

CSC 211: Computer Programming

Number Systems, Further look into DataTypes

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Administrative Notes

Number Systems

Number systems

- A way to represent numbers
 - ✓ numbers are expressed in a certain **base**
- Why study number systems in CS?
 - ✓ to understand data representation
- Examples of number systems
 - ✓ binary
 - ✓ decimal
 - ✓ octal
 - ✓ hexadecimal

Positional number systems

assuming base **b**:

$$\dots d_2 b^2 + d_1 b^1 + d_0 b^0 + d_{-1} b^{-1} + d_{-2} b^{-2} \dots$$

$$43.23 = 4 \cdot 10^1 + 3 \cdot 10^0 + 2 \cdot 10^{-1} + 3 \cdot 10^{-2}$$

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Decimal number system

▸ Base 10

▸ Symbols

0 1 2 3 4 5 6 7 8 9

$$456 = 4 \cdot 10^2 + 5 \cdot 10^1 + 6 \cdot 10^0$$

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Binary number system

▸ Base 2

▸ Symbols

0 1

Most
Significant Bit

Least
Significant Bit

$$1010 = (1 \cdot 2^3) + (0 \cdot 2^2) + (1 \cdot 2^1) + (0 \cdot 2^0)$$



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Binary to Decimal?

1 0 0 1 0 1 0 0 0

2^0	2^1	2^2	2^3	2^4	2^5	2^6	2^7	2^8
1	2	4	8	16	32	64	128	256

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Try these ..

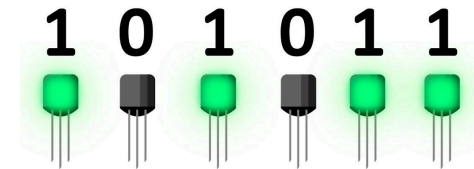
1 0 0 1 1 1 0 1
1 1 0 1 0 0 1 1
1 1 1 1 1 1 1 1

What is a **bit**? What is a **byte**?

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Bits and computers

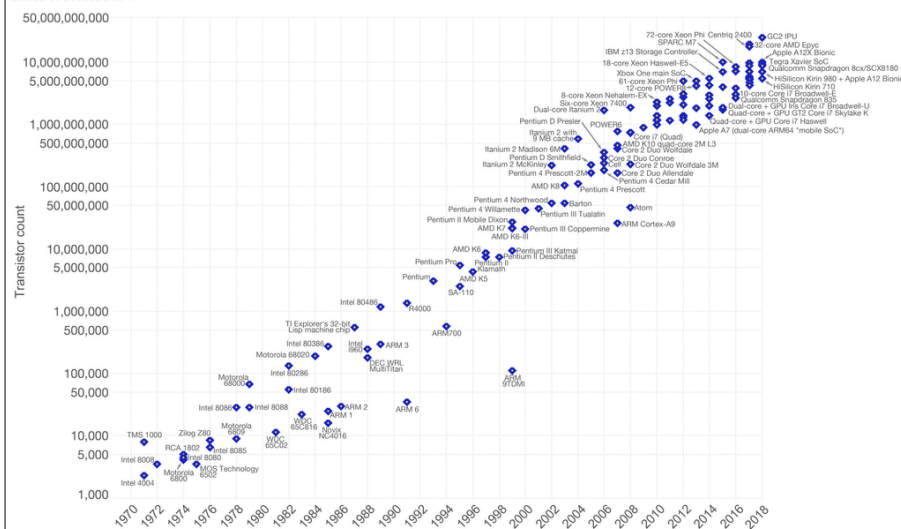
- A bit can only have two values (states)
 - ✓ easy to embed into physical devices
- **Transistor**
 - ✓ processors have billions of transistors
 - ✓ transistors can be switched **on** and **off**



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Moore's Law – The number of transistors on integrated circuit chips (1971-2018)
Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important as other aspects of technological progress – such as processing speed or the price of electronic products – are linked to Moore's law.

Our World in Data



Data source: Wikipedia (https://en.wikipedia.org/wiki/Transistor_count)
The data visualization is available at OurWorldinData.org. There you find more visualizations and research on this topic.

