1. **Preparation tasks (done before the lab at home):**
   - **Table with segments values for display 0 to 9 on a common anode 7-segment display**,

Digit	A	B	C	D	E	F	G	DP
0	0	0	0	0	0	0	1	1
1	1	0	0	1	1	1	1	1
2	0	0	1	0	0	1	0	1
3	0	0	0	0	1	1	0	1
4	1	0	0	1	1	0	0	1
5	0	1	0	0	1	0	0	1
6	0	1	0	0	0	0	0	1
7	0	0	0	1	1	1	1	1
8	0	0	0	0	0	0	0	1
9	0	0	0	0	1	0	0	1

   - **In your words, describe the difference between Common Cathode and Common Anode 7-segment display.**

7-segment display with common cathode has common cathode for LEDs of all 7 segments and decimal point. So any segment can be lit seting its anode pin to 0. Common anod is oposite. Segments are lit with 1.

2. **7-segment library. Submit:**
   - **Listing of library source file `segment.c`,**

```
/***********************************************************************
 *
 * Seven-segment display library for AVR-GCC.
 * ATmega328P (Arduino Uno), 16 MHz, AVR 8-bit Toolchain 3.6.2
 *
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 * Dept. of Radio Electronics, Brno University of Technology, Czechia
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 *
 **********************************************************************/

/* Includes ----------------------------------------------------------*/
#define F_CPU 16000000
#include <util/delay.h>
#include "gpio.h"
#include "segment.h"

/* Variables ---------------------------------------------------------*/
// Active-low digits 0 to 9
uint8_t segment_value[] = {
```

```
        // abcdefgDP
        0b00000011,          // Digit 0
        0b10011111,          // Digit 1
        0b00100101,          // Digit 2
        0b00001101,          // Digit 3
        0b10011001,          // Digit 4
        0b01001001,          // Digit 5
        0b01000001,          // Digit 6
        0b00011111,          // Digit 7
        0b00000001,          // Digit 8
        0b00001001};  // Digit 9

// Active-high position 0 to 3
uint8_t segment_position[] = {
        // p3p2p1p0....
        0b00010000,          // Position 0
        0b00100000,          // Position 1
        0b01000000,          // Position 2
        0b10000000};  // Position 3



/* Function definitions ----------------------------------------------*/
void SEG_init(void)
{
    /* Configuration of SSD signals */
    GPIO_config_output(&DDRD, SEGMENT_LATCH);
    GPIO_config_output(&DDRD, SEGMENT_CLK);
    GPIO_config_output(&DDRB, SEGMENT_DATA);
}

/*-------------------------------------------------------------------*/
void SEG_update_shift_regs(uint8_t segments, uint8_t position)
{
    uint8_t bit_number;
    segments = segment_value[segments];     // 0, 1, ..., 9
    position = segment_position[position];  // 0, 1, 2, 3

    // Pull LATCH, CLK, and DATA low
       GPIO_write_low(&PORTD, SEGMENT_LATCH);
       GPIO_write_low(&PORTD, SEGMENT_CLK);
       GPIO_write_low(&PORTB, SEGMENT_DATA);
    // Wait 1 us
       _delay_us(1);

    // Loop through the 1st byte (segments)
    // a b c d e f g DP (active low values)
    for (bit_number = 0; bit_number < 8; bit_number++)
    {
        // Output DATA value (bit 0 of "segments")
              if ((segments & 1) == 0)
              {
                     GPIO_write_low(&PORTB, SEGMENT_DATA);
              }
              else
              {
                     GPIO_write_high(&PORTB, SEGMENT_DATA);
              }
        // Wait 1 us
              _delay_us(1);
        // Pull CLK high
              GPIO_write_high(&PORTD, SEGMENT_CLK);
```

```
        // Wait 1 us
              _delay_us(1);
        // Pull CLK low
              GPIO_write_low(&PORTD, SEGMENT_CLK);
        // Shift "segments"
        segments = segments >> 1;
    }

    // Loop through the 2nd byte (position)
    // p3 p2 p1 p0 . . . . (active high values)
    for (bit_number = 0; bit_number < 8; bit_number++)
    {
        // Output DATA value (bit 0 of "position")
              if ((position % 2) == 0)
              {
                     GPIO_write_low(&PORTB, SEGMENT_DATA);
              }
              else
              {
                     GPIO_write_high(&PORTB, SEGMENT_DATA);
              }
        // Wait 1 us
        _delay_us(1);
        // Pull CLK high
        GPIO_write_high(&PORTD, SEGMENT_CLK);
        // Wait 1 us
        _delay_us(1);
        // Pull CLK low
        GPIO_write_low(&PORTD, SEGMENT_CLK);
        // Shift "position"
        position = position >> 1;
    }

    // Pull LATCH high
       GPIO_write_high(&PORTD, SEGMENT_LATCH);
    // Wait 1 us
       _delay_us(1);
}

/*-------------------------------------------------------------------------*/
/* SEG_clear */
void SEG_clear()
{
       uint8_t seg_off = 0b00000000;
       uint8_t data_clear = 0b11111111;
       uint8_t bit_number;

       GPIO_write_low(&PORTD,SEGMENT_LATCH);
       GPIO_write_low(&PORTD,SEGMENT_CLK);
       GPIO_write_low(&PORTB,SEGMENT_DATA);

       for (bit_number = 0; bit_number < 8; bit_number++)
       {
              // Output DATA value (bit 0 of "position")
              if ((data_clear & 1) == 0)
              {
                     GPIO_write_low(&PORTB,SEGMENT_DATA);
              }
              else
              {
                     GPIO_write_high(&PORTB,SEGMENT_DATA);
              }
```

```
            _delay_us(1);                                               // Wait 1 us

            GPIO_write_high(&PORTD,SEGMENT_CLK);            // Pull CLK high
            _delay_us(1);                                               // Wait 1 us
            GPIO_write_low(&PORTD,SEGMENT_CLK);                     // Pull CLK low


            data_clear = data_clear >> 1;
      }
      for (bit_number = 0; bit_number < 8; bit_number++)
      {

            // Output DATA value (bit 0 of "position")
            if ((seg_off & 1) == 0)
            {
                  GPIO_write_low(&PORTB,SEGMENT_DATA);
            }
            else
            {
                  GPIO_write_high(&PORTB,SEGMENT_DATA);
            }

            _delay_us(1);                                               // Wait 1 us

            GPIO_write_high(&PORTD,SEGMENT_CLK);            // Pull CLK high
            _delay_us(1);                                               // Wait 1 us

            GPIO_write_low(&PORTD,SEGMENT_CLK);                     // Pull CLK low


            seg_off = seg_off >> 1;
      }

      GPIO_write_high(&PORTD,SEGMENT_LATCH);                // Pull LATCH high
      _delay_us(1);                                                     // Wait 1 us
}


/*-------------------------------------------------------------------*/
/* SEG_clk_2us */
void SEG_clk_2us()
{
      GPIO_write_high(&PORTD,SEGMENT_CLK);                  // set pin "Segment_clk"
to 1
      _delay_us(1);                                                     // Wait 1 us
      GPIO_write_low(&PORTD,SEGMENT_CLK);                     // set pin
"Segment_clk" to 0
      _delay_us(1);                                                     // Wait 1 us
}
```

