Diodes:

$i=I_S(exp(v/nV_T)-1)$

BJTs:

$$i_C = I_S \exp(v_{BE}/V_T)$$

$$i_B = \frac{i_C}{\beta}$$

$$i_E = \frac{i_C}{\alpha}$$

$$i_B = (1-\alpha) i_E = \frac{i_E}{\beta+1}$$

$$i_E = (\beta+1) i_B$$

$$g_m = \frac{I_C}{V_T} \quad r_e = \frac{V_T}{I_E} = \alpha \frac{V_T}{I_C} = \frac{\alpha}{g_m}$$

$$r_\pi = \frac{V_T}{I_B} = \frac{\beta}{g_m} \quad r_o = \frac{V_A}{I_C}$$

$$r_\pi = (\beta+1) r_e$$

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

FETs:

NMOS:

Cutoff: $V_{GS} < V_t \qquad I_D = 0$

Triode: $V_{GS} > V_t \qquad I_D = k'_n \frac{W}{L}\left[(V_{GS} - V_t)V_{DS} - \frac{1}{2}V_{DS}^2\right]$

$V_{DS} < V_{GS} - V_t$

Saturation: $V_{GS} > V_t$

$V_{DS} > V_{GS} - V_t \qquad I_D = \frac{1}{2}k'_n \frac{W}{L}(V_{GS} - V_t)^2(1 + \lambda V_{DS})$

Body effect: $V_t = V_{t0} + \gamma\left(\sqrt{2\phi_f + V_{SB}} - \sqrt{2\phi_f}\right)$

PMOS:

Cutoff: $V_{GS} > V_t \qquad I_D = 0$

Triode: $V_{GS} < V_t \qquad I_D = k'_p \frac{W}{L}\left[(V_{GS} - V_t)V_{DS} - \frac{1}{2}V_{DS}^2\right]$

$V_{DS} > V_{GS} - V_t$

Saturation: $V_{GS} < V_t$

$V_{DS} < V_{GS} - V_t \qquad I_D = \frac{1}{2}k'_p \frac{W}{L}(V_{GS} - V_t)^2(1 + \lambda V_{DS})$

Body effect: $|V_t| = |V_{t0}| + \gamma\left(\sqrt{2\phi_f + |V_{SB}|} - \sqrt{2\phi_f}\right)$

SMALL SIGNAL

$$g_m = \frac{2 \cdot I_D}{V_{GS} - V_t}$$

$$g_m = k_n' \frac{W}{L}\left(V_{GS} - V_t\right)\left(1 + \lambda \cdot V_{DS}\right)$$

$$g_m = \sqrt{2k_n'}\sqrt{\frac{W}{L}}\sqrt{1 + \lambda \cdot V_{DS}}\sqrt{I_D}$$

$$r_o = \frac{1}{\lambda \cdot I_D}$$

$$g_{mb} = \chi \cdot g_m$$

$$\chi = \frac{\gamma}{2} \cdot \frac{1}{\sqrt{2\phi_f + V_{SB}}}$$