# DATA STORAGE

COMS W1001 Introduction to Information Science

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### **Today's Topics**

- Bits and Logic Gates
- Bits, Bytes and the Binary System
- Binary, Decimal, Octal, Hexadecimal
- Representing Numbers
- Representing Text

- Bit binary digits: on/off, true/false, 0/1
- Boolean operation in honor of mathematician George Boole

<ul> <li>AND</li> </ul>	$\frac{AND}{0}$	AND 1 0	$\frac{\text{AND}  0}{0}$	AND 1 1
• OR	0 0 0 0	0 0R 1 1	0R 0 1	0R 1 1
<ul> <li>NOT</li> <li>NO<sup>2</sup></li> <li>NO<sup>2</sup></li> </ul>	T 0 -> 1 T 1 -> 0			
• XOR (	exclusive or)			
	XOR 0 0	XOR 1 1	XOR 0 1	$\frac{\text{XOR}}{1} \frac{1}{0}$

- Gate A device that produces the output of a Boolean operation when given operation's input value
  - Electronic circuits in modern computer
  - Represent digits 0 and 1 using voltage levels



- Flip-flops
  - A circuit that produces an output value of 0 or 1, which remains constant until a temporary pulse from another circuit causes it to shift to the other value
  - Consider the following two constructions of flip-flops
    - As long as both inputs remain 0, the output will not change
    - Temporarily giving a signal 1 on the upper input will force the output to be 1
    - Temporarily giving a signal 1 on the lower input will force the output to be 0



- VLSI Very large-scale integration
  - A technology that millions electronic components (e.g. flip-flops) are used inside a computer (on a wafer, or called chip) as a means of recording information that is encoded as patterns of 0s and 1s

### Bits, Bytes and the Binary System

- Byte 8 bits
- Kilobyte (KB) 1024 bytes (2<sup>10</sup> bytes)
- Megabyte (MB) 1024 KB 1,048,576 bytes (2<sup>20</sup> bytes)
- Gigabyte (GB) 1024 MB 1,073,741,824 bytes (2<sup>30</sup> bytes)
- Terabyte (TB) 1024 GB 1,099,511,627,776 bytes (2<sup>40</sup> bytes)
- Petabype (PB)

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- A means of representing numeric value (and other information) using only 0 and 1
- Binary Notation



Conversion from binary to decimal



#### Conversion from decimal to binary

- Step 1. Divide the value by two and record the remainder.
- Step 2. As long as the quotient obtained is not zero, continue to divide the newest quotient by two and record the remainder.
- Step 3. Now that a quotient of zero has been obtained, the binary representation of the original value consists of the remainders listed from right to left in the order they were recorded.



### Binary Addition

Fractions in Binary



### Binary, Decimal, Octal, Hexadecimal

### Conversion

- Binary to decimal
- Decimal to binary
- Binary to octal
- Binary to Hexadecimal
- To convert decimal to octal
  - First convert decimal to binary
  - Then make 3-bit a group
- To convert decimal to hexadecimal
  - First convert decimal to binary
  - Then make 4-bit a group

#### Two's Complement Notation

#### a. Using patterns of length three

Bit pattern	Value represented
011	3
010	2
001	1
000	0
111	-1
110	-2
101	-3
100	-4

#### b. Using patterns of length four

Bit	Value
pattern	represented
0111	7
0110	6
0101	5
0100	4
0011	3
0000	2
0001	1
0000	0
1111	-1
1110	-2
1100	-3
1101	-4
1011	-5
1010	-6
1001	-7
1000	-8

- Sign bit leftmost bit
- Complement 0->1 or 1->0
- Example of negative integer:

Encoding the value -6 in two's complement notation using 4 bits



### Addition

Problem in base ten	Problem in two's complement	Answer in base ten
3 + 2	0011 + 0010 0101	→ 5
-3 +-2	+ 1101 + 1110 1011	→ -5
7 +-5	$ \xrightarrow{ 0111 \\ + 1011 \\ 0010 } $	→ 2

