POLITECNICO
MILANO 1863

MICROCONTROLLERS

LAB – PWM

Overview

PIC 18F45K22 has:

- 3 enhanced CCP modules (ECCP1/2/3)
- 2 standard CCP modules (CCP4/5)

Every CCP Module can be configured as:

CAPTURE | COMPARE | PWM

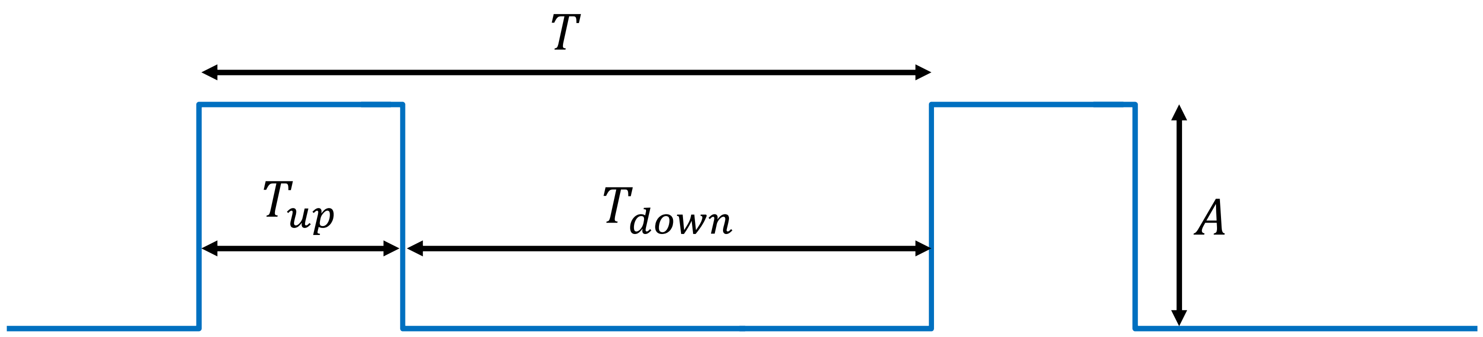
CCP modules use the Timer modules for work, please read the datasheet:

- Chapter 12 Timer 1/3/5 for capture and compare
- Chapter 13 Timer 2/4/6 for PWM
- Chapter 14 CCP Modules

For now we will only use PWM mode

Pulse Width Modulation (PWM) - Review

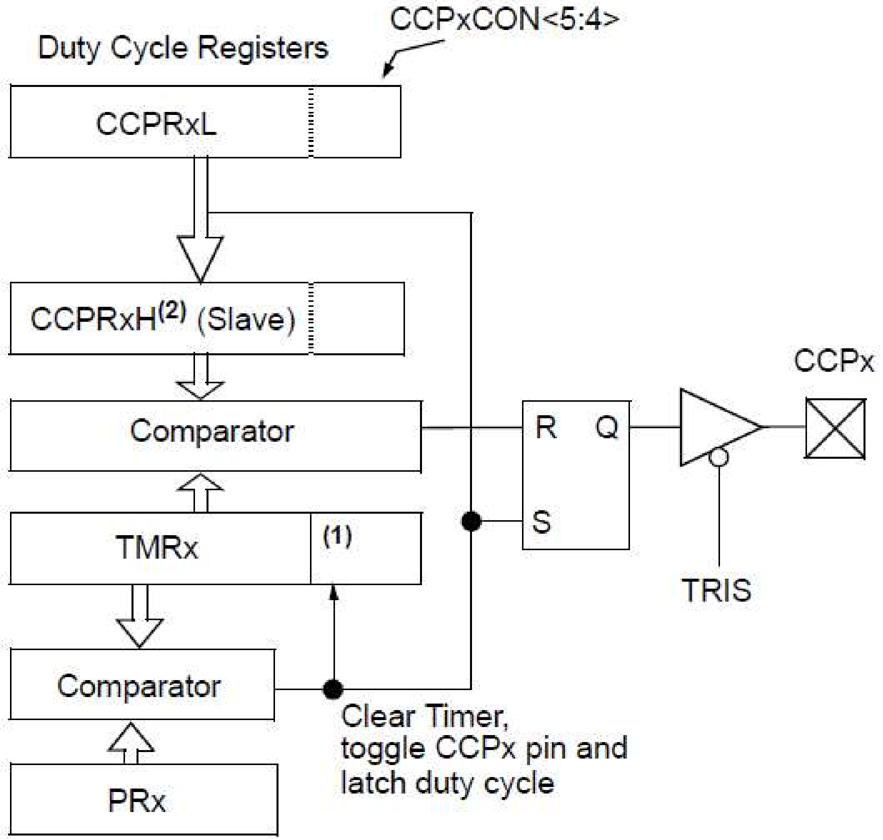
- It's a digital modulation;
- It encodes the amplitude of a signal into the **width of the pulse** (duration) of another signal.



