2 stage

Miller comp.
RHP zero
mirror doublet

Common mode gain

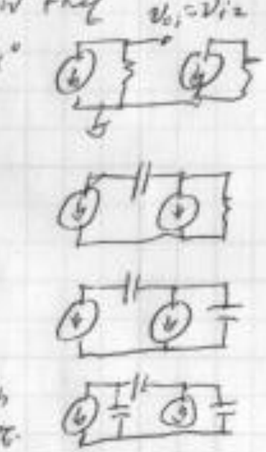
slewing

$\omega_{p1} = \frac{1}{R_{o1}C_{o1}}$ add C_c → $\omega_{p1c} \approx \frac{1}{G_{m2}R_{o2}R_{o1}C_c}$

$\omega_{p2} = \frac{1}{R_{o2}C_{o2}}$ $\omega_{p2c} = ?$

$\omega_{uc} = ?$

low freq



$$\omega_{p2c} = \frac{G_{m2}}{C_1 + C_2 + \frac{C_1 C_2}{C_c}}$$

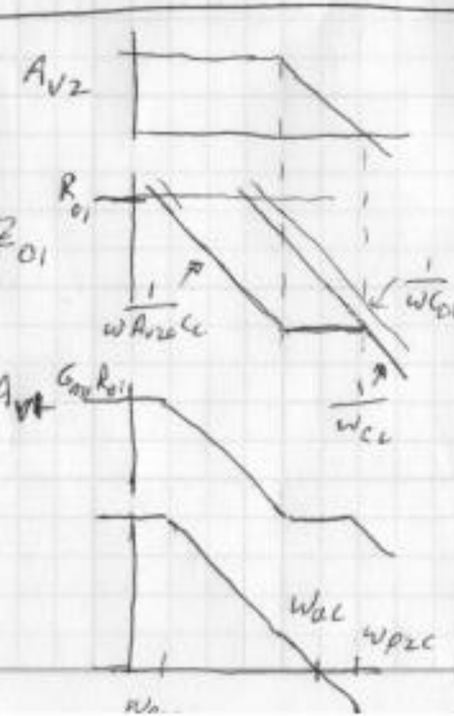
$$\approx \frac{G_{m2}}{C_1 + C_2}$$

iff $C_c >> C_1$ or $C_c >> C_2$

$$\omega_{uc} = \omega_{p1c}(A_{v10}A_{v20})$$

$$= \frac{G_{m1}R_{o1}G_{m2}R_{o2}}{G_{m2}R_{o2}R_{o1}C_c}$$

$$= \frac{G_{m1}}{}$$



for PM > 45° need $\omega_{uc} < \omega_{p2c}$
in unity gain

$$\frac{G_{m1}}{C_c} < \frac{G_{m2}}{C_1 + C_2 + \frac{C_1 C_2}{C_c}} \approx \frac{G_{m2}}{C_1 + C_2}$$

Rough sizing of C_c:

1) ~~Est~~ calc how much poles need to split ($\approx$ low freq gain)

2) ~~make~~ $C_c = C_1$ need $G_{m2}R_{o1}C_c \approx \sqrt{\text{split}}\, C_{o1}$

Other frequency (phase) trouble

C_c gives RHP zero

G_m calc: $i_o = g_{m4} v_{o1} + sC_c(v_{o2} - v_{o1})$

$= (g_{m4} - sC_c) v_{o1}$

$G_{m2} = \frac{i_{o2}}{v_{o1}} = g_{m4}(1 - s/\omega_z) \quad \omega_z = \frac{g_{m4}}{C_c}$

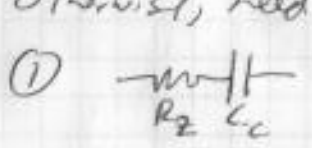
if $g_{m4} = 10 g_{m1}$, not a problem

$\omega_{uc} = \frac{g_{m1}}{C_c} \quad \omega_z = \frac{g_{m4}}{C_c}$

$\Rightarrow \leq 6^\circ$ negative phase at unity gain

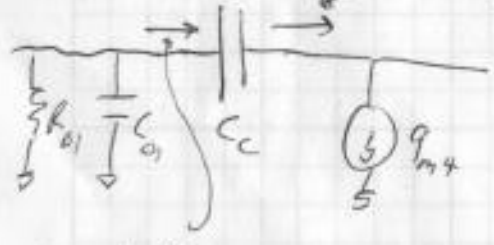
or if $f \leq 0.1$, and $g_{m1} = g_{m4}$, something.

otherwise, need to fix phase.

①  $\omega_z = \frac{1}{C_c\left(\frac{1}{g_{m4}} - R_z\right)}$

push zero to higher freq, → infinity → LHP!
cancel a LHP pole?!?

Or get rid of that feedforward current

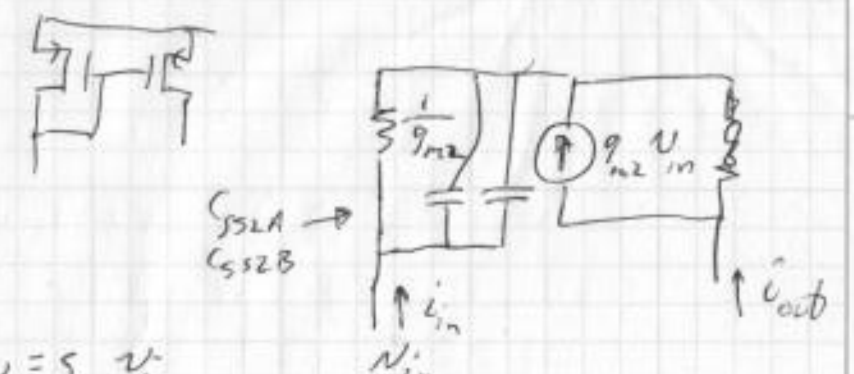


want to get rid of this one to avoid RHP zero

need this one for Miller comp

Many options. On HW.

