Exam study
MOS & BJT characteristics
differential pair
$v_o/v_i\,(s)$; poles & zeros
small signal equivalents

EE 303 Tu 10/14/08

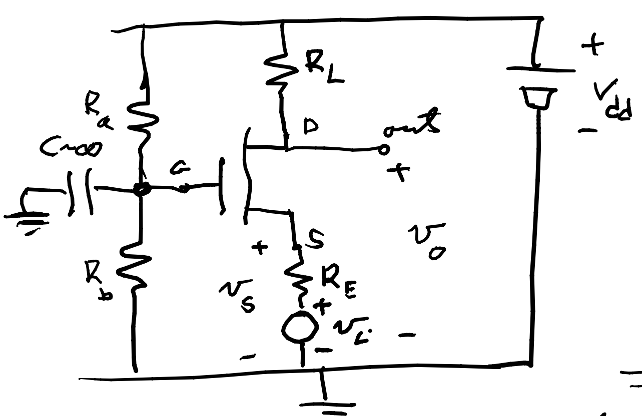
For subthreshold use of MOS ~ $I_D \approx$ pico amp range
uses BSIM models; level 8 of PSpice
" 49 in Cadence HSpice

NMOS

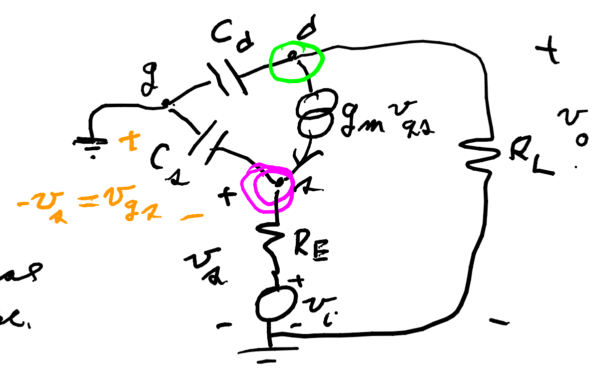
$$I_D \simeq \frac{KP}{2}\cdot\frac{W}{L}(VT)^2 e^{1.8}\, e^{(v_{GS}-VTO)/nVT}\cdot\left(1-e^{-V_{DS}/V_T}\right)$$

from CMOS by Baker, Li & Boyce (eq. (6.51))

Grounded Gate amplifier



$\Longrightarrow$ small signal equiv. circ.



desire $\frac{v_o}{v_i}(s)$ = transfer function

at ○ use KCL leaving $\Sigma = 0$

1) $sC_d v_o + g_m(-v_s) + G_L v_o = 0$ where $G_L = 1/R_L$

1′) $v_s = \frac{sC_d + G_L}{g_m}\cdot v_o$

at ⓪ use KCL leaving $\Sigma = 0$

2) $$sC_s(+v_s) + G_E(v_s - v_i) - g_m(-v_s) = 0$$

$$(sC_s + G_E + g_m)v_s = G_E v_i$$ $G_E = 1/R_E$

2') $$v_s = \frac{G_E}{(sC_s + (G_E + g_m))} \cdot v_i$$

equate 1' & 2'

3) $$\frac{sC_d + G_L}{g_m} v_o = \frac{G_E}{(sC_s + (G_E + g_m))} \cdot v_i$$

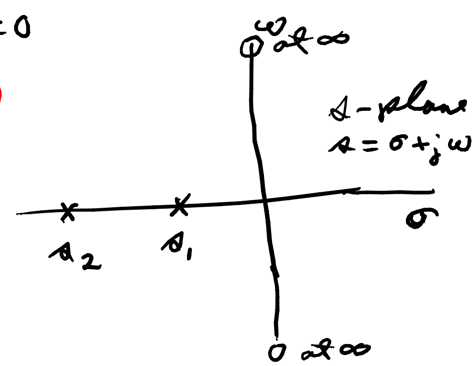
$$\frac{v_o}{v_i}(s) = \frac{G_E g_m}{(sC_d + G_L)(sC_s + (G_E + g_m))}$$

$\omega = 0$ gain $= \frac{v_o}{v_i}(0) = \frac{G_E g_m}{G_L(G_E + g_m)} = \frac{R_L}{R_E} \cdot \frac{g_m}{g_m + G_E}$

zeroes: where $\frac{v_o}{v_i} \approx 0$ in s; has a double zero at $s = \infty$

poles: $sC_d + G_L = 0$, $sC_s + (G_E + g_m) = 0$

$$s_1 = -\frac{G_L}{C_d} \qquad s_2 = \frac{-(G_E + g_m)}{C_s}$$

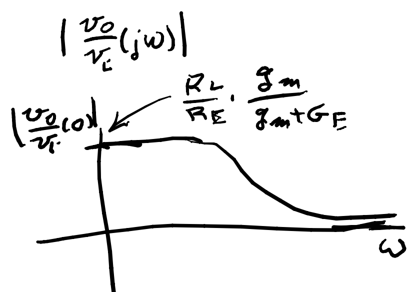


For the frequency response

$s = j\omega$

$$\frac{v_o}{v_i}(j\omega) = \frac{G_E g_m}{(G_L + j\omega C_s)((G_E + g_m) + j\omega C_d)}$$

$$\left|\frac{v_o}{v_i}(j\omega)\right|^2 = \frac{G_E g_m}{(G_L^2 + \omega^2 C_s^2)((G_E + g_m)^2 + \omega^2 C_d^2)}$$



a low pass filter

$$\measuredangle \frac{v_o}{v_i}(j\omega) \Rightarrow \frac{v_o}{v_i}(j\omega) = \left|\frac{v_o}{v_i}(j\omega)\right| e^{j\measuredangle \frac{v_o}{v_i}}$$

$$= |\cdot| e^{-j\measuredangle(G_L + j\omega C_s)} \cdot e^{-j\measuredangle((g_m + G_E) + j\omega C_d)}$$

$$= |\cdot| e^{-j \arctan \frac{\omega C_s}{G_L} - j \arctan \frac{\omega C_d}{g_m + G_E}}$$

Let $v_i(t) = V_i \sin(8t) = V_i \left(\frac{e^{j8t} - e^{-j8t}}{2j}\right)$ $\quad V_i > 0$

$$v_i = \frac{V_i e^{j8t}}{2j} - \frac{V_i e^{-j8t}}{2j}$$

Excite with $v_{i_1} = \frac{V_i e^{j8t}}{2j}$

$$v_{o_1}(t) = \left(\left.\frac{v_o}{v_i}(s)\right|_{s=j8}\right) \cdot \frac{V_i}{2j} e^{j8t} = \left.\frac{G_E g_m}{(sC_d + G_L)(sC_d + (G_E + g_m))} \frac{V_i}{2j} e^{j8t}\right|_{s=j8}$$

$$= \frac{G_E g_m}{(G_L + j8C_d)((G + g_m) + j8C_d)} \frac{V_i}{2j} e^{j8t}$$

$v_{o_2}(t) = v_{o_1}^*(t)$ by having real coefficients = real valued components

$v_o(t) = v_{o_1}(t) + v_{o_1}^*(t)$ by linearity