PWM Tips and Tricks

Pulse-Width Modulation (PWM) Tips and Tricks

Introduction

The 16-bit PWM module features built-in comparison functionality and dual outputs that are individually controllable. The justification and duty cycle of each PWM output can be controlled individually, which can be advantageous for many different types of PWM applications. This document describes some of the basic configuration modes that this PWM module can be configured to operate with.

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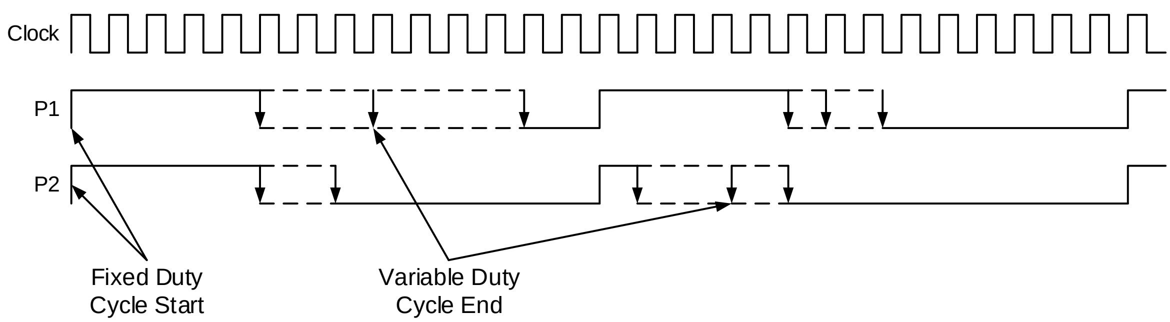
In Left-Aligned mode, the active part of the PWM signal is at the start of the period. As an example, if the PWM module has been configured to have a left-aligned output with a 75% duty cycle, the output will be active for the first 75% of the period and then transition to inactive for the remaining 25% of the period.

To configure the PWM module to generate a left-aligned output, the MODE bits of the PWM Configuration registers are used to select the output alignment mode and the P1 or P2 parameter registers are used to determine the resulting period of the output signal. The code example below shows an initialization routine that can be used to generate two left-aligned PWM outputs. The P1 output is a left-aligned PWM output with a 75% duty cycle and the P2 output shows a left-aligned PWM output with a 50% duty cycle. The figure below shows the left-aligned PWM output signals side-by-side, along with the corresponding PWM clock.

Figure 1-1. Left-Aligned Mode



Example 1-1. PWM Left-Aligned Initialization

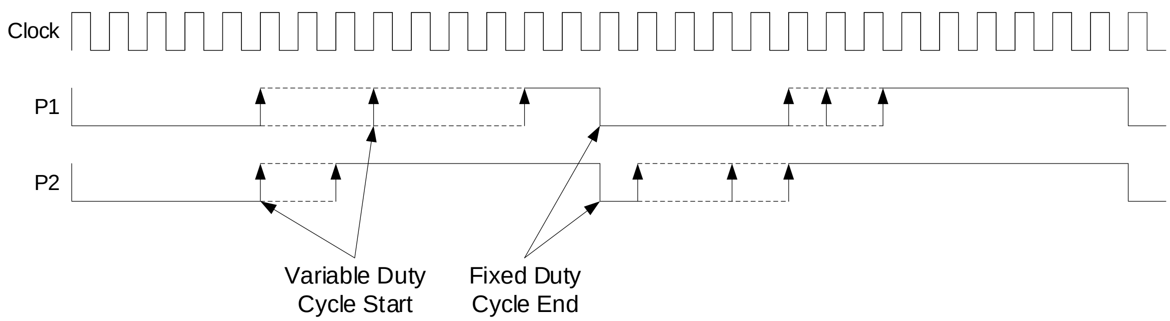
```
void PWM1_Initialize(void)
{
    PWM1ERS = 0x00;     // PWMERS External Reset Disabled;
    PWM1CLK = 0x02;     // PWMCLK FOSC;
    PWM1LDS = 0x00;     // PWMLDS Autoload disabled;
    PWM1PRL = 0x0F;     // PWMPRL 15;
    PWM1PRH = 0x00;     // PWMPRH 0;
    PWM1CPRE = 0x00;    // PWMCPRE No prescale;
    PWM1PIPOS = 0x00;   // PWMPIPOS No postscale;
    PWM1GIR = 0x00;     // PWMS1P2IF PWM2 output match did not occur;
                        // PWMS1P1IF PWM1 output match did not occur;
    PWM1GIE = 0x00;     // PWMS1P2IE disabled; PWMS1P1IE disabled;
    PWM1S1CFG = 0x00;   // PWMPOL2 disabled; PWMPOL1 disabled; PWMPPEN
                        // disabled; PWMMODE PWMOUT1,PWMOUT2 in left
                        // aligned mode
    PWM1S1P1L = 0x0C;   // PWMS1P1L 12;
    PWM1S1P1H = 0x00;   // PWMS1P1H 0;
    PWM1S1P2L = 0x08;   // PWMS1P2L 8;
    PWM1S1P2H = 0x00;   // PWMS1P2H 0;
    PWM2CON = 0x80;     // PWMEN enabled; PWMLD disabled; PWMERSPOL
                        // disabled; PWMERSNOW disabled;
}
```

