Lecture #20

Let's illustrate compensation with an example, similar to Lab 3.

Consider the following differential amplifier: - active amplifier we ideal (R_0 = \infty, R_{out} = 0)

\[ R_1 = 10k, C_1 = 1nF \]
\[ R_2 = 1k, C_2 = 1nF \]

We want to predict its stability when used in a feedback configuration.

1. Determine the open loop gain, \( A(s) \)
   - consider stages are at a time
   1. \( A_1(s) = \frac{100 \cdot \frac{5C_1}{R_1}}{1 + s \cdot R_1 \cdot C_1} \)
   2. \( A_2(s) = \frac{100}{1 + s \cdot R_2 \cdot C_2} \)

Total transfer function: \( A(s) = A_1(s) \cdot A_2(s) = \frac{10,000}{1 + s \cdot R_1 \cdot C_1 \cdot R_2 \cdot C_2} \)

\[ \begin{align*}
   W_{pi} &= \frac{1}{R_1 C_1} = 10^5 \\
   W_{pe} &= \frac{1}{R_2 C_2} = 10^4 \\
   W_{p} &= \frac{1}{R_1 C_1} \\
   V_{n} &= \frac{1}{R_1 C_1} = 10^5 \\
   \end{align*} \]

2. Will this be stable?
   - depends on feedback factor, \( \beta \)

Let's consider different configurations.
- Type of feedback? 
  
  → Series - Shunt

- β? 
  
  → β = 1

- Phase margin = 0°, unstable, needs compensation

- Type of feedback? 
  
  → Series - Shunt (no change)

- β? 
  
  → β = \frac{1}{99+1} = 0.01

- Draw in 20 \log (\frac{1}{β}) = 20 \log 100 = 40 \text{ dB} \text{ like in } |A(s)| \text{ plot.}

  → Phase margin = 22°, stable, but would like a greater phase margin

- For the β=1 case, let's compensate this op-amp to have a phase margin of 45°.

  - Need dotted line on bode plots, move dominant pole to a lower frequency
  - Move \omega_p back to \omega_p

  → Need \omega_p' = 10^2

  - Achieve this by introducing additional capacitance at node C.

  need \quad 10^2 = \frac{1}{R_1(C_1+C) + 10^4(C_1+C)} = \quad C_1 + C_c = 10^{-6} = 1 \text{ μF}

  \therefore C_c = 0.999 \text{ μF}

- New amplifier:

- New GBW product = 10^2 \cdot 10,000 = 10^6 \text{ (greatly reduced)}

  - 1 \text{ μF is a huge capacitance to have to add to the circuit.}

  - If we take advantage of the Miller Effect using the second stage, we could reduce this by a factor proportional to the gain of the second stage.