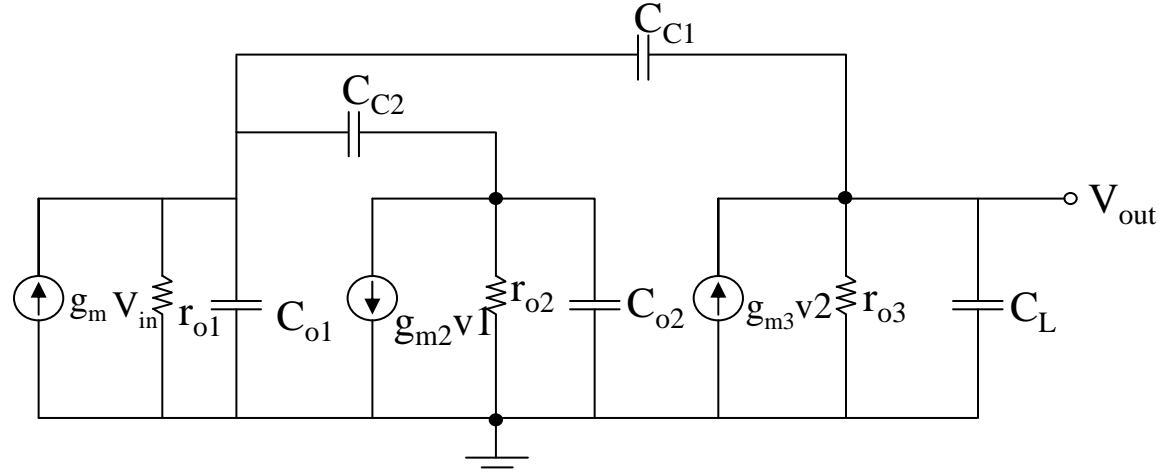
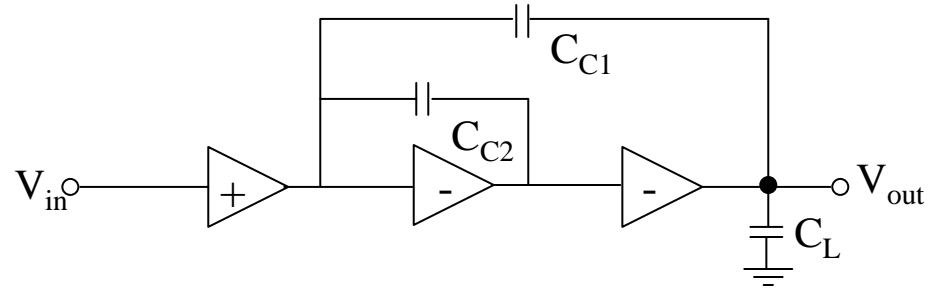


# REVERSED NESTED MILLER COMPENSATION AMPLIFIERS

ELEN 607 (ESS)

