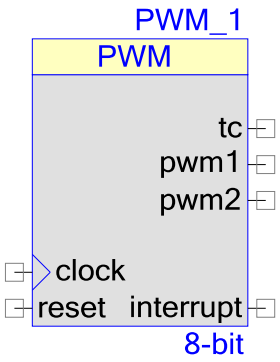
Pulse Width Modulator (PWM)
1.0

Features

- 8 or 16-Bit Resolution
- Multiple Pulse Width Output Modes
- Configurable Trigger
- Configurable Capture
- Configurable Hardware/Software Enable
- Configurable Dead-Band
- Multiple Configurable Kill Modes
- Customized Configuration tool



General Description

The PWM component provides compare outputs to generate single or continuous timing and control signals in hardware. The PWM is designed to provide an easy method of generating complex real time events accurately with minimal CPU intervention. The PWM features may be combined with other analog and digital components to create custom peripherals.

The PWM generates up to 2 left or right aligned PWM outputs or 1 center aligned or dual edged PWM output. The PWM outputs are double buffered to avoid glitches due to duty cycle changes while running. Left aligned PWMs are used for most general purpose PWM uses. Right aligned PWMs are typically only used in special cases which require alignment opposite of left aligned PWMs. Center aligned PWMs are most often used in AC motor control to maintain phase alignment. Dual edge PWMs are optimized for power conversion where phase alignment must be adjusted.

The optional deadband provides complementary outputs with adjustable dead time where both outputs are low between each transition. The complementary outputs and dead time are most often used to drive power devices in half bridge configurations to avoid shoot through currents and resulting damage. A kill input is also available that immediately disables the deadband outputs when enabled. Three kill modes are available to support multiple use scenarios.

Two hardware dither modes are provided to increase PWM flexibility. The first dither mode increases effective resolution by 2-bits when resources or clock frequency preclude a standard implementation in the PWM counter. The second dither mode uses a digital input to select one of the two PWM outputs on a cycle by cycle basis typically used to provide fast transient response in power converts.

PRELIMINARY

The trigger and reset inputs allow the PWM to be synchronized with other internal or external hardware. The optional trigger input is configurable so that a rising edge starts the PWM. A rising edge on the reset input causes the PWM counter to reset its count as if the terminal count was reached. The enable input provides hardware enable to gate PWM operation based on a hardware signal.

An interrupt can be programmed to be generated under any combination of the following conditions; when the PWM reaches the terminal count or when a compare output goes high.

When to use a PWM

The most common use of the PWM is to generate periodic waveforms with adjustable duty cycles. The PWM also provides optimized features for power control, motor control, switching regulators and lighting control. The PWM can also be used as a clock divider by driving a clock into the clock input and using the terminal count or a PWM output as the divided clock output.

PWMs, Timers and Counters share many capabilities but each provides specific capabilities. A Counter component is better used in situations that require the counting of a number of events but also provides rising edge capture input as well as a compare output. A Timer component is better used in situations focused on timing the length of events, measuring the interval of multiple rising and/or falling edges, or for multiple capture events.

Input/Output Connections

This section describes the various input and output connections for the PWM. An asterisk (*) in the list of I/O's states that the I/O may be hidden on the symbol under the conditions listed in the description of that I/O.

Clock – Input

The clock input defines the signal to count. The counter is incremented or decremented on each rising edge of the clock.

reset – Input

Resets the period counter to "Period" and continues normal operation.

enable – Input *

The enable input works in conjunction with software enable and trigger input (if the trigger input is enabled) to enable the period counter. The enable input will not be visible if the EnableMode parameter is set to "Software Only." This input is not available when the "Fixed Function" PWM implementation is chosen.

kill – Input *

The kill input disables the PWM output(s). There are several kill modes available all of which rely on this input to implement the final kill of the output signal(s). If deadband is implemented only the deadband outputs (ph1 and ph2) are disabled and the pwm, pwm1, and pwm2 outputs are not disabled. The kill input is not visible if the kill mode parameter is set to “Disabled”. When the “Fixed Function” PWM implementation is chosen kill will only kill the deadband outputs if deadband is enabled. It will not kill the comparator output when deadband is disabled.

cmp_sel – Input *

The cmp_sel input selects either pwm1 or pwm2 output as the final output to the pwm terminal. When the input is “0” (low) the pwm output is pwm1 and when the input is “1” (high) the pwm output is pwm2 as shown in the configuration tool waveform viewer. The cmp_sel input is visible when the PWM mode parameter is set to “Hardware Select”.

