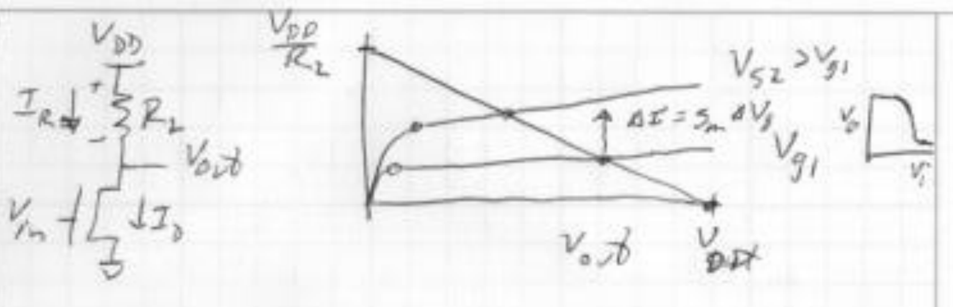
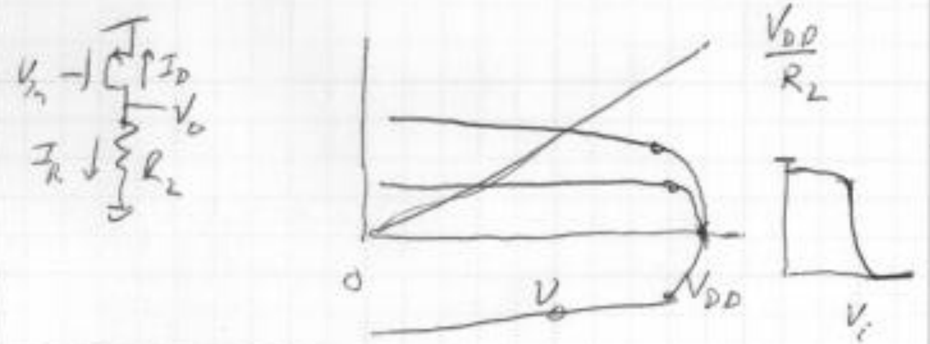
Midterm 2 weeks from today
- in class
- 1 page, 2 sides notes
- no calculators
- HW 1-4
- Lab 1+(2?)

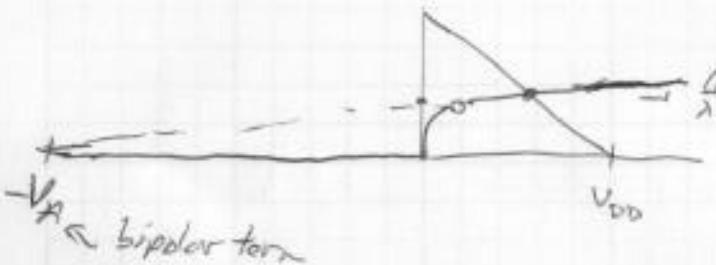
CS amp.
- Load line
- small signal model (W3L1 p 4)





Usually $r_o >> R_L$

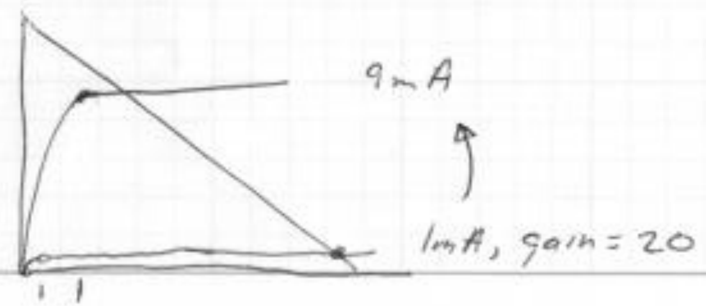
slope of I_d vs V_{ds} << slope of $\frac{1}{R}$ } why?

