Embedded Systems with ARM Cortex-M3 Microcontrollers in Assembly Language and C

Chapter 15
General-purpose Timers

Dr. Yifeng Zhu
Electrical and Computer Engineering
University of Maine

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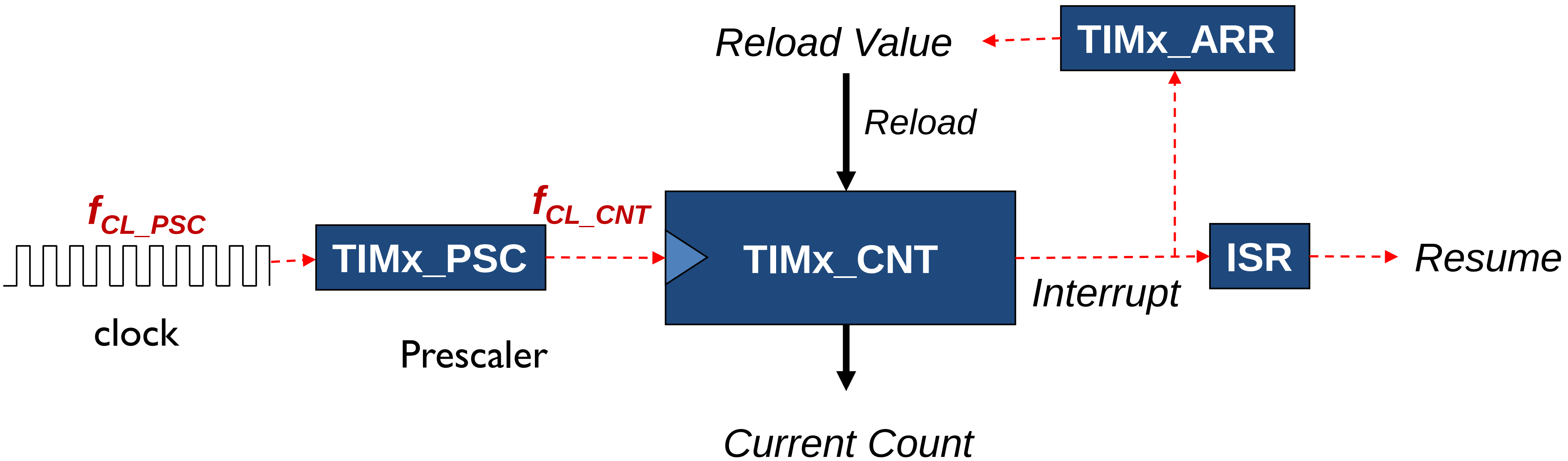
Timer

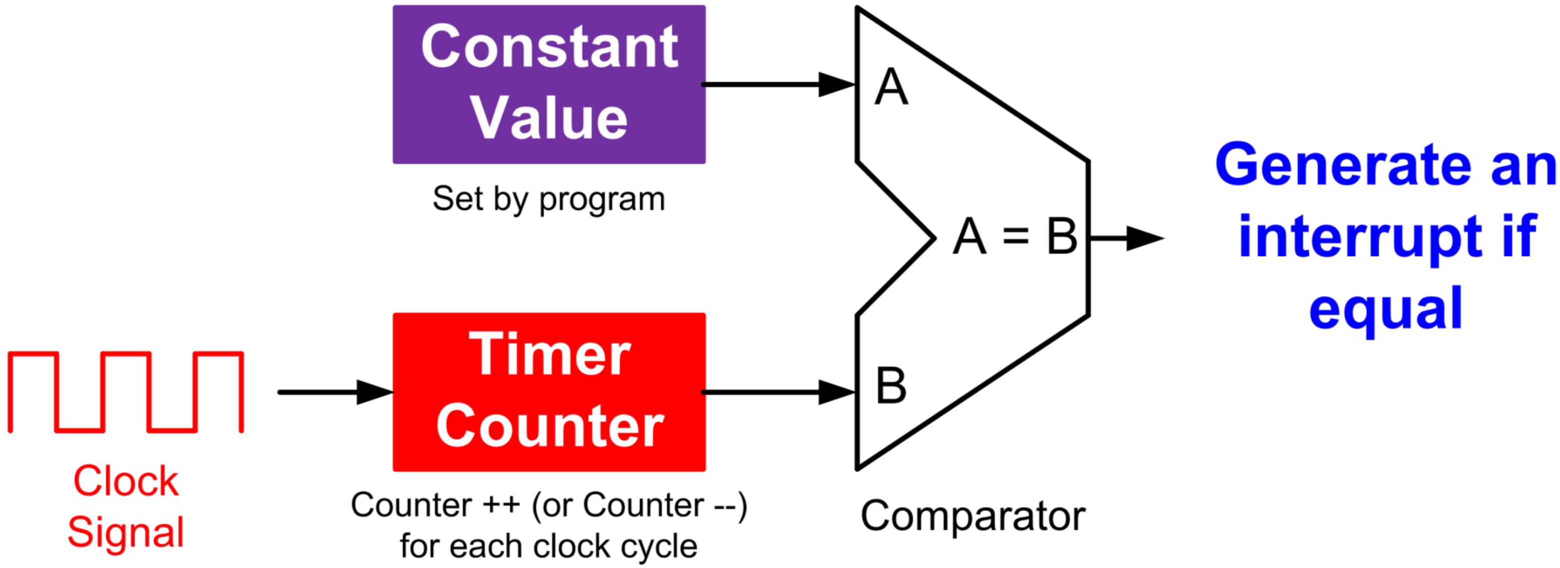
- Free-run counter (independent of processor)
- Functions
  - Input capture
  - Output compare
  - Pulse-width modulation (PWM) generation
  - One-pulse mode output

