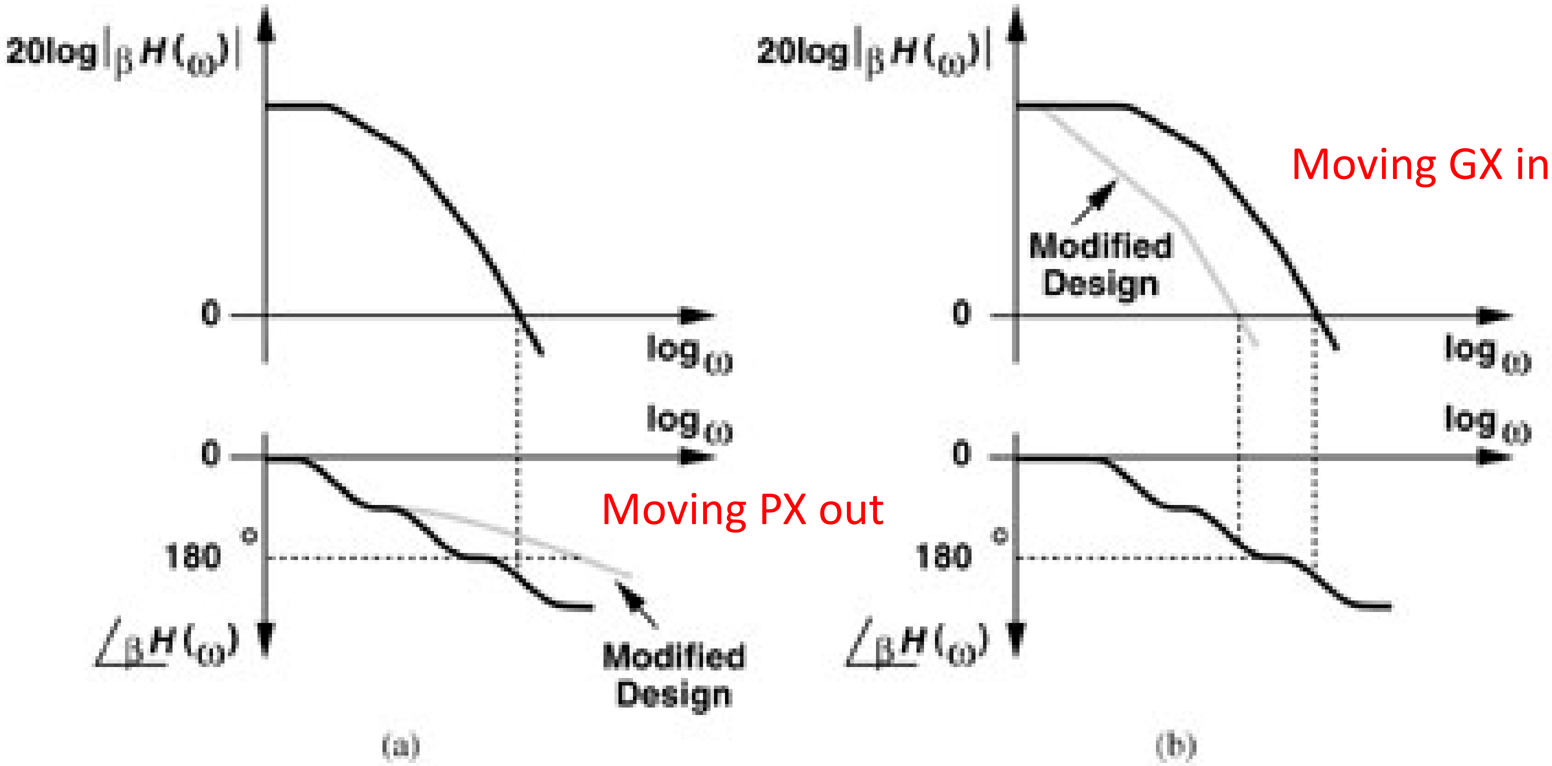
Lecture 11
IL2218 Analog electronics, advanced course

