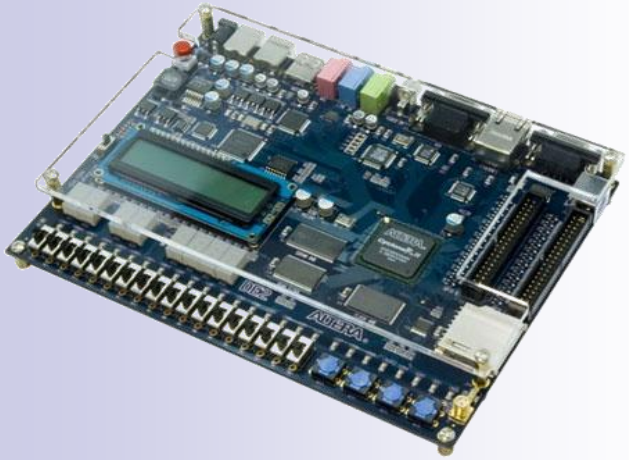
Selection from

Susta:Computer System Structures

& John Loomis: Computer organization

*& M.Mudawar:*Computer Architecture & Assembly Language

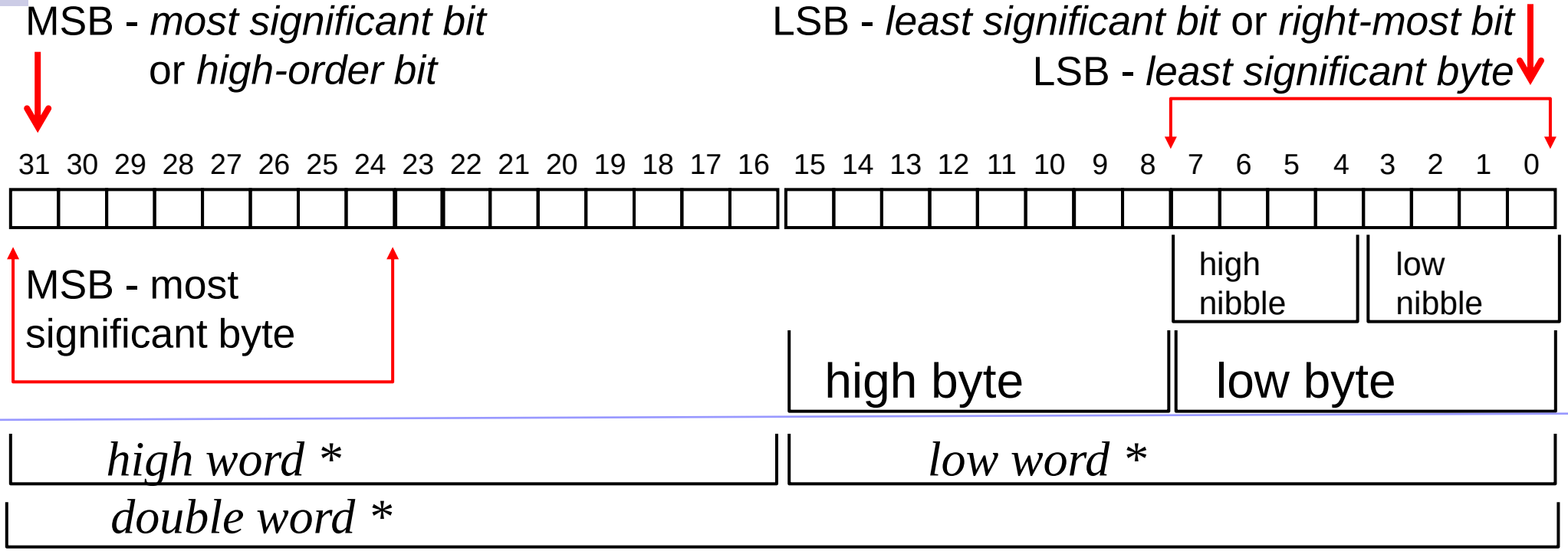
Version: 1.0



1st Practical Exercise

ČVUT-FEL in Prague,

Bytes, Nibbles, and Bits

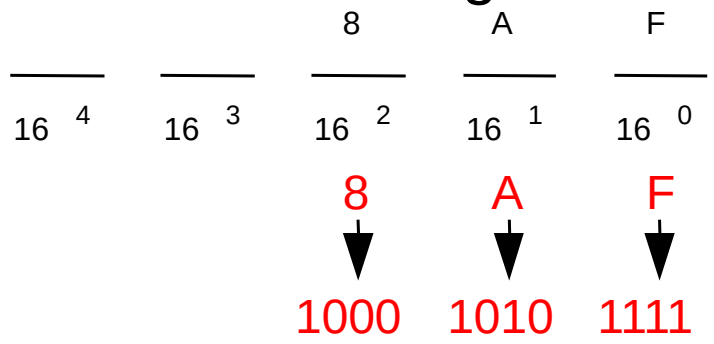


- **byte** or octet – 8 bits, *alternation of bite (cz:sousto) = a small piece of food, morsel*
- **nibble** (cz: ždibec, kousíček) – *a bit (as of food) such as might be taken in a small bite*
- ***bit*** *(cz:troška, špetka) - a small piece, portion, or quantity of some material thing*