Timer's Clock



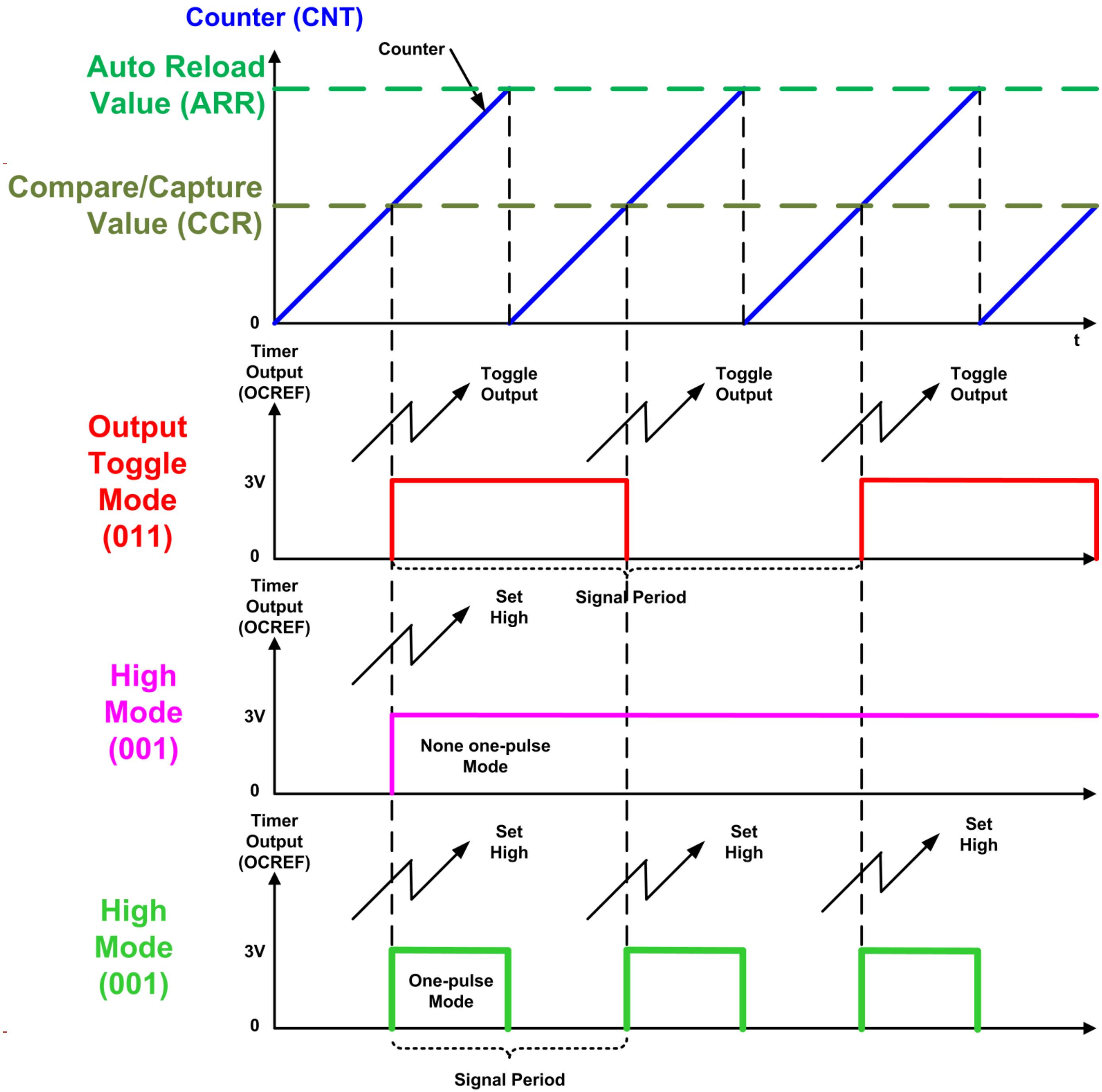
$$f_{CK\_CNT} = \frac{f_{CL\_PSC}}{Prescaler + 1}$$

Output Compare



Output Compare Mode (OCM)	Timer Output (OCREF)
`000`	Frozen
`001`	High if CNT == CCR
`010`	Low if CNT == CCR
`011`	Toggle if CNT == CCR
`100`	Forced low (always low)
`101`	Forced high (always high)

Output Mode



Counter (CNT)
Counter
Auto Reload Value (ARR)
Compare/Capture Value (CCR)
0
t
Timer Output (OCREF)
Toggle Output
Toggle Output
Toggle Output
Output Toggle Mode (011)
3V
0
Signal Period
Timer Output (OCREF)
Set High
High Mode (001)
3V
None one-pulse Mode
0
Timer Output (OCREF)
Set High
Set High
Set High
High Mode (001)
3V
One-pulse Mode
0
Signal Period

