**1. Preparation task**

fCPU = 16 MHz   [Timer overflow](https://github.com/tomas-fryza/Digital-electronics-2/blob/master/Labs/04-interrupts/Images/timer_overflow.png)

| **Module** | **Number of bits** | **1** | **8** | **32** | **64** | **128** | **256** | **1024** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Timer/Counter0 | 8 | 16 u | 128 u | -- | 1,024 m | -- | 4,096 m | 16,38 m |
| Timer/Counter1 | 16 | 4,096 m | 32,8 m | -- | 262,1 m | -- | 1049 m | 4194 m |
| Timer/Counter2 | 8 | 16 u | 128 u | 512 u | 1,024 m | 2048 u | 4,096 m | 16,38 m |

**2. Timer library**

Table with ATmega328P counters

| **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: 0, 010: 8, 011: 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, CS21, CS20  (000: stopped, 001: 0, 010: 8, 011: 32, 100: 64, 101: 128, 110: 256, 111: 1024) TCNT2[7:0]  TOIE2 (1: enable, 0: disable) |

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 number 1 |
| 0x0006 | PCINT0 | PCINT0\_vect | Pin Change Interrupt Request 0 |
| 0x0008 | PCINT1 | PCINT1\_vect | Pin Change Interrupt Request 1 |
| 0x000A | PCINT2 | PCINT2\_vect | Pin Change Interrupt Request 2 |
| 0x000C | WDT | WDT\_vect | Watchdog Time-out Interrupt |
| 0x0012 | TIMER2\_OVF | TIM2\_OVF\_vect | Overflow of Timer/Counter2 value |
| 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 | TIM0\_OVF\_vect | Overflow of Timer/Counter0 value |
| 0x0024 | USART\_RX | USART\_RX\_vect | USART Rx Complete |
| 0x002A | ADC | ADC\_vect | ADC Conversion Complete |
| 0x0030 | TWI | TWI\_vect | 2-wire Serial Interface |

timer.h:

#ifndef TIMER\_H

#define TIMER\_H

/\* Includes ----------------------------------------------------------\*/

#include <avr/io.h>

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

// @note F\_CPU = 16 MHz

// @brief Defines prescaler CPU frequency values for Timer/Counter0.

#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() TCCR0B &= ~(1<<CS01); TCCR0B |= (1<<CS02) | (1<<CS00);

// @brief Defines prescaler CPU frequency values for Timer/Counter1.

#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 prescaler CPU frequency values for Timer/Counter2.

#define TIM2\_stop() TCCR2B &= ~((1<<CS22) | (1<<CS21) | (1<<CS20)); // 000

#define TIM2\_overflow\_16us() TCCR2B &= ~((1<<CS22) | (1<<CS21)); TCCR2B |= (1<<CS20); // 001

#define TIM2\_overflow\_128us() TCCR2B &= ~((1<<CS22) | (1<<CS20)); TCCR2B |= (1<<CS21); // 010

#define TIM2\_overflow\_512us() TCCR2B &= ~(1<<CS22); TCCR2B |= (1<<CS21) | (1<<CS20); // 011

#define TIM2\_overflow\_1ms() TCCR2B &= ~((1<<CS21) | (1<<CS20)); TCCR2B |= (1<<CS22); // 100

#define TIM2\_overflow\_2ms() TCCR2B &= ~(1<<CS21); TCCR2B |= (1<<CS22) | (1<<CS20); // 101

#define TIM2\_overflow\_4ms() TCCR2B &= ~(1<<CS20); TCCR2B |= (1<<CS22) | (1<<CS21); // 110

#define TIM2\_overflow\_16ms() TCCR2B |= (1<<CS22) | (1<<CS21) | (1<<CS20); // 111

/\*\*

\* @brief Defines interrupt enable/disable modes for Timer/Counter0.

\*/

#define TIM0\_overflow\_interrupt\_enable() TIMSK0 |= (1<<TOIE0);

#define TIM0\_overflow\_interrupt\_disable() TIMSK0 &= ~(1<<TOIE0);

/\*\*

\* @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);

/\*\*

\* @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

main.c:

/\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

\*

\* 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

\*

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

#define LED\_D1 PB5

#define LED\_D2 PB4

#define LED\_D3 PB3

#define LED\_RED PC0

#define BTN PD0

#define BLINK\_DELAY 500

#define *F\_CPU* 16000000 // CPU frequency in Hz required for delay

/\* Includes ----------------------------------------------------------\*/

#include <avr/io.h> // AVR device-specific IO definitions

#include <util/delay.h>

#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);

GPIO\_config\_output(&DDRB, LED\_D2);

GPIO\_write\_low(&PORTB, LED\_D2);

GPIO\_config\_output(&DDRB, LED\_D3);

GPIO\_write\_low(&PORTB, LED\_D3);

/\* RED LED \*/

GPIO\_config\_output(&DDRC, LED\_RED);

GPIO\_write\_high(&PORTC, LED\_RED);

/\* push button \*/

GPIO\_config\_input\_pullup(&DDRD, BTN);

/\* 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 \*/

// Pause several milliseconds

*\_delay\_ms*(BLINK\_DELAY);

if(!GPIO\_read(&PIND,BTN))