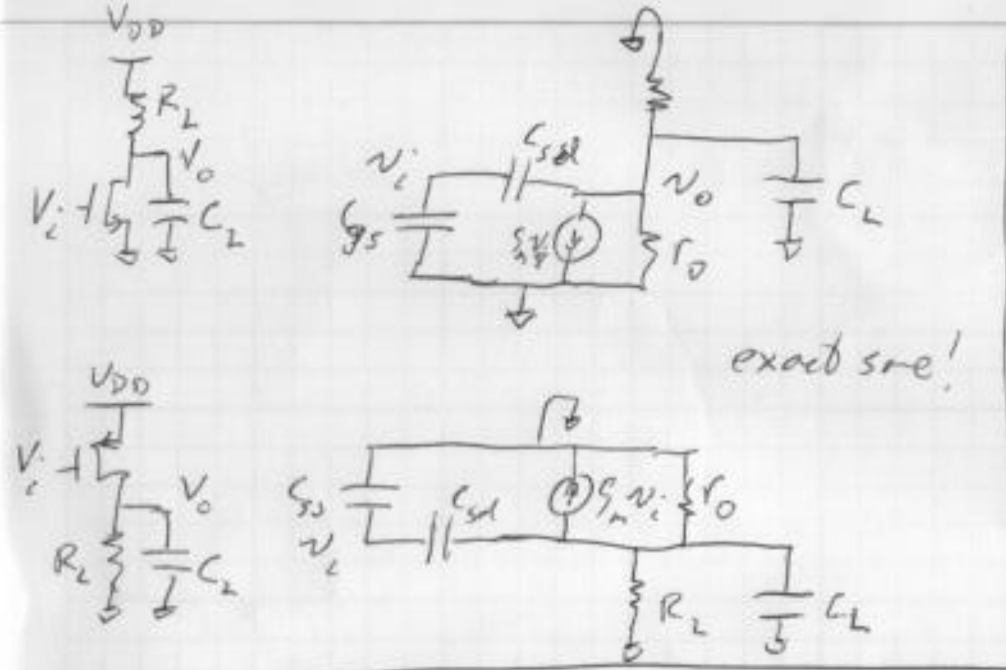


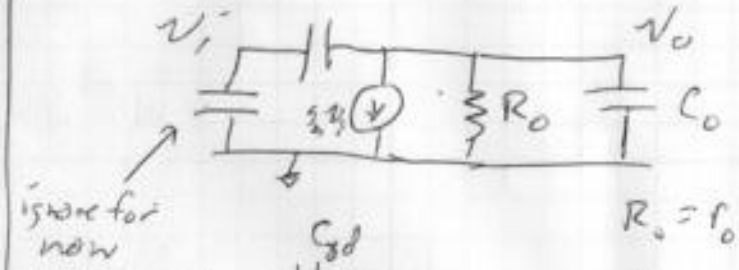
$\frac{(1+\lambda I_D)}{\lambda I_D} = \frac{1}{\lambda I_{D0}}$

note that g_m is changing w/ bias point

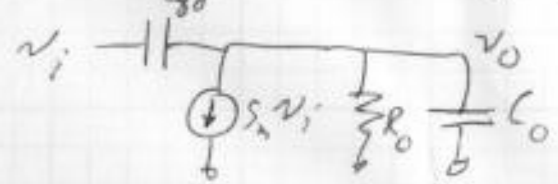
$$g_m = \begin{cases} \frac{2I_D}{V_{OV}} \\ \mu_n C_{ox} \frac{W}{L}(V_{OV})(1+\lambda V_{DS}) \\ \sqrt{I_D \cdot 2\mu_n C_{ox} \frac{W}{L}(1+\lambda V_{DS})} \end{cases}$$







$R_o = r_o \| R_L$



C_o typ $\gg C_{gd}$

"inspection" – really low freq } goal: eliminate
" high freq } components
in between

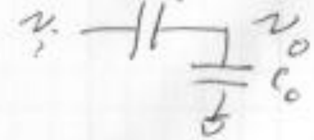
low freq: Z_c huge – ignore caps
↳ compared to: R_o, $\frac{1}{g_m}$

