MORE ABOUT CHANNEL-LENGTH MODULATION

- L CHANGES WITH V_{DS}. THE USUAL APPROXIMATION IS TO ASSUME A LINEAR DEPENDENCE:

$$L_{eff} \cong L - \left|\frac{\partial L}{\partial V_{DS}}\right| V_{DS}$$

$$I_D = I_{SQ}\frac{W}{L_{eff}}\left(i_f - i_r\right) \xrightarrow[\text{ACTIVE}]{\text{ASSUME}} I_D \simeq I_{SQ}\frac{W}{L_{eff}} i_f$$

(CHANNEL MODULATION USUALLY IGNORED IN TRIODE REGION)

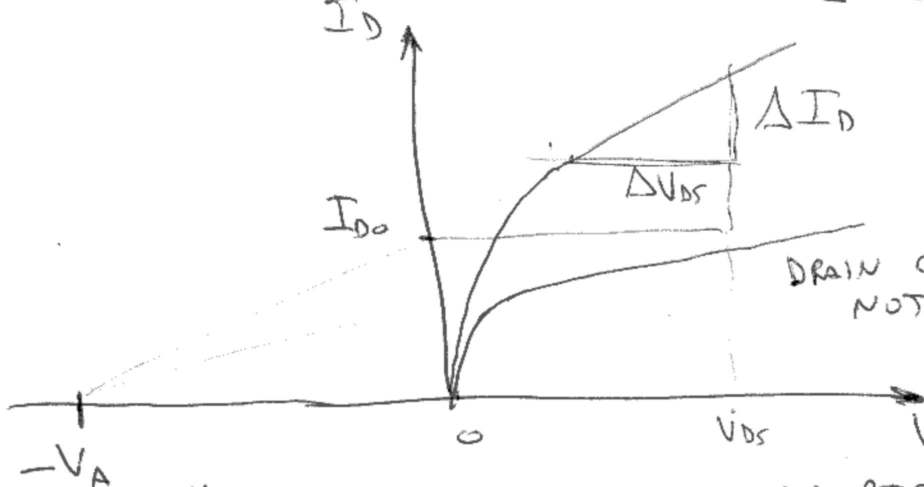
$$\frac{W}{L_{eff}} \cong \frac{W}{L - \left|\frac{\partial L}{\partial V_{DS}}\right| V_{DS}} \xrightarrow{\text{TAYLOR'S EXPANSION AROUND } V_{DS}=0} \frac{d\left(\frac{W}{L_{eff}}\right)}{dV_{DS}} = -\frac{W}{L_{eff}^2} \times \left(-\left|\frac{\partial L}{\partial V_{DS}}\right|\right)$$

$$\frac{W}{L_{eff}} \simeq \frac{W}{L} + \frac{W}{L^2} \times \left|\frac{\partial L}{\partial V_{DS}}\right| V_{DS}$$

$$= \frac{W}{L}\left(1 + \lambda V_{DS}\right) \quad \text{WITH:}$$

$$\lambda = \left|\frac{\partial L}{\partial V_{DS}}\right| \times \frac{1}{L}$$

$$\frac{1}{\lambda} = V_A \quad \text{EARLY VOLTAGE}$$



DRAIN CURRENT NOT CONSTANT DUE TO CHANNEL MODULATION

$$\frac{\Delta V_{DS}}{\Delta I_D} = \text{CONSTANT} = r_o \quad \text{OUTPUT RESISTANCE}$$

$$I_D = I_{SQ}\frac{W}{L} i_f \left(1 + \lambda V_{DS}\right) = I_{D0} + \overbrace{I_{D0}\lambda V_{DS}}^{\Delta I_D}$$

$$\therefore \frac{\Delta I_D}{\Delta V_{DS}} \simeq I_{D0}\lambda = \frac{I_{D0}}{V_A} = \frac{1}{r_o} \Rightarrow r_o = \frac{V_A}{I_D} = \frac{1}{\lambda I_D} = \frac{L}{\left|\frac{\partial L}{\partial V_{DS}}\right| I_D}$$