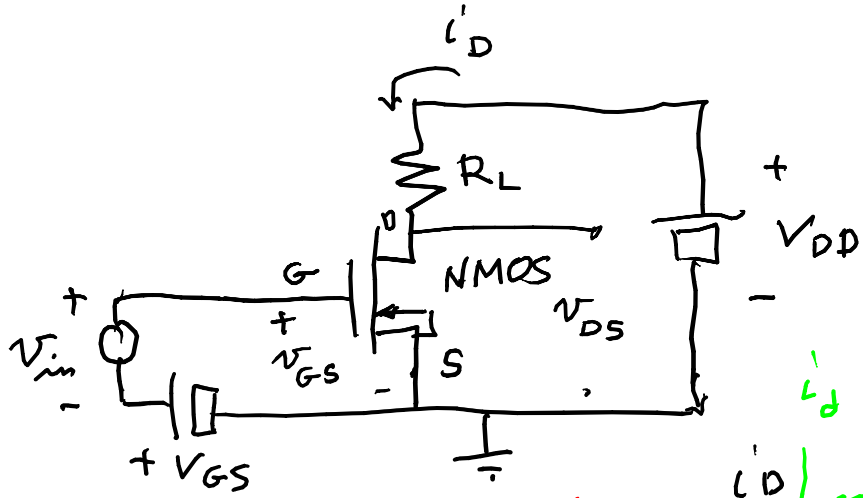
Common Source amplifier

EE 303
02/06/06



$0 \le |v_{in}(t)| << V_{GS}$

$V_{DD} > 0$

$V_{GS} > VTO$

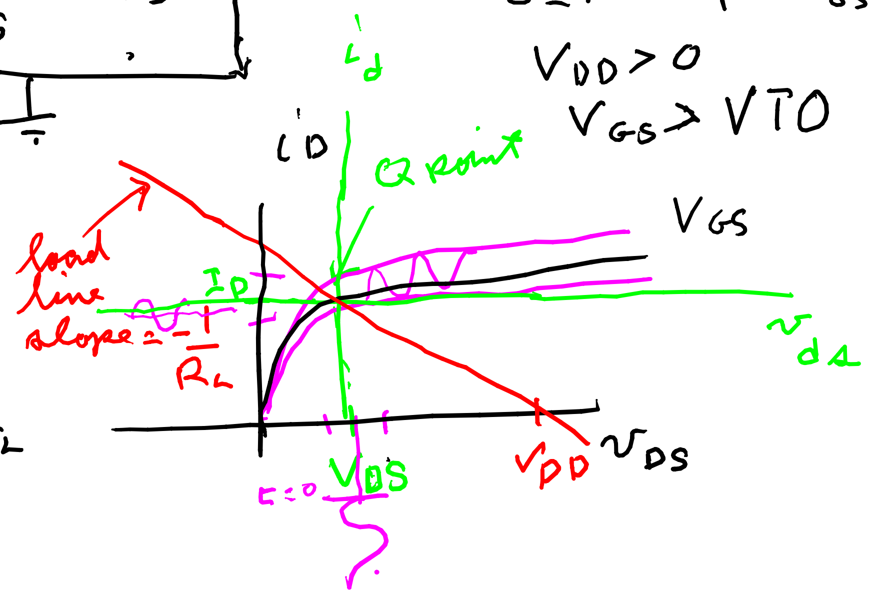
$i_D = f(v_{DS}, v_{GS})$

$v_{DS} = -R_L i_D + V_{DD}$

$\Downarrow$

$i_D = (V_{DD} - v_{DS}) \cdot G_L$

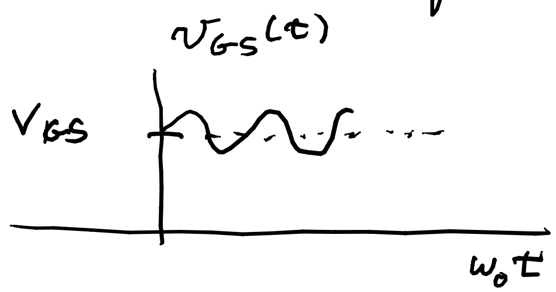
$G_L = 1/R_L$



$v_{GS} = V_{GS} + v_{in}$ if $v_{in} = V_{in} \sin \omega_o t$; $|V_{in}| << V_{GS}$

$\Downarrow$

small signal



$$i_D(v_{DS}, v_{GS}) = i_D = \underbrace{i_D(V_{DS}, V_{GS})}_{Q\ point} + \left.\frac{\partial i_D}{\partial v_{GS}}\right|_{\substack{v_{GS}=V_{GS} \\ v_{DS}=V_{DS}}} (v_{GS} - V_{GS}) + \left.\frac{\partial i_D}{\partial v_{DS}}\right|_{Q\ point} (v_{DS} - V_{DS})$$

