

III B.Tech II Semester Supplementary Examinations, Apr/May 2008
DIGITAL SIGNAL PROCESSING

(Common to Electronics & Communication Engineering, Electronics &
Instrumentation Engineering, Electronics & Control Engineering,
Electronics & Telematics and Instrumentation & Control Engineering)

Time: 3 hours

Max Marks: 80

Answer any FIVE Questions
All Questions carry equal marks

1. (a) Find the impulse response for the causal system $y(n) - y(n-1) = x(n) + x(n-1)$
(b) Find the response of the above system to inputs $x(n) = u(n)$ and $x(n) = 2^{-n}u(n)$. Test its stability. [6+10]
2. (a) A discrete system is given by the following difference equation:
 $y(n) - 5y(n-1) = x(n) + 4x(n-1)$
where $x(n)$ is the input and $y(n)$ is the out put. Find the impulse response. Determine its magnitude and phase response as a function of frequency.
(b) Show that the frequency response of a discrete system is a periodic function of frequency. [8+8]
3. (a) Compute the discrete Fourier transform of each of the following finite length sequences considered to be of length N .
i. $x(n) = \delta(n)$
ii. $x(n) = \delta(n - n_0)$ where $0 < n_0 < N$
iii. $x(n) = a^n$ $0 \leq n \leq N - 1$
(b) Let $x_2(n)$ be a finite duration sequence of length N and $x_1(n) = \delta(n - n_0)$ where $n_0 < N$. Obtain the circular convolution of two sequences. [8+8]
4. (a) Implement the decimation in time FFT algorithm for $N=16$.
(b) In the above Question how many non - trivial multiplications are required. [10+6]
5. (a) Determine the frequency response , magnitude response and phase response for the system given by $y(n) - \frac{3}{4}y(n-1) + \frac{1}{8}y(n-2) = x(n) - x(n-1)$
(b) A causal LTI system is described by the difference equation $y(n) = y(n-1) + y(n-2) + x(n-1)$, where $x(n)$ is the input and $y(n)$ is the output. Find
i. The system function $H(Z) = Y(Z)/X(Z)$ for the system, plot the poles and zeroes of $H(Z)$ and indicate the region of convergence.
ii. The unit sample response of the system.
iii. Is this system stable or not? [6+10]
6. Determine the system function $H(Z)$ of the lowest order Chebyshev and Butterworth digital filter with the following specification

- (a) 3 db ripple in pass band $0 \leq w \leq 0.2\pi$
(b) 25 db attenuation in stop band $0.45\pi \leq w \leq \pi$ [16]
7. (a) Design a band stop filter to reject frequencies in the range 1-2 radians/second using rectangular window $N=7$
(b) Write the magnitude and phase function of FIR filter when impulse response is anti symmetric and N is odd function. [8+8]
8. (a) Realize the following systems with minimum number of multipliers.
 $H(Z) = \frac{1}{4} + \frac{1}{2}Z^{-1} + \frac{3}{4}Z^{-2} + \frac{1}{2}Z^{-3} + \frac{1}{4}Z^{-4}$
 $H(Z) = [1 + \frac{1}{2}Z^{-1} + Z^{-2}] [1 + \frac{1}{4}Z^{-1} + Z^{-2}]$
(b) Explain the principles of VOCODERS. [10+6]

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1. (a) Define a linear-time invariant system in discrete time. Define the terms causality and stability of such systems. Discuss the properties for the following sequences.

$$y(n) = \begin{cases} x(n), & \text{for } n \geq 1 \\ 0, & \text{for } n = 0 \\ x(n+1), & \text{for } n \leq -1 \end{cases}$$

- (b) Find the:

- i. impulse response
- ii. output response for a step input applied at $n=0$ of a discrete time linear time invariant system whose difference equation is given by $y(n) = y(n-1) + 0.5 y(n-2) + x(n) + x(n-1)$. [8+8]

