

SEC204

程序代写代做 CS编程辅导

Computer Architecture and Low Level Programming



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Outline

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2

- Positional Numbering Systems
- Converting Positional Numbering Systems
- Basic Binary Arithmetic Operations
- Signed Integer Representation
- Floating Point Representation
- Character Codes



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What to do...

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3

- In this file you will find  slides together with **some extra slides**
- **These extra slides are for you to understand and solve on your own**

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- **Study all the examples that follow and try to solve them on Assignment Project Exam Help
your own...**

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- **Pay attention to the following slides**

□ 15-21

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□ 24-27

□ 35-42

□ 48-49

Basics (1)

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4

- The bit is the most basic unit of information in a computer
 - Switching activity
- A Byte is a group of 8 bits
 - A byte is the smallest possible addressable unit of computer storage
 - The term, “addressable,” means that a particular byte can be retrieved according to its location in memory
- A word is a contiguous group of bytes, e.g., an integer uses 4 bytes
- Word sizes of 4 or 8 bytes are most common



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Basics (2)

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Kilo- (K) = 1 thousand = 10^3 and 2^{10}



Mega- (M) = 1 million = 10^6 and 2^{20}

Giga- (G) = 1 billion = 10^9 and 2^{30}

Tera- (T) = 1 trillion = 10^{12} and 2^{40}

Peta- (P) = 1 quadrillion = 10^{15} and 2^{50}

Exa- (E) = 1 quintillion = 10^{18} and 2^{60}

Zetta- (Z) = 1 sextillion = 10^{21} and 2^{70}

Yotta- (Y) = 1 septillion = 10^{24} and 2^{80}

Normally, powers of 2 are used for measuring capacity

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Milli- (m) = 1 thousandth = 10^{-3}
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Micro- (μ) = 1 millionth = 10^{-6}

Nano- (n) = 1 billionth = 10^{-9}

Pico- (p) = 1 trillionth = 10^{-12}

Basics (3)

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6

- Hertz = clock cycles per second (frequency)
 - 1MHz = 1,000,000 cycles per second
 - Processor speeds are measured in MHz or GHz
- Byte = a unit of storage
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 - 1KB = 2^{10} = 1024 Bytes
 - 1MB = 2^{20} = 1,048,576 Bytes
 - 1GB = 2^{30} = 1,099,511,627,776 Bytes
- Main memory (RAM) is measured in GB
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- Disk storage is measured in GB for small systems, TB (2^{40}) for large systems
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Think Pair Share activity

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- How many milliseconds (ms) are in 1 second?



- How many nanoseconds (ns) are in 1 millisecond?

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- How many kilobytes (KB) are in 1 gigabyte (GB)?

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- How many bytes are in 20 megabytes?

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POSITIONAL NUMBERING SYSTEMS

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8



- Positional numbering systems are systems in which the placement of a digit in connection to its intrinsic value determines its actual meaning in a numeral string
- The organization of any computer depends considerably on how it represents numbers, characters, and control information

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- There are several positional numbering systems such as Decimal, Binary, Octal, Hexadecimal etc.

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- The positioning system is provided as a subscript, e.g., 14_{10} , 10101_2 , 82_{16}
- Our decimal system is the base-10 system. It uses powers of 10 for each position in a number

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- The binary system is also called the base-2 system
- The hexadecimal system is the base-16 system
- The Mayan and other Mesoamerican cultures used a number system based in a base-20 system

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Decimal System

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9

- **Decimal system:** Our common and used system.
 - It uses 10 different digits: **1,2,3,4,5,6,7,8,9**
 - Our decimal system is a base-10 system. It uses powers of 10 for each position in a number
 - For example, the decimal number 947 in powers of 10 is
947 =
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- The decimal number 1382.46 in powers of 10 is (**$3 \times 10^3 + 8 \times 10^2 + 1 \times 10^1 + 2 \times 10^0 + 4 \times 10^{-1} + 6 \times 10^{-2}$**)

Binary System (1)

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10

- A binary number is expressed in the base-2 numeral system or binary numeral system which uses only two symbols: typically 0 (zero) and 1 (one)



- The base is 2
 - **2 different digits are used: 0, 1**
 - For example, $101_2 = 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$
= $1 \times 4 + 0 \times 2 + 1 \times 1$

- The binary number ~~11001~~^{QQ: 749389476} in powers of 2 is: $1 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 = 16 + 8 + 0 + 0 + 1 = 25_{10}$

□ $1011.101_2 = \textcolor{red}{\text{https://tutorcs.com}}$

$$\begin{aligned} &= 1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 + 1 \times 2^{-1} + 0 \times 2^{-2} + 1 \times 2^{-3} = \\ &= 1 \times 8 + 0 \times 4 + 1 \times 2 + 1 \times 1 + 1 \times 0.5 + 0 \times 0.25 + 1 \times 0.125 \\ &= 11.625_{10} \end{aligned}$$

Binary System (2)

