EEC 212
Problem Set 4

Professor Hurst

1

Find an expression for $\left(\frac{W}{L}\right)_6$ in terms of $\left(\frac{W}{L}\right)_1$ that biases M_1 at the edge of saturation, which assures maximum output swing if the cascoded current source in Figure 1 is used in the output stage of an op-amp. Take $\lambda = 0$ and $\gamma = 0$. M_1 through M_4 all have the same $\left(\frac{W}{L}\right)$. $\left(\frac{W}{L}\right)_5 = \frac{1}{9}\left(\frac{W}{L}\right)_1$.

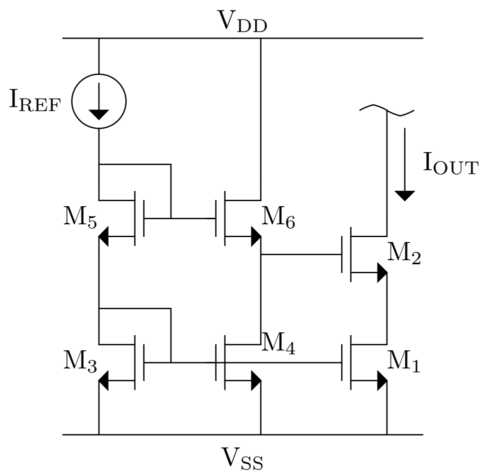


Figure 1: Current Source for Problem 1

2

(a) Use Blackman's impedance formula to find a formula for the output resistance of the current mirror in Figure 2. All transistors are in saturation and $\left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_2 = \left(\frac{W}{L}\right)_3$. Find $R_{out} = fn(A, g_{m1}, r_{o1}, g_{m2}, r_{o2}, ...)$.

(b) What V_{BIAS} voltage gives the maximum output swing? Assume $A \gg 1$.

(c) What is R_{out} for the current source in Figure 3? All transistors are in saturation and $\left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_2 = \left(\frac{W}{L}\right)_3 = \left(\frac{W}{L}\right)_4$.

3

(a) Use return-ratio feedback analysis to find the closed-loop gain, $A_{CL} = \frac{v_{out}}{v_{in}}$, and output resistance for the inverting amplifier in Figure 4. For the op-amp, take $R_{in} = 1\text{M}\Omega$, $R_{out} = 10\text{k}\Omega$, and $a_v = 200$.

(b) By looking at the return ratio, show that the two-node feedback amp in Figure 5 is always stable if each impedance is either an R or a C. a_v is a constant voltage gain.

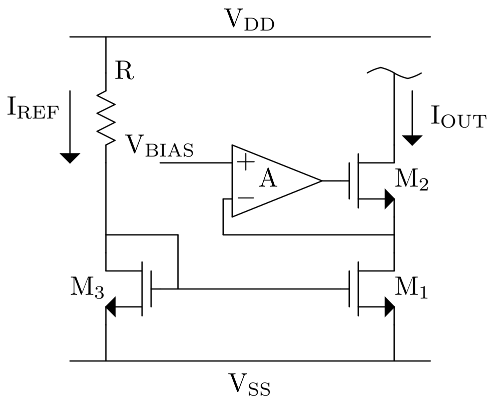


Figure 2: Current Source for Problem 2a.

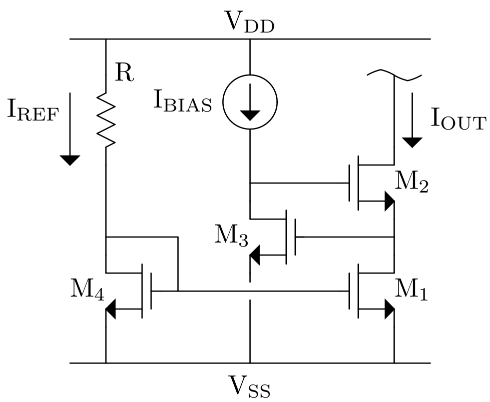


Figure 3: Current Source for Problem 2c.

