System-Level Programming

9 Functions

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What is a Function?

- **Function** ::= subprogram
  - program piece (block) that has an **identifier**
  - **parameter** can be passed when calling the function
  - a **return value** can be passed after finishing

- Functions are elementary program pieces
  - structure extensive tasks in smaller, manageable components
  - enable a simple reuse of components
  - enable a simple exchange of components
  - hide implementation details: **black-box** principle
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```
function \mapsto language
```

- Identifier and parameters [abstract](#)
  - from the actual program piece
  - from the representation and usage of data
- Enables a step-by-step abstraction and refinement
Example

Function (abstraction) `sb_led_setMask()`

```c
#include <led.h>
void main(void) {
    sb_led_setMask(0xaa);
    while(1) {}
}
```

Implementation in `libspiciboard`

```c
void sb_led_setMask(uint8_t setting) {
    uint8_t i = 0;
    for (i = 0; i < 8; i++) {
        if ((setting >> i) & 1) {
            sb_led_on(i);
        } else {
            sb_led_off(i);
        }
    }
}
```
Example

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    }
}
```
Function Definitions

Syntax:  \[
\text{type identifier ( formalParam}_{opt}\) \{block\}
\]
- **type**  type of the returned value, \texttt{void} if nothing is returned
- **identifier**  name of the function, which is used for calling it
- **formalParam}_{opt}**  list of formal parameters:
  \[
  \text{type}_1 \ id_{1\ opt}, \ldots, \text{type}_n \ id_{n\ opt}
  \]
  (parameter identifiers are optional)
  \texttt{void}, if no parameter is expected
- **\{block\}**  implementation; formal parameters can be used as local variables

Examples:

```java
int max(int a, int b) {
  if (a > b) return a;
  return b;
}
```

```java
void wait(void) {
  volatile uint16_t w;
  for (w = 0; w < 0xffff; w++) {
  }
}
```
Function Calls

Syntax: \texttt{identifier \ ( \ actParam \ )}

- \texttt{identifier} name of the function to be jumped into
- \texttt{actParam} list of actual parameters (passed values, have to be compatible in type and count to the list of formal parameters)

Examples:

```java
int x = max(47, 11);
```

Call of the \texttt{max()} function. 47 and 11 are the actual parameters, which are mapped to the formal parameters \(a\) and \(b\) of the \texttt{max()}-function (\(\rightarrow\ 9-4\)).

```java
char text[] = "Hello, World";
int x = max(47, text);
```

Error: text is not promotable to type \texttt{int}

```java
max(48, 12);
```

The returned value can be ignored (even though it makes no sense here)
General types of parameter passing

- **call by value**
  Formal parameters are copies of the actual parameters. Changes made to the formal parameters are lost when the function is exited.
  
  *This is the standard case in C.*

- **call by reference**
  Formal parameters are references to the actual parameters. Changes made to the formal parameters directly affect the actual parameters as well.
  
  *In C possible with the help of pointers.*

Note:

- arrays are always passed *by reference*
- the order in which parameters are evaluated is *undefined!*
Functions can call themselves (recursion)

```java
int fak(int n) {
    if (n > 1)
        return n * fak(n - 1);
    return 1;
}
```

Recursive definition of the factorial function.

Recursion leads to a significant runtime and memory cost! For each recursion step: Memory has to be provided for: return address, parameters and all local variables. Rule: When possible, avoid any recursion when writing system-level code!
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**recursion ➔ $$$**

Recursion leads to a significant runtime and memory cost!

For each recursion step:
- Memory has to be provided for: return address, parameters and all local variables
- Parameter are copied, and a function call is performed

**Rule:** When possible, **avoid any recursion** when writing system-level code!
Functions have to be declared (\(\mapsto\) made known) in the source code prior to being used.

- When defining a function upfront, this definition serves as declaration.
- Otherwise, (if the function is implemented “further below” in the source code or is defined in another module) it has to be declared explicitly.

Syntax: \(\text{type identifier ( formalParam ) }\);

Example:

// declaration by definition
int max(int a, int b) {
    if (a > b) return a;
    return b;
}

void main(void) {
    int z = max(47, 11);
}

// explicit declaration
int max(int, int);

void main(void) {
    int z = max(47, 11);
}

int max(int a, int b) {
    if (a > b) return a;
    return b;
}
Functions shall **should** be **declared** in the code prior to being used.
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**Attention:** C does not enforce this!

- Possibility to call functions that are **not declared**
  (↔ implicit declaration)
- Such calls are however **not type-safe**
  - the compiler does not know the list of formal parameters
  ~ it cannot verify whether the actual parameters match
- Possibility to pass **anything**
- Modern compilers at least generate a **warning**
  ~ Always take compiler warnings seriously!
Functions shall **should** be declared in the code prior to being used.

**Example:**

```c
#include <stdio.h>

int main(void) {
    double d = 47.11;
    foo(d);
    return 0;
}

void foo(int a, int b) {
    printf("foo: a:%d, b:%d\n", a, b);
}
```
Functions shall **should** be declared in the code prior to being used.

**Example:**

```c
#include <stdio.h>

int main(void) {
    double d = 47.11;
    foo(d);
    return 0;
}

void foo(int a, int b) {
    printf("foo: a:%d, b:%d\n", a, b);
}
```

Function `foo()` is not declared; the compiler **warns**, but accepts any actual parameters.
Functions shall **should** be **declared** in the code prior to being used.

**Example:**

```c
#include <stdio.h>

int main(void) {
    double d = 47.11;
    foo(d);
    return 0;
}

void foo(int a, int b) {
    printf("foo: a:%d, b:%d\n", a, b);
}
```

`foo()` is **defined** with formal parameters `(int, int)`. Everything that is passed as actual parameters will be interpreted as `int`!
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**Example:**

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#include <stdio.h>

int main(void) {
    double d = 47.11;
    foo(d);
    return 0;
}

void foo(int a, int b) {
    printf("foo: a:%d, b:%d\n", a, b);
}
```

**What will be printed?**

```
foo: a:47, b:11
```

Functions **shall** **should** be **declared** in the code prior to being used.

- Functions that are declared with an **empty list of formal parameters** will also accept any parameter → **no type safety**
- The compiler does **not** warn in this case. The problems remain!
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**Example:**

```c
#include <stdio.h>

void foo(); // "open" declaration

int main(void) {
    double d = 47.11;
    foo(d);
    return 0;
}

void foo(int a, int b) {
    printf("foo: a:%d, b:%d\n", a, b);
}
```

Function `foo()` has been declared with **empty** list of formal parameters \(\sim\) this is a formally **valid call!**
Functions shall **should** be declared in the code prior to being used.

- Functions that are declared with an empty list of formal parameters will also accept any parameter ~ **no type safety**
- The compiler does **not** warn in this case. The problems remain!

**Attention: Risk of confusion**

- In Java, `void foo()` would define a **parameterless** method
  - In C, one has to explicitly write `void foo(void)`
- In C, `void foo()` declares an **open** function
  - This is only useful in (rare) cases!
  - Generally it is considered bad style ~ **point deduction**

**Rule:** Functions always need to be **declared completely!**