AN1468

Peripheral Brief: Programmable Switch Mode Controller (PSMC)

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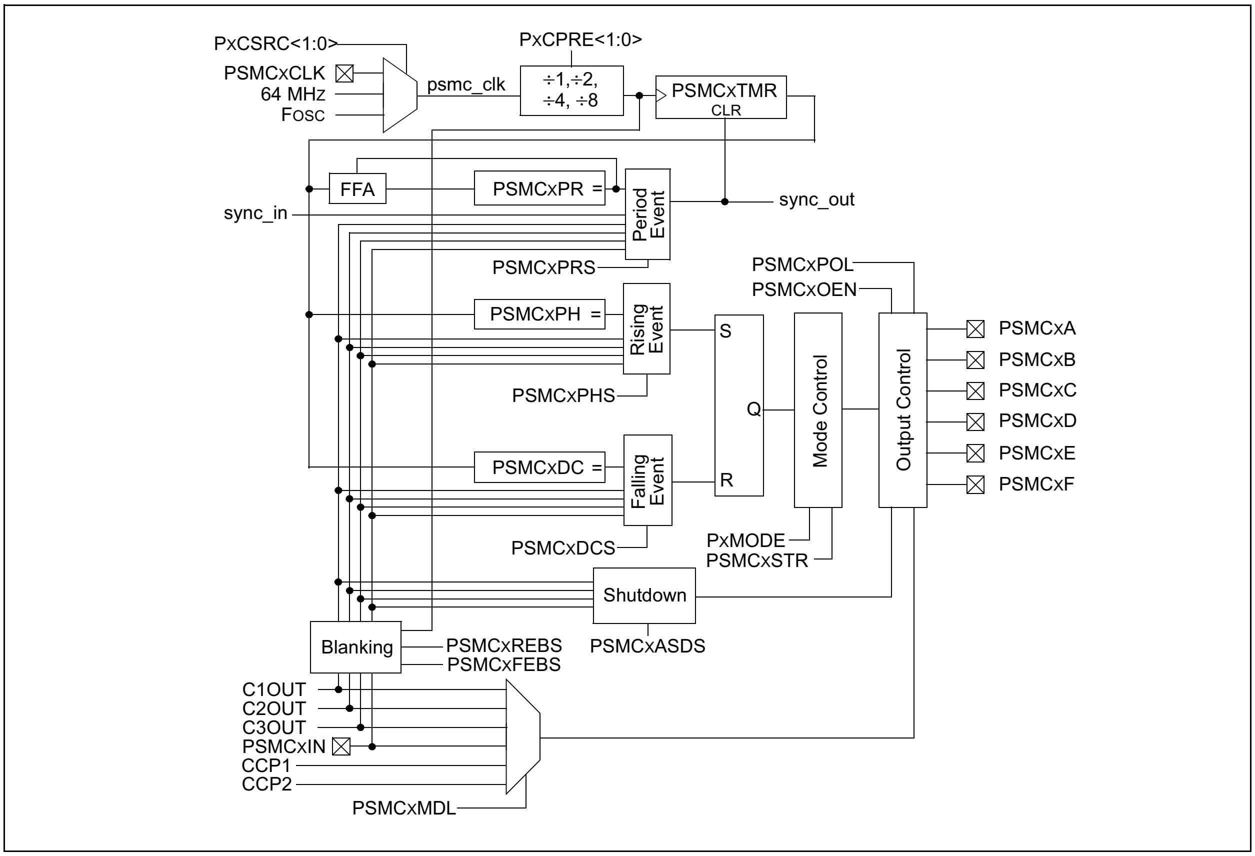
INTRODUCTION

This peripheral brief reviews the basic functionality of the Programmable Switch Mode Controller (PSMC), as well as discusses which PIC® MCUs have this peripheral, and some suggested applications examples utilizing this peripheral.

WHAT IS THE PSMC?

The Programmable Switch Mode Controller (PSMC) is a high-performance 16-bit pulse-width modulator (PWM), that can be configured to operate in one of many modes to support single or multiple phase applications. It was designed to meet a need to intelligently and efficiently drive the MOSFET switching of various Switch Mode Power Supplies, lighting, and motor drive applications. Basically, it is a PWM Swiss army knife that gives you 12 different modes of PWM generation, and the flexibility to be used with other on-board peripherals to solve or update real world applications. The PIC16(LF)F178X family of devices are the first PIC microcontrollers introduced with the PSMC module, which are also equipped with advanced analog peripherals, such as 12-bit ADCs, high-speed comparators, operational amplifiers, 8-bit DACs, capture/compare/PWMs, Fixed Voltage Reference, multiple timers, I^{2}C™/SPI/EUSART communications, debug capability, and low-power features. Refer to the PIC16(L)F1782/3 product page at www.microchip.com, and the product data sheet (DS41579) for more details and information.

FIGURE 1: PSMC SIMPLIFIED BLOCK DIAGRAM



FUNDAMENTAL OPERATION

Blanking

The inputs to the PSMC can be selected from: the on-board high-speed comparator outputs (CxOUT), an external input pin (PSMCxIN), or the output of the on-board CCP (capture/compare/PWM) modules can be used for PSMC modulation, which will be discussed later. The inputs from the comparators or the external input pin can then go through an input blanking control. Input blanking is a function whereby the inputs (PSMC input pin and/or any of the comparator outputs) may be driven inactive for a short period of time. This is to prevent electrical transients, from the turning on and/or off of power components, from generating a false event.

Inputs

After blanking control, the input signals will then go to the core of the PSMC, where the fundamental operation begins. Here, the PSMC operates based on a sequence of three events; the Period Event, the Rising Edge Event, and the Falling Edge Event. Each of these three events are triggered by the user selecting a combination of external inputs (comparator outputs and PSMC input pin), or time-based counter inputs derived from an internal clock (PSMCxPR, PSMCxPH, PSMCxDC, and PSMCxTMR registers) – see Figure 1.

Period Event

The period event determines the frequency of the output pulse, which of its sources include any combination of the PSMC timer/counter match, PSMC input pin, and/or any of the comparator outputs (see Figure 2). During a period, the rising edge event and falling edge event are each permitted to occur only once. Subsequent rising or falling edge events that may occur within the period are suppressed, thereby preventing output chatter from spurious inputs (see Figure 3 and Figure 4).

Rising Edge Event

The rising edge event determines the start of the output pulse. Depending on the PSMC mode, one or more of the PSMC outputs will change in immediate response to the rising edge event (see Figure 2). A rising edge event that occurs after a falling edge event within the same period is suppressed, resulting in no PWM output signal (see Figure 5).

Falling Edge Event

The falling edge event determines the end of the output pulse. The falling edge event is also referred to as the duty cycle, because varying the falling edge event, while keeping the rising edge event and period events fixed, varies the active drive duty cycle. Depending on the PSMC mode, one or more of the PSMC outputs will change in immediate response to the falling edge event (see Figure 2). If a falling edge event continues on into the next cycle period, the rising edge event of that next cycle period is suppressed, resulting in no PWM output signal for that cycle period (see Figure 6).

Clock Selection

The PSMC module is clocked from one of three options; an external clock pin, 64 MHz, or the system oscillator frequency (FOSC). An external clock source can range from 32 kHz to 20 MHz, depending on the crystal used, independently from the oscillator selection of the microcontroller CPU. Using the 64 MHz clock option, the user can have the PSMC running at 64 MHz, while the rest of the microcontroller is running at 32 kHz, thus allowing the CPU to run in a lower power mode while the PSMC runs at a much faster speed. As a final option, the user can setup the PSMC to run at the same clock speed as the CPU. See Figure 1 for a PSMC Simplified Block Diagram.

