TB3137

High-Precision 16-Bit PWM Technical Brief

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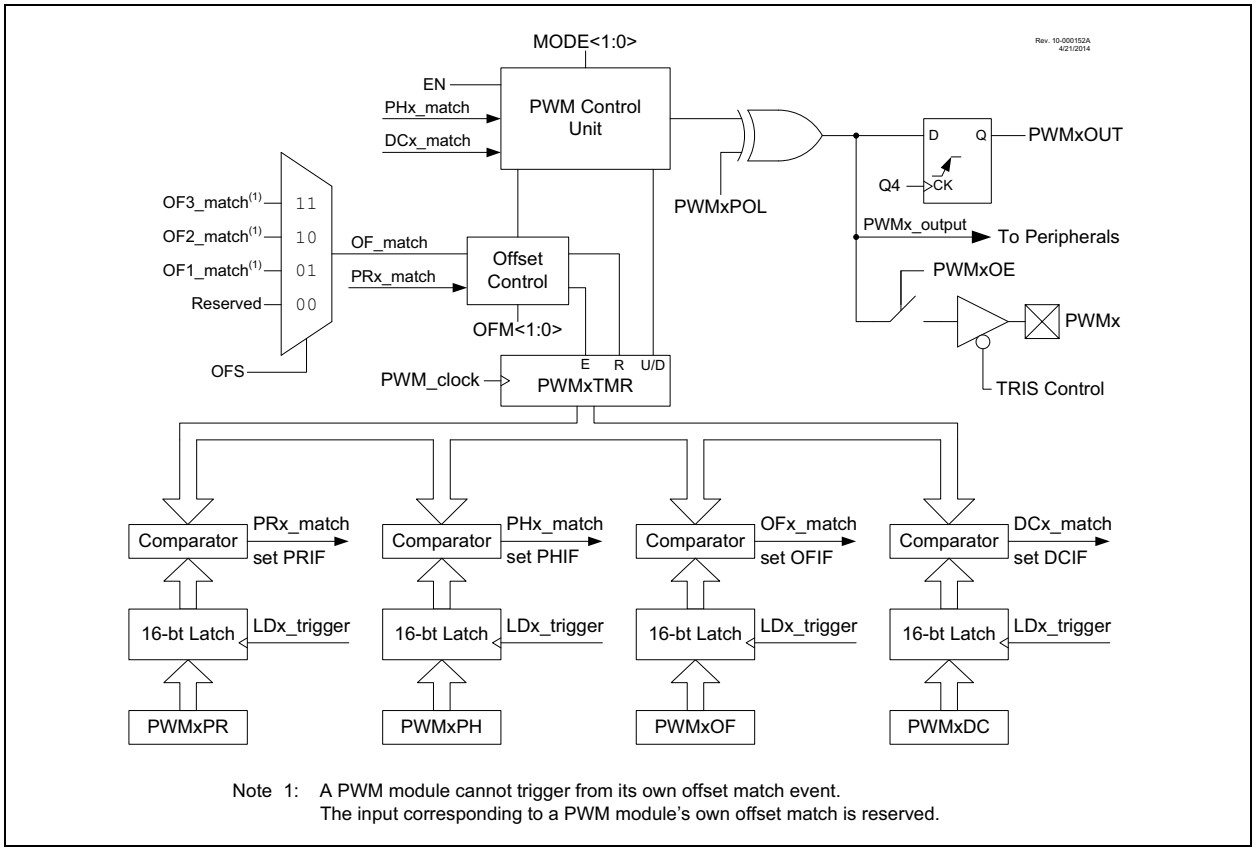
INTRODUCTION

The high-precision 16-bit PWM available in various PIC16 devices such as the PIC16F157X product family, delivers advanced features beyond those found on standard PWM modules. These innovative features allow the user to easily vary phase, duty cycle and offset event count with greater precision. Via the offset modes, each PWM output can offset its waveform relative to any other PWM module on the same device. The high-precision 16-bit PWM is ideal for power supplies, LED lighting, color mixing, and motor control applications. In addition, when not using the PWM outputs the module can be used to add up to four additional general purpose 16-bit timers.

