5.5.7 Comparison between Linear Block Codes and Convolutional Codes

The convolutional codes and block codes can be compared on the basis of their encoding methods, decoding methods, error correcting capabilities, complexity etc points.

Sr. No.	Linear block codes	Convolutional codes
1	Block codes are generated by, $X = MG$ or $X(p) = M(p)G(p)$	Convolutional codes are generated by convolution between message sequence and generating sequence. i.e. $x_i = \sum_{l=0}^{M} g_l m_{i-l}, i = 0, 1, 2, ...$
2	For a block of message bits, encoded block (code vector) is generated.	Each message bit is encoded separately. For every message bit, two or more encoded bits are generated.
3	Coding is block by block.	Coding is bit by bit.
4	Syndrome decoding is used for most likelihood decoding.	Viterbi decoding is used for most likelihood decoding.
5	Generator matrices, parity check matrices and syndrome vectors are used for analysis.	Code tree, code trellis and state diagrams are used for analysis.
6	Distance properties of the code can be studied from code vectors.	Distance properties of the code can be studied from transfer function.
7	Generating polynomial and generator matrix are used to get code vectors.	Generating sequences are used to get code vectors.
8	Error correction and detection capability depends upon minimum distance d_{min}.	Error correction and detection capability depends upon free distance d_{free}.

Table 5.9 Comparison of linear block codes and convolutional codes

2 MARKS

1. What is hamming distance ?

The hamming distance between the two code vectors is equal to the number of elements in which they differ. For example, let the two codewords be,

$$X = (101)\ and\ Y = (110)$$

These two codewords differ in second and third bits. Therefore the hamming distance between X and Y is two.

2. Define code efficiency?

The code efficiency is the ratio of message bits in a block to the transmitted bits for that block by the encoder i.e.,

$$code\ efficiency = \frac{message\ bits}{Transmitted\ bits} = \frac{k}{n}$$

3. What is meant by systematic and nonsystematic codes?

In a systematic block code, message bits appear first and then check bits. In the nonsystematic code, message and check bits cannot be identified in the code vector.

4. What is meant by linear code?

A code is linear if modulo-2 sum of any two code vectors produces another code vector. This means any code vector can be expressed as linear combination of other code vectors.

5. What are the error detection and correction capabilities of Hamming codes?

The minimum distance (d_{min}) of Hamming codes is '3'. Hence it can be used to detect double errors or correct single errors. Hamming codes are basically linear block codes with $d_{min} = 3$. .

6. What is meant by cyclic code ?

Cyclic codes are the subclass of linear block codes. They have the property that a cyclic shift of one codeword produces another codeword. For example consider the codeword.

$$X = (x_{n-1}, x_{n-2}, \dots x_1, x_0)$$

Let us shift above code vector to left cyclically,

$$X' = (x_{n-2}, x_{n-3}, \dots x_0, x_1, x_{n-1})$$

Above code vector is also a valid code vector.

7. How syndrome is calculated in Hamming codes and cyclic codes ?

In Hamming codes the syndrome is calculated as,

$$S = YH^T$$

Here Y is the received and H^T is the transpose of parity check matrix.

In cyclic code, the syndrome vector polynomial is given as,

$$S(p) = rem\left[\frac{Y(p)}{G(p)}\right]$$

Here $Y(p)$ is received vector polynomial and $G(p)$ is generator polynomial.

8. What is BCH code-?

BCH codes are most extensive and powerful error correcting cyclic codes. The decoding of BCH codes is comparatively Simpler. For any positive integer 'm' and 't' (where $t < 2^{m-1}$) there exists a BCH code with following parameters:

Block length : $n = 2^{m-1}$
Number of parity check bits : $n - k \leq mt$
Minimum distance : $d_{min} \geq 2t + 1$

9. What is RS code ?

These are nonbinary BCH codes. The encoder for RS codes operate on multiple bits simultaneously. The *(n,k)* RS code takes the groups of m - bit symbols of the incoming binary data stream. It takes such *'k'* number of symbols in one block. Then the encoder adds *(n-k)* redundant symbols to form the codeword of *'n'* symbols.

RS code has:

Block length : $n = 2^m - 1$ symbols
Message size : k symbols
Parity check size : $n - k = 2t$ symbols
Minimum distance : $d_{min} = 2t + 1$ symbols

10. What is the difference between block codes and convolutional codes ?

Block codes take *'k'* number of message bit simultaneously and form 'n'-bit code vector. This code vector is also called block. Convolutional code takes one message bit at a time and generates two or more encoded bits. Thus convolutional codes generate a string of encoded bits for input message string.

11. Define constraint length in convolutional codes .

Constraint length is the number of shifts over which the single message bit can influence the encoder output. It is expressed in terms of message bits.

12. Define free distance and coding gain.

Free distance is the minimum distance between code vectors. It is also equal to minimum weight of the code vectors.

