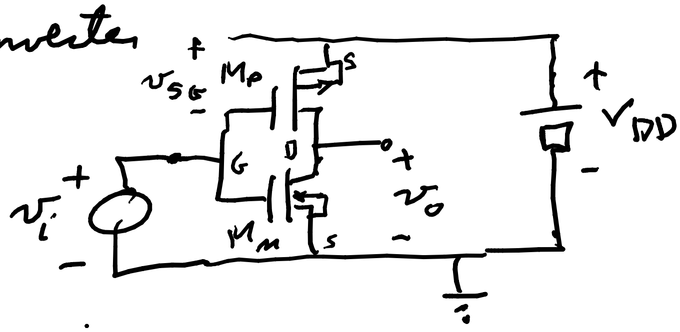
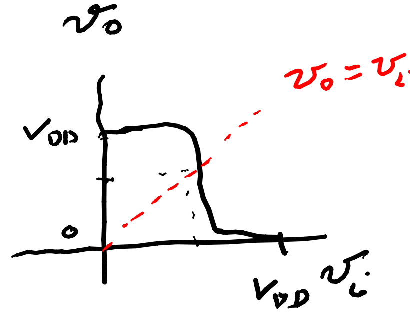
EE303

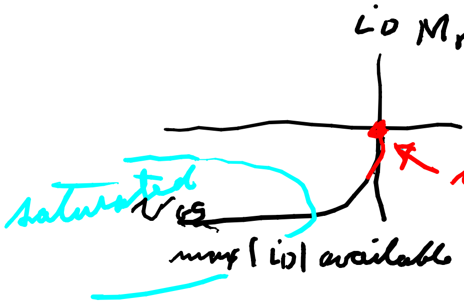
10/23/12

Note Title 10/23/2012

CMOS inverter







$v_{DS} = v_o$ when $v_i = 0$

implies M_p is in Ohmic = (triode) region & M_n is cut-off

$v_{SG} = V_{DD}$ when M_n channel has $v_{GS} = 0 = v_i$

But if $v_o = v_i$ then $v_{DS_n} = v_{GS_n} > v_{GS_n} - VTO_n$ if $VTO > 0$ enhancement mode MOS

$\Rightarrow M_n$ is saturated

then M_p $\quad v_{SG_p} = V_{DD} - v_i$, $\quad v_{SD_p} = V_{DD} - v_o = V_{DD} - v_i$

$v_{SD_p} = v_{SG_p} \geq v_{SG_p} - (-VTO_p)$ saturation

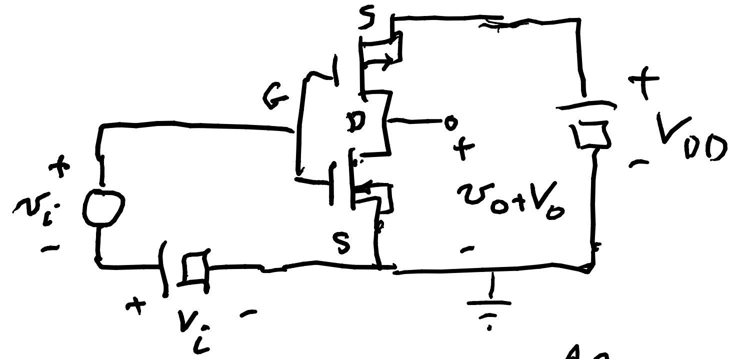
$\Rightarrow$ at $v_o = v_i$ both M_n & M_p are in saturation

