Chapter 6

PROGRAMMING THE TIMERS

Lesson 1

Programmable Timer-Counter Device

Timer-Counter Prescaling

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Timer Pre-scaling 8051 T0 in Mode 0 Example

Pre-scaling of TH0 by 32 through TL0

```
┌──────────────┬──────────┐
│  5-bit TL0  →│  TH0     │
└──────────────┴──────────┘
        │││││││ │││││││
   ┌───────────────────────┐
   │    13-bit counter      │
   └───────────────────────┘
```

Count Inputs from internal clock or from pin T1

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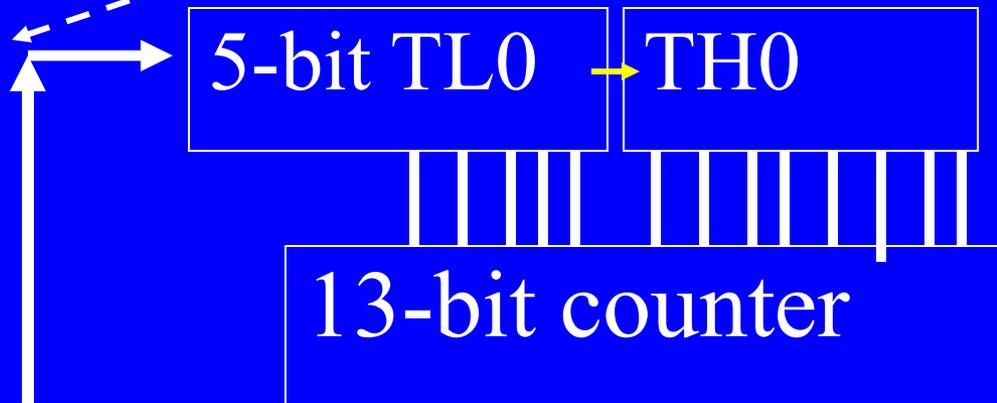
68HC11 TCNT (Time-Counter) Example

Pre scaling of E-clock inputs by PR0-PR1 bits programmable as 1, 4, 8 or 16 with in 64 clock cycles on power up reset

16-bit counter

TCNT Register

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

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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 will be 1FB0H; after next 1024 μs, 20B0H.

Timer-Counter Reset to 0000H

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8051/52 16-bit Counters Resetting

- Timer-counter T1 resets on 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

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68HC11 16-bit Counters Resetting

- Timer-counter T1 resets on TCNT overflow

68HC11 TCNT Overflow example

Timer overflow interrupt if not masked, an ISR executes

16-bit counter

Example

Overflows after 2^{16} inputs after each $2^{16} \times$ p $\times$ 0.5 µs from instance when count bits all 0s
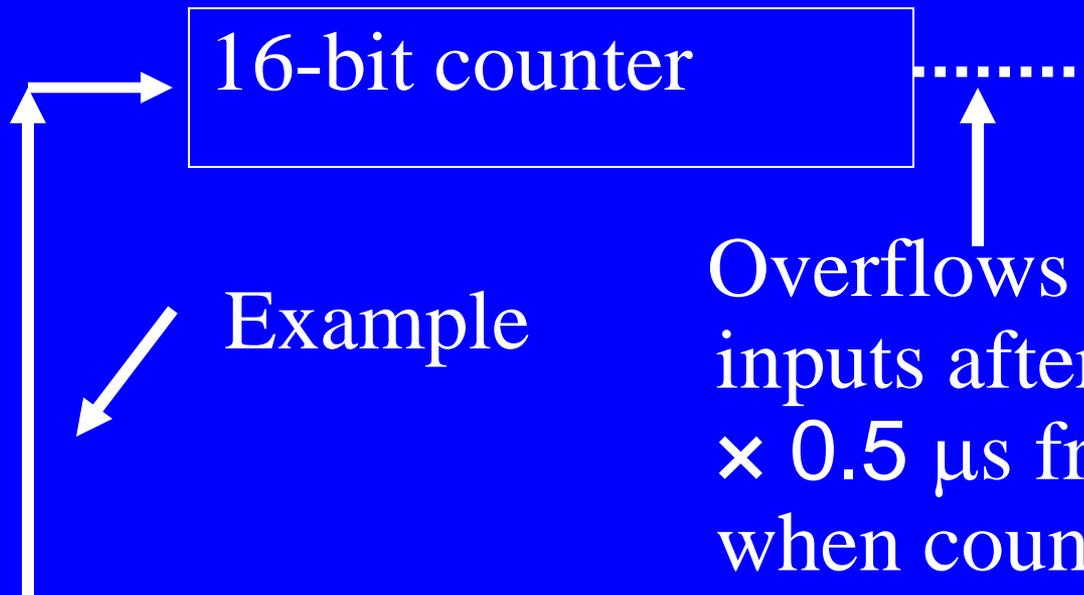
Clock Inputs period = 0.5 µs for 8 MHz XTAL, pre-scaling factor set = p = 1 or 4 or 8 or 16