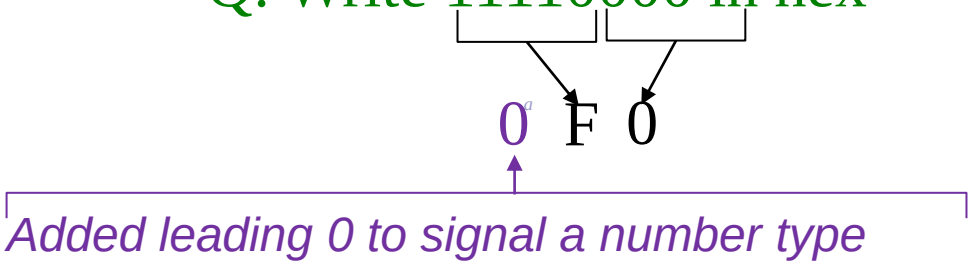
* ***Note:*** *The size of a word is not a standard, but only a natural unit reflecting computer's structure. It varies from 8 to 64 bits. The most frequent sizes are now 32, 64, or 16 bits (x86 family). Special processors, e.g. for digital signal processing, may use other sizes, (e.g. Apollo Guidance Computers used 15 bit words).*

Hexadecimal or *Hex* aka Base Sixteen

- 4 bits to 1 hex digits - **compact writing of binary numbers**



Q: Write 11110000 in hex



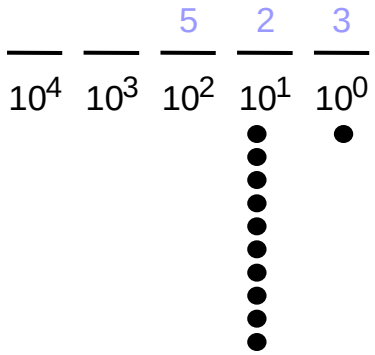
h e x	binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111

h e x	binary
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

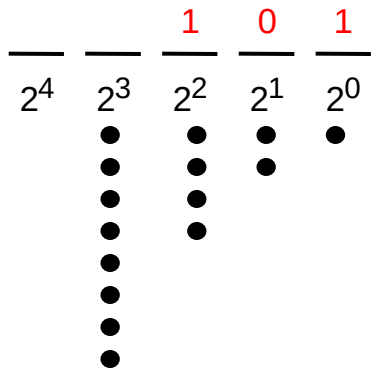
Binary Encoded Unsigned Integers

- Each position represents a quantity; symbol in position means how many of that quantity

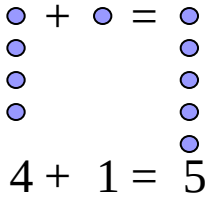
Base ten (***decimal***)



Base two (***binary***)



Q: How much?



n	2^n
0	1
1	2
2	4
3	8
4	16
5	32
6	64
7	128
8	256
9	512
10	1,024
11	2,048
12	4,096
13	8,192
14	16,384
15	32,768
16	65,536

Converting Unsigned Integer to Binary

- Decimal number: 13

By dividing

13/2 = 6 rem 1 ← LSB
6/2 = 3 rem 0
3/2 = 1 rem 1
1/2 = 1 rem 1 ← MSB

By subtracting - *binary weights added up to the decimal quantity*

32	16	8	4	2	1	
_	_	_	_	_	_	
1	_	_	_	_	_	=32 too much
0	1	_	_	_	_	=16 too much
0	0	1	_	_	_	=8 ok, 13-8=5
0	0	1	1	_	_	=8+4=12 ok, 5-4=1
0	0	1	1	0	_	=8+4+2 too much
0	**0**	**1**	**1**	**0**	**1**	=8+4+1=13 1-1=0

