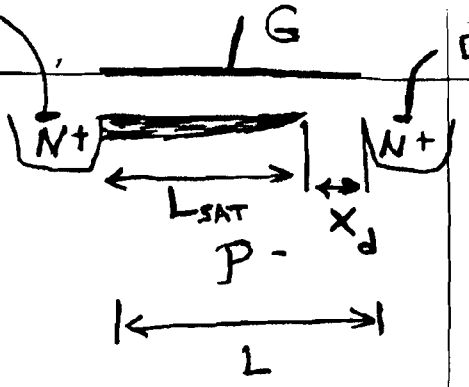
MOSFET r_o:

P. Hurst v2

Calculating λ:



X_d = depletion region length = $\sqrt{\frac{2\epsilon_{Si}}{qN_A}(V_{DS} - V_{DS_{SAT}} + \phi)}$

(channel ends at $V_{CHANNEL} = V_{GS} - V_T = V_{DS_{SAT}}$)

$$I_d = \frac{1}{2}\mu_n C_{ox}\frac{W}{L - X_d}(V_{gp} - V_T)^2$$

$$\frac{1}{r_o} = \left.\frac{\partial I_d}{\partial V_{ds}}\right|_{\text{op pt}} = \underbrace{\frac{1}{2}\mu_n C_{ox}\frac{W}{(L-X_d)^2}(V_{gp} - V_T)^2}\cdot\left.\frac{\partial X_d}{\partial V_{ds}}\right|_{\text{op pt}}$$

$$= \frac{I_D}{L - X_d}\cdot\frac{1}{2}\sqrt{\frac{2\epsilon_{Si}}{qN_A}}\left(V_{DS} - V_{DS_{SAT}} + \phi\right)^{-\frac{1}{2}}$$

$$= \frac{I_D}{L - X_d}\cdot\sqrt{\frac{\epsilon_{Si}}{2qN_A(V_{DS} - V_{DS_{SAT}} + \phi)}} = \lambda I_D$$

$$\Rightarrow \lambda = \frac{1}{L - X_d}\sqrt{\frac{\epsilon_{Si}}{2qN_A(V_{DS} - V_{DS_{SAT}} + \phi)}}$$

$$\underset{L \gg X_d}{\approx} \frac{1}{L}\sqrt{\frac{\epsilon_{Si}}{2qN_A(V_{DS} - V_{DS_{SAT}} + \phi)}}$$