4

Consider the fully differential circuit in Figure 6. For (a) and (b) find:
$A'_{DM} = \frac{v_{od}}{v_{id}}$, $A'_{CM} = \frac{v_{oc}}{v_{ic}}$, $A'_{CM-DM} = \frac{v_{od}}{v_{ic}}$, $A'_{DM-CM} = \frac{v_{oc}}{v_{id}}$

(a) $R_1 = R_2 = 1\text{k}\Omega$, $R_3 = R_4 = 5\text{k}\Omega$, and an ideal differential op-amp with infinite differential mode gain and zero common mode gain.

(b) $R_1 = 1.01\text{k}\Omega$, $R_2 = 0.99\text{k}\Omega$, $R_3 = R_4 = 5\text{k}\Omega$, and the ideal op-amp in (a).

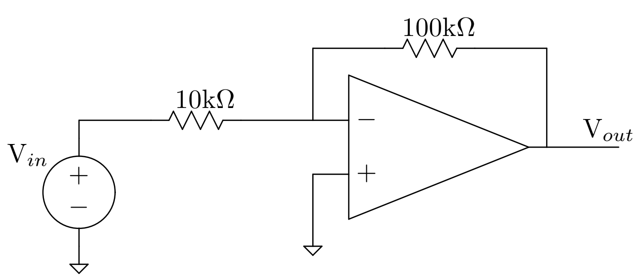


Figure 4: Amplifier for Problem 3a.

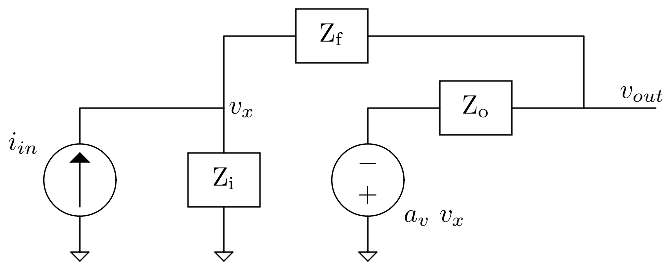


Figure 5: Circuit for Problem 3b.

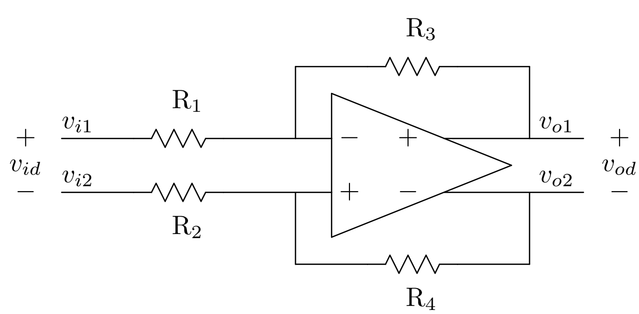


Figure 6: Circuit for Problem 4.

5.a) Compute the return ratio for the circuit in Fig. 7b, and show that it can be written as

$$\mathcal{R} = \underbrace{\frac{G_m R_o}{1 + s R_o C_L'}}_{\text{"gain"} = -\frac{v_o}{v_x}} \cdot \underbrace{\frac{C_2}{C_2 + C_1 + C_{in}}}_{\text{"fb factor"} = \frac{v_o}{v_x}}$$

b) Assume $\mathcal{R}(DC) = G_m R_o >> 1$ and the feedforward is negligible ($d \simeq 0$).

Then $A_{CL} = \frac{v_o}{v_{in}} \simeq A_\infty \frac{\mathcal{R}}{1+\mathcal{R}}$

what is A_∞ in Fig 7a?

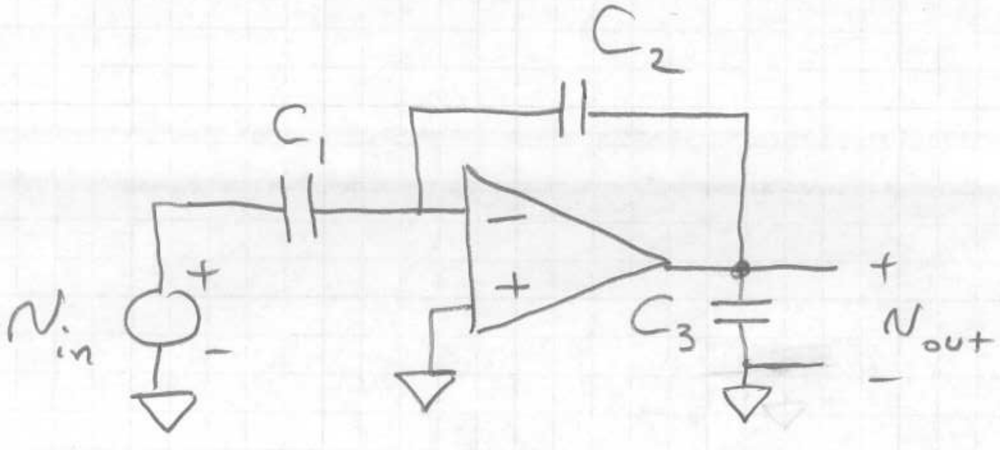
Assume $w_u' >> \frac{1}{R_o C_L'}$ & $R_o = \mathcal{R}(DC) >> 1$

