Chapter 6

PROGRAMMING THE TIMERS
Lesson 1

Programmable Timer-Counter Device
Timer-Counter Prescaling
Timer Pre-scaling 8051 T0 in Mode 0 Example

Pre-scaling of TH0 by 32 through TL0

Count Inputs from internal clock or from pin T1
68HC11 TCNT (Time-Counter) Example

Count Inputs from internal E-clock 2 MHz for 8 MHz

Pre scaling of E-clock inputs by PR0-PR1 bits programmable as 1, 4, 8 or 16 within 64 clock cycles on power up reset.
Example- 68HC11 TCNT

- Let XTAL clock = 8 MHz, therefore counter clock-input period = 0.5 µs.
- Let Pre-scaling factor programmed = 8
- Therefore, clock-inputs to TCNT at each 8×0.5 µs = 4 µs interval
- When TCNT = 1FA0H, then after 4×16 µs TCNT reading will be 1FB0H; after next 1024 µs, 20B0H.
Timer-Counter Reset to 0000H
8051/52 16-bit Counters  Resetting

- Timer-counter T1 resets on writing 00H-00H at TH1-TL1 or on T0 overflow
- Timer-counter T0 resets on writing 00H-00H at TH0-TL0 or on overflow of T0
- Timer-counter T2 resets on writing 00H-00H at TH2-TL2 or on overflow of T2
68HC11 16-bit Counters Resetting

- Timer-counter T1 resets on TCNT overflow
68HC11 TCNT Overflow example

16-bit counter

Example

Timer overflow interrupt if not masked, an ISR executes

Overflows after $2^{16}$ inputs after each $2^{16} \times p \times 0.5 \, \mu s$ from instance when count bits all 0s

Clock Inputs period = 0.5 \, \mu s for 8 MHz XTAL, pre-scaling factor set = p = 1 or 4 or 8 or 16
8051 Timer-Counter Start/Stop
Timer-Counter start, stop and reset

- Finding time interval between two events.
- Finding period of a pulse at a port pin
- Find time taken for a motor for 1 or more revolutions

- Reset timer \( T \) counts = 0, and mode set for internal clock-inputs. On first event, start \( T \) and second event stop \( T \).
8051 TH0-TL0 Mode 1

- Let XTAL clock = 12 MHz, therefore counter clock-input period = 1 μs.
- Let Mode T0 is C/T = 0 (internal clock mode)
- Let T0 be programmed in mode 1 (TH0,TL0) 16-bit counter.
  - When TR0 is set, timer T0 starts and TR0 reset T0 stops.
8051 T1 in Mode 1 Example

Count Inputs from internal clock or from pin T1

16-bit counter

TH1 TL1

0 or 1 at External gate pin INT1 and 1 or 0 TR1 together starts/stops when programming of T1 is like that else set/reset of TR1 only starts/stops as per programming.
8052 T2 Example

1. External CP/RL2 for counter reload on overflow if EXEN2 bit set
2. TR2 bit set/reset programmed to start/stop

16-bit counter

Count Inputs from internal clock or from pin C/T2 as per programming of T2
68HC11 Timer-Counter Non-programmability except for Prescaling or counting rate setting
68HC11 TCNT Non-Programmability

- Internal clock input rate or the prescaling only programmable
- No TR bit; Start/stop and No reset programmable

Count Inputs from internal clock

16-bit counter

TCNT Register
8051 Timer-Counter Loading and Reload
8051 T0 in Mode 3 Example

TH0 is written the counts = x0.

TH0 overflows (256-x0) inputs from the start.

TL0 is written the counts = x1.

TL0 overflows after (256-x1) inputs from the start.

Count Inputs from internal clock or from pin T1

Loading of TH0 and TH0 by writing counts x0 and x1.

Resetting by writing 0000H into TCNT.
8051 T1 in Mode 2 Example

TH1 is first written the counts, x0.

TL1 auto-reloads x0 from TH1 on each overflow.

Count Inputs from internal clock or from pin T1
8052 T2 Example

Count Inputs from internal clock or from pin C/T2 as programmed

Load by writing $x$ at TH2-TL2. TH2-TL2 overflows after $(2^{16} - x)$ inputs
8052 T2 Example

16-bit counter

Count Inputs from internal clock or from pin C/T2 as programmed

External CP/RL2 for counter reload if EXEN2 bit set. Reloads from the TH2-TL2 registers
68HC11 TCNT Example

Count Inputs from internal clock.

16-bit counter TCNT

Internal clock input rate/ Prescaling factors only programmable

Read Only
No loading of TCNT,
No resetting by writing 0000H into TCNT.
An overflow delay two or four or eight times when pre-scaling factor = 2 or 4 or 8
Overflow after a Period
Example- 8051 TH1-TL1 Mode 1

- Let XTAL clock = 12 MHz, therefore counter clock-input period = 1 µs.
- Let Mode T1 is C/T, internal clock mode
- Let T1 be programmed in mode 1 (TH1, TL1) 16-bit counter.
- When TH1-TL1 written (loaded) E0H-01H then timer T1 will timeout and overflow after 1FFFFH inputs.
Example- 8051 TL0 Mode 2

• Let XTAL clock = 12 MHz, therefore counter clock-input period = 1 µs.

