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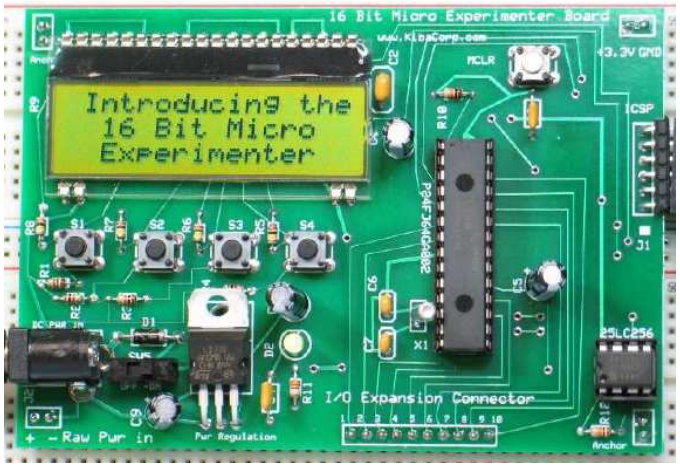


First Experiments Part 3

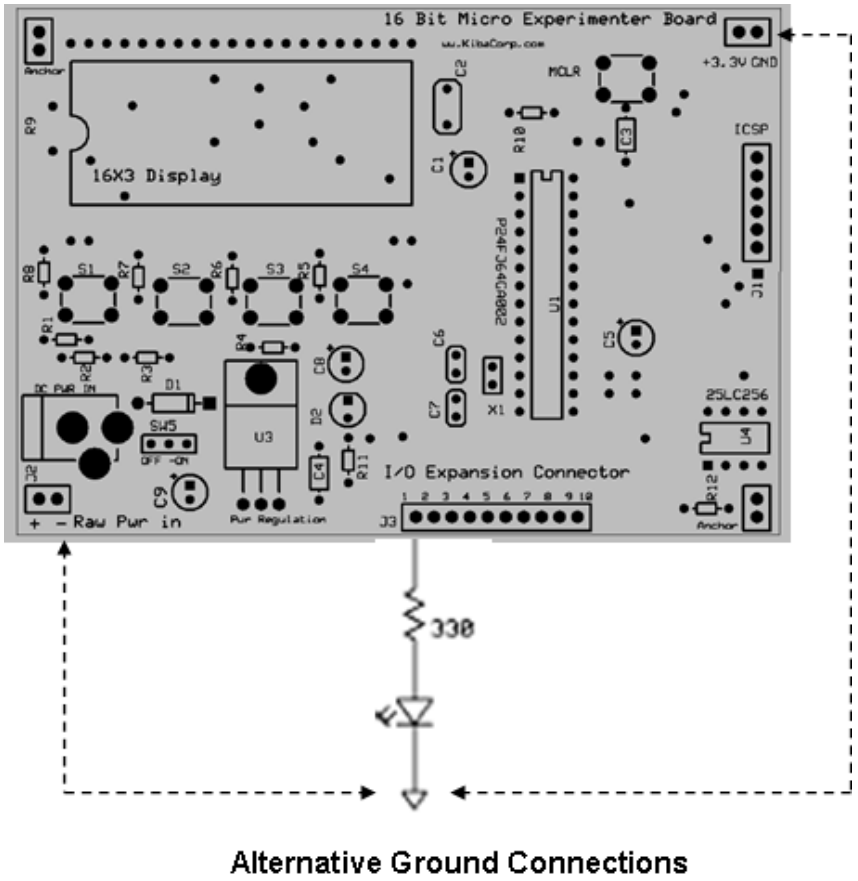
1. **“CCP ” and PPS**
2. **“CCP and ADC”**

Contents

- Directions and descriptions for beginner 16 bit Experimenter starting experiments
  - Each experiment builds on another
  - Theme has been LED light control
- Recommend review of “Quick Start Guide” (available on www.kibacorp.com) to better understand tools installation
- Good references
  - Microchip datasheet for PIC24F64GA002 http://www.microchip.com/wwwproducts/Devices.aspx?dDocName=en026374#1
  - Di Jasio Book “Programming 16 bit Microcontroller in C” http://www.flyingthepic24.com/

