Computer Fundamentals

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Lecture 5

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Numbering Systems

- Numbering system in common use → decimal
- Numbering system in computers → binary
- Other numbering systems → with different bases
- Conversion from one system to another

Digits in Numbering Systems

- Binary numbering system (base 2)
  - 0, 1
- Octal numbering system (base 8)
  - 0, 1, 2, 3, 4, 5, 6, 7
- Decimal numbering system (base 10)
  - 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
- Hexadecimal numbering system (base 16)
  - 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F

Conversion Table

Binary	Octal	Decimal	Hexadecimal
0	0	0	0
1	1	1	1
10	2	2	2
11	3	3	3
100	4	4	4
101	5	5	5
110	6	6	6
111	7	7	7
1000	10	8	8
1001	11	9	9
1010	12	10	A

Decimal System

- Decimal (base 10) numbers expressed in positional notation

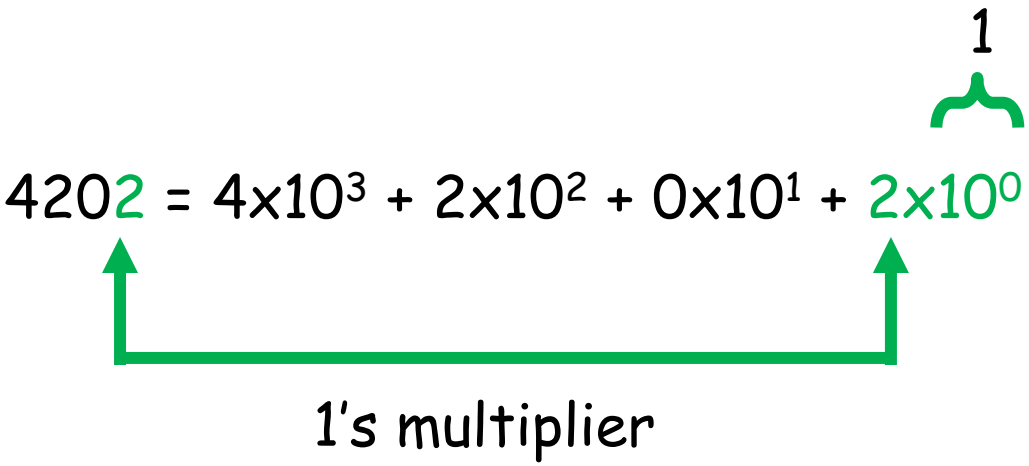
The right-most is the least significant digit

$$4202 = 4\times10^3 + 2\times10^2 + 0\times10^1 + 2\times10^0$$

The left-most is the most significant digit

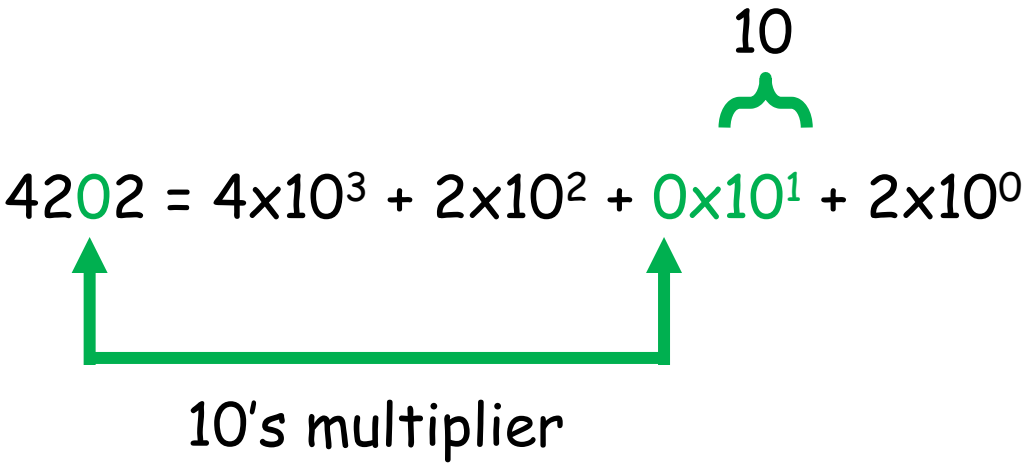
Decimal System (cont.)

