Principle and Interface Techniques of Microcontroller

--8051 Microcontroller and Embedded Systems Using Assembly and C

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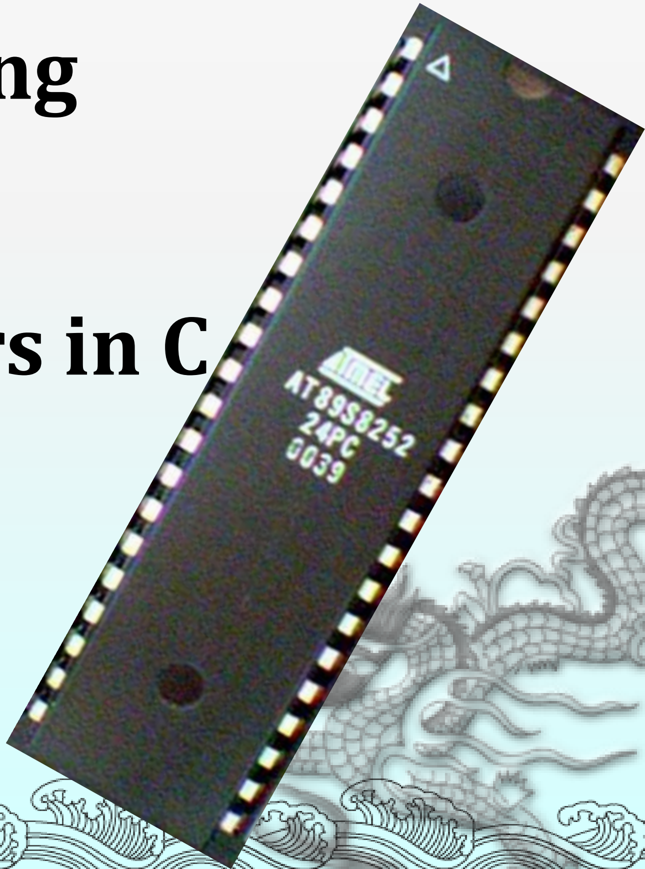
Chapter 10
Timer Programming

Outline

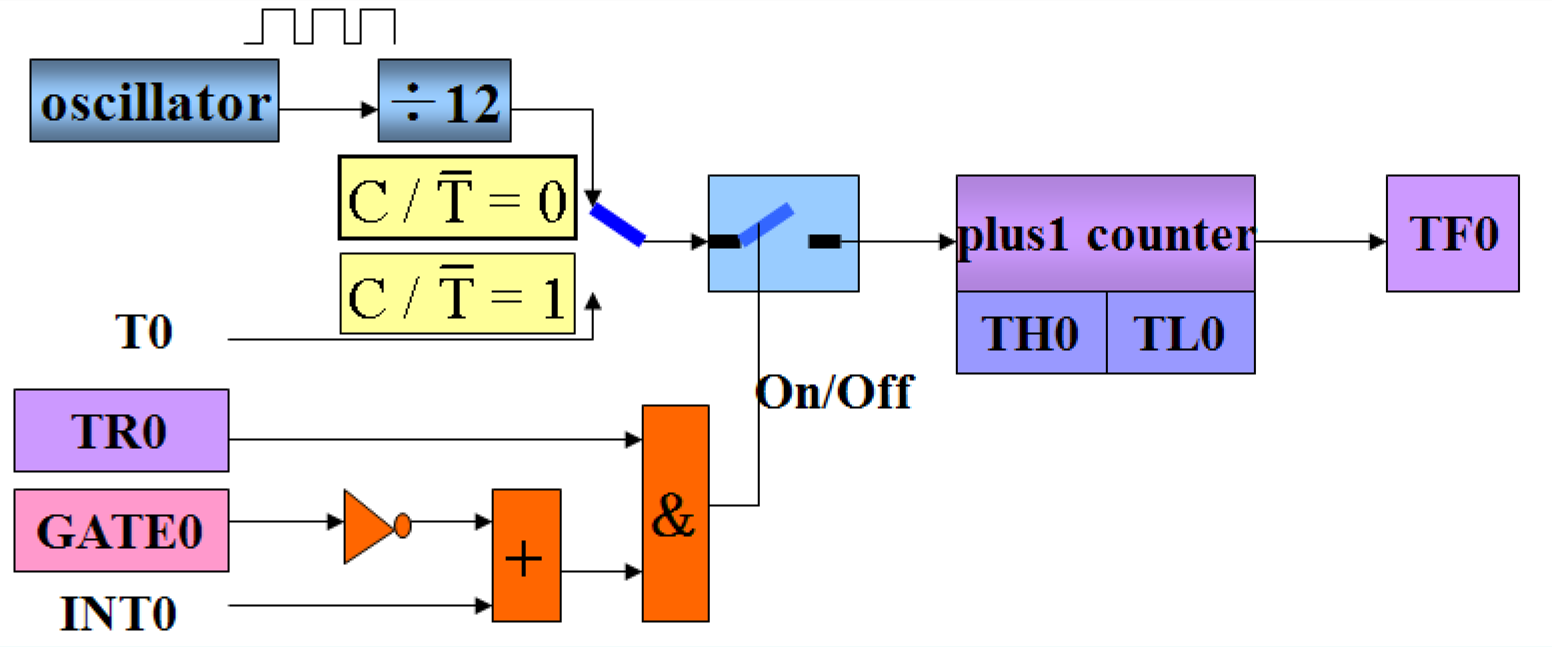
- § 10-1 Programming Timer
- § 10-2 Counter Programming
- § 10-3 Programming Timers in C



