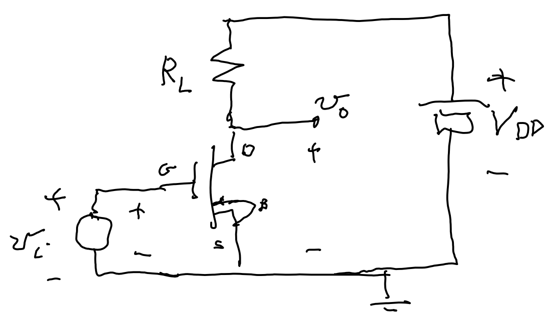
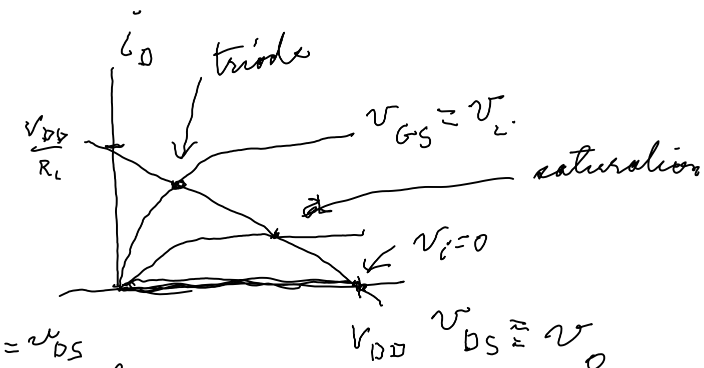
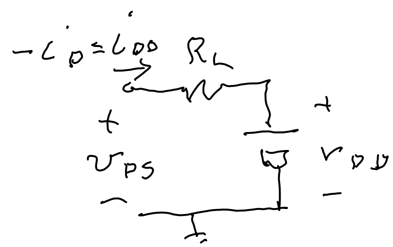
Note Title 4/2/2019

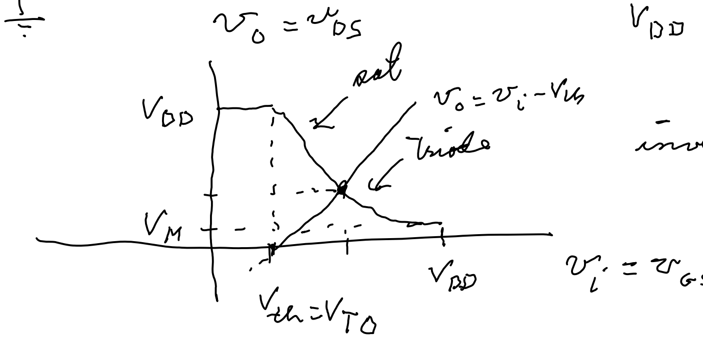
ENEED 303
04/02/19

P.1100 Inverter









inverter curve

$v_o = V_{DD} - R_L i_D$

in saturation $v_{DS} = v_o \geq v_{GS} - V_{th} = v_i - V_{TO}$, in triode (ohmic) $v_{DS} = v_o \leq v_i - V_{th}$

common point $v_o = v_i - V_{th}$ $\qquad k = \frac{KP}{2} \cdot \frac{W}{L}$; $KP = \mu C_{ox}$ $\qquad C_{ox} = \frac{\epsilon_{\text{gate dielectric}}}{t_{ox}}$

t_{ox} = gate dielectric thickness

here $i_D = k(v_i - V_{TO})^2 = k\left(2(v_i - V_{th})v_o - v_o^2\right)$ as $v_o = v_i - V_{TO}$ gives

$v_o = V_{DD} - R_L\left(k\left[v_o + V_{TO}\right]^2\right)$ gives v_o given R_L, k, V_{TO}, V_{DD}