$$frequency = \frac{1}{T} \qquad duty\ cycle = 100 \cdot \frac{T_{up}}{T} \qquad mean\ value = A \cdot \frac{T_{up}}{T}$$

Module

- It's able to generate a PWM square wave;
- Every time the value of TMR is equal to the PR value, the PIN is set;
- Every time the value of TMR is equal to the CCPR value, the PIN is cleared;
- ECCP modules have four dedicated pins for half/full bridge PWM.



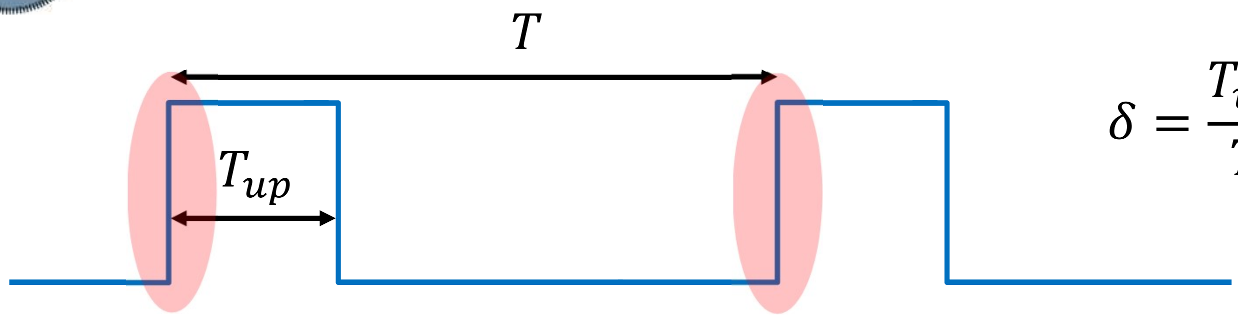
Note 1: The 8-bit timer TMRx register is concatenated with the 2-bit internal system clock (FOSC), or 2 bits of the prescaler, to create the 10-bit time base.

2: In PWM mode, CCPRxH is a read-only register.

$$T = (PRx + 1) \cdot TMRxPS \cdot \frac{4}{f_{osc}}$$

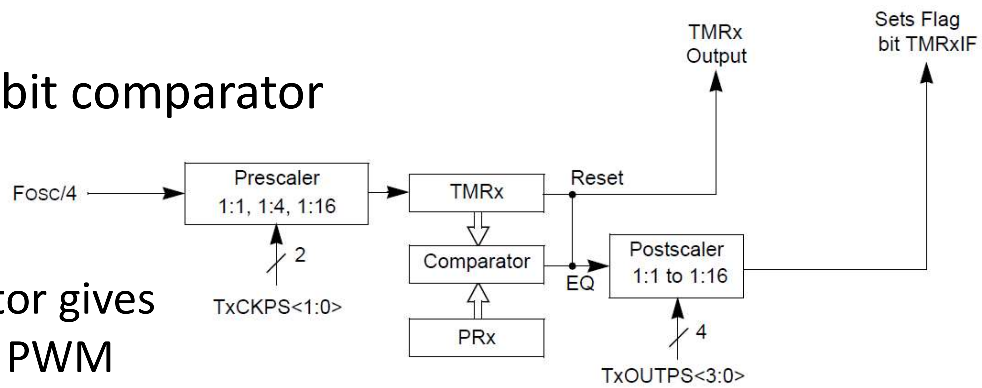
$$T_{up} = (CCPRxL: CCPxCON < 4:5 >) \cdot TMRxPS \cdot \frac{1}{f_{osc}}$$

