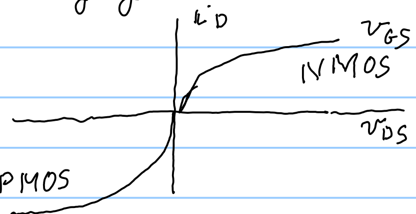
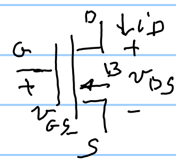
Note Title 9/27/2016

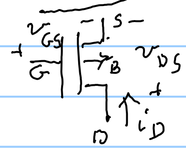
EE 303H

09/27/16

Redoing of black board:







for NMOS

In saturation region $v_{GS} - V_{th} < v_{DS}$

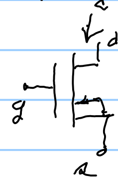
$i_D = \frac{KP}{2} \cdot \frac{W}{L}\left((v_{GS} - V_{th})^2 (1 + \lambda v_{DS})\right)$ if on $(v_{GS} > V_{th})$

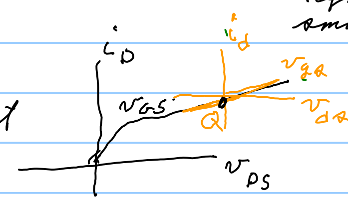
$(= 0$ if off, $v_{GS} \leq V_{th})$

$V_{th} = VTO$ if $B = S$

$i_D = I_D + g_m (v_{GS} - V_{GS}) + g_o (v_{DS} - V_{DS}) + ($higher orders ignore if small signal

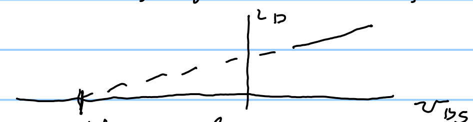
$\Rightarrow i_d = g_m v_{gs} + g_o v_{ds}$; $i_d = i_D - I_D$

$\Rightarrow$  on shift of origin to Q point



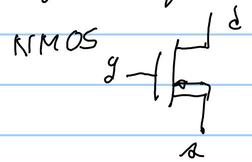
from eq. $g_m = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_Q = 2 \frac{KP}{2} W/L (V_{GS} - V_{th})(1 + \lambda V_{DS}) = 2 \frac{I_D}{(V_{GS} - V_{th})}$, $V_{GS} - V_{th} = V_{overdrive}$

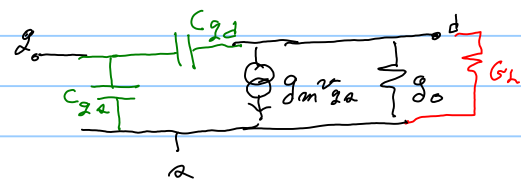
$$g_o = \frac{\partial i_D}{\partial v_{DS}} = \frac{KP}{2}\frac{W}{L}(v_{GS} - V_{th})^2 \times \lambda \; ; \quad \text{for } \lambda \text{ small, } g_o \approx \lambda I_D$$



$-1/\lambda$ = a large negative voltage

gives equivalent circuit





if load in $R_L = 1/G_L$ & $g_o \approx 0$ then v

$$\frac{v_o}{v_i} = \frac{v_{ds}}{v_{gs}} = -g_m R_L$$

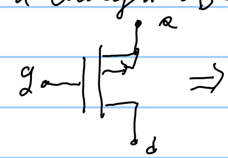
add in C_{gs} & C_{gd} from gate $C_g = C_{gs} + C_{gd} = C_{ox} \cdot W \cdot L$

in saturation $C_{gs} = \frac{2}{3} C_g$, $C_{gd} = \frac{1}{3} C_g$

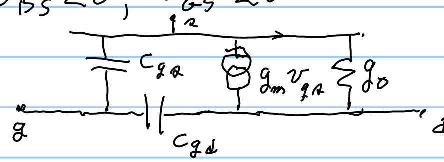
For PMOS slopes, etc, give positive derivatives $g_m = \frac{\partial i_D}{\partial v_{GS}}$, $g_o = \frac{\partial i_D}{\partial v_{DS}}$

even though $i_D < 0$, $v_{DS} < 0$, $v_{GS} < 0$

so



$\Rightarrow$

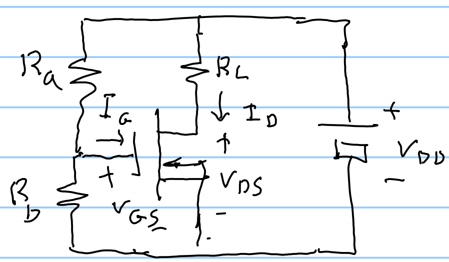


Need to bias @ Q point to get $A_v = -g_m R_L \Rightarrow$ need to set

$i_D = I_D$, $v_{GS} = V_{GS}$, $v_{DS} = V_{DS}$ (when no signal) at DC Q point.

a big problem in general as need to isolate signal circuit from bias circuit.

