ECE 342
Electronic Circuits

Lecture 8
MOSFET Small Signal Model

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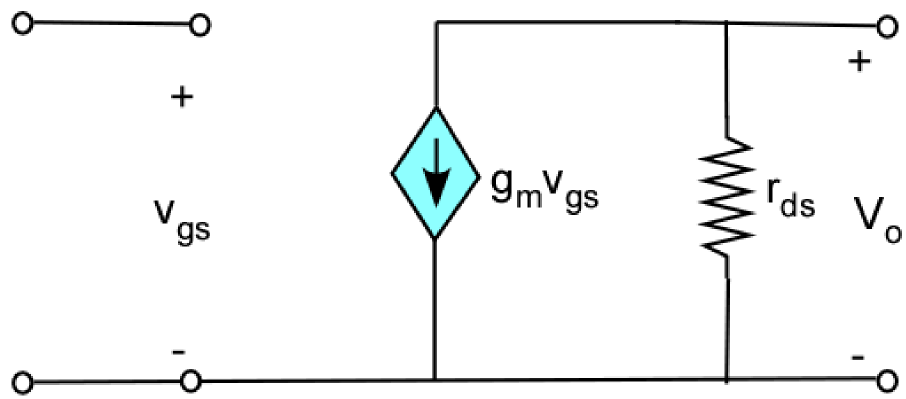
Biasing of MOS Transistors

- **Bias Characteristics**
  - Operation in saturation region
  - Stable and predictable drain current

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

Common Source MOSFET Amplifier

Small-Signal Equivalent Circuit for MOS (device only)



$$I_D = \frac{1}{2} k_n^{'} \frac{W}{L} \left(V_{GS} - V_T \right)^2$$

$$g_m = \left. \frac{\partial I_D}{\partial V_{GS}} \right|_{V_{GS}=V_{GSQ}} = \frac{2 I_D}{V_{eff}}$$

$$where\; V_{GS} - V_T = V_{eff}$$

Which leads to

$$g_m = \sqrt{2k_n^{'}}\,\sqrt{W/L}\,\sqrt{I_D}$$

$$g_m \text{ is proportional to } = \sqrt{W/L}$$

MOSFET Output Impedance

To calculate r_{ds}, account for λ

$$r_{ds} = \left.\frac{\partial V_{DS}}{\partial I_D}\right|_{V_{GS}=V_{GSQ}} = \frac{1}{\lambda \mu \frac{W}{2L} C_{ox}\left[V_{GS}-V_T\right]^2} = \frac{1}{\lambda I_{DP}}$$

$$I_{DP} = \frac{1}{2} k_n^{'} \frac{W}{L}\left(V_{GS}-V_T\right)^2$$

$$r_{ds} = \frac{V_A}{I_D}$$

r_{ds}, accounts for channel width modulation resistance.

Body Effect

- **The body effect**
  - V_T varies with bias between source and body
  - Leads to modulation of V_T

Potential on substrate affects threshold voltage

$$V_T(V_{SB}) = V_{To} + \gamma\left[\left(2|\phi_F| + V_{SB}\right)^{1/2} - \left(2|\phi_F|\right)^{1/2}\right]$$

$$|\phi_F| = \left(\frac{kT}{q}\right)\ln\left(\frac{N_a}{n_i}\right)$$ Fermi potential of material

$$\gamma = \frac{\left(2qN_a\varepsilon_s\right)^{1/2}}{C_{ox}}$$ Body bias coefficient

Body Effect – (Con't)

Define g_{mb} as the body transconductance

$$g_{mb} = \left.\frac{\partial I_D}{\partial V_{BS}}\right|_{\substack{V_{GS}=\text{constant} \\ V_{DS}=\text{constant}}}$$

Can show that $$g_{mb} = \chi g_m$$

$$where\ \chi = \frac{\partial V_T}{\partial V_{SB}} = \frac{\gamma}{2\sqrt{\phi_F + V_{SB}}}$$