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 $\underline{T}$ counts = 0, and mode set for internal clock-inputs. On first event, start $\underline{T}$ and second event stop $\underline{T}$.

8051 TH0-TL0 Mode 1

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

● Let Mode T0 is $C/\overline{T}$ =0 (internal clock mode)

• Let T0 be programmed in mode 1 (TH0,TL0) 16-bit counter.

● WhenTR0 is set,timer T0 starts and TR0 reset T0 stops.

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8051 T1 in Mode 1 Example
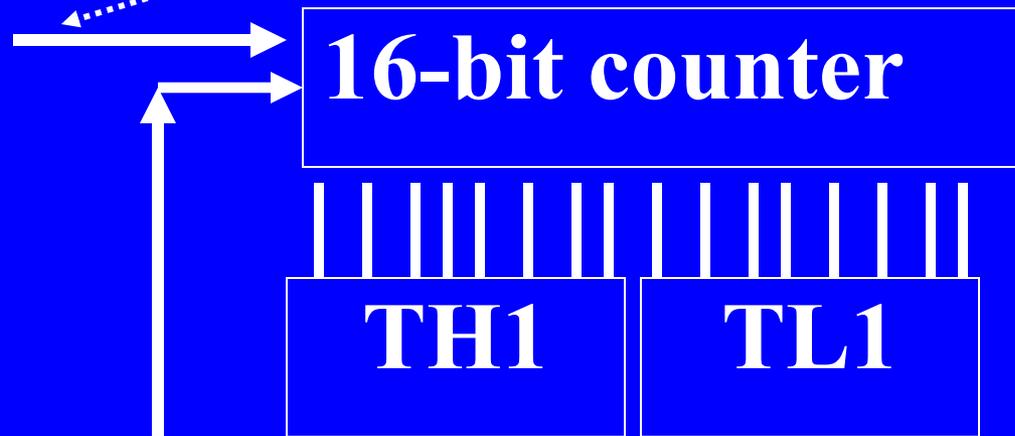
0 or 1 at External gate pin INT1 and 1 or 0 TR1 together starts/stops when programming of T1 is like that else set/reset of TR1 only starts/stops as per programming.

16-bit counter

TH1   **TL1**

Count Inputs from internal clock or from pin T1

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8052 T2 Example

16-bit counter

| | | | | | | | | | | | | | | | | | | | | |
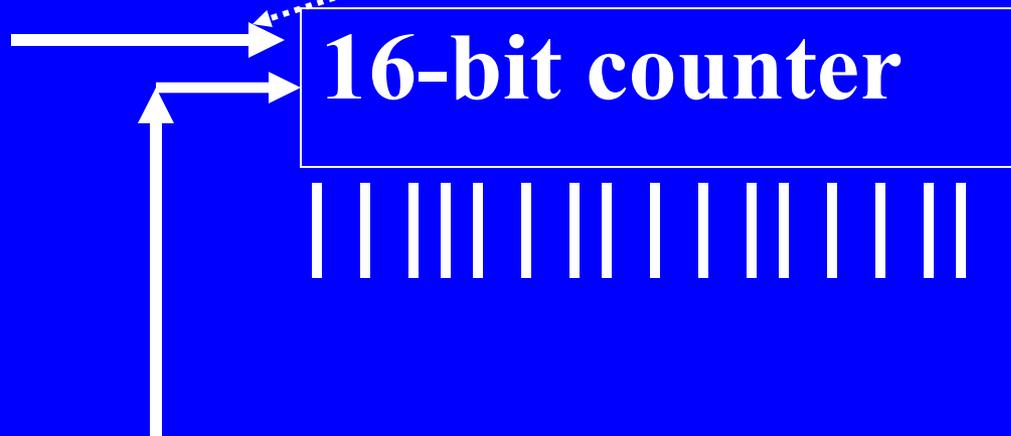
Count Inputs from internal clock or from pin C/T2 as per programming of T2