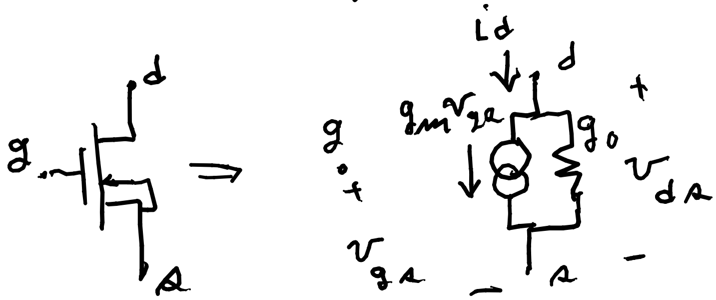
drop for small signals ⇒ linear behavior

$$+ \frac{\partial^2 i_D}{\partial v_{GS} \partial v_{DS}} (v_{GS} - V_{GS}) \times (v_{DS} - V_{DS}) + \dots$$

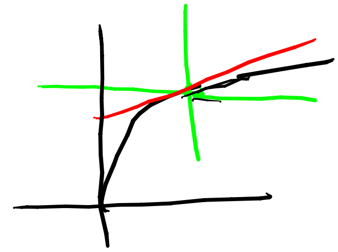
$$\approx \quad i_D = I_D + \left.\frac{\partial i_D}{\partial v_{GS}}\right|_Q (v_{gs}) + \left.\frac{\partial i_D}{\partial v_{DS}}\right|_Q (v_{ds})$$

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

here
$i_d = i_D - I_D$
$v_{gs} = v_{GS} - V_{GS}$
$v_{ds} = v_{DS} - V_{DS}$
↑ signal ↑ total ↑ bias



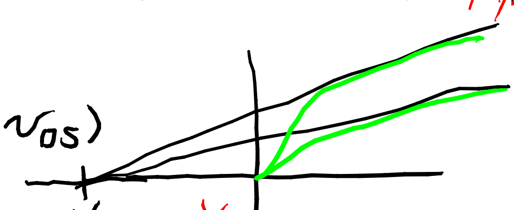
$$g_m = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_Q \quad ; \quad g_o = \left.\frac{\partial i_D}{\partial v_{DS}}\right|_Q$$



if in saturation; $v_{GS} - VTO \leq v_{DS}$

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

$\lambda = \frac{1}{V_A}$



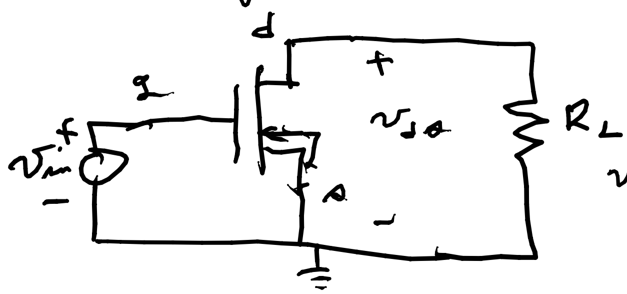
$$\frac{\partial i_D}{\partial v_{GS}} = \left(\frac{KP}{2} \cdot \frac{W}{L}\right) \cdot 2 (v_{GS} - VTO)(1 + \lambda v_{DS})$$

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

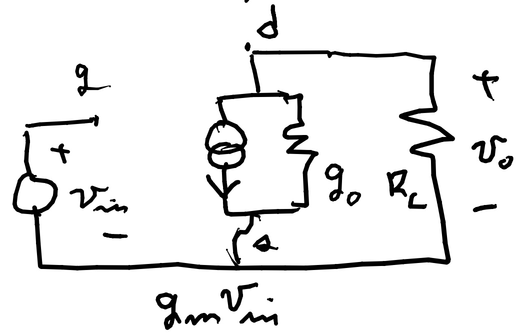
$$= \frac{2 \cdot I_D}{(V_{GS} - VTO)}$$

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

amplifier becomes for small signals



$v_o = v_{ds}$



now linear

$\frac{v_o}{v_{in}}$: $v_o = -(g_m v_{in})\left(\frac{r_o R_L}{r_o + R_L}\right) \approx - g_m R_L \cdot v_{in}$

if $g_o \approx 0 \Rightarrow r_o = \frac{1}{g_o} = \infty$

$\frac{v_o}{v_{in}} \approx -g_m R_L$ small signal gain at small ω (as ignored input capacitance)

Typical:

$KP = 1\times 10^{-5} \cdot \frac{A}{V^2}$, $W = L = 10\mu = 10u$

$VTO = 0.8\ V$

$\lambda = 0.01$

$V_{GS} = 3V$, $V_{DS} = 4V$

g_m: $I_D = \frac{1}{2}\times 10^{-5} \times \frac{1}{1}(3-0.8)^2(1+0.01\times 4)$

$= \frac{(2.2)^2}{2} \times 1.04\times 10^{-5} = 2.517\times 10^{-3} \times 10^{-2} = 0.025\ m\mho$

gain ≈ -2 : then $R_L = 2/g_m = 0.8\ K\Omega$