FUNDAMENTAL OPERATION

Each PWM module has the ability to have its timer be independently clocked via a selection of three sources: LFINTOSC, HFINTOSC and FOSC. In addition, the PWM clock source can be divided down with seven selectable prescalers to better suit the user's needs. The timer value is then compared to event count registers in order to generate a multitude of PWM waveforms. Four 16-bit count registers are available to manipulate the phase, duty cycle, period and offset: PWMxPH, PWMxDC, PWMxPR and PWMxOF. See the 16-bit PWM block diagram in Figure 1.

FIGURE 1: 16-BIT PWM BLOCK DIAGRAM



Note 1: A PWM module cannot trigger from its own offset match event.
The input corresponding to a PWM module's own offset match is reserved.

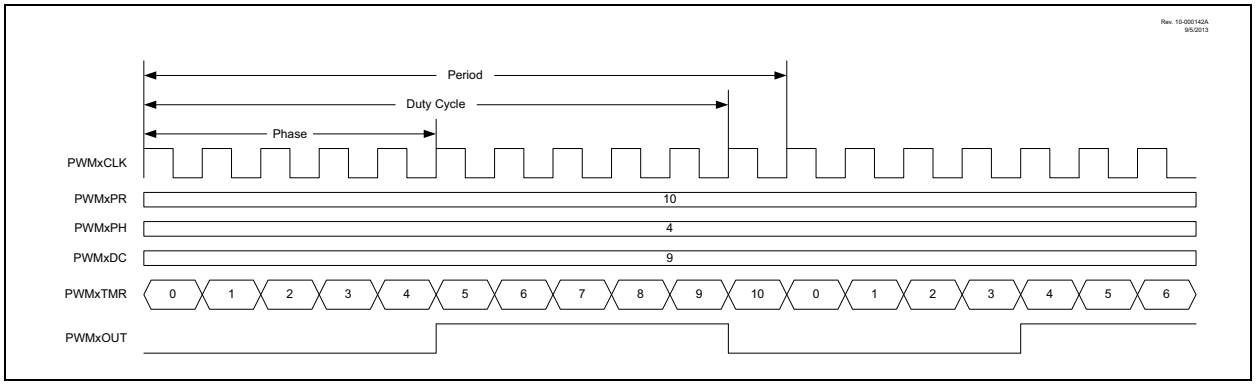
PWM MODES

Each PWM module has four selectable modes of operation.

1. Standard
2. Set-on-Match
3. Toggle-on-Match
4. Center Aligned

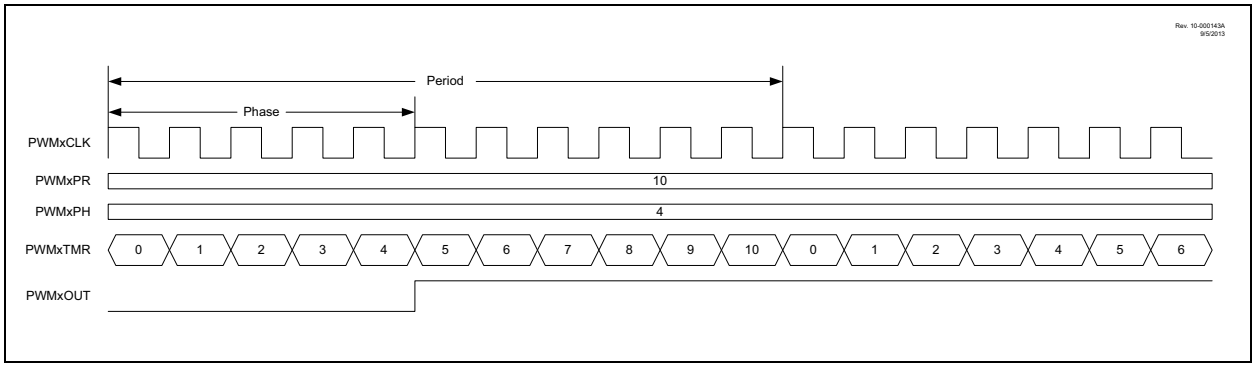
The Standard mode produces a single-phase PWM waveform, which is constructed by comparing and matching the PWM counter value to the 16-bit phase, period and duty cycle registers. Upon a match of the phase count register, the start of the duty cycle begins. The end of the duty cycle occurs upon a match of the duty cycle count register (see Figure 2).

