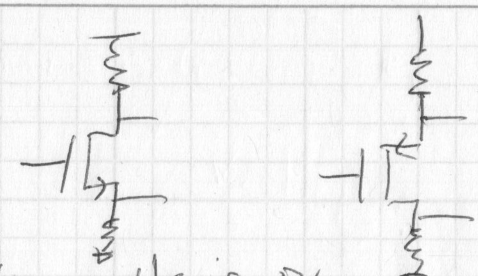
140/240A 17 SP W5L2

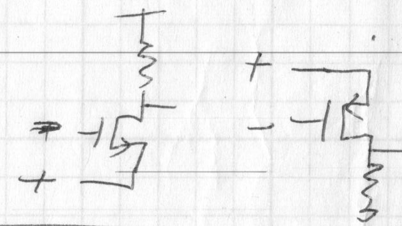
Midterm Friday

Moving to Cory 540 Monday!!



in	out	G_m	R_o	R_i
G	D			
G	S			
S	D			

simplest op-amp:

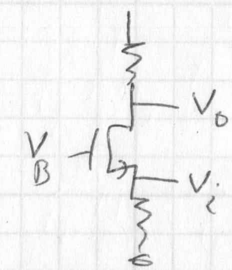


Last time: CS, w/ R_s

$$R_o = r_o + (1+g_m r_o) R_s \approx \begin{cases} r_o & R_s < \frac{1}{g_m} \\ g_m r_o R_s & R_s > \frac{1}{g_m} \end{cases}$$

$$G_m = \frac{g_m}{1 + g_m R_s + \frac{R_s}{r_o}} \approx \begin{cases} g_m & R_s < \frac{1}{g_m} \\ 1/R_s & R_s \gg \frac{1}{g_m} \end{cases}$$

Common Gate



$G_m = -g_m$

R_o = ~~same as CB~~ same as CS but w/ src impedance

$$R_i = \frac{1}{g_m}\left(1 + \frac{R_D}{r_o}\right) \approx \begin{cases} 1/g_m & R_D < r_o \\ \frac{R_D}{g_m r_o} & R_D > r_o \end{cases}$$

but if

__But__ these voltages & currents are only true under the special circumstances

$v_o = 0$ or $v_i = 0$

Be careful not to confuse "G_m calc" and "R_o calc" conditions for what happens when you wiggle v_i.

in	out	G_m	R_o	R_i
G	D	$\frac{g_m}{1+g_m R_S + \frac{R_S}{r_o}}$	$r_o + R_S(1+g_m r_o)$	sig (miller)
G	S	$\frac{-g_m}{1+\frac{R_D}{r_o}}$	~~same, but w/ R_{SRC}~~ $R_S \parallel \frac{1}{g_m}\left(1+\frac{R_D}{r_o}\right)$	same
S	D	$-g_m$	same as CS but w/ R_{SRC}	$\frac{1}{g_m}\left(1+\frac{R_D}{r_o}\right)$

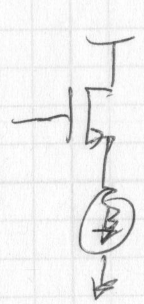
what is the input capacitance of a common drain amp w/ $g_{mb} = 0.2 g_m$ $\quad g_m r_o = 100$

$$A_v = -G_m R_o = \frac{-(-g_m)}{g_m + g_{mb}} \cdot \frac{1}{1+\frac{1}{g_m r_o}} \approx \frac{1}{1.2} \approx 0.8$$

$$C_{in} = C_{gd} + C_{gs}(1-A)$$

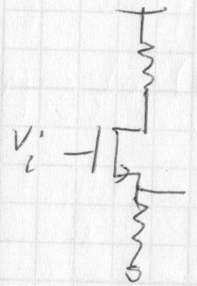
$$= C_{gd} + 0.2\, C_{gs}$$

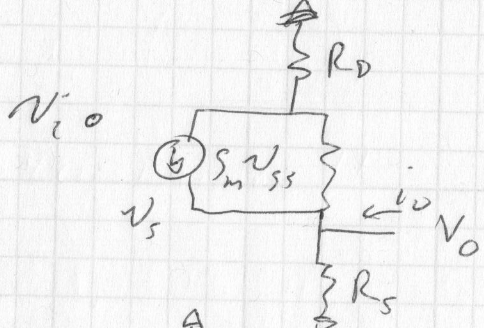
$W C_{ol}'$ $\qquad \frac{2}{3} W L C_{ox}$



