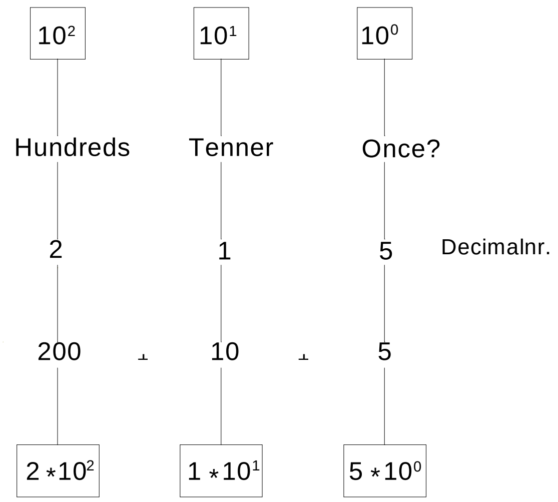
1 Number systems

A programmable logical controller uses the binary system rather than the decimal system to process memory cells, inputs, outputs, timers, flags etc.

1.1 DECIMAL SYSTEM

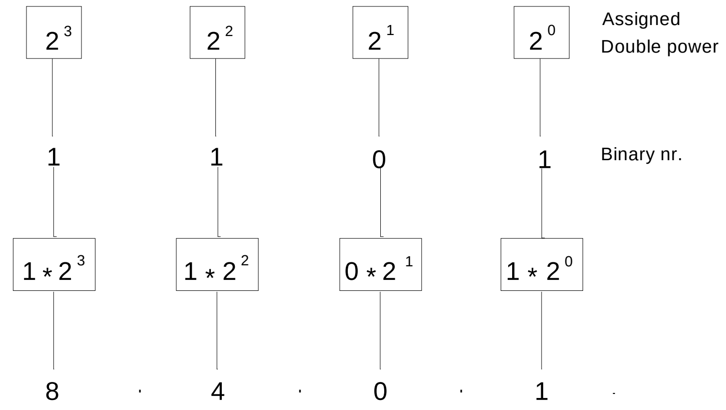
In order to understand the binary number system we must first examine the decimal system. The example below shows the structure of the number 215. The 2 represents the hundreds, the 1 represents the tens and the 5 represents the ones. The number 215 should really be written: 200+10+5. If the expression 200+10+5 is written down as shown below and decades are used, it can be seen that each digit of the number has a decade assigned to it.



Each digit within the decimal number has a decade assigned to it.

1.2 THE BINARY SYSTEM

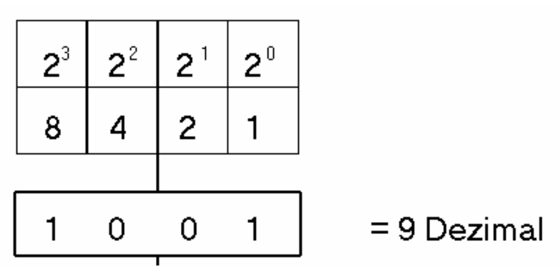
The binary system only uses the digits 0 and 1, which are easy to display and evaluate in data processing systems. It is therefore a binary number system.
Each binary digit in a binary number has the power of two assigned to it, as shown below.



Each digit within a binary number has the power of two assigned to it.

1.3 BCD code (8-4-2-1 code)

In order to display large numbers in a clearer way, BCD code (binary coded decimal) is often used. The decimal numbers are represented using the binary number system. The biggest decimal digit is 9, and 2^3 bits are required to represent this value, i.e. a total of 4 bits.



Because 4 bits are needed to represent the largest decimal digit, a four-bit unit is provided for each decimal digit (a tetrade). BCD code is therefore 4-bit code.

Each decimal number is individually coded. The number 285, for example, consists of three decimal digits. Each decimal digit appears in the BCD code as a four-bit unit (tetrade).

2	8	5
0010	1000	0101

Each decimal digit is shown with individual coding, using a tetrade.

