Ministerul Educației al Republicii Moldova

Universitatea Tehnică a Moldovei

RAPORT

la Programarea aplicațiilor incorporate și independente de platformă

Lucrare de laborator Nr.5

Tema:”Task runner using Timer”

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Chişinău 2017

Topic:

Timers and interrupts.

Objectives

- Implement a task runner (scheduler)
- Implement descriptor for task
- Use timers for controlling tasks in time.

Task

Write a C program and schematics for task runner(scheduler) which will run a **task** in defined interval of time with defined run properties. This will look like multi tasking.

Overview of the work:

1. Timers

Timers are used everywhere. Without timers, you would end up nowhere! The range of timers vary from a few microseconds (like the ticks of a processor) to many hours, and AVR is suitable for the whole range! AVR boasts of having a very accurate timer, accurate to the resolution of microseconds! This feature makes them suitable for timer applications. Let's see how.

2. Timers as registers

So basically, a timer is a register! But not a normal one. The value of this register increases/decreases automatically. In AVR, timers are of two types: 8-bit and 16-bit timers. In an 8-bit timer, the register used is 8-bit wide whereas in 16-bit timer, the register width is of 16 bits. This means that the 8-bit timer is capable of counting 2^8=256 steps from 0 to 255 as demonstrated below.

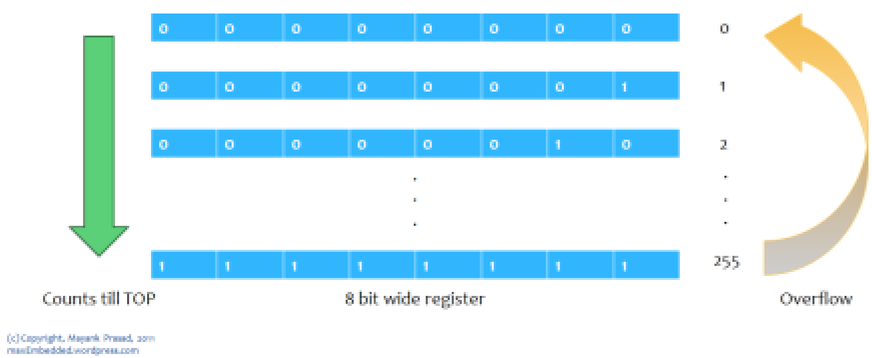


Figure 1 8 bit Counter

Similarly, a 16-bit timer is capable of counting 2^16=65536 steps from 0 to 65535. Due to this feature, timers are also known as counters. Now what happens once they reach their MAX? Does the program stop executing? Well, the answer is quite simple. It returns to its initial value of zero. We say that the timer/counter overflows.

In ATMEGA32, we have three different kinds of timers:

- TIMER0 – 8-bit timer
- TIMER1 – 16-bit timer
- TIMER2 – 8-bit timer

The best part is that the timer is totally independent of the CPU. Thus, it runs parallel to the CPU and there is no CPU's intervention, which makes the timer quite accurate.

Apart from normal operation, these three timers can be either operated in normal mode, CTC mode or PWM mode.

3. The Prescaler

Assuming F_CPU = 4 MHz and a 16-bit timer (MAX = 65535), and substituting in the above formula, we can get a maximum delay of 16.384 ms. Now what if we need a greater delay, say 20 ms? We are stuck?!

Well hopefully, there lies a solution to this. Suppose if we decrease the F_CPU from 4 MHz to 0.5 MHz (i.e. 500 kHz), then the clock time period increases to 1/500k = 0.002 ms. ***Now*** if we substitute **Required Delay = 20 ms** and **Clock Time Period = 0.002 ms**, we get **Timer Count = 9999**. As we can see, this can easily be achieved using a 16-bit timer. At this frequency, a maximum delay of 131.072 ms can be achieved.

Now, the question is how do we actually reduce the frequency? This technique of frequency division is called prescaling. We do not reduce the actual F_CPU. The actual F_CPU remains the same (at 4 MHz in this case). So basically, we derive a frequency from it to run the timer. Thus, while doing so, we divide the frequency and use it. There is a provision to do so in AVR by setting some bits which we will discuss later.

