UNIVERSITY OF GHANA

BACHELOR OF SCIENCE IN ENGINEERING
SECOND SEMESTER EXAMINATIONS: 2016/2017

CPEN 304: DIGITAL SIGNAL PROCESSING (3 Credits)

INSTRUCTION: *Answer any five (5) Questions of your choice.*

TIME ALLOWED: *THREE (3) HOURS*

1. **(a)** With the support of simple diagrams, briefly explain the difference between analog signal processing and digital signal processing. [8 marks]
(b) Give four reasons why you will prefer digital signal processing systems over analog signal processing systems. [4 marks]
(c) Briefly describe how you will use the digital signal processing system in an audio studio to process speech signals for recording. You may use an architectural diagram to support your answer. [4 marks]
(d) The resolution of a heart-monitoring device in a hospital is 0.25Hz. To monitor a patient, a doctor needs to capture at least 90 harmonics. The heart rate to be measured is between 60 and 200 beats per second. Find the sampling rate required for the monitoring and the number of points to be captured. [4 marks]

2. **(a)** Explain the difference between a continuous time system and a discrete time system. Support your answer with simple diagrams. [4 marks]
(b) Explain the following terms: *linear system*, *time invariant system*, *linear time invariant system*, *causal system*, and *stable system*. [5 marks]
(c) An audio signal $x(t)$ defined below is passed through a system for processing.
$x(t) = 6\cos(120\pi t) + 2\cos(680\pi t) + 4\cos(1000\pi t)$.
(i) Find the distinct frequency components in the signal and the rate at which the signal should be sampled for it to be fully recovered. [3 marks]
(ii) Find the discrete version of the audio signal (in a reduced form) and the angular

 EXAMINER: DR. G. A. MILLS

frequency if a sampling rate of 400 Hz is used for the sampling. [5 marks]

(iii) Find the output reconstructed signal $y(t) = y[n] = x[tF_s]$. Is the output y(t) the same as the input signal x(t)?. Explain your answer. [3 marks]

3. (a) A linear time invariant (LTI) system relating an input to the output of a system is defined by the linear difference equation below.

$$y[n] = 0.9x[n-1] + 0.3x[n] + 0.24x[n-1]$$

(i) Write an expression for the convolution sum relating the output response to the input and find the impulse response $h[n]$ of the system. [5 marks]

(ii) If the input of the system is $x[n] = \{3, 5, 2, 7\}$, write an expression for the input sequence in terms of the unit impulse function. Find the output response $y[n]$ of the system for the given input $x[n] = \{3, 5, 2, 7\}$ [4 marks]

(b) The input and output of a certain discrete time system are related by the linear constant coefficient difference equation defined by the expression below:

$$y[n] - 5y[n-1] + 6y[n - 2] = x[n] + 3x[n-1] + 5x[n-2]$$

(i) Sketch the system implementation structure using direct form 1. [1 mark]

(ii) Find the transfer function of the system and plot the zero-pole map. Will you expect this system to be stable? Explain your answer. [5 marks]

(iii) Find the impulse response $h[n]$ of the system. [5 marks]

4. (a) Explain the difference between a finite impulse response (FIR) and infinite impulse response (IIR) filter. Give one example of each filter type and sketch its implementation diagram. [6 marks]

(b) Give two reasons why you will prefer FIR digital filter over IIR filter and state two limitations of the FIR filter. [4 marks]

(c) Write an expression for the moving average filter of length M. Find the frequency response of this filter for the case when M = 2. Sketch the frequency response and indicate the type of filter characteristics the response represents. Find the phase delay and the group delay of the system. [6 marks]

(d) Design a first order highpass IIR digital filter to meet a specification of a 3-dB cutoff frequency ω_c of 0.6π. [4 marks]

5. (a) Outline the steps you will follow to design an FIR digital filter. [5 marks]

(b) Briefly describe three design methods that could be used to design linear phase FIR digital filter. [3 marks]

(c) As a computer engineer working with the Tema Oil Refinery (TOR), you need to design and implement a linear phase lowpass FIR digital filter to remove interference noise on the controller system digitally at the plant. Your filter is required to meet the following specifications: passband and stopband frequencies of 2.5 kHz and 3.5 kHz, respectively, passband and stopband attenuation values of 0.1 dB and 50 dB, and sampling rate of 20 kHz. Show all the steps you will follow to design the FIR digital filter. Use the properties of the fixed window function provided in Table 1 below for your design. [12 marks]

6. **(a)** Outline the steps you will follow to design an IIR digital filter. [5 marks]

(b) Compute the DFT of a discrete time sequence that is defined as: $x[n] = 1$ for $0 \leq n \leq 5$, and $x[n] = 0$, otherwise. [4 marks]

(c) Suppose instead of an FIR digital filter design as in **Q 5 (c)** above, you opted for the design of IIR digital filter. Assume the given filter specifications resulted in the following analog filter expression:

$$H(s) = 12 / [(s + 12)(s + 5)].$$

Explain how you will use the Bilinear transform method and the Step Invariant method to design the IIR digital filter $H(z)$. Show all steps in the design. [6 marks]

(d) Design a first order active lowpass filter circuit with a cutoff frequency of 2 kHz and a gain of 5 for deployment in a digital stethoscope. Sketch the circuit diagram and show all calculations for your design. [5 marks]

Table 1 - Window selection table

No	**Window**	**Side lobe (dB)**	**Upper boundary ($\Delta\omega$)**	**Exact ($\Delta\omega$)**	$\delta_P \approx \delta_S$	**A_P (dB)**	**A_S (dB)**
	Rectangular	-13	$4\pi/L$	$1.8\pi/M$	0.09	0.75	51
	Barlett	-25	$8\pi/L$	$6.1\pi/M$	0.05	0.45	26
	Hanning	-31	$8\pi/L$	$6.2\pi/M$	0.0063	0.055	44
	Hamming	-41	$8\pi/L$	$6.6\pi/M$	0.0022	0.019	53
	Blackman	-57	$12\pi/L$	$11\pi/M$	0.0002	0.0017	74

 EXAMINER: DR. G. A. MILLS

Useful Formulae

1. $(1-\delta_p) = \dfrac{1}{\sqrt{1+\varepsilon^2}}$

2. $H_{LP}(z) = \dfrac{(1-\alpha)}{2}\dfrac{[1+z^{-1}]}{[1-\alpha z^{-1}]}$

3. $\cos\omega_c = \dfrac{2\alpha}{1+\alpha^2}$

4. $\omega_a = \tan(\omega_D/2)$

5. $N \geq \dfrac{1}{2}\dfrac{\log_{10}\left[(10^{0.1\alpha_s}-1)/(10^{0.1\alpha_p}-1)\right]}{\log_{10}(\omega_s/\omega_p)}$

6. $N \geq \dfrac{1}{2}\dfrac{\log_{10}[(A^2-1)/\varepsilon^2]}{\log_{10}(\omega_s/\omega_p)}$

7. $|H(\omega)|^2 = \dfrac{1}{[1+(\omega/\omega_C)^{2N}]} = \dfrac{1}{1+\varepsilon^2} = \dfrac{1}{A^2}$

8. $H(s) = \dfrac{\omega_c^N}{s^N + \sum_{k=0}^{N-1} d_k s^k}$