

SOLUTIONS

PROBLEMS 2

$$1) C_{BL} = C_{dm} W_3 = \underline{\underline{0.5 \text{ fF}}}$$

$$C_{\bar{BL}} = C_{BL} = 0.5 \text{ fF}$$

$$C_A = C_{gu} (W_2 + W_6) + C_{dm} (W_1 + W_3 + W_5)$$

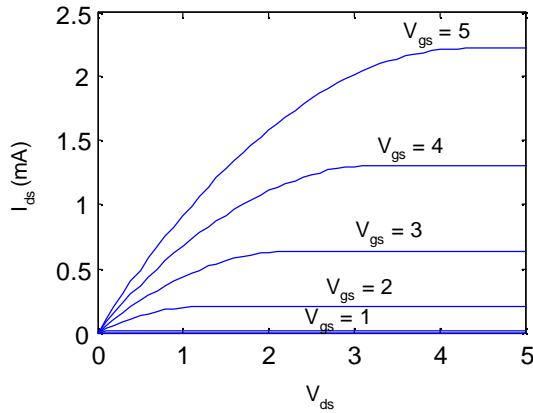
$$= 3 \text{ fF} + 2 \text{ fF}$$

$$= \underline{\underline{5 \text{ fF}}}$$

$$C_B = C_A = \underline{\underline{5 \text{ fF}}}$$

2.1

$$\mathbf{b} = \mathbf{m}C_{ox} \frac{W}{L} = (350) \left(\frac{3.9 \cdot 8.85 \cdot 10^{-14}}{100 \cdot 10^{-8}} \right) \left(\frac{W}{L} \right) = 120 \frac{W}{L} \mathbf{mA}/V^2$$



2.2 In (a), the transistor sees $V_{gs} = V_{DD}$ and $V_{ds} = V_{DS}$. The current is

$$I_{DS1} = \frac{\mathbf{b}}{2} \left(V_{DD} - V_t - \frac{V_{DS}}{2} \right) V_{DS}$$

In (b), the bottom transistor sees $V_{gs} = V_{DD}$ and $V_{ds} = V_1$. The top transistor sees $V_{gs} = V_{DD} - V_1$ and $V_{ds} = V_{DS} - V_1$. The currents are

$$I_{DS2} = \mathbf{b} \left(V_{DD} - V_t - \frac{V_1}{2} \right) V_1 = \mathbf{b} \left((V_{DD} - V_1) - V_t - \frac{(V_{DS} - V_1)}{2} \right) (V_{DS} - V_1)$$

Solving for V_1 , we find

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

Substituting V_1 into the I_{DS2} equation and simplifying gives $I_{DS1} = I_{DS2}$.

2.3 The body effect does not change (a) because $V_{sb} = 0$. The body effect raises the threshold of the top transistor in (b) because $V_{sb} > 0$. This lowers the current through the series transistors, so $I_{DS1} > I_{DS2}$.

2.4 $C_{\text{permicron}} = \epsilon L / t_{ox} = 3.9 * 8.85e-14 \text{ F/cm} * 90e-7 \text{ cm} / 16e-4 \mu\text{m} = 1.94 \text{ fF}/\mu\text{m}$.

- 2.5 The minimum size diffusion contact is $4 \times 5 \lambda$, or $1.2 \times 1.5 \mu\text{m}$. The area is $1.8 \mu\text{m}^2$ and perimeter is $5.4 \mu\text{m}$. Hence the total capacitance is

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

At a drain voltage of VDD, the capacitance reduces to

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

- 2.6 The new threshold voltage is found as

$$f_s = 2(0.026) \ln \frac{2 \cdot 10^{17}}{1.45 \cdot 10^{10}} = 0.85V$$

$$g = \frac{100 \cdot 10^{-8}}{3.9 \cdot 8.85 \cdot 10^{-14}} \sqrt{2(1.6 \cdot 10^{-19})(11.7 \cdot 8.85 \cdot 10^{-14})(2 \cdot 10^{17})} = 0.75V^{1/2}$$

$$V_t = 0.7 + g(\sqrt{f_s + 4} - \sqrt{f_s}) = 1.66V$$

The threshold increases by 0.96 V.

- 2.7 No. Any number of transistors may be placed in series, although the delay increases with the square of the number of series transistors.
- 2.8 The threshold is increased by applying a negative body voltage so $V_{sb} > 0$.
- 2.9 (a) $(1.2 - 0.3)2 / (1.2 - 0.4)2 = 1.26$ (26%)

$$(b) \frac{e^{\frac{-0.3}{1.4 \cdot 0.026}}}{e^{\frac{-0.4}{1.4 \cdot 0.026}}} = 15.6$$

$$(c) v_T = kT/q = 34 \text{ mV}; \frac{e^{\frac{-0.3}{1.4 \cdot 0.034}}}{e^{\frac{-0.4}{1.4 \cdot 0.034}}} = 8.2; \text{ note, however, that the total leakage}$$

will normally be higher for both threshold voltages at high temperature.

- 2.10 The current through an ON transistor tends to decrease because the mobility goes down. The current through an OFF transistor increases because V_t decreases. A chip will operate faster at low temperature.