Example: Toggle LED Every Second

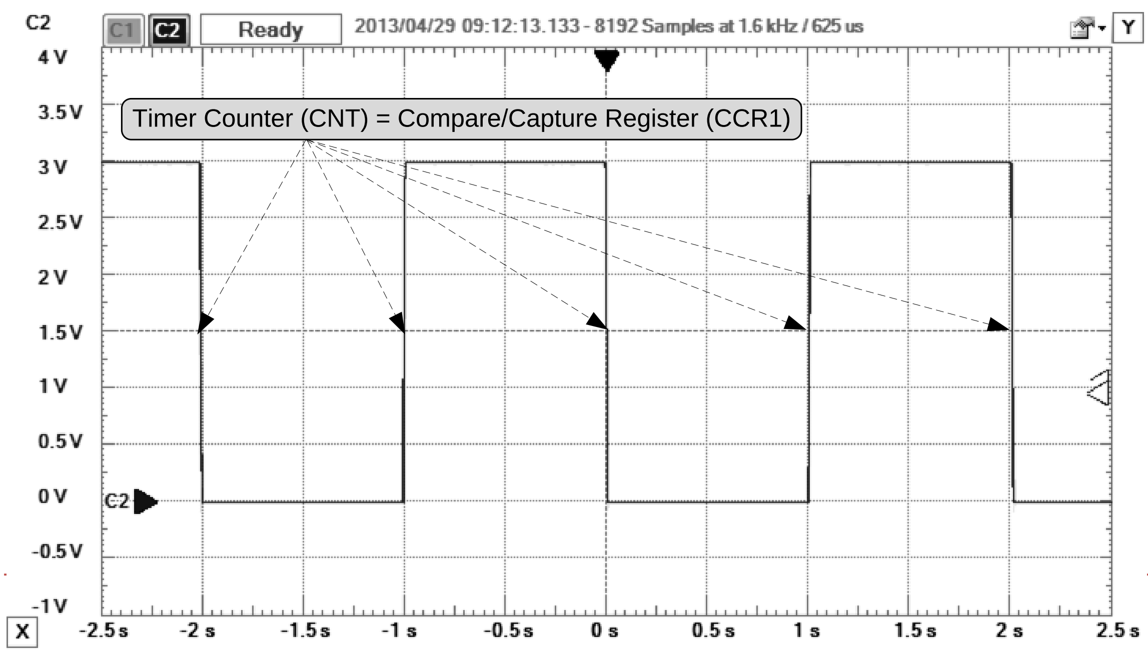
- Slow down the counter clock to 1 KHz

$$f_{CK\_CNT} = \frac{f_{CL\_PSC}}{Prescaler + 1}$$

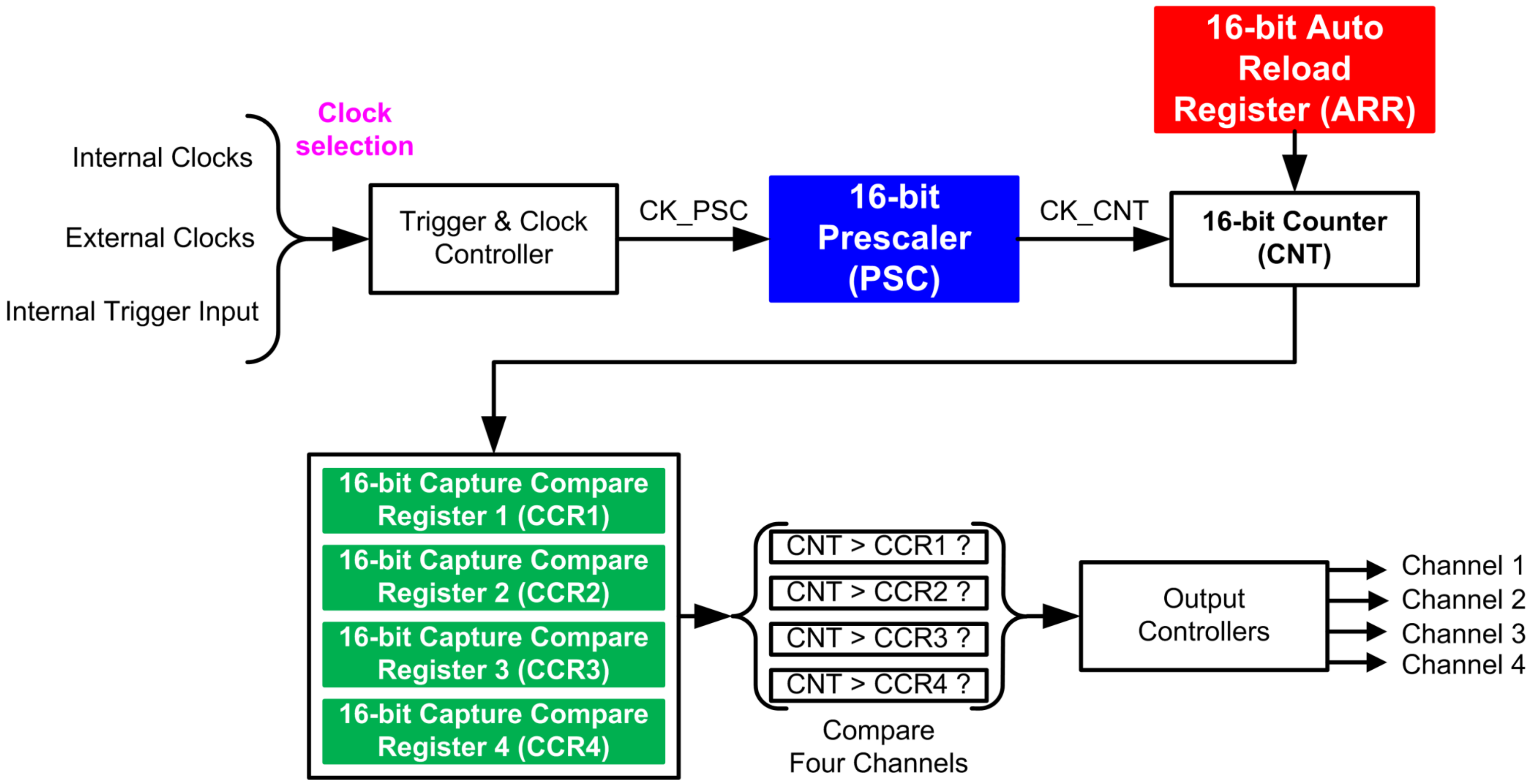
We get

$$Prescaler = \frac{f_{CL\_PSC}}{f_{CK\_CNT}} - 1 = \frac{2.097MHz}{1KHz} - 1$$
$$= 2096$$

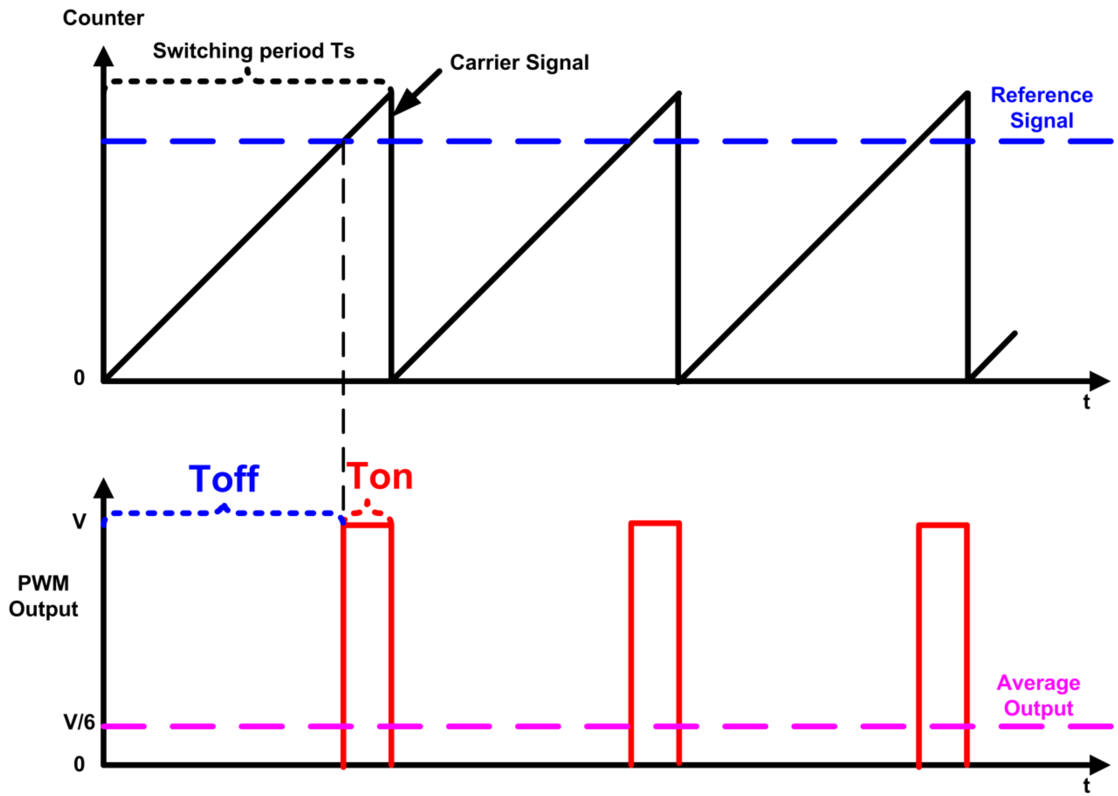
Set ARR to 999. The timer counts from 0 to 999 repeatedly (1000 steps).



