Electrical Engineering - Optional For IAS (UPSC)

Digital Communication - 2015-2021

UPSC – ELECTRICAL Engineering optional – 2015 Questions

1. Explain the role of Protocol Data Unit (PDU) in communication within seven layers of OSI-ISO model. **[10M]**

2. Differentiate between the problems of error detection and correction. How many check/parity bits are required to correct a single error in a message of m bits? **[10M]**

3. Differentiate between the Pulse Code Modulation (PCM) and Delta Modulation (DM) explaining why DM is considered as a better alternative to PCM. How does the choice of the two parameters-quantization level (δ) and sampling interval T_s affect the performance-noise and accuracy/data rate? **[10M]**

4. Draw the waveforms showing modulation of the binary signal 0011010010 using ASK, FSK and PSK. **[10M]**

5. What is Quadrature Phase Shift Keying (QPSK)? How does it help to improve the data transmission rate? **[10M]**

6. Describe the Cyclic Redundancy Check (CRC) scheme for error detection. Explain how the Frame Check Sequence (FCS) and divisor /pattern are chosen. Given a message $M = 1010001101$ (10 bits), pattern $P = 110101$ (6 bits), illustrate how FCS can be calculated. **[10M]**

UPSC – ELECTRICAL Engineering optional – 2016 Questions

1. What do you mean by aliasing? How can aliasing be removed? State and explain Shannon's sampling theorem. **[10M]**

2. (i) Discuss the concept of 'Hamming distance'. How is the minimum Hamming distance between a set of code words related to the error detection and error correction properties of the code? Find the correct 4-bit messages from the following two Hamming codes, assuming at most a single error has occurred: $C_1 = 0110101$, $C_2 = 1011001$ **[10M]**

(ii) Explain Delta Modulation, comparing it with Differential Pulse Code Modulation. Discuss how the choice of step size in Delta modular affects slope overload distortion and granular noise. **[10M]**

3. (i) An accelerometer has an input range of $0 - 100\ m/s^2$. It has a mass of 10g and works on a frequency of 10 Hz. Find the range for the displacement transducer used to measure the displacement of the accelerometer.

(ii) An information signal $x(t) = 5\cos(2000)\pi t \cos(5000)\pi t$ is sampled. Calculate the minimum sampling rate that will be needed to recover the signal back from its samples. **[10M]**

4. (i) Show that the (7, 4) cyclic codes generated by the two polynomials

$g_1(P) = P^3 + P^2 + 1$, and

$g_2(P) = P^3 + P + 1$

are equivalent. Find the codes for the four messages: **[10M]**

$(0011), (0101), (1010), (1101)$

(ii) Discuss and differentiate between ISO/OSI and TCP/IP. Explain how the functions of each of the seven layers of ISO/OSI are carried out by TCP/IP. **[10M]**

5. Eight messages are generated by a source with the following probabilities:

Message m_i	m_0	m_1	m_2	m_3	m_4	m_5	m_6	m_7
Probability p_i	0.02	0.04	0.07	0.10	0.13	0.18	0.22	0.24

(i) Use Huffman scheme to code these messages.

(ii) Explain and illustrate the prefix property of the code.

(iii) Determine the average number of bits per message (1) with the Huffman coding, and (2) with uniform coding assuming the messages to be equiprobable. Also find the information content (entropy) in the message and hence efficiency of the Huffman coding. **[20M]**

UPSC – ELECTRICAL Engineering optional – 2017 Questions

1. A delta modulation system is designed to accommodate a bandlimited analog analog signal with maximum frequency of 5000 Hz. The sampling rate is five times the Nyquist rate. A signal $x(t) = \sin(2000\pi t)$ is applied to this system.

Determine:

(i) the minimum step size required to process the signal without slope overload distortion and

(ii) maximum signal-to-quantization noise ratio of the system. **[10M]**

2. A discrete memoryless source is emitting the symbols x_1, x_2 and x_3 with probabilities, respectively, 0.2, 0.45 and 0.35. Construct optimal binary Huffman code for the second extension of the source and calculate the coding efficiency. **[15M]**

3. An information source is modeled as a bandlimited process with a bandwidth of 6000 Hz. This process is sampled at a rate higher than the Nyquist rate to provide a guard band of 2000 Hz. The resulting samples takes one of the value in the set $\{-4, -3, -1, 2, 4, 7\}$ with corresponding probabilities $\{0.2, 0.1, 0.15, 0.05, 0.3, 0.2\}$. Determine the rate of information of the source. **[10M]**

4. A convolutional code is described by the following generator sequences:

$$g_1 = [1 \quad 0 \quad 0]$$

$$g_2 = [1 \quad 0 \quad 1]$$

$$g_3 = [1 \quad 1 \quad 1]$$

(i) Construct the encoder circuit corresponding to this code.