LED Light Dimming using CCP

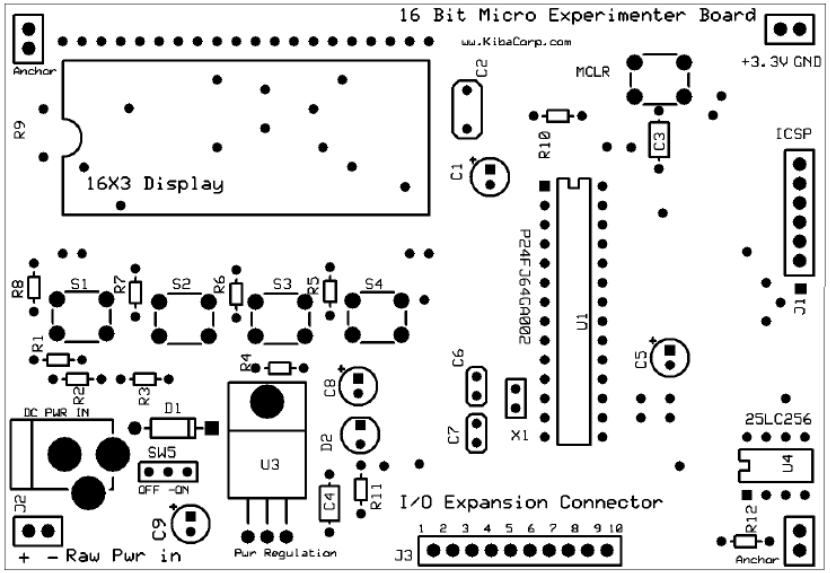
- Use a digital peripheral within the PIC24F to pulse width modulate +3.3V to 0 V DC to LED thereby controlling its brightness
- Similar hardware hook up to earlier experiments
- We will use software to change functionality of pin 1 of expansion Bus



Alternative Ground Connections

Many possible configurations for PIN 1?

- Pin 1 can have many configurations
- Normal PIC24F Chip level Pin assignments
  - Analog:
    - AN14 analog ADC input channel 14
    - Comparator input (C1IN)
  - Digital
    - SDA2 (I2C data in)
    - CN16 –change detect 16
    - Simple Digital Port I/O Port B pin 2 (RB2)
- Peripheral programmable Assigned using RP2
  - **Redirect** in/**out** of any other on chip digital peripherals (UART,SPI, **CCP**) to this pin
  - ***We are interested in using RP2 as a CCP OC digital PWM function***



J3 I/O Expansion Bus

J3 I/O bus PIN	Normal Assigned PIN	Programmable PIN
PIN 1	AN4,C1IN-,SDA2,CN6,RB2	RP2
PIN 2	AN5,C1IN+,SCL2,CN7,RB3	RP3
PIN 3	SDA1,CN27,RB5	RP5
PIN 4	INT0,CN23,RB7	RP7
PIN 5	SCL1/CN22/RB8	RP8
PIN 6	SDA1/CN21/RB9	RP9
PIN 7	AN12/CN14,RB12	RP12
PIN 8	AN11/CN13,RB13	RP13
PIN 9	AN10,CVREF,RTCC,CN12,RB14	RP14
PIN 10	AN9,CN11,RB15	RP15

Rules for Pin Priorities

- Both analog and PPS are high priority but require a SW configuration
  - We will examine how this is done configuring RP2 PIN 1 of Exp 16 Expansion I/O bus as a CCP OC PWM output
- Next priority is fixed digital peripherals—again they need to be SW configured
- Digital I/O is enabled during power up –*but is configured as input*

- **Peripheral priorities:**

1.	**Analog Functions**	ANx, Vref+/-
2.	**PPS Outputs**	UART TX, SDO, OC
3.	**PPS Inputs**	UART RX, SDI, IC
4.	**Fixed Digital Peripheral Outputs**	I^2C™, CN, I/O Ports
5.	**Fixed Digital Peripheral Inputs**	I^2C, CN, I/O Ports

Uses of Capture Compare Peripheral (CCP)

- Multiple Capabilities
  - Non-software intensive
  - Capture and Input Compare (IC)
    - Measure the period of an external square wave with or without averaging
    - Measuring Pulse width of external signals
  - Output Compare (OC)
    - Can generate PWM and other specific modulation formats

Output Compare and PWM

- PIC24F64GA002 has 5 CCP peripherals
- Timer 2 or Timer 3 as time base
- 16 Bit Compare
- We will configure CCP1 OC1 for PWM generation

