Midterm 1 in class F 2/17 wk 5

Midterm 2 in class extended 3:10 – 4:30

F 3/24 wk 10

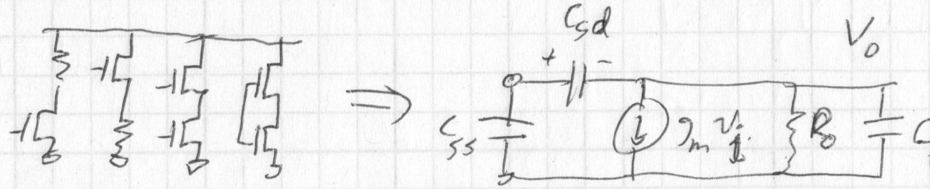
see me if that's a problem

Move room to Corr if possible??

Single pole amps

CMOS C.S.

CS



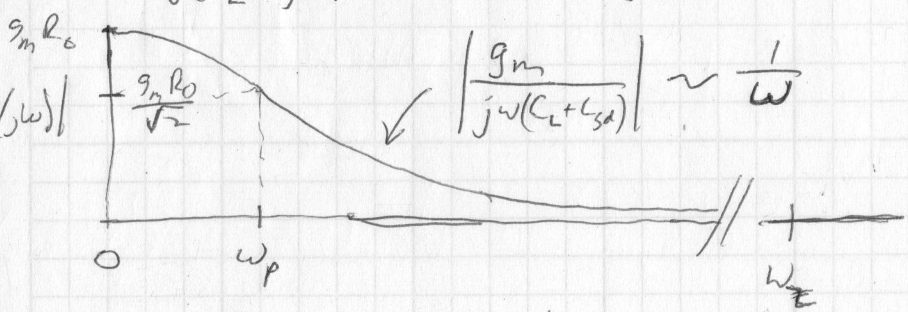
With Widen KCL @ V_o

$$g_m v_i + \frac{1}{R_o} V_o + sC_L V_o + sC_{sd}(V_o - V_i) = 0$$

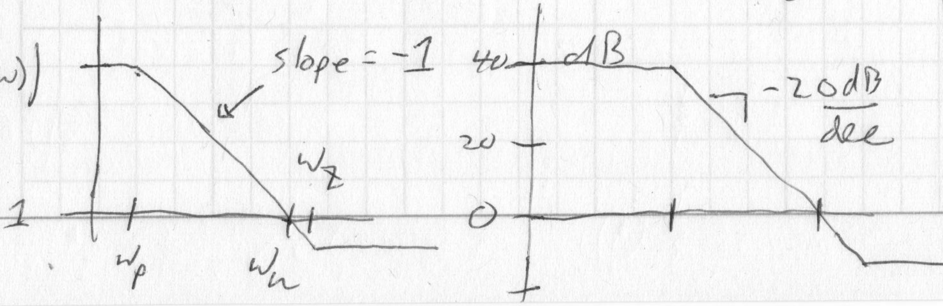
$$V_o\left(\frac{1}{R_o} + s(C_L + C_{sd})\right) = \cancel{g_m} - v_i(g_m - sC_{sd})$$

$$\frac{v_o}{v_i} = \frac{-(g_m - sC_{sd})}{\frac{1}{R_o} + s(C_L + C_{sd})} = -g_m R_o \frac{1 - s/\omega_z}{1 + s/\omega_p} = H(s)$$

$$\omega_p = \frac{1}{R_o(C_L + C_{gd})} \qquad \omega_z = \frac{g_m}{C_{gd}} \text{ in R.H.P.!}$$



$$\left|\frac{g_m}{j\omega(C_L + C_{sd})}\right| \sim \frac{1}{\omega}$$



effect of

increasing R_o

$A_{vo} \nearrow$ $\omega_p \searrow$

by same amount

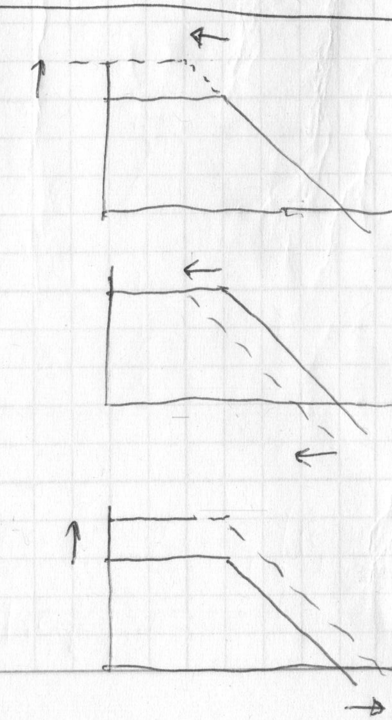
increase C_L

$\omega_p \searrow$ $\omega_u \searrow$

increase g_m

$A_{vo} \nearrow$ $\omega_u \nearrow$

good!



