4th year (Communication)
Subject: Electronics (4-A)

1- Ch5 - P160 (CMOS Digital Integrated Circuits)
(Sung-Mo Kang & Yusuf Leblebici)

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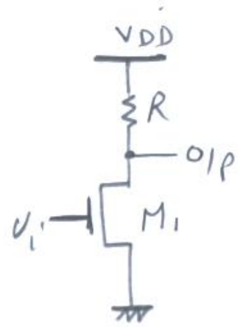



$(V_{OL})$ $M_1$ is Linear

$$\frac{K_n}{2}\left(2\,(V_{DD}-V_{T0})\,V_{OL}-V_{OL}^2\right) = \frac{V_{DD}-V_{o/p}}{R_L}$$

$$V_{OL} = V_{DD}-V_{T0}+\frac{1}{k_nR_L}-\sqrt{\left(V_{DD}-V_{T0}+\frac{1}{k_nR_L}\right)^2-\frac{2V_{DD}}{K_nR_L}}$$

$$V_{OL} = 5-0.9+\frac{1}{50*10^{-6}*150*10^{3}}-\sqrt{17.9211-1.333}$$

$$= 4.2332-4.0728 = 0.1605\,V$$

$V_{OH}$ $M_1$ is cut off

$I_R = 0 \quad \therefore \frac{V_{DD}-V_o}{R_L} = 0 \qquad V_o = V_{OH} = V_{DD} = 5\,V$

$V_{iH} \Rightarrow M_1$ is linear

$$\frac{V_{DD}-V_o}{R_L} = \frac{K_n}{2}\left(2\,(V_{iH}-V_{T0})\,V_o-V_o^2\right)$$

$$V_{iH} = V_{T0}+\sqrt{\frac{8}{3}\frac{V_{DD}}{K_nR_L}}-\frac{1}{K_nR_L} = 2.1\,V$$

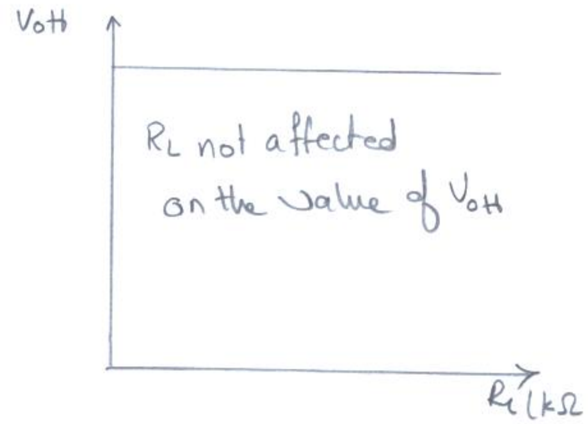
$V_{iL} \rightarrow M_1$ is sat.

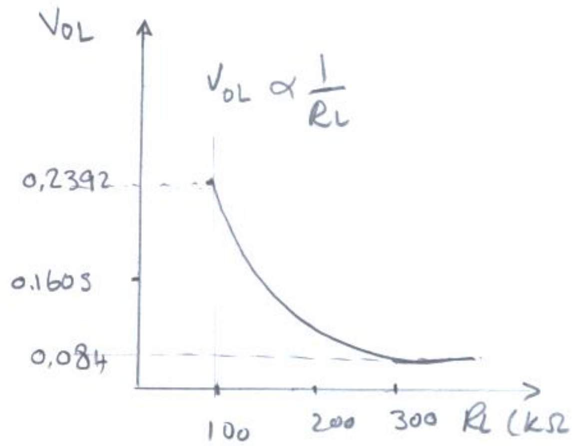
2 $\dfrac{V_{DD} - V_o}{R_L} = \dfrac{K_n}{2}(V_{iL} - V_{T0})^2$

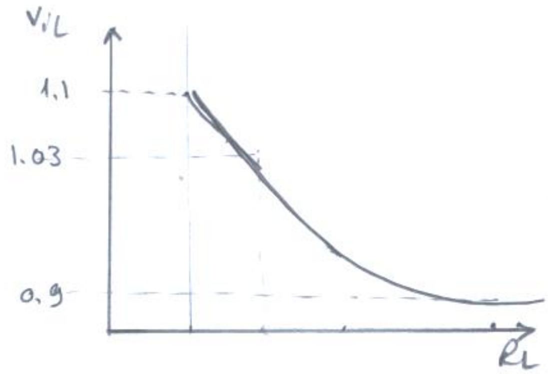
$\dfrac{K_n}{2} 2(V_{iL} - V_{T0}) = \dfrac{1}{R_L}$ $\qquad V_{iL} = \dfrac{1}{K_n R_L} + V_{T0} = 1.0333V$

