EN 580.471 Fall 2008

Principles of Design of Biomedical Instrumentation

Lab 2: Differential and Instrumentation Amplifiers - Biopotential Amplifiers

In order to study electrophysiology, we need to be able to record various biopotentials (i.e. ECG, EMG, EOG, EEG, etc.). The basic biopotential amplifier requires an appropriate amplitude amplification range, frequency range, and should include some type of noise reduction. The basic building blocks of biopotential amplifiers are differential and instrumentation amplifiers. In this lab, you will begin by designing and characterizing a single op-amp differential amplifier, and move on by adding a two op-amp input stage to complete a low-noise, high-gain instrumentation amplifier.

You will **save the final instrumentation amplifier** from today's lab session for the ECG and EMG amplifiers, so make sure to implement a clean and uncluttered circuit.

Lab Procedure

Part 1: Single Op-amp Differential Amplifier

1. Construct a differential amplifier according to the specifications listed below:
   a. Differential gain = 20
   b. Common mode gain as low as possible
   c. CMRR > 60 dB
2. Measure the differential and common mode gain of the circuit.

Part 2: Two Op-amp Input Stage

1. Build the 2-op-amp input stage of the instrumentation amplifier with an input stage gain of 50.

Part 3: Instrumentation Amplifier

1. Next, cascade the input stage from the second part with the differential amplifier from the first part.
2. Measure the differential and common mode gain of the circuit.
3. Give any input signal to the instrumentation amplifier and record the input/output waveforms.

Pre-lab (due at the beginning of the current lab) [20 points]

The pre-lab is intended to ensure that you understand the theory behind the circuits you will build, and thus maximize the time you have available for lab work. The pre-labs will be collected at the beginning of the lab session. So make sure you keep its copy with yourself, so that you can refer to it during the lab.

1. Briefly explain common mode gain, differential gain, and CMRR. Explain how you would measure each in an instrumentation amplifier. [6]

2. Provide schematic diagrams for (Use the resistor values that are available in the lab in planning your circuit):
   a. Single op-amp differential amplifier. Calculated your expected differential and common mode gain. [5]
      Hint: You will need a potentiometer in order to maximize CMRR. Think about which resistor to replace to get the best CMRR.
   b. Two op-amp input stage. Calculated your expected differential and common mode gain. [5]
   c. Indicate how the input stage should be connected to the differential amplifier. [2]
3. A 10mV differential sine wave signal is applied to the inputs of your instrumentation amplifier. There is a common offset of 5 V. Assuming your amplifier perfectly meets the specifications given for this lab, calculate the resulting output signal. [2]

<u>Lab Write-Up</u> (due at the beginning of the next lab) [40 points]

You must provide clear and concise answers to questions. No credit will be given for elaborate essays that are not on the topic. Show that you know and understand the major concepts taught in class and lab. **While you are allowed to consult with your lab partner, each student must turn in his/her own work and acknowledge any references and collaborators.**

1. Purpose: Briefly explain the purpose of the lab and your circuit. [2]
2. Design: Show complete circuit schematic of the final instrumentation amplifier with all components properly drawn and labeled. [10]
3. Results:
   a. Calculate the CMRR of the final instrumentation amplifier. [6]
   b. Compare the true CMRR of the instrumentation amplifier with the expected value. [2]
   c. Show the input/output waveforms you recorded during the lab. [2]
4. Explain the different roles of the single op-amp differential output stage and the two op-amp input stage of the instrumentation amplifier. [8]
5. Why is the instrumentation amplifier better than just a differential amplifier? What are the reasons for using instrumentation amplifiers in biopotential measurements? [6]
6. Suppose that we want to amplify a differential signal that varies between 0 and 10 mV, riding on 2 V of common mode noise. Noise must be kept to 0.01% of the desired output signal. Neglecting all other noise sources, what is the required CMRR?[4]

<u>References</u>

Webster, JG. Medical Instrumentation
Horowitz and Hill. The Art of Eletronics. 1989