§ 10-1 Programming Timer

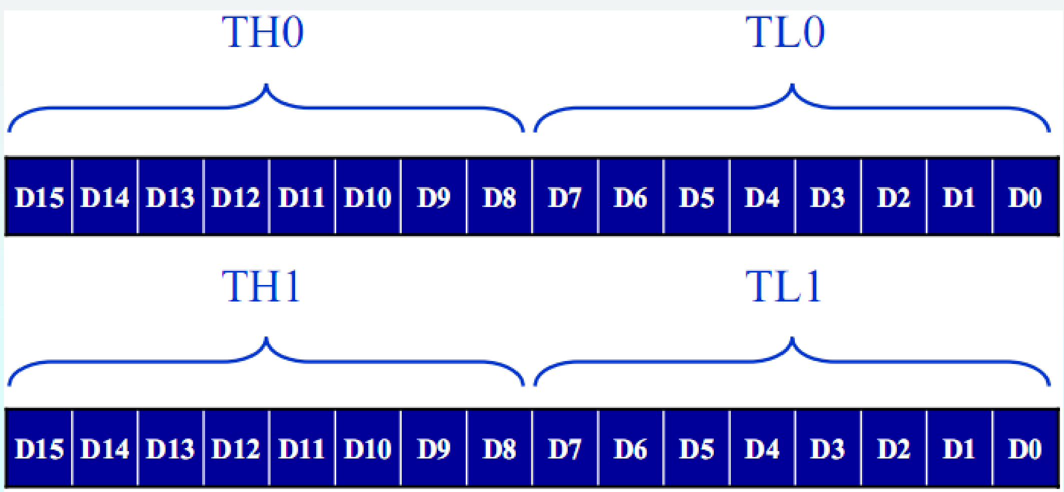
- The 8051 has two timers/counters, they can be used either as
  - Timers to generate a time delay or as
  - Event counters to count events happening outside the microcontroller
- Both Timer 0 and Timer 1 are 16 bits wide
  - Since 8051 has an 8-bit architecture, each 16-bits timer is accessed as two separate registers of low byte and high byte

- Structure of Timer0



Timer 0 & 1 Registers

- Accessed as low byte and high byte
  - The low byte register is called TL0/TL1 and
  - The high byte register is called TH0/TH1
  - Accessed like any other register
    - MOV TL0,#4FH
    - MOV R5,TH0



TMOD Register

- Both timers 0 and 1 use the same register, called TMOD (timer mode), to set the various timer operation modes TMOD is a 8-bit register
  - The lower 4 bits are for Timer 0
  - The upper 4 bits are for Timer 1
  - In each case,
    - The lower 2 bits are used to set the timer mode
    - The upper 2 bits to specify the operation

(MSB)							(LSB)
GATE	C/T	M1	M0	GATE	C/T	M1	M0
Timer1				Timer0			

TMOD Register

(MSB)							(LSB)
GATE	C/T	M1	M0	GATE	C/T	M1	M0
Timer1				Timer0			

Timer or counter selected
Cleared for timer operation (input from internal system clock)
Set for counter operation (input from Tx input pin)

Gating control when set. Timer/counter is enable only while the INTx pin is high and the TRx control pin is set
When cleared, the timer is enabled whenever the TRx control bit is set

M1	M0	Mode	Operating Mode
0	0	0	**13-bit timer mode** 8-bit timer/counter THx with TLx as 5-bit prescaler
0	1	1	**16-bit timer mode** 16-bit timer/counter THx and TLx are cascaded; there is no prescaler
1	0	2	**8-bit auto reload** 8-bit auto reload timer/counter; THx holds a value which is to be reloaded TLx each time it overfolws
1	1	3	**Split timer mode**

TMOD Register

Example 10-1

Indicate which mode and which timer are selected for each of the following.

(a) MOV TMOD, #01H (b) MOV TMOD, #20H (c) MOV TMOD, #12H

Solution:

We convert the value from hex to binary. From Figure 9-3 we have:

(a) TMOD = 00000001, mode 1 of timer 0 is selected.

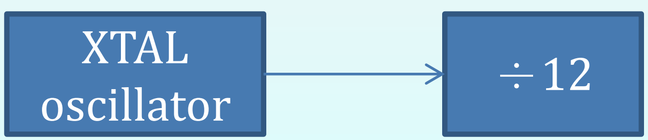
(b) TMOD = 00100000, mode 2 of timer 1 is selected.

(c) TMOD = 00010010, mode 2 of timer 0, and mode 1 of timer 1 are selected.

Example 10-2

Find the timer's clock frequency and its period for various 8051-based system, with the crystal frequency 11.0592 MHz when C/T bit of TMOD is 0.

Solution:



If C/T = 0, it is used as a timer for time delay generation. The clock source for the time delay is the crystal frequency of the 8051

$1/12 \times 11.0529$ MHz = 921.6 MHz;

T = 1/921.6 kHz = 1.085 us

TMOD Register

- Timers of 8051 do starting and stopping by either software or hardware control
  - In using software to start and stop the timer where GATE=0
    - The start and stop of the timer are controlled by way of software by the TR (timer start) bits TR0 and TR1
      - The SETB instruction starts it, and it is stopped by the CLR instruction
      - These instructions start and stop the timers as l… TMOD register
  - The hardware way of starting and stopping the t… source is achieved by making GATE=1 in the TM…

- Timer 0, mode 2
- C/T = 0 to use XTAL clock source
- gate = 0 to use internal (software) start and stop method.

