CSC 211: Computer Programming

Number Systems, Further look into DataTypes

Michael Conti

Department of Computer Science and Statistics
University of Rhode Island

Spring 2022

Original design and development by Dr. Marco Alvarez

Administrative Notes

Administrative notes

- A00 due 06/05
- Lab02 due 06/05

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**:

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

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

Decimal number system

- Base 10
- Symbols

0 1 2 3 4 5 6 7 8 9

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

Binary number system

- Base 2
- Symbols

0 1

Most Significant Bit

Least Significant Bit

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

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	258

Try these ..

1 0 0 1 1 1 0 1

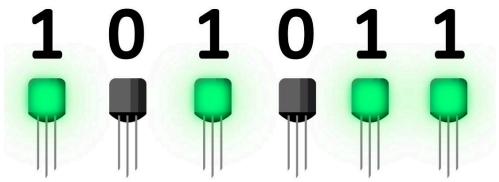
1 1 0 1 0 0 1 1

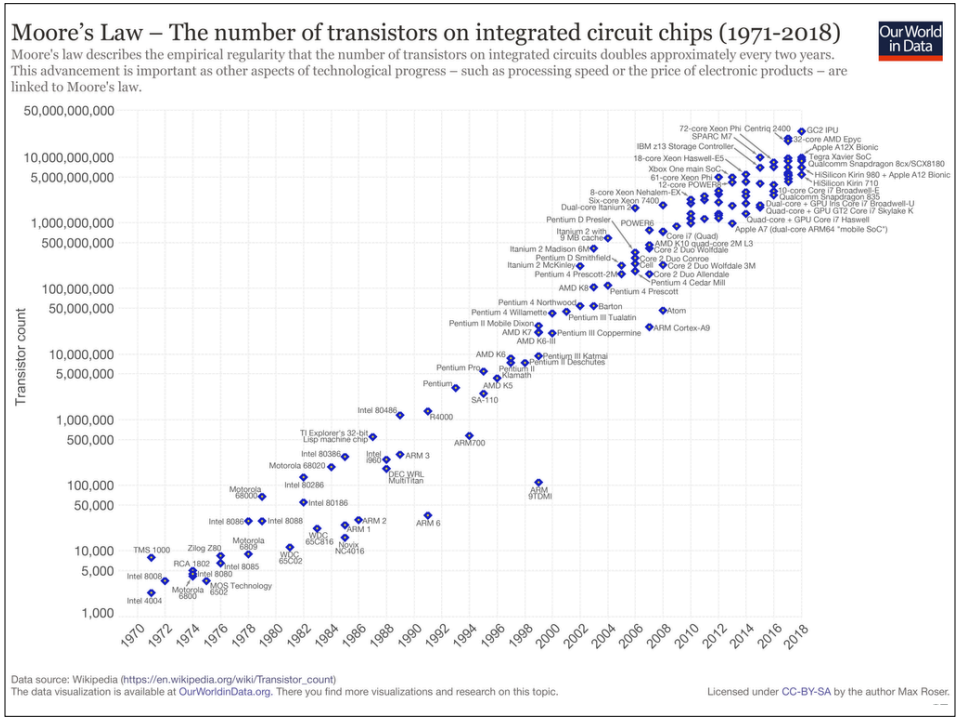
1 1 1 1 1 1 1 1

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

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**





Decimal to other bases

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

57_{10}

- 57 / 2 = 28 R 1
- 28 / 2 = 14 R 0
- 14 / 2 = 7 R 0
- 7 / 2 = 3 R 1
- 3 / 2 = 1 R 1
- 1 / 2 = 0 R 1

111001_2

Hexadecimal number system

- Base 16
- Symbols

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

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

Hexadecimal to decimal

1 D Bx16

A 0 1 0 F

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.**

Color codes

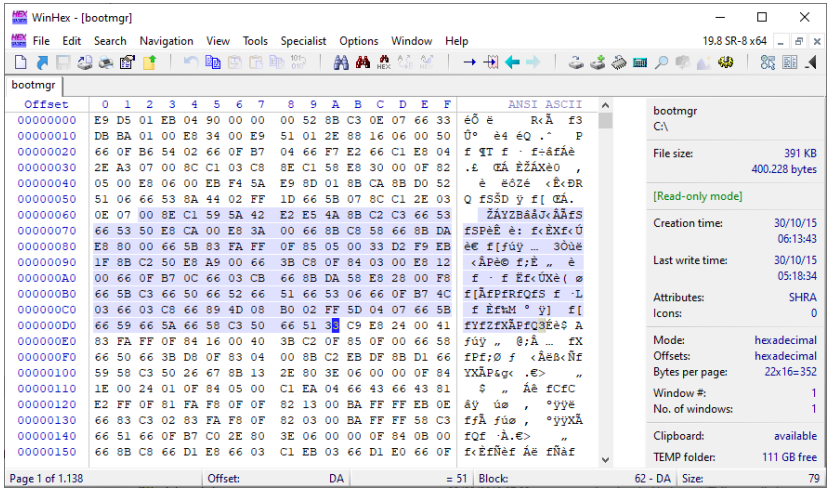
Shades of yellow color chart

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)

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

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

Forensic Analysis



31 oct = 25 dec?