{

GPIO\_toggle(&PORTC,LED\_RED);

}

}

// 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);

}

/\*\*

\* ISR starts when Timer/Counter1 overflows. Toggle LED D2 on

\* Multi-function shield. \*/

ISR(TIMER1\_OVF\_vect)

{

GPIO\_toggle(&PORTB, LED\_D2);

}

/\*\*

\* ISR starts when Timer/Counter2 overflows. Toggle LED D3 on

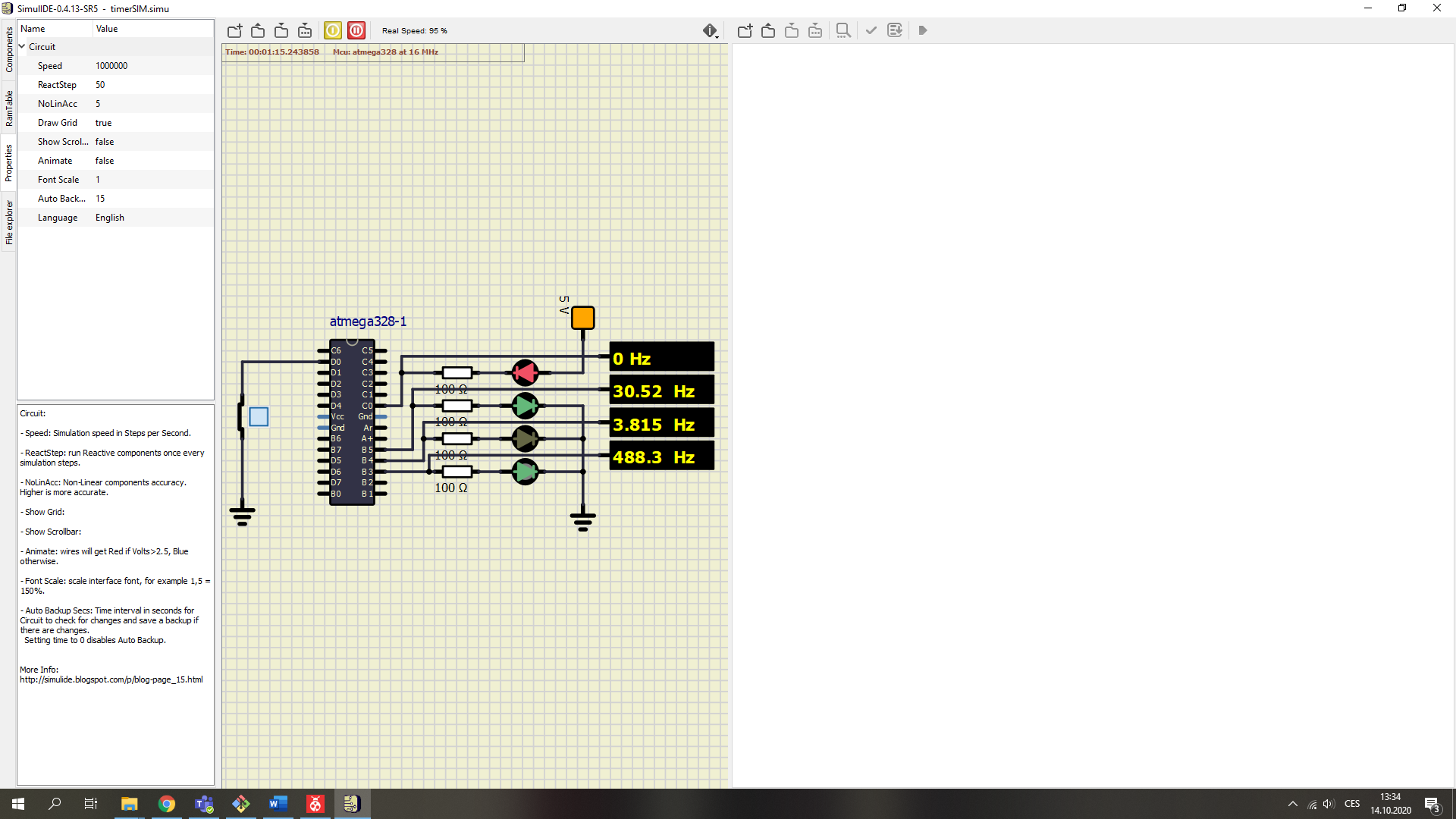
\* Multi-function shield. \*/

ISR(TIMER2\_OVF\_vect)

{

GPIO\_toggle(&PORTB, LED\_D3);

}

simulIDE circuit: 

difference between a common C function and interrupt service routine:

Common C function has to check required condition in every cycle of its loop.

Iterrupt service routine works like this: periphery sends interrupt request to the main function. function stops, completes the task requested from periphery. Then continues, where it stopped.

**3. PWN submit:**

Table with PWM channels of ATmega328P:

|  |
| --- |
|  |
| **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 |

fast PWM mode:

Option of making pulse width modulated signal. A digital signal with changeable width of pulse (changeable duty). Its using moving with interrupt flags on TCNTn signal.

Usable for regulating light intensity of LEDs.