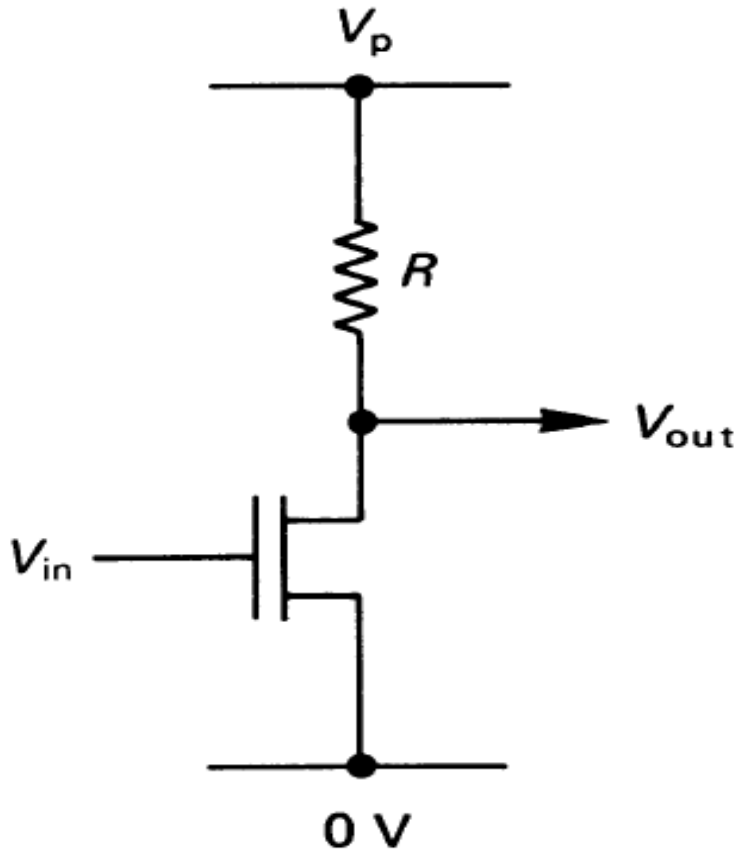


Fig: NMOS NOT gate (Inverter) with resistor load.

Question: How much practical is it to use resistors in IC design?

Ans: Using resistors in IC design is not very practical.

Because resistor is most expensive thing in IC design. It takes most space in IC.

Size of 1 Resistor = Size of 300 MOS transistors.

Question: How can we avoid using resistor in IC design?

Ans: MOS transistor has high impedance property which can be exploited in IC design. It means it is possible to use MOS transistor as resistor in IC design. So, solution is CMOS.

CMOS = PMOS (act as Resistor) + NMOS (act as Transistor)

Question: Implement NOT gate (Inverter) using CMOS.

Answer:

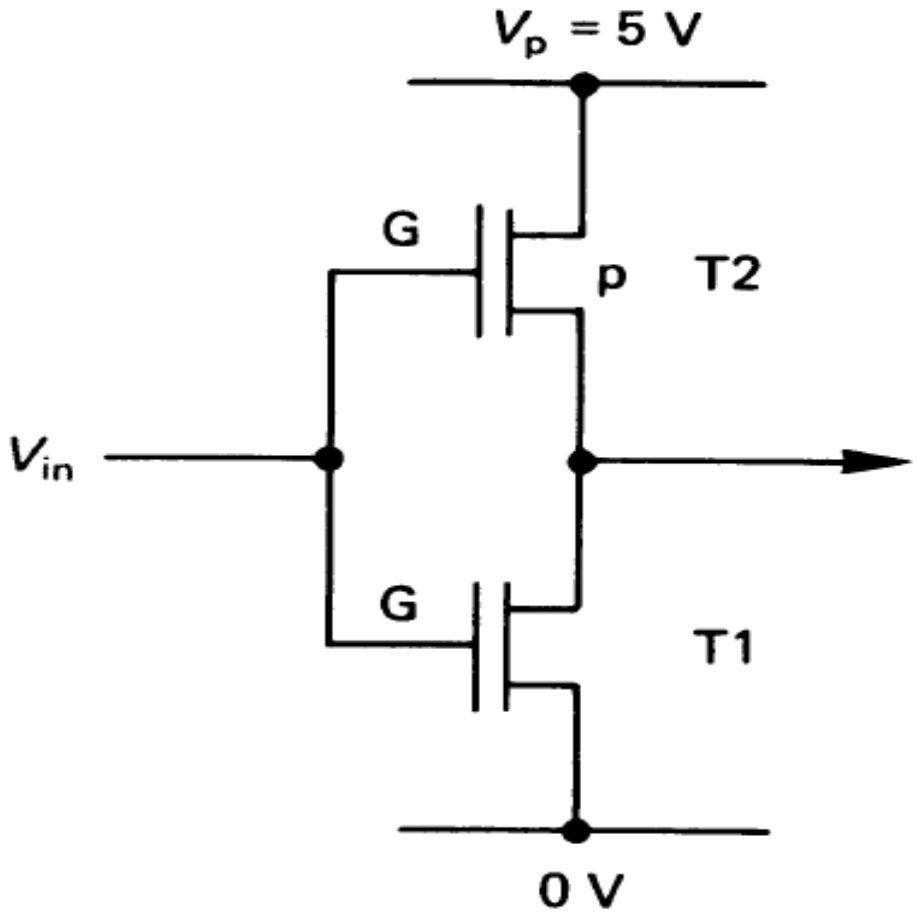


Figure: CMOS Inverter.

Question: Implement NOR using NMOS and CMOS.

Answer:

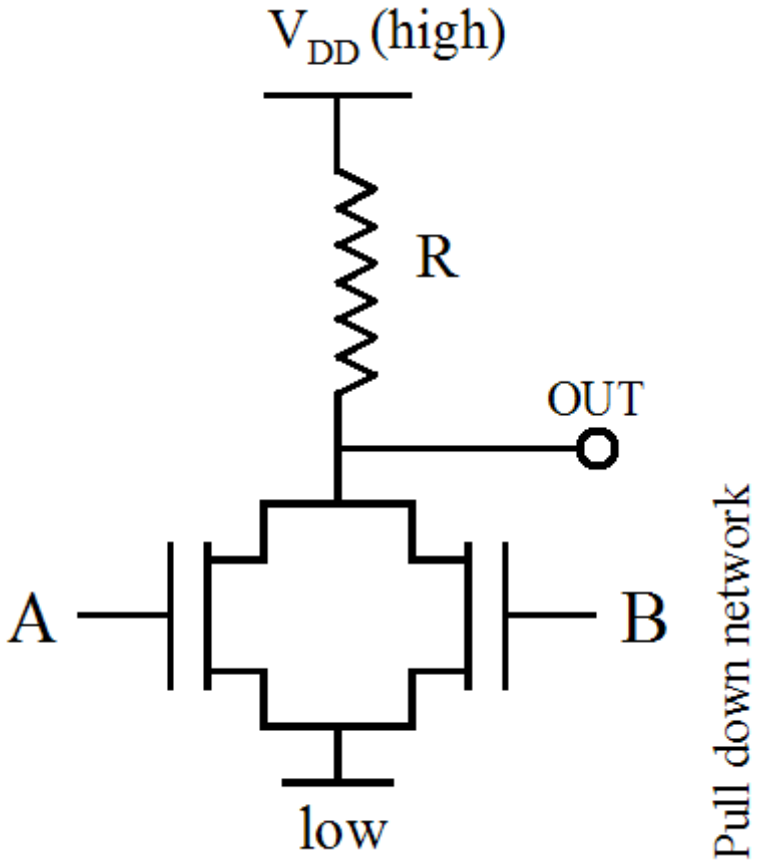


Figure: NMOS NOR gate with resistor load.

Question: Implement NOR using NMOS and CMOS.

