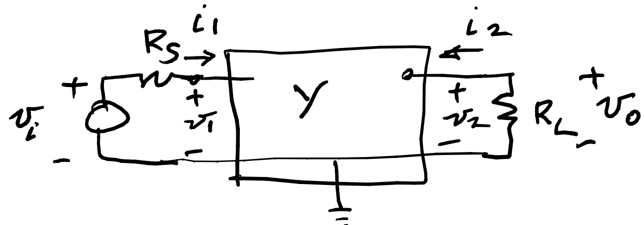
EE 303
02/16/07

small signal with bias



$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

$$i = Y v$$

$$v_1 = v_i - R_S i_1$$

$$v_2 = v_o = -R_L i_2 \Rightarrow i_2 = y_{21} v_1 + y_{22} \underset{v_o}{\underset{\shortparallel}{v_2}} =$$

$$-R_L i_2 = v_o = -R_L y_{21} v_1 - R_L y_{22} v_o \qquad (1)$$

need v_1

$$v_1 = v_i - R_S i_1 = v_i - R_S (y_{11} v_1 + y_{12} v_2)$$

$$(1 + R_S y_{11}) v_1 = v_i - R_S y_{12} v_o \qquad (2)$$

solve (2) for v_1 $\Rightarrow$ $$v_1 = \frac{1}{(1+R_S y_{11})} v_i - \frac{R_S y_{12}}{(1+R_S y_{11})} v_o \qquad (3)$$

(3) $\rightarrow$ (1):

$$v_o = \frac{-R_L y_{21}}{(1+R_S y_{11})} v_i + \frac{R_L R_S y_{21} y_{12}}{(1+R_S y_{11})} v_o - R_L y_{22} v_o$$

for v_o $\Rightarrow$ $$\left(1 + R_L y_{22} - \frac{R_L R_S y_{21} y_{12}}{1+R_S y_{11}}\right) v_o = -\frac{R_L y_{21}}{1+R_S y_{11}} v_i$$

$$(1 + R_S y_{11} + R_L y_{22} + \underbrace{R_S R_L y_{11} y_{22} - R_L R_S y_{21} y_{12}}_{R_S R_L \Delta Y}) v_o = -R_L y_{21} v_i$$

$R_S R_L \Delta Y \rightarrow \Delta$ = determinant of Y

$$\frac{v_o}{v_i} = \frac{-R_L y_{21}}{(1 + R_S y_{11} + R_L y_{22} + R_S R_L \Delta Y)}$$ = Voltage to Voltage 2-port transfer function from source to load

The transfer function from "transistor" = 2-port input

is $$\frac{v_o}{v_1} = \frac{-R_L y_{21}}{1 + R_L y_{22}}$$

For $Y = \begin{bmatrix} sC_{in} & 0 \\ g_m & g_o \end{bmatrix}$ then $\frac{v_o}{v_1} = \frac{-R_L g_m}{1 + R_L g_o}$

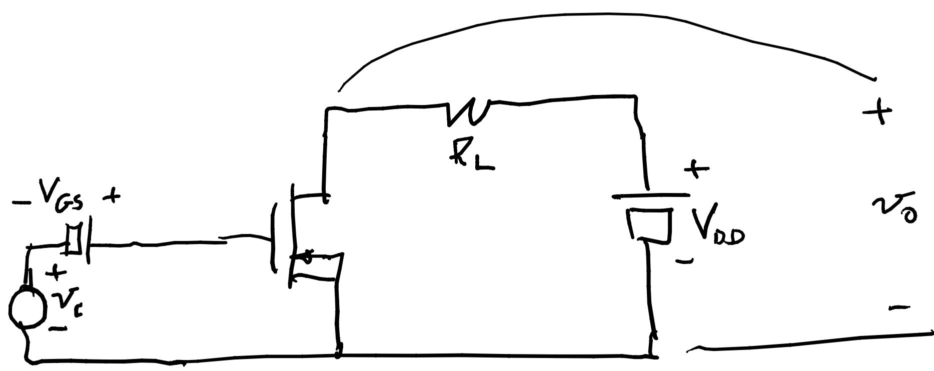
if $R_L g_o \ll 1$ $\quad \frac{v_o}{v_1} = -R_L g_m$