- Ch 10 Frequency compensation
  - Compensation to improve gain margin
  - Compensation of two-stage op amps
  - Right half-plane zero problem

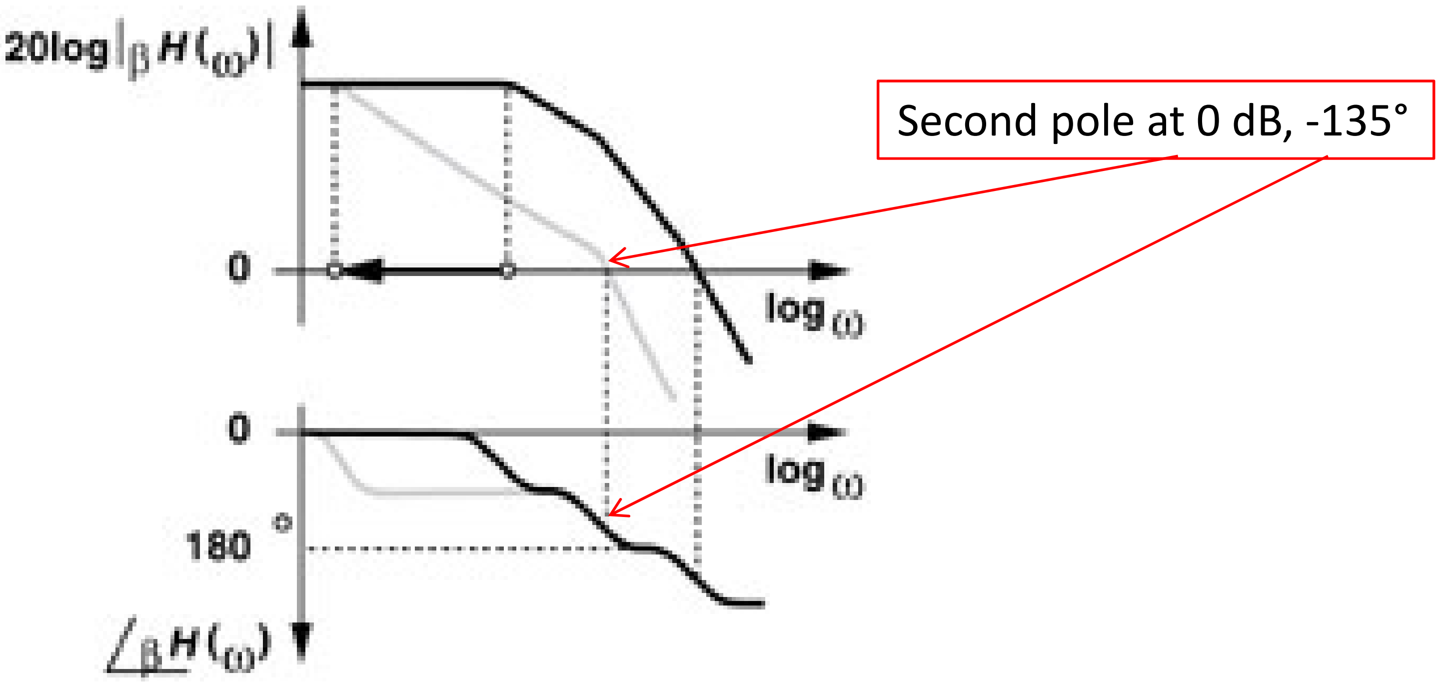