Answer:

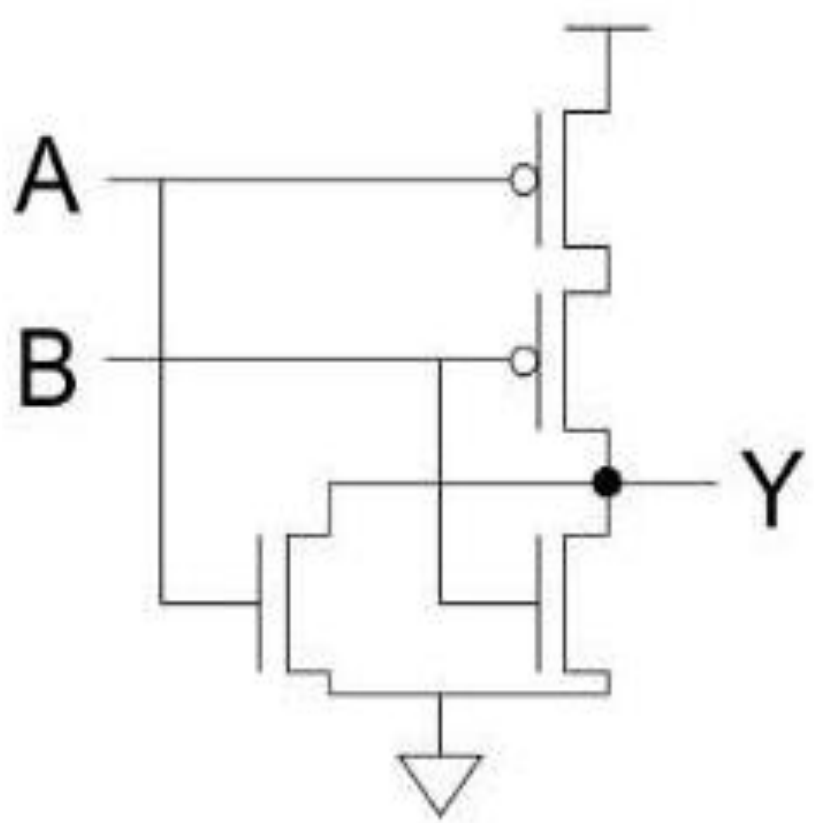
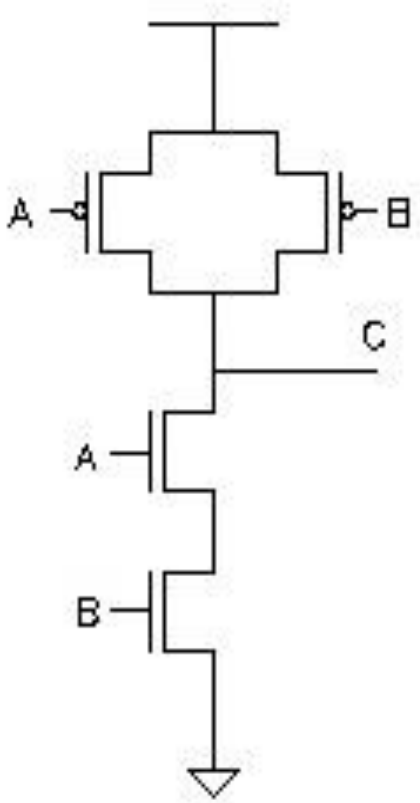
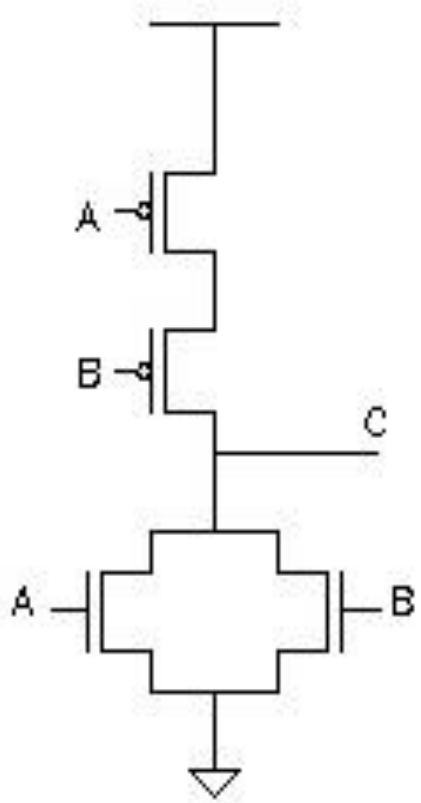


Figure: CMOS NOR gate.