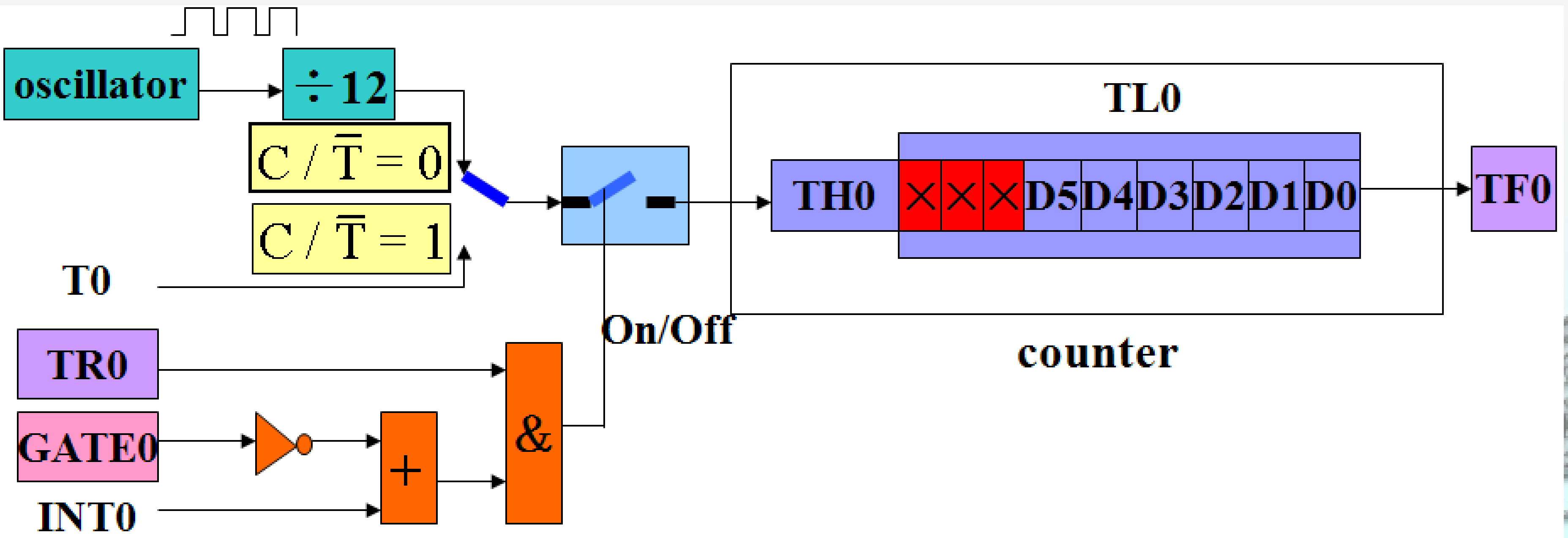
Find the value for TMOD if we want to program timer 0 in mode 2, use 8051 XTAL for the clock source, and use instructions to start and stop the timer.

TMOD = 0000 0010

Mode 0

- 13-bit timer mode

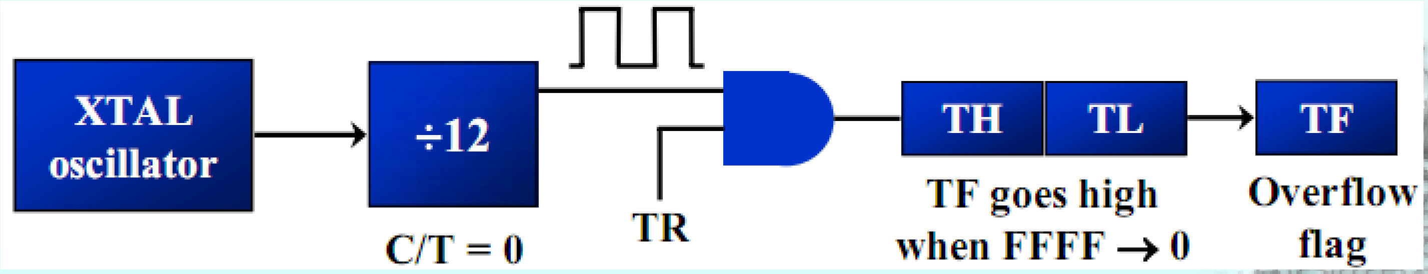
  8-bit timer/counter THx with TLx as 5-bit prescaler



Mode 1 Programming

- The following are the characteristics and operations of mode1:

  1. It is a 16-bit timer; therefore, it allows value of 0000 to FFFFH to be loaded into the timer's register TL and TH
  2. After TH and TL are loaded with a 16-bit initial value, the timer must be started
     - This is done by SETB TR0 for timer 0 and SETB TR1 for timer 1
  3. After the timer is started, it starts to count up
     - It counts up until it reaches its limit of FFFFH



Mode 1 Programming

- When it rolls over from FFFFH to 0000, it sets high a flag bit called TF (timer flag)
  - Each timer has its own timer flag: TF0 for timer 0, and TF1 for timer 1
  - This timer flag can be monitored
- When this timer flag is raised, one option would be to stop the timer with the instructions CLR TR0 or CLR TR1, for timer 0 and timer 1, respectively

4. After the timer reaches its limit and rolls over, in order to repeat the process

- TH and TL must be reloaded with the original value, and TF must be reloaded to 0

Steps to Mode 1 Program

To generate a time delay

1. Load the TMOD value register indicating which timer (timer 0 or timer 1) is to be used and which timer mode (0 or 1) is selected
2. Load registers TL and TH with initial count value
3. Start the timer
4. Keep monitoring the timer flag (TF) with the JNB TFx, target instruction to see if it is raised
   - Get out of the loop when TF becomes high
5. Stop the timer
6. Clear the TF flag for the next round
7. Go back to Step 2 to load TH and TL again

Example 10-3

In the following program, we create a square wave of 50% duty cycle (with equal portions high and low) on the P1.5 bit. Timer 0 is used to generate the time delay. Analyze the program

```
        MOV  TMOD,#01 ;Timer 0, mode 1(16-bit mode)
HERE:   MOV  TL0,#0F2H ;TL0=F2H, the low byte
        MOV  TH0,#0FFH ;TH0=FFH, the high byte
        CPL  P1.5 ;toggle P1.5
        ACALL DELAY
        SJMP HERE
```

In the above program notice the following step.

1. TMOD is loaded.
2. FFF2H is loaded into TH0-TL0.
3. P1.5 is toggled for the high and low portions of the pulse.

```
DELAY:
            SETB TR0          ;start the timer 0
AGAIN:      JNB  TF0,AGAIN    ;monitor timer flag 0 until it rolls over
            CLR  TR0          ;stop timer 0
            CLR  TF0          ;clear timer 0 flag
            RET
```

4. The DELAY subroutine using the timer is called.
5. In the DELAY subroutine, timer 0 is started by the SETB TR0 instruction.
6. Timer 0 counts up with the passing of each clock, which is provided by the crystal oscillator. As the timer counts up, it goes through the states of FFF3, FFF4, FFF5, FFF6, FFF7, FFF8, FFF9, FFFA, FFFB, and so on until it reaches FFFFH. One more clock rolls it to 0, raising the timer flag (TF0=1). At that point, the JNB instruction falls through.

7. Timer 0 is stopped by the instruction CLR TR0. The DELAY subroutine ends, and the process is repeated.

Notice that to repeat the process, we must reload the TL and TH registers, and start the process is repeated

Example 10-4

In Example 10-3, calculate the amount of time delay in the DELAY subroutine generated by the timer. Assume XTAL = 11.0592MHz.