2. Right-Aligned Mode

In Right-Aligned mode, the active part of the PWM signal is at the end of the period. As an example, If the PWM module has been configured to have a right-aligned output with a 75% duty cycle, the output will be inactive for the first 25% of the period and then transition to active for the remaining 75% of the period.

To configure the PWM module to generate a right-aligned output, the MODE bits of the PWM Configuration registers are used to select the output alignment mode and the P1 or P2 parameter registers are used to determine the resulting period of the output signal. The code example below shows an initialization routine that can be used to generate two right-aligned PWM outputs. The P1 output is a right-aligned PWM output with a 75% duty cycle and the P2 output shows a right-aligned PWM output with a 50% duty cycle. The figure below shows the right-aligned PWM output signals side-by-side, along with the corresponding PWM clock.

Figure 2-1. Right-Aligned Mode



Example 2-1. PWM Right Align Initialization

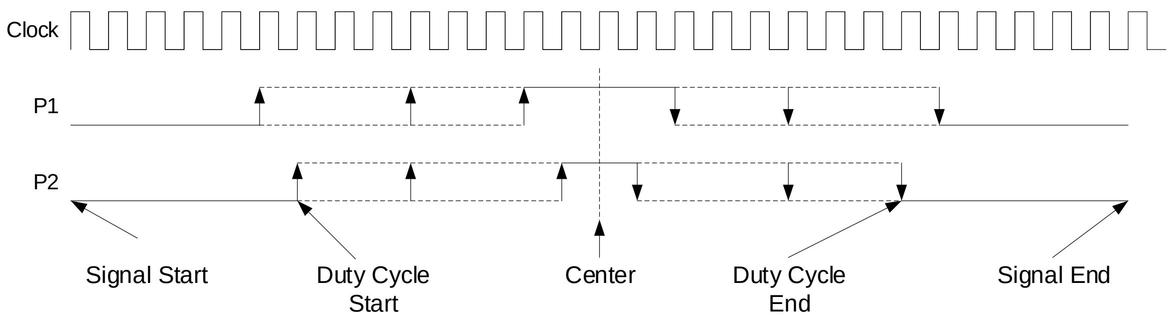
```
void PWM1_Initialize_RightAlign(void)
{
    PWM1ERS = 0x00;          // External Reset Disabled;
    PWM1CLK = 0x02;          // FOSC;
    PWM1LDS = 0x00;          // Autoload disabled;
    PWM1PRL = 0x0F;          // PWMPRL 15;
    PWM1PRH = 0x00;          // PWMPRH 0;
    PWM1CPRE = 0xF9;         // Prescale by 250;
    PWM1PIPOS = 0x00;        // PWMPIPOS No postscale;
    PWM1GIR = 0x00;          // PWMS1P2IF PWM2 output match did not occur;
                             // PWMS1P1IF PWM1 output match did not occur;
    PWM1S1CFG = 0x01;        // PWMPOL2 disabled; PWMPOL1 disabled; PWMPPEN
                             // disabled; PWMMODE PWMOUT1 and PWMOUT2 in
                             // right-aligned mode;
    PWM1S1P1L = 0x0C;        // PWMS1P1L 12;
    PWM1S1P1H = 0x00;        // PWMS1P1H 0;
    PWM1S1P2L = 0x08;        // PWMS1P2L 8;
    PWM1S1P2H = 0x00;        // PWMS1P2H 0;
    PWM1GIRbits.S1P1IF = 0;  // Clear PWM1 slice 1, output 1 interrupt flag
    PWM1GIRbits.S1P2IF = 0;  // Clear PWM1 slice 1, output 2 interrupt flag
    PWM1CON = 0x80;          // PWMEN enabled; PWMLD disabled; PWMERSPOL
                             // disabled; PWMERSNOW disabled;
}
```

