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.

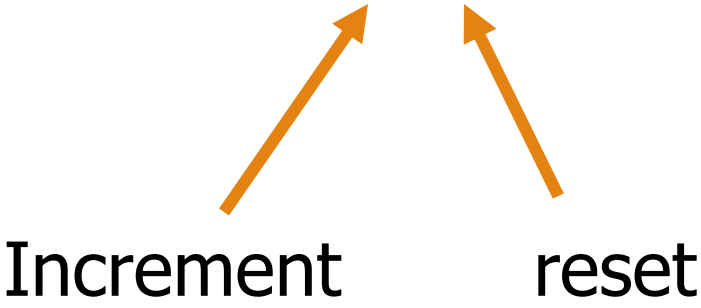
Decimal Numbers: Basic Idea

- Decimal: contains 10 digits

0 1 2 3 … 8 9 → ?

- Increment to the next digit, reset current:

0 9 → 1 0



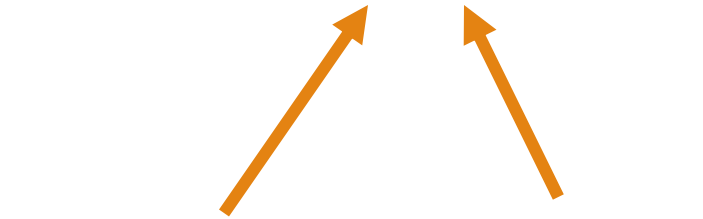
Binary Numbers: Basic Idea

- Binary: contains only 2 digits, 0 and 1

0 1 → ?

- Increment to the next digit, reset current:

0 1 → 1 0



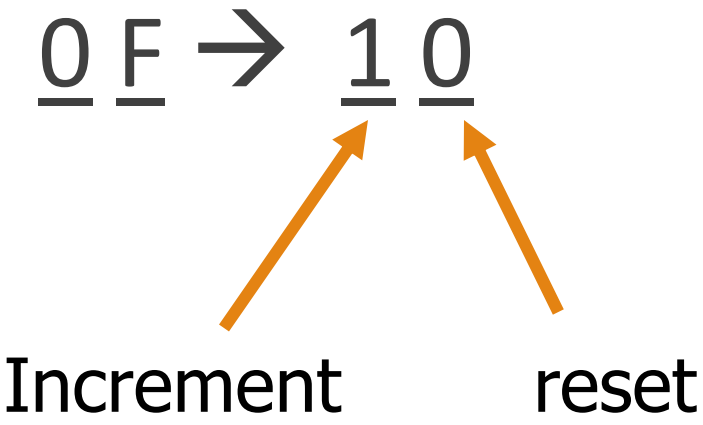
000 001 010 011 100 101 110 111

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
  - $1010\ (B) = 1*2^3 + 0*2^2 + 1*2^1 + 0*2^0$
    $= 1*8 + 0*4 + 1*2 + 0*1$
    $= 10\ (D)$
- 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
  - $1010\ (H) = 1*16^3 + 0*16^2 + 1*16^1 + 0*16^0$
    $= 1 *4096 + 0* 256 + 1* 16 + 0 * 1$
    $= 4112\ (D)$
- Number set : (0 ~ 9, A, B, C, D, E, F)
- Operations: addition, multiplication, etc.