Frequency compensation



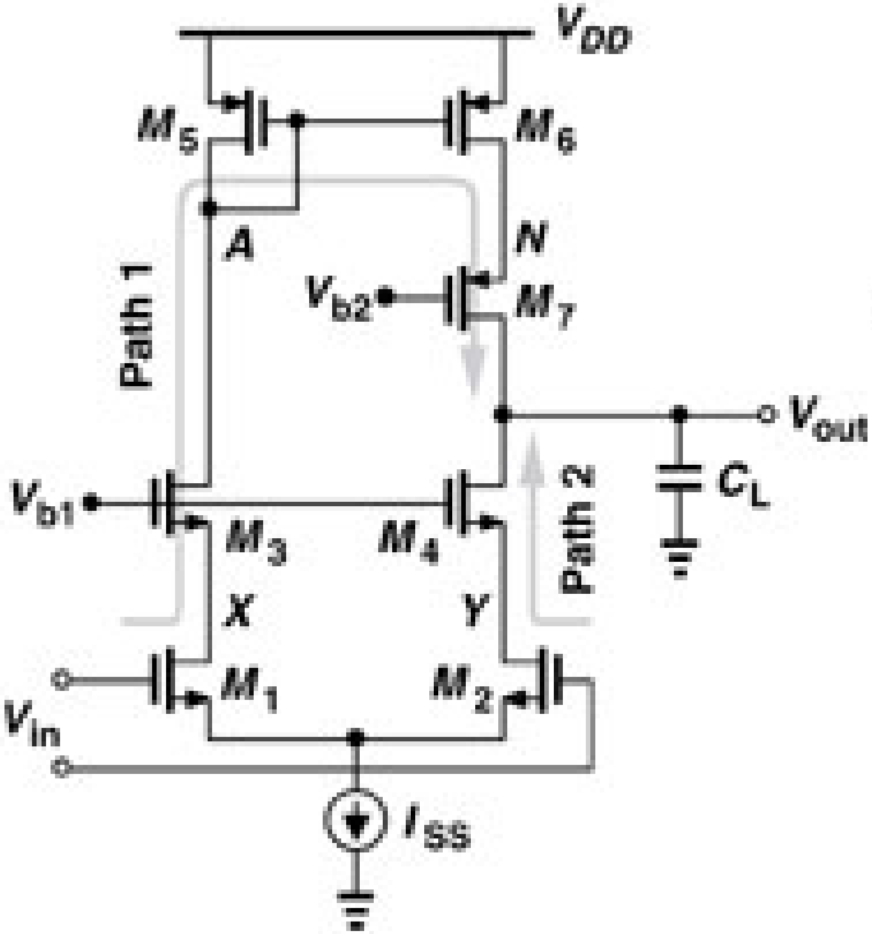
Compensation is the manipulation of gain and/or pole positions to improve phase margin.