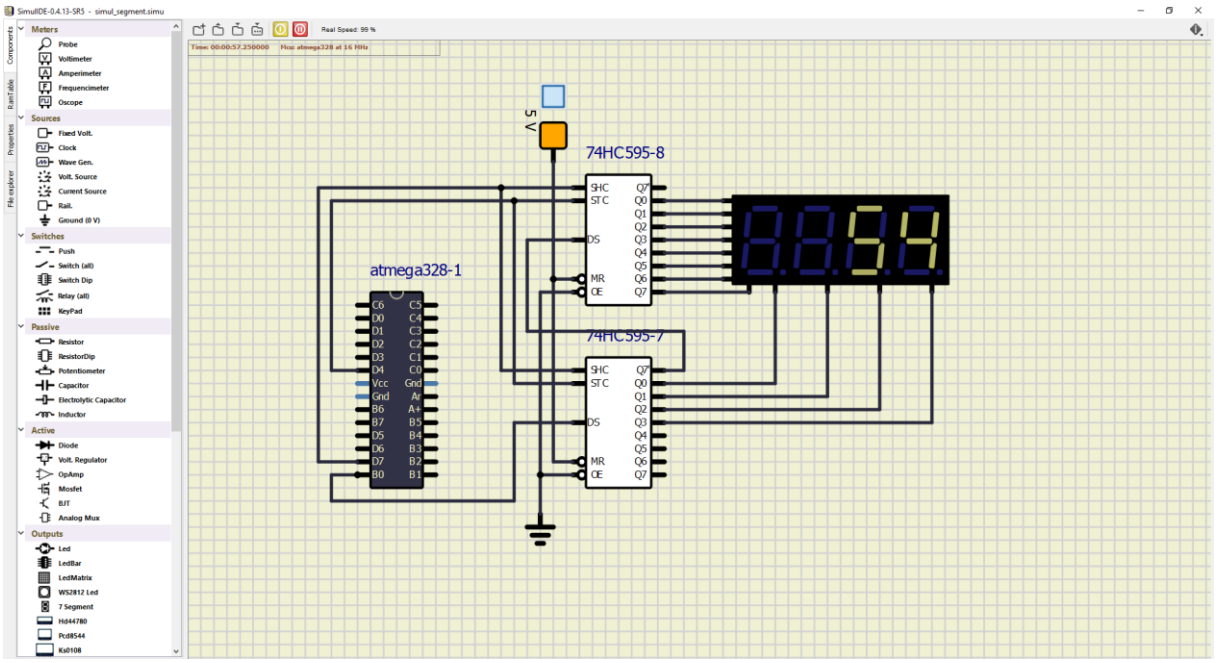
- **Listing of decimal counter application `main.c` (at least two-digit decimal counter, ie. from 00 to 59),**

```
/************************************************************************
 *
 * Decimal counter with 7-segment output.
 * ATmega328P (Arduino Uno), 16 MHz, AVR 8-bit Toolchain 3.6.2
 *
 * Copyright (c) 2018-2020 Tomas Fryza
 * Dept. of Radio Electronics, Brno University of Technology, Czechia
 * This work is licensed under the terms of the MIT license.
```

```
 *
 ***********************************************************************/

/* Includes ------------------------------------------------------------*/
#include <avr/io.h>         // AVR device-specific IO definitions
#include <avr/interrupt.h>  // Interrupts standard C library for AVR-GCC
#include "timer.h"          // Timer library for AVR-GCC
#include "segment.h"        // Seven-segment display library for AVR-GCC

uint8_t singles = 0;
uint8_t decimals = 0;

/* Function definitions ------------------------------------------------*/
/**
 * Main function where the program execution begins. Display decimal
 * counter values on SSD (Seven-segment display) when 16-bit
 * Timer/Counter1 overflows.
 */
int main(void)
{
    // Configure SSD signals
    SEG_init();

    /* Configure 16-bit Timer/Counter0
     * Set prescaler and enable overflow interrupt */
      TIM0_overflow_4ms();
      TIM0_overflow_interrupt_enable();
    /* Configure 16-bit Timer/Counter1
     * Set prescaler and enable overflow interrupt */
      TIM1_overflow_1s();
      TIM1_overflow_interrupt_enable();

    // Enables interrupts by setting the global interrupt mask
       sei();
    // Infinite loop
    while (1)
    {
        /* Empty loop. All subsequent operations are performed exclusively
         * inside interrupt service routines ISRs */
    }

    // Will never reach this
    return 0;
}

/* Interrupt service routines ------------------------------------------*/

/**
 * ISR starts when Timer/Counter0 overflows. Display value on SSD
 */
ISR(TIMER0_OVF_vect)
{
       static uint8_t position = 0;
       if (position == 0)
       {
              SEG_update_shift_regs(singles, 0);
              position = 1;
       }
       else
       {
              SEG_update_shift_regs(decimals, 1);
              position = 0;
```

```
	}

}


/**
 * ISR starts when Timer/Counter1 overflows. Increment decimal counter
 */
ISR(TIMER1_OVF_vect)
{
	singles++;
	if(singles > 9)
	{
		singles = 0;
		decimals++;
		if(decimals > 5)
		{
			decimals = 0;
		}
	}
}
```

