University of Portsmouth
Faculty of Technology
Department of Electronic and Computer Engineering

Module: *Digital Electronics and Microprocessors*
Module Code: *B122*
Module Topic: *Microcontroller Applications*
Lecturer: *Branislav Vuksanovic*

Lecture Notes:

Programming Timers on 8051

The purpose of this handout is to explain how to use the internal 8051 timers to generate time delays.

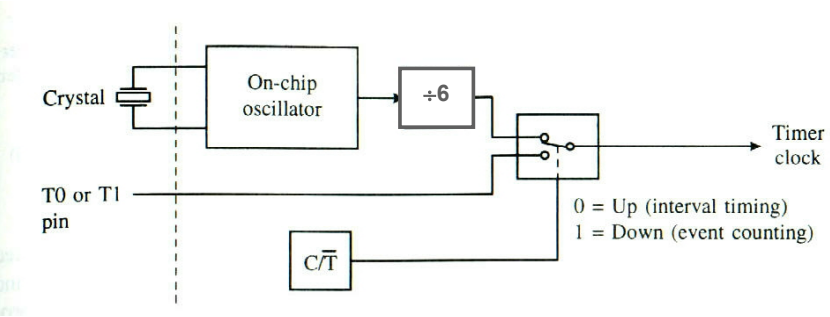
Content

Uses of Timers & Counters

- Interval Timing
    - Periodic event timing
    - Time base for measurements
- Event Counting
- Baud Rate Generation

8051 Timers

- 2 timers (Timer 0 and Timer 1)
- 16-bit timers (65,535) max
- Flag is set when the timer overflows
- Timers can be based on internal clock (OSC/6) or from external source (counter mode).

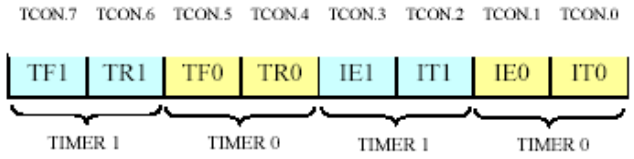


Internal operation of the 8051 timer (same for both timers)

Timer Registers

- TCON Timer Control
- TMOD Timer Mode
- TH0/TL0 Timer 0 16 bit register (byte addressable only)
- TH1/TL1 Timer 1 16 bit register (byte addressable only)

