

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

Exercise 8

Maxim Ritter von Onciul
Eva Dengler

Lehrstuhl für Informatik 4
Friedrich-Alexander-Universität Erlangen-Nürnberg



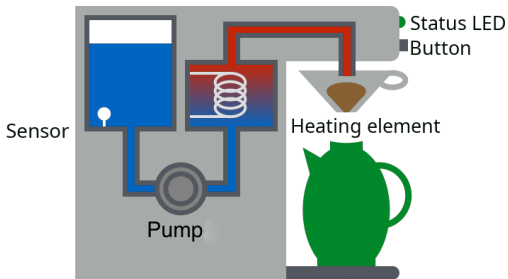
Lehrstuhl für Informatik 4
Systemsoftware



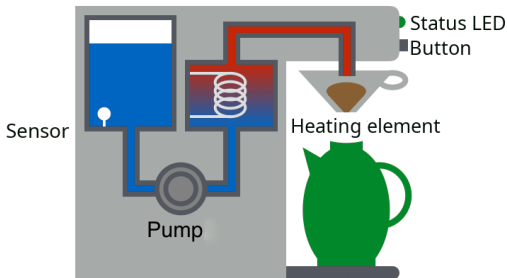
Friedrich-Alexander-Universität
Faculty of Engineering

Presentation Assignment 4

Hands-on: Coffee Machine



- Learning goals:
 - Finite state machines
 - Timers and alarms
 - Interrupts & sleep modes



■ Wiring:

- Pump & heating: Port D, Pin 5 (active-low)
- Button: INT0 an Port D, Pin 2 (active-low)
- Sensor: INT1 an Port D, Pin 3 (water: high; no water: low)
- State LED:
 - BLUE0: **STANDBY**
 - GREEN0: **ACTIVE**
 - RED0: **NO_WATER**



STANDBY

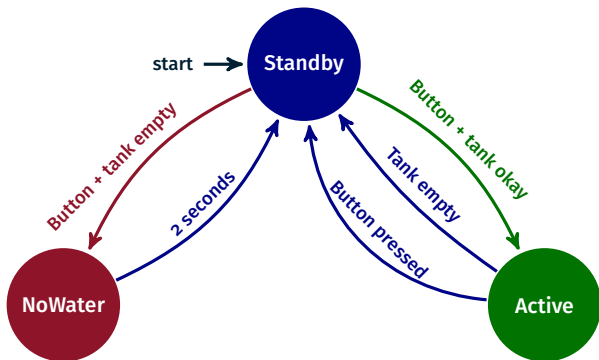
- Machine is switched off
- Pump and heating are off
- User can start making coffee by pressing the button
- Initial state

ACTIVE

- Machine is switched on
- Pump and heating are on
- Water tank is not empty
- User can stop the machine by pressing the button

NO_WATER

- Coffee machine shows that not enough water is in the tank
- Pump and heating are off
- Time period: 2 seconds



■ Hints:

- Pressed button & change of water level by interrupts
- State LED: `void setLEDState(state_t state)`
- Waiting phases can be implemented using the single-shot alarms
- During waiting phases always enter a power-saving mode



DDRx Configuration of pin i of port x as in-/output

- Bit $i = 1 \rightarrow$ Pin i as output
- Bit $i = 0 \rightarrow$ Pin i as input

PORTx Mode of operation **depends on DDRx**:

- If pin i is **configured as output**, then bit i in the PORTx register controls whether a high level or a low level has to be generated at pin i
 - Bit $i = 1 \rightarrow$ high level at pin i
 - Bit $i = 0 \rightarrow$ low level at pin i
- If pin i is **configured as input**, then the internal pull-up resistor can be activated
 - Bit $i = 1 \rightarrow$ pull-up resistor at pin i (level is pulled high)
 - Bit $i = 0 \rightarrow$ pin i configured as tri-state

PINx Bit i returns the current level of pin i at port x (read only)



- Interrupt sense control (ISC) bits of the ATmega328PB are located at the external interrupt control register A (EICRA)
- Position of the ISC-bits inside the register defined by macros

Interrupt INT0		Interrupt on	Interrupt INT1	
ISC01	ISC00		ISC11	ISC10
0	0	low level	0	0
0	1	either edge	0	1
1	0	falling edge	1	0
1	1	rising edge	1	1

