MOS Continued

October 19, 2019 18:43

Recall that MOS has two operating modes: LINEAR & SATURATION

↳ Determined by V_{DS}:

LINEAR: if $V_{DS} < (V_{GS} - V_T) // E_c \cdot L$

SATURATION: if $V_{DS} \geq (V_{GS} - V_T) // E_c \cdot L$

} where E_c is the critical field
NMOS: 6 [V/μm]
PMOS: 24 [V/μm]

Current:

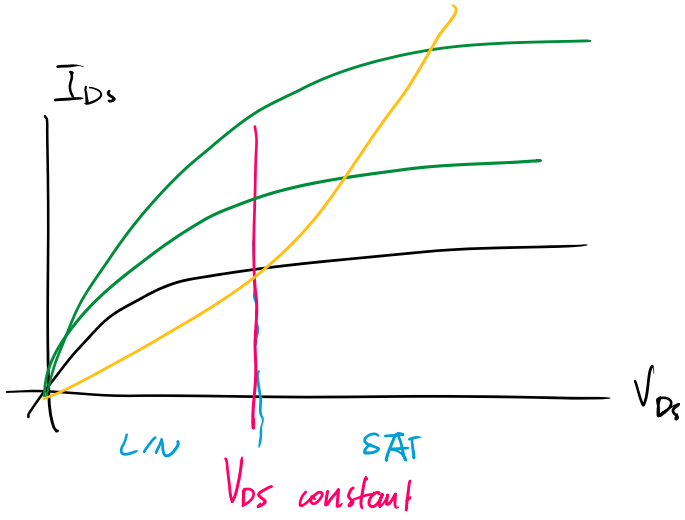
LINEAR: $$I_{DS} = \frac{W}{L} \cdot \frac{\mu_e C_{ox}}{\left(1 + \frac{V_{DS}}{E_c \cdot L}\right)} \cdot \left(V_{GS} - V_T - \frac{V_{DS}}{2}\right) \cdot V_{DS}$$

SATURATION: $$I_{DS} = W \cdot v_{sat} \cdot C_{ox} \cdot \frac{(V_{GS} - V_T)^2}{(V_{GS} - V_T) + E_c \cdot L}$$

For long-channel devices, $E_c \cdot L >> V_{GS}$ and V_{DS}:

LINEAR: $$I_{DS} = \frac{W}{L} \cdot \frac{\mu_e C_{ox}}{\left(1 + \frac{V_{DS}}{E_c \cdot L}\right)} \cdot \left(V_{GS} - V_T - \frac{V_{DS}}{2}\right) \cdot V_{DS} = \frac{W}{L} \cdot \mu_e C_{ox} \cdot \left(V_{GS} - V_T \cdot \frac{V_{DS}}{2}\right) \cdot V_{DS}$$

SATURATION: $$I_{DS} = W \cdot v_{sat} \cdot C_{ox} \cdot \frac{(V_{GS} - V_T)^2}{(V_{GS} - V_T) + E_c \cdot L} = W \cdot v_{sat} \cdot C_{ox} \cdot \frac{(V_{GS} - V_T)^2}{E_c \cdot L}$$



Sub-Threshold Current

Even when $V_{GS} \leq V_{th}$, there is still leakage current (I_{sub}):

$$I_{sub} = I_S \cdot e^{\frac{q(V_{GS} - V_T - V_{offset})}{nkT}} \cdot \left(1 - e^{\frac{-qV_{DS}}{kT}}\right)$$

q: charge of electron

T: temperature

SLOPE FACTOR : $S = \Delta V_{GS}$

$$S = \frac{nkT}{q} \cdot \ln(10)$$