ADVANCED DIGITAL SIGNALS AND SYSTEMS
(AEI5101)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) For energy signals, the energy will be finite and the average power will be
(a) infinite (b) finite
(c) zero (d) cannot be defined

(ii) Condition for aliasing problem is
(a) $f_s < f_m$ (b) $f_s < 2f_m$
(c) $f_s = f_m$ (d) all of these

(iii) A real valued signal x(n)is called as anti-symmetric if
(a) $x(n) = \mathrm{x}(-\mathrm{n})$ (b) $x(n) = -\mathrm{x}(-\mathrm{n})$
(c) $x(n) = -\mathrm{x}(\mathrm{n})$ (d) none of the mentioned

(iv) An LTI discrete time system is causal if and only if,
(a) $h(n) \neq 0$ for $n < 0$ (b) $h(n) = 0$ for $n < 0$
(c) $h(n) \neq \infty$ for $n < 0$ (d) $h(n) \neq 0$ for $n > 0$

(v) IIR filters
(a) use feedback
(b) are sometimes called recursive filters
(c) can oscillate if not properly designed
(d) all of above

(vi) In bilinear transformation, the left-half s-plane is mapped to which of the following in the z-domain?
(a) Entirely outside the unit circle |z|=1 (b) Partially outside the unit circle |z|=1
(c) Partially inside the unit circle |z|=1 (d) Entirely inside the unit circle |z|=1

(vii) In which of the following, sampling rate conversion is used?
(a) Narrow band filters (b) Digital filter banks
(c) Quadrature mirror filters (d) All of the mentioned

(viii) What is the main advantage of an adaptive filter in digital signal processing?
(a) Fixed parameters
(b) Limited applications
(c) Stable behavior
(d) Adaptability to changing with signal characteristics

(ix) Autocorrelation is a function of
(a) time (b) frequency
(c) time difference (d) frequency difference

(x) Autocorrelation is a _____ function.
(a) real and even (b) real and odd
(c) complex and even (d) complex and odd

Fill in the blanks with the correct word

(xi) A real valued signal x(n) is called as anti-symmetric if _____ .

(xii) The system described by the input-output equation $y(n) = nx(n) + bx^3(n)$ is a _____ system.

(xiii) In linear phase realization, equal valued coefficients are taken common for reducing the requisite number of _____.

(xiv) Autocorrelation function of periodic signal is equal to _____ of the signal.

(xv) An LTI system is causal if and only if its impulse response is _____ for negative values of n.

Group - B

2. (a) What are energy and power signals? *[(CO1)(Remember/LOCQ)]*

(b) Determine whether the signal $x(n) = \left(\frac{3}{8}\right)^n u(n)$ is energy or power signal? *[(CO1)(Analyze/LOCQ)]*

(c) Consider the analog signals $x_1(t) = 2\cos(2\pi 10t)$ and $x_2(t) = 1.5\cos(2\pi 40t)$. Derive a sampling frequency, so that the 40 Hz signal is an alias of the 10 Hz signal. *[(CO1)(Apply/IOCQ)]*

4 + 4 + 4 = 12

3. (a) Consider a digital sequence sampled at the rate of 10 kHz. If we use a size of 1024 data points and apply the 1024-point DFT to compute the spectrum, then determine (i) the frequency resolution and (ii) the highest frequency in the spectrum. *[(CO2)(Analyse/IOCQ)]*

(b) Given a sequence $x(n)$ for $0 \leq n \leq 3$, where $x(0) = 1, x(1) = 2, x(2) = 3$ and $x(3) = 4$. Evaluate its DFT X(k) using the decimation-in-time FFT method? *[(CO2)(Apply/IOCQ)]*

(c) State the drawbacks of the DFT. *[(CO2)(Remember/LOCQ)]*

4 + 6 + 2 = 12

Group - C

4. (a) What are the constraints of IIR digital filter design? State the reasons for IIR filter design approach from its analog counterpart. *[(CO3)(Remember/LOCQ)]*

   (b) Compute the digital IIR filter transfer function by converting the analog filter transfer function $H(s) = \frac{1}{(s+2)^2(s+1)}$ using bilinear transform technique. Consider $T = 1$sec. *[(CO3)(Analyze/IOCQ)]*