PWM Diagram

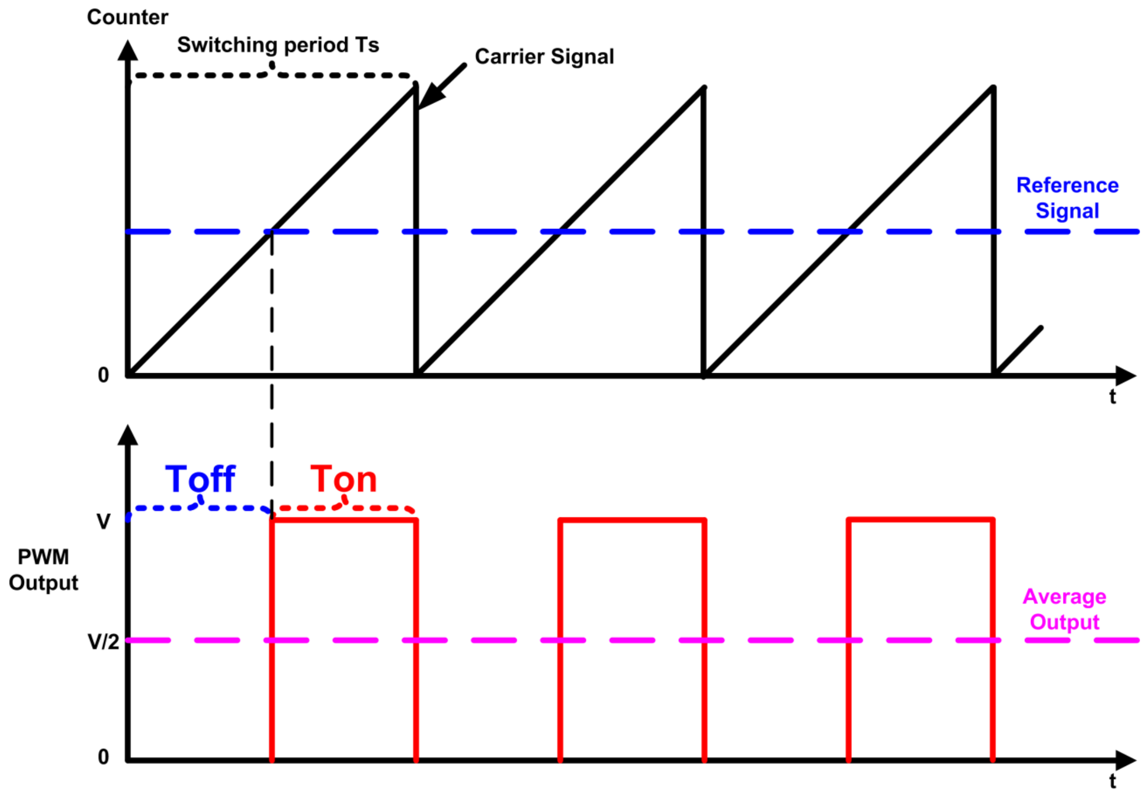

Clock selection
Internal Clocks
External Clocks
Internal Trigger Input
Trigger & Clock Controller
CK_PSC
16-bit Prescaler (PSC)
CK_CNT
16-bit Auto Reload Register (ARR)
16-bit Counter (CNT)
16-bit Capture Compare Register 1 (CCR1)
16-bit Capture Compare Register 2 (CCR2)
16-bit Capture Compare Register 3 (CCR3)
16-bit Capture Compare Register 4 (CCR4)
CNT > CCR1 ?
CNT > CCR2 ?
CNT > CCR3 ?
CNT > CCR4 ?
Compare Four Channels
Output Controllers
Channel 1
Channel 2
Channel 3
Channel 4

Duty Cycle = 1/6



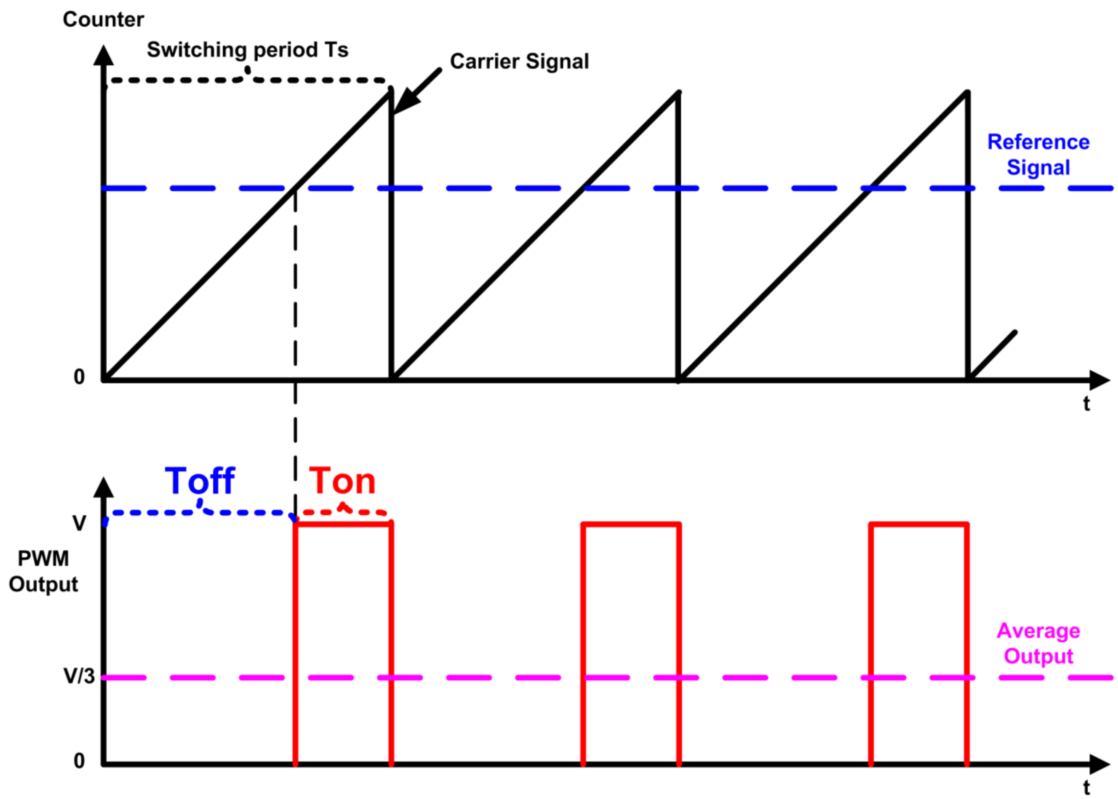
Mode	Counting Mode	Counter < Reference	Counter ≥ Reference
PWM mode 1	Upcounting	Active	Inactive
	Downcounting	Active	Inactive
PWM mode 2	**Upcounting**	**Inactive**	**Active**
	Downcounting	Inactive	Active

