類比積體電路設計概論 HW8, 不用交.

HW8.1 (40 points)

如圖 8.1 所示，是一個 Two-Satge Opamp 的 Miller compensation 相關電路。

(a) 請列出在使用Miller Capacitor (C)做極點分離之頻率補償時，若沒有Rz的問題是甚麼? 請說明此問題的原因為何?

(b) 在滿足極點一零點抵消之情況下，假設C_E可忽略，M9, M11 (g_m, W/L, Id), Cc, and C_L皆是已知。請設計M13, M14, M15 and I_1。

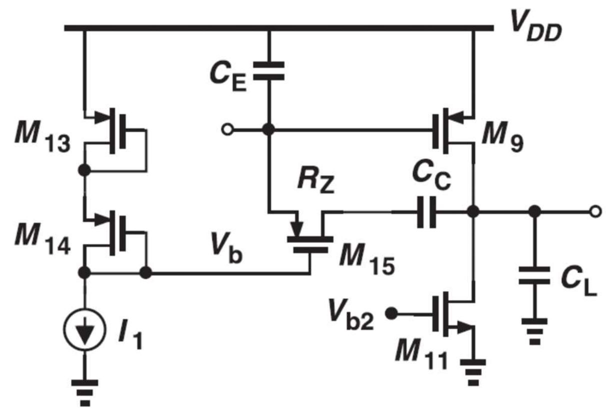


Fig. 8.1

HW8.2 (30 points)

Suppose the open-loop transfer function of a two-stage op amp is expressed as

$$H_{open}(s) = \frac{A_0\left(1+\frac{s}{\omega_z}\right)}{\left(1+\frac{s}{\omega_{p1}}\right)\left(1+\frac{s}{\omega_{p2}}\right)}$$

(a) 假如$\omega_{p2}=10A_0\omega_{p1}$ and $\omega_z=10\omega_{p2}$，請劃出$H_{open}(s)$'s bode plots for Magnitude and phase 並標示出unit-gain frequency ω_u = ?.

(b) 承上，其phase margin (PM) = ?

(c) 若是$\omega_{p2}=A_0\omega_{p1}$ and $\omega_z=2\omega_{p2}$，其phase margin (PM) = ?

類比積體電路設計概論 HW8, 不用交.

HW8.3 (15 points)

The two-stage op amp of Fig. 8.3 incorporates Miller compensation to reach a phase margin of 45∘. Estimate the compensation capacitor value. Usimg all teansistors' small-signal parameters (g_m, r_o).

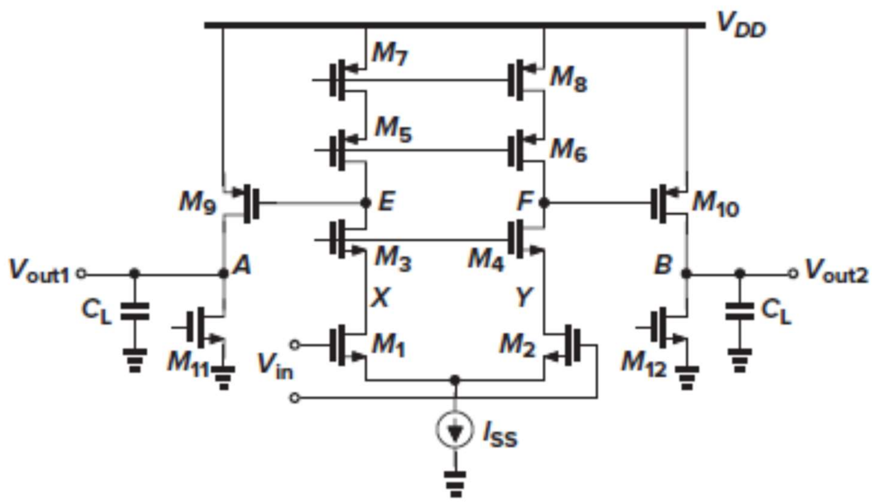


Fig. 8.3

HW8.4 (15 points)

Consider the transimpedance amplifier shown in Fig. 8.4, where R_D = 1 kΩ, R_F = 10 kΩ, $g_{m1} = g_{m2}$ = 1/(100Ω), and $C_A = C_X = C_Y$ = 100 fF. Neglecting all other capacitances and assuming that $\lambda = \gamma = 0$, compute the phase margin of the circuit. (Hint: break the loop at node X.)