FIGURE 2: STANDARD PWM MODE TIMING DIAGRAM



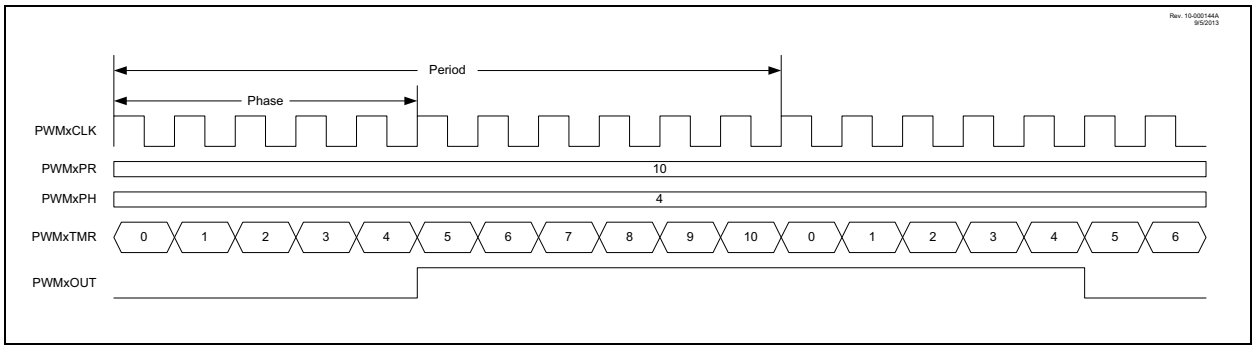
The Set-on-Match mode generates an output when the phase count register matches the PWM timer. This output will remain active until the OUT bit of the PWMxCON is cleared or the PWM module is disabled. See the Set-on-Match PWM mode timing diagram in Figure 3.

FIGURE 3: SET-ON-MATCH PWM MODE TIMING DIAGRAM



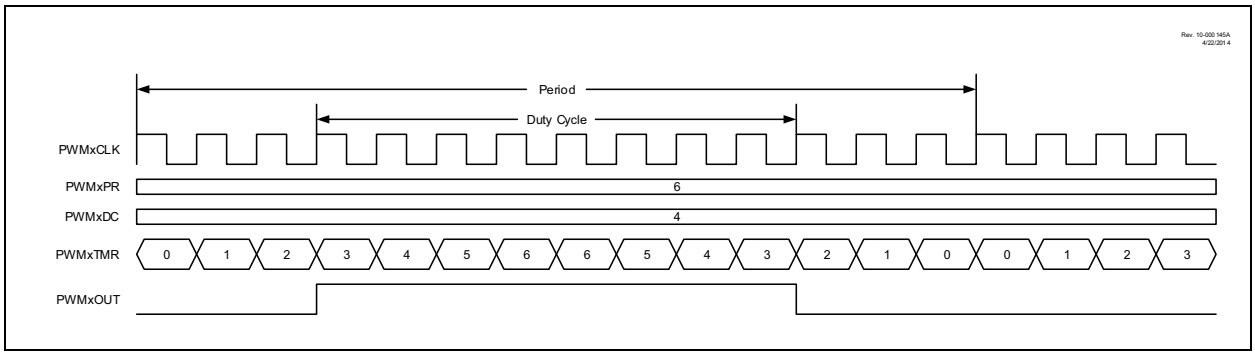
The Toggle-on-Match mode produces a 50% duty cycle PWM waveform with a period twice as long as that of the Standard PWM mode. The phase count registers determine how many PWM timer periods after a period event the PWM waveform will toggle (see Figure 4).

FIGURE 4: TOOGLE-ON-MATCH PWM MODE TIMING DIAGRAM



The Center-Aligned mode generates a PWM waveform which is centered to the PWM period. The period is twice that of the PWMxPR count registers. In this mode, the PWM timer will count until a match is met with the PWMxPR registers and then count back down to a value match of '0'. The active rising and falling edge of the PWM waveform is determined by the duty cycle count registers. See the Center-Aligned PWM mode in Figure 5.

