Laboratory 1

Differential amplifiers; measuring the performance of a differential amplifier;
Two stage differential amplifier; AC coupled differential amplifier

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Scope of the lab:

- Introduce the fundamental properties of differential amplifiers
- Present the measurement of common mode gain; CMRR; CMR
- Illustrate the effect of DC bias on amplified signal
- Analyze the properties of a multi-stage instrumentation amplifier
- Become familiar with MacECE Biomed Lab platform.

Before the lab:

1. Review the schematics of a three OP-AMP differential amplifier. Review the computation of CMMR.
2. Download and read the documentation for the instrumentation amplifier LT1920 and for the operational amplifier TLC2274.
3. Review the passive filters theory; review the active filters theory.

Objectives during the lab:

A. Identify the different components of the MacECE Biomed Lab platform
   1. Identify the different modules on the board (instrumentation stage, HP filter stage, etc.)
   2. Identify the breadboard module
   3. Identify the isolation amplifier

B. Measure the amplifier gain and compare it with the theoretical one.
   1. Using a 5.5kΩ resistor, build the instrumentation amplifier on stage 1 of the board. This will amplify the input signal by a gain of 10 ($G_{Differential} = 10$).
   2. Connect the input of the instrumentation amplifier to the signal generator and the output to the oscilloscope. Use the settings presented in Figure 1.
   3. Compute the theoretical gain of the signal and verify that the signal displayed on the oscilloscope has the amplitude $G_{Differential} * V_{in}$.
   4. Without changing the instrument settings connect the circuit as in Figure 2.
   5. What is the amplitude of the signal now? What about its phase?
   6. Repeat the measurements for 100Hz, 1kHz, 10kHz, 100kHz, 500kHz, 600kHz, 700kHz.
   7. Plot the measured gain as a function of frequency.

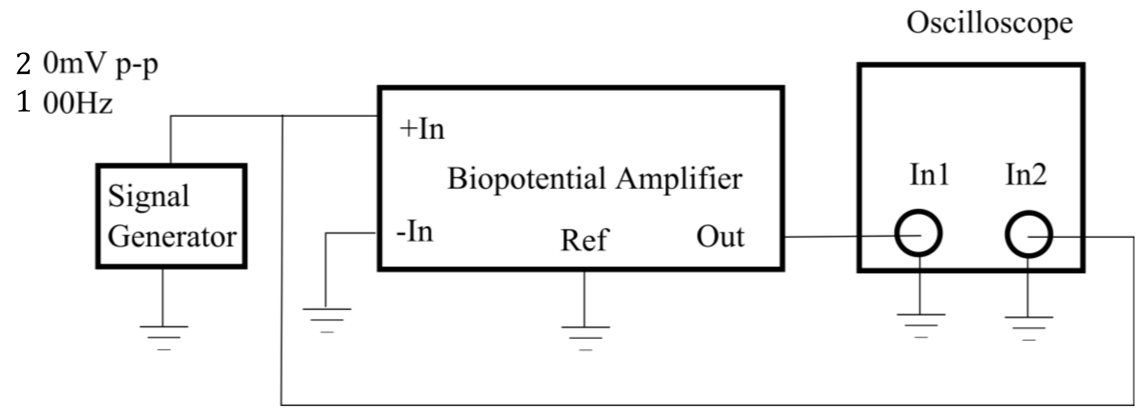

Figure 1: Schematic for measuring non-inverting gain.

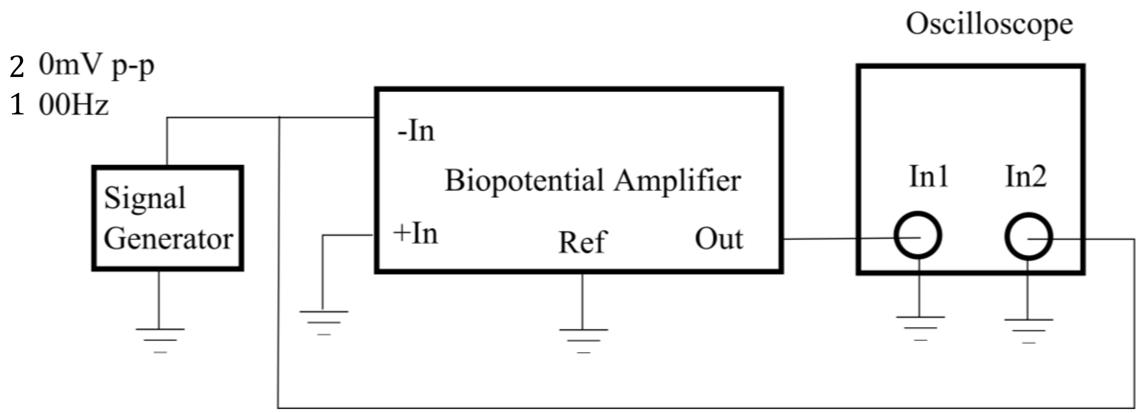

Figure 2: Schematic for measuring inverting gain.