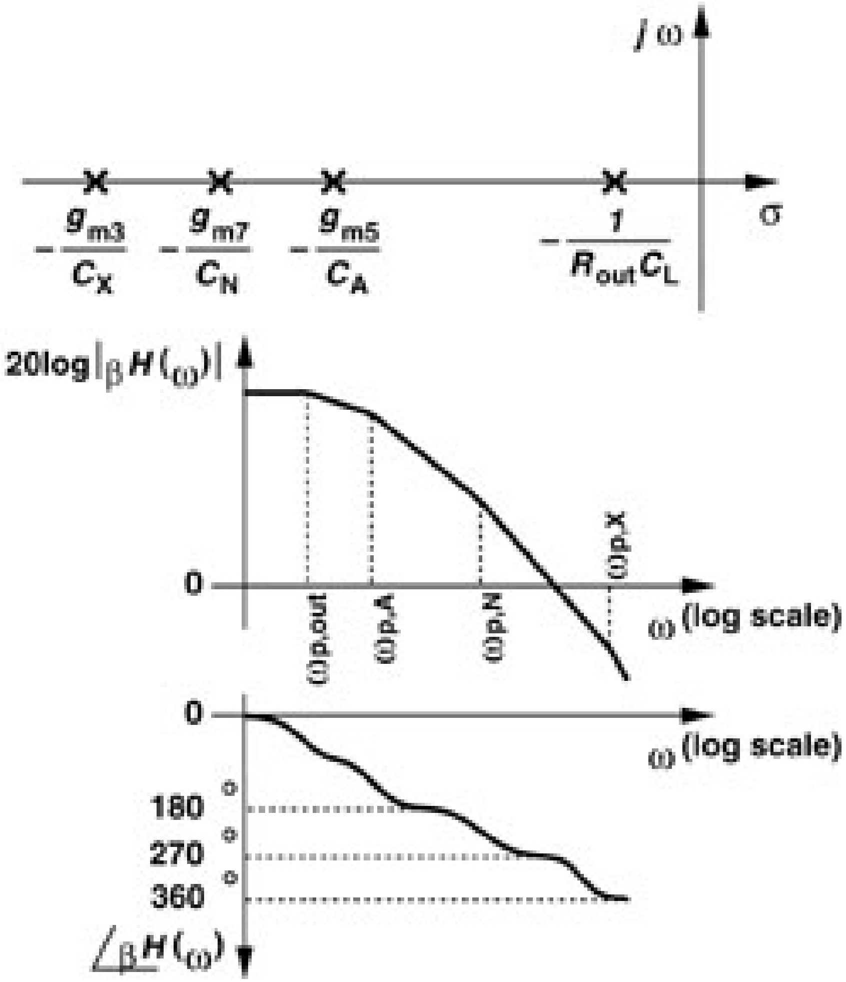
Dominating pole

Translating the dominant pole toward the origin for 45° phase margin

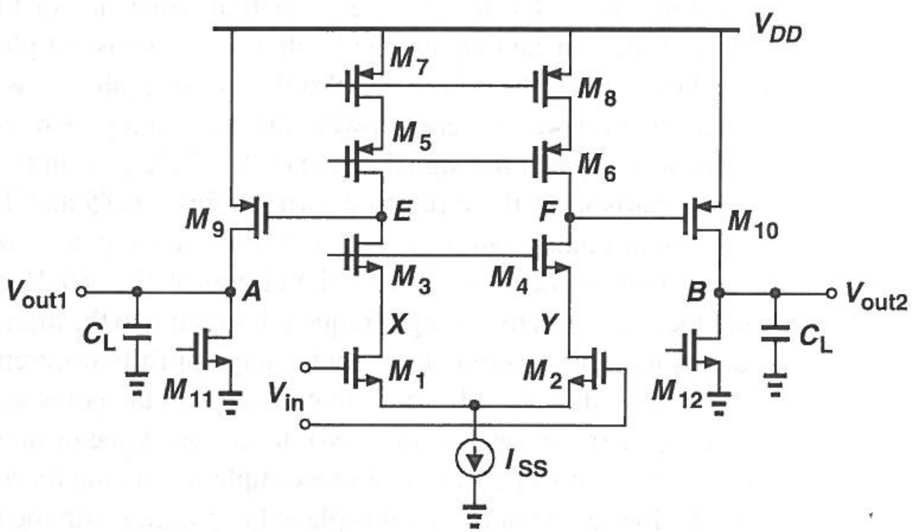


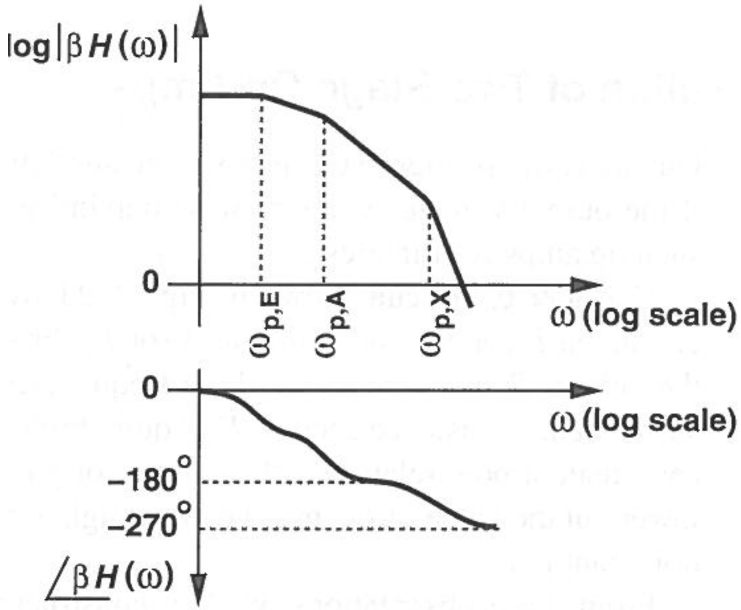
Telescopic op amp with Dominant pole at output