Special Codes

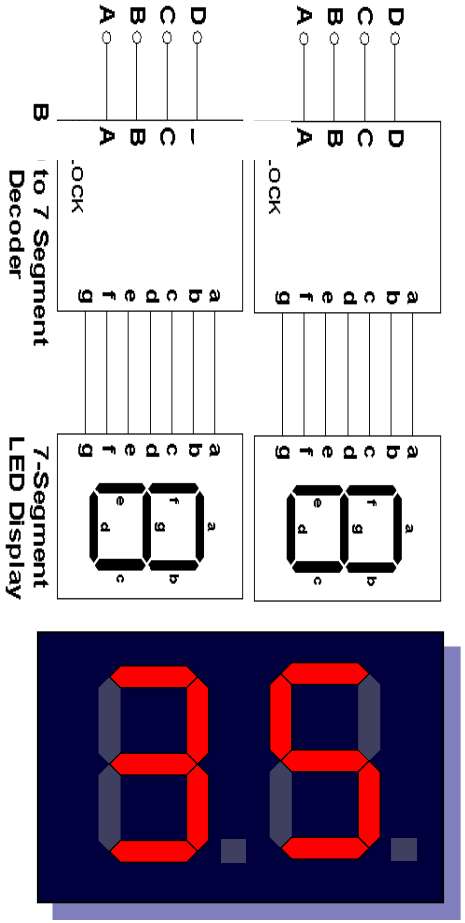
Dec.	Binary 8 4 2 1	Octal 421	Hex (VHDL syntax)	BCD binary / hex
0	0000	00	x”0”	0000 0000 = x"00"
1	0001	01	x”1”	0000 0001 = x"01"
2	0010	02	x”2”	0000 0010 = x"02"
3	0011	03	x”3”	0000 0011 = x"03"
4	0100	04	x”4”	0000 0100 = x"04"
5	0101	05	x”5”	0000 0101 = x"05"
6	0110	06	x”6”	0000 0110 = x"06"
7	0111	07	x”7”	0000 0111 = x"07"
8	1000	10	x”8”	0000 1000 = x"08"
9	1001	11	x”9”	0000 1001 = x"09"
10	1010	12	x”A”	0001 0000 = x"10"
11	1011	13	x”B”	0001 0001 = x"11"
12	1100	14	x”C”	0001 0010 = x"12"
13	1101	15	x”D”	0001 0011 = x"13"
14	1110	16	x”E”	0001 0100 = x"14"
15	1111	17	x”F”	0001 0101 = x"15"

35 as binary = x"23"

= 10 0011

35 as BCD = x"3 5"