FIGURE 5: CENTER-ALIGNED PWM MODE TIMING DIAGRAM



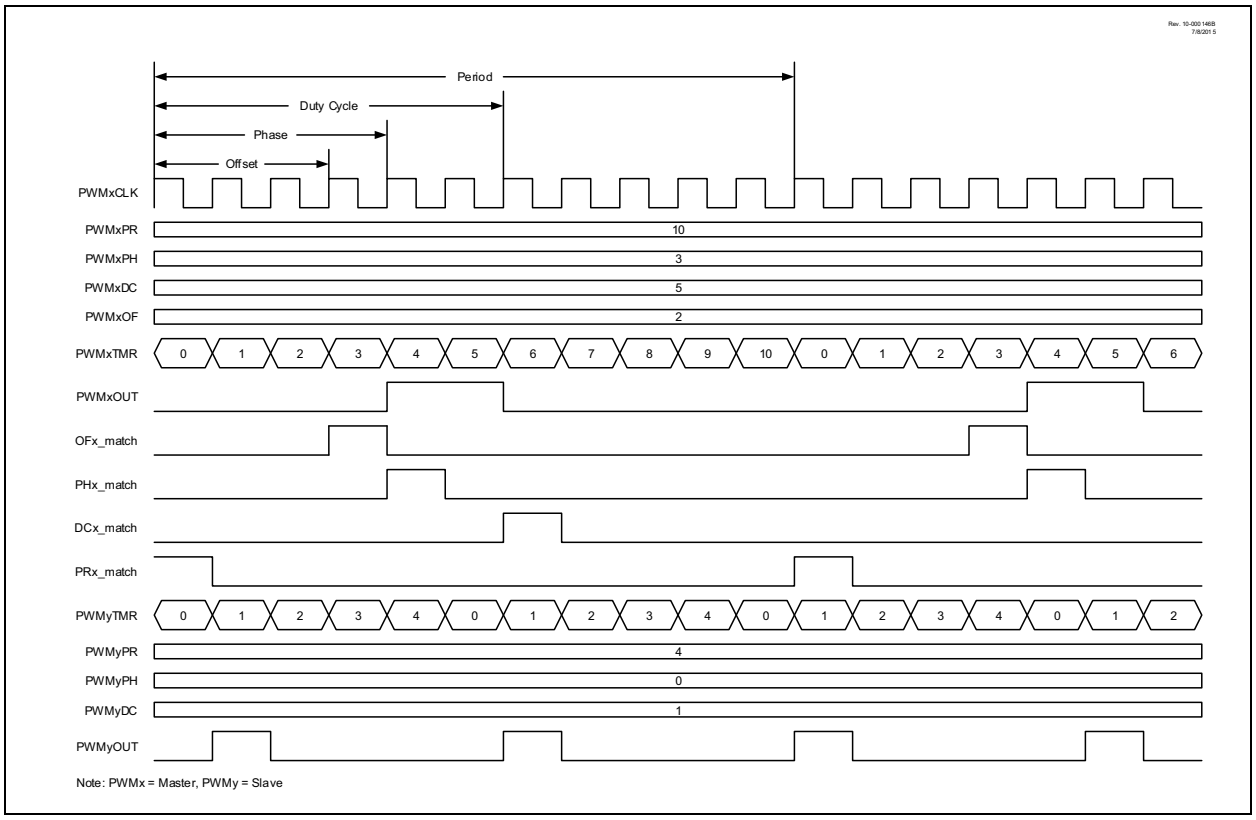
Offset Mode

In addition to these PWM modes, each PWM module also has four offset modes which can offset its waveform relative to any other PWM module. These are the following modes:

- Independent Run
- Slave Run with Synchronous Start
- One-Shot Slave with Synchronous Start
- Continuous Run Slave with Synchronous Start and Timer Reset

In Independent Run mode, the PWM Offset, Phase, Duty Cycle and Period are unaffected by any of the other PWM modules. In this mode, the PWM will continually run while enabled. See Independent Run mode timing diagram in Figure 6.