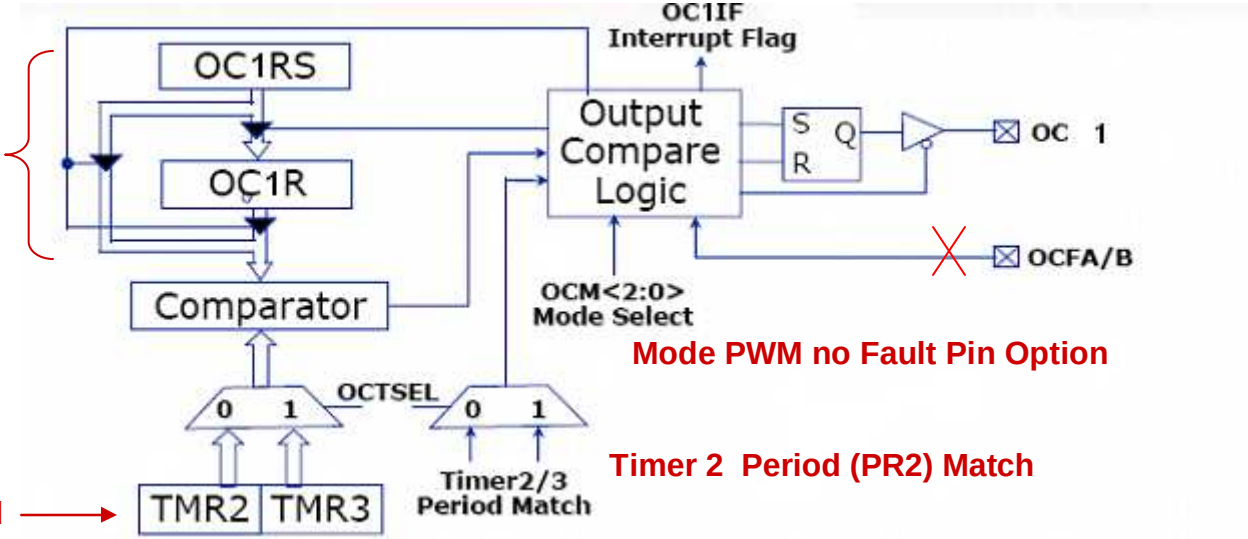
Uses of PWM

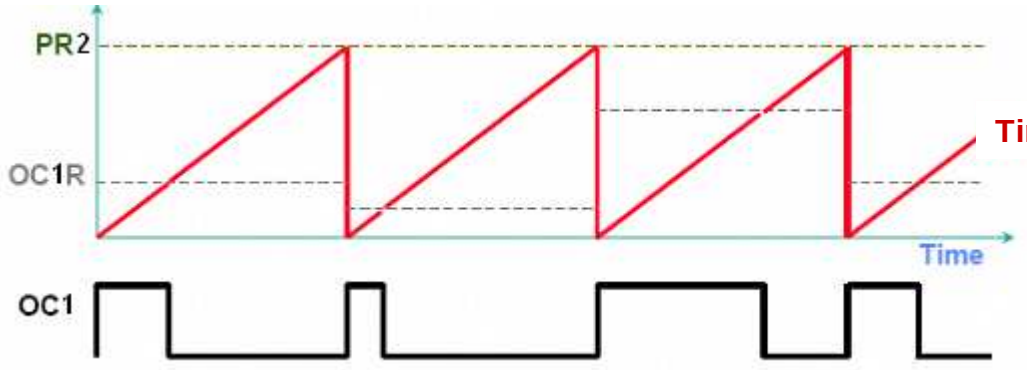
- Can generate controls for motors
- Can generate through addition of a LOW PASS Filter analog signals
- Can generate tones with a buzzer
- Can work in light dimming

Output Compare OC1

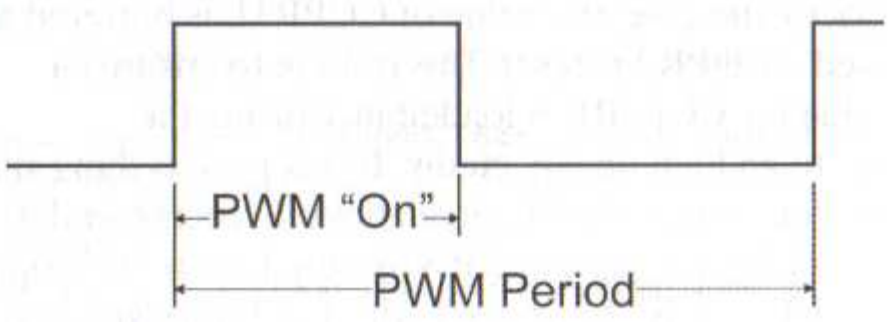
OC1RS sets Pulse Width

OC1RS
auto loads
OC1R
every PR2





OC 1 PWM Output



Duty Cycle = (PWM "On" time) / PWM period

If PWM waveform swings between +3.3 to 0 Volts then the Duty Cycle determines the average DC delivered to a load

