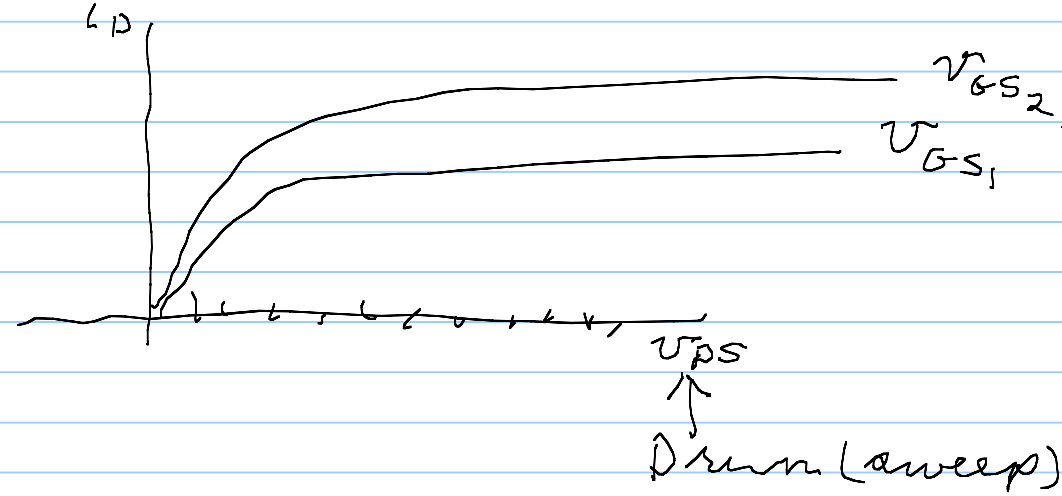
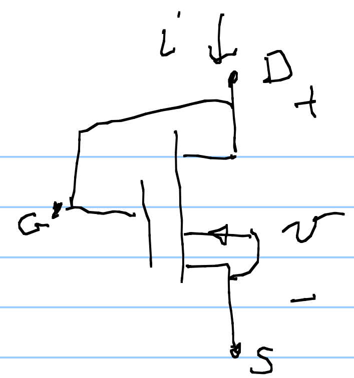
Note Title 9/6/2014

EE303H
09/11/14

For Spice i_D vs v_{DS} & v_{GS} curves





$v_{GS} = v_{DS} > V_{TO}$

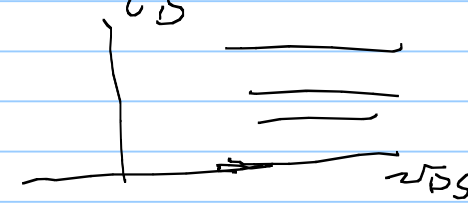
$0 < v_{GS} - V_{TO} < v_{DS} = v_{GS}$

↑ Turn on

↑ >0 = enhancement N channel

NMOS

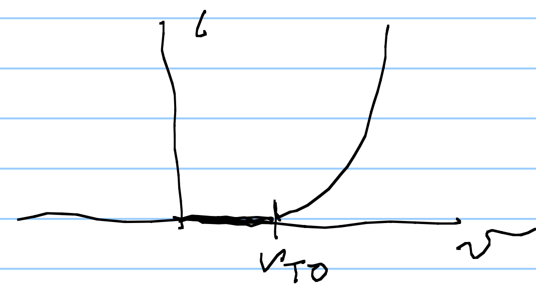
for $v_{DS} < V_{TO}$, $i_D = 0$ as off

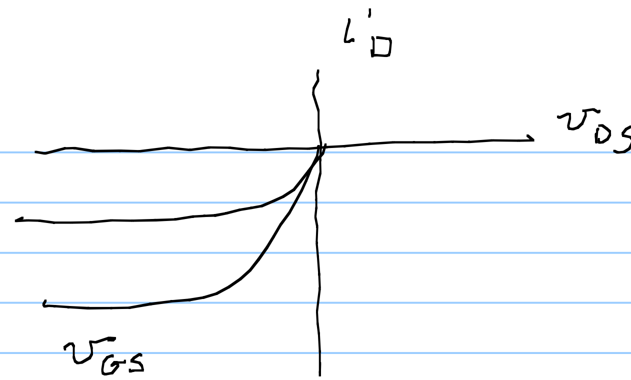


for $v_{DS} > V_{TO}$ are in saturation

$$i_D = \frac{KP}{2}\frac{W}{L}(v_{DS} - V_{TO})^2(1 + \lambda v_{DS})$$

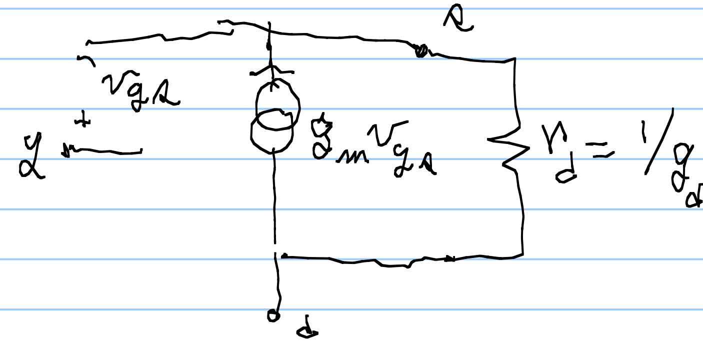
$$\simeq \frac{KP}{2}\frac{W}{L}(v_{DS} - V_{TO})^2$$



