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RAPORT

la Programarea aplicațiilor incorporate și independente de platformă

Lucrare de laborator Nr.5

A efectuat st. gr. FAF-141: Mihai Trofim

A verificat: Andrei Bragarenco

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Topic

Interrupts , Timers and Tasks

Task

Write a C program and schematics for task runner which will run a task in defined interval of time with defined run properties.

Short theory

Timers

Just about every microcontroller comes with one or more (sometimes many more) built-in timer/counters, and these are extremely useful to the embedded programmer - perhaps second in usefulness only to GPIO. The term timer/counter itself reflects the fact that the underlying counter hardware can usually be configured to count either regular clock pulses (making it a timer) or irregular event pulses (making it a counter). This tutorial will use the term “timer” rather than “timer/counter” for the actual hardware block, in the name of simplicity, but will try and make it clear when the device is acting as an event counter rather than a normal timer. Also note that sometimes timers are called “hardware timers” to distinguish them from software timers which are bits of software that perform some timing function.

Timer basics

A typical timer will consist of a prescaler, an N-bit timer/counter register (typically N is 8, 16 or 32 bits), one or more N-bit capture registers, and one or more N-bit compare registers. There will also be control and status registers to configure and monitor the timer. The fundamental hardware involved is an up-counter, which counts incoming pulses. A counter, any counter, becomes a timer when the incoming pulses are at a fixed, known frequency. I will often use the terms “counter” and “timer” interchangeably, but just keep in mind that the hardware is always a counter, and that the counter becomes a timer if we are feeding it a fixed, known frequency to count.

It is also worth noting that the size in bits of a timer is not directly related to the size in bits of the CPU architecture. Nothing prevents an 8-bit microcontroller from having 16-bit timers (most do, in fact), nor does anything prevent a 32-bit uC from having 16-bit timers (and some do).

Something else that you may see are uCs that have multiple timers of different size. For example, most AVRs have both 8-bit and 16-bit timers, and some LPC2xxx devices have both 32-bit and 16-bit timers.

Prescaler

The prescaler takes the basic timer clock frequency (which may be the CPU clock frequency or may be some higher or lower frequency) and divides it by some value before feeding it to the timer, according to how the prescaler register(s) are configured. The prescaler values that may

be configured might be limited to a few fixed values (powers of 2), or they may be any integer value from 1 to 2^P, where P is the number of prescaler bits.
The purpose of the prescaler is to allow the timer to be clocked at the rate you desire. For shorter (8 and 16-bit) timers, there will often be a tradeoff between resolution (high resolution requires a high clock rate) and range (high clock rates cause the timer to overflow more quickly). For example, you cannot (without some tricks) get 1us resolution and a 1sec maximum period using a 16-bit timer. If you want 1us resolution you are limited to about 65ms maximum period. If you want 1sec maximum period, you are limited to about 16us resolution. The prescaler allows you to juggle resolution and maximum period to fit your needs.

As an example of a fixed selection prescaler, many AVR devices allow for fixed prescale values of 1, 8, 64, 256 and 1024. If the system clock frequency is e.g. 8MHz, this results in a timer clock period of 0.125, 1, 8, 32 or 128 microseconds per clock tick. Likewise, the 9S12 prescaler allows fixed prescale values in powers of 2: 1, 2, 4, 8, 16, 32, 64 and 128.

As an example of a fully configurable prescaler, the NXP LPC2000 family has 32-bit timers that have 32-bit prescalers, which allow for any prescale value between 1 and 2^32. Such fully configurable prescalers are of course more flexible than fixed selection prescalers, but in practice the fixed selection prescalers are usually adequate, though they may require that more thought be given to choosing a system clock frequency and other timing values.

In the prescaler section I also include any configuration logic to clock the timer with an external signal, present on an input pin of the μC. If this external signal is a fixed frequency then the counter hardware continues to act as a timer, but if the external signal consists of pulses that are not fixed and regular then the counter is simply acting as a counter, as was discussed
above. When a timer/counter is configured as a counter, it is most commonly used in conjunction with some timebase (another onboard timer or an external timebase signal) to count pulses per some time interval.

What is an Interrupt?

An interrupt is a signal (an "interrupt request") generated by some event external to the CPU , which causes the CPU to stop what it is doing (stop executing the code it is currently running) and jump to a separate piece of code designed by the programmer to deal with the event which generated the interrupt request. This interrupt handling code is often called an ISR (interrupt service routine). When the ISR is finished, it returns to the code that was running prior to the interrupt, which then resumes running with no awareness that it has been pre-empted by the interrupt code. It is this ability to run the appropriate code for an external event at any point in time that is both the chief benefit of, and the potential source of difficulties from, interrupts.

A computer interrupt can be compared to interruptions in everyday life. For example, the ringing of your telephone or a knock on your door are interrupt-type events. Your phone or your doorbell can ring at any point during your day, and when they do ring you will typically stop what you are doing, deal with the reason behind the phone call or front door visit, and then go back to what you were doing. Likewise, just as you can ignore a phone call or doorbell if what you are doing requires your immediate and undivided attention, so it is possible to program the CPU to defer interrupts during certain critical sections of code, or even to ignore them entirely.

