

## 11.4 QUIZ INTRODUCTION

Assume that a **(9, 4, 4)** block code is generated by taking a block of four data bits [**D1 D2 D3 D4**] and appending five parity bits [**P1 P2 P3 P4 P5**], where **P1** through **P4** are chosen to ensure that each row or column in the figure below has even parity, and P5 is computed to ensure the entire codeword has even parity.

D <sub>1</sub>	D <sub>2</sub>	P <sub>1</sub>
D <sub>3</sub>	D <sub>4</sub>	P <sub>2</sub>
P <sub>3</sub>	P <sub>4</sub>	P <sub>5</sub>

The resulting codeword is [**D1 D2 D3 D4 P1 P2 P3 P4 P5**].

For the codewords given in the following quiz questions, assume that at most two bit errors have occurred within each nine bit codeword, and that we wish to correct errors if possible. Determine how many (if any) bit errors occurred and whether any changes should be made to the received data bits **D1** through **D4**.

### 11.4 QUIZ QUESTION 1 (1 point possible)

Received codeword: [0 1 1 0 0 1 1 0 1]

Please select the correct answer.

- ☐ No bit errors occurred, and the data bits do not need to be corrected.
- ☒ One bit error occurred, and one of the data bits should be corrected. ✓
- ☐ One bit error occurred, but the data bits need not be corrected.
- ☐ Two bit errors occurred, and at least one of the data bits should be corrected.
- ☐ Two bit errors occurred, but we cannot determine which bits to correct.

#### EXPLANATION

According to coding rule given in the above table, we can rearrange the received codeword as below.

```

0 1 0
1 0 1
1 0 1

```

Compute 5 syndrome bits as:

D <sub>1</sub>	D <sub>2</sub>	P <sub>1</sub>	S <sub>1</sub>	
D <sub>3</sub>	D <sub>4</sub>	P <sub>2</sub>	S <sub>2</sub>	0 1 0 1
P <sub>3</sub>	P <sub>4</sub>	P <sub>5</sub>		1 0 1 0
S <sub>3</sub>	S <sub>4</sub>		S <sub>5</sub>	1 0 1
				0 1 1

Since **S5** = 1, a 1-bit error has occurred. We check the other syndrome bits to see which bit to correct. Since **S1** and **S4** both equal one, the data bit **D2** must be corrected.

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## 11.4 QUIZ QUESTION 2 (1 point possible)

Received codeword: [1 0 0 0 0 0 0 1]

Please select the correct answer.

- ☐ No bit errors occurred, and the data bits do not need to be corrected.
- ☐ One bit error occurred, and one of the data bits should be corrected.
- ☐ One bit error occurred, but the data bits need not be corrected.
- ☐ Two bit errors occurred, and at least one of the data bits should be corrected.
- ☒ Two bit errors occurred, but we cannot determine which bits to correct. ✓

### EXPLANATION

According to coding rule given in the above table, we can rearrange the received codeword as below.

```

1 0 0
0 0 0
0 0 1

```

Compute 5 syndrome bits as:

$D_1$	$D_2$	$P_1$	$S_1$	
$D_3$	$D_4$	$P_2$	$S_2$	1 0 0 1
$P_3$	$P_4$	$P_5$		0 0 0 0
$S_3$	$S_4$		$S_5$	0 0 1
				1 0 0

Since  $S_5 = 0$ , either zero or two errors have occurred. Since some of the other parity bits are nonzero ( $S_1$  and  $S_3$ ), a 2-bit error must have occurred. However, since there are two valid codewords a Hamming distance of two away from the received codeword, we cannot determine which bits to correct. In particular, either there could have been errors in the parity bits  $P_1$  and  $P_3$ , or there could have been errors in the data bit  $D_1$  and the parity bit  $P_5$ .

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## 11.4 QUIZ QUESTION 3 (1 point possible)

Received codeword:  $[0\ 0\ 0\ 1\ 0\ 1\ 0\ 1\ 1]$ 

Please select the correct answer.

- ☒ No bit errors occurred, and the data bits do not need to be corrected. ✓
- ☐ One bit error occurred, and one of the data bits should be corrected.
- ☐ One bit error occurred, but the data bits need not be corrected.
- ☐ Two bit errors occurred, and at least one of the data bits should be corrected.
- ☐ Two bit errors occurred, but we cannot determine which bits to correct.

## EXPLANATION

According to coding rule given in the above table, we can rearrange the received codeword as below.

```

0 0 0
0 1 1
0 1 1

```

Compute the five syndrome bits:

$D_1$	$D_2$	$P_1$	$S_1$	
$D_3$	$D_4$	$P_2$	$S_2$	0 0 0 0
$P_3$	$P_4$	$P_5$		0 1 1 0
$S_3$	$S_4$		$S_5$	0 1 1 0
				0 0 0 0

Since all syndrome bits are 0, no error occurred. No correction is needed.

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#### 11.4 QUIZ QUESTION 4 (1 point possible)

Received codeword:  $[1\ 0\ 1\ 0\ 0\ 1\ 0\ 0\ 0]$

Please select the correct answer.

- ☐ No bit errors occurred, and the data bits do not need to be corrected.
- ☐ One bit error occurred, and one of the data bits should be corrected.
- ☒ One bit error occurred, but the data bits need not be corrected. ✓
- ☐ Two bit errors occurred, and at least one of the data bits should be corrected.
- ☐ Two bit errors occurred, but we cannot determine which bits to correct.

#### EXPLANATION

According to coding rule given in the above table, we can rearrange the received codeword as below.

```

1  0  0
1  0  1
0  0  0

```

Compute 5 syndrome bits:

$D_1$	$D_2$	$P_1$	$S_1$	
$D_3$	$D_4$	$P_2$	$S_2$	1 0 0 1
$P_3$	$P_4$	$P_5$		1 0 1 0
$S_3$	$S_4$		$S_5$	0 0 0
				0 0 1

Since  $S_5 = 1$ , a 1-bit error has occurred. We check the other syndrome bits to see which bit to correct. Since only  $S_1 = 1$ , only  $P_1$  is wrong. Thus, no correction is needed for the data bits.

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