Analog and Mixed-Signal Center, TAMU

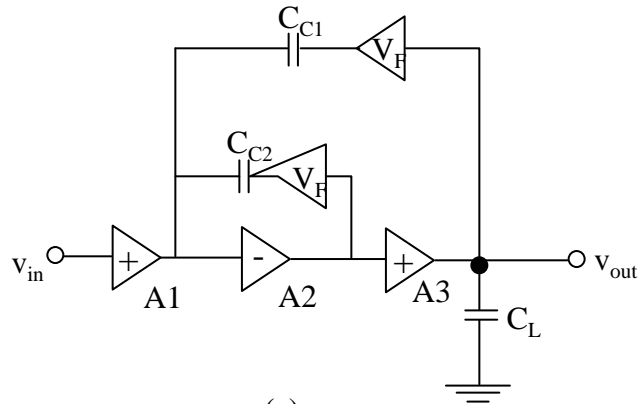


Three-stage amplifier with reversed nested Miller compensation

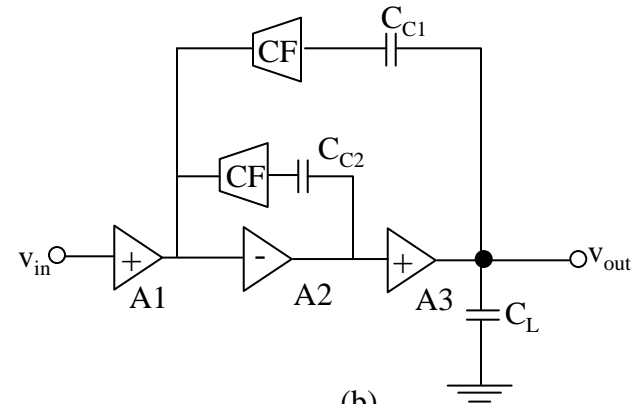
$$A(s) = A_o \frac{1 - \left( \frac{C_{C2}}{g_{m2}} + \frac{C_{C1}}{g_{m2}g_{m3}r_{o2}} \right) s - \frac{C_{C1}C_{C2}}{g_{m2}g_{m3}} s^2}{\left( 1 + \frac{s}{\omega_{p1}} \right) \left[ 1 + \left( \frac{C_{C2}C_L}{g_{m3}C_{C1}} - \frac{C_{C2}}{g_{m2}} + \frac{C_{C2}}{g_{m3}} \right) s + \frac{C_{C2}C_L}{g_{m2}g_{m3}} s^2 \right]}$$

where  $A_o$  is the DC open-loop gain equal to  $A_1A_2A_3 = g_{m1}r_{o1}g_{m2}r_{o2}g_{m3}r_{o3}$  and  $\omega_{p1}$

$$\omega_{p1} \approx \frac{1}{r_{o1}A_2A_3C_{C1}} = \frac{1}{r_{o1}g_{m2}r_{o2}g_{m3}r_{o3}C_{C1}}$$



(a)



(b)

Techniques for the RHP-zero elimination: a) with voltage followers, b) with current followers.

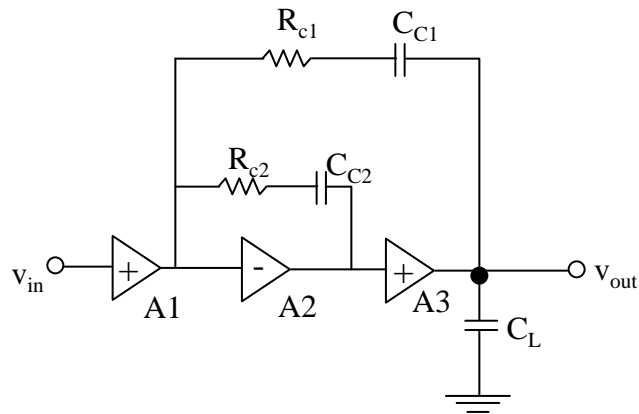
$$A(s) = A_o \frac{1}{\left(1 + \frac{s}{\omega_{P1}}\right) \left[1 + \frac{C_{C2}(C_{C1} + C_L)}{g_{m3}C_{C1}}s\right]}$$

$$\tan m_\varphi = \frac{g_{m3}}{g_{m1}} \frac{C_{C1}^2}{C_{C2}C_L}$$

$$A(s) = A_o \frac{1}{\left(1 + \frac{s}{\omega_{P1}}\right) \left(1 + \frac{C_{C2}C_L}{g_{m3}C_{C1}}s\right)}$$

$$\tan m_\varphi = \frac{g_{m3}}{g_{m1}} \frac{C_{C1}^2}{(C_{C1} + C_L)}$$

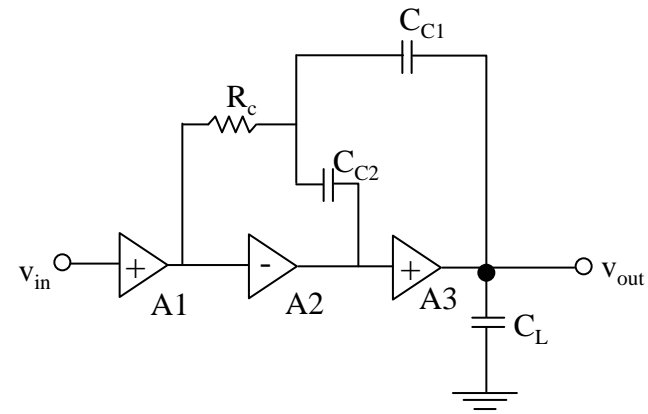
Where  $m_\varphi$  is the phase margin



Conventional scheme for the RHP-zero elimination with two nulling resistors.

$$g_{m2} = g_{m3}$$

$$A(s) = A_o \frac{1}{\left(1 + \frac{s}{\omega_{P1}}\right) \left(1 + \frac{C_{C2} C_L}{g_{m3} C_{C1}} s\right)}$$

