LAB 2.4

Instrumentation Amplifier

(See Section 2.4.2, p. 76 of Sedra/Smith)

OBJECTIVES:

To study an instrumentation amplifier circuit by:

- Completing the analysis of the circuit and selecting resistors that satisfy design specifications.
- Simulating the circuit to compare the results with the paper analysis.
- Implementing the circuit in an experimental setting, taking measurements, and comparing its performance with theoretical and simulated results.

MATERIALS:

- Laboratory setup, including breadboard
- Three 741-type operational amplifiers
- Several wires and resistors of varying sizes

PART 1: DESIGN AND ANALYSIS

Consider the circuit shown in Figure L2.4:

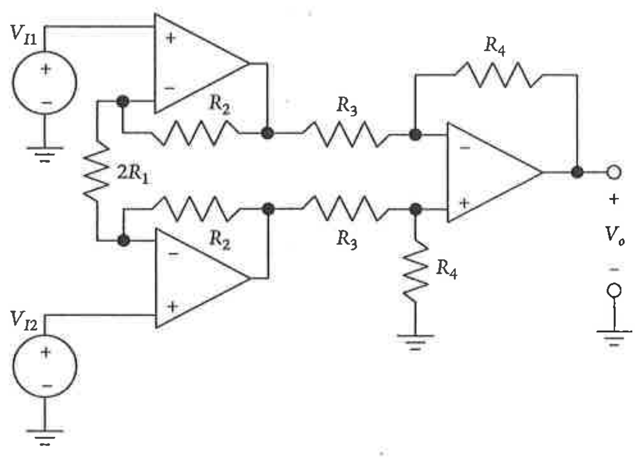

FIGURE L2.4: Instrumentation amplifier. Based on Fig. 2.20(c), p. 77 S&S.

Design the circuit in Figure L2.4 such that A_d = 110 V/V. Select resistor values such that the first stage provides a gain of 11 V/V (magnitude) and R_1 = 1 kΩ and the second stage provides a gain of –10 V/V. Use supplies of $V_+ = -V_- = 15$ V.

Hand calculations

- Sketch the circuit in your lab book, clearly labeling the op-amp terminals.
- What values of R_1, R_2, R_3, and R_4 do you need to use to meet the gain and input resistance specifications? Is the problem completely specified?

Simulation

- Use a 50-mV$_{pk-pk}$ 1-kHz input sine wave applied to v_{I1} and another 50-mV$_{pk-pk}$ 1-kHz input sine wave applied to v_{I2} that is 180° out of phase with V_{I1}. In your simulation, assume your input voltage sources have an output resistance of 50 Ω. What are V_{Id} and V_{Icm}? What are V_{Od} and V_{Ocm}?
- Plot the input and output waveforms for all simulations.
- For all simulations, report the DC voltage at the inverting terminal and output of each op-amp.
- What are the simulated values of differential and common-mode gain?

PART 2: PROTOTYPING AND MEASUREMENT

- Assemble the circuit onto a breadboard. Do not include the 50-Ω output resistance of your signal sources.
- While leaving v_{i2} grounded, provide a DC input to v_{I1} in increments of 0.01 V, from –0.1 V to +0.1 V. Record the values of v_O and plot your results.
- While leaving v_{i1} grounded, provide a DC input to v_{I2} in increments of 0.01 V, from –0.1 V to +0.1 V. Record the values of v_O and plot your results.
- Using a function generator, provide a 1-kHz 50-mV$_{pk-pk}$ sine wave to input v_{I1} and ground input v_{I2}. Using an oscilloscope, capture the output voltage waveform.
- Using a function generator, provide a 1-kHz 50-mV$_{pk-pk}$ sine wave to input v_{I2} and ground input v_{I1}. Using an oscilloscope, capture the output voltage waveform.
- Using a digital multimeter, measure all resistors to three significant digits.

PART 3: POST-MEASUREMENT EXERCISE

- Calculate the values of A_d and A_{cm} obtained in your measurement. What is the common-mode rejection ratio (CMRR) of the circuit? Express the CMRR in units of decibels. Explain any discrepancies between the experiments, simulations, and hand analysis.

- Recalculate the theoretical gains of the circuit, using the measured resistor values. Are the recalculated values closer to your measured gains?

PART 4 [OPTIONAL]: EXTRA EXPLORATION

- In your measurement setup, replace R_4 with a resistor that is 10% smaller in value and remeasure A_d and A_{cm}. How do their values change? What do you conclude?