Introduction to C Programming

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Lecture 01

B3B36PRG – C Programming Language

Part II

Part 2 – Introduction to C Programming

C Programming Language

- Low-level programming language
- System programming language (operating system)

  Language for (embedded) systems — MCU, cross-compilation
- A user (programmer) can do almost everything

  Initialization of the variables, release of the dynamically allocated memory, etc.
- Very close to the hardware resources of the computer

  Direct calls of OS services, direct access to registers and ports
- Dealing with memory is crucial for correct behaviour of the program

  One of the goals of the PRG course is to acquire fundamental principles that can be further generalized for other programming languages. The C programming language provides great opportunity to became familiar with the memory model and key elements for writting efficient programs.

It is highly recommended to have compilation of your program fully under control.

It may look difficult at the beginning, but it is relatively easy and straightforward. Therefore, we highly recommend to use fundamental tools for your program compilation. After you acquire basic skills, you can profit from them also in more complex development environments.

Writing Your C Program

- Source code of the C program is written in text files
  - Header files usually with the suffix **.h**
  - Sources files usually named with the suffix **.c**

- Header and source files together with **declaration** and **definition** (of functions) support
  - **Organization** of sources into several files (modules) and libraries
  - **Modularity** – Header file declares a visible interface to others

    A description (list) of functions and their arguments without particular implementation
  - **Reusability**
    - Only the "interface" declared in the header files is need to use functions from available binary libraries

- Escape sequences for writting special symbols
  - \o, \oo, where o is an octal numeral
  - \xh, \xhh, where h is a hexadecimal numeral

```c
int i = 'a';
int h = 0x61;
int o = 0141;

printf("i: %i h: %i o: %i c: %c\n", i, h, o, i);
printf("oct: \141 hex: \x61\n");
```

E.g., \141, \x61 `lec01/esqdho.c`

- \0 – character reserved for the end of the text string (null character)

Writing Identifiers in C

- Identifiers are names of variables (custom types and functions)

  Types and functions, viz further lectures
- Rules for the identifiers
  - Characters a–z, A–Z, 0–9 a _
  - The first character is not a numeral
  - Case sensitive
  - Length of the identifier is not limited

    First 31 characters are significant – depends on the implementation / compiler
- Keywords$_{32}$

  auto break case char const continue default do double else enum extern float for goto if int long register return short signed sizeof static struct switch typedef union unsigned void volatile while

  C98

C99 introduces, e.g., `inline`, `restrict`, `_Bool`, `_Complex`, `_Imaginary`
C11 further adds, e.g., `_Alignas`, `_Alignof`, `_Atomic`, `_Generic`, `_Static_assert`, `_Thread_local`

Simple C Program

```c
#include <stdio.h>

int main(void)
{
   printf("I like B3B36PRG!\n");

   return 0;
}
```

lec01/program.c

- Source files are compiled by the compiler to the so-called **object files** usually with the suffix **.o**

  Object code contains relative addresses and function calls or just references to function without known implementations.

- The final executable program is created from the object files by the linker

Program Compilation and Execution

- Source file `program.c` is compiled into runnable form by the compiler, e.g., `clang` or `gcc`

```
clang program.c
```

- There is a new file `a.out` that can be executed, e.g.,

```
./a.out
```

Alternatively the program can be run only by `a.out` *in the case the actual working directory is set in the search path of executable files*

- The program prints the argument of the function `printf()`

```
./a.out
I like B3B36PRG!
```

- If you prefer to run the program just by `a.out` instead of `./a.out` you need to add your actual working directory to the search paths defined by the environment variable `PATH`

```
export PATH="$PATH:`pwd`"
```

Notice, this is not recommended, because of potentially many working directories.

