BJT Transistors

$$i_C = I_S e^{\frac{v_{BE}}{V_T}} (1 + \frac{v_{CE}}{V_A})$$

$$\beta = \frac{\alpha}{1-\alpha} \quad \alpha = \frac{\beta}{1+\beta}$$

$$i_C = \beta i_B = \alpha i_E$$

Small signal Parameters

$$g_m = \frac{I_C}{V_T}$$

$$r_\pi = \frac{\beta}{g_m} = \frac{V_T}{I_B}$$

$$r_e = \frac{\alpha}{g_m} = \frac{V_T}{I_E} \sim \frac{1}{g_m}$$

$$r_o = \frac{V_A}{I_C}$$

MOS Transistors

NMOS

Linear region

$$i_D = k_n\left[(v_{GS} - V_{tn})v_{DS} - \frac{1}{2}v_{DS}^2\right] for\ v_{DS} < v_{GS} - V_{tn}$$

Saturation

$$i_D = \frac{k_n}{2}(v_{GS} - V_{tn})^2(1 + \lambda v_{DS})\ for\ v_{DS} > v_{GS} - V_{tn}$$

PMOS

Linear region

$$i_D = k_p\left[\left(v_{SG} - |V_{tp}|\right)v_{SD} - \frac{1}{2}v_{SD}^2\right] for\ v_{SD} < v_{SG} - |V_{tp}|$$

Saturation

$$i_D = \frac{k_p}{2}\left(v_{SG} - |V_{tp}|\right)^2(1 + \lambda v_{SD})\ for\ v_{SD} > v_{SG} - |V_{tp}|$$

$$k_n = k_n'\left(\frac{W}{L}\right)_n \quad \& \quad k_p = k_p'\left(\frac{W}{L}\right)_p$$

$$k_n' = \mu_n C_{ox} \quad \& \quad k_p' = \mu_p C_{ox}$$

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}}$$