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11

2^n representation	2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}	2^{-3}
number	1024	512	256	128	64	32	16	8	4	2	1	0.5	0.25	0.125

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Convert the following binary number 1101.101 to decimal

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$$\begin{aligned}1101.101_2 &= 1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 + 1 \times 2^{-1} + 0 \times 2^{-2} + 1 \times 2^{-3} \\&= 8 + 4 + 0 + 1 + 0.5 + 0 + 0.125 = 13.625_{10}\end{aligned}$$

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Octal system

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12

- The base is 8
- **8 different digits** only: 0,1,2,3,4,5,6,7
- For example: 436₈ = $4 \times 8^2 + 3 \times 8^1 + 6 \times 8^0$



$$\begin{aligned} &= 4 \times 64 + 3 \times 8 + 6 \times 1 \\ &\text{WeChat: cstutorcs} \\ &= 286_{10} \end{aligned}$$

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Convert the following octal number 205.24_8 to decimal:
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$$\begin{aligned} 205.24_8 &= 2 \times 8^2 + 0 \times 8^1 + 5 \times 8^0 + 2 \times 8^{-1} + 4 \times 8^{-2} \\ &\text{QQ: 749389476} \\ &= 2 \times 64 + 0 + 5 + 2 \times 0.125 + 4 \times 0.015625 \\ &= 133.3125_{10} \end{aligned}$$

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Hexadecimal system

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- The base is 16
- 16 different digits



0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F

(we do not use numbers with 2 digits like 10, 11, 12, ...), but

A instead of 10, B instead of 11, C instead of 12, etc)

- Example: $3B1_{16} = 3 \times 16^2 + 11 \times 16^1 + 1 \times 16^0$

$$= 3 \times 256 + 11 \times 16 + 1 =$$

$$= 768 + 176 + 1 =$$

$$= 945_{10}$$

Convert the following hexadecimal number 20C.2₁₆ to decimal

$$20C.2_{16} = 2 \times 16^2 + 0 \times 16^1 + 12 \times 16^{-1} =$$

$$= 2 \times 256 + 0 + 12 \times 1 + 2 \times 0.0625 =$$

$$= 512 + 12 + 0.125 =$$

$$= 524.125_{10}$$

Positional Numbering Systems - General case

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14

- Base: r
- Uses r different digits $A_{n-1}, A_{n-2}, \dots, A_1, A_0, A_{-1}, A_{-2}, \dots, A_{-(m-1)}, A_{-m}$



- $N_r = A_{n-1} A_{n-2} \dots A_1 A_0 A_{-1} A_{-2} \dots A_{-(m-1)} A_{-m}$
- $N_r = A_{n-1} \times r^{n-1} + A_{n-2} \times r^{n-2} + \dots + A_1 \times r^0 + A_0 \times r^{-1} + A_{-1} \times r^{-2} + \dots + A_{-(m-1)} \times r^{-(m-1)} + A_{-m} \times r^{-m}$

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For example if $234.03_5 = ?$, then $n=3$, $m=2$ and $r=5$

- The left most digit (A_{n-1}) is called Most Significant Bit-(MSB) while the right most (A_{-m}) Least Significant Bit-(LSB)

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Converting Positional Numbering Systems

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From Decimal to Binary



$$37 / 2 = 18 \text{ remainder } 1$$

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Base Quotient Remainder

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Procedure:

- a. Divide the decimal with 2
- b. Write down the quotient and the remainder
- c. Divide quotient with 2
- d. Write down the quotient and the remainder
- e. Repeat the process (c)-(d) until the quotient becomes zero
- f. Write down the binary number from bottom (MSB) to top (LSB)

From Decimal to Binary, an example

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$$83_{10} = ?_2$$

$$83 \div 2 = 41 \text{ remainder } 1$$

$$41 \div 2 = 20 \text{ remainder } 1$$

$$20 \div 2 = 10 \text{ remainder } 0$$

$$10 \div 2 = 5 \text{ remainder } 0$$

$$5 \div 2 = 2 \text{ remainder } 1$$

$$2 \div 2 = 1 \text{ remainder } 0$$

$$1 \div 2 = 0 \text{ remainder } 1$$

$$83_{10} = 1010011_2$$



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If the decimal number is lower than 1,
e.g., 0.25, or contains a fractional part
the procedure applied is different

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(MSB)

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Our result, is the remainders in reverse order (reading from bottom to top)

Convert From Decimal To Another Base

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17

- We follow the same process as in the previous slide (from decimal to binary) but instead of base we use the r-base.



