HW3
Lab2

IC Design?

Single pole model

What are the specs that we work from?
Often vague - "you're the analog person - figure it out!"

try to translate into

gain, bandwidth

power, (noise)

input/output swing

source, load impedance

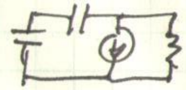
gain stability (feedback, stability)

Project helps you tie it all together

Circuit design - library of building blocks
CS, CG, CD, diff pair, current mirror
cascode, ...

find operating point
solve nonlinear algebraic equations

find linear model there



redraw circuit in local coords v_i, i_o, v_o

apply linear systems tools
Bode plots
transient analysis

estimate nonlinear effects
output swing, gain variation

What are we designing?

choose a collection of building blocks & assemble

each transistor has design choices

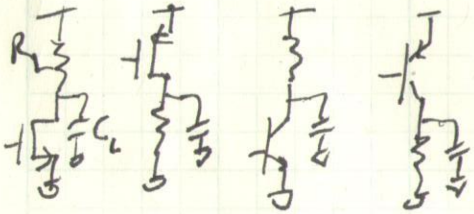
bipolar: emitter area, current

MOS $I_d = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{gs} - V_{th})^2 (1 + \lambda V_{ds})$

process parameters
sometimes w/ a few discrete choices, e.g. thick oxide, high V_t, ...

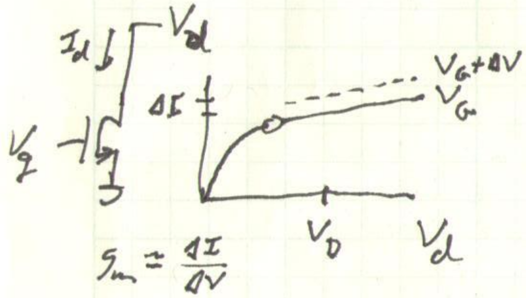
design

bias pt.



all CS or CE

all have ≈ same small signal model

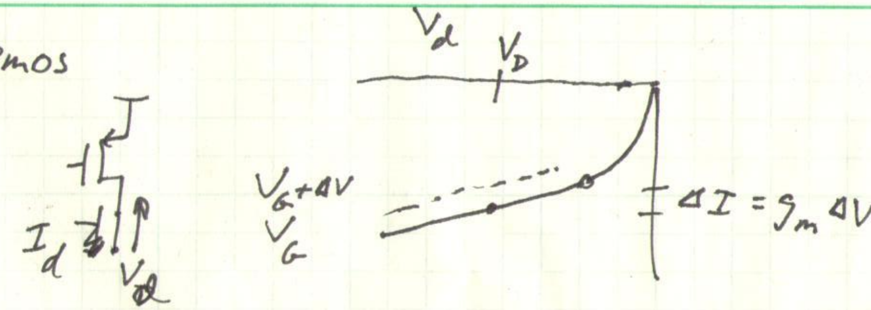


$g_m \approx \frac{\Delta I}{\Delta V}$

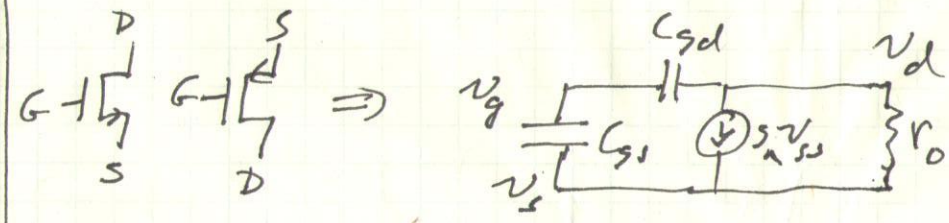
positive ΔV

$\Rightarrow$ positive $\Delta I = g_m \Delta V$

Pmos

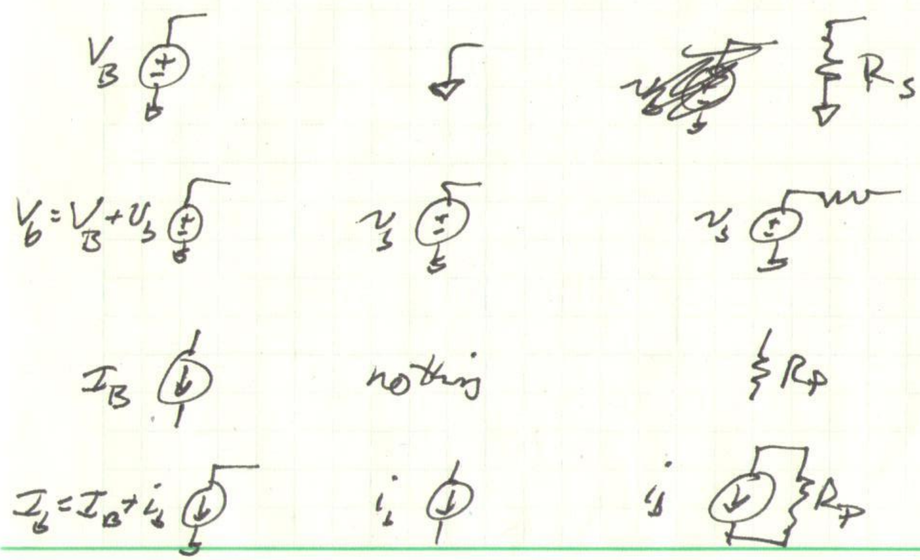


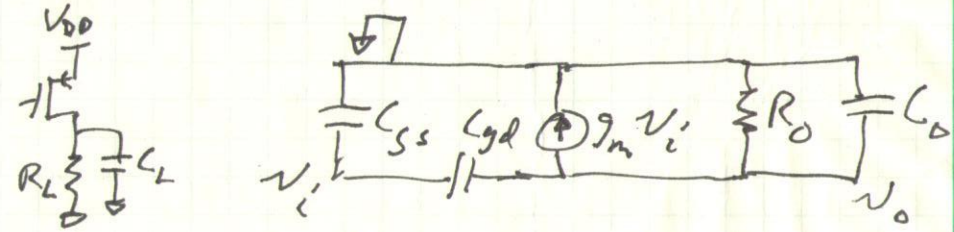
positive $\Delta V \Rightarrow$ positive ΔI (I_d less negative)



