

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

Homework #8

EECS 140

B. E. Boser

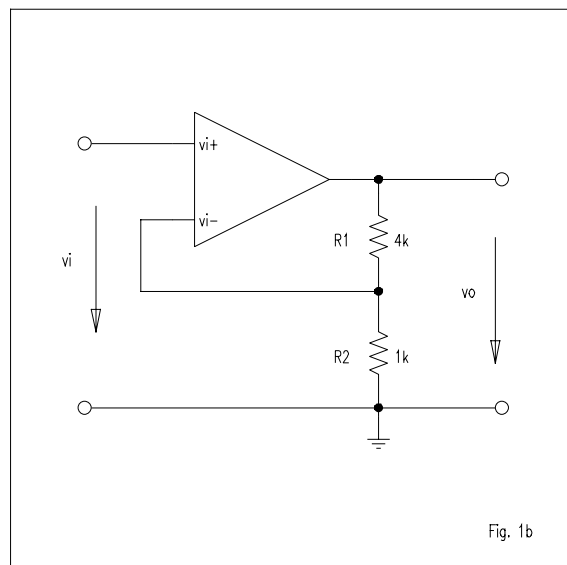
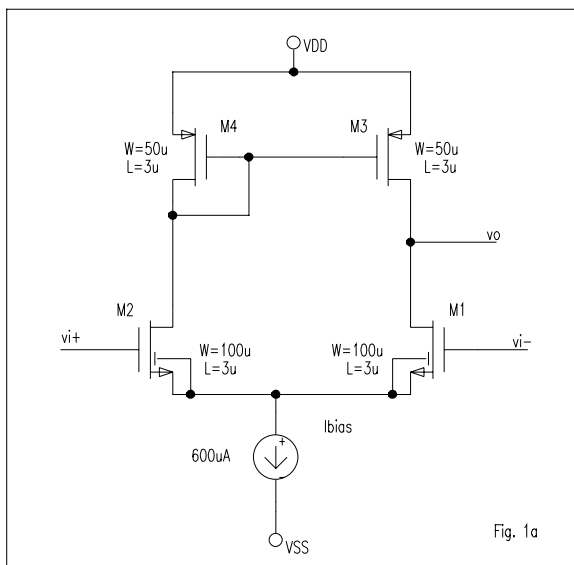
Due 10/22/99 before noon in 497 Cory

Fall 1999

Note: Use the device parameters given in the class handout “Device Parameters & SPICE Models” and also available on the EECS 140 website, <http://kowloon.eecs.berkeley.edu/~courses/140>

Grading: Problem 1: 25% Problem 2: 25% Problem 3: 50%

- 1) Consider the circuits shown in Fig. 1a and 1b.
 - a) Calculate the differential mode transconductance G_m , the output resistance R_o and the open loop gain A_{dmo} of the OTA shown in Fig. 1a.
 - b) Suppose that the given OTA was used in a topology with resistive feedback, as shown in Fig. 1b. Which overall gain v_o/v_i would result? What is the effective open loop gain v_o/v_{id} of the OTA when it is loaded with the feedback resistors?
Note: Break the feedback loop (i.e. connection from the resistors to the V_i -terminal of the amplifier) to calculate the open loop gain.
 - c) For comparison, calculate the expected gain v_o/v_i when an OpAmp consisting of the OTA shown in Fig. 1a followed by an ideal buffer with gain 1 and $R_o=0$ is used instead.
 - d) Explain why **OTAs** cannot be used in a resistive feedback topology that is typically used in discrete circuits with **OpAmps**.
 - e) Despite the fact that OTAs can typically not be used with resistive feedback networks, list at least two reasons why one might prefer to use OTAs over OpAmps in an integrated circuit. What is a common way to implement feedback networks for on-chip OTAs?



- 2) Problem 6.10 of the course reader (page 6T.59)
- 3) An OTA is operated open loop with a capacitive load as shown in Fig. 3a. Design the circuit, i.e. find all W/L and I_{bias} to meet the following specifications:
- Low frequency voltage gain $A_{dm0} \geq 100$ for $-4.5V < V_o < 4V$.
 - Unity gain frequency $f_u \geq 30MHz$ for $C_L = 10pF$.
 - Minimize the input capacitance of the amplifier
 - Use $L = 2\mu m$ for all devices
- a) Determine the maximum value of V_{dsat} in the differential pair to meet the specifications. Use this value for the design since it minimizes the input capacitance of the amplifier. Use the same V_{dsat} in all other devices for simplicity.
 - b) Determine the minimum transconductance G_m and I_{bias} that are needed to meet the specifications.
 - c) Determine the W/L ratios of all devices. Hint: Determine the optimal input common-mode voltage and all other DC bias voltages first and include the $\lambda \cdot V_{DS}$ terms in your calculations.
 - d) Draw a schematic showing all node voltages, branch currents and V_{dsat} and g_m of all devices.
 - e) Using a SPICE .dc analysis, plot the low-frequency small-signal gain v_o/v_{id} as a function of V_o . Setup the input stimuli using voltage controlled voltage sources (SPICE source “E”) as shown in Fig. 2b, thus separating common mode and differential mode input. Mark the gain requirement ($A_{dm0} \geq 100$ for $-4.5V < V_o < 4V$) in the plot.
 - f) Perform a .ac analysis to plot the frequency response of v_o/v_{id} . Mark the simulated and required unity-gain bandwidth in the plot.

Important note on problem 3) part e):

The plot for $v_o/v_{id} = dV_{od}/dV_{id}$ as a function of V_{od} can be generated as follows:

- After running the DC analysis, the default x-axis is V_{id} since you are sweeping V_{id} in the analysis. Change the x-axis variable to V_{od} .
- Most graphical postprocessors (Awaves, Probe, ...) can only find the derivative of curves with respect to their x-axis. Therefore, we will have to make use of the fact that $dV_{od}/dV_{id} = (dV_{id}/dV_{od})^{-1}$.
- If you are using Probe, this will translate into the trace expression “1/d(Vid)” which will then give us the desired graph.
- If you are using Awaves, the same should be doable using the “derivative()” function in the expression builder. Unfortunately, the Awaves version that we are currently using outputs an error message if you are trying to do the above. A workaround would be to simply display dV_{od}/dV_{id} and V_{od} with V_{id} being on the x-axis and then crossprobe between the two curves (see HW7 - problem 4). *However:*

*The **first** student who finds a way to display the desired curve (dV_{od}/dV_{id} as a function of V_{od}) using Awaves will receive **10% extra credit on this homework!!!** E-mail to “bmurmann@eecs.berkeley.edu”.*

