UNIVERSITY OF GHANA

BACHELOR OF SCIENCE IN ENGINEERING
SECOND SEMESTER EXAMINATIONS: 2015/2016

DEPARTMENT OF COMPUTER ENGINEERING
CPEN 304: DIGITAL SIGNAL PROCESSING (3 Credits)

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

TIME ALLOWED: *THREE (3) HOURS*

1. **(a)** Explain the difference between the conventional signal processing system and the digital signal processing system. Give two (2) advantages and disadvantages of each of the signal processing systems. [6 marks]

   (b) With the support of a block diagram, explain how signals from a pressure sensor could be processed digitally for display. [6 marks]

   (c) If the signal $x(t)$ from the pressure sensor in 1 (b) above is described by the expression below,:

   $x(t) = 3cos(60\pi t) + 3sin(300\pi t) + 2cos(340\pi t) + 4cos(500\pi t) + 10sin(660\pi t)$.

   Find the equivalent discrete signal (in a reduced form) and the angular frequency if the signal is sampled at 200 Hz. Do you think the signal can be reconstructed from its discrete version y(n). Justify your answer. [8 marks]

2. **(a)** State two (2) reasons why FIR filters are most often preferred over their IIR counterpart in certain applications. Give one (1) example of each filter type and sketch the corresponding filter block diagram. [8 marks]

   (b) The impulse response of a filter at the VRA plant for processing temperature is given by the expression: $h[n] = \delta[n] - \delta[n-1]$. Find the output y[n] of this filter if it is presented with an input signal: $x[n] = 0.5\delta[n] + 0.5\delta[n-1] + 0.5\delta[n-2]$. *Hint*: $y[n] = h[n]*x[n]$. [4 marks]

   (c) Suppose the filter system in 2 (b) is an active highpass first order RC filter.

Sketch the circuit diagram and derive an expression for the transfer function of the filter system. If the cutoff frequency is 250 Hz and C is 30nF, design the filter circuit to meet gain specification of 200. [8 marks]

3. (a) Write an expression for the moving average filter of length M and find the frequency response of this filter for the case when M = 2. Sketch the frequency response and indicate the type of filter response this represents. [8 marks]

(b) Design a first order highpass IIR digital filter with a 3-dB cut-off frequency of 0.4π for the processing of voice signals. [6 marks]

(c) Show that the 3-dB cut-off frequency ω_c of the first order lowpass IIR digital filter $H_{LP}(z)$ that is defined below is $cos(\omega_c) = 2\alpha/(1+\alpha^2)$. [6 marks]

$H_{LP}(z) = 0.5*[1 - \alpha]*(1 + z^{-1})/(1 - \alpha z^{-1})$

4. (a) The input $x[n]$ and output $y[n]$ of an LTI filter system are related by the linear difference equation: $2y[n] + 3y[n-1] + y[n-2] = 3x[n-1] + 2x[n]$.

Sketch the filter structure and find the zero-pole diagram and the impulse response $h[n]$ of the filter. [13 marks]

(b) Derive an expression for the z-transform and show its relationship with the discrete Fourier transform. [3 marks]

(c) An ideal lowpass filter with frequency response $H(e^{j\omega})$ is defined by :

$$H_{LP}(e^{j\omega}) = \begin{cases} 1, & 0 \leq |\omega| \leq \omega_c \\ 0, & \omega_c \leq |\omega| \leq \pi . \end{cases}$$

Sketch the frequency response and find the inverse DTFT, h[n]. [4 marks]

5. (a) Briefly explain three (3) design methods that could be used to design FIR digital filters. [6 marks]

(b) Outline the steps you will follow to design an FIR digital filter using a window function. [3 marks]

(c) Design a linear phase lowpass FIR digital filter using the concept of window functions to meet the following specifications: passband frequency of 1.8 kHz, stopband frequency of 2 kHz, sampling frequency of 12 kHz, peak passband ripple and stopband attenuation values of 0.012 and 0.018 respectively. Show all steps in your calculation. Use the window properties given in table 1 below for your work to determine the choice of window and the filter length. [11 marks]

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

(b) Design a lowpass IIR digital filter with flat magnitude characteristics to meet the following filter specifications: passband edge frequency of 800 Hz, stopband frequency of 1000 Hz, sampling rate of 4 kHz, peak passband ripple of 0.5dB, and minimum stopband attenuation of 40dB. Show all the steps required to obtain the IIR digital filter. Use the bilinear transformation method with coefficient of unity for the filter design. Assume that the analog filter transfer function $H_a(s)$ from your specification is given by the expression below: [12 marks]

$$H_a(s) = \frac{(s+2)}{(s+3)(2s+5)}$$

(c) Is your filter order in 6 (b) the same as the order obtained using the Kaiser approximation method is used? [4 marks]

Table 1

Type of Window	Mainlobe width	Mainlobe/ sidelobe	Minimum stopband attenuation
Rectangular	4π/M	-13dB	-20.9 dB
Hanning	8π/M	-32dB	-43.9 dB
Hamming	8π/M	-43dB	-54.5 dB
Blackman	12π/M	-58dB	-75.3 dB

Useful Formulae

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

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

3. $\alpha = (1-\sin\omega_c)/\cos\omega_c$

4. $\omega_c = \cos^{-1}(\beta)$

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

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

7. $N \geq \dfrac{1}{2}\dfrac{\log_{10}\left(\dfrac{A^2-1}{\varepsilon^2}\right)}{\log_{10}\left(\dfrac{\omega_S}{\omega_P}\right)}$

8. $N = \dfrac{-20\log_{10}(\delta_P\delta_S)^{1/2}-13}{14.6(\omega_S-\omega_P)/2\pi}$

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

10. $H(s) = \dfrac{\omega_C^N}{\prod_{k=0}^{N-1}(s-s_k)}$

11.

$$Hanning: w[n] = 0.5 + 0.5\cos\left(2\pi\frac{n}{2M+1}\right), \quad -M \leq n \leq M$$

$$Ham\min g: w[n] = 0.54 + 0.46\cos\left(2\pi\frac{n}{2M+1}\right), \quad -M \leq n \leq M$$

$$Blackman: w[n] = 0.42 + 0.5\cos\left(2\pi\frac{n}{2M+1}\right) + 0.08\cos\left(4\pi\frac{n}{2M+1}\right) \quad -M \leq n \leq M$$