--so we can control DC voltage to LED thereby controlling its brightness!

Peripheral Pin select

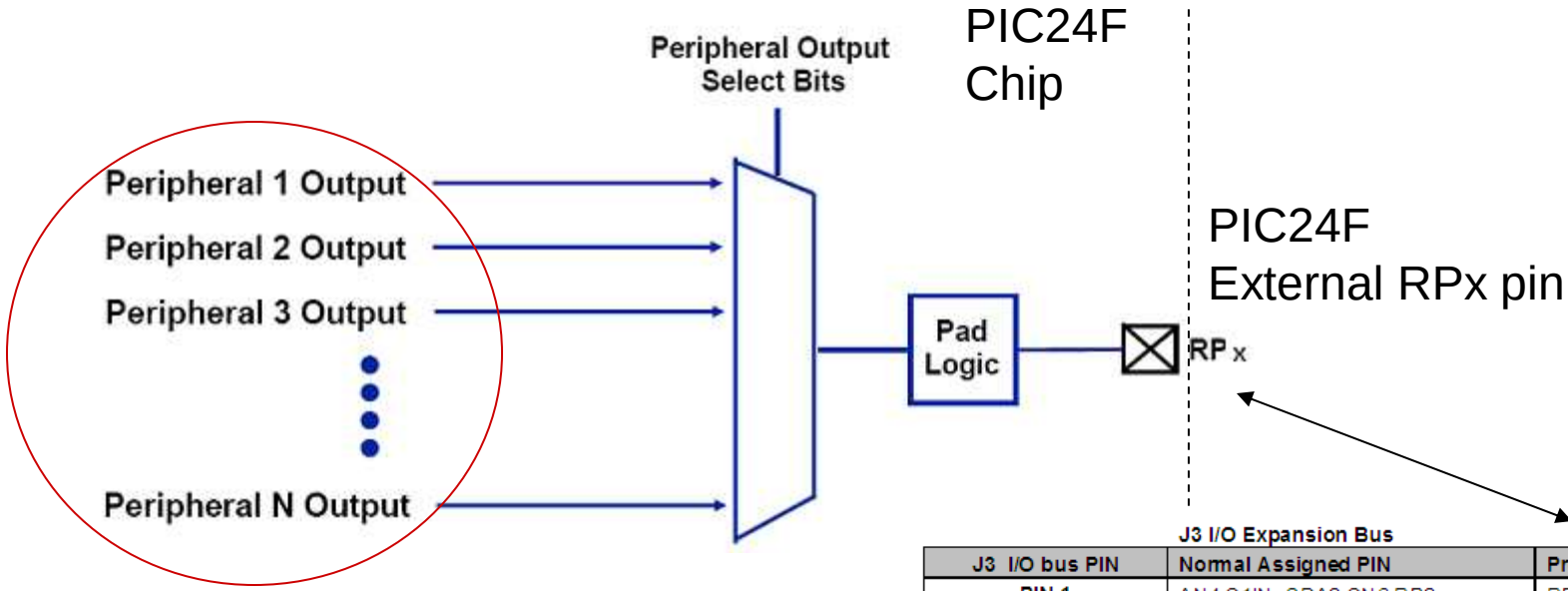
- With smaller Chip packages (with a large number of internal peripherals) not all the internal peripherals can be assigned to pins on the package
- Peripheral Pin Select of PPS is pin multiplexing that allows the user to select the pin out of digital functions
- Allows optimal usage of on-chip peripherals
- Allows pin redefinition via software

CCP 1 OC1 output will need to be mapped to Pin 1 I/O Exp Bus using PPS

PPS Implementation Details

- **Any function can remap to any RP pin**
  - Multiple functions on one pin is supported
- **Inputs vs. Outputs**
  - Inputs assign a pin to a specific peripheral
  - Outputs assign a peripheral to a specific pin
- **Pinout is set in software**
  - Allows on-the-fly configuration or one-shot configuration