$v_o = (-g_m v_i) R_o$

$= -g_m R_o v_i$

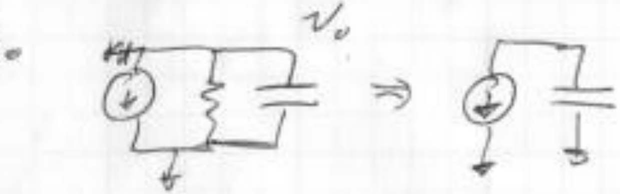
$\frac{v_o}{v_i} = -g_m R_o$

high freq: Z_c small
↳ compared to R_o, $\frac{1}{g_m}$



$\frac{v_o}{v_i} = \frac{C_{gd}}{C_{gd}+C_o}$

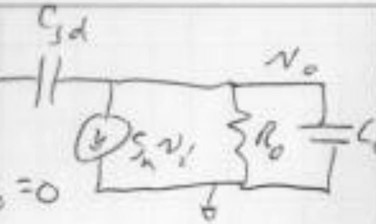
mid ignore r_o $r_o \gg \frac{1}{\omega C_o}$
ignore C_{gd} $g_m > \omega C_{gd}$



$v_o = (-g_m v_i) Z_c$

$\frac{v_o}{v_i} = \frac{-g_m}{sC_o}$

or KCL @ v_o



$$sC_{gd}(v_o - v_i) + g_m v_i + \frac{1}{R_o} v_o + sC_o v_o = 0$$

$$v_o\left(sC_{gd} + sC_o + \frac{1}{R_o}\right) = -(g_m - sC_{gd}) v_i$$

$$H(s) = \frac{v_o}{v_i} = \frac{-g_m\left(1 - \frac{sC_{gd}}{g_m}\right)}{\frac{1}{R_o}\left(1 + s(C_o + C_{gd})R_o\right)} = -g_m R_o \frac{1 - s/\omega_z}{1 + \frac{s}{\omega_p}}$$

$$\omega_z = \frac{g_m}{C_{gd}} \quad \text{RHP} \qquad \omega_p = \frac{1}{R_o(C_o + C_{gd})}$$

Soln

$g_m = 100\mu S$ $R_o = 1M$ $C_L = 1pF$ $C_{gd} = 10fF$

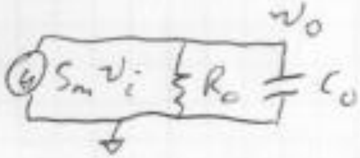
$A_{v_o} = 100$

$\omega_p = 10^6$ rad/s

$\omega_z = \frac{10^{-4}}{10^{-14}} = 10^{10} \frac{rad}{s}$

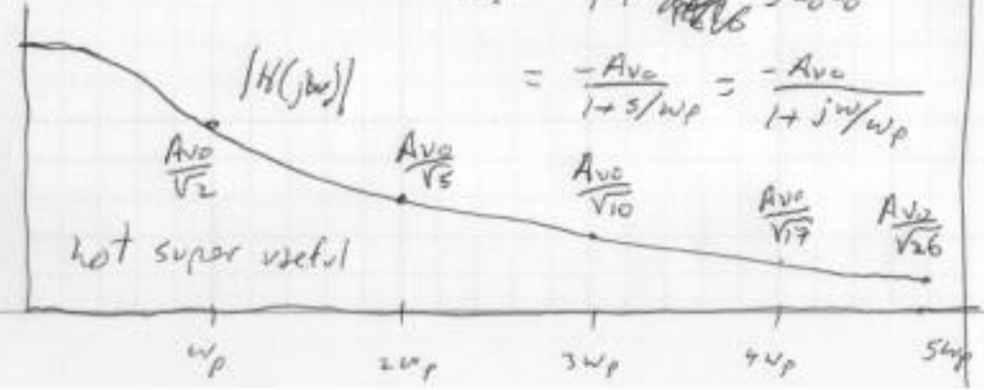
			ϕ
$H(s) = $	-100	$\omega \ll 10^6$ rad/s	-180
	$-\frac{10^8}{j\omega}$	in between	-270
	$\frac{1}{100}$	$\omega \gg 10^{10}$ rad/s	0

