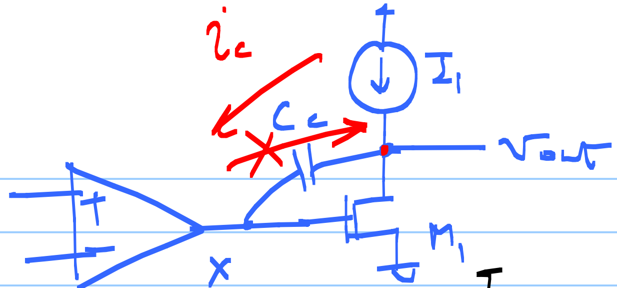
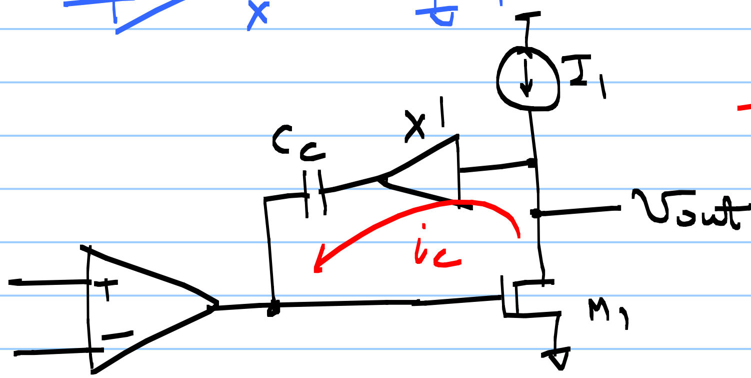
ECE 5411 → Lecture 24

Note Title 4/27/2011

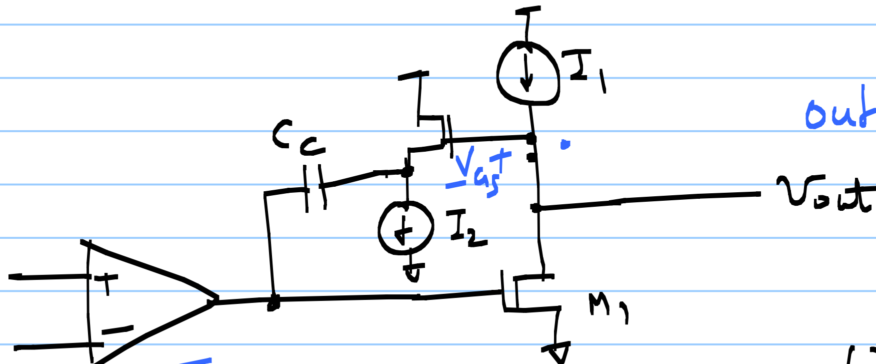
$\Rightarrow \quad \phi_M = 63.5^{\circ} \qquad \xi = \frac{1}{\sqrt{2}} \qquad t_{settle}$ is minimize



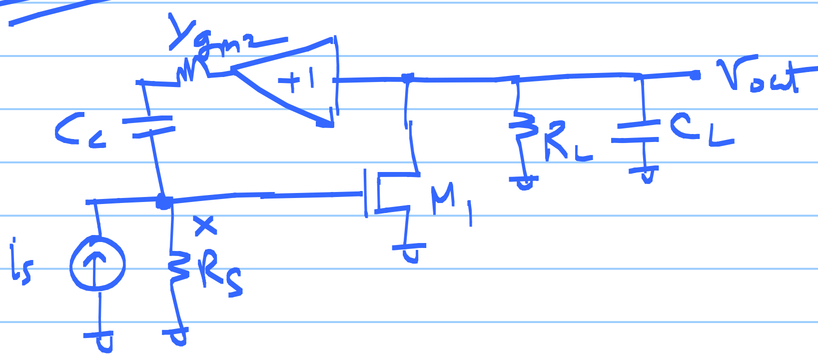
Miller



* No RHP zero



output swing is less.



