Lab Assignment 4

Masauso Lungu 209533

1. Preparation task.

Table with overflow Times

Module	Number of bits	1	8	32	64	128	256	1024
Timer/Counter0	8	16us	128us	--	1.024ms	--	4.096ms	16.384ms
Timer/Counter1	16	4.096ms	32.768ms	--	262.144ms	--	1.048576s	4.194304s
Timer/Counter2	8	16us	128us	512us	1.024ms	2.048ms	4.096ms	16.384ms

2. Timer Library

Module	Operation	I/O register(s)	Bit(s)
Timer/Counter0	Prescaler 8-bit data value Overflow interrupt enable	TCCR0B TCNT0 TIMSK0	CS02, CS01, CS00 (000: stopped, 001: 1, 010: 64, 100: 256, 101: 1024) TCNT0[7:0] TOIE0(1: enable, 0: disable)
Timer/Counter1	Prescaler 16-bit data value Overflow interrupt enable	TCCR1B TCNT1H, TCNT1L TIMSK1	CS12, CS11, CS10 (000: stopped, 001: 1, 010: 8, 011: 64, 100: 256, 101: 1024) TCNT1[15:0] TOIE1 (1: enable, 0: disable)
Timer/Counter2	Prescaler 8-bit data value Overflow interrupt enable	TCCR2B TCNT2 TIMSK2	CS22, CS11, CS10 (000: stopped, 001: 1, 010: 8, 011: 32, 100: 64, 101: 128, 110: 256, 111: 1024) TCNT2[7:0] TOIE2(1: enable, 0; disable)