- The command `pwd` prints the actual working directory, see `man pwd`

Structure of the Source Code – Commented Example

- Commented source file `program.c`

```c
/* Comment is inside the markers (two characters)
   and it can be split to multiple lines */
// In C99 - you can use single line comment
#include <stdio.h> /* The #include direct causes to
    include header file stdio.h from the C standard
    library */

int main(void) // simplified declaration
{              // of the main function
   printf("I like B3B36PRG!\n"); /* calling printf()
    function from the stdio.h library to print string
    to the standard output. \n denotes a new line */
   return 0; /* termination of the function. Return
    value 0 to the operating system */
}
```

Program Building: Compiling and Linking

- The previous example combines three particular steps of the program building in a single call of the command (`clang` or `gcc`). The particular steps can be performed individually

1. Text preprocessing by the **preprocessor**, which utilizes its own macro language (commands with the prefix #)

   All referenced header files are included into a single source file

2. Compilation of the source file into the object file

   Names of the object files usually have the suffix ***.o***

   ```
   clang -c program.c -o program.o
   ```

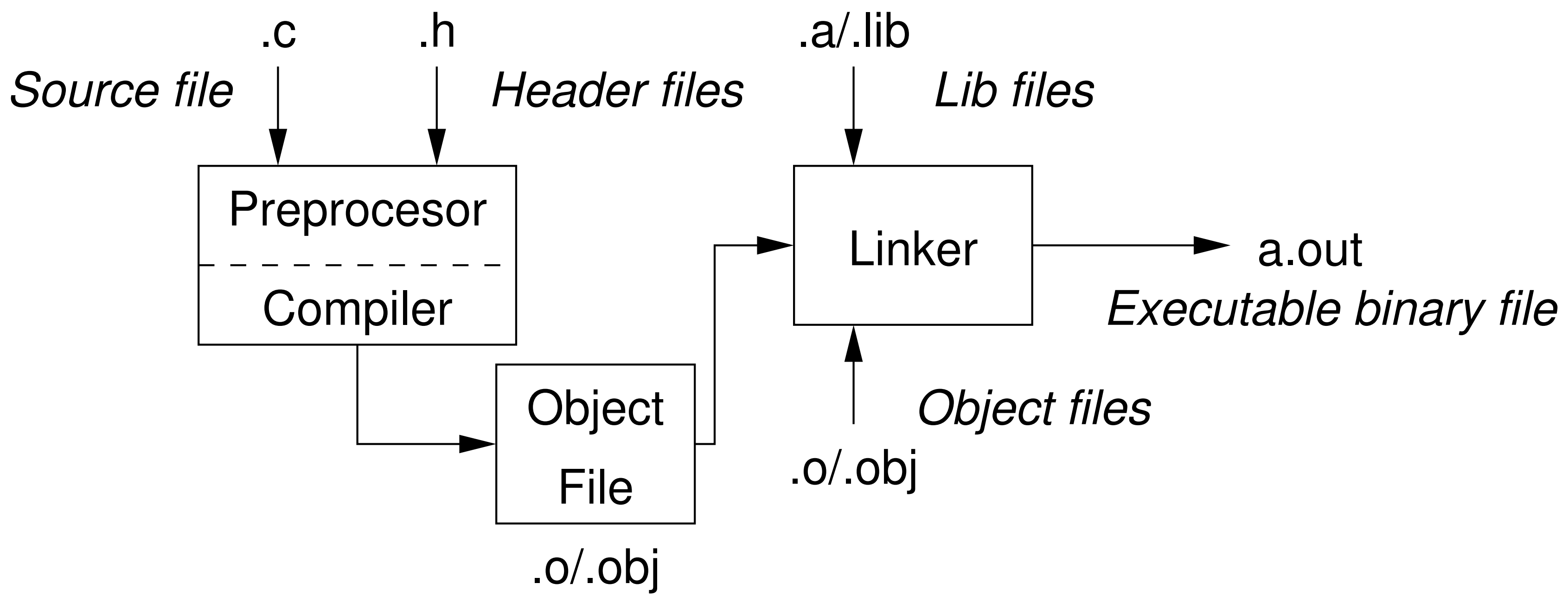
   The command combines preprocessor and compiler.

3. Executable file is linked from the particular object files and referenced libraries by the linker (linking), e.g.,

   ```
   clang program.o -o program
   ```

Compilation and Linking Programs

- Program development is editing of the source code (files with suffixes .c and .h); *Human readable*
- Compilation of the particular source files (.c) into object files (.o or .obj) ; *Machine readable*
- Linking the compiled files into executable binary file;
- Execution and debugging of the application and repeated editing of the source code.



