Exercises in System Level Programming (SLP) – Summer Term 2026

Exercise 1

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Lehrstuhl für Informatik 4
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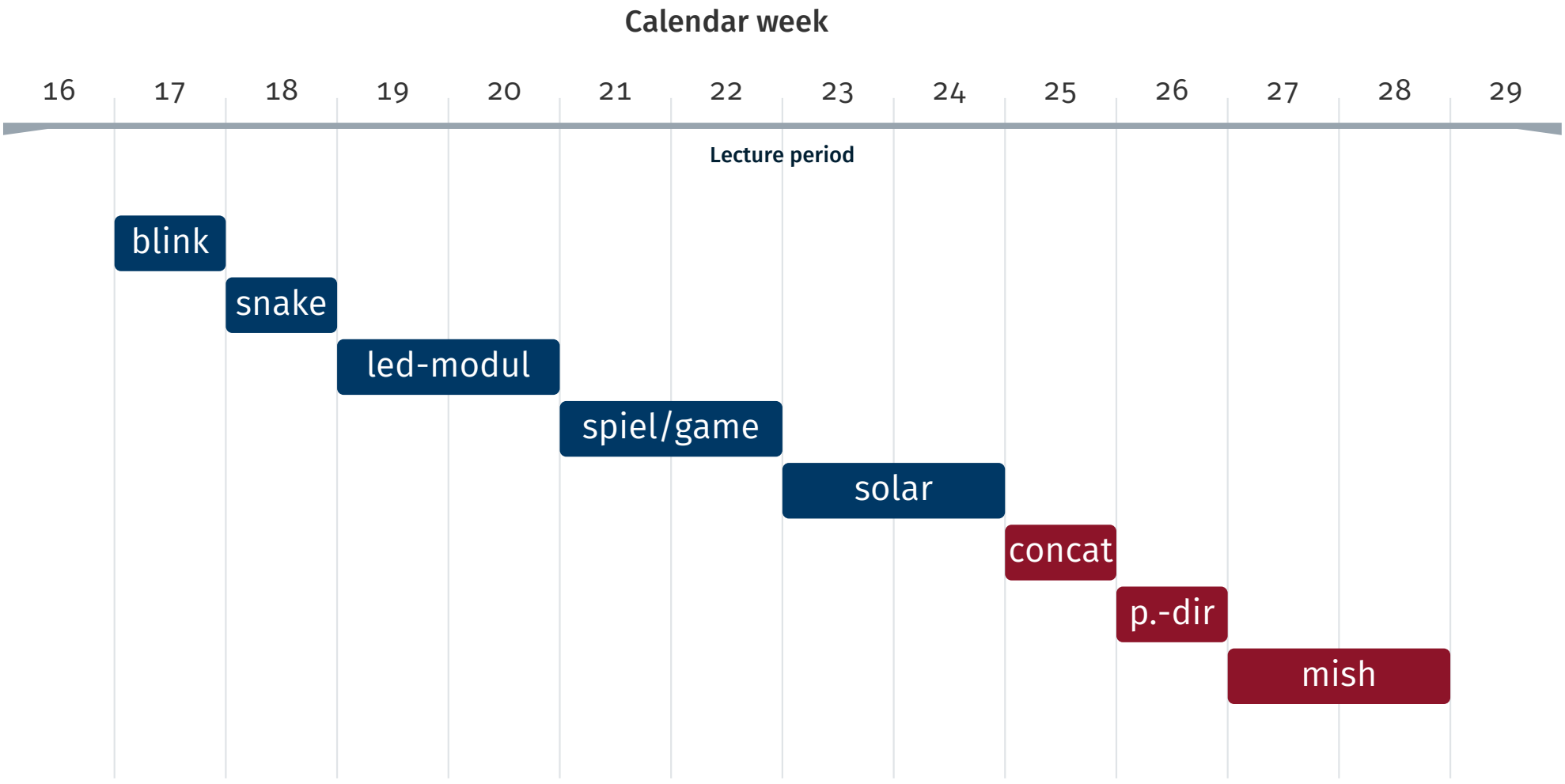
Faculty of Engineering

Organizational Matters

Tutorial

- Concept of Tutorial:
  1. Correct the last programming assignment
  2. Deepen lecture contents
  3. Introduction to the new programming assignments
  4. Possibly development of a solution sketch
  5. Hands-on: joined programming
- Slides are not necessarily made to be studied on their own
  → attendance required, write along
- Overview for the term and SLP appointments:
  `https://sys.cs.fau.de/lehre/ss26/slp/`