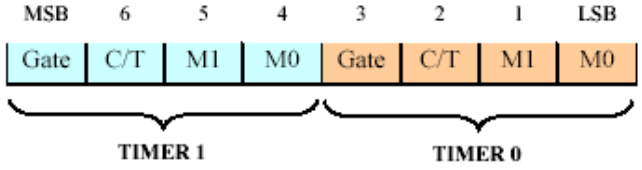
TCON



TCON SFR and its individual bits

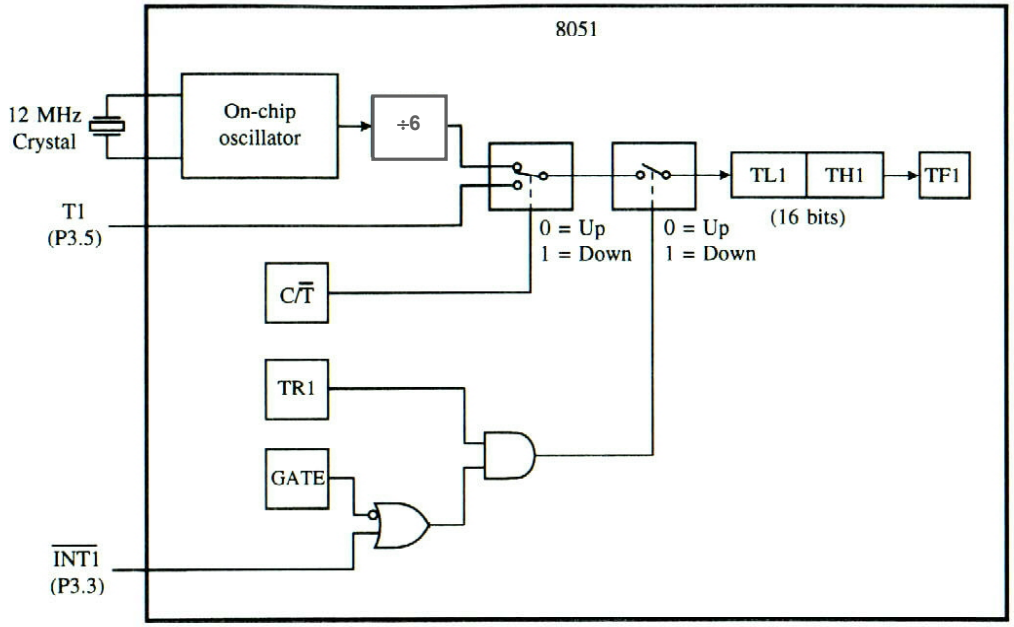
- IT0/IT1: Used for timer Interrupts
- IE0/IE1: Used for external Interrupts
- TR0/TR1: Timer 0/1 run control flag
    - 1 = Run
- TF0/TF1: Timer 0/1 overflow flag
    - 1 = Overflow

TMOD



TMOD SFR and its individual bits

- M0/M1: sets the Mode of the respective timer
- C/T: External Counter/Internal Timer select
    - 1 = Counter, 0 = Timer
- Gate: When set (1), timer runs only when respective INT input is high.



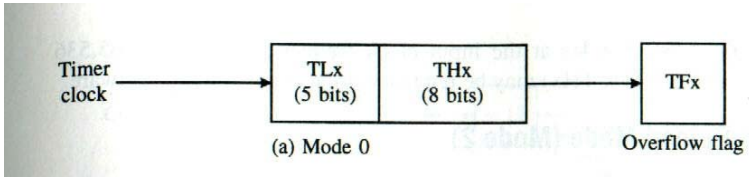
Internal architecture of the 8051 timer. The diagram shows timer 1. Timer 0 has an identical architecture

Timer Modes

- 0: 13 bit timer
- 1: 16-bit timer
- 2: 8-Bit auto reload
- 3: Split timer mode

Mode 0: 13-Bit Timer

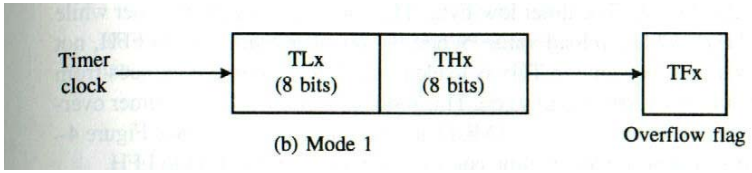
- Lower byte (TL0/TL1) + 5 bits of upper bytes (TH0/TH1).
- Backward compatible to the 8048
- Not generally used



Timer operation in Mode 0

Mode 1: 16-bit

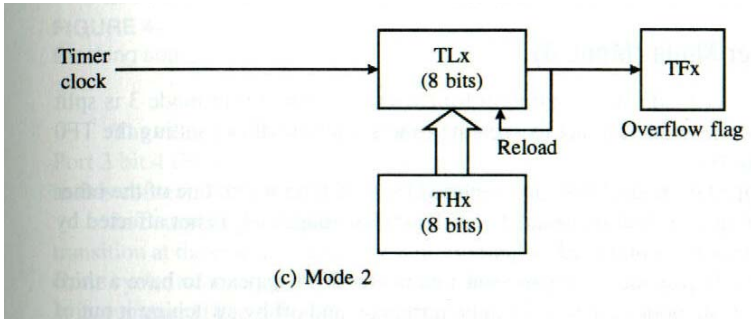
- All 16 bits of the timer (TH0/TL0, TH1,TL1) are used.
- Maximum count is 65,536
- At 12Mhz, maximum interval is 65536 microseconds or 65.536 milliseconds
- TF0 must be reset after each overflow
- THx/TLx must be manually reloaded after each overflow.



