CARLETON UNIVERSITY
Department of Systems and Computer Engineering

SYSC 3203
Project Title: EMG-Controlled Mouse
Laboratory: Milestone #2: Instrumentation Amplifier

Milestone #2 consists in designing an instrumentation amplifier for measuring the electromyography (EMG) signal from the forearm muscles. Figure 1 represents the circuit schematic for lab #2. The circuit uses two integrated circuits: an AD620A instrumentation amplifier and an OP97 operational amplifier. The output of the instrumentation amplifier is an amplified version of the differential +/- INPUT EMG signal. The common-mode drive (CM_DRV) output generates a signal through the body that minimizes the common-mode present at the inputs of the instrumentation amplifier.

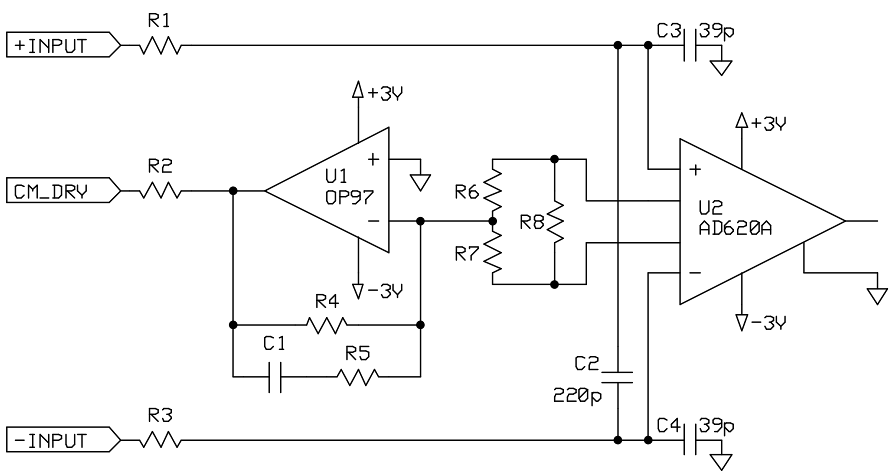

Figure 1: Circuit schematic for lab #2.

1. Patient safety

All circuits for this lab will be mounted on a breadboard and powered by two sets of AA batteries. One battery set will provide +3V while the other will provide -3V. The common terminal of the two AA battery sets will be considered the ground. Especially during *in vivo* measurement, there should be no electrical connections to anything but the human subject forearm. Be aware that connecting any instrument like an oscilloscope or a multimeter that is not battery operated will break the isolation barrier and may therefore compromise the safety of the human subject connected to the circuit.

Resistors R1, R2 and R3 further improve the safety of the circuit by ensuring any applied current cannot exceed 50 µA whether the circuit is operating properly or not. The worst case scenario would be that the instrumentation amplifier and/or the operational amplifier are defective or there is a short-circuit somewhere that makes full power being applied to the patient. Given the fact that the circuits are powered by ±3V, what should be a minimum value for R1, R2, and R3 to ensure safe operation? Explain your calculations for R1, R2 and R3 and what happens if the resistor values are set too high to the instructor and have him/her sign the instructor verification sheet.

2. Common-mode driver

The common-mode driver is implemented using the OP97 operational amplifier, capacitor C1, and resistors R4 through R7. This inverting amplifier circuit measures the common-mode voltage present at the differential inputs of the instrumentation amplifier and applies an amplified and inverted signal to the human subject in order to automatically reduce the common-mode voltage. The specification for this inverting amplifier is to have a DC gain of -91 and a cut-off frequency of around 160 Hz. Calculate values for R4, R5, R6, R7, and C1 to achieve this specification. Have your component values verified by the instructor and have him/her sign the instructor verification sheet. Note that R8 will have no effect on the gain of this circuit, so you do not need to select its value yet. On the other hand, R6 and R7 will have an effect on the choice of R8, in the next section.

Verify the frequency response (DC gain and cut-off frequency) of the common-mode driver using a function generator and an oscilloscope. Show proper operation of the common-mode driver to the instructor and have him/her sign the instructor verification sheet. Why do we have to limit the frequency response of the common mode driver to lower frequencies? To help answer, you can experiment by looking at the frequency response while component R5 and C1 are removed to see what happens at higher frequencies. Validate your answer with the instructor and have him/her sign the instructor verification sheet.

