LAB 3 - PERFORM COMPARE, CAPTURE AND PWM OPERATIONS USING PIC16F877A

Aim:

To perform the Compare, Capture and PWM mode operations using CCP module in PIC16F877A

Requirements:

i. **Hardware** – PIC16F877A, 20Mhz oscillator, capacitors -33pf, Oscilloscope, power supplies.

ii. **Software** – Proteus (simulation software), MPLAB IDE

Theory:

The PIC16F877A Microcontroller consists of a special module called Compare Capture module (CCP Module). This is a multi-purpose module that we can switch between 3 different modes of operation. At each mode of operation, this module can perform a specific task that could be useful for many applications. Each of the Capture/Compare/PWM (CCP) Modules contains a 16-bit register which can operate as a:

- 16-Bit Capture Register
- 16-Bit Compare Register
- PWM Duty Cycle Register

PIC16F877A Chip has two of identical CCP modules CCP1 & CCP2 , identical in structure and operation The 16-Bit Data Register for CCP modules is actually a couple of 8-Bit SFRs (CCPRxL-CCPRxH) where x maybe 0 or 1 for CCP1 & CCP2 modules.

Both the CCP1 & CCP2 module require a hardware timer as a resource for their operation. The hardware timer module being used for both of CCP modules is determined based on the mode of operation. The table below indicates which timer module is being used for each mode.

CCP Mode	TIMER Resource
Capture	Timer 1
Compare	Timer 1
PWM	Timer 2

This diagram displays the register associated with the CCP module that is CCPCON registers, it states the different configuration bits used for Capture/ Compare/PWM operations. The operation of both CCP1 & CCP2 modules is controlled via the CCPxCON Registers which is a of 8-Bit SFRs (CCP1CON & CCP2CON) respectively.

CCP1CON – CCP OPERATION REGISTER (ADDRESS: 17h)

U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	—	CCP1X	CCP1Y	CCP1M3	CCP1M2	CCP1M1	CCP1M0
bit 7							bit 0

bit 7-6 **Unimplemented**: Read as '0'

bit 5-4 **CCP1X:CCP1Y**: PWM Least Significant bits

Capture Mode
Unused

Compare Mode
Unused

PWM Mode
These bits are the two LSbs of the PWM duty cycle. The eight MSbs are found in CCPRxL.

bit 3-0 **CCP1M<3:0>**: CCPx Mode Select bits

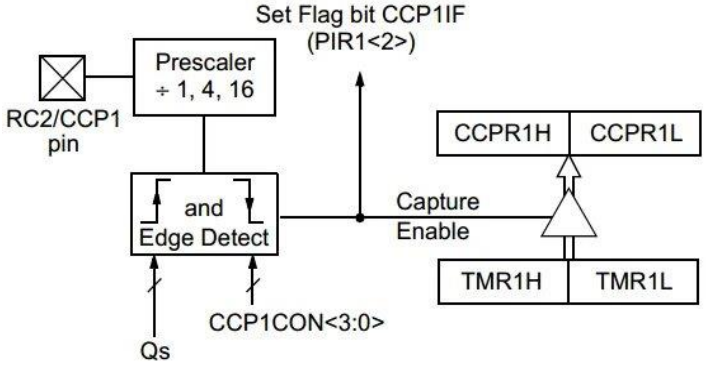
0000 = Capture/Compare/PWM off (resets CCP1 module)
0100 = Capture mode, every falling edge
0101 = Capture mode, every rising edge
0110 = Capture mode, every 4th rising edge
0111 = Capture mode, every 16th rising edge
1000 = Compare mode, set output on match (CCP1IF bit is set)
1001 = Compare mode, clear output on match (CCP1IF bit is set)
1010 = Compare mode, generate software interrupt on match (CCP1IF bit is set, CCP1 pin is unaffected)
1011 = Compare mode, trigger special event (CCP1IF bit is set; CCP1 resets TMR1
11xx = PWM mode

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
-n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

Capture: In Capture mode, the CCP module captures the 16-Bit value of Timer1 module in the CCPRx register upon a specific user-defined event. While the Timer1 module is running in either timer-mode or synchronized counter-mode. The event that fires a capture signal can be :

- Every rising edge
- Every falling edge
- Every 4th rising edge
- Every 16th rising edge

The type of event that fires the capture signal is configured by the 4-control bits (CCP1M3:CCP1M0)



