Lab 7: Beyond the Instrumentation Amplifier

INTRODUCTION:

In Lab 6, a simple instrumentation amplifier was implemented and tested. This lab will expand upon the instrumentation amplifier by improving circuit performance and by building a LabVIEW user interface. The resulting circuit and user interface can be used to implement many different biomedical instruments and will likely be an important element in upcoming design projects.

This lab will be completed by design teams of 2 students (ideally, you will work with your design project team members, if they are in your lab section). Each team will work on a single circuit. The prelab tasks should be completed by individual students, but team members are encouraged to work together and share their ideas and results before attending their assigned lab session. That is, consider this lab as a means to start working together with your design project team.

REQUIRED PARTS AND MATERIALS:

Materials Needed

- Lab 7 Grading Sheet and your plans from Lab 7 Prelab.
- Instrumentation amplifier from Lab 6
- A single turn trimmer (tunable resistor)
- Computer with DAQ card and LabVIEW
- All the instruments on the lab bench
- Other resistors and capacitors as needed.
- ~~3 ECG electrodes wires and patches~~
- 1 OP467 quad opamp (one additional opamp per lab station)

Deliverables

- modified breadboard instrumentation amplifier
- basic LabVIEW interface to instrumentation amplifier
- real biosignal data acquisition

BACKGROUND:

Review this lab and the referenced tutorials and help files if you need any help with the LabVIEW portions of this assignment.

PRELAB:

1. Print the Prelab and Lab7 Grading Sheets. Answer all of the questions in the Prelab Grading Sheet and bring the Lab7 Grading Sheet with you when you come to lab. ***The Prelab Grading Sheet must be turned in to the TA before beginning your lab assignment.***
2. Read the LABORATORY PROCEDURE before coming to lab. Note: you are not required to print the lab procedure; you can view it on the PC at your lab bench.

LABORATORY PROCEDURE:

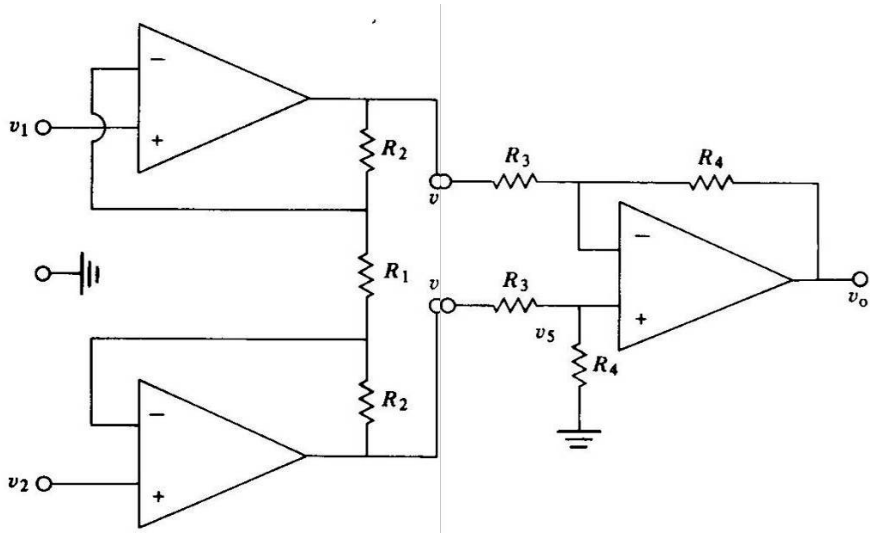
A. Preparation

1. Submit your prelab to the TA
2. Retrieve your instrumentation amplifier breadboards (Lab 6) from the lockers.

3. Complete any steps from Lab 6 that were not previously completed or were unclear. If you completed Lab 6, jump to the next step.