PWM (Review) - SET



$$\delta = \frac{T_{up}}{T} \qquad f = \frac{1}{T}$$

- TMRx is a TMR2/4/6 and it is clocked with $f_{TMRx} = \left(\frac{f_{osc}}{4}\right) \cdot \frac{1}{TMRxPR}$ where $TMRxPR$ is the prescaler.
- The TMRx has only 8-bit.
- PRx is the reference of an 8-bit comparator



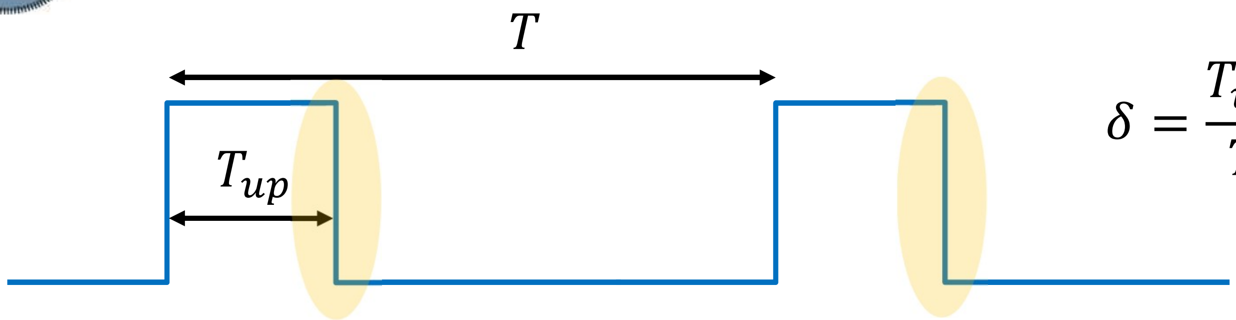
⇩

The output of the 8-bit Comparator gives the SET (0→1 transaction) of the PWM

⇩

$$\boldsymbol{T = (PRx + 1) \cdot TMRxPS \cdot \frac{4}{f_{osc}}}$$

PWM (Review) – RESET, a



$$\delta = \frac{T_{up}}{T}$$

$$f = \frac{1}{T}$$

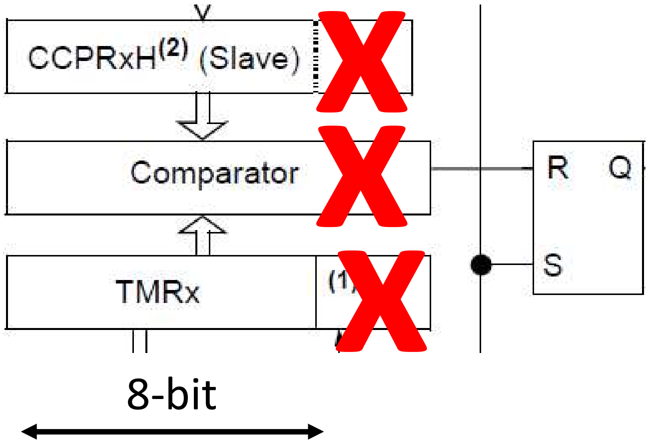
- The CCPxH contains the value that is use as reference of the second Comparator respect to the TMRx for the RESET of the PWM.
- Consider **NOW** the Comparator at 8-bit