3. Instrumentation amplifier

The instrumentation amplifier is realized with an AD620A whose gain is programmable via a resistor. We want this instrumentation amplifier to have a gain of 10. In the specification of the AD620A, the resistance between pins 1 and 8 is RG. In our circuit, RG is the parallel combination of R8 and (R6+R7). You have already selected a value for R6 and R7. Calculate value for R8 to achieve this specification. Have your R8 value verified by the instructor and have him/her sign the instructor verification sheet. Verify the frequency response (gain and cut-off frequency) for this instrumentation amplifier using a function generator and an oscilloscope. Vary the gain value up to 100 and verify the effect on the frequency response. Show the instructor the proper operation of the instrumentation amplifier circuit and, specifically, that the gain is +10. Have him/her sign the instructor verification sheet.

4. Capacitors C2, C3 and C4

In figure 1, capacitors C2, C3 and C4 are respectively set at 220 pF, 39 pF and 39 pF. What are these capacitors useful for? What kind of filter is produced by these components? What is the cut-off frequency? (This is designed to achieve filter out signal pickup at radio frequency because the leads to the patient can act like an antenna. For this lab, you can probably get away without them, but good biomedical amplifier design would use them)

5. EMG signal

Once the circuit in figure 1 is fully assembled, the next step is to connect the circuit to a human subject to see the EMG signal. Since the goal for the whole project, is to operate the left-mouse button by closing the left hand, you will have to figure where to place the electrodes. Try to figure which muscle is activated when you close your left hand by looking at your forearm and/or some forearm anatomy pictures from a book or the internet. The +INPUT and –INPUT electrodes should be put in the vicinity of this muscle to produce maximum EMG signal. The CM_DRV electrode can be simply put close to the other two electrodes. Show the instructor where you plan to put the electrodes and have him/her sign the instructor verification sheet. The instructor will then give you some electrodes to proceed with your first EMG measurement. Connect the electrodes on the forearm electrode sites you identified and a scope at the output of the instrumentation amplifier. In order to safely use an oscilloscope, it must have sufficient resistance in the connection to the subject, so that any fault to the line voltage will not result in unsafe currents. For the probes we use in the lab, two adjustments are required: 1) set the scope into 10x mode (which provides a series input resistance of 10MΩ), and 2) place a 1MΩ resistor in series with the ground connector (alligator clip); electrical tape should be used to ensure no inadvertent connections to the unprotected connector.

Look at the EMG signal while you are closing your hand. You should clearly see bursts whenever you close your hand. Show your EMG signal to the instructor and have him/her sign the instructor verification sheet. Do you notice any other component on the output signal (DC, 60 Hz, etc.). Explain where these components come from? Propose some ideas that could be implanted to remove them. Validate your answers with the instructor and have him/her sign the instructor verification sheet.

Laboratory: Milestone #2
SYSC 3203
Fall 2016
Instructor Verification Sheet

Submit this page to the lab instructor.

Name: ______________________________________ Student ID:___________________________

Name: ______________________________________ Student ID:___________________________

1.1: Explain your calculations for R1, R2 and R3 and what happens if the resistor values are set too high:

Verified: ____________________________________ Date/Time:__________________________

2.1: Have your component values (R4, R5, R6, R7 and C1) verified for the common-mode driver:

Verified: ____________________________________ Date/Time:__________________________

2.2: Show proper operation of the common-mode driver:

Verified: ____________________________________ Date/Time:__________________________

2.3: Why do we have to limit the frequency response of the common mode driver to lower frequencies?

Verified: ____________________________________ Date/Time:__________________________

3.1: Have your R8 value verified:

Verified: ____________________________________ Date/Time:__________________________

3.2: Show the instructor the proper operation of the instrumentation amplifier circuit:

Verified: ____________________________________ Date/Time:__________________________

4.1: What are C2, C3 and C4 capacitors useful for? What filter is produced?

Verified: ____________________________________ Date/Time:__________________________

5.1: Show the instructor where you plan to put the electrodes:

Verified: ____________________________________ Date/Time:__________________________

5.2: Show your EMG signal:

Verified: ____________________________________ Date/Time:__________________________

5.3: Explain where these components come from:

Verified: ____________________________________ Date/Time:__________________________