

Exercises in System Level Programming (SLP) – Sommersemester 2024

Exercise 1

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und Betriebssysteme



FRIEDRICH-ALEXANDER
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TECHNISCHE FAKULTÄT

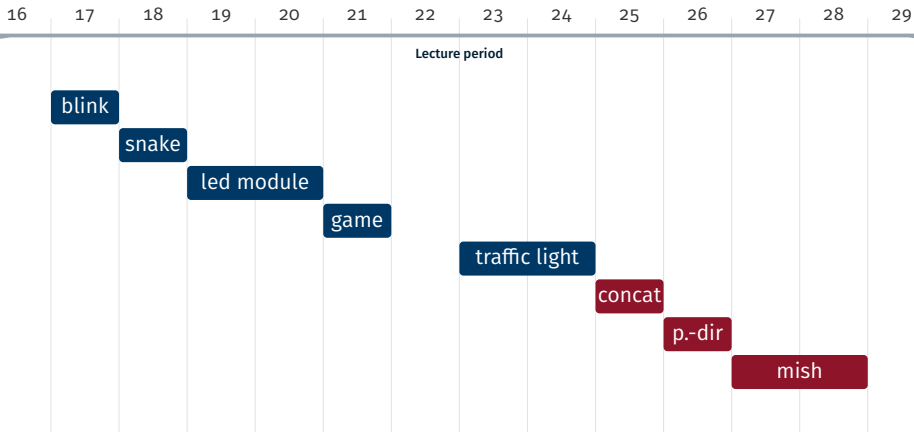
Organizational Matters



- Concept of Tutorial:
 1. Correct the last programming assignment
 2. Deepen lecture materials
 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/SS24/spic/>



Calendar week





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

⇒ If in doubt talk to your tutor
- Deduction of points
 - -1 point for each compiler warning
 - -50% of possible points if the code does not compile
- (Helpful) comments in the code can help you and your tutor










- 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)
 - 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




- 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

CipMap

CIP2 Bib-CIP CIP1 CIP1-N Win-CIP CIP3 CIP4 Huber-CIP Tutorlogin

-  Lecture Mode
-  Opt-In
-  FAQ
-  Settings
-  Legal Notice
-  Privacy Policy
-  Collapse sidebar



Oda

Ode Odd

Odc Odb

Odi Odh

Odg Odf



1. Visit the site cipmap.cs.fau.de
2. Choose the room where the Computer exercise takes place (e. g. 01.153-113)
3. Click on *Lecture Mode*.
 - **colored PC**: request sent
 - **grey PC**: no request
4. By clicking *Request Tutor*, a request will be queued
5. After your question is answered: click on the button again to mark the request as finished

Please note:

- You can only make requests during the time of Computer exercises
- When logging off, all open requests get deleted



- Consult the slides
- Write an e-mail

Questions on lecture contents (tutors):

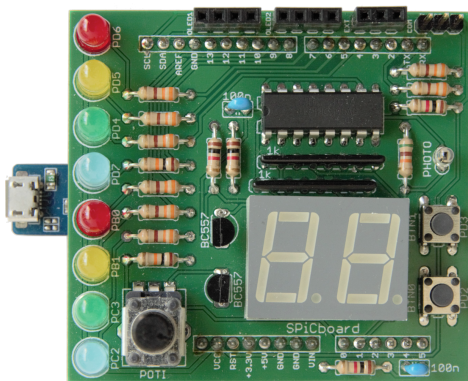
`i4slp@i4.cs.fau.de`

Organizational questions (all staff):

`i4slp-orga@i4.cs.fau.de`

Development Environment

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





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

boardtest.elf on atmega328pb (16 MHz / 5.0 V): 172.940.385 cycles (running)



- Supervised programming for the assignments during Computer exercises
 - ⇒ 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



- `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/SS24/spic/uebung/spicboard/libapi>



- Public directory `/proj/i4spic/<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



- Public directory `/proj/i4spic/<login>/pub/`
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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/<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



```
blink.c
1  #include <stdint.h>
2  #include <led.h>
3
4  static void sleep(void) {
5
6  }
7
8  void main(void) {
9
10
11
12
13
14
15
16 }
17
```



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

Manuals



- 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.



- 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!



- 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`



1. Registration for the exercises via Waffel: <https://waffel.cs.fau.de>
 - For submission and correction of assignments⇒ from **Thursday, 18.04.2024, 6:00 PM**
2. 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



- 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

⇒ 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



- 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



```
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



■ 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 ;}
```



- Assembler with optimizations

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



- Assembler with optimizations

```
01 ; void wait(void){  
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```

- 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



- 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



- 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/SS24/spic/uebung/spicboard/libapi>
- File to be submitted: `blink.c`

Hands-on: Light

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



- 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