- Convert the decimal 524_{10} to hexadecimal
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$524:16 = 32$ remainder 12 | Assignment Project Exam Help

$32:16 = 2$ remainder 0

$2:16 = 0$ remainder 2

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Thus, $524_{10} = 20C_{16}$ QQ: 749389476

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$128_{10} = ?_{16}$

Convert from binary to octal

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18

Procedure:

1. **To convert a binary number to octal**, we group all the 1's and 0's in the binary number in sets of three starting from the far right
2. Start from the right to make your groups
3. Add zeros to the left of the last digit if you don't have enough digits to make a set of three
4. Write down the decimal representation of every group



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$$101011_2 = ?_8$$

$$= 101 \quad 011$$

$$= 5 \quad 3$$

$$101011_2 = 53_8$$

$$10011011_2 = 233_8$$

	Binary	Octal
0	0	0
0	0	1
0	1	2
0	1	3
1	0	4
1	0	5
1	1	6
1	1	7

Convert from Octal to binary

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19



- Converting from octal to binary is as easy as converting from binary to octal. Simply look up each octal digit to obtain the equivalent group of three binary digits.

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$$317.2_8 = ?_2$$

$$= 011\ 001\ 111.\ 010$$

$$= 11001111.01_2$$

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Octal	Binary		
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1

Convert Binary to Hexadecimal

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20

Procedure:

1. Cut your string of binary digits  into groups of four, starting from the right
2. Add extra zeros to the front of the first number if it is not four digits
3. Convert one 4-digit group at a time. To convert between Binary and Hexadecimal, you simply replace each Hex digit with its 4-bit binary equivalent and vice versa

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Binary and Hexadecimal, you simply replace each Hex digit with its 4-bit binary equivalent and vice versa

$$10001101011_2 = ?_{16}$$

$$= \begin{array}{ccc} 100 & 0110 & 1011 \end{array}$$

$$= \begin{array}{ccc} 0100 & 0110 & 1011 \end{array}$$

$$= \begin{array}{ccc} 4 & 6 & B \end{array}$$

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$$100_2 = 0 + 4 + 0 + 0 = 4_{16}$$

$$0110_2 = 0 + 4 + 2 + 0 = 6_{16}$$

$$1011_2 = 8 + 0 + 2 + 1 = 11 = B_{16}$$

$$10001101011_2 = 46B_{16}$$

Hexadecimal	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

Convert Hexadecimal to Binary

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21

- Likewise from Octal to
- Simply look up each hexadecimal digit to obtain the equivalent group of four binary digits



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$8B.2_{16} = 1000\ 1011.0010_2$ Assignment Project Exam Help

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- That's why we use hexadecimal in computer systems! Humans can still understand it, and computers can calculate Hex faster than decimal values!

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

Basic arithmetic operations

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22

- The basic arithmetic operations are applied to all the previous numerical systems. They are:
 - Addition
 - Subtraction
 - Multiplication
 - Division
- For the remainder of this lecture we will focus on the binary system



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Binary Addition (1)

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23

Binary addition is like decimal addition:

1. Put the numbers in a column, aligning the decimal points
2. Add each column of digits starting on the right and working left. If the sum of a column is more than ten, "carry" digits to the next column on the left.

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457 +
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148

605
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(011 Carry)

- In the example above we add 8+7 and write 5 instead of 15. We propagate 10 (which is the base) to the left and we write the remainder
- For every propagation we add 1 carry to the next addition (left)
- The same holds when adding different numerical system numbers too

Binary Addition (2)

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24

Binary addition:



$$\begin{array}{r} 10110111 + \\ 1110110 \\ \hline 100101101 \\ (011110110 \text{ carry}) \end{array}$$

$$\begin{array}{r} 11111011 + \\ 11101011 \\ \hline 111100110 \end{array}$$

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(carry)

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Note that:

0+0= 0 and carry 0

1+0=0+1= 1 and carry 0

1+1= 0 and carry 1, as $1 + 1 = 10_2 = 2_{10}$

1+1+1= 1 and carry 1, as $1 + 1 + 1 = 11_2 = 3_{10}$

Binary Subtraction (1)

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25

Binary subtraction is like decimal subtraction:

1. Put the numbers in a column, aligning the decimal points.
2. Subtract each column, starting on the right and working left. If the digit being subtracted in a column is larger than the digit above it, "borrow" a digit from the next column to the left. When we borrow a carry, we add 1 to the subtrahend of the next subtraction

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4 3 5 6

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-2 1 8 9

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2 1 6 7

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(0 0 1 1 borrow carry from the left)

Binary Subtraction (2)

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26

For binary subtraction:

$$0 - 0 = 0$$

$$1 - 0 = 1$$

$$1 - 1 = 0$$

$$10 - 1 = 1, \quad \text{as } 10_2 = 2_{10}$$

The first three are the same as in decimal. The fourth fact is the only new one; it is the borrow case. It applies when the “top” digit in a column is 0 and the “bottom” digit is 1

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$$\begin{array}{r} 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 1 \\ - & 1 & 1 & 0 & 1 & 1 & 0 \\ \hline 0 & 1 & 0 & 1 & 1 & 1 & 1 \\ & 0 & 1 & 0 & 0 & 1 & 1 & 1 \end{array}$$

0 ->2
0 ->2
0 ->2

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$$\begin{array}{r} 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 1 & 1 \\ - & 1 & 1 & 0 & 1 & 1 & 0 \\ \hline 0 & 1 & 1 & 0 & 1 & 0 & 1 \\ & (& 1 & 1 & 0 & 1 & 0 & 0 & \text{carry}) \end{array}$$