- Constituents of a decimal number



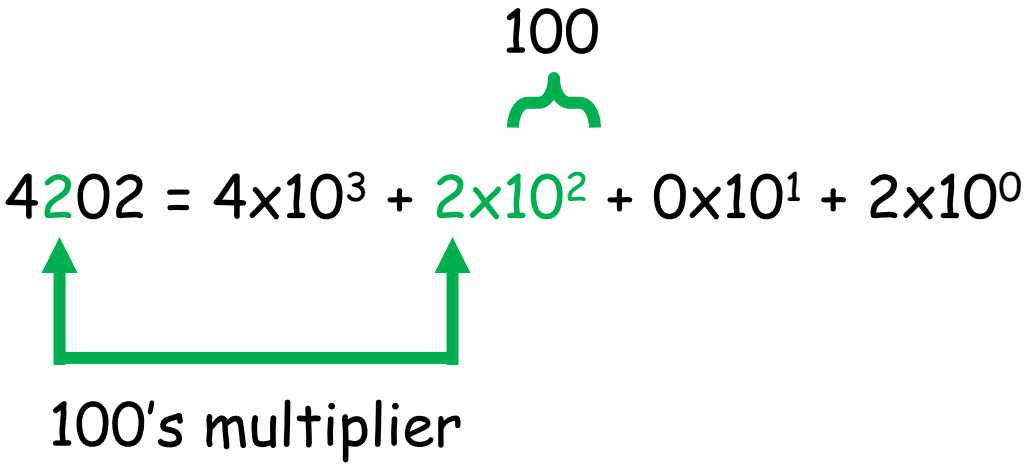
Decimal System (cont.)

- Constituents of a decimal number



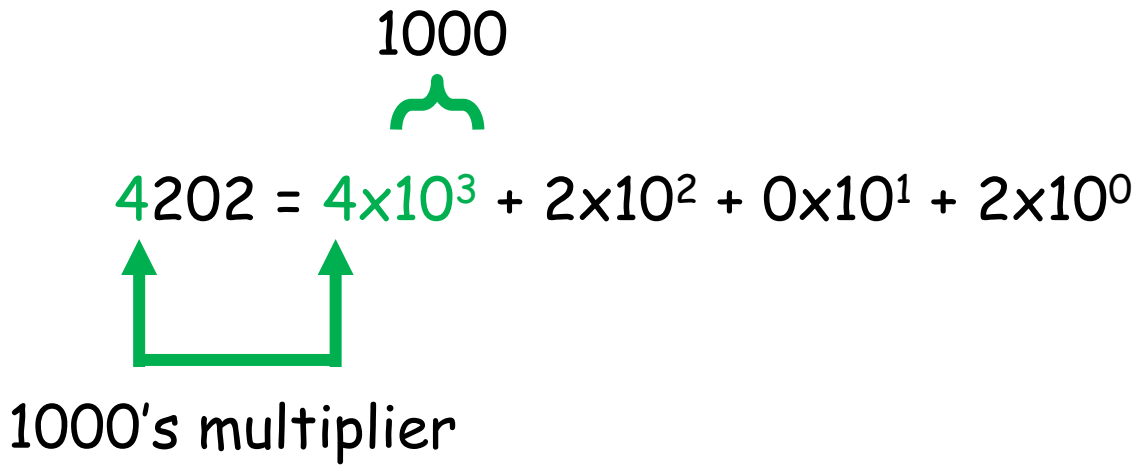
Decimal System (cont.)

- Constituents of a decimal number



Decimal System (cont.)

- Constituents of a decimal number



Binary System

- Binary (base 2) numbers also expressed in positional notation

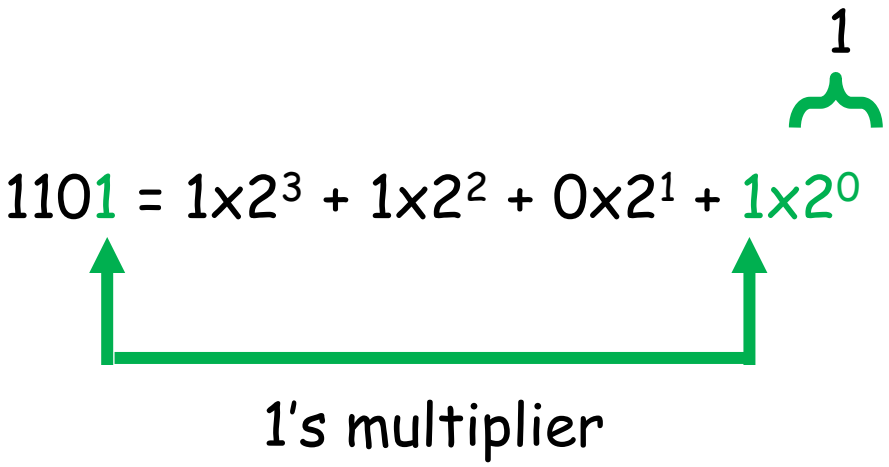
The right-most is the least significant digit