1.4 THE HEXADECIMAL NUMBER SYSTEM

The hexadecimal number system is a positional notation system. Potentials of the value 16 are used as positional values. The hexadecimal system is therefore a base-16 number system.
Each digit within a hexadecimal number has the power of sixteen assigned to it. A total of 16 digits are required, including the zero. The decimal system is used for digits 0 to 9, and the letters A to F are used for digits 10 to 15.

Each digit within a hexadecimal number has the power of sixteen assigned to it.

1.5 NUMBER SYSTEM REPRESENTATION

Dezimalzahl	Dualzahl					Hexadezimalzahl
	16	8	4	2	1	
0					0	0
1					1	1
2				1	0	2
3				1	1	3
4			1	0	0	4
5			1	0	1	5
6			1	1	0	6
7			1	1	1	7
8		1	0	0	0	8
9		1	0	0	1	9
10		1	0	1	0	A
11		1	0	1	1	B
12		1	1	0	0	C
13		1	1	0	1	D
14		1	1	1	0	E
15		1	1	1	1	F
16	1	0	0	0	0	1 0
17	1	0	0	0	1	1 1
18	1	0	0	1	0	1 2
19	1	0	0	1	1	1 3

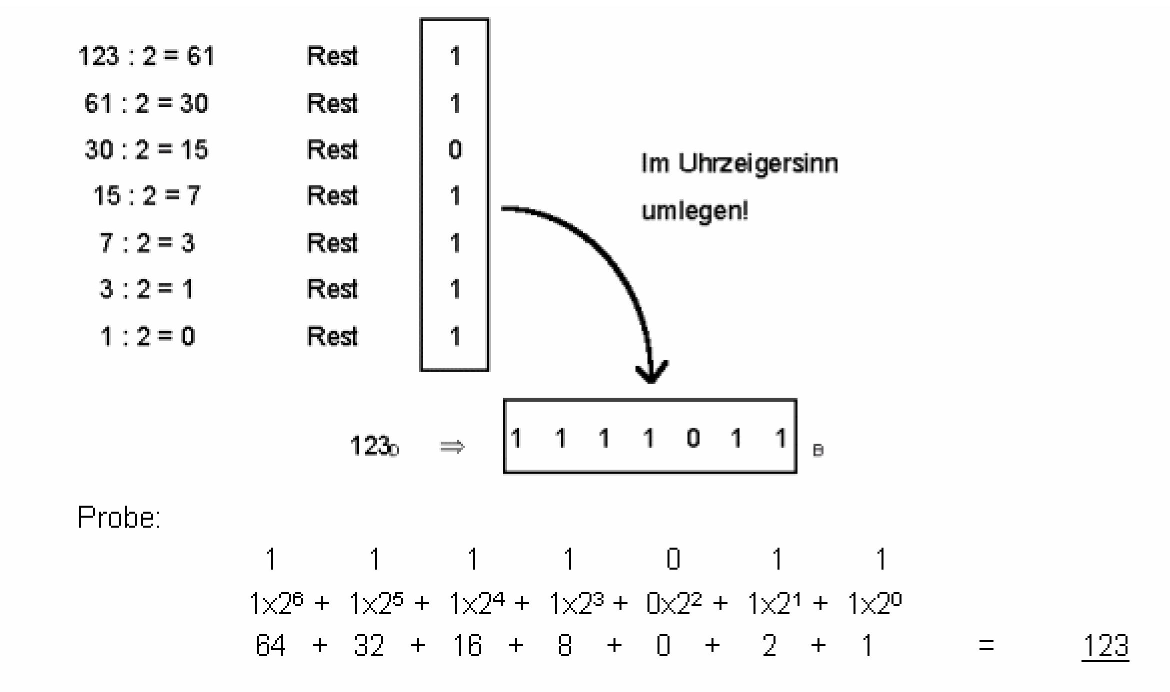
1.6 CONVERSION RULES

Converting between the different number systems is based upon some simple rules. The PLC user must master these rules, since they are often used when dealing with this technology. In order to identify the number system upon which a given number is based, it is marked with an index to the right of the number.
“D” stands for Decimal, “B” stands for Binary and “H” stands for Hexadecimal. This identifier is often needed, since a sequence of digits produces a totally different value depending on the number system that is being used.
For example, “111” in the decimal system is the number 111D (one hundred and eleven), in the binary system 111B would be a decimal value of 7 ($1x2^0 + 1x\ 2^1 + 1x2^2$) and as a hexadecimal value 111H would be a decimal value of 273 ($1x16^0 + 1x16^1 + 1x\ 16^2$).