Binary Subtraction (3)

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27

- The procedure explained in the previous slides **holds only when we subtract X-Y where X>Y**
- If $X < Y$ then a different method is used which is out of the scope of this module
- In the next slides you will be taught another method (two's complement, slide 37) Assignment Project Exam Help



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Binary Multiplication

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- As in the decimal



0111 X

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Note that $1+1+1+1= 0$ and carry

000000

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110111
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110111
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1011001011

(0111221100) Carry

Signed integer representation

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29

Introduction



- In practice we have to handle negative binary numbers too. **We need to define signed binary**

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- ✓ There are three ways in which signed binary integers may be expressed:

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1. Signed magnitude

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2. One's complement

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<https://tutorcs.com>

Signed Magnitude Representation (1)

30

- Allocate the high-order bit to indicate the sign of a number
 - The high-order bit is the sign bit. It is also called the most significant bit
 - 0 is used to indicate a positive number; 1 indicates a negative number
- The remaining bits contain the value of the number
- Note that we also pay attention to the number of bits used to represent signed binary numbers
 - i.e. if using 4 bit numbers, then we use 0001_2 rather than 1_2
- In an 8-bit word, signed magnitude representation places the absolute value of the number in the 7 bits to the right of the sign bit



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For example:

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+3 is: 00000011

-3 is: 10000011

Signed Magnitude Representation (2)

31

- The "binary addition rule" does NOT work with sign-magnitude



$$0 \ 011_2 = 3_{10}$$

$$1 \ 100_2 = -4_{10}$$

$$\begin{array}{r} 0 \quad 011 \\ 1 + 100 \\ \hline \end{array}$$

1 111 this is wrong
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Signed Magnitude: intuitive for humans, difficult for computers

32

- Signed magnitude representation is easy for people to understand, but it's complicated computer hardware
- Also it allows two different representations for zero: positive zero and negative zero



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- As such, computer systems employ complement systems for signed number representation

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Signed Integer Representation

Complement Systems

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- In binary systems, these are:
 - **One's Complement.** To represent negative values, invert all the bits in the binary representation of the number (swapping 0s for 1s and vice versa)
 - 1 becomes 0 and 0 becomes 1
 - To represent positive numbers no change is applied



For example, using 8-bit one's complement representation

+ 3 is: 00000011
- 3 is: 11111100

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More examples

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X=11011100, 1C(X)=00100011

X=1011, 1C(X)=? QQ: 749389476

<https://tutorcs.com>

- One's complement still has the disadvantage of having two different representations for zero, positive zero and negative zero
- In addition positive and negative integers need to be processed separately
- Two's complement solves this problem
- **Two's complement**
- One's Complement add 1

Signed Integer Representation

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34

Two's complement 2C(X)



- You represent positive numbers just like the unsigned numbers
- To represent negative values, start with the corresponding positive number, invert all the bits. Then add 1
- For example, using 8-bit two's complement representation:
+ 3 is: **00000011**

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T.Start with positive number

11111100 Email: tutors@163.com

$$\begin{array}{r} + \\ \hline -3 \text{ is: } 11111101 \\ \hline 1 \end{array}$$

3. Add 1
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-3 in 8-bit Two's Complement Representation is 11111101
<https://tutors.cs>

✓ Negative numbers must always start with '1'

✓ Both positive and negative numbers must have the same number of bits

Signed Integer Representation

Two's Complement Example 1

35

- Example: $X=01001$ 5 bits $\rightarrow Y=2C(X)=10111 = -9_{10}$

Check: $X+Y=$

01001

+10111

100000=00000



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The carry is discarded as the result must be 5 bits
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- We can always check whether the Two's complement result is correct by adding the two numbers. The result has to be zero. Note that the result of the addition must be ~~of the n bits, where n is the number of bits of the inputs~~ QQ: 749389476
- Find the negative binary number (Two's complement) of the following positive number with 7bits 0101101 (45_{10})

Answer 1010011

Signed Integer Representation

Two's Complement – Example 2

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36



Find the negative binary

-12_{10})

- Write down the positive binary $12_{10} = 00001100_2$
- Decide the number of the bits. We can use 5 or more. Let say 8 bits
- Find the two's complement as follows

$$12_{10} = 00001100_2, -12_{10} = 11110011 + 1 = 11110100$$

$$-12_{10} = 11110100 \text{ (negative number)}$$

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Wrap up

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37

Given a positive binary number, we find its negative binary number by following the procedure:



1. We decide the number of bits of the positive number. At least one '0' has to appear on its left.
2. We find its two's complement
3. If the MSB (the left most) is not 0, then we made a mistake...