Exercise

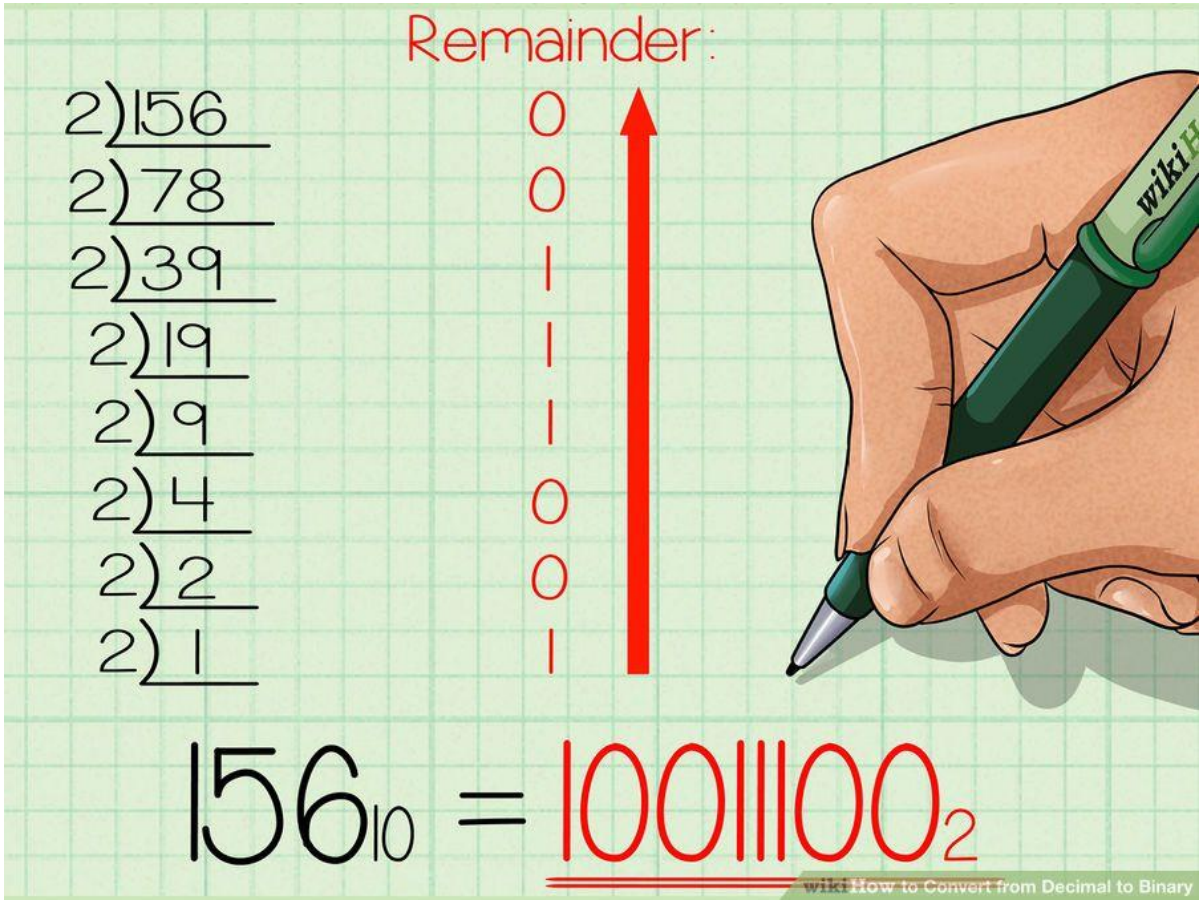
- Write the numbers from 0 - 16 (decimal) in binary and hex.
- Why do we have Hex numbering system?

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 x 101, calculate for decimal and binary.
- More commonly, binary numbers are used for logical operations.

Conversion: Decimal to Binary



- Same rule applies to Decimal to Hexadecimal.

Conversion: Binary to Decimal

- Convert 100011 (B) to decimal.

  $1x2^5 + 0x2^4 + 0x2^3 + 0x2^2 + 1x2^1 + 1x2^0$

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

  $= 35$

- 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 (D) → ? (B)→? (H)
- 73 (D) → ? (B)→? (H)
- 101101 (B)→ ? (D) → ? (H)
- 1A3 (H)→ ? (B) → ? (D)

Addition (Binary and Hex)

- 11000111 (B) + 1101001 (B) = ? (D) and (H)
- C7 (H) + 69 (H) = ? (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 (B) + C7 (H) = ? (D)

Quiz

4.