Steps of Compiling and Linking

- **Preprocessor** – allows to define macros and adjust compilation the particular environment

  The output is text ("source") file.

- **Compiler** – Translates source (text) file into machine readable form

  Native (machine) code of the platform, bytecode, or assembler alternatively

- **Linker** – links the final application from the object files

  Under OS, it can still reference library functions (dynamic libraries linked during the program execution), it can also contains OS calls (libraries).

- Particular steps **preprocessor**, **compiler**, and **linker** are usually implemented by a "single" program that is called with appropriate arguments.

  E.g., `clang` *or* `gcc`

Compilers of C Program Language

- In PRG, we mostly use compilers from the families of compilers:
  - `gcc` – GNU Compiler Collection

    https://gcc.gnu.org
  - `clang` – C language family frontend for LLVM

    http://clang.llvm.org

Under Win, two derived environments can be utilized: ***cygwin*** https://www.cygwin.com/ *or* ***MinGW*** http://www.mingw.org/

- Basic usage (flags and arguments) are identical for both compilers

  `clang` *is compatible with* `gcc`
- Example
  - compile: `gcc -c main.c -o main.o`
  - link: `gcc main.o -o main`

Functions, Modules, and Compiling and Linking

- Function is the fundamental building block of the **modular** programming language

  Modular program is composed of several modules/source files

- **Function definition** consists of the
  - **Function header**
  - **Function body**

  Definition is the function implementation.

- **Function prototype** (**declaration**) is the function header to provide information how the function can be called

  It allows to use the function prior its definition, i.e., it allows to compile the code without the function implementation, which may be located in other place of the source code, or in other module.

- **Declaration** is the **function header** and it has the form

```
type function_name(arguments);
```

Functions in C

- Function definition inside other function is not allowed in C.
- Function names can be exported to other modules

  Module is an independent file (compiled independently)
- Function are implicitly declared as **extern**, i.e., visible
- Using the **static** specifier, the visibility of the function can be limited to the particular module

  Local module function
- Function arguments are **local variables** initialized by the values passed to the function

  Arguments are passed by value (call by value)
- **C allows recursions** – local variables are automatically allocated at the stack

  Further details about storage classes in next lectures.
- Arguments of the function are not mandatory – void arguments

  `fnc(void)`
- The return type of the function can be `void`, i.e., a function without return value – `void fnc(void);`

Example of Program / Module

```c
#include <stdio.h> /* header file */
#define NUMBER 5 /* symbolic constatnt */

int compute(int a); /* function header/prototype */

int main(int argc, char *argv[])
{ /* main function */
    int v = 10; /* variable declaration */
    int r;
    r = compute(v); /* function call */
    return 0; /* termination of the main function */
}

int compute(int a)
{ /* definition of the function */
  int b = 10 + a; /* function body */
  return b; /* function return value */
}
```

Program Starting Point – `main()`

- Each executable program must contain at least one definition of the function and that function must be the `main()`
- The `main()` function is the starting point of the program
- The `main()` has two basic forms
  1. Full variant for programs running under an Operating System (OS)

     ```
     int main(int argc, char *argv[])
     {
         ...
     }
     ```

     - It can be alternatively written as

       ```
       int main(int argc, char **argv)
       {
           ...
       }
       ```

  2. For embedded systems without OS

     ```
     int main(void)
     {
         ...
     }
     ```

Arguments of the `main()` Function

- During the program execution, the OS passes to the program the number of arguments (`argc`) and the arguments (`argv`)

  In the case we are using OS

  - The first argument is the name of the program

```c
int main(int argc, char *argv[])
{
    int v;
    v = 10;
    v = v + 1;
    return argc;
}
```

lec01/var.c

- The program is terminated by the `return` in the `main()` function
- The returned value is passed back to the OS and it can be further use, e.g., to control the program execution.