2. Prove the following properties of the discrete Fourier series for periodic sequences.
- | Sequences | Discrete Fourier Series |
|-----------------------|--|
| (a) $x(n+m)$ | $W_N^{-Km} X(K)$ |
| (b) $x^*(n)$ | $X^*(-K)$ |
| (c) $x^*(-n)$ | $X^*(K)$ |
| (d) $\text{Re}[x(n)]$ | $X_e(K)$ |
| (e) $\text{Im}[x(n)]$ | $X_o(K)$ [16] |

3. (a) Define DFT of a sequence $x(n)$. Obtain the relationship between DFT and DTFS.
- (b) Consider a sequence $x(n) = \{2, -1, 1, 1\}$ and $T = 0.5$ compute its DFT and compare it with its DTDT. [8+8]
4. (a) Implement the Decimation in frequency FFT algorithm of N-point DFT where $N=8$. Also explain the steps involved in this algorithm.
- (b) Compute the FFT for the sequence $x(n) = \{1, 1, 1, 1, 1, 1, 1, 1\}$ [8+8]
5. (a) Explain how the analysis of discrete time invariant system can be obtained using convolution properties of Z transform.
- (b) Determine the impulse response of the system described by the difference equation $y(n) - 3y(n-1) - 4y(n-2) = x(n) + 2x(n-1)$ using Z transform. [8+8]

6. Determine the system function $H(Z)$ of the lowest order Chebyshev and Butterworth digital filter with the following specification
- (a) 3 db ripple in pass band $0 \leq w \leq 0.2\pi$
 - (b) 25 db attenuation in stop band $0.45\pi \leq w \leq \pi$ [16]
7. (a) Define Infinite Impulse Response & Finite Impulse Response filters and compare.
- (b) Design a low pass Finite Impulse Response filter with a rectangular window for a five stage filter given:
Sampling time 1 msec; $f_c = 200Hz$
Draw the filter structure with minimum number of multipliers. [6+10]
8. (a) A causal system is represented by the following difference equation.
 $y(n) + \frac{1}{4}y(n-1) = x(n) + \frac{1}{2}x(n-1)$
Find the system transfer function $H(Z)$, unit sample response and frequency response of the system
- (b) Realize $H(Z) = 1 + \frac{1}{2}Z^{-1} + \frac{1}{8}Z^{-2} + \frac{3}{4}Z^{-3} + \frac{1}{8}Z^{-4} + \frac{1}{2}Z^{-5} + Z^{-6}$ with minimum number of multipliers. [8+8]

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1. (a) Represent the following sequence graphically $x(n) = \delta(n+3) - 2\delta(n+2) + 3\delta(n+1) + \delta(n-1) - 4\delta(n-3)$
- (b) If the above $x(n)$ is given as input to a system with $h(n) = u(n) - u(n-5)$, Plot the Output $y(n)$.
- (c) Define stability and causality of a time invariant system and prove the stability condition. [4+6+6]
2. (a) A discrete system is given by following difference equation $y(n) - 5y(n-1) = x(n) + 4x(n-1)$ where $x(n)$ is the input and $y(n)$ is the out put. Determine its magnitude and phase response as a function of frequency.
- (b) State and prove convolution theorem. [8+8]
3. (a) Compute Discrete Fourier transform of the following finite length sequence considered to be of length N .
 - i. $x(n) = \delta(n + n_0)$ where $0 < n_0 < N$
 - ii. $x(n) = \infty^n$ where $0 < \infty < 1$.
- (b) If $x(n)$ denotes a finite length sequence of length N , show that $x((-n))_N = x((N-n))_N$. [8+8]
4. (a) Implement the decimation in time FFT algorithm for $N=16$.
- (b) In the above Question how many non - trivial multiplications are required. [10+6]
5. (a) An LTI system is described by the equation $y(n) = x(n) + 0.81x(n-1) - 0.81x(n-2) - 0.45y(n-2)$. Determine the transfer function of the system. Sketch the poles and zeroes on the Z-plane.
- (b) Define stable and unstable system test the condition for stability of the first-order IIR filter governed by the equation $y(n) = x(n) + bx(n-1)$. [8+8]
6. Determine the system function $H(Z)$ of the lowest order Chebyshev digital filter that meets the following specifications.
 - (a) 1 db ripple in the passband $0 \leq |W| \leq 0.3\pi$
 - (b) At least 60 db attenuation in the stopband $0.35\pi \leq |W| \leq \pi$. Use the bilinear transformation. [16]