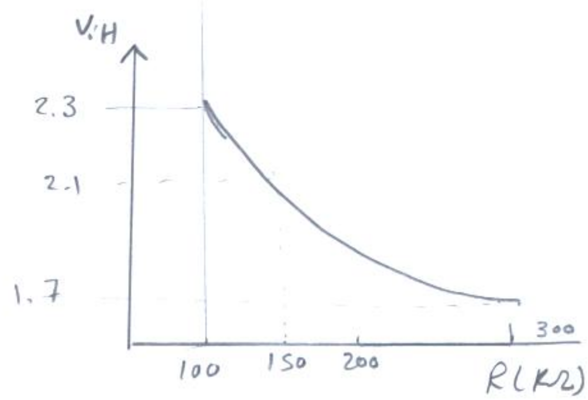
$NM_L = V_{iL} - V_{oL} = 1.033 - 0.16053 = 0.87277$

$NM_H = V_{OH} - V_{iH} = 5 - 2.1 = 2.9$



4- $V_{DD} = 5V$

(1) average Current method

$$\tau_{fall} = \frac{\Delta V_{CL}}{I_{av\,Fall}}$$

$$I_{av\,fall} = \frac{k_n}{4}\left[(V_{DD}-V_{TC})^2 + \left(2(V_{DD}-V_{T0})V_{OL} - V_{OL}^2\right)\right]$$

$$= \frac{200 * 10^{-6}}{4}\left[16 + (2*4*0.5 - 0.5^2)\right] = 9.875*10^{-4}$$

$$\tau_{fall} = \frac{(4.5-0.5)*10^{-12}}{9.875*10^{-4}} = 4.05\ ns$$

Using diff. equ.

$$\tau_{fall} = -\frac{C_L}{K_n/2}\int_{V_{90\%}}^{V_{DD}-V_T}\frac{dV_o}{(V_{DD}-V_{T0})^2} = \frac{-2C_L}{K_n(V_{DD}-V_{T0})^2} * \frac{(V_{DD}-V_{T0}-V_{90\%})}{1}$$

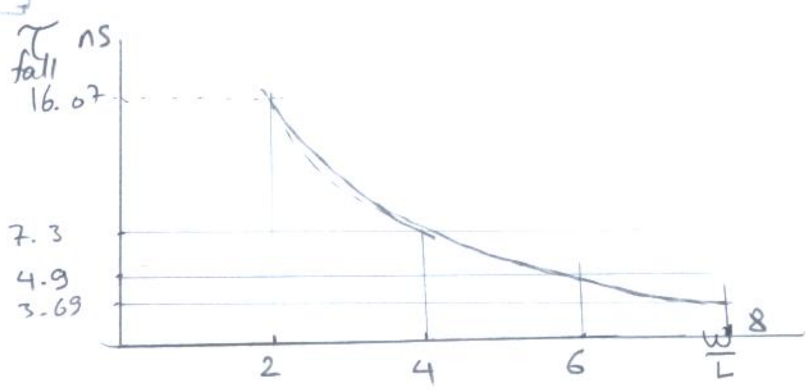
$$\boxed{= 0.3125\ ns}$$

$$\tau_{delay} = \frac{-2C_L}{K_n}\int_{V_{DD}-V_T}^{V_{10\%}}\frac{dV_o}{(2(V_{DD}-V_{T0})V_o - V_o^2)}$$

$$= \frac{C_L}{K_n(V_{DD}-V_{T0})} * \ln\left[\frac{2(V_{DD}-V_{T0})}{V_{10\%}} - 1\right] =$$

$$\boxed{= 3.385\ ns}$$

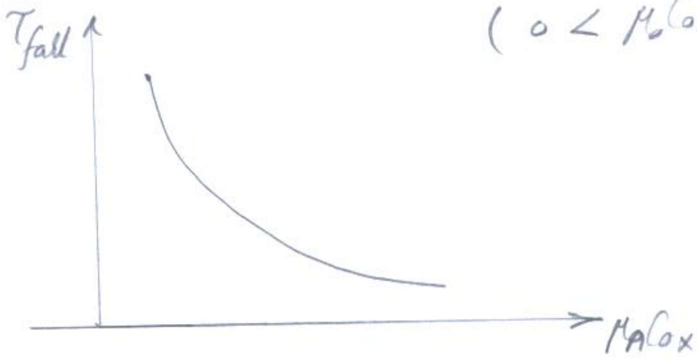
b $\frac{W}{L} =$



$\because \tau_{fall} \propto \frac{1}{\mu_A C_{ox}}$

So as $\tau_{fall}$ increase $\mu_n C_{ox}$ decrease

$( 0 < \mu_n C_{ox} \leq 25 \mu A/V^2)$

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5. chapter 7 p. 260

6.