3. Center-Aligned Mode

In Center-Aligned mode, the active part of the PWM signal is in the middle of the signal. A typical use case is using PWM to drive LEDs to prevent sudden current draw changes when all of the LEDs switch to active at once. In this mode, the effective frequency is half of the configured value. As an example, if the PWM module has been configured to have a center-aligned output with a 50% duty cycle, the output grows symmetrically from the center for an active time of 50% and an inactive time of 25% on each side.

To configure the PWM module to generate a center-aligned output, the MODE bits of the PWM Configuration registers are used to select the output alignment and the P1/P2 parameter registers are used to determine the resulting period of the output signal. The code example below shows an initialization routine that can be used to generate a center-aligned PWM output. The P1 output is a center-aligned PWM output with a 75% duty cycle and the P2 output shows a center-aligned PWM output with a 50% duty cycle. The figure below shows the center-aligned PWM output signals side-by-side, along with the corresponding PWM clock.

Figure 3-1. Center-Aligned Mode



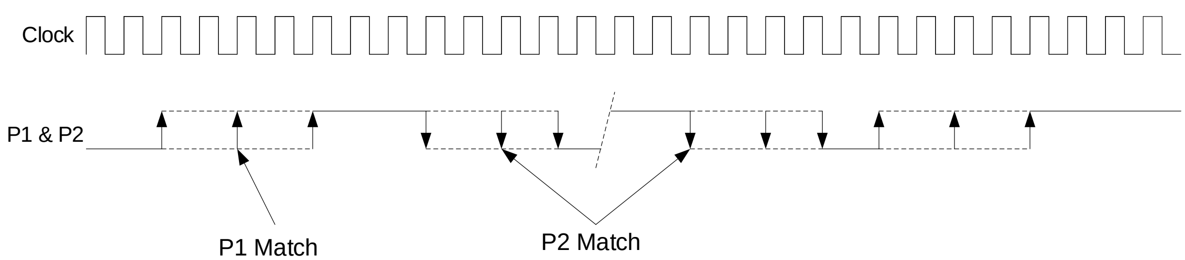
Example 3-1. PWM Center-Aligned Initialization

```
void PWM1_Initialize(void)
{
    PWM1ERS   = 0x00;   //PWMERS External Reset Disabled;
    PWM1CLK   = 0x02;   //PWMCLK FOSC;
    PWM1LDS   = 0x00;   //PWMLDS Autoload disabled;
    PWM1PRL   = 0xFF;   //PWMPRL 255;
    PWM1PRH   = 0x7C;   //PWMPRH 124;
    PWM1CPRE  = 0x00;   //PWMCPRE No prescale;
    PWM1PIPOS = 0x00;   //PWMPIPOS No postscale;
    PWM1GIR   = 0x00;   //PWMS1P2IF PWM2 output match did not occur;
                        //PWMS1P1IF PWM1 output match did not occur;
    PWM1S1CFG = 0x02;   //PWMPOL2 disabled; PWMPOL1 disabled; PWMPPEN
                        //disabled; PWMMODE PWMOUT1 and PWMOUT2 in center
                        //aligned mode;
    PWM1S1P1L = 0xC0;   //PWMS1P1L 192;
    PWM1S1P1H = 0x5D;   //PWMS1P1H 93;
    PWM1S1P2L = 0x80;   //PWMS1P2L 128;
    PWM1S1P2H = 0x3E;   //PWMS1P2H 62;
    PWM1CON   = 0x80;   //PWMEN enabled; PWMLD disabled; PWMERSPOL disabled;
                        //PWMERSNOW disabled;
}
```

4. Variable-Aligned Mode

In Variable-Aligned mode, the active part of the PWM signal can be at any part of the PWM period. A variable-aligned PWM is commonly used in power supply and motor control applications where a fixed pulse width is needed, but the effective ON time of the MOSFETs needs to be controlled. In this mode, when the PWM timer and parameter P1 match, the output transitions to the Active state. When the PWM timer and parameter P2 match, the output transitions to the Inactive state. Adjusting the P1 and P2 values will move the transition edges. Both the PWM outputs are identical in this mode. As an example, if P1 is 20% of the period, and P2 is 50% of the period, the output will be low for the first 20% of the period, high for the next 30%, and return to low for the remaining 50%.