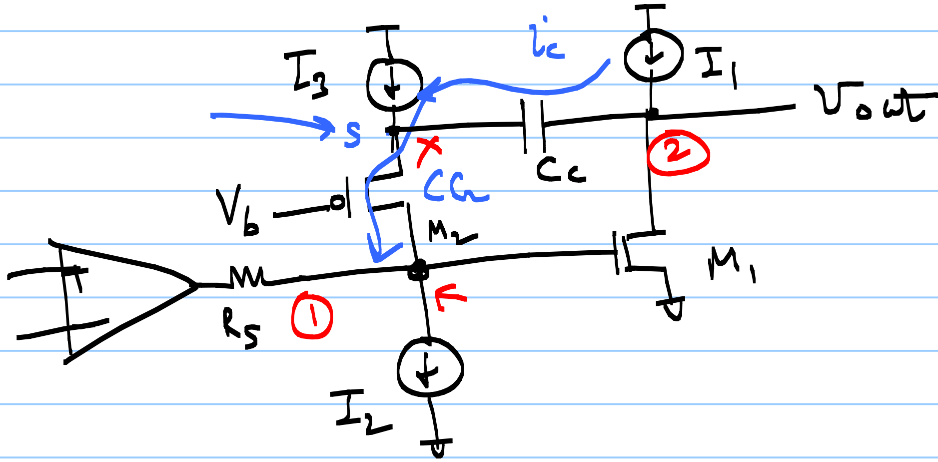
$$\omega_{p1} \simeq \frac{1}{g_{m1} R_L R_S C_c}$$

$$\omega_{p2} \simeq \frac{g_{m1}}{C_L}$$

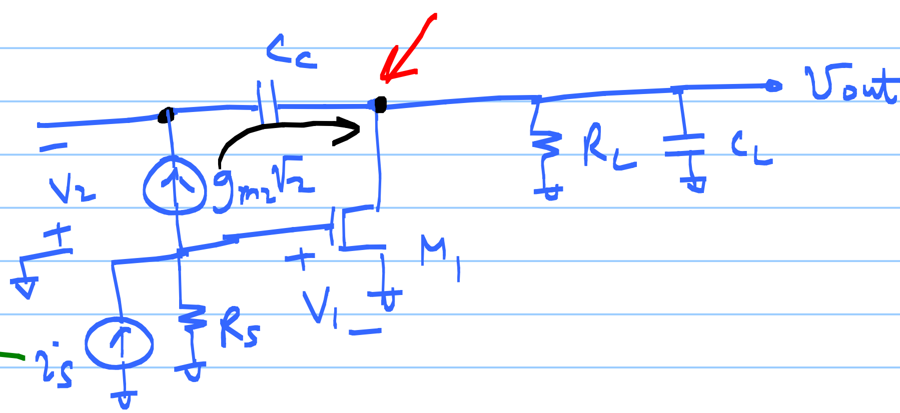
$$\omega_z = -\frac{g_{m2}}{C_c} \leftarrow \text{LHP zero}$$

Use a CG Stage

"1983 Ahuja Compensation"



Assume $\lambda = \gamma = 0$



$g_m v_{in}$

KVL $\Rightarrow$ $$v_{out} + \frac{g_{m2} V_2}{sC_c} = -V_2$$

$$\Rightarrow \quad V_2 = -v_{out} \frac{sC_c}{g_{m2} + sC_c} \longrightarrow (1)$$

KCL @ V_{out} $\Rightarrow$ $$g_{m1} V_1 + v_{out} \left(R_L^{-1} + sC_L \right) = g_{m2} V_2 \longrightarrow (2)$$

KCL @ input $\Rightarrow$ $$i_{in} = \frac{V_1}{R_s} + g_{m2} V_2 \longrightarrow (3)$$

$$\frac{v_{out}}{i_s} = \frac{-g_{m1} R_s R_L \left(g_{m2} + sC_c \right)}{R_L C_L C_c s^2 + \left[(1 + g_{m1} R_s) g_{m2} R_L C_c + C_c + g_{m2} R_L C_L \right] s + g_{m2}}$$

$$\omega_z = -\frac{g_{m2}}{C_c}$$ CG Device $\Leftarrow$ Can use to improve ϕ_M

$$\omega_{p1} \simeq \frac{1}{g_{m1} R_L R_S C_c}$$ $\leftarrow$ Same as Miller

$$\omega_{p2} \simeq (g_{m2} R_S) \frac{g_{m1}}{C_L} \leftarrow \underline{\underline{(g_{m2} R_S)}} \times \omega_{p_2,\text{Miller}}$$ CG

