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Q2	
Q3	
Q4	
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UNIVERSITI TENAGA NASIONAL

The Energy University

COLLEGE OF ENGINEERING
PUTRAJAYA CAMPUS
TEST 2
SEMESTER 1, 2021/2022

PROGRAMME	: Bachelor of Electrical & Electronics Engineering (Honours) / Bachelor of Electrical Power Engineering (Honours)
SUBJECT CODE	: EEEB363/EEEB3024
SUBJECT	: Digital Signal Processing
DATE	: 29^{th} December 2021
DURATION	: 2.5 hours

INSTRUCTIONS TO CANDIDATES:

1. This paper contains **FOUR (4)** questions.
2. **Answer all questions.**

DO NOT OPEN THE QUESTION PAPER UNTIL YOU ARE TOLD TO DO SO

THIS QUESTION PAPER CONSISTS OF FIVE (5) PRINTED PAGES INCLUDING THIS COVER PAGE

QUESTION 1 [20 MARKS]

(a) A causal finite impulse response filter is given as $h_1[n] = \{ 1, 2, 2, 1 \}; 0 \leq n \leq 3$.

(i) Write $h_1[n]$ as a function of delayed unit impulses, $\delta[n]$. Then determine its z-transform, $H_1(z)$.

[3 marks]

(ii) Sketch the poles of $H_1(z)$ on a z-plane.

[3 marks]

(iii) Describe the stability and causality of the finite impulse response filter above based on its region of convergence (ROC).

[2 marks]

(b) A digital filter transfer function is given by

$$H_2(z) = \frac{z^2 + z - 2}{z^2 + 0.9z + 0.18}$$

(i) Sketch the poles of $H_2(z)$ on another z-plane.

[3 marks]

(ii) Determine the various possible ROC for $H_2(z)$.

[3 marks]

(c) A digital filter transfer function is given by

$$H_3(z) = \frac{1}{1 - 0.6\, e^{-j\frac{\pi}{2}}\, z^{-1}} + \frac{1}{1 - 0.6\, e^{j\frac{\pi}{2}}\, z^{-1}}$$

(i) Sketch the poles of $H_3(z)$ on another z-plane.

[3 marks]

(ii) If the system $H_3(z)$ is stable and causal, determine the impulse response $h_3[n]$.

[3 marks]

QUESTION 2 [30 MARKS]

(a) A linear time-invariant (LTI) discrete-time system is described in **Figure 1**.

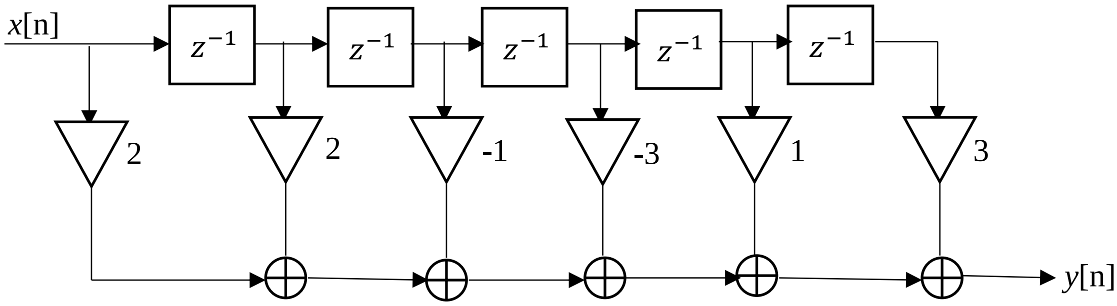

Figure 1: Linear Time Invariant (LTI) discrete-time system

(i) Analyze the block diagram in **Figure 1** and develop the relation between output, $y[n]$ and input, $x[n]$.

[3 marks]

(ii) Determine the impulse response, $h[n]$, of above LTI discrete-time system.

[5 marks]

(iii) Determine **AND** explain the linearity and causality condition of $h[n]$.

[4 marks]

(iv) Determine the group delay value of $h[n]$.

[3 marks]

(b) A typical transmission channel is characterized by a causal transfer function, $H(z)$.

$$H(z) = \frac{(0.5z - 2)(4z + 12)(2z - 3)}{(z - 0.1)(z + 0.3)(z + 0.2)}$$

(i) Determine all poles **AND** zeros value of $H(z)$.

[3 marks]

(ii) Classify $H(z)$ as a minimum, maximum or mixed phase system. In your own words, discuss on the choice of phase class.

[4 marks]

(iii) Represent $H(z)$ as a minimum phase function, $H_{min}(z)$ in cascade with all pass phase function, $H_{ap}(z)$.

[8 marks]

<u>QUESTION 3 [25 MARKS]</u>

Consider the cascade of two causal first order and second order linear time-invariant (LTI) discrete time system shown in **Figure 2**.

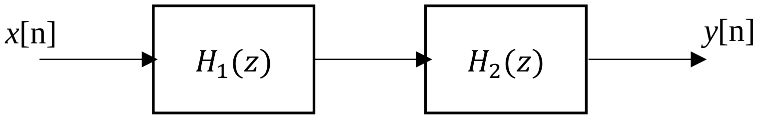

Figure 2: First order and second order LTI-DT system

where,

$$H_1(z) = \frac{2 - 0.2z^{-1}}{1 + 0.1z^{-1}} \;\; and \; H_2(z) = \frac{(1 + 2z^{-1})(1 + z^{-1})}{(1 + 0.3z^{-1})(1 - 0.1z^{-1})}$$

(a) Determine the transfer function of the overall cascade system, $H(z) = H_1(z) \times H_2(z)$.

[3 marks]

(b) Develop the realization of the overall system, $H(z)$ in Direct Form I **AND** Direct Form II.

[12 marks]

(c) In your own words, describe the differences between Direct Form I and Direct Form II.

[4 marks]

(d) Develop the cascade form realization of $H(z)$ with the least number of coefficients in the structure.

[6 marks]

QUESTION 4 [25 MARKS]

(a) When selecting digital filters for an application, compare between finite impulse response (FIR) and infinite impulse response (IIR) filters as below:

(i) Discuss the differences between FIR and IIR based on their phase response and the number of coefficients.

[2 marks]

(ii) What needs to be done in the design steps to narrow the transition bandwidth in FIR and IIR filters respectively? Please explain.

[2 marks]

(b) Somebody hacked your Discord server and now all voice chats have some audio noise at a specific frequency. You recorded the noise and managed to identify the noise frequencies by analyzing its frequency spectrum. Following your findings, a digital filter is proposed to attenuate the noise, with a sampling frequency of 2000Hz and the following specifications:

$$0.90 \leq \left|H\left(e^{j\omega}\right)\right|^2 \leq 1.00\ ;\ |f| \leq 600Hz$$

$$\left|H\left(e^{j\omega}\right)\right|^2 \leq 0.10\ ;\ |f| \geq 800Hz$$

(i) According to the specifications mentioned above, sketch the expected graph / tolerance diagram of its squared magnitude response $|H(e^{j\omega})|^2$ versus normalized angular frequency ω. Carefully label the gains, passband edge frequency, stopband edge frequency, passband and stopband frequency ranges.

[6 marks]

(ii) Design a Butterworth infinite impulse response (IIR) filter using the above specifications.

[15 marks]