Remappable Outputs



1 of 5 CCP Out , 1 of 2 UART TX ,
1 of 2 SPI CLK or SDO,
1 of 2 Comparator Out

J3 I/O Expansion Bus

J3 I/O bus PIN	Normal Assigned PIN	Programmable PIN
PIN 1	AN4,C1IN-,SDA2,CN6,RB2	RP2
PIN 2	AN5,CIN+,SCL2,CN7,RB3	RP3
PIN 3	SDA1,CN27,RB5	RP5
PIN 4	INT0,CN23,RB7	RP7
PIN 5	SCL1/CN22/RB8	RP8
PIN 6	SDA1/CN21/RB9	RP9
PIN 7	AN12/CN14,RB12	RP12
PIN 8	AN11/CN13,RB13	RP13
PIN 9	AN10,CVREF,RTCC,CN12,RB14	RP14
PIN 10	AN9,CN11,RB15	RP15

16 bit Exp Expansion Bus

Experimenter 16 Expansion I/O

- Each of the 10 pins has both fixed and programmable functionality
- RPx indicates the PPS designator for the Pin

J3 I/O Expansion Bus

J3 I/O bus PIN	Normal Assigned PIN	Programmable PIN
PIN 1	AN4,C1IN-,SDA2,CN6,RB2	RP2
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PIN 8	AN11/CN13,RB13	RP13
PIN 9	AN10,CVREF,RTCC,CN12,RB14	RP14
PIN 10	AN9,CN11,RB15	RP15

Remappable Peripheral Outputs

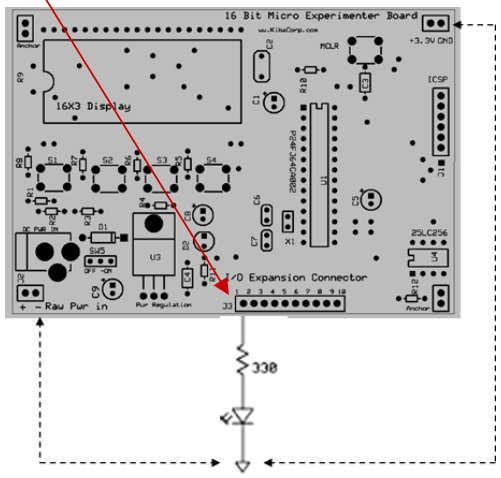
Function	Output Function Number(1)	Output Name
NULL(2)	0	NULL
C1OUT	1	Comparator 1 Output
C2OUT	2	Comparator 2 Output
U1TX	3	UART1 Transmit
$\overline{\text{U1RTS}}$(3)	4	UART1 Request To Send
U2TX	5	UART2 Transmit
$\overline{\text{U2RTS}}$(3)	6	UART2 Request To Send
SDO1	7	SPI1 Data Output
SCK1OUT	8	SPI1 Clock Output
SS1OUT	9	SPI1 Slave Select Output
SDO2	10	SPI2 Data Output
SCK2OUT	11	SPI2 Clock Output
SS2OUT	12	SPI2 Slave Select Output
OC1	18	Output Compare 1
OC2	19	Output Compare 2
OC3	20	Output Compare 3
OC4	21	Output Compare 4
OC5	22	Output Compare 5

This is the peripheral we select for our experiment Output function # 18

J3 I/O Expansion Bus

J3 I/O bus PIN	Normal Assigned PIN	Programmable PIN
PIN 1	AN4,C1IN-,SDA2,CN6,RB2	RP2
PIN 2	AN5,C1IN+,SCL2,CN7,RB3	RP3
PIN 3	SDA1,CN27,RB5	RP5
PIN 4	INT0,CN23,RB7	RP7
PIN 5	SCL1/CN22/RB8	RP8
PIN 6	SDA1/CN21/RB9	RP9
PIN 7	AN12/CN14,RB12	RP12
PIN 8	AN11/CN13,RB13	RP13
PIN 9	AN10,CVREF,RTCC,CN12,RB14	RP14
PIN 10	AN9,CN11,RB15	RP15

