• Binary Codes

→ Digital systems use signals that have two distinct values and circuit elements that have two stable states.

→ Digital systems represent and manipulate not only binary numbers, but also many other discrete elements of information.

→ Any discrete element of information that is distinct among a group of quantities can be represented with a binary code (i.e., a pattern of 0's and 1's)

→ The codes must be in binary because, in today's technology, only circuits that represent and manipulate

patterns of 0's and 1's can be manufactured economically for use in computers.

→ An n-bit binary code is a group of n-bits that assumes up to 2^n distinct combinations of 1's and 0's, with each combination representing one element of the set that is being coded.

→ The bit combination of an n-bit code is determined from the count in binary from 0 to $2^n - 1$.

→ Each element must be assigned a unique binary bit combination, and no two elements can have the same value.

→ A set of four elements can be coded with two bits, with each element assigned one of the bit combinations: 00, 01, 10, 11

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.

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

Other Codes
5211
5421
642-3

→ Each code uses only 10 out of possible 16 bit combinations that can be arranged with four bits.

→ The other six unused combinations have no meaning and should be avoided.

→ 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.

→ BCD and the 2421 code are examples of weighted codes.

→ BCD code has weights of 8, 4, 2 and 1, which correspond to the power-of-two values of each bit.

→ For example, the bit assignment 0110 is interpreted by the weights to represent decimal 6 because $8\times0 + 1\times4 + 1\times2 + 0\times1 = 6$

→ The bit combination 1101, when weighted by the respective digits 2421, gives the decimal equivalent of $1\times2 + 1\times4 + 0\times2 + 1\times1 = 7$

→ Some digits can be coded in two possible ways in the 2421 code.

→ For example, decimal 4 can be assigned to bit combination 0100 or 1010, since both combinations add up to a total weight of 4.

→ The 2421 and the excess-3 code are examples of self-complementing codes.

→ Self-complementing codes have the property that the 9's complement of a decimal number is obtained directly by changing 1's to 0's and 0's to 1's (i.e. by complementing each bit in the pattern).

→ For example, decimal 395 is represented in the excess-3 code as 0110 1100 1000. The 9's complement is 604 represented as 1001 0011 0111, which is obtained simply by complementing each bit of the code.

→ Excess-3 is an unweighted code in which each coded combination is obtained from the corresponding binary value plus 3.

→ 8, 4, -2, -1 code is an example of assigning both positive and negative weights to a decimal code.

→ For example, the bit combination 0110 is interpreted as decimal 2 and is calculated from $8\times0+4\times1+(-2)\times1+(-1)\times0=2$.

Gray Code (Unit Distance Codes)

→ Cyclic codes are those in which each successive code word differs from the preceding one in only one bit position. They are also called unit distance codes.

→ The unit distance codes have special advantage of minimizing transitional errors or flashing.

→ A reflective code is a binary code in which the n least significant bits for code words 2^n through $2^{n+1}-1$ are the mirror images of those for 0 through 2^n-1.

→ Gray code is used to represent digital data that have been converted from analog data.

→ For example, the analog data by a continuous change in the angular position of a shaft is represented in Gray code.

→ Gray code is a non-weighted code, which is both reflective and unit distance. It is not a BCD 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

→ The Gray code is used in applications in which the normal sequence of binary numbers generated by the hardware may produce an error or ambiguity during the transition from one number to the next

→ If binary numbers are used, a change from 0111 to 1000 may produce an intermediate erroneous number 1001 if the value of the rightmost bit takes longer to change than the values of the other three bits.

→ This could have serious consequences for the machine using the information.

→ The Gray code eliminates this problem, since only one bit changes its value during any transition between two numbers.