

CMOS Operational Amplifier

ECE 3200 Electronics II
version 9 April 2021

References

1. K. C. Smith, *Laboratory Explorations for Microelectronic Circuits Fourth Edition*, Oxford University Press, 4th edition, 1998. **This experiment is based on EXPERIMENT #10 CMOS OP AMPS of this text.**
2. A. S. Sedra and K. C. Smith, *Microelectronic Circuits*, 8th ed., Oxford University Press, 2009.

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!

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
I_D								
V_{GS}								
g_m								
r_o								

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.

- 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.*
- 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

- 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.
- 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

Credits, Copyright, and Use

Refer to front matter available at <http://homepages.wmich.edu/~miller/ECE3200.html> for material credits, further copyright information, and use guidelines.

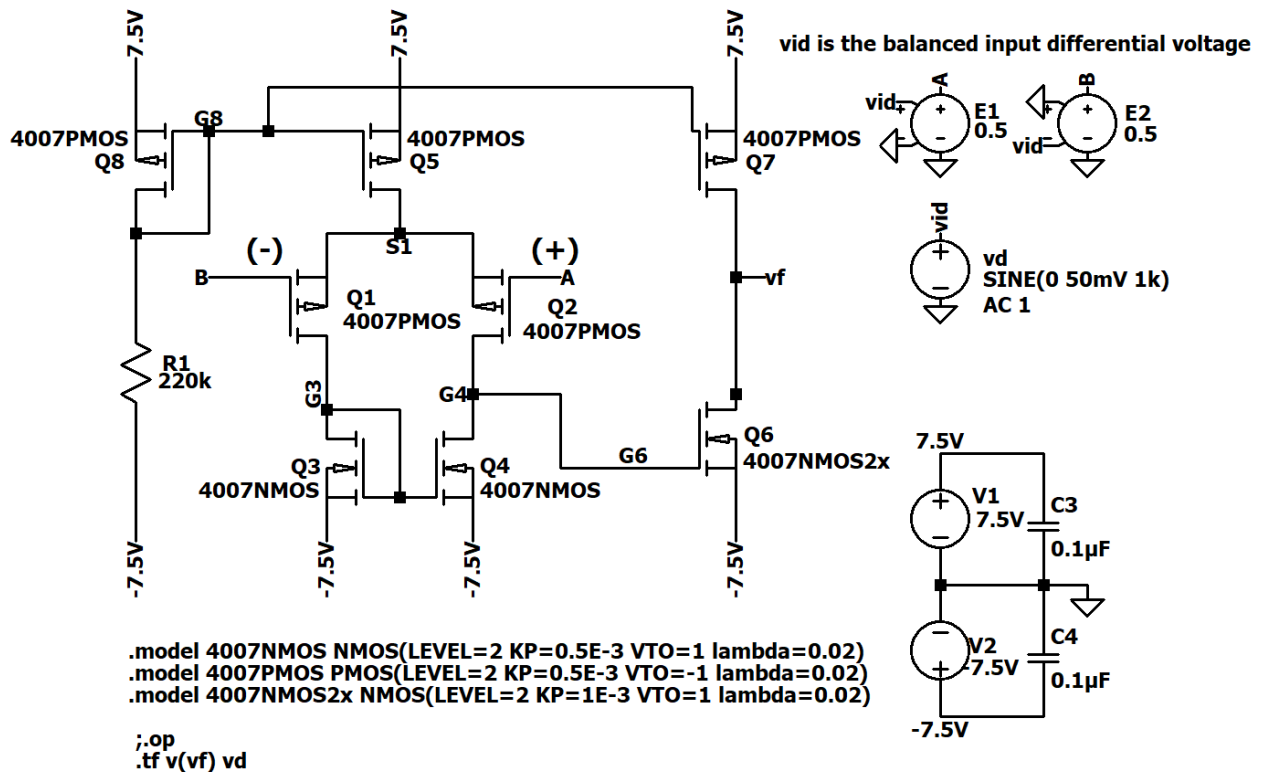


Figure 1. CMOS Operational Amplifier. Adapted from [1].

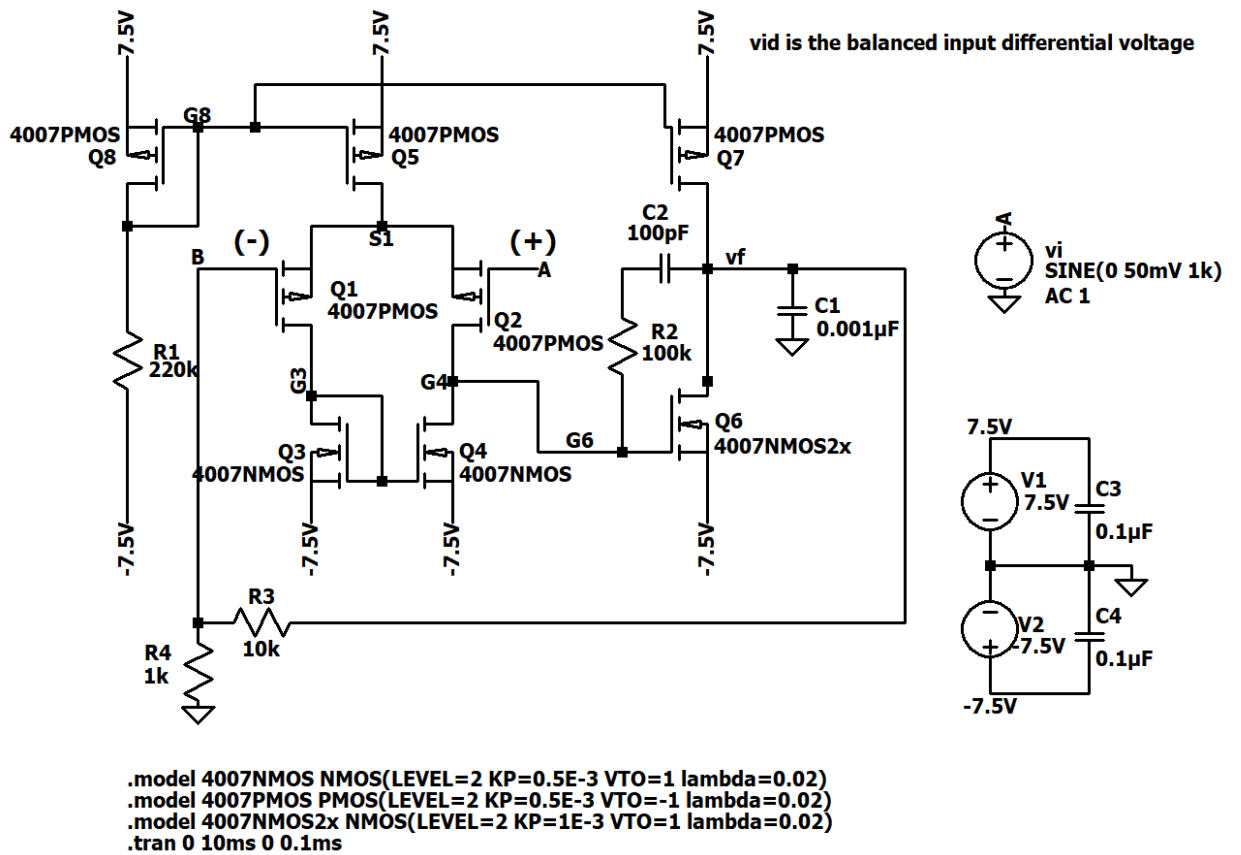


Figure 2. 11x Non-Inverting Amplifier Using the CMOS OA of Figure 1.
Adapted from [1].