1. **External CP/$\overline{\text{RL}}$2 for counter reload on overflow if EXEN2 bit set**

2. **TR2 bit set/reset programmed to start/stop .**

68HC11 Timer-Counter Non-programmability except for Prescaling or counting rate setting

68HC11 TCNT Non-Programmability
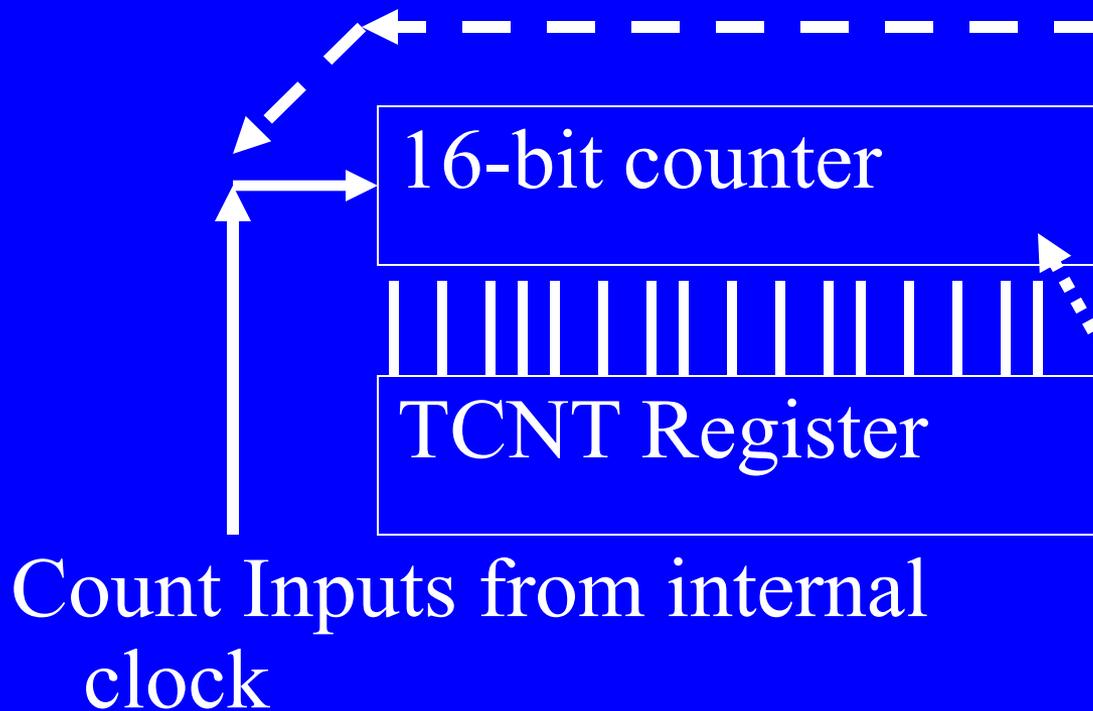
Internal clock input rate or the prescaling only programmable

