UNIVERSITY OF CALIFORNIA
College of Engineering
Department of Electrical Engineering
and Computer Sciences

EE140 **Final Exam** **Dec. 14, 2001**

Name ______________________________ **SID#** ____________________
(10pts)

grad ☐ **undergrad** ☐

- **Closed book except for 2 8.5" x 11" sheets of your notes.**
- **There are three problems. Be sure to show all your work to receive full or partial credit.**

1	
2	
3	
Total	

1.

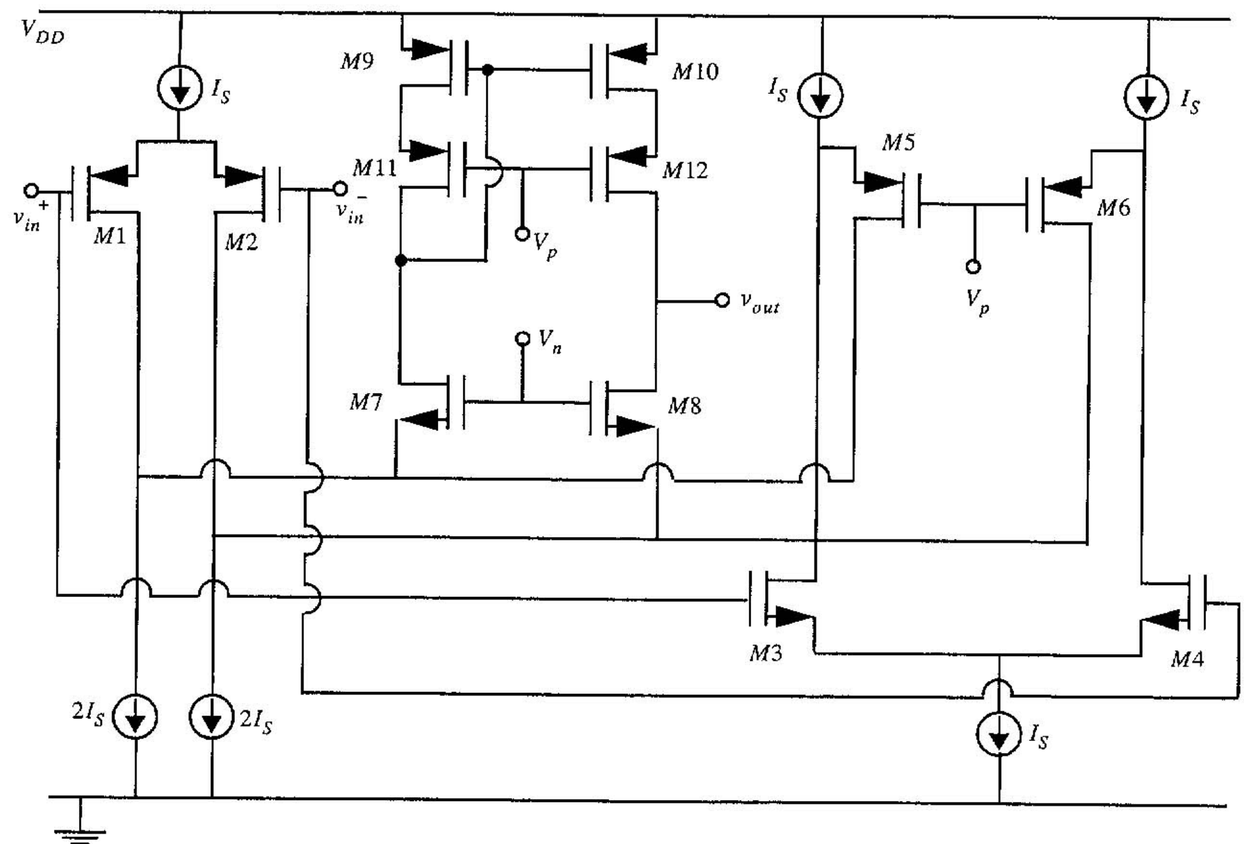

Fig. 1: Rail-Rail Input Op-Amp

The circuit of Fig. 1 is proposed as a rail-to-rail input op-amp. Assume bias voltage V_n is chosen so that $M7, 8$ remain active, and bias voltage V_p is chosen so that $M5, 6$ and $M9-12$ all remain active. Assume ΔV_{1-12} are all equal when all devices are active.