capture – Input *

The capture input forces the period counter value into the read FIFO. There are several modes defined for this input in the CaptureMode parameter. The capture input is not visible if the CaptureMode parameter is set to “None”. When the “Fixed Function” PWM implementation is chosen the capture input is always rising edge sensitive.

trigger – Input *

The trigger input enables the operation of the PWM. The functionality of this input is defined by the TriggerMode and RunMode parameters. After the “Start” API command the PWM is enabled but the counter does not decrement until the trigger condition has occurred. The trigger condition is set with the TriggerMode parameter. The trigger input is not visible if the trigger mode parameter is set to “None”.

tc – Output

The terminal count output is ‘1’ when the period counter is equal to zero. In normal operation this output will be ‘1’ for a single cycle where the counter is reloaded with period. If the PWM is stopped with the period counter equal to zero then this signal will remain high until the period counter is no longer zero.

Interrupt – Output *

The interrupt output is the logical OR of the group of possible interrupt sources. This signal will go high while any of the enabled interrupt sources are true. The interrupt output is not visible if the UseInterrupt parameter is not set. This allows the status register to be removed for resource optimization as necessary.

pwm/pwm1 – Output *

The pwm or pwm1 output is the first or only pulse width modulated output. This signal is defined by the PWM mode, compare modes(s), and compare value(s) as indicated in waveforms in the configuration tool. When the instance is configured in one output, Dual Edged, Hardware Select, Center Aligned, or Dither PWM modes then the output “pwm” is visible. Otherwise the output “pwm1” is visible with “pwm2” the other pulse width signal.

pwm2 – Output *

The pwm2 output is the second pulse width modulated output. The pwm2 output is only visible when the PWM Mode is set to “Two Outputs”.

ph1/ph2 – Output *

The ph1 and ph2 outputs are the deadband phase outputs of the PWM. In all modes where only the pwm output is visible these are the phased outputs of the pwm signal which is also visible. In two output mode these signals are the phased outputs of the pwm1 signal only. Both of these outputs are visible if deadband is enabled in 2-4 or 2-256 modes and are not visible if deadband is disabled.

Parameters and Setup

The following sections describe the PWM parameters, and how they are configured in the parameter editor.

Figure 1 Configure PWM Dialog – Configure Tab

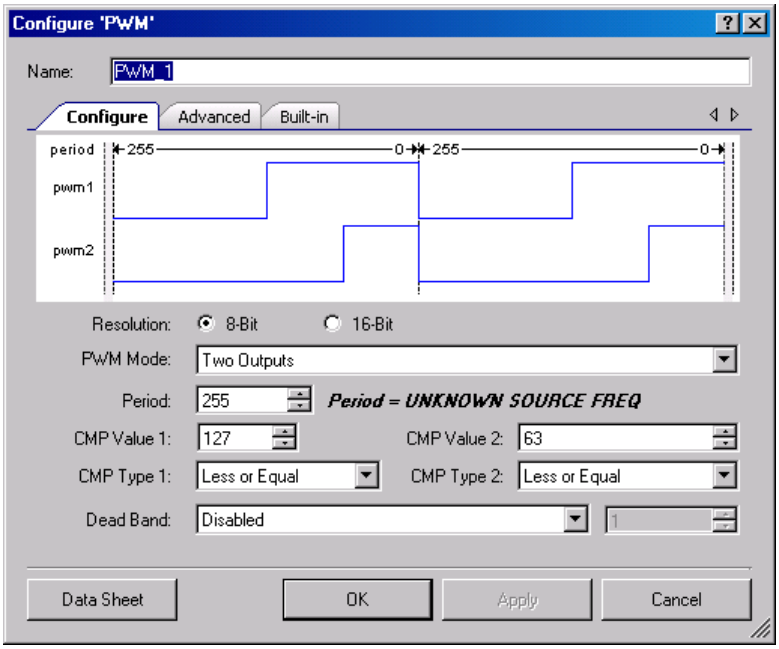
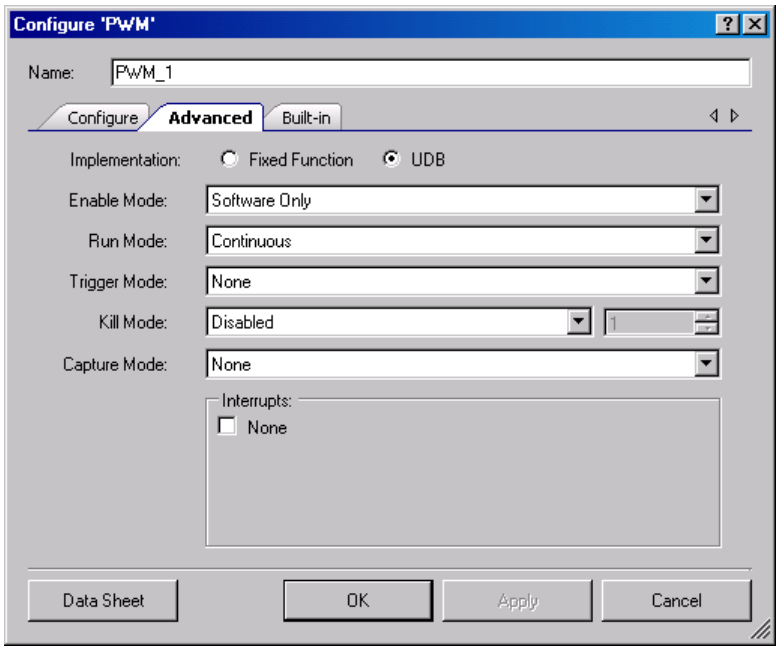