This is the pin that We want to map it to OC1 of using RP2



Alternative Ground Connections

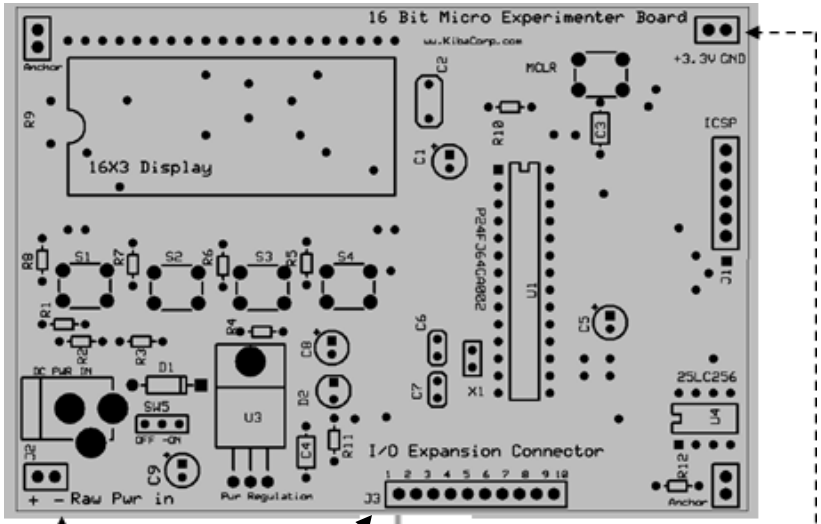
Making it Happen

```
//Required Code Statement
// 'C' structure
RPOR1bits.RP2R =18;
```

SFR RPOR1
Controls RP2/RP3
PPS assignments

RP2
Configure
Bits with
RPOR1

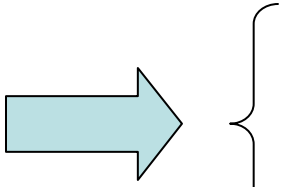
PPS assignment
Function # 18 ->OC1



This now transforms from a digital output to an CCP module generating PWM

Initializing a PPS Application

- Initialize the pin out by mapping pins to desired peripheral input/output functions
  - Unlock
  - Map RPx pins -> Peripheral Input Functions
  - Map RPx pins -> peripheral Output Functions
  - Lock the RPx SFR(s) using ‘lock sequence
- Configure peripherals later in your code before use.



```
45  main()
46  {
47
48  __builtin_write_OSCCONL(OSCCON & 0xbf) ; //clear bit 6  unlock
49
50  //input//  PPS first -there are none
51
52  //output // PPS second
53  //do PPS on RB2 pin 1 of I/O EXP  to make it OC1 output
54      RPOR1bits.RP2R = 18;        // Make Pin 1 I/O EXP bus (RP2)  OC1
55
56  __builtin_write_OSCCONL(OSCCON | 0x40) ; //set bit 6 lock
57
58      int setting =DutyCycle100percent ;
59
60      setPWM(setting);
61
62      while(1);
63  } // main
64
```

CCP Code

```
16  #define NoDutyCycle           0
17  #define DutyCycle12percent    0x03ff/8
18  #define DutyCycle25percent    0x03ff/4
19  #define DutyCycle50percent    0x03ff/2
20  #define DutyCycle100percent   0x03ff
21
22  void turnoff(void) {
23      //turn off pin 1 I/O EXP  RB2, Timer2 and any OC1 configuration on this pin
24      T2CON =0;
25      OC1CON =0x0000;
26      TRISBbits.TRISB2 = 1;
27
28  }
29  void turnon(int setting) {
30          //turn on pin 1 I/O EXP RB2, Timer2 and any OC1 configuration on this pin
31      PR2=DutyCycle100percent ;
32      TMR1 =0;
33      OC1R =setting;
34      OC1RS =setting;
35      OC1CON = 0x0006;  //timer2 and edge aligned PWM
36      T2CON =0x8000;
37
38  }
39  void setPWM(int setting) {
40
41  turnoff();
42  turnon(setting);
43  }
44
45  main()
46  {
47
48  __builtin_write_OSCCONL(OSCCON & 0xbf) ; //clear bit 6  unlock
49
50  //input//  PPS first -there are none
51
52  //output // PPS second
53  //do PPS on RB2 pin 1 of I/O EXP  to make it OC1 output
54      RPOR1bits.RP2R = 18;        // Make Pin 1 I/O EXP bus (RP2)  OC1
55
56  __builtin_write_OSCCONL(OSCCON | 0x40) ; //set bit 6 lock
57
58      int setting =DutyCycle100percent ;
59
60      setPWM(setting);
61
62      while(1);
63  } // main
```

