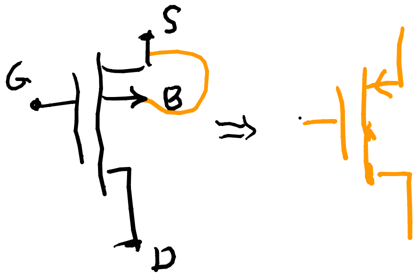
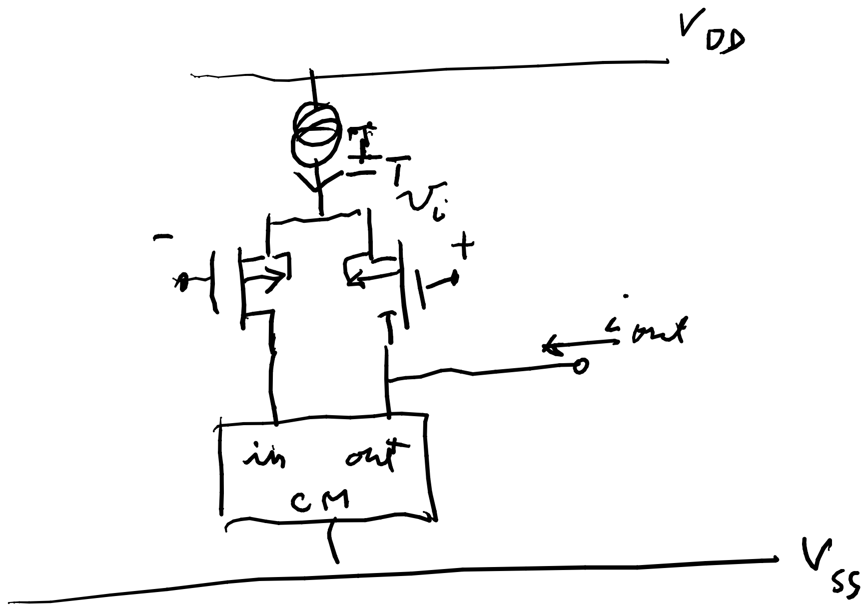
for PMOS diff. pairs