Assignments



Solutions

- Assignments are submitted via Linux
- Automatic check for plagiarism
  - Comparison to all other solutions (including old ones)
  - Plagiarism yields 0 points

  $\Rightarrow$ If in doubt talk to your tutor
- Points
  - 100% for excellent submissions + feedback discussion
  - 80% for submissions + feedback discussion
  - 0% for AI submissions or obviously wrong submissions
- (Helpful) comments in the code can help you and your tutor during submission
- Registration for submission discussions via StudOn

Bonus Points

- Submitted assignments get graded with bonus points
- If you reach 20% or more of all bonus points, there is a bonus for the exam
- For 80% or more you get rewarded with full bonus points for the exam
- Conversion of points from the assignments into bonus points for the exam (up to 10% of points)

  $\longrightarrow$ Example: 80% of points from the assignments yield 9 bonus points if the exam has 90 points total
- However, you *cannot pass* the exam by the help of bonus points
- Bonus points cannot be transferred to the next semester

Computer Exercise

- Room for the Computer exercise: 01.153-113 (WinCIP)
- Help from the tutor during your work with the assignment

  „First come, first served“-principle
- If after 30 minutes after the beginning of the Computer exercise no student is present, the exercise is cancelled

Computer Exercises

Time	Mon.	Tue.	Wed.	Thu.	Fri.
08:15–09:45			R06		
10:15–11:45	**R00**		R07		R10
12:15–13:45	R01				
14:15–15:45	R02	**R04**			
16:15–17:45	**R03**	**R05**	R08	**R09**	**R11**

All **marked** slots have a tutor which speaks english.

If a Problem occurs

- Consult the slides
- Ask in the StudOn Forum:

  `https://www.studon.fau.de/studon/go/frm/6915327`
- Write an e-mail

  Questions on lecture contents (tutors):
  i4slp@i4.cs.fau.de

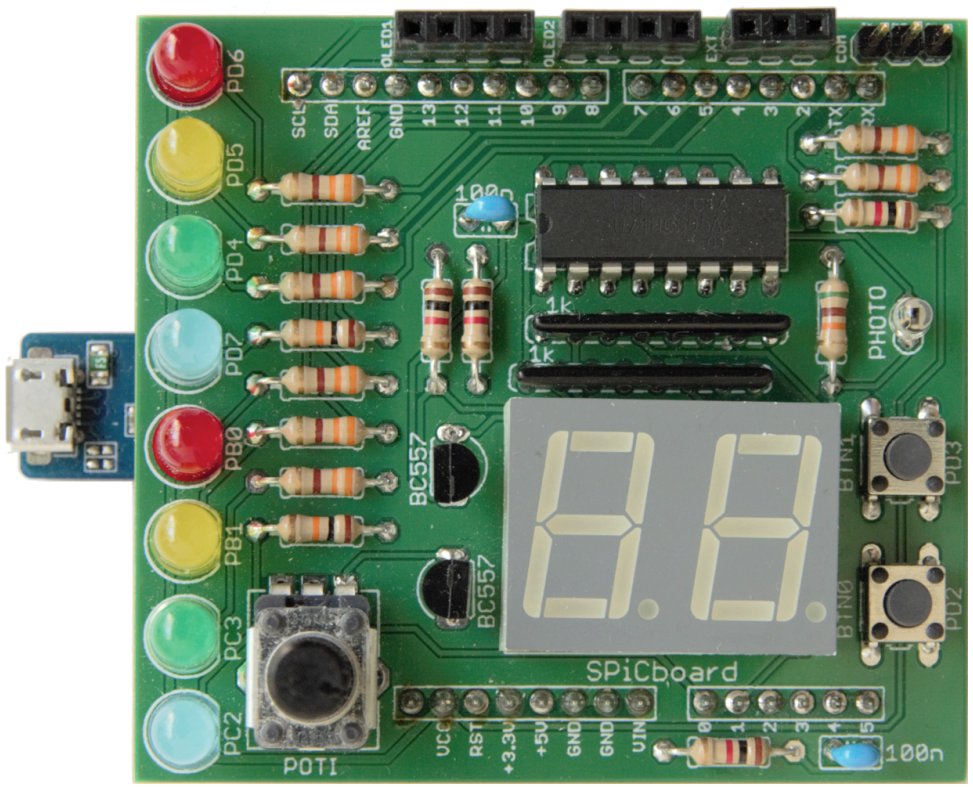
  Organizational questions (all staff):
  i4slp-orga@i4.cs.fau.de

