Exercises in System Level Programming (SLP) – Summer Term 2025

Exercise 2

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Variables

Usage von `int`

- The size of the `int` type is not defined exactly
- For example on ATmega328PB: 16 bit
  - ⇒ Especially in the context of µC, this can yield slower code and/or be a potential source for errors
- For working on the assignments, we decided
  - Usage of `int` counts as an error
  - Instead: Use types defined in `stdint.h`: `int8_t`, `uint8_t`, `int16_t`, `uint16_t`, etc.
- Range of value
  - `limits.h`: `INT8_MAX`, `INT8_MIN`, ...
- Memory is limited and therefore expensive on µC (SPIC BOARD/ATmega328PB only has 2048 byte SRAM)

⇝ Only use as little memory as necessary!

Typedefs & Enums

```
01 #define PB3 3
02
03 typedef enum {
04     BUTTON0 = 0, BUTTON1 = 1
05 } BUTTON;
06
07 typedef enum {
08     PRESSED = 0, RELEASED = 1, UNKNOWN = 2
09 } BUTTONSTATE;
10
11 void main(void) {
12     /* ... */
13     PORTB |= (1 << PB3); // not (1 << 3)
14
15     // Declaration: BUTTONSTATE sb_button_getState(BUTTON btn);
16     BUTTONSTATE state = sb_button_getState(BUTTON0); // not
        ↪ sb_button_getState(0)
17     /* ... */
18 }
```

- Use predefined types
- Only use explicit integer values if necessary

Bits & Bytes

Number Systems

- Numbers can be represented using different bases
  - $\Rightarrow$ Usually: decimal (10), hexadecimal (16), octal (8) and binary (2)
- Nomenclature:
  - Bits: Digits of binary numbers
  - Nibbles: Groups of 4 bits
  - Bytes: Groups of 8 bits

Bit Operations

- Bit operations: Bitwise logical expressions
- Possible operations:

~	
0	1
1	0

not

&	0	1
0	0	0
1	0	1

and

|	0	1
0	0	1
1	1	1

or

^	0	1
0	0	1
1	1	0

exclusive or

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- Example:

$$\sim 1001_2 = 0110_2$$

$$1100_2 \;\&\; 1001_2 = 1000_2$$

$$1100_2 \;|\; 1001_2 = 1101_2$$

$$1100_2 \;\hat{}\; 1001_2 = 0101_2$$

Shift Operations

- Example:

```
uint8_t x = 0x9d;
x = x << 2;
x = x >> 2;
```

1	0	0	1	1	1	0	1
0	1	1	1	0	1	**0**	**0**
0	**0**	0	1	1	1	0	1

- Setting single bits:

```
(1 << 0)
(1 << 3)
(1 << 3) | (1 << 0)
```

0	0	0	0	0	0	0	**1**
0	0	0	0	**1**	0	0	0
0	0	0	0	**1**	0	0	**1**

- **Caution:**
  When shifting `signed` variables, the behaviour of the `>>`-operator is not well defined in every case.

Assignment: snake

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- Snake consisting of adjecent LEDs
- Length (1 to 5 LEDs) is configured with the potentiometer (`POTI`)
- Speed depends on the environment brightness (`PHOTO`)
  - ⇝ The brighter the environment is, the faster the snake should move
- Mode of the snake can be toggled with a button (`BUTTON0`)
  - Normal: Switched on LEDs represent the snake
  - Inverted: Switched off LEDs represent the snake

⇒ You *should* work on the assignment in teams of two:
The `submit` scripts asks for your partner

General Remarks

- Variables in functions behave similar to Java/Python
  - ⇝ To solve the assignment, only local variables are necessary
- The C compiler reads files from top to bottom
  - ⇝ Functions have to be declared in the right order:
    1. `wait()`
    2. `drawsnake()`
    3. `main()`

⇒ Details on compiler internals are discussed in the lecture.

Description of the Snake

- Position of its head
  - Number associated with a LED
  - Range of value $\{0, 1, \ldots, 7\}$
- Length of the snake
  - Integer in range of $\{1, 2, \ldots, 5\}$
- Mode of the snake
  - Normal or inverted
  - Can be represented as 0 and 1
- Speed of the snake
  - Here: Number of iterations of an active waiting loop

Divide-and-conquer

- Basic program flow: Which steps do always repeat?
- Prevent duplicate code:
  - ⇝ Reoccurring problems can be addressed by helper functions

Basic Rundown snake

- Basic program flow: Represent snake, move snake, ...
- Pseudo code:

```
01 void main(void) {
02   while(1) {
03     // calculate length
04     length = ...
05
06     // draw snake
07     drawSnake(head, length, mode);
08
09     // put head to next position
10     ...
11
12     // wait and determine mode
13     ...
14
15   } // end of main loop
16 }
```