But don't think that you can use prescaler freely. It comes at a cost. There is a trade-off between resolution and duration. As you must have seen above, the overall duration of measurement has increased from a mere 16.384 ms to 131.072 ms. So, has the resolution. The resolution has also increased from 0.00025 ms to 0.002 ms (technically the resolution has actually decreased). This means each tick will take 0.002 ms. So, what's the problem with this? The problem is that the accuracy has decreased. Earlier, you were able to measure duration like 0.1125 ms accurately (0.1125/0.00025 = 450), but now you cannot (0.1125/0.002 = 56.25). The new timer can measure 0.112 ms and then 0.114 ms. No other value in between.

4. Interrupts

Well, this is not exclusively related to timers, but I thought of discussing it as it is used in a variety of places. Let me explain it using an analogy. Say now you are reading my post. It's dinner time and your mom (only if you live with your mom ;)) calls you for dinner. What do you do (if she gets too creepy)? You save your work and attend to your mom's call, then return and resume reading. This is an example of interrupt.

In most microcontrollers, there is something called interrupt. This interrupt can be fired whenever certain conditions are met. Now whenever an interrupt is fired, the AVR stops and saves its execution of the main routine, attends to the interrupt call (by executing a special routine, called the **Interrupt Service Routine**, **ISR**) and once it is done with it, returns to the main routine and continues executing it.

For example, in the condition of counter overflow, we can set up a bit to fire an interrupt whenever an overflow occurs. Now, during execution of the program, whenever an overflow occurs, an interrupt is fired and the CPU attends to the corresponding ISR. Now it's up to us what do we want to do inside the ISR. We can toggle the value of a pin, or increment a counter, etc.

5. Tools used during this laboratory work

Using Interrupts with CTC Mode

The AVR will compare TCNT1 with OCR1A. Whenever a match occurs, it sets the flag bit OCF1A, and also fires an interrupt! We just need to attend to that interrupt, that's it! No other headache of comparing and stuffs! There are three kinds of interrupts in AVR – overflow, compare and capture. We need to enable the compare interrupt. The following register is used to enable interrupts.

TIMSK Register

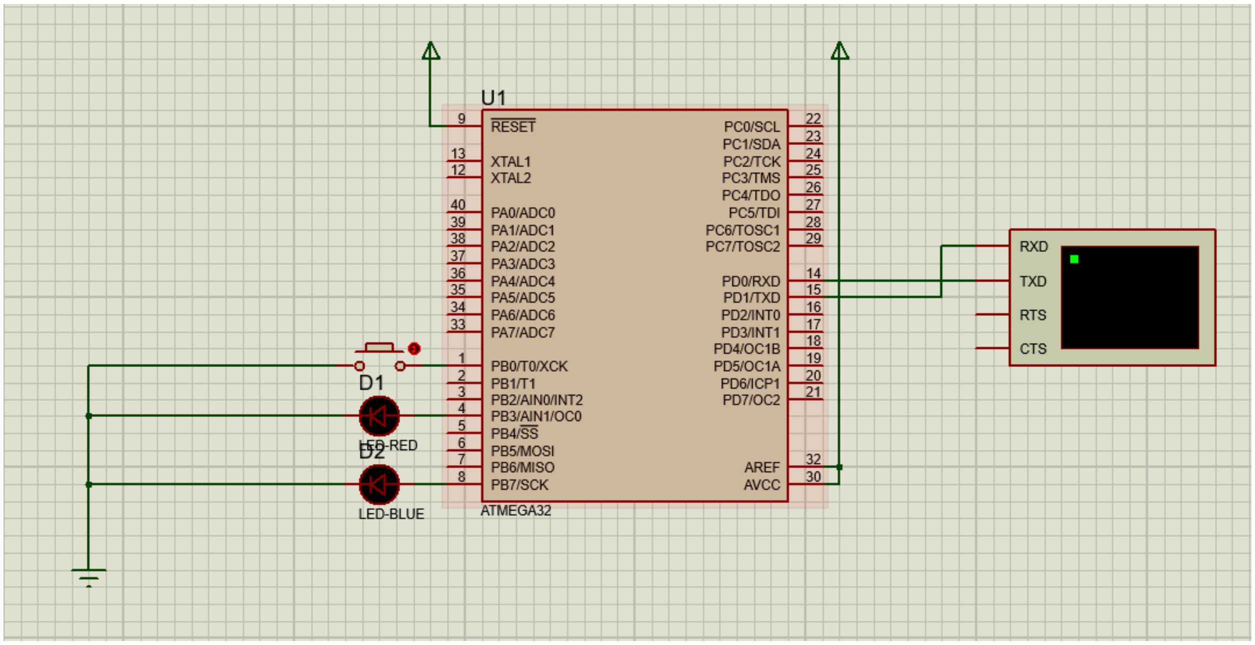
The Timer/Counter Interrupt Mask Register– TIMSK Register is as follows. It is a common register to all the timers. The greyed-out bits correspond to other timers.