Chatroom for students:
`https://to.chat.fau.de/#/room/#spic:fau.de`

Development Environment

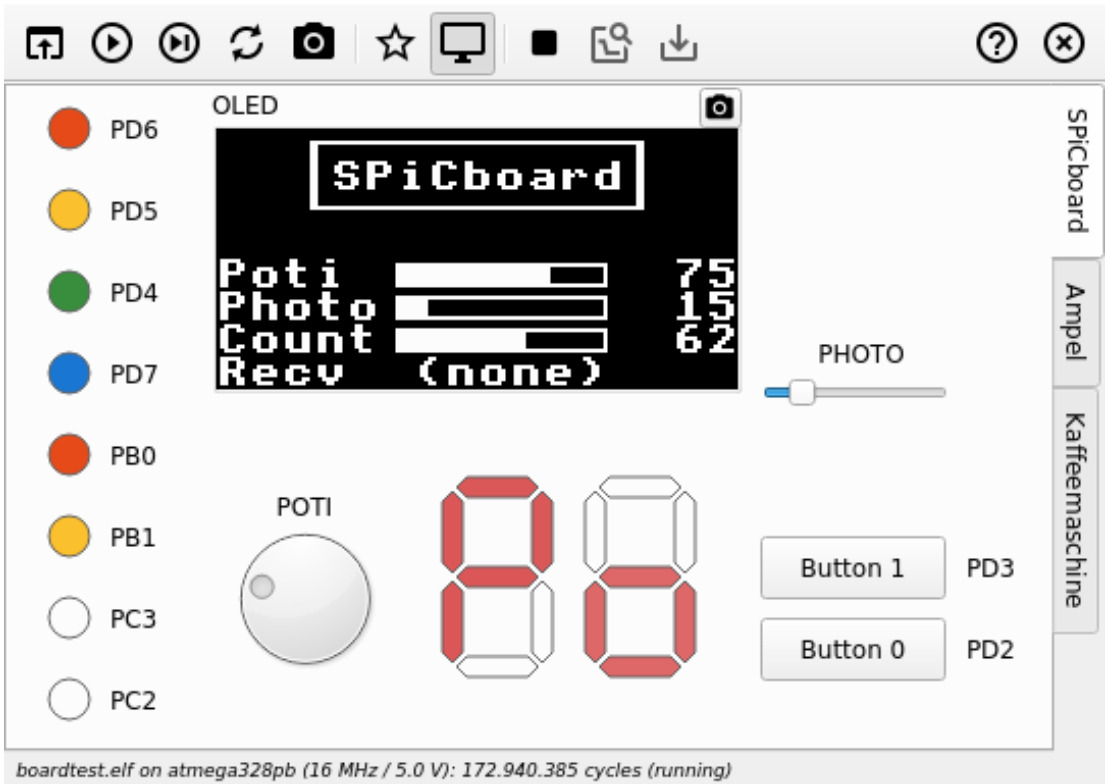
Hardware: SPiCboard

- **ATmega328PB Xplained Mini:**
  Micro-controller board with integrated programmer/debugger
- Custom-made extension PCB for SPiC/SLP



Simulator: SPiCsim

- **SPiCsim:**
  Simulates ATmega328PB and SPiCBoard
- Makes recording and visualizing of signals possible



Handling the Assignments

- Supervised programming for the assignments during Computer exercises
  - $\Rightarrow$ Hardware is made available during the exercises
- Independent working style (partially) required
  - Using own SPiCboard: can be soldered at the soldering night
  - SPiCboard Simulator: `SPiCsim`

Function Libraries

- `libspicboard`: function library for addressing the hardware

  Example: `sb_led_on(GREEN0);` switches on the first green LED
- Direct configuration of the hardware by the application developer is not needed
- Usage mainly for the first assignments, later the functions of the `libspicboard` have to be implemented by yourself
- Documentation online:

  `https://sys.cs.fau.de/lehre/ss26/spic/uebung/spicboard/libapi`

Important Directories

- Public directory `/proj/i4spic/<idm-login>/pub/`
  - Auxiliary material for each assignment can be found in `aufgabeX/`
  - `libspicboard` with documentation and minimal working examples
  - All lecture slides in `lecture/`
  - All exercise slides in `exercise/`
  - Assistance for dealing with the language *C*