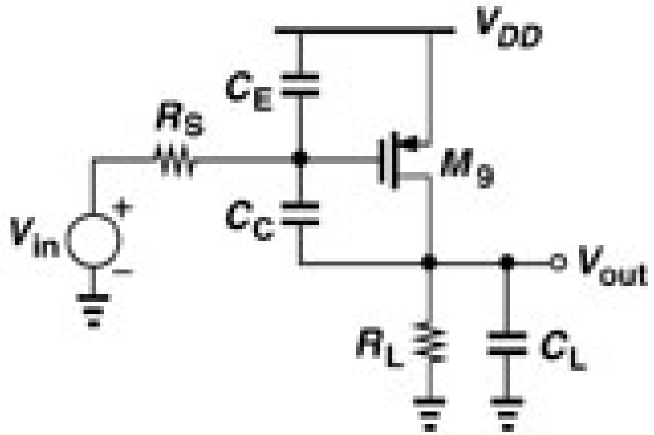
Two stage Op amp





Miller compensation of two stage Op amp

Simplified circuit of two stage op amp



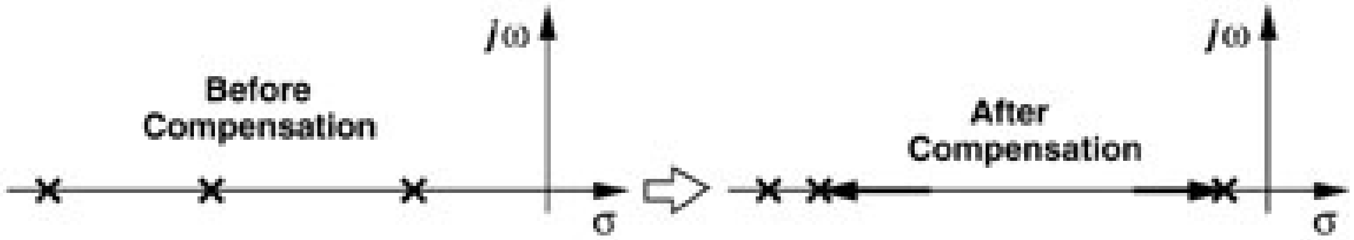
$$f_{p,in} = \frac{1}{2\pi\left(R_S\left[C_E + (1+g_m R_L)C_C\right] + R_L(C_C + C_L)\right)}$$

$$f_{p,in} \approx \frac{1}{2\pi R_S\left[C_E + (1+g_m R_L)C_C\right]}$$

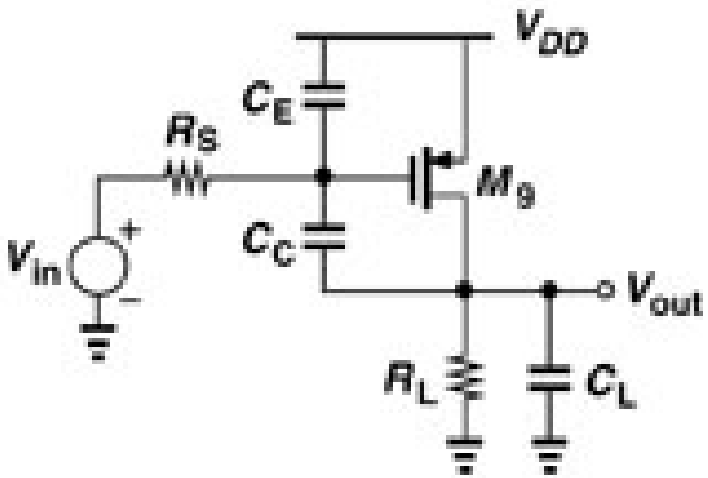
$$f_{p,out} = \frac{R_S(1+g_{m9}R_L)C_C + R_S C_E + R_L(C_C + C_L)}{2\pi R_S R_L(C_E C_C + C_E C_L + C_C C_L)}$$