$$1101 = 1x2^3 + 1x2^2 + 0x2^1 + 1x2^0$$

The left-most is the most significant digit

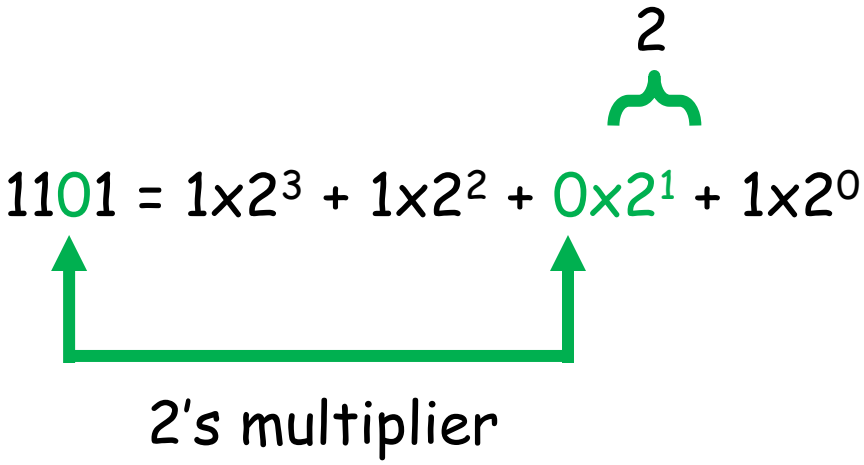
Decimal System (cont.)

- Constituents of a binary number



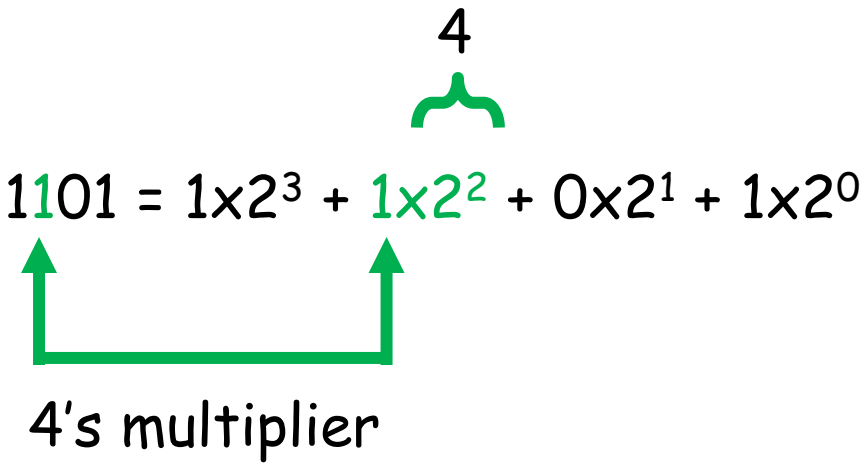
Decimal System (cont.)

- Constituents of a binary number



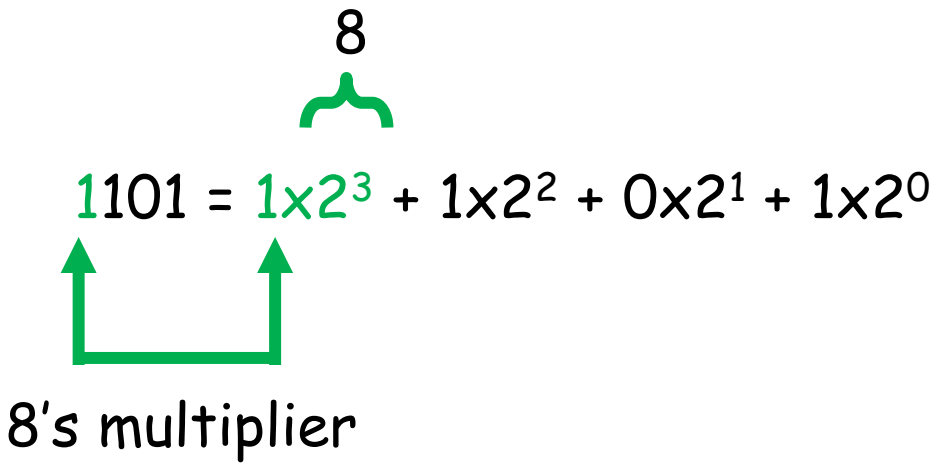
Decimal System (cont.)

- Constituents of a binary number



Decimal System (cont.)

- Constituents of a binary number



Why Binary?

- Natural for digital computers
- Fundamental building block of a digital computer
  - Switch – possesses two natural states, ON & OFF
- Easy to represent these states binary system
  - Only two symbols, 1 and 0
- In some ways, the binary number system is natural to us humans. How?

- BIT = BInary digiT
- BYTE = 8 bits

Binary – Decimal Conversion

- Convert 75 from decimal to binary

2	75	remainder
2	37	1
2	18	1
2	9	0
2	4	1
2	2	0
2	1	0
	0	1

1001011

Binary – Decimal Conversion (cont.)