PWM Output: Duty Cycle = $\frac{Ton}{Ton+Toff}$

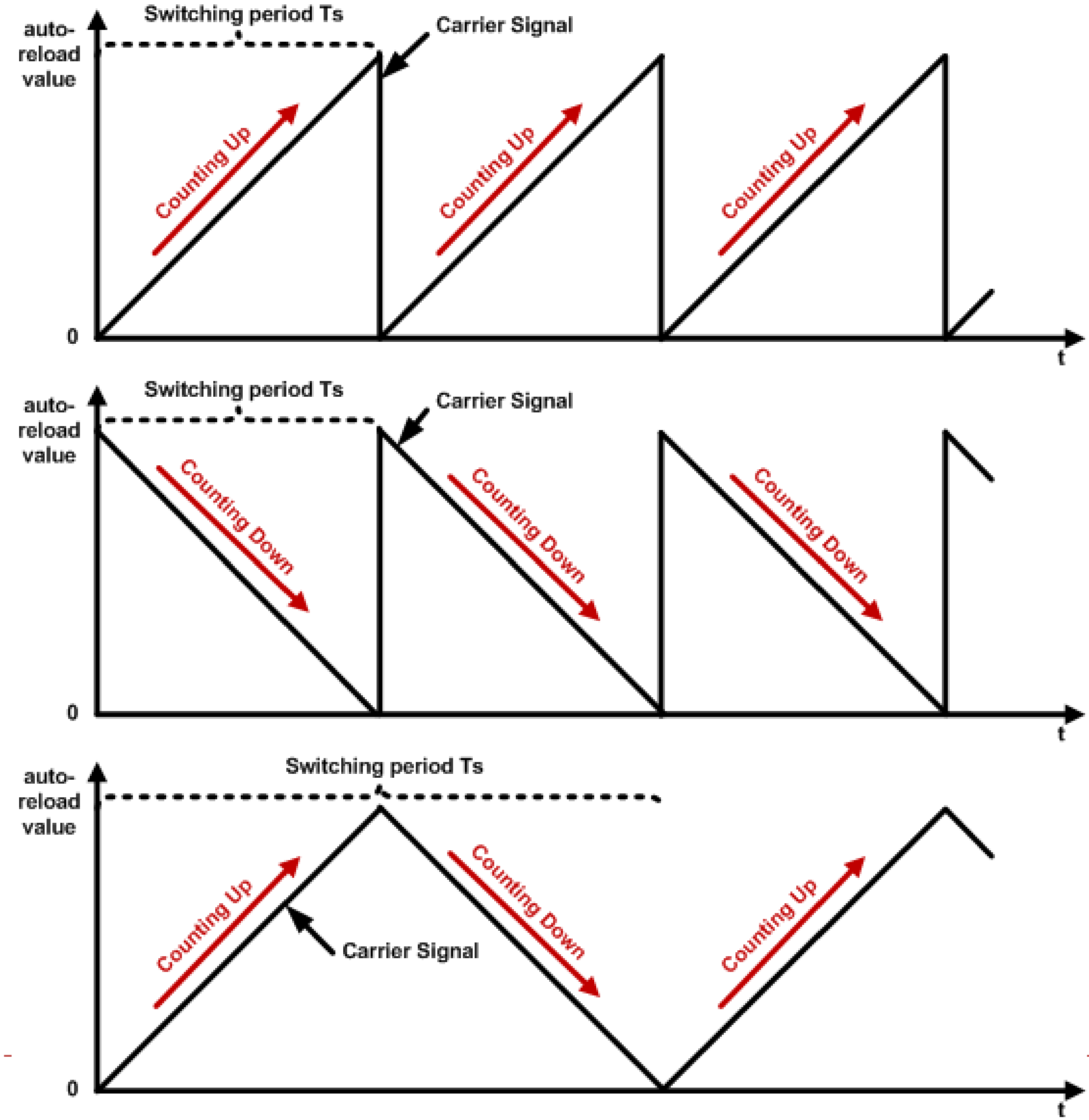


$$duty\ cycle = \frac{pulse\ on\ time}{pulse\ switching\ period} \times 100\% = \frac{T_{on}}{T_{on} + T_{off}} \times 100\%$$