C. Measure the CMRR
   1. Connect the equipment as shown in Figure 3.
   2. Set the input as shown in Figure 3. (100Hz, 3Vpp). This will be your common mode voltage.
   3. Measure the common mode output voltage and explain what is happening.
   4. Calculate the common mode gain: $G_{CM} = V_{out}$ CM / V_{in} CM.
   5. Calculate the common mode rejection ratio CMRR = $G_{Differential}$ / G_{CM} and C_{MR}(dB) = $20\log_{10}$(CMRR)
   6. Repeat the measurements for 100Hz, 1kHz, 10kHz, 100kHz, 500kHz, 600kHz, 700kHz.
   7. Plot the measured CMRR as a function of frequency.

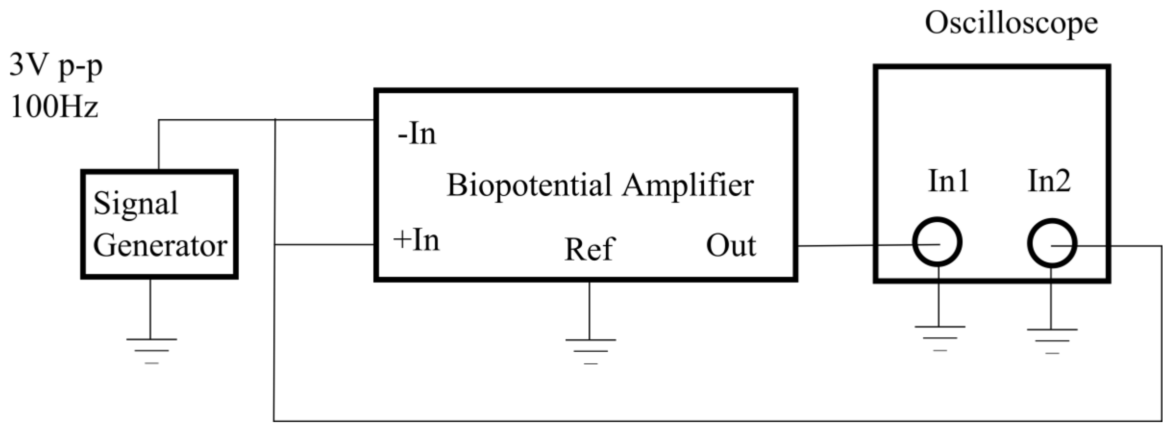

Figure 3: Schematic for measuring common mode gain

D. Add the second amplification stage
   1. Add a second amplification stage with a gain of 11 to the differential amplifier as shown in Figure 4. Use the TLC2274. What is the new gain of the circuit?
   2. Generate a sinusoidal signal with > 20mV p-p amplitude and 100Hz frequency. Use the non-inverting input (Figure 1) and verify the correct gain. What is happening to the signal?
   3. Repeat the measurements 100Hz, 1kHz, 10kHz, 100kHz, 500kHz, 600kHz, 700kHz.
   4. Plot the gain versus frequency. Explain what is happening and why.

