University of Swaziland
Faculty of Science
Department of Electrical and Electronic Engineering
Main Examination 2015

Title of Paper : **Digital Communication Systems**

Course Number : **EE543**

Time Allowed : **3 hrs**

Instructions :

1. **Answer any four (4) questions**
2. **Each question carries 25 marks**
3. **Useful information is attached at the end of the question paper**

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The paper consists of six (6) pages

Question 1

(a) An analog signal is quantized and transmitted by using a PCM system. If each sample at the receiving end of the system must be known to be within ± 0.5 percent of the peak-to-peak full scale value, how many binary digits must each sample contain. [4]

(b) Assuming a 4-bit ADC channel accepts analog input ranging from 0 to 5 volts, determine the following: [5]

(i) Number of quantization levels
(ii) Step size of the quantizer or resolution
(iii) Quantization level when the analog voltage is 3.2 volts
(iv) Binary code produced
(v) Quantization error

(c) Consider the binary sequence 0100101. Draw the waveforms for the following signalling formats. [6]
(i) Unipolar NRZ signalling format
(ii) Bipolar RZ signalling format
(iii) AMI (alternate mark inversion) RZ signalling format

(d) A communication channel of bandwidth 75 kHz is required to transmit binary data at a rate of 0.1 Mb/s using raised-cosine pulses. Determine the roll-off factor α. [2]

(e) Differentiate between source coding and code efficiency? [3]

(f) In a binary system $s_i(t)$ is a +A –V or –A-V pulse during the interval (0, T). Using the integrate and dump detector we have $P(s_1) = P(s_2) = \frac{1}{2}, \eta/2 = 10^{-9} W/Hz$, A = 10 mV and the transmission rate of data (bit rate) is $10^4 b/s$.

(i) Find the probability of error P_e . ($P_e = Q(\sqrt{\frac{2A^2T}{\eta}})$) .[2]
(ii) If the bit rate is increased to 10^5 b/s, what value of A is needed to attain the same P_e as in part (i)? [3]

Question 2

(a) Consider an AWGN channel with 4 kHz bandwidth and the noise power spectral density $\frac{\eta}{2} = 10^{-12}\, W/Hz$. The signal power required at the receiver is 0.1mW. Calculate the capacity of this channel. [4]

(b) The output SNR of a Matched filter receiver is given by [7]

$$(\frac{S}{N})_0 = \frac{2E_d}{\eta} = \frac{2}{\eta}\int_0^T [s_1(t) - s_2(t)]^2 dt$$

Now suppose that we want $s_1(t)$ and $s_2(t)$ to have the same signal energy. Show that the optimum choice of $s_2(t)$ is

$$s_2(t) = -s_1(t)$$

and the resultant output SNR is

$$(\frac{S}{N})_0 = \frac{8}{\eta}\int_0^T s_1^2(t)\,dt = \frac{8E}{\eta}$$

(c) Given the following random binary sequence 10011011001110. Perform partial response signalling, that is, show the signal formed assuming the initialization bit is 1.[2]

(d) Determine the output SNR in a DM system for a 1 kHz, sampled at 40 kHz, without slope overload, and followed by a 3 kHz postreconstruction filter. [2]

(e) A certain telephone line bandwidth is 3.5 kHz. Calculate the data rate (in b/s) that can be transmitted if we use binary signalling with a raised-cosine pulse and a roll-off factor $\alpha = 0.25$. [2]

(f) A DMS X has four symbols x_1, x_2, x_3, x_4 with probabilities $P(x_1) = 0.4, P(x_2) = 0.3, P(x_3) = 0.2, P(x_4) = 0.1$

- (i) Calculate H(X) [2]
- (ii) Find the amount of information contained in the messages $x_1\, x_2 x_1\, x_3$ and $x_4 x_3\, x_3\, x_2$ and compare with the H(X) obtained in part (i). [6]

Question 3

(a) Consider an audio signal with spectral components limited to frequency band of 300 to 3300 Hz. A PCM signal is generated with a sampling rate of 8000 samples/s. The required output signal-to-quantizing-noise ratio is 40 dB.

- (i) What is the number of uniform quantizing levels needed, and what is the minimum number if bits per sample needed? [4]
- (ii) Calculate the minimum system bandwidth required. [2]
- (iii) Repeat parts (i) and (ii) when μ law compander is used with $\mu = 200$. [6]

(b) A DMS X has fours symbols x_1, x_2, x_3 *and* x_4 with $P(x_1) = \frac{1}{2}, P(x_2) = \frac{1}{4}$, and $P(x_3) = P(x_4) = \frac{1}{8}$. Construct a Shannon-Fano code for X, Show that this code has the optimum property that $n_i = I\,(x_i)$ and that the code efficiency is 100 percent. [12]

(c) For $A = 0$, how does the compression characteristics look like. [1]