⇩

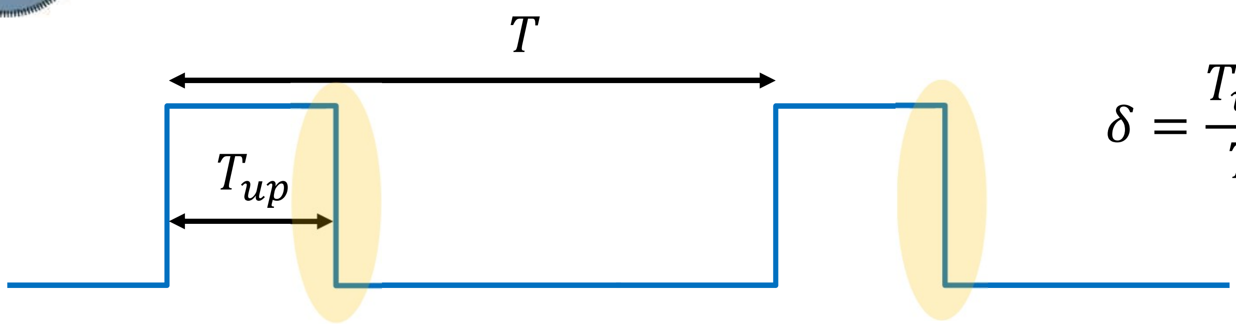
The output of the 8-bit Comparator gives the RESET (1→0 transaction) of the PWM

⇩

$$\boldsymbol{T_{up} = (CCPRxH) \cdot TMRxPS \cdot \frac{4}{f_{osc}}}$$



PWM (Review) – RESET, b

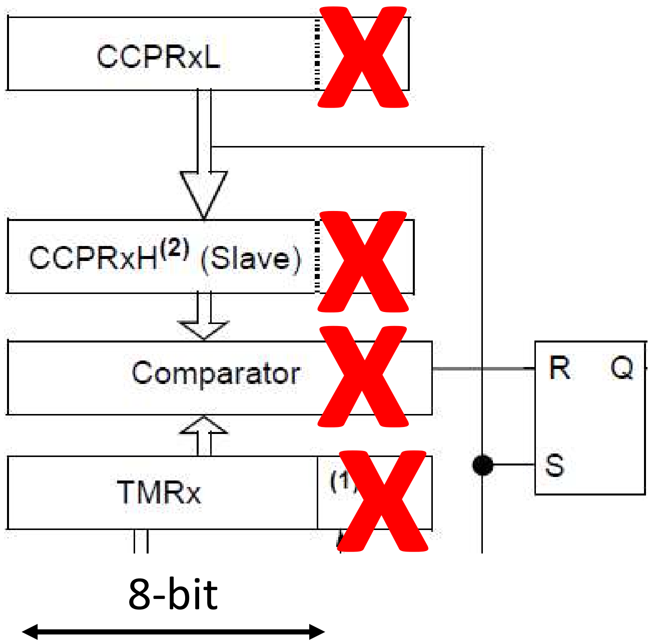


$$\delta = \frac{T_{up}}{T} \qquad f = \frac{1}{T}$$

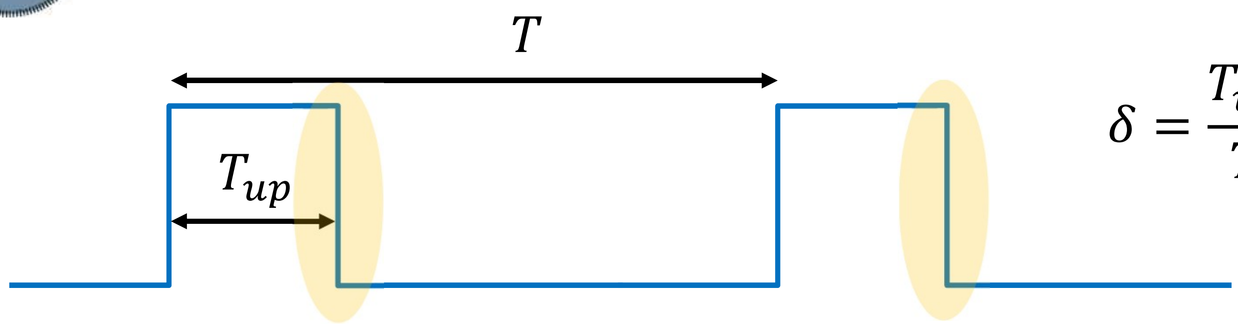
- The CCPxL is copy into CCPxH that is only ready in the SET phase, these guarantee no spurious value of duty-cycle.