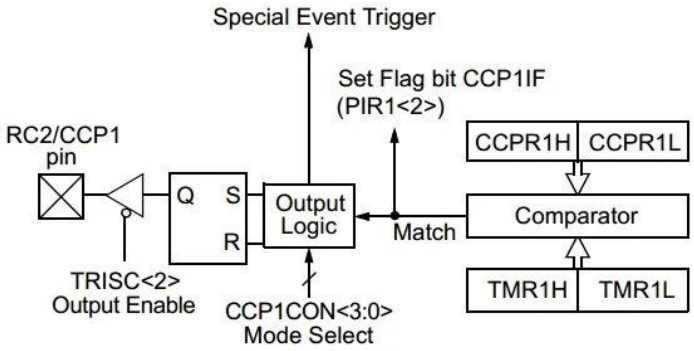
Configuration Steps for Capture Operations

1. Set Timer1 module to operate in timer/counter mode.
2. Turn ON Timer1 module
3. Configure the CCP1 module to operate in Capture Mode (using CCP1CON register).
4. Choose the event on which a capture occurs (using CCP1CON register – CCP1Mx Bits).
5. Configure the CCP1 interrupt
6. Write The ISR Handler for CCP-Capture Interrupt

Compare: In Compare Mode, the 16-Bit CCPR1 (CCPR1H:CCPR1L) register is constantly compared against the TMR1 register. When a match occurs, The CCP1 pin (RC2) is:

- Driven Low
- Driven High
- Remains Unchanged

The type of event that fires the capture signal is configured by the 4-control bits (CCP1M3:CCP1M0)



Configuration Steps for Capture Operations

1. Set Timer1 module to operate in timer or counter mode
2. Turn ON Timer1 module
3. Preload The CCPR1 Register with the desired value (from calculations)
4. Configure the CCP1 module to operate in Compare Mode (using CCP1CON register)
5. Choose the event on the RC2 pin when a match occurs (using CCP1CON register – CCP1Mx Bits)
6. Configure the CCP1 interrupt
7. Write The ISR Handler for CCP-Capture Interrupt

Pulse Width Modulation (PWM): - PWM is a digital signal which is most commonly used in control circuitry. This signal is set high (5v) and low (0v) in a predefined time and speed. The time during which the signal stays high is called the "on time" and the time during which the signal stays low is called the "off time". There are two important parameters for a PWM.

i. **Duty cycle of the PWM**
The percentage of time in which the PWM signal remains HIGH (on time) is called as duty cycle. If the signal is always ON it is in 100% duty cycle and if it is always off it is 0% duty cycle.

$$Duty\ cycle = \frac{T_{on}}{T_{on} + T_{off}}$$

ii. Frequency of a PWM:

The frequency of a PWM signal determines how fast a PWM completes one period. One Period is complete ON and OFF of a PWM signal as shown in the above figure.

PWM signals can be generated in our PIC Microcontroller by using the CCP (Compare Capture PWM) module. The resolution of our PWM signal is 10-bit, that is for a value of 0 there will be a duty cycle of 0% and for a value of 1024 (2^10) there be a duty cycle of 100%. There are two CCP modules in the PIC MCU (CCP1 and CCP2), this means two PWM signals on two different pins (pin 17 and 16) can be generated. The registers associated with CCP module are,

- CCP1CON (CCP1 control Register)
- T2CON (Timer 2 Control Register)
- PR2 (Timer 2 modules Period Register)
- CCPR1L (CCP Register 1 Low)

Prescaler is set by making the bit T2CKPS0 as high and T2CKPS1 as low the bit TMR2ON is set to start the timer.

T2CON: TIMER2 CONTROL REGISTER (ADDRESS 12h)

U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	TOUTPS3	TOUTPS2	TOUTPS1	TOUTPS0	TMR2ON	T2CKPS1	T2CKPS0
bit 7							bit 0

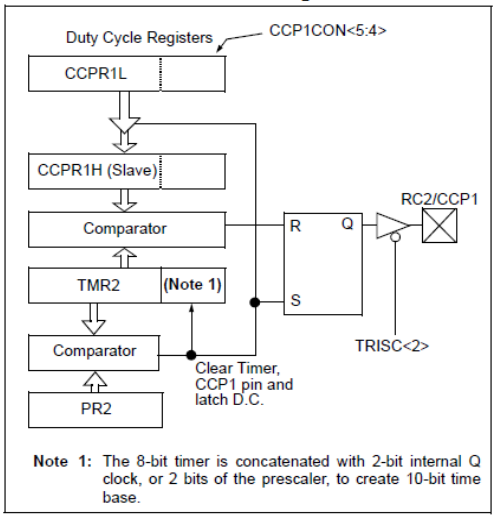
bit 1-0 **T2CKPS1:T2CKPS0**: Timer2 Clock Prescale Select bits

