

E151 Lecture 14 – MOSFET Design

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Disclaimer

These are notes for Prof. Spencer to give the lecture, they were not intended as a reference for students. Students asked for them anyway, so I'm putting them up as a courtesy. Remember that they are not intended as a substitute for attending lecture.

How Much Drain Current?

- Apply V_{ds} to make current move
- Do current continuity at every spot y in the channel
- Conduction product of charge density (C_{ox} helps) & speed (μ helps)

$$dQ(y) = WC_{ox}(V_{GS} - V_T - V(y))dy \quad \rightarrow \quad I_D = \frac{dQ(y)}{dt} = \frac{dQ(y)}{dy} v(y) \quad \leftarrow \quad v(y) = \mu_n E(y) = \mu_n \frac{dV}{dy}$$

$$I_D = \mu_n WC_{ox}(V_{GS} - V_T - V(y))dV/dy$$

$$\int_0^L I_D dy = \mu_n WC_{ox} \int_0^{V_{DS}} (V_{GS} - V_T - V(y))dV \quad \text{Assume linear region}$$

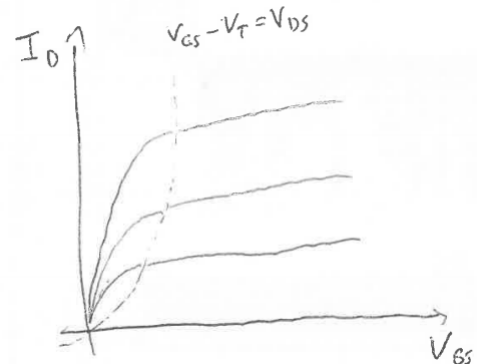
$$I_D = \mu_n \frac{W}{L} C_{ox} \left((V_{GS} - V_T)V_{DS} - \frac{V_{DS}^2}{2} \right)$$

Large Signal Model

- If we assume sat instead

$$\int_0^{L-\Delta L} I_D dy = \mu_n WC_{ox} \int_0^{V_{GS}-V_T} (V_{GS} - V_T - V(y))dV$$

$$I_D = \frac{1}{2} \mu_n \frac{W}{L} C_{ox} (V_{GS} - V_T)^2 (1 + \lambda V_{DS}) \quad \leftarrow \quad \lambda \text{ From } \Delta L/L, \text{ like } 1/V_A$$

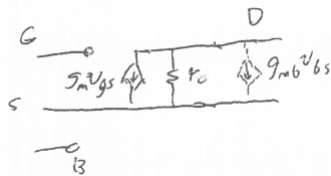


$$I_D = \begin{cases} \mu_n C_{ox} \frac{W}{L} \left((V_{GS} - V_T)V_{DS} - \frac{V_{DS}^2}{2} \right) & V_{GS} > V_T \text{ \& } V_{GD} > V_T \\ \mu_n C_{ox} \frac{W}{L} \frac{(V_{GS} - V_T)^2}{2} (1 + \lambda V_{DS}) & V_{GS} > V_T \text{ \& } V_{GD} < V_T \end{cases}$$

$(V_{GS} - V_{DS} > V_T)$
 $(V_{GS} - V_{DS} < V_T)$

Small Signal Model

- Take derivatives to linearize as before



$$\frac{\partial i_D}{\partial v_{GS}} = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_T) (1 + \lambda V_{DS})$$

$$\approx \sqrt{\mu_n C_{ox} \frac{W}{L} I_D} \quad \text{if } \lambda V_{DS} \ll 1$$

$$\equiv g_m$$

$$\frac{\partial i_D}{\partial v_{DS}} = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_T)^2 \cdot \lambda$$

$$\approx \lambda I_D$$

$$\equiv 1/r_o$$

Practical Calculations for g_m

- Often don't have μ_n and C_{ox} for discrete devices

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_T)^2$$

$$g_m = \frac{\partial i_D}{\partial v_{GS}} = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_T)$$

$$V_{ov} = V_{GS} - V_T = \sqrt{\frac{2I_D}{\mu_n C_{ox} \frac{W}{L}}}$$

$$g_m = \sqrt{\frac{2I_D}{\mu_n C_{ox} \frac{W}{L}}} \mu_n C_{ox} \frac{W}{L}$$

$$\boxed{g_m V_{ov} = 2I_D}$$

Can get V_{sw} and a_v from a large signal xfer fn.

- Slope in linear region is a_v
- Leaving linear region defines bounds of swing