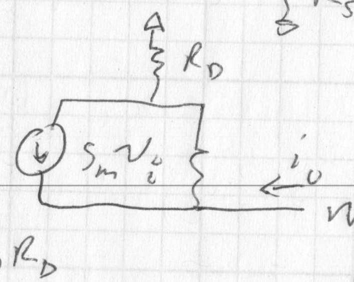
Next up: 2 stage op-amp

Common Drain





$G_m = \frac{i_o}{v_i}\Big|_{v_o=0}$



$v_d = i_o R_D$

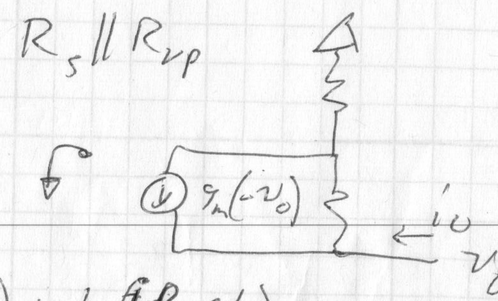
KCL @ v_o $\quad i_o + g_m v_i + \frac{1}{r_o}\left(i_o R_D - \cancel{v_o}^{\,0}\right) = 0$

$i_o\left(1 + \frac{R_D}{r_o}\right) = -g_m v_i$

$G_m = \frac{i_o}{v_i} = \frac{-g_m}{1 + \frac{R_D}{r_o}}$ ← does not get g_{mb} due to body effect

$R_o = \frac{v_o}{i_o}\Big|_{v_i=0} = R_S \| R_{vp}$

$R_{vp} = \frac{v_o}{i_{vp}}\Big|_{v_i=0}$



$i_{vp} + g_m(-v_o) + \frac{1}{r_o}(i_{vp}R_D - v_o) = 0$

$\cancel{i_{vp} = (g_m + \frac{1}{r_o})}$ $\quad \left(1 + \frac{R_D}{r_o}\right) i_{vp} = \left(g_m + \frac{1}{r_o}\right) v_o$

$R_{vp} = \frac{v_o}{i_{vp}} = \frac{1 + \frac{R_D}{r_o}}{g_m + \frac{1}{r_o}} \approx \frac{1}{g_m}\frac{\left(1 + \frac{R_D}{r_o}\right)}{1 + \frac{1}{g_m r_o}}$

$R_o \approx R_S \| \frac{1}{g_m}\left(1 + \frac{R_D}{r_o}\right)$

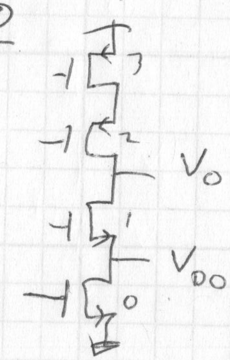
all of these $g_m \Rightarrow g_m + g_{mb}$

$A_v = -G_m R_o = +\frac{g_m}{g_m + g_{mb}} \frac{\left(\cancel{1 + \frac{R_D}{r_o}}\right)}{\left(1 + \frac{1}{g_m r_o}\right)}$

$= \frac{1}{1 + \frac{1}{g_m r_o}}$ w/ no body effect

$\approx \frac{g_m}{g_m + g_{mb}}$ w/ body effect and good intr. gain

SO



$A_v = \frac{v_o}{v_i} = -G_m R_o$

$A_{vDO} = \frac{v_{do}}{v_i} = -G_{mDO} R_{oDO}$

One way: write down small signal for everything, solve all equations (spice)

simpler: find G_m (set to ground v_o)
find R_o (set to ground v_i)