Example of Compilation and Program Execution

- Building the program by the `clang` compiler – it automatically joins the compilation and linking of the program to the file `a.out`

```
clang var.c
```

- The output file can be specified, e.g., program file `var`

```
clang var.c -o var
```

- Then, the program can be executed

```
./var
```

- The compilation and execution can be joined to a single command

```
clang var.c -o var; ./var
```

- The execution can be conditioned to successful compilation

```
clang var.c -o var && ./var
```

Programs return value — 0 means OK

Logical operator && depends on the command interpret, e.g., `sh`, `bash`, `zsh`*.*

Example – Program Execution under Shell

- The return value of the program is stored in the variable $?

  sh, bash, zsh

- Example of the program execution with different number of arguments

```
./var

./var; echo $?
1

./var 1 2 3; echo $?
4

./var a; echo $?
2
```

Example – Processing the Source Code by Preprocessor

- Using the -E flag, we can perform only the preprocessor step

  `gcc -E var.c`

  Alternatively `clang -E var.c`

```c
# 1 "var.c"
# 1 "<built-in>"
# 1 "<command-line>"
# 1 "var.c"
int main(int argc, char **argv) {
   int v;
   v = 10;
   v = v + 1;
   return argc;
}
```

lec01/var.c

Example – Compilation of the Source Code to Assembler

- Using the -S flag, the source code can be compiled to Assembler

```
clang -S var.c -o var.s
```

```
    .file "var.c"
    .text
    .globl  main
    .align  16, 0x90
    .type main,@function
main:
                  # @main
    .cfi_startproc
# BB#0:
   pushq %rbp
.Ltmp2:
    .cfi_def_cfa_offset 16
.Ltmp3:
    .cfi_offset %rbp, -16
   movq  %rsp, %rbp
.Ltmp4:
    .cfi_def_cfa_register %rbp
   movl  $0, -4(%rbp)
   movl  %edi, -8(%rbp)
   movq  %rsi, -16(%rbp)
   movl  $10, -20(%rbp)
   movl  -20(%rbp), %edi
   addl  $1, %edi
   movl  %edi, -20(%rbp)
   movl  -8(%rbp), %eax
   popq  %rbp
   ret
.Ltmp5:
   .size main, .Ltmp5-main
   .cfi_endproc


   .ident  "FreeBSD clang
     version 3.4.1 (tags/
     RELEASE_34/dot1-final
     208032) 20140512"
   .section  ".note.GNU-stack","
     ",@progbits
```

Example – Compilation to Object File

- The souce file is compiled to the object file

`clang -c var.c -o var.o`

```
% clang -c var.c -o var.o
% file var.o
var.o: ELF 64-bit LSB relocatable, x86-64, version 1
    (FreeBSD), not stripped
```

- **Linking** the object file(s) provides the executable file

`clang var.o -o var`

```
% clang var.o -o var
% file var
var: ELF 64-bit LSB executable, x86-64, version 1 (
    FreeBSD), dynamically linked (uses shared libs),
    for FreeBSD 10.1 (1001504), not stripped
```

dynamically linked
not stripped

Example – Executable File under OS 1/2

- By default, executable files are "tied" to the C library and OS services
- The dependencies can be shown by `ldd var`

ldd – list dynamic object dependencies

```
ldd var
var:
        libc.so.7 => /lib/libc.so.7 (0x2c41d000)
```

- The so-called static linking can be enabled by the `-static`

```
clang -static var.o -o var
% ldd var
% file var
var: ELF 64-bit LSB executable, x86-64, version 1 (
    FreeBSD), statically linked, for FreeBSD 10.1
    (1001504), not stripped
% ldd var
ldd: var: not a dynamic ELF executable
```

Check the size of the created binary files!

Example – Executable File under OS 2/2

- The compiled program (object file) contains symbolic names (by default)

E.g., usable for debugging.

```
clang var.c -o var
wc -c var
    7240 var
```

wc – word, line, character, and byte count

*-c – byte **c**ount*

- Symbols can be removed by the tool (program) **strip**

```
strip var
wc -c var
    4888 var
```

Alternatively, you can show size of the file by the command `ls -l`

Writting Values of the Numeric Data Types – Literals

- Values of the data types are called **literals**
- C has 6 type of constants (literals)
  - Integer
  - Rational

    We cannot simply write irrational numbers
  - Characters
  - Text strings
  - Enumerated

    Enum
  - Symbolic – `#define NUMBER 10`

    Preprocessor

Integer Literals

- Integer values are stored as one of the integer type (keywords): `int`, `long`, `short`, `char` and their `signed` and `unsigned` variants

