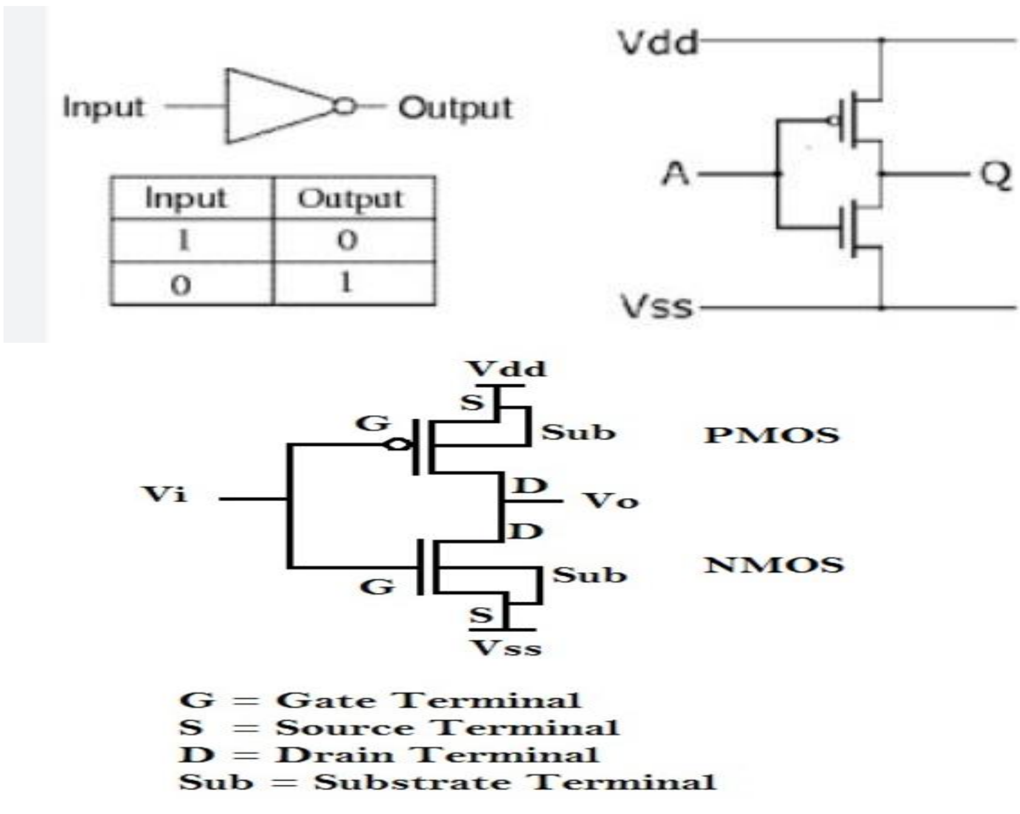
CMOS Inverter

INTRODUCTION

- CMOS stands for “Complementary Metal Oxide Semiconductor”.
- Two different types of field-effect transistors: PMOS and NMOS. PMOS transistors use P-type semiconductor materials, while NMOS transistors use N-type semiconductor materials.
- CMOS technology is used for constructing integrated circuit (IC) chips, including microprocessors, microcontrollers, memory chips (including CMOS BIOS), and other digital logic circuits.
- CMOS technology is also used for analog circuits such as image sensors (CMOS sensors), data converters, RF circuits (RF CMOS), and highly integrated transceivers for many types of communication.

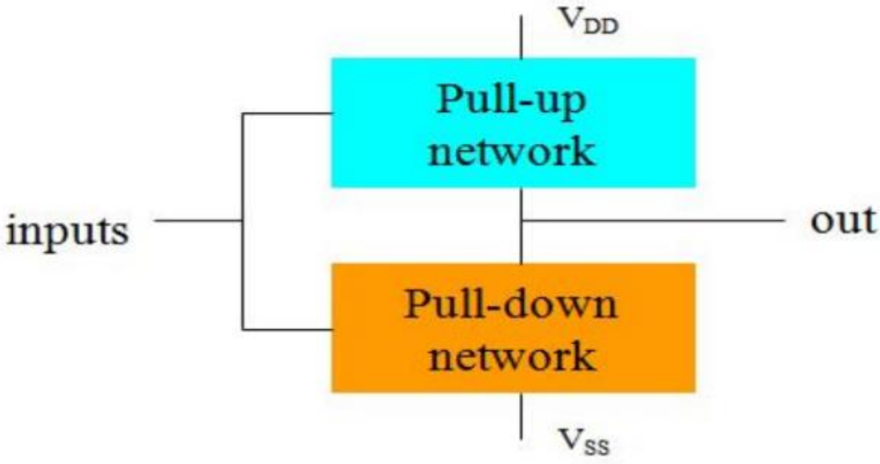
CMOS Inverter Schematic Diagram



Schematic diagram of CMOS Inverter

CMOS Inverter Operation & Working

Pull-up and pull-down networks:



