PIC Microcontroller: CCP modules

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ABSTRACT
There are many applications which are based on Microcontroller. They are user friendly and capable of interacting with the external peripherals. To accomplish these tasks, a microcontroller device has digital inputs/outputs, pulsed inputs/outputs analog inputs/outputs, etc. There are serial and parallel data communications which are used in data communication. Parallel communication required more number of wires, and can communicate more number of bits at a time whereas Serial communication has gained more importance now-a-day. This is more appropriate to discuss some more PIC functions that can support the above mentioned requirements. Another requirement is External events and their occurrence at the exact point of time and generation of precise timing at the output pins of the microcontroller on a real time. There are two CCP modules in 16F877 supporting capture/compare and PWM functions discuss in present paper. This module allows detecting exact timing of the occurrence of an event or can generate exact timing at the output.

Keywords: PIC 16F877, CCP1, CCP2, PWM

I. INTRODUCTION
Microcontroller-based designs are very flexible and compact. Use of supporting integrated circuits for interfacing sensors and transducers makes the design very simple and cost effective. Use of serial ADC, SPI and I²C bus interface can save the number of microcontroller pins.

Measurement of physical quantities is an integral part of any engineering application. Various sensors are used to extract the information from a physical media and this information is then converted into suitable form.

Transmission of this information to a remote place is a need where it is monitored and used to take certain action. The role of microcontrollers must be very clear in all these systems. Earlier measurement systems used to have analog circuits for signal conditioning. However, due to digital processing of signals, today it is possible to carry out more complex functions in a better manner and then communicate this information more precisely to the display or controlling device. Two-way communication among various instruments is possible due to the built-in facilities of serial communication in microcontrollers. Newer design of signal transmitters, converters and controllers use digital processing of signals. Use of microcontroller-based instruments makes the system more reliable, flexible and powerful with many more facilities to fulfill the needs of control systems.

II. CAPTURE/COMPARE/PWM (CCP) MODULES IN PIC 16F877
A Capture/Compare/PWM (CCP) module supports the measurement, control and the generation of pulsed signals with respect to time precisely. In capture mode, it is possible to transfer the contents of an internal 16-bit timer into a special function register, upon detection of a rising or falling edge. The compare mode generates an interrupt, or changes the status of an output pin, when timer 1 matches a predefined comparison value. Pulse Width modulation (PWM) mode allows generating a rectangular wave with programmable duty cycle at the user set frequency. There are two CCP modules in PIC 16F877, namely, CCP1 and CCP2. Both have almost similar operations in supporting capture, compare and PWM functions. Each of the CCP modules has a 16-bit capture register, a 16-bit compare register and a PWM
master/slave duty cycle register. CCP1CON register controls the operation of CCP1 module, whereas CCP2CON register controls the operation of CCP2 module. The capture/compare/PWM register (CCPR1) consists of CCPR1L and CCPR1H. Similarly, CCPR2 consists of two 8-bit registers CCPR2L and CCPR2H. CCPxCON is shown in figure (1) and table (1). RC2/CCP1 (Pin-17) and RC1/T1OSI/CCP2 (Pin-16) are the corresponding 16F877 pins used in capture, compare and PWM operations.

At the occurrence of an event (rising or falling edge) at pin RC2/CCP1 (or RC1/T1OSI/CCP2 as desired), a 16-bit capture register CCPR1 [CCPR1H: CCPR1L] capture the 16-bit value of TMR1 register. The event at pin RC2/CCP1 can be either a rising or falling edge, depends on bits in CCP1CON. Either CCP1 or CCP2 module, along with timer 1 can serve the purpose.

![Capture Mode Operation of CCPx Module](image3.png)

Consider the application requirement of capturing the contents of timer 1, when a rising edge appears at pin RC2/CCP1 of 16F877, as shown in figure (3).

![Capturing Rising Edge Event](image4.png)

In capture mode of CCP1 module, it is necessary to configure pin RC2/CCP1 as input. Further, CCP1CON bits CCP1M3, CCP1M2, CCP1M1, CCP1M0 define the capture event as shown in Table (1). For capture on the rising edge, the CCP1CON is loaded with B’00000010. After the capture operation, the contents of CCPR1L and CCPR1H are automatically copied into TMR1L and TMR1H, respectively. An interrupt flag bit CCP1IF is set. This flag is then cleared in the interrupt service routine by software instruction to allow next capture event condition to be detected. Timer 1 must be running in timer mode. In case of counter mode, capture operation is only possible, if the mode of the CCP module is synchronized counter mode. In asynchronous counter mode, it is not possible to use capture feature.