$\Downarrow$

$$T_{up} = (CCPRxL) \cdot TMRxPS \cdot \frac{4}{f_{osc}}$$



PWM (Review) – 10 bit Extension

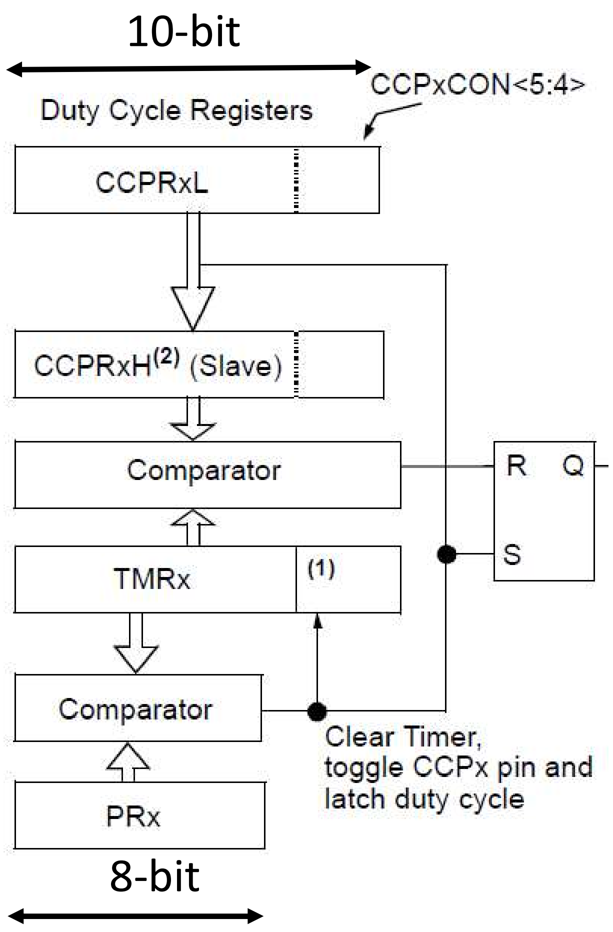


$$\delta = \frac{T_{up}}{T}$$

$$f = \frac{1}{T}$$

- The Comparator of the RESET phase is extended from 8-bit to 10-bit
- The 2-bit more are set by CCPxCOM<4:5>
- For make possible the extension at 10-bit the TMRx is extended with a little 2-bit counter clocked at $f_{OSC}/TMRxPR$
- The PRx register and its Comparator are keet at 8-bit

$$T_{up} = (CCPRxL) \cdot TMRxPS \cdot \frac{4}{f_{osc}} +$$
$$+ CCPxCOM < 4:5 > TMRxPS \cdot \frac{1}{f_{osc}}$$



PWM (Review) – Formula

$$T_{up} = (CCPRxL) \cdot TMRxPS \cdot \frac{4}{f_{osc}} + CCPxCOM < 4:5 > TMRxPS \cdot \frac{1}{f_{osc}}$$

$$T_{up} = \left[(CCPRxL) + \frac{CCPxCOM < 4:5 >}{4} \right] TMRxPS \cdot \frac{4}{f_{osc}}$$

$$T = (PRx + 1) \cdot TMRxPS \cdot \frac{4}{f_{osc}}$$

$$\delta = \frac{T_{up}}{T} = \frac{\left[(CCPRxL) + \frac{CCPxCOM < 4:5 >}{4} \right] TMRxPS \cdot \frac{4}{f_{osc}}}{(PRx + 1) \cdot TMRxPS \cdot \frac{4}{f_{osc}}}$$