(ii) Draw the state diagram for this code.

(iii) Draw the trellis diagram for a message sequence length of 5 bits.

(iv) Determine the encoded sequence for the message sequence 10111. [**20M]**

5. Write down expression for the signal set and draw signal diagram for coherent quadri-phase shift keying system. For the input binary sequence 11001001, sketch inphase and quadrature components of the modulated quadri-phase shift keying signal. **[15M]**

UPSC – ELECTRICAL Engineering optional – 2018 Questions

1. A signal having probability density function

$$f(x) = \begin{cases} ke^{-|x|}; -4 < x < 4 \\ 0 ; \text{ elsewhere} \end{cases}$$

is quantized with four quantization levels.

(i) Determine the value of k.

(ii) Determine step size s.

(iii) Determine the four quantization levels. [**10M]**

2. Design a PCM system that multiplexes three signals m_1, m_2 and m_3 having bandwidths 5 kHz, 10 kHz and 5 kHz respectively. Each signal is sampled at its Nyquist rate and quantized to 256 levels.

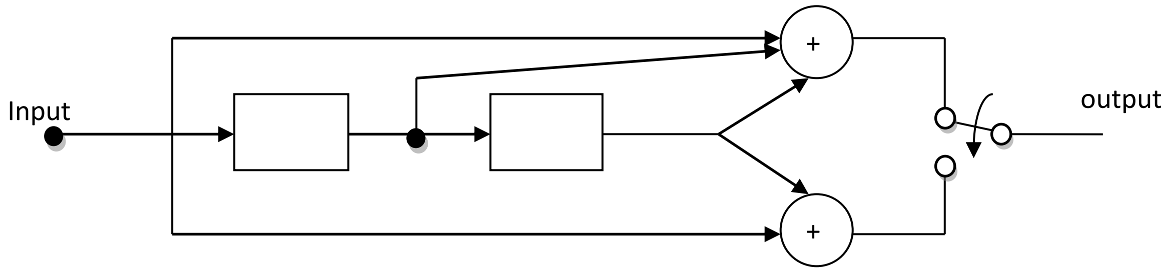
(i) Sketch the block diagram of the system.

(ii) What is the maximum bit duration that can be used?

(iii) What is the channel bandwidth required to pass the PCM signal?

(iv) What is the commutator speed in revolutions per second? **[20M]**

3. A convolutional encoder is shown below:



(i) Write down all the generator sequences and corresponding generator polynomial.

(ii) Determine the output sequence V, If the input sequence is $U = (1\ 0\ 0\ 1\ 1)$. **[10M]**

4. Write the step-by-step procedure to obtain source code by using Shannon-Fano algorithm.

[10M]

5. Obtain the source code for a source that generates messages with the following probabilities: **[10M]**

$m_1 \quad p_1 = 1/4$

$m_2 \quad p_2 = 1/4$

$m_3 \quad p_3 = 1/8$

$m_4 \quad p_4 = 1/8$

$m_5 \quad p_5 = 1/16$

$m_6 \quad p_6 = 1/16$

$m_7 \quad p_7 = 1/16$

$m_8 \quad p_8 = 1/16$

Also calculate the efficiency of the code.

6. (i) Draw the block diagram of a DPSK communication system.

(ii) The data stream to be transmitted by means of DPSK is $d(t) = 00100110011110$. Determine the DPSK bit stream.

(iii) Sketch BPSK waveform if the transmitted data stream is 101000 and carrier frequency is f_c. **[10M]**

UPSC – ELECTRICAL Engineering optional – 2019 Questions

1. (i) In a binary PCM system, if the quantizing noise amplitude N_q is not to exceed P percent of the peak-to-peak analog level, show that the number of bits n in each PCM word needs to be

$$n \geq \log_2 10 \left[\log_{10}\left(\frac{50}{P}\right)\right] = 3.32\log_{10}\left(\frac{50}{P}\right)$$ **[05M]**

2. A 700 Mbyte CD is used to store PCM data. Suppose a voice frequency (VF) signal is sampled at 8000 samples per second and the encoded PCM signal is to have an average SNR of at least 40 dB. How many minutes of VF conversation can be stored on the hard disc? **[05M]**