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Subtraction with two's complement

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38

- We know that $A - B = A + (-B)$
- So, instead of applying subtraction we can make an addition with the opposite number, i.e., B 's two's complement. *The procedure follows:*
 1. Find $-B$, i.e., its two's complement
 2. Add A with B 's two's complement
 3. The result has as many bits as the inputs



Make the subtraction $Z=12-5$ Email: tutors@163.com

$$12_{10} = 01100_2, 5_{10} = 00101_2, -5_{10} = 11011_2$$

$$Z = 01100 + 11011 = 100111_2, \text{ but we need 5 bits thus } Z = 00111_2 = 7_{10}$$

Z=00111

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Make the subtraction $9-12$ (use 5 digits)

$$9_{10} = 01001_2, 12_{10} = 01100_2, -12_{10} = 10100_2$$

$$Z = 01001 + 10100 = 11101 \text{ and thus } Z = 11101 (-3_{10})$$

Z=11101

Unsigned and Signed Integer Representation

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39

- Both signed and unsigned numbers are useful
 - For example, memory addresses are always unsigned
- Using the same number of bits, unsigned integers can express twice as many “positive” values as signed numbers.

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- 0000_2 to 1111_2 (or 0 to 15) as unsigned
- 0111_2 to 1111_2 (or +7 to -7) as signed magnitude
- 0111_2 to 1000_2 (or +7 to -8) as two's complement

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Example #1

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40



What decimal value does the binary number 10011110 have if

- a) it is interpreted as a signed number?
- b) it is on a computer using signed-magnitude representation?
- c) it is on a computer using one's complement representation?
- d) it is on a computer using two's complement representation?

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Answer:

- a. $10011110_2 = 1 \times 2^7 + 1 \times 2^6 + 1 \times 2^5 + 1 \times 2^3 + 1 \times 2^1 = 128 + 64 + 32 + 8 + 2 = 158_{10}$
- b. $10011110_2 = 1$ (negative) $0011110_2 = -1 \times 2^4 + 1 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 = -30_{10}$
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- c. Find the positive of 10011110_2 ; invert the bits of 10011110_2 and therefore 01100001_2 . $01100001_2 = 1 \times 2^6 + 1 \times 2^5 + 1 \times 2^0 = 64 + 32 + 1 = 97_{10}$. Since the original number was negative, the number is -97_{10}
- d. Find the positive of 10011110_2 ; invert the bits of 10011110_2 and add 1; therefore 01100010_2 . $01100010_2 = 1 \times 2^6 + 1 \times 2^5 + 1 \times 2^1 = 64 + 32 + 2 = 98_{10}$. Since the original number was negative, the number is -98_{10}

