CHAPTER 8

Feedback

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8.8.1 Transfer Function of the Feedback Amplifier

Open-loop gain: A, A(s)

Loop gain: Aβ, A(s)β(s)

Close-loop gain: $A_f = \frac{A}{1+A\beta}$ $A_f(s) = \frac{A(s)}{1+A(s)\beta(s)}$ $A_f(j\omega) = \frac{A(j\omega)}{1+A(j\omega)\beta(j\omega)}$

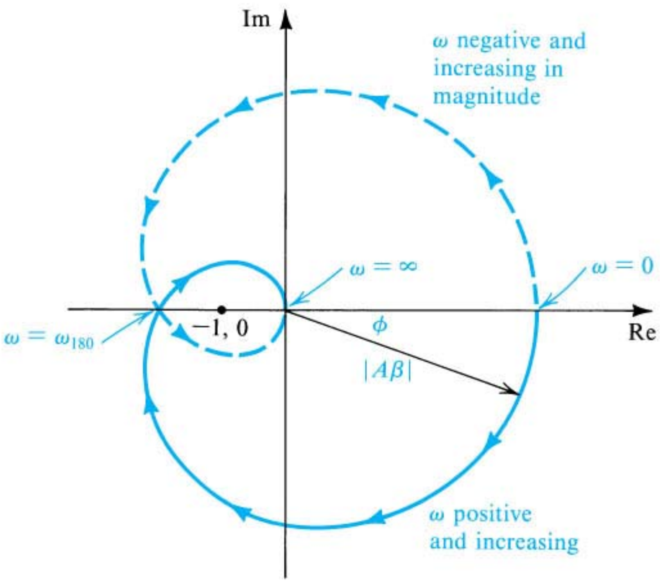
$$L(j\omega) \equiv A(j\omega)\beta(j\omega) = |A(j\omega)\beta(j\omega)| e^{j\phi(\omega)}$$

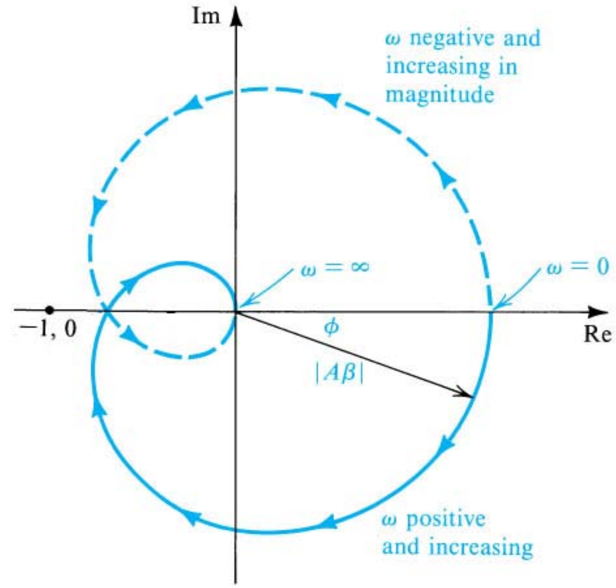
For $\omega = \omega_{180}$ $L(j\omega) \Rightarrow -|A(j\omega)\beta(j\omega)|$

If $|A(j\omega)\beta(j\omega)| < 1$, then $A_f(j\omega) > A(j\omega) \Rightarrow$ stable
Else $\Rightarrow$ unstable

Oscillator: =-1, zero input, infinite output

8.8.2 The Nyquist Plot





If $|A(j\omega)\beta(j\omega)| < 1$, then $A_f(j\omega) > A(j\omega) \Rightarrow$ stable
Else $\Rightarrow$unstable

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8.9.3 Amplifier with a single pole

$$A_f(s) = \frac{A(s)}{1 + A(s)\beta(s)}$$

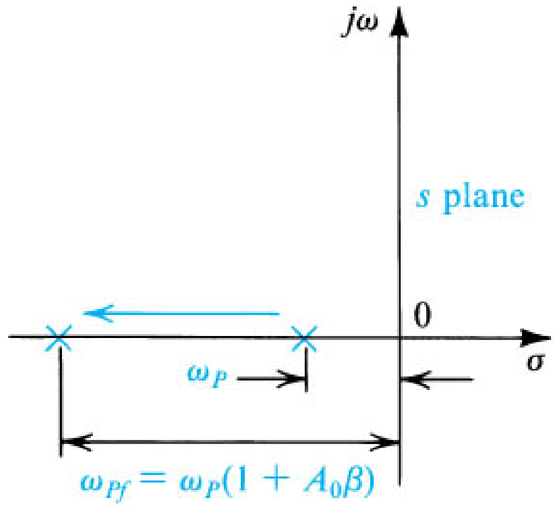
Simplified case

$$A(s) = \frac{A_0}{1 + s/\omega_p} \qquad A_f(s) = \frac{A_0/(1 + A_0\beta)}{1 + s/\omega_p(1 + A_0\beta)}$$