CCP Experiment

- Map red led to output compare 1 to perform PWM on led thereby controlling its brightness
- Open Loop.mcp
- Examine source
- What is the RPX pin are we configuring?
- Where does the PPS occur?
  - Note lock and unlock sequences
- What is the initial duty cycle of the PWM?
  - Compare PR2 with OC2RS
- Select Debug to PICKIT2
- Build, download and Run
- Verify operation
- Change duty cycle, build, download, run and notice effects on LED
  - (Brightness should be changing)

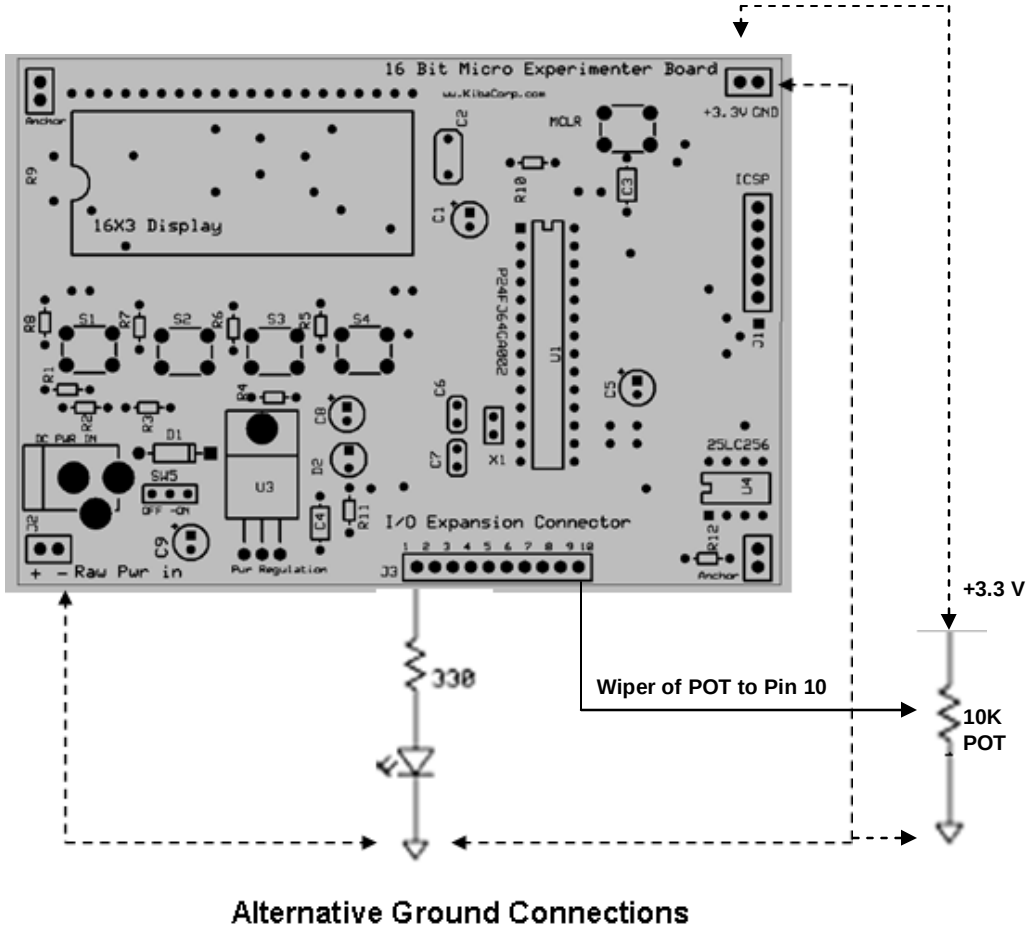
```
#define NoDutyCycle           0
#define DutyCycle12percent    0x03ff/8
#define DutyCycle25percent    0x03ff/4
#define DutyCycle50percent    0x03ff/2
#define DutyCycle100percent   0x03ff
```

```
int setting =DutyCycle100percent ;

setPWM(setting);
```