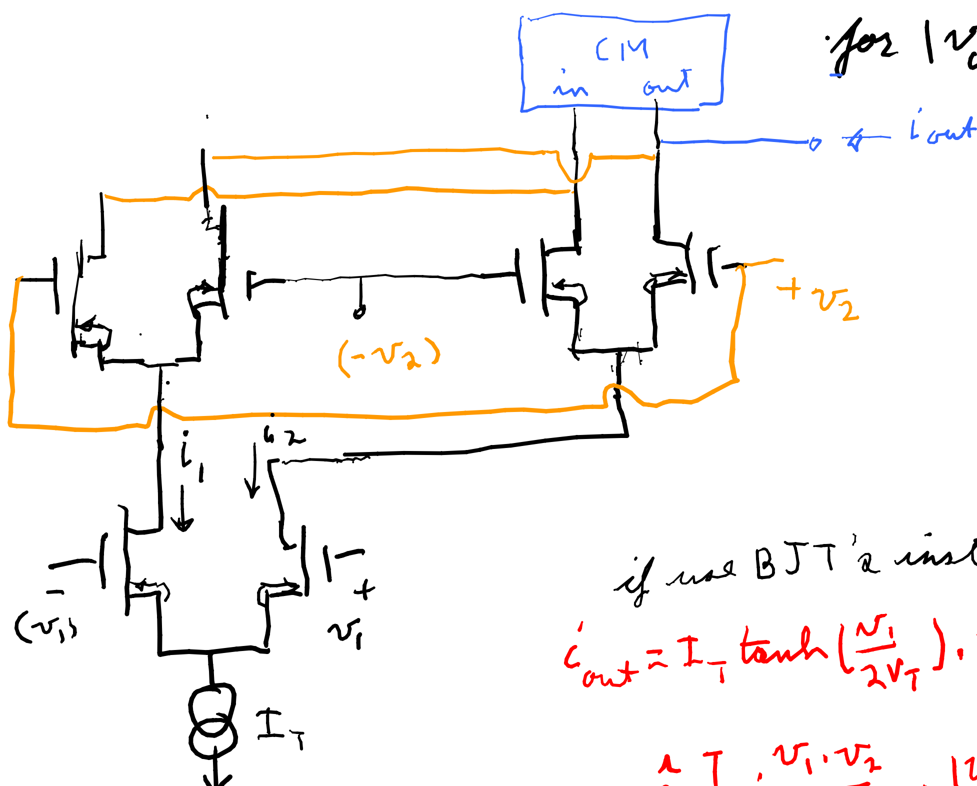


PMOS



if use BJT $\quad i_o = I_T \tanh(v_i/2V_T) \approx I_T \cdot \frac{v_i}{2V_T}$

for $|v_i|$ small

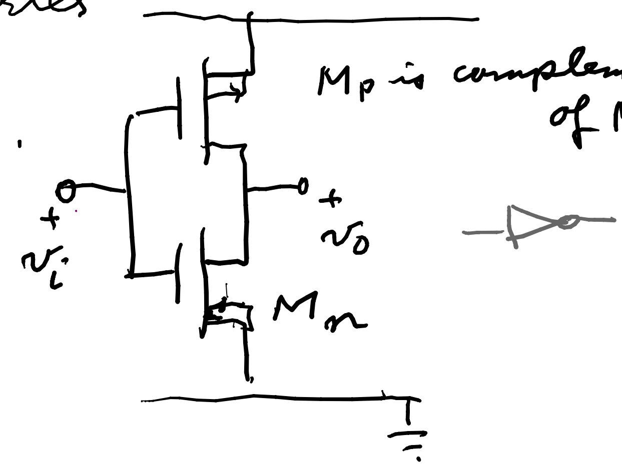


if use BJT's instead

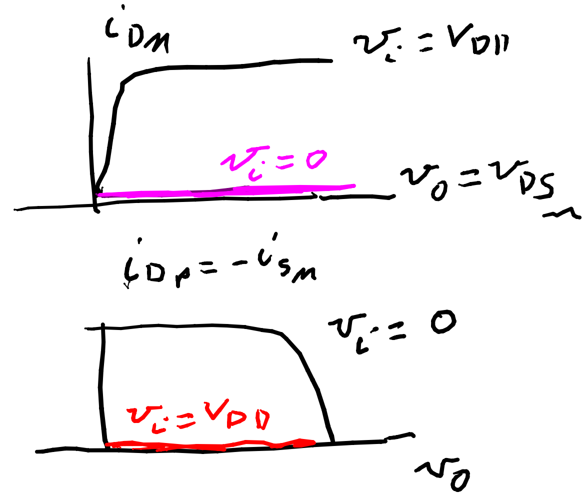
$$i_{out} = I_T \tanh\left(\frac{v_1}{2V_T}\right) \cdot \tanh\left(\frac{v_2}{2V_T}\right)$$

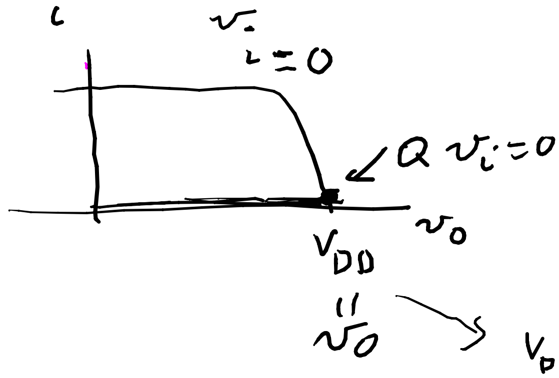
$$\approx I_T \cdot \frac{v_1 \cdot v_2}{4V_T^2}, \quad |v_1|, |v_2| \text{ small}$$