1.6.1 Converting decimal → binary

Integer decimal values are divided by base 2 until the result is zero. The sequence of remainders of the division (0 or 1) produces the binary number. Attention must be paid to the direction of the “remainders”: The remainder of the first division is the first bit on the right (lowest-order bit).

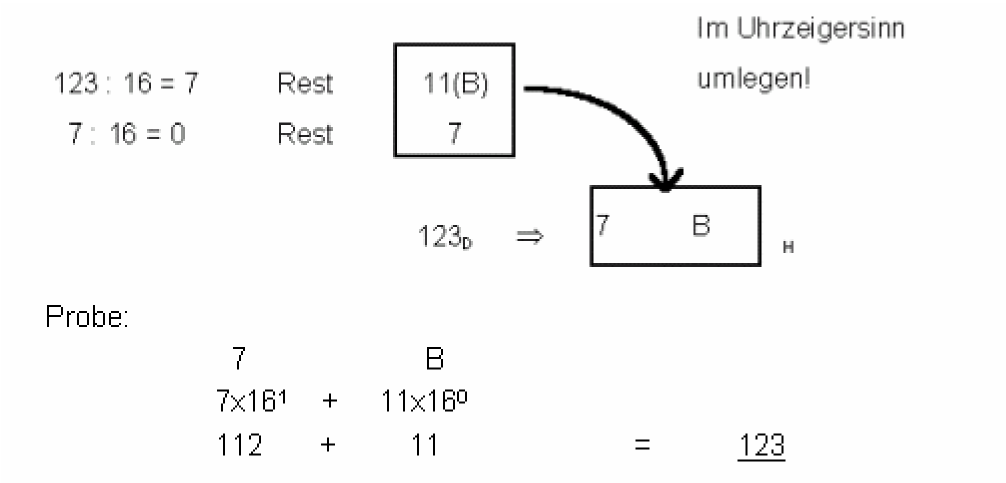
Example: Converting decimal value 123 into an appropriate binary number.



1.6.2 Converting decimal → hexadecimal

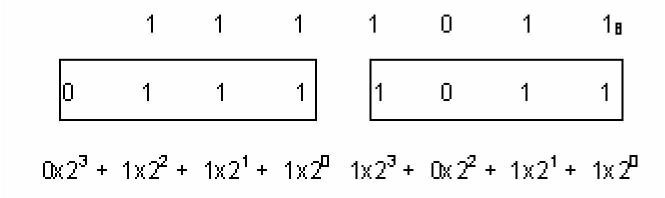
Conversion takes place in the same way as decimal → binary conversion. The difference here is that base 16 is used instead of base 2. In other words, you divide by 16 instead of 2.

Example: Converting decimal value 123 into an appropriate Hex number.



1.6.3 Converting binary → hexadecimal

In order to convert a binary number into a Hex number, the decimal value of the binary number must first be determined (add up the values). This decimal number could then be converted into a Hex number by dividing by 16.
However, it is also possible to convert directly from the binary number to the relevant Hex value.
The binary digits must first be split up into groups of four, starting from the right. Each of the groups of four then produces a digit in the hexadecimal number system. The left-most group must be padded with zeroes if necessary.
Example: Converting binary value 1111011 into an appropriate Hex number.



7 B $_{\text{Hex}}$

1.7 Twos complement

Description:
When a twos complement is being formed, the individual bits are inverted, i.e. the zeroes become ones and the ones become zeroes. Then a “1” is added to the result.

Example:
Twos complement of number 5 = binary 0101

Number 5 in binary	0	1	0	1
invert	1	0	1	0
+1				1
Number = -5 (twos complement)	1	0	1	1