00 = Prescaler is 1
01 = Prescaler is 4
1x = Prescaler is 16

The desired frequency has to be set in the PR2 register, the formulae is , Here, _XTAL_Freq is 20Mhz

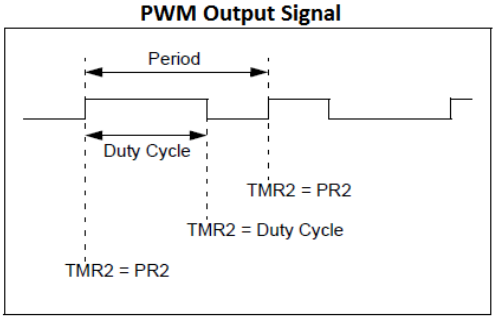
$$PR2 = \frac{\_XTAL\_Freq}{freq * 4 * TMR2prescale} - 1$$

PWM Block Diagram



Note 1: The 8-bit timer is concatenated with 2-bit internal Q clock, or 2 bits of the prescaler, to create 10-bit time base.

PWM Output Signal



Procedure:

Step 1: - Open the proteus simulator and select the components required and connect the circuit as per the circuit diagram**.**

Step 2: - After successful connection of the circuit, open MPLab IDE to program the controller.

Step 3: - Select the configuration bit, desired operation Capture/Compare/PWM. From the configuration steps

Step 4: - Write the ISR handler for Compare and Capture

Step 5: -. Configure the CCPCON register from the data sheet for desired output

CAPTURE MODE OPERATION

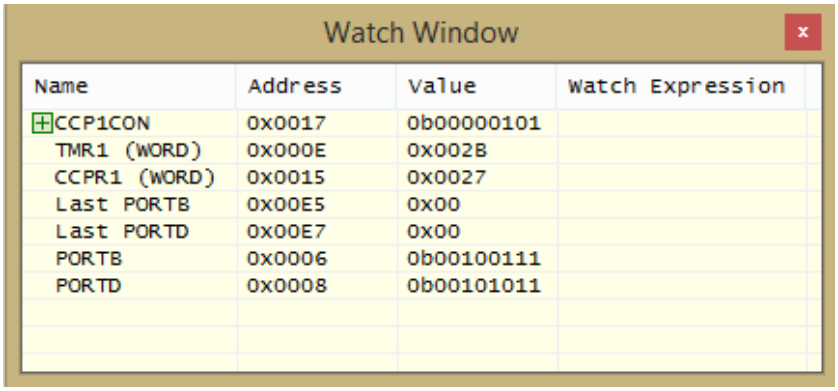
In this experiment the Timer 1 is configured in counter mode and is incremented by input pulse for a push button. When the CCP1(RC2) is driven HIGH (Rising edge), the TMR1 counts are written to the Port B (blinks the led in the 8bit binary sequence)

