# Question Paper

Exam Date & Time: 06-May-2024 (02:30 PM - 05:30 PM)

## MANIPAL ACADEMY OF HIGHER EDUCATION

VI SEMESTER B.TECH. (BME) DEGREE END SEMESTER EXAMINATIONS MAY 2024

**ELECTIVE-ADVANCED BIOMEDICAL SIGNAL PROCESSING [BME 4055]**

**Marks: 50** **Duration: 180 mins.**

**Descriptive Questions**

**Answer all the questions.** Section Duration: 180 mins

1) Consider three motor units with action potentials (SMUAPs) that are of different biphasic and triphasic shapes. Consider the initial stages of contraction of the related muscle. (3)

A) Estimate three plots of the net EMG of the three motor units for increasing levels of contraction with the spatial and temporal recruitment phenomena invoked individually and in combination. Assume low levels of contraction, and that the SMUAPs do not overlap.

B) The signal $x_1(t)$ (a pulse of duration 0.1s) shown in Figure 1b below is input to a linear time-invariant system and the signal y1(t) is observed at the output. If the signal $x_2(t)$ (a sequence of 4 pulses 0.5 apart) is input, determine the output with neat diagram. (2)

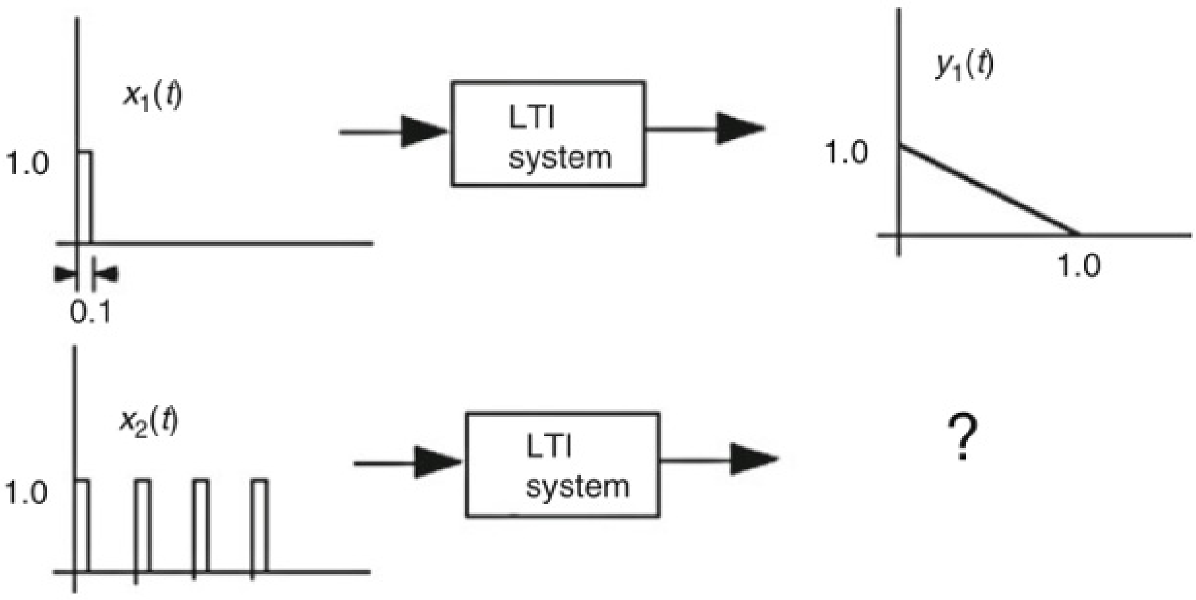


Figure 1b

C) Explain length transformation technique to detect the T wave in the ECG signal, given that it typically occurs after the QRS wave. (5)

2) Design a frequency-domain filter to remove periodic artifacts in ECG, such as power-line interference. (4)

A) Determine the transfer function and pole-zero response of the filter. (Plot the magnitude response of the filter.)