FIGURE 2: BASIC PWM WAVEFORM GENERATION

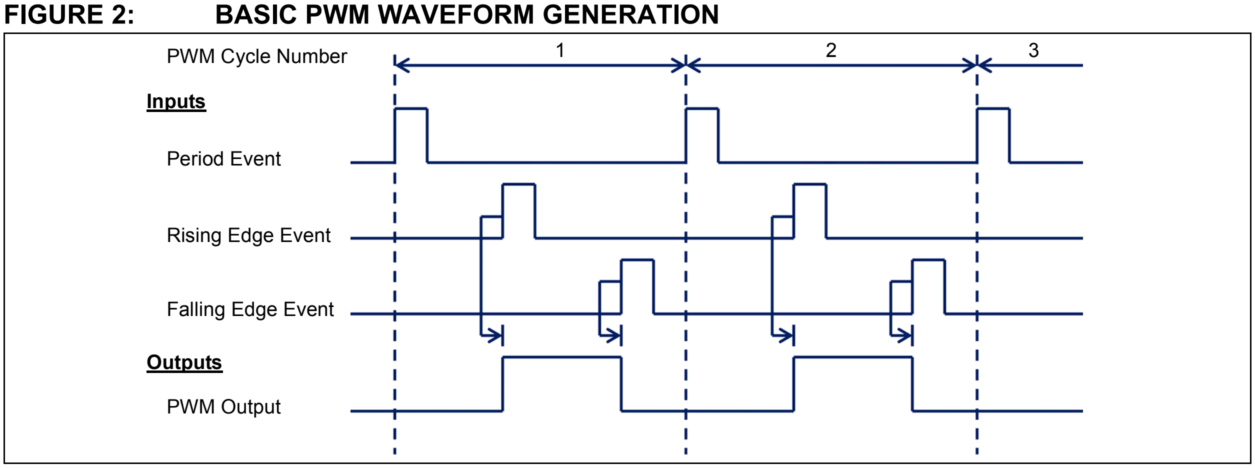


FIGURE 3: SUBSEQUENT RISING EDGE EVENT WAVEFORM

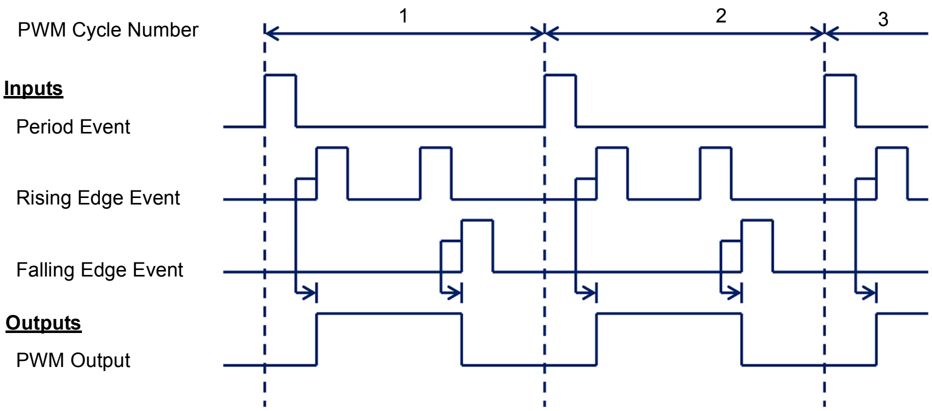
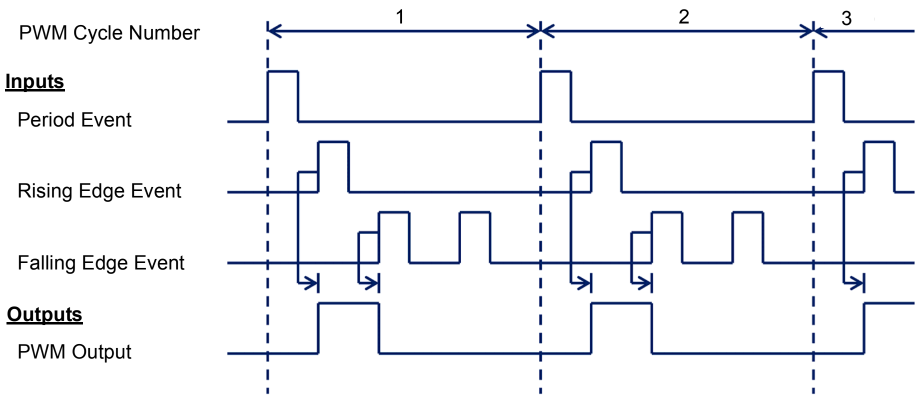
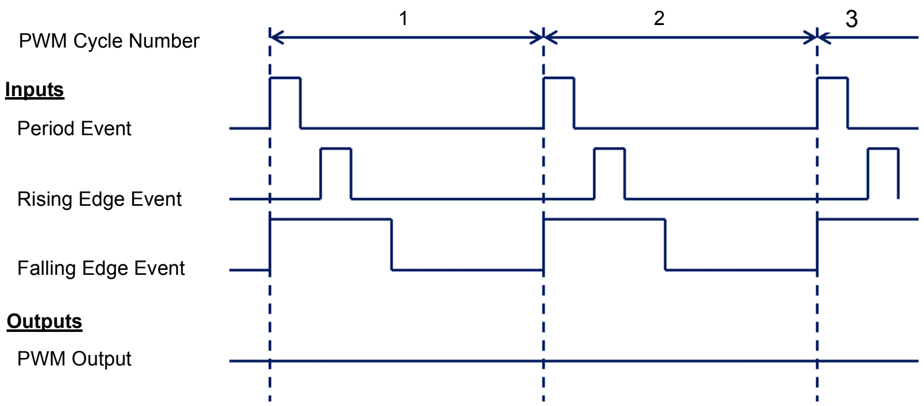


FIGURE 4: SUBSEQUENT FALLING EDGE EVENT WAVEFORM



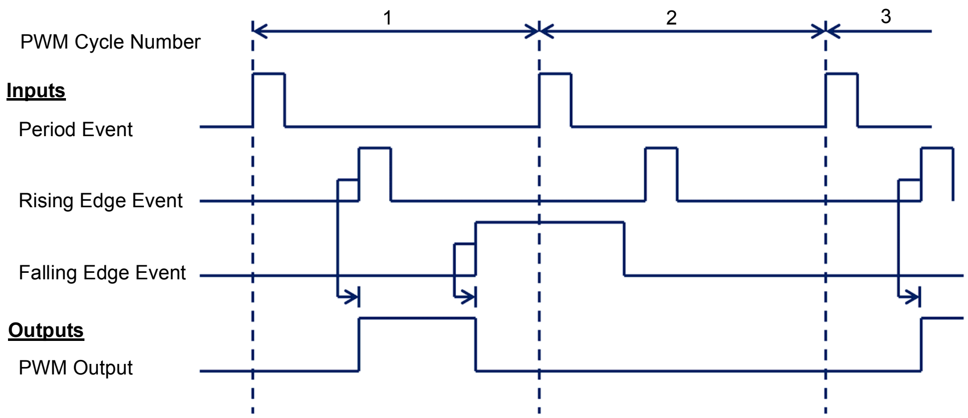
The first falling edge event in a cycle period is permitted to cause action in the PWM output signal, all other falling edge events.

FIGURE 5: RISING EDGE EVENT AFTER A FALLING EDGE EVENT



A rising edge event that occurs after a falling edge event in the same cycle period is also suppressed.