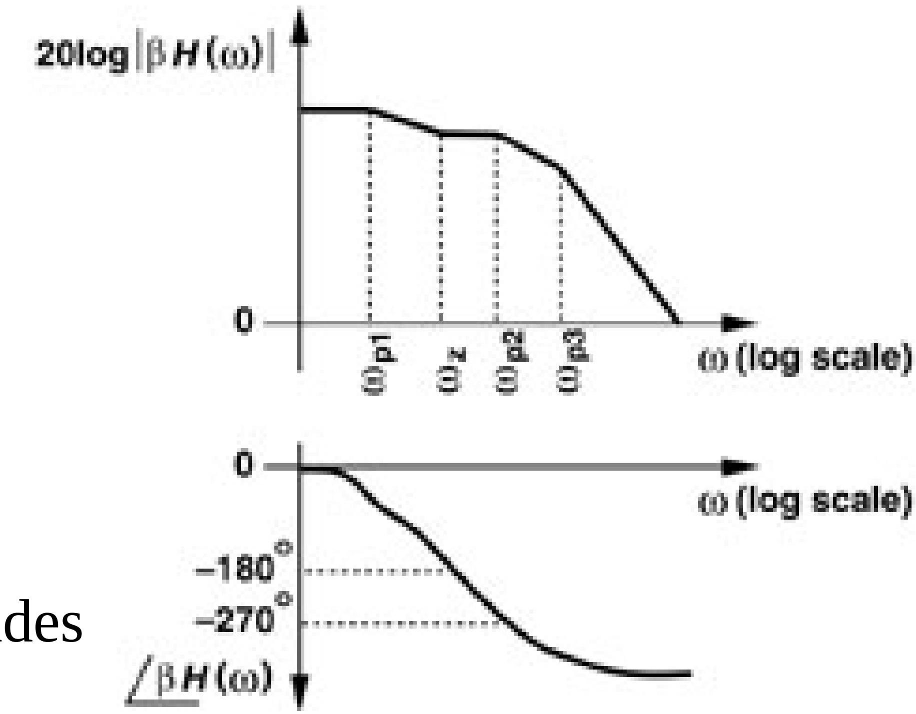
$$f_{p,out} \approx \frac{R_S g_{m9} R_L C_C + R_L C_C}{2\pi R_S R_L(C_E C_C + C_C C_L)} = \frac{g_{m9}}{2\pi(C_E + C_L)}$$

Miller compensation splitts the poles. Moves output pole away from origin and moves intermediate pole closer to origin.