Question 4

(a) Show that in a PCM system, the output signal-to-quantizing-noise ratio can be expressed as

$$\left(\frac{S}{N_q}\right)_0 = \frac{3}{2}\left(4^{f_{PCM}/f_m}\right)$$

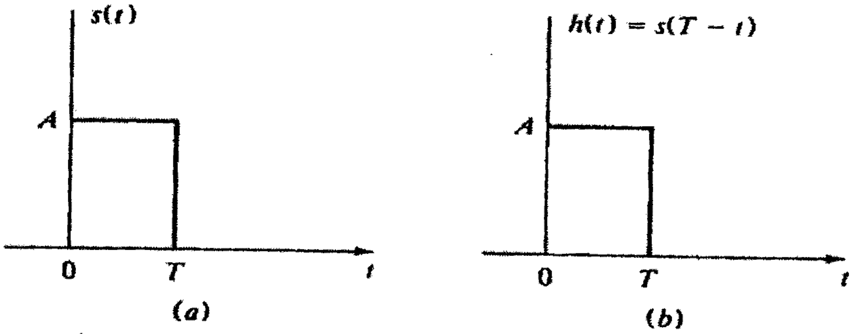
where f_{PCM} is the channel bandwidth and f_m is the message bandwidth. [4]

(b) State two (2) advantages of digital communication. [2]

(c) Show that the code C = { 0 0 0 0, 0 1 0 1, 1 0 1 0, 1 1 1 1} is a linear cyclic code. [4]

(d) A bipolar binary signal $s_i(t)$ is a +1 V or -1 V pulse during the interval (0, T). Additive white noise with power spectral density $\eta/2 = 10^{-5}\ W/Hz$ is added to the signal. Determine the maximum bit rate that can be sent with a bit error probability of $P_e \leq 10^{-4}$ [4]

(e) Find the output of the matched filter and determine the maximum value of $(S/N)_0$ in the input s(t) is a rectangular pulse of amplitude A and duration T as shown in figure 1. [8]



(f) For a QPSK modulator with an input data rate equal to 10 Mbps and carrier frequency of 70 Mhz. Determine the minimum double sided bandwidth and the output waveform of the balanced modulator. [3]

Question 5

(a) An analog signal having 4 kHz bandwidth is sampled at 1.25 times the Nyquist rate, and each sample is quantized into one of 256 equally likely levels. Assume that the successive samples are statistically independent.

(i) What is the information rate of this source? [2]

(ii) Can the output of this source be transmitted without error over an AWGN channel with a bandwidth of 10 kHz and S/N ratio of 20 dB? [2]

(iii) Find the S/N ratio required for error-free transmission for part (ii) [3]

(iv) Find the bandwidth required for an AWGN channel for error-free transmission of the output of this source if the S/N ratio is 20 dB. [2]

(b) For a sinusoidal modulating signal

$$m(t) = A\cos\omega_m t \qquad\qquad \omega_m = 2\pi f_m$$

Show that the maximum output signal-to-quantizing-noise ratio in a DM system under the assumption of no slope overload is given by

$$(SNR)_0 = \left(\frac{S}{N_q}\right) = \frac{3f_s^3}{8\pi f_m^2 f_M}$$

Where $f_s = \frac{1}{T_s}$ is the sampling rate and f_M is the cutoff frequency of a low-pass filter at the output end of the receiver. [8]

(c) State the Nyquist no-ISI condition. [2]

(d) State two (2) factors that influence the choice of digital modulation system.[2]

(e) The fundamental trade-off in source coding is made between what? [2]

(f) An analog signal is sampled at the Nyquist rate f_s and quantized into L levels. Find the time duration τ of 1 b of the binary-encoded signal. [2]

Table 1

z	$Q(z)$	z	$Q(z)$	z	$Q(z)$	z	$Q(z)$
0.00	0.5000	1.00	0.1587	2.00	0.0228	3.00	0.00135
0.05	0.4801	1.05	0.1469	2.05	0.0202	3.05	0.00114
0.10	0.4602	1.10	0.1357	2.10	0.0179	3.10	0.00097
0.15	0.4404	1.15	0.1251	2.15	0.0158	3.15	0.00082
0.20	0.4207	1.20	0.1151	2.20	0.0139	3.20	0.00069
0.25	0.4013	1.25	0.1056	2.25	0.0122	3.25	0.00058
0.30	0.3821	1.30	0.0968	2.30	0.0107	3.30	0.00048
0.35	0.3632	1.35	0.0885	2.35	0.0094	3.35	0.00040
0.40	0.3446	1.40	0.0808	2.40	0.0082	3.40	0.00034
0.45	0.3264	1.45	0.0735	2.45	0.0071	3.45	0.00028
0.50	0.3085	1.50	0.0668	2.50	0.0062	3.50	0.00023
0.55	0.2912	1.55	0.0606	2.55	0.0054	3.55	0.00019
0.60	0.2743	1.60	0.0548	2.60	0.0047	3.60	0.00016
0.65	0.2578	1.65	0.0495	2.65	0.0040	3.65	0.00013
0.70	0.2420	1.70	0.0446	2.70	0.0035	3.70	0.00011
0.75	0.2266	1.75	0.0401	2.75	0.0030	3.75	0.00009
0.80	0.2169	1.80	0.0359	2.80	0.0026	3.80	0.00007
0.85	0.1977	1.85	0.0322	2.85	0.0022	3.85	0.00006
0.90	0.1841	1.90	0.0287	2.90	0.0019	3.90	0.00005
0.95	0.1711	1.95	0.0256	2.95	0.0016	3.95	0.00004
4.00	0.00003						
4.25	10^{-5}						
4.75	10^{-6}						
5.20	10^{-7}						
5.60	10^{-8}						