Coding gain is used as a basis of comparison for different coding methods. To achieve the same bit error rate the coding gain is defined as,

$$A = \frac{\left(\frac{E_b}{N_o}\right) encoded}{\left(\frac{E_b}{N_o}\right) coded}$$

For convolutional coding, the coding gain is given as,

$$A = \frac{r d_f}{2}$$

Here 'r' is the code rate

And $'d_f'$ is the free distance

13. What is meant by syndrome of linear block code?

The non-zero output of the produce *YHT* is called syndrome and it is used to detect the errors in y. syndrome is denoted by 'S' and it is given as,

$$S = YH^T$$

14. How is the syndrome computed for block codes? (Refer Q.7.)

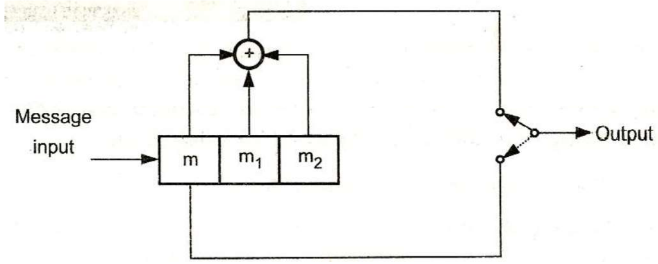
15. Draw the diagram of a convolutional encoder of rate 1/2 with generator polynomial :

$$g^{(1)}(D) = 1 + D + D^2 \text{ and } g^{(2)}(D) = 1.$$

Here $g_0^{(1)} = 1,\ g_1^{(1)} = 1$ and $g_2^{(1)} = 1$

and $g_0^{(2)} = 1,\ g_1^{(2)} = 0$ and $g_2^{(2)} = 0$

The generating sequences are {1 1 1} and {1 0 0} Fig. shows convolutional encoder for these sequences.



16. What is meant by RS coding? (Refer Q.9.)

17. What is convolutional code?

Fixed number of input bits are stored in the shift register and they are combined with the help of mod-2 adders. This operation is equivalent to binary convolution and hence it is called convolution coding.

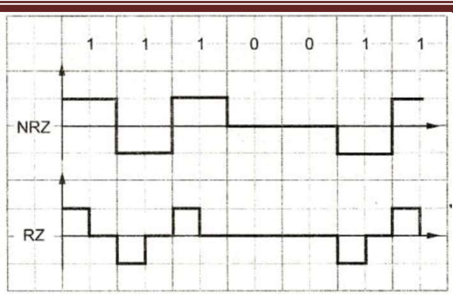
18. Explain the fundamental difference between block codes and convolutional codes. (Refer Q.10.)

19. How will you define coding gain with reference to error control codes? (Refer Q.12.**)**

20. What is meant by BCH code? (Refer answer of Q.8.**)**

21. What is meant by "pseudoternary signaling"?

Pseudoternary signaling: Successive 1s are coded with alternate positive and negative pulses. There are no pulses for zeros. Thus there are three voltage levels, + 1, - 1 and 0. It can be NRZ as well as RZ type. Fig. shows the waveforms for pseudoternary signaling.



22. What are the fundamental properties exhibited by cyclic codes ?

Following properties are exhibited by cyclic codes :

i) Linearity property : It states that sum of any two codewords is also a valid codeword. For example if X_1 and X_2 are two codewords,

$$X_3 = X_1 \oplus X_2$$

Here X_3 is also a valid codeword.

ii) Cyclic property : Every cyclic shift of a valid code vector produces another valid code vector.

For example, $X = \{x_{n-1}, x_{n-2}, \ldots . x_1, x_0\}$

Shifting the bits of above code vector to left cyclically by one bit,

$$X' = \{x_{n-2}, x_{n-3}, \ldots . x_1, x_0, x_{n-1}\}$$

Here X' is also a valid code vector.

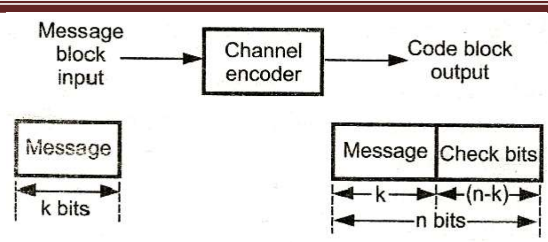
23. What is meant by RS coding? (Refer answer of Q.16)

24. Define minimum distance.

Minimum distance : It is the smallest hamming distance between the valid code vectors. The error detecting and correcting capabilities of the codes depend upon minimum distance.

25. Define linear block code.

Linear block codes: For the block of *'k'* message bits, *(n - k)* parity bits or check bits are added. Hence the total bits at the output of channel encoder are *'n'*. Such codes are called *(n, k)* block codes.



26. **What is meant by constraint length of a convolutional code ?** (Refer Q.11.)
27. **Define Hamming distance between linear block codes. Give the error correction and error detection capability interms of Hamming distance.**

Hamming distance : Refer answer of Q.l.

Error detection and correction capabilities :

28. **Define Hamming distance of a block code.** (Refer Q.1.)
29. **What are the error detection and error correction capabilities of Hamming code?** (Refer Q.5.)
30. **List the differences between block codes and convolutional codes.** (Refer Q.10.)
31. **Define Hamming weight and minimum Hamming distance.**

Hamming weight: The number of 1's in the code word of the Hamming code is called Hamming weight.

Minimum Hamming distance: Refer Q.l

32. **Define Hamming distance and calculate the hamming distance value for two code words 11100 and 11011**

Hamming distance: Refer Q.l

The two code words 1 1 1 0 0 and 1 1 0 1 1 differ in 3rd , 4th and 5th bits. Since 'three' bits differ between the two code words, the Hamming distance is '3'.

33. **Draw the NRZ and RZ code for the digital data 10110001.**