EE 302 Final Exam 2005

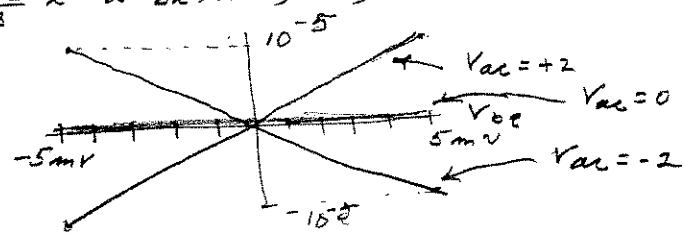
#1. $\frac{I_B}{\beta} = \frac{V_{ac} V_{be}}{1 + 0.001|V_{be}|}$ is odd in V_{be} for a fixed V_{ac} of which there are 3.

for $V_{be} > 0$ $\frac{I_B}{\beta} = \frac{-2\times10^{-3} V_{be}}{1+0.001 V_{be}}, \; 0, \; \frac{+2\times10^{-3} V_{be}}{1+0.001 V_{be}}$ and over $-5mV < V_{be} < 5mV$ $0.001 \times 5\times10^{-3} = 5\times10^{-6}$ is much smaller than 1 & can be ignored (for larger V_{be} it keeps I_B bound)

$\therefore$ over $-5mV < V_{be} < 5V$

$\frac{I_B}{\beta} \approx -2 V_{be}\times10^{-3}, \; 0, \; +2 V_{be}\times10^{-3}$

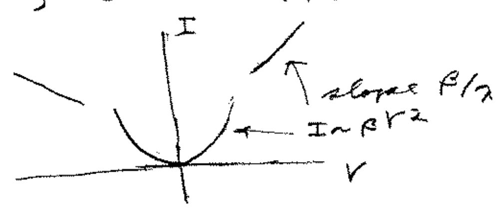
a)



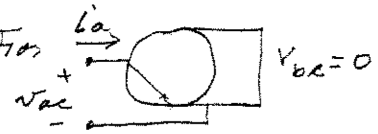
For the connection of b), $V_{ac} = V_{be} = V$, $I_B = I = \beta \frac{V^2}{1+\lambda|V|}$

near $V = 0$, $I \sim \beta V^2$ ~

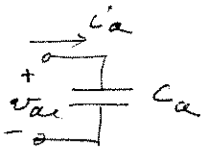
b) as $V \to \pm\infty$, $I \sim \frac{\beta}{\lambda}|V|$



For



$\Rightarrow$ $i_a = C_a \frac{dv_{ac}}{dt}$ $\Rightarrow$



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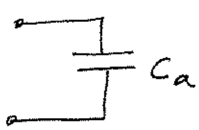


#2. When $I_a = I_b$ there is complete symmetry about a vertical line through the middle of I_T, so

a) $I_{D_{Ma_2}} = I_{D_{Mb_2}} = \frac{1}{2} I_T$, so $I_c = I_{D_{Mb_2}} - I_{D_{Ma_2}} \equiv \underline{\underline{0 = I_c}}$

For part b), If $I_a = 1$ma the drain of Ma_1 will be at its highest potential while if at the same time $I_b = 0$ma the drain of Mb_1 will be ground potential (so Mb_1 is turned off). Thus all of I_T goes through Ma_2 so that

$I_{D_{Ma_2}} = I_T$, $I_{D_{Mb_2}} = 0 \Longrightarrow I_c = I_{D_{Mb_2}} - I_{D_{Ma_2}} = -I_T$

By symmetry, when $I_a = 0$, $I_b = 1$ma, then

$I_{D_{Mb_2}} = I_T$, $I_{D_{Ma_2}} = 0 \Longrightarrow I_c = I_{D_{Mb_2}} - I_{D_{Ma_2}} = I_T$

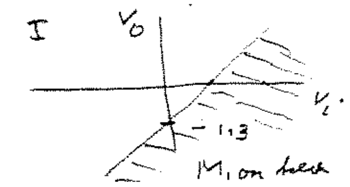
The table is thus

b)