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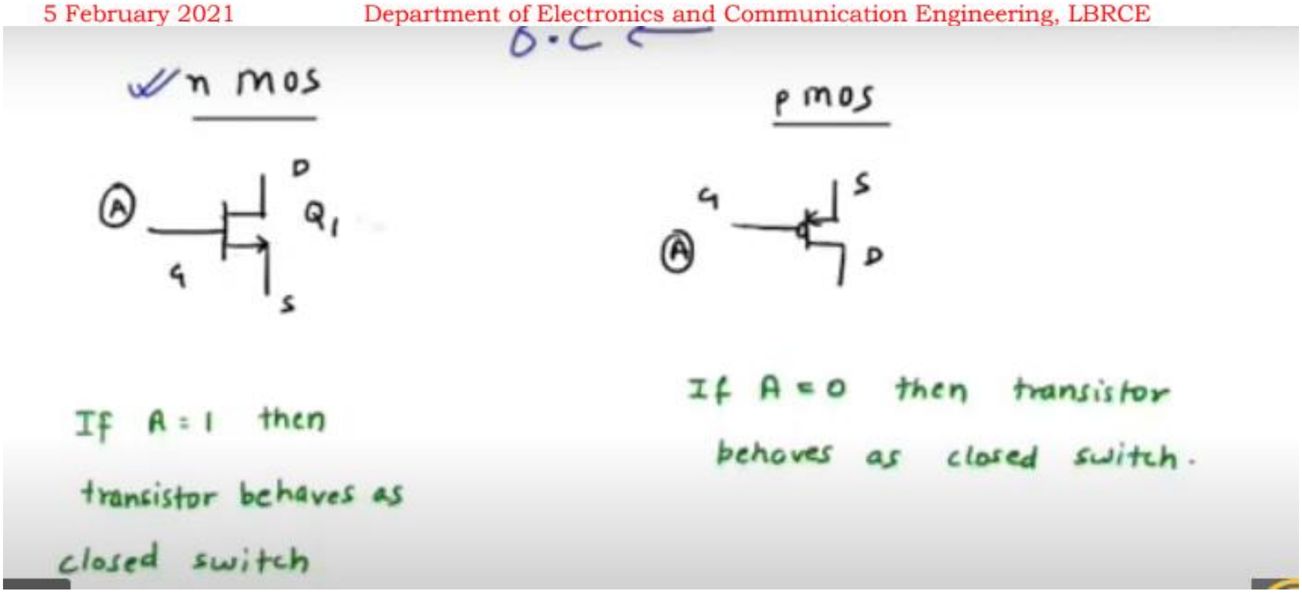


Given (V_{th} = 0.2 V_{dd}), we can analyze the behavior of the transistors under different (V_{gs}) conditions.

NMOS Transistor Behavior

1. **When the gate-source voltage is less than the threshold voltage, the NMOS transistor is in the cutoff region**
Cutoff Region: The NMOS transistor is OFF, and there is no current flowing from drain to source

2. **When the gate-source voltage is greater than the threshold voltage, the NMOS transistor is in the active region (also known as the linear or saturation**
-Active Region: The NMOS transistor is ON, and it can conduct current from drain to source.

