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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   : 29th 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 $h_1[n] = \{ 1, 5, 5, 1 \}; 0 \leq n \leq 3$.

    (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

$$H_2(z) = \frac{z^2 + 2z - 3}{z^2 + 0.7z + 0.12}$$

    (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

$$H_3(z) = \frac{1}{1 - 0.7\, e^{-j\frac{\pi}{2}}\, z^{-1}} + \frac{1}{1 - 0.7\, e^{j\frac{\pi}{2}}\, z^{-1}}$$

    (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**.
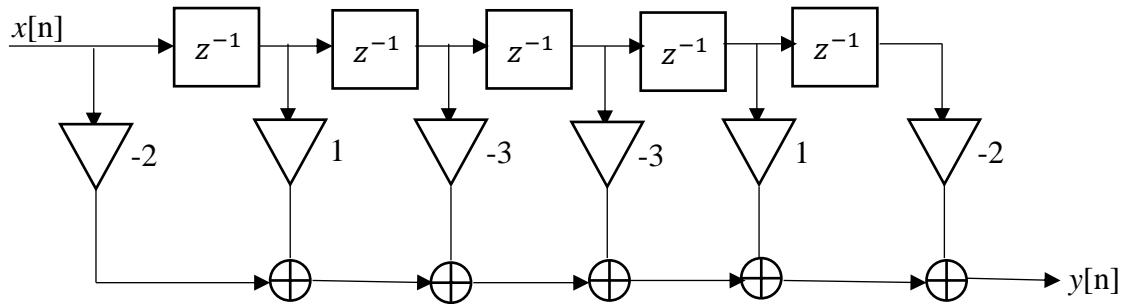

Figure 1: Linear Time Invariant (LTI) discrete-time system

(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, $H(z)$.

$$H(z) = \frac{(0.5z - 2)(4z + 2)(5z + 4)}{(z - 0.1)(z - 0.2)(z + 0.3)}$$

(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 linear phase function, $H_{lin}(z)$.

[8 marks]

QUESTION 3 [25 MARKS]

Consider the cascade of two causal first order and second order linear time-invariant (LTI) discrete time system shown in **Figure 2**.
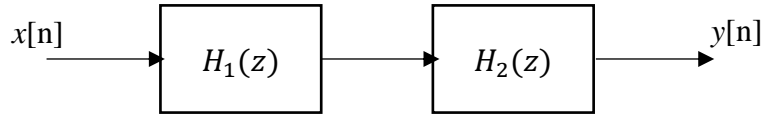
$$x[n] \longrightarrow \boxed{H_1(z)} \longrightarrow \boxed{H_2(z)} \longrightarrow y[n]$$

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

where,

$$H_1(z) = \frac{2 + 0.1z^{-1}}{1 + 0.5z^{-1}} \ \ and \ H_2(z) = \frac{(1 - 3z^{-1})(2 + 3z^{-1})}{(1 + 0.3z^{-1})(1 - 0.2z^{-1})}$$

(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 higher 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 1000Hz and the following specifications:

$$0.90 \le \left| H\!\left(e^{j\omega}\right) \right|^2 \le 1.00 \; ; \; |f| \le 200Hz$$

$$\left| H\!\left(e^{j\omega}\right) \right|^2 \le 0.10 \; ; \; |f| \ge 300Hz$$

   (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]