Bias circuit: Given one battery $V_{DD} \Rightarrow$ here $I_G = 0$ as see a capacitor at the gate $\Rightarrow V_{GS}$ via voltage divider



$$V_{GS} = \frac{R_b}{R_a + R_b} V_{DD} = \frac{1}{1 + \frac{R_a}{R_b}} V_{DD}$$

$$\Rightarrow \frac{R_a}{R_b} = \frac{V_{DD} - V_{GS}}{V_{GS}} = \frac{V_{DD}}{V_{GS}} - 1$$

$\Rightarrow$ only ratio given so choose very large for small current drained from V_{DD}

$\therefore$ set Q pt V_{GS} by R_a, R_b. If given V_{DS} then $V_{DD} - V_{DS} = R_L I_D$ ($\Rightarrow$ load line)

Given I_D from curve or in saturation $I_D = \frac{KP}{2}\frac{W}{L}(V_{GS}-VTO)^2(1+\lambda V_{DS})$

$$\approx \frac{KP}{2}\frac{W}{L}(V_{GS}-VTO)^2$$

& $g_m \approx \dfrac{2 I_D}{(V_{GS}-VTO)}$

but also want $A_v = -g_m R_L$

Ex: $I_D = 2\times10^{-4}(V_{GS}-VTO)^2$ If $V_{GS}=3$, $VTO=1 \Rightarrow I_D = 2\times4\times10^{-4}$
$= 0.8\,mA$

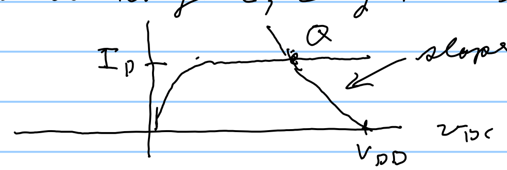
$g_m = \dfrac{2 I_D}{V_{overdrive}} = \dfrac{8\times10^{-4}}{4} = 2\times10^{-4} = 0.2\,m℧$

If $A_v = -12 = -g_m R_L \Rightarrow R_L = \dfrac{12}{g_m} = \dfrac{12}{2\times10^{-4}} = 60\times10^{3} = 60\,k\Omega$

If $V_{DD} = 9V$ then for $V_{GS}=3 \Rightarrow \dfrac{R_a}{R_b} = \dfrac{V_{DD}}{V_{GS}} - 1 = \dfrac{9}{3} - 1 = 5$

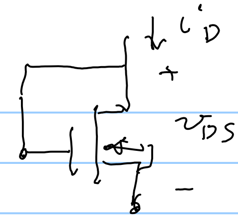
$\therefore$ if $R_b = 10\,MEG\Omega \Rightarrow R_a = 50\,MEG\Omega$

So looks good, & if $\lambda = 0$ is ok, but $\lambda \neq 0$ throws in a monkey wrench



slope $= -1/R_L$; can choose any V_{DS} if $\lambda = 0$
but not if $\lambda \neq 0$; so use above
as 1st approximation $\Rightarrow$ turn to Spice

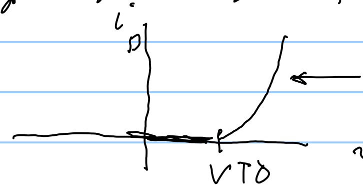
Diode connected



$v_{DS} = v_{GS}$ then $v_{GS} - VTO < v_{GS} = v_{DS}$

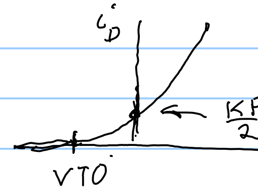
so in saturation

on if $v_{GS} - VTO > 0$; if $VTO > 0$ ($\equiv$ enhancement mode)



$$i_D = \frac{KP}{2}\frac{W}{L}(v_{DS} - VTO)^2 \underbrace{(1 + \lambda v_{DS})}_{\text{makes curve slightly above } \frac{KP}{2}\frac{W}{L}(v_{DS} - VTO)^2}$$

If $VTO < 0$ then we have depletion mode ($\Leftrightarrow$ dope the channel)



$\leftarrow \frac{KP}{2}\frac{W}{L}(-VTO)^2$