=0011 0101



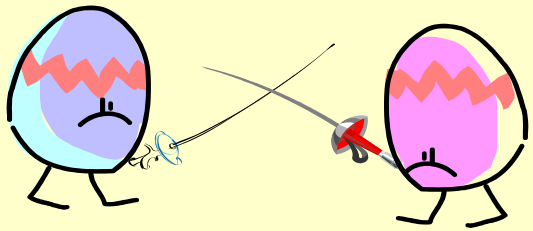
Storage number in memory

Big Endian - downto

0x100	0x101	0x102	0x103		
		01	23	45	67		

Little Endian - to

0x100	0x101	0x102	0x103		
		67	45	23	01		

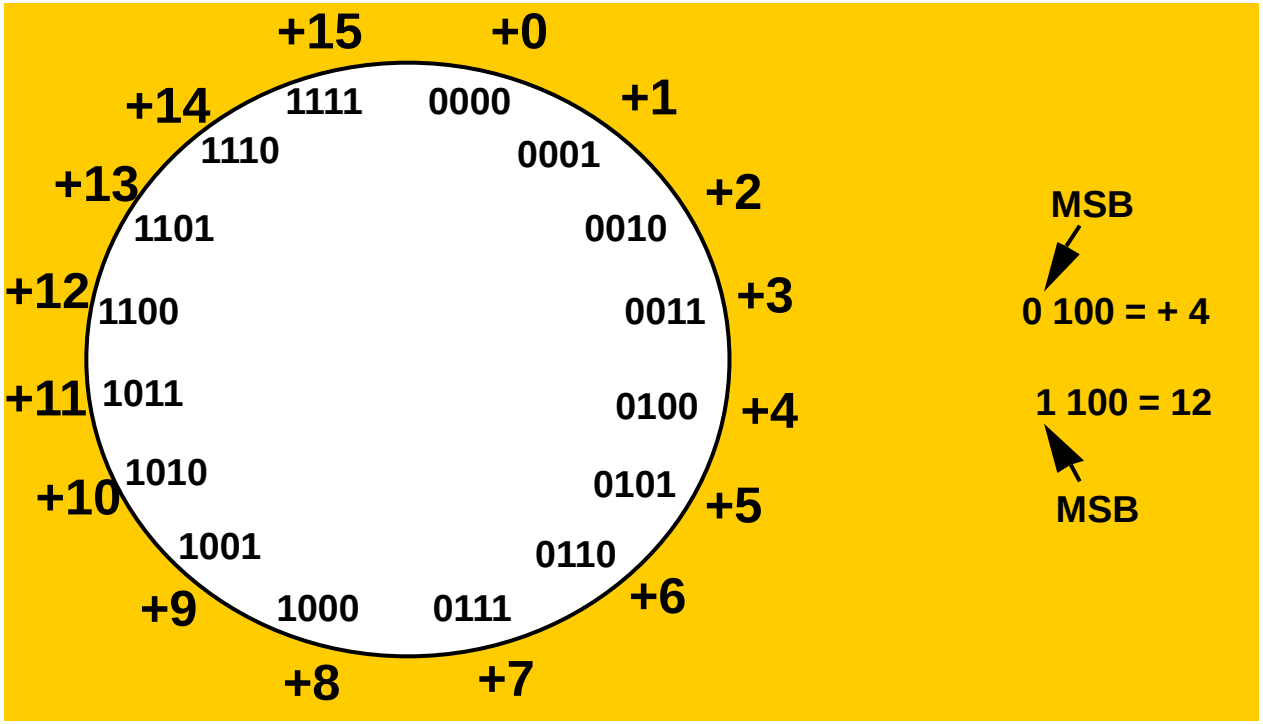


Little Endien comes from the book Gulliver's Travels , Jonathon Swift 1726, in which denote one of the two feuding factions of Lilliputs. Her followers ate eggs from the narrower end to a wider, while the **Big Endien** proceeded in reverse. A war could not be long in coming ...

Remember, how war had ended?

Assumptions:we'll assume a 4 bit machine word

Unsigned 4-bit numbers



- Cumbersome subtraction

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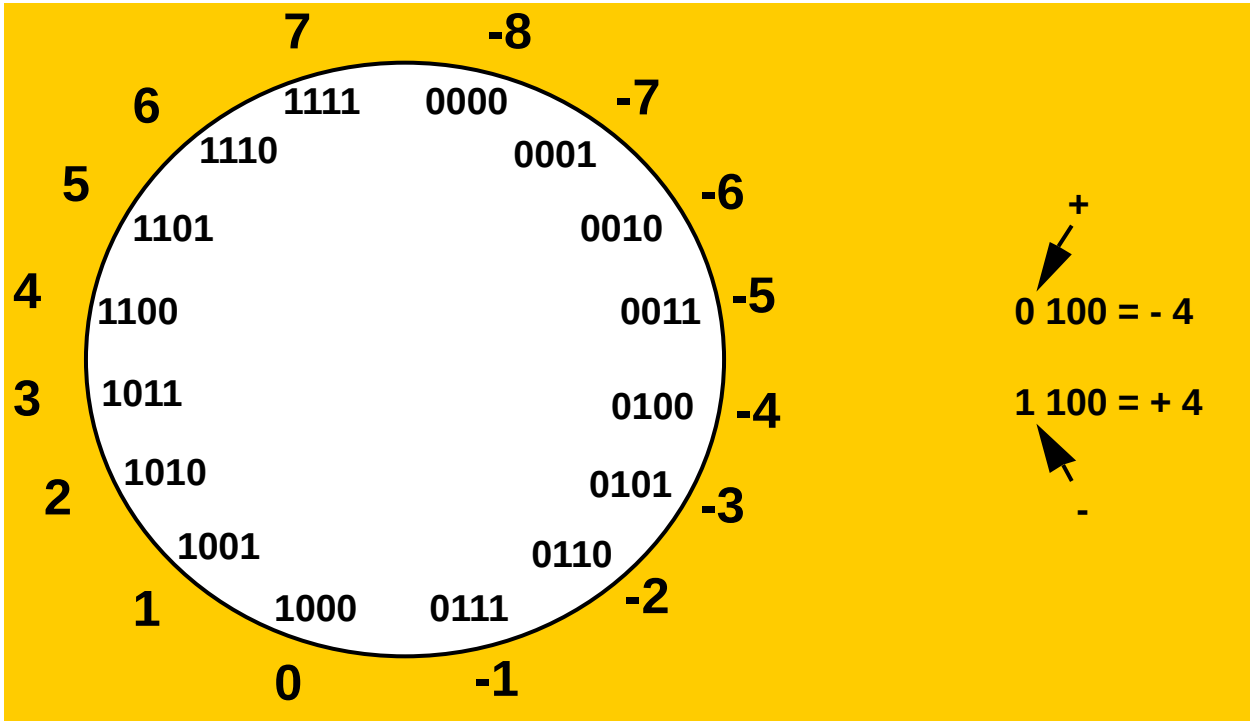
Excess-K, offset binary or biased representation



- One 0 representation, we can select count of negative numbers - *used e.g. for exponents of real numbers*..
- Integer arithmetic unit are not designed to calculate with Excess-K numbers