Figure 4-1. Variable-Aligned Mode



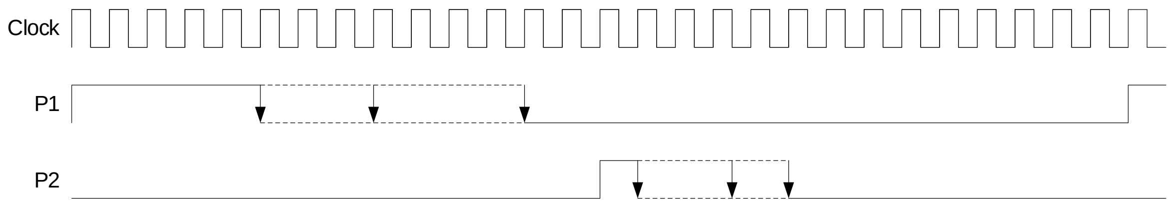
Example 4-1. PWM Variable-Aligned Initialization

```
void PWM1_Initialize_V_Aligned(void)
{
    PWM1ERS = 0x00;   //PWMERS External Reset Disabled;
    PWM1CLK = 0x02;   //PWMCLK FOSC;
    PWM1LDS = 0x00;   //PWMLDS Autoload disabled;
    PWM1PRL = 0x9F;   //PWMPRL 159;
    PWM1PRH = 0x0F;   //PWMPRH 15;
    PWM1CPRE = 0x00;  //PWMCPRE No prescale;
    PWM1PIPOS = 0x00; //PWMPIPOS No postscale;
    PWM1GIR = 0x00;   //PWMS1P2IF PWM2 output match did not occur;
                      //PWMS1P1IF PWM1 output match did not occur;
    PWM1S1CFG = 0x03; //PWMPOL2 disabled; PWMPOL1 disabled; PWMPPEN
                      //disabled; PWMOUT1 and PWMOUT2 in variable
                      //aligned mode;
    PWM1S1P1L = 0xF0; //PWMS1P1L = 240;
    PWM1S1P1H = 0x09; //PWMS1P1H  = 9;
    PWM1S1P2L = 0xA0; //PWMS1P2L = 160;
    PWM1S1P2H = 0x0E; //PWMS1P2H = 14;
    PWM1CON = 0x80;   //PWMEN enabled; PWMLD disabled; PWMERSPOL
                      //disabled; PWMERSNOW disabled;
}
```


5. Push-Pull Mode

The Push-Pull mode generates two PWM outputs alternately on the P1 and P2 channels. The duty cycle of the two outputs are still independently controllable. This mode works with Left-Aligned and Right-Aligned modes. Typically, this mode is used to generate an AC drive for either a motor or transformer primary drive using a full-bridge driver.