  Further integer data types are possible

- Integer values (literals)

Decimal	123 450932	
Hexadecimal	0x12 0xFAFF	(starts with `0x` or `0X`)
Octal	0123 0567	(starts with `0`)
`unsigned`	12345U	(suffix `U` or `u`)
`long`	12345L	(suffix `L` or `l`)
`unsigned long`	12345ul	(suffix `UL` or `ul`)
`long long`	12345LL	(suffix `LL` or `ll`)

- Without suffix, the literal is of the type typu `int`

Literals of Rational Numbers

- Rational numbers can be written
  - with floating point – `13.1`
  - or with mantissa and exponent – `31.4e-3` or `31.4E-3`

Scientific notation

- Floating point numeric types depends on the implementation, but they usually follow IEEE-754-1985 `float`, `double`
- Data types of the rational literals:
  - `double` – by default, if not explicitly specified to be another type
  - `float` – suffix `F` or `f`

`float f = 10f;`

  - `long double` – suffix `L` or `l`

`long double ld = 10l;`

Character Literals

- Format – single (or multiple) character in apostrophe

  `'A'`, `'B'` or `'\n'`
- Value of the single character literal is the code of the character

  `'0'`$\sim$ 48, `'A'`$\sim$ 65

  Value of character out of ASCII (greater than 127) depends on the compiler.
- Type of the character constant (literal)
  - **character constant is the `int` type**

String literals

- Format – a sequence of character and control characters (escape sequences) enclosed in quotation (citation) marks

```
"This is a string constant with the end of line character \n"
```

  - String constants separated by white spaces are joined to single constant, e.g.,

    ```
    "String literal"  "with the end of the line character\n"
    ```

    is concatenate into

    ```
    "String literal with end of the line character\n"
    ```

- Type
  - String literal is stored in the array of the type `char` terminated by the `null` character `'\0'`
    E.g., String literal `"word"` is stored as

'w'	'o'	'r'	'd'	'\0'

The size of the array must be about 1 item longer to store `\0`!

More about text strings in the following lectures and labs

Constants of the Enumerated Type

- Format
  - By default, values of the enumerated type starts from 0 and each other item increase the value about one
  - Values can be explicitly prescribed

```
enum {
   SPADES,
   CLUBS,
   HEARTS,
   DIAMONDS
};
```

```
enum {
   SPADES = 10,
   CLUBS, /* the value is 11 */
   HEARTS = 15,
   DIAMONDS = 13
};
```

The enumeration values are usually written in uppercase.

- Type – enumerated constant is the `int` type
  - Value of the enumerated literal can be used in loops

```
enum { SPADES = 0, CLUBS, HEARTS, DIAMONDS, NUM_COLORS };
for (int i = SPADES; i < NUM_COLORS; ++i) {
   ...
}
```

Symbolic Constant – `#define`

- Format – the constant is established by the preprocessor command `#define`
  - It is macro command without argument
  - Each `#define` must be on a new line

```
#define SCORE 1
```

Usually written in uppercase

- Symbolic constants can express constant expressions

```
#define MAX_1   ((10*6) - 3)
```

- Symbolic constants can be nested

```
#define MAX_2   (MAX_1 + 1)
```

- **Preprocessor performs the text replacement of the define constant by its value**

```
#define MAX_2   (MAX_1 + 1)
```

It is highly recommended to use brackets to ensure correct evaluation of the expression, e.g., the symbolic constant `5*MAX_1` *with the outer brackets is 5*((10*6) - 3)=285 vs 5*(10*6) - 3=297.*

Variable with a constant value modifier (keyword) (`const`)

- Using the keyword **const**, a variable can be marked as constant

  Compiler checks assignment and do not allow to set a new value to the variable.
- A constant value can be defined as follows

```
const float pi = 3.14159265;
```

- In contrast to the symbolic constant

```
#define PI 3.14159265
```

- Constant values have type, and thus it supports **type checking**

Example: Sum of Two Values

```c
#include <stdio.h>

int main(void)
{
  int sum; // definition of local variable of the int type

  sum = 100 + 43; /* set value of the expression to sum */
  printf("The sum of 100 and 43 is %i\n", sum);
  /* %i formatting commend to print integer number */
  return 0;
}
```