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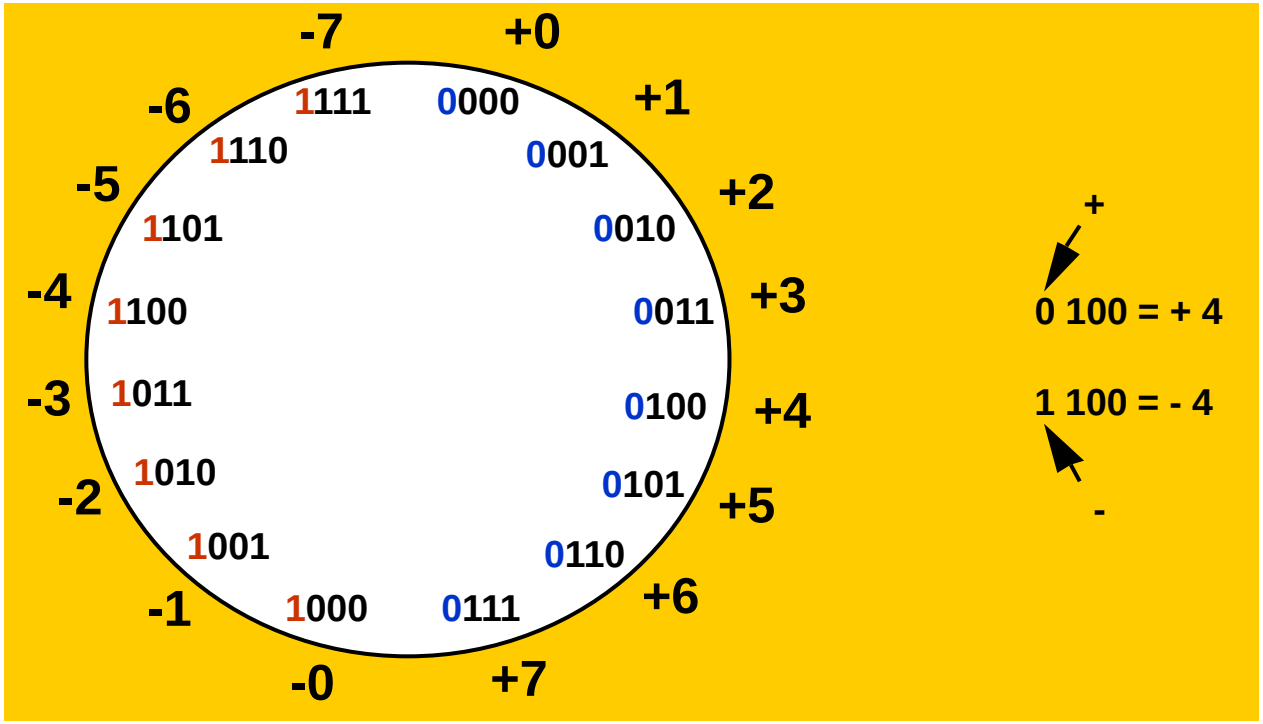
Sign and Magnitude Representation



- Cumbersome addition/subtraction
- *Sign+Magnitude usually used only for float point numbers*

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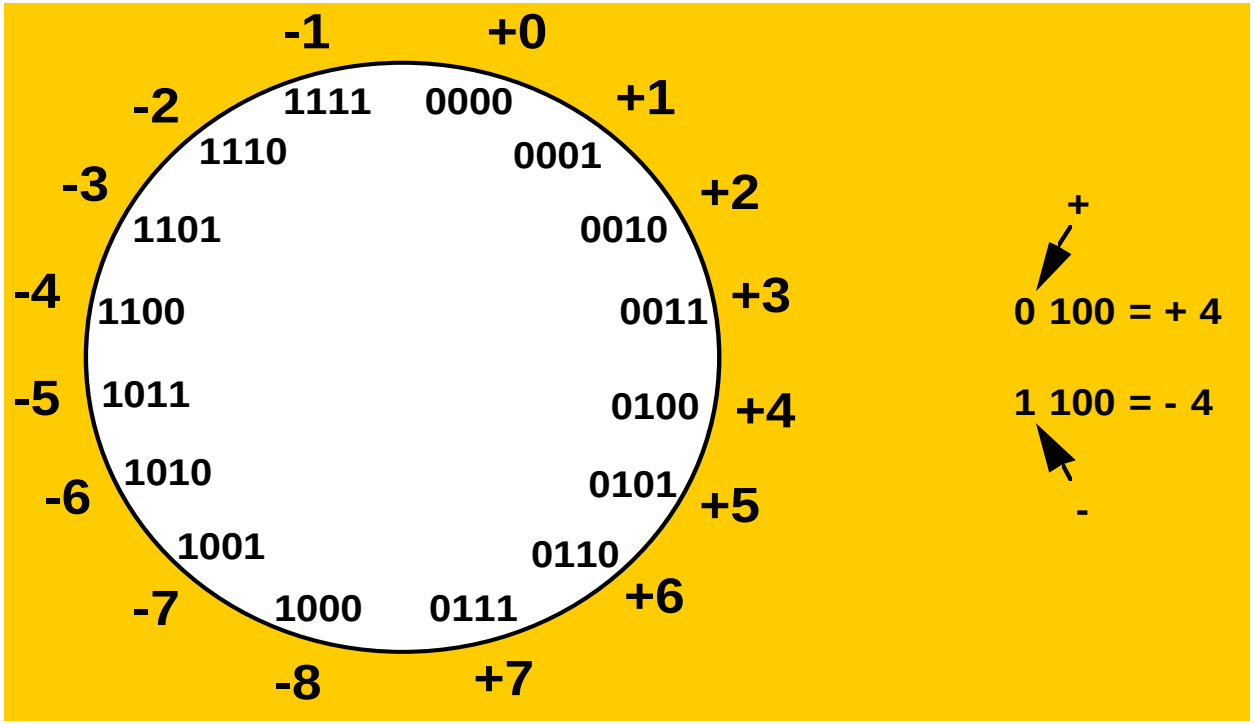
Twos Complement
(In Czech: Druhý doplněk)