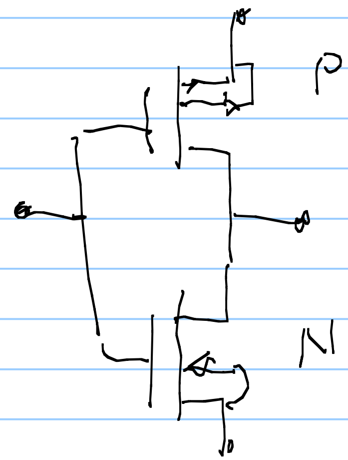


all signs reversed from NMOS

⇓

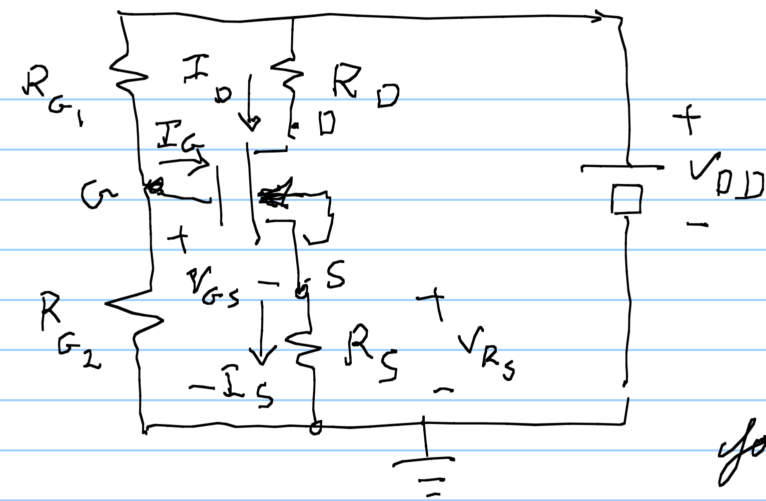


CMOS

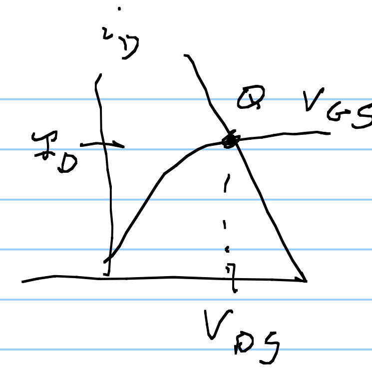


biasing

$I_G = 0$



$V_{R_S} = R_S I_D$



$V_{GS} = V_{R_{G_2}} - V_{R_S}$

forces i_D to stabilize

$V_{R_{G_2}} = V_G = \frac{R_{G_2}}{R_{G_1} + R_{G_2}} E$ as a voltage divides when $i_G = 0$

Ex: if $I_D = 2\,ma$, $R_D = 1\,K\Omega$, $R_S = 1\,K\Omega$

$V_{DS} = E - I_D(R_S + R_D) = E - 2\times10^{-3} \times 2\times10^{3} = E - 4$

$\Rightarrow$ given $V_{DS} = 3v \Rightarrow E = 7v$

if $V_{GS} = 1.5\,V$ then $\Rightarrow V_{R_{G2}} = V_{GS} + V_{R_S} = 1.5 + 2\times10^{-3} \times 1\times10^{3} = 3.5\,V$

$$V_{R_{G2}} = \frac{R_{G2}/R_{G1}}{1 + R_{G2}/R_{G1}} \times E \Rightarrow \frac{3.5}{7} = \frac{1}{1 + R_{G1}/R_{G2}} \Rightarrow$$

$$\Rightarrow \frac{R_{G1}}{R_{G2}} = \frac{7}{3.5} - 1 = 2 - 1 = 1 \Rightarrow R_{G_1} = R_{G_2} \quad \text{choose } R_{G_1} = 1\,Meg = R_{G_2}$$

$$g_m = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_Q = \frac{2 I_D}{(V_{GS} - V_{TO})} = \frac{2\times2\times10^{-3}}{(1.5 - V_{TO})}$$

$$g_d = \left.\frac{\partial i_D}{v_{DS}}\right|_Q = \lambda I_D = \lambda \times 2\times10^{-3}$$

$$= \frac{d}{d v_{DS}}\left(\frac{KP}{2}\frac{W}{L}(V_{GS} - V_{TO})^2(1 + \lambda v_{DS})\right)$$

if $V_{TO} = 1/2\ V$ $\qquad \lambda = \frac{1}{10}$

then $g_m = 4 \times 10^{-3}\ \mho$ $\qquad g_d = \frac{1}{10} \times 2 \times 10^{-3} = 2 \times 10^{-4}$

$r_d = \frac{10^4}{2} = 5 \times 10^{+3}\ \Omega$

if may $\frac{v_o}{v_i} = -g_m R_L = -4 \times 10^{-3} \times 1 \times 10^{3} = -4$

but R_L becomes in parallel with $g_d \Rightarrow g_{m\,eff} = \frac{5}{6} g_m$