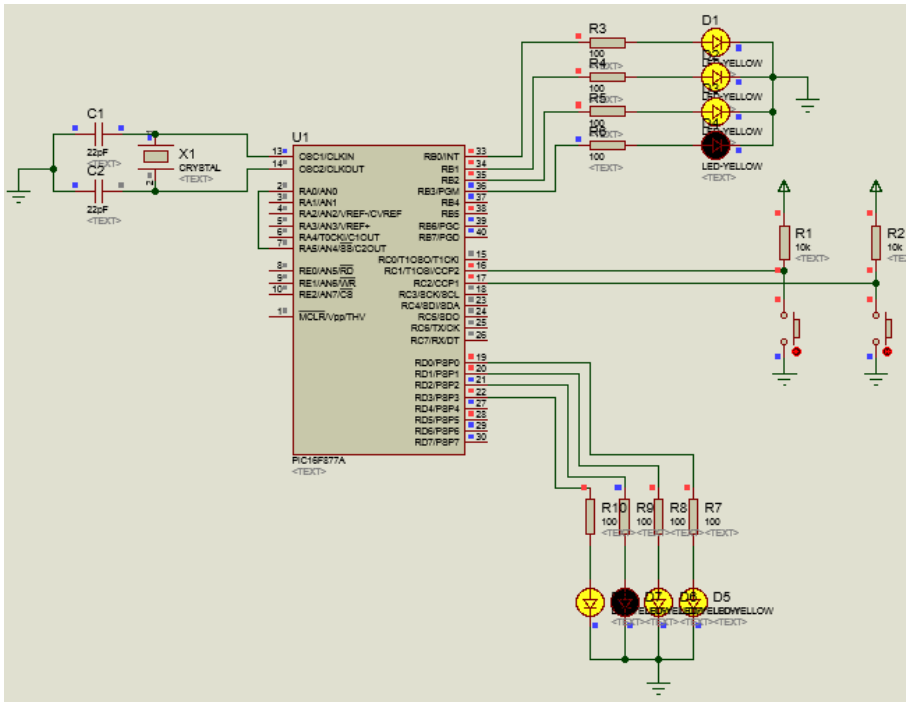
Code:

```
/*
 * File:   capture.c
 * Author: Guga
 */


// 'C' source line config statements

// CONFIG
#pragma config FOSC = HS
#pragma config WDTE = OFF
#pragma config PWRTE = OFF
#pragma config BOREN = ON
#pragma config LVP = OFF
#pragma config CPD = OFF
#pragma config WRT = OFF
#pragma config CP = OFF

#include <xc.h>

#define _XTAL_FREQ 20000000 //XTAL crystal FREQ


void main(void)
{
  // PORTB as out for Capture Operation (CCPR1 register)
  TRISB = 0x00; // Set output
  PORTB = 0x00; // Initial State
  // PORTD as out for TIMER Operation (TMR1 register)
  TRISD = 0x00; // Set output
```

```
  PORTD = 0x00; // Initial State
  // Initializing Timer one in Counter mode
  TMR1 = 0;
  T1CKPS0 = 0;
  T1CKPS1 = 0;
  TMR1CS = 1;
  T1OSCEN = 1;
  T1SYNC = 0;
  TMR1ON = 1;
  // Initializing CCP1 module for capture operation
  CCP1M0 = 1;
  CCP1M1 = 0;
  CCP1M2 = 1;
  CCP1M3 = 0;
  // Enable CCP1 Interrupt
  CCP1IE = 1;
  PEIE = 1;
  GIE = 1;
  // Create The Main Loop Of The System
  while (1)
  {
    // Read & Print Out The TMR1 Counts
    PORTD = TMR1;
   // On rise of interrupt ISR will be executed here
  }
  return;
}

// ISR Handler
void __interrupt() isr(void)
{
  if (CCP1IF)
  {
    // when Capture event Occurs, the CCPR1 register's value is
written to PORTB
    PORTB = CCPR1;
    CCP1IF = 0;
  }
}
```

OUTPUT

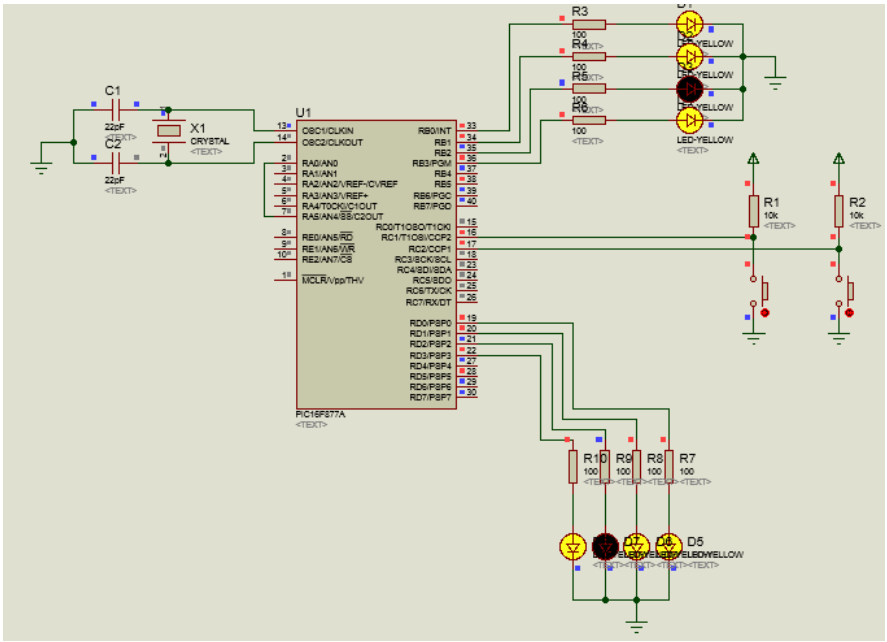




On rising edge is driven HIGH

Watch Window

Name	Address	Value	Watch Expression
⊞CCP1CON	0x0017	0b00000101	
TMR1 (WORD)	0x000E	0x002B	
CCPR1 (WORD)	0x0015	0x002B	
Last PORTB	0x00E5	0x00	
Last PORTD	0x00E7	0x00	
PORTB	0x0006	0b00101011	
PORTD	0x0008	0b00101011	