FIGURE 6: FALLING EDGE EVENT COVERING MULTIPLE CYCLE PERIODS

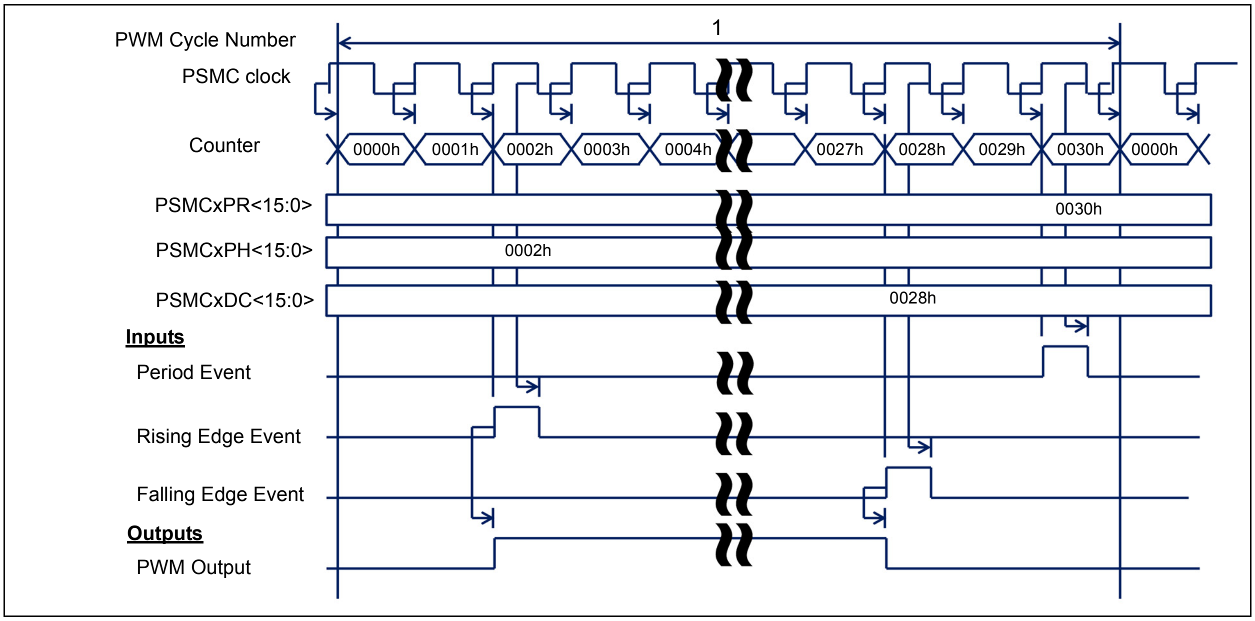


If a falling edge event continues into the next cycle period, the rising edge event is suppressed until the next cycle period.

Time-Based Events

If your application requires a PWM output based on very specific rising and falling edge events for a specific period, that all three can be preloaded, then using time-based event sources is the way to go. The PSMCxTMR register (a 16-bit counter) is used as a timing reference for each PWM period. The counter starts at 0000h and increments to FFFFh on the rising edge of the PSMC clock signal. The PSMCxPR period register is used to determine a period event referenced to the 16-bit digital counter PSMCxTMR. A match between the PSMCxTMR and the PSMCxPR registers will generate a period event. For example; if PSMCxPR = 0030h, PSMCxTMR will increment from 0000h to 0030h, then roll over to 0000h, and so on. Thus, each set of 0030h counts will be one PWM cycle number or one PWM output period. The PSMCxPH phase register is used to determine a rising edge event referenced to the 16-bit PSMCxTMR digital counter. A match between the PSMCxTMR and the PSMCxPH register values will generate a rising edge event. For example; if PSMCxPH = 0002h, when the PSMCxTMR counter increments to 0002h, a rising edge event will occur. The PSMCxDC duty cycle register is used to determine a synchronous falling edge event referenced to the 16-bit PSMCxTMR digital counter. A match between the PSMCxTMR and the PSMCxDC register values will generate a falling edge event. For example; if PSMCxDC = 0028h, when the PSMCxTMR counter increments to 0028h, a falling edge event will occur. Also, to configure the PWM output for a zero percent duty cycle operation, set PSMCxDC equal to PSMCxPH. This will trigger a falling edge event simultaneously with the rising edge event, thus preventing an output PWM signal. Likewise, with a 100% duty cycle operation, set PSMCxDC greater than PSMCxPR. This will prevent a falling edge event from occurring, as the PSMCxDC value and the time base counter value will never be equal. These rising and falling edge events will determine the PWM output signal for the given PWM cycle number period. For an example of a PWM waveform generated with the time-based event sources, see Figure 7.

FIGURE 7: BASIC PWM WAVEFORM GENERATED BY TIME-BASED EVENT SOURCES



MODES OF OPERATION

After the rising and falling edge events are logically combined, via an SR latch, various output PWM pulse signals are produced based on the mode of operation selected. Here the user can select one of 12 modes, each with its own set of features, to drive almost any type of MOSFET switching application available, from Switch Mode Power Supplies to lighting or motor control. Because this peripheral can be used for so many applications, a short summary table with a complete list of modes with features and application examples for each of the 12 different PSMC modes of operation is shown in Table 1.

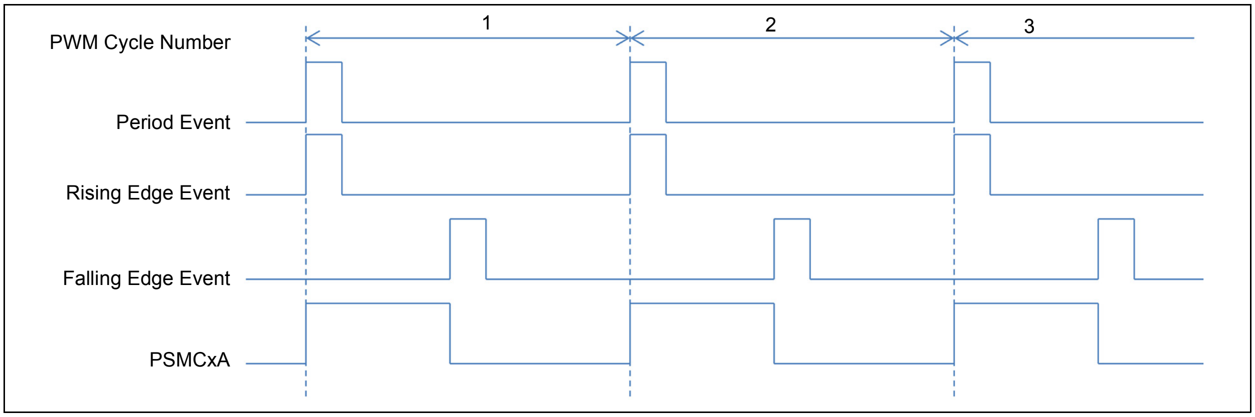
TABLE 1: PSMC MODES OF OPERATION

Modes of Operation	Dead-Band Delay	PWM Steering	Primary Outputs	Complementary Outputs	Fractional Freq. Adjust (FFA)	Application Examples
Single Phase PWM	No	Yes	A,B,C,D,E,F	—	No	- Stepper motor control - Brushed DC motor control - Power supplies
Complementary PWM	Yes	Yes	A,C,E	B,D,F	No	
Push-Pull PWM	No	No	A,B	—	No	- Half and full bridge power supplies - Synchronous drives
Push-Pull PWM w/ Complementary Outputs	Yes	No	A,E	B,F	No	
Push-Pull PWM w/4 Full-Bridge Outputs	No	No	A,B,C,D	—	No	- DC to AC inverters - Class-D output drives - Induction motor drives
Push-Pull PWM w/4 Full-Bridge and Complementary Outputs	Yes	No	A,B,C,D	E,F	No	
Pulse Skipping PWM	No	No	A	—	No	- High efficiency boost converters - Voltage mode boost controllers
Pulse Skipping PWM w/ Complementary Outputs	Yes	No	A	B	No	
ECCP Compatible Full-Bridge PWM	Yes (Forward and Reverse)	No	A,B,C,D	—	No	- Brushed DC motor control
Variable Freq. – Fixed Duty Cycle PWM	No	No	A	—	Yes	- Resonant converters - Fluorescent dimming ballasts
Variable Freq. – Fixed Duty Cycle PWM w/ Complementary Outputs	Yes	No	A,C,E	B,D,F	Yes	- Resonant power supplies - Induction motor drives with speed control
3-Phase PWM	No	Yes	A and D A and F C and F C and B E and B E and D	—	No	- 3-Phase BLDC motors - AC inverters

Single-Phase PWM

The single-phase PWM is the most basic of all the waveforms generated by the PSMC module. Common application examples are motor control and power supply drivers. It consists of a single output that uses all three events (rising edge, falling edge and period events) to generate the waveform. This mode of operation does not have dead-band delay control, but the PWM output can be steered to any combination of the six output pins. See Figure 8 for an example waveform of single-phase PWM operation.

