

DFSC 1316: digital forensic and information assurance fundamentals I

2. NUMBER SYSTEMS: BINARY, DECIMAL, AND HEXADECIMAL

Number System

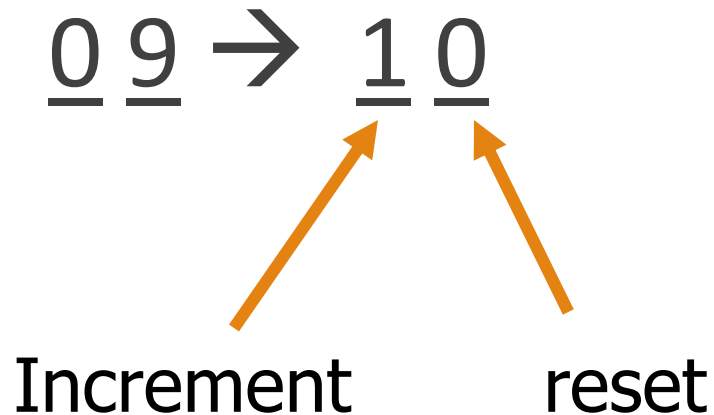
- Set of numbers.
- One or more operations, e.g. addition, subtraction, multiplication, division, etc.
- Examples: natural numbers (1, 2, 3, ...), integers (... , -2, -1, 0, 1, 2, ...), decimal numbers, binary numbers, hexadecimal numbers, etc.

Decimal Numbers: Basic Idea

- Decimal: contains 10 digits

0 1 2 3 ... 8 9 → ?

- Increment to the next digit, reset current:



Binary Numbers: Basic Idea

- Binary: contains only 2 digits, 0 and 1

0 1 → ?

- Increment to the next digit, reset current:

0 1 → 1 0

Increment

reset

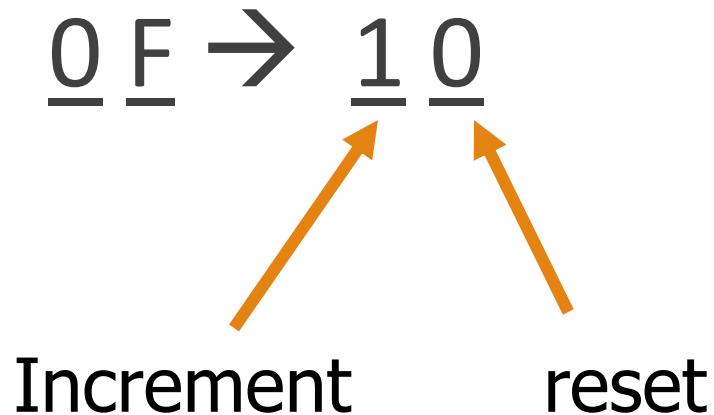
000 001 010 011 100 101 110 111

Hexadecimal Numbers: Basic Idea

- Hex: contains 16 digits

0 1 2 ... 9 A B C D E F

- Increment to the next digit, reset current:



Decimal Numeral System

- Number set : (0, 1, 2, ..., 8, 9)
- Base 10 positional notation
 - $1010 (D) = 1*10^3 + 0*10^2 + 1*10^1 + 0*10^0$
 $= 1*1000 + 0*100 + 1*10 + 0*1$
 $= 1010 (D)$
- Operations: addition, multiplication, etc.

Binary Numeral System

- Number set : (0 & 1)
- Base 2 [positional notation](#)
 - $1010 \text{ (B)} = 1*2^3 + 0*2^2 + 1*2^1 + 0*2^0$
 $= 1*8 + 0*4 + 1*2 + 0*1$
 $= 10 \text{ (D)}$
- Operations: addition, multiplication, etc.
 - Addition: $1001 + 1100 = 10101$
- Good for computer systems – logical gates with only two different values or states.

Hexadecimal Numeral System

- Base 16 positional notation
 - $1010 \text{ (H)} = 1 * 16^3 + 0 * 16^2 + 1 * 16^1 + 0 * 16^0$
 $= 1 * 4096 + 0 * 256 + 1 * 16 + 0 * 1$
 $= 4112 \text{ (D)}$
- Number set : (0 ~ 9, A, B, C, D, E, F)
- Operations: addition, multiplication, etc.

Exercise

- Write the numbers from 0 - 16 (decimal) in binary and hex.
- Why do we have Hex numbering system?

Decimal	Binary	Hexadecimal
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		

Operations

- The same operation rules apply also to binary and hex number.
- However, multiplication and division is not intuitive.
 - Exercise: $1001 + 101$, calculate for decimal and binary.
 - Exercise: 1001×101 , calculate for decimal and binary.
- More commonly, binary numbers are used for logical operations.

Conversion: Decimal to Binary

The diagram shows the conversion of the decimal number 156 to binary. On the left, a series of division steps are shown, each with a quotient and a remainder:

Division	Quotient	Remainder
2) 156	78	0
2) 78	39	0
2) 39	19	1
2) 19	9	1
2) 9	4	1
2) 4	2	0
2) 2	1	0
2) 1	0	1

To the right of the division steps, the remainders are listed vertically, with a red arrow pointing upwards from the bottom remainder (1) to the top remainder (0). The remainders, read from bottom to top, are 1, 0, 0, 1, 1, 1, 0, 0.

At the bottom, the final binary result is shown: $156_{10} = 10011100_2$. The binary number is written in red and underlined.

A hand holding a green pen is shown on the right side of the diagram, pointing towards the binary result.

wikiHow to Convert from Decimal to Binary

- Same rule applies to Decimal to Hexadecimal.

Conversion: Binary to Decimal

- Convert 100011 (B) to decimal.

$$1 \times 2^5 + 0 \times 2^4 + 0 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$$

$$= 32 + 0 + 0 + 0 + 2 + 1$$

$$= 35$$

- Same rule applies to Hex to Dec.
 - Exercise: convert EFF to decimal.

Binary ↔ Hexadecimal ↔ Decimal

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

Exercise

- $19 \text{ (D)} \rightarrow ? \text{ (B)} \rightarrow ? \text{ (H)}$
- $73 \text{ (D)} \rightarrow ? \text{ (B)} \rightarrow ? \text{ (H)}$
- $101101 \text{ (B)} \rightarrow ? \text{ (D)} \rightarrow ? \text{ (H)}$
- $1A3 \text{ (H)} \rightarrow ? \text{ (B)} \rightarrow ? \text{ (D)}$

Addition (Binary and Hex)

- $11000111 \text{ (B)} + 1101001 \text{ (B)} = ? \text{ (D) and (H)}$
- $C7 \text{ (H)} + 69 \text{ (H)} = ? \text{ (B) and (D)}$

Application

- Character encoding
 - ASCII -- American Standard Code for Information Interchange
 - 7 bits to represent all US characters.
 - <http://www.asciitable.com/>
 - Unicode
 - Uses variable length bits to represent characters in all languages.
 - <http://unicode.org/charts/>

Application

- Fingerprinting file types
 - Microsoft word has the file signature 50 4B (H)
 - .jpg file has the file signature FF D8 (H)
 - https://en.wikipedia.org/wiki/List_of_file_signatures

Application

- Basic file analysis
 - For example, steganography, i.e., hiding information in other files (such as a figure).

Quiz

1. Convert the decimal value 55 to binary and hexadecimal number.
2. Convert the binary value 10110011010 to decimal and hexadecimal number.
3. What is the base 2 positional notation of 111001010 ?
4. What is the base 16 positional notation of AF190DE?
5. $11000111 \text{ (B)} + C7 \text{ (H)} = ? \text{ (D)}$

Quiz

4.