16-bit counter

TCNT Register

Count Inputs from internal clock

No TR bit; Start/stop and No reset programmable

8051 Timer-Counter Loading and Reload

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8051 T0 in Mode 3 Example
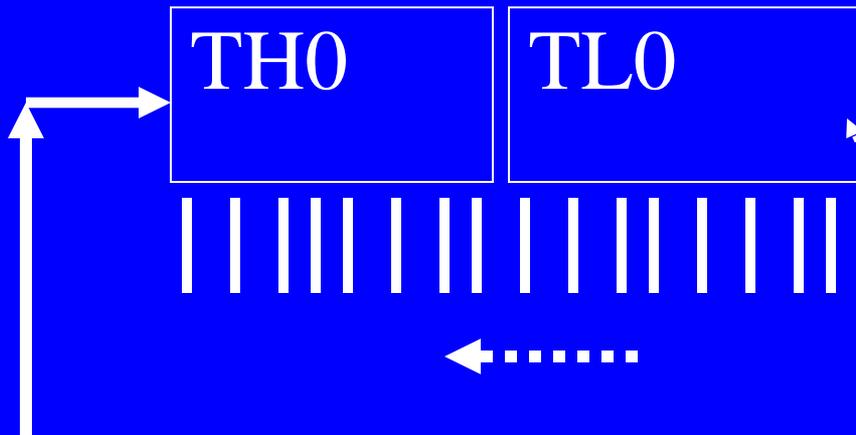
TH0 is written the counts = x0.

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

TH0	TL0

TL0 is written the counts = x1.

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

Count Inputs from internal clock or from pin $\overline{T1}$

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.
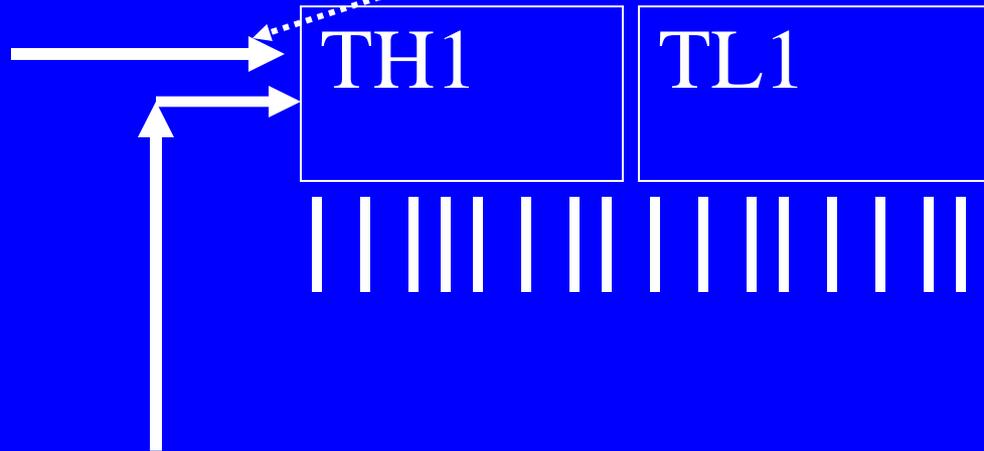
TH1   TL1

Count Inputs from internal clock or from pin $\overline{T1}$

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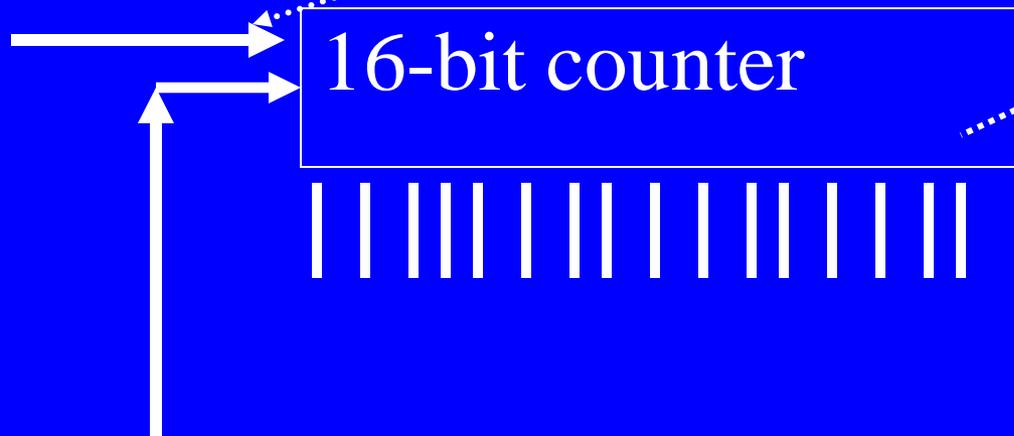
8052 T2 Example