- Convert 1001011 from binary to decimal

$$1001011 = 1x2^6 + 0x2^5 + 0x2^4 + 1x2^3 + 0x2^2 + 1x2^1 + 1x2^0$$

$$= 64 + 0 + 0 + 8 + 0 + 2 + 1$$

$$= 75$$

Binary – Octal Conversion

- Convert 1001011 from binary to octal

- Make groups of three bits from right
- Add additional zeroes on the left side (if required)
- Convert each group into corresponding number

$$\underbrace{001}\ \underbrace{001}\ \underbrace{011}$$

- Convert from octal to binary in similar fashion

Binary – Hexadecimal Conversion

- Convert 1001011 from binary to hexadecimal

- Make groups of four bits from right
- Add additional zeroes on the left side (if required)
- Convert each group into corresponding number

$$\underbrace{01\ 00}\quad\underbrace{1011}$$

- Convert from hexadecimal to binary in similar fashion

Binary Numbers with Fractions

- Decimal numbers have decimal point
  - E. g. 43.781
- Similarly binary numbers have binary points
  - E. g. 10111.1011
- Decimal – binary conversion possible

Binary Numbers with Fractions (cont.)

- Convert 75.56 from decimal to binary up to 5 binary points

2	75	remainder
2	37	1
2	18	1
2	9	0
2	4	1
2	2	0
2	1	0
	0	1

2 x 0.56 =	1.12
2 x 0.12 =	0.24
2 x 0.24 =	0.48
2 x 0.48 =	0.96
2 x 0.96 =	1.92

1001011.10001

Binary Numbers with Fractions (cont.)

- Convert 1011.11 from binary to decimal

$1011.11 = 1x2^3 + 0x2^2 + 1x2^1 + 1x2^0 + 1x2^{-1} + 1x2^{-2}$

$= 8 + 0 + 2 + 1 + 0.5 + 0.25$

$= 11.75$

Binary Addition

- Basic additions
  - 0 + 0 = 0
  - 0 + 1 = 1
  - 1 + 0 = 1
  - 1 + 1 = 10
  - 1 + 1 + 1 = 11

- Add 1011.1101 with 11.001

```
  1011.1101
+   11.0010
-----------
= 1110.1111
```

Binary Subtraction

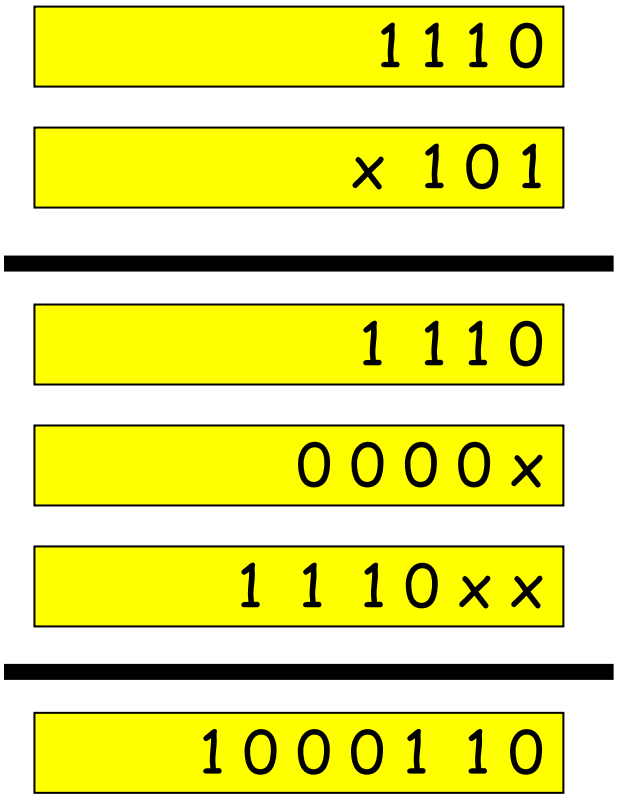
- Basic subtractions
  - 0 - 0 = 0
  - 1 - 0 = 1
  - 1 - 1 = 0
  - 10 - 1 = 1
  - 11 – 1 = 10

- Subtract 11.001 from 1110.1111

```
  1110.1111
-   11.0010
------------
= 1011.1101
```

Binary Multiplication

- Basic Multiplications
  - 0 x 0 = 0
  - 0 x 1 = 0
  - 1 x 0 = 0
  - 1 x 1 = 1
- Multiply 101 by 1110



Binary Division

- Basic Divisions
  - 0 / 1 = 0
  - 1 / 1 = 1
- Divide 11010 by 101

```
      101
   ------
101 |11010
     101
     ----
      011
      000
      ---
       110
       101
       ---
       001
```