

VL02 Memory and Elementary Types

Ondřej Havel

`<ondra.havel@gmail.com>`

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Data Representation

- Memory types
- Memory organization
- Elementary number types
- Data endianness
- Boolean logic
- Binary and hexadecimal radix, conversions

Memory Types

- RAM - Random Access Memory
 - SRAM - Static RAM - embedded in CPU, registers, cache
 - DRAM - Dynamic RAM - external chips, compacter, slower
- ROM - Read Only Memory
 - PROM - Programmable ROM
 - EPROM - Erasable and Programmable ROM
 - EEPROM - Electrically Erasable and Programmable ROM
- Flash ROM
 - Further developed version of EEPROM
 - Many different types
 - Better flexibility, higher speeds and capacity



Figure 1. EPROM chip with exposed erase window

Memory Access - Technical Aspects

- Power consumption
- Access times - write can be significantly slower than read
- Limited cycle count (EEPROM)
- Memory paging (FLASH)
- Memory management (time consumption)

Example: Atmega328 Datasheet

- 4/8/16/32K Bytes of In-System Self-Programmable Flash program memory
- 256/512/512/1K Bytes EEPROM
- 512/1K/1K/2K Bytes Internal SRAM
- Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
- Data retention: 20 years at 85°C/100 years at 25°C

Memory Organization

- Byte - smallest addressable unit; 1 B
- Bit - smallest accessible unit; 1 b
- Chunk - smallest exchangeable unit
 - Hardware/memory type specific
 - If used, contains multiple bytes (2, 4)
 - Accessing a single byte might not be the best idea
 1. Get a memory chunk
 2. Extract a specific byte from there \Rightarrow it could be faster to use larger data types
 3. Similar problem as extracting a bit from a byte
- Page - larger organization unit consisting of multiple bytes (4096, 8192, ..)
 - FLASH ROM access asymmetry (device specific):
 - Read anything anywhere
 - Write chunk on a page only once
 - Erase the page \Rightarrow now it is possible to write data again

Elementary number types

- Byte, word, double word, quad word, etc.
- C/Java types: char, short, int, long
 - Take special care - language/compiler specific!
 - Example: sizeof(char), sizeof(short), etc.

```
// A small comparison showing differences  
between different compilers.  
#include <stdio.h>  
  
void main() {  
  
                                     // this  
former  
    printf("%d\n", sizeof(char));    // 1  
1  
    printf("%d\n", sizeof(short));    // 2  
2  
    printf("%d\n", sizeof(int));      // 4  
2  
    printf("%d\n", sizeof(long));      // 8  
4  
    printf("%d\n", sizeof(long int));  // 8  
4  
    printf("%d\n", sizeof(long long)); // 8  
4  
}
```

- Explicit number types: uint8_t, uint16_t, uint32_t
 - Use for portable code where type size needs to be consistent

```
#include <stdio.h>
```

```
#include <stdint.h>

void main() {
    printf("%d\n", sizeof(uint8_t));
    // 1
    printf("%d\n", sizeof(uint16_t));
    // 2
    printf("%d\n", sizeof(uint32_t));
    // 4
    printf("%d\n", sizeof(uint64_t));
    // 8
}
```

Data Endianness

In computing, endianness refers to the order of bytes (or sometimes bits) within a binary representation of a number. It can also be used more generally to refer to the internal ordering of any representation, such as the digits in a numeral system or the sections of a date.

— Wikipedia

LSB, MSB - Least/Most Significant Byte

Consider the unsigned hexadecimal number 0x1234.

- requires at least two bytes to represent
- arrangement of the bytes
 - big-endian ordering 0x12, 0x34
 - little-endian ordering 0x34, 0x12
- Type casting, consider `uint16_t` \Rightarrow `uint8_t` conversion with little and big endian.

Boolean Operations

A	B	A AND B	A OR B	A XOR B	NOT A	NOT B
0	0	0	0	0	1	1
0	1	0	1	1	1	0
1	0	0	1	1	0	1
1	1	1	1	0	0	0

- Complementary operations: nand, nor, nxor
- AND
 - binary multiplication
 - A AND A, A && B
- OR
 - inclusive binary addition
 - A OR B, A || B
- NOT
 - unary operation
 - NOT(A), !A
- $A \text{ XOR } B = (!A \ \&\& \ B) \ || \ (A \ \&\& \ !B)$

Boolean Expressions

- Right to left interpretation (C-based languages)
- Programming essentials: simplify/negate logical expressions

```
/* one way */
if(is_engine_ready() && test_engine()) {
    start_engine();
} else {
    do_something_else();
}

/* or another */
if(!is_engine_ready() || !test_engine()) {
    do_something_else();
} else {
    start_engine();
}
```

- Avoid tautology and contradiction

```
if(a == 1 || a != 1) {

}
```

- Might be handy for easily de-activating a block of code during the development.

```
if(0) { // equivalent if(false) {
// this block is now deactivated
}

if(1) { // equivalent if(true) {
// yes, this shall run
}
```

}

Bitwise Operations

- Counterparts of binary operations applied on whole numbers.

A	B	A AND B	A OR B	A XOR B	NOT A	NOT B
10001111	11010000	10000000	11011111	11011111	01110000	00101111

- A AND B; A & B
- A OR B; A | B
- NOT(A); ~A
- SHL <<, SHR >>

Code Review I

- What does the code do and why?
- Convert the values of a and b to hexadecimal

```
int a = 100;  
int b = 160;
```

```
a = a ^ b;  
b = a ^ b;  
a = a ^ b;
```

Exercise 0

Implement an algorithm:

Input: unsigned integer value Output: number of bits with value 1 in its binary representation

Exercise 1

Consider the following code snippet in Basic. How would the Java/C counterpart look like?

```
While row < lastrow
  For i As Integer = 0 To lastcol
    If i = 5 Then
      Continue While
    End If
  Next i
End While
```

Exercise 2

Implement and write an algorithm!

Iterate the following transformations with input data:

- Replace every 0 with 1 and replace every 1 with 10
 - Example: $101 \Rightarrow 10110$
- Use the newly created data for the next iteration

Use 0 as initial input. What can be seen?