Bit	7	6	5	4	3	2	1	0	
	OCIE2	TOIE2	TICIE1	OCIE1A	OCIE1B	TOIE1	OCIE0	TOIE0	TIMSK
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

Figure 2 TIMSK Register

We have already come across TOIE1 bit. Now, the **Bit 4:3 – OCIE1A:B – Timer/Counter1, Output Compare A/B Match Interrupt Enable bits** are of our interest here. Enabling it ensures that an interrupt is fired whenever a match occurs. Since there are two CTC channels, we have two different bits OCIE1A and OCIE1B for them.
Thus, to summarize, whenever a match occurs (TCNT1 becomes equal to OCR1A = 24999), an interrupt is fired (as OCIE1A is set) and the OCF1A flag is set. Now since an interrupt is fired, we need an Interrupt Service Routine (ISR) to attend to the interrupt. Executing the ISR clears the OCF1A flag bit automatically and the timer value (TCNT1) is reset.

Proteus schemes:



Used elements:

1. Push button
2. Red led
3. Blue led

This model has 3 tasks:

1. Switches **red led** output bit
2. Switches **blue led** output bit
3. Button press checker

Initially blue led is toggling. When pressing push button, then this toggle task is disabled, and red toggle task is enabled.

Conclusion

In order to implement task runner, I had used 16-bit timer, because that timer, on prescaller 8 and CTC Mode with breaking 1250. Which exactly gives us interval of 0.01 s or 10 ms.

$$\frac{1}{10^6} * 1250 * 8 = 0.01\,s$$

Having runner with 10 milliseconds interval, we can schedule task with interval of 10 or more milliseconds.

That's enough for initial purpose. Next thing what I had to do, is to implement t mechanism for registering task and check in each 10 miliseconds if task should be run.

Appendix

Main

```c
#include <avr/io.h>
#include <avr/interrupt.h>

// ******************************************************************************
// Interrupt Routines
// ******************************************************************************

uint32_t counter = 0;

// timer0 overflow
ISR(TIMER0_OVF_vect) {
   // XOR PORTA with 0x01 to toggle the second bit up

	toggle_led(counter);
	counter++;
	if(counter >= 3) {
		counter = 0;
	}
}

int main( void ) {
    // Configure PORTA as output
    DDRA = 0xFF;
    PORTA = 0xFF;
    // enable timer overflow interrupt for both Timer0 and Timer1
    TIMSK=(1<<TOIE0) | (1<<TOIE1);
    // set timer0 counter initial value to 0
    TCNT0=0x00;

    TCCR1B |= (1 << CS01);
    // enable interrupts
    sei();
    while(1) {
    }
}
```

Led.h

```c
#ifndef SRC_LED_H_
#define SRC_LED_H_
#include <avr/io.h>
#include "stdint.h"

void init_led();
void turn_on(uint32_t pin);
void turn_off(uint32_t pin);
void toogle_led(uint32_t pin);

#endif /* SRC_LED_H_ */
```

Led.c

```c
#include "led.h"
#include <stdint.h>
#define MAX 5

void init_led() {
	DDRA |= 0xFF;
}

void turn_on(uint32_t pin) {
	PORTA |= pin;
}

void turn_off(uint32_t pin) {
	PORTA &= pin;
}

void toggle_led(uint32_t pin) {
	 PORTA ^= (1 << pin);
}
```