Solution:

The timer works with a clock frequency of 1/12 of the XTAL frequency; therefore, we have 11.0592 MHz / 12 = 921.6 kHz as the timer frequency. As a result, each clock has a period of T = 1/921.6kHz = 1.085us. In other words, Timer 0 counts up each 1.085us resulting in delay = number of counts $\times$ 1.085us.

The number of counts for the roll over is FFFFH – FFF2H = 0DH (13 decimal). However, we add one to 13 because of the extra clock needed when it rolls over from FFFF to 0 and raise the TF flag. This gives 14 $\times$ 1.085us = 15.19us for half the pulse. For the entire period it is T = 2 $\times$ 15.19us = 30.38us as the time delay generated by the timer.

(a) in hex(FFFF – YYXX + 1) $\times$ 1.085 us, where YYXX are TH, TL initial values respectively.
Notice that value YYXX are in hex.

(b) in decimal Convert YYXX values of the TH, TL register to decimal to get a NNNNN decimal, then (65536 - NNNN) $\times$ 1.085 us

Example 10-5

In Example 10-4, calculate the frequency of the square wave generated on pin P1.5.

Solution:

In the timer delay calculation of Example 9-5, we did not include the overhead due to instruction in the loop. To get a more accurate timing, we need to add clock cycles due to this instructions in the loop. To do that, we use the machine cycle from Table A-1 in Appendix A, as shown below.

```
                                                  Cycles
HERE:     MOV  TL0,#0F2H                             2
          MOV  TH0,#0FFH                             2
          CPL  P1.5                                  1
          ACALL DELAY                                2
          SJMP  HERE                                 2
DELAY:
          SETB TR0                                   1
AGAIN:    JNB  TF0,AGAIN                            14
          CLR  TR0 1
          CLR  TF0 1
          RET                                        2
                                                Total 28
```

$T = 2 \times 28 \times 1.085$ us = 60.76 us and F = 16458.2 Hz

Example 10-6

Find the delay generated by timer 0 in the following code, using both of the Methods of Figure 9-4. Do not include the overhead due to instruction.

```
        CLR  P2.3           ;Clear P2.3
        MOV  TMOD,#01       ;Timer 0, 16-bitmode
HERE:   MOV  TL0,#3EH       ;TL0=3Eh, the low byte
        MOV  TH0,#0B8H      ;TH0=B8H, the high byte
        SETB P2.3           ;SET high timer 0
        SETB TR0            ;Start the timer 0
AGAIN:  JNB  TF0,AGAIN      ;Monitor timer flag 0
        CLR  TR0            ;Stop the timer 0
        CLR  TF0            ;Clear TF0 for next round
        CLR  P2.3
```

Solution:

(a) (FFFFH – B83E + 1) = 47C2H = 18370 in decimal and

18370 $\times$ 1.085 us = 19.93145 ms

(b) Since TH – TL = B83EH = 47166 (in decimal) we have

65536 –47166 = 18370. This means that the timer counts from B38EH to FFFF. This plus Rolling over to 0 goes through a total of 18370 clock cycles, where each clock is 1.085 us in duration. Therefore, we have 18370 $\times$ 1.085 us = 19.93145 ms as the width of the pulse.

Example 10-7

Modify TL and TH in Example 10-6 to get the largest time delay possible. Find the delay in ms. In your calculation, exclude the overhead due to the instructions in the loop.

Solution:

To get the largest delay we make TL and TH both 0. This will count up from 0000 to FFFFH and then roll over to zero.

```
        CLR  P2.3 ;Clear P2.3
        MOV  TMOD,#01 ;Timer 0, 16-bitmode
HERE:   MOV  TL0,#0 ;TL0=0, the low byte
        MOV  TH0,#0 ;TH0=0, the high byte
        SETB P2.3 ;SET high P2.3
        SETB TR0 ;Start timer 0
AGAIN:  JNB  TF0,AGAIN ;Monitor timer flag 0
        CLR  TR0 ;Stop the timer 0
        CLR  TF0 ;Clear timer 0 flag
        CLR  P2.3
```

Making TH and TL both zero means that the timer will count from 0000 to FFFF, and then roll over to raise the TF flag. As a result, it goes through a total Of 65536 states. Therefore, we have delay $=(65536 - 0)\times 1.085$ us = 71.1065ms.

Example 10-8

The following program generates a square wave on P1.5 continuously using timer 1 for a time delay. Find the frequency of the square wave if XTAL = 11.0592 MHz. In your calculation do not include the overhead due to instructions in the loop.

```
        MOV  TMOD,#10        ;Timer 1, mod 1 (16-bitmode)
AGAIN:  MOV  TL1,#34H        ;TL1=34H, low byte of timer
        MOV  TH1,#76H        ;TH1=76H, high byte timer
        SETB TR1             ;start the timer 1
BACK:   JNB  TF1,BACK        ;till timer rolls over
        CLR  TR1             ;stop the timer 1
        CPL  P1.5            ;comp. p1. to get hi, lo
        CLR  TF1             ;clear timer flag 1
        SJMP AGAIN           ;is not auto-reload
```

Solution:

Since FFFFH – 7634H = 89CBH + 1 = 89CCH and 89CCH = 35276 clock count and 35276 $\times$ 1.085 us = 38.274 ms for half of the square wave.

The frequency = 13.064Hz.

Also notice that the high portion and low portion of the square wave pulse are equal. In the above calculation, the overhead due to all the instruction in the loop is not included.

Finding the Loaded Timer Values

- To calculate the values to be loaded into the TL and TH registers, look at the following example
  - Assume XTAL = 11.0592 MHz, we can use the following steps for finding the TH, TL registers' values

1. Divide the desired time delay by 1.085 us
2. Perform 65536 – n, where n is the decimal value we got in Step1
3. Convert the result of Step2 to hex, where yyxx is the initial hex value to be loaded into the timer's register
4. Set TL = xx and TH = yy

Example 10-9

Assume that XTAL = 11.0592MHz. What value do we need to load the timer's register if we want to have a time delay of 5 ms (milliseconds)? Show the program for timer 0 to create a pulse width of 5 ms on P2.3.