- Only one representation for 0
- One more negative number than positive number

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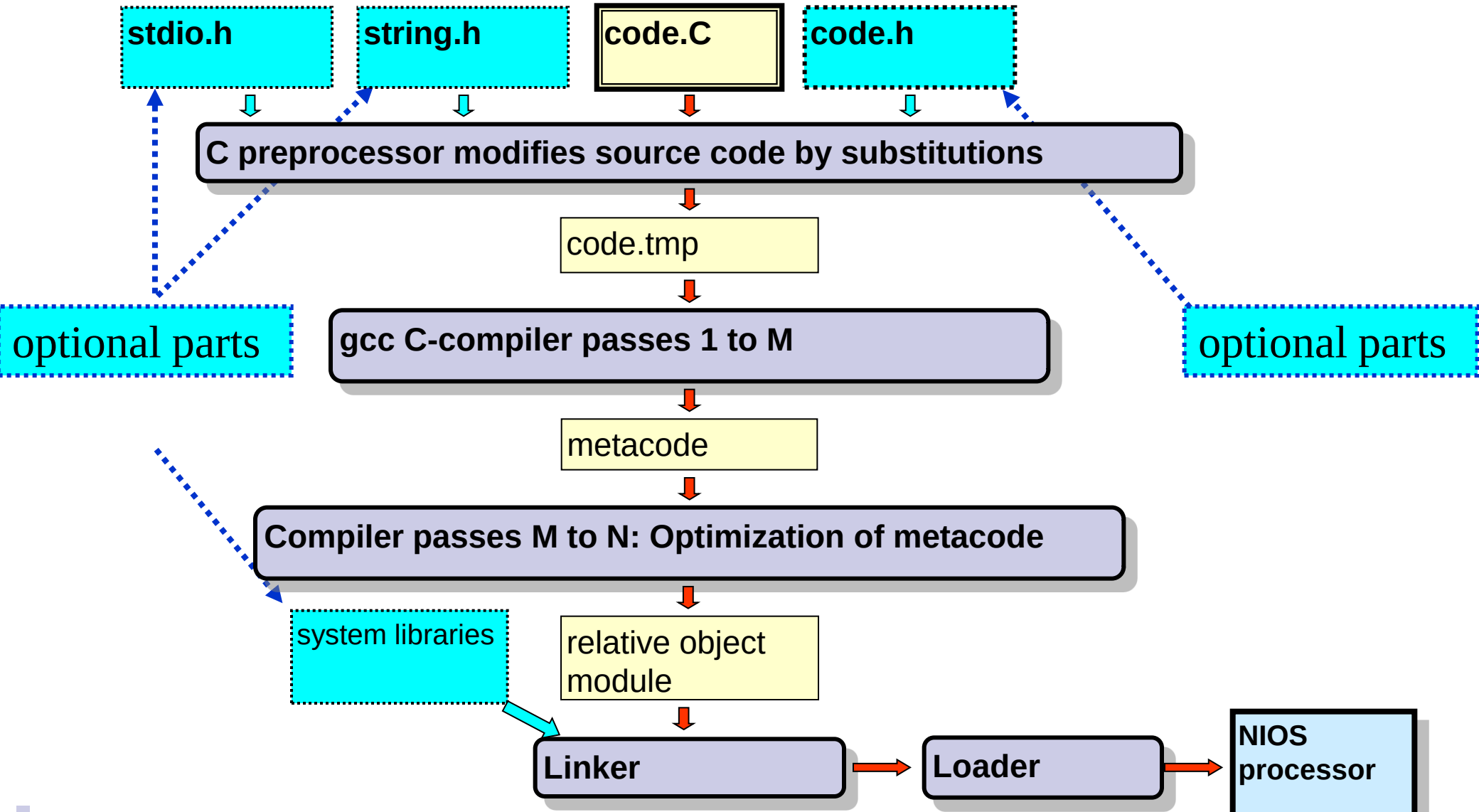
Basic Steps of C Compiler



