EN 580.471 Fall 2007

Principles of Design of Biomedical Instrumentation

Lab 3: Electrocardiogram (ECG) & Electromyogram (EMG) Amplifiers

In this lab, you will construct an ECG and an EMG amplifier.

The ECG amplifier should be followed by a simple QRS detection circuit that will blink an LED when the QRS complex occurs. The EMG amplifier should have an output that can be used to drive an LED, which will light when the muscle is flexed and will stay on for the duration of the flexion.

We need to keep in mind three important and basic functions of any biopotential amplifier: patient protection, signal amplification, and signal filtering.

Lab Procedure

Part 1: ECG Amplifier

[ECG is an electrical signal with typical amplitude of 500 μV and a frequency range of 0.01 to 250 Hz. Thus the desired output from our ECG amplifier is a 5V maximum amplitude signal, with a frequency range of 0.5 to 100 Hz. Therefore, our amplifier will have a gain of 1000, and the filter will have a passband of 0.5 to 100 Hz.]

1. Change the specifications of the active bandpass filter to the following:
   a. Unity gain in passband
   b. Passband: 0.5 to 100 Hz

   Report the experimental values for the gain and corner frequencies of the filter.
2. Change the specifications of the instrumentation amplifier to the following:
   a. Differential gain = 1000
   b. Common mode gain as low as possible
   c. CMRR > 60 dB

   Report the observed CMRR and differential gain.
3. Cascade the filter with the instrumentation amplifier.
4. Build the patient protection circuit and connect it to your amplifier.
5. Ask your TA for the electrodes. It is important to establish a good electrical contact between the electrode and skin. Place one electrode near each shoulder and a reference ground (third electrode) on the ankle of the right leg.
6. You will be using BioBench to record your ECG. Connect the output of your amplifier to the DAQ card inputs. Hook up the electrodes to your circuit and record your ECG with the lead wires twisted and another with the wires untwisted. Show the results to your TA.
7. Construct a simple QRS detection circuit that will blink an LED when the QRS complex occurs. Connect it to the amplifier and show its correct operation to your TA.

Part 2: EMG Amplifier

1. Construct and characterize your EMG amplifier.
2. Take at least two recordings from your EMG amplifier and show them to your TA (try lifting different weights and see the differences in signal).
3. Construct the circuit to drive an LED, which will light when the muscle is flexed and will stay on for the duration of the flexion.
4. Sample the output during flexion and extension and show the results to your TA.

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. Provide schematic diagrams for (Use the resistor and capacitor values that are available in the lab in planning your circuit):
   a. Patient protection circuit using diodes at the input. [2]
   b. Complete ECG amplifier. [4]
   c. Simple QRS detection circuit that will blink an LED when the QRS complex occurs. [2]
   d. Complete EMG amplifier. [4]
   e. Circuit to drive an LED, which will light when the muscle is flexed and will stay on for the duration of the flexion. [2]
   Hint: The LED driver circuit in its simplest form will probably involve an integrator and an active half-wave rectifier.
2. Sketch a simple waveform of the ECG. [2]
3. Sketch a simple waveform of the EMG. How would the EMG differ for a person lifting a 1-lb weight versus a 10-lb weight? [2+2]

Lab Write-Up (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. Design: Show complete circuit schematic of the
   a. ECG amplifier (including the patient protection circuit and QRS detection circuit) with all components properly drawn and labeled. [10]
   b. EMG amplifier (including the patient protection circuit and LED driver circuit) with all components properly drawn and labeled. [10]
2. Results:
   a. Attach two recordings of your ECG (one with the lead wires twisted and another with the wires untwisted). What is the difference between the two? Calculate your heart rate from your twisted-wire recording. [6]
   b. Attach 2 recordings of your EMG, flexed and relaxed. [2]

3. Find the State-of-the-art ECG and EMG amplifiers (cite references if necessary) and write down their characteristics. What are the most important specifications for these amplifiers? [12]

Study Question (due with Lab Write-Up) [20]

One day, you try to go back from the Hospital Food court to Traylor Building where your lab is. You get lost and suddenly you find yourself in the Epilepsy Research Center. You see a patient that has a bunch of wires coming out of his head and connected to a 64 channel EEG recording system on the wall. What is the first thing that comes to your mind? How can you get rid of the wires? What advances have been made in this field and what is the focus in this research area now (Since we are in the Instrumentation class, we are just thinking of new devices and technologies). Suppose you are a junior faculty and had a meeting with Dr. Greg Bergey, head of this center, for an interdisciplinary research grant. (Dr. Bergey is a well-known physician and is used to giving a lot of advice.) What do you think Dr. Bergey's advice was on what the goal of this grant should be?

References

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