Single pole amplifier - ignore C_{gd} for now



$$\text{KCL @ } v_o \Rightarrow H(s) = \frac{v_o}{v_i} = \frac{-g_m R_o}{1 + sR_oC_o}$$

$$= \frac{-A_{vo}}{1 + s/\omega_p} = \frac{-A_{vo}}{1 + j\omega/\omega_p}$$



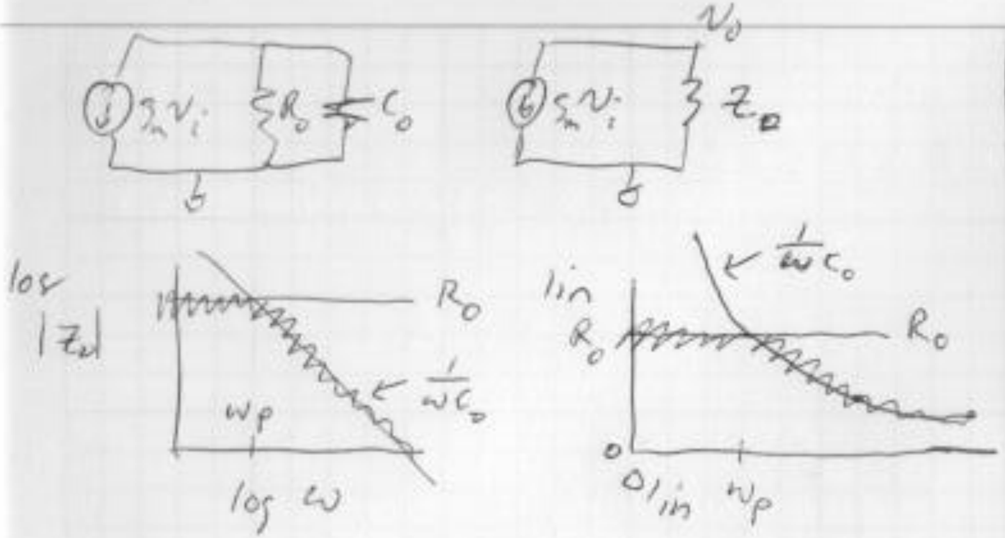
when is $|H(j\omega)| = 1$?

$$|H(j\omega_u)| = 1 = \frac{g_m R_o}{|1 + j\omega_u R_o C_o|} \approx \frac{g_m R_o}{\omega_u R_o C_o} = \frac{g_m}{\omega_u C_o}$$

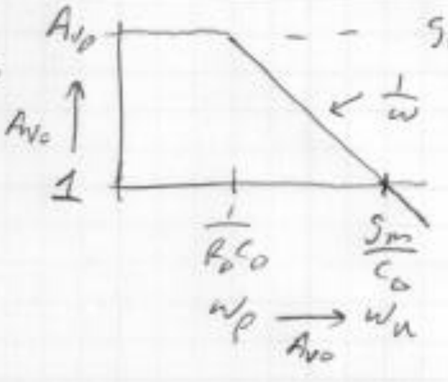
$$\omega_u = \frac{g_m}{C_o}$$

-or-

$$\omega_u = A_{vo}\,\omega_p = (g_m R_o)\frac{1}{R_o C_o} = \frac{g_m}{C_o}$$



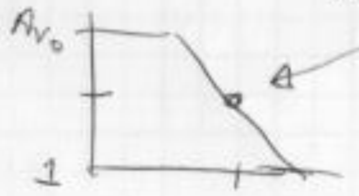
$A_v = -g_m Z_o$



$\{A_{vo}, \omega_p, \omega_u\}$ $\{g_m, R_o, C_o\}$

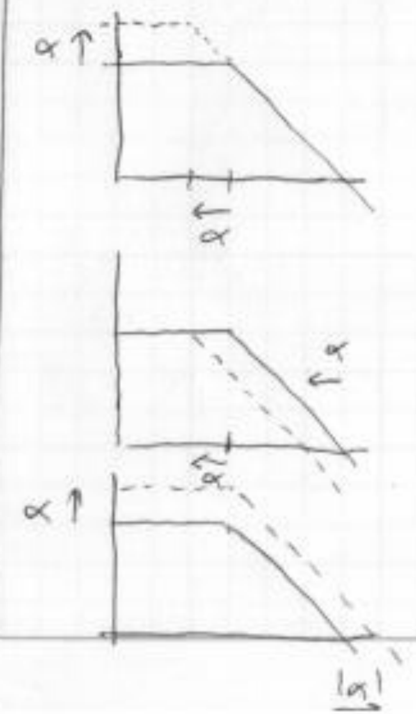
often got a spec w/ ω_u, C_o, A_{vo}

need a gain of 100 at 1M rad/s, 1pF load



any point on this curve gives ω_u

• bounds A_{vo} below



increase R_O by α

increase C_o by α

increase g_m by α