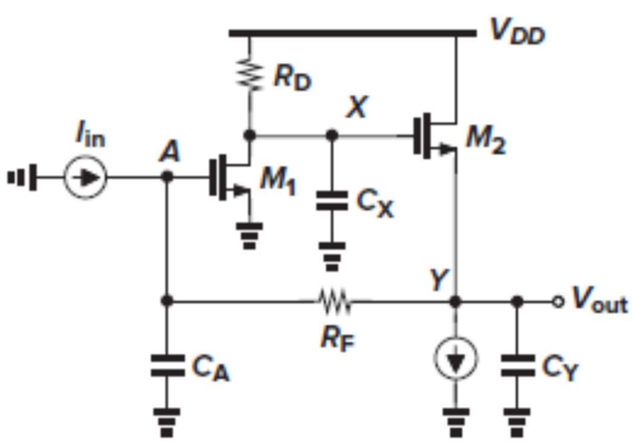


Fig. 8.4

HW 8.1

(a) 若沒有使用R_z，將会產生 RHP 的 zero $W_z = \frac{g_{m9}}{C_c}$
而 RHP 的 zero，將使得 Phase 往下掉，因此當电路接成閉迴路時，若 W_z 與 GBW 相鄰較近時会使得 Phase Margin 較差。

(b) 設計使得 $P_2 = Z_1$ (pole and zero cancellation) —①

$$\Rightarrow \frac{-g_{m9}}{C_L} = \frac{1}{(g_{m9}^{-1} - R_z)C_c}$$

$$\Rightarrow R_z = \frac{1}{g_{m9}}\left(1 + \frac{C_L}{C_c}\right)$$

並設計 M_9 與 M_{13} 具有相同的 V_{ov} —②

$$\frac{I_1}{I_{D9}} = \frac{\frac{\beta_{13}}{2} V_{ov}^2}{\frac{\beta_9}{2} V_{ov}^2} \Rightarrow I_1 = I_{D9} \times \frac{(W/L)_{13}}{(W/L)_9}$$ 已知

選擇適当的 I_1 後，將推得 $(W/L)_{13}$ 為何

由② 的條件可推得 $R_z = \frac{1}{g_{m14}} \frac{(W/L)_{14}}{(W/L)_{15}}$

$$\Rightarrow \frac{1}{g_{m9}}\left(1 + \frac{C_L}{C_c}\right) = \frac{1}{g_{m14}} \frac{(W/L)_{14}}{(W/L)_{15}}$$

$$\Rightarrow (W/L)_{15} = \frac{g_{m9}}{g_{m14}} (W/L)_{14} \frac{C_c}{C_L + C_c}$$

由 $g_m = \sqrt{2\beta I_D}$ 推得

→ 選擇 $(W/L)_{14}$ 後 即可獲得 $(W/L)_{15}$

$$\Rightarrow (W/L)_{15} = \sqrt{(W/L)_9 (W/L)_{14}} \sqrt{\frac{I_{D9}}{I_1}} \frac{C_c}{C_L + C_c}$$ 已知

HW8.2

Suppose the open-loop transfer function of a two-stage op amp is expressed as

$$H_{open}(s) = \frac{A_0\left(1+\frac{s}{\omega_z}\right)}{\left(1+\frac{s}{\omega_{p1}}\right)\left(1+\frac{s}{\omega_{p2}}\right)}$$

Assume ω_z 為 RHP and $A_0 > 10$

(a) 假如 $\omega_{p2}=10A_0\omega_{p1}$ and $\omega_z=10\omega_{p2}$，請劃出 $H_{open}(s)$'s bode plots for Magnitude and phase 並標示出unit-gain frequency ω_u = ?.

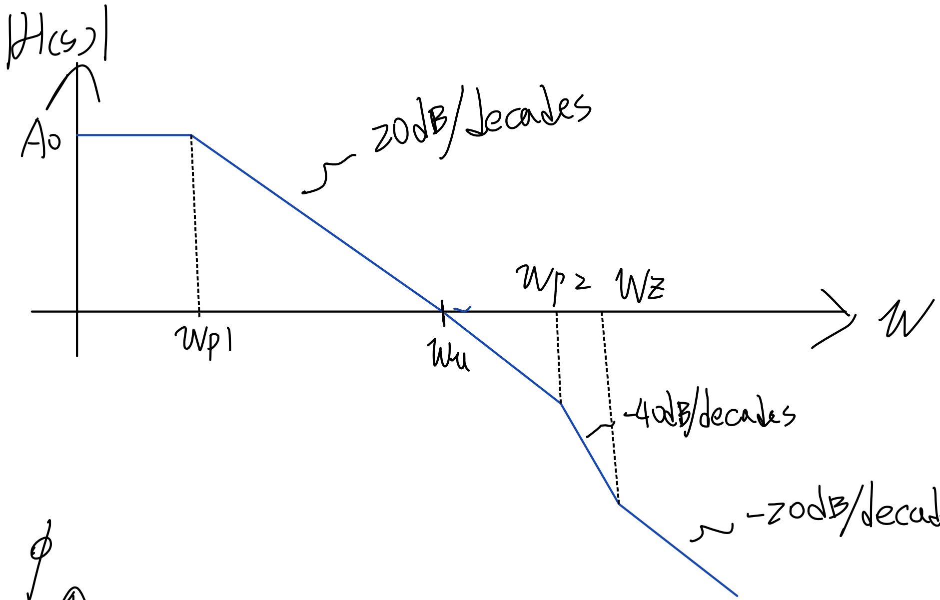
(b) 承上，其phase margin (PM) = ?

