Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2011-2012 (2 hours)

EEE6410 Digital Communications 6

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1. **a.** You are required to establish a synchronous connection between two digital systems and realise that some form of line coding is necessary to avoid distortion.

i) State the key parameters that need to be considered when evaluating a particular line coding scheme. **(3)**

ii) List the two main classes of line coding techniques that could be used giving an example of each class. **(3)**

b. For the two line coding schemes illustrated in Fig.Q.1.a, and Fig.Q.1.b below, derive the bit pattern sequence that corresponds to both of the timing diagrams shown. Contrast the two codes explaining their advantages and drawbacks and what applications each might be suitable for.

(6)

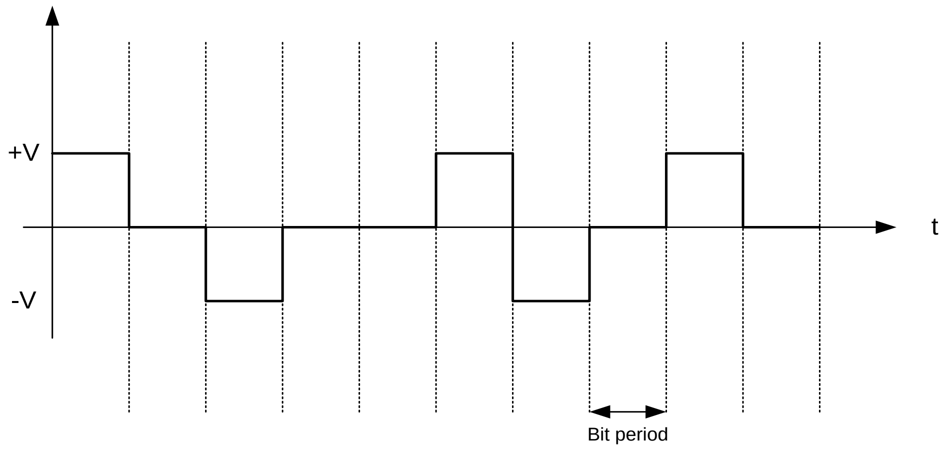

Figure Q.1.a

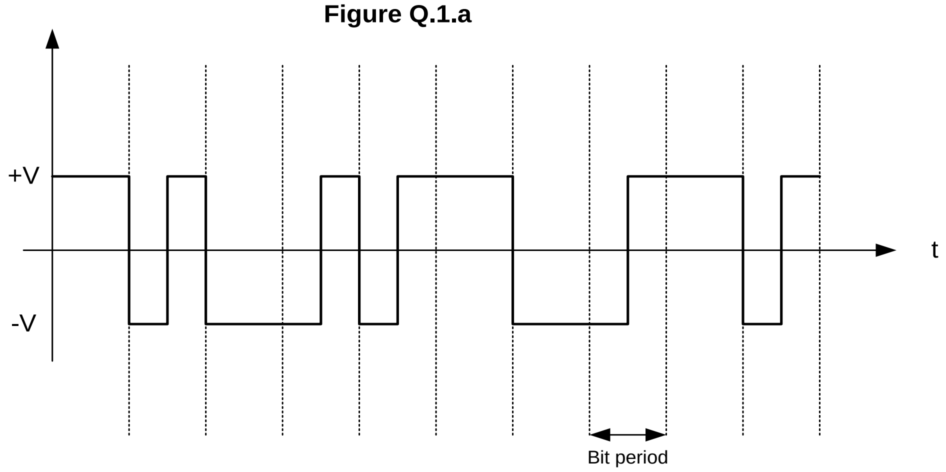

Figure Q.1.b

c. An RS232 asynchronous transmission connection is set up with even parity and 7-bit data between a Start and a Stop bit. The master clock is set to run at a nominal rate that is a multiple $\boldsymbol{m}$ of the baud rate with a clock tolerance of **±2%**. Determine a reliable value for $\boldsymbol{m}$ for this connection, assuming the worst case conditions correspond to the transmitter's clock being fast, the receiver's clock being slow, and the start bit sampled at the receiver one cycle late. **(8)**

2. **a.** A 3-bit message ***(110)*** is encoded using Cyclic Redundancy Check (CRC) bits generated by the generator polynomial $\boldsymbol{g(x) = x^4 + x^3 + 1}$.

i) Derive the resulting codeword. **(4)**

ii) Give the error detection reliability figure of the CRC used. **(2)**

b. During transmission over a noisy channel, a CRC codeword ***(110100010)*** generated using the CRC in **a.** was corrupted by the error pattern ***(011001000).*** Perform a CRC check to check the integrity of the received message and justify your result. **(6)**

c. A message encoded using a ***(15,7)*** primitive ***BCH*** (Bose-Chaudhuri-Hocquenghem) code defined over Galois Field $\boldsymbol{GF(2^4)}$ using the primitive polynomial $\boldsymbol{p(x)=x^4+x+1}$, is received after transmission over a noisy channel as $\boldsymbol{r(x)=x^{14}+x^{11}+x^9+x^7+x^3+x^2+x+1}$ with 2 errors that have affected the 4 least significant bits (LSBs). Algebraic decoding of the received message yielded the following error locator polynomial $\boldsymbol{\sigma(x)}$: **(8)**

$$\sigma(x) = x^2 + S_1 x + \frac{S_3 + S_1^3}{S_1}$$

where S denotes a syndrome. Correct the received message.

