Department of Electrical Engineering
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ELEG3923 Microprocessor
Ch.9 Timer Programming

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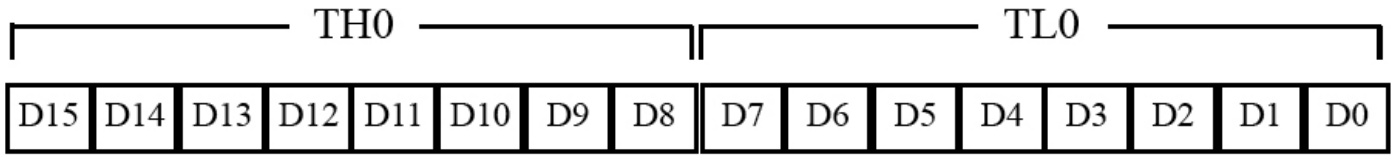
OUTLINE

- **Programming 8051 Timers**
- **Counter programming**
- **Timer programming in C**

TIMERS

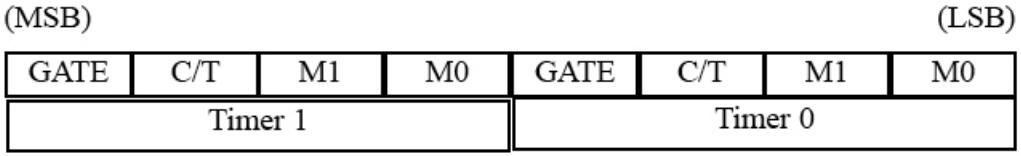
- **Timers**
  - 8051 has 2 built-in timers: timer 0 and timer 1
    - They can be used to generate a specific time delay (more accurate and easier than loops)
    - Or, can be used as counters to count events happening outside the uC.
  - Both timers are 16 bits wide.
- **Timer registers**
  - The contents of each timer is stored in two 8-bit registers
  - Timer 0: TH0 (higher byte), TL0 (lower byte)
  - Timer 1: TH1 (higher byte), TL1 (lower byte)
  - E.g.

```
MOV TL0, #4FH
MOV R5, TH1
```



TIMERS: MODE

- **TMOD (timer mode) register**
  - TMOD: 8-bit register, used to set the operation modes of timer
    - higher nibble: timer 1; lower nibble: timer 0



  - M1, M0: the combination of the two bits specify the operation modes of the timer
    - (M1,M0)= 00: mode 0; 01: mode 1; 10: mode 2; 11: mode 3.
  - C/T (counter/timer)
    - Whether the timer will be used as a delay generator (timer) or event counter
    - C/T = 0: used as timer for time delay generation
    - C/T = 1: event counter
  - Gate
    - Gate = 0: the timer is started or stopped by software
    - Gate = 1: the timer is started or stopped by external hardware

TIMERS: CLOCK SOURCE

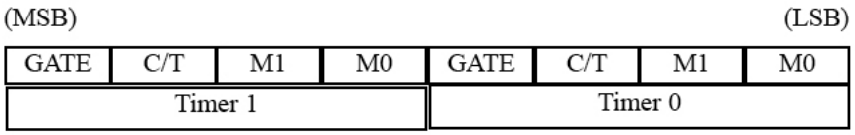
- **Clock source for timer**
  - Every timer needs a clock pulse to tick.
  - When C/T = 0 (timer)
    - The timer use XTAL oscillator as clock source
    - The frequency of the timer is XTAL frequency /12
    - Example:
      - Find the timer's clock frequency is the XTAL frequency is 11.0592MHz