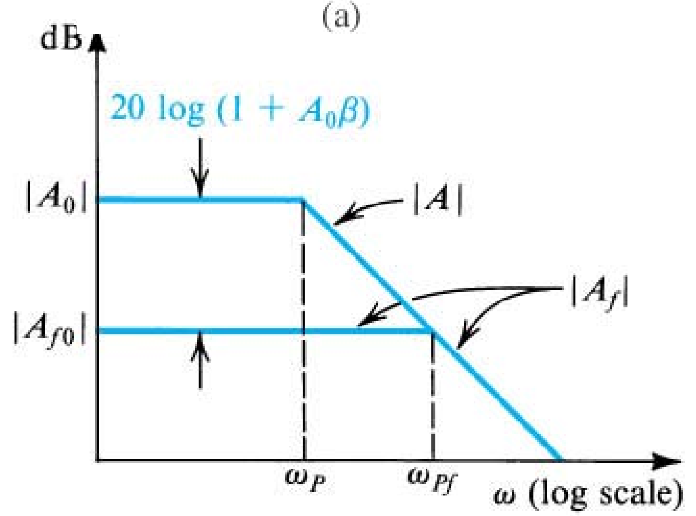
$$\omega_f = \omega_p(1 + A_0\beta)$$

$$\omega >> \omega_p(1 + A_0\beta)$$

$$A_f(s) \to \frac{A_0\omega_p}{s} \approx A(s)$$



(a)



(b)

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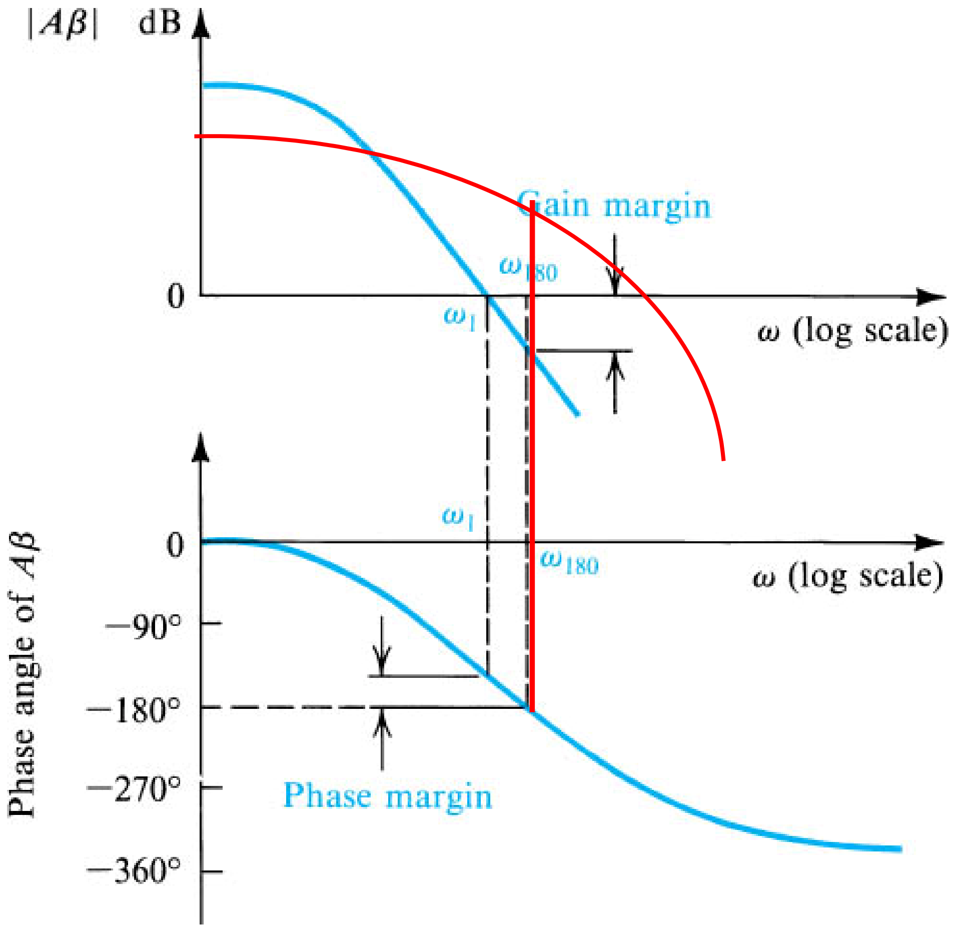
8.10.1 Gain and Phase Margin