Example #2

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Q: 00010001

A: 17

B: 17

C: 17

D: 17

E: 17

F: 17

G: 17

H: 17

I: 17

J: 17

K: 17

L: 17

M: 17

N: 17

O: 17

P: 17

Q: 17

R: 17

S: 17

T: 17

U: 17

V: 17

W: 17

X: 17

Y: 17

Z: 17

A: 17

B: 17

C: 17

D: 17

E: 17

F: 17

G: 17

H: 17

I: 17

J: 17

K: 17

L: 17

M: 17

N: 17

O: 17

P: 17

Q: 17

R: 17

S: 17

T: 17

U: 17

V: 17

W: 17

X: 17

Y: 17

Z: 17

A: 17

B: 17

C: 17

D: 17

E: 17

F: 17

G: 17

H: 17

I: 17

J: 17

K: 17

L: 17

M: 17

N: 17

O: 17

P: 17

Q: 17

R: 17

S: 17

T: 17

U: 17

V: 17

W: 17

X: 17

Y: 17

Z: 17

A: 17

B: 17

C: 17

D: 17

E: 17

F: 17

G: 17

H: 17

I: 17

J: 17

K: 17

L: 17

M: 17

N: 17

O: 17

P: 17

Q: 17

R: 17

S: 17

T: 17

U: 17

V: 17

W: 17

X: 17

Y: 17

Z: 17

A: 17

B: 17

C: 17

D: 17

E: 17

F: 17

G: 17

H: 17

I: 17

J: 17

K: 17

L: 17

M: 17

N: 17

O: 17

P: 17

Q: 17

R: 17

S: 17

T: 17

U: 17

V: 17

W: 17

X: 17

Y: 17

Z: 17

A: 17

B: 17

C: 17

D: 17

E: 17

F: 17

G: 17

H: 17

I: 17

J: 17

K: 17

L: 17

M: 17

N: 17

O: 17

P: 17

Q: 17

R: 17

S: 17

T: 17

U: 17

V: 17

W: 17

X: 17

Y: 17

Z: 17

A: 17

B: 17

C: 17

D: 17

E: 17

F: 17

G: 17

H: 17

I: 17

J: 17

K: 17

L: 17

M: 17

N: 17

O: 17

P: 17

Q: 17

R: 17

S: 17

T: 17

U: 17

V: 17

W: 17

X: 17

Y: 17

Z: 17

A: 17

B: 17

C: 17

D: 17

E: 17

F: 17

G: 17

H: 17

I: 17

J: 17

K: 17

L: 17

M: 17

N: 17

O: 17

P: 17

Q: 17

R: 17

S: 17

T: 17

U: 17

V: 17

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X: 17

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Z: 17

A: 17

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C: 17

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Q: 17

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W: 17

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Y: 17

Z: 17

A: 17

B: 17

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O: 17

P: 17

Q: 17

R: 17

S: 17

T: 17

U: 17

V: 17

W: 17

X: 17

Y: 17

Z: 17

A: 17

B: 17

C: 17

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E: 17

F: 17

G: 17

H: 17

I: 17

J: 17

K: 17

L: 17

M: 17

N: 17

</div

Example #3

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42

Perform the following binary subtraction using two's complement representation: $Z = 8 - 6$



Answer:

1. Instead of subtraction we do addition: $8 - 6 = 8 + (-6)$
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2. Choose the number of bits to represent 8 and 6 decimal numbers to binary. **At least one zero has to appear on the left**. Thus, we need 5 bits or more
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$$8_{10} = 01000_2$$

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$$6_{10} = 00110_2$$

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3. Find -6_{10} (two's complement)
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3. Make the addition (*The result has 5 bits*)

$$\begin{array}{r} 01000 \\ 11010 \\ \hline 100010 \end{array} \rightarrow 00010_2 = 2_{10}$$

Signed Integer Representation

Multiplication and Division by 2 (1)

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43

- Binary multiplication and division by 2 is very easy. (as easy as it is to multiply and divide by 10 in the decimal system)
- Simply use an arithmetic shift operation

$$\begin{aligned}1_2 &= 1_{10} \\10_2 &= 2_{10}\end{aligned}$$

$$\begin{aligned}100_2 &= 4_{10} \\1000_2 &= 8_{10}\end{aligned}$$

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- A left arithmetic shift inserts a 0 in for the rightmost bit and shifts everything else left one bit; in effect, it multiplies by 2
- A right arithmetic shift shifts everything one bit to the right, but copies the sign bit; it divides by 2

Signed Integer Representation

Multiplication and Division by 2 (2)

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44

□ Multiplication by 2

- Shift left by one place
- E.g. to calculate $2 * 7$



Binary	Decimal
0000 0111	+7
0000 1110	+14

□ Division by 2

- Shift right by one place
- E.g., to calculate $14 / 2$

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To multiply by 4, we perform a left shift twice

To divide by 4, we perform a right shift twice

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➤ Using arithmetic shifting, perform the following:

- a) double the value 0001010_2
- b) quadruple the value 00110111_2
- c) divide the value 11001010_2 in half

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Floating-Point Representation (1)

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- To represent real numbers with fractional values, floating-point representation is used.
- Floating-point numbers can be written expressed in scientific notation
 - For example: $0.125 = 1.25 \times 10^{-1}$
- Remember that when a number is multiplied by its base, e.g., 10, then we add a zero or we move the ‘.’ by one position to the right
 - $235 \times 10 = 2350$
 - $1.345 \times 10 = 13.45$
 - $110_2 \times 2 = 1100_2$ ($6 \times 2 = 12_{10}$)
 - $101.11_2 \times 2 = 1011.1$ ($5.75 \times 2 = 11.5_{10}$)



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Floating-Point Representation (2)

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- Computers use a form of scientific notation for floating-point representation
 - Single Precision floating point format 32-bit
 - Double Precision floating point format 64-bit
- Numbers written in scientific notation have three components:

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Significand

Sign or Mantissa Exponent

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+ 1.25 × 10⁻¹

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Single precision Floating-Point format (1)

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47

A binary number is represented in floating-point format as follows:

1. We write the number in scientific notation with a single non-zero digit before the radix point :

e.g., $1011010010001 = 1.1011010010001 \times 2^{12}$

$1101.10111 = 1.10110111 \times 2^3$

2. Then we transform the number to the following format using 32 bits

$$N = (-1)^S (1+F)(2^{E-127})$$

Sign-S 1-bit	Exponent-E 8 - bits	Mantissa (Fraction) - F 23 - bits
-----------------	------------------------	--------------------------------------

S: Sign, 0/1 for positives/negatives, respectively

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E: Exponent. $E-127 = exp$, where exp is the corresponding exponent

F: Significant or Mantissa. We write the fractional part in 23 bits

$E=127+exp$ in order to avoid using negative numbers. $exp=[-127,128]$ and therefore $E=[0,255] - 255$ needs 8 bits

Single precision Floating-Point format (2)

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48

Convert the positive number $s=0, e=1011010010001$ in Floating point format



Step1: $1011010010001 = 1.011010010001 \times 2^{12}$

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Step2: $N = (-1)^s (1+F)(2^{E-127})$

$S = 0$ (positive number)

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$E - 127 = 12$, and thus $E = 130_{10}$ and $E = 1011_2$

$F = 011010010001000000000000$

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Therefore N in FP format is:

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0	10001011	011010010001000000000000
---	----------	--------------------------