CMOS NOR and NAND gate

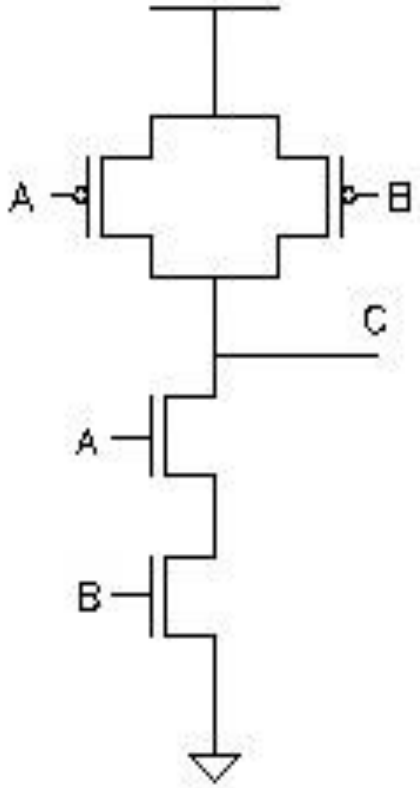


NAND

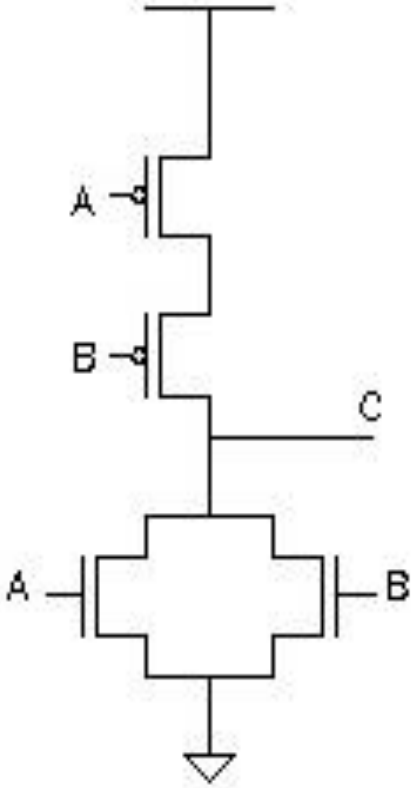


NOR

CMOS NOR and NAND gate



NAND



NOR

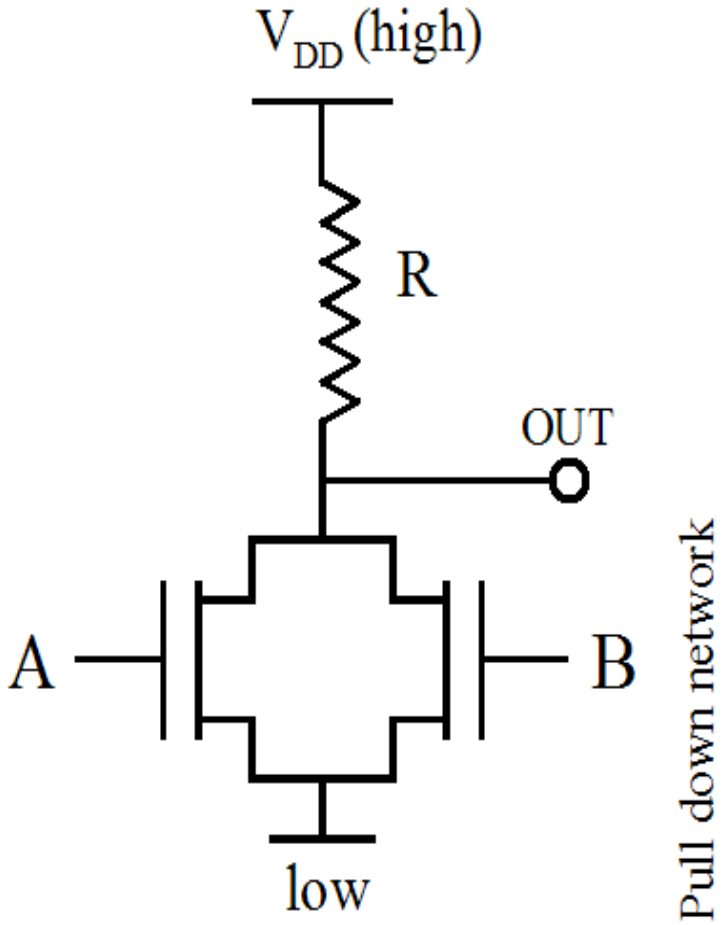
Important observation here is that output is always inverted.