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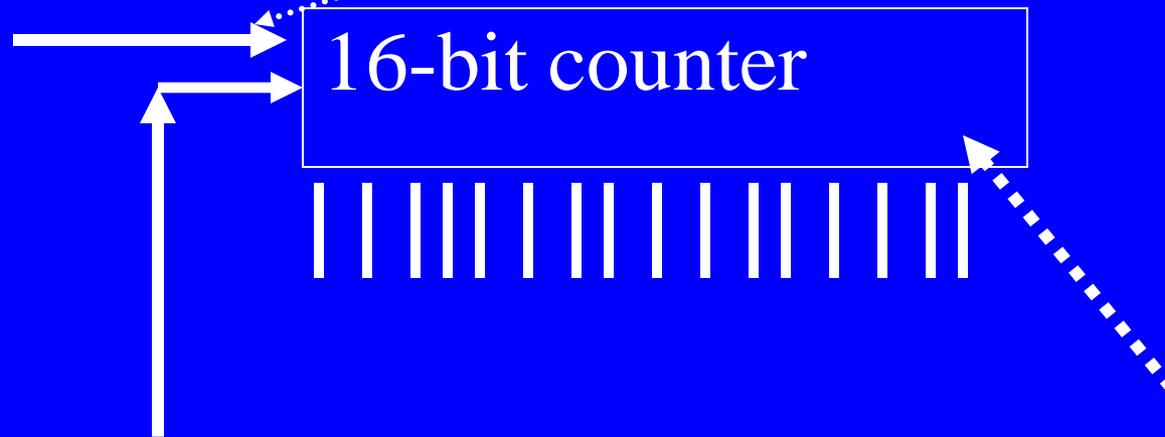
16-bit counter

Count Inputs from internal clock or from pin C/$\overline{T2}$ as programmed

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8052 T2 Example

External CP/$\overline{\text{RL2}}$ for counter reload if EXEN2 bit set. Reloads from the TH2-TL2 registers

16-bit counter

Count Inputs from internal clock or from pin C/$\overline{\text{T2}}$ as programmed

68HC11 TCNT Example

Internal clock input rate/ Prescaling factors only programmable

16-bit counter TCNT

Read Only

No loading of TCNT,
No resetting by writing 0000H into TCNT.

Count Inputs from internal clock.

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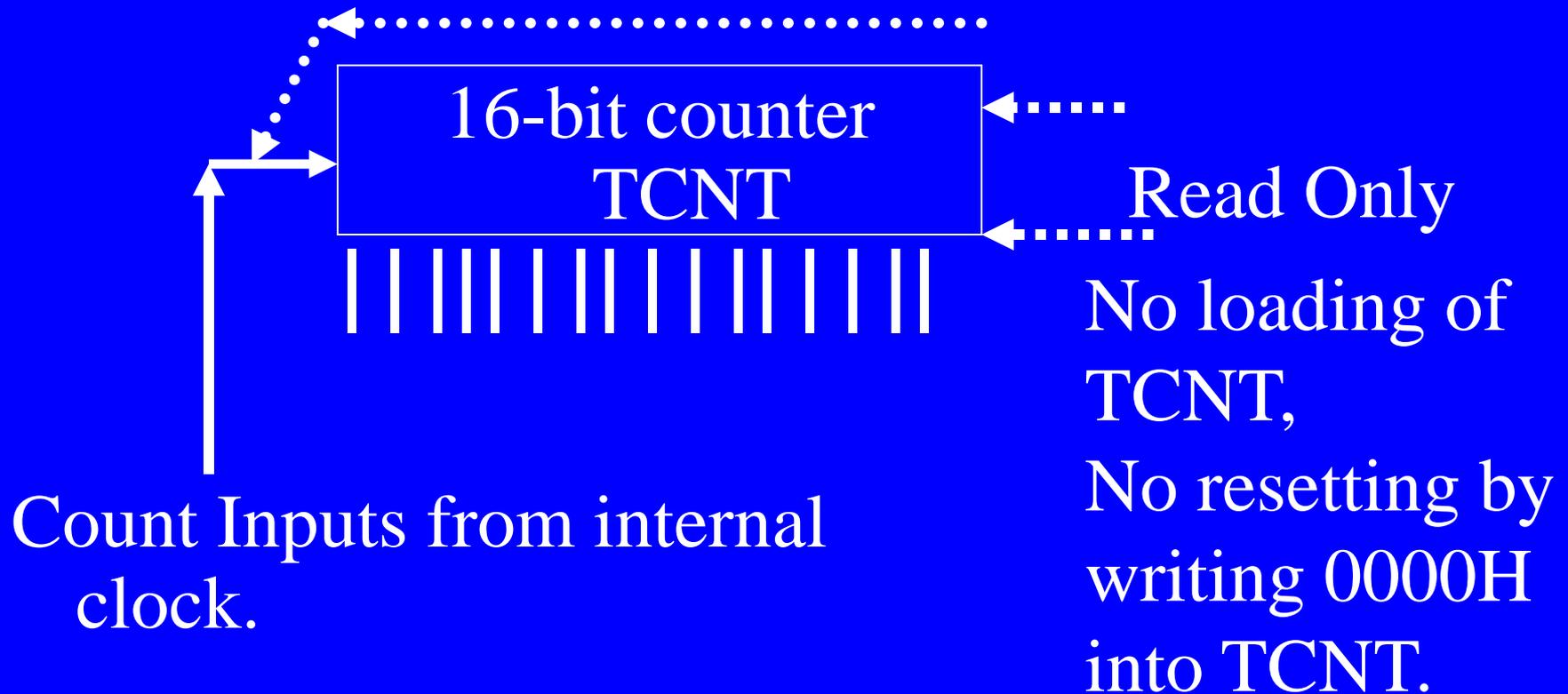
An overflow delay two or four or eight times when pre-scaling factor = 2 or 4 or 8

