4.3

given condition: constant-field scaling

\[ L, W, (V_g - V_t) \sim \frac{1}{\kappa} \]

\[ C_{ox} = \frac{\varepsilon}{t_{ox}} \sim \kappa \]

\[ V_{sat} \sim 1 \]

\[
\begin{align*}
(1) \quad I_{total} &= C_{ox} W V_{sat} (V_g - V_t) \sqrt{\frac{1 + 2 \mu_{eff} (V_g - V_t)/ (mv_{sat} L) - 1}{1 + 2 \mu_{eff} (V_g - V_t)/ (mv_{sat} L) + 1}} \\
&= \frac{1}{\kappa} I_{total}
\end{align*}
\] (3.78)

\[
\begin{align*}
I_{scaled}^{dissipated} &= (\kappa)(1/\kappa)(1)(1/\kappa)(1) I_{total} = \frac{1}{\kappa} I_{total}
\end{align*}
\]

\[
\begin{align*}
(2) \quad I_{total} &= C_{ox} W V_{sat} (V_g - V_t) \\
&= \frac{1}{\kappa} I_{total}
\end{align*}
\]

4.9

\[ Q(V) = -q \int_{\psi_s}^{\psi} \left( \frac{n_i^2 / N_a}{\xi_s} \right) e^{\psi - V/kT} d\psi \] (3.12)

given conditions: 1) subthreshold region \( \rightarrow \) \( \xi(\psi, V) = \xi_s \)

2) low drain bias \( \rightarrow \) \( V = 0 \)

\[ Q(V) = -q \int_{\psi_s}^{0} \left( \frac{n_i^2 / N_a}{\xi_s} \right) e^{\psi - V/kT} d\psi = -q n_i^2 \frac{kT}{N_a \xi_s} \left[ e^{\psi + V/kT} \right]_{\psi}^{0} = -\frac{kT n_i^2}{\xi_s N_a} e^{\psi + V/kT} \]

5.2

\[ V_{dd} = RC \frac{dV(t)}{dt} + V(t) \]

(1) \( V: 0 \rightarrow V_{dd} \)

\[ V(t = 0) = 0, \quad V(t = \infty) = V_{dd} \]

\[ V(t) = V_{dd} (1 - e^{-t/RC}) \]

\[ E_{dissipated}^{dissipated} = \int_{0}^{\infty} i(t) v(t) dt = \int_{0}^{\infty} \left( \frac{V_{dd} - V(t)}{R} \right)^2 dt = \frac{V_{dd}^2}{R} \int_{0}^{\infty} e^{-2t/RC} dt = \frac{CV_{dd}^2}{2} \]

\[ E_{stored} = \frac{QV}{2} = \frac{CV_{dd}^2}{2} \]
(2) $V: V_{dd} \to 0$

The energy stored in $C$, $E_c^{stored}$, will be dissipated in the resistor.

5.3

(1) linear region

$$I_{ds} = \mu_{eff} C_w \frac{W}{L} (V_g - V_t) V_{ds}$$

$$C_g = W L C_w$$

$$Q = W L C_w (V_g - V_t)$$

$$\tau_t = Q / I = \frac{L^2}{\mu_{eff} V_{ds}}$$

(2) saturation

$$I_{ds} = \mu_{eff} C_w \frac{W}{L} \frac{(V_g - V_t)^2}{2m}$$

$$C_g = \frac{2}{3} W L C_w$$

$$Q = \frac{2}{3} W L C_w (V_g - V_t)$$

$$\tau_t = Q / I = \frac{4}{3} \frac{mL^2}{\mu_{eff} (V_g - V_t)}$$