$A_{vo} = g_m R_o$

$\omega_p = \frac{1}{R_o(C_L + C_{gd})}$

$\omega_u = \frac{g_m}{C_L + C_{gd}}$

must have that

$A_{vo}\,\omega_p = \omega_u$ (slope $= -1$) $\frac{1}{\omega}$

$(g_m R_o)\left(\frac{1}{R_o(C_L + C_{gd})}\right) = \frac{g_m}{C_L + C_{gd}} = \omega_u$

check!

for single pole

$\underbrace{A_{vo} \quad \omega_p \quad \omega_u}_{\text{pick any 2}} \qquad \underbrace{g_m \quad R_o \quad C_L}_{\text{independent, but...}}$

$\{\text{any } 2\} + \{\text{any } 1\} \Rightarrow$ fully specified

I love this table on midterm 1

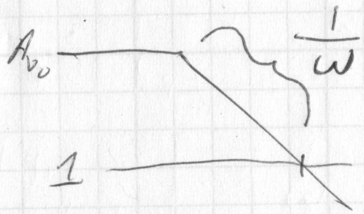
(prob 4 on HW)

for single pole

if $1 < A < A_{vo}$

then knowing (A, ω_A)

gives $\omega_u = A\omega_A$



ω_u, C_L place a lower limit on current

$\omega_u = \frac{g_m}{C_L}$

need $g_m \geq \omega_u C_L$

$g_m = \frac{I_D}{nV_T}$ best case so $I_D \geq nV_T g_m \geq nV_T \omega_u C_L$

$(A_{vo}, \omega_p, \omega_u) \longleftrightarrow (g_m, R_o, C_L) \longleftrightarrow I_D, W, L, V_{ov}$

$I_D = \underbrace{\frac{\mu_n C_{ox}}{2}}_{\text{process variables (choose from small set)}} \frac{W}{L}(V_{gs} - V_{th})^2(1 + \lambda V_{DS})$

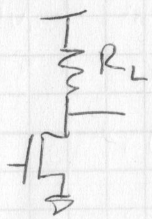
design variables

$g_m = \frac{2I_D}{V_{ov}} = \mu_n C_{ox} \frac{W}{L} V_{ov}$

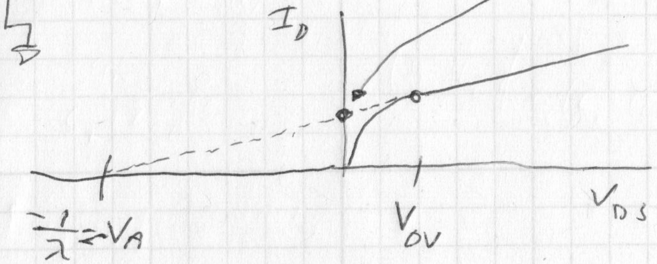
$r_o = \frac{(1 + \lambda V_{DS})}{\lambda I_D}$

$(g_m, r_o, C_{par}) \longleftrightarrow (\underbrace{I_D, \frac{W}{L}, V_{ov}}_{\text{choose any 2}}, L)$

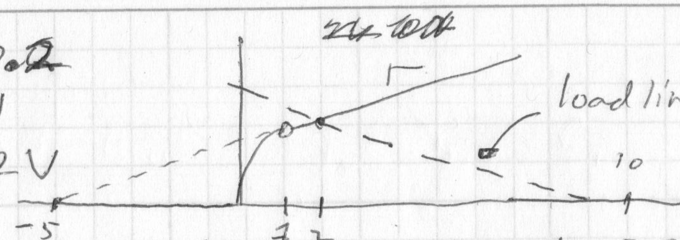
why CMOS CS?



$I_D = \frac{\mu_n C_{ox}}{2} \frac{W}{L}\left(V_{OV}^2\right)\left(1+\lambda V_{DS}\right)$



say $\lambda = 0.\cancel{2}$
$V_{OV} = 1$
$V_{out} = 2V$



What resistor should I use to get good gain?

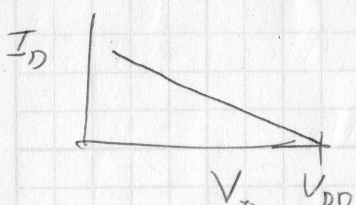
Ideally $R_L > r_o$, so we need $V_{DD} > 2+7 = 9V$

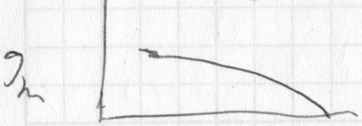
What if $V_{DD} = 5V$?

can't get that R_L at that current.

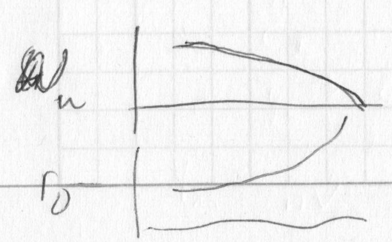
if $V_{DD} < \frac{1}{\lambda}$ R_L always $< r_o$

what ~~does~~ $(I_D, g_m) \Rightarrow (A_{vo}, \omega_p, \omega_u)$ look like vs. V_{out}?



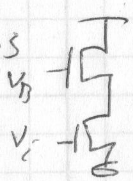


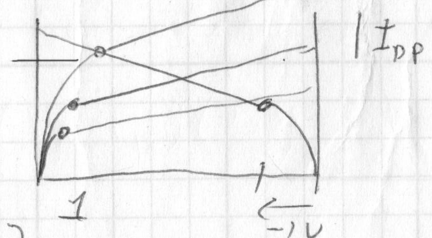
$\sim \sqrt{I_D}$ w/ const $\frac{W}{L}$



swing? 1V on low side
high side depends on other specs

CMOS





$r_{op} = r_{on}$ if $\lambda_p = \lambda_n$

current still not constant but less variation

$A_{vo}, \omega_p, \omega_u$ roughly constant over output swing

which is $[V_{ovn}, V_{DD} - |V_{ovp}|]$

current varies less than λV_{DD}

Why not make $L_p \gg L_n$? (so that $\lambda_p \ll \lambda_n$)

OK up to pt where $C_{gdp} + C_{dbp}$ affect performance