7.2) $V_m = 1.3\,V$ $\quad V_{DD} = 3V$ $\quad V_{Tn} = 0.6$ $\quad |V_{Tp}| = 0.82$

$k'_n = 110\,\mu A/V^2$ $\quad \mu_n = 2.2\,\mu_p$

$$\frac{\beta_n}{\beta_p} = \left(\frac{V_m - V_{DD} + |V_{Tp}|}{V_{Tn} - V_m}\right)^2 = \left(\frac{1.3 - 3 + 0.82}{0.6 - 1.3}\right)^2 = \boxed{1.58}$$

$$\frac{\beta_n}{\beta_p} = \frac{\mu_n C_{ox} \left(\frac{W}{L}\right)_n}{\mu_p C_{ox} \left(\frac{W}{L}\right)_p} = 2.2\,\frac{\left(\frac{W}{L}\right)_n}{\left(\frac{W}{L}\right)_p} = 1.58$$

$$\boxed{1.39 \cdot \left(\frac{W}{L}\right)_n = \left(\frac{W}{L}\right)_p}$$

prob 7.3 from text

$\beta_n = 2.1\ mA/V^2$

$V_{Tn} = 0.6V$

$V_{DD} = 5V$

$C_{FET} = 74 fF$

$\beta_p = 1.8\ mA/V^2$

$V_{Tp} = -0.7V$

(a) Find V_{th} (or V_M)

$$V_{th} = \frac{V_{DD} - |V_{Tp}| + \sqrt{\frac{\beta_n}{\beta_p}} V_{Tn}}{1 + \sqrt{\frac{\beta_n}{\beta_p}}} = \frac{5v - 0.7 + 1.08 \cdot 0.6}{1 + 1.08}$$

$$\boxed{V_{th} = 2.38\ V}$$

(b) Find R_n & R_p

$$R_n = \frac{1}{\beta_n (V_{DD} - V_{Tn})} = 108.2\ \Omega$$

$$R_p = \frac{1}{\beta_p (V_{DD} - |V_{Tp}|)} = 129.2\ \Omega$$

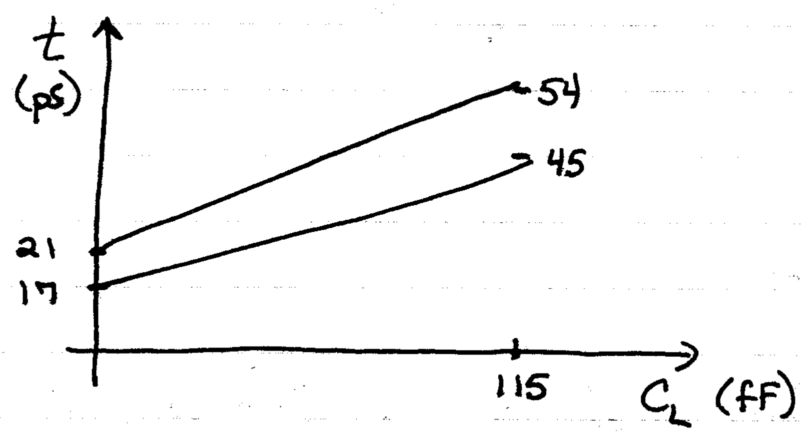
(c) $t_{HL} \approx 2.2\ \tau_n = 2.2\ R_n C_{FET} = 17.6\ ps$

$t_{LH} \approx 2.2\ \tau_p = 2.2\ R_p C_{FET} = 21.03\ pS$

(d) $t_{HL} = 2.2\ R_n (C_{FET} + C_L) = 44.9\ ps$

$t_{LH} = 2.2\ R_p (C_{FET} + C_L) = 54.1\ ps$

(e)



$\alpha_n = 2.2\ R_n = 237\ \Omega$

$\alpha_p = 2.2\ R_p = 286\ \Omega$

Problem 3

$t_{ox} = 150 \times 10^{-10} m$

$V_{DD} = 3V$

$\mu_n = 580\ cm^2/V\text{-}s$

$V_{TOn} = 0.75\ V$

$\left(\frac{W}{L}\right)_n = 12$

$\mu_p = 235\ \frac{cm^2}{V\text{-}s}$

$V_{TOp} = -0.8V$

$\left(\frac{W}{L}\right)_p = 12$

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = \frac{(3.9)(8.854 \times 10^{-14})}{150 \times 10^{-8} cm} = 2.3\ fF/\mu m^2$$

$$\beta_n = \mu_n C_{ox} \left(\frac{W}{L}\right)_n = \left(580\ \frac{cm^2}{V\text{-}s}\right)\left(\frac{100 \times 10^6 \mu m^2}{1 cm^2}\right)\left(2.30\ fF/\mu m^2\right)(12) = 1.6\ \frac{mA}{V^2}$$

$$\beta_p = \mu_p C_{ox} \left(\frac{W}{L}\right)_p = \left(235\ \frac{cm^2}{V\text{-}s}\right)\left(\frac{100 \times 10^6 \mu m^2}{1 cm^2}\right)\left(2.3\ \frac{fF}{\mu m^2}\right)(12) = 648\ \frac{\mu A}{V^2}$$