Licensed under CC-BY-SA by the author Max Roser.

Decimal to other bases

- Repeatedly divide by **base**
 - ✓ collect remainders
 - ✓ output in reverse order

57₁₀

$57 / 2 = 28 \text{ R } 1$
 $28 / 2 = 14 \text{ R } 0$
 $14 / 2 = 7 \text{ R } 0$
 $7 / 2 = 3 \text{ R } 1$
 $3 / 2 = 1 \text{ R } 1$
 $1 / 2 = 0 \text{ R } 1$

111001₂

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Decimal to other bases

- Another way to convert:

57₁₀

111001₂

2 ⁰	2 ¹	2 ²	2 ³	2 ⁴	2 ⁵	2 ⁶	2 ⁷	2 ⁸
1	2	4	8	16	32	64	128	256

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Hexadecimal number system

- Base 16
- Symbols

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

$$4A1C = (4 \cdot 16^3) + (10 \cdot 16^2) + (1 \cdot 16^1) + (12 \cdot 16^0)$$

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Hexadecimal to decimal

1 D Bx16

A 0 1 0 F

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Binary to hexadecimal

Hex	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Bin	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
Dec	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Oct	0	1	2	3	4	5	6	7	10	11	12	13	14	15	16	17

1 0 0 1 1 1 0 1

1 1 0 1 0 0 1 1














1 1 1 1 1 1 1 1

Humans think in **base 10**. Computers think in **base 2**.
Humans use **base 16** to easily manipulate data in **base 2**.

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Color codes

Shades of yellow color chart

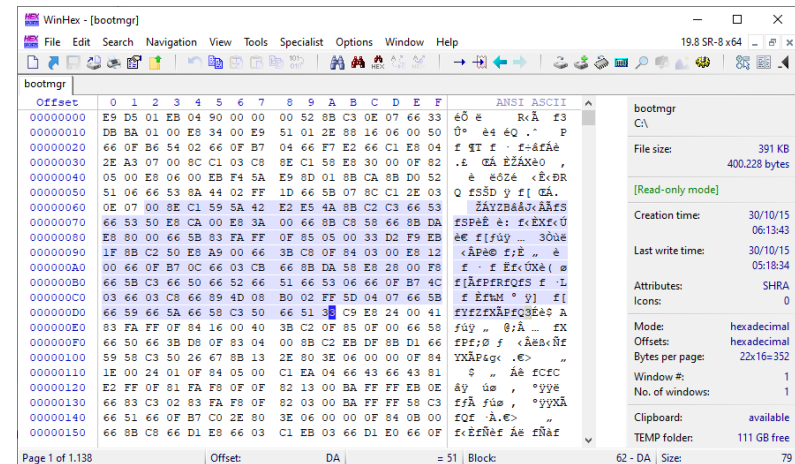
Color	HTML / CSS Color Name	Hex Code #RRGGBB	Decimal Code (R,G,B)
	lightyellow	#FFFFE0	rgb(255,255,224)
	lemonchiffon	#FFFACD	rgb(255,250,205)
	lightgoldenrodyellow	#FAFAD2	rgb(250,250,210)
	papayawhip	#FFEFD5	rgb(255,239,213)
	moccasin	#FFE4B5	rgb(255,228,181)
	peachpuff	#FFDAB9	rgb(255,218,185)
	palegoldenrod	#EEE8AA	rgb(238,232,170)
	khaki	#F0E68C	rgb(240,230,140)
	darkkhaki	#BDB76B	rgb(189,183,107)
	yellow	#FFFF00	rgb(255,255,0)
	olive	#808000	rgb(128,128,0)
	greenyellow	#ADFF2F	rgb(173,255,47)
	yellowgreen	#9ACD32	rgb(154,205,50)

https://www.rapidtables.com/web/color/Yellow_Color.html

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What is the color code of 'greenyellow' in binary?

Forensic Analysis



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31 oct = 25 dec?

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Going back to C++ ...