$\Rightarrow$ ω_{p2} gets pushed away by a large factor

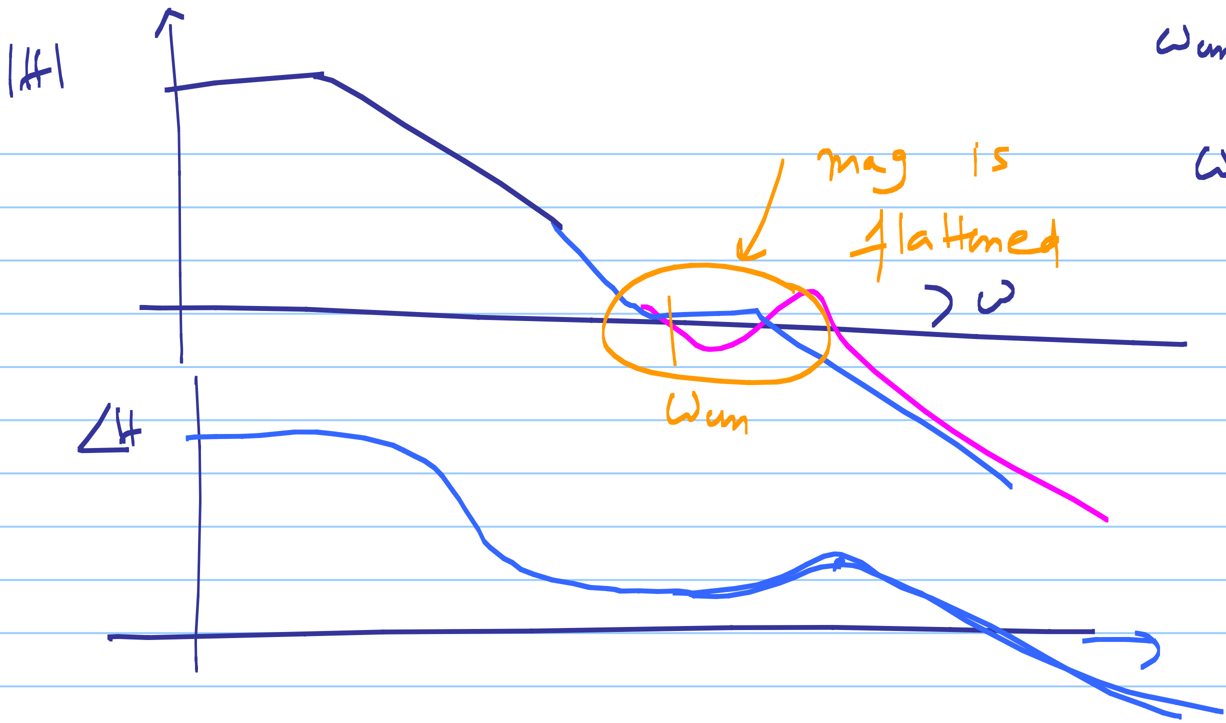
$\times$ $\omega_{p2} \uparrow$ for lower C_c

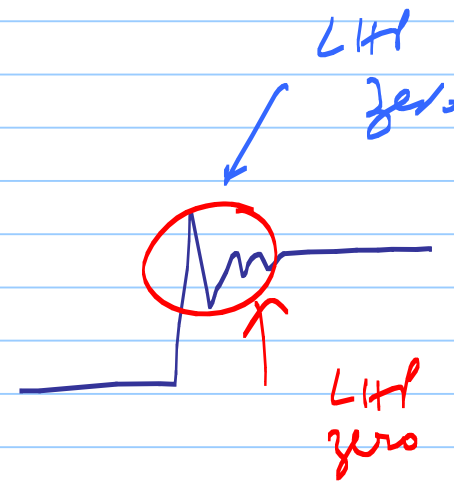
$\Rightarrow$ $f_{un} \uparrow\uparrow = \frac{g_{m1}}{2\pi C_c}$