Single precision Floating-Point format (3)

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49



Suppose that the 32-bit floating-point representation pattern is the following. Find the number

1	10010001	100011100010000000000000000000
---	----------	--------------------------------

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S is 1 and thus the number is positive

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E is $10010001 = 145_{10}$, and thus the exponent is $\text{exp} = E - 127 = 145 - 127 = 18$

F = 100011100010000000000000000000

$N = (-1)^S (1+F)(2^{E-127})$ <https://tutorcs.com>

N is $(-1)^1 \times 1.100011100010000000000000000000 \times 2^{18}$ or

N = -1100011100010000000

Floating-Point Representation (1)

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50



- No matter how many bits we use in a FP representation, the model is finite
 - The real number system is, however, infinite, so our models can give nothing more than an approximation of a real value
 - e.g., how to represent 33.33333333333333333333333333?
- At some point, every model breaks down, introducing errors into our calculations
 - By using a greater number of bits in our model, we can reduce these errors, but we can never totally eliminate them

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Why is $0.1 + 0.2$ not equal to 0.3 in most programming languages?

51

- computers use a binary floating point format that cannot accurately represent a number
- 0.1_{10} is already rounded to the nearest number in that format
- 0.1_{10} doesn't exist in the FP representation
- 0.1_{10} is already rounded to the nearest number in that format, which results in a small rounding error
- This means that 0.1_{10} is converted to a binary number that's just very close to 0.1_{10}
- The error is tiny since 0.1_{10} is $0.100000000000000055511151231257827$
- The constants 0.2_{10} and 0.3_{10} are also approximations to their true values
- So, $0.1_{10} + 0.2_{10} == 0.300000000000000044408920985006_{10}$



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Character Codes

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52

- So far, we have learnt how to represent numbers. How about text?
- To represent text characters, we assign character codes
 - Essentially, we assign a code or each character we want to represent
- As computers have evolved, character codes have evolved. Larger computer memories and storage devices permit richer character codes
- Some of the character codes are

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1. BCD
 2. ASCII (American Standard Code for Information Interchange) (7 bits)
 3. Extended ASCII (8-bits)
 4. Unicode
 5. and others
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- A binary number of n bits gives 2^n different codes
 - For n=2 there are $2^2 = 4$ different codes, i.e., bit combinations {00, 01, 10, 11}

Binary Coded Decimal (BCD) code

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53

- when numbers, letters are represented by a specific group of symbols, it is said that a number, letter or word is being encoded. The group of symbols is called a code



Binary Coded Decimal (BCD) code

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- In this code each decimal digit is represented by a 4-bit binary number
- BCD is a way to express each of the decimal digits with a binary code
- In the BCD, with four bits we can represent sixteen numbers (0000 to 1111)

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$$256_{10} = 0010\ 0101\ 0110_{BCD}$$

And vice versa

$$0011\ 1000\ 1001_{BCD} = 389_{10}$$

ASCII Code

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54

- The most widely accepted character code is called the American Standard Code for Information Interchange (ASCII).
- The ASCII code associates an integer value for each symbol in the character set, such as letters, digits, punctuation marks, special characters, and control characters.
- The ASCII table has 128 characters, with values from 0 through 127. Thus, 7 bits are sufficient to represent a character in ASCII.



