Equation Sheet

Constants:

$V_T = \frac{kT}{q} \approx 25mV$ at room temperature $\qquad k = 1.38 \times 10^{-23} JK^{-1} \qquad q = 1.6 \times 10^{-19} C$

Diode equations:

General expression: $i_D = I_S(e^{v_D/nV_T} - 1)$

$$i_D = I_S e^{v_D/nV_T}$$

Forward biased region: $v_D = 2.303 nV_T \log(i_D/I_S)$

$$v_{D2} - v_{D1} = 2.303 nV_T \log(i_{D2}/i_{D1})$$

Small-signal resistance: $r_d = \frac{nV_T}{I_D}$

NMOS Transistor Equations:

Saturation (or active) region: $i_D = \frac{\mu_n C_{ox}}{2}\frac{W}{L}(v_{GS} - V_{tn})^2(1 + \lambda v_{DS})$

Triode region: $i_D = \mu_n C_{ox}\frac{W}{L}\left[(v_{GS} - V_{tn})v_{DS} - \frac{v_{DS}^2}{2}\right]$

Deep triode region: $r_{DS} = \frac{1}{\mu_n C_{ox}\frac{W}{L}(v_{GS} - V_{tn})}$

PMOS Transistor Equations:

Saturation (active) region: $i_D = \frac{\mu_p C_{ox}}{2}\frac{W}{L}(v_{GS} - V_{tp})^2(1 + \lambda v_{DS})$

Triode region: $i_D = \mu_p C_{ox}\frac{W}{L}\left[(v_{GS} - V_{tp})v_{DS} - \frac{v_{DS}^2}{2}\right]$

Deep triode region: $r_{DS} = \frac{1}{\mu_p C_{ox}\frac{W}{L}|v_{GS} - V_{tp}|}$

Small-signal transistor equations (for NMOS in Saturation):

Transconductance: $g_m = \sqrt{2\mu_n C_{ox}\frac{W}{L}I_D} = \mu_n C_{ox}\frac{W}{L}(V_{GS} - V_{tn}) = \frac{2I_D}{V_{GS} - V_{tn}}$

Output resistance $r_o = \frac{1}{\lambda I_D} = \frac{V_A}{I_D}$

For PMOS transistors: same formulas as for NMOS except using $|V_{OV}|$, $|V_A|$, $|\lambda|$, and μ_p