### Table (1): CCP1CON and CCP2CON Description

<table>
<thead>
<tr>
<th>Bit 7 Bit 6 Bit 5 Bit 4 Bit 3 Bit 2 Bit 1 0</th>
<th>Unimplemented</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCPxCON (bit 0)</td>
<td>PWM least significant bit, which defines the PWM duty cycle. These bits are not used in capture as well as compare mode.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CCPxCON (bit 0)</th>
<th>CCPxCON (bit 0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Capture/compare/PWM module OFF (most CCPx modules).</td>
</tr>
<tr>
<td>1</td>
<td>Capture mode, every falling edge.</td>
</tr>
<tr>
<td>1</td>
<td>Capture mode, every rising edge.</td>
</tr>
<tr>
<td>0</td>
<td>Capture mode, every 4th rising edge.</td>
</tr>
<tr>
<td>0</td>
<td>Capture mode, every 8th rising edge.</td>
</tr>
<tr>
<td>1</td>
<td>Compare mode, set output on match (CCPxIF bit is set).</td>
</tr>
<tr>
<td>0</td>
<td>Compare mode, clear output on match (CCPxIF bit is set).</td>
</tr>
<tr>
<td>0</td>
<td>Compare mode, generate software interrupt on match (CCPxIF bit is set, CCPx pin is unaffected).</td>
</tr>
<tr>
<td>0</td>
<td>Compare mode, trigger special event (CCPxIF bit is set, CCPx pin is unaffected).</td>
</tr>
<tr>
<td>1</td>
<td>Compare mode, trigger special event (CCPxIF bit is set, CCPx pin is unaffected).</td>
</tr>
<tr>
<td>0</td>
<td>PWM mode.</td>
</tr>
</tbody>
</table>

# III. CAPTURE MODE

The basic function performed in the capture mode by CCP1 or CCP2 module is that the exact point of the time occurrence of the input edge change can be detected. For this purpose, timer 1 must be running in timer mode.
IV. APPLICATION OF CAPTURE MODE
One typical application of the capture mode is that of pulse width measurement. The pulse input signal appearing at RC2/CCP1 will have one rising edge and one falling edge. Initially it is necessary to configure the capture module to detect the rising edge and save the captured value. Then it is possible to configure the CCP module to detect the falling edge. Pulse width can be obtained by subtracting the previously captured value from the current captured value. Note that if this pulse width is less than 65,535 µs and the oscillator frequency is 4 MHz, then it is possible that the corresponding count can fit into a 16-bit register. CCP modules play a very important role in precise timing generation and detection of occurrence of an event. This feature may be useful in a very broad spectrum of applications.

V. COMPARE MODE
The basic function of CCP module, along with timer 1, in compare mode is to change the pin status at a precisely controlled point of time. This is independent of the CPU operation, which may be busy in doing something else at that time. In compare mode of CCP module, the 16-bit contents of CCPR1 register are compared with TMR1 contents and whenever a match occurs, RC2/CCP1 pin is made high/low/unchanged depending on the setting of bits CCP1M3: CCP1M0 in CCP1CON and an interrupt flag CCP1IF is set. In this mode again pin RC2/CCP1 must be configured as an output. Timer 1 must run in timer mode or synchronous counter mode. The compare operation may not work in asynchronous counter mode. Figure (4) shows the compare mode operation.

VI. PULSE WIDTH MODULATION (PWM) MODE
Pulse width modulated outputs are needed in applications where the average value of the output variable is to be controlled. For example, in case of the electric heater power control, changing the duty cycle of the PWM output can control the average electric power supplied to the heater. Another application of PWM is in generating analog outputs or digital-to-analog conversion (DAC) function. In PIC 16F877 PWM mode RC2/CCP1 and RC1/CCP2 pins output a 10-bit resolution pulse width modulated waveform. To generate a rectangular waveform on pin RC2/CCP1, the pin is configured as output. PR2 register sets the PWM period. CCPR1L register and CCP1CON bits 5 and 4, define the duty cycle of PWM output. TMR2 prescale value is defined. T2CON then starts TMR2. Finally, CCP1 module is configured in PWM mode. Figure (5) shows the PWM functional blocks. The corresponding PWM waveform timing can be seen in figure (6).

![PWM Module Block Diagram](image)

![PWM Waveform Showing Period and Duty Cycle](image)

The duty cycle and period definitions are clear from the figure (6) itself. The PWM Period, Duty Cycle and Resolution are calculated by these formulas:
Period = [(PR2) + 1] × 4 × Tosc × (TMR2 Prescale Value)

Duty Cycle = (CCPR1L:CCP1CON<5:4>) × Tosc × (TMR2 Prescale value)

Resolution = \[\log \left(\frac{F_{OSC}}{F_{PWM}}\right)\]/[\log(2)] bits

In generating dc output using PWM, it is important to see how fast the average value changes. If the PWM period is shorter, the changes in the average value will be faster. If the frequency corresponding to the PWM period is \(F_{PWM}\), then the cutoff frequency of the low pass filter can be decided so that the fundamental \(F_{PWM}\) and its higher harmonics are filtered out and only the slowly varying dc component is allowed to pass through the filter. Further, the signal frequency must be lesser than the cutoff frequency of the filter. Figure (7) shows a filter circuit for such applications, where dc analog output is required.

![Figure](image)

Figure(7)

VII. CONCLUSION

Timers provide clock pulse to microcontrollers but timing is must to communicate with outside world. External events and their occurrence at the exact point of time and generation of precise timing at the output pins of the microcontroller on a real time basis is done by CCP module. A Capture/Compare/PWM (CCP) module supports the measurement, control and the generation of pulsed signals with respect to time precisely.

REFERENCES