(a) $V_{th} = \dfrac{V_{DD} - |V_{Tp}| + \sqrt{\frac{\beta_n}{\beta_p}}\, V_{Tn}}{1 + \sqrt{\frac{\beta_n}{\beta_p}}} = \boxed{1.31\ V}$

(b) FIND V_{IL} & V_{IH}

V_{IL}:
$$\frac{\beta_n}{2}(V_{IL} - V_{Tn})^2 = \frac{\beta_p}{2}\left[2(V_{DD} - V_{IL} - |V_{Tp}|)(V_{DD} - V_{OUT}) - (V_{DD} - V_{OUT})^2\right]$$

$$V_{IL}\left(1 + \frac{\beta_n}{\beta_p}\right) = 2V_{OUT} - |V_{Tp}| + \frac{\beta_n}{\beta_p} V_{Tn}$$

Use Maple to solve simultaneously

$\boxed{V_{IL} = 1.09\ V}$

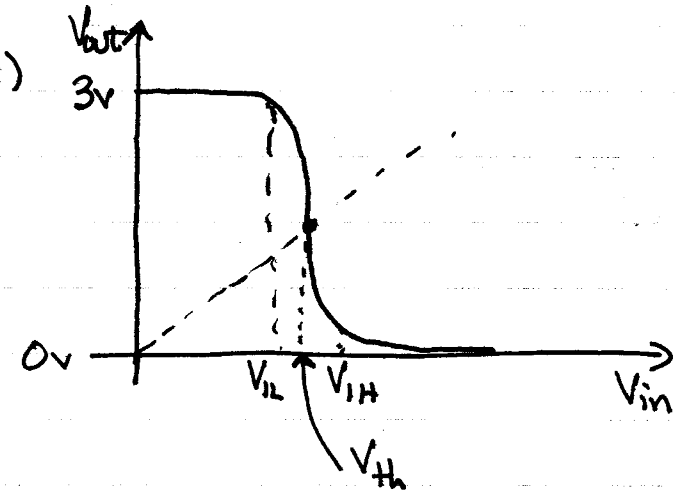
V_{IH}:
$$\frac{\beta_n}{2}\left(2(V_{IH} - V_{Tn})(V_{out}) - V_{out}^2\right) = \frac{\beta_p}{2}(V_{DD} - V_{IH} - |V_{Tp}|)^2$$

$$V_{IH}\left(1 + \frac{\beta_p}{\beta_n}\right) = 2V_{out} + V_{Tn} + \frac{\beta_p}{\beta_n}(V_{DD} - |V_{Tp}|)$$

Use Maple

$\boxed{V_{IH} = 1.44\ V}$

(c)



$V_{IL} = 1.09V$

$V_{th} = 1.31V$

$V_{IH} = 1.44V$

(D) Assuming $C_{out} = 140\ fF$

$$t_{HL} = 2.2 R_n C_{out} = \frac{2.2(140\times10^{-15})}{(1.6\times10^{-3})(2.25)} = \boxed{86\ ps}$$

$$t_{LH} = 2.2 R_p C_{out} = \frac{2.2(140\times10^{-15})}{(648\times10^{-6})(2.2)} = \boxed{216\ ps}$$

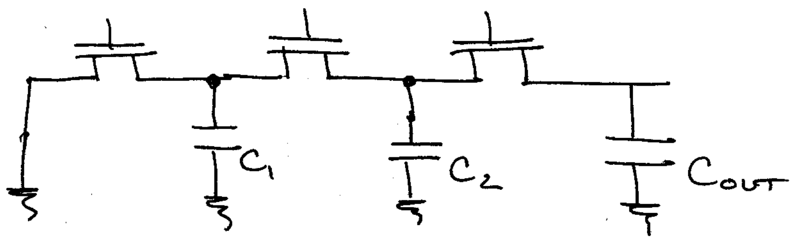
7.8) $\frac{1}{2.2}\beta_p = \beta_n$

$$V_M = \frac{V_{DD} - |V_{Tp}| + 2\sqrt{\frac{\beta_n}{\beta_p}}\, V_{Tn}}{1 + 2\sqrt{\frac{\beta_n}{\beta_p}}}$$

$$\frac{\beta_n}{\beta_p} = \frac{1}{2.2} \qquad \sqrt{\frac{\beta_n}{\beta_p}} = 0.674$$

$$V_M = \frac{3.3 - 0.8 + 2(0.674)\,0.65}{1 + 2(0.674)} = \boxed{1.43\text{ V}}$$

7.10



$C_1 = 36\ fF$
$C_2 = 36\ fF$
$C_{OUT} = 130\ fF$

$\beta_n = 2.0\ mA/V^2$
$V_{DD} = 3.3\ V$
$V_{Tn} = 0.7\ V$

$$R_n = \frac{1}{\beta_n (V_{DD} - V_{Tn})} = 192\ \Omega$$

(a) USING ELMORE

$$\tau = C_{OUT}(3R_n) + C_2(2R_n) + C_1 R_n$$

$$= 7.48 \times 10^{-11}\ s + 1.38 \times 10^{-11}\ s + 6.91 \times 10^{-12}\ s$$

$$= 95.53\ ps$$

(b) $\tau = C_{OUT}(3R_n) = 7.48 \times 10^{-11}\ s = 74.8\ ps$

% difference : $\frac{95.53 - 74.8}{95.53} = 22\%$