EE 324 LAB 10

A Study of the Effects on Feedback Stability

In this lab, you will observe how the use of feedback influences the stability of an amplifier, and what measures can be taken to improve this effect.

Prelab:

1. An uncompensated Op-Amp has the following transfer function from the differential voltage $V_p - V_n$ to the output voltage V_o:

$$A(s) = \frac{10^5}{(1 + 10^{-4}s)(1 + 10^{-6}s)}$$

2. Carefully sketch the Bode plot corresponding to $A(s)$. Make sure that your axes are correctly labeled and the asymptotes are evident.

3. If the Op-Amp is compensated by the resistive network shown in Figure 1, provide a relationship between the two compensator resistors, so that the closed-loop transfer function $T(s)$ from V_p to V_o has a DC gain equal to 10.

   To answer this question, assume ideal Op-Amp that V_o is not affected by the load provided by the compensator network (output impedance is zero), and that the current flowing into the (-) terminal is zero (input impedance is infinity), thus V_n is determined by the compensator transfer function acting as feedback gain multiplied to V_o. Also note that the "error signal" between input V_p and return V_n is amplified by forward gain $A(s)$.

4. Take $R_1 = 9\ k\Omega$ and $R_2 = 1\ k\Omega$.

5. Represent the Bode plot of the open-loop system $L(s) = \frac{R_2}{R_1+R_2} A(s)$. Compute its phase margin. (Using the gain plot, find the "gain crossover frequency" ω_g at which $|L(j\omega_g)| = 1$, and then the phase-margin is found from the phase-plot and it equals: $\left| |\angle L(j\omega_g)| - \pi \right|$.)

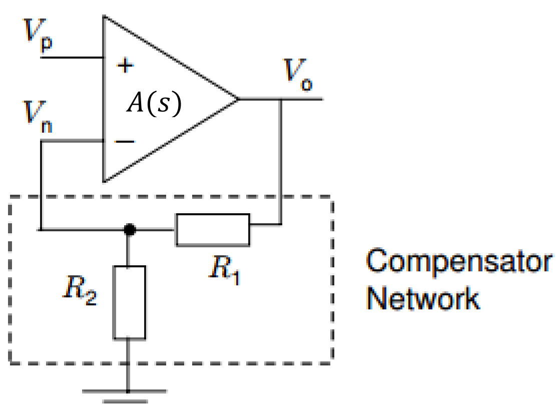

Figure 1 Op-Amp Circuit with Static Compensator

6. Notice the effect of the phase margin on the Bode plot of the closed-loop system transfer function, $T(s)$. What is its main feature? (If closed-loop transfer function has complex poles, then bode plot of T has a "bump" in its magnitude plot.)

7. Using your intuition about pole locations (real or complex), sketch the unit step response of the compensated amplifier $T(s)$. Note a phase-margin in L is related to amount of damping in overshoot in step-response of T. (More phase-margin means more negative reinforcement going around the loop, and so more damping and less overshoot.)

Laboratory Assignment:

1. Using MATLAB, verify the Bode plot of $L(s)$, phase margin, and bode plot and step-response of $T(s)$. You may use the `margin` command (which gives the Bode plot and also the gain and phase margins).

2. To improve the response, control engineers use a lead compensator. A lead compensator is a system which can provide positive phase (and so a "phase lead"). Such a compensator can be built by putting a capacitor in parallel to one of the resistors. Draw the correct circuit and verify your answer. For this, compare the transfer functions of the feedback path for "$(R_1 \parallel C)$ and R_2" vs. that of "R_1 and $(R_2 \parallel C)$", and find their phase, and see which one has a positive phase.

3. Keeping the values of the resistors given in Part 4 of Prelab, find a value for the capacitor in the lead compensator setup found above, which improves the closed-loop step response by reducing the overshoot to maximum possible (note that more phase-margin means more damping and less overshoot). For each value of the capacitor you try, represent the Bode plot of the open-loop transfer function $L(s)$ along with the phase margin, the Bode plot of the closed-loop transfer function $T(s)$ along with the closed loop bandwidth, and the unit-step response of $T(s)$ along with the amount of overshoot. Tabulate against the capacitor values: the phase margin, the closed-loop bandwidth, and the overshoot in the unit-step response. Determine the capacitor value that provides the "best/highest" phase margin. (Hint: Look for capacitance values of around 10 pF).