- **Screenshot of SimulIDE circuit.**



3. **Snake. Submit:**
    - **Look-up table with snake definition,**

number	snake position	7seg binary code
0		0b11111111
1	¯	0b01111111
2	'	0b10111111
3	,	0b11011111
4	_	0b11101111
5	,	0b11110111
6	'	0b11111011

    - **Listing of your snake cycling application `main.c`.**

```
/*******************************************************************
 *
 * Decimal counter with 7-segment output.
 * ATmega328P (Arduino Uno), 16 MHz, AVR 8-bit Toolchain 3.6.2
 *
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 *
 *******************************************************************/

/* Includes ----------------------------------------------------------*/
#include <avr/io.h>         // AVR device-specific IO definitions
#include <avr/interrupt.h>  // Interrupts standard C library for AVR-GCC
#include "timer.h"          // Timer library for AVR-GCC
#include "segment.h"        // Seven-segment display library for AVR-GCC

uint8_t singles = 0;
uint8_t decimals = 0;

/* Function definitions ----------------------------------------------*/
/**
 * Main function where the program execution begins. Display decimal
 * counter values on SSD (Seven-segment display) when 16-bit
 * Timer/Counter1 overflows.
 */
int main(void)
{
    // Configure SSD signals
    SEG_init();

    /* Configure 16-bit Timer/Counter0
     * Set prescaler and enable overflow interrupt */
       TIM0_overflow_4ms();
       TIM0_overflow_interrupt_enable();
    /* Configure 16-bit Timer/Counter1
     * Set prescaler and enable overflow interrupt */
       TIM1_overflow_262ms();
       TIM1_overflow_interrupt_enable();

    // Enables interrupts by setting the global interrupt mask
       sei();
    // Infinite loop
```

```
    while (1)
    {
        /* Empty loop. All subsequent operations are performed exclusively
         * inside interrupt service routines ISRs */
    }

    // Will never reach this
    return 0;
}

/* Interrupt service routines --------------------------------------*/

/**
 * ISR starts when Timer/Counter0 overflows. Display snake on SSD
 */
ISR(TIMER0_OVF_vect)
{
	static uint8_t position = 0;
	if (position == 0)
	{
		SEG_update_shift_regs(singles, 0);
		position = 1;
	}
	else
	{
		SEG_update_shift_regs(decimals, 1);
		position = 0;
	}

}


/**
 * ISR starts when Timer/Counter1 overflows. Increment decimal counter
 */
ISR(TIMER1_OVF_vect)
{
	if(decimals == 0)
	{
		singles++;
		if(singles > 4)
		{
			singles = 0;
			decimals = 4;
		}
	}
	else if(decimals > 3)
	{
		decimals++;
		if (decimals > 6)
		{
			decimals = 1;
		}
	}
	else if(decimals == 1)
	{
		decimals = 0;
		singles = 1;
	}
}
```