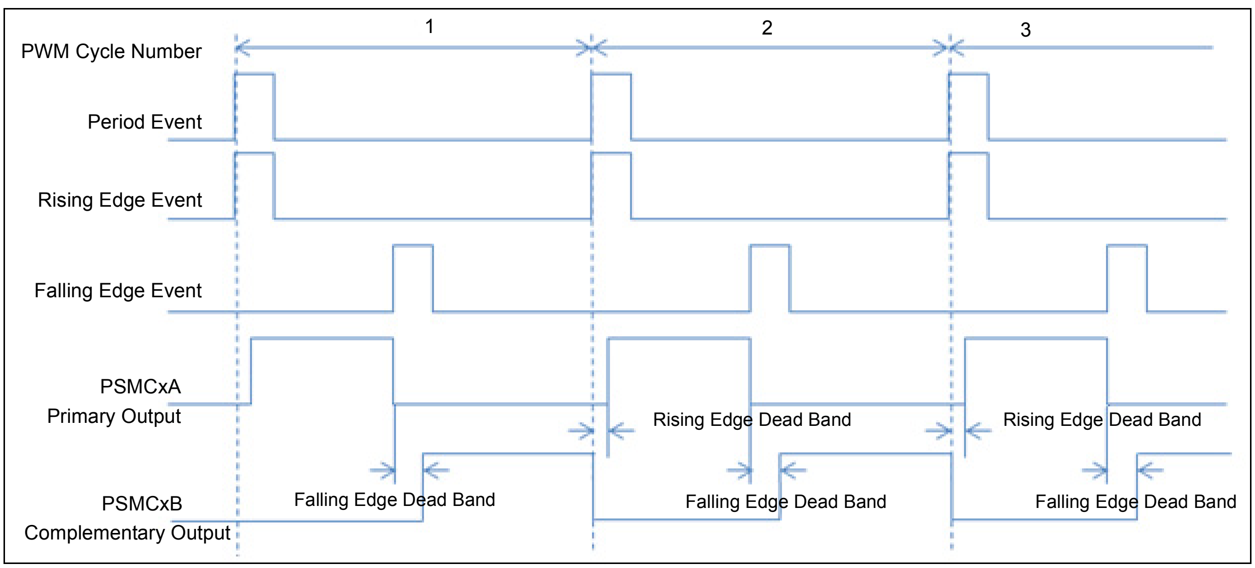
FIGURE 8: SINGLE-PHASE PWM MODE



Complementary PWM

The complementary PWM uses the same event sources as the single phase PWM, but two waveforms are generated instead of only one. The two waveforms are opposite in polarity to each other, thus one is the complement of the other. The two waveforms will also have dead-band control as well. The dead-band control provides non-overlapping PWM signals to prevent shoot-through current in series connected power switches. Dead-band control is available only in modes with complementary waveform capability. The module contains independent 8-bit dead-band counters for rising edge and falling edge dead-band control. The PWM outputs can be steered to three primary PWM output pins and three complementary output pins. See Figure 9 for an example waveform of complementary PWM operation.

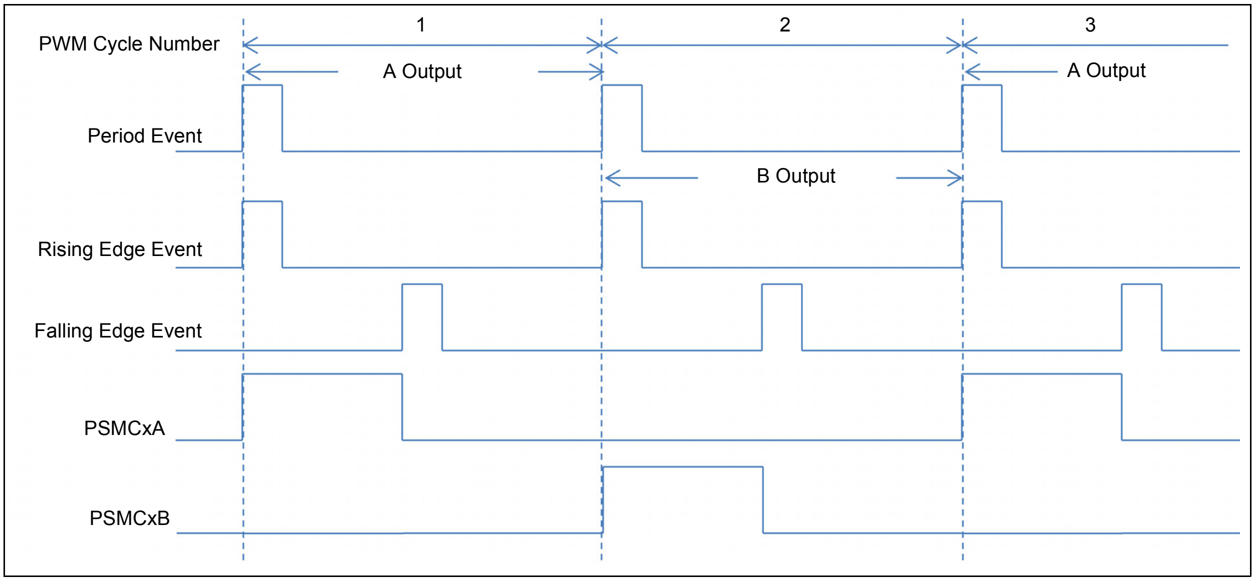
FIGURE 9: COMPLEMENTARY PWM MODE



Push-Pull PWM

The push-pull PWM is used to drive half and full-bridge power supplies, as well as other synchronous drives. It uses at least two outputs and generates PWM signals that alternate between the two outputs in even and odd cycles. This mode does not use dead-band delay or output steering control. The PWM outputs are only available on two of the six output pins. See Figure 10 for an example waveform of push-pull PWM operation.