C primitive types

Size	Java	C	C alternative	Range
1	boolean	any integer, true if !=0	BOOL(1	0 to !=0
8	byte	char(2	signed char	–128 to +127
8		unsigned char	BYTE(1	0 to 255
16	short	int	signed short	–32768 to +32767
16		unsigned short		0 to + 65535
32	int	int	signed int	-2^31 to 2^31-1
32		unsigned int	DWORD(1	0 to 2^32-1
64	long	long	long int	-2^63 to 2^63-1
64		unsigned long	LWORD(1	0 to 2^64-1

1) In many implementations, it is not a standard C datatype, but only common custom for user's "#define" macro definitions, see next slides

2) Default is signed but it is best to specify.

Definition of BYTE and BOOL

// by substitution rule no ; and no type check

- #define BYTE unsigned char
- #define BOOL int

// by introducing new type, ending ; is required

- typedef unsigned char BYTE;
- typedef int BOOL;

C language has no strict type checking #define ~ typedef,
but typedef is usually better integrated into compiler.

Defining a Parameterized Macro

#define PRINT_MEM(a) print_mem((unsigned char*)&(a), sizeof(a))

- Similar to a C function, preprocessor macros can be defined with a parameter list; parameters are without data types.
- Syntax:

  `#define MACRONAME(`*`parameter_list`*`) text`

- No white space before (.

Examples:

```
#define MAXVAL(A,B) ((A) > (B)) ? (A) : (B)

#define PRINT(e1,e2) printf("%c\t%d\n",(e1),(e2));

#define putchar(x) putc(x, stdout)
```

#define PRINT_MEM(a) print_mem((unsigned char*)&(a), sizeof(a))

Side-effects!!!

Example:

```
#define PROD1(A,B) A * B
```

Wrong result:

```
PROD1(1+3,2) → 1+3 * 2
```

Improved example with ()

```
#define PROD2(A,B) (A) * (B)

PROD2(1+3,2) → (1+3) * (2)
```

Sign Extension Example in C

```
short int x =  15213;
int       ix = (int) x;
short int y = -15213;
int       iy = (int) y;
```

	Decimal	Hex	Binary
x	15213	3B 6D	00111011 01101101
ix	15213	00 00 C4 92	00000000 00000000 00111011 01101101
y	-15213	C4 93	11000100 10010011
iy	-15213	FF FF C4 93	11111111 11111111 11000100 10010011

Bitwise Logic Instructions

		Examples:
AND	&	n = n & 0xF0;
OR	|	n = n | 0xFF00;
XOR	^	n = n ^ 0x80;
left shift	<<	n = 0xFF << 4;
right shift	>>	n = n >> 4
NOT	~	n = ~0xFF;

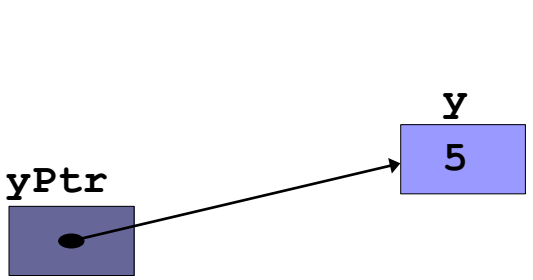
In C, operator << usually behaves as logical for unsigned operand and as arithmetic shift for signed operands.

Pointer Operators

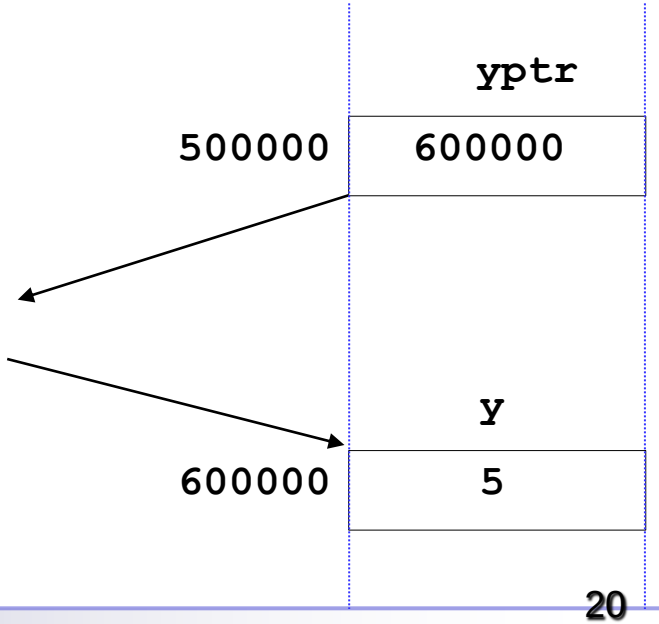
- **&** (address operator)
  - Returns the address of its operand
  - Example

```
int y = 5;
int *yPtr;
yPtr = &y;     // yPtr gets address of y
```