- The variable `sum` of the type `int` represents an integer number. Its value is stored in the memory
- `sum` is selected symbolic name of the memory location, where the integer value (type `int`) is stored

Example of Sum of Two Variables

```c
#include <stdio.h>

int main(void)
{
   int var1;
   int var2 = 10; /* inicialization of the variable */
   int sum;

   var1 = 13;

   sum = var1 + var2;

   printf("The sum of %i and %i is %i\n", var1, var2, sum);

   return 0;
}
```

- Variables `var1`, `var2` and `sum` represent three different locations in the memory (allocated automatically), where three integer values are stored.

Variable Declaration

- The variable declaration has general form

  declaration-specifiers declarators;

- Declaration specifiers are:
  - **Storage classes**: at most one of the `auto`, `static`, `extern`, `register`
  - **Type quantifiers**: `const`, `volatile`, `restrict`

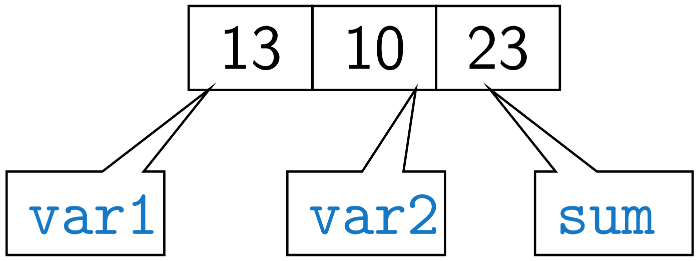
    Zero or more type quantifiers are allowed
  - **Type specifiers**: `void`, `char`, `short`, `int`, `long`, `float`, `double`, `signed`, `unsigned`. In addition, `struct` and `union` type specifiers can be used. Finally, own types defined by `typedef` can be used as well.

    Detailed description in further lectures.

Assignment, Variables, and Memory – Visualization
`unsigned char`

```c
unsigned char var1;
unsigned char var2;
unsigned char sum;

var1 = 13;
var2 = 10;

sum = var1 + var2;
```

- Each variable allocate 1 byte
- Content of the memory is not defined after allocation
- Name of the variable "references" to the particular memory location
- Value of the variable is the content of the memory location

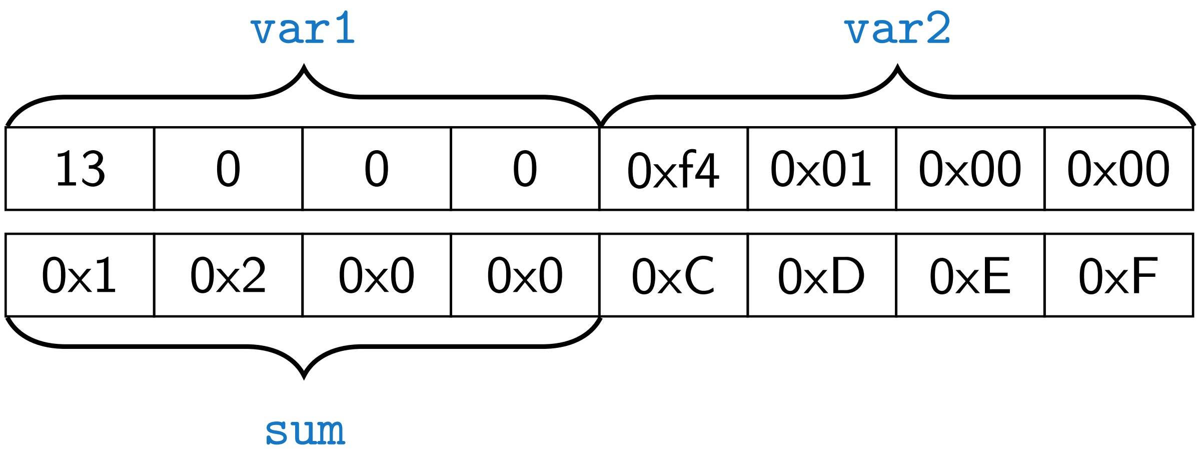


Assignment, Variables, and Memory – Visualization `int`

```c
int var1;
int var2;
int sum;

// 00 00 00 13
var1 = 13;

// x00 x00 x01
    xF4
var2 = 500;

sum = var1 +
    var2;
```