Solution:

Since XTAL = 11.0592 MHz, the counter counts up every 1.085 us. This means that out of many 1.085 us intervals we must make a 5 ms pulse. To get that, we divide one by the other. We need 5 ms / 1.085 us = 4608 clocks. To Achieve that we need to load into TL and TH the value 65536 – 4608 = EE00H. Therefore, we have TH = EE and TL = 00.

```
        CLR  P2.3           ;Clear P2.3
        MOV  TMOD,#01       ;Timer 0, 16-bitmode
HERE:   MOV  TL0,#0         ;TL0=0, the low byte
        MOV  TH0,#0EEH      ;TH0=EE, the high byte
        SETB P2.3           ;SET high P2.3
        SETB TR0            ;Start timer 0
AGAIN:  JNB  TF0,AGAIN      ;Monitor timer flag 0
        CLR  TR0            ;Stop the timer 0
        CLR  TF0            ;Clear timer 0 flag
```

Example 10-10

Assume that XTAL = 11.0592 MHz, write a program to generate a square wave of 2 kHz frequency on pin P1.5.

Solution:

This is similar to Example10-9, except that we must toggle the bit to generate the square wave. Look at the following steps.

(a) T = 1 / f = 1 / 2 kHz = 500 us the period of square wave.

(b) 1 / 2 of it for the high and low portion of the pulse is 250 us.

(c) 250 us / 1.085 us = 230 and 65536 – 230 = 65306 which in hex is FF1AH.

(d) TL = 1A and TH = FF, all in hex. The program is as follow.

```
        MOV  TMOD,#01       ;Timer 0, 16-bitmode
AGAIN:  MOV  TL1,#1AH       ;TL1=1A, low byte of timer
        MOV  TH1,#0FFH      ;TH1=FF, the high byte
        SETB TR1            ;Start timer 1
BACK:   JNB  TF1,BACK       ;until timer rolls over
        CLR  TR1            ;Stop the timer 1
        CLR  P1.5           ;Clear timer flag 1
        CLR  TF1            ;Clear timer 1 flag
        SJMP AGAIN          ;Reload timer
```

Example 10-11

Assume XTAL = 11.0592 MHz, write a program to generate a square wave of 50 kHz frequency on pin P2.3.

Solution:

Look at the following steps.

(a) T = 1 / 50 = 20 ms, the period of square wave.

(b) 1 / 2 of it for the high and low portion of the pulse is 10ms.

(c) 10 ms / 1.085 us = 9216 and 65536 – 9216 = 56320 in decimal, and in hex it is DC00H.

(d) TL = 00 and TH = DC (hex).

```
        MOV  TMOD,#10H      ;Timer 1, mod 1
AGAIN:  MOV  TL1,#00        ;TL1=00,low byte of timer
        MOV  TH1,#0DCH      ;TH1=DC, the high byte
        SETB TR1            ;Start timer 1
BACK:   JNB  TF1,BACK       ;until timer rolls over
        CLR  TR1            ;Stop the timer 1
        CLR  P2.3
        SJMP AGAIN          ;Reload timer mode 1 isn't auto-reload
```

Example 10-12

Examine the following program and find the time delay in seconds. Exclude the overhead due to the instructions in the loop.

```
        MOV  TMOD,#10H      ;Timer 1, mod 1
        MOV  R3,#200
AGAIN:  MOV  TL1,#08H       ;TL1=08,low byte of timer
        MOV  TH1,#01H       ;TH1=01,high byte
        SETB TR1            ;Start timer 1
BACK:   JNB  TF1,BACK       ;until timer rolls over
        CLR  TR1            ;Stop the timer 1
        CLR  TF1            ;clear Timer 1 flag
        DJNZ R3,AGAIN       ;if R3 not zero then reload timer
```

Solution:

TH-TL = 0108H = 264 in decimal and 65536 – 264 = 65272.

Now 65272 $\times$ 1.085 μs = 70.820 ms, and for 200 of them we have 200 $\times$ 70.820 ms = 14.164024 seconds.

Mode 2 Programming

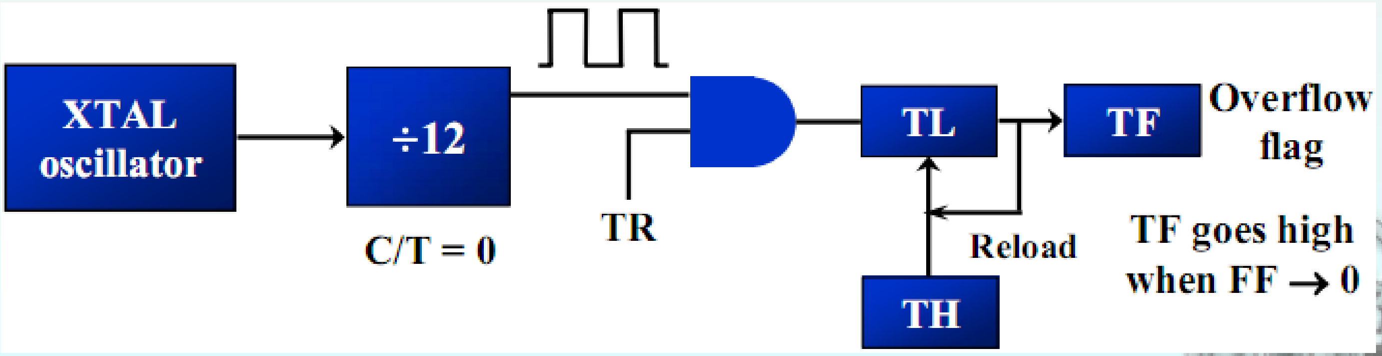
- The following are the characteristics and operations of mode 2:

1. It is an 8-bit timer; therefore, it allows only values of 00 to FFH to be loaded into the timer's register TH
2. After TH is loaded with the 8-bit value, the 8051 gives a copy of it to TL
   - Then the timer must be started
   - This is done by the instruction SETB TR0 for timer 0 and SETB TR1 for timer 1
3. After the timer is started, it starts to count up by incrementing the TL register
   - It counts up until it reaches its limit of FFH
   - When it rolls over from FFH to 00, it sets high the TF (timer flag)

Mode 2 Programming

4. When the TL register rolls from FFH to 0 and TF is set to 1, TL is reloaded automatically with the original value kept by the TH register