3. **a.** Compare block codes and convolutional codes, as applied to error correction, giving typical situations where each one might be employed. **(4)**

b. An ***(n,k) RS*** (Reed-Solomon) code defined over Galois Field $\mathbf{GF(2^3)}$ using the primitive polynomial $\boldsymbol{p(x)=x^3+x+1}$, is used to encode a 3-symbol message before transmission over a noisy channel so that any 2-symbol errors can be corrected.

i) Determine the required number of parity check symbols to be added to the message to enable this error correction capability; hence define the resulting *RS* code. What form can these errors take? **(3)**

ii) After transmission over a noisy channel a message encoded using the above ***RS*** code is received with a single symbol error as ***(111001100111010001001).*** Using algebraic decoding, derive the corrected codeword given that for a single symbol error correction the error location, $\boldsymbol{X_1}$, and the error magnitude, $\boldsymbol{Y_1}$, are given respectively by the equations: **(6)**

$$X_1 = \sigma_1 = \frac{S_2}{S_1} \quad \text{and} \quad Y_1 = \frac{S_1^{\,2}}{S_2}$$

where S_1 and S_2 are the first 2 syndromes

c. The sequence ***000 111 011 101 111 110 010 001 100*** encoded (in the order Q0Q1Q2) using the convolutional encoder shown in Figure Q.3 below, is received at the Viterbi decoder with no more than 3 bit errors. Correct this received sequence, and hence derive the initial input data. **(7)**

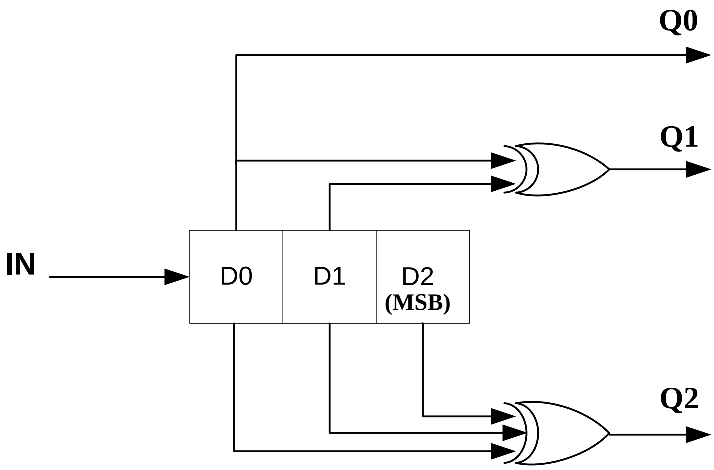

Figure Q.3

4. **a.** Why is it possible to compress data in many applications **(2)**

b. The Discrete Cosine transform (DCT) is widely used in practice in image and video applications.

i) What are the attributes of the DCT that are attractive for data compression. What are the potential limitations of DCT- based compression? **(3)**

ii) Draw a generic model for a DCT-based image compression system explaining briefly how compression is achieved. **(2)**

iii) Evaluate the DCT of the 4x4 data block below; what do you conclude from this on the energy compaction efficiency of the DCT.

$$\begin{bmatrix} 10 & 10 & 10 & 10 \\ 10 & 10 & 10 & 10 \\ 10 & 10 & 10 & 10 \\ 10 & 10 & 10 & 10 \end{bmatrix}$$

(6)

The *k-th/n-th DCT/IDCT* pair of an N-sample block input is given by:

$$X_k = \sqrt{\frac{2}{N}} \sum_{n=0}^{N-1} \alpha_k x_n \cos\left[\frac{(2n+1)k\pi}{2N}\right]$$

$$x_n = \sqrt{\frac{2}{N}} \sum_{k=0}^{N-1} \alpha_k X_k \cos\left[\frac{(2n+1)k\pi}{2N}\right]$$

$$\alpha_0 = \frac{1}{\sqrt{2}}$$

$$\alpha_k = 1(k \neq 0)$$

c. Consider the following DCT coefficients block obtained after the quantisation step in baseline JPEG:

$$\begin{bmatrix} 45 & 25 & -3 & 0 & 0 & 0 & 0 & 0 \\ -18 & -12 & -2 & 0 & 0 & 0 & 0 & 0 \\ 15 & 14 & 1 & 0 & 0 & 0 & 0 & 0 \\ 11 & -2 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

What is the total number of bits taken by the AC coefficients given the Huffman codewords for the Run/size combinations shown below in table Q.4. Find the average bit rate and hence the compression rate achieved in this case. Assume that the DC value is encoded separately and requires 5 bits.

(7)

Run/Size	1/2	0/5	0/4	0/2	0/1	0/0
Huffman code	11011	11010	1011	01	00	1010

Table Q.4

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