Lab 1 – Prelab

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Ans-2) NMOS :-

$$I_{ds} = \begin{cases} 0 & , V_{GS} < V_t \quad \text{(cutoff)} \\ \beta \left(V_{GT} - V_{DS}/2 \right) \cdot V_{DS} & , V_{DS} < V_{GS} - V_t , \; V_{GS} > V_t \quad \text{(linear)} \\ \beta/2 \cdot V_{GT}^2 & , V_{DS} \geq V_{GS} - V_t , \; V_{GS} > V_t \quad \text{(saturation)} \end{cases}$$

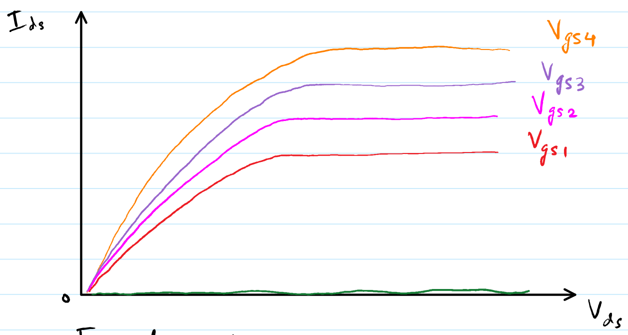

Figure 1 : I-V Characteristics of Ideal NMOS Transistor

PMOS :-

$$I_{SD} = 0 \quad , V_{SG} < |V_t| \quad \text{(cutoff)}$$

$$\mu_p \cdot C_{ox} \left(\frac{W}{L} \right) \cdot \left[(V_{SG} - |V_t|) - \frac{V_{SD}}{2} \right] \cdot V_{SD} \quad , V_{SD} < V_{SG} - |V_t| , \; V_{SG} > |V_t| \quad \text{(linear)}$$

$$1/2 \cdot \mu_p \cdot C_{ox} \left(\frac{W}{L} \right) \cdot \left(V_{SG} - |V_t| \right)^2 \quad , V_{SD} \geq V_{SG} - |V_t| , \; V_{SG} > |V_t| \quad \text{(saturation)}$$

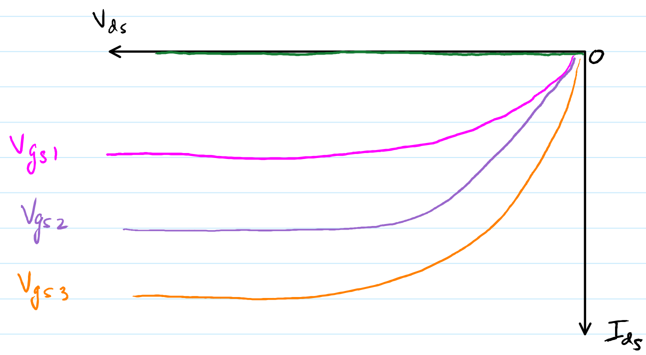

Figure 2 : I-V Characteristics of Ideal PMOS Transistor

Ans-3) $V_t = V_{t0} + \gamma \left(\sqrt{\phi_s + V_{SB}} - \sqrt{\phi_s} \right)$

Applying $V_{SB} \Rightarrow$ threshold voltage increases as V_{SB} increases

Ans-4) Assuming that the surface voltage is approximately the body voltage, that is, $V_{db} = V_{ds}$

The effective channel length $L_{eff} = L - L_d$ ← depletion region

- L_d increases as V_{db} increases

Hence, increasing V_{ds} will decrease effective channel length.

- A shorter channel length leads to higher current.

Hence, I_{ds} increases with V_{DS} in saturation.

Saturation :-

$$I_{ds} = \frac{\beta}{2} \cdot V_{GT}^2 \cdot \left(1 + \frac{V_{ds}}{V_A}\right)$$

- This equation accounts for CLM for drain-current equation.
- V_A is proportional to the channel length.

Therefore, the effects of CLM are more important in short channel devices.

Ans-5) In an ideal transistor, the current doesn't get cutoff when $V_{gs} < V_t$, rather drops exponentially.

The subthreshold leakage current increases significantly with V_{ds} due to drain induced barrier lowering.

There is a lower limit on I_{ds} set by drain junction leakage.

$$I_{ds} = I_{dso} \cdot e^{\frac{V_{gs} - V_{t_0} + n \cdot V_{ds} - K\gamma \cdot V_{sb}}{n V_t}} \cdot \left(1 - e^{\frac{-V_{ds}}{V_t}}\right)$$

Ans-6)