$\Leftarrow$ Look out for ω_{px}

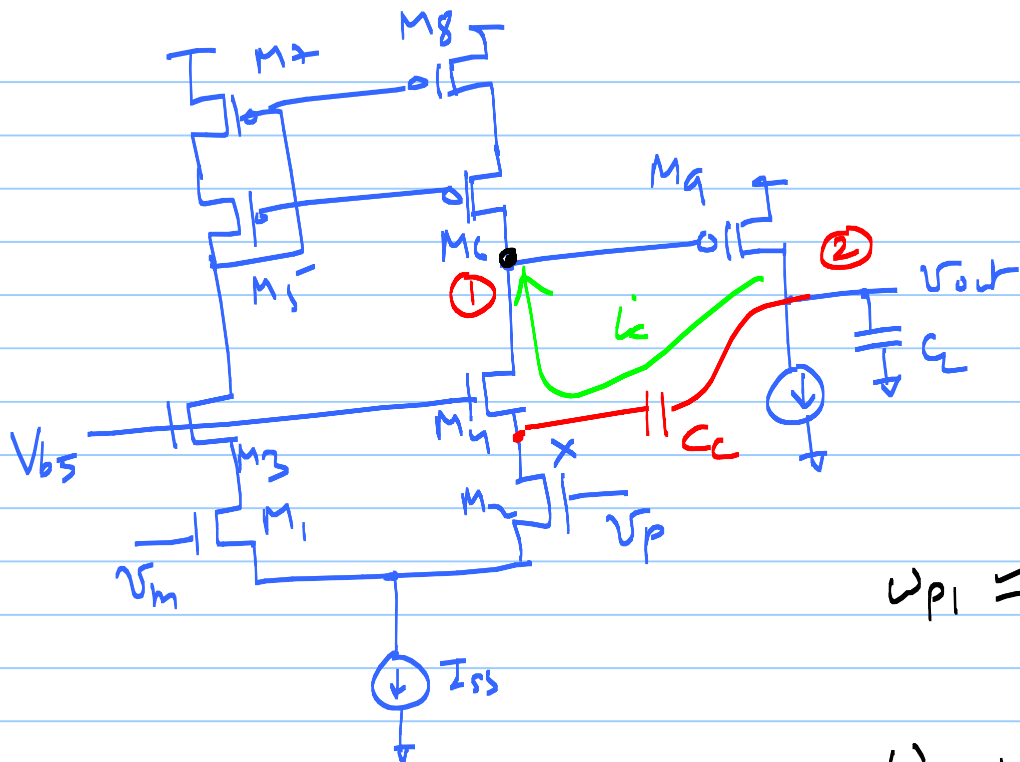
$$\omega_{un} = -\frac{g_{m1}}{C_c}$$

$$\omega_z = -\frac{g_{m,esn}}{C_c}$$

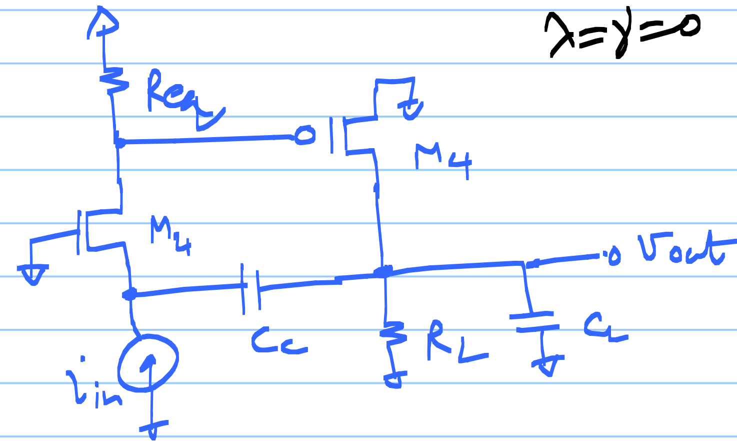




Cascode compensation



$\lambda = \gamma = 0$



$$\omega_{p_1} \simeq \frac{1}{R_{eq}\, g_{m9}\, R_L C_c}$$

$$\omega_{p_2} \simeq (g_{m2} R_{eq}) \frac{g_{m9}}{C_L}$$

$$\omega_z = -(g_{m4} R_{eq}) \frac{g_{m9}}{C_c} \gg \frac{g_{m4}}{C_c}$$