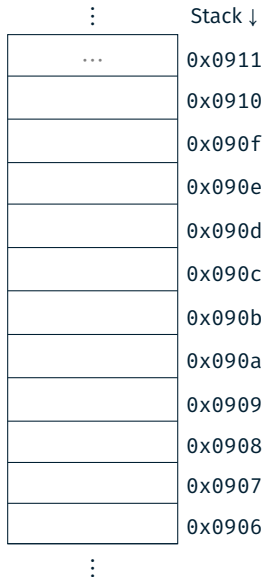
- ATmega328PB: External interrupt mask register (EIMSK)
- The position of the bits in this register is also defined by macros INTn

Hands-on: Ticker



- char: Single character (e.g. 'a')
- String: Array of chars (e.g. "Hello")
- C: Last char of a string: '\0'
⇒ Memory requirement: $\text{strlen}(s) + 1$

```
01 char s[] = "World\n";  
02 char c = s[0];  
03 c = s[4];  
04 char *s2 = s + 2;  
05 c = s2[1];
```





- char: Single character (e.g. 'a')
- String: Array of chars (e.g. "Hello")
- C: Last char of a string: '\0'
⇒ Memory requirement: $\text{strlen}(s) + 1$

```
01 char s[] = "World\n";  
02 char c = s[0];  
03 c = s[4];  
04 char *s2 = s + 2;  
05 c = s2[1];
```

	:	Stack ↓
	...	0x0911
s[6]	'\0'	0x0910
s[5]	'\n'	0x090f
s[4]	'd'	0x090e
s[3]	'l'	0x090d
s[2]	'r'	0x090c
s[1]	'o'	0x090b
s[0]	'W'	0x090a
		0x0909
		0x0908
		0x0907
		0x0906
	:	



- char: Single character (e.g. 'a')
- String: Array of chars (e.g. "Hello")
- C: Last char of a string: '\0'
⇒ Memory requirement: $\text{strlen}(s) + 1$

```
01 char s[] = "World\n";  
02 char c = s[0];  
03 c = s[4];  
04 char *s2 = s + 2;  
05 c = s2[1];
```

	⋮	Stack ↓
	...	0x0911
s[6]	'\0'	0x0910
s[5]	'\n'	0x090f
s[4]	'd'	0x090e
s[3]	'l'	0x090d
s[2]	'r'	0x090c
s[1]	'o'	0x090b
s[0]	'W'	0x090a
C	'W'	0x0909
		0x0908
		0x0907
		0x0906
	⋮	



- char: Single character (e.g. 'a')
- String: Array of chars (e.g. "Hello")
- C: Last char of a string: '\0'
⇒ Memory requirement: $\text{strlen}(s) + 1$

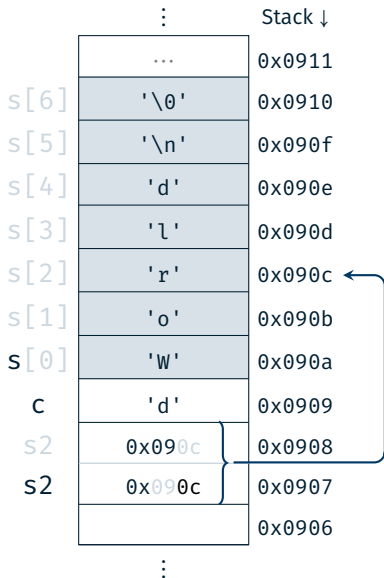
```
01 char s[] = "World\n";  
02 char c = s[0];  
03 c = s[4];  
04 char *s2 = s + 2;  
05 c = s2[1];
```

	:	Stack ↓
	...	0x0911
s[6]	'\0'	0x0910
s[5]	'\n'	0x090f
s[4]	'd'	0x090e
s[3]	'l'	0x090d
s[2]	'r'	0x090c
s[1]	'o'	0x090b
s[0]	'W'	0x090a
C	'd'	0x0909
		0x0908
		0x0907
		0x0906
	:	



- char: Single character (e.g. 'a')
- String: Array of chars (e.g. "Hello")
- C: Last char of a string: '\0'
⇒ Memory requirement: $\text{strlen}(s) + 1$

