FEEDBACK CONCEPTS IN OP AMPS CIRCUITS

ECEN – 457 (ESS)
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From Circuit

\[ A_{\text{Closed Loop}} = \frac{Z_1}{1 + \frac{1}{A} \left( 1 + \frac{Z_2}{1 + \frac{Z_2}{Z_1}} \right)} \]  \hspace{1cm} (1)

Where

\[ \beta = \left( 1 + \frac{Z_2}{Z_1} \right)^{-1} \]

From Block Diagram

\[ A_{CL} = \frac{v_o}{v_i} = \frac{A}{1 + \beta A} \]  \hspace{1cm} (2)

\[ \frac{v_o}{v_i} = \frac{A}{1 + T} \] ; \hspace{0.5cm} T = \beta A
From (1)

\[ A_{\text{Closed Loop}} = \frac{\beta}{1 + \frac{1}{A\beta}} = \frac{A}{1 + A\beta} \]

\[ A_{\text{Closed Loop}} = A_{\text{CL}} \approx \frac{A}{1 + \frac{1}{A\beta_{\beta>>1}}} = \frac{1}{1 + \frac{Z_2}{Z_1}} \]

Sensitivity Concept

\[ S_x^f = \frac{\partial f}{\partial x} \frac{x}{f} \]

This will be a metric to discuss effects of process variations on closed loop gain.
Let \( f = A_{CL} \) and \( x = A \), thus

\[
S_{A}^{ACL} = \frac{\partial A_{CL}}{\partial A} \frac{A}{A_{CL}}
\]

\[
\frac{\partial A_{CL}}{\partial A} = \frac{(1 + \beta A) - A\beta}{(1 + \beta A)^{2}} = \frac{1}{(1 + \beta A)^{2}}
\]

\[
S_{A}^{ACL} = \frac{1}{(1 + \beta A)^{2}} \frac{A}{1 + \beta A} = \frac{1}{1 + \beta A} = \frac{1}{1 + T}
\]

We can write also as

\[
\frac{\Delta A_{CL}}{A_{CL}} \approx S_{A}^{ACL} \frac{\Delta A}{A}
\]
EXAMPLE: We want to know how much change in the closed loop gain will occur due to changes in the feedback component or/and in the open loop gain $A$.

$$A = 10^5$$

$$\Delta A = \pm 10\%$$

$$\beta = 10^{-3}, \ T = A\beta = 10^2$$

Thus

$$\frac{\Delta A_{CL}}{A} = \frac{1}{1 + T} \left( \frac{\pm \Delta A}{A} \right) = \frac{\pm 1}{1 + 100} \times 10\% = \pm 0.099\%$$

Exercise. Try for $\beta = 4 \times 10^{-3}$, $A = 2 \times 10^5$ and $\Delta A = \pm 25\%$

What is

$$\frac{\Delta A_{CL}}{A} \ ?$$

$$A$$