→ nano-CMOS

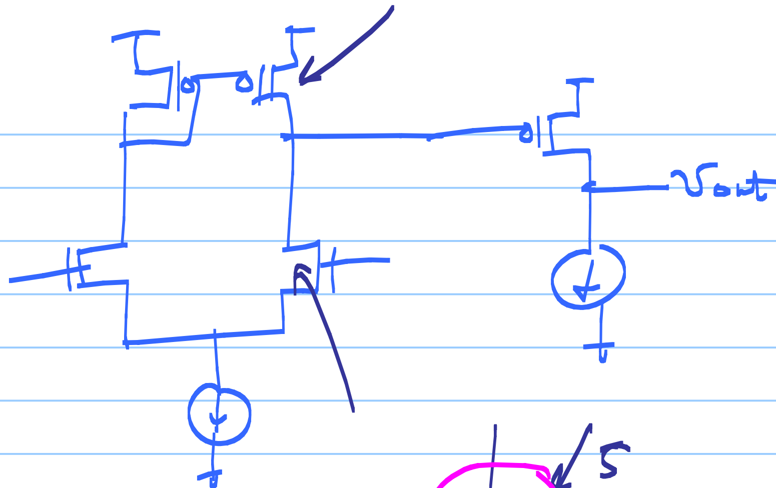
① $V_{DD} \downarrow$ $\quad V_{TH_{N,P}} \longleftrightarrow$ $\Rightarrow$ headroom is shrinking

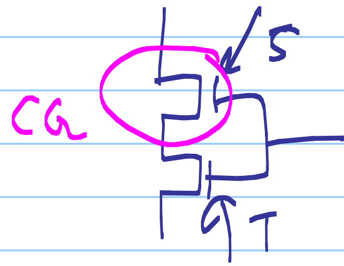
(−) ② $\sigma_{\Delta V_{TH}} \propto \frac{1}{\sqrt{WL}}$ → offsets $\quad$ (+) $f_T \uparrow\uparrow$

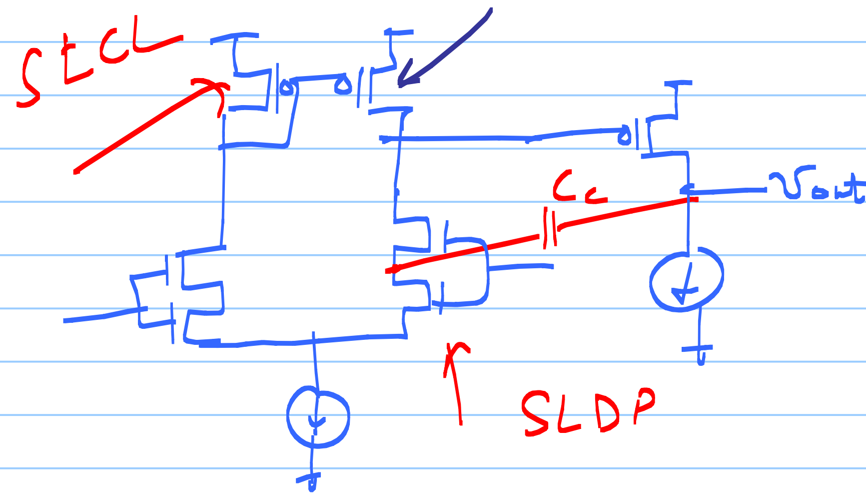
③ $g_m r_o \downarrow$ $\quad$ (+) $(W, L) \downarrow\downarrow$