Integer literals in C++

```
int d = 42;
int o = 052;
int x = 0x2a;
int X = 0X2A;
int b = 0b101010; // C++14
```

- ✓ **decimal-literal** is a non-zero decimal digit (1, 2, 3, 4, 5, 6, 7, 8, 9), followed by zero or more decimal digits (0, 1, 2, 3, 4, 5, 6, 7, 8, 9)
- ✓ **octal-literal** is the digit zero (0) followed by zero or more octal digits (0, 1, 2, 3, 4, 5, 6, 7)
- ✓ **hex-literal** is the character sequence 0x or the character sequence 0X followed by one or more hexadecimal digits (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, A, b, B, c, C, d, D, e, E, f, F)
- ✓ **binary-literal** is the character sequence 0b or the character sequence 0B followed by one or more binary digits (0, 1)

https://en.cppreference.com/w/cpp/language/integer_literal

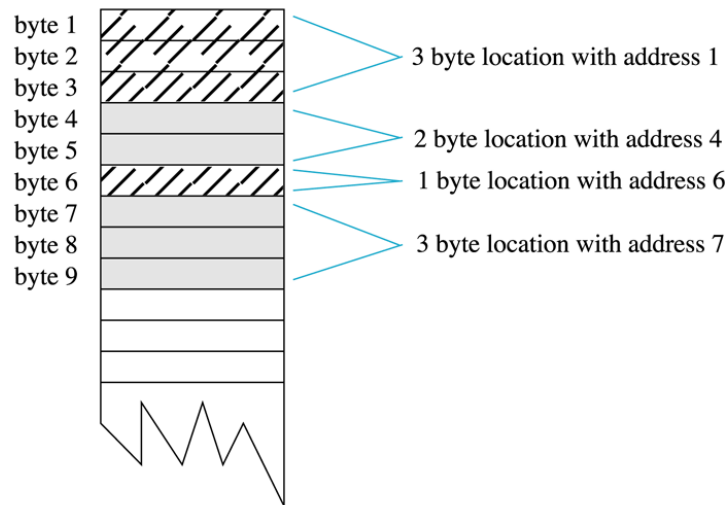
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Type	Size in bits	Format	Value range	
			Approximate	Exact
character	8	signed		-128 to 127
		unsigned		0 to 255
	16	unsigned		0 to 65535
integer	32	unsigned		0 to 1114111 (0x10ffff)
	16	signed	$\pm 3.27 \cdot 10^4$	-32768 to 32767
		unsigned	0 to $6.55 \cdot 10^4$	0 to 65535
	32	signed	$\pm 2.14 \cdot 10^9$	-2,147,483,648 to 2,147,483,647
		unsigned	0 to $4.29 \cdot 10^9$	0 to 4,294,967,295
	64	signed	$\pm 9.22 \cdot 10^{18}$	-9,223,372,036,854,775,808 to 9,223,372,036,854,775,807
floating point				
	32	IEEE-754 ϕ	<ul style="list-style-type: none"> min subnormal: $\pm 1.401,298,4 \cdot 10^{-45}$ min normal: $\pm 1.175,494,3 \cdot 10^{-38}$ max: $\pm 3.402,823,4 \cdot 10^{38}$ 	<ul style="list-style-type: none"> min subnormal: $\pm 0x1p-149$ min normal: $\pm 0x1p-126$ max: $\pm 0x1.ffffep+127$
	64	IEEE-754 ϕ	<ul style="list-style-type: none"> min subnormal: $\pm 4.940,656,458,412 \cdot 10^{-324}$ min normal: $\pm 2.225,073,858,507,201,4 \cdot 10^{-308}$ max: $\pm 1.797,693,134,862,315,7 \cdot 10^{308}$ 	<ul style="list-style-type: none"> min subnormal: $\pm 0x1p-1074$ min normal: $\pm 0x1p-1022$ max: $\pm 0x1.ffffffffffffp+1023$

<https://en.cppreference.com/w/cpp/language/types>

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Memory Locations and Bytes



from: Problem Solving with C++, 10th Edition, Walter Savitch

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