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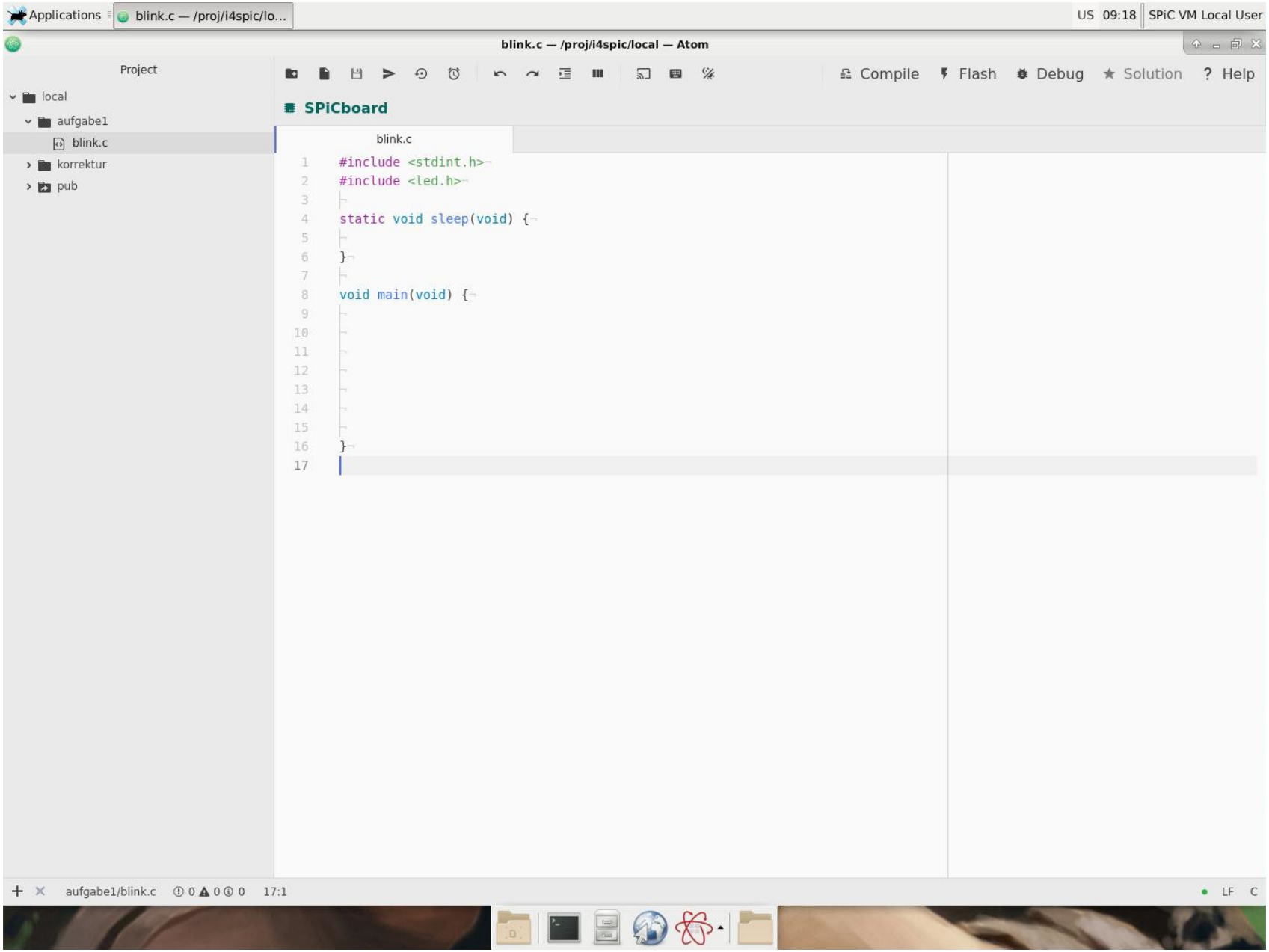
  - All lecture slides in `lecture/`
  - All exercise slides in `exercise/`
  - Assistance for dealing with the language *C*
- Project directory
  - `/proj/i4spic/<idm-login>/`
  - Solutions have to be saved in subdirectories `aufgabeX`
    - ⇒ The program for submitting searches only there
  - Others cannot read this directory
  - Directory is created automatically
  - Contains symbolic links to the public directory