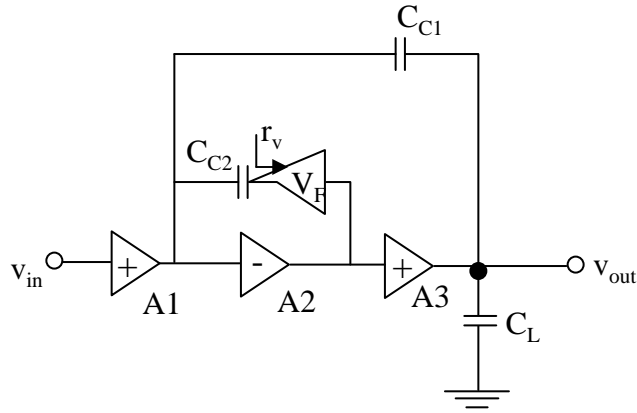


Technique for the RHP-zero elimination with one nulling resistor.

$$C_{C2} C_L > 4 C_{C1}^2$$

$$C_{C2} = \frac{C_{C1}^2 g_{m3}}{\tan m_\phi C_L g_{m1}}$$

$$\frac{g_{m2,3}}{g_{m1}} > 4 \tan m_\phi$$



$$r_v = \frac{\gamma}{g_{m3}}$$

Technique for the RHP-zero elimination with one voltage follower.

$$A(s) = \frac{A_o}{\left(1 + \frac{s}{\omega_{P1}}\right)} \frac{(1 + r_v C_{C2} s) \left(1 - \frac{C_{C1}}{g_{m2} g_{m3} r_{o2}} s\right)}{\left[1 + \frac{C_{C2}(C_L + C_{C1} + g_{m3} r_v C_{C1})}{g_{m3} C_{C1}} s\right] \left[1 + \frac{C_{C1} C_L r_v}{g_{m2} r_{o2} (C_L + C_{C1} + g_{m3} r_v C_{C1})} s\right]}$$

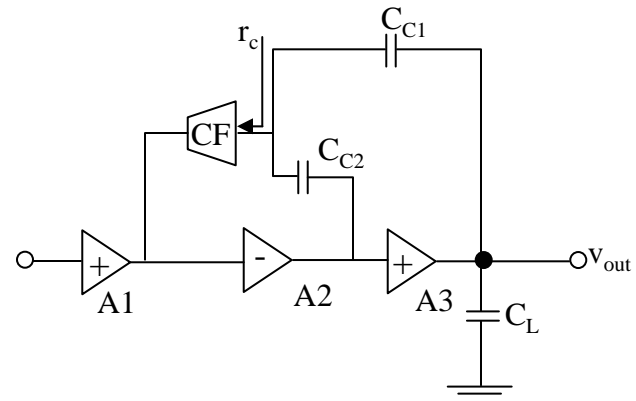
$$\omega_{P2} = \frac{g_{m3}}{C_{C2} \left(\frac{C_L}{C_{C1}} + 1 + \gamma\right)}$$

$$\omega_{P3} = \frac{C_L + 1 + \gamma}{C_{C1}} \frac{g_{m3} g_{m2} r_{o2}}{\gamma}$$