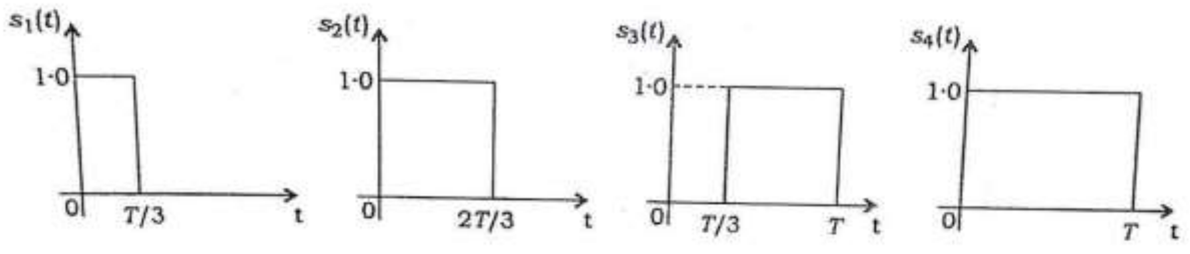
3. Sketch a block diagram for a differential encoding and decoding system. Explain the working of the system by showing the encoding and decoding of the sequence 101100011001. Assume that the reference digit is a binary 1. Show that error propagation cannot occur with this arrangement. **[06M]**

4. Consider a continuous input signal whose amplitude m lies in the range $(-m_{max}, +m_{max})$. This is applied to a uniform quantizer of mid-rise type where the step size is given by $\Delta = \frac{2 \cdot m_{max}}{L}$, where L denotes the number of representation levels. Let σ_Q^2 represent the variance of the quantization error and R represent the number of bits per sample. Show that $\sigma_Q^2 = \frac{\Delta^2}{12}$.Using this result, show that $\sigma_Q^2 = \frac{1}{3} m_{max}^2 \cdot 2^{-2R}$and that the output signal to noise ratio of a uniform quantizer is

$$(SNR)_0 = \left(\frac{3P}{m_{max}^2}\right) \cdot 2^{-2R}$$ **[08M]**

5. Consider a sine wave of frequency f_m and amplitude $A_{m,}$ that is applied to a delta modulator of step size Δ. Derive the condition which, if satisfied, leads to the occurrence of slope overload error. **[06M]**

6. Four signals $s_1(t), s_2(t), s_3(t)$and $s_4(t)$ are shown in the figure below. Find an orthonormal basis for this set of signals by making use of the Gram-Schmidt orthogonalization procedure. Draw the corresponding signal space diagram: **[10M]**



7. Consider an ON-OFF keying version of a binary ASK system, where symbol 1 (hypothesis H_1) is denoted by transmitting a DC level of amplitude A and symbol 0 (hypothesisH_0)is denoted by not communicating any signal over the channel. Assume that symbols 0 and 1 occur with equal probability. The channel is perturbed by Additive White Gaussian Noise (AWGN) with zero mean and variance σ^2. Show that the average probability of error for this ASK system is

$$P_e = Q\left[\frac{A}{2}\right], \text{ where } Q(\propto) \underline{\underline{\Delta}} \frac{1}{\sqrt{2\pi}} \int_{\alpha}^{\infty} e^{-u^2/2} du$$ **[10M]**

8. Consider a phase-locked loop (PLL) consisting of a multiplier, loop filter and voltage-controlled oscillator (VCO). Let the signal applied to the multiplier input be defined as $s(t) = A_c \cos\left[2\pi f_c t + k_p \cdot m(t)\right]$, where k_p is the phase sensitivity and data signal is having value $+1$ for binary symbol 1 and -1 for binary symbol 0. The VCO output is $\mathrm{r(t)} = \mathrm{A_v} \sin[2\pi f_c + \theta(\mathrm{t})]$. Evaluate the loop filter output, assuming that the filter removes the modulated components with frequency $2f_c$. Show that the loop filter output is proportional to the data signal$m(t)$, when the loop is phase-locked, that is, $\theta(\mathrm{t}) = 0$. Illustrate your answer with a neat sketch. **[10M]**

9. Consider a discrete memoryless source, whose output can be modeled as a discrete random variable S taking on symbols from a fixed alphabet $\xi = \{s_0, s_1, \dots, s_{K-1}\}$ with probabilities $P(S = s_k) = p_k;\ \ k = 0, 1, 2, \dots, K-1$. Further $\sum_{k=0}^{K-1} p_k = 1$. Assume that the symbols emitted by the source during successive signaling intervals are statistically independent. Show that the entropy $H(\xi)$ of such a source is bounded by

$$0 \le H(\xi) \le \log_2 K$$

Where K represents the number of symbols of the source alphabet. **[10M]**

10. A memoryless source S emits 6 message symbols with probabilities 0.3, 0.25, 0.15, 0.12, 0.1 and 0.08. Determine a 4-ary (quaternary) Huffman code for this source. Determine the average word length, the entropy and the efficiency of this Huffman code.