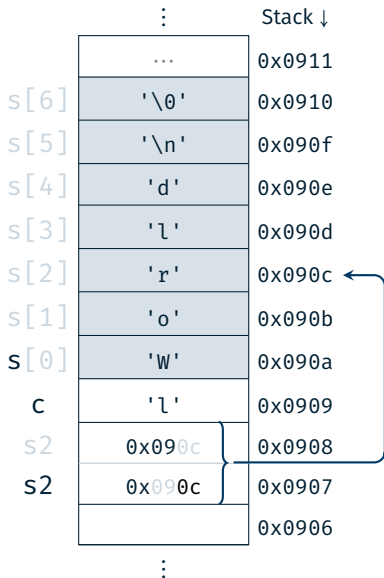
```
01 char s[] = "World\n";  
02 char c = s[0];  
03 c = s[4];  
04 char *s2 = s + 2;  
05 c = s2[1];
```





- char: Single character (e.g. 'a')
- String: Array of chars (e.g. "Hello")
- C: Last char of a string: '\0'
⇒ Memory requirement: $\text{strlen}(s) + 1$

```
01 char s[] = "World\n";  
02 char c = s[0];  
03 c = s[4];  
04 char *s2 = s + 2;  
05 c = s2[1];
```





- **Functionality:**
Displaying a text step-by-step on the 7-segment display
- **Learning goals:**
 - Strings in C
 - Pointers & pointer arithmetic
 - Alarms & sleep modes
- **Procedure:**
 - Recurring alarms with `TIMER0`
 - Combining the current substring
 - Output via the 7-segment display
 - During waiting phases, the microcontroller has to enter a sleep mode (passive waiting)



```
01 const char *string = "HELLO SPIC";
02 const char *current = string;
03 // current[0] == 'H' && current[1] == 'E'
04 ++current;
05 // current[0] == 'E' && current[1] == 'L'
06 // [...]
07 // current[0] == '\0', current[1] == ??
08 current = string;
```



```
01 const char *string = "HELLO SPIC";  
02 const char *current = string;  
03 // current[0] == 'H' && current[1] == 'E'  
04 ++current;  
05 // current[0] == 'E' && current[1] == 'L'  
06 // [...]  
07 // current[0] == '\0', current[1] == ??  
08 current = string;
```





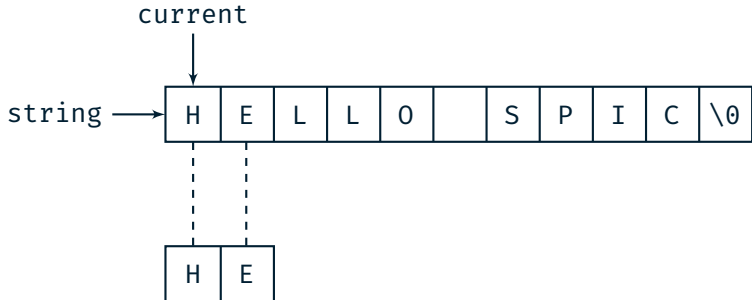
```
01 const char *string = "HELLO SPIC";  
02 const char *current = string;  
03 // current[0] == 'H' && current[1] == 'E'  
04 ++current;  
05 // current[0] == 'E' && current[1] == 'L'  
06 // [...]  
07 // current[0] == '\0', current[1] == ??  
08 current = string;
```



Hands-on: Ticker – Determine Substrings



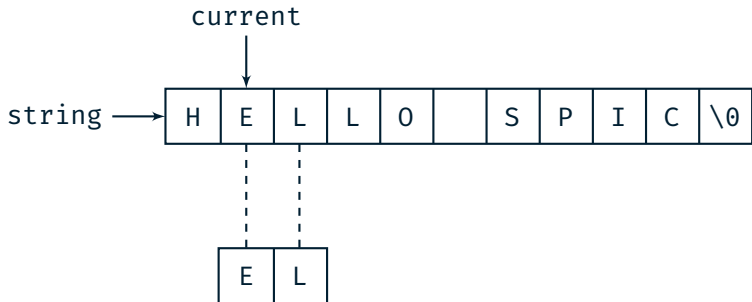
```
01 const char *string = "HELLO SPIC";  
02 const char *current = string;  
03 // current[0] == 'H' && current[1] == 'E'  
04 ++current;  
05 // current[0] == 'E' && current[1] == 'L'  
06 // [...]  
07 // current[0] == '\0', current[1] == ??  
08 current = string;
```