B. Circuit Improvements

1. The basic instrumentation amplifier schematic from Lab 6 is repeated below. Follow the steps below to modify your circuit where a variable resistor can be used to tune the DC offset voltage and the common mode gain.
    a. Use the multimeter to measure the resistance of the tunable resistor (hereafter called a *trimmer*) across different legs and at different points of the single-turn dial. *Be sure you know which turning direction increases and decreases the trimmers resistance value.* We will be replacing the **R4** resistor at the positive input of the second stage amplifier with this trimmer. Once you understand how the resistor works, set it to the value of **R4** it will be replacing and record this value on your Grading Sheet.
    b. On your circuit breadboard, remove the **R4** resistor between the positive opamp input and ***agnd***.
    c. Connect the trimmer to replace the **R4** resistor. You circuit should now work just as it did in Lab 6, but you have added the capability to turn common mode gain.
2. Repeating what you had done in Lab 6, verify your modified circuit works correctly. Connect ***v1*** to a DC reference voltage (agnd) and apply a sinusoidal signal with 100mVpp and 1KHz to ***v2***. Measure the output max and min voltages and estimate the gain and record these on your Grading Sheet. Compare it to results from Lab 6 and comment on differences. If the values are not close to the same, check for errors in your circuit and repeat until your values are correct.



Basic instrumentation amplifier configuration.

3. Demonstrate to the TA that you have the circuit working with the trimmer added. Ask the TA to check off on the Grading Sheet.

C. New Circuit Modification and Characterization with LabVIEW

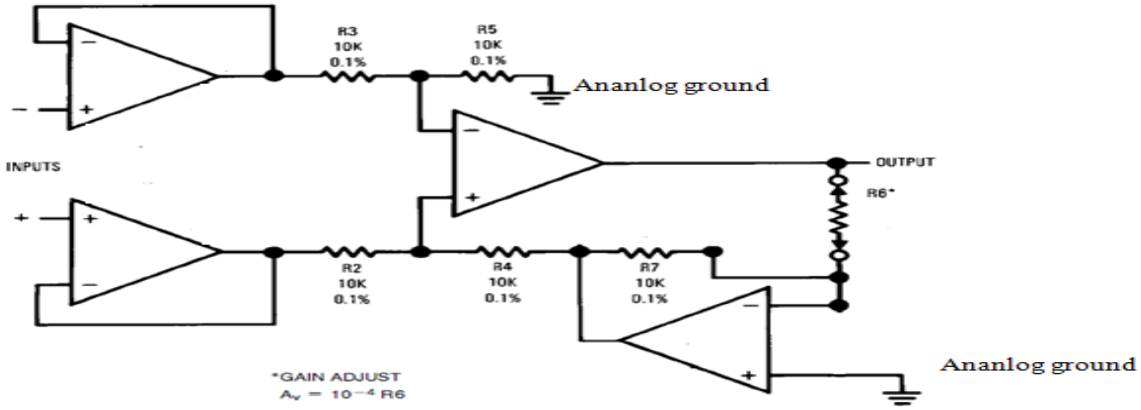
1. Build a LabVIEW interface to acquire signals from the amplifier that will measure the DC transfer function, differential gain, and common mode gain. If you need help with LabVIEW, go back to Lab 3 for reference. If you have any questions about how to measure these parameters, check back to Lab 6. Show the TA your LabVIEW interface before continuing.

2. Use your LabVIEW interface to test the characteristics of your circuit and record these values on the Grading Sheet.
3. To minimize the common mode gain, adjust the trimmer resistance and observe the output voltage. Find the trimmer position that minimized the common mode gain. Then power down your circuit, remove the trimmer, measure its resistance with a multimeter, and record this value on the Grading Sheet.
4. Show the TA your circuit and demonstrate some of its functions. Ask the TA to check off on this portion of your lab.

D. Variable Gain Instrumentation Amplifier

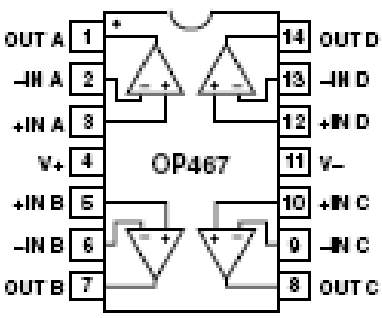
The instrumentation amplifier constructed in Lab 6 has a fixed gain. Sometimes a variable gain amplifier is required for biomedical signals with different amplitudes. The schematic below shows an instrument amplifier where the gain is linearly adjustable with a single resistor, R6. More specifically, the gain is equal to 10^{-4}×R6. Furthermore, because the opamp in the feedback loop always presents a very low impedance to the feedback resistor, this circuit also provides a constant and high common mode rejection ration, even as the gain is adjusted.