[06M]

11. The generator matrix of a $(7, 4)$ linear block code is given by

$$\mathbf{G} = \left[\begin{array}{ccc:cccc} 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 1 \end{array}\right]$$

$$\underbrace{\qquad\qquad}_{\mathbf{P}} \qquad \underbrace{\qquad\qquad\qquad}_{I_K}$$

(1) Determine a parity check matrix H for this code.

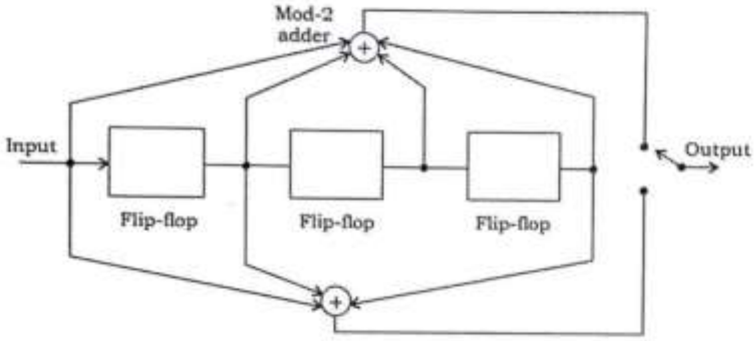
(2) Show that $G \cdot H^T = 0$

(3) Determine all right code words of the dual code.

(4) Find the minimum distance of the dual code. **[08M]**

12. The figure shows the encoder for a rate $R = \frac{1}{2}$, constraint length $K = 4$ convolutional code. Determine the encoder output produced by the message sequence $u = 1011$.

[06M]



UPSC – ELECTRICAL Engineering optional – 2020 Questions

1. For a linear block code $C_b(4,2)$ over $GF(3)$, the generator matrix (G) is given by

$$G = \begin{bmatrix} 1 & 0 & 2 & 1 \\ 1 & 2 & 0 & 2 \end{bmatrix}$$ [**10M**]

(i) Determine all right code words for this code.

(ii) How many errors can this code correct?

2. (i) Explain the power efficiency and bandwidth efficiency of a digital modulation scheme.

(ii) Comment on the power efficiency for a given bandwidth efficiency for a good modulation scheme.

(iii) Comment on the bandwidth efficiency for a given power efficiency for a good modulation scheme.

(iv) Compare the bandwidth efficiency of ASK and QAM modulation techniques.

[**20M**]

3. (i) Write down Hamming bound condition for code $C(n,k)$ of size M in $GF(q)$, which can correct t errors.

(ii) Explain perfect code using Hamming bound condition in GF(2).

(iii) Check whether n-repetition code (for odd value of n) is perfect code or not. [**10M**]

4. (i) Consider the primitive polynomial $p(x) = x^3 + x + 1$ over GF(2). Construct GF(8) field using the given primitive polynomial.

(ii) Find the minimal polynomial for the primitive element α.

(iii) Find the BCH code length $n = 15$, which can correct at least one error. **[20M]**

5. What is grading of cables? What are the different methods of grading? What are its limitations? **[10M]**

UPSC – ELECTRICAL Engineering optional – 2021 Questions

1. A DPCM system uses a linear predictor with a single tap. The normalized autocorrelation function of the input signal for a lag of one sampling interval is 0.75. The predictor is designed to minimize the prediction error variance. Determine the processing gain attained by the use of the predictor. **[10M]**

2. Consider a signal detector with an input **[20M]**

$r = \pm A + n$

Where $+A$ and $-A$ occur with equal probability and the noise variable n is characterized by the Laplacian pdf shown.

(i) Determine the probability of error as a function of the parameters A and σ.

(ii) Determine the SNR required to achieve an error probability of 10^{-6}.

3. A discrete memoryless source (DMS) has five symbols x_1, x_2, x_3, x_4 and x_5 with $P(x_1) = 0.4$, $P(x_2) = 0.19$, $P(x_3) = 0.16$, $P(x_4) = 0.15$ and $P(x_5) = 0.1$. **[10M]**

(i) Construct a Shannon Fano code for the source and calculate the efficiency of the code.

(ii) Repeat for Huffman code. Compare the results of (i) and (ii).

4. Consider a connected graph $G = (N, A)$ with N nodes and A arcs, and a weight ω_{ij} for each arc $(i, j) \in A$. **[10M]**

(i) Define minimum weight spanning tree (MST).

(ii) If all arc weights of G are distinct, prove that there exists a unique MST.

5. Prove that the minimum distance of any linear (n, k) block code satisfies

$d_{min} \leq 1 + n - k$. **[10M]**

6. Show that the minimum Hamming distance of a linear block code is equal to the minimum number of columns of its parity check matrix that are linearly dependent. Form this conclude that the minimum Hamming distance of a Hamming code is always equal to 3. **[10M]**