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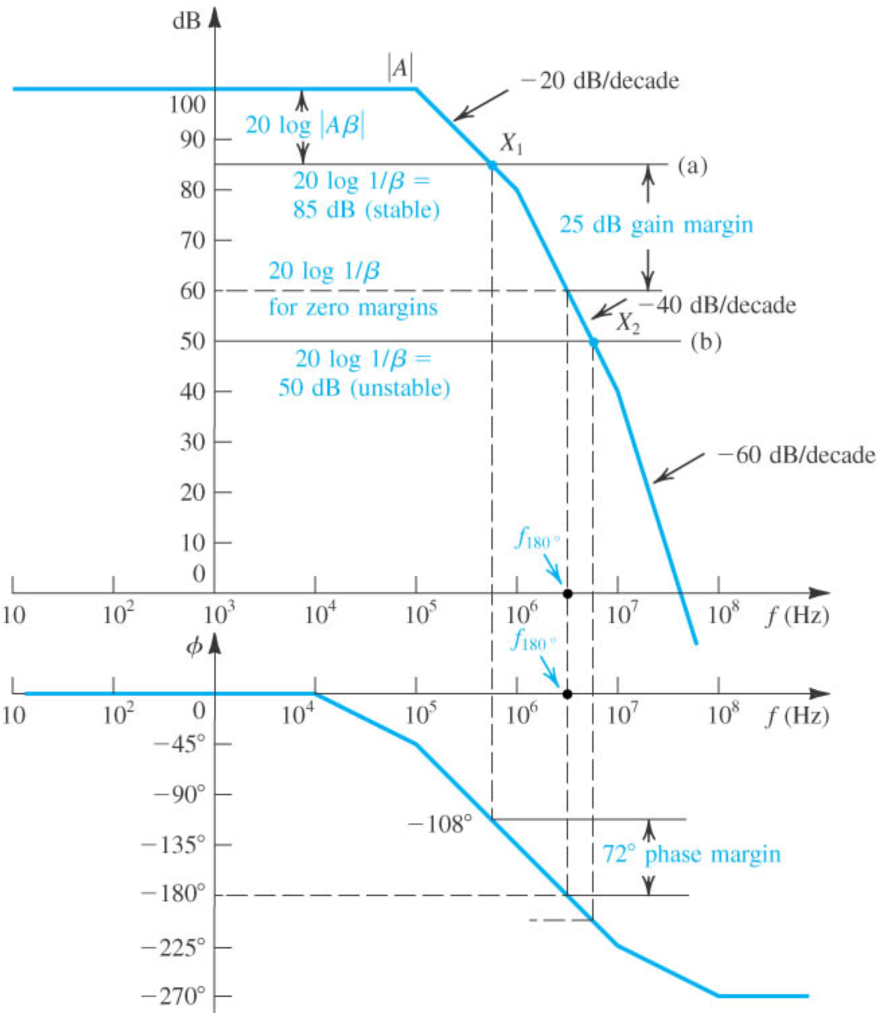
8.10.3 An Alternative Approach for Investigating Stability



