EE5390: Analog Integrated Circuit Design; Assignment 3

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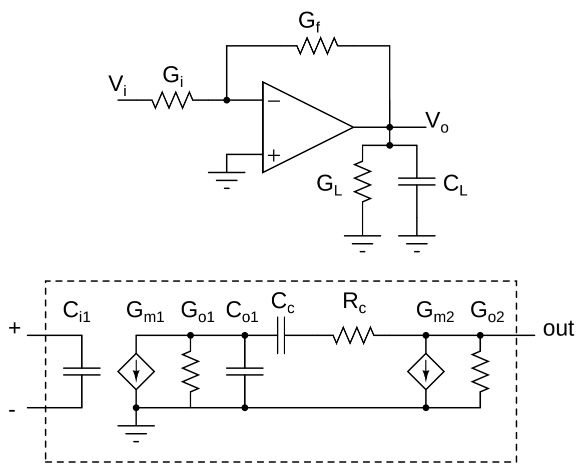

Figure 1: Problem 1

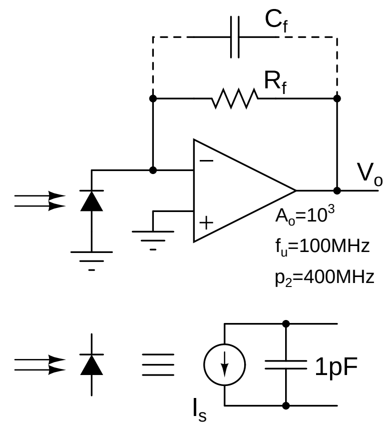

Figure 2: Problem 2

1. $G_{m1} = 20\mu$S, $G_{o1} = 0.25\mu$S, $G_{m2} = 80\mu$S, $G_{o2} = 2\mu$S, $G_L = G_f = G_i = 4\mu$S, $C_{i1} = 10$ fF, $C_{o1} = 40$ fF, $C_c = 250$ fF, $C_L = 1$ pF, $R_c = 12.5$ kΩ.

   Determine the poles and zeros of the loop gain—Calculate them based on approximations discussed in the class, and by calculating the Loop gain function symbolically and extracting the roots numerically. Comment on the accuracy of approximations.

   Determine the closed loop transfer function and calculate its poles and zeros. How do these relate to poles and zeros of the loop gain function.

   Plot the unit step response and the loop gain magnitude and phase response.

   Change each (one at a time) of C_c, R_c, $G_L = G_f = G_i$ to $0.5\times$ and $2\times$ their nominal values. Plot the unit step response and the loop gain magnitude and phase response (overlaid on the same plot for each case). Comment on the results.

2. Fig. 2 shows a transimpedance amplifier driven by a photodiode. The photodiode can be modelled as a current source in parallel with a capacitor. The opamp has $A_o = 10^3$, $\omega_u/2\pi = 100$ MHz and $p_2/2\pi = 400$ MHz (Make a model of the opamp using controlled sources and passive elements. A parameterized macromodel of the opamp is very useful for future circuit designs).

   (Don't include C_f for this part) What is the largest transimpedance R_f you can have without peaking in the frequency response V_o/I_s? Show the ac magnitude response and the transient response to a current step of $1/R_f$ Amperes with a 100 ps risetime?

   Increase R_f by $20\times$ and show the ac magnitude response step response (current step of $1/R_f$ Amperes. Compare this to the earlier case and comment on the results.

   Calculate $|V_o/I_s|$ including C_f. Find the condition for maximal flatness. Calculate C_f for the increased value of R_f and show the magnitude response and the step response. What does the loop gain look like for this circuit?

Calculate the expression for the “gain-bandwidth product” with C_f (gain = R_f).

(For analytical calculations of maximally flat magnitude response, it’ll be simpler to use an ideal integrator model for the opamp, and then adjust the values to account for the second pole).

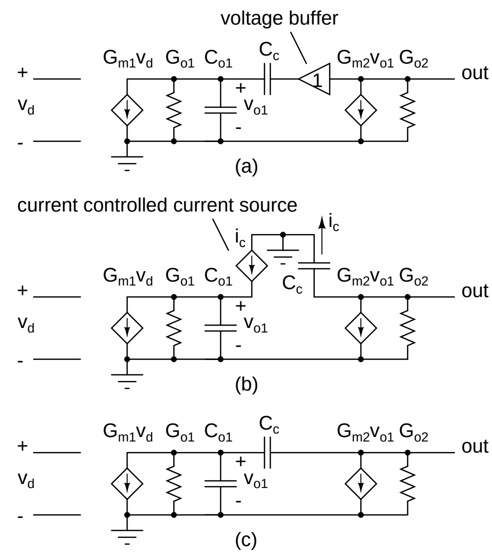

Figure 3: Problem 3

3. The circuits in Fig. 3(a, b) are modified versions of the two stage miller compensated opamp (Fig. 3(c)). Calculate their transfer functions and compare them to that of the conventional structure. What is the difference? Explain the results.

4. Design a three stage opamp (Fig. 4(a)) using the opamp in Fig. 1 as the “inner” opamp (Fig. 4(b)). Exclude R_c, C_{i1}, G_i, G_f, and G_L from Fig. 1. Use $C_3 = 1$ pF. For the first stage of Fig. 4, use the same values as in the first stage of Fig. 1. Determine the value of C_{m1} to obtain a phase margin of 60°. What is the unity gain frequency of the three stage opamp?

   Where are the poles and zeros? (Derive the expression assuming $G_1 = G_2 = G_3 = 0$ and find the roots exactly. Calculate the dc gain and unity gain frequency separately). Comment on the location of the zeros.

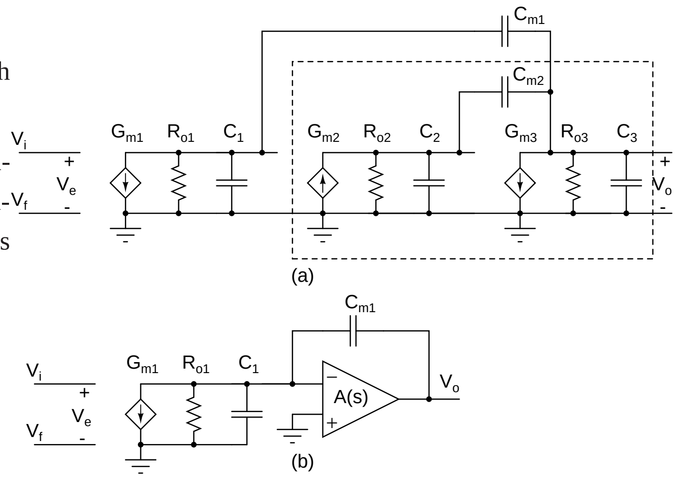

Figure 4: Problem 4

Connect a zero cancelling resistor in series with C_{m2} such that the corresponding zero moves to infinity. What is the phase margin?

With the zero cancelling resistor in place, adjust C_{m1} such that the phase margin is 60°. What is the new unity gain frequency?