timer.h file.

```
/*
 * timer.h
 *
 * Created: 10/14/2020 11:23:08
 * Author : masau
 */

#ifndef TIMER_H
#define TIMER_H

/***********************************************************************
 *
 * Timer library for AVR-GCC.
 * ATmega328P (Arduino Uno), 16 MHz, AVR 8-bit Toolchain 3.6.2
 *
 * Copyright (c) 2019-2020 Tomas Fryza
 * Dept. of Radio Electronics, Brno University of Technology, Czechia
 * This work is licensed under the terms of the MIT license.
 *
 **********************************************************************/

/**
 * @file  timer.h
 * @brief Timer library for AVR-GCC.
 *
 * @details
 * The library contains macros for controlling the timer modules.
 *
 * @note
 * Based on Microchip Atmel ATmega328P manual and no source file is
 * needed for the library.
 *
 * @copyright (c) 2019-2020 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>

/* Defines -----------------------------------------------------------*/

//Timer/counter0
/**
 * @brief Defines prescaler CPU frequency values for Timer/Counter1.
 * @note  F_CPU = 16 MHz
 */
#define TIM0_stop()              TCCR0B &= ~((1<<CS02) | (1<<CS01) | (1<<CS00));
#define TIM0_overflow_16us()     TCCR0B &= ~((1<<CS02) | (1<<CS01)); TCCR0B |= (1<<CS00);
#define TIM0_overflow_128us()    TCCR0B &= ~((1<<CS02) | (1<<CS00)); TCCR0B |= (1<<CS01);
#define TIM0_overflow_1ms()      TCCR0B &= ~(1<<CS02); TCCR0B |= (1<<CS01) | (1<<CS00);
#define TIM0_overflow_4ms()      TCCR0B &= ~((1<<CS01) | (1<<CS00)); TCCR0B |= (1<<CS02);
#define TIM0_overflow_16ms()     TCCR1B &= ~(1<<CS01); TCCR0B |= (1<<CS02) | (1<<CS00);

/**
 * @brief Defines interrupt enable/disable modes for Timer/Counter1.
 */
#define TIM0_overflow_interrupt_enable()    TIMSK0 |= (1<<TOIE0);
#define TIM0_overflow_interrupt_disable()   TIMSK0 &= ~(1<<TOIE0);


//Timer/counter1
/**
 * @brief Defines prescaler CPU frequency values for Timer/Counter1.
 * @note  F_CPU = 16 MHz
 */
#define TIM1_stop()             TCCR1B &= ~((1<<CS12) | (1<<CS11) | (1<<CS10));
#define TIM1_overflow_4ms()     TCCR1B &= ~((1<<CS12) | (1<<CS11)); TCCR1B |= (1<<CS10);
#define TIM1_overflow_33ms()    TCCR1B &= ~((1<<CS12) | (1<<CS10)); TCCR1B |= (1<<CS11);
#define TIM1_overflow_262ms()   TCCR1B &= ~(1<<CS12); TCCR1B |= (1<<CS11) | (1<<CS10);
#define TIM1_overflow_1s()      TCCR1B &= ~((1<<CS11) | (1<<CS10)); TCCR1B |= (1<<CS12);
#define TIM1_overflow_4s()      TCCR1B &= ~(1<<CS11); TCCR1B |= (1<<CS12) | (1<<CS10);

/**
 * @brief Defines interrupt enable/disable modes for Timer/Counter1.
 */
#define TIM1_overflow_interrupt_enable()    TIMSK1 |= (1<<TOIE1);
#define TIM1_overflow_interrupt_disable()   TIMSK1 &= ~(1<<TOIE1);


//Timer/counter2
/**
 * @brief Defines prescaler CPU frequency values for Timer/Counter1.
 * @note  F_CPU = 16 MHz
 */
#define TIM2_stop()              TCCR2B &= ~((1<<CS22) | (1<<CS21) | (1<<CS20));
#define TIM2_overflow_16us()     TCCR2B &= ~((1<<CS22) | (1<<CS21)); TCCR2B |= (1<<CS20);
#define TIM2_overflow_128us()    TCCR2B &= ~((1<<CS22) | (1<<CS20)); TCCR2B |= (1<<CS21);
#define TIM2_overflow_512us()    TCCR2B &= ~(1<<CS22); TCCR2B |= (1<<CS21) | (1<<CS00);
#define TIM2_overflow_1ms()      TCCR2B &= ~((1<<CS21) | (1<<CS20)); TCCR2B |= (1<<CS22);
#define TIM2_overflow_2ms()      TCCR2B &= ~(1<<CS21); TCCR2B |= (1<<CS22) | (1<<CS20);
#define TIM2_overflow_4ms()      TCCR2B &= ~(1<<CS20); TCCR2B |= (1<<CS22) | (1<<CS21);
#define TIM2_overflow_16ms()     TCCR2B &= ~(1<<CS22) | (1<<CS20) | (1<<CS21);

/**
 * @brief Defines interrupt enable/disable modes for Timer/Counter2.
 */
#define TIM2_overflow_interrupt_enable()    TIMSK2 |= (1<<TOIE2);
#define TIM2_overflow_interrupt_disable()   TIMSK2 &= ~(1<<TOIE2);



#endif
```