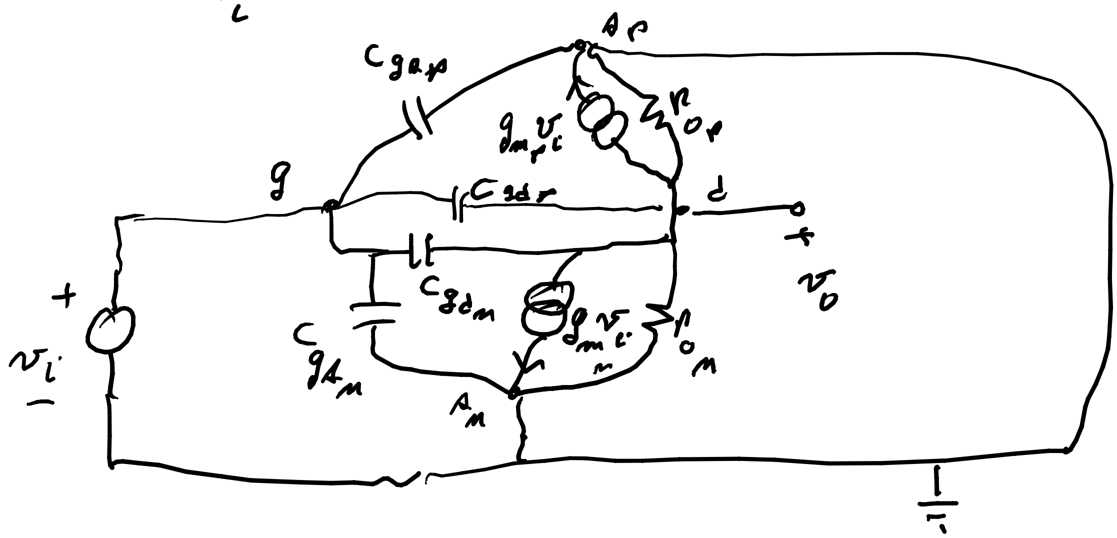
$$\Rightarrow I_{D_n} = \frac{KP_n}{2}\left(\frac{W}{L}\right)_n (v_i - VTO_n)^2 (1 + \lambda_n v_o)$$

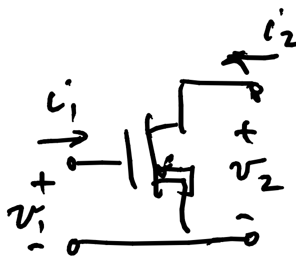
$$= I_{S_p} = \frac{KP_p}{2}\left(\frac{W}{L}\right)_p (V_{DD} - v_i - (-VTO_p))^2 (1 + \lambda_n [V_{DD} - v_o])$$

usually know all but $(W/L)_p$ & as $\frac{KP_p}{2} < \frac{KP_n}{2}$
need $(W/L)_p > (W/L)_n$

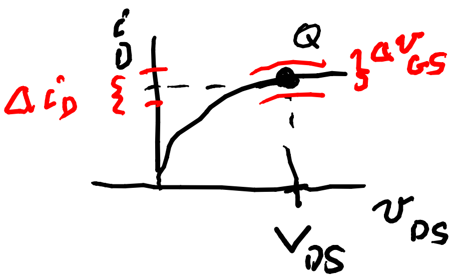
assume bias at $v_i = V_i = V_o$ & inject small signal







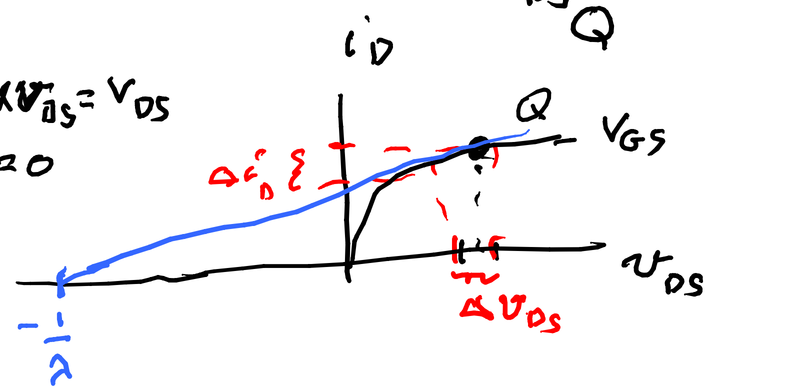
$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = Y \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} v_1 = v_{gs} \\ v_2 = v_{ds} \end{bmatrix} = \begin{bmatrix} i_g \\ i_d \end{bmatrix}$$