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ASCII Code

Dec	Hx	Oct	Char	Dec	Hx	Oct	Char	Dec	Hx	Oct	HTML	Chr			
0	0 000	NUL	(null)	32	20 040	 	Space	64	40 100	@	Ø	96	60 140	`	`
1	1 001	SOH	(start of heading)	33	21 041	!	!	65	41 101	A	A	97	61 141	a	a
2	2 002	STX	(start of text)	34	22 042	"	"	66	42 102	B	B	98	62 142	b	b
3	3 003	ETX	(end of text)	35	23 043	#	#	67	43 103	C	C	99	63 143	c	c
4	4 004	EOT	(end of transmission)	36	24 044	$	\$	68	44 104	D	D	100	64 144	d	d
5	5 005	ENQ	(enquiry)	37	25 045	%	%	69	45 105	E	E	101	65 145	e	e
6	6 006	ACK	(acknowledge)	38	26 046	&	&	70	46 106	F	F	102	66 146	f	f
7	7 007	BEL	(bell)	39	27 047	'	'	71	47 107	G	G	103	67 147	g	g
8	8 010	BS	(backspace)	40	28 048	((72	48 110	H	H	104	68 150	h	h
9	9 011	TAB	(horizontal tab)	41	29 051))	73	49 111	I	I	105	69 151	i	i
10	A 012	LF	(NL line feed, new line)	42	2A 052	*	*	74	4A 112	J	J	106	6A 152	j	j
11	B 013	VT	(vertical tab)	43	2B 053	+	,	75	4B 113	K	K	107	6B 153	k	k
12	C 014	FF	(NP form feed, new page)	44	2C 054	,	,	76	4C 114	L	L	108	6C 154	l	l
13	D 015	CR	(carriage return)	45	2D 055	-	-	77	4D 115	M	M	109	6D 155	m	m
14	E 016	SO	(shift out)	46	2E 056	.	:	78	4E 116	N	N	110	6E 156	n	n
15	F 017	SI	(shift in)	47	2F 057	/	:	79	4F 117	O	O	111	6F 157	o	o
16	10 020	DLE	(data link escape)	48	30 060	0	Ø	80	50 120	P	P	112	70 160	p	p
17	11 021	DC1	(device control 1)	49	31 061	1	¡	81	51 121	Q	Q	113	71 161	q	q
18	12 022	DC2	(device control 2)	50	32 062	2	¢	82	52 122	R	R	114	72 162	r	r
19	13 023	DC3	(device control 3)	51	33 063	3	¤	83	53 123	S	S	115	73 163	s	s
20	14 024	DC4	(device control 4)	52	34 064	4	¤	84	54 124	T	T	116	74 164	t	t
21	15 025	NAK	(negative acknowledgement)	53	35 065	5	¤	85	55 125	U	U	117	75 165	u	u
22	16 026	SYN	(synchronous idle)	54	36 066	6	¤	86	56 126	V	V	118	76 166	v	v
23	17 027	ETB	(end of trans. block)	55	37 067	7	¤	87	57 127	W	W	119	77 167	w	w
24	18 030	CAN	(cancel)	56	38 070	8	¤	88	58 130	X	X	120	78 170	x	x
25	19 031	EM	(end of medium)	57	39 071	9	¤	89	59 131	Y	Y	121	79 171	y	y
26	1A 032	SUB	(substitute)	58	3A 072	:	:	90	5A 132	Z	Z	122	7A 172	z	z
27	1B 033	ESC	(escape)	59	3B 073	;	:	91	5B 133	[[123	7B 173	{	{
28	1C 034	FS	(file separator)	60	3C 074	<	<	92	5C 134	\	\	124	7C 174	|	
29	1D 035	GS	(group separator)	61	3D 075	=	=	93	5D 135]]	125	7D 175	}	}
30	1E 036	RS	(record separator)	62	3E 076	>	>	94	5E 136	^	^	126	7E 176	~	~
31	1F 037	US	(unit separator)	63	3F 077	?	?	95	5F 137	_	_	127	7F 177		DEL



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Extended ASCII Characters

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- ASCII was designed for teleprinters and telegraphy, and some computing
- The number of printable characters was deliberately kept small, to keep teleprinters and line printers inexpensive
- When computers and peripherals standardized on eight-bit bytes, it became obvious that computers and software could handle text that uses 256-character sets at almost no additional cost in programming, and no additional cost for storage
- An eight-bit character set (using one byte per character) encodes 256 characters, so it can include ASCII plus 128 more characters
- The extra characters represent characters from foreign languages and special symbols for drawing pictures



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A set of codes that extends the basic ASCII set. The extended ASCII character set uses 8 bits, which gives it an additional 128 characters

128	Ç	144	É	160	à	176	ç	192	Ł	208	ł	224	¤	240	≡
129	Ü	145	æ	161	í	177	ú	193	ł	209	Ł	225	ß	241	±
130	é	146	Æ	162	í	178	ú	194	ł	210	Ł	226	Γ	242	≥
131	á	147	ø	163	í	179	ú	195	ł	211	Ł	227	π	243	≤
132	ä	148	ö	164	í	180	ú	196	—	212	Ł	228	Σ	244	∫
133	à	149	ò	165	í	181	ú	197	+	213	F	229	¤	245	ʃ
134	ã	150	ó	166	í	182	ú	198	ł	214	Ł	230	μ	246	÷
135	ş	151	ù	167	í	183	ú	199	F	215	+	231	τ	247	¤
136	ë	152	ÿ	168	í	184	ú	200	Ł	216	+	232	Φ	248	°
137	è	153	ö	169	í	185	ú	201	F	217	+	233	Θ	249	.
138	è	154	Ü	170	í	186	ú	202	Ł	218	+	234	Ω	250	.
139	í	155	¢	171	í	187	ú	203	Ł	219	■	235	δ	251	√
140	í	156	£	172	í	188	ú	204	F	220	■	236	∞	252	¤
141	í	157	⌘	173	í	189	ú	205	=	221	■	237	◊	253	²
142	Ä	158	⌘	174	í	190	ú	206	Ł	222	■	238	ε	254	■
143	À	159	ƒ	175	»	191	ú	207	Ł	223	■	239	~	255	

Source: www.LookupTables.com

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UNICODE

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58

- Many of today's systems use Unicode that can encode the characters of every language in the world
 - The Java programming language, and some operating systems now use Unicode as their default character code
 - UTF-8 (8-bits: essentially the extended ASCII Table)
 - UTF-16 (16 bits: Most spoken languages in the world, widely used)
 - UTF-32 (32 bits: includes past languages, space inefficient)



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Any questions?

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59



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