Module	Number of bits	1	8	32	64	128	256	1024
Timer/Counter0	8	16u	128u	--	1m	--	4m	16.3m
Timer/Counter1	16	4m	32m	--	262m	--	1s	4.2s
Timer/Counter2	8	16u	128u	512u	1m	2m	4m	16.3m

Module	Operation	I/O register(s)	Bit(s)
Timer/Counter0	Prescaler 8-bit data value Overflow interrupt enable	TCCR0B TCNT0H TCNT0L TIMSK0	CS02,CS01,CS00 (000: stopped, 001: 1, 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 TCNT2H, TCNT2L TIMSK2	CS22,CS21,CS20 (000: stopped, 001: 1, 010: 8, 011: 32, 100: 64, 101: 128,110:256, 111:1024) TCNT2[7:0] TOIE2 (1: enable, 0: disable)

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
0x000A	PCINT2	PCINT2_vect	Pin Change Interrupt Request 2
0x000C	WDT	WDT_vect	Watchdog Time-out Interrupt
0x0012	TIMER2_OVF		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_RX_vect	USART Rx Complete
0x002A	ADC	ADC_vect	ADC Conversion Complete
0x0030	TWI	TWI_vect	2-wire Serial Interface

Module	**Description**	**MCU pin**	**Arduino pin**

Timer/Counter0	OC0A	PD6	6
	OC0B	PD5	5
Timer/Counter1	OC1A	PB1	6
	OC1B	PB2	10
Timer/Counter2	OC2A	PB3	11
	OC2B	PD3	3