Right half plane zero



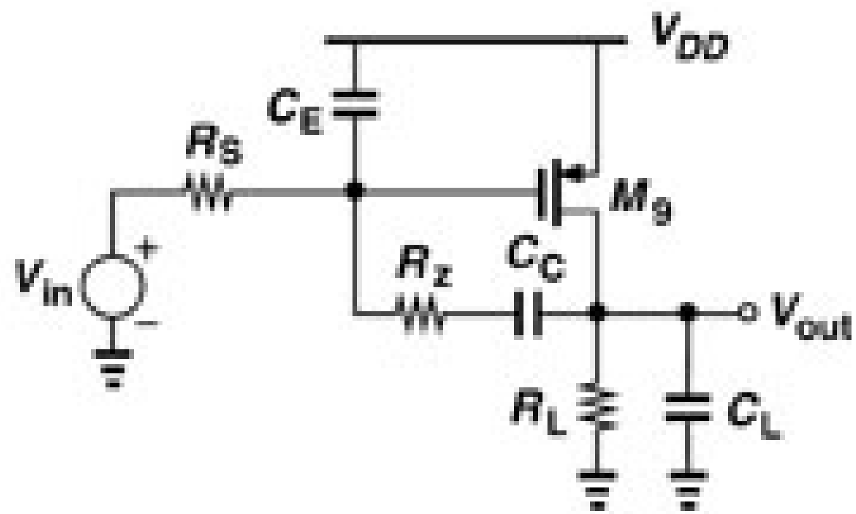


Recall, transfer function includes $(1 - s/\omega_z)$ numerator term and

$$f_Z(RHP) = \frac{g_{m9}}{2\pi C_C}$$

RHP zero introduces negative phase shift while maintaining high gain
→ Dangerous

RHP Zero removal



$$f_Z = \frac{1}{2\pi C_C(1/g_{m9} - R_Z)}$$

Rz is typically realized by a MOS transistor in the triode region

It is possible to set Rz to cancel first non-dominat pole

$$f_Z = \frac{1}{2\pi C_C(1/g_{m9} - R_Z)}$$

Could set $R_z = 1/g_{m9}$, or cancel other non-dominant pole

$$\frac{1}{C_C(1/g_{m9} - R_Z)} = \frac{-g_{m9}}{C_L + C_E}$$

$$R_Z = \frac{C_L + C_E + C_C}{g_{m9}C_C} \approx \frac{C_L + C_C}{g_{m9}C_C}$$

Problem 10.11

10.11. In the two-stage op amp of Fig. 10.43, $W/L = 50/0.5$ for all transistors except for $M_{5,6}$, for which $W/L = 60/0.5$. Also, $I_{SS} = 0.25$ mA and each output branch is biased at 1 mA.

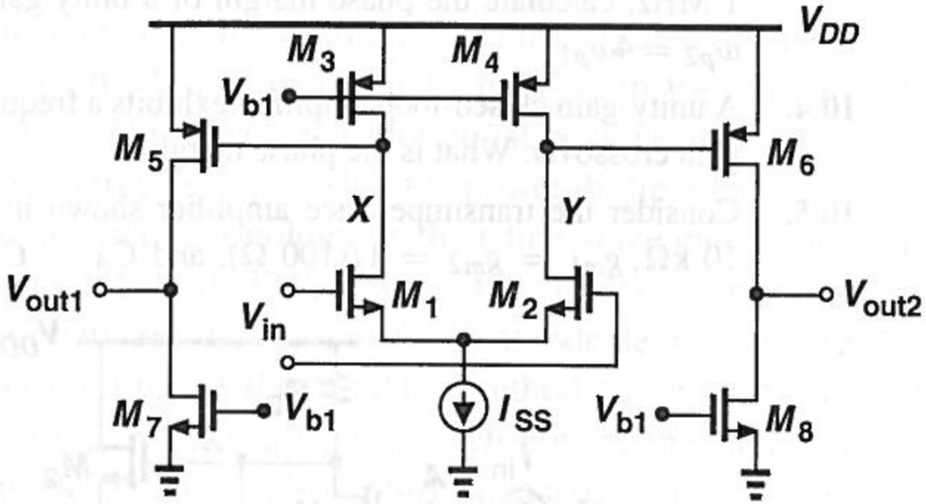


Figure 10.43

(a) Determine the CM level at nodes X and Y.

(b) Calculate the maximum output voltage swing.

(c) If each output is loaded by a 1-pF capacitor, compensate the op amp by Miller multiplication for a phase margin of 60° in unity-gain feedback. Calculate the pole and zero positions after compensation.