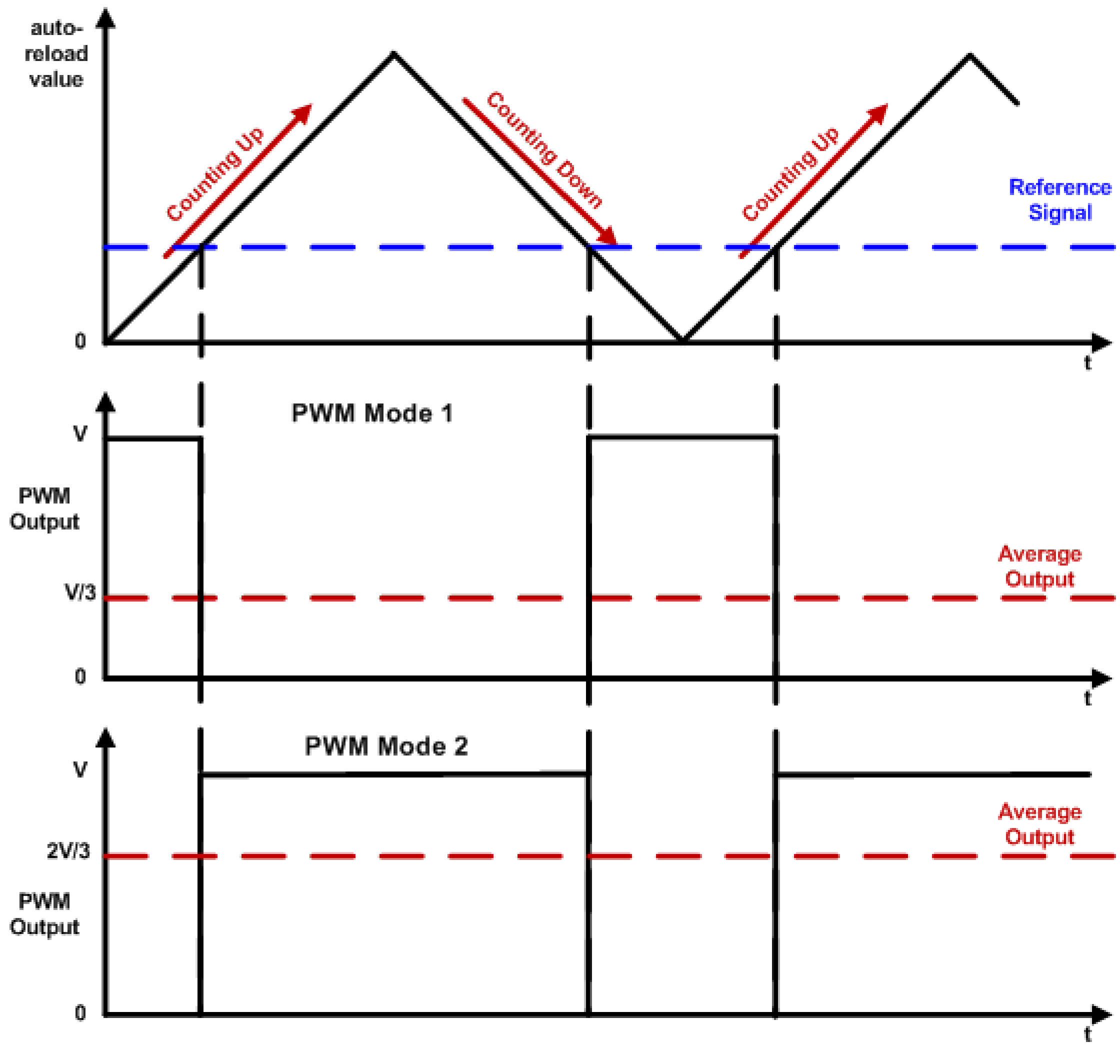
Duty Cycle = 1/3



Counting up, down, center

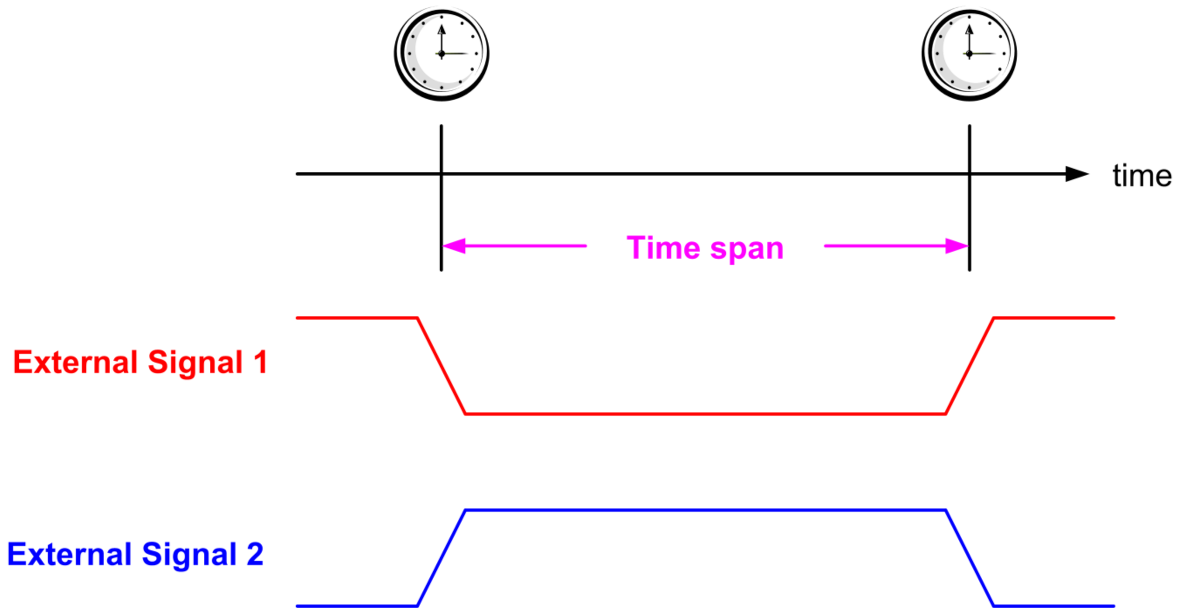


PWM Mode 1 vs PWM Mode 2



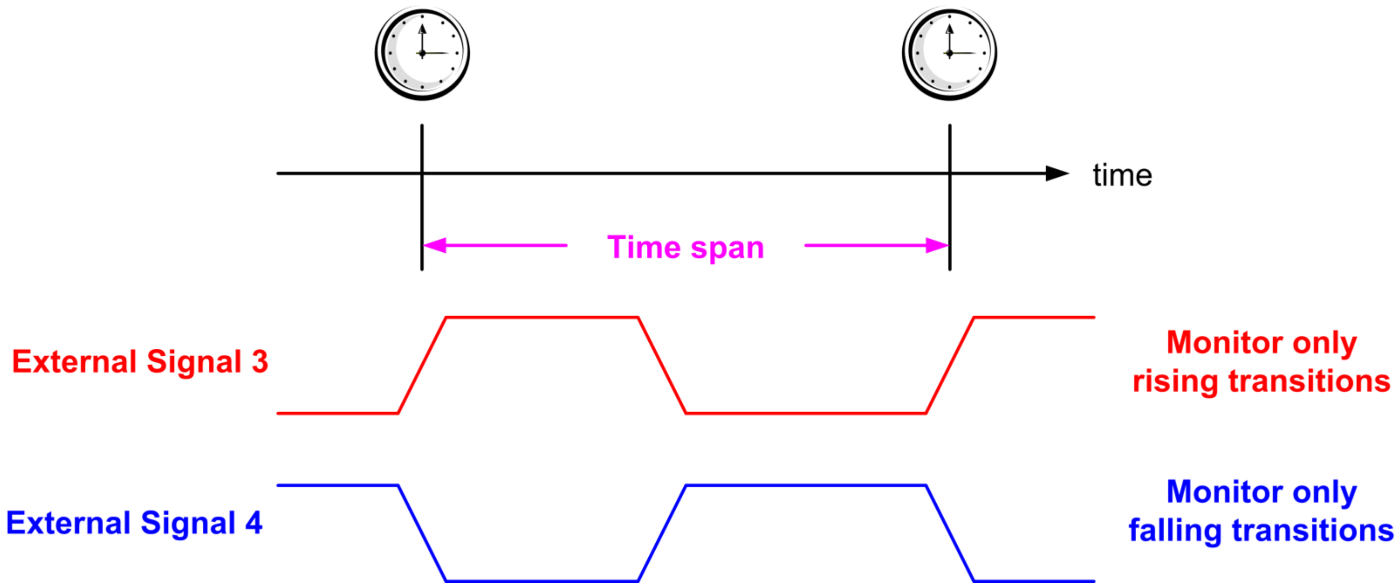