Table with ATmega328P selected interrupt sources

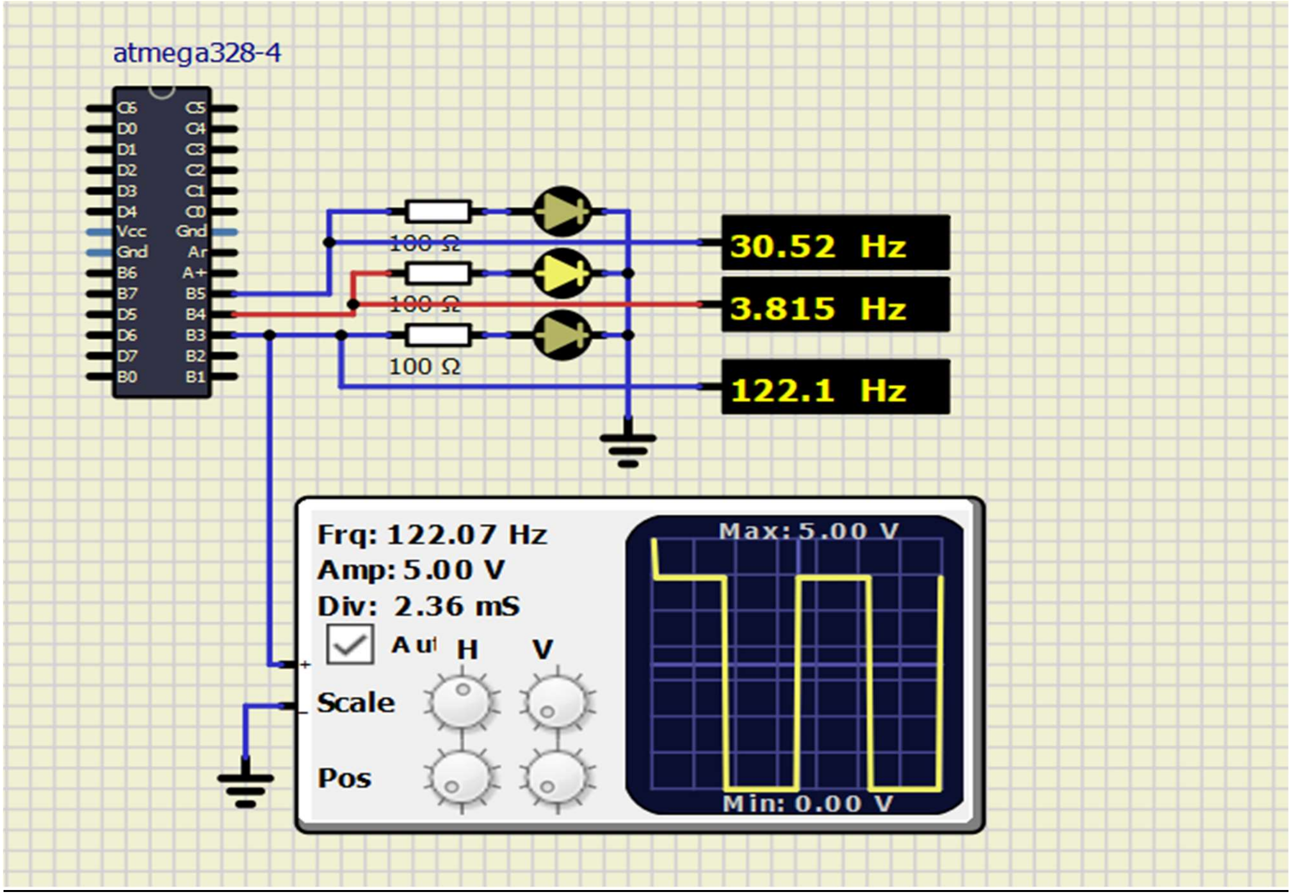
Program address	Source	Vector name	Description
0x0000	RESET	--	Reset of the system
0x0002	INT0	`INT0_vect`	External interrupt request number 0
0x0004	INT1	`INT1_vect`	External interrupt request 1
0x0006	PCINT0	`PCINT0_vect`	Pin change interrupt request 0
0x0008	PCINT1	`PCINT1_vect`	Pin change interrupt request 1
0x00A	PCINT2	`PCINT2_vect`	Pin change interrupt request 2
0x00C	WDT	`WDT_vect`	Watchdaog Time-out interrupt
0x0012	TIMER2_OVF	`TIMER2_OVF_vect`	Timer/counter2 Overflow
0x0018	TIMER1_COMPB	`TIMER1_COMPB_vect`	Compare match between Timer/Counter1 value and channel B compare value
0x001A	TIMER1_OVF	`TIMER1_OVF_vect`	Overflow of Timer/Counter1 value
0x0020	TIMER0_OVF	`TIMER0_OVF_vect`	Timer/Counter0 Overflow
0x0024	USART_RX	`USART_vect`	USART_Rx complete
0x002A	ADC	`ADC_vect`	ADC Conversion Complete
0x0030	TWI	`TWI_vect`	2-wire Serial interface

