Analog Integrated Circuit Design

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Assignment 4

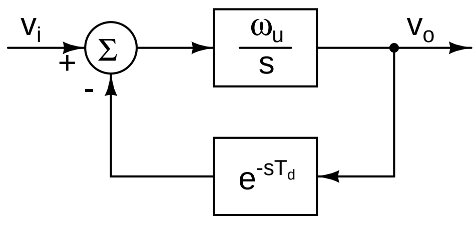

Figure 1: Problem **??**

1. (a) Setup the differential equation for the system above.

   (b) V_i is 1 V for a long time and changes to 0 V at $t = 0$. What is the equation for $t > 0$?

   (c) Assume that the solution is of the form $V_p \exp(\sigma t)$ with real σ. Obtain the equation from which you will determine σ (You are not required to solve it).

   (d) What is the largest value of T_d for which real solutions for σ exist? To do this, express the above equation as $f(\sigma) = 0$. Sketch $f(\sigma)$. Determine the extremum of $f(\sigma)$ in terms of T_d. For what value of T_d does the extremum become equal to zero?

   (e) Assume that the solution is of the form $V_p \exp((\sigma + j\omega)t)$. Obtain the equations from which you will determine σ and ω (You are not required to solve them).

   (f) Reduce the above to a single equation in ω.

2. Fig. 2 shows the model for a photodiode. The diode is setup in reverse bias (biasing arrangement not shown) and when light shines on it, a current is produced. The current can be converted to voltage using the schemes in Fig. 2(b) to (d). This circuit

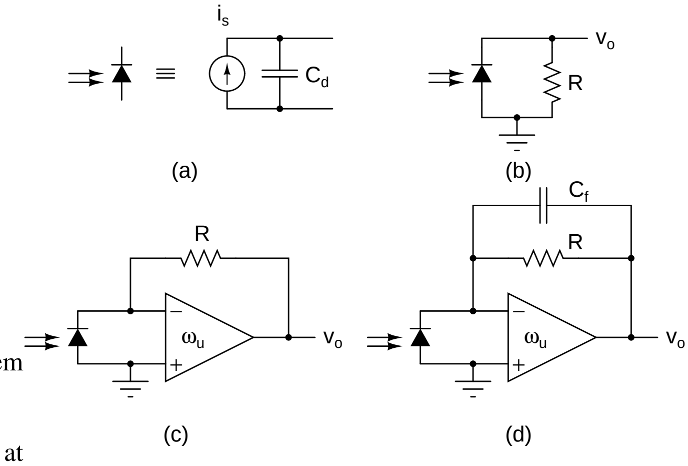

Figure 2: Problem 2

is used in optical communication systems. The goal is to maximize the gain as well as the bandwidth of conversion from i_s to v_o. Do the following for a given R (gain). Model the opamp as an ideal integrator with a unity gain frequency ω_u.

   (a) What is the bandwidth in Fig. 2(b)? What is the gain bandwidth product?

   (b) What is the bandwidth in Fig. 2(c)? Choose the opamp's ω_u such that you get a maximally flat magnitude response (maximum possible bandwidth without peaking; derivatives $d^n/d\omega^n |H(j\omega)|^2$ should be zero to the maximum degree n that is possible.). What is the gain bandwidth product? What are the advantages and disaadvantages of Fig. 2(c) when compared to Fig. 2(b)? (One sentence each!)

   (c) What is the bandwidth in Fig. 2(c)? Choose an ω_u for the opamp and then choose C_f such that you get a maximally flat magnitude response (maximum possible bandwidth without peaking; derivatives $d^n/d\omega^n|H(j\omega)|^2$ should be zero to the maximum degree n that is possible.). What is the gain bandwidth product? What are the advantages and disaadvantages of Fig. 2(d) when compared to Fig. 2(b, c)? (One sentence each!)