$$A = \frac{10^5}{(1+jf/10^5)(1+jf/10^6)(1+jf/10^7)}$$

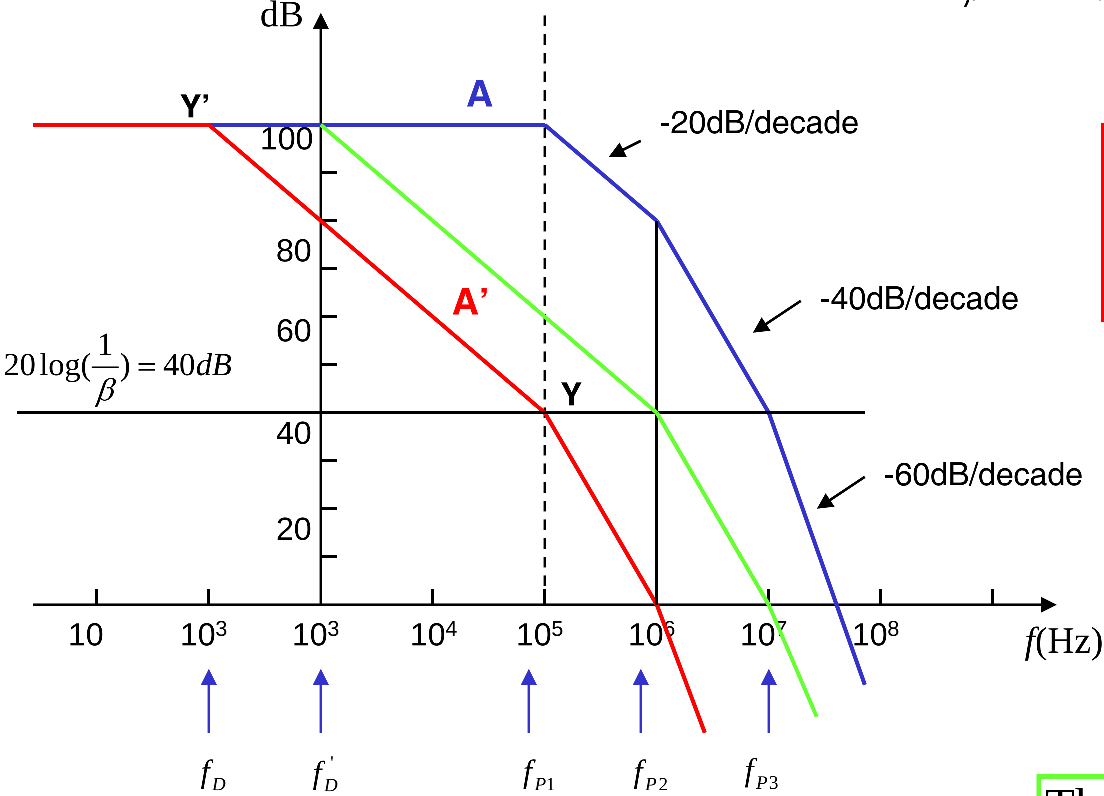
$$A = \frac{10^5}{(1+jf/10^5)(1+jf/10^6)(1+jf/10^7)}$$

$|AB|<1 \Rightarrow 20\log|A| < 20\log(1/\beta)$

The closed-loop amplifier will be stable if the $20\log(1/\beta)$ line intersects the $20\log|A|$ curve at a point on the -20-dB/decade segment.

8.11.1 Theory

$\beta = 10^{-2} \Rightarrow 20\log(\frac{1}{\beta}) = 40dB$



- Four poles
- Simplest
- Reduced the bandwidth

Three poles

Shift Pole: $f_{p1} \rightarrow f_D^{'}$

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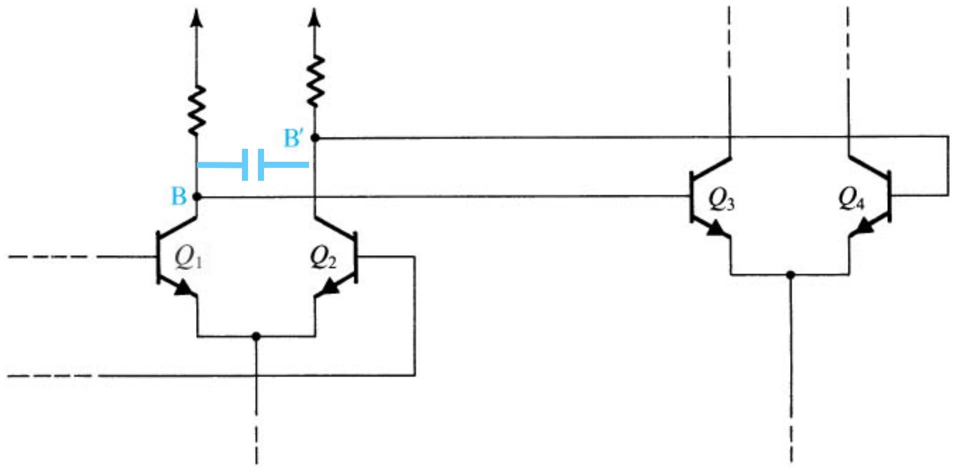
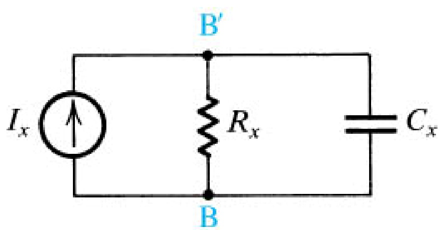
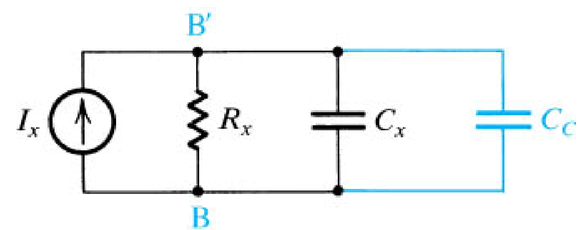
8.11.2 Implementation