Figure 2 Configure PWM Dialog – Advanced Tab



Hardware Configuration Options

Hardware configuration options change the way the project is synthesized and placed in the hardware. You must rebuild the hardware if you make changes to any of these options.

Resolution (8, 16):

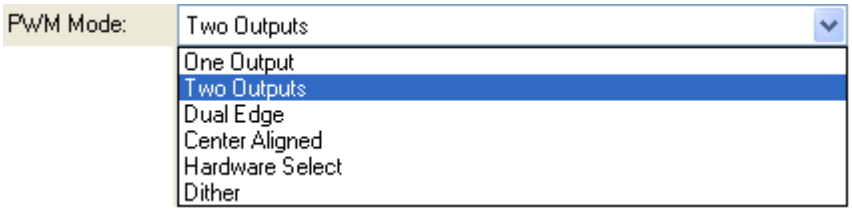
The Resolution parameter defines the bit-width resolution of the period counter.

Resolution	Maximum Period Count Values
8	255
16	65,535

Center align mode requires counting up to the period value and then back down to zero. Thus, doubling the period of the PWM. In this mode the limit for an 8-bit PWM is 254 cycles (x2 = 508 cycles), and 65,534 (x2 = 131,068 cycles) for a 16-bit PWM

PWMMode (enum):

The PWM Mode parameter defines the overall functionality of the PWM.

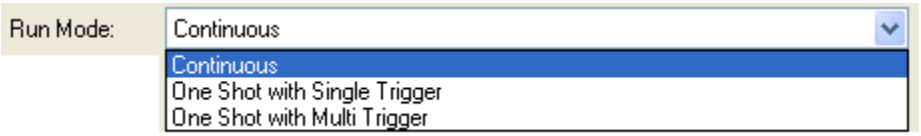


This parameter has a large influence on the visible pins of the symbol as well as the functionality of the pwm, pwm1, and pwm2 outputs as depicted in the waveforms shown in the configuration tool. The “PWMModes” enumerated types are defined as follows:

- **“One Output”**: Only a single PWM output. In this mode the “pwm” output is visible
- **“Two Output”**: Two individually configurable PWM outputs. In this mode the “pwm1” and “pwm2” outputs are visible
- **“Dual Edge”**: A single dual edged output created by AND’ing together the pwm1 and pwm2 signals. In this mode the “pwm” output is visible.
- **“Center Align”**: A single center aligned output created by having the counter count up to the period value and back down to zero while creating one center aligned pulse width based on the compare value. In this mode the “pwm” output is visible.
- **“Hardware Select”:** A single output selected from the two internal pwm signals by a hardware input pin cmp_sel. When cmp_sel is low the pwm1 signal is output on the pwm output pin, when cmp_sel is high the pwm2 signal is output on the pwm output pin. In this mode the “pwm” output is visible.
- **“Dither”:** A single output selected from the two internal pwm signals (pwm1 and pwm2) by a hardware state machine included in the pwm hardware implementation. The user selects between a .00, .25, .50 or .75 bit increase in the output pulse width and the hardware controls the selection between the two pwm signals to make this happen. In this case the compare values are set to compare and compare+1. In this mode the “pwm” output is visible.

