Ref No: Ex/EE/PC/B/T/224/2023

B.E. ELECTRICAL ENGINEERING SECOND YEAR SECOND SEMESTER EXAMINATION 2023

DIGITAL SIGNAL PROCESSING

Full Marks 100

Time: Three hours **(50 marks for each part)**

Use a separate Answer-Script for each part

Question No.	PART- I	Marks
	Answer any ***THREE*** questions Two marks reserved for neatness	
1. (a)	Consider the discrete-time sequence $x[n] = \text{Cos}\left(\frac{n\pi}{8}\right)$. Find two different continuous-time signals that would produce this sequence when sampled at a frequency of $f_s = 10$ Hz.	4
(b)	If a bandlimited continuous-time signal $x(t)$ has a Nyquist sampling rate of ω_s, what is the Nyquist sampling rate for each of the following signals derived from $x(t)$? (i) $x(3t)$ (ii) $x^3(t)$ (iii) $2x(t)\text{Cos}(\omega_0 t)$. Justify your answers.	6
(c)	Starting from the basic expression of Z-transform, and utilizing any of its property (if necessary), obtain the closed form expression for the Z-transform H(z) of the following discrete-time sequence. (i) $h[n] = \lvert n\rvert\left(\frac{1}{2}\right)^{\lvert n\rvert}$ State clearly the location of the poles, their multiplicity and the ROC of H(z).	6
2. (a)	Which of the following functions of z could be the Z-transform of a causal sequence? *Explain without actually determining the inverse transforms.* (i) $X(z) = \frac{d}{dz}\frac{\left(1-2z^{-1}\right)^2}{\left(3-2z^{-1}\right)^2}$ (ii) $X(z) = \frac{(z-1)^3}{\left(z^{-1}-\frac{1}{4}\right)^2}$	4

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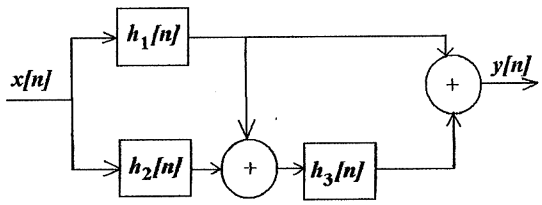
Question No.	PART I	Marks
(b)	Determine the impulse response of the complete system shown in Fig. [A], where the subsystems have impulse responses $h_1[n] = \left(\frac{1}{3}\right)^n u[n]$, $h_2[n] = \left(\frac{1}{6}\right)^n u[n]$ **and** $h_3[n] = \left(\frac{1}{6}\right)^n u[n]$.  **Fig. [A]** Also obtain the difference equation relating the output and the input sequences.	6
	OR	
(b)	The impulse responses of two discrete-time LTI systems are, $g[n] = \{1, 8, 2, -1\}$ and $h[n] = \{1, -5, 2, -1\}$. $\qquad\uparrow \qquad\qquad\qquad\qquad \uparrow$ Performing time-domain computation, find the impulse response of the two systems in cascade.	6
(c)	The Z-transform of a sequence $f[n]$ is $F(z) = \log\left(1 - \frac{1}{2}z^{-1}\right); \quad \lvert z\rvert > \frac{1}{2}$. Verify whether or not $f[n] = -\frac{1}{n}\left(\frac{1}{2}\right)^n u[n-1]$	6
3.(a)	The transfer function of a causal DTLTI system is $H(z) = \frac{1}{1 + az^{-1} + 0.3z^{-2}}$	6

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Question No.	PART I	Marks
	Determine the range of values of a for which the system will be stable	
(b)	The transfer function of a discrete-time linear time-invariant system is . $$G(z) = \frac{z^4 - \frac{9}{4}z^3 + \frac{7}{2}z^2 - \frac{25}{4}z}{z^2 - \frac{13}{4}z + \frac{3}{4}}$$ Identify all possible ROCs of **G**(z),and find out the closed form expressions for the impulse response sequence for each case. Also comment on the causality and stability of the system.	10
4. (a)	Design a low pass digital Butterworth filter with a dc gain of 0 dB, an attenuation of 3 dB at 2 kHz and an attenuation of at least 15 dB at 6 kHz. The sampling frequency is 12 kHz. Use impulse invariant transformation. Obtain the difference equation relating the output and the input sequences of the filter.	10
(b)	Prove the warping formulae associated with the designing of filters using bilinear transformation, point out their significance and also explain why the bilinear transformation technique is free from the problem of 'Characteristic Aliasing'.	6
5.	Write short notes on *any two* of the following.	8+8
(a)	Frequency spectra of uniformly sampled signals.	
(b)	Mapping of left half of s-plane on to z-plane	
(c)	Recursive and non-recursive systems and their frequency responses.	

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Full Marks 100

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No. of Questions	**PART II**	**Marks**
	Answer all the questions.	
1.	Describe in detail how can inverse discrete Fourier transform be computed from N-point DFT coefficients X_n (n=0,1,...,(N-1))? (CO1-K1) OR Prove that the multiplication of the DFTs of two sequences is equivalent to the circular convolution of the same two sequences in time domain. (CO1-K1)	10
2. (a)	What are the common window functions employed in designing FIR digital filters? Describe the causal and non-causal forms of any three such window functions. Comment on the approximate width of main lobes for those window functions. (CO2-K2) OR How can the frequency response of a digital filter having truncated impulse sequence be expressed using a rectangular window sequence and a circular complex convolution integral? Why is this convolution integral called both "complex" and "circular"? (CO2-K2)	09
(b)	Derive the structure for direct realization of a causal M-tap FIR digital filter and show that, for odd M, the number of multiplications required is ((M+1)/2). (CO2-K2) OR State and prove periodicity and symmetry properties of frequency response $H(\omega)$ of linear phase digital filters. Hence plot the real and imaginary parts of $H(\omega)$ separately as functions of ω. (CO2-K2)	07
3.	Write a short note on ***any one*** of the following: (CO3-K3)	08
(*i*)	One-dimensional FIR filters for offline analysis of signals.	
(*ii*)	Bit reversal procedures for 4-point and 8-point FFTs.	

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No. of Questions	PART II	Marks
4.	Design an M-tap causal digital filter with stepped characteristic in its frequency response given as: For $\frac{-\omega_s}{2} \le \omega \le \frac{\omega_s}{2}$, $H(\omega) = a_1 e^{-j\omega\tau(M-1)/2}$, for $\lvert\omega\rvert \le \omega_1$ $= a_2 e^{-j\omega\tau(M-1)/2}$, for $\omega_1 < \lvert\omega\rvert \le \omega_2$ $= 0$, otherwise where $a_1 > a_2$, and all other symbols have usual meaning. The filter coefficients are smoothened using Hann window. (CO4-K3)	08
5.	Justify or correct ***any two*** of the following statements with suitable reasons/derivations, in brief. (CO5-K4)	04×02 =08
i)	An N-point FFT requires (N/4) number of butterfly computations in each iteration.	
ii)	The circular shift of a discrete sequence can be expressed in terms of a modulo operation.	
iii)	For a distortionless linear phase FIR digital filter, the group delay is constant and is independent of the order of the filter designed.	