(a)



(b)

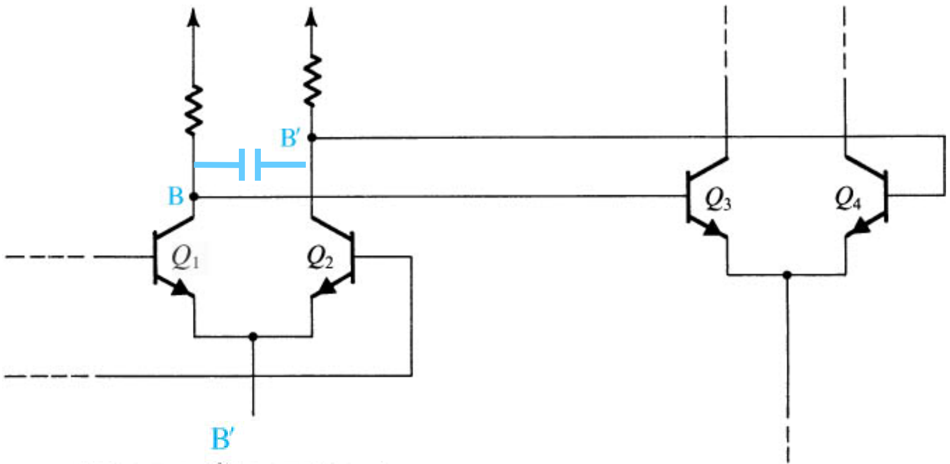


(c)

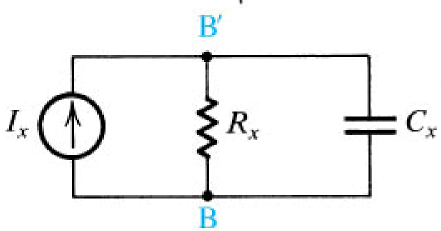
$$f_{p1} = \frac{1}{2\pi C_x R_x}$$

$$f_{p1} = \frac{1}{2\pi (C_x + C_C) R_x}$$

8.11.2 Implementation

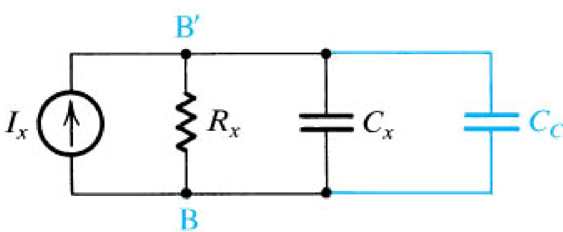


(a)



(b)

$$f_{p1} = \frac{1}{2\pi C_x R_x}$$



(c)

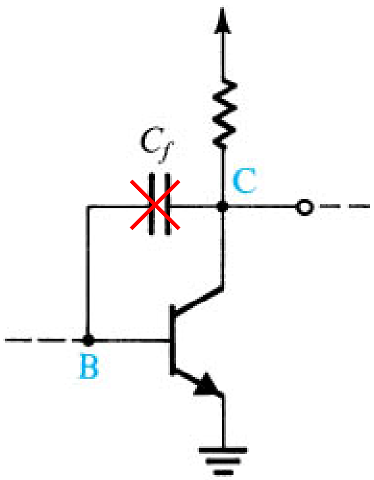
$$f_{p1} = \frac{1}{2\pi (C_x + C_C) R_x}$$