Hands-on: Ticker – Determine Substrings



```
01 const char *string = "HELLO SPIC";  
02 const char *current = string;  
03 // current[0] == 'H' && current[1] == 'E'  
04 ++current;  
05 // current[0] == 'E' && current[1] == 'L'  
06 // [...]  
07 // current[0] == '\\0', current[1] == ??  
08 current = string;
```





```
01 const char *string = "HELLO SPIC";  
02 const char *current = string;  
03 // current[0] == 'H' && current[1] == 'E'  
04 ++current;  
05 // current[0] == 'E' && current[1] == 'L'  
06 // [...]  
07 // current[0] == '\0', current[1] == ??  
08 current = string;
```

string →

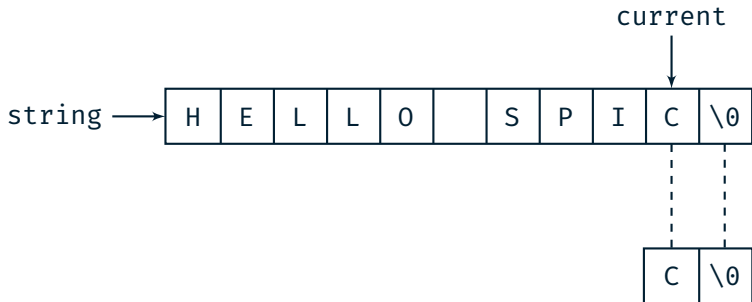
H	E	L	L	O		S	P	I	C	\0
---	---	---	---	---	--	---	---	---	---	----

...

Hands-on: Ticker – Determine Substrings



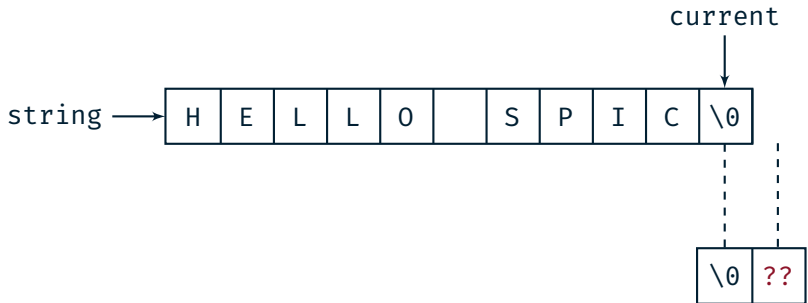
```
01 const char *string = "HELLO SPIC";  
02 const char *current = string;  
03 // current[0] == 'H' && current[1] == 'E'  
04 ++current;  
05 // current[0] == 'E' && current[1] == 'L'  
06 // [...]  
07 // current[0] == '\0', current[1] == ??  
08 current = string;
```



Hands-on: Ticker – Determine Substrings



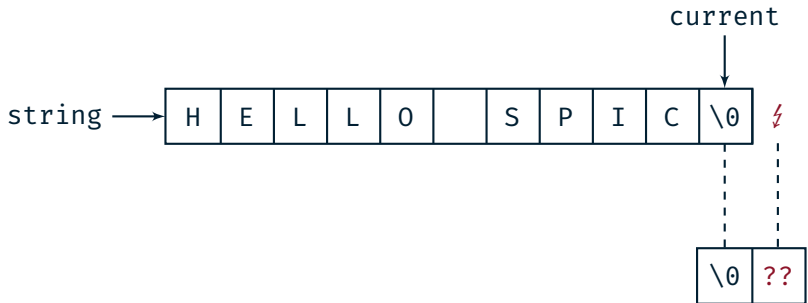
```
01 const char *string = "HELLO SPIC";  
02 const char *current = string;  
03 // current[0] == 'H' && current[1] == 'E'  
04 ++current;  
05 // current[0] == 'E' && current[1] == 'L'  
06 // [...]  
07 // current[0] == '\0', current[1] == ??  
08 current = string;
```



Hands-on: Ticker – Determine Substrings



```
01 const char *string = "HELLO SPIC";  
02 const char *current = string;  
03 // current[0] == 'H' && current[1] == 'E'  
04 ++current;  
05 // current[0] == 'E' && current[1] == 'L'  
06 // [...]  
07 // current[0] == '\0', current[1] == ?? ⚡  
08 current = string;
```



Hands-on: Ticker – Determine Substrings



```
01 const char *string = "HELLO SPIC";  
02 const char *current = string;  
03 // current[0] == 'H' && current[1] == 'E'  
04 ++current;  
05 // current[0] == 'E' && current[1] == 'L'  
06 // [...]  
07 // current[0] == '\0', current[1] == ?? ⚡  
08 current = string;
```

