CMOS Operational Amplifier

ECE 3200 Electronics II
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References

Objectives
1. Analyze and simulate a CMOS operational amplifier (OA).
2. Simulate the OA used in a closed-loop non-inverting configuration.

Procedures

Analysis and Simulation of a CMOS Operational Amplifier

1. For the OA of Figure 1:
   Assume that $k_n = 0.5 \text{ mA/V}^2$, $k_p = 0.5 \text{ mA/V}^2$, $V_{tn} = 1 \text{V}$, and $V_{tp} = -1 \text{V}$, where $k_n = \mu_n C_{oX} W/L$ and $k_p = \mu_p C_{oX} W/L$.
   For Q6 $k_p = 1 \text{ mA/V}^2$.
2. Find the DC quantities $I_D$ and $V_{GS}$ of Table 1 assuming $V_A = V_B = 0 \text{V}$. Use the table format in your report. Use correct signs (NO absolute values allowed). Hint: start with Q8!

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<th>Q1</th>
<th>Q2</th>
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<td>$I_D$</td>
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<td>$r_o$</td>
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Table 1. DC and AC OA parameters

3. Verify that your Table 1 DC results are approximately correct by conducting a DC operating point LTspice® simulation. Tabulate your simulation results using the same table format. Note any major discrepancies.
4. Find the AC small signal model parameters $g_m$ and $r_o$ of Table 1.
5. Use your data from Table 1 to estimate the DC open-loop gain \( v_f/v_{ab} \) of the CMOS OA. Proceed as in Example 9.6 of Sedra and Smith [2] but be careful to use correct signs as discussed in class.

6. Use LTspice® to find the DC open-loop gain \( v_f/v_{ab} \) of the CMOS OA using the .tf directive. Compare with your hand analysis result of Procedure 5.

Simulation of the CMOS OA in a Non-Inverting Circuit

7. Add the C2-R2 frequency compensation network; R1-R2 feedback network; and load capacitance C1 to your circuit as in Figure 2. Verify that the closed-loop gain is approximately 11 V/V by plotting the output voltage vs. the input voltage using a transient analysis for the indicated sinusoid applied at the non-inverting terminal.

8. Use the simulated open-loop DC gain to provide an estimate of the closed-loop gain for Procedure 7. Compare to the result of Procedure 7

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Figure 1. CMOS Operational Amplifier. Adapted from [1].
Figure 2. 11x Non-Inverting Amplifier Using the CMOS OA of Figure 1. Adapted from [1].