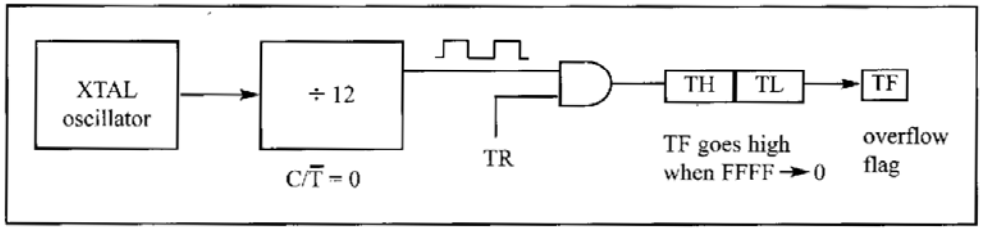
f =11.0592MHz/12 = 921.6 KHz

T = 1/f = 1/921.6KHz = 1.085 uS

TIMERS: MODE 1

- **Mode 1**
  - 16-bit timer: all 16 bits of timer are used.
  - Steps: (we use timer0 as example)
    - 1. **Load TMOD value** (set the operation mode of timer)
      - E.g. MOV TMOD, #01H; timer 0, C/T=0, GATE=0, mode = 1
    - 2. **Load TL and TH with initial count values**
      - E.g. MOV TL0, #0F2H ; load init value to timer 0
        MOV TH0, #0FFH ; init value: FFF2
    - 3. **Start timer**
      - SETB TR0 ; start timer 0
        - » TR0 (timer start 0): when set to 1, timer 0 will start
      - Once timer is started, values in (TH0, TL0) will automatically increase by 1 for every timer tick (every 1.085us if 11.0592 MHz XTAL)
      - when (TH0, TL0) = FFFFH, it will overflow in the next clock period
        - » FFFFH → 0000H,
        - » When overflow, TF0 (timer flag for timer 0) will automatically set to 1.
        - » By monitoring TF0, we will know when timer expires





TIMERS: MODE 1

- **Mode 1**
  - Steps (Cont'd)
    - **4. Monitoring timer flag**
      - HERE: JNB TF0, HERE ; exit loop when TF0 = 1 (timer expires)
    - **5. When timer overflows, stop timer**
      - CLR TR0 ; set TR0 = 0 will stop timer 0
      - The duration of timer is determined by the initial value of timer
    - **6. Clear timer flag for next round**
      - CLR TF0
  - The duration of timer is determined by the initial value in timer and timer clock
    - E.g. before timer starts, (TH0)=FFH, (TL0)=F2H. XTAL = 11.0592MHz. What is the duration of the timer (how long it takes for timer to overflow)?

(FFFFH – YYXXH + 1)*clock period **(65535 – nnnn + 1)*clock period**

TIMERS: MODE 1

- **Example**
  - Find the delay generated by timer 0 in the following code. Do not include the overhead due to instructions

```
        CLR P2.3
        MOV TMOD, #01          ; 1. timer 0, mode 1 (16-bit)
HERE:   MOV TL0, #3EH          ; 2. load init value
        MOV TH0, #0B8H
        SETB P2.3              ; set P2.3 high
        SETB TR0               ; 3. start timer
AGAIN:  JNB TF0, AGAIN         ; 4. monitor TF0 until timer overflows
        CLR TR0                ; 5. stop timer
        CLR TF0                ; 6. clear flag

        CLR P2.3
```

  - Find the maximum delay that can be incurred by a 16-bit timer

    - To generate larger delay, use loops to repeat the timer (example 9-13)

TIMERS: MODE 1

- **Example**
  - Write a program generate a square waveform on P1.5. The waveform has 50% duty cycle with period 1 ms.

```
                MOV TMOD, #10                   ; timer 1, mode 1
HERE:           SETB P1.5
                ACALL DELAY
                CLR P1.5
                ACALL DELAY
                SJMP HERE

                ;-----------delay subroutine-------------------
DELAY:
                MOV TL1, #YYH                   ; load initial value
                MOV TH1, #XXH
                SETB TR1            ; start timer
AGAIN:          JNB TF1, AGAIN                  ; monitor flag
                CLR TR1                         ; stop timer
                CLR TF1                         ; clear flag
                RET
```

Self study: Examples 9-5 ~ 9-13

TIMER: MODE 0 AND MODE 2

- **Mode 0: 13-bit timer**
  - The timer will set TF = 1 when it reaches 1FFFH
  - MOV TMOD, #00H (mode 0)
  - The remaining operation is the same as mode 1
- **Mode 2: auto-reload 8-bit timer**
  - Timer range: 00H - FFH
  - Operations (use timer 0 as example)
    - 1. Set timer 0 to mode 2: MOV TMOD, #02H (timer 0, mode 2)
    - 2. Load 8-bit init value to TH0: MOV TH0, #32H
    - 3. 8051 automatically copies the init value to TL0
    - 4. Start timer: SETB TR0
      - TL0 starts counting until it reaches FFH
    - 5. Monitor TF0
      - When TL0 overflows from FFH to 00H, it sets TF = 1
    - 6. When TL0 overflows to 00H and TF = 1, the init value is automatically reloaded from TH0 to TL0.
    - 7. Clear TF. The timer will continue to run (go back to step 5)

TIMER: MODE 2

- **Example**
  - (1) Find the frequency of the square wave; (2) the smallest frequency achievable in this program and the TH value to do that

```
        MOV TMOD, #20H      ; timer 1, mode 2
        MOV TH1, #5; init value
        SETB TR1            ; start timer
BACK:   JNB TF1, BACK       ; monitor TF1
        CPL P1.0
        CLR TF1             ; clear TF0
        SJMP BACK           ; repeat
```

