Lecture 21: Choosing Cc

• Announcements:
  - Lab#3: Note that models have been online

• Lecture Topics:
  - Review of Pole/Zero Plots
  - Compensation: Narrowbanding & Pole-Splitting
  - Choosing Cc

• Last Time: Compensation of OP Amps

To compensate, need the distance between p₁ and p₂ to be large enough to encompass the largest expected loop gain.

\[20 \log |p₂| - 20 \log |p₁| = 20 \log |\text{Tomax}|\]

For stability at Pm = 45°

Two Ways to Compensate:

1. Narrowbanding
2. Pole-Splitting

Narrowbanding

\[\text{dominant} = 0'\]

Introduce a pole p₀ so that is sufficient separation between p₀ and p₁.

Add a compensation capacitor: \(C_{\text{pol}}\)

Visualization of the compensation process.
Remember: NarrowBand

1. Assumptions: $p_1, p_2, p_3$ don’t move when $p_d$ is introduced (often not true, but think worst isn’t that bad)

2. Summary: choose $p_d$ such that $\left|\frac{f(j\omega)}{f_3db}\right| = 0$ dB $\approx p_1$ (which becomes the “new 2nd most dominant pole”) by this gives $PM = 45^\circ$ (for $|p_2| > |p_1|$ & $|p_3| > |p_1|$)

3. Why do this? Wouldn’t it be much better to just move the original $p_1$ (i.e., pole-split)

Do it when you have no other choice, e.g., when you have a packaged opamp & have access only to a few terminals, not the optimum compensation node.

4. $|p_{d1}| = \left|\frac{p_1}{\text{Tomax}}\right|$ maximum expected needed loop gain

Problem:

1. often, $|p_{d1}| < |p_1|$ : $f_{3db}$ BW of the group will be very small

2. $\text{Wcundup} = |p_1|$ which isn’t that large

Solution: Pole-Splitting

- move $p_1$ doesn’t either keep $|p_1|$ still or move $|p_1|$ up simultaneously

- do this:

  1. $f_{3db} = |p_1|$
  2. $\text{Wcundup} = |p_2|$
EE 140: Analog Integrated Circuits
Lecture 21w: Choosing $C_c$

Choosing $C_c$ (assume no RHP zeroes $\frac{1}{P_1} >> \frac{1}{P_2}$)

- assume $\frac{1}{sC_c} <<$ surrounding impedance @ high freq.

Case: Two-Stage Amplifier, Miller comparison

- $V_0$ of op amp
- transconductor $\rightarrow (N-1)$ gain
- compared to output @ high freq.

Unity-Gain Stable Op Amps $\rightarrow$ e.g., 741 op amp

Monolithically compensated w/ an internal $C_c$

To be stable when $A_0 = 1$

[Diagram of op amp with compensated $C_c$]

Wide for unity gain compensated op amp

What if this case the lowest gain you needed $> 1$?

Could have done this! $\rightarrow$ compensated for the $A_0$ you need $\rightarrow$ add higher rail (vs. unity gain comp.)
\[ V_0 = \frac{i_X}{sC_C} \Rightarrow \begin{aligned} V_0 &= \frac{G_m}{sC_C}V_i \rightarrow \frac{N_0}{N_i} &= \frac{G_m}{sC_C} \end{aligned} \]

**Choosing \( C_c \)**

\[ \frac{N_0}{N_i} \text{[dB]} = \frac{G_m}{sC_C} = \text{This should equal } A_o @ \text{frequency } \omega \text{ corresponding to the target phase margin} \]

**For PM: 45°:**

\[ \omega_{ul} = \omega @ |\text{gain}| = 1 \]

**Note:** "\( \omega_{ul} \)" = "unity loop transmission"

**For PM: 45°** \( \rightarrow \omega_{ul} = \omega \) = freq of 2nd pole in the \( a(j\omega) \) transfer func.

\[ \frac{N_0}{N_i} \text{[dB]} = A_o = \frac{G_m}{sC_C} \rightarrow C_c = \frac{G_m}{sC_C} \]

For PM: 60°:

\[ \omega_{ul} = \frac{\omega \sqrt{2}}{\sqrt{3}} \rightarrow |\frac{N_0}{N_i} \text{[dB]}| = A_o = \frac{G_m}{\omega \sqrt{2} C_c} \]

\[ C_c = \frac{1.73 G_m}{\omega \sqrt{2} A_o} \]

\( \text{provided } |P_{31}| > |P_{31}| \)

**Case 2:** Two Stage Amplifier, Shunt \( C_c \) Compensation

\[ a_2 \quad -sN_o \]

Copyright © 2012 Regents of the University of California