Input Capture

- Monitor both rising and falling edge

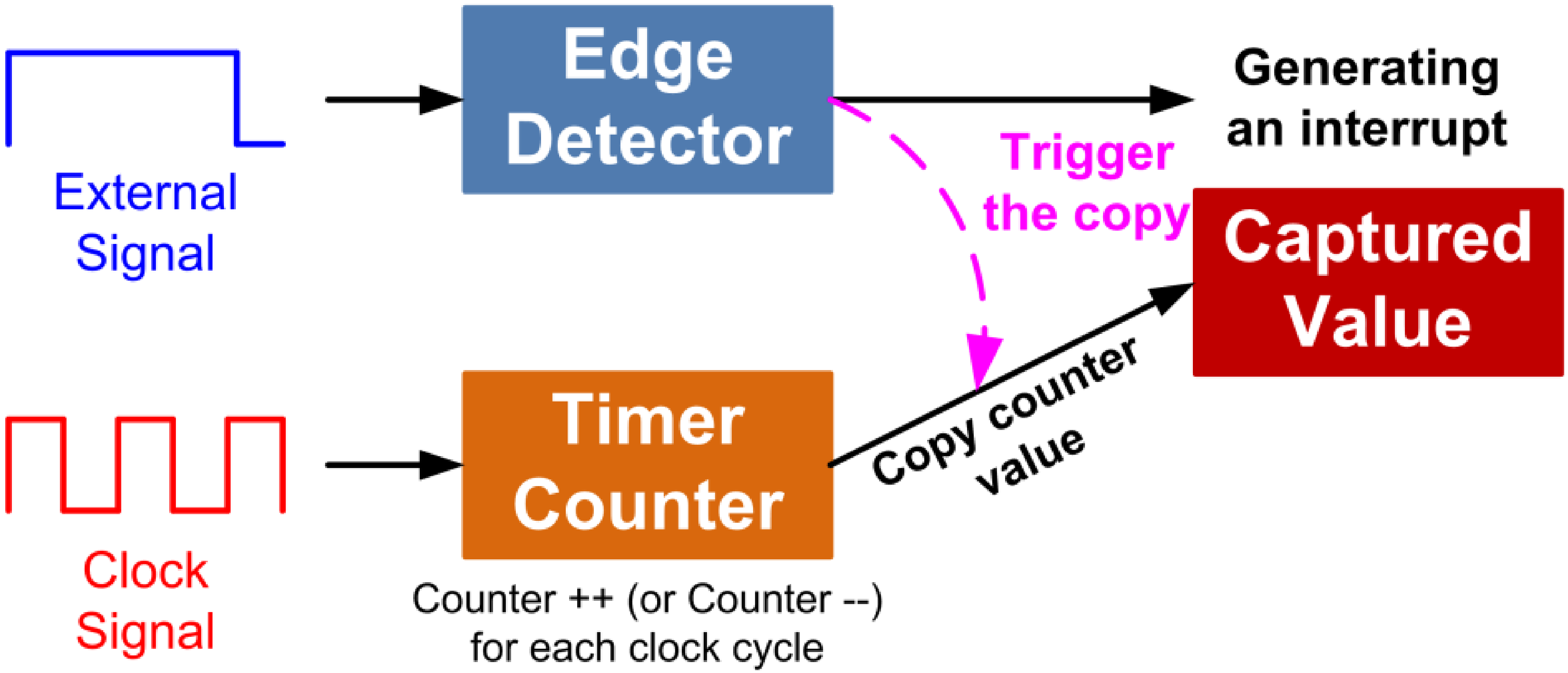


Input Capture

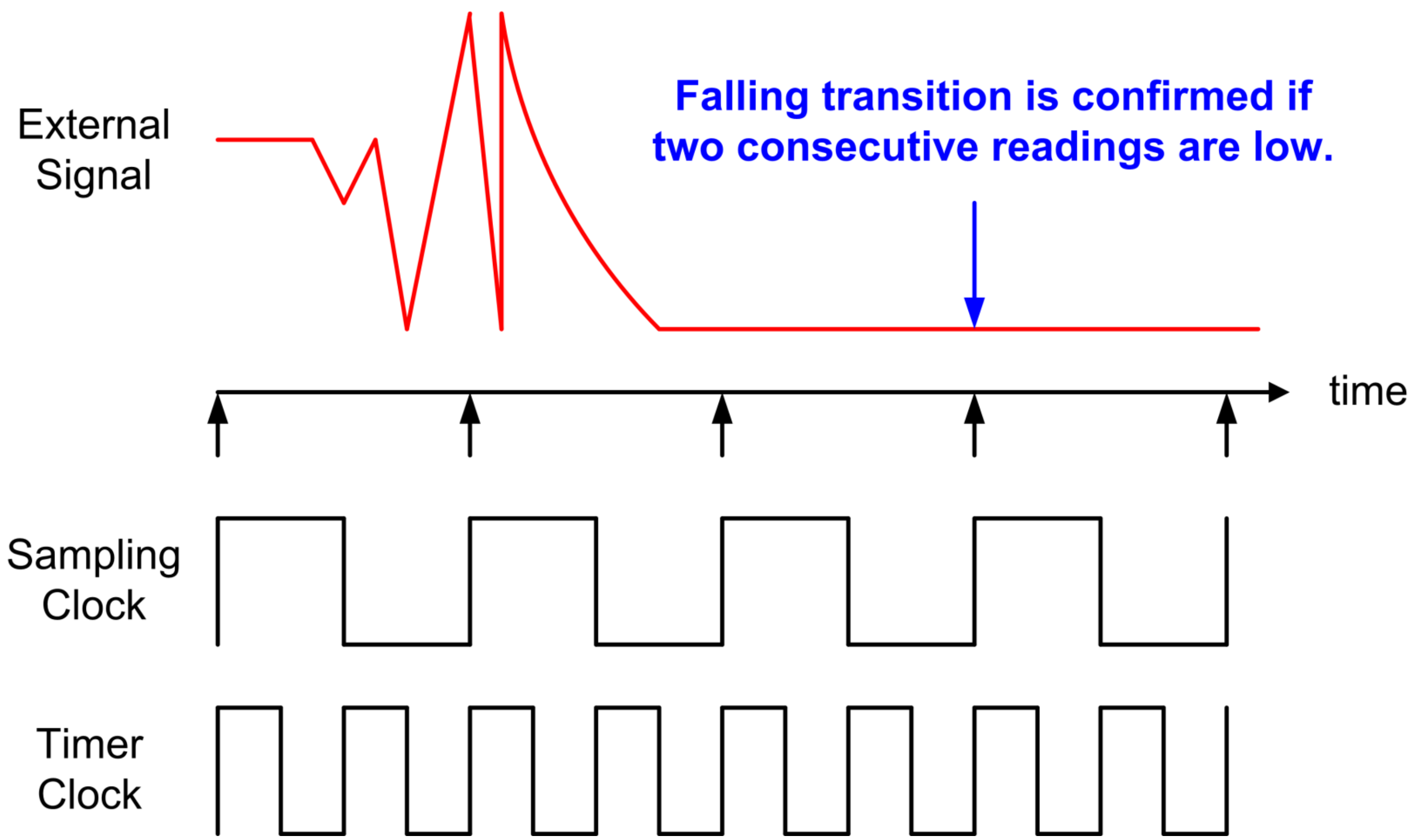
- Monitor only rising edges or only falling edge