To gain additional experience with an alternative instrumentation amplifier design, you will be constructing the amplifier below. To do this, you will use an additional OP467 quad op amp. **Do not deconstruct your instrumentation amplifier from Lab 6**; you will need it again in Lab 8. Get a new OP467 from the TA to complete this exercise. Also, remember to always turn off the power supply when connecting modifying or adding components to your circuit board. Finally, please note that you will need to remove the new OP467 at the end of this exercise so it can be used by another lab section (unlike your Lab 6 amplifier which your team will keep all semester).



Variable Gain Instrumentation Amplifier Configuration

1. Obtain a new OP467 chip and wire it up to implement the variable gain instrumentation amplifier circuit shown above. The pin diagram for the chip is shown here for reference, and a wiring sketch pad (optional) is provided at the end of this document to assist in wiring the circuit.
2. In place of R6, the resistor that determines gain, insert the trimmer resistor. Remove the trimmer from your other circuit, but replace it when you are done for use in Lab 8.

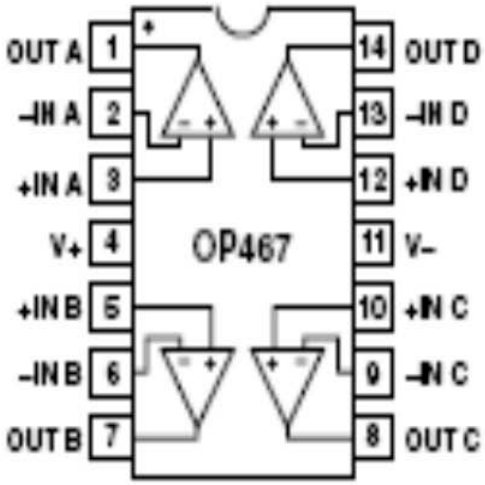


OP467 Pin Diagram

3. Set one power supply to 10V (+ terminal at 10V, - terminal is 0V ground reference). Connect the OP467 V+ to 10V and V- to 0V.
4. Set a second power supply to 5V. This will provide the analog ground. Connect the – terminal of both power supplies together to provide a common ground. Then connect the 5V supply to the analog ground nodes defined in the new circuit.
5. Connect negative input of the amplifier to analog ground. Connect positive input to a signal generator with a 100mVpp 1KHz sign wave. Remember to set the DC reference voltage of the signal generator to analog ground (5V).
6. With the power supplies and signal generator on, your new amplifier should be working. Use the oscilloscope to observe the input and output signals. If you do not see a proper amplifier output, debug your circuit setup (remember, there is a debugging guide in Lab 6).
7. Once everything is working, change the resistance of the trimmer and observe its affect on Vpp of the output. Record what you observe on the Grading Sheet.
8. Set the resistance of the trimmer so that the amplifier has maximum gain. Record the output Vpp. Next, adjust the input frequency to 10KHz, 100KHz, 1MHz and 10MHz consecutively and record Vpp for each input frequency. Use this data to sketch the frequency response on the Grading Sheet. Use a log scale for the X axis and normalize the Y axis to the output amplitude at 1KHz.
9. Adjust the frequency until the output amplitude is half the value recorded at 1KHz in Step 8. Record this frequency as the 3dB bandwidth of your amplifier.
10. Compare this frequency response with that obtained in Lab 6 for the basic instrumentation amplifier. Record a comment on the comparison.
11. Ask the TA to check off on the grading sheet.

E. Wrap Up

1. Once the TA has checked off your circuit, clean up your lab bench and put all wire trimmings in the trash. Store your breadboard in a locker for use in the next lab.
2. Turn off all instruments and power supplies.
3. Turn in your Grading Sheet to the TA, one for each team.


OUT A
1
–IN A
2
+IN A
3
V+
4
+IN B
5
–IN B
6
OUT B
7
14
OUT D
13
–IN D
12
+IN D
11
V–
10
+IN C
9
–IN C
8
OUT C
OP467