The Editor


Applications
blink.c — /proj/i4spic/lo...
US 09:18
SPiC VM Local User
blink.c — /proj/i4spic/local — Atom
Project
local
aufgabe1
blink.c
korrektur
pub
Compile
Flash
Debug
Solution
Help
SPiCboard
blink.c
#include <stdint.h>
#include <led.h>
static void sleep(void) {
}
void main(void) {
}
aufgabe1/blink.c
17:1
LF
C

The Editor

- Can be found in the start menu in *FAU Courses* as *SPiC-IDE*
- Designed in particular for SPiC, based on Pulsar
- Combines editor, compiler and debugger into a signle environment
- Cross-compiler for creating programs for different architecture
  - Host system: Intel-PC
  - Target system: AVR-Mikrocontroller
- More information in the SPiC-Wiki

Manuals

CIP-Login

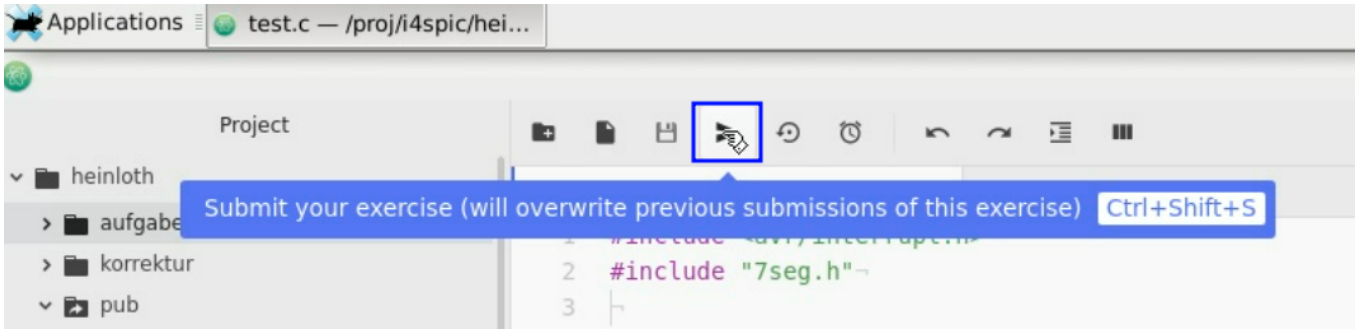
- To use the CIP infrastructure (and therefore the tools for assignment submission) a login for the CIP is required

  When running into problems, please contact the CIP Admins

- Criteria for a secure password
  - At least 8 characters, 10 is better
  - At least 3 different types of characters, 4 are better (capitalized letters, small letters, digits, special characters)
  - **Do not** use any dictionary words, names, login, etc.

Submitting Assignments (1)

- At the latest after testing the program, you should submit your solution for grading
- When working with a partner, only ONE of you is allowed to submit the assignment!
  - Your partner has to take part in the same Tutorial
  - When submitting, you can specify your partner
- Submission in the SPiC IDE with the click of a button



- Or open a terminal window and execute the following command (`aufgabeX` has to be replaced):
  `/proj/i4spic/bin/submit aufgabeX`
  - Important: **green text** indicates that the submission was successful,
    red text indicates an error!

Submitting Assignments (2)

- Causes for an error
  - Necessary files are not present in the right directory
  - `aufgabeX` has to be written without capitalization
  - `.c`-file has been wrongly named
  - Deadline was missed
- Useful tools
  - Show the source code of the submitted assignment:
    `/proj/i4spic/bin/show-submission aufgabeX`
  - Differences between submitted version and current version in the project directory `/proj/i4spic/<login>`:
    `/proj/i4spic/bin/show-submission aufgabeX -d`
  - Show deadline:
    `/proj/i4spic/bin/get-deadline aufgabeX`

Your Todos

1. Registration in StudOn

   `https://www.studon.fau.de/studon/go/crs/6792385`

   - Forum for Questions
2. Registration for the exercises via Waffel

   `https://waffel.cs.fau.de`

   - For submission and correction of assignments
3. Registration for the CIP

   `https://account.cip.cs.fau.de`

   - For working on the assignments, submitting them and receiving feedback

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Since the registration for the CIP can take up to 24 hours until you can log in with your new account, please make sure to **register asap**. Without an account you cannot take part in working on the assignments!

