Ref No: **Ex/PG/EE/T/1210B/2018**

M.E. ELECTRICAL ENGINEERING FIRST YEAR SECOND SEMESTER EXAMINATION, 2018

SUBJECT: - ADVANCED DIGITAL SIGNAL PROCESSING

Full Marks 100

Time: Three hours (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)	Prove that, in discrete Wiener filter, the mean square error with optimal h_m can be obtained as: $E\left[e_n^2\right] = R_{dd}(0) - \sum_{k=0}^{N-1} h_k R_{xd}(k)$, where each symbol has its usual meaning.	08
(b)	"The optimal system function $H(z)$ of the unconstrained Wiener filter is a function of the discrete cross spectral density between the filter input and the desired output and the discrete power spectral density of the desired output." – Justify or rectify the statement.	05
(c)	Prove that in an adaptive digital FIR filter, designed using the steepest descent method, the gradient vector is given as $\nabla = 2RV$, where each symbol has its usual meaning. Also determine an expression for the time constant of decay of mean square error in this adaptive filter, under pth mode.	07+05
2. (a)	Why do we need to implement a running-average filter in normalized LMS method?	04
(b)	A 9th order adaptive digital FIR filter is adapted using LMS algorithm. The step size in the LMS adaptation algorithm is chosen as 80% of the step size required to achieve the maximum permissible speed of convergence. The running estimate of the average power of reference input signal is 2.35. The theoretical minimum value of mean square error is 0.16. The magnitude of the average Eigen value of the reference correlation matrix **R** is 1.68. What will be the values of the learning curve time constant and excess mean square error for this system?	07
(c)	What is the importance of regularization parameter and exponential weighting factor in designing an RLS adaptation algorithm? Describe in detail how an RLS algorithm can be designed using recursive	04+10

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No. of Questions	PART I	Marks
	formulation of the generalized versions of autocorrelation matrix and crosscorrelation vector, $R_{R(n)}$ and $P_{PR(n)}$ respectively, where each symbol has its usual meaning.	
3. (a)	How can contrast stretching and dynamic range compression be effectively carried out to achieve enhancement in image quality?	05
(b)	Describe in detail how can homomorphic filtering be utilized for image filtering purposes.	07
(c)	What are the basic conditions to be fulfilled to perform image segmentation? What are the typical edge models considered for image segmentation purposes and how can they be useful in performing edge detection? How can edge detection be carried out using image gradient?	03+03 +07
4.	Write short notes on *any two* of the following:	$12\frac{1}{2}\times 2 = 25$
(i)	Equivalence between (a) 3rd order direct-form FIR filter and 3-stage Lattice filter and (b) 4th order direct-form FIR filter and 4-stage Lattice filter.	
(ii)	Edge linking and boundary detection using Local Processing.	
(iii)	Frequency domain methods for low-pass image filtering.	

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No. of Questions	PART II	Marks
	Answer any *TWO* questions	
1. (a)	Define ideal '*White Noise*" and sketch its autocorrelation function and power spectral density (PSD). Why can not such a noise occur in practice? Indicate clearly the more realistic varieties of white noise. Explain how white noise can be utilized to identify the impulse response of an unknown linear time-invariant system.	6+3
(b)	Introduce the concept of "Power Spectral Density" of random processes. State and prove " Wiener-Khintchine-Einstein" theorem.	3+5
(c)	An unknown DTLTI system is modeled as a moving average (MA) system of order *p*. The actual system is excited by a known sequence *x[n]*. Elucidate, with relevant derivations, how the optimum values of the coefficients of the difference equation representing the model can be determined. *Under what condition will the cross-PSD of the output and the input sequences represent the frequency response of the system?*	8
2. (a)	"The discrete-time exponential averager is a notch filter in which the nulls occur at several frequencies across the frequency band." Starting from the difference equation model of an exponential averager, derive expression and give relevant sketch to justify or correct the above statement.	6
(b)	Define *"Constant Neighbourhood", "Impulse"* and *"Edge"* in connection with median filtering. Point out the merits of a median filter compared to a linear filter.	

No. of Questions	PART II	Marks
	A step sequence 2 *u[n-2]* is contaminated by an impulse 5δ[n-5]+4δ[n-6]+3δ[n-7]. Investigate whether or not the contaminating impulse can be completely removed by appropriately processing the contaminated signal by a real-time median filter. Can the original sequence be exactly restored on removing the impulse?	3+2 +6
(c)	Derive the expressions for the autocorrelation sequence and the power spectral density of the output *y[n]*, when the DTLTI system described by each of the following difference equations is excited by a sample realization of a white noise process with an autocorrelation sequence $R_X[m]=2\delta[m]$. (i) $y[n]=-0.9y[n-1]+2x[n-2]$ (ii) $y[n]=2x[n]-0.9x[n-1]$	8
3 (a)	In a bipolar Nyquist rate analog-to-digital converter (ADC), it is desired that quantization noise power level should be at least 80 dB below the full scale unclipped sinusoidal signal power level. Find the minimum number of bits required for the ADC. *Derive the expression used.*	7
(b)	In a first-order sigma-delta modulator ADC that uses one-bit DAC and one-bit-quantizer, if the OSR is 40, determine the *effective number of bits* (ENOB). *Derive any expression used for this purpose.* Sketch a suitable architecture for such an ADC.	10
(c)	Explain how biased as well as unbiased estimates of the autocorrelation sequence of a wide-sense stationary random process may be determined.	8
4.	Answer any two of the following.	
(a)	Explain how innovations representation and Wold representation of a wide-sense stationary random process can be obtained.	12 ½ + 12 ½

No. of Questions	PART II	Marks
(b)	The presence of a rectangular pulse $x(t)= u(t-2)-u(t-4)$ has to be detected in a contaminated environment by maximizing the signal-to-noise ratio at t= 5.5 time units. Derive the expression for the frequency response of a discrete-time matched filter that can be used for this purpose. Consider the contaminant as white noise. How would you tackle the problem if the contaminant is coloured noise?	
(c)	Formulate the Yule-Walker equations considering an ARMA model for a stochastic discrete-time process. Also explain how, from this formulation, the power spectral density of an AR process can be obtained.	
(d)	Write a short note on discrete-time linear average,	
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