Main.c

```
/*
 * timers.c
 *
 * Created: 10/14/2020 11:23:08
 * Author : masau
 */

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

```
 *
 * Control LEDs using functions from GPIO and Timer libraries. Do not
 * use delay library any more.
 * 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.
 *
 **********************************************************************/

/* Defines -----------------------------------------------------------*/
#define LED_D1  PB5
#define LED_D2  PB4
#define LED_D3  PB3
#define LED_D4  PC0


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

/* Function definitions ----------------------------------------------*/
/**
 * Main function where the program execution begins. Toggle three LEDs
 * on Multi-function shield with internal 8- and 16-bit timer modules.
 */
int main(void)
{
    /* Configuration of three LEDs */
    GPIO_config_output(&DDRB, LED_D1);
    GPIO_write_low(&PORTB, LED_D1);
    // WRITE YOUR CODE HERE
       GPIO_config_output(&DDRB, LED_D2);
       GPIO_write_low(&PORTB, LED_D2);

       GPIO_config_output(&DDRB, LED_D3);
       GPIO_write_low(&PORTB, LED_D3);



    /* Configuration of 8-bit Timer/Counter0 */
       TIM0_overflow_16ms();
       TIM0_overflow_interrupt_enable();


    /* Configuration of 16-bit Timer/Counter1
     * Set prescaler and enable overflow interrupt */
    TIM1_overflow_262ms();
    TIM1_overflow_interrupt_enable();

    /* Configuration of 8-bit Timer/Counter2 */
       TIM2_overflow_4ms();
       TIM2_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. Toggle LED D1 on
 * Multi-function shield. */
ISR(TIMER0_OVF_vect)
{
       GPIO_toggle(&PORTB, LED_D1);
}

/* Interrupt service routines ----------------------------------------*/
/**
 * ISR starts when Timer/Counter1 overflows. Toggle LED D2 on
 * Multi-function shield. */
ISR(TIMER1_OVF_vect)
{
    // WRITE YOUR CODE HERE
       GPIO_toggle(&PORTB, LED_D2);
}

/* Interrupt service routines ----------------------------------------*/
/**
 * ISR starts when Timer/Counter2 overflows. Toggle LED D3 on
 * Multi-function shield. */
ISR(TIMER2_OVF_vect)
{
       GPIO_toggle(&PORTB, LED_D3);
}
```

SimulIDE circuit



Frq: 122.07 Hz
Amp: 5.00 V
Div: 2.36 mS

<u>Difference between a C function and an Interrupt service routine(ISR)</u>

Both ISR and C function are a set of instruction to perform a particular task. The difference between C function and ISR is in the way they get called.

The C function is generally called in the main program code and get executed.

While an ISR code get executed automatically whenever an interrupt is triggered in the hardware peripheral or processor exception signals. ISR takes no parameters and returns no results and unlike the normal function, ISR can be called at anytime when an interrupt occur.

3. PWM

<u>Table with channels of ATmega328P</u>

Module	Description	MCU pin	Arduino pin
Timer/Counter0	OC0A	PD6	6
	OC0B	PD5	5
Timer/Counter1	OC1A	PB1	9
	OC1B	PB2	10
Timer/Counter2	OC2A	PB3	11
	OC2B	PD3	3

The behavior of Clear Timer on Compare and Fast PWM modes

In Clear Timer on Compare (CTC) mode, the OCR0 Register is used to manipulate the counter resolution.

-The counter is cleared to zero when the counter value (TCNT0) matches the OCR0.

-There is greater control of the Compare Match output frequency.

In fast fast PWM mode, the counter is incremented until the counter value matches the TOP value, then cleared at the following timer clock cycle.

- The counter counts from BOTTOM to TOP then restarts from BOTTOM