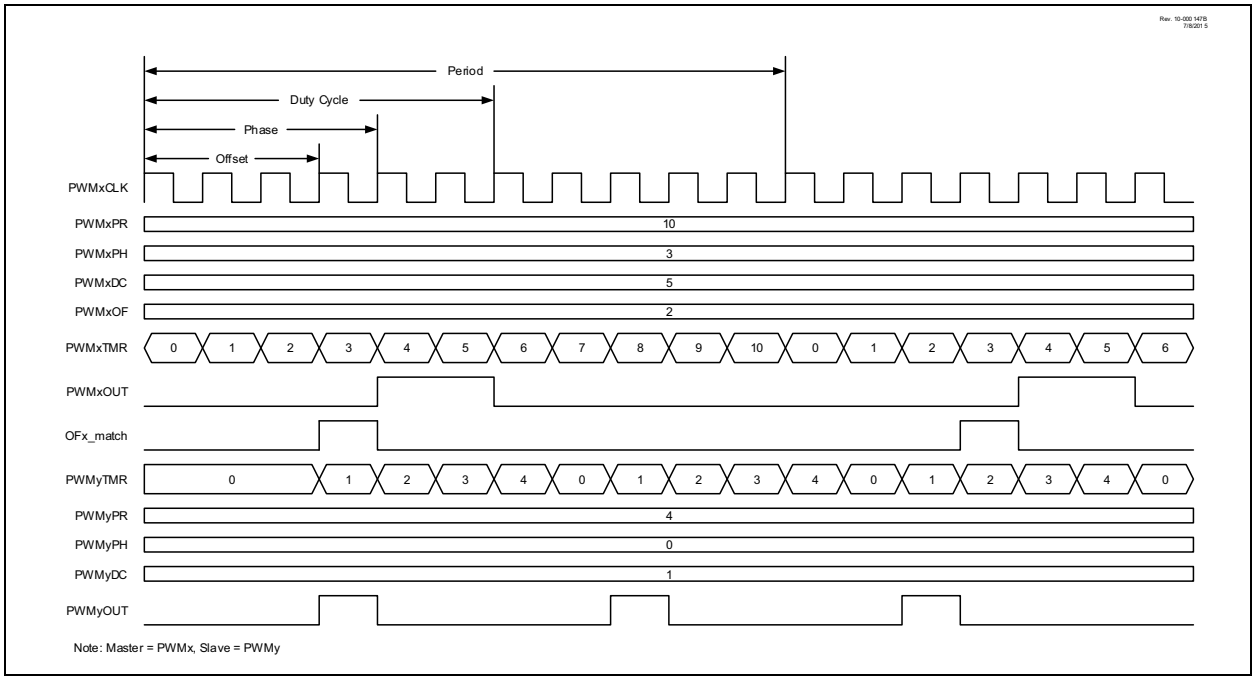
FIGURE 6: INDEPENDENT RUN MODE TIMING DIAGRAM



Slave Run with Synchronous Start

In Slave Run with Synchronous Start, it is required to have at least two or more PWM modules active, allowing for a master/slave pair. In this mode, the slave will wait until the offset event of the master is matched in order to begin counting and will continue counting as long as it remains enabled. See Slave Run with Synchronous Start timing diagram in Figure 7.