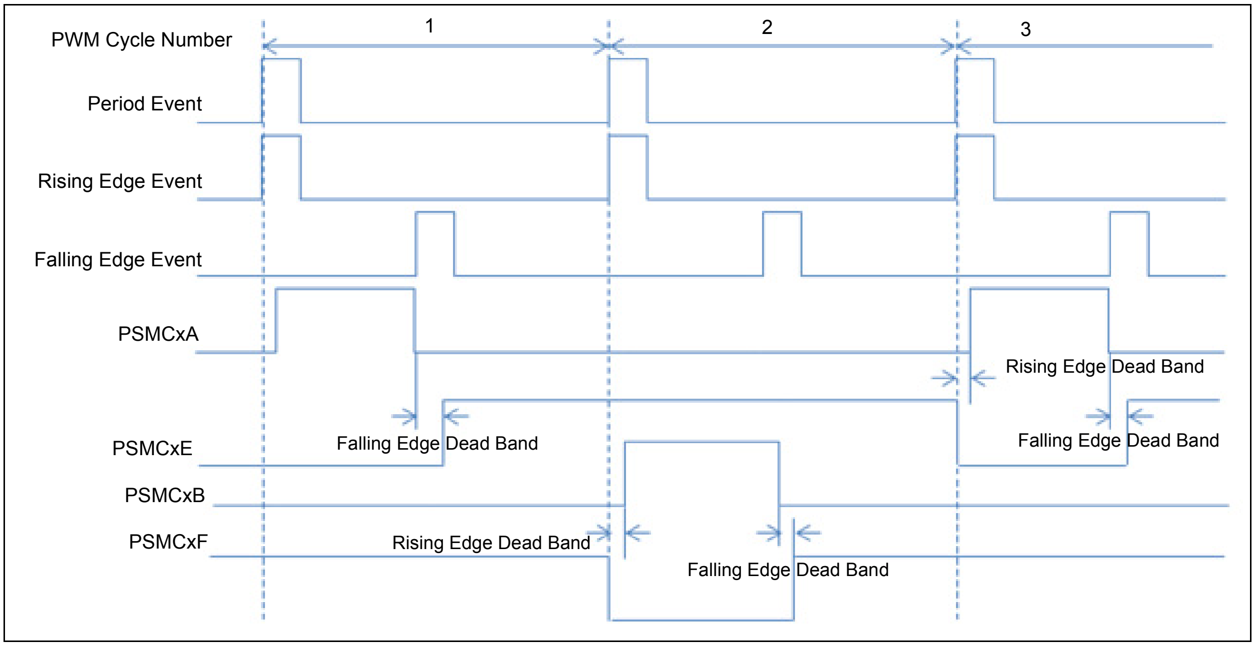
FIGURE 10: PUSH-PULL PWM MODE



Push-Pull PWM with Complementary Outputs

The complementary push-pull PWM is used to drive transistor bridge circuits, as well as synchronous switches on the secondary side of the bridge. The PWM waveform outputs on four pins presented as two pairs of two-output signals with a primary and complementary output in each pair. This mode of operation uses dead-band delay control but not output steering control. See Figure 12 for an example waveform of push-pull PWM with complementary outputs operation.

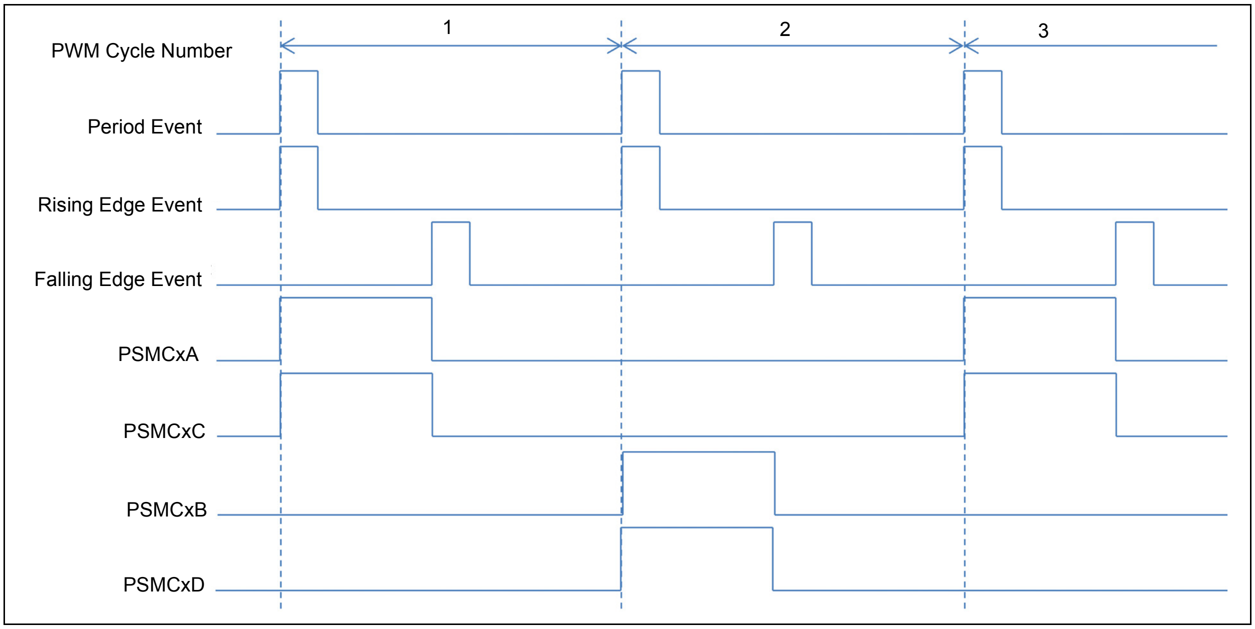
FIGURE 11: PUSH-PULL WITH COMPLEMENTARY OUTPUTS PWM MODE



Push-Pull PWM with Four Full-Bridge Outputs

The full-bridge push-pull PWM is used for DC to AC inverters, Class D output drives and induction motor drive systems. This mode does not utilize dead-band delay or output PWM steering control and the output signals are only available on four of the six output pins. See Figure 12 for an example waveform of push-pull PWM with four full-bridge outputs operation.

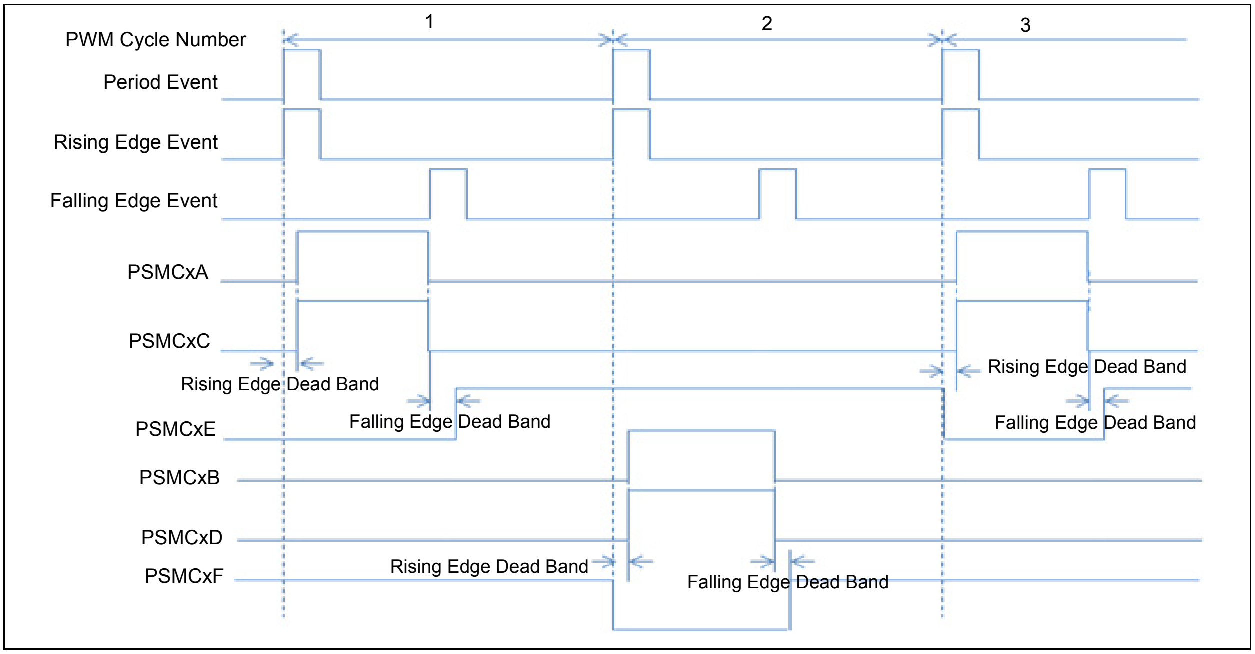
FIGURE 12: PUSH-PULL WITH 4 FULL-BRIDGE OUTPUTS PWM MODE



Push-Pull PWM with Four Full-Bridge and Complementary Outputs

The push-pull PWM with four full-bridge and complementary outputs is used for DC to AC inverters, Class D output drives and induction motor drive systems. This mode does not utilize PWM steering control, but it does use dead-band delay control and sends the primary PWM outputs to four pins and the complementary outputs to the remaining two of the six output pins. See Figure 13 for an example waveform of push-pull PWM with four full-bridge and complementary outputs operation.