  - Find the delay of the following timer

```
        MOV TMOD, #2H               ; timer 0, mode 2
        MOV TH0, #-150              ; TH0 = -150 = 6AH (2's complement of -150)
AGAIN:  SETB P1.3
        ACALL DELAY
        CLR P1.3
        ACALL DELAY
        SJMP AGAIN

DELAY:  SETB TR0                    ; start timer
  BACK: JNB TF0, BACK               ; monitor TF0
        CLR TR0                     ; stop timer (the init value has already been reloaded)
        CLR TF0
        RET
```

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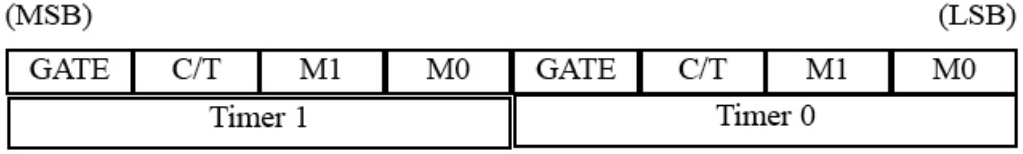
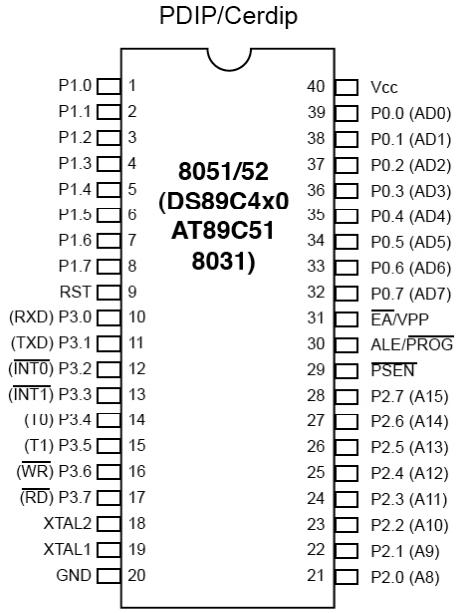
COUNTER

- **Counter (C/T=1)**
  - Counting the events happening outside of 8051.
  - Counter v.s. timer
    - If C/T=0, timer. The clock source is XTAL/12
      - The value of TH0, TL0 increases by 1 for each clock
    - If C/T = 1, counter. The clock source is an outside pulse to be counted
      - The value of TH0, TL0 increases by 1 for each outside pulse
      - We can use the counter to count the # of pulses
  - The remaining operations are the same for counter and timer (e.g. mode 0, 1, 2)
  - Connection
    - External pulses are connected through P3.4 (T0) or P3.5 (T1)





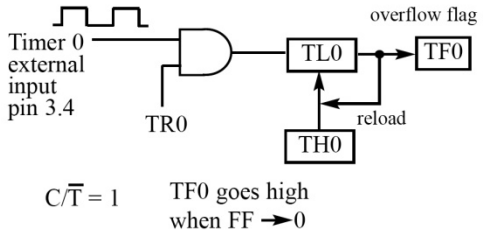
COUNTER

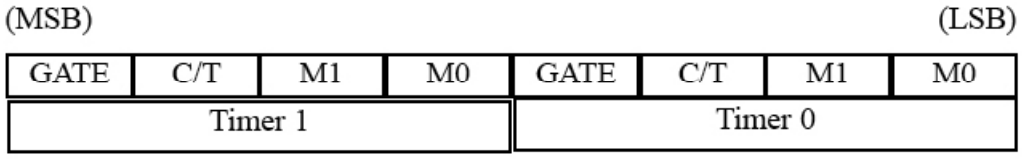
- **Example**
  - Assume a 1 Hz frequency pulse is connected to input pin P3.5 (T1). Use mode 2 of counter 1 to count the pulses and display results on P2

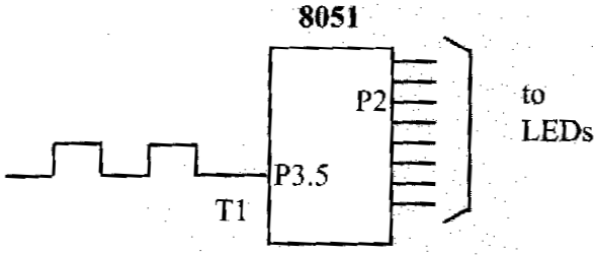
```
        MOV TMOD, #01100000B    ; counter 1, mode 2, C/T = 1

        MOV TH1, #0             ; counting from 0
        SETB P3.5               ; make T1 input mode
AGAIN:  SETB TR1                ; start timer 1
BACK:   MOV A, TL1              ; get copy of count from TL1 (mode 2!)
        MOV P2, A               ; send result to P2 (LCD)
        JNB TF1, BACK           ; keep doing it if TF=0 (no overflow)

        CLR TR1                 ; stop timer
        CLR TF1                 ; clear TF
        SJMP AGAIN
```







