HW-2

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Q1

a

As $V_{GS} = V_{DD} - V_{OH}$ and only when $V_{OH} \leq V_{DD} - V_{Th}$ could guarentee the transistor is turned on. And the maximum value is the output voltage before t = 0.

$$\begin{aligned} V_{OH} &= V_{DD} - V_{Th} \\ &= V_{DD} - V_{T0} - \gamma(\sqrt{2|\phi_F| + V_{OH}} - \sqrt{2|\phi_F|}) \\ &= \end{aligned} \tag{1}$$

c

When $t \to \infty$,

$$\begin{aligned} V_{out} &= I_{DSAT} R_{SW} \\ &= \frac{1}{2}\kappa[V_{DD} - V_{out} - V_{T0} - \gamma(\sqrt{2|\phi_F| + V_{out}} - \sqrt{2|\phi_F|})]^2 R_{SW} \\ &= \end{aligned} \tag{2}$$

b

As informed in the question, V_{Th} is constant and is the average of its maximum and minimum, which is

$$\begin{aligned} V_{Th} &= V_{T0} + \frac{1}{2}\gamma(\sqrt{2|\phi_F| + V_{OH}} + \sqrt{2|\phi_F| + V_{OH}/2}) - \gamma\sqrt{2|\phi_F|} \\ &= \end{aligned} \tag{3}$$

As $V_{out} = V_{OH} \to V_{OH}/2$, $V_{DS} = V_{DD} - V_{OH} \to V_{DD} - V_{OH}/2$. Thus,

$$\begin{aligned} R_{eq} &= \frac{1}{2}\left[\frac{V_{DD} - V_{OH}}{\frac{1}{2}\kappa(V_{DD} - V_{OH} - V_{Th})^2} + \frac{V_{DD} - V_{OH}/2}{\frac{1}{2}\kappa(V_{DD} - V_{OH}/2 - V_{Th})^2}\right] \\ &= \frac{V_{DD} - V_{OH}}{\kappa(V_{DD} - V_{OH} - V_{Th})^2} + \frac{V_{DD} - V_{OH}/2}{\kappa(V_{DD} - V_{OH}/2 - V_{Th})^2} \\ &= \end{aligned} \tag{4}$$

Q2

$$
\begin{aligned}
V_X =& V_{DD} - I_{SD}R_1 \\
=& V_{DD} + \frac{1}{2}\kappa\frac{W}{L}(V_X - V_{in} + V_{T0})^2(1+\lambda V_X)R_1 \\
=&
\end{aligned} \tag{5}
$$

a

b

$$
\frac{W}{L} = 3.24 \tag{6}
$$

Q3

a

$$
\begin{aligned}
t_{pLH} &= R_{eq}C_L ln\frac{V_{DD}}{V_{DD} - V_{out}} \\
&= R_{eq}C_L ln\frac{2V_{DD}}{V_{DD} + V_{Tn}} \\
&= \frac{3V_{DD}R_{eq}C_L}{2\kappa\frac{W}{L}(V_{DD} - V_{Tn})^2}(1 - \frac{5}{6}\lambda V_{DD}) ln\frac{2V_{DD}}{V_{DD} + V_{Tn}} \\
&=
\end{aligned} \tag{7}
$$

b

$$
\begin{aligned}
\Delta t_{pLH} &= 0.69R_{eq}C_0W_0 \\
&= t_0
\end{aligned} \tag{8}
$$

c

$$
\begin{aligned}
t_{pHL} &= 0.69RC_L \\
&= 1.735 \times 10^{-6}(s)
\end{aligned} \tag{9}
$$

d

With $\beta_n = \beta_p$, and $|\gamma_n| = |\gamma_p|$ with $|\lambda_n| = |\lambda_p|$ from the table coming with questions. $\frac{t_{pLH,n}}{t_{pLH,p}}$ becomes,

$$
\begin{aligned}
\frac{t_{pLH,n}}{t_{pLH,p}} &= \frac{R_{eq,n}}{R_{eq,p}}\frac{ln\frac{2V_{DD}}{V_{DD}+V_{Tn}}}{ln\frac{2V_{DD}}{V_{DD}+V_{Tp,0}}} \\
&= \frac{(V_{DD} - V_{Tp,0})^2(1 - \frac{5}{6}\lambda_n V_{DD}) ln\frac{2V_{DD}}{V_{DD}+V_{Tn}}}{(V_{DD} - V_{Tn})^2(1 - \frac{5}{6}\lambda_p V_{DD}) ln\frac{2V_{DD}}{V_{DD}+V_{Tp,0}}}
\end{aligned} \tag{10}
$$

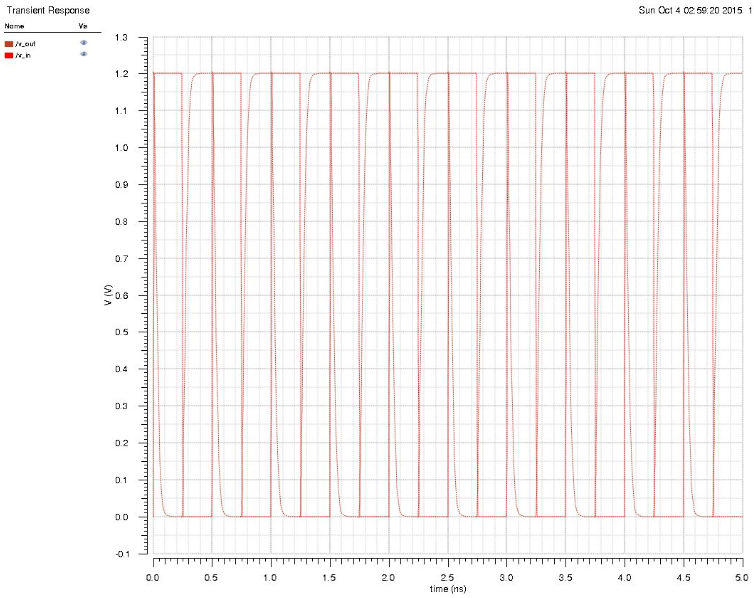

Figure 1: Q4_b

Q4

a

For $V_M = 0.5V_{DD}$, $\frac{W_n}{W_p} = \frac{90}{127.50575} \approx \frac{90}{127.5}$.
(((The following table need to be ploted!!!)))

90/90	0.5576
90/100	0.5715
90/110	0.5819
90/120	0.5925
90/127.5	0.6
90/140	0.6116
90/150	0.6202
90/160	0.6283
90/170	0.6357

b

For high-to-low delay equals low-to-high delay, $\frac{W_n}{W_p} = \frac{90}{135.75}$.

c

(((The following table need to be ploted)))

D_input(ps)	t_pHL
0.1	n/c
50	n/c
100	n/c
150	n/c
200	n/c
500	n/c