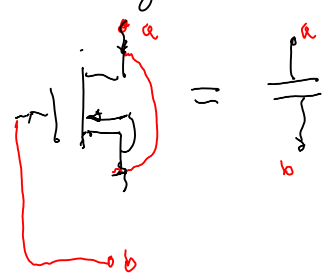
When input $= V_{DD}$ (a binary 1) then $v_o \neq 0$ (a binary 0)

$v_o = V_M = V_{\text{minimum}}$

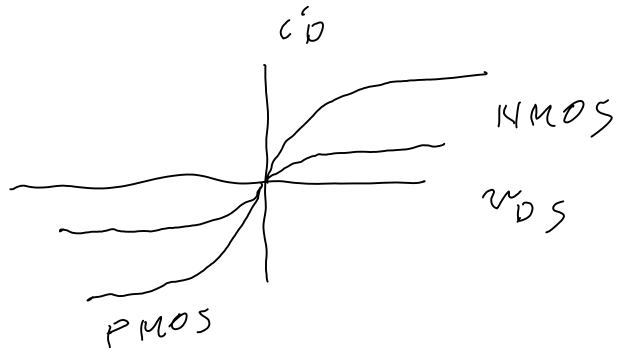
$V_M = v_o = V_{DD} - R_L k\left(2(V_{DD} - V_{TO})v_o - v_o^2\right)$ $\Rightarrow$ can find as quadratic in v_o

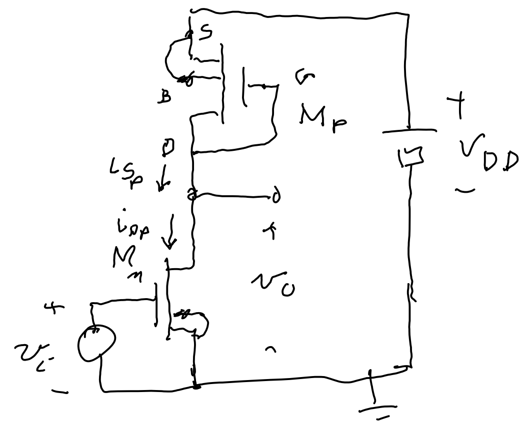
$\left(\frac{v_o - V_{DD}}{kR_L}\right) = v_o^2 - 2(V_{DD} - V_{TO})v_o \Longrightarrow v_o^2 - 2\left(V_{DD} - V_{TO} - \frac{1}{kR_L}\right)v_o + \frac{V_{DD}}{kR_L} = 0$

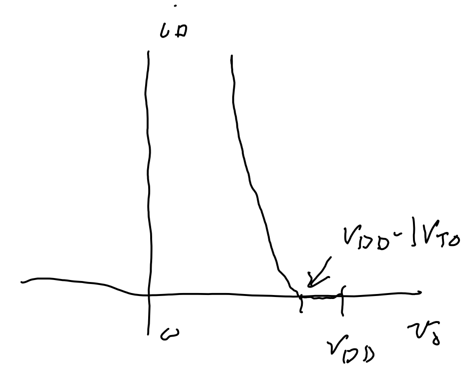
to make a capacitor from a CMOS transistor



$C = C_{ox} \times W \times L$







$$v_{SD_p} = v_{SG_p} > v_{SG_p} - |V_{TO}|_p$$

$\Downarrow$

M_p is in saturation

here rests for a given v_i with $i_{D_n} = i_{S_p} = -i_{D_p}$

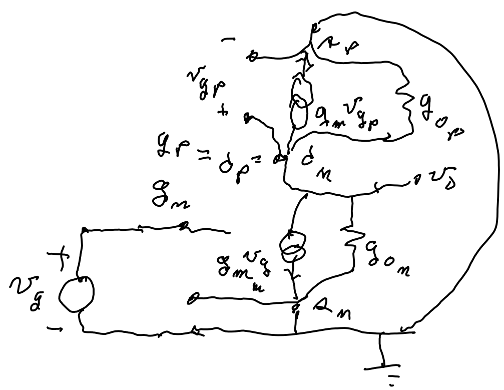
for M_n in saturation $\quad k_n(v_i - V_{TO_n})^2 = k_p(V_{DD} - v_o - |V_{TO_p}|)^2$