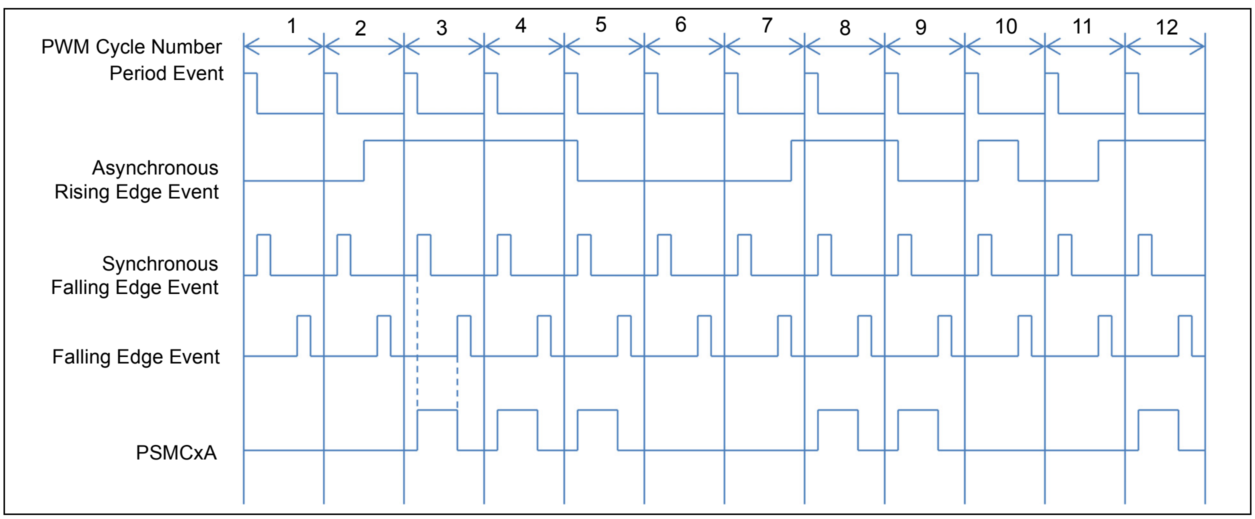
FIGURE 13: PUSH-PULL WITH 4 FULL-BRIDGE AND COMPLEMENTARY OUTPUTS PWM MODE



Pulse-Skipping PWM

The pulse-skipping PWM is used to generate a series of fixed-length pulses that can be triggered at each period event. This type of PWM signal is useful for high efficiency and Voltage mode boost converters. In order for an output PWM signal to be asserted, an asynchronous rising edge event must be active (`1`) and a synchronous rising edge event must occur within the same single/multiple set of period events, otherwise no output will be generated. This mode does not utilize dead-band delay or output steering control and the output signal is limited to one output pin. See Figure 14 for an example waveform of pulse-skipping PWM.

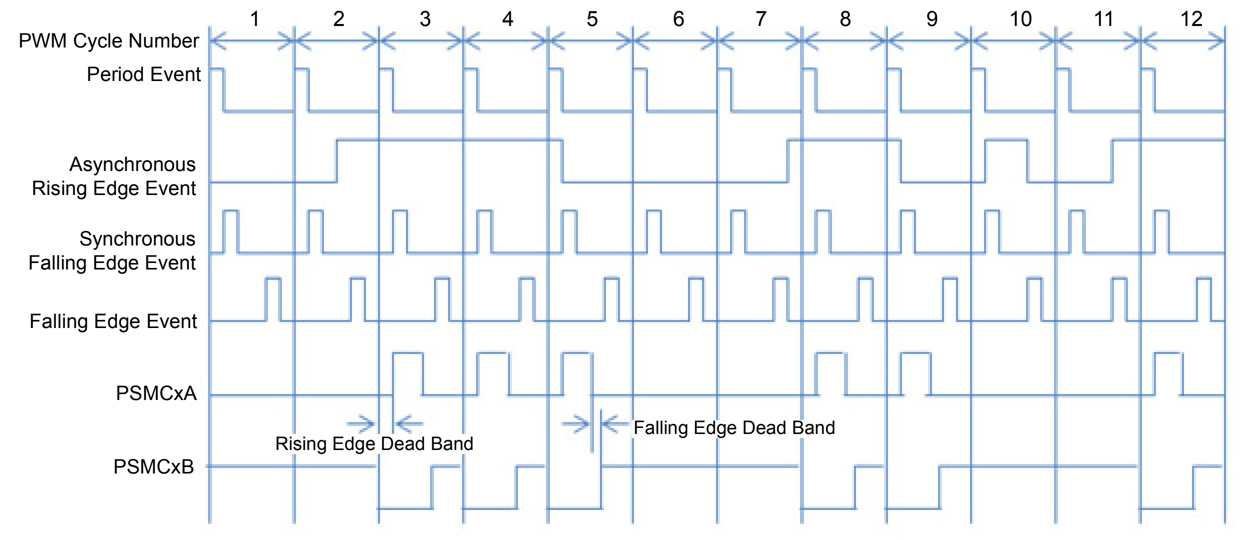
FIGURE 14: PULSE-SKIPPING PWM MODE



Pulse-Skipping PWM with Complementary Output

This Pulse-Skipping mode works exactly the same as the last mode, with one exception: a complementary output signal is generated. Thus, this mode utilizes dead-band delay control and the complementary output is available on a separate output pin. See Figure 15 for an example waveform of pulse-skipping with complementary output PWM.

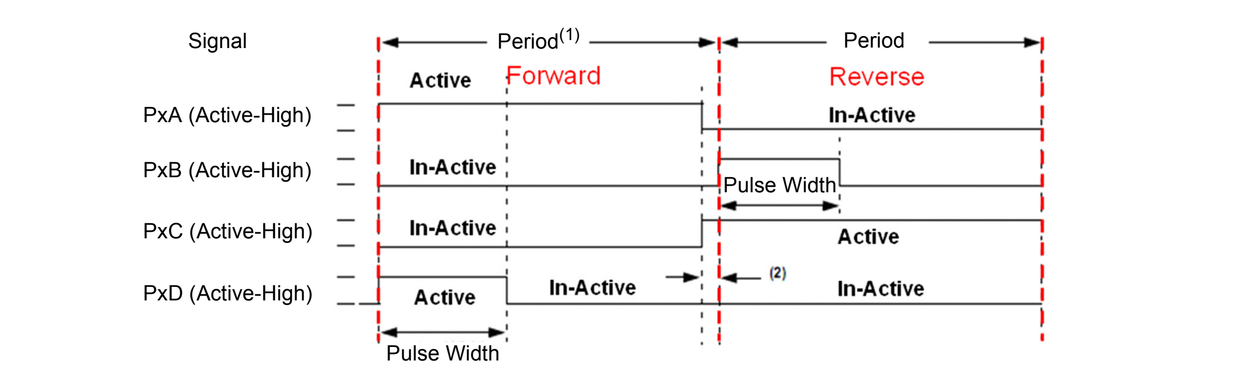
FIGURE 15: PULSE-SKIPPING PWM MODE



ECCP Compatible Full-Bridge PWM

This mode of operation is designed to match the Full-Bridge mode from the ECCP module. It is called ECCP compatible, because this mode replicates the PWM output signals needed to drive a full-bridge drive circuit in the forward and reverse directions, see Figure 16.