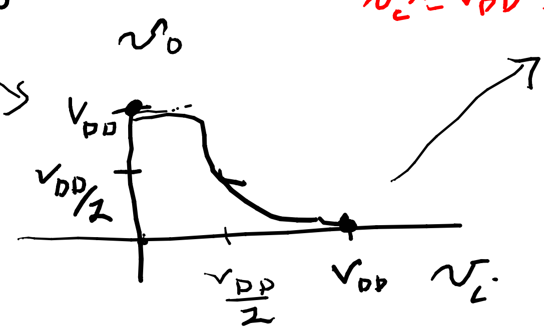
Inverter:

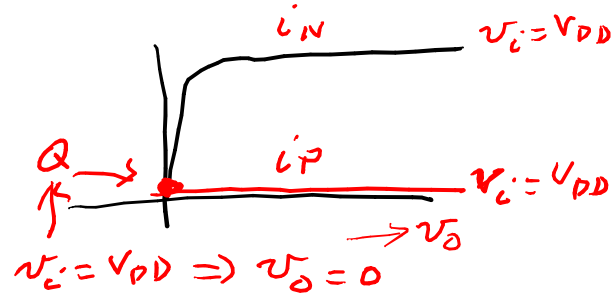


M_p is complement of M_n

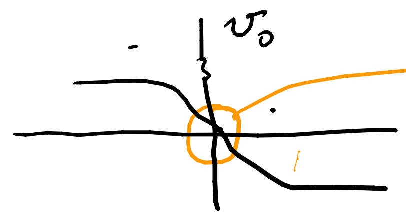








if $V_{SS} < 0$
$= -V_{DD}$



at $v_i = (V_{DD} + V_{SS})/2$, M_n & M_p are in saturation

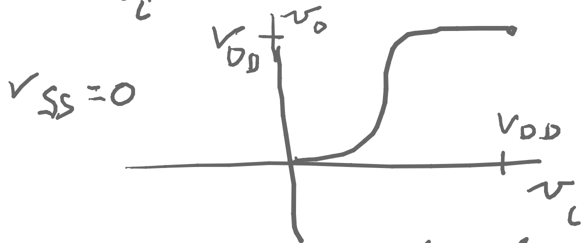
if $V_{SS} = 0$,

$$i_{D_n} = \frac{KP}{2}\frac{W}{L}(v_i - V_{th})^2(1 + \lambda v_o)$$

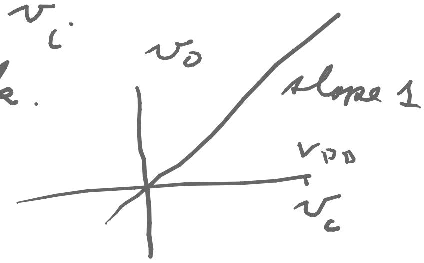
$$-i_{D_p} = \frac{KP_{2p}}{2}\frac{W}{L}(V_{DD} - v_i - |V_{thp}|)^2(1 + \lambda_p[V_{DD} - v_o])$$

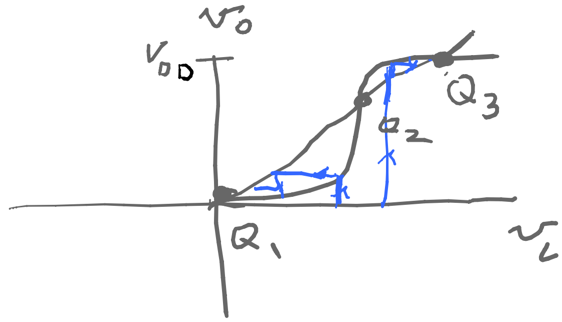
set $i_{D_n} = -i_{D_p}$ & solve for v_o vs v_i (only when M_p & M_n are in saturation)

In cascade



if $v_o = v_i$ by feedback.





Q_1 & Q_3 are stable but Q_2 is not

if $v_i = v_{i,Q_2} + \epsilon$ goes to v_{Q_3} if $\epsilon > 0$ (or V_{Q_1} if $\epsilon < 0$)

$v_o = v_i$ connection

memory

a good binary memory as Q_1 & Q_3 are stable