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Binary Codes:-

Codes have been used for security reasons, so that others will not be able to read the message. There are many types of codes, each one of them have 4-bits, but the weight must be chosen in such a way that these sums is not greater than 15 and less than 9.

- BCD (8421) code:-

The binary coded decimal (BCD) is a type of binary code used to represent a given decimal number in an equivalent binary form. BCD-to-decimal and decimal-to-BCD conversions are very easy and straightforward. The BCD equivalent of a decimal number is written by replacing each decimal digit in integer and fractional parts with its four-bit binary equivalent. Table below gives the four bit code for one decimal digits:-

Decimal Symbol	BCD digit 8421
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001

Note:- ① It is important to realize that BCD numbers are decimal numbers and not binary numbers although they use bits in their representation.

② It is unable to decode binary numbers greater than 9. (The binary combination 1010 through 1111 are not used and have no meaning in the BCD code) because the decimal system do not have greater than 9.

Ex:- Convert each of the following decimal numbers to BCD code:

a) $(185)_{10}$ b) $(23.15)_{10}$ c) $(2469)_{10}$

Solution:- a) $(185)_{10}$

$(0001\ 1000\ 0101)_{BCD}$.

b) $(23.15)_{10}$

$(0010\ 0011\ .0001\ 0101)_{BCD}$

c) $(2469)_{10}$

$(0010\ 0100\ 0110\ 1001)_{BCD}$.

Ex:- Convert each of the following BCD codes to decimal:- *(H.w) and binary

a) $(0011\ 0101\ 0001)_{BCD}$ b) $(0010\ 1001 . 0111\ 0101)_{BCD}$

Solution:- a) $(\underset{3}{0011}\ \underset{5}{0101}\ \underset{1}{0001})_{BCD} \rightarrow (351)_{10}$

b) $(\underset{2}{0010}\ \underset{9}{1001} . \underset{7}{0111}\ \underset{5}{0101})_{BCD} \rightarrow (29.75)_{10}$

H.w:- Convert the following decimal number to BCD code and binary number.

a) 171.625 b) 171

- Other Decimal Codes :-

Many different codes can be formulated by arranging four bits into 10 distinct combination. The representative codes are shown in table below. Each code used only 10 out of a possible 16-bit combinations that can be arranged with four bits. The other six unused combinations have no meaning and should be avoided.

Decimal digit	2421*	84-2-1	7421	6311	5421	4221	Excess-3
0	0000	0000	0000	0000	0000	0000	0011
1	0001	0111	0001	0001	0001	0001	0100
2	0010	0110	0010	0011	0010	0010	0101
3	0011	0101	0011	0100	0011	0011	0110
4	0100	0100	0100	0110*	0100	1000	0111
5	1011	1011	0101	0111	1000	0111*	1000
6	1100	1010	0110	1000	1001	1100	1001
7	1101	1001	1000	1001	1010	1101	1010
8	1110	1000	1001	1011	1011	1110	1011
9	1111	1111	1010	1100	1100	1111	1100

Note:- ① The BCD and the 2421 codes are weighted codes. In weighted code, each position is assigned a weighting factor in such a way that each digit can be evaluated by adding the weights to all the 1's in the coded combination. The 84-2-1 code is an example of assigning both positive and negative weights to decimal code:-

$(6)_{10} = (0110)_{BCD} = (0*8)+(1*4)+(1*2)+(0*1)$

$(7)_{10} = (1101)_{2421} = (2*1)+(4*1)+(2*0)+(1*1)$

$(2)_{10} = (0110)_{84-2-1} = (8*0)+(4*1)+(-2*1)+(-1*0)$

② The Ex-3 code is a digital code obtained by adding three to each decimal digit and then converting the result to 4 bit binary. It is unweight code. It is example of self-complementing codes. The 9's complement is obtained directly by changing 1's → 0's and 0's → 1 in the code. $(395)_{10} \rightarrow (0110\ 1100\ 1000)_{Ex3}$

$(604)_{10} \rightarrow (1001\ 0011\ 0111)_{Ex3}$

Ex:- Convert the following decimal numbers:-

a) $(16)_{10} \rightarrow$ BCD code

b) $(7)_{10} \rightarrow$ 2421 code

c) $(395)_{10} \rightarrow$ EX-3 code.

Solution:-

a) $(16)_{10} \rightarrow (0001\ 0110)_{BCD}$

b) $(7)_{10} \rightarrow (1101)_{2421}$

c) $(395)_{10} \rightarrow (0110\ 1100\ 1000)_{EX-3}$

H.W:- Write the following decimal number in 4221 and 5421 codes ? $(98.16)_{10}$

Gray Code:-

The Gray code is unweighted and is not an arithmetic code; that is, there are no specific weights assigned to the bit positions. The important feature of the Gray code is that is exhibits only a single bit change from one code word to the next in sequence. This property is important in many applications, such as shaft position encoders, where error susceptibility increases with the number of bits changes between adjacent numbers in a sequence. Like binary numbers, the Gray code can have any number of bits. In going from decimal 3 to decimal 4, the Gray code changes from 0010 to 0110 while the binary code change from 0011 to 0100, a change of three bits.

a) Binary to Gray Code Conversion:-

The MSB in the Gray code is the same as the corresponding MSB in the binary number. Going from left to right, add each adjacent pair of binary code bits to get the next Gray code bit. Discard carries.

Ex:- Convert the binary number (10110) to Gray code:-

Solution: 1 + 0 + 1 + 1 + 0 ← binary

↓ ↓ ↓ ↓ ↓

1 1 1 0 1 ← Gray code

$(10110)_2 \longrightarrow (11101)_{\text{Gray code}}$

b) Gray to Binary Conversion:-

The MSB in the binary code is the same as the corresponding bit in the Gray code. Add each binary bit generated to the Gray code bit in the next adjacent position. Discard carries.

Ex:- Convert the Gray code (11011) to binary:-

Solution:-

1 1 0 1 1 Gray

1 0 0 1 0 binary

$(11011)_{\text{Gray}} \longrightarrow (10010)_2$

H.W(1): List the 4-bit Gray code for decimal numbers from 0 → 15.

H.W(2): (a) Convert binary 101101 to Gray code

(b) Convert Gray code 100111 to binary.