Note:

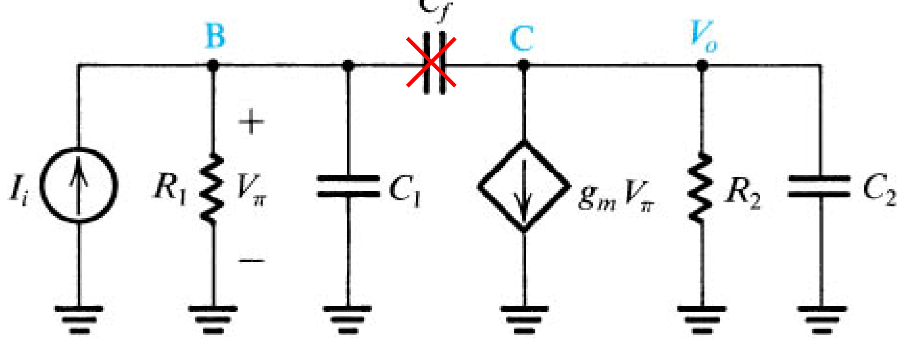
1. Adding C_c will result in changes in the locations of the other poles

2. C_c is usually large, which is difficult for IC implementation

8.11.3 Miller Compensation and Pole Splitting



(a)

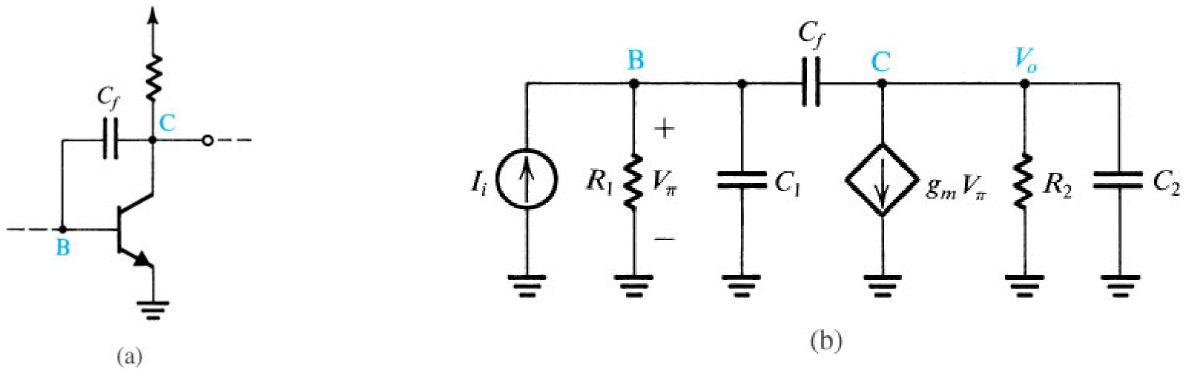


(b)

$$f_{p1} = \frac{1}{2\pi C_1 R_1}$$

$$f_{p2} = \frac{1}{2\pi C_2 R_2}$$

8.11.3 Miller Compensation and Pole Splitting (cont.)



$$\frac{V_o}{I_i} = \frac{(sC_f - g_m)R_1R_2}{1 + s[C_1R_1 + C_2R_2 + C_f(g_mR_1R_2 + R_1 + R_2)] + s^2[C_1C_2 + C_f(C_1 + C_2)]R_1R_2}$$

$$D(s) = \left(1 + \frac{s}{\omega'_{P1}}\right)\left(1 + \frac{s}{\omega'_{P2}}\right) = 1 + s\left(\frac{1}{\omega'_{P2}} + \frac{1}{\omega'_{P1}}\right) + \frac{s^2}{\omega'_{P1}\,\omega'_{P2}}$$

$$\omega'_{P1} = \frac{1}{C_1R_1 + C_2R_2 + C_f(g_mR_1R_2 + R_1 + R_2)} \cong \frac{1}{C_f g_m R_1 R_2}$$

$$\omega'_{P2} \cong \frac{g_m C_f}{C_1C_2 + C_f(C_1 + C_2)}$$

$$\text{Pole splitting}: C_f \uparrow, \omega'_{P1} \downarrow, \omega'_{P2} \uparrow$$

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Homework:

8.37, 8.43, 8.47, Ex-8.14, 8.70, 8.76, 8.77, 8.79