- To repeat the process, we must simply clear TF and let it go without any need by the programmer to reload the original value
- This makes mode 2 an auto-reload, in contrast with mode 1 in which the programmer has to reload TH and TL



Steps to Mode 2 Program

- To generate a time delay

1. Load the TMOD value register indicating which timer (timer 0 or timer 1) is to be used, and the timer mode (mode 2) is selected
2. Load the TH registers with the initial count value
3. Start timer
4. Keep monitoring the timer flag (TF) with the

   JNB TFx , target instruction to see whether it is raised

   - Get out of the loop when TF goes high
5. Clear the TF flag
6. Go back to Step4, since mode 2 is auto-reload

Example 10-13

Assume XTAL = 11.0592 MHz, find the frequency of the square wave generated on pin P1.0 in the following program

```
        MOV   TMOD,#20H ;T1/8-bit/auto reload
        MOV   TH1,#5 ;TH1 = 5
        SETB  TR1 ;start the timer 1
BACK:   JNB   TF1,BACK  ;till timer rolls over
        CPL   P1.0 ;P1.0 to hi, lo
        CLR   TF1 ;clear Timer 1 flag
        SJMP  BACK ;mode 2 is auto-reload
```

Solution:

First notice the target address of SJMP. In mode 2 we do not need to reload TH since it is auto-reload. Now $(256 - 05) \times 1.085$ us $= 251 \times 1.085$ us $=$ 272.33us is the high portion of the pulse. Since it is a 50% duty cycle square wave, the period T is twice that; as a result $T = 2 \times 272.33$ us = 544.67us and the frequency = 1.83597 kHz

Example 10-14

Find the frequency of a square wave generated on pin P1.0.

Solution:

```
            MOV   TMOD,#2H  ;Timer 0, mod 2 (8-bit, auto reload)
            MOV   TH0,#0
AGAIN:      MOV   R5,#250    ;multiple delay count
            ACALL DELAY
            CPL   P1.0
            SJMP  AGAIN
DELAY:      SETB TR0 ;start the timer 0
BACK:       JNB   TF0,BACK  ;stay timer rolls over
            CLR   TR0 ;stop timer
            CLR   TF0 ;clear TF for next round
            DJNZ  R5,DELAY
            RET
```

T = 2 (250 × 256 × 1.085 us) = 138.88ms, and frequency = 72 Hz

Example 10-15

Assuming that we are programming the timers for mode 2, find the value (in hex) loaded into TH for each of the following cases.

(a) MOV TH1,#-200 (b) MOV TH0,#-60
(c) MOV TH1,#-3 (d) MOV TH1,#-12
(e) MOV TH0,#-48

Solution:

You can use the Windows scientific calculator to verify the result provided by the assembler. In Windows calculator, select decimal and enter 200. Then select hex, then +/- to get the TH value. Remember that we only use the right two digits and ignore the rest since our data is an 8-bit data.

Decimal	2's complement (TH value)
-3	FDH
-12	F4H
-48	D0H
-60	C4H
-200	38H

The number 200 is the timer count till the TF is set to 1

The advantage of using negative values is that you don't need to calculate the value loaded to THx

§ 10-2 Counter Programming

- Timers can also be used as counters counting events happening outside the 8051
  - When it is used as a counter, it is a pulse outside of the 8051 that increments the TH, TL registers
  - TMOD and TH, TL registers are the same as for the timer discussed previously
- Programming the timer in the last section also applies to programming it as a counter
  - Except the source of the frequency

C/T Bit in TMOD Register

- The C/T bit in the TMOD registers decides the source of the clock for the timer
  - When C/T = 1, the timer is used as a counter and gets its pulses from outside the 8051
    - The counter counts up as pulses are fed from pins 14 and 15, these pins are called T0 (timer 0 input) and T1 (timer 1 input)

Port 3 pins used for Timers 0 and 1

Pin	Port Pin	Function	Description
14	P3.4	T0	Timer/counter 0 external input
15	P3.5	T1	Timer/counter 1 external input

Example 10-16

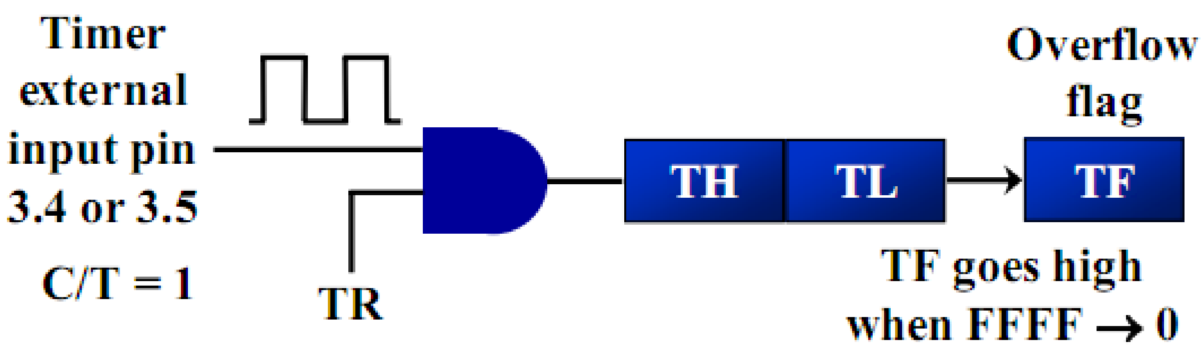
Assuming that clock pulses are fed into pin T1, write a program for counter 1 in mode 2 to count the pulses and display the state of the TL1 count on P2, which connects to 8 LEDs.