- Variables of the `int` types allocate 4 bytes

  Size can be find out by the operator `sizeof(int)`
- Memory content is not defined after the definition of the variable to the memory



500 (dec) is 0x01F4 (hex)

513 (dec) is 0x0201 (hex)

For Intel x86 and x86-64 architectures, the values (of multi-byte types) are stored in the ***little-endian*** *order.*

Expressions

- **Expression** prescribes calculation value of some given input
- Expression is composed of **operands**, **operators**, and **brackets**
- Expression can be formed of
  - literals
  - variables
  - constants
  - unary and binary operators
  - function calling
  - brackets
- The order of operation evaluation is prescribed by the operator **precedence** and **associativity**.

Example

```
10 + x * y      // order of the evaluation 10 + (x * y)
10 + x + y      // order of the evaluation (10 + x) + y
```

** has higher priority than +*
+ is associative from the left-to-right

Operators

- Operators are selected characters (or a sequences of characters) dedicated for writting expressions
- Five types of binary operators can be distinguished
  - **Arithmetic** operators – additive (addition/subtraction) and multiplicative (multiplication/division)
  - **Relational** operators – comparison of values (less than, greater than, ...)
  - **Logical** operators – logical `AND` and `OR`
  - **Bitwise** operators – bitwise `AND`, `OR`, `XOR`, bitwise shift (left, right)
  - Assignment operator $=$ – a variables (l-value) is on its left side
- Unary operators
  - Indicating positive/negative value: $+$ and $-$

    Operator $-$ modifies the sign of the expression
  - Modifying a variable : $++$ and $--$
  - Logical negation: **!**
  - Bitwise negation: $\sim$
- Ternary operator – conditional expression **? :**

Variables, Assignment Operator, and Assignment Statement

- Variables are defined by the type and name
  - Name of the variable are in lowercase
  - Multi-word names can be written with underscore _

    Or we can use CamelCase
  - Each variable is defined at new line

```
int n;
int number_of_items;
int numberOfItems;
```

- Assignment is setting the value to the variable, i.e., the value is stored at the memory location referenced by the variable name
- Assignment operator

$$\langle \textbf{l-value} \rangle = \langle \textbf{expression} \rangle$$

Expression is literal, variable, function calling, ...

  - The side is the so-called **l-value – location-value, left-value**

    It must represent a memory location where the value can be stored.
  - Assignment is an expression and we can use it everywhere it is allowed to use the expression of the particular type.
- Assignment statement is the assignment operator = and ;

Basic Arithmetic Expressions

- For an operator of the numeric types `int` and `double`, the following operators are defined

  Also for `char`, `short`, and `float` numeric types.

  - Unary operator for changing the sign −
  - Binary addition + and subtraction −
  - Binary multiplication * and division /
- For integer operator, there is also
  - Binary module (integer reminder) %
- If both operands are of the same type, the results of the arithmetic operation is the same type
- In a case of combined data types **int** and **double**, the data type `int` is converted to **double** and the results is of the **double** type.

  Implicit type conversion

Example – Arithmetic Operators 1/2

```c
int a = 10;
int b = 3;
int c = 4;
int d = 5;
int result;

result = a - b; // subtraction
printf("a - b = %i\n", result);

result = a * b; // multiplication
printf("a * b = %i\n", result);

result = a / b; // integer divison
printf("a / b = %i\n", result);

result = a + b * c; // priority of the operators
printf("a + b * c = %i\n", result);

printf("a * b + c * d = %i\n", a * b + c * d);         // -> 50
printf("(a * b) + (c * d) = %i\n", (a * b) + (c * d)); // -> 50
printf("a * (b + c) * d = %i\n", a * (b + c) * d);     // -> 350
```