$$\delta = \frac{4CCPRxL + CCPxCOM < 4:5 >}{4(PRx + 1)}$$

- The 2-bit more, CCPxCOM<4:5>
- $4 = 2^2$

PWM (Review) – Plot

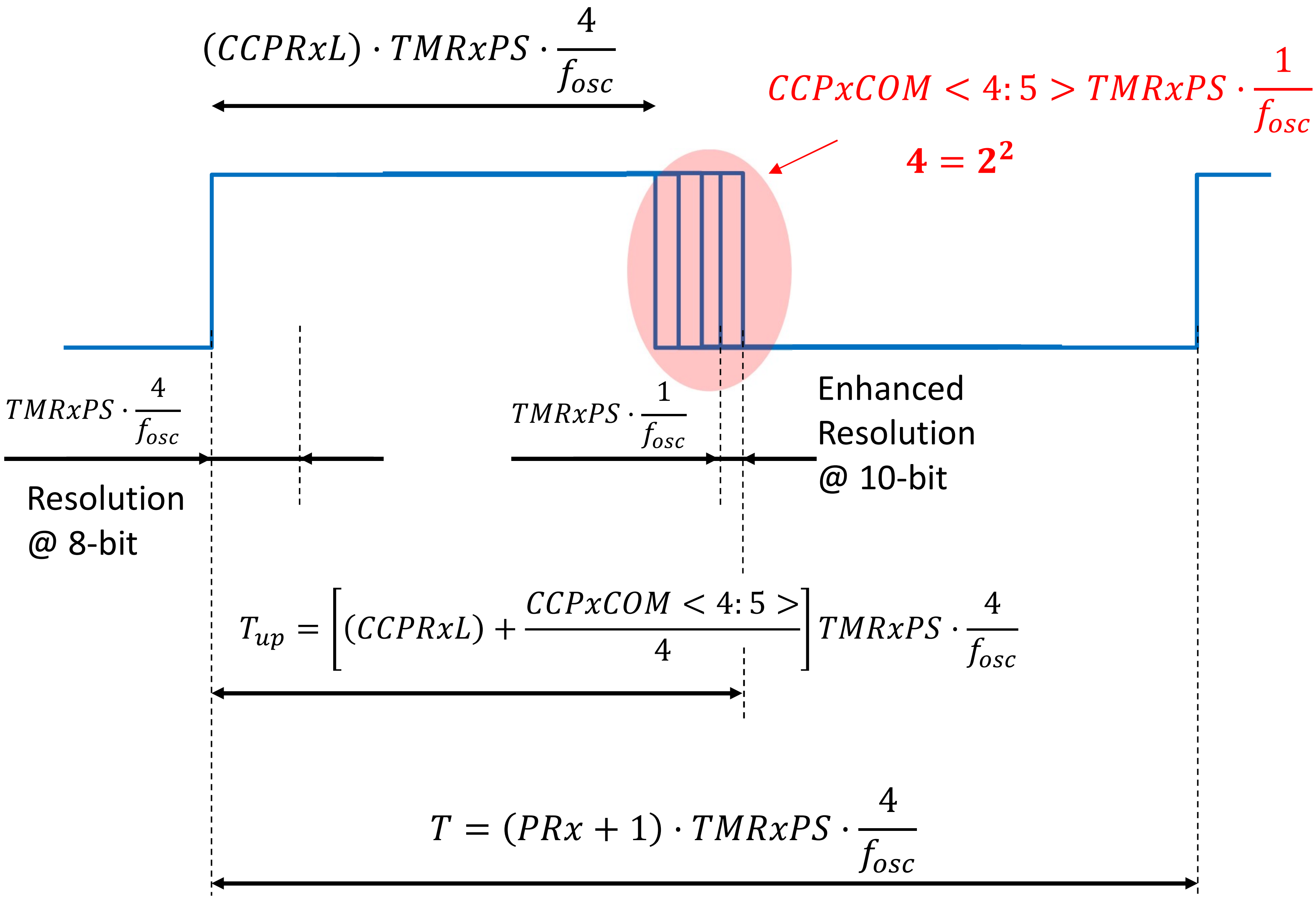


TABLE 14-7: EXAMPLE PWM FREQUENCIES AND RESOLUTIONS (Fosc = 32 MHz)