FIGURE 16: EXAMPLE OF PWM DIRECTION CHANGE

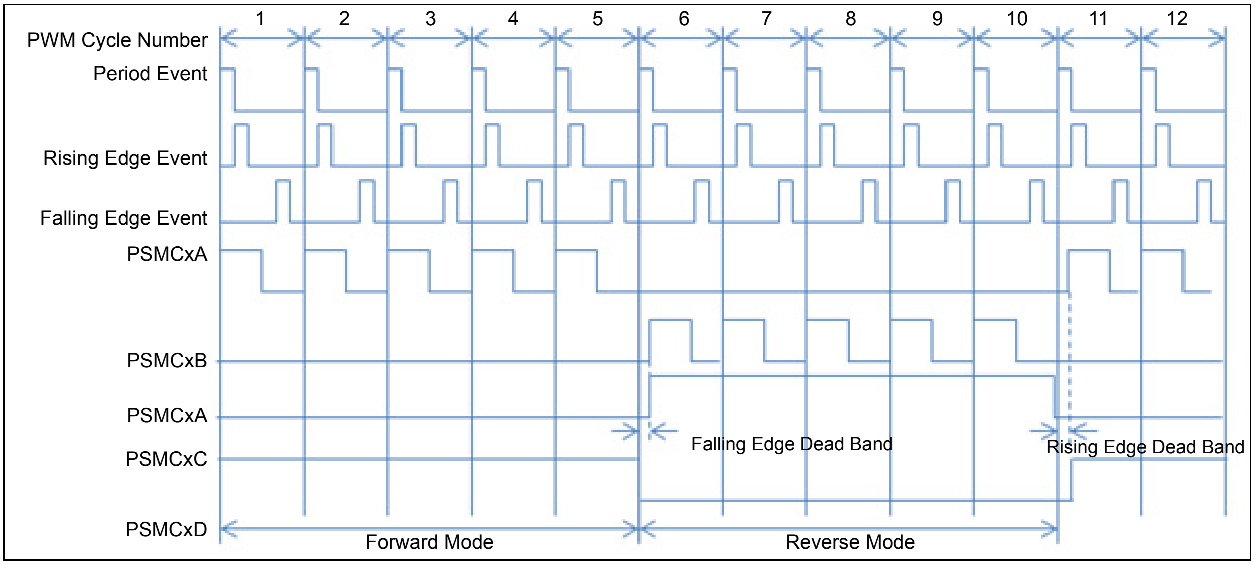


Note 1: The direction bit PxM1 of the CCPxCON register is written any time during the PWM cycle.

2: When changing directions, the PxA and PxC signals switch before the end of the current PWM cycle. The modulated PxB and PxD signals are inactive at this time. The length of this time is four Timer counts.

The Full-Bridge Compatible mode uses the same waveform events as the single-phase PWM mode to generate the output waveforms. There are both Forward and Reverse modes available for this operation, again to match the ECCP implementation. This mode utilizes dead-band delay control with respect to the forward and reverse direction changes. See Figure 17 for an example waveform of ECCP compatible full-bridge PWM.

FIGURE 17: ECCP COMPATIBLE FULL-BRIDGE PWM MODE



Variable Frequency – Fixed Duty Cycle PWM

This mode of operation is quite different from all of the other modes. It uses only the period event for waveform generation. At each period event, the PWM output is toggled, producing a fixed duty cycle PWM signal. The rising edge and falling edge events are unused in this mode. This mode is useful for resonant converters and fluorescent dimming ballasts. The dead-band delay and output steering controls are not utilized in this mode, however, fractional frequency adjust can be used for making fine period timing adjustments. See Figure 18 for an example waveform of Variable Frequency Fixed Duty Cycle PWM. The Fractional Frequency Adjust (FFA) is a method by which PWM resolution can be improved on 50% fixed duty cycle signals. Higher resolution is achieved by altering the PWM period by a single count for calculated intervals. This increased resolution is based upon the PWM frequency averaged over a large number of PWM periods. So, after every period event, the FFA adds the PSMCxFFA register value with the previously accumulated result. This addition causes an overflow and the period event time is increased by one. See Figure 19 for a simplified block diagram of the fraction frequency adjust.

FIGURE 18: VARIABLE FREQUENCY – FIXED DUTY CYCLE PWM MODE

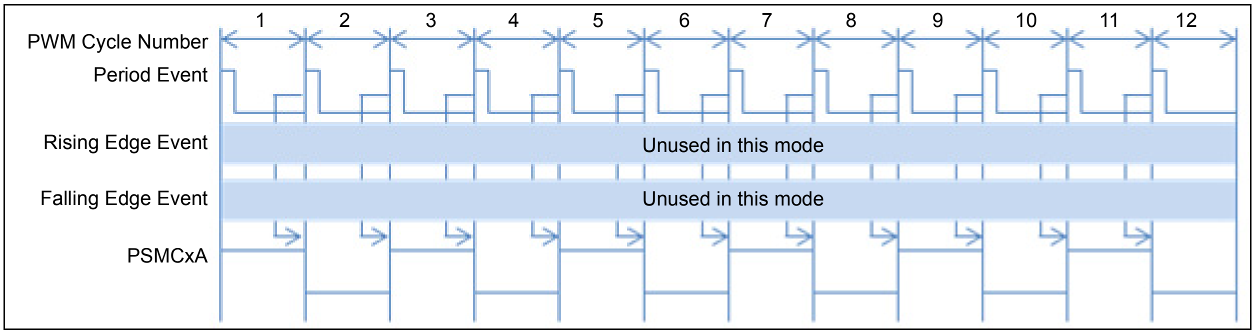
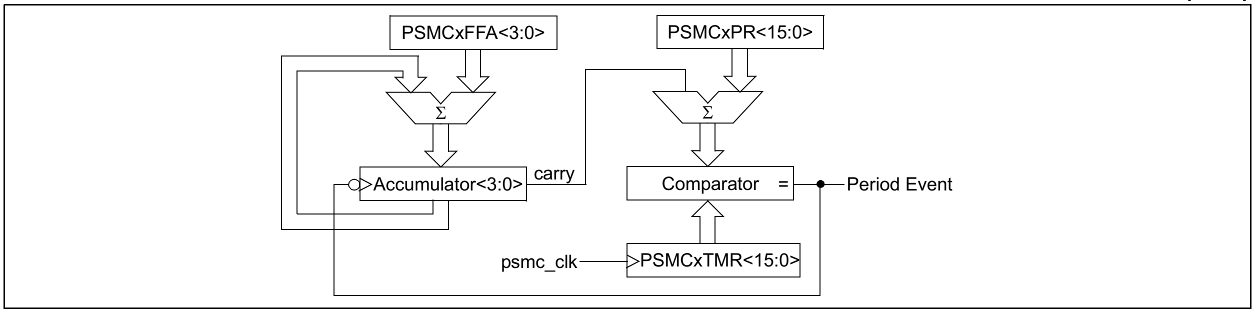


