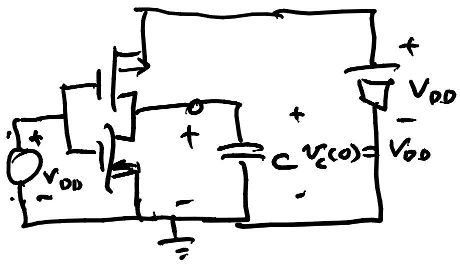
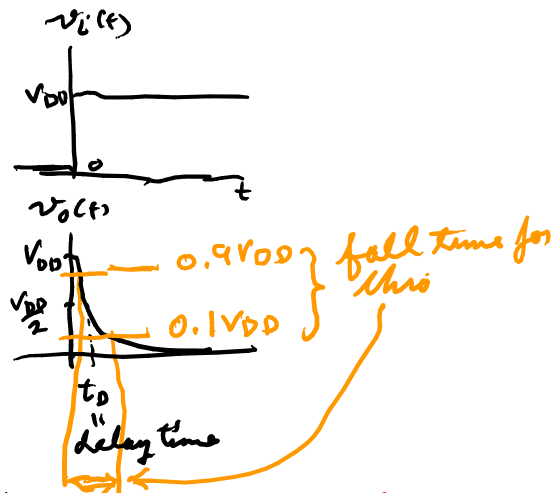
Today's homework now due Th

EE 303
03/02/10

$$t_2 - t_1 = \frac{1}{\frac{KP}{2}\frac{W}{L}\cdot\frac{2}{C}(V_{DD}-V_{TO})}\cdot\left[\ln\left(1-\frac{2(V_{DD}-V_{TO})}{v_o(t_2)}\right) - \ln\left(1-\frac{2(V_{DD}-V_{TO})}{v_o(t_1)=}\right)\right]$$





$$t_2 - t_1 = \frac{C}{\frac{KP}{2}\frac{W}{L}\cdot 2(V_{DD}-V_{TH})}\ln\left[\frac{(v_o(t_2)-2(V_{DD}-V_{TO})}{(v_o(t_1)-2(V_{DD}-V_{TO})}\cdot\frac{v_o(t_1)}{v_o(t_2)}\right]$$ when in ohmic

$$t_1 = \frac{C\,V_{TO}}{I_D}$$ when in saturation

numerical evaluation

$V_{DD}=9$, $V_{TO}=0.8 = V_{TH}$, $C=10\,pF$, $W/L=1$, $KP=2\times10^{-5}$

$V_{DD}-V_{TO}=8.2$, $0.1\times V_{DD}=0.9$, $0.9\times V_{DD}=8.1$

$$I_D = \frac{KP}{2}\frac{W}{L}(V_{DD}-V_{TO})^2 = 10^{-5}\times(8.2)^2$$

$$t_1 = \frac{10\times10^{-12}\cdot(0.8)}{10^{-5}\times(8.2)^2} = 10^{-6}\times\frac{(0.8)}{(8.2)^2} = 0.0119\times10^{-6} = 0.0119\,\mu sec$$

delay time $= t_2 - t_1 + t_1$ for $v(t_2)=V_{DD}/2$, $v(t_1)=V_{DD}-V_{TO}$

$$t_2 - t_1 = \frac{C}{\frac{KP}{2}\cdot 2(V_{DD}-V_{TO})}\times\ln\left[\frac{\frac{V_{DD}}{2}-2(V_{DD}-V_{TO})}{(V_{DD}-V_{TO})-2(V_{DD}-V_{TO})}\cdot\frac{V_{DD}-V_{TO}}{V_{DD}/2}\right]$$

$$= \frac{10\times10^{-12}}{2\times10^{-5}(8.2)}\cdot\ln\left[\frac{4.5-2(8.2)}{-2}\cdot\frac{1}{4.5}\right] = \frac{10^{-6}}{1.64\times10}\cdot\ln\left[\frac{5.95}{4.5}\right]$$

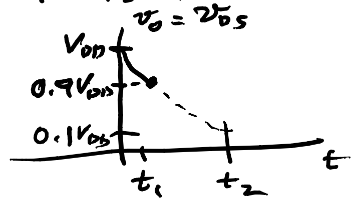
$$= \frac{10^{-7}}{1.64}\times0.279 = 1.7\times10^{-8} = 0.017\,\mu sec$$

delay $= 0.0119 + 0.017 = 0.029\,\mu sec$

for 10-90% fall time: to check state of inverter NMOS

$$v_{DS} = 0.9 \times V_{DD} = 8.1\ \text{V}$$

$$v_{GS} - V_{TO} = 9 - 0.8 = 8.2\text{V} > v_{DS} \Rightarrow \text{in ohmic region}$$