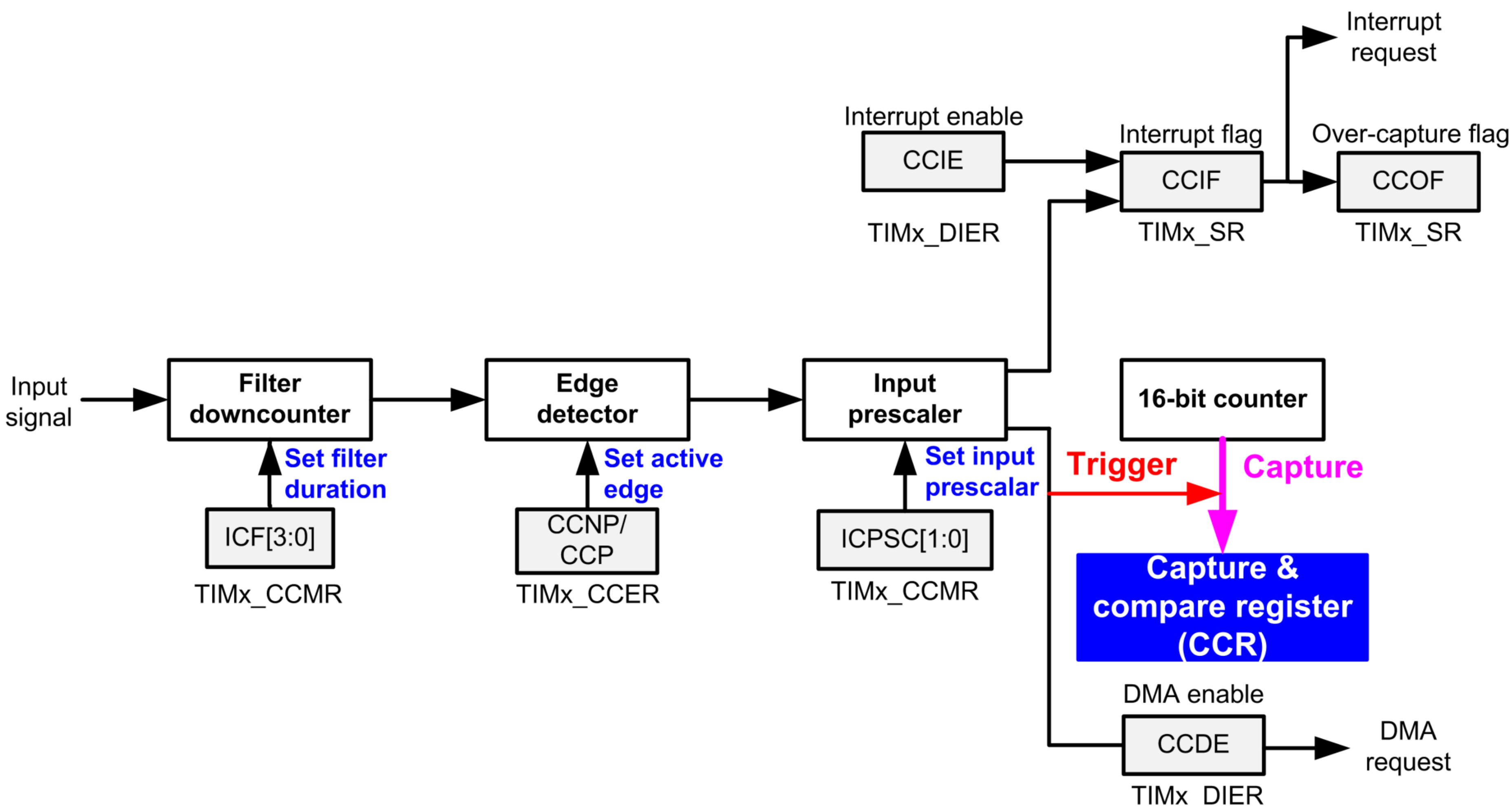
Input Capture



Input Filtering



Input Capture Diagram



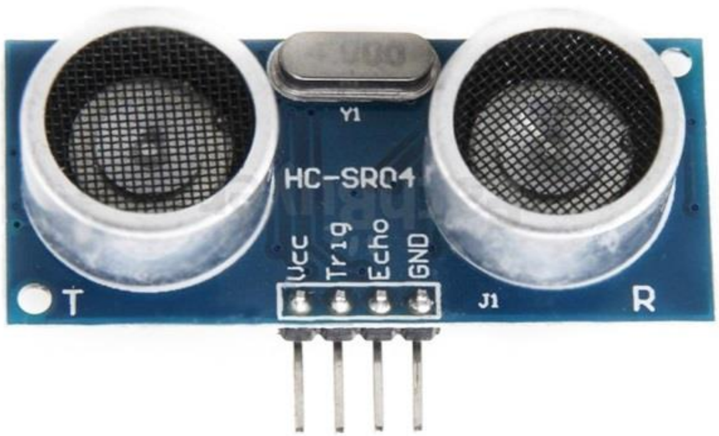
Ultrasonic Distance Sensor

$$Distance = \frac{Round\ Trip\ Time \times Speed\ of\ Sound}{2}$$

$$= \frac{Round\ Trip\ Time(\mu s) \times 10^{-6} \times 340 m/s}{2}$$

$$= \frac{Round\ Trip\ Time(\mu s)}{58}$$

Ultrasonic Distance Sensor

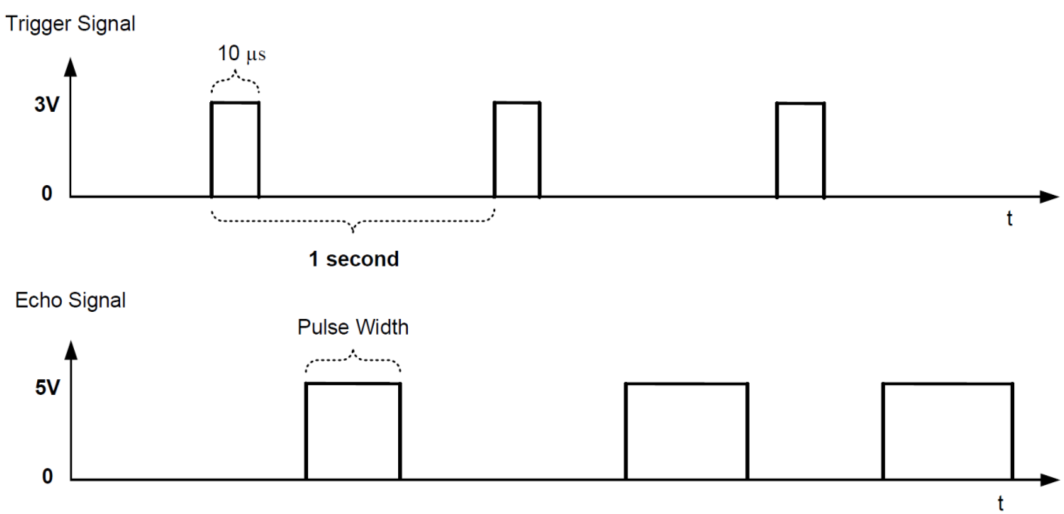


The echo pulse width corresponds to round-trip time.

$$Distance\ (cm) = \frac{Pulse\ Width\ (\mu s)}{58}$$

or

$$Distance\ (inch) = \frac{Pulse\ Width\ (\mu s)}{148}$$



If pulse width is 38*ms*,
no obstacle is detected.

Ultrasonic Distance Sensor