UNIVERSITY OF CALGARY

DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

BIOMEDICAL SIGNAL ANALYSIS

ENEL 563

FINAL EXAMINATION

Tuesday, December 13th, 2005
8:00 A.M. – 11:00 A.M.
ENA 123
3 hours

Total: 50 Marks

NOTE:

1. *This is a closed-book exam.*
2. *Calculators with text/program storage capabilities are not allowed.*
3. *Answer all questions.*
4. *In case of problems requiring numerical or algebraic manipulation, show all steps clearly.*
   In case of problems requiring descriptive answers, provide clear statements in point form; long essays are not required.
   In case of problems requiring algorithms, provide the reason/logic for each step.
5. *Specify units or dimensions when appropriate.*
6. *In drawing plots of signals, spectra, etc. label the axes clearly.*

Marks (6)

3 1. (a) Draw the waveforms of the phonocardiogram (PCG) and electrocardiogram (ECG), over one cardiac cycle, as expected in the case of a patient with aortic stenosis.

3 (b) Label and indicate the normal and abnormal parts of the signals. Explain the main features expected in the abnormal part(s) of the signal(s).

Marks (8)

2. For a given signal x(t), a researcher obtains the following function:

$$y(\tau) = \int_{t=-\infty}^{\infty} x(t)\, x(t+\tau)\, dt$$

3 (a) Explain the nature of the operation performed above. In particular, explain the relationship between x and y, and that between t and τ.

5 (b) Apply the continuous-time Fourier transform to $y(\tau)$, and, showing all steps, derive and explain the relationship between the Fourier transforms of x and y.

Marks (6)

3. A signal processing system is defined as the combination of the following three operations in series (cascade):

   A. The first derivative (difference) given as
   $y_1(n) = x(n) - x(n-1)$.

   B. The squaring operation as
   $y_2(n)=[y_1(n)]^2$.

   C. A low-pass filter defined as
   $y_3(n)= \frac{1}{2} [y_2(n) + y_2(n-1)]$.

3 (a) Using the test signal x(n) = { 0,0,1,1,1,1,0,0 } as the input, compute the signals $y_1(n)$, $y_2(n)$, and $y_3(n)$.

Plot the four signals mentioned above and interpret the results.

3 (b) By mistake, a researcher places the squaring operation first (followed by the derivative and low-pass filters). Using the same test signal x(n) given in part (a) above, compute the outputs of each operation in the modified system.

Plot the four signals and explain the difference between the results in part (a) and part (b).

Marks (8)

4. The frequency response of the Wiener filter is given as

$$W(\omega) = \frac{S_d(\omega)}{S_d(\omega) + S_\eta(\omega)} .$$

Consider the following conditions:

i. The bandwidth of operation is 0 – 200 Hz.

ii. The power spectral density (PSD) of the desired signal $S_d(\omega)$ is a rectangular function with the value 4.0 over the range 0 – 100 Hz and zero outside this range.

iii. The PSD of the noise $S_\eta(\omega)$ is uniform over the range 0 – 200 Hz with the value 1.0.

4 (a) Plot the frequency response of the Wiener filter and explain its operation at frequencies where the signal is stronger or weaker than the noise.

4 (b) Modify the noise PSD above to include the additional presence of power-line interference with the value of 2.0 over the range 59 – 61 Hz. Derive and plot the frequency response of the Wiener filter. Explain the difference with respect to the filter in part (a) above.

Marks (10)

5. A biomedical engineer working in a neurophysiology laboratory is frustrated by the appearance of the electrocardiogram (ECG) as an artifact in the electroencephalogram (EEG) of a patient. You are hired to help the engineer.

2 (a) Compare the typical amplitude ranges and frequency bandwidths of the of the two signals.

2 (b) Would you recommend the use of a fixed lowpass, highpass, or bandpass filter to remove the artifact? If yes, give the essential characteristics of the filter that you recommend. If not, explain your reasons.

6 (c) The engineer has heard about adaptive filters (adaptive noise cancellers). Draw a schematic (block) diagram of an adaptive noise canceller. In the context of the problem mentioned above, explain what the primary input should be; how and from where on the patient you would obtain an appropriate reference input; and how the various inputs and outputs of the system relate to one another.

Explain the basic assumptions made in the design and application of the filter.

Note: You DO NOT have to derive any equation in your answer to this problem.

Marks (12)

6. A researcher has obtained a system to record the electromyogram (EMG) signal from a muscle that is directly involved in breathing (respiration). Help the researcher in understanding the nature of the signal and developing a signal processing system to analyze the signal as follows:

1 (a) Draw a schematic representation of the EMG over two cycles of respiration, showing the ranges of inspiration and expiration.

3 (b) Propose an algorithm to obtain the envelope of the EMG signal. Describe the nature and purpose of each step in your algorithm. Give an equation for each step, and plot the result of the operation on the EMG signal.

3 (c) Propose a method to obtain a measure of activity (to indicate how 'busy' the signal is) as a function of time, in order to characterize the variation in the signal with breathing. Give an equation and describe the nature of the method. Plot the result of the operation on the EMG signal.

2 (d) The peak values in the envelope and activity functions over a given cycle of respiration are expected to be correlated with the peak air flow to the lungs. Propose algorithms to detect the peak envelope and peak activity values.

3 (e) For each procedure that you propose in items (b), (c), and (d) above, discuss potential artifacts that could mislead your procedure and indicate how you would prevent them.

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