7. A low pass filter is to be designed with the following desired frequency response.

$$H_d(e^{j\omega}) = \begin{cases} e^{-j2\omega}, & -\pi/4 \leq \omega \leq \pi/4 \\ 0, & \pi/4 \leq |\omega| \leq \pi \end{cases}$$

Determine the filter coefficients $h_d(n)$ if the window function is defined as

$$\omega(n) = \begin{cases} 1, & 0 \leq n \leq 4 \\ 0, & \text{otherwise} \end{cases}$$

Also determine the frequency response $H(e^{j\omega})$ of the designed filter. And plot the magnitude and phase spectra. [16]

8. (a) Explain the structures for realisation of FIR system and draw the direct form structure of the FIR system described by the transfer function

$$H(Z) = 1 + \frac{1}{2}Z^{-1} + \frac{3}{4}Z^{-2} + \frac{1}{4}Z^{-3} + \frac{1}{2}Z^{-4} + \frac{1}{8}Z^{-5}$$

- (b) Realize the following IIR system by cascade and parallel forms.

$$y(n) + \frac{1}{4}y(n-1) - \frac{1}{8}y(n-2) = x(n) - 2x(n-1) + x(n-2) \quad [8+8]$$

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1. By explicitly evaluating the convolution sum, evaluate the convolution $y(n) = (n) * h(n)$ of the sequences

$$h(n) = \begin{cases} \alpha^n & 0 \leq n < N \\ 0 & \text{elsewhere} \end{cases}$$

$$X(n) = \begin{cases} \beta^{n-n_0}, & n_0 \leq n \\ 0 & , \quad n \leq n_0 \end{cases} \quad [16]$$

2. (a) State and prove time and frequency shifting properties of Fourier transform.

- (b) Find the Fourier transform of the following signals

i. $x(n) = (\alpha^n \sin w_0 n) u(n) \quad |\alpha| < 1$

ii. $x(n) = (1/4)^n u(n+4) \quad [8+8]$

3. (a) Distinguish between DFT and DTFT .

- (b) Consider a sequence $x(n)$ of length L . Consider its DTFT $X_d(w)$ is sampled and N is the number of frequency samples. Discuss the relation between L and N for inverse DTFT = inverse DFT comment on the aliasing problem.

- (c) Compute the DFT of $x(n) = \{1, 0, 0, 0\}$ and compare with $X_d(w)$. $[4+6+6]$

4. (a) Implement the Decimation in frequency FFT algorithm of N -point DFT where $N=8$. Also explain the steps involved in this algorithm.

- (b) Compute the FFT for the sequence $x(n) = \{1, 1, 1, 1, 1, 1, 1, 1\}$ $[8+8]$

5. (a) With reference to Z-transform, state the initial and final value theorem.

- (b) Determine the causal signal $x(n)$ having the Z-transform $X(Z) = \frac{Z^2+Z}{(Z-\frac{1}{2})^2(Z-\frac{1}{4})}$. $[6+10]$

6. (a) What is an IIR digital filter?

- (b) How are IIR digital filter realized?

- (c) What are the various realizability constraints imposed on transfer function of an IIR digital filter. $[6+4+6]$

7. (a) What is the principle of designing FIR filters using windows.

- (b) Using a rectangular window technique design a low pass filter with pass band gain of unity, cut-off frequency of 1kHz and working at a sampling frequency of 5 kHz. The length of the impulse response should be 7. $[6+10]$

8. Realise the FIR transfer function

$H(z) = (1 + 0.8Z^{-1})^5 = 1 + 4Z^{-1} + 6.4Z^{-2} + 5.12Z^{-3} + 2.048Z^{-4} + 0.32768Z^{-5}$ in the following forms.

- (a) Two different direct forms.
- (b) Cascade of first-order sections
- (c) Cascade of one first - order and two second order sections and
- (d) Cascade of one second - order and one third order sections.

Compare the computational complexity of each and above realizations. [16]