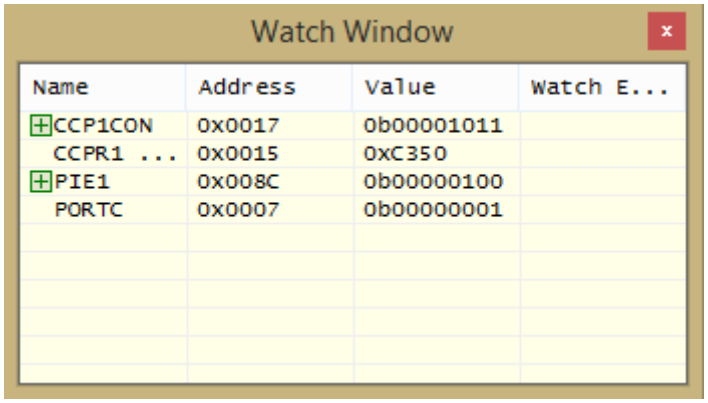
COMPARE MODE OPERATION

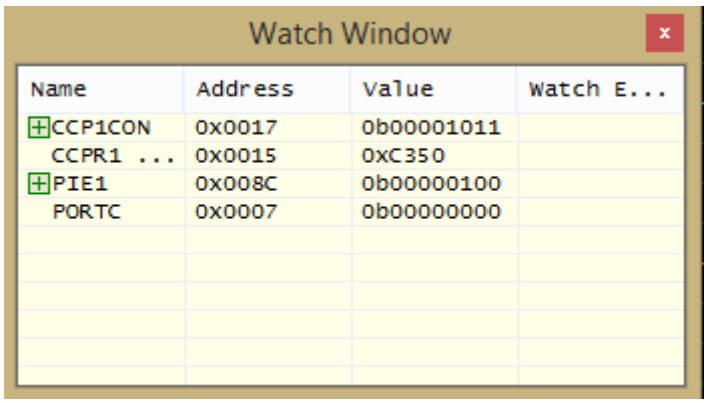
In this experiment, the timer1 is used to generate a square wave of 50Hz with 50% duty cycle. The Ton off the square wave is 10ms (which is approximated to 50,000 counts from 0) and the Toff is 10ms again. The CCPR1 register is written with the value 50000 (0xC350). An interrupt is raised whenever the Timer 1 value matches the CCPR1 register and the LED is toggled (ideally every 10ms the LED is toggled)

