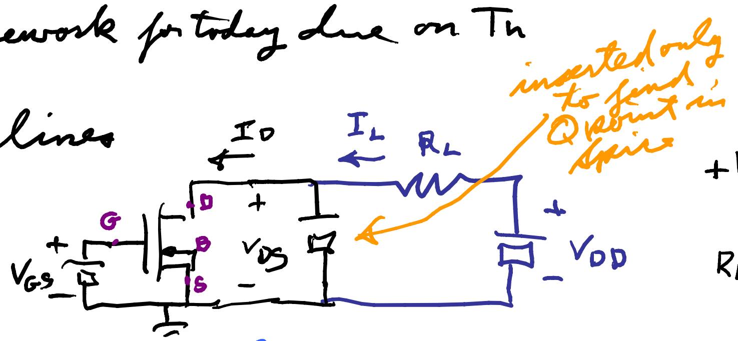
Homework for today due on Th

EE 303H
09/15/09

Load lines



$+V_{DS} + R_L I_L - V_{DD} = 0$

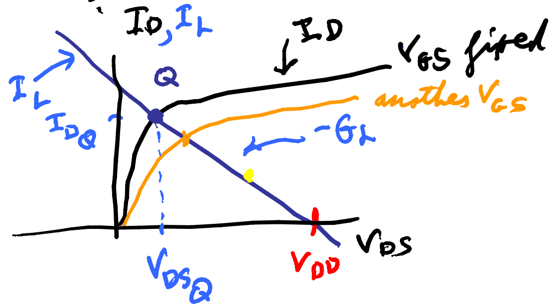
KVL

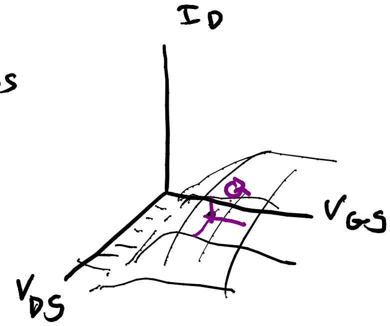
$R_L I_L = +V_{DD} - V_{DS}$

$I_L = G_L V_{DD} - G_L V_{DS}$

if $I_L = 0$, $V_{DS} = V_{DD}$

slope $= -G_L$ for I_L / V_{DS}





$I_D = f(V_{GS}, V_{DS})$ = DC version

$i_D = f(v_{GS}, v_{DS})$ for total behavior

^ v_{BS} (ignore for now)

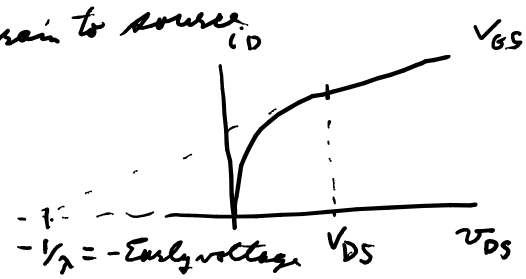
$$i_D = I_D + \left.\frac{\partial f}{\partial v_{GS}}\right|_Q (v_{GS} - V_{GS}) + \left.\frac{\partial f}{\partial v_{DS}}\right|_Q (v_{DS} - V_{DS}) + \text{higher order terms}$$

$i_D - I_D = i_d$ signal current

$v_{GS} - V_{GS} = v_{gs}$ signal voltage gate to source

$v_{DS} - V_{DS} = v_{ds}$ " " drain to source

$$i_d = \left.\frac{\partial f}{\partial v_{GS}}\right|_Q v_{gs} + \left.\frac{\partial f}{\partial v_{DS}}\right|_Q v_{ds}$$



for $\left.\frac{\partial f}{\partial v_{DS}}\right|_Q$ hold $v_{GS} = V_{GS}$

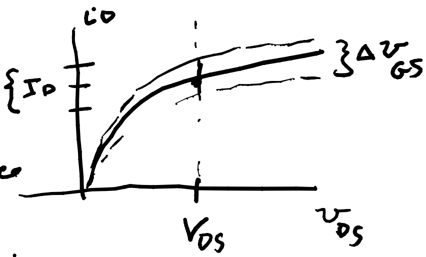
= slope @ the Q point

= incremental drain to source conductance

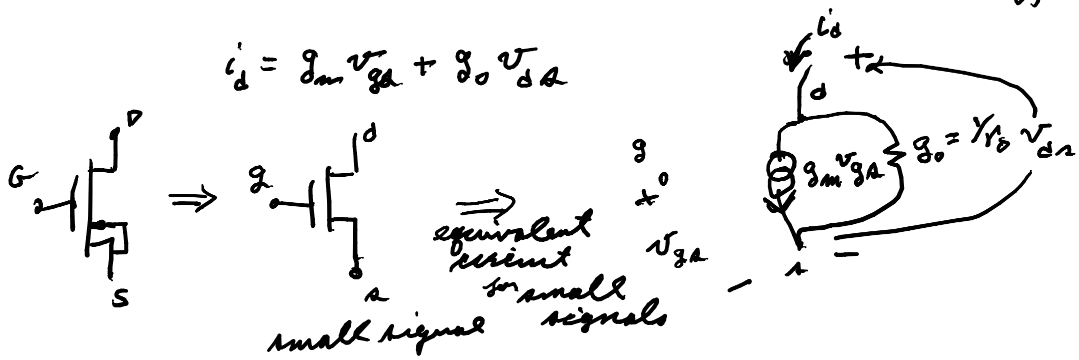
$= g_o$

for $\left.\frac{\partial i_D}{\partial v_{GS}}\right|_Q$ Q = V_{DS} = constant, small changes around V_{GS}