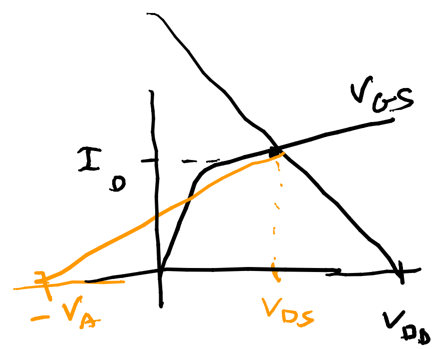
If at low frequencies ($\approx$ DC) $sC_{in} \to 0$

$$\frac{v_o}{v_i} = \frac{-R_L g_m}{1 + R_S \times 0 + R_L g_o + R_L R_S \times 0}$$

$\Delta = 0$ if $sC_{in} \to 0$

an NMOS bias: $\quad I_D = \frac{KP}{2}\frac{W}{L}(V_{GS} - VTO)^2(1 + \lambda V_{DS})$





Ex: $\frac{KP}{2} = 2 \times 10^{-4}$, $VTO = 0.99$, $W = L = 10\mu = 10^{-5}\,m$

$\lambda = \frac{1}{V_A} = \frac{1}{100}$; $V_{DD} = 5$, $t_{ox} = 400\mathring{A} = 400 \times 10^{-10}\,m$

$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} = \frac{3.45 \times 10^{-11}\,Fd/m}{4 \times 10^{-8}\,m}$; $C_{gate} = W \times L \times C_{ox}$

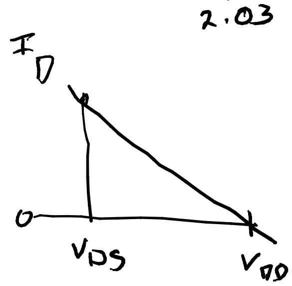
$= 10^{-5} \times 10^{-5} \times \frac{3.45}{4} \times 10^{-3}\,F_d$

to check or saturation ; use $V_{GS} = 2 \times VTO$ $= 1.98\,v$, $I_D = 0.2\,ma$ (choose)

use $I_D = \frac{KP}{2}\frac{W}{L}(V_{GS} - VTO)^2(1 + \lambda V_{DS})$ to get V_{DS}

$$V_{DS} = \frac{-1 + \frac{I_D}{\frac{KP}{2}\frac{W}{L}(V_{GS} - VTO)^2}}{\lambda} = \left(-1 + \frac{0.2 \times 10^{-3}}{2 \times 10^{-4}(0.99)^2}\right) \times V_A = 2.03\,v$$

for sat: $\underset{2.03}{\overset{}{V_{DS}}} > V_{GS} - VTO = VTO = 0.99 \Rightarrow$ in saturation



$$\text{slope} = G_L = \frac{I_D}{V_{DD} - V_{DS}} = \frac{0.2\times10^{-3}}{5 - 2.03} = 0.673\times10^{-3}$$

$$R_L = 1/G_L = 1.485\ K\Omega = 1,485\ \Omega$$

$$g_m = \frac{2I_D}{V_{GS} - VTO} = \frac{2\times0.2\times10^{-3}}{0.99} = 4.04\times10^{-4}\ \mho$$

$$g_o = \frac{I_D}{V_A} = \frac{0.2\times10^{-3}}{100} = 2\times10^{-6}, \quad r_o = \frac{1}{2\times10^{-6}} = 500K\Omega$$

$$C_{gs} = C_{in} = \frac{2}{3}C_{gate} = \frac{2}{3}\times\frac{3.45}{4}\times10^{-13} = 0.0575\times10^{-12}\ Fd$$
$$= 0.06\ pFd$$

$$Y = \begin{bmatrix} sC_{in} & 0 \\ g_m & g_o \end{bmatrix}, \quad -R_L g_m = -1.485\times10^{3}\times4.04\times10^{-4}$$
$$= -6\times10^{-1} = -0.6$$

∴ near DC get a "loss"

to eliminate the 1st battery