Compiler Optimizations

Compiler Optimizations: Background

- AVR micro-controller, as well as nearly all CPUs cannot execute operations directly on memory
- Procedure of operations:
  1. **Load** the operands from the memory into processor registers
  2. **Execute** the operations using the registers
  3. **Store** the result into memory

  $\Rightarrow$ More detailed description in the lecture
- The compiler is allowed to arbitrarily change the code as long as the “global” state after exiting a function stays the same
- Optimizations can lead to drastically faster code

Compiler Optimizations: Examples

- Typical optimizations:
  - When entering a function the variable is loaded into a register and only written back to memory when leaving the function
  - Redundant and “dead” code is removed
  - Some instructions get reordered
  - For automatic variables no memory is reserved; they are placed in processor registers instead
  - If possible, the compiler does some calculations (constant folding):
    `a = 3 + 5;` is replaced `a = 8;`
  - The range of values of automatic variables gets adapted: Instead of `0` to `10`, one can count from `246` to `256` (`= 0` for `uint8_t`) and then check if an overflow occurred

Compiler Optimizations: Example (1)

```
01 void wait(void) {
02   uint8_t u8 = 0;
03   while(u8 < 16) {
04     u8++;
05   }
06 }
```

- Incrementing the variable u8 up to a value of 16
- Used for e. g. active waiting

Compiler Optimizations: Example (2)

- Assembler without optimizations

```
01 ; void wait(void){
02 ; uint8_t u8;
03 ; [Prologue (store registers, initialize Y, etc.)]
04 rjmp while       ; jump to while
05 ; u8++;
06 addone:
07 ldd r24, Y+1     ; load data from Y+1 into register 24
08 subi r24, 0xFF   ; subtract 255 (add 1)
09 std Y+1, r24     ; write data from register 24 into Y+1
10 ; while(u8 < 16)
11 while:
12 ldd r24, Y+1     ; load data from Y+1 into register 24
13 cpi r24, 0x10    ; compare register 24 with 16
14 brcs addone      ; if smaller, jump to addone
15 ;[Epilogue (restore registers)]
16 ret              ; return from the function
17 ;}
```

Compiler Optimizations: Example (3)

- Assembler with optimizations

```
01 ; void wait(void){
02 ret             ; Return from the function
03 ; }
```

Compiler Optimizations: Example (3)

- Assembler with optimizations

```
01 ; void wait(void){
02 ret             ; Return from the function
03 ; }
```

- C does not know the semantics of a waiting loop
- The loop does not have any effect on the (global) state

⇝ The compiler optimises the loop by removing it

Keyword volatile

- Variables can be declared as `volatile`

⇝ The compiler is not allowed to optimise the variable:

  - **Memory has to be reserved** for the variable
  - The **life span** cannot be shortened
  - Prior to each operation, the variable has to be **loaded from memory** and afterwards it has to be written back to memory
  - The **range of value** of the variable cannot be adapted

- Possible uses of `volatile`:
  - Active waiting loops: prevents optimization of the loop
  - Concurrent execution (later in the lecture)
    - Variable is used in the interrupt handler and in the main loop
    - Changes of the variable have to be “made observable”
  - Access to hardware (e. g. pins) ⇝ important for the LED module
  - (Debugging: the value cannot be removed due to optimizations)

Task: blink

Task Description: blink

- Learning objective:
  - Make first experiences with the programming environment and the submission system
  - Active waiting
- Flashing LEDs `YELLOW0` and `YELLOW1`
  - Switching on and off alternately (warning light)
  - Frequency of approx. 2 times per second
  - Use of the library functions for addressing the LEDs
  - Implementation by active waiting (loop with counter)
- Documentation of the library:

  `https://sys.cs.fau.de/lehre/ss26/spic/uebung/spicboard/libapi`
- File to be submitted: `blink.c`

Hands-on: Light

Screencast: `https://www.video.uni-erlangen.de/clip/id/13444`

Hands-on: Light

- Inside the SPiC-IDE:
  - Create new folder (e. g. hands-on/licht)
  - Create new source file (e. g. `licht.c`)
- Create the program:
  - Switch on one LED (e. g. `GREEN0`)
  - Wait inside an endless loop
- Inside the SPiC-IDE:
  - Compile the program
  - Test and execute the program in the simulator or on an actual SPiCboard