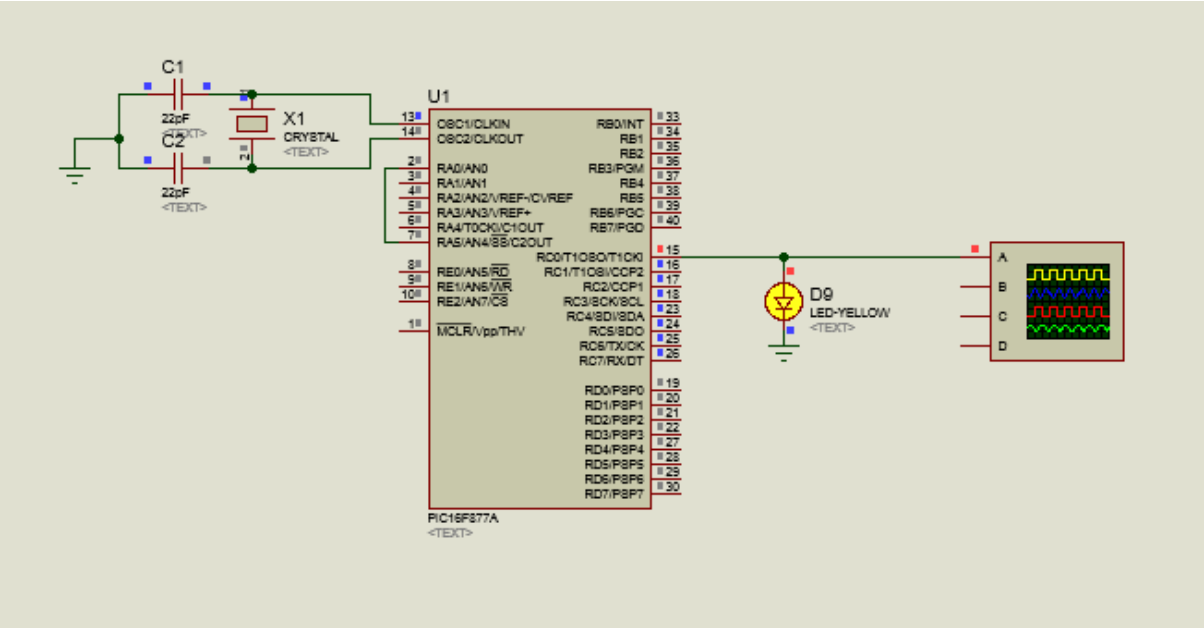
```
/*
 * File:   compare.c
 * Author: Gopika
 *
 * Created on 15 December, 2021, 5:36 PM
 */
// CONFIG
#pragma config FOSC = HS
#pragma config WDTE = OFF
#pragma config PWRTE = OFF
#pragma config BOREN = ON
#pragma config LVP = OFF
#pragma config CPD = OFF
#pragma config WRT = OFF
#pragma config CP = OFF

#include <xc.h>

#define _XTAL_FREQ 20000000 //XTAL crystal FREQ

void main(void)
{
    // PORTC as out for Compare Operation (CCPR1 register)
    PORTC = 0;
    TRISC = 0;
    //Setting up CCPCON register and enabling interrupt
    CCP1CON = 11;
    CCP1IE = 1;
    GIE = 1;
    PEIE = 1;
    // Compare Values written to CCPR1 register
    CCPR1H = 0xC3;
    CCPR1L = 0x50;
    //CCPR1 = 0xC350 = 50000
    // Initializing Timer 1
    T1CON = 0x01; //Prescaler 1:1, start Timer 1
    while(1){
    //Do whatever else is required
    }
}

void __interrupt() isr(void)
{
  if (CCP1IF)
```

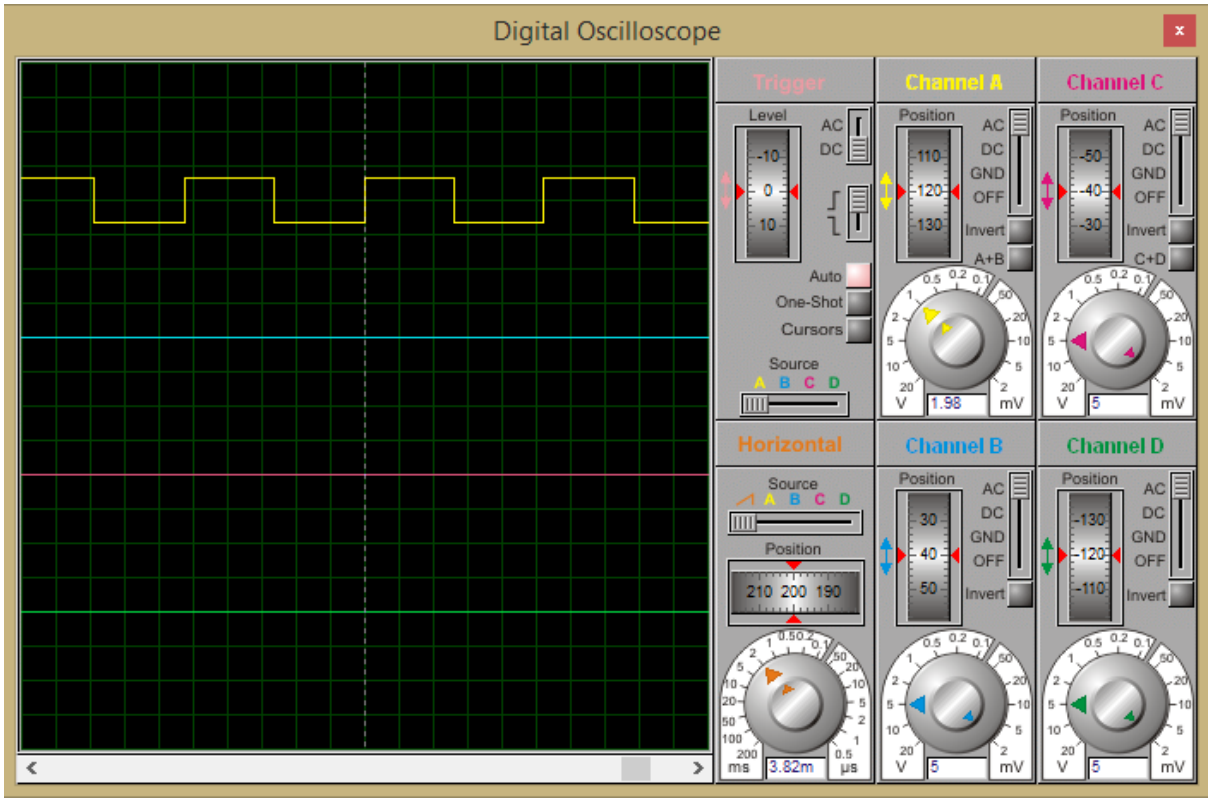
```
    {
        RC0 = ~RC0; // Toggle Port RC0 on match event
        CCP1IF = 0; // Clearing the Register Flag
    }
}
```