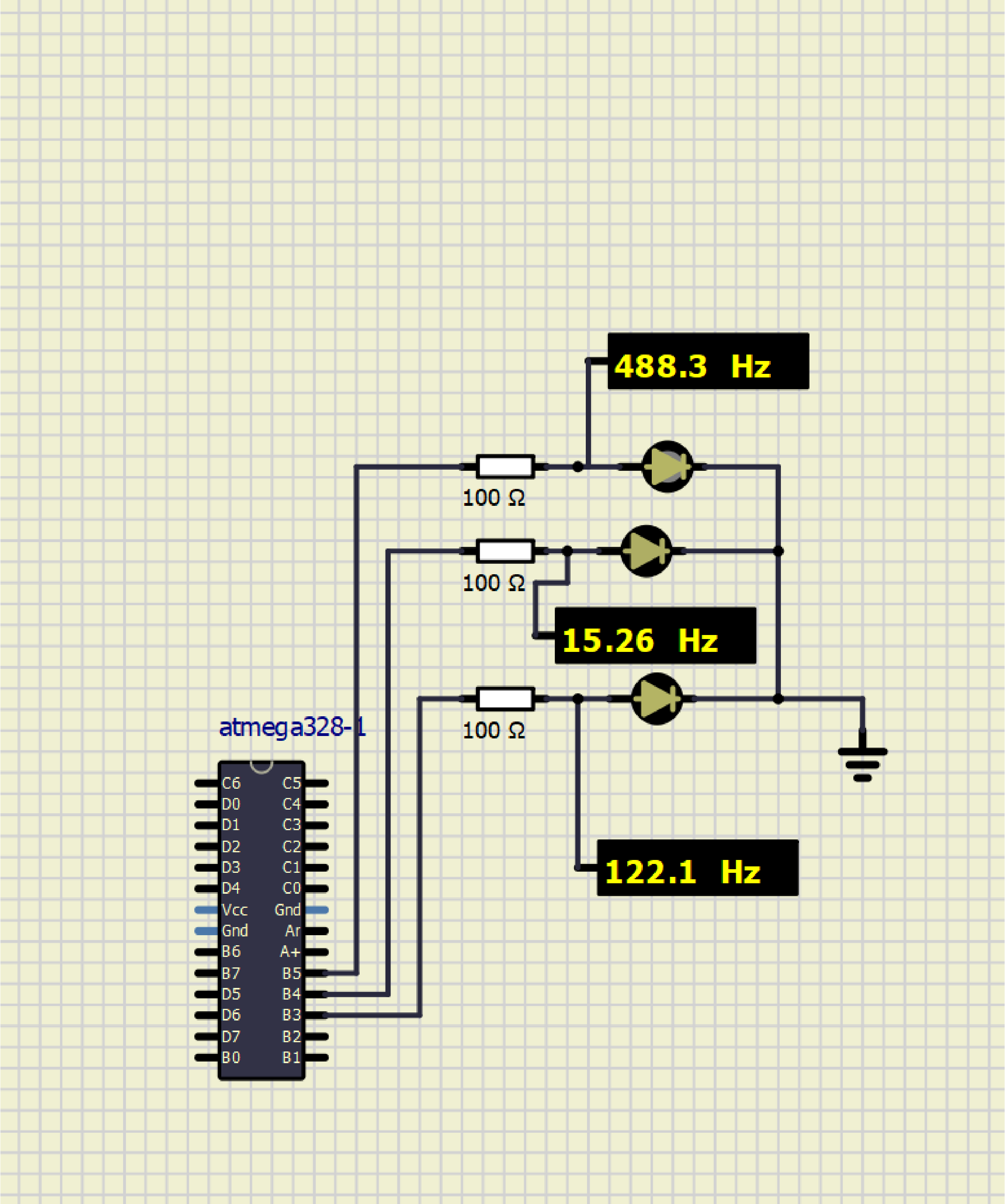
Timer.h

```
#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 -----------------------------------------------------------*/
```

```
 /* @brief Defines prescaler CPU frequency values for Timer/Counter0.
 * @note  F_CPU = 16 MHz
 */
#define TIM0_stop()             TCCR0B &= ~((1<<CS02) | (1<<CS01) | (1<<CS00));
#define TIM0_overflow_16u()     TCCR0B &= ~((1<<CS02) | (1<<CS01)); TCCR0B |= (1<<CS00);
#define TIM0_overflow_128u()    TCCR0B &= ~((1<<CS02) | (1<<CS00)); TCCR0B |= (1<<CS01);
#define TIM0_overflow_1m()         TCCR0B &= ~(1<<CS02); TCCR0B |= (1<<CS01) | (1<<CS00);
#define TIM0_overflow_4m()      TCCR0B &= ~((1<<CS01) | (1<<CS00)); TCCR0B |= (1<<CS02);
#define TIM0_overflow_16m()     TCCR0B &= ~(1<<CS01); TCCR0B |= (1<<CS02) | (1<<CS00);

/**
 * @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 prescaler CPU frequency values for Timer/Counter2.
 * @note  F_CPU = 16 MHz
 */

#define TIM2_stop()             TCCR2B &= ~((1<<CS22) | (1<<CS21) | (1<<CS20));

#define TIM2_overflow_16u()        TCCR2B &= ~((1<<CS22) | (1<<CS21)); TCCR2B |=
(1<<CS20);
#define TIM2_overflow_128u()    TCCR2B &= ~((1<<CS22) | (1<<CS20)); TCCR2B |= (1<<CS21);

#define TIM2_overflow_512u()       TCCR2B &= ~(1<<CS22); TCCR2B |= (1<<CS21) | (1<<CS20);
#define TIM2_overflow_1m()         TCCR2B &= ~((1<<CS21) | (1<<CS20)); TCCR2B |=
(1<<CS22);
#define TIM2_overflow_2m()      TCCR2B &= ~(1<<CS21); TCCR2B |= (1<<CS22) | (1<<CS20);
#define TIM2_overflow_4m()      TCCR2B &= ~(1<<CS20); TCCR2B |= (1<<CS22) | (1<<CS21);
#define TIM2_overflow_16m()     TCCR2B |= (1<<CS22) | (1<<CS20) | (1<<CS22);

/**
 * @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);

#define TIM0_overflow_interrupt_enable()    TIMSK0 |= (1<<TOIE0);
#define TIM0_overflow_interrupt_disable()   TIMSK0 &= ~(1<<TOIE0);

#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
*
* 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

/* 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_D2);
       GPIO_write_low(&PORTB, LED_D2);
       // WRITE YOUR CODE HERE
       GPIO_config_output(&DDRB, LED_D1);
       GPIO_write_low(&PORTB, LED_D1);
       GPIO_config_output(&DDRB, LED_D3);
       GPIO_write_low(&PORTB, LED_D3);
       /* Configuration of 8-bit Timer/Counter0 */
       // WRITE YOUR CODE HERE
       TIM0_overflow_1m();
       TIM0_overflow_interrupt_enable();
       /* Configuration of 16-bit Timer/Counter1
       * Set prescaler and enable overflow interrupt */
       TIM1_overflow_33ms();
       TIM1_overflow_interrupt_enable();

       /* Configuration of 8-bit Timer/Counter2 */
       // WRITE YOUR CODE HERE
       TIM2_overflow_4m();
       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/Counter1 overflows. Toggle LED D2 on
* Multi-function shield. */
ISR(TIMER1_OVF_vect)
{
       GPIO_toggle(&PORTB,LED_D2);

}

// ISR starts when Timer/Counter0 overflows. Toggle LED D1 on
ISR(TIMER0_OVF_vect)
{
       GPIO_toggle(&PORTB,LED_D1);

}
// ISR starts when Timer/Counter0 overflows. Toggle LED D3 on
ISR(TIMER2_OVF_vect)
{
       GPIO_toggle(&PORTB,LED_D3);

}
```


488.3 Hz
100 Ω
100 Ω
15.26 Hz
100 Ω
122.1 Hz
atmega328-1
C6
D0
D1
D2
D3
D4
Vcc
Gnd
B6
B7
D5
D6
D7
B0
C5
C4
C3
C2
C1
C0
Gnd
Ar
A+
B5
B4
B3
B2
B1

Otázky

- Rutina přerušení se volá automaticky vždy po vyvstanutí daného přerušení jejím argumentem je vždy dané přerušení, obyčejnou funkci lze volat kdykoliv z těla program, nicméně pokud v té době dojde k přerušení nastává čas zpracovat rutinu přerušení, jelikož má přednost.
- Fast PWM využívá pro kódování celé periody pouze period jedinného přetečení časovače, proto může mít dvojnásobnou frekvenci oproti fázově korektnímu PWM. Střída se nastavuje hodnotou komparačního registru OCRXA