Cairo University **May 2001**
Faculty of Engineering **Time: 2 Hours**
Biomedical Engineering Department **OPEN BOOK**

BIOMEDICAL DIGITAL SIGNAL PROCESSING FINAL EXAM

Question Group 1: (Maximum number of points= 40)

1. [10 Points] One method for ECG arrhythmia detection relies on modeling segments of the ECG signal and comparing model parameters to the known model parameters of normal and abnormal ECG conditions. Given that the normal ECG signal has a frequency range between 0.1-100 Hz, design a digital signal processing unit that can be used to filter and provide model parameters for the ECG signal within a time window of 3 seconds of signal length. Assume the sampling rate of the original signal to be 250Hz. Assume any missing information.

2. [10 Points] In Doppler ultrasound, a 3.5 MHz carrier frequency is transmitted and gets shifted by the different velocity components within the blood vessels to create a new signal of bandwidth 1K around that center frequency. It is required to start from the analog signal of the returned Doppler signal and design the sampling and digital signal processing required to obtain the spectrogram of the returned signal. Assume any missing information.

3. [10 Points] In ultrasound imaging, image formation is done in the digital domain in most high-end systems. The sampling rate of such systems is 20MHz. It is required to design two types of filters based on FIR and IIR topologies to do this task. Assume that your signal has a 3dB bandwidth of 2 MHz centered at 5 MHz. Compare the two techniques and provide your own preference for this application. Assume any missing information.

4. [10 Points] In PET imaging, it is required to obtain the delay between two signals in order to determine the location of the signal source within the body. Starting from two signals sampled at 10 MHz, design a digital signal processing system that can be used to initially remove noise from both signals and then to detect the delay between the two signals to the highest possible accuracy. Assume any missing information.

5. [4 Points] Design a step by step procedure to design a high-pass filter of cut-off $\omega=0.2\,\pi$ using the bilinear transformation from an analog filter. In particular, provide the analog specifications for the analog filter design step and the transformations used to obtain the desired filter.

6. [4 Points] To design an FIR low-pass filter of cut-off frequency 10Hz (given the sampling frequency of 40Hz), it is desired to have a 4 point filter which satisfy the following constraints: a) H(0 Hz)=1, H(8 Hz)=1, H(10 Hz)=1, H(12 Hz)=0. Select a method to solve this problem and write down the equations to be solved to calculate the filter coefficients.

7. [4 Points] In calculating the averaged periodogram estimate of the N-point power spectrum of a signal, describe in brief the implementation and the required original signal length.

Question Group 2: (Maximum number of points = 20)

8. [5 Points] For each of the following systems, determine whether or not the system is: (1) Linear, (2) shift invariant, and (3) stable.

(a) $y(n) = T[x(n)] = \sum_{k=n-3}^{k=n+3} k \cdot x(k)$

(b) $y(n) = T[x(n)] = \max_{n+1>k>n-1} \{x(k)\}$

(c) $y(n) = T[x(n)] = 2x(n-1) + 3x(n-2)$

(d) $y(n) = T[x(n)] = 10(x(n)+1)$

(e) $y(n) = T[x(n)] = \sum_{k=-\infty}^{\infty} g(k) \cdot x(n)$

9. [3 Points] Consider a discrete-time LTI filter with impulse response h(n). If the input x(n) is a periodic sequence with period N, would the output y(n) be also periodic? If yes, determine the period.

10. [3 Points] Let *h(n)* denote the impulse response of a 1-D low-pass filter. Show that the filter *g(n)* defined as: $g(n) = (-1)^n \cdot h(n)$ represents a high-pass filter.

11. [4 Points] Consider the linear system described by the following equation:

$$y(n) = x(n) - y(n-1) - 0.5y(n-2)$$

Derive the linear system transfer function. Derive the coefficients of an inverse filter that would enable the estimation of *x(n)* given *y(n).* Comment on the stability characteristics of this filter.
(*Hint*: Look at the problem as a difference equation and use the relationship between the z-transform and the Fourier transform)

12. [4 Points] Consider the two sequences: [0,0,0,1,2,3], [0,0,1,0,1]. Obtain the results of linear and circular convolutions of these sequences.

13. [6 Points] Obtain the inverse z-transformation for the following:

One) $H(z) = 1 + z^{-1} + 0.5z^{-2}$

Two) $H(z) = 1/(1 + 0.2z^{-1})$, $|z| > 1$

Three) $H(z) = (1 - 0.1z^{-1})/(1 - 0.2z^{-1} + z^{-2})$, $|z| > 1$

BEST OF LUCK