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

DISPLAY 2.2 Some Number Types

Type Name	Memory Used	Size Range	Precision
short (also called *short int*)	2 bytes	-32,768 to 32,767	(not applicable)
int	4 bytes	-2,147,483,648 to 2,147,483,647	(not applicable)
long (also called *long int*)	4 bytes	-2,147,483,648 to 2,147,483,647	(not applicable)
float	4 bytes	approximately 10^{-38} to 10^{38}	7 digits
double	8 bytes	approximately 10^{-308} to 10^{308}	15 digits
long double	10 bytes	approximately 10^{-4932} to 10^{4932}	19 digits

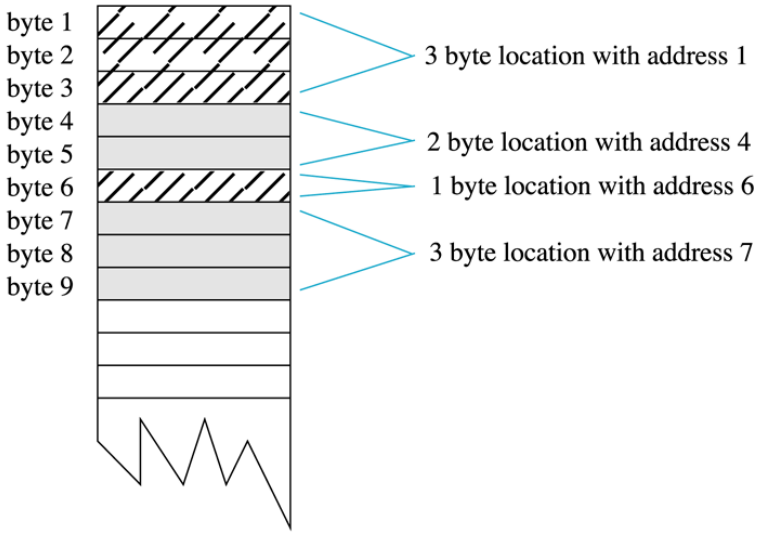
These are only sample values to give you a general idea of how the types differ. The values for any of these entries may be different on your system. `Precision` refers to the number of meaningful digits, including digits in front of the decimal point. The ranges for the types `float`, `double`, and `long double` are the ranges for positive numbers. Negative numbers have a similar range, but with a negative sign in front of each number.

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

Type	Size in bits	Format	Value range	
			Approximate	Exact
character	8	signed		**-128** to **127**
		unsigned		**0** to **255**
	16	unsigned		**0** to **65535**
	32	unsigned		**0** to **1114111** (**0x10ffff**)
integer	16	signed	**± 3.27 · 10^4**	**-32768** to **32767**
		unsigned	**0** to **6.55 · 10^4**	**0** to **65535**
	32	signed	**± 2.14 · 10^9**	**-2,147,483,648** to **2,147,483,647**
		unsigned	**0** to **4.29 · 10^9**	**0** to **4,294,967,295**
	64	signed	**± 9.22 · 10^{18}**	**-9,223,372,036,854,775,808** to **9,223,372,036,854,775,807**
		unsigned	**0** to **1.84 · 10^{19}**	**0** to **18,446,744,073,709,551,615**
floating point	32	IEEE-754	• min subnormal: **± 1.401,298,4 · 10^{-45}** • min normal: **± 1.175,494,3 · 10^{-38}** • max: **± 3.402,823,4 · 10^{38}**	• min subnormal: **±0x1p-149** • min normal: **±0x1p-126** • max: **±0x1.fffffep+127**
	64	IEEE-754	• min subnormal: **± 4.940,656,458,412 · 10^{-324}** • min normal: **± 2.225,073,858,507,201,4 · 10^{-308}** • max: **± 1.797,693,134,862,315,7 · 10^{308}**	• min subnormal: **±0x1p-1074** • min normal: **±0x1p-1022** • max: **±0x1.fffffffffffffp+1023**

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

Memory Locations and Bytes



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