- Overflow
  - positive + positive = negative
  - negative + negative = positive

#### Excess Notation

- 3 bit pattern excess 4 notation
- 4 bit pattern excess 8 notation
- 5 bit pattern excess 16 notation

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An excess notation system using bit patterns of length three

Bit pattern	Value represented
111	3
110	2
101	1
100	0
011	-1
010	-2
001	-3
000	-4

An excess eight conversion table

Bit pattern	Value represented
1111	7
1110	6
1101	5
1100	4
1011	3
1010	2
1001	1
1000	0
0111	-1
0110	-2
0101	-3
0100	-4
0011	-5
0010	-6
0001	-7
0000	-8

### **Representing Fractions**

- Floating-Point Notation
  - Decide sign bit
  - Write down the normalized form
  - Filled the exponent and mantissa section



Truncation Errors



### **Representing Text**

#### ASCII – American Standard Code for Information Interchange

$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	<ul> <li>Use 8 bit per symbol</li> </ul>	Symbol	ASCII	Hex	Symbol	ASCII	Hex	Symb	ol ASCII	Hex
carriage return space         0001011         0B         7         00111111         3F          01011111         5F           Unicode         1         0010000         20         @         01000000         40         a         0110000         60           *         0010001         21         A         0100001         42         b         01100010         61           *         0010010         22         B         01000014         42         b         0110010         64           *         0010010         24         D         0100010         44         d         0110010         66           *         0010110         25         E         0100101         45         e         0110011         66           *         0010100         28         H         0100100         48         h         0110101         68           *         0010101         29         I         0100101         44         j         0110101         68           *         0010101         20         J         0100101         44         j         0110101         60           *         01010101         20         J <td></td> <td>line feed</td> <td>00001010</td> <td>0A</td> <td>&gt;</td> <td>00111110</td> <td>ЗE</td> <td>^</td> <td>01011110</td> <td>5E</td>		line feed	00001010	0A	>	00111110	ЗE	^	01011110	5E
Unicode         space         00100001         20         @         01000001         40         1         01100000         60           • Use 16 bits per symbol         #         0010011         22         B         0100010         42         b         0110010         62           #         0010011         23         C         0100010         44         d         0110010         62           #         0010010         24         D         0100010         44         d         0110010         64           %         0010011         25         E         0100011         45         e         0110010         65           &         0010110         26         F         0100011         45         e         0110101         66           *         0010101         28         H         0100100         48         h         0110100         69           *         0010101         29         I         0100101         44         5         0110100         60           *         0010101         2A         J         0100101         4A         5         0110101         60           *         00101010         2C <td></td> <td>carriage return</td> <td>00001011</td> <td>0B</td> <td>?</td> <td>00111111</td> <td>3F</td> <td>_</td> <td>01011111</td> <td>5F</td>		carriage return	00001011	0B	?	00111111	3F	_	01011111	5F
Unicode       !       0010001       21       A       0100001       41       a       0110001       61         • Use 16 bits per symbol       #       0010011       23       C       0100010       44       d       0110010       63         * 0010010       24       D       0100010       44       d       0110010       64         * 0010110       26       F       0100010       48       h       0110100       68         * 0010100       28       H       0100100       48       h       0110100       68         • 00101010       29       I       0100101       44       j       0110100       68         • 00101010       24       J       0100101       48       h       0110100       68         • 00101010       24       J       0100101       44       j       0110100       68         • 00101010       24       J       0100101       44       j       0110100       68         • 00101010       24       J       0100101       44       j       0110101       61         • 00101010       24       J       0100101       44       j       0110100		space	00100000	20	@	01000000	40	*	01100000	60