Split-Length Compensation

Low-V_{DD}







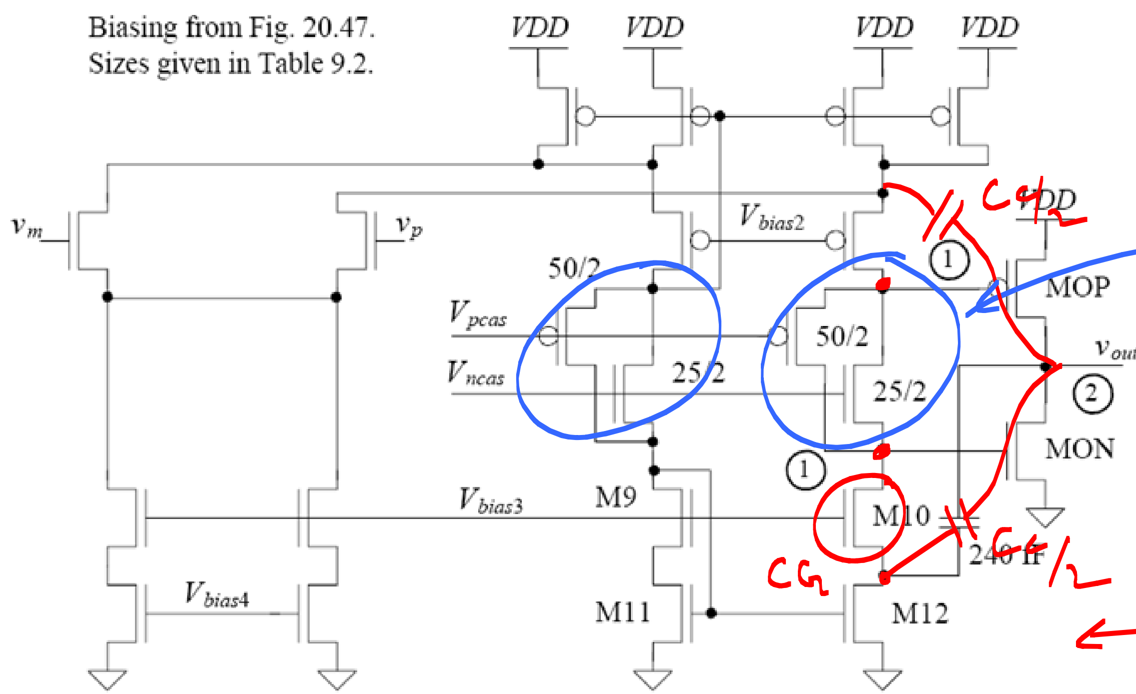
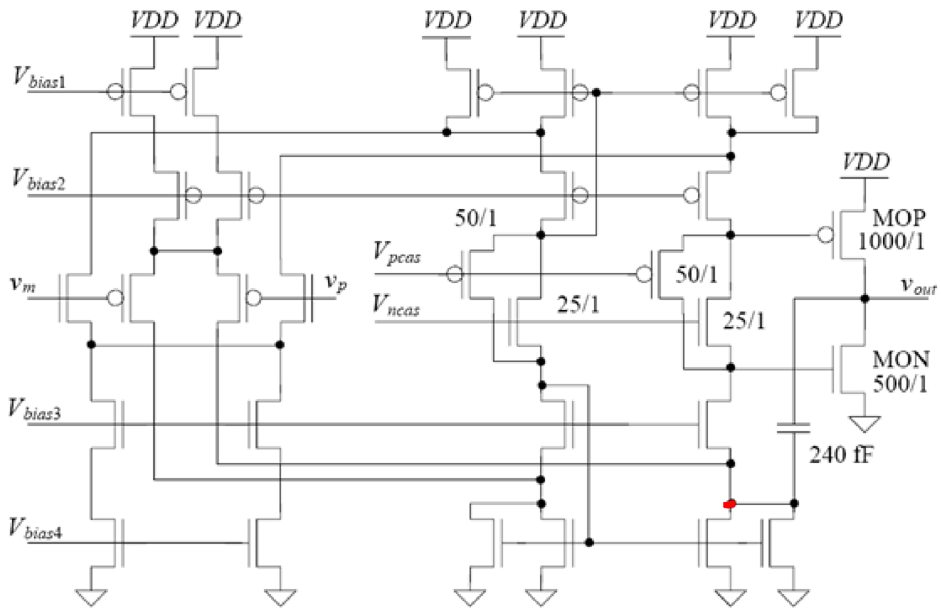


Figure 24.44 Folded-cascode op-amp with class AB output buffer.

Floating CM is embedded into FC structure

← indirect (cascode) compensated.