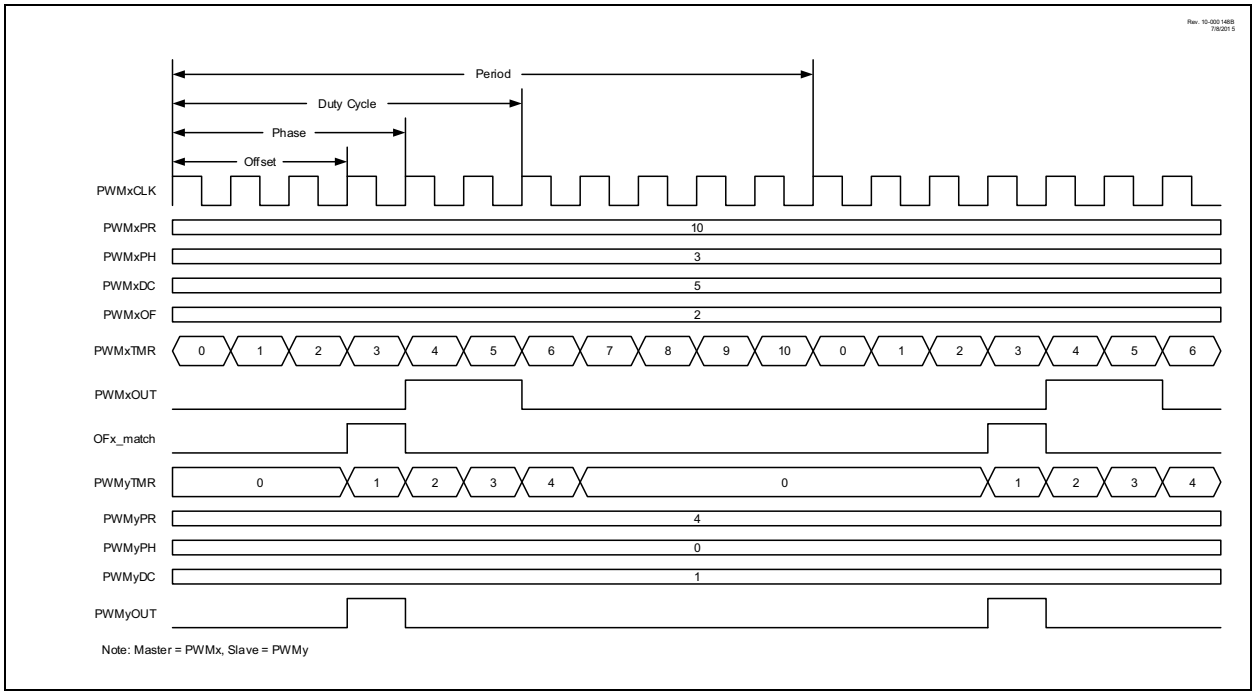
FIGURE 7: SLAVE RUN MODE WITH SYNCHRONOUS START TIMING DIAGRAM



One-Shot Slave with Synchronous Start

Much like the Slave Run with Synchronous Start mode, the One-Shot Slave with Synchronous Start mode also requires more than one PWM active, with one being master and the other slave. In this mode, the timer begins counting, starting with a preconfigured value already in the timer and does so until the period match event. The PWM timer then waits for a match with the master offset value before repeating the cycle. See the Slave Run with Synchronous Start timing diagram in Figure 8.

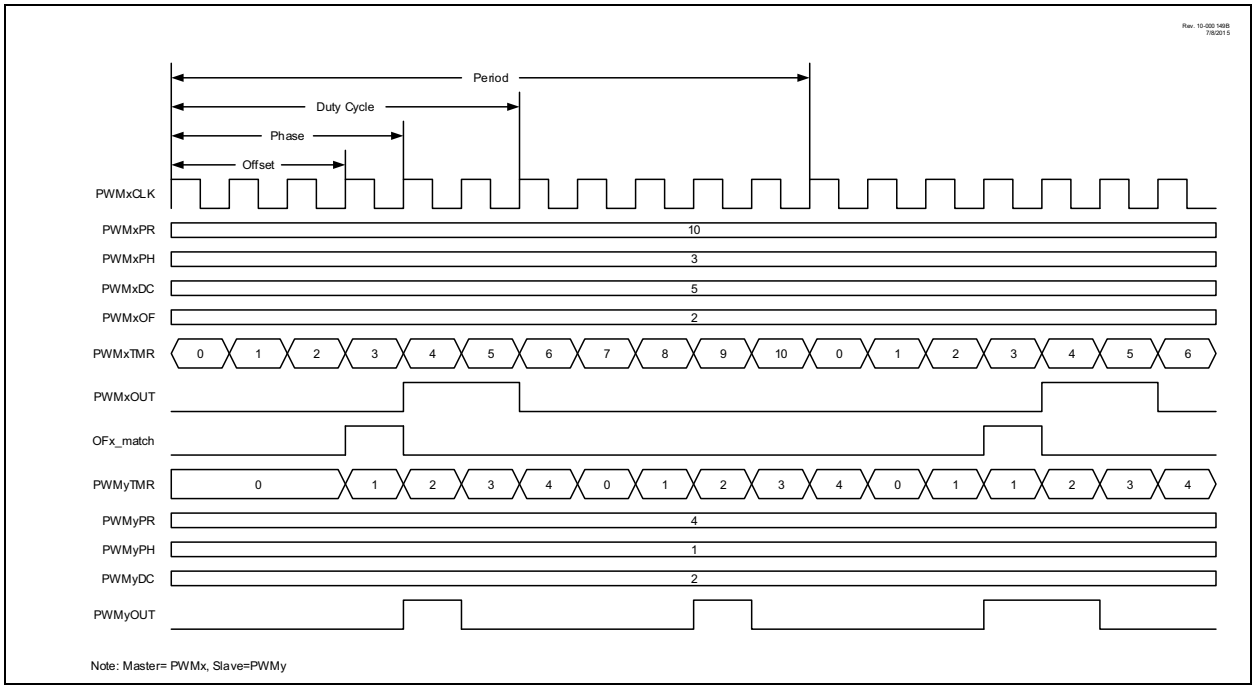
FIGURE 8: ONE-SHOT SLAVE WITH SYNCHRONOUS START TIMING DIAGRAM



Continuous Run Slave with Synchronous Start and Timer Reset

In the Continuous Run Slave with Synchronous Start and Timer Reset, the slave PWM timer does not start counting until the first match of the master offset event. Subsequent master offset match events will then reset the slave PWM timer value back to “1”, after which it will continue counting. See the Continuous Run Slave with Synchronous Start and Timer Reset timing diagram in Figure 9.

