Non ideal MOS model

Instructor – Dr. Madhav Rao

Ideal I-V

Long Channel

Non Ideal I-V

Short Channel

Non ideal behavior due to Short Channel

1. Velocity Saturation:

$\mu E_{ds} \neq v$ at high $E_{ds} = \frac{V_{ds}}{L}$

Velocity ceases to increase with Eds, hence lower Ids than expected for higher Vds.

2. Mobility Degradation:

$(V_{gs}/t_{ox}) \uparrow$

Carrier scattered at oxide interface which further slows the progress for majority carriers started from source to reach drain. Hence lower Ids than expected for higher Vgs.

3. Channel Length modulation

At higher Vds, Ids_{sat} increases slowly (not constant as in Ideal case) because of short channel at higher Vds, the depletion region near drain increases, and shortens the effective channel length.

Mobility Degradation : Empirical Model

$$\mu_{eff-n} = \frac{540\,cm^2/V\text{-}sec}{1 + \left[\dfrac{V_{gs} + V_t}{0.54\left(\dfrac{V}{nm}\right) t_{ox}}\right]^{1.85}}$$

$$\mu_{eff-p} = \frac{185\,cm^2/V\text{-}sec}{1 + \dfrac{|V_{gs} + 1.5\,V_t|}{0.338\left(\dfrac{V}{nm}\right) t_{ox}}}$$

Example#1: Compute effective-mobilities when the transistors are ON,

Vgs = 1 V, Vt = 0.3 V, t_{ox} = 1.05 nm for 65 nm Technology node.

$$\mu_{eff-p} = \frac{185}{1 + \dfrac{|1 + 1.5(0.3)|}{0.338\left(\frac{V}{nm}\right) 1.05\,nm}} = 36.37\ cm^2/V\text{-}sec$$

$$\mu_{eff-n} = \frac{540}{1 + \left[\dfrac{1 + 0.3}{0.54\left(\frac{V}{nm}\right) 1.05\,nm}\right]^{1.85}} = 95.7\ cm^2/V\text{-}sec$$

Velocity Saturation

$$v = \frac{\mu_{eff} E}{1 + E/E_c}, \quad E < E_c$$

$$v = v_{sat}, \quad E \geq E_c$$

$$v = \frac{\mu_{eff} E}{1 + \frac{E}{E_c}} \quad \text{for } E < E_c$$

For Low E, $\boxed{v = \mu_{eff} E}$

For $E = E_c$, $\boxed{v_{sat} = \frac{\mu_{eff} E_c}{2}}$

$$\boxed{E_c = \frac{2 v_{sat}}{\mu_{eff}}}$$

Example#: Determine Vc-n, and Vc-p for 65 nm Technology node (L = 50 nm)

$$E_c = \frac{2 v_{sat}}{\mu_{eff}} \Rightarrow E_{C-N} = \frac{2 \times 10^7}{95.71} = \frac{V_{C-N}}{L}$$

$$\boxed{V_{C-N} = 1.044 V}$$

$$\boxed{V_{C-P} = 2.1996 V}$$

Conclusion: PMOS is not as badly velocity saturated as NMOS.
NMOS reaches saturation velocity at earlier voltage than PMOS.