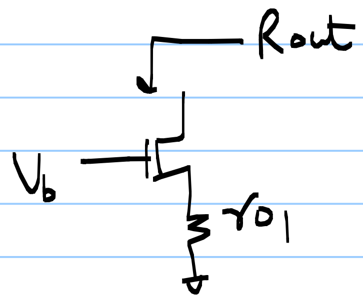


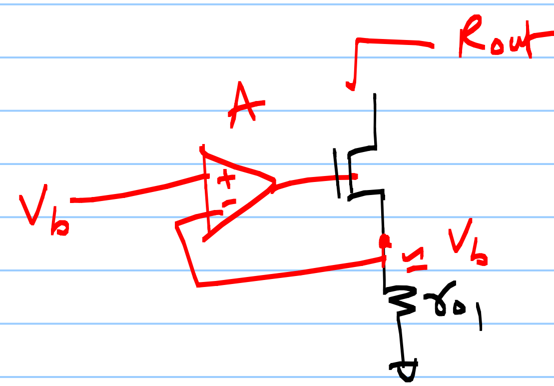
Biasing from Fig. 20.47.
Unlabeled NMOS are 50/1.
Unlabeled PMOS are 100/1.

Figure 24.48 An op-amp with an input common-mode range that extends beyond the power supply rails and that can drive heavy loads.

Rail-to-Rail operation

Gain Boosting / Enhancement





$$\simeq \underline{\underline{A\, g_{m2}\, r_{o2}\, r_1}}$$

Razavi Sec 9.8

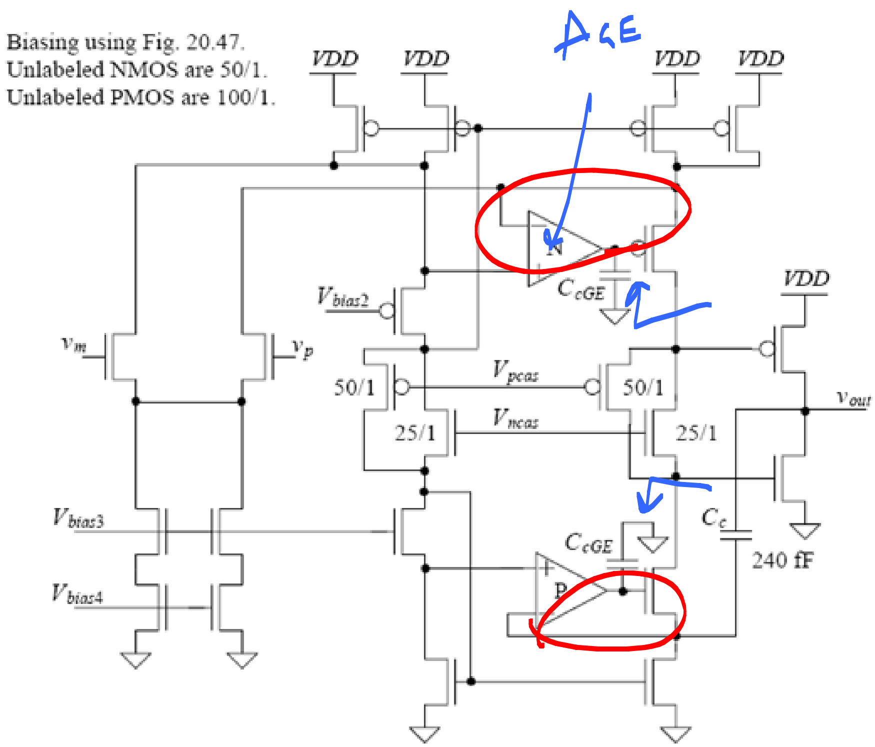
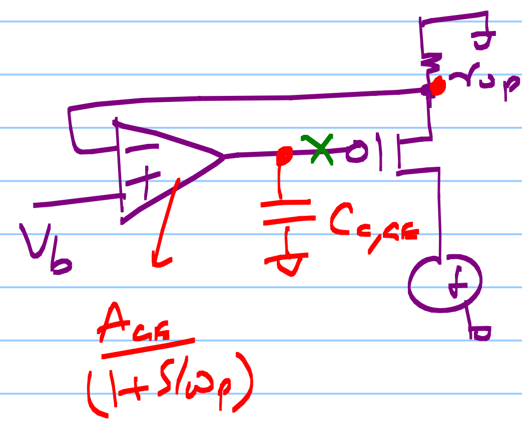
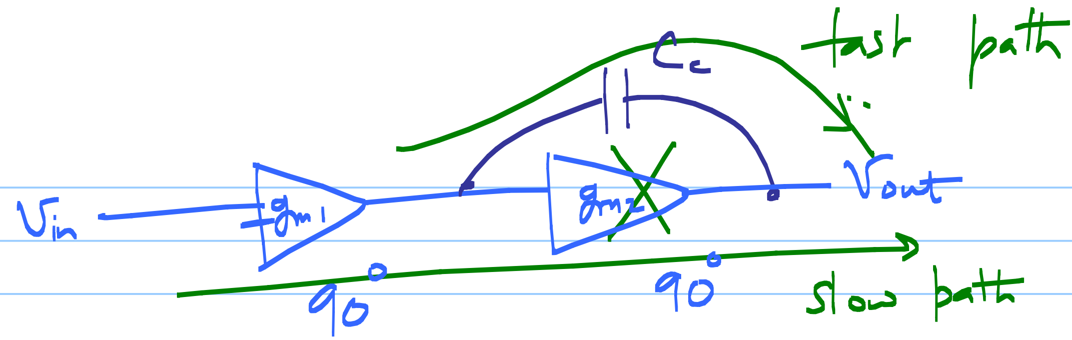