• Let Mode T0 is C/T, internal clock mode

• Let T0 be programmed in mode 2; TL0 loads counts from TH0, TL0 runs as 8-bit counter.

• When TH0 (loaded) E0H then timer T0 uses TL0 and will timeout and overflow after each 20H inputs (= 32 µs) as TL0 reloads also from TH0 on overflow.
Program for finding the Time Interval of Counting in 8051/52
One Timer as Timer and other as counter

Counter-timer device 1 programs the Timer for counting time interval in timer mode

When device 1 starts, the counter mode timer-counter device 2 also starts counting.

When device 1 overflows (timeouts), the ISR stops the device 2 counting.
Example- 8051 TH0-TL0 Mode 3

Let XTAL clock = 12 MHz, therefore counter clock-input period = 1 µs.

Let Mode T1 is C/T1 = 1 for count mode TH0 and mode T0 is is C/T0 = 0 for timer mode TL0

Let T0 programmed in mode 3. TH0-TL0 independent counters and TL0 be written 7DH, to set the interval to (100H-7EH) = 83H = 131 µs for timeout and overflow.
8051 TH0-TL0 Mode 3

Step 1: Set TR0 = 1, reset TH0 = 00H
Step 2: Run TH0 by setting TR1 = 1, so that TH0 starts counting from 00H.
Step 3: TL0 overflows and interrupts after counting interval = 131 µs, the ISR resets TR1 = 0, it stops TH0.

TH0 will gives the count pulses at C/T1 pin received in 131 µs.
Timer-Counter Overflow Events
Example of

Timer-Counter Overflow Event

- Timer-counter T1 model on overflow after one input from FFFFH and new reading = 0000H at TH1-TL1
Masking Interrupt Service on Timer-Counter Overflow Event

- T0 or T1 or T2 or TCNT overflow interrupt maskable
- If masked, no interrupt service routine executes on overflow
8051 TL0 timer mode 2 example

Example

Clock Inputs period = 1 μs for 12 MHz XTAL

8-bit counter

Timer overflow interrupt if it is not masked, an ISR executes

Overflows after 256 inputs in 256 μs if initial count bits all 0s.
68HC11 TCNT example

Clock Inputs period = 1/2 µs for 8 MHz XTAL, prescaling factor set = 1

Example

Overflows after $2^{16}$ inputs in $2^{16}/2$ µs from count bits all 0s.

Timer overflow interrupt if not masked, an ISR executes

16-bit counter
Example- 8051 TH0 Mode 3

Let XTAL clock = 12 MHz, therefore counter clock-input period = 1 μs.

Let Mode T1 is C/T, internal clock mode.

Let T0 programmed in mode 3. TH0-TL0 independent counters and TH0 be written 81H.

When TH0 starts by setting TR1 = 1, Over-flow will be after \((100H-81H) = 127 \, \mu s\)
Preset time interval ON-OFF of a unit

- Load timer $T$ counts = x, and mode set for internal clock-inputs. Start $T$. switch ON and on over flow interrupt, switch OFF.

- Application- Output change (s) for a pre-fixed interval
Preset long time interval on-off of a unit

Load n-bit timer \( T \) counts = \( x \), define number of overflows = \( k \), mode set for internal clock inputs. Switch on an output, Start \( T \) and on overflow interrupt, reload the counts on 1 to \((k-1)_{\text{th}}\) overflows and switch off the output on \( k_{\text{th}} \) overflow interrupt.

Delay = \( k.(2^n - x).x.p.t \), where \( t = \) clock input period, \( p = \) pre scaling factor.
Exemplary Applications

• Moving robot arm for a defined period.
• Output change for a pre-fixed interval
• Current output for a fixed interval
• A microwave oven ON for a fixed interval
Finding a long time interval between two events

Reset timer $T$ counts $= 0$, and mode set for internal clock-inputs. On first event, start $T$ and till second event, find $k$ the number of overflows and on second event stop $T$.

Exemplary Applications

Find time taken for a weight-lifter to lift

Find time taken for an input event change
Time interval

Time interval $= [(2^n \cdot k) + x_1] \cdot p \cdot t$, where $t =$ clock input period, $p =$ pre scaling factor, $x_1 =$ final counts at the n-bit at $T$. 
Summary
we learnt

Two types of timer-counter devices -

• Start, stop, reset and preloading a count programmable

• Free running timer-counter: start, stop, reset and preloading counts $x$, each one is not programmable
We learnt

Pre-scaling of timer-counter device -

• Programmable in TCNT 68HC11
• Programmable as 32 in mode-0 at T1 or T0 in 8051
• Pre-scaling extends the overflow rates and extends the increment interval of counts by pre-scaling factor
We learnt

Loading of timer-counter device -

• Not Programmable in TCNT 68HC11
• Programmable in T0, T1 or T2 at 8051
we learnt

Overflow interrupt(s) of timer-counter device -

• Initiate an action

• Initiate an action after pre-fixed number of overflows