Timer operation in Mode 1

Mode 2: 8-bit Auto Reload

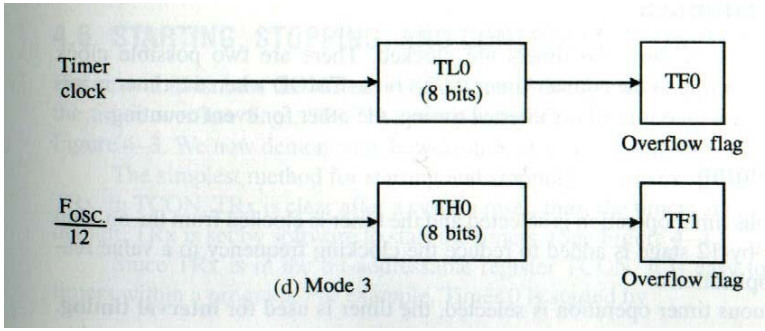
- Only the lower byte (TLx) is used for counting.
- Upper byte (THx) holds the value to reload into TLx after an overflow.
- TFx must be manually cleared.
- Maximum count is 256
- Maximum interval is 256 Microseconds or .256 milliseconds



Timer operation in Mode 2

Mode 3- Split Timer

- Splits Timer 0 into two 8-bit timers
- TL0 sets TF0
- TH0 sets TF1
- Timer 1 is available for other 3 modes, but the TF1 is not available.



Timer operation in Mode 3

Timer Delay and Timer Reload Value

Timer Delay = Delay Value × Timer Clock Cycle Duration

Delay Value = how many counts before register(s) roll over

Timer Clock Cycle Duration = 6/oscillator frequency

Delay Value = Maximum Register Count – Timer Reload Value

Maximum Register Count = 65535

Timer Reload Value = ?

Example 1

Calculation of Timer 0 reload value needed to achieve timer delay of 20 ms. Oscillator frequency is 11.0592 MHz.

Delay Value = Timer Delay / Timer Clock Cycle Duration

$$= \frac{20 \times 10^{-3}}{\frac{6}{11.0592 \times 10^{6}}}$$

= 36864 (must be rounded to the nearest integer)

Timer Reload Value = Maximum Register Count - Delay Value

= 65535 – 36864

= 28671

= 0x6FFF

so Timer 0 is loaded with:

TH0 = 0x6F;

TL0 = 0xFF;

Example 2

Function to generate 100 μs delay using timer 0.

Procedure is:

- *Initialise TMOD register*
- *Initialise TL0 and TH0*
- *Start the Timer*
- *Monitor TF0 until it is set*

```
Delay:      MOV   TMOD,#01H   ; initialise TMOD
            MOV   TL0,#47H    ; initialise TL0
            MOV   TL0,#FFH    ; initialise TH0
            SETB  TR0         ; start timer

Wait:       JNB   TF0,Wait    ; wait for TF0
            CLR   TR0         ; stop timer
            CLR   TF0         ; clear TF0
            RET
```

Delay Value $= \frac{100 \times 10^{-3}}{\frac{6}{11.0592 \times 10^{6}}} = 184$

Timer Reload Value = 65535 – 184 = 65351 = 0xFF47

so Timer 0 is loaded with:

TH0 = 0x6F; TL0 = 0xFF;

Example 3

C version of the function from Example 2.

```
void Delay(void)
{
      TMOD = 0x01;
      TL0 = 0x47;
      TH0 = 0xFF;
      TR0 = 1;
      while(!TF0)
      TR0 = 0;
      TF0 = 0;
}
```