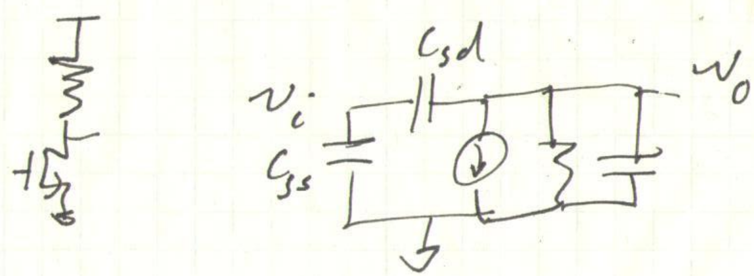
small signal model

$V_x = V_X + v_x$

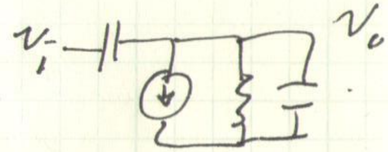


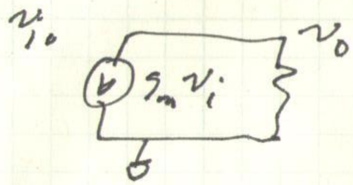


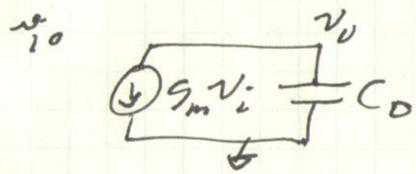
$R_O = R_L \| r_o \quad C_O = C_L \| C_{dbp}$

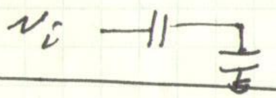


exact same circuit

simplify: 

low frq:  $v_o = -g_m R_O$

high frq (above $\frac{1}{R_O C_O}$)  $v_o = \frac{-g_m}{j\omega C_L}$

highest frq above $\frac{g_m}{C_{gd}}$  $v_o = \frac{C_{gd}}{C_{gd}+C_O}$

KCL @ v_o: $sC_{gd}(v_o - v_i) + g_m v_i + \frac{1}{R_O} v_o + sC_O v_o = 0$

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

$$H(s) = \frac{v_o}{v_i} = \frac{-g_m \left(1 - \frac{sC_{gd}}{g_m}\right)}{\frac{1}{R_O} + s(C_O + C_{gd})}$$

$$= -g_m R_O \frac{1 - s/\omega_z}{1 + s/\omega_p} \qquad \omega_p = \frac{1}{R_O(C_O + C_{gd})}$$

when $s = j\omega$ $\omega \ll \omega_p$ $\omega \ll \omega_z$

$$H(j\omega) \cong -g_m R_O$$

when $\omega_p < \omega < \omega_z$

$$H(j\omega) \approx \frac{-g_m R_O}{\frac{j\omega}{\omega_p}} = \frac{-g_m R_O}{j\omega R_O (C_O + C_{gd})} = \frac{-g_m}{j\omega(C_O + C_{gd})}$$

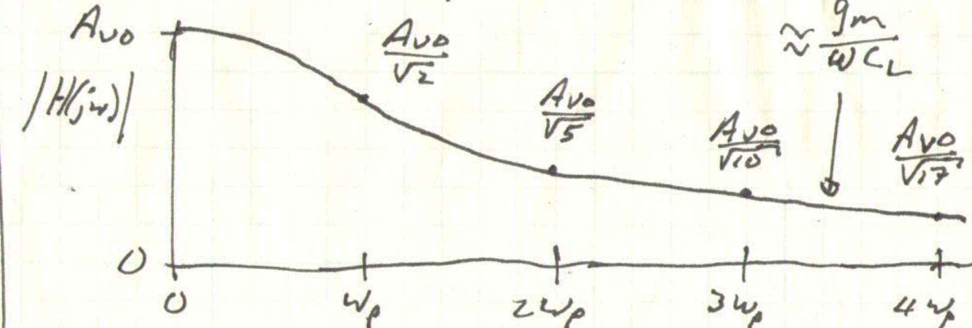
when $\omega_p < \omega_z < \omega$

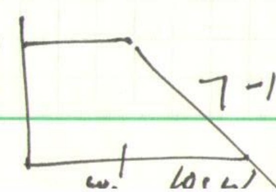
$$H(j\omega) \approx -g_m R_O \left(\frac{-\omega_p}{\omega_z}\right) = g_m R_O \frac{1}{R_O(C_O + C_{gd})} \frac{C_{gd}}{g_m}$$

$$= \frac{C_{gd}}{C_O + C_{gd}}$$

Simplify even further: $C_{gd} = 0$

$$H(s) = \frac{v_o}{v_i} = \frac{-g_m R_O}{1 + s/\omega_p} = \frac{A_{vo}}{1 + s/\omega_p}$$





$\to -1$ $-\frac{20dB}{dec}$, $\frac{1}{\omega}$