c) Show that the $-3dB$ bandwidth is equal to the freq w_u' where $|\mathcal{R}(w_u')| = 1$

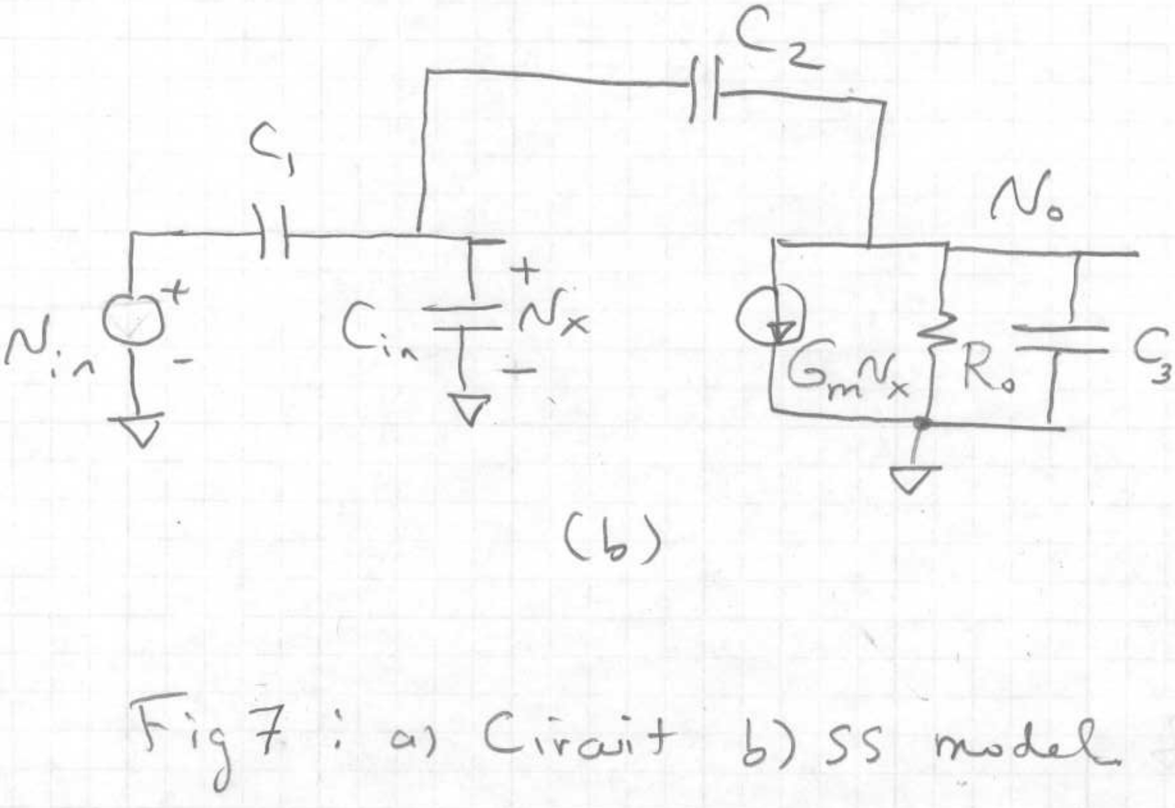
Hint: see GHLM eqns 9.11 - 9.20 for 1 option.

d) How does w_u' change (increase, decrease, or no change) if C_L' increases?

If fb factor increases (assume C_L' does not change)? If R_o increases?



(a)



(b)

Fig 7 : a) Circuit b) SS model