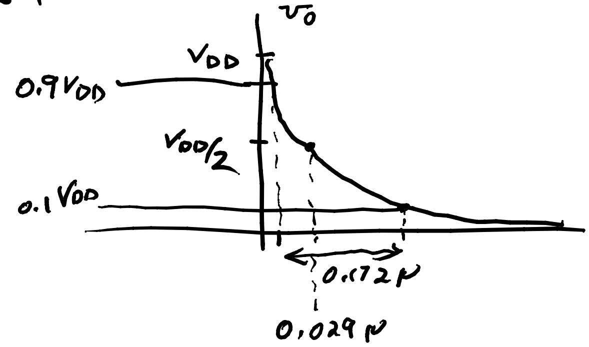


$t_2 - t_1$ for 10-90% fall time

$$= \frac{C}{\frac{KP}{2}\frac{W}{L}\cdot 2(V_{DD}-V_{TO})} \ln\left[\frac{0.1V_{DD} - 2(V_{DD}-V_{TO})}{0.9V_{DD} - 2(V_{DD}-V_{TO})} \cdot \frac{0.9V_{DD}}{0.1V_{DD}}\right]$$

$$= \frac{10\times 10^{-12}}{2\times 10^{-5}(8.2)} \ln\left[\frac{0.9 - 2(8.2)}{8.1 - 2(8.2)} \cdot 9\right] = \frac{10^{-6}}{16.4} \ln\left[\frac{0.9 - 16.4}{8.1 - 16.4} \times 9\right]$$

$$= \frac{10^{-6}}{16.4} \ln\left[\frac{15.5}{8.3} \times 9\right] = 10^{-6} \times \frac{2.822}{16.4} = 0.172\ \mu\text{sec}$$



to include Early effect

$$i_D = \frac{KP}{2}\frac{W}{L}\begin{cases}(v_{GS}-V_{TO})^2(1+\lambda v_{DS}) & \text{saturation} \\ \left[2(v_{GS}-V_{TO})v_{DS} - v_{DS}^2\right](1+\lambda v_{DS}) & \text{ohmic}\end{cases}$$

$$i_D = \left(\frac{KP}{2}\frac{W}{L}\cdot\lambda\right) v_{DS}\left[2(v_{GS}-V_{TO}) - v_{DS}\right]\left(\frac{1}{\lambda} + v_{DS}\right)$$

for $\dfrac{1}{i_D} = \dfrac{k_0}{v_{DS}} + \dfrac{k_1}{v_{DS} - 2(v_{GS}-V_{TO})} + \dfrac{k_3}{v_D + 1/\lambda}$ for partial fraction

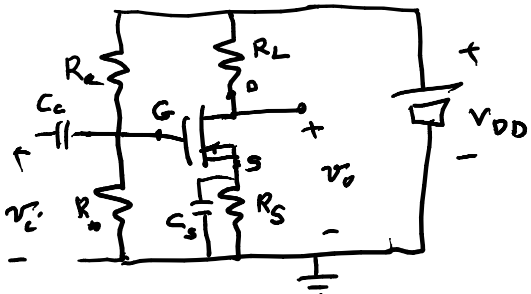
$$\approx \ln\left[\frac{\quad}{v_{DS}} \cdot \qquad\qquad\right]$$ still goes to ∞ if t_2 is when $v_{DS} = 0$

next time

p. 1026 = astable multivibrator

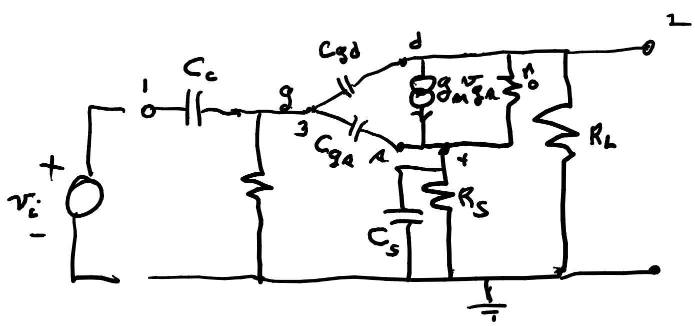
p. 967 = CMOS gates

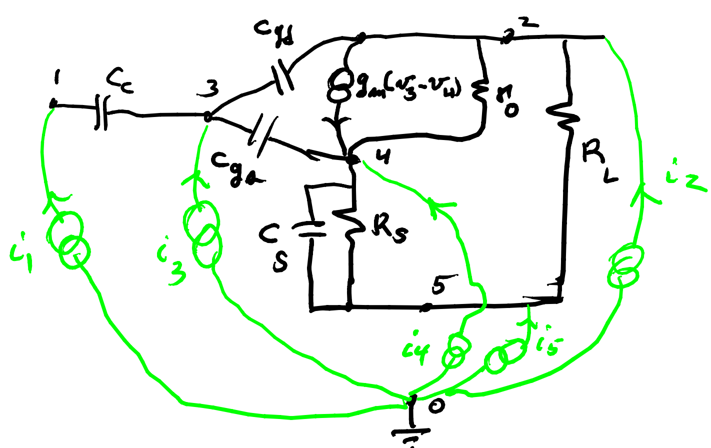
small signal evaluation (Y matrix) for biased amplifiers



biased

for small signal gain ⇒





$$\begin{bmatrix} i_1 \\ i_2 \\ i_3 \\ i_4 \\ i_5 \end{bmatrix} = Y_{ind} \begin{bmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \\ v_5 \end{bmatrix} \Rightarrow \text{yields} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = Y_{2\text{-port}} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

after some work