  - **yPtr** "points to" **y**



address of y is value of yptr



Pointer Operators

- **`&`** (address operator)
  - Returns the address of its operand
- * dereference address
  - Get operand stored in address location
- **`*`** and **`&`** are inverses
  (*though not always applicable*)
  - Cancel each other out

```
*&myVar == myVar
```

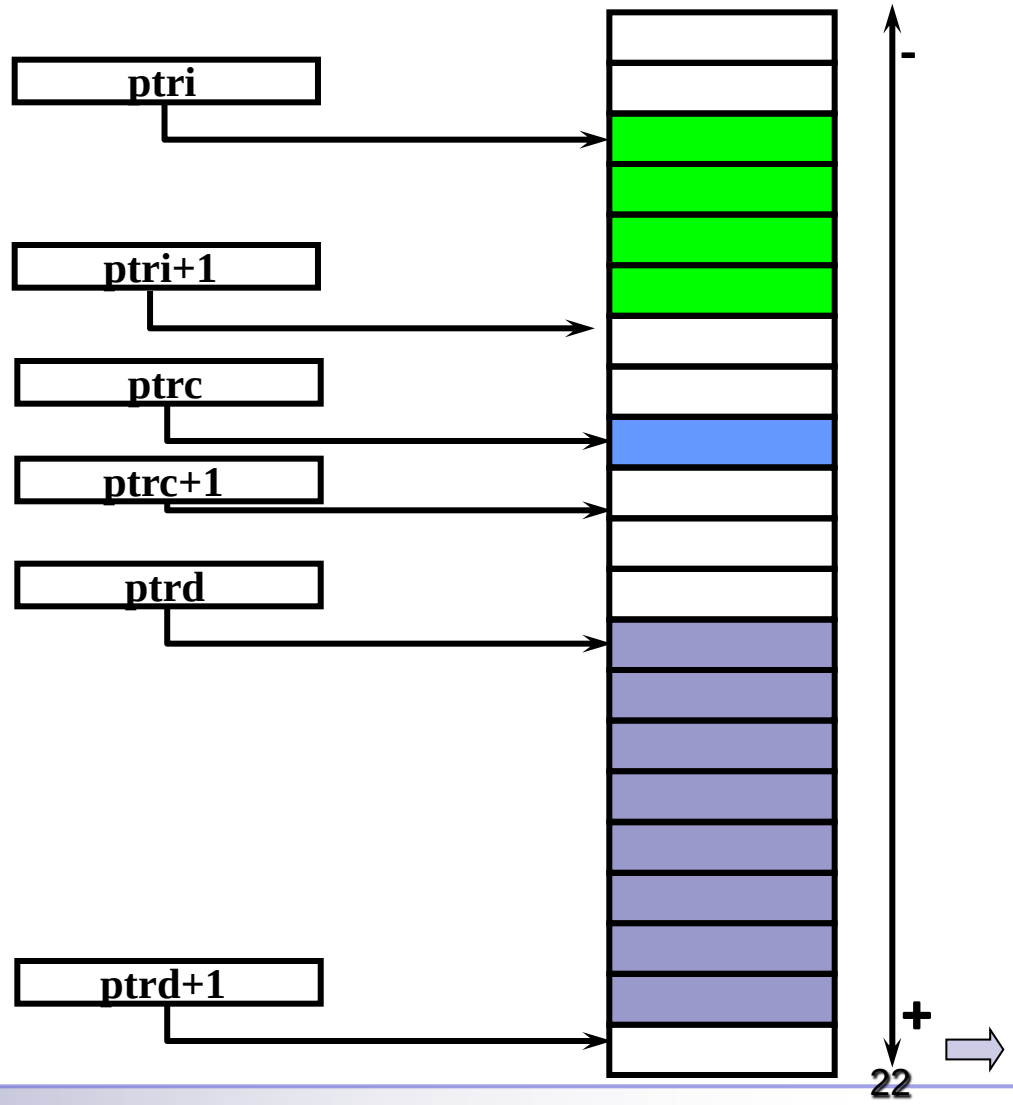
and

```
&*yPtr == yPtr
```

Size of Pointer in C-kod

```
int * ptri;
char * ptrc;
double * ptrd;
```

*ptrx ≡ ptrx[0]
*(ptrx+1) ≡ ptrx[1]
*(ptrx+n) ≡ ptrx[n]
*(ptrx-n) ≡ ptrx[-n]



nr1 = sizeof (double);
nr2 = sizeof (double*);

nr1 != nr2