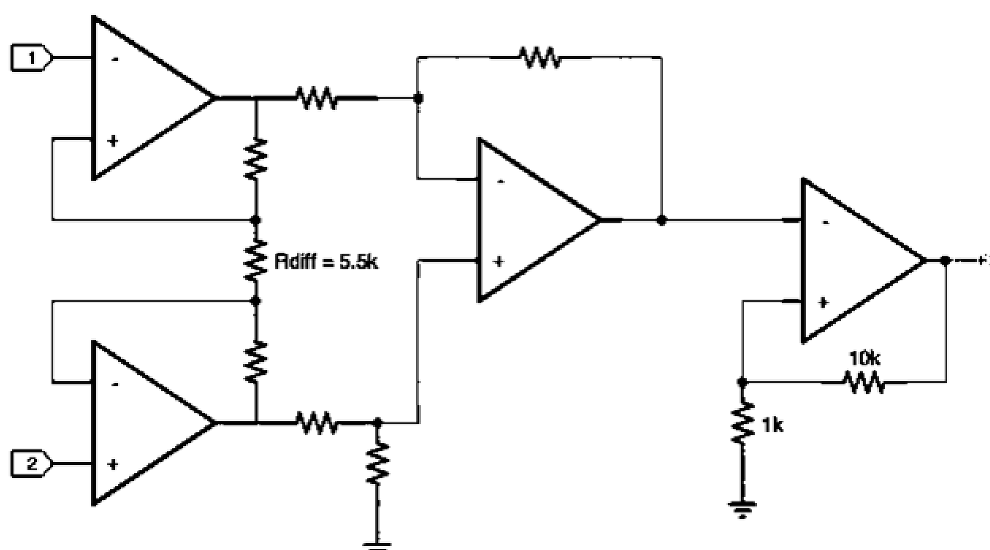

Figure 4: Instrumentation amplifier with second amplification stage.

E. Study the effect of a DC offset on the output.
   1. Set the signal generator to add an offset of 20mV to the sinusoidal signal.
   2. What does the output signal look like? Explain what is going on.
   3. DC offsets may be present in biomedical signals. What can you do to remove them?

F. Biomedical Amplifier with first-order HP and LP filters
1. Insert a passive HP and an active LP filter in the biomedical amplifier as shown in Figure 5. Calculate the component values so that you achieve a band-pass filter with cutoff-frequencies of 1.5Hz and 400Hz.
2. Generate a sinusoidal signal with 10mV p-p amplitude and 100Hz frequency and 20mV DC offset. Connect the biomedical amplifier to the signal generator and to the oscilloscope.
   - What does your output look like?
3. Verify that the high-pass filter effectively removes the DC component from the input signal.

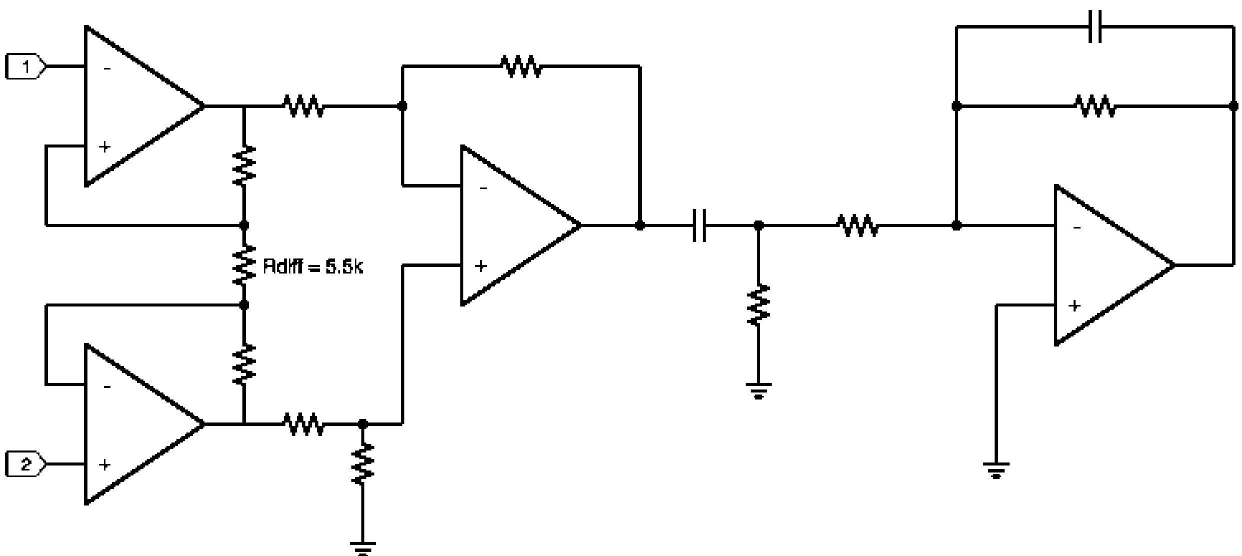

Figure 5: Instrumentation amplifier with HPF and LPF.

Lab Report
- Due <u>one week</u> after you do your lab.
- Prepare a formal lab report with the questions/calculations/plots required by questions:
  - **B3. B5. B7.**
  - **C3. C4. C5. C7.**
  - **D1. D2. D4.**
  - **E2. E3.**
  - **F1. F2.**

Always include your code in your lab report!