B) With a block diagram, represent various steps in the Pan-Tompkins method to detect QRS complexes in ECG signals. Explain the purpose and nature of each step in the procedure, including detection of the peaks in the output corresponding to the QRS complexes. (No equations are required in your answer) (4)

C) Consider a signal contaminated with noise so that the recorded signal $y(t) = x(t) + w(t)$ where $x(t)$ is the pure signal and $w(t)$ is the pure noise. The power spectra of the signal and noise are known a priori as shown in Figure 2c: (2)

Determine the optimal filter for extracting the signal from the noise.

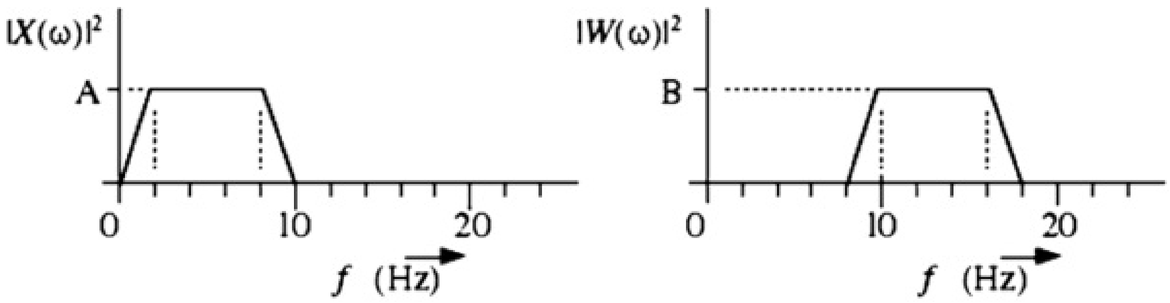


Figure 1c

3)

A) Distinguish between ensemble averaging and temporal (time) averaging procedures to process 11 cycles of noisy ECG signal (Fs = 1000Hz). Identify applications of first-order averages of both types in ECG analysis with a detailed example and plot the results. (Note: Assume the first cardiac cycle as template for alignment. Show the subplots of noisy and denoised ECG in the results). (5)

B) Consider the difference equation: (3)

$$y(n) = y(n-1) + \frac{1}{8}x(n) - \frac{1}{8}x(n-8).$$

i. Determine the transfer function of the system and obtain the frequency response of the filter

ii. Identify the filter for the given difference equation.

Describe the type of artefact or frequency content the given filter would cancel out.

C) For a given nonstationary signal, explain the disadvantages of applying Fourier transform to it. Identify a transform to overcome such limitation. (Write the detailed expression of the transform.) (2)

4)

A) In recording the EEG in a clinical laboratory, some channels were found to contain the ECG as an artifact. Will simple lowpass or bandpass filtering help in removing the artifact? Why (not)? Design a filter to remove the artifact (Design the filter with detailed expressions). (4)

B) Design time domain filters to remove the following physiological artefacts encountered in an ECG signal. Specify the type of filter to be designed. (3)

i. Baseline drift

ii. Powerline interference

(Note: Determine the transfer functions and frequency response of the filters in each case.)

(Hint: Limit the impulse response of filters to three sample points in your design.)

C) Consider the following signal: $y(t) = p(t)x(t)$ (3)

Design a homomorphic filter to separate the combined signals in $y(t)$. (Note: Explain the procedure in each step illustrated with a detailed block diagram)

5) Construct a suitable model of a system when the input to the system is unknown but the measured EEG signal is known. Determine the signal flow diagram and transfer function of the system? (4)

A)

B) Design a mathematical model to represent the firing pattern of the SA node in a normal cardiac rhythm (Note: consider 10 cardiac cycles and sketch the results). (3)

C) Consider a continuous-time sinusoidal signal of frequency 10 Hz. (3)

a. Analyze the autocorrelation function (ACF) for the given signal with expression and a schematic plot of the ACF, including detailed labeling of the time axis.

b. Write an analytical expression for the Power spectral density (PSD) of the given signal and draw a schematic plot of the PSD, including detailed labeling of the frequency axis.

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