## Summary (extended Table 12.3)

### Emitter injection efficiency (12.31a), (12.35a), & (12.35b)

$$\gamma = \frac{J_{nE}}{J_{nE} + J_{pE}} \simeq \frac{1}{1 + \dfrac{p_{E0}\, D_E\, L_B}{n_{B0}\, D_B\, L_E} \dfrac{\tanh(x_B / L_B)}{\tanh(x_E / L_E)}} \approx \frac{1}{1 + \dfrac{N_B}{N_E} \dfrac{D_E}{D_B} \dfrac{x_B}{x_E}}$$

where $x_B << L_B$, $x_E << L_E$, & $V_t << V_{BE}$.

### Base transport factor (12.31b), (12.38), (12.39a), & (12.39b)

$$\alpha_T = \frac{J_{nC}}{J_{nE}} = \frac{e^{V_{BE}/V_t} + \cosh(x_B / L_B)}{1 + e^{V_{BE}/V_t} \cosh(x_B / L_B)} = \frac{1}{\cosh(x_B / L_B)} \approx \frac{1}{1 + \dfrac{1}{2}\left(\dfrac{x_B}{L_B}\right)^2}$$

where $x_B << L_B$ & $V_t << V_{BE}$.

### Recombination factor (12.31c) & (12.44)

$$\delta = \frac{J_{nE} + J_{pE}}{J_{nE} + J_R + J_{pE}} \approx \frac{1}{1 + \dfrac{J_{r0}}{J_{s0}} e^{-V_{BE}/2V_t}} \quad \text{when } J_{pE} << J_{nE}, \text{ and}$$

$J_{r0} = \dfrac{e\, x_{BE}\, n_i}{2\tau_0}$ (12.41), $\tau_0 = \dfrac{\tau_{E0} + \tau_{B0}}{2}$ (8.39), and $J_{s0} = \dfrac{e\, D_B\, n_{B0}}{L_B \tanh(x_B / L_B)}$ (12.43).

### Common-base current gain

$$\alpha = \frac{i_C}{i_E} = \frac{J_{nC}}{J_{nC} + J_R + J_{pE}} = \left(\frac{J_{nE}}{J_{nE} + J_{pE}}\right)\left(\frac{J_{nC}}{J_{nE}}\right)\left(\frac{J_{nE} + J_{pE}}{J_{nE} + J_R + J_{pE}}\right) = \gamma\, \alpha_T\, \delta$$

$$\approx \frac{1}{1 + \dfrac{N_B}{N_E} \dfrac{D_E}{D_B} \dfrac{x_B}{x_E} + \dfrac{1}{2}\left(\dfrac{x_B}{L_B}\right)^2 + \dfrac{J_{r0}}{J_{s0}} e^{-V_{BE}/2V_t}}$$

### Common-emitter current gain

$$\beta = \frac{i_C}{i_B} = \frac{\alpha}{1 - \alpha} \approx \frac{1}{\dfrac{N_B}{N_E} \dfrac{D_E}{D_B} \dfrac{x_B}{x_E} + \dfrac{1}{2}\left(\dfrac{x_B}{L_B}\right)^2 + \dfrac{J_{r0}}{J_{s0}} e^{-V_{BE}/2V_t}}$$

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