EE 531
Spring 2009

Homework #5 Solutions

2. $$\mu_{eff} = \frac{\mu_o}{1 + \alpha \bar{\mathcal{E}}_{vert} \mu_o}$$

$$|\bar{\mathcal{E}}_{vert}| = \frac{1}{2}\left[\frac{|Q_S'|}{K_S\epsilon_0} + \frac{|Q_B'|}{K_S\epsilon_0}\right] = \frac{1}{2K_S\epsilon_0}\left(2|Q_B'| + |Q_I'|\right)$$

$$Q_I' = C_{ox}'\left(V_{GC} - V_T'\right), \quad Q_B' = \sqrt{2qK_S\epsilon_0 N_a\left(2\phi_B + \underbrace{V_{CS} + V_{SB}}_{V_{CB}}\right)}$$

$$|\bar{\mathcal{E}}_{vert}| = \sqrt{\frac{2qN_a}{K_S\epsilon_0}}\left(2\phi_B + V_{CS} + V_{SB}\right)^{1/2} + \frac{C_{ox}'}{2K_S\epsilon_0}\left(V_{GC} - V_T'\right)$$

$$V_T' = V_T + \delta V_{CS} = V_T + (m-1)V_{CS} \qquad V_T' = V_T + mV$$

$$V_{GC} - V_T' = V_{GS} - V_T - V_{CS} - (m-1)V_{CS}$$

$$= V_{GS} - V_T - mV_{CS}$$

$$|\bar{\mathcal{E}}_{vert}| = \sqrt{\frac{2qN_a}{K_S\epsilon_0}}\left(2\phi_B + V_{CS} + V_{SB}\right)^{1/2} + \frac{C_{ox}'}{2K_S\epsilon_0}\left(V_{GS} - V_T - mV_{CS}\right)$$

Several mobility models can give this field dependence (most are more complicated). In general, they use the local $\mathcal{E}_\perp$ (field perpendicular to direction of current flow), which averaged over inversion charge gives an average value similar to $|\bar{\mathcal{E}}_{vert}|$ above.

With Matthiessen's rule $\left(\frac{1}{\mu} = \sum \frac{1}{\mu_i}\right)$, a term of the form $\frac{1}{\alpha \mathcal{E}_\perp}$ along w/ μ_o gives $\mu = \left(\alpha\mathcal{E}_\perp + \frac{1}{\mu_o}\right)^{-1} = \mu_o/(1+\alpha\mathcal{E}_\perp\mu_o)$. This form is possible with Lombardi Model using just 1st term of Eq. 169, or with University of Bologna model with $\lambda = 1$ in Eq. 177.

3 (Problem 3.8) For $v = \frac{\mu_{eff}\mathcal{E}}{\left[1+(\mathcal{E}/\mathcal{E}_c)^n\right]^{1/n}}$ w/ $n=1$

$$I_{ds}^{sat} = C_{ox}' W v_{sat} (V_g - V_T) \frac{\sqrt{1+2\mu_{eff}(V_g-V_T)/(m v_{sat} L)} - 1}{\sqrt{1+2\mu_{eff}(V_g-V_T)/(m v_{sat} L)} + 1}$$

$I_{ds} = \boxed{W Q v}$ At source $Q \cong -C_{ox}'(V_g - V_T)$

$$v = v_{sat} \frac{\sqrt{\quad} - 1}{\sqrt{\quad} + 1}$$

For $L \to 0$ $\sqrt{1+2\mu_{eff}(V_g-V_T)/m v_{sat} L} \Rightarrow \infty$

$v \to v_{sat}$

For $v_{sat} \to \infty$ $\sqrt{\quad} \to 1$, need more accurate correction

$\sqrt{1+\epsilon} \cong 1 + \frac{\epsilon}{2}$ $\left(\epsilon = \frac{2\mu_{eff}(V_g - V_T)}{m v_{sat} L} \right)$

$$v \cong v_{sat} \left[\frac{\cancel{1} + \frac{\cancel{2}\mu_{eff}(V_g - V_T)}{\cancel{2} m v_{sat} L} \cancel{-1}}{2} \right] = \frac{\mu_{eff}(V_g - V_T)}{2 m L}$$

$$I_{ds}^{sat} = \boxed{C_{ox}' \mu_{eff} \frac{W}{L} \frac{(V_{gs} - V_T)}{2m}}$$ as derived w/o velocity saturation