$$\sqrt{\frac{k_n}{k_p}} \cdot (v_i - V_{TO_n}) = V_{DD} - |V_{TO_p}| - v_o$$

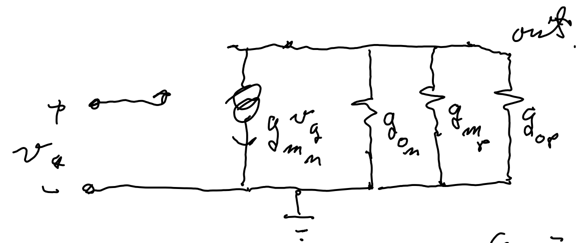
$$v_o = V_{DD} - |V_{TO_p}| + \sqrt{\frac{k_n}{k_p}} \cdot V_{TO_n} - \sqrt{\frac{k_n}{k_p}} \cdot v_i$$

if M_p is completely complementary then $v_o = -v_i$

If $v_i = V_G + v_g$, V_G = bias on gate & v_g small signal, $|v_g| << V_G$
to get small signal gain use Π equivalent circuits



$\equiv$

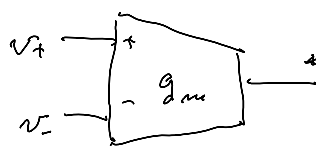


$\equiv$

$G_L = g_{o_n} + g_{o_p} + g_{m_p}$

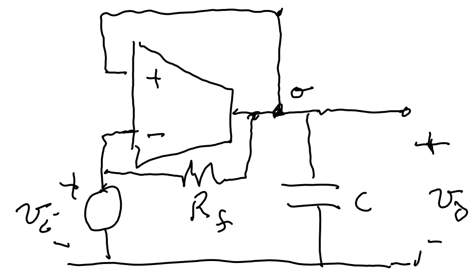
$$\frac{v_o}{v_i} = -g_{m_n} \cdot \frac{1}{G_L} = -g_{m_n} R_L$$

OTA $\quad Y = \begin{bmatrix} 0 & 0 \\ g_m & 0 \end{bmatrix}$



$i_2 = g_m(v_+ - v_-$

lossy integrator



$G_f = 1/R_f$ (in Mhos

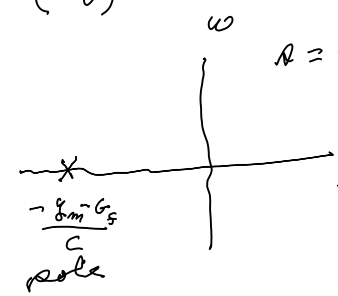
KCL: $0 = g_m(v_o - v_i) + G_f(v_o - v_i) + sC(v_o)$

@ s

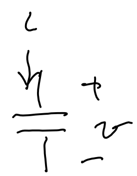
$$\left(g_m + G_f + sC\right) v_o = (g_m + G_f) v_i$$

$$\frac{v_o}{v_i} = \frac{g_m + G_f}{sC + (g_m + G_f)} = \frac{(g_m + G_f)/C}{s + \frac{(g_m + G_f)}{C}}$$

$s = \sigma + j\omega$



$$C\frac{dv_o}{dt} + (g_m + G_f)v_o = (g_m + G_f)v_i$$



$i = \frac{d}{dt}q, \quad q = Cv$

$= \frac{dC}{dt} \cdot v + C\frac{dv}{dt}$ if $C(t) =$ constant $\Rightarrow i = C\frac{dv}{dt} = C\, s \cdot v$

$s = d/dt$

also $= s$ in $\mathcal{L}[v] = V(s)$

$$= \int_{-\infty}^{\infty} v(t) e^{-st}\, dt$$