U.S. DEPARTMENT OF ENERGY'S CYBERFORCE® PROGRAM

CyberForce® 101

Base Tutorial

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Base 10 to Base 2, 8, 16

Introduction

Modern computing uses a series of different numerical bases and exponents to express integer values. The most popular bases are binary (base 2), octal (base 8), decimal (base 10), and hexadecimal (base 16). It is important to know how to translate binary, octal and hexadecimal into decimal.

Decimal

Decimal depends on positional notation. Positional notation is a concept where a number's value depends on both the digit's value and its location. For example, 1 (one) has value, but by shifting the 1 left it makes 10 (ten) and changes the number's value. Another way of picturing this it through addition:

200
030
+04
234

This can also be shown as:

(2x100) + (3x10) + (4x1) = 234

An expanded version of this is:

(2x10^2) + (3x10^1) + (4x10^0) = 234

Every number can be expressed as a multiple of a power of ten.

Binary

Binary also depends on positional notation but there are only two numbers used: 1 (true) and 0 (false). Like decimal, binary depends on exponents, except two is the base instead of ten. Each digit is called a bit and a group of eight bits is called a byte. The bit that is furthest to the right is the least significant digit (meaning it represents 2^0 because computers increment from 0).

For example:

0101 (binary) = 5 (decimal)

This can be shown as:

0000 + 100 + 00 + 1 = 0101 = 5

An expanded version of this is:

$(0 \times 2^3) + (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0) = 0 + 4 + 0 + 1 = 5$

Octal

Octal also depends on positional notation but only uses eight numbers (0-7). Like decimal and binary, octal relies on exponents, except 8 is the base number.

For example:

147 (octal) = 103 (decimal)

This can be shown as:

100 + 40 + 7 = 147 = 103

An expanded version of this is:

$(1 \times 8^2) + (4 \times 8^1) + (7 \times 8^0) = 64 + 32 + 7 = 103$

Hexadecimal

Hexadecimal depends on positional notation but uses numbers (0-9) and letters (A-F). In decimal, A is 10, B is 11, C is 12, D is 13, E is 14, and F is 15. Hexadecimal's base number is 16.

For example:

3B (hexadecimal) = 59 (decimal)

This can be shown as:

30 + B = 3B = 59

An expanded version of this is:

$(3 \times 16^1) + (B \times 16^0) = 48 + 11 = 59$

Conclusion

Bases are used in a wide variety of computing operations, so it is important to understand how they work and how they can be converted.

Decimal	Binary	Octal	Hexadecimal
0	00000	0	0
1	00001	1	1
2	00010	2	2
3	00011	3	3
4	00100	4	4
5	00101	5	5
6	00110	6	6
7	00111	7	7
8	01000	10	8
9	01001	11	9
10	01010	12	A
11	01011	13	B
12	01100	14	C
13	01101	15	D
14	01110	16	E
15	01111	17	F
16	10000	20	10

Resources

https://www.rapidtables.com/convert/number/binary-to-decimal.html

https://www.rapidtables.com/math/number/Numeral_system.html