Equation Sheet

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General Semiconductor:

$$n_0 = n_i e^{\left(\frac{(E_F - E_{Fi})}{kT}\right)} \quad p_0 = n_i e^{\left(\frac{(E_{Fi} - E_F)}{kT}\right)} \quad n_i^2 = N_C N_V e^{\left(\frac{-E_g}{kT}\right)} = n_0 p_0 \quad V = IR \quad L_{n,p} = \sqrt{D_{n,p}\tau_{n,p}}$$

$$J_{drift} = \sigma E \quad \sigma = e(\mu_n n + \mu_p p) = \frac{1}{\rho} \quad J_{diff} = eD_n \frac{dn}{dx} - eD_p \frac{dp}{dx} \quad J = \frac{I}{A} \quad \frac{D}{\mu} = \frac{kT}{e} \quad \mu = \frac{e\tau_c}{m_c^*} = \frac{g_m L^2}{V_{DS} C_{ox}}$$

pn Junctions:

$$V_{bi} = \frac{kT}{e}\ln\left(\frac{N_a N_d}{n_i^2}\right) \quad x_n = \left[\frac{2\varepsilon_s\varepsilon_0}{e}\frac{N_a}{N_d(N_a+N_d)}V_{bi}\right]^{1/2} \quad x_p = \left[\frac{2\varepsilon_s\varepsilon_0}{e}\frac{N_d}{N_a(N_a+N_d)}V_{bi}\right]^{1/2}$$

$$W = \left[\frac{2\varepsilon_s\varepsilon_0}{e}\frac{N_a+N_d}{N_a N_d}V_{bi}\right]^{1/2} \quad W_{RB} = \left[\frac{2\varepsilon_s\varepsilon_0}{e}\frac{N_a+N_d}{N_a N_d}(V_{bi}+V_R)\right]^{1/2} \quad n_p(-x_p) = n_{p0} e^{\left(\frac{eV_a}{kT}\right)} \quad p_n(x_n) = p_{n0} e^{\left(\frac{eV_a}{kT}\right)}$$

$$\delta n_p(x) = n_{p0}\left[e^{\left(\frac{eV_a}{kT}\right)} - 1\right] e^{\left(\frac{x_p + x}{L_n}\right)} \quad \delta p_n(x) = p_{n0}\left[e^{\left(\frac{eV_a}{kT}\right)} - 1\right] e^{\left(\frac{x_n - x}{L_p}\right)} \quad E_{Fn} = E_{Fi} + kT\ln\left(\frac{n}{n_i}\right) \quad E_{Fp} = E_{Fi} - kT\ln\left(\frac{p}{n_i}\right)$$

$$J_{ID} = J_S\left(e^{\left(\frac{eV_a}{kT}\right)} - 1\right) \quad J_S = \frac{eD_p p_{n0}}{L_p} + \frac{eD_n n_{p0}}{L_n} \quad J_{rec} = \frac{eWn_i}{2\tau_0} e^{\left(\frac{eV_a}{2kT}\right)} \quad g_d = \frac{1}{r_d} = \frac{I_{DQ}}{V_t} \quad C_d = \frac{1}{2V_t}\left(I_{p0}\tau_{p0} + I_{n0}\tau_{n0}\right)$$

MOS Capacitors:

$$C'(acc) = C_{ox} = \frac{\varepsilon_{ox}\varepsilon_0}{t_{ox}} \quad C'(depl) = \frac{\varepsilon_{ox}\varepsilon_0}{t_{ox} + \left(\frac{\varepsilon_{ox}}{\varepsilon_s}\right)x_d} \quad C'_{\min} = \frac{\varepsilon_{ox}\varepsilon_0}{t_{ox} + \left(\frac{\varepsilon_{ox}}{\varepsilon_s}\right)x_{dT}} \quad C'_{FB} = \frac{\varepsilon_{ox}\varepsilon_0}{t_{ox} + \left(\frac{\varepsilon_{ox}}{\varepsilon_s}\right)\sqrt{V_t\left(\frac{\varepsilon_s\varepsilon_0}{eN_{a,d}}\right)}}$$

$$V_{FB} = \phi_{ms} - \frac{Q'_{ss}}{C_{ox}} \quad e\phi_s = E_{Fi}\big|_{bulk} - E_{Fi}\big|_{surf} \quad V_{TN} = \frac{|Q'_{SD}(\max)|}{C_{ox}} + V_{FB} + 2\phi_{fp} \quad V_{TP} = \frac{-|Q'_{SD}(\max)|}{C_{ox}} + V_{FB} - 2\phi_{fn}$$

p-type: $\phi_{ms} = \phi'_m - \left(\chi' + \frac{E_g}{2e} + \phi_{fp}\right) \quad \phi_{fp} = V_t\ln\left(\frac{N_a}{n_i}\right) \quad x_d = \left(\frac{2\varepsilon_s\varepsilon_0\phi_s}{eN_a}\right)^{1/2} \quad x_{dT} = \left(\frac{4\varepsilon_s\varepsilon_0\phi_{fp}}{eN_a}\right)^{1/2} \quad |Q'_{SD}(\max)| = eN_a x_{dT}$

n-type: $\phi_{ms} = \phi'_m - \left(\chi' + \frac{E_g}{2e} - \phi_{fn}\right) \quad \phi_{fn} = V_t\ln\left(\frac{N_d}{n_i}\right) \quad x_d = \left(\frac{2\varepsilon_s\varepsilon_0\phi_s}{eN_d}\right)^{1/2} \quad x_{dT} = \left(\frac{4\varepsilon_s\varepsilon_0\phi_{fn}}{eN_d}\right)^{1/2} \quad |Q'_{SD}(\max)| = eN_d x_{dT}$

MOSFETs:

$$g_m = \frac{\delta I_D}{\delta V_{GS}} \quad SS = \left(\frac{\delta(\log(I_D))}{\delta V_{GS}}\right)^{-1} \quad f_T = \frac{g_m}{2\pi(C_{gsT} + C_M)} = \frac{g_m}{2\pi C_G} \quad C_M = C_{gdT}(1 + g_m R_L)$$

p-type: $I_D = \frac{W\mu_p C_{ox}}{2L}\left[2(V_{SG} + V_T)V_{SD} - V_{SD}^2\right] \quad I_D(sat) = \frac{W\mu_p C_{ox}}{2L}(V_{SG} + V_T)^2 \quad K_p = \frac{W\mu_p C_{ox}}{2L} \quad k'_p = \mu_p C_{ox}$

n-type: $I_D = \frac{W\mu_n C_{ox}}{2L}\left[2(V_{GS} - V_T)V_{DS} - V_{DS}^2\right] \quad I_D(sat) = \frac{W\mu_n C_{ox}}{2L}(V_{GS} - V_T)^2 \quad K_n = \frac{W\mu_n C_{ox}}{2L} \quad k'_n = \mu_n C_{ox}$

$k = 8.62x10^{-5} eV/K = 1.38x10^{-23} J/K \quad h = 4.14x10^{-15} eV\cdot s = 6.63x10^{-34} J\cdot s \quad \hbar = \frac{h}{2\pi}$

$q = 1.602x10^{-19} C$ Si at T = 300 K: n_i = 1.5x10^{10} cm^{-3}, E_g = 1.12 eV, ε_s = 11.7 SiO_2: ε_{ox} = 3.9

kT = 0.026 eV at room temperature ε_0 = 8.85x10^{-14} F/cm