Ref No: Ex/PG/EE/T/1210B/2017

M.E. ELECTRICAL ENGINEERING FIRST YEAR SECOND SEMESTER EXAMINATION, 2017

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 that, for an adaptive noise cancellation scheme, the system function of an optimal filter is given by: $H_W(z)=\frac{S_{RN}(z)}{S_{RR}(z)}$, where each symbol has its usual meaning. State any assumption(s) made in deriving this relation.	06
(b)	Under what circumstances and how a decorrelation delay is utilized in developing an adaptive noise canceller?	05
(c)	"In correlation LMS method, the step size is chosen as function of $E(E_nR_n)$ where E_n is the error at the nth instant and R_n is the reference input signal vector at nth instant." – Justify or rectify the statement.	04
(d)	What is the general time-varying performance criterion utilized in RLS algorithm for adapting digital filters? Describe in detail how an RLS algorithm can be developed using Kalman gain vector.	03+07
2. (a)	Design an optimum Wiener FIR filter with three taps to filter a noisy input sequence x_n. The auto-correlation quantities of the input sequence are specified as: $R_{xx}(0)$ = 0.92, $R_{xx}(1)$ = 0.86, and $R_{xx}(2)$ = 0.41. The cross-correlation quantities between x_n and the desired output sequence d_n are specified as: $R_{xd}(0)$ = 0.21, $R_{xd}(1)$ = 0.93, and $R_{xd}(2)$ = 0.82. Derive any relation used in solving this problem. State any assumption(s) made. What will be the MSE of this optimum filter if auto-correlation of d_n, $R_{dd}(0)$, is 0.83?	08
(b)	Describe in detail how a 2nd order digital FIR filter can be designed using two first order lattice stages in cascade? What is reflection coefficient in a lattice filter?	05+02

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No. of Questions	PART I	Marks
2. (c)	Prove that in an m-stage lattice filter, the $B_m(z)$ polynomial is the reverse polynomial of $A_m(z)$ polynomial, where each symbol has its usual meaning.	07
(d)	"The lattice form of realization of a digital FIR filter is more compact than the corresponding direct-form of realization." – Justify or rectify the statement.	03
3. (a)	Under what circumstances median filtering is employed for the purpose of image enhancement? What is the importance of high frequency emphasis filtering in image enhancement?	04+04
(b)	Differentiate between similarity based approaches and discontinuity based approaches in developing image segmentation algorithms. How can special line detection masks be employed for image segmentation?	04+04
(c)	Describe in detail how can Hough transform be employed for the purpose of edge linking and boundary detection in images.	09
4.	Write short notes on ***any two*** of the following:	
(i)	Steepest descent based adaptation algorithms for digital filters.	$12\frac{1}{2}\times 2$
(ii)	Thresholding based image segmentation.	$= 25$
(iii)	Comparison of first derivative and second derivative filters for image sharpening.	

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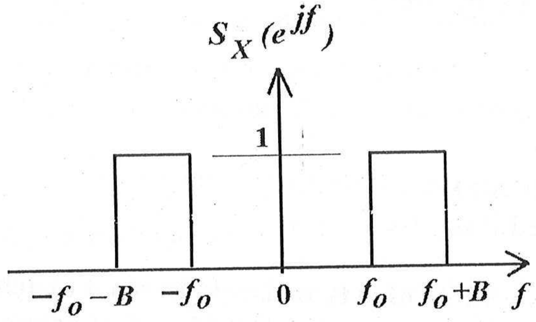
No. of Questions	PART II	Marks
	Answer any *TWO* questions	
1. (a)	Give an appropriate real-life example of a deterministic random process, where the sample functions are sinusoids. Examine whether or not the random process is wide-sense stationary (WSS) and ergodic.	2+6
(b)	Let $X(n)$ be a random process whose 'Power Spectral Density' (PSD) is shown in the Fig. [A]. A new random process is formed by multiplying $X(n)$ by a carrier to produce $Y(n) = X(n)\, Cos\left(2\pi f_o n + \Theta\right)$. where Θ is uniformly distributed over $[0, 2\pi)$ and statistically independent of $X(n)$. Find and sketch the PSD of the process $Y(n)$.  Fig. [A]	8
(c)	For each of the following functions, determine whether or not it is a valid autocorrelation function for a discrete-time WSS random process, where m is the lag time-index. (i) $\mathrm{Sin}(m)$ (ii) $\mathrm{Cos}(m)$ (iii) $exp(-m^2/2)$ (iv) $exp(-\|m\|)$ (v) $m^2 exp(-\|m\|)$ (vi) $rect(m/(2M))$.	9

No. of Questions	PART II	Marks
2. (a)	A 2V DC signal is contaminated by noise that is a sample realization of an ergodic random process. The power spectral density of the contaminated signal is $S_X(j\omega)=8\pi\delta(\omega)+\frac{40}{4+\omega^2}$ W/Hz. The corrupted signal is digitized and then processed by a running linear averager with a window length of 30 samples. Determine the RMS value of the noise component of the output. Derive the expression used.	12
(b)	Develop the Yule-Walker equations considering an ARMA model for a discrete-time random process. Also explain how, from this formulation, the power spectral density of an MA process can be obtained.	13
3 (a)	A signal of the form $s(t) = 5e^{-(t+2)}u(t+2)$ is to be detected in the presence of white noise having a PSD of 0.25 V^2/Hz using a matched filter. The output signal-to-noise ratio at time t_0 is maximized by the filter. (i) For $t_0 = 2$ s, find the value of the impulse response of the matched filter at t = 0, 2, and 4 s. (ii) Find the maximum output signal-to-noise ratio that can be achieved if $t_0 = \infty$. (iii) Find the value of t_0 that should be used to achieve an output signal-to noise ratio that is 0.95 of that achieved in part (ii).	10
(b)	Explain in details, how the signal-to-quantization noise ratio can be improved by using oversampling type analog-to-digital converter (ADC) with noise-shaping. Use necessary mathematical derivations and relevant sketches. If an 8 bit bipolar ADC is used in such an arrangement, what will be the effective number of bits, for an oversampling ratio of 30 ?	15

No. of Questions	PART II	Marks
4.	Answer any two of the following.	
	(a) Write a brief note on real-time median filters, and their implementation using binary thresholding.	12 ½ + 12 ½
	(b) Write a short note on "White Noise", and explain one of its practical application.	
	(c) State and prove the "Wiener-Khintchine-Einstein Theorem".	
	(d) Let $X(n) = \sum_{m=1}^{\infty} [A_m Cos(m\omega n) + B_m Sin(m\omega n)]$ be a random sequence, where A_m and B_m are random variables such that E[A_m]=E[B_m]=0. E[$A_K B_m$]= 0, $E\left[A_k A_m\right] = \delta_{k,m} E\left[A_m^2\right]$, $E\left[B_k B_m\right] = \delta_{k,m} E\left[B_m^2\right]$ for all K and m, where $\delta_{K,m}$ is the Kronecker delta sequence defined as $\delta_{k,m} = 1$ for k=m, =0 for k $\neq$ m	
	(i) Find the time-varying autocorrelation function $R_X(n, n+m)$.	
	(ii) If $E\left[A_m^2\right] = E\left[B_m^2\right]$, is this process WSS ?	
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