Interrupts are one of the most powerful and useful features one can employ in embedded systems. They can make the system more efficient and more responsive to critical events, and they can also make the software easier to write and understand. However, they can also be a confusing and error-prone feature in a program, and some people avoid them for that reason. But every embedded programmer should be at home with interrupts, should consider them as useful tools and not monsters in the closet, and use them whenever appropriate. It is fairly uncommon that an embedded system does not use at least one interrupt.

An interrupt request is generated when some device external to the CPU (but not necessarily external to the microcontroller – it may be an on-board peripheral) sends a signal (the interrupt request signal) to the CPU. The CPU, if configured by the software to do so, will respond to this interrupt request by finishing the current instruction it is executing, and then jumping or “vectoring” to the correct interrupt service routine (ISR) for this interrupt. This jumping or vectoring is similar to a subroutine call but not identical. The CPU will save the program counter (on the hardware stack or in a special register), and depending on design may also save some status information (perhaps on the stack), and then begin executing the interrupt code that the user has designated for this interrupt source. At the end of the interrupt code there will be a return-from-interrupt instruction which will restore any automatically-saved status information followed by the saved program counter, which then results in the previously running code being resumed without any indication that the interrupt has occurred. Beyond any state information that is automatically saved and restored in the interrupt process, it is up to the

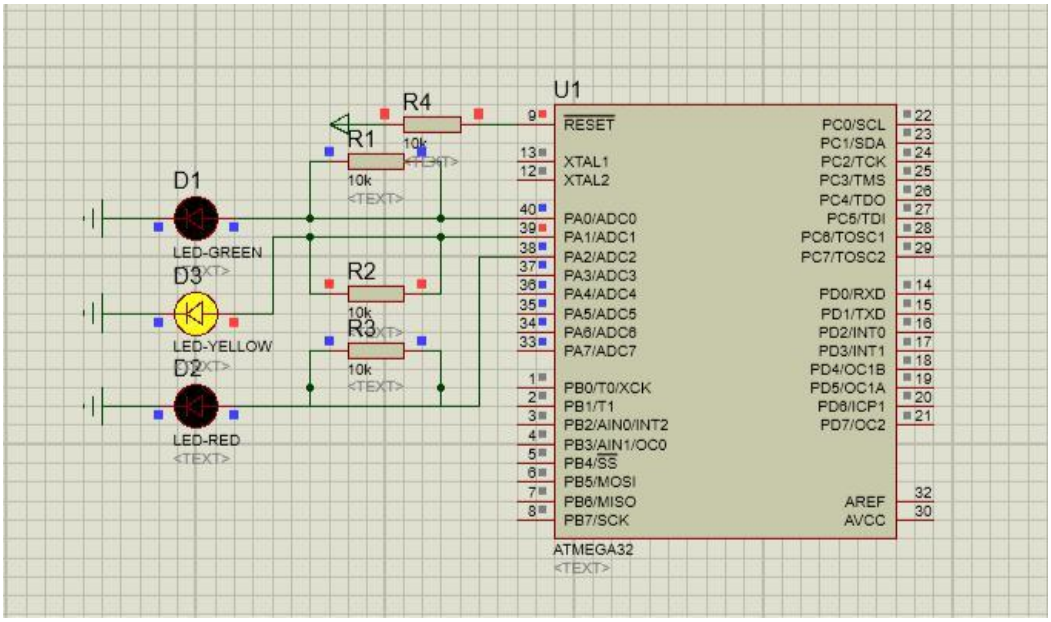
programmer to save and restore any additional resources such as registers that are used in the ISR.

The Interrupt Service Routine is defined as follows:

```
ISR (TIMER1_COMPA_vect){
   // code here
}
```

Circuit scheme

I have connected three different LEDs to micro-controllers that will be turned on one by one trough scheduler on an interval of time.



Conclusion

In this laboratory work I learnt more concepts about microcontroller programming in C language and I designed a circuit in Proteus using timers and that timers are crucial component of most embedded systems

Appendix

main.c

```
#include <avr/io.h>
#include <avr/interrupt.h>
#include <util/delay.h>


// Interrupt Routines

uint32_t counter = 0;

// timer0 overflow
ISR(TIMER1_OVF_vect) {
	// XOR PORTA with 0x01 to toggle the second bit
	up turn_off(0);
	turn_off(1);
	turn_off(2);
	turn_off(3);
	turn_off(4);
	turn_off(5);
	toggle_led(counter);
	counter++;

	if(counter >= 6) {
		counter = 0;
	}


}

int main( void ) {
	// Configure	PORTA	as
	output DDRA = 0xFF;
	PORTA = 0x00;

	// enable timer overflow interrupt for both Timer0 and Timer1
	TIMSK=(1<<TOIE0) | (1<<TOIE1);
	// set timer0 counter initial value to 0
	TCNT1=0x00;

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

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);
}
```

led.h

```c
#ifndef LED_H_
#define 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
```