PWM Frequency	1.95 kHz	7.81 kHz	31.25 kHz	125 kHz	250 kHz	333.3 kHz
Timer Prescale (1, 4, 16)	16	4	1	1	1	1
PRx Value	0xFF	0xFF	0xFF	0x3F	0x1F	0x17
Maximum Resolution (bits)	10	10	10	8	7	6.6

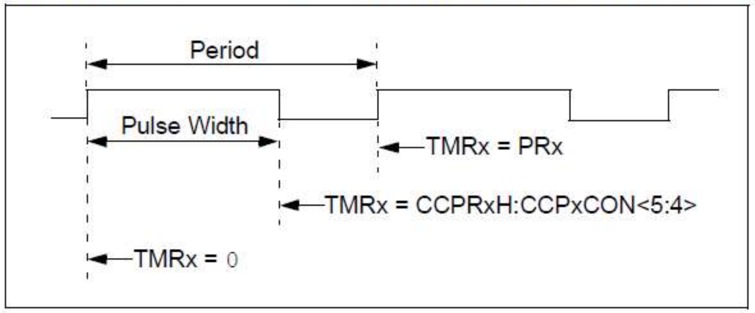
EQUATION 14-3: DUTY CYCLE RATIO

$$Duty\ Cycle\ Ratio = \frac{(CCPRxL:CCPxCON<5:4>)}{4(PRx + 1)}$$

EQUATION 14-4: PWM RESOLUTION

$$Resolution = \frac{\log[4(PRx + 1)]}{\log(2)}\ bits$$

FIGURE 14-3: CCP PWM OUTPUT SIGNAL



Setup instructions

14.3.2 SETUP FOR PWM OPERATION

The following steps should be taken when configuring the CCP module for standard PWM operation:

1. Disable the CCPx pin output driver by setting the associated TRIS bit.
2. Select the 8-bit TimerX resource, (Timer2, Timer4 or Timer6) to be used for PWM generation by setting the CxTSEL<1:0> bits in the CCPTMRSx register.[1]
3. Load the PRx register for the selected TimerX with the PWM period value.
4. Configure the CCP module for the PWM mode by loading the CCPxCON register with the appropriate values.
5. Load the CCPRxL register and the DCxB<1:0> bits of the CCPxCON register, with the PWM duty cycle value.
6. Configure and start the 8-bit TimerX resource:
   - Clear the TMRxIF interrupt flag bit of the PIR2 or PIR4 register. See Note 1 below.
   - Configure the TxCKPS bits of the TxCON register with the Timer prescale value.
   - Enable the Timer by setting the TMRxON bit of the TxCON register.
7. Enable PWM output pin:
   - Wait until the Timer overflows and the TMRxIF bit of the PIR2 or PIR4 register is set. See Note 1 below.
   - Enable the CCPx pin output driver by clearing the associated TRIS bit.

Note 1: In order to send a complete duty cycle and period on the first PWM output, the above steps must be included in the setup sequence. If it is not critical to start with a complete PWM signal on the first output, then step 6 may be ignored.

Registers

REGISTER 14-3: CCPTMRS0: PWM TIMER SELECTION CONTROL REGISTER 0

R/W-0	R/W-0	U-0	R/W-0	R/W-0	U-0	R/W-0	R/W-0
C3TSEL<1:0>		—	C2TSEL<1:0>		—	C1TSEL<1:0>	
bit 7							bit 0

REGISTER 14-4: CCPTMRS1: PWM TIMER SELECTION CONTROL REGISTER 1

U-0	U-0	U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0
—	—	—	—	C5TSEL<1:0>		C4TSEL<1:0>	
bit 7							bit 0

REGISTER 14-1: CCPxCON: STANDARD CCPx CONTROL REGISTER

U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	—	DCxB<1:0>		CCPxM<3:0>			
bit 7							bit 0

REGISTER 13-1: TxCON: TIMER2/TIMER4/TIMER6 CONTROL REGISTER

U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	TxOUTPS<3:0>				TMRxON	TxCKPS<1:0>	
bit 7							bit 0