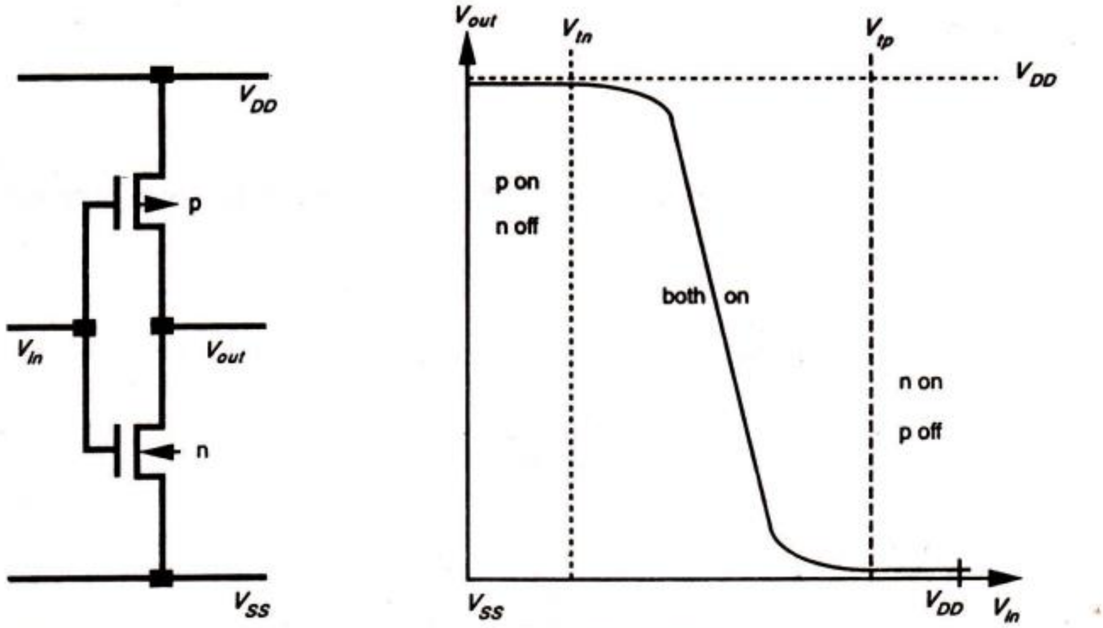
PMOS Transistor Behavior

1. **For a PMOS transistor, the gate-source voltage is negative .**

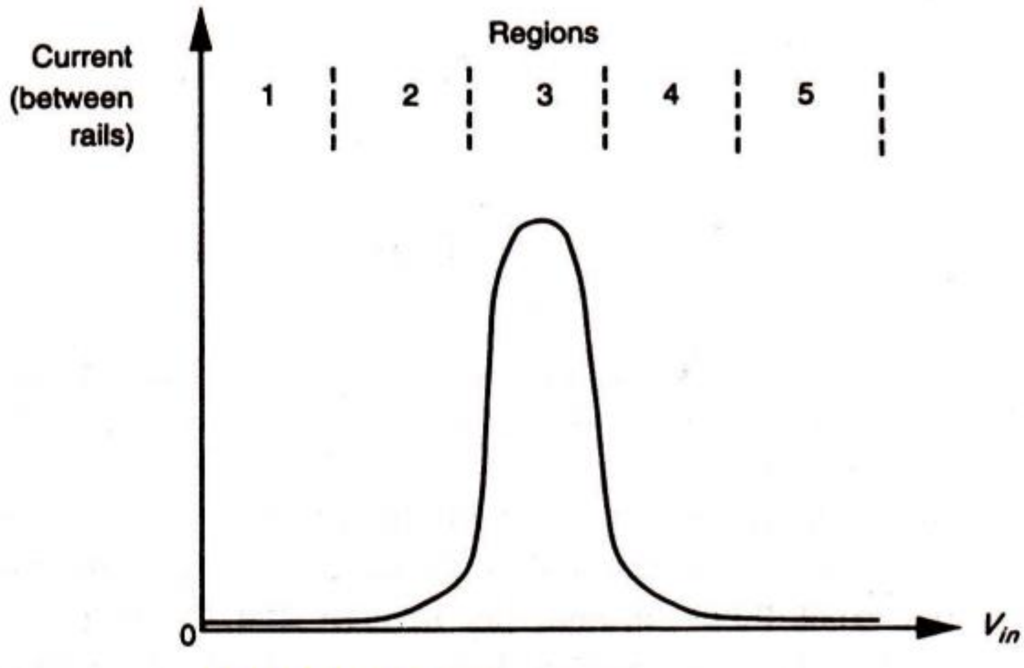
- When the magnitude of the gate-source voltage is less than the magnitude of the threshold voltage. the PMOS transistor is in the cutoff region.

2.When the magnitude of the gate-source voltage is greater than the magnitude of the threshold voltage., the PMOS transistor is in the active region.

Active Region: The PMOS transistor is ON, and it can conduct current from source to drain..



(a) Circuit (b) Transfer characteristic



(c) CMOS inverter current versus V_{in}

$$I_{ds} = K\frac{W}{L}(V_{gs} - V_t)V_{ds} - \frac{V_{ds}^2}{2}$$

CMOS

1. $$I_{ds} = \frac{(\mu C_0)}{2} \frac{W}{L} (V_{gs} - V_t)^2$$

$$= \frac{\beta}{2} (V_{gs} - V_t)^2 \text{ [In saturation]}$$

with $|V_{tp}| = 0.2V_{DD}$, then

$$\tau_r \div \frac{3C_L}{\beta_p V_{DD}}$$

Advantages

1. Low Power Consumption:

***Static Power**: CMOS inverters consume very little power when in a stable state (i.e., when the input is either high or low), as there is minimal current flow through the circuit.*

***Dynamic Power:** During switching, the power consumption is primarily due to the charging and discharging of load capacitances, which is relatively low compared to other technologies.*

2.High Noise Margin

3.High Input Impedance

Disadvantages

1. **Switching Speed**
2. **Susceptibility to Radiation**
3. **Complexity in Fabrication:**
4. **Subthreshold Leakage:**
5. **Temperature Sensitivity:**

Applications

- **Logic Gates:** Basic building blocks for creating other logic gates like NAND, NOR, etc.
- **Ring Oscillators:** Used in clock generation circuits.

- **Buffer and Amplifier:** Used to drive loads with higher capacitance.
- **Memory Cells:** Fundamental components in SRAM and DRAM.