Chapter 3

Number Systems and Codes In PLC

3.1 Decimal number system.
3.2 Binary number system.
3.3 Octal number system.
3.4 Hexadecimal number system.
3.5 BCD number system.
3.6 Encoding and decoding.

3.1 Decimal Number System

The decimal number system, which is most common to us, has a base of 10 and uses digits from 0 to 9. The value of decimal number depends on the digits that make up the number and the place value of each digit. A place (weight) value is assigned to each position that a digit would hold from right to left. Consider the following example:

Weight value	3	2	1	0
Decimal number	1	9	6	2_{10}

Weight (points to the weight value 0)

Base (points to the subscript 10)

$2 \times 10^0 = 2 \times 1 = 2$

$6 \times 10^1 = 6 \times 10 = 60$

$9 \times 10^2 = 9 \times 100 = 900$

$1 \times 10^3 = 1 \times 1000 = 1000$

Sum of product 1962_{10}

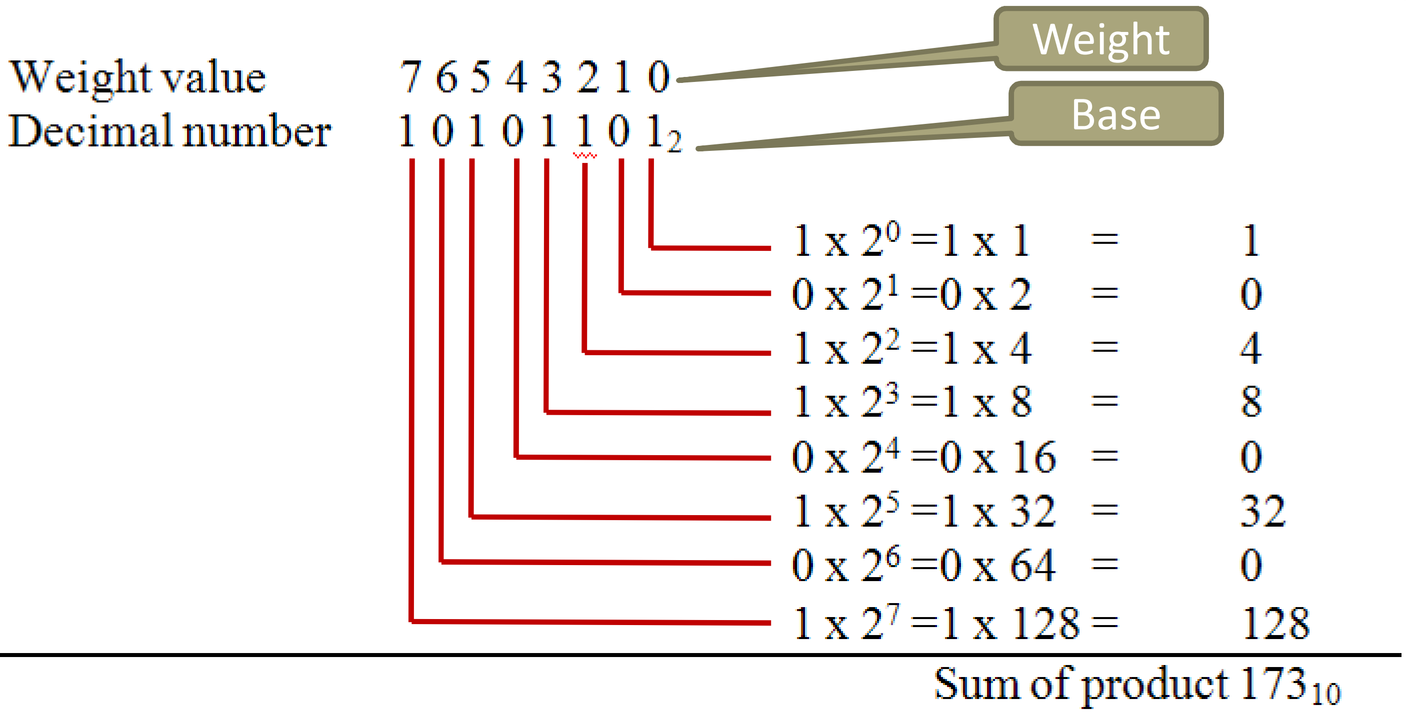
3.1 Binary Number System

The binary system uses the number 2 as base and only two digits are use of 0 and 1. In digital circuit, digit 1 or logic 1 is used for high voltage (e.g. +5Volts) and digit 0 or logic 0 is used for low voltage (e.g. 0 Volts). Binary system is used in PLC's and computer systems.

Binary system uses only two digits, each position of a binary number can go through only two changes, and then a 1 is carried to the immediate left position as shown in table 3.1.

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

3.2 Binary Number System



Data in PLC like Computer System:
Bit, Byte, Word, Double Word, ..

