MACHAKOS UNIVERSITY

University Examinations for 2020/2021

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

FIFTH YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONICS ENGINEERING)

EEE 558: DIGITAL SIGNAL PROCESSING

DATE: 12/8/2021 **TIME: 8:30 – 10:30 AM**

INSTRUCTIONS:

This paper consists of **FIVE** questions. Answer Question **ON**E and any other **TWO** questions

QUESTION ONE (COMPULSORY) (30 MARKS)

a) Distinguish between FIR and IIR filters (2 marks)

b) Find the inverse Z-transform of

$$H(z) = \frac{3z}{z^2 + z + 1}$$

(3 marks)

c) A discrete system is described by the difference equation $y[n] = 3x[n] + 1$. Determine whether the system is

i. linear
ii. time-invariant

(6 marks)

d) Explain the application of DFT on OFDM in Wireless communications

(3 marks)

e) Given a sequence $x[n]$ where $x(0) = 1, x(1) = 1, x(2) = 3, x(3) = 2$. Evaluate its 4-point DFT X(k).

(4 marks)

f) A discrete-time processing operation is defined by the recurrence equation

$$\mathrm{y[n] = x[n] + 2x[n-1] + 3x[n-3]}$$

Determine the unit sample response $h[n]$ of the processor

(3 marks)

g) Given a second order transfer function

$$H(z) = \frac{0.6(1 - z^{-2})}{1 + 1.3z^{-1} + 0.36z^{-1}}$$

Perform the filter realization and write the difference equations using the following realizations:

i. Direct I form

ii. Direct II form

(5 marks)

h) A signal in a vector space is given by $x = \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}$. For this signal obtain **and** explain the physical significance of the:

i. 2-norm

ii. ∞-norm

(4 marks)

QUESTION TWO (20 Marks)

a) An analog filter transfer function is given by $H_a(s)$, using the impulse-invariant method, obtain the digital filter equivalent

$$H_a(s) = \frac{(s+2)}{(s+1)(s+3)}$$

(7 marks)

b) The transfer function of an LTI system is

$$H(z) = \frac{z}{(z - 0.75)(z + 0.5)}$$

i. For each possible region of convergence, find the corresponding impulse response of the system

ii. State the ROC where the system is causal and the ROC for which it is stable

(7 marks)

c) For the function $H(z) = \frac{1}{2} + \frac{1}{4}z^{-1} + \frac{1}{4}z^{-2} + \frac{1}{2}z^{-3}$, draw and label each of the following realizations:

i.Direct form realization

ii.Cascade realization

(6 marks)

QUESTION THREE (20 MARKS)

a) Distinguish between decimation-in-time and decimation in frequency as used in FFT

(2 marks)

b) i) Write down the equations for the decimation-in-time algorithm for N=4 and derive the corresponding signal-flow graph

(ii) Using the signal flow graph in (b)(i) determine the DFT of the sequence $x(n) = \{ \underbrace{1}_{\uparrow}, 2,2,1\}$

(10 marks)

c) By means 4- point DFT and IDFT, determine the response of the FIR filter with impulse response

$$h(n) = \{\underbrace{1}_{\uparrow}, 1, 1,1\}$$

to the input sequence

$$x(n) = \{ \underbrace{1}_{\uparrow}, 2,1,1\}$$

(8 marks)

QUESTION FOUR (20 MARKS)

a) Explain the importance of block convolution

(2 marks)

b) Given that $h(n) = \{1,1,1\}$ and $h(n) = \{3, -1 , 0 , 1, 3, 2, 0, 1, 2,1 \}$, convolve the two sequences by using the following block convolution methods

i. Overlap and add;
ii. Overlap and save;

(10 marks)

c) The desired frequency response of a low pass filter is given by

$$H_d\left(e^{-j\omega}\right) = \begin{cases} e^{-j\omega\tau} & |\omega| \le \omega_c \le \pi \\ 0 & otherwise \end{cases}$$

i. Determine the filter coefficients $h_d(n)$
ii. Determine the new filter coefficients $h_n = \omega_H(n)(h_d(n)$ where $\omega(n)$ is the Hamming window defined by

$$\omega_H(n) = 0.54 - 0.46cos\left(\frac{2\pi n}{N-1}\right) \quad 0 \le n \le N-1$$

(Take $N = 7, \tau = 3\ \omega_c = 1\ rad/s$)

(8 marks)

QUESTION FIVE (20 MARKS)

a) Show that in the Bilinear transformation the complex frequency variable s is given by

$$s = \frac{2}{T}\frac{1 - z^{-1}}{1 + z^{-1}}$$

(7 marks)

b) Explain the need of pre-warping in bilinear transformation of digital design (5 marks)

c) It is required to design a low pass digital filter with a 3-dB cut off frequency of 2kHz and minimum attenuation of 30dB at 4.25 khz for a sampling rate of 10kHz

i. Obtain the pre-warped frequencies
ii. Determine the order of the filter and hence write down the transfer function

iii. Obtain the digital equivalent by use bilinear transformation

(8 marks)