CS 225 – Digital Logic and Design

Week 11 Lecture 2
Binary Codes

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Binary Codes

- Binary-Coded Decimal Code
- Other Decimal Codes
- Gray Code
- ASCII Character Code
- Error-Detecting Code

Binary Coded Decimal Code

Table 1.4 gives the four-bit code for one decimal digit. A number with k decimal digits will require $4k$ bits in BCD. Decimal 396 is represented in BCD with 12 bits as 0011 1001 0110, with **each group of 4 bits representing one decimal digit.** A decimal number in BCD is the same as its equivalent binary number only when the number is between 0 and 9. A BCD number greater than 10 looks different from its equivalent binary number, even though both contain 1's and 0's. Moreover, **the binary combinations 1010 through 1111 are not used and have no meaning in BCD.** Consider decimal 185 and its corresponding value in BCD and binary:

$$(185)_{10} = (0001\,1000\,0101)_{BCD} = (10111001)_2$$

Table 1.4 – Binary Coded Decimal (BCD)

Table 1.4
Binary-Coded Decimal (BCD)

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

Binary Coded Decimal Code (Contd.)

- ***$(185)_{10} = (0001\ 1000\ 0101)_{BCD} = (10111001)_2$***
- The BCD value has 12 bits to encode the characters of the decimal value, but the equivalent binary number needs only 8 bits.
- It is obvious that the representation of a BCD number needs more bits than its equivalent binary value. However, there is an advantage in the use of decimal numbers, because computer input and output data are generated by people who use the decimal system.
- It is important to realize that BCD numbers are decimal numbers and not binary numbers, although they use bits in their representation.
- The only difference between a decimal number and BCD is that decimals are written with the symbols ***0***, ***1***, ***2***,..., ***9*** and BCD numbers use the binary code ***0000***, ***0001***, ***0010***, c, ***1001***.
- The decimal value is exactly the same.

Binary Coded Decimal Code (Contd.)

- Decimal ***10*** is represented in BCD with eight bits as ***0001 0000*** and decimal ***15*** as ***0001 0101***.
- The corresponding binary values are ***1010*** and ***1111*** and have only four bits.

Other Decimal Codes

- Binary codes for decimal digits require a minimum of four bits per digit.
- Many different codes can be formulated by arranging four bits into 10 distinct combinations.
- BCD and three other representative codes are shown in Table 1.5.
- Each code uses 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.

Table 1.5 – Other Decimal Codes

Table 1.5
Four Different Binary Codes for the Decimal Digits

Decimal Digit	BCD 8421	2421	Excess-3	8, 4, −2, −1
0	0000	0000	0011	0000
1	0001	0001	0100	0111
2	0010	0010	0101	0110
3	0011	0011	0110	0101
4	0100	0100	0111	0100
5	0101	1011	1000	1011
6	0110	1100	1001	1010
7	0111	1101	1010	1001
8	1000	1110	1011	1000
9	1001	1111	1100	1111
	1010	0101	0000	0001
Unused	1011	0110	0001	0010
bit	1100	0111	0010	0011
combi-	1101	1000	1101	1100
nations	1110	1001	1110	1101
	1111	1010	1111	1110

Table 1.5 – Weighted and Un-weighted Codes

- ***BCD*** and the ***2421*** code are examples of weighted codes.
- In a weighted code, each bit position is assigned a weighting factor in such a way that each digit can be evaluated by adding the weights of all the ***1's*** in the coded combination.
- The ***BCD*** code has weights of ***8***, ***4***, ***2***, and ***1***, which correspond to the power-of-two values of each bit.
- The ***excess-3 code*** has been used in some older computers because of its self complementing property.
- ***Excess-3*** **is an** ***un-weighted code*** **in which each coded combination is obtained from the corresponding binary value plus 3.**

Gray Code / Reflected Code

- The output data of many physical systems are quantities that are continuous. Must be converted into digital form to a digital system.
- Analog-to-Digital Converter
- It is sometimes convenient to use the Gray code shown in Table 1.6 to represent digital data that have been converted from analog data.
- The advantage of the Gray code over the straight binary number sequence is that only one bit in the code group changes in going from one number to the next.
- For example, in going from ***7*** to ***8***, the Gray code changes from ***0100*** to ***1100***. Only the first bit changes, from 0 to 1; the other three bits remain the same.
- By contrast, with binary numbers the change from ***7*** to ***8*** will be from ***0111*** to ***1000***, which causes all four bits to change values.

Table 1.6 – Gray Code / Reflected Code

Table 1.6
Gray Code

Gray Code	Decimal Equivalent
0000	0
0001	1
0011	2
0010	3
0110	4
0111	5
0101	6
0100	7
1100	8
1101	9
1111	10
1110	11
1010	12
1011	13
1001	14
1000	15

Table: Decimal – Gray – Binary

Decimal	Gray	Binary
0	0000	0000
1	0001	0001
2	0011	0010
3	0010	0011
4	0110	0100
5	0111	0101
6	0101	0110
7	0100	0111

Gray Code / Reflected Code (Contd.)

- Gray Code

Conversion from Binary to Gray Code

- Binary Number: ***11000110***
- Corresponding Gray Code: ***10100101***

1. Write MSB as it is
2. Add first MSB and second MSB, place the result at second MSB location by discarding carry, if any.
3. Repeat step 2 until number ends.

Conversion from Gray Code to Binary

- Gray Code: ***10100101***
- Corresponding Binary Number: ***11000110***

1. Write MSB as it is.
2. Add first MSB of new binary number and second MSB of Gray Code and place the result at second MSB location of new binary number by discarding carry, if any.
3. Repeat step 2 until number ends.

- That's end of the presentation ! ☺