Digital Integrated Circuits HW #3

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Exercise 2.1

Initial conditions:

$\frac{\mathrm{W}}{\mathrm{L}} = \frac{4}{2}\lambda = \frac{1.2}{0.6}\mu m,\ t_{ox} = 100 \times 10^{-8}\ cm$

$\mu_n = 350 cm^2/V$

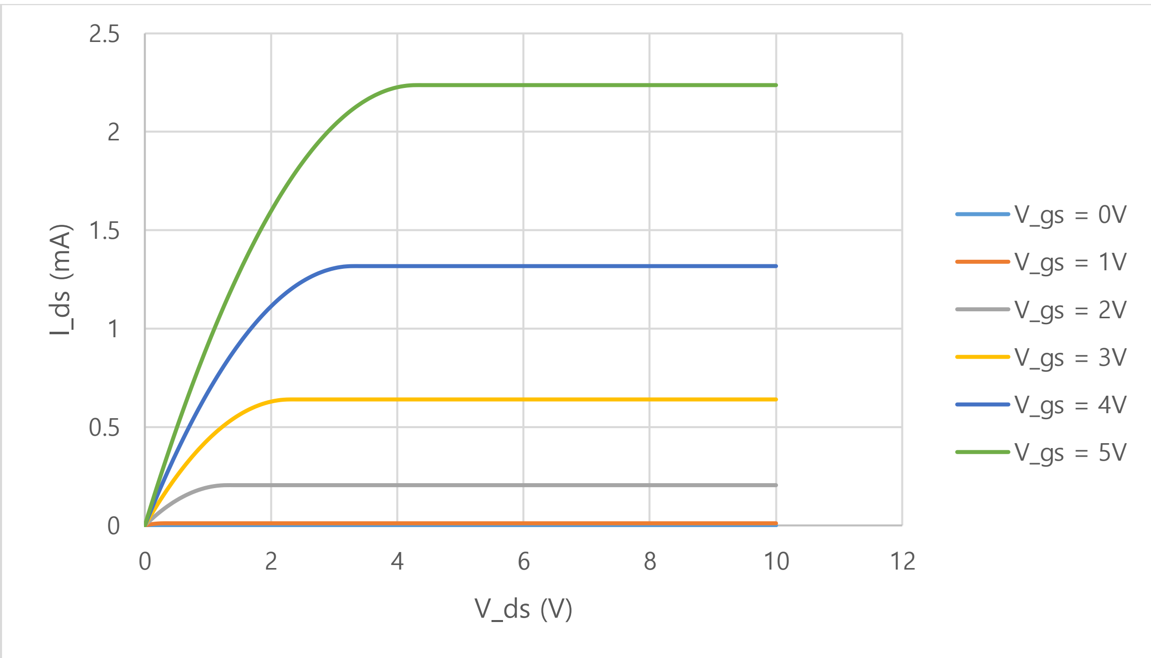
$V_t = 0.7V$

We can divide IV characteristics in 3 states. ($\beta = \mu_n C_{ox}\frac{W}{L} = 242\mu A/V^2$)

Subthreshold: $I_d = 0$ at $V_{gs} < V_t$

Linear region: $I_d = \beta\left(V_{gs} - V_t - \frac{V_{ds}}{2}\right)V_{ds}$ at $V_{gs} > V_t$ and $V_{ds} < V_{gs} - V_t$

Saturation region: $I_d = \frac{\beta}{2}(V_{gs} - V_t)^2$ at $V_{gs} > V_t$ and $V_{ds} > V_{gs} - V_t$



Exercise 2.2

In Fig 2.32 (a), the current is

$$I_{DS1} = \beta\left(V_{DD} - V_t - \frac{V_{DS}}{2}\right)V_{DS} \text{ --- ①}$$

In Fig 2.32 (b), the current is

$$I_{DS2} = \beta'\left(V_{DD} - V_t - \frac{V_1}{2}\right)V_1 = \beta'\left((V_{DD} - V_1) - V_t - \frac{V_{DS} - V_1}{2}\right)(V_{DS} - V_1) \text{ --- ②}$$

($\beta = \mu_n C_{ox}\frac{W}{2L}$, $\beta' = \mu_n C_{ox}\frac{W}{L}$)

Using equation of ②, find V_1 value.

$$V_1 = (V_{DD} - V_t) - \sqrt{(V_{DD} - V_t)^2 - \left(V_{DD} - V_t - \frac{V_{DS}}{2}\right)V_{DS}} \text{ --- ③}$$

(The lower transistor on (b) is in the linear region so $V_1 < V_{DD} - V_t$ should be satisfied.

V_1 is not $(V_{DD} - V_t) + \sqrt{(V_{DD} - V_t)^2 - \left(V_{DD} - V_t - \frac{V_{DS}}{2}\right)V_{DS}}$ because of $V_1 > V_{DD} - V_t$.)

Insert the equation of ③ in $I_{DS2} = \beta'\left(V_{DD} - V_t - \frac{V_1}{2}\right)V_1$.

Then, $I_{DS2} = I_{DS1}$.