FIGURE 9: CONTINUOUS RUN SLAVE WITH SYNCHRONOUS START AND TIMER RESET



APPLICATION EXAMPLE

The provided code set offers an example on how to use the 16-bit PWM in One-Shot mode for RGB LED color mixing. The method used provides a high resolution solution for a Hue, Saturation and Value (HSV) color wheel.

The microcontrollers used in this code example are the PIC12(L)F1572, 8-pin MCU with high-precision 16-bit PWMs devices. The application uses all three available PWM's, configured as the following:

- PWM1 = Red
- PWM2 = Green
- PWM3 = Blue

There is one master PWM used to trigger the other two slave PWM's, configured as the following:

- PWM1 = Master
- PWM2 = Slave
- PWM3 = Slave

PWM1 is further configured in Standard mode with an Independent Run offset mode applied. Both PWM2 and PWM3 are also configured in Standard mode, but with One-Shot Slave mode with Sync Start offset applied. The offset trigger used in this example is OF1_match. Configuring the PWM's in this manner allows for the three PWM output signals to overlap one another and for each duty cycle to be independently controlled via the PWMxDC registers. The duty cycle for each PWM can vary from 0% to 100% in 65535 steps. The PWM frequency used throughout is 122 Hz, which means that each increment of the PWMxDC register will increase the duty cycle by 125 ns. See the Equation 1 below:

EQUATION 1: DUTY CYCLE INCREMENT SIZE

$$1 / 122\ Hz = 8.1967\ ms$$

$$8.1967\ ms / 65535 = 125.07\ ns$$

The code example will cycle through the complete HSV color wheel by periodically incrementing and decrementing the PWMxDC register values as needed. See Figure 10 below.

