RW14
05/18/04b
P.1

EE302 – final exam solution

#1 a) To minimize M_n current, $W_n = 5\mu$

Both M_n & M_p are in saturation due to D=G:

$$I_{D_n} = \frac{KP_n}{2} \cdot \frac{W_n}{L_n}(V_{ref} - VTO_n)^2 = \frac{250}{3\times 2}\times 10^{-6} \times \frac{5}{10}\left(2.5 - \frac{0.3}{1.5}\right)^2$$

$$= I_{S_p} = \frac{KP_p}{2}\frac{W_p}{10\mu}(V_{dd} - V_{ref} - |VTO_p|)^2 = \frac{250}{5\times 2}\times 10^{-6}\frac{W_p}{10\mu}(V_{dd} - V_{ref} - 0.3)^2$$

$$\therefore \frac{W_p}{10\mu} = \frac{5}{2\times 3}(V_{ref} - 0.2)^2/(V_{dd} - V_{ref} - 0.3)^2 = \frac{5}{6}(2.5 - 0.2)^2/(2.5 - 0.3)^2$$

$$= \frac{5}{6}\cdot\left(\frac{2.3}{2.2}\right)^2 = 0.911 \Rightarrow W_p = 9.1\mu$$

b) $$I_{D_{na}} = \frac{KP_n}{2}\frac{W_{na}}{10\mu}(V_{ref} - 0.2)^2 = \frac{250}{3\times 2}\times 10^{-6}\times\frac{W_{na}}{10\mu}(2.3)^2 = 0.2\times 10^{-3}\text{ amp}$$

$$\Rightarrow W_{na} = 10\mu \times \left(\frac{0.2\times 10^{-3}\times 2\times 3}{250\times 10^{-6}\times(2.3)^2}\right) = 10\mu\times 10^{3}\times 0.00454\times 0.2$$

$$= 9.08\mu$$

$$I_{S_p} = \frac{KP_p}{2}\frac{W_{pa}}{10\mu}(V_{DD} - V_{ref} - |VTO_p|)^2 = \frac{50\times 10^{-6}}{2}\frac{W_{pa}}{10\mu}(2.5 - 0.3)^2 = 0.2\times 10^{-3}$$

$$\Rightarrow W_{pa} = 10\mu \times \left(\frac{0.2\times 10^{-3}\times 2}{50\times 10^{-6}(2.2)^2}\right) = 10\mu\times 10^{3}\times 0.008264\times 0.2$$

$$= 16.52\mu$$

Note: these are large since KP's are for a "small" technology where currents are normally μamps

This assumes any loads on M_{na} & M_{pa} keeps them in saturation

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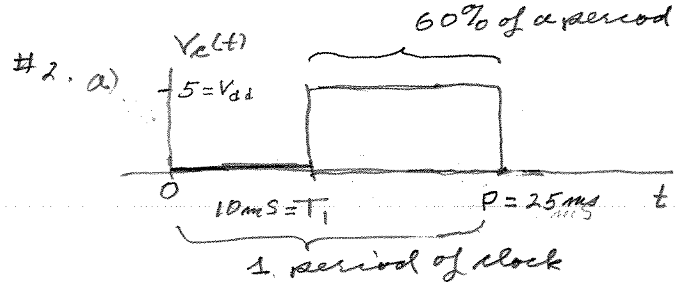
#2. a)



$T_1 = 0.4$ Period $\Rightarrow P = \frac{10}{0.4} = 25\,ms$

b) as $V_a = V_{dd} \geq$ any other voltage $\geq V_b$ then $V_a - V_b \geq 0$
$\Rightarrow V_a$ is always the drain, never the source.

c) at $t=0$, $V_c = V_{gate} = V_b = V_{source}$ or $V_{GS} = 0 < VTO_n$
so M_{pass} is <u>cutoff</u>

d) as $V_c = V_{dd}$ is possible, M_{pass} can be on whenever
$V_c - v \geq V_{th}$ or $v \leq V_{dd} - V_{th} \leq 5 - 1 = 4v$.
due to V_{ab}, $V_{th} = VTO_n + \gamma(\sqrt{2\phi_s + V_{SB}} - \sqrt{2\phi_s}) \geq VTO_n$
@ $V_{ab} = VTO_n = 0.2 + 0.01(\sqrt{0.8} - \sqrt{0.6}) = 0.2 + 0.0012$ $\quad 0.3/1.5 = 0.2$
$\therefore v_{max} = 4.799 \approx 4.8 = V_{dd} - VTO_n \Rightarrow$ achieved as $t \to \infty$ or long period clock

e) M_{pass} is cutoff for $0 < t < T_1$
M_{pass} is saturated for $T_1 < t < P$ since $V_D = V_G$

$\therefore$

$$i_\ell = C_\ell \frac{dv}{dt} = \begin{cases} 0 & \text{for } 0<t<T_1 \quad (M_{pass} \text{ cut off}) \\ \frac{KP_n}{2}\frac{W_{pass}}{L_{pass}}(V_C - V_{th})^2 - \frac{1}{R_\ell}v & \text{for } T_1 < t < P \end{cases}$$

where $V_{th} = VTO_n + \gamma(\sqrt{2\phi_s + V_{SB}} - \sqrt{2\phi_s})$, $V_c = 5$
$= 1 + 0.01(\sqrt{0.6+v} - \sqrt{0.6})$

thus

$$20\times10^{-12}\frac{dv}{dt} = \begin{cases} 0 & t < T_1 \\ \frac{250\times10^{-6}}{3\times2}\times\frac{40}{10}(5 - 0.2 - 0.01(\sqrt{0.6+v} - \sqrt{0.6}))^2 - 10^{-5}v \end{cases}$$

or

$$\frac{dv}{dt} = \begin{cases} 0 \\ 8.33\times10^{6}(4.8 - 0.01(\sqrt{0.6+v} - \sqrt{0.6}))^2 - 0.5\times10^6 v, & t > T_1 \end{cases}$$

$v(T_1) = 0$