(10 pts) **a)** Determine the range of common-mode input voltage $v_{in_{cm}} = v_{in}^+ = v_{in}^-$ for which $M1, 2$ are active. Leave your answer in terms of V_{DD}, dc voltages V_n and V_p, transistor overdrive voltages ΔV_{1-12}, and transistor threshold voltages V_{T1-12}.

(10 pts) **b)** Determine the range of common-mode input voltage $v_{in_{cm}} = v_{in}^{+} = v_{in}^{-}$ for which $M3, 4$ are active.

(10 pts) **c)** Determine the circuit G_m if all transistors are active. In this part and subsequent parts, leave your expression in terms of transistor small signal parameters g_m, r_o, etc. Neglect body effect. You may make reasonable simplifying approximations, but do explain these.

(10 pts) **d)** Determine the circuit G_m if all transistors except $M1, 2$ are active. (Assume $M1, 2$ cut-off.)

(10 pts) **e)** Determine the circuit G_m if all transistors except $M3, 4$ are active. (Assume $M3, 4$ cut-off.)

(10 pts) **f)** Determine R_{out} if all transistors are active.

2.

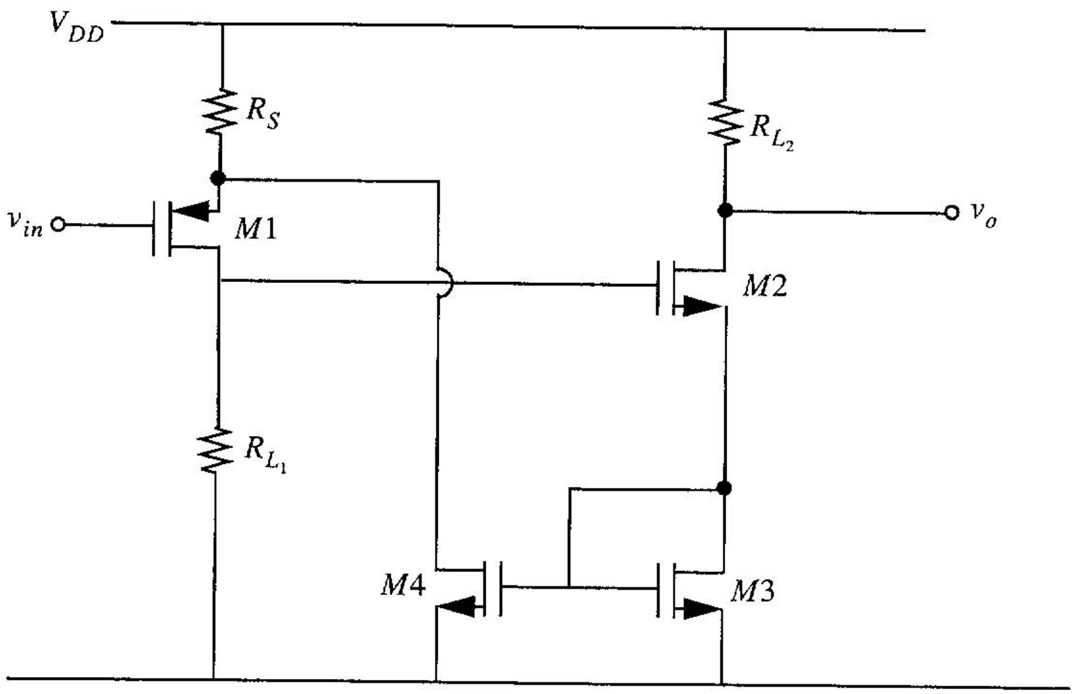

Fig. 2: Feedback Amplifier

Assume all devices are biased in the active region. Consider $M3$, $M4$, and R_S as providing feedback around the amplifier $M1 - M2$. For parts b-f, express your answers in terms of symbolic small signal parameters, e.g. g_m, r_o, etc. Ignore body effect.

(10 pts) **a)** What type of feedback is used?