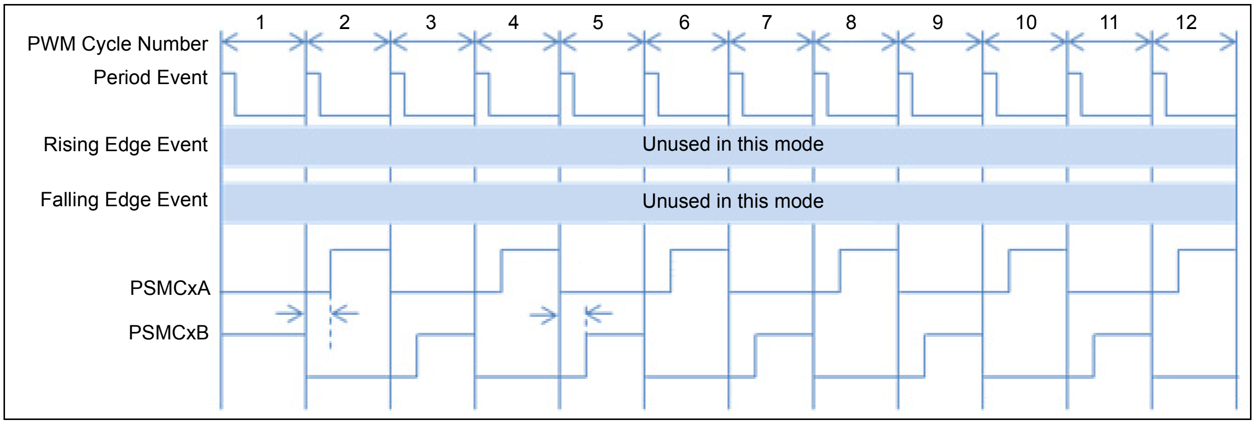
FIGURE 19: SIMPLIFIED BLOCK DIAGRAM OF THE FRACTIONAL FREQUENCY ADJUST (FFA)



Variable Frequency – Fixed Duty Cycle PWM with Complementary Outputs

This mode is the same as the single output Fixed Duty Cycle mode above, except a complementary output with dead-band control is generated. See Figure 20 for an example waveform of Variable Frequency Fixed Duty Cycle with Complementary PWM.

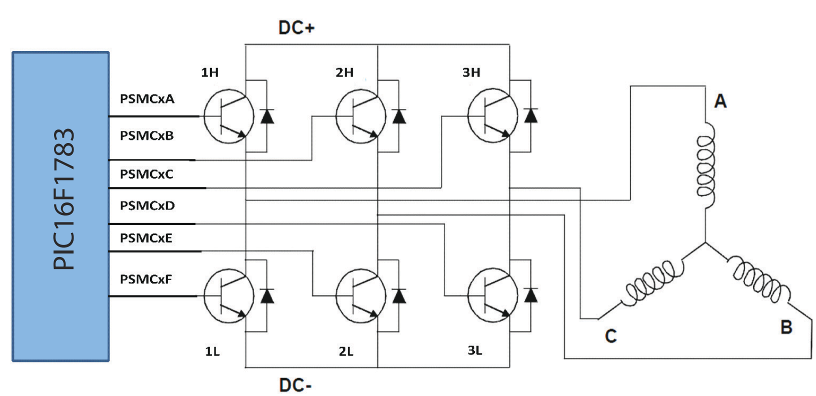
FIGURE 20: VARIABLE FREQUENCY – FIXED DUTY CYCLE WITH COMPLEMENTARY PWM MODE



3-Phase PWM

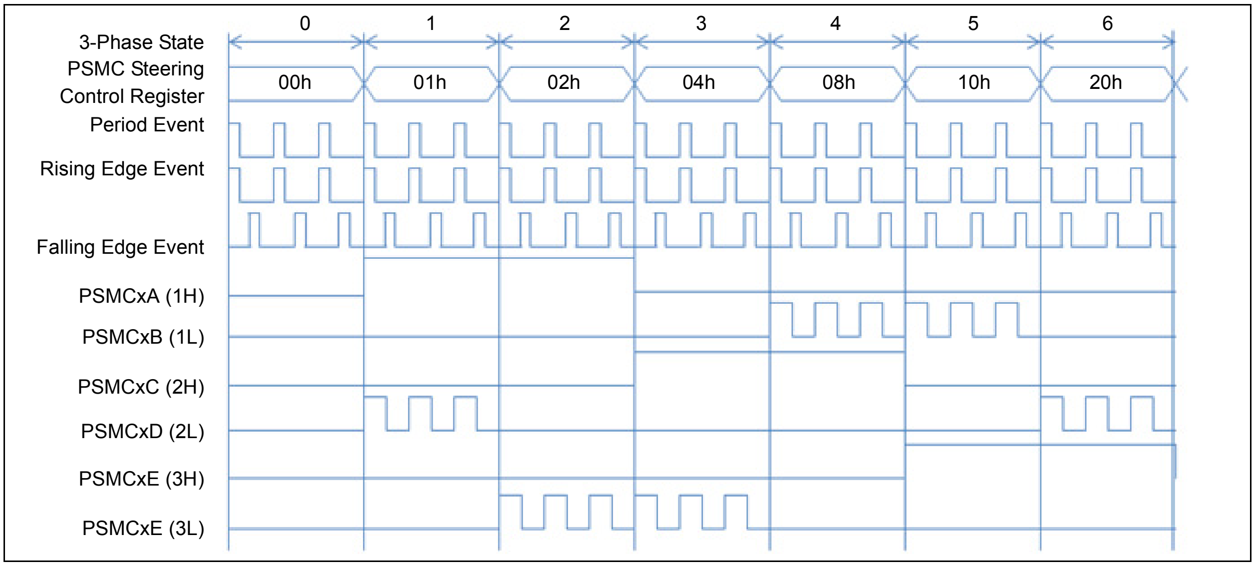
The 3-Phase mode of operation is used in 3-phase power supply and motor drive applications configured half-bridges, see Figure 21.

FIGURE 21: 3-PHASE DRIVE APPLICATION



A half-bridge configuration consists of two power driver devices in series, between the positive power rail (high side) and negative power rail (low side). The three outputs come from the junctions between the two drivers in each half-bridge. When the steering control selects a phase drive, power flows from the positive rail through a high-side power device to the load and back to the power supply through a low-side power device. In this mode of operation, all six PSMC outputs are used, but only two are active at a time. The two active outputs consist of a high-side driver and low-side driver output. Now, in order for the motor to rotate forward, the PSMC steering control register values are selected. The timing speed at which these values are selected will determine the speed of the motor, likewise when the PSMC steering register values are selected in reverse. See Figure 22 for an example waveform of 3-phase PWM.

FIGURE 22: 3-PHASE PWM MODE



OTHER PSMC FEATURES

Auto-Shutdown

PSMC operation can be quickly terminated without software intervention by the auto-shutdown control. Auto-shutdown can be triggered by any combination of the comparator outputs, manually and/or externally to the microcontroller via an input pin. Auto-shutdown is a method to immediately override the PSMC output levels with specific overrides that allow for safe shutdown of the application. This feature also includes a mechanism (auto-restart) to allow the application to restart under different conditions manually or automatically.

PSMC Synchronization

It is possible to synchronize the periods of two or more PSMC modules together, provided that both modules are on the same device. Synchronization is achieved by sending a sync signal from the master PSMC module to the desired slave modules. This sync signal generates a period event in each slave module, thereby aligning all slaves with the master. This is useful when an application requires different PWM signal generation from each module, but the waveforms must be consistent within a PWM period.

PSMC Modulation

PSMC modulation is a method to stop/start PWM operation of the PSMC without having to disable the module. It also allows other modules to control the operational period of the PSMC. This is also referred to as Burst mode. This is a method to implement PWM dimming for use in LED lighting, and for start-up and shutdown in power supply design.

CONCLUSION

The Programmable Switch Mode Controller (PSMC) is a 16-bit PWM that is an ideal peripheral suited for power supply, lighting, and motor control applications, such as buck converters, boost converters, brushed DC, brushless, 3-phase, etc. This peripheral brief describes the basic function and modes of operation of the PSMC, which can be applied to many real-world applications. Currently, the PSMC peripheral is only available on the PIC16(L)F1782 and PIC16(L)F1783 devices, however, stay tuned to www.microchip.com for future devices that will have the PSMC on board.

Finally, keep in mind that, in order to take advantage of all the benefits of this peripheral, the user must utilize and/or optimize the other capabilities of the selected PIC MCU.

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