

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

Exercise 2

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Variables



- The size of the `int` type is not defined exactly
 - For example on ATMEGA328PB: 16 bit
 - ⇒ Especially in the context of μ C, 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 μ C (SPICBOARD/ATMEGA328PB only has 2048 byte SRAM)
- ~> Only use as little memory as necessary!



```
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
17     ↪ sb_button_getState(0)
18     /* ... */
19 }
```

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

Bits & Bytes



- Numbers can be represented using different bases
 - ⇒ 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: Bitwise logical expressions
- Possible operations:

| \sim | |
|--------|---|
| 0 | 1 |
| 1 | 0 |

not

| $\&$ | 0 | 1 |
|------|---|---|
| 0 | 0 | 0 |
| 1 | 0 | 1 |

and

| \mid | 0 | 1 |
|--------|---|---|
| 0 | 0 | 1 |
| 1 | 1 | 1 |

or

| \wedge | 0 | 1 |
|----------|---|---|
| 0 | 0 | 1 |
| 1 | 1 | 0 |

exclusive
or



- 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

- Example:

$$\begin{array}{r} \sim 1001_2 \\ \hline 0110_2 \end{array}$$

$$\begin{array}{r} 1100_2 \\ \& 1001_2 \\ \hline 1000_2 \end{array}$$

$$\begin{array}{r} 1100_2 \\ | 1001_2 \\ \hline 1101_2 \end{array}$$

$$\begin{array}{r} 1100_2 \\ \wedge 1001_2 \\ \hline 0101_2 \end{array}$$



- 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:

| | | | | | | | | |
|----------------------------|---|---|---|---|---|---|---|---|
| $(1 \ll 0)$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| $(1 \ll 3)$ | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| $(1 \ll 3) \mid (1 \ll 0)$ | 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



- Snake consisting of adjacent LEDs
- Length (1 to 5 LEDs) is configured with the potentiometer (POT1)
- 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



- 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.



- Position of its head
 - Number associated with a LED
 - Range of value $\{0, 1, \dots, 7\}$
- Length of the snake
 - Integer in range of $\{1, 2, \dots, 5\}$
- 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



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



- 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 }
```



- 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

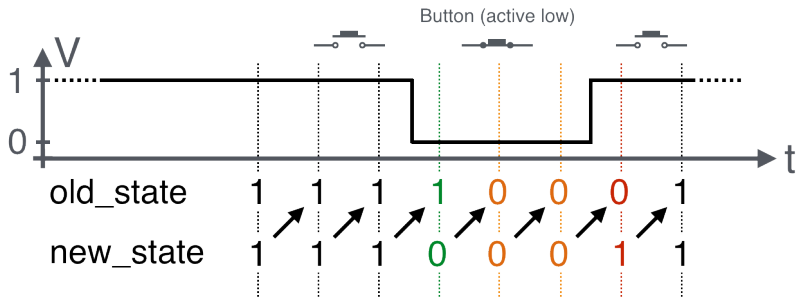


- Moving the snake
 - Modify the position of the head independent of the direction of movement
 - Problem: What happens at the end of the LED band?
- A solution: The modulo operator %
 - Remainder of an integer division
 - **Attention:** In C the result is negative for negative divisors
 - Example: $b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

| | | | | | | | | | | | | |
|---|----|----|----|----|----|---|---|---|---|---|---|---|
| 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 |



- 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>



- 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/ss26/spic/uebung/spicboard/libapi>
- Insert comments in the source code