Overflow after a Period

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Example- 8051 TH1-TL1 Mode 1

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

- Let Mode T1 is C/$\overline{T}$,internal clock mode

- Let T1 be programmed in mode 1 (TH1,TL1) 16-bit counter.

- WhenTH1-TL1 written (loaded) E0H-01H then timer T1 will timeout and overflow after 1FFFH inputs.

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Example- 8051 TL0 Mode 2

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

• Let Mode T0 is C/$\overline{T}$,internal clock mode

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

• WhenTH0 (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.

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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/$\overline{\text{T}}$1= 1 for count mode TH0 and mode T0 is is C/$\overline{\text{T}}$0= 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

Step1: Set TR0 = 1, reset TH0 = 00H

Step 2: Run TH0 by setting TR1 =1, so that TH0 starts counting from 00H.

Step3: TL0 overflows and interrupts after counting interval = 131 µs, the ISR resets TR1 = 0, it stopsTH0.

TH0 will gives the count pulses at C/$\overline{\text{T}}$1 pin received in 131 µs.

Timer-Counter Overflow Events

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Example of

<u>Timer-Counter Overflow Event</u>

- Timer-counter T1 mode1 on overflow after one input from FFFFH and new reading = 0000H at TH1-TL1

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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

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

8-bit counter

Example

Overflows after 256 inputs in 256 μs if initial count bits all 0s.

Clock Inputs period = 1 μs

for 12 MHz XTAL

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68HC11 TCNT example

Timer overflow interrupt if not masked, an ISR executes

16-bit counter

Example

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

Clock Inputs period = 1/2 μs for 8 MHz XTAL, pre-scaling factor set = 1

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Example- 8051 TH0 Mode 3

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

Let Mode T1 is C/$\overline{T}$,internal clock mode

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

WhenTH0 starts by setting TR1 = 1, Over-flow will be after (100H-81H) = 127 µs

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Preset time interval ON-OFF of a unit

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

- Application- Output change (s) for a pre-fixed interval

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Preset long time interval on-off of a unit

Load n-bit timer $\underline{T}$ counts = x, define number of overflows = k, mode set for internal clock-inputs. Switch on an output, Start $\underline{T}$ and on overflow interrupt, reload the counts on 1 to $(k-1)^{th}$ overflows and switch off the output on k^{th} over flow 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 $\underline{T}$ counts = 0, and mode set for internal clock-inputs. On first event, start $\underline{T}$ and till second event, find *k* the number of overflows and on second event stop $\underline{T}$.

Exemplary Applications

Find time taken for a weight-lifter to lift

Find time taken for an input event change

Time interval

Time interval = $[(2^n.k) + x1].p.t$, where t = clock input period, p = pre scaling factor, $x1$ = final counts at the n-bit at $\underline{T}$.

Summary

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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

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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