Solution:

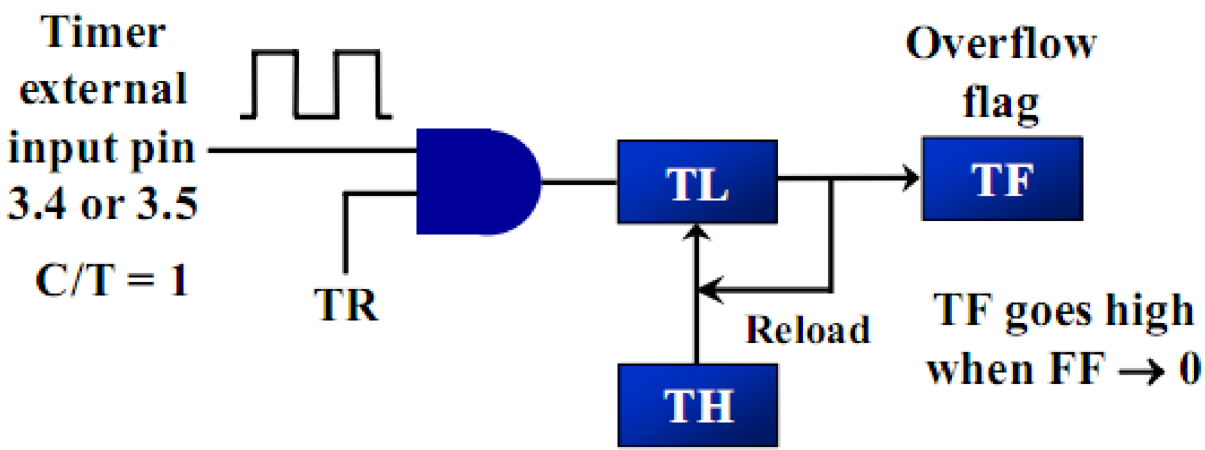
```
          MOV   TM0D,#01100000B   ;counter 1, mode 2,
                                  ;C/T=1 external pulses
          MOV   TH1,#0            ;clear TH1
          SETB  P3.5              ;make T1 input
AGAIN:    SETB  TR1               ;start the counter
BACK:     MOV   A,TL1             ;get copy of TL
          MOV   P2,A              ;display it on port 2
          JNB   TF1,Back          ;keep doing, if TF = 0
          CLR   TR1               ;stop the counter 1
          CLR   TF1               ;make TF=0
          SJMP  AGAIN             ;keep doing it
```

Notice in the above program the role of the instruction SETB P3.5. Since ports are set up for output when the 8051 is powered up, we make P3.5 an input port by making it high. In other words, we must configure (set high) the T1 pin (pin P3.5) to allow pulses to be fed into it.

Timer with external input (Mode 1)



Timer with external input (Mode 2)



TCON Register

- TCON (timer control) register is an 8-bit register

TCON: Timer/Counter Control Register

TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0

The upper four bits are used to store the TF and TR bits of both timer 0 and 1

The lower 4 bits are set aside for controlling the interrupt bits

TCON Register

- TCON register is a bit-addressable register

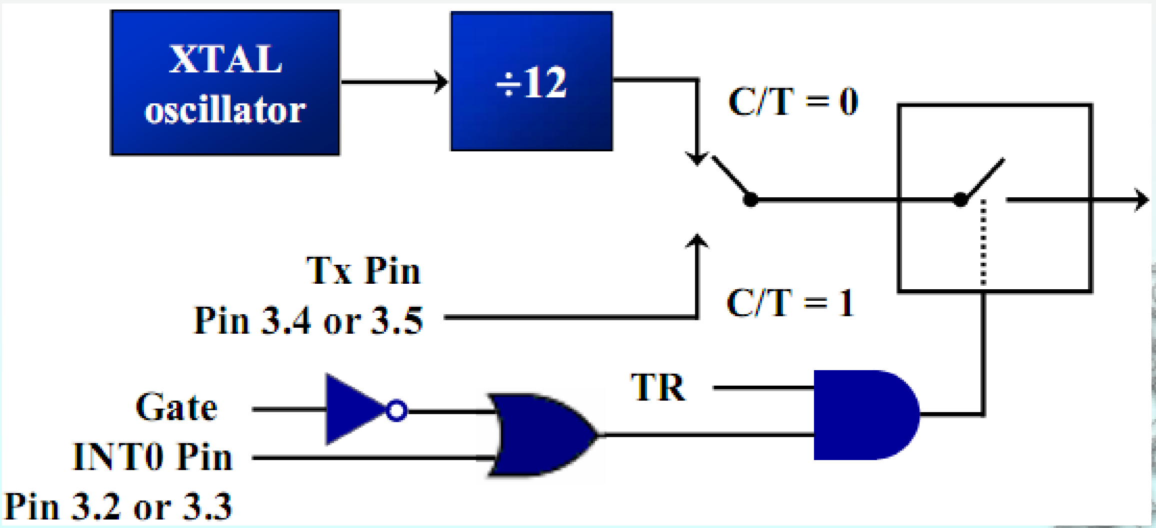
Equivalent instruction for the Timer Control Register

For timer 0				
SETB	TR0	=	SETB	TCON.4
CLR	TR0	=	CLR	TCON.4
SETB	TF0	=	SETB	TCON.5
CLR	TF0	=	CLR	TCON.5
For timer 1				
SETB	TR1	=	SETB	TCON.6
CLR	TR1	=	CLR	TCON.6
SETB	TF1	=	SETB	TCON.7
CLR	TF1	=	CLR	TCON.7

TCON Register

Case of GATE = 1

- If GATE = 1, the start and stop of the timer are done externally through pins P3.2 and P3.3 for timers 0 and 1, respectively
  - This hardware way allows to start or stop the timer externally at any time via a simple switch



§ 10-3 Programming Timers in C

Accessing Timer Registers

Example 10-17

Write an 8051 C program to toggle all the bits of port P1 continuously with some delay in between. Use Timer 0, 16-bit mode to generate the delay.

Solution:

```
#include <reg51.h>
void T0Delay(void);
void main(void){
   while (1) {
      P1=0x55;
      T0Delay();
      P1=0xAA;
      T0Delay();
   }
}

void T0Delay(){
   TMOD=0x01;
   TL0=0x00;
   TH0=0x35;
   TR0=1;
   while (TF0==0);
   TR0=0;
   TF0=0;
}
```

FFFFH – 3500H = CAFFH
= 51967 + 1 = 51968
$51968 \times 1.085\mu s = 56.384ms$
is the approximate delay

Calculating Delay Length Using Timers

- To speed up the 8051, many recent versions of the 8051 have reduced the number of clocks per machine cycle from 12 to four, or even one

- The frequency for the timer is always $1/12^{th}$ the frequency of the crystal attached to the 8051, regardless of the 8051 version

Times 0/1 Delay Using Mode 1 (16-bit Non Auto-reload)

Example 10-18

Write an 8051 C program to toggle only bit P1.5 continuously every 50ms. Use Timer 0, mode 1 (16-bit) to create the delay. Test the program on the (a) AT89C51 and (b) DS89C420.