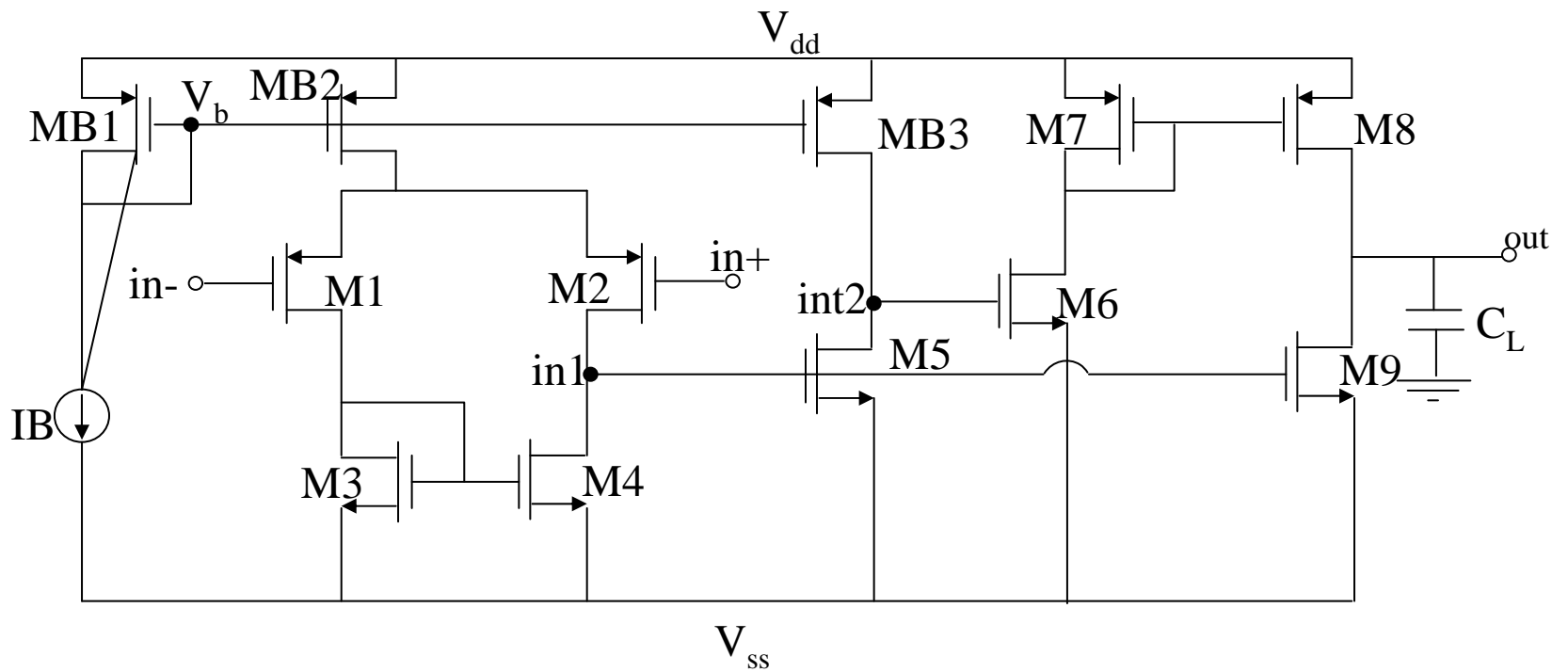
$$\omega_{Z1} = \frac{g_{m3}}{\gamma C_{C2}} = \frac{1}{\alpha} \omega_{P2}$$

$$\omega_{Z2} = -\frac{g_{m3} g_{m2} r_{o2}}{C_{C1}}$$

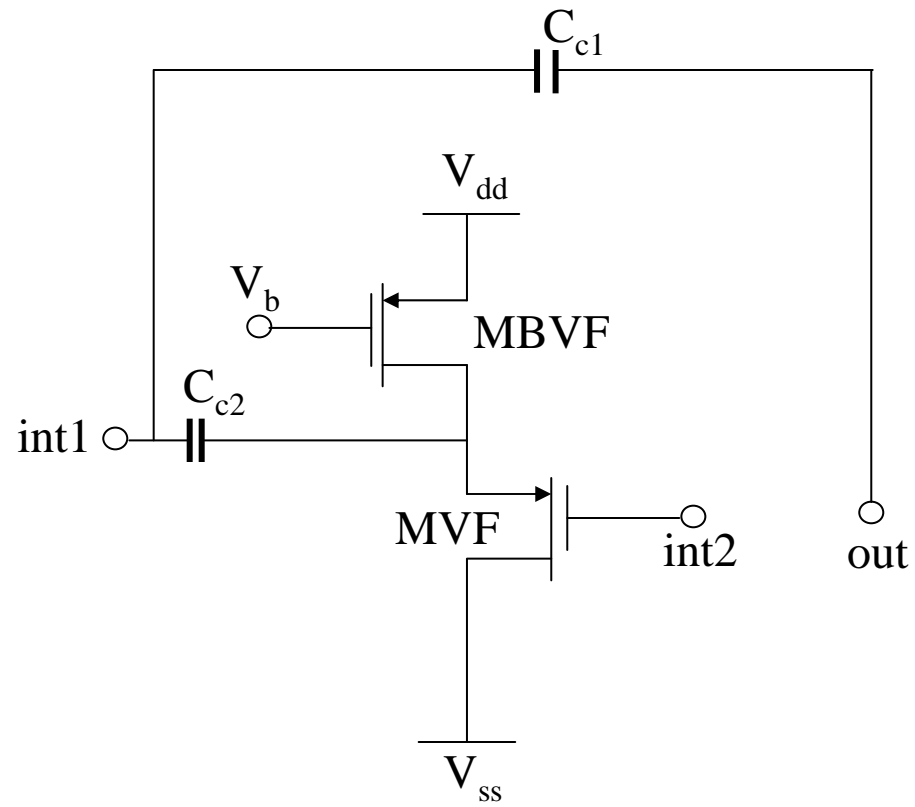
$$\alpha = \frac{\gamma C_{C1}}{C_L + (1 + \gamma) C_{C1}}$$