RunMode (enum):

The run mode parameter defines the how the PWM is triggered to start running and continue running. The PWM will run dependant on the enable inputs as described by the enumerated types below.



- **"RunModes"** enumerated type:
  - **"Continuous":** The PWM runs forever on a trigger event.
  - **"One-Shot Single Trigger":** The PWM runs once on a trigger event
  - **"One-Shot Multi Trigger":** The PWM runs once on a trigger event. If trigger is still active at the end of the period the PWM continues running.

TriggerMode (enum):

The trigger mode parameter defines what is a valid trigger event. The trigger input is not visible when trigger mode is set to None.

- **"TriggerModes"** enumerated type:
  - **"None":** No Trigger is enabled (Trigger is treated as always true)
  - **"Rising Edge":** A trigger event is signaled on a rising edge of the trigger input.
  - **"Falling Edge":** A trigger event is signaled on the falling edge of the trigger input.
  - **"Either Edge":** A trigger event is signal on either a rising edge or a falling edge of the trigger input.

CaptureMode (enum):

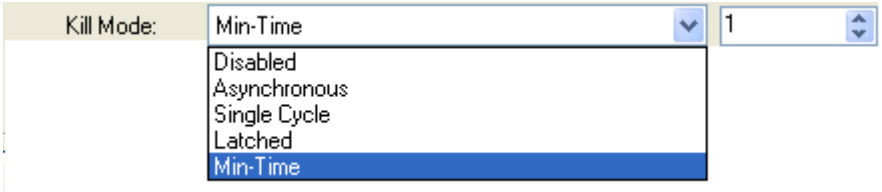
The capture mode parameter defines what hardware event will cause a capture of the period counter value to the read FIFO. Software captures are always possible.

The capture input is not visible when the capture mode is set to “None”.

- **“CaptureMode"** enumerated type:
  - **“None”:** No capture is enabled
  - **“Rising Edge”:** A capture event is signaled on a rising edge of the capture input.
  - **“Falling Edge”:** A capture event is signaled on the falling edge of the capture input.
  - **“Either Edge”:** A capture event is signal on either a rising edge or a falling edge of the capture input.

KillMode (enum):

The kill mode parameter defines how the hardware handles the pwm output(s) when the hardware kill input is active.

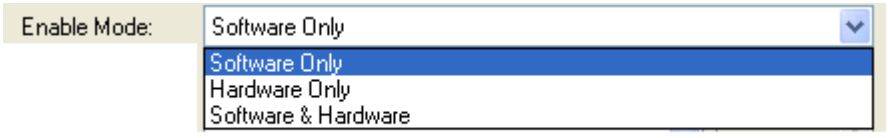


The “kill” input is not visible in when the kill mode is set to “Disabled”.

- **“KillModes"** enumerated type:
  - **“Disabled”:** No kill is enabled
  - **“Asynchronous”:** The pwm output(s) are disabled while kill is active.
  - **“Single Cycle”:** The pwm output(s) are disabled while kill is active and are not re-enabled until the end of the period has been reached (i.e. tc).
  - **“Latched”:** Thw pwm output(s) are disabled on kill and remain disabled until the PWM is reset.
  - **“Min Time”:** The pwm output(s) are disabled while kill is active and are not re-enabled until the minimum time has elapsed.

EnableMode (enum):

The enable mode parameter defines what hardware and software combination is required to enable the overall functionality of the PWM.

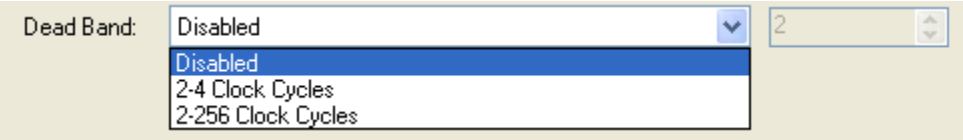


The enable input is not visible when the enable mode is set to “Software Only”

- **"EnableModes"** enumerated type:
  - **"Software Only":** The PWM is only enabled when the enable bit in the control register is set by software.
  - **"Hardware Only":** The PWM is only enabled while the hardware enable input is active (high).
  - **"Hardware And Software":** The PWM is enabled while both the bit in the control register and the hardware input are active(high).