It means Logic functions can be implemented using NAND/NOR gates which is more practical/efficient than implementing it using AND/OR gates.

Example: NMOS

Question: Implement **NOR** logic gate by using NMOS transistor.

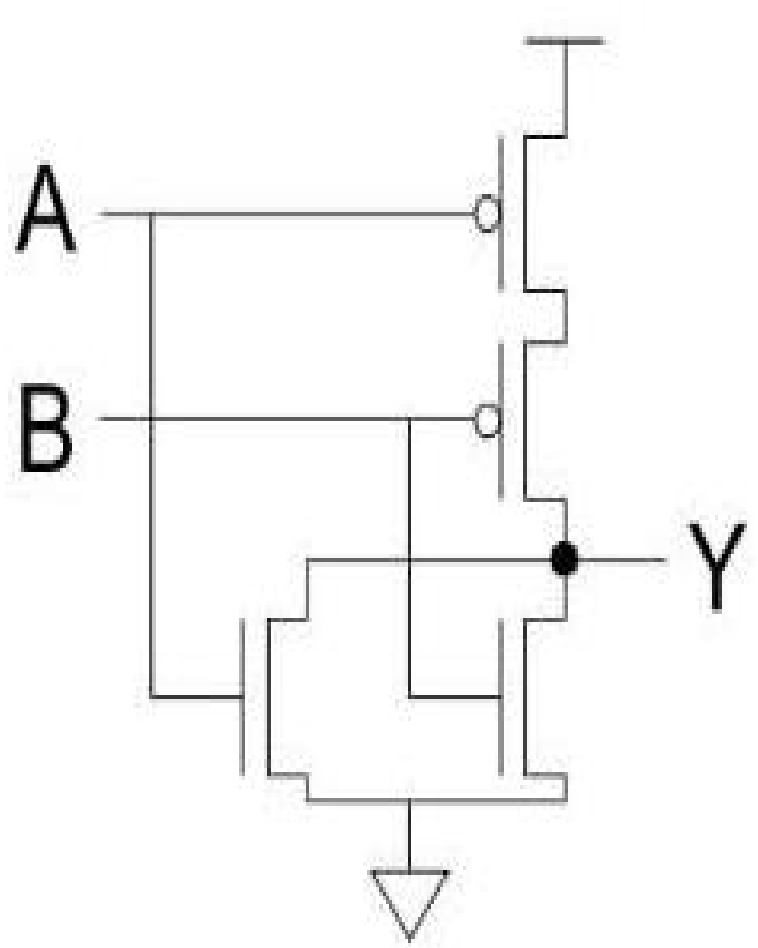
Answer:



Example: CMOS

Question: Implement **($\overline{A + B}$)** logic gate by using CMOS transistor.

Answer:



Exercises

1. Implement **NOR ($\overline{A+B}$) / $\overline{A+B+C}$/$(\overline{A+B})(\overline{B+C})$/any Boolean expression** by using NMOS transistor.
2. Implement **NOR ($\overline{A+B}$) / $\overline{A+B+C}$/$(\overline{A+B})(\overline{B+C})$/any Boolean expression** by using CMOS transistor.

Thank You ☺