Figure 24.51 Folded-cascode op-amp with class AB output buffer and gain-enhancement.

$$A_{OL} = A_{OL1} \cdot A_{GE}$$

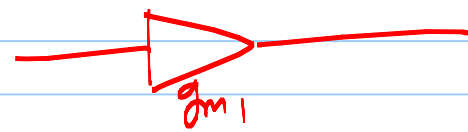


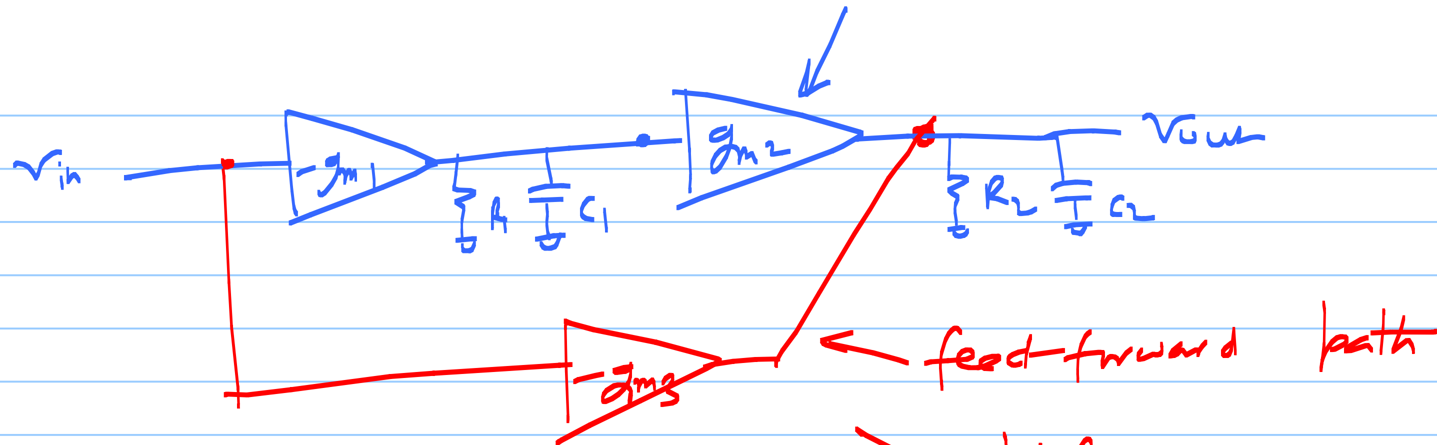


$A = g_{m1} r_1 \cdot g_{m2} r_2$

@ high frequency

$SR = \frac{I_{ss}}{C_c}$





→ LHP zero

$\omega_{p2} = \omega_z$

$$\frac{v_o}{v_i}(s) = \frac{-(A_{v1}A_{v2}+A_{v3})\left[1+\frac{A_{v3}\,s}{(A_{v1}A_{v2}+A_{v3})\,\omega_{p1}}\right]}{(1+s/\omega_{p1})(1+s/\omega_{p2})}$$

$$A_{v_R} = g_{m_R} \cdot R_R$$

$$\omega_z = \omega_{p1}\left[1 + A_{v1}\frac{g_{m2}}{g_{m3}}\right]$$