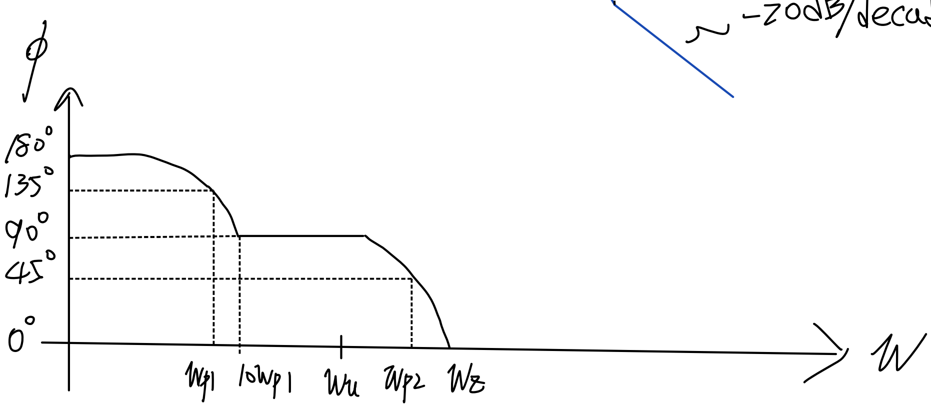
(c) 若是 $\omega_{p2}=A_0\omega_{p1}$ and $\omega_z=2\omega_{p2}$，其phase margin (PM) = ?

(a)

由於 $\omega_{p2} >> \omega_{p1}$ 因此可做主極點近似

$\omega_u \cong GBW = A_0\omega_{p1}$





#

(b)

$$PM = 180^\circ - \tan^{-1}\left(\frac{w_u}{w_{p1}}\right) - \tan^{-1}\left(\frac{w_u}{w_{p2}}\right) - \tan^{-1}\left(\frac{w_u}{w_z}\right)$$

$$= 180^\circ - \tan^{-1}(10) - \tan^{-1}(0.1) - \tan^{-1}(0.01)$$

$$\simeq 180^\circ - 84.28^\circ - 5.7 - 0.57 = 89.45^\circ \#$$

(c)

$$PM = 180^\circ - \tan^{-1}\left(\frac{w_u}{w_{p1}}\right) - \tan^{-1}\left(\frac{w_u}{w_{p2}}\right) - \tan^{-1}\left(\frac{w_u}{w_z}\right)$$

$$= 180^\circ - \tan^{-1}(10) - \tan^{-1}(1) - \tan^{-1}(0.1)$$

$$\simeq 180^\circ - 84.28^\circ - 45^\circ - 5.7^\circ = 45^\circ \#$$

HW8.3

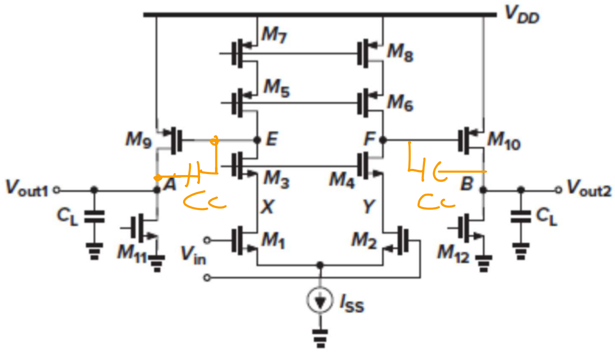


Fig. 8.3

$R_{o1} \simeq g_{m3,4} r_{o3,4} r_{o1,2} \,//\, g_{m5,6} r_{o5,6} r_{o7,8}$

$A_1 \simeq g_{m1,2} R_{o1}$ $\quad A_2 \simeq g_{m9,10}(r_{o9,10} \,//\, r_{o11,12})$

