Ref No: Ex/PG/EE/T/1210B/2019

M.E. ELECTRICAL ENGINEERING FIRST YEAR SECOND SEMESTER EXAMINATION, 2019

SUBJECT: - ADVANCED DIGITAL SIGNAL PROCESSING

Time: Three hours

Full Marks 100
(50 marks for each part)

Use a separate Answer-Script for each part

No. of Questions	PART I	Marks
	Answer any TWO questions	
1. (a)	Show the schematic representation of a discrete Wiener filter. Hence prove that, for minimum mean square error condition, $RH=P$, where each symbol has its usual meaning. Under what circumstances does the relation: $S_{xx}(z) = S_{ss}(z) + S_{nn}(z)$ get satisfied, where also each symbol has its usual meaning?	03+06 +03
b)	In an adaptive FIR digital filter, employing steepest descent method of adaptation, prove that $V'_{n+1} - (I - 2\mu \wedge)V'_n = 0$, where each symbol has its usual meaning. How can you justify that this relation is uncoupled and each mode can be solved independently? In this context, what is the importance of employing primed co-ordinates?	08+ 03+02
2. (a)	A three-stage lattice filter is designed with coefficients: $K_1 = \frac{2}{3}, K_2 = \frac{2}{5}$ and $K_3 = \frac{3}{5}$. Determine the FIR filter coefficients for an equivalent direct-form structure.	06
(b)	Under what circumstances and how is the Leaky LMS algorithm used?	05
(c)	What is the general time varying performance criterion employed in RLS algorithm? How does the performance of an RLS algorithm depend on the choices of its parameters? What is the specialty of a growing window RLS algorithm?	02+03 +04
(d)	"In correlation LMS algorithm, the step size μ is chosen directly proportional to the cross-correlation of the error signal with the primary input signal." – Justify or correct the statement.	05

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No. of Questions	PART I	Marks
3. (a)	Describe in detail how is two-dimensional convolution employed in spatial domain filtering for image enhancement. How are two dimensional masks employed for this purpose in real implementations?	06
(b)	What are the basic constraints to be fulfilled in implementing first derivative and second derivative image filters? Describe in detail how the different filter masks are developed using Laplacian for the purpose of image sharpening. How can the original background features be preserved in the output in employing these filters?	10
(c)	"An edge detection algorithm must necessarily employ an image smoothing operation as its pre-processing step." – Justify or correct the statement.	04
(d)	How are special line detection masks employed in image processing? How are Prewitt and Sobel masks employed to detect diagonal edges?	05
4.	Write short notes on ***any two*** of the following:	$12\frac{1}{2}\times 2$ $= 25$
(i)	RLS algorithm employing Kalman gain vector.	
(ii)	Power-law transformation, unsharp masking and high frequency emphasis filtering techniques for image enhancement.	
(iii)	Similarity based algorithms for image segmentation.	

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PART II

Answer any *TWO* questions

1.(a) Can the autocorrelation of a wide-sense stationary (WSS) random process have the same unit as variance? Explain. 2

(b) A noise having a two-sided *power spectral density* (PSD) of 1 V^2 is applied to the input of a linear time-invariant system having an impulse response of $h[n] = ne^{-2n}u[n]$. Find the value of the output PSD at a frequency of $\Omega = 3$ radians, and the mean-square value of the output. Derive the expression(s) used. 7

(c) A discrete time LTI system has an impulse response $g[n] = \{\underset{\uparrow}{0}, -1, 1, 3\}$. The system is excited by a wide-sense stationary random sequence with autocorrelation function $R_X[m] = \{1, 2, 3, \underset{\uparrow}{5}, 3, 2, 1\}$. Perform *time-domain operation* to determine the autocorrelation sequence of the output. Derive the expression used. 6

OR

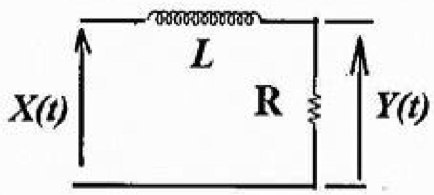
(c) $X[n]$ is a WSS random sequence with autocorrelation function $R_X[k]$. The random sequence $Y[n]$ is obtained from $X[n]$ as $Y[n] = (-1)^n X[n]$. 6

(i) Express the autocorrelation function of $Y[n]$ in terms of $R_X[k]$.

(ii) Express the cross-correlation function of $X[n]$ and $Y[n]$ in terms of $R_X[k]$.

(iii) Is $Y[n]$ wide sense stationary?

(iv) Are $X[n]$ and $Y[n]$ jointly wide sense stationary?

	PART I I	
(d)	For the RL network in Fig. [A] , let $X(t) = A$ Sin $(2\pi f_c t + \Theta) + N(t)$, where $N(t)$ is white, WSS, Gaussian noise with unit PSD and Θ is a random variable uniformly distributed over $[0, 2\pi)$. Assuming zero initial conditions, determine the (ii) output PSD, and sketch it. (ii) output signal-to-noise ratio (SNR). (iii) difference equation representing the *discrete-time equivalent of the network with the cut-off frequency optimized so as to maximize the SNR at the output.* Consider the time period of the input sinusoid as 50 ms and sampling period as 10 ms.  Fig. [A]	10
2.(a)	An eight bit, bipolar analog-to-digital converter (ADC) with a full-scale of ±10V, is used to digitize a zero-mean random signal with a variance of 16 V^2 and a bandwidth of 100 Hz. Determine the signal-to-quantization noise ratio when the sampling frequency is 300 Hz and also when the sampling frequency is 5 kHz. Comment on the difference in the result for the two cases, *with the help of mathematical analysis and illustration.* What happens to the effective number of bits?	10
(b)	Clarify the problem encountered when the determination of the impulse response of an unknown LTI system is attempted by exciting it with a rectangular pulse of very narrow width. As a remedial measure, can any random signal with accurately known statistical properties be utilized? Elaborate, also pointing out the bandwidth requirement of such a random process for practical implementation.	6

Question No.	PART II	Marks
	OR	
(b)	Cite appropriate examples to illustrate the 'Zero-Input Limit Cycle' and the 'Dead-Band Effect' in IIR (recursive) filters. Give real-life example of the problem that such a phenomenon may cause.	6
(c)	Distinguish between different forms of stationarity of random processes. What is meant by ergodicity of random processes? Verify the following statement with mathematical derivations. "A WSS discrete-time random process {X[n]} is ergodic if $\lim_{N\to\infty}\frac{1}{N}\sum_{k=-N+1}^{N-1}\left(1-\frac{\lvert m\rvert}{N}\right)C_x(m)=0$". *The symbols have their usual meaning.*	4+5
3. (a)	What is a *'General Linear Process'* ? How can the model parameters of the *most generalized form* of such a random process be determined from a finite set of measured values of its autocorrelation sequence ? Elaborate.	10
(b)	A discrete-time, WSS random sequence x[n] is to be generated by *filtering* a white Gaussian noise with *unit variance*. If the autocorrelation sequence of x[n] is $R_x[m]=\frac{1}{2}e^{-\lvert m\rvert}$, obtain the closed-form expression for the *impulse response sequence of the causal and stable filter* required for this purpose.	8
(c)	"If the autocorrelation sequence of a WSS random process is periodic, then the random process is mean-square periodic". ---- Investigate the validity of the above statement.	7

Question No.	PART II	Marks
4.	Write brief notes on <u>any two</u> of the following.	
(a)	Real-time median filters and their implementation using binary threshold decomposition.	12 ½ + 12 ½
(b)	Sigma-Delta modulator type ADC.	
(c)	Digital comb filter.	
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