Université d'Ottawa
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School of Information Technology and Engineering

ELG4139
Electronics III

MIDTERM EXAMINATION

Length of Examination: 80 minutes **October 22, 2015**

Professor: Riadh Habash

Family Name: ____

Other Names: ____

Student Number: ___________

Signature ___________________________

Closed book.

If you do not understand a question, clearly state an assumption and proceed.

At the end of the exam, when time is up:
- Stop working and turn your exam upside down.
- Remain silent.
- Do not move or speak until all exams have been picked up, and a TA or the Professor gives the go-ahead to leave.

Question 1 (8 marks): Brief Design of an Artificial Leg

Suppose you plan to design an artificial arm or leg that could be controlled by the thought of the wearer. Myogenic control is the mechanism to realize. Myogenic mechanisms originate in the muscle of blood vessels, especially in small arteries and arterioles. When the lumen of a blood vessel is suddenly expanded, as occurs when intravascular pressure is suddenly increased, the smooth muscles respond by contracting. Conversely, a reduction in intravascular pressure results in smooth muscle relaxation and vasodilation.

When a muscle is caused to move or twitch, the tiny movement of electrolytes in the muscles below the skin cause an electric field that induces a small voltage on the surface of the skin. This voltage is quite small; otherwise we would shock each other every time we shocked. It ranges from microvolts to millivolts and may be mixed with other biopotential signals. The objective is to sense and isolate these small voltages and convert them into signals capable of switching something like an electric motor that could be attached to a prosthetic device. Here is the problem! How can we design a data acquisition system that uses the surface skin potential from a muscle as an input using 4 sensors to control 4 actuators such as electric motors? Outline the approach in the following block diagram:

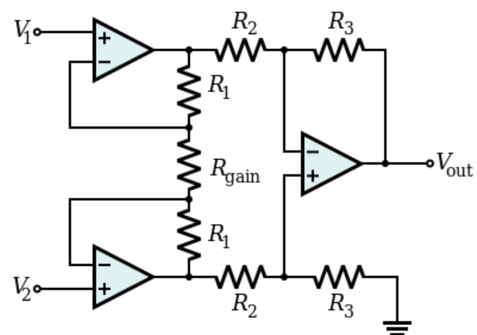
1. Draw the system block diagram

In order to sense the voltage at the skin we need a sensor that convert below the skin electrolyte ion currents to very small electron current and voltage in the electronic system. Also, a considerable amount of 60 Hz background noise and other signals can obscure the signal associated with the muscle. In addition, the above device requires high input impedance.

2. The sensor is specified of having a 120 ms time constant. Estimate the required cut off frequency.

This is system application that requires an instrumentation amplifier to provide the high input impedance, high common mode rejection ratio, and gain necessary to extract the biopotential signal produced by the contracting muscle.

3. Assume the sensor maximum output voltage = 10 mV but a maximum of 2 V is allowed by the ADC. Design an instrumentation amplifier with the required gain using $R_2 = R_{gain} = 10\ k\Omega$. Meaning find the values of R_1 and R_3.



The above device was chosen because it can extract a very small signal difference and attenuates noise resulting from electromagnetic interference. However, something called a motion artifact can still occur due to relative motion between electrodes and the tissue. The frequencies of the motion artifact are usually at the low end of the electromagnetic spectrum. Accordingly a filter (specify) is needed.

4. Determine the order N of the Butterworth filter for which A_{max} = 1 dB, $A_{min} \geq$ 20 dB, selectivity ratio =1.3, and Q = 13. Draw the circuit diagram of the filter and find the values of the components.

To process 4 signals we require an analog multiplexer

5. Draw a block diagram for the required multiplexer/demultiplexer.

Now the analog signal is needed to be converted to a digital by designing a Flash analog to digital converter (DAC) with an accuracy of 1%. The DAC requires a sample and hold circuit.

6. Design a sample and hold circuit that uses a FET ON resistance of 20 Ω and requirement for charging up to 95% of the input value in 1 µs. Draw the circuit and find the value of the capacitance.

7. Design an appropriate Flash ADC

Following the microcontroller you require a digital to analog converter (DAC). The output signals are to drive actuators with a maximum operating bandwidth of 10 Hz, but which are affected by higher-frequency signals. The actuators require signals to an accuracy of at least 5 %. In this regards, you require a DAC, demultiplexer, and reconstruction filters.

8. Design an *R-2R* ladder DAC. Find the output voltage of the DAC when the digital input is 100. Use V_{ref} = 10 V and *R* = 2 kΩ.