FIGURE 10: PWMxDC HSV

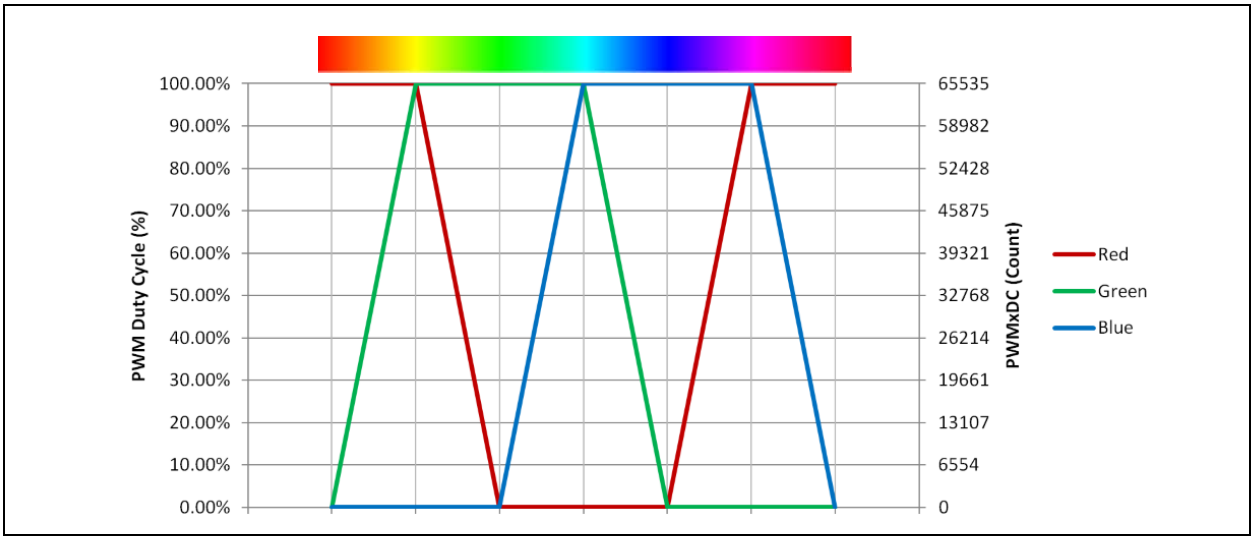
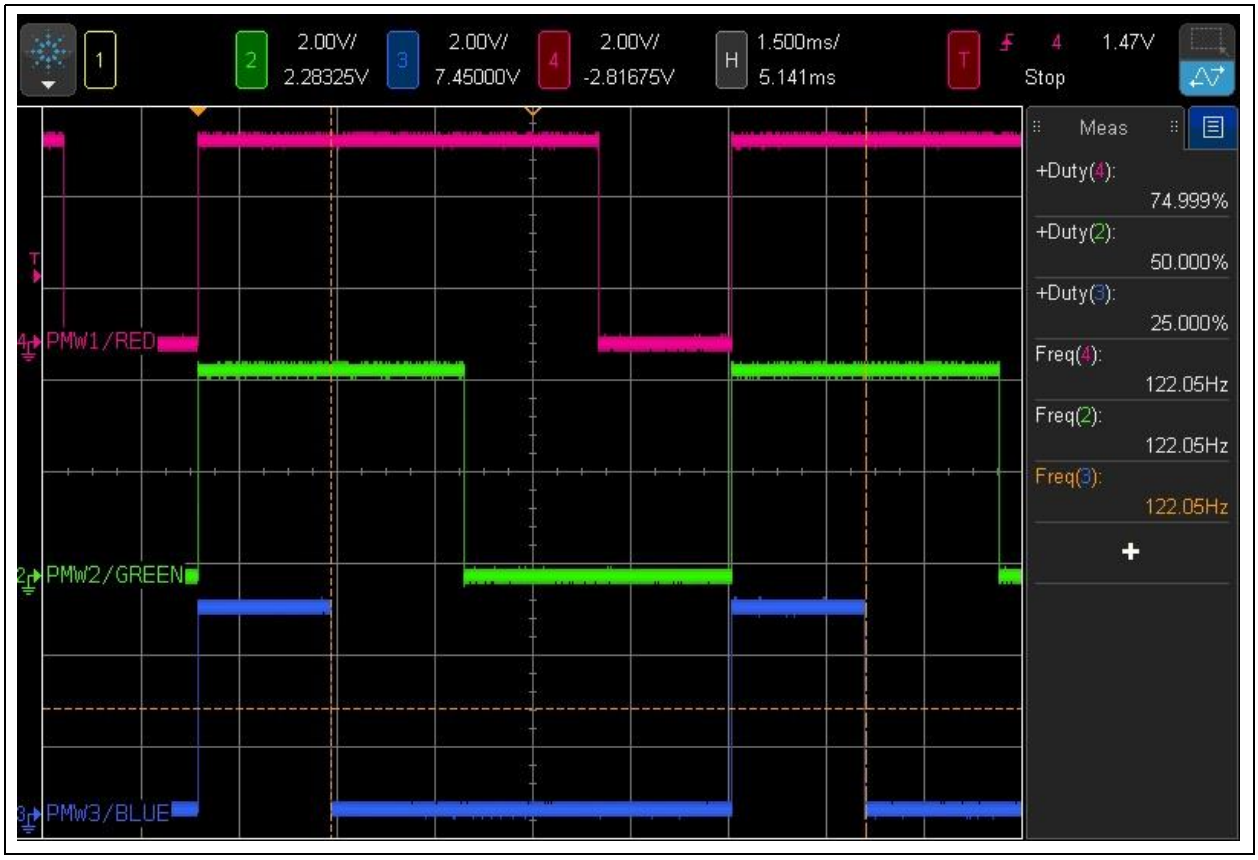


Figure 11 below shows what the three PWM output signals should look like using the same configuration just described with the exception of simultaneously having all three PWM outputs active at the same time. The duty cycle values shown in Figure 11 are listed below.

- PWM1DC = 49151 = 75% (65535*0.75).
- PWM2DC = 32767 = 50% (65535*0.50).
- PWM2DC = 16383 = 25% (65535*0.25).

FIGURE 11: PWM EXAMPLE OUTPUT



REFERENCES

For additional information regarding the use and configuration of the High Precision 16-bit PWM, see the following data sheets:

- "*PIC12(L)F1571/2 8-Pin MCU with High-Precision 16-bit PWMs*" (DS40001723)
- "*PIC16(L)F1574/5/8/9 14/20-Pin MCUs with High-Precision 16-bit PWMs*" (DS40001782)

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