Self study: example 9-19

COUNTER: TCON AND TMOD

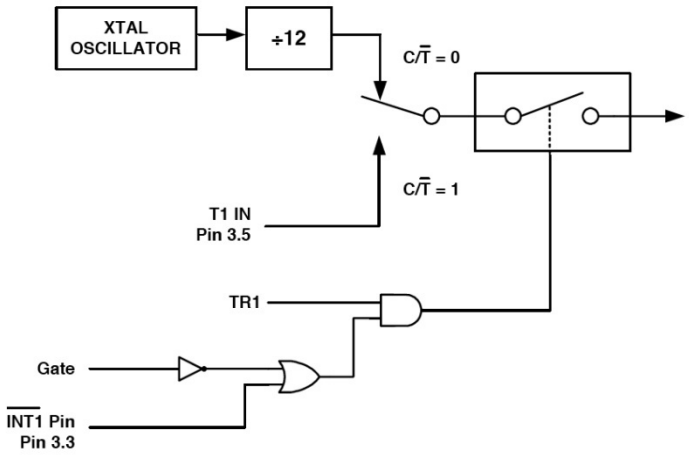
- **TCON register**
  - 8-bit register

TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0

  - TR0, TF0, TR1, TF1
    - SETB TR0 is the same as SETB TCON.4
  - IE1, IT1, IE0, IT0 are used by interrupt (will be discussed in Ch. 11)
- **Gate bit of TMOD**
  - Gate = 0
    - Start timer: SETB TR0; stop timer: CLR TR0
  - Gate = 1
    - The start and stop of timer is done externally through P3.2 for timer 0 or P3.3 for timer 1 via a simple switch (e.g. stop watch)

(MSB) (LSB)

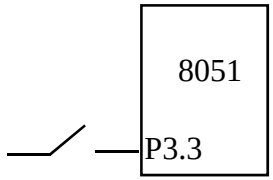
GATE	C/T	M1	M0	GATE	C/T	M1	M0
Timer 1				Timer 0			



COUNTER:

- **Example**
  - Design a simple stop watch that can count from 0 second to 59 seconds. Use a switch to control the start and stop of the watch. When the value of the stop watch arrives at 60 seconds, reset it to 0.

```
                SW BIT P3.3
                SETB SW                         ; input
                MOV A, #0
                MOV TMOD, #00001001     ; Gate = 1, C/T = 0, mode = 1 (16-bit counter)
START:          ACALL DELAY1SEC
                INC A
                CJNE A, #60, DISPLAY
                MOV A, #0                       ; if A = 60, reset the display of the stop watch
DISPLAY:        ACALL LCD
                SJMP START
;--------- subroutine ----------------------------
DELAY1SEC:      MOV R2, #200                    ; 5 ms x 200 loops
    AGAIN:      MOV TH0, #0EEH
                MOV TL0, #00H                   ; init = EE00,  5ms delay
      HERE:     JNB TF0, HERE
                CLR TF0
                DJNZ R2, AGAIN
                RET
```



OUTLINE

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PROGRAMMING IN C

- **Example**
  - Write a program to toggle P1.5 every 250 ms. Use timer 0, mode 2 (8-bit auto reload)

```
#include <reg51.h>
void T0M2delay25us(void);
sbit mybit = P1^5;
void main(void)
{
        unsigned int x;
        while(1)
        {
                mybit = ~mybit;
                for (x = 0; x < 10000; x++)
                        T0M2delay25us();
        }
}
void T0M2delay25us(void)
{
   TMOD = 0x02;          // timer 0, mode 2
   TH0 = -23;            // count 23 times, then overflow. 23*1.085 = 25 us
   TR0 = 1;
   while (TF0 = = 0);
   TR0 = 0;
   TF0=0;
}
```

PROGRAMMING IN C

- **Example**
  - Assume a 1 Hz external clock is being fed into pin T0 (P3.4). Write a C program for counter T0 in mode 1 (16-bit) to display TH0 and TL0 on P2 and P1, respectively.

```
#include <reg51.h>
void main( )
{
        T0 = 1;                 //(make T0 an input)
        TMOD = 0x05;            // 0000 0101 (C/T = 1, mode 1)
        TL0 = 0;
        TH0 = 0;                //clear counters
        while(1)
        {
                do
                {
                        TR0=1;          //start timer
                        P1 = TL0;
                        P2 = TH0;
                }while(TF0 = = 0);
                TR0 = 0;                //stop timer
                TF0 = 0;                //clear TF
        }

}
```