Figure 5-1. Push-Pull Mode



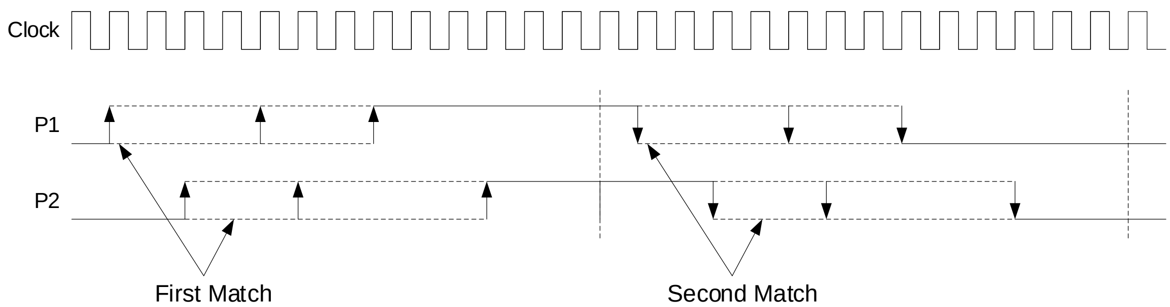
Example 5-1. PWM Push-Pull Initialization

```
void PWM1_Initialize(void)
{
    PWM1ERS = 0x00;         //PWMERS External Reset Disabled;
    PWM1CLK = 0x02;         //PWMCLK FOSC;
    PWM1LDS = 0x00;         //PWMLDS Autoload disabled;
    PWM1PRL = 0x1F;         //PWMPRL 31;
    PWM1PRH = 0x00;         //PWMPRH 0;
    PWM1CPRE = 0x00;        //PWMCPRE No prescale;
    PWM1PIPOS = 0x00;       //PWMPIPOS No postscale;
    PWM1GIR = 0x00;         //PWMS1P2IF PWM2, PWMS1P1IF PWM1 no match
    PWM1S1CFG = 0x0A;       //PWMPOL2 disabled; PWMPOL1 disabled;
                            //PWMPPEN disabled; PWMMODE PWMOUT1 and
                            //PWMOUT2 in center-aligned mode;
    PWM1S1P1L = 0x10;       //PWMS1P1L 16;
    PWM1S1P1H = 0x00;       //PWMS1P1H 0;
    PWM1S1P2L = 0x10;       //PWMS1P2L 16;
    PWM1S1P2H = 0x00;       //PWMS1P2H 0;
    PWM1GIRbits.S1P1IF = 0; //Clear PWM1 slice 1, output 1 interrupt flag
    PWM1GIRbits.S1P2IF = 0; //Clear PWM1 slice 1, output 2 interrupt flag
    PWM1CON = 0x80;         //PWMEN enabled; PWMLD disabled;
                            //PWMERSPOL disabled; PWMERSNOW disabled;
}
```


6. Toggle on Compare

This output mode toggles the PWM slice output when the duty cycle compare match fires. The result is two 50% duty cycle outputs, with double the PWM period, and offset from each other by the difference in the duty cycle settings. If both duty cycle registers are set to the same value, both outputs will rise and fall together. If the duty cycle registers are set with a 20 μs difference, the two 50% duty cycle outputs will be offset from each other by 20 μs. This output mode allows the users to generate 50% duty cycle clock signals with a programmable phase difference. The following code generates a 10 kHz output with a 30 μs offset.

Figure 6-1. Toggle Mode



Example 6-1. PWM Toggle Initialization

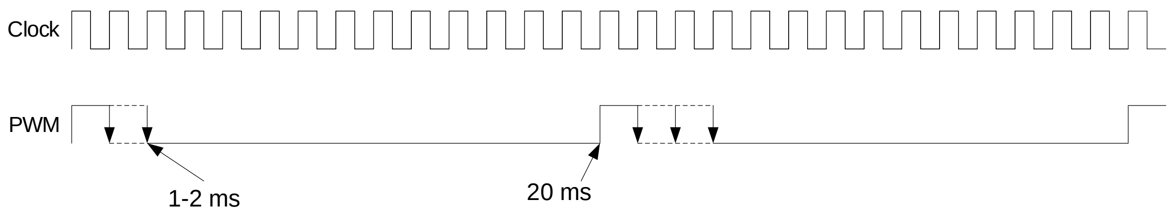
```
void PWM1_Initialize(void)
{

    PWM1ERS = 0x00;     //PWMERS External Reset Disabled;
    PWM1CLK = 0x03;     //PWMCLK HFINTOSC;
    PWM1LDS = 0x00;     //PWMLDS Autoload disabled;
    PWM1PRL = 0xC7;     //PWMPRL 199;
    PWM1PRH = 0x00;     //PWMPRH 0;
    PWM1CPRE = 0x00;    //PWMCPRE No prescale;
    PWM1PIPOS = 0x00;   //PWMPIPOS No postscale;
    PWM1GIR = 0x00;     //PWMS1P2IF PWM2 output no match; PWMS1P1IF PWM1 output
                        //no match;
    PWM1GIE = 0x00;     //PWMS1P2IE disabled; PWMS1P1IE disabled;
    PWM1S1CFG = 0x05;   //PWMPOL2 disabled; PWMPOL1 disabled; PWMPPEN disabled;
                        //PWMMODE Toggle PWMOUT1 and PWMOUT2 on compare match;
    PWM1S1P1L = 0x27;   //PWMS1P1L 39;
    PWM1S1P1H = 0x00;   //PWMS1P1H 0;
    PWM1S1P2L = 0x9F;   //PWMS1P2L 159;
    PWM1S1P2H = 0x00;   //PWMS1P2H 0;
    PWM1CON = 0x80;     //PWMEN enabled; PWMLD disabled; PWMERSPOL disabled;
}
```