$\omega_{p1} \simeq \dfrac{-1}{R_{o1} A_2 C_c}$ $\quad \omega_{p2} \simeq \dfrac{-g_{m9,10}}{C_L}$ $\quad \omega_z \simeq \dfrac{g_{m9,10}}{C_c}$

$\omega_u \simeq A_1 \times A_2 \times \omega_{p1} = \dfrac{g_{m1,2}}{C_c}$

若設計 $\omega_u = \omega_{p2}$ 且 $\omega_z = 10\omega_u$

則可獲得 $PM \simeq 45^\circ$

$\dfrac{g_{m10}}{C_c} = 10\dfrac{g_{m10}}{C_L} \Rightarrow C_c = 0.1C_L$

$\dfrac{g_{m1,2}}{C_c} = \dfrac{g_{m9,10}}{C_L} \Rightarrow \dfrac{g_{m1,2}}{0.1C_L} = \dfrac{g_{m9,10}}{C_L} \Rightarrow g_{m1,2} = 0.1 g_{m9,10}$

HW8.4

Consider the transimpedance amplifier shown in Fig. 8.4, where $R_D = 1\ \text{k}\Omega$, $R_F = 10\ \text{k}\Omega$, $g_{m1} = g_{m2} = 1/(100\Omega)$, and $C_A = C_X = C_Y = 100$ fF. Neglecting all other capacitances and assuming that $\lambda = \gamma = 0$, compute the phase margin of the circuit. (Hint: break the loop at node X.)

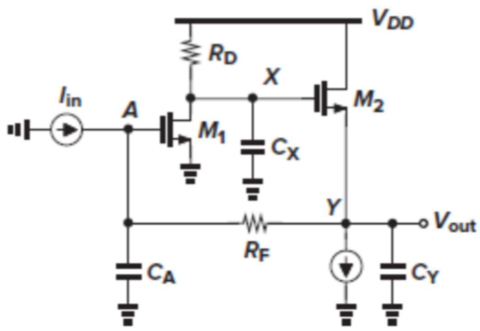
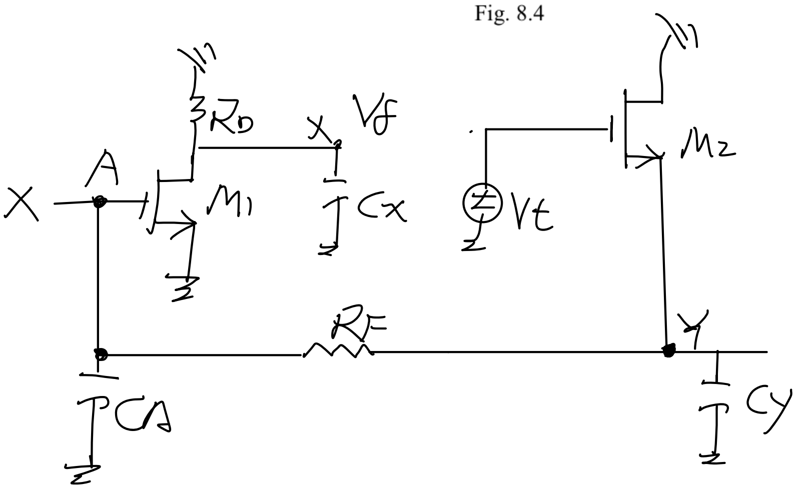


Fig. 8.4



先找到 $s=0$ 下的 loop gain

$$\beta A_0(s=0) = \frac{V_f}{V_t} = 1 \times (-g_m R_D) = -g_m R_D = -10$$

找出各節點上的 pole (利用 open circuit time constant Method)

實際上不能直接用來找 pole

僅能找到 $\omega_{3dB} = \frac{1}{\tau_1 + \tau_2 + \tau_3}$

但這邊為了快速找到各個 pole 的趨勢

因此簡化過程!!

$$\omega_X \simeq \frac{1}{R_D C_X} = 10\,\omega_A$$

$$\omega_A = \frac{1}{(R_F + g_{m2}^{-1}) C_A} \simeq \frac{1}{R_F C_A}$$

$$\omega_Y = \frac{g_{m2}}{C_Y} = 100\,\omega_A$$

$$H(s) = \frac{\beta A_0 (s=0)}{(1+\frac{s}{w_A})(1+\frac{s}{w_x})(1+\frac{s}{w_y})}$$

$$w_u = 10\, w_A = w_x$$

$$\Rightarrow PM = 180^\circ - \tan^{-1}(\frac{w_u}{w_A}) - \tan^{-1}(\frac{w_u}{w_x}) - \tan^{-1}(\frac{w_u}{w_y})$$

$$= 180^\circ - 84.28^\circ - 45^\circ - 5.7^\circ = 45^\circ \ \#$$