lec01/arithmetic_operators.c

Example – Arithmetic Operators 2/2

```c
#include <stdio.h>

int main(void)
{
   int x1 = 1;
   double y1 = 2.2357;
   float x2 = 2.5343f;
   double y2 = 2;

   printf("P1 = (%i, %f)\n", x1, y1);
   printf("P1 = (%i, %i)\n", x1, (int)y1);
   printf("P1 = (%f, %f)\n", (double)x1, (double)y1);
   printf("P1 = (%.3f, %.3f)\n", (double)x1, (double)y1);

   printf("P2 = (%f, %f)\n", x2, y2);

   double dx = (x1 - x2); // implicit data conversion to float
   double dy = (y1 - y2); // and finally to double

   printf("(P1 - P2)=(%.3f, %0.3f)\n", dx, dy);
   printf("|P1 - P2|^2=%.2f\n", dx * dx + dy * dy);
   return 0;
}
```

lec01/points.c

Standard Input and Output

- An executed program within Operating System (OS) environments has assigned (usually text-oriented) standard input (`stdin`) and output (`stdout`)

  Programs for MCU without OS does not have them
- The `stdin` and `stdout` streams can be utilized for communication with a user
- Basic function for text-based input is `getchar()` and for the output `putchar()`

  Both are defined in the standard C library `<stdio.h>`
- For parsing numeric values the `scanf()` function can be utilized
- The function `printf()` provides formatted output, e.g., a number of decimal places

They are library functions, not keywords of the C language.

Formatted Output – `printf()`

- Numeric values can be printed to the standard output using `printf()`

  `man printf` *or* `man 3 printf`

- The first argument is the format string that defines how the values are printed
- The conversion specification starts with the character `'%'`
- Text string not starting with % is printed as it is
- Basic format strings to print values of particular types are

`char`	`%c`
`_Bool`	`%i`, `%u`
`int`	`%i`, `%x`, `%o`
`float`	`%f`, `%e`, `%g`, `%a`
`double`	`%f`, `%e`, `%g`, `%a`

- Specification of the number of digits is possible, as well as an alignment to left (right), etc.

  Further options in homeworks and lab exercises.

Formatted Input – `scanf()`

- Numeric values from the standard input can be read using the `scanf()` function `man scanf` *or* `man 3 scanf`
- The argument of the function is a format string *Syntax is similar to* `printf()`
- It is necessary to provide a memory address of the variable to set its value from the `stdin`
- Example of readings integer value and value of the `double` type

```c
#include <stdio.h>

int main(void)
{
   int i;
   double d;

   printf("Enter int value: ");
   scanf("%i", &i); // operator & returns the address of i

   printf("Enter a double value: ");
   scanf("%lf", &d);
   printf("You entered %02i and %0.1f\n", i, d);

   return 0;
}
```

lec01/scanf.c

Example: Program with Output to the `stdout` 1/2

- Instead of `printf()` we can use `fprintf()` with explicit output stream `stdout`, or alternatively `stderr`; both functions from the `<stdio.h>`

```c
#include <stdio.h>

int main(int argc, char **argv) {
   fprintf(stdout, "My first program in C!\n");
   fprintf(stdout, "Its name is \"%s\"\n", argv[0]);
   fprintf(stdout, "Run with %d arguments\n", argc);
   if (argc > 1) {
      fprintf(stdout, "The arguments are:\n");
      for (int i = 1; i < argc; ++i) {
         fprintf(stdout, "Arg: %d is \"%s\"\n", i, argv[i]);
      }
   }
}
```

Example: Program with Output to the stdout 2/2

- Notice, using the header file `<stdio.h>`, several other files are included as well to define types and functions for input and output.

  Check by, e.g., `clang -E print_args.c`

```
clang print_args.c -o print_args
./print_args first second
My first program in C!
Its name is "./print_args"
It has been run with 3 arguments
The arguments are:
Arg: 1 is "first"
Arg: 2 is "second"
```

Extended Variants of the `main()` Function

- Extended declaration of the `main()` function provides access to the environment variables

  For Unix and MS Windows like OS

  ```
  int main(int argc, char **argv, char **envp) { ... }
  ```

  The environment variables can be accessed using the function `getenv()` *from the standard library* `<stdlib.h>`.

  `lec01/main_env.c`

- For Mac OS X, there are further arguments

  ```
  int main(int argc, char **argv, char **envp, char **apple)
  {
     ...
  }
  ```