7. Servo Control

The 16-bit PWM module is an excellent choice to be used as a servo motor controller, which requires minimal software intervention. Servo motors usually have three-pin connectors consisting of V_{DD}, V_{SS} and a Control Pin (PWM Output from the microcontroller). The typical PWM output signal used to drive servo motors generates a pulse every 20 ms that lasts anywhere from 1 ms to 2 ms. This equates to a PWM frequency of 50 Hz with a varying duty cycle of 5% to 10%, depending upon the desired position of the output shaft. A pulse width of 1 ms typically corresponds to the -90° position of the servo output shaft, and a 2 ms pulse will cause the output shaft to move to the 90° position.

To use the PWM module to drive a servo motor, the PWM frequency should be configured to be 50 Hz by selecting the appropriate PWM clock source and clock prescaler value. The user should then generate a left-aligned PWM output with a duty cycle of 5% to 10% to generate a pulse between 1 ms and 2 ms by using the corresponding PR register to change the duty cycle of the signal. The Example 1 below shows how the 16-bit PWM module can be initialized to drive a servo motor, and Example 2 includes a code snippet that can be used to sweep the servo motor output shaft between 0° and 180°. The figure below illustrates the PWM output signals that can be used to drive a servo motor between 0° and 180°.

Figure 7-1. PWM Output Signals



Example 7-1. PWM Servo Motor Control Initialization

```
void PWM1_Initialize(void)
{
    PWM1ERS = 0x00;            //PWMERS External Reset Disabled;
    PWM1CLK = 0x03;            //PWMCLK HFINTOSC;
    PWM1LDS = 0x00;            //PWMLDS Autoload disabled;
    PWM1PRL = 0x3F;            //PWMPRL 63;
    PWM1PRH = 0x9C;            //PWMPRH 156;
    PWM1CPRE = 0x01;           //PWMCPRE Prescale by 2;
    PWM1PIPOS = 0x00;          //PWMPIPOS No postscale;
    PWM1GIR = 0x00;            //PWMS1P2IF PWM2 output match did not occur;
                               //PWMS1P1IF PWM1 output match did not occur;
    PWM1GIE = 0x00;            //PWMS1P2IE disabled; PWMS1P1IE disabled;
    PWM1S1CFG = 0x00;          //PWMPOL2 disabled; PWMPOL1 disabled;
                               //PWMPPEN disabled; PWMMODE PWMOUT1 and PWMOUT2
                               //in left-aligned mode;
    PWM1S1P1L = 0xA0;          //PWMS1P1L 160;
    PWM1S1P1H = 0x0F;          //PWMS1P1H 15;
    PWM1S1P2L = 0x80;          //PWMS1P2L 128;
    PWM1S1P2H = 0x0C;          //PWMS1P2H 12;
    PIR4bits.PWM1PIF = 0;      //Clear PWM1 period interrupt flag
    PIR4bits.PWM1IF = 0;       //Clear PWM1 interrupt flag
    PWM1GIRbits.S1P1IF = 0;    //Clear PWM1 slice 1, output 1 interrupt flag
    PWM1GIRbits.S1P2IF = 0;    //Clear PWM1 slice 1, output 2 interrupt flag
    PIE4bits.PWM1IE = 0;       //PWM1 interrupt enable bit
    PIE4bits.PWM1PIE = 0;      //PWM1 period interrupt enable bit
    PWM1CON = 0x80;            //PWMEN enabled; PWMLD disabled; PWMERSPOL
                               //disabled; PWMERSNOW disabled;
}
```

Example 7-2. Servo Motor 5% to 10%

```
while (1)
{
   PWM1_SetSlice1Output1DutyCycleRegister(0x07D0);    //PWM duty cycle at 5%
   PWM1CONbits.LD = 1;                                //PWM Reload Period &
                                                      //Duty Cycle Registers
                                                      //Bit
   __delay_ms(1000);
   PWM1_SetSlice1Output1DutyCycleRegister(0x0FA0);    //PWM duty cycle at 10%
   PWM1CONbits.LD = 1;                                //PWM Reload Period &
                                                      //Duty Cycle Registers
                                                      //Bit
   __delay_ms(1000);
}
```

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