Exercise 2.3

The single transistor in (a) and the bottom transistor in (b) are not affected by body effect because of $V_{sb} = 0$. However, the threshold voltage of the top transistor in (b) would be raised because of $V_{sb} > 0$. Therefore, the overdrive voltage would be decreased and the current would be decreased. Therefore, $I_{DS2} < I_{DS1}$.

Exercise 2.4

$$C_{permicron} = \frac{\varepsilon_{ox}}{t_{ox}} L = \frac{3.9 \times 8.85 \times 10^{-14}\ (F/cm)}{16 \times 10^{-10}\ (m)} \times 90 \times 10^{-7}\ (cm) = 1.94 \times 10^{-9}\ F/m$$

Exercise 2.5

Unit-size diffusion contact: $4 \times 5\ \lambda = 1.2 \times 1.5\ \mu\mathrm{m}$ -> Area: $1.8\mu m^2$, Perimeter: $5.4\mu\mathrm{m}$

$$C_{db}(at\ 0V) = 1.8\ \times 0.42 + 5.4 \times 0.33 = 2.54fF$$

$$C_{db}(at\ 5V) = 1.8 \times 0.42 \times (1 + \frac{5}{0.98})^{-0.44} + 5.4 \times 0.33 \times (1 + \frac{5}{0.98})^{-0.12} = 1.78fF$$

Drawing Potential Graph

$$I_d = WC_{ox}[V_g - V(x) - V_t]\mu_n \frac{dV(x)}{dx}$$

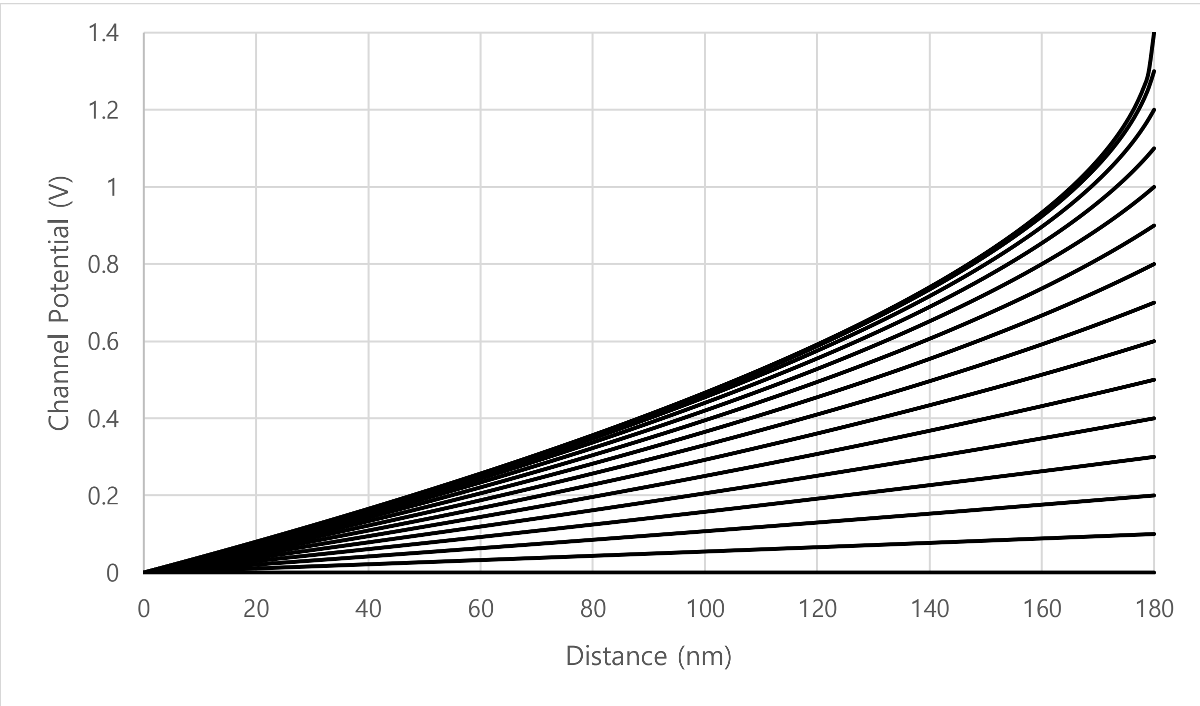
$$\int_0^x \frac{I_d}{\mu_n W C_{ox}}\, dx = \int_0^{V_x} [V_g - V(x) - V_t] dV(x)$$

$$\frac{I_d}{\mu_n W C_{ox}} x = -\frac{1}{2}\left(V_g - V_x - V_t\right)^2 + \frac{1}{2}(V_g - V_t)^2$$

$$V_x = \left(V_g - V_t\right) \pm \sqrt{(V_g - V_t)^2 - \frac{2I_d}{\mu_n W C_{ox}} x}$$

$$V_x = \left(V_g - V_t\right) - \sqrt{(V_g - V_t)^2 - \frac{2I_d}{\mu_n W C_{ox}} x} \quad \text{because of } V_x < V_g - V_t$$

$$V_x = \left(V_g - V_t\right) - \sqrt{(V_g - V_t)^2 - \frac{2\left(V_g - V_t\right)V_{ds} - {V_{ds}}^2}{L} x}$$



This graph shows the relationship between channel potential and distance at $V_{ds} = 0V$ to 1.4V.