$= g_m$ = mutual conductance
= transconductance



$$i_d = g_m v_{gs} + g_o v_{ds}$$



If NMOS is at a Q point in its saturation region

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

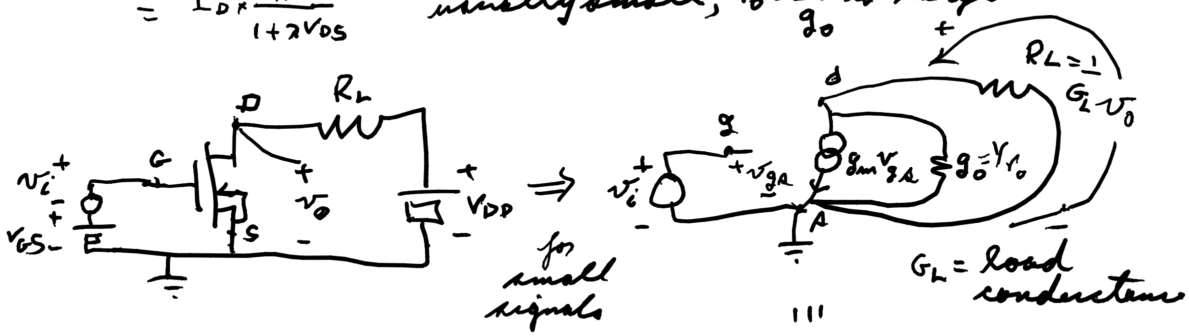
$$g_m = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_Q = 2\left(\frac{KP}{2}\frac{W}{L}\right)(v_{GS}-VTO)(1+\lambda v_{DS})\Big|_Q = 2\,\frac{\left(\frac{KP}{2}\frac{W}{L}\right)(V_{GS}-VTO)^2(1+\lambda V_{DS})}{(V_{GS}-VTO)}$$

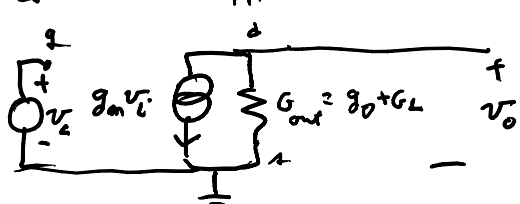
$$= 2\,\frac{I_D}{V_{GS}-VTO}$$

$$g_o = \left.\frac{\partial i_D}{\partial v_{DS}}\right|_Q = \left(\frac{KP}{2}\frac{W}{L}\right)(v_{GS}-VTO)^2\cdot\lambda\Big|_Q =$$

$$= I_D \times \frac{\lambda}{1+\lambda V_{DS}}$$

usually small, $r_o = \frac{1}{g_o}$ is large



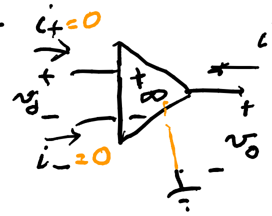


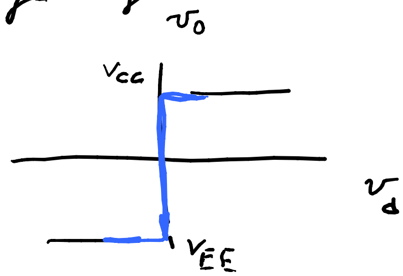
$$v_o = \frac{1}{G_{out}}(-g_m v_i)$$

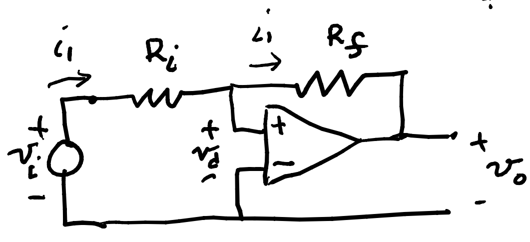
$$= -\frac{g_m}{G_{out}}\,v_i$$

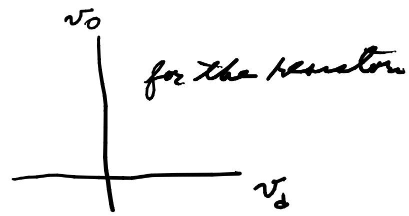
$$\frac{v_o}{v_i} \approx -g_m R_L$$ slow small signal (DC)

Load line on op-amps for large signal at low frequency









$$\left.\begin{aligned}(v_i - v_d) &= R_i i_1\\ (v_d - v_{o_R}) &= R_f i_1\end{aligned}\right\} \Rightarrow v_i - v_d = \frac{R_i}{R_f}(v_d - v_{o_R})$$

$$v_i - \left(1 + \frac{R_i}{R_f}\right) v_d = -\frac{R_i}{R_f} v_{o_R}$$

$$v_{o_R} = -\frac{R_f}{R_i} v_i + \left(1 + \frac{R_f}{R_i}\right) v_d$$