(d) If you are now told that the opamp also has a non-dominant pole p_2, how would you change the solution to Fig. 2(d) so that the behavior is approximately the same as before? (You can of course solve everything from scratch, but try to do it using loop gain and the effect of extra poles and zeros on it as discussed in the class)

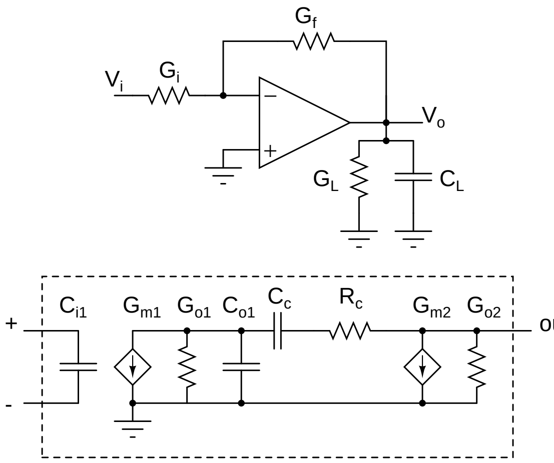

Figure 3: Problem 3

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

   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.

4. The circuits in Fig. 4(a, b) are modified versions of the two stage miller compensated opamp (Fig. 4(c)).

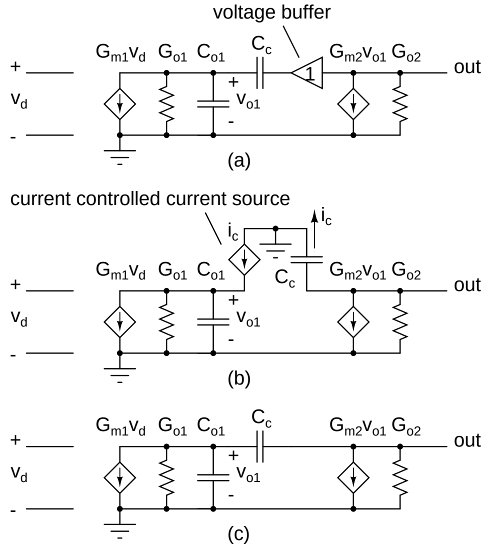

Figure 4: Problem 4

Calculate their transfer functions and compare them to that of the conventional structure. What is the difference? Explain the results.

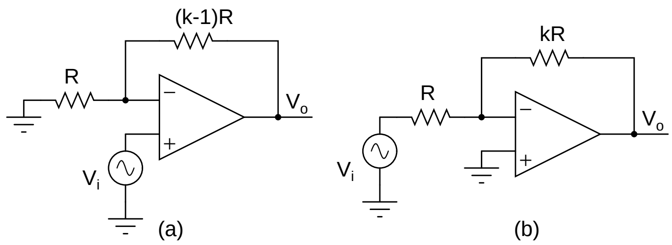

Figure 5: Problem 5

5. Fig. 5(a) and Fig. 5(b) shows amplifiers which realize gains of k and $-k$ respectively with ideal opamps. Compare the following parameters of the two circuits. Model the opamp as an integrator ω_u/s.

   (a) Input impedance

   (b) Bandwidth

   (c) Differential $(V_+(s) - V_-(s))$ and common mode $((V_+(s) + V_-(s))/2)$ input voltages of the opamps

   Assuming that the sign of the gain is unimportant in your application, what would make you choose one over the other? Is there any reason to choose Fig. 5(b) at all?

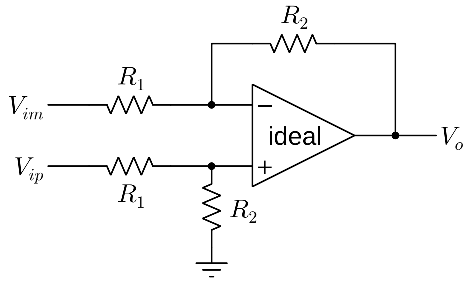

Figure 6: Problem 6

6. Determine the differential and common-mode gains of the amplifier shown in Fig. 6. What is the common-mode rejection ratio (CMRR)? Evaluate the CMRR if the resistors are mismatched. Assume that the mismatch standard deviation is σ_{R1} and σ_{R2} between the respective resistor pairs.