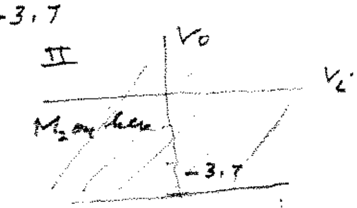
I_a	I_b	I_c	$\lvert I_c \rvert$
0	0	0	0 ma ⇒ 0
1 ma ⇒ 1	1 ma ⇒ 1	0	0 ma ⇒ 0
1 ma ⇒ 1	0	−1 ma	1 ma ⇒ 1
0	1 ma ⇒ 1	1 ma	1 ma ⇒ 1

c) Thus $\lvert I_c \rvert$ is the XOR of I_a & I_b when treated as representations of binary numbers

#3. For M_1 on, $V_{GS_1} = V_i - V_0 \geq VTO_n = 1.3 \Rightarrow V_0 \leq V_i - 1.3 \Rightarrow$



For M_2 on, $V_{GS_2} = V_0 - V_{ss} \geq VTO_n \Rightarrow V_0 \geq V_{ss} + VTO_n = -5 + 1.3 = -3.7 \Rightarrow$

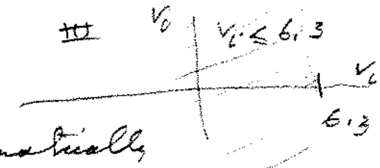


$\therefore$ M_1 & M_2 both on in $-3.7 \leq V_0 \leq V_i - 1.3$

For M_1 in saturation (& on) $0 \leq V_{GS_1} - VTO_n \leq V_{DS_1}$

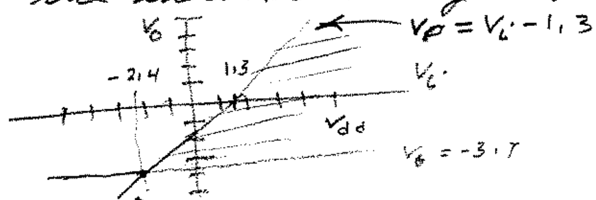
which is $0 \leq V_i - V_0 - VTO_n \leq V_{dd} - V_0$

$\Rightarrow V_i \leq V_{dd} + VTO_n = 5 + 1.3 = 6.3 \Rightarrow$



For M_2 in saturation (& on), region II is automatically true

The region for both transistors on & in saturation we have the intersection of regions I, II, III



intersection $V_0 = -3.7 = V_i - 1.3 \Rightarrow V_i = -2.4$

a) $\therefore$ For $-2.4 \leq V_i \leq 6.3$ M_1 & M_2 = on & sat.

In this region $I_{D_{M_1}} = I_{D_{M_2}}$ which is

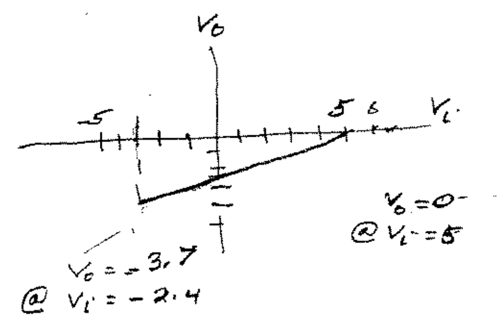
$$\frac{KP}{2}\frac{W}{L}(V_i - V_0 - VTO_n)^2 = \frac{KP}{2}\frac{W}{L}(V_0 - V_{ss} - VTO_n)^2$$

Using the + square root as both M_1 & M_2 are on

$$V_i - V_0 - \cancel{VTO_n} = V_0 - V_{ss} - \cancel{VTO_n}$$

which is $2V_0 = V_i + V_{ss} = V_i - 5$

b) or $V_0 = \frac{1}{2}V_i - 2.5$



c) although $V_0 < 0$ when $V_i > 0$ this does not give a sharp transition or a strong zero or one, so it is not a good digital inverter

Since $\frac{dV_0}{dV_i} > 0$ this is not a good small signal inverter, as it does not invert.