LED Light Dimming using CCP and ADC

- Use a digital peripheral within the PIC24F to pulse width modulate +3.3V to 0 V DC to LED thereby controlling its brightness
- Similar hardware hook up to earlier experiments but we are now adding a 10K pot as shown
- We will use Pin 1 as a OC1 for PWM of LED and Use Pin 10 as a analog input to control duty cycle of PWM thought POT setting
- As you move wiper CW or CCW ADC readings will be placed in OC1 OC1RS to control pulse width. Reading should be controlled between 0-0x3ff or 0 to 100% duty cycle



ADC

- The PIC24 Analog to Digital Converter (ADC) is a 10 bit converter that has up to 11 input channels and performs conversion up to 500K per sec.
- With the Experimenter *5 of these 11 channels are available* to as ADC inputs with the I/O Expansion Bus.
- **They are I/O expansion pins 1, 7, 8, 9, and 10**.

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PIN 4	INT0,CN23,RB7	RP7
PIN 5	SCL1/CN22/RB8	RP8
PIN 6	SDA1/CN21/RB9	RP9
PIN 7	AN12/CN14,RB12	RP12
PIN 8	AN11/CN13,RB13	RP13
PIN 9	AN10,CVREF,RTCC,CN12,RB14	RP14
PIN 10	AN9,CN11,RB15	RP15

We will be configure pin 10 to be analog input 9 of ADC We will leave PIN 1 as an OC1

KibaCorp ADC Library

- An ADCDEMO program using the ADC library is made available
- Using our ADC library we are able to make any of these pins act as an ADC input and perform an ADC conversion.
- The conversion automatically converts voltage signal at the input of the pin between 0 volts to +3.3 Volts to a binary ten bit value 0 to 1023 representing that voltage
- The ADC library functions that are used are:
- **InitADC (IOpin) –** initializes the designated Expansion bus pin for ADC operation as an input channel. The are only five possible pin available for this use on the I/O expansion and they designed in the code as :
  - **pin1, pin7, pin8, pin9, pin10** (make sure to use exact syntax for pin shown here). This function must be called first before any ADC library function. Only one pin can be designated as an input at a time.
- **ReadADC (IOpin) -** this function performs an ADC conversion on the input voltage present on the pin (see pin designations shown above) and returns an integer value from 0 to 1023 representing the measured voltage.

CCP with ADC

```
17  #define DELAY   8000
18  int adcvalue =0;  //creaet adc output variable
19
20  void turnoff(void) {
21      //turn off pin 1 I/O EXP  RB2, Timer2 and any OC1 configuration on this pin
22      T2CON =0;
23      OC1CON =0x0000;
24      TRISBbits.TRISB2 = 1;
25      }
26  void turnon(int setting) {
27          //turn on pin 1 I/O EXP RB2, Timer2 and any OC1 configuration on this pin
28      PR2=0x03ff ;
29      TMR1 =0;
30      OC1R =setting;
31      OC1RS =setting;
32      OC1CON = 0x0006;  //timer2 and edge aligned PWM
33      T2CON =0x8000;
34      }
35  void setPWM(int setting) {
36
37  turnoff();
38  turnon(setting);
39  }
40  main()
41  {
42  __builtin_write_OSCCONL(OSCCON & 0xbf) ; //clear bit 6  unlock
43  //input//  PPS first -there are none
44  //output // PPS second
45  //do PPS on RB2 pin 1 of I/O EXP  to make it OC1 output
46      RPOR1bits.RP2R = 18;        // Make Pin 1 I/O EXP bus (RP2)  OC1
47
48  __builtin_write_OSCCONL(OSCCON | 0x40) ; //set bit 6 lock
49
50      T1CON = 0x8030; // TMR1 on, prescale 1:256 Tclk/2 --use timer1 for delay
51       initADC(pin10);  //make pin 10 an analog input a9
52
53          while( 1)
54      {
55          //1. change PWM to ADC value
56      adcvalue = readADC(pin10);      //read ADC
57      setPWM(adcvalue);               // set PWM
58
59      //  2. delay for min time using timer1 read before next change
60          TMR1 = 0;
61          while ( TMR1 < DELAY)
62          {
63          }
64  }
65  } // main
```

CCP with ADC Experiment

- Hook up hardware as shown in earlier slide
- Open Loop.mcp
- Examine source –examine where ADC value is used to change PWM setting
- Note that Timer 1 is used as a delay
- Select Debug to PICKIT 2
- Build, download and Run
- Verify operation -Change POT set CW and CCW and note instantaneous LED brightness change