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0       00110000       30       P       01010000       50       p       01110000       70         1       00110001       31       Q       01010001       51       q       01110001       71         2       00110010       32       R       01010010       52       r       01110010       72         3       00110011       33       S       01010010       52       r       01110010       72         4       00110101       33       S       01010011       53       s       01110010       74         5       00110101       34       T       01010100       54       t       01110101       75         6       00110101       36       V       01010101       56       v       01110101       76         7       00110101       36       V       01010101       57       w       01110101       78         9       00111001       39       Y       01010101       59       y       01111001       79         1       0011101       3A       Z       01011010       5A       Z       0111100       7A         9       00111001       3A <t< td=""><td></td><td>/</td><td>00111111</td><td>21</td><td>0</td><td>01001111</td><td>4</td><td>0</td><td>01101111</td><td>61</td></t<>		/	00111111	21	0	01001111	4	0	01101111	61
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$\begin{array}{cccccccccccccccccccccccccccccccccccc$		3	00110011	33	5	01010011	53	S	01110011	73
5       00110101       35       0       01010101       55       1       01110101       75         6       00110110       36       V       01010110       56       v       01110110       76         7       00110111       37       W       01010111       57       w       01110111       77         8       00111000       38       X       0101000       58       x       0111000       78         9       00111001       39       Y       01011001       59       y       0111100       78         1       00111001       3A       Z       01011001       59       y       0111100       78         2       0011101       3A       Z       01011001       59       y       0111100       78         3       0011101       3A       Z       01011001       5A       z       0111100       7A         3       0011101       3B       [       01011010       5A       z       0111101       7B         4       00111010       3C       \vdot01011100       5C       \vdot01011100       7C         4       00111100       3C       \vdot0101100		4	00110100	34	1	01010100	54	t	01110100	74
6       00110110       36       V       01010110       56       V       01110110       76         7       00110111       37       W       01010111       57       w       01110111       77         8       00111000       38       X       01010100       58       x       01110101       78         9       00111001       39       Y       01011001       59       y       01111001       79         :       00111010       3A       Z       01011010       5A       z       01111010       7A         ;       00111011       3B       [       01011010       5A       z       01111010       7A         ;       00111011       3B       [       01011010       5A       z       01111010       7A         ;       00111011       3B       [       01011010       5A       z       01111010       7A         ;       00111011       3B       [       01011010       5C               01111010       7C          00111100       3C       \       01011010       5C               01111010       7C		5	00110101	35	U	01010101	55	u	01110101	75
7       00110111       37       W       01010111       57       W       01110111       77         8       00111000       38       X       01010100       58       x       01111000       78         9       00111001       39       Y       01011001       59       y       01111001       79         :       00111010       3A       Z       01011010       5A       z       01111010       7A         ;       00111011       3B       [       01011011       5B       {       01111010       7A         <		0	00110110	30	V	01010110	50	V	01110110	76
8       00111000       38       X       01011000       58       X       01111000       78         9       00111001       39       Y       01011001       59       y       01111001       79         :       00111010       3A       Z       01011010       5A       z       01111010       7A         ;       00111011       3B       [       01011011       5B       {       0111101       7A         <		/	00110111	37	vv	01010111	57	W	01110111	77
9       00111001       39       1       01011001       59       9       01111001       79         :       00111010       3A       Z       01011010       5A       z       01111010       7A         ;       00111011       3B       [       01011011       5B       {       01111011       7B         <		8	00111000	38	X	01011000	58	x	01111000	78
i     i <td></td> <td>9</td> <td>00111001</td> <td>39</td> <td>ř Z</td> <td>01011001</td> <td>59</td> <td>У ,</td> <td>01111001</td> <td>79</td>		9	00111001	39	ř Z	01011001	59	У ,	01111001	79
<ul> <li></li> <li><td></td><td>:</td><td>00111010</td><td>3A 2D</td><td>Z</td><td>01011010</td><td>5A E D</td><td>Z</td><td>01111010</td><td>78</td></li></ul>		:	00111010	3A 2D	Z	01011010	5A E D	Z	01111010	78
		;	00111011	38	l	01011011	28	( 1	01111011	7B 7C
$=$ 00111101 3D $=$ 01011101 5D $\}$ 0111101 7D		< =	00111101	3D	1	01011101	50 5D	}	01111101	7D

### **References & Photo Credits**

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