(10 pts) **b)** Determine the feedback factor f.

(10 pts) **c)** Determine the open-loop circuit $\tilde{G}_m$ including loading effects. $\tilde{G}_m$ may be defined as the circuit G_m obtained if the gate of $M4$ is disconnected from $M3$, and connected to an appropriate dc bias voltage instead.

(10 pts) **d)** Determine the loop transmission T.

(10 pts) **e)** Determine the closed-loop circuit G_m.

(10 pts) **f)** Determine R_{out} for the closed-loop circuit.

3.

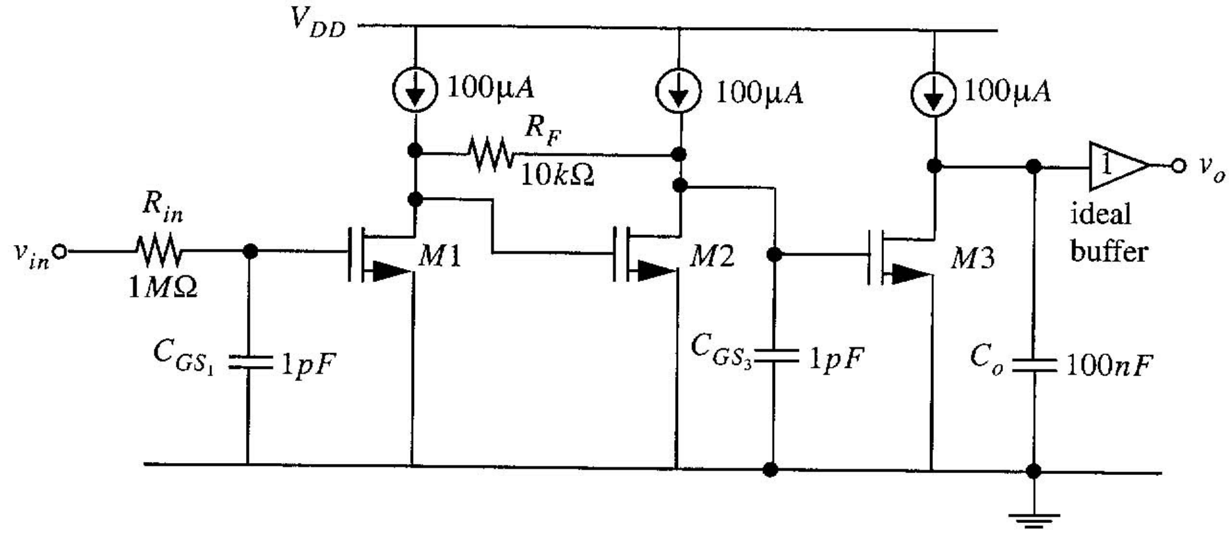

Fig. 3

In the circuit of Fig. 3, ignore all device capacitances. Include only C_{GS_1}, C_{GS_3}, and C_o in your calculations. Take $\lambda_n = 0.01$ and $\Delta V_{1,2,3} = 0.2V$. Also take $C_{GS_1} = C_{GS_2} = 1pF$ and $C_o = 100nF$. Assume $M1 - 3$ are active.

(10 pts) **a)** Determine the poles of the amplifier of Fig. 3 if $R_F = \infty$, i.e. if R_F is removed.

(10 pts) **b)** Determine the low frequency gain of the amplifier of Fig. 3 if $R_F = \infty$.

(10 pts) **c)** If the amplifier of Fig. 3 with $R_F = \infty$ was connected in a unity gain connection, i.e. connect v_{in} to v_o, would the circuit be stable? Explain.

(10 pts) **d)** Determine the poles of the amplifier with $R_F = 10k\Omega$.

(10 pts) **e)** Determine the low frequency gain of the amplifier if $R_F = 10k\Omega$.

(10 pts) **f)** Estimate the phase margin if you were to connect the amplifier of Fig. 1 with $R_F = 10k\Omega$ in a unity gain feedback connection, i.e. connect v_{in} to v_o.

(10 pts) **g)** Estimate the frequency of the lowest pole (or pole-pair) in the unity gain feedback connection of part (f).