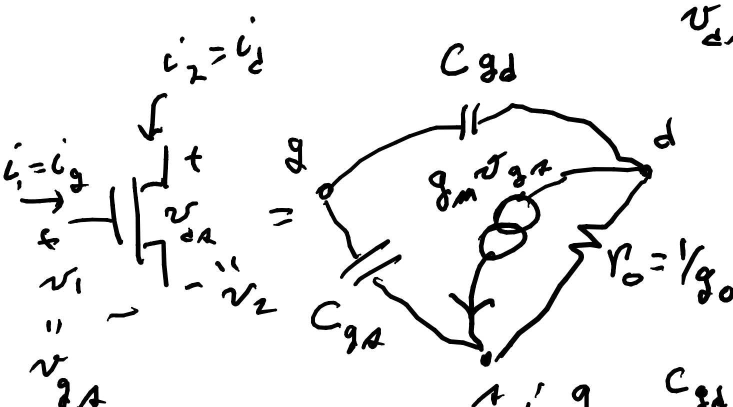


$$\left.\frac{\partial i_D}{\partial v_{GS}}\right|_Q = y_{21} = g_m, \quad y_{22} = \left.\frac{\partial i_D}{\partial v_{DS}}\right|_Q \approx \frac{I_D}{\lambda} = g_o$$

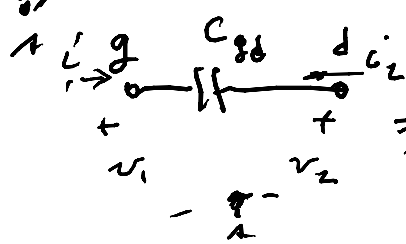
hold $v_{DS} = V_{DS}$

$v_{ds} = 0$

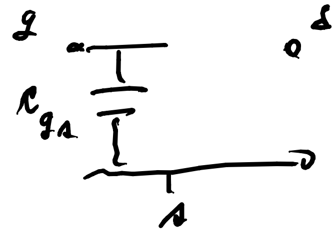




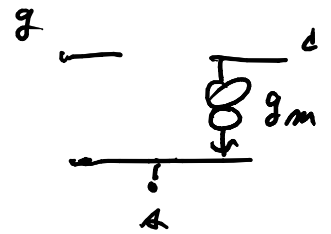
$\Rightarrow Y \Rightarrow$



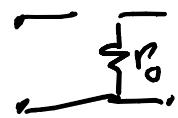
$$\Rightarrow Y_{gd} = \begin{bmatrix} sC_{gd} & -sC_{gd} \\ -sC_{gd} & sC_{gd} \end{bmatrix}, \quad i = Yv$$



$$\Rightarrow Y_{gs} = \begin{bmatrix} sC_{gs} & 0 \\ 0 & 0 \end{bmatrix}$$



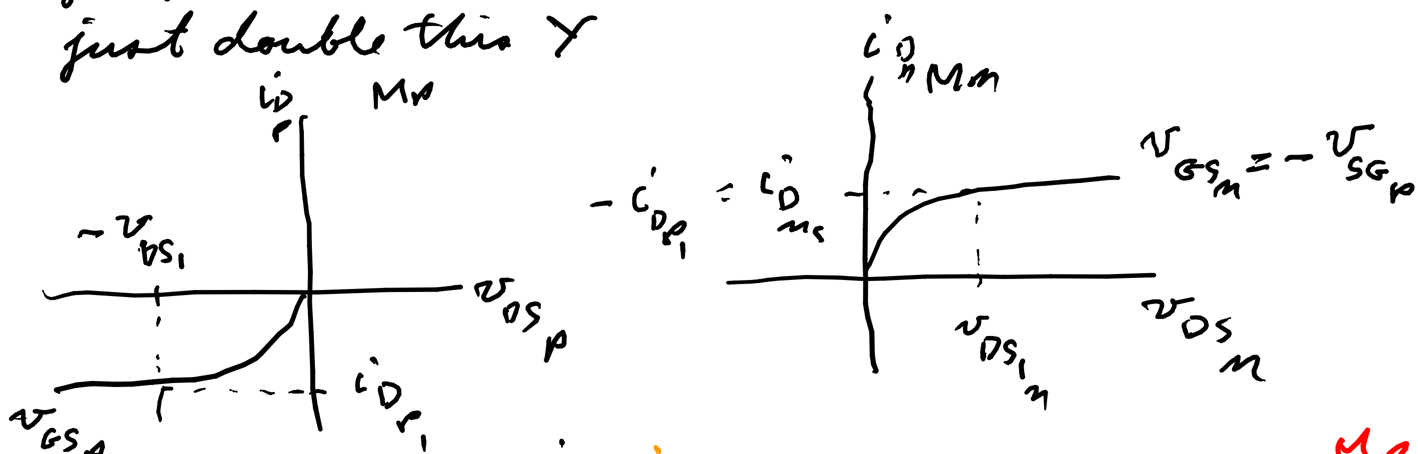
$$\Rightarrow Y_{g_m} = \begin{bmatrix} 0 & 0 \\ g_m & 0 \end{bmatrix},$$