DeadBand (enum):

The Dead Band parameter enables/disables the dead band functionality of the PWM.



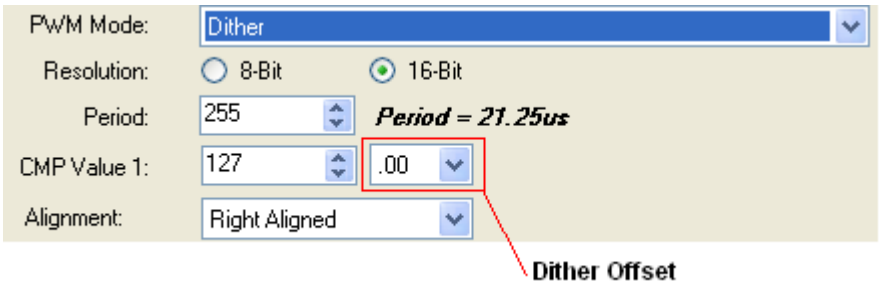
Dead band modes are slightly different in the fixed function implementation as shown here:

If dead band mode is one of the two enabled options then the "ph1" and "ph2" outputs are visible.

- **"DeadBandModes"** enumerated type:
  - **"Disabled":** No dead band
  - **"Enabled 1-4 Counts":** Dead Band is implemented on the "pwm" or the "pwm1" output with a maximum of 3 counts. This is implemented in PLD logic and does not tie up a Datapath for the counter.
  - **"Enabled 1-256 Counts":** Dead Band is implemented on the "pwm" or the "pwm1" output with a maximum of 255 counts. This is implemented in a datapath for the counter.

DitherOffset (enum):

The dither offset parameter configures the functionality of the “pwm” output when the PWM is configured in “Dither” PWM Mode.



Dither implements an internal state machine to choose between pwm1 and pwm2 outputs as the final “pwm” output. The pwm1 and pwm2 outputs are configured to be 1-off period values of each other where pwm1 is true for the compare value and pwm2 is true for the compare value + 1.

- **“DitherOffsets"** enumerated type:
  - **“DO00”:** No Dither. The output is always pwm1.
  - **“DO25”:** 0.25 Dither. The output is pwm1 for three of four period counts, and pwm2 for a single period counts.
  - **“DO50”:** 0.50 Dither. The output is pwm1 for two of four period counts, and pwm2 for two of the four period counts.
  - **“DO75”:** 0.75 Dither. The output is pwm1 for one of four period counts, and pwm2 for three of the four period counts.

FixedFunction (bool):

The Fixed Function parameter allows the user to choose between a Fixed Function Counter/Timer/PWM block and a UDB implementation.

If this parameter is true then the PWM is implemented in a fixed function block with the associated limitations of that block.

InterruptOnTC (bool):

The interrupt on terminal count parameter allows the user to configure the initial interrupt sources. This value is OR’d with any of the other “InterruptOn” parameters to give a final group of events that can trigger an interrupt. The software can re-configure this mode at any time as long as Interrupts were not set the “None”, this parameter simply defines an initial configuration.

InterruptOnCMP1 (bool):

The interrupt on compare 1 true parameter allows the user to configure the initial interrupt sources. This value is OR'd with any of the other "InterruptOn" parameters to give a final group of events that can trigger an interrupt. The software can re-configure this mode at any time as long as Interrupts were not set the "None", this parameter simply defines an initial configuration.

InterruptOnCMP2 (bool):

The interrupt on compare 2 true parameter allows the user to configure the initial interrupt sources. This value is OR'd with any of the other "InterruptOn" parameters to give a final group of events that can trigger an interrupt. The software can re-configure this mode at any time as long as Interrupts were not set the "None", this parameter simply defines an initial configuration.