OUTPUT








Digital Oscilloscope
Trigger
Level
AC
DC
Auto
One-Shot
Cursors
Source
A B C D
Channel A
Position
AC
DC
GND
OFF
Invert
A+B
1.98
mV
Channel C
Position
C+D
5
mV
Horizontal
Source
A B C D
Position
210 200 190
3.82m
ms
µs
Channel B
Position
5
mV
Channel D
Position
5
mV

PWM MODE OPERATION

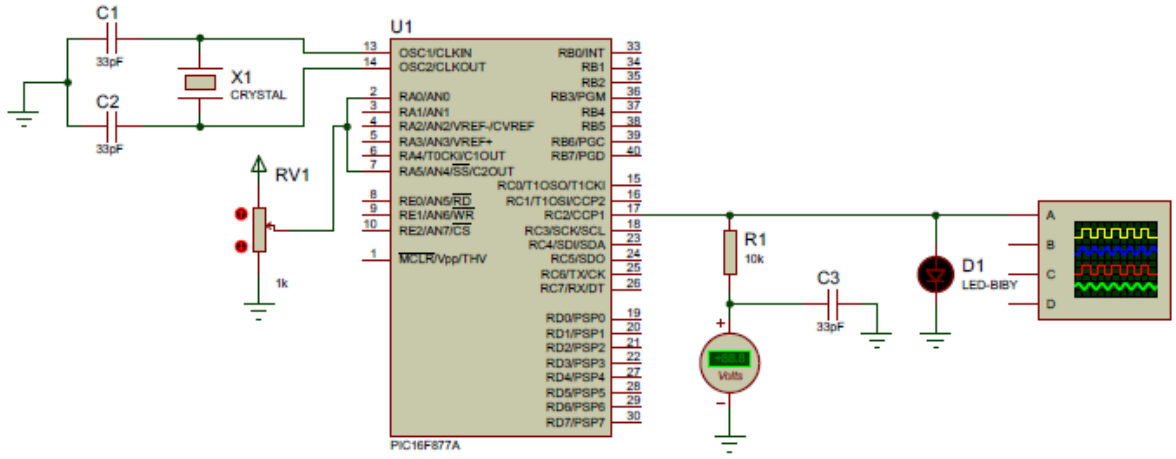
In this experiment CCP module is configured to operate in PWM mode, Analog voltage of 0-5v from a potentiometer which is connected to ADC port of the controller is read and mapped to 0-1024 using our ADC module. PWM signal with frequency 5000Hz is generated and its duty cycle is varied based on the input Analog voltage. That is 0-1024 will be converted to 0%-100% Duty cycle by writing the value to the CCP1 register.

Code:

