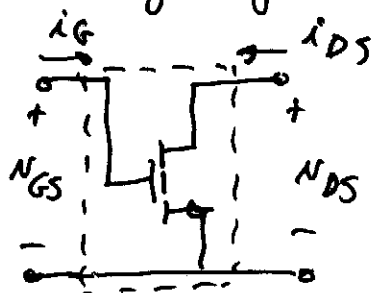


Derivation of the MOSFET S.S. Model

Large Signal -

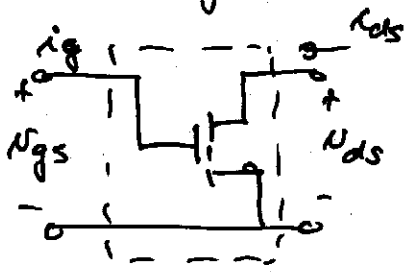


Math
Model

$$i_{DS} = \frac{K_n}{2} (V_{GS} - V_{TN})^2 (1 + \lambda V_{DS})$$

$$i_G = 0$$

Small Signal -



Math
Model

$$i_{ds} = k_1 v_{gs} + k_2 v_{ds}$$

$$i_g = 0$$

$$k_1 = \left. \frac{i_{ds}}{v_{gs}} \right|_{v_{ds}=0} = \left. \frac{\partial i_{DS}}{\partial V_{GS}} \right|_Q = K_n (V_{GS} - V_{TN}) (1 + \lambda V_{DS}) = g_m$$

$$(V_{GS} - V_T) = \sqrt{\frac{2 I_{DS}}{K_n (1 + \lambda V_{DS})}}$$

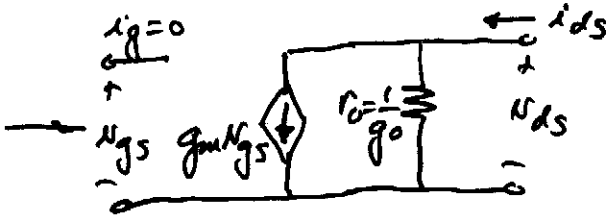
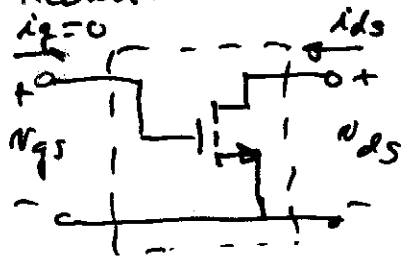
$$g_m = k_1 = K_n \sqrt{\frac{2 I_{DS}}{K_n (1 + \lambda V_{DS})}} (1 + \lambda V_{DS}) = \sqrt{2 I_{DS} K_n (1 + \lambda V_{DS})} = g_m$$

In general $\lambda V_{DS} \approx 0 \rightarrow g_m = \sqrt{2 K_n I_{DS}} = \sqrt{2 K_n' \frac{W}{L} I_{DS}}$

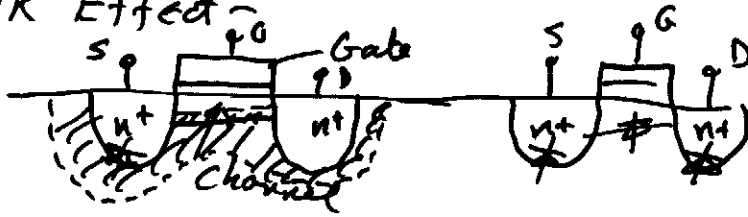
$$k_2 = \left. \frac{i_{ds}}{v_{ds}} \right|_{v_{gs}=0} = \left. \frac{\partial i_D}{\partial V_{DS}} \right|_Q = \lambda \frac{K_n}{2} (V_{GS} - V_{TN})^2 =$$

$$= \frac{\lambda K_n}{2} \left(\frac{2 I_{DS}}{K_n (1 + \lambda V_{DS})} \right) = \frac{\lambda I_{DS}}{1 + \lambda V_{DS}} = g_o = \frac{1}{r_o}$$

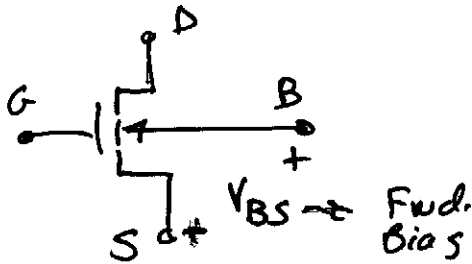
Result:



Bulk Effect -



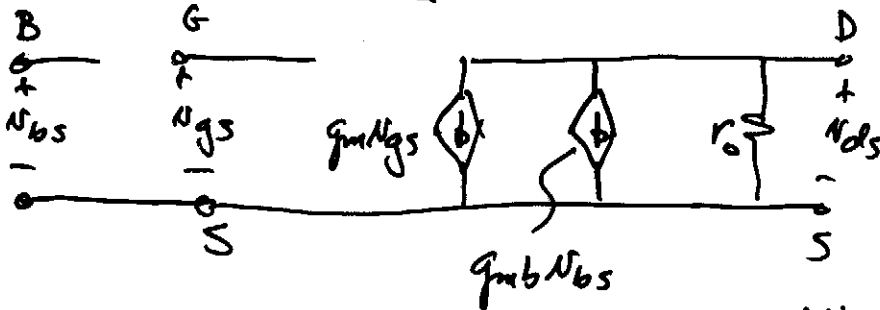
Substrate (Bulk) ρ^-



$$I_{DS} = \frac{K_n}{2} (V_{GS} - V_{TN})^2 \quad \lambda \approx 0$$

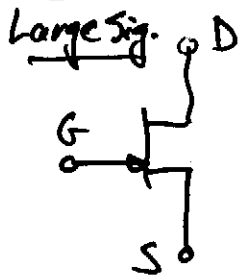
$$V_{TN} = V_{T0} + \gamma \sqrt{2\phi_F + N_{SB}} - \gamma \sqrt{2\phi_F}$$

$$g_{mb} = \left. \frac{\partial I_{DS}}{\partial V_{BS}} \right|_Q = M g_m \quad 0 \leq M \leq 1 \quad (M \approx \frac{1}{10})$$



$$g_m = \sqrt{2K_n I_{DS} (1 + \lambda V_{DS})}, \quad r_o = \frac{1 + \lambda V_{DS}}{\lambda I_{DS}}, \quad g_{mb} = \frac{\gamma}{2\sqrt{V_{SB} + 2\phi_F}} g_m$$

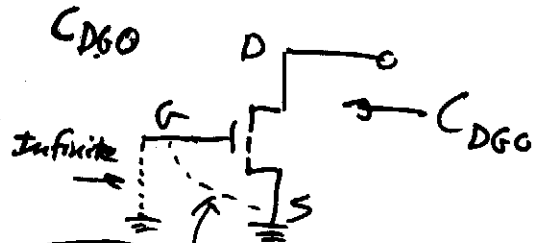
JFET SS Model



Math
Model

$$I_D = I_{DSS} \left[1 - \frac{V_{GS}}{V_P} \right]^2 (1 + \lambda V_{DS})$$

$I_{DSS} = I_{DS}$ when $V_{GS} = 0$



$$I_D = k_1 V_{GS} + k_2 V_{DS}$$

$$k_1 = g_m = \frac{2}{|V_P|} \sqrt{I_{DSS} I_{DS} (1 + \lambda V_{DS})}$$

$$k_2 = g_o = \frac{1}{r_o} = \frac{\lambda I_{DS}}{1 + \lambda V_{DS}}$$