Solution:

```
#include <reg51.h>
void T0M1Delay(void);
sbit mybit=P1^5;
void main(void)
{
  while (1)
   {
     mybit=~mybit;
     T0M1Delay();
    }
 }
```

```
void T0M1Delay(void)
{
   TMOD=0x01;
   TL0=0xFD;
   TH0=0x4B;
   TR0=1;
   while (TF0==0);
   TR0=0;
   TF0=0;
 }
```

FFFFH – 4BFDH = B402H
= 46082 + 1 = 46083
$46083 \times 1.085\ \mu s = 50ms$

Times 0/1 Delay Using Mode 1 (16-bit Non Auto-reload)

Example 10-19

Write an 8051 C program to toggle all bits of P2 continuously every 500ms. Use Timer 1, mode 1 to create the delay.

Solution:

//tested for DS89C420, XTAL = 11.0592 MHz

```
#include <reg51.h>
void T1M1Delay(void);
void main(void)
 {
  unsigned char x;
  P2=0x55;
  while (1)
  {
   P2=~P2;
   for (x=0;x<20;x++)
   T1M1Delay();
  }
 }
```

```
void T1M1Delay(void)
{
 TMOD=0x10;
 TL1=0xFE;
 TH1=0xA5;
 TR1=1;
 while (TF1==0);
 TR1=0;
 TF1=0;
}
```

A5FEH = 42494 in decimal
65536 – 42494 = 23042
$23042 \times 1.085\mu s = 25ms$ and
$20 \times 25ms = 500ms$

Times 0/1 Delay Using Mode 1 (16-bit Non Auto-reload)

Example 10-20

A switch is connected to pin P1.2. Write an 8051 C program to monitor SW and create the following frequencies on pin P1.7:

SW=0: 500Hz

SW=1: 750Hz, use Timer 0, mode 1 for both of them.

Solution:

FC67H = 64615

65536 – 64615 = 921

$921 \times 1.085\ \mu s = 999.285\mu s$

$1 / (999.285\mu s \times 2) = 500Hz$

```
#include <reg51.h>
sbit mybit=P1^5;
sbit SW=P1^7;
void T0M1Delay(unsigned char);
void main(void){
   SW=1;
   while (1) {
      mybit=~mybit;
      if (SW==0)
      T0M1Delay(0);
      else
      T0M1Delay(1);
   }
}
```

```
void T0M1Delay(unsigned char c){
   TMOD=0x01;
   if (c==0) {
     TL0=0x67;
     TH0=0xFC;
   }
   else {
     TL0=0x9A;
     TH0=0xFD;
   }
  TR0=1;
  while (TF0==0);
  TR0=0;
  TF0=0;
}
```

Times 0/1 Delay Using Mode 2 (8-bit Auto-reload)

Example 10-21

Write an 8051 C program to toggle only pin P1.5 continuously every 250ms. Use Timer 0, mode 2 (8-bit auto-reload) to create the delay.

Solution:

```
#include <reg51.h>
void T0M2Delay(void);
sbit mybit=P1^5;
void main(void){
   unsigned char x,y;
   while (1) {
   mybit=~mybit;
   for (x=0;x<250;x++)
   for (y=0;y<36;y++) //we put 36, not 40
   T0M2Delay();
   }
}
```

```
void T0M2Delay(void){
 TMOD=0x02;
 TH0=-23;
 TR0=1;
 while (TF0==0);
 TR0=0;
 TF0=0;
}
```

Due to overhead of the for loop in C, we put 36 instead of 40

$256 - 23 = 233$
$23 \times 1.085\mu s = 25\mu s$ and
$25\mu s \times 250 \times 40 = 250ms$

Example 10-22

Write an 8051 C program to create a frequency of 2500 Hz on pin P2.7. Use Timer 1, mode 2 to create delay.

Solution:

```
#include <reg51.h>
void T1M2Delay(void);
sbit mybit=P2^7;
void main(void){
   unsigned char x;
   while (1) {
   mybit=~mybit;
   T1M2Delay();
   }
}
void T1M2Delay(void){
   TMOD=0x20;
   TH1=-184;
   TR1=1;
   while (TF1==0);
   TR1=0;
   TF1=0;
}
```

$1/2500\text{Hz} = 400\mu s$
$400\mu s / 2 = 200\mu s$
$200\ \mu s / 1.085\mu s = 184$

C Programming of Timers as Counters

Example 10-23

Assume that a 1-Hz external clock is being fed into pin T1 (P3.5). Write a C program for counter 1 in mode 2 (8-bit auto reload) to count up and display the state of the TL1 count on P1. Start the count at 0H.

Solution:

```
#include <reg51.h>
sbit T1=P3^5;
void main(void){
   T1=1;
   TMOD=0x60;
   TH1=0;
   while (1) {
     do {
     TR1=1;
     P1=TL1;
    }
   while (TF1==0);
   TR1=0;
   TF1=0;
  }
}
```

Example 10-24

Assume that a 1-Hz external clock is being fed into pin T0 (P3.4). Write a C program for counter 0 in mode 1 (16-bit) to count the pulses and display the state of the TH0 and TL0 registers on P2 and P1,respectively.

Solution:

```
#include <reg51.h>
void main(void){
   T0=1;
   TMOD=0x05;
   TL0=0
   TH0=0;
   while (1) {
     do {
     TR0=1;
     P1=TL0;
     P2=TH0;
     }
   while (TF0==0);
   TR0=0;
   TF0=0;
   }
}
```

Discussion: What's new in Timer

- **More Timer/Counter**
- **More clock source**
- **16 bits reload**
- **PWM output automatically**
- **Up/Down counter**
- **Dynamic trigger level**
- **Watch dog**

实验：参考实验六、七、八（详见实验讲义）

要求：

1. 编写程序，统计按键次数；
2. 在LED数码管上显示按键个数；
3. 支持长按键，即按键时间超过1秒后，每0.2秒键值+1；

THANK YOU!!