Example 4

Program to toggle pin 7 on Port 1 with a time delay of 20 ms.

```
#include <reg66x.h>

#define off 0
#define on 1

sbit pin7 = P1^7; // label pin7 is port 1 pin 7

main()
{
      TMOD = 0x01;
      // timer 0 mode 1,
      // TH0TL0 = 16 bit register

      while(1)
      // keep repeating the following section
      {
            pin7 = on;
            // pin 7 to 5 volts, i.e. logic 1

            // use timer 0 to generate delay
            TH0 = 0x6F; // hex 6F into TH0
            TL0 = 0xFF; // hex FF into TL0
            TR0 = on;   // start timer
            while(!TF0);
            // wait here until TF0 = 1
            TR0 = off;  // stop timer
            TF0 = off;  // clear overflow flag


            pin7 = off;
            // pin 7 to 0 v0lts, i.e. logic 0

            // repeat timer delay
            TH0 = 0x6F; // hex 6F into TH0
            TL0 = 0xFF; // hex FF into TL0
            TR0 = on;   // start timer
            while(!TF0);
            // wait here until TF0 = 1
            TR0 = off;  // stop timer
            TF0 = off;  // clear overflow flag
      }
}
```

Alternative Technique for Timers Loading

Example 5

Load the timer 0 in order to produce 1 kHz square wave (i.e. cycle time of 1000 μs and delay time 500 μs). Oscillator frequency is 11.0592 MHz.

Delay Value = $\dfrac{\dfrac{500\times10^{-6}}{6}}{\dfrac{1}{11.0592\times10^{6}}}$ = 922

Timer Reload Value = 65535 – 922 = 64614 = 0xFC66

so Timer 0 is loaded with: TH0 = 0xFC; TL0 = 0x66

Alternatively if we use: TH0 = ~(922/255);

result of integer division 922/255 = 3 will be byte complemented to 0xFC and stored in TH0

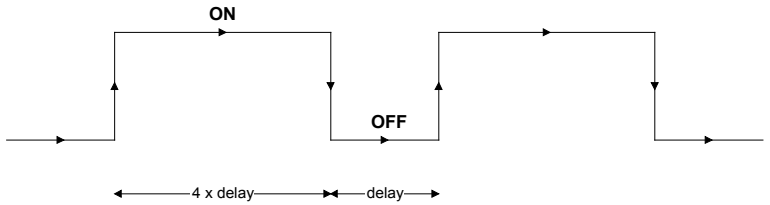
Second line to fill up lower timer 0 register: TL0 = -(922%255)

will negate reminder of division 922/255 and store the result in TL0

i.e. 922%255 = 154
-(922%255) = 256-154 = 102 = 0x66

Example 6

C program to generate 1 kHz square wave from figure below. Square wave should be generated on pin 7 of port 1. Functions are used to generate two delays needed in the program. (delay = 200 μs)




```
// header file containing SFR adresses
#include<reg66x.h>

// to make program more readable:

// define ON and OFF states
#define on 1
#define off 0

// give a name to output pin
sbit pwm = P1^7;

// long and short delay functions
void delay_on();
void delay_off();
```

```
main()
{
      TMOD = 0x01;
      // initialise TMOD for Timer 0 in mode 1

      while(1)    // repeat this
      {
            pwm = on;     // output pin high
            delay_on();   // 800 us delay
            pwm = off;    // output pin low
            delay_off();  // 200 us delay
      }
}

// 800 us delay function
void delay_on()
{
      // loading Timer 0 for longer delay
      TH0 = ~(1475/256);
      TL0 = -(1475%256);
      TR0 = on;     // turn the Timer 0 ON
      while(!TF0);  // wait for timer overflow
      TR0 = off;    // switch the Timer 0 off
      TF0 = off;    // clear the overflow flag
}

// 200 us delay function
void delay_off()
{
      // loading Timer 0 for shorter delay
      TH0 = ~(369/256);
      TL0 = -(369%256);
      TR0 = on;
      while(!TF0);
      TR0 = off;
      TF0 = off;
}
```