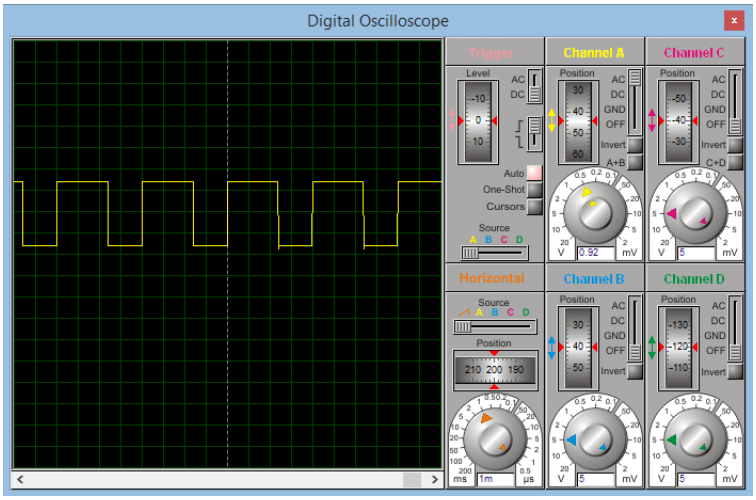
```
// CONFIG
#pragma config FOSC = HS
#pragma config WDTE = OFF
#pragma config PWRTE = ON
#pragma config BOREN = OFF
#pragma config LVP = ON
#pragma config CPD = OFF
#pragma config WRT = OFF
#pragma config CP = OFF

#define _XTAL_FREQ 20000000
#define TMR2PRESCALE 4

#include <xc.h>

long PWM_freq = 5000;

PWM_Initialize()
{
  PR2 = (_XTAL_FREQ/(PWM_freq*4*TMR2PRESCALE)) - 1;
    CCP1M3 = 1; CCP1M2 = 1;  //Configure the CCP1 module
    T2CKPS0 = 1;T2CKPS1 = 0; TMR2ON = 1;
      //Configure the Timer module
    TRISC2 = 0; // make port pin on C as output
}

PWM_Duty(unsigned int duty)
{
      if(duty<1023)
  {

    duty = ((float)duty/1023)*(_XTAL_FREQ/(PWM_freq*TMR2PRESCALE));
// On reducing //duty = (((float)duty/1023)*(1/PWM_freq)) /
((1/_XTAL_FREQ) * TMR2PRESCALE);
    CCP1X = duty & 1; //Store the 1st bit
    CCP1Y = duty & 2; //Store the 0th bit
    CCPR1L = duty>>2;// Store the remining 8 bit
  }
}
```

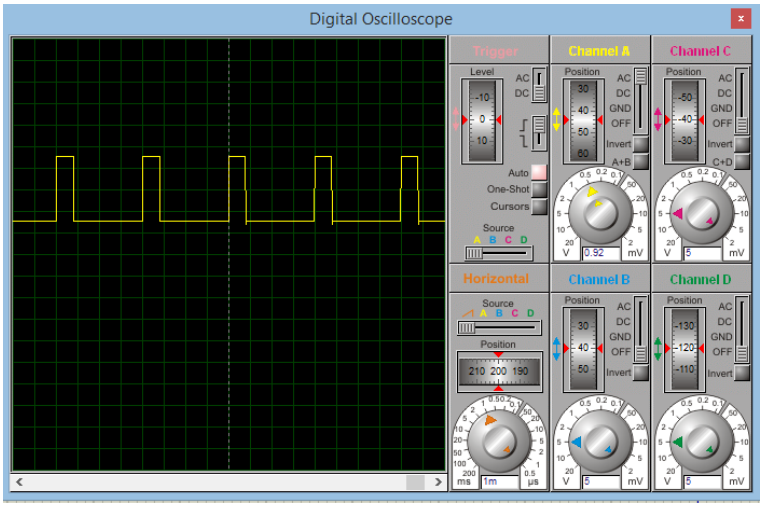
```
void ADC_Initialize()
{
  ADCON0 = 0b01000001; //ADC ON and Fosc/16 is selected
  ADCON1 = 0b11000000; // Internal reference voltage is selected
}
unsigned int ADC_Read(unsigned char channel)
{
  ADCON0 &= 0x11000101;
  ADCON0 |= channel<<3;
  __delay_ms(2);
  GO_nDONE = 1;
  while(GO_nDONE); //Wait for A/D Conversion to complete
  return ((ADRESH<<8)+ADRESL); //Returns Result
}

void main()
{
    int adc_value;
  TRISC = 0x00; //PORTC as output
  TRISA = 0xFF; //PORTA as input
  TRISD = 0x00;
  ADC_Initialize(); //Initializes ADC Module
  PWM_Initialize();  //This sets the PWM frequency of PWM1

  do
  {
    adc_value = ADC_Read(4); //Reading Analog Channel 0
    PWM_Duty(adc_value);

      __delay_ms(50);

  }while(1); //Infinite Loop

}
```

Circuit Diagram:



PWM Waveform:





RESULT:

The CCP module of PIC16F877A is studied and verified for the operations of Compare/ Capture/ PWM modes.