University of Calgary
Schulich School of Engineering
Department of Electrical and Computer Engineering

ENEL 563 Biomedical Signal Analysis
Professor Rangaraj M. Rangayyan
Final Examination

EEEL 345, Saturday, 18 April 2015
3:30 p.m. – 6:30 p.m. (180 minutes)
Total Marks: 50

Instructions:

1. This is a closed-book, closed-notes exam.
2. Calculators and electronic devices of any kind are NOT permitted in the exam.
3. Answer all (six) questions.
4. For questions requiring mathematical derivation, show all steps clearly.
5. For questions requiring algorithms, provide the reason or logic for each step.
6. Specify units or dimensions when appropriate.
7. When drawing plots of signals, spectra, etc., label the axes clearly.

Question 1:

(a) Write an equation to define the autocorrelation function of two discrete-time signals, $x(n)$ and $y(n)$, $n = 0, 1, 2, \ldots, N-1$.

(b) Write an equation to define the discrete Fourier transform of the signal $x(n)$ as in part (a).

(c) Apply the discrete Fourier transform to the autocorrelation function as in part (a) and derive the final result in the Fourier domain. Show all steps and explain the result.

(7 marks)

Question 2:

(a) Give an equation to define the mean frequency of a power spectral density function. Explain the role of each item of your equation.

(b) Give a step-by-step algorithm to compute the mean frequency of the power spectral density of a discrete-time signal, $x(n)$, $n = 0, 1, 2, \ldots, N-1$, using the the discrete (or fast) Fourier transform. Explain the relationship between the discrete frequency index and the true frequency in Hz. Explain how you obtain the mean frequency in Hz.

(6 marks)

Question 3:

(a) Write an equation to define the output of a discrete-time linear time-invariant system with the impulse response $h(n)$, $n = 0, 1, 2, \ldots, M-1$, when the input is $x(n)$, $n = 0, 1, 2, \ldots, N-1$, with $M << N$. Specify the duration or length of the output signal.

(b) Explain how the input–output relationship in part (a) may be expressed using vectors or matrices. Show all steps. Explain how the approaches in parts (a) and (b) lead to the same result.

(7 marks)

Question 4: You are given a discrete-time signal $x(n)$, $n = 0, 1, 2, \ldots, N-1$. Write mathematical expressions to define or compute the following measures:

(a) The mean value.

(b) The root-mean-squared value.

(c) The standard deviation.

(d) The form factor.

(7 marks)

Question 5:

(a) Define the impulse response $h(t)$ of a matched filter to detect a signal of interest $x(t)$ in an arbitrary input signal. Explain the relationships between the two signals. (You do not have to derive the impulse response; just state the definition and explain what it means.)

(b) Showing all steps, derive an expression for the output of the matched filter when the input is $x_2(t) = a\,x(t - t_a) + b\,x(t - t_b)$. Explain how this output may be used to detect occurrences of the signal of interest.

(7 marks)

Question 6: A researcher attempts to record the knee-joint vibroarthrographic (VAG) signal during swinging movement of the leg, but observes that the vibromyographic (VMG) signal from the thigh muscle is contaminating the VAG signal as an artifact. Advise the researcher on how the VMG artifact may be suppressed using an adaptive noise cancellation (ANC) filter.

(a) Draw a schematic block diagram of a suitable ANC filter. Explain how and from where each input to the ANC filter is to be obtained.

(b) State all assumptions made and conditions to be satisfied for the ANC filter to function as desired (that is, to provide the VAG signal in the output).

(c) Explain how the assumptions and conditions stated in part (b) are satisfied (or not) in the present application.

(d) Write mathematical expressions to give the relationships between the signals at every point in the ANC filter.

(e) Explain how minimizing the average power of the output causes the output to be an estimate of the desired signal.

(16 marks)

******