   (c) Design an analog Butterworth low pass filter to meet the following specifications: $T = 1$ second and magnitude response satisfies $0.707 \leq \left|H\left(e^{j\omega}\right)\right| \leq 1$ for; $0 \leq \omega \leq 0.4\pi$ and $\left|H\left(e^{j\omega}\right)\right| \leq 0.25$; for $0.6\pi \leq \omega \leq \pi$. *[(CO3)(Evaluate/HOCQ)]*

3 + 3 + 6 = 12

5. (a) What is the necessary and sufficient condition for linear phase characteristics in FIR filter? *[(CO4)(Remember/LOCQ)]*

   (b) Develop the linear phase realization of the following FIR system: $H(Z) = \frac{1}{4} + \frac{1}{2}z^{-1} + \frac{3}{4}z^{-2} + \frac{1}{2}z^{-3} + \frac{1}{4}z^{-4}$. *[(CO4)(Apply/IOCQ)]*

   (c) Realize the direct form-I and direct form-II structures of the following LTI system governed by the equation: $y(n) = -0.1y(n-1) + 0.2y(n-2) + 3x(n) + 3.6x(n-1) + 0.6x(n-2)$. *[(CO4)(Design/HOCQ)]*

2 + 3 + 7 = 12

Group - D

6. (a) With the help of block diagram explain the sampling rate conversion by a rational factor 'I/D'. Obtain necessary expressions. *[(CO5)(Remember /LOCQ)]*

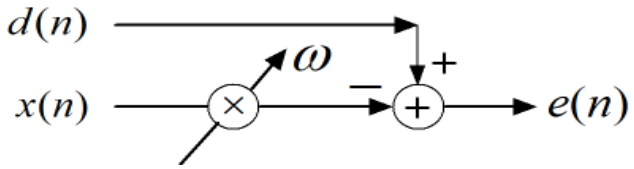
   (b) Given the sequence $(n) = \{\ldots\ldots, 4, 3, \underline{2}, 6, 3, 5, 9, 4, \ldots\ldots\}$, find out the output y(n) and Y(z)of a down-sampler with down sampling factor 2. *[(CO5)(Analyse /IOCQ)]*

   (c) What is poly phase decomposition of filter? Develop a two band poly-phase decomposition of the IIR filter having transfer function$H(z) = \frac{2+3.1z^{-1}+1.5z^{-2}}{1+0.9z^{-1}+0.8z^{-2}}$. *[(CO5)(Apply/IOCQ)]*

4 + 4 + 4 = 12

7. (a) Derive weight update expression of an adaptive filter using LMS algorithm. *[(CO5)(Analyze/IOCQ)]*

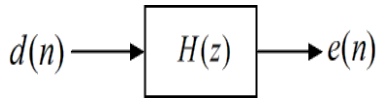
   (b) Consider the single-weight adaptive filter shown in figure below:



(i) Write down the LMS algorithm for updating the weight ω.

(ii) Suppose that $x(n)$ is a constant: $x(n) = \begin{cases} K & for\ n \geq 0 \\ 0 & otherwise \end{cases}$.

Find the system function relating $d(n)$ to e(n) using the LMS algorithm, i.e., find $H(Z)$ in the figure below.



(iii) Determine the range of values for μ for which $H(Z)$ is stable. *[(CO5)(Apply/IOCQ)]*

4 + 8 = 12

Group - E

8. (a) What is linear prediction? Give all pole linear prediction filter model expression and state its advantages on signal processing application. *[(CO6)(Remember/LOCQ)]*

   (b) Illustrate general Wiener filtering problem with a block diagram. Hence deduce the Wiener-Hopf equations for the FIR Wiener filter and the minimum mean square error. *[(CO6)(Analyze/IOCQ)]*

(2 + 2 + 2) + (2 + 4) = 12

9. (a) What are AR and ARMA processes? *[(CO6)(Remember/LOCQ)]*

   (b) An 1st order auto regressive (AR) process is given by $(n) = Ax(n) + \omega(n)$, where A is a constant and $\omega(n)$ is a white noise process of zero mean and variance σ^2. Find the mean and autocorrelation function of the process $H\{x(n)\}$. *[(CO6)(Apply/IOCQ)]*

(2 + 2) + 8 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	30.20	56.25	13.54