| A | B | O/P |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

($V_{OH}$ $V_A = V_B = 0$

$$\frac{K_L}{2}\left(-|V_{T_L}(V_o)|(V_{DD}-V_o) - (V_{DD}-V_o)^2\right) = 0$$

$V_o = V_{OH} = V_{DD} = 5V$

$V_{OL} \longrightarrow A = 0 , \quad B = 1$

$$\frac{K_L}{2}\left(-V_{T_L}(V_o)\right)^2 = \frac{K_n}{2}\left(2(V_{DD}-V_{T_0})V_{OL} - V_{OL}^2\right)$$

$$V_{OL} = V_{DD} - V_{T_0} - \sqrt{(V_{DD}-V_{T_0})^2 - \frac{K_L}{K_B}\left(V_{T_L}(V_0)\right)^2}$$

$$V_{T_L} = V_{T_{0L}} - \gamma\left(\sqrt{|2\phi_F + V_{OL}} - \sqrt{|2\phi_F|}\right.$$

$= -3 - 0.4 * 0.14214 = -2.95V$

$V_{OL} = 0.0917V$

$V_{oL} \Rightarrow A = 1 \;,\; B = 0$

$$V_{oL} = V_{DD} - V_{T0} - \sqrt{(V_{DD} - V_{T0})^2 - \frac{K_L}{K_A}\left(V_{T_L}(V_0)\right)^2}$$

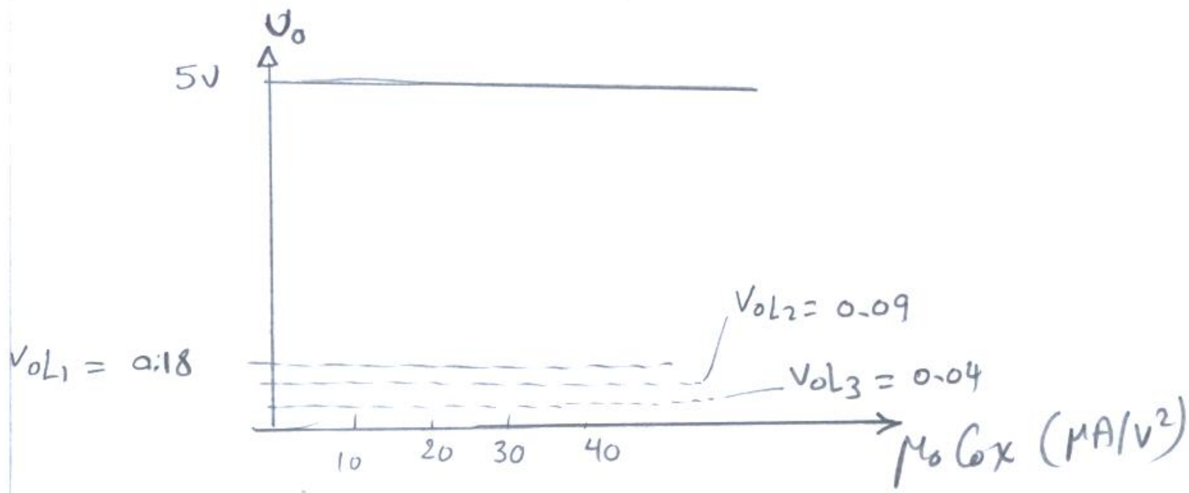
$$= 0.1856\,V$$

$V_{oL} \Rightarrow A = 1 \;,\; B = 1$

$$\frac{K_L}{2}\left(1 - V_{TL}(V_0)\right)^2 = \frac{K_A}{2}\left(2\left(V_{DD} - V_{T0}\right)V_{oL} - V_{oL}^2\right) + \frac{K_B}{2}\left(2\left(V_{DD} - V_{T0}\right)V_{oL} - V_{oL}^2\right)$$

$$V_{oL} = 0.04558\,V$$

b

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