Representation of the Snake

- Parameters of representation
  - Position of the head
  - Length
  - Mode
- Function signature:
  ```
  void drawSnake(uint8_t head, uint8_t length,
  ↪ uint8_t modus)
  ```
- Representation depends on following parameters:
  - Normal mode (glowing snake):
    - Switch on all LEDs that belong to the snake
    - Switch off all remaining LEDs
  - Inverted mode (dark snake):
    - Switch off the LEDs belonging to the snake
    - Switch on all remaining LEDs

The Modulo Operator

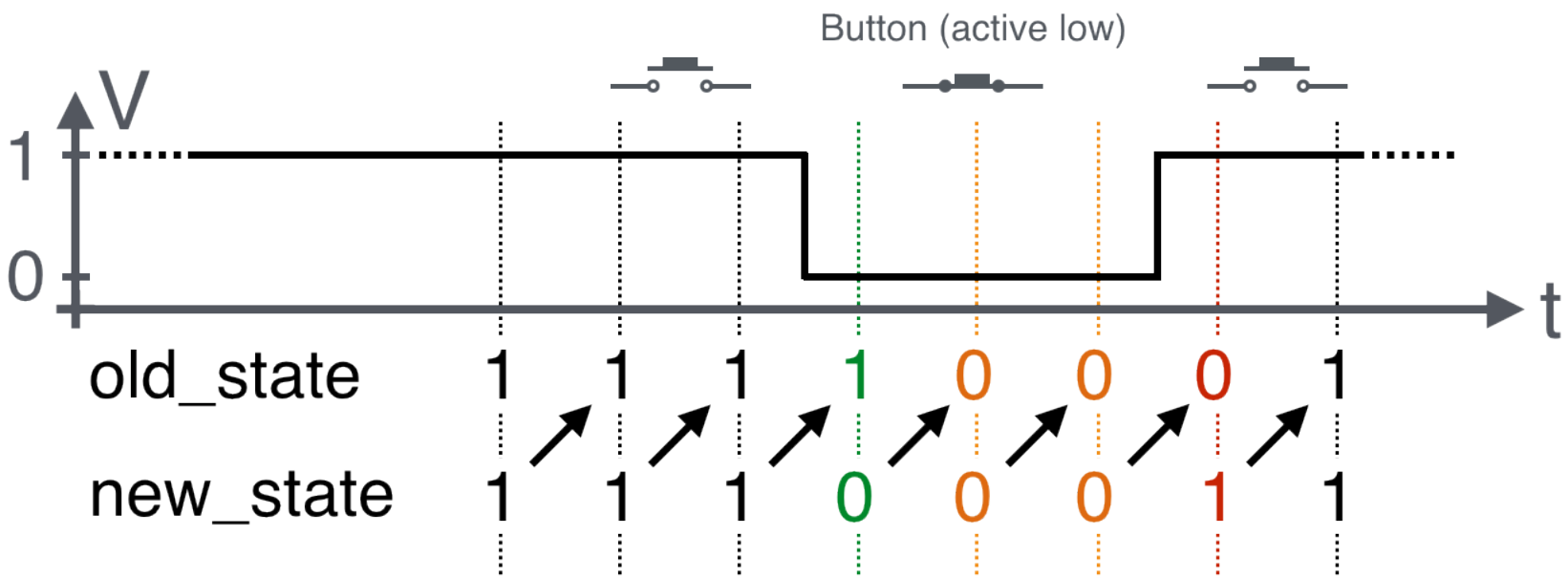
- Moving the snake
  - Modify the position of the head independent of the direction of movement
  - Problem: What happens at the end of the LED band?
- A solution: The modulo operator %
  - Remainder of an integer division
  - **Attention**: In C the result is negative for negative divisors
  - Example: `b = a % 4;`

a	-5	-4	-3	-2	-1	0	1	2	3	4	5	6
b	-1	0	-3	-2	-1	0	1	2	3	0	1	2

Edge Detection without Interrupts

- Active waiting between movements of the snake
  - Detect whether the button has been pressed
  - Detect an edge by **cyclic polling** the level
  - Differentiate between **active-high** & **active-low**

  → Not relevant for implementation, use PRESSED and RELEASED
  - Later: Implementation using interrupts



Hands-on: Signal Lamp

Screencast: https://www.video.uni-erlangen.de/clip/id/14038

Hands-on: Signal Lamp

- Send Morse signals via `RED0`
- Controllable with `BUTTON1`
- Usage of library functions for button and LED
- Documentation of the library inside the SPiC IDE or via
  `https://sys.cs.fau.de/lehre/ss25/spic/uebung/spicboard/libapi`
- Insert comments in the source code