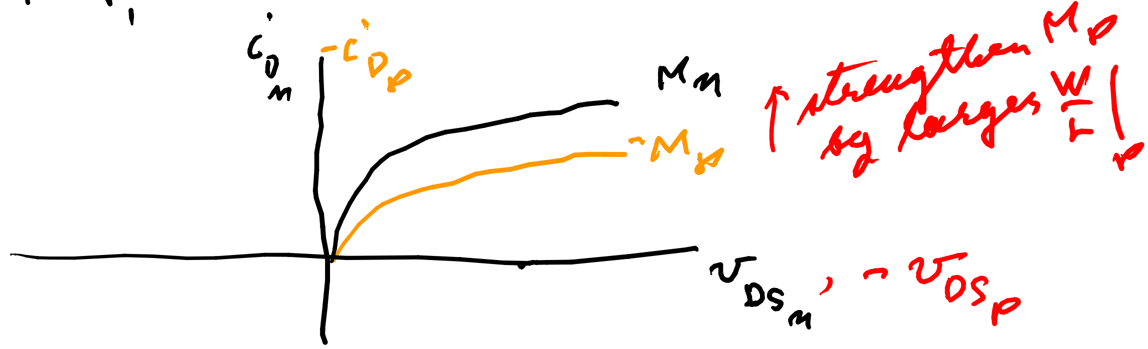


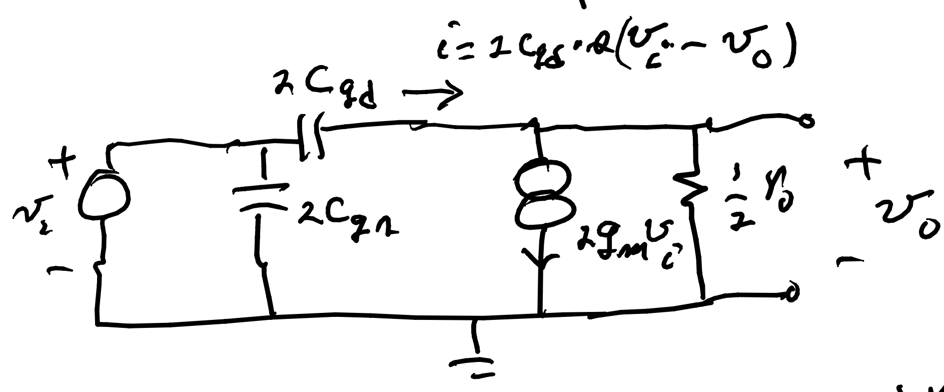
$$= Y_{g_o} = \begin{bmatrix} 0 & 0 \\ 0 & g_o \end{bmatrix}$$

$$Y = Y_{gd} + Y_{gs} + Y_{g_m} + Y_{g_o} = \begin{bmatrix} sC_{gd} + sC_{gs} & -sC_{gd} \\ g_m - sC_{gd} & g_o + sC_{gd} \end{bmatrix}$$

if M_p is complement numerically then for the inverter just double this Y







to find v_o / v_i

$$v_o = -2g_m \tfrac{1}{2} r_o v_i + 2C_{gd} s(v_i - v_o)\frac{r_o}{2}$$

solve: $$\left(1 + 2g_m \tfrac{1}{2} r_o + 2C_{gd}\tfrac{r_o}{2} s\right) v_o = \left(2C_{gd} s - 2g_m \tfrac{r_o}{2}\right) v_i$$

$$\frac{v_o}{v_i} = \frac{s\left(C_{gd}\cdot s - g_m\frac{r_o}{2}\right)}{s\left(C_{gd}\frac{r_o}{2}s + g_m\frac{r_o}{2} + \frac{1}{2}\right)}$$

pole @ $s = -\left(g_m\frac{r_o}{2} + \frac{1}{2}\right) \Big/ C_{gd}\cdot\frac{r_o}{2}$

zero @ $s = (g_m r_o/2)(C_{gd})$