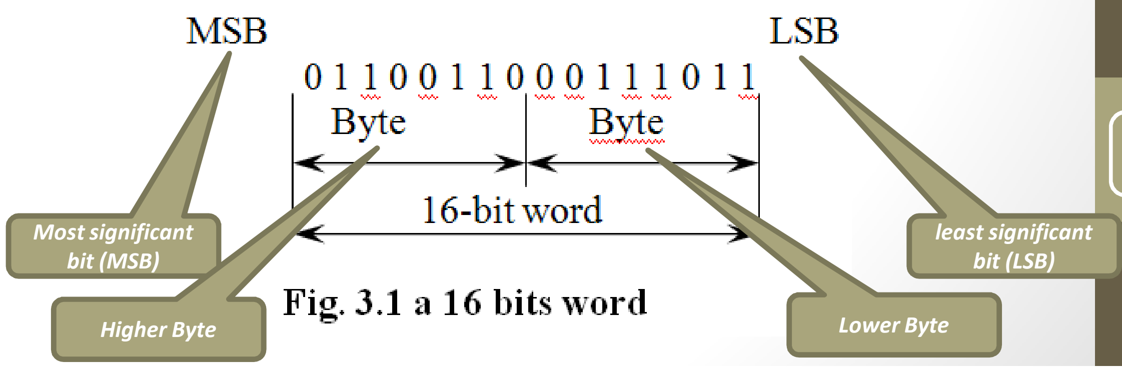


Fig. 3.1 a 16 bits word

3.2 Binary Number System

To convert a decimal number to its binary equivalent, we must perform a series of divisions by 2 as shown in the following illustrated example:

Decimal No.				
47	/ 2 = 23	with a remainder of	1	LSB
23	/ 2 = 11	with a remainder of	1	
11	/ 2 = 5	with a remainder of	1	
5	/ 2 = 2	with a remainder of	1	
2	/ 2 = 1	with a remainder of	0	
1	/ 2 =	with a remainder of	1	MSB

The obtained binary number is : 101111_2

Decimal No.

3.3 Octal Number System

To express the number in binary system requires many more digits than in the decimal number system. Too many binary digits become cumbersome to read or write. To solve this problem the octal and hexadecimal number systems are used. The octal system use number 8 as its base and makes use of eight digits from 0 through 7 to form octal number. As in all other number systems, each digit in an octal number has a weighted decimal value according to its position. The following example illustrates how the octal number 462 is converted to its decimal equivalent 306.

Decimal weight	2	1	0
Octal number	4	6	2_8

Weight

Base

$$\begin{aligned} 2 \times 8^0 &= 2 \times 1 = 2 \\ 6 \times 8^1 &= 6 \times 8 = 48 \\ 4 \times 8^2 &= 4 \times 64 = 256 \end{aligned}$$

Sum of product 306_{10}

3.3 Octal Number System

Table 3.2 Counting to decimal 7 in octal number system

Octal number	Binary number
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

The octal number 462 can be converted to its binary equivalent by assembling the 3-bit groups as illustrated below, Fig 3.2

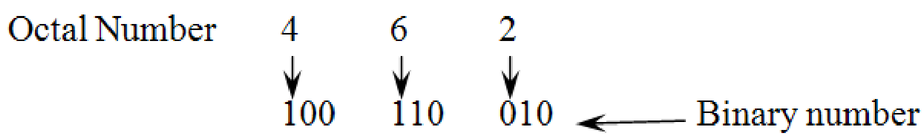


Fig. 3.2 Converting an octal to binary.

3.4 Hexadecimal Number System

The hexadecimal (Hex) numbering system provides even shorter notation than octal. Hexadecimal uses a base of 16. It employs 16 digits: number 0 through 9, and letters A through F, with A through F substituted for numbers 10 to 15, respectively, see Table 3.3.

Hexadecimal numbers can be expressed as their decimal equivalents by using the sum of weights method, as shown in the following example:

Weight	2	1	0
Hex. Number	1	B	7

$$7 \times 16^0 = 7 \times 1 = 7$$
$$11 \times 16^1 = 11 \times 16 = 176$$
$$1 \times 16^2 = 1 \times 256 = 256$$

Sum of products 439_{10}

3.4 Hexadecimal Number System

Hex. Number 1 B 7

0001 1011 0111 ← Binary number

Table 3.3 Hexadecimal numbering systems.

Hexadecimal	Binary	Decimal
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
A	1010	10
B	1011	11
C	1100	12
D	1101	13
E	1110	14
F	1111	15

3.5 BCD (Binary Coded Decimal) Number System

The BCD system provides a convenient means to handle large numbers that need to be input to or output from a PLC or PC computer. The BCD system represents decimal numbers as patterns of 1's and 0's. This system provides a means of converting a code readily handled by humans (decimal) to code readily handled by the equipment (binary).

The BCD system uses 4 bits to represent each decimal digit. The 4 bits used are the binary equivalents of the number 0 to 9. In BCD system, the largest decimal number that can be displayed by any four digits is 9. Table 3.4 shows the 4-bit binary equivalents for each decimal number 0 through 9.

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

3.5 BCD (Binary Coded Decimal) Number System

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

The BCD representation of a decimal number is obtained by replacing each decimal digit by its BCD equivalent, as illustrated in the following example:

Decimal number : $(7 \quad 8 \quad 6 \quad 3)_{10}$

0111 1000 0110 0011 BCD number

BROBLEMS

3.1) Convert the following binary numbers to; decimal, octal and hexadecimal and to BCD ?

a) 00011111
b) 01001110
c) 00100101
d) 00111001
e) 000100100111

3.2) Convert the following hexadecimal numbers to binary ?

a) A1B4
b) B123
c) 23457

3.3) Convert the following octal numbers to binary ?

a) 771
b) 710
c) 650

3.4) Express the decimal number 17_{10} in each of the following number codes:

a) Binary.
b) Hexadecimal.
c) Octal.
d) BCD.