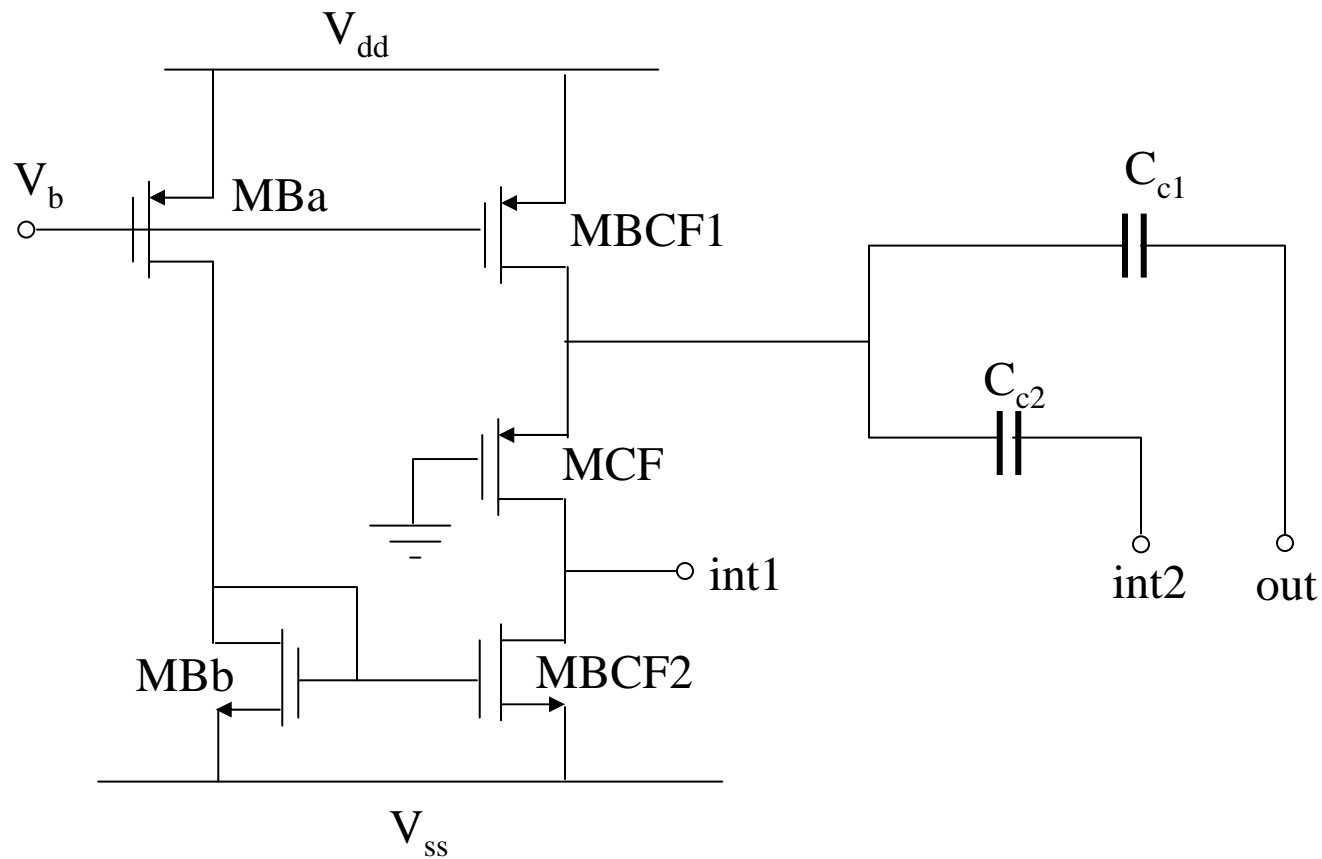
Technique for the RHP-zero elimination with one current follower.



Simplified schematic of the core amplifier used for the simulations.



Voltage-follower based compensation network.



Current-follower based compensation network.

REFERENCE: *R. Mita, G. Palumbo and S. Pennisi, "Design Guidelines for Reversed Nested Miller Compensation in Three-Stage Amplifier", IEEE Trans. on Circuits and Systems II, vol. 50, n0.5, pp227-233, May 2003*