Mirror freq response



$i_{out} = g_{m2} v_{in}$

$i_{in} = v_{in}\left[g_{m2} + s(2C_{gs2})\right] = v_{in} g_m \left[1 + \frac{s}{\omega_{pm}}\right]$

$v_{in} = i_{in} \frac{1}{g_{m2}} \frac{1}{1 + s/\omega_{pm}} \quad \omega_{pm} = \frac{g_{m2}}{2C_{gs}} = \frac{1}{2}\omega_T$

$$i_{out} = g_{m2} v_{in} = \frac{g_{m2} i_{in}}{g_{m2}} \frac{1}{\left(1 + \frac{s}{w_{pm}}\right)} = i_{in} \frac{1}{\left(1 + \frac{s}{w_{pm}}\right)}$$

$G_{m1} = g_{m1}$ at low freq.

but at high freq $G_{m1} \approx \frac{g_{m1}}{2}$

$$-i_o = g_{m1A} \frac{v_{id}}{2} \frac{1}{\left(1 + \frac{s}{w_{pm}}\right)} + g_{m1B} \frac{v_{id}}{2}$$

$$G_{m1} = \frac{i_o}{v_{id}} = -\frac{g_{m1}}{2} \frac{1}{\left(2 + \frac{s}{w_{pm}}\right)} = -g_{m1}\left(1 + \frac{s}{2w_{pm}}\right)$$

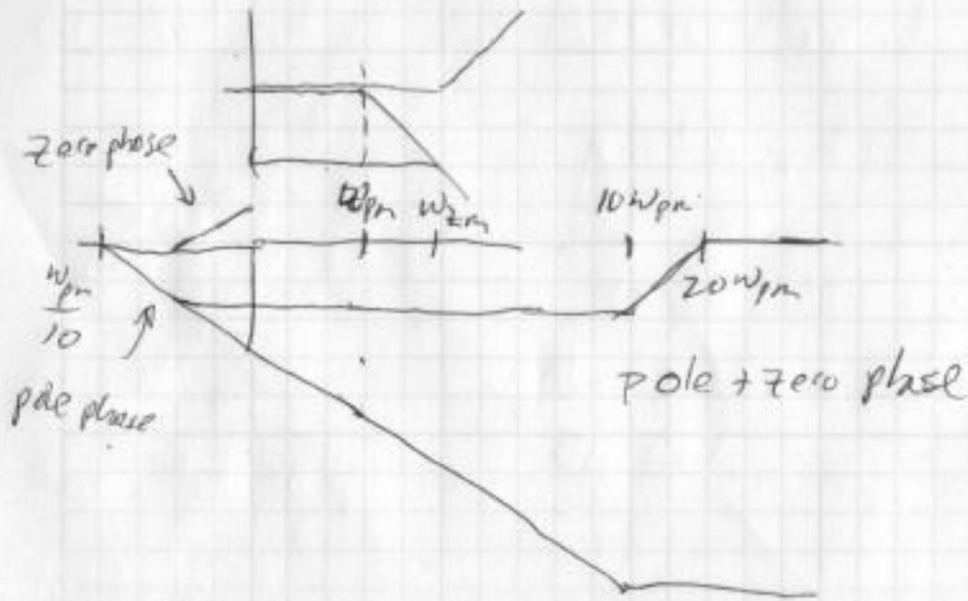
$$G_{m1} = \frac{i_o}{v_{id}} = -\frac{g_{m1}}{2}\left[1 + \frac{1}{1 + \frac{s}{w_{pm}}}\right]$$

$$= -\frac{g_{m1}}{2}\left[\frac{2 + s/w_{pm}}{1 + s/w_{pm}}\right]$$

$$= -g_{m1}\left[\frac{1 + s/w_{zm}}{1 + \frac{s}{w_{pm}}}\right]$$

$w_{pm} = \frac{g_{m2}}{2C_{gs}}$ $\quad w_{zm} = 2w_{pm} = \frac{g_{m2}}{C_{gs}} = w_T$

"Doublet"



Summary

uncompensated

$w_{p1} = \frac{1}{R_{o1}C_{o1}}$

$w_{p2} = \frac{1}{R_{o2}C_{o2}}$

$w_u = ?$

$w_z = \frac{g_{m4}}{C_c}$

$w_{pm} = \frac{g_{m2}}{2C_{gs2}}$

$w_{zm} = 2w_{pm}$

$A_{v0} = g_{m1} r_{o1} g_{m2} r_{o2}$

compensated

$w_{p1c} = \frac{1}{g_{m2} R_{o2} R_{o1} C_c}$

$w_{p2c} = \frac{g_{m4}}{C_1 + C_2 + \frac{C_1 C_2}{C_c}}$

$w_u = \frac{g_{m1}}{C_c}$