InterruptOnKill (bool):

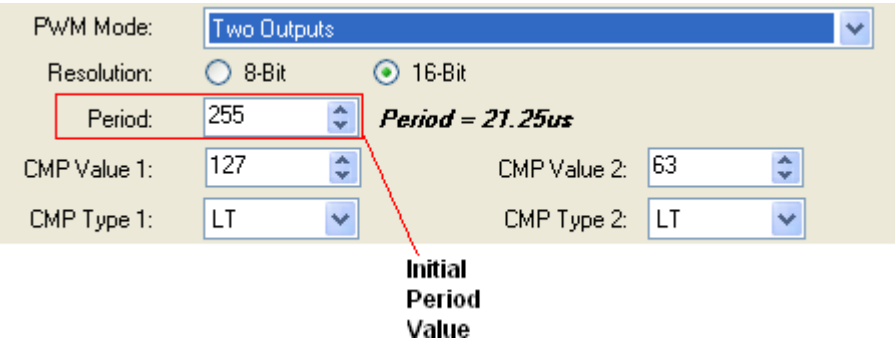
The interrupt on kill true parameter allows the user to configure the initial interrupt sources. This value is OR'd with any of the other "InterruptOn" parameters to give a final group of events that can trigger an interrupt. The software can re-configure this mode at any time as long as Interrupts were not set the "None", this parameter simply defines an initial configuration.

Software Configuration Options

Software configuration options do not affect synthesis or placement. When setting these parameters before build time you are setting their initial value which may be modified at any time with the API provided.

Period (uint8/16):

The period value parameter defines the initial starting value of the counter and any time the terminal count is reached and the PWM mode allows reloading of the period counter.

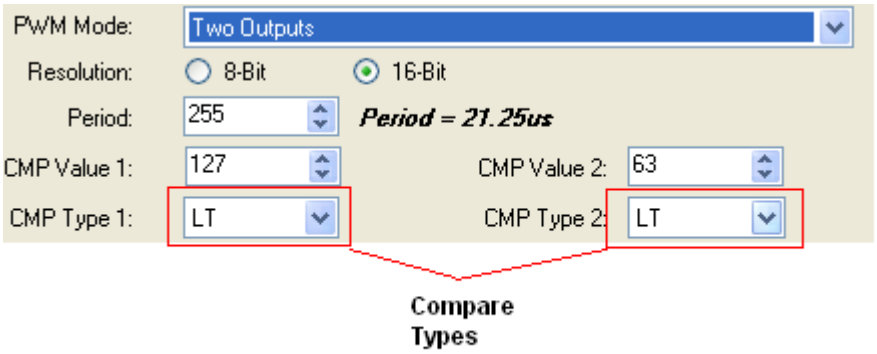


The PWM is implemented as a down counter counting from the Period value to zero. The Period must be greater than 1 and is limited on the high side by the resolution of the PWM. For an 8-bit PWM the period value has a maximum of 255. Otherwise the period value has a maximum of 65535. When the PWM mode is configured in "Center Aligned" mode the PWM counts up from zero to the period value and then back down to zero. The period value in Center Aligned mode is twice as long as all other modes because of this special functionality. The period value may be

changed at any time by the WritePeriod(period) API Call. The parameter holds only the initial value written during configuration.

CompareMode1/CompareMode2 (enum):

The compare mode parameters define the two period counter comparisons that make up the PWM outputs.



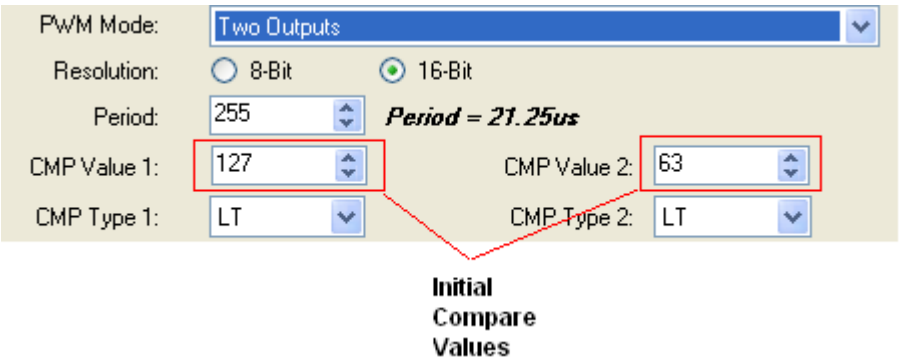
These are implemented differently for each of the PWM modes so they are typically controlled with the configuration tool. Each of the two compare mode parameters can be set independently to one of the following enumerated types.

- **"CompareModes"** enumerated type:
  - **"Less Than":** Compare output is true if period counter is less than the corresponding compare value.
  - **"Less Than or Equal To":** Compare output is true if period counter is less than or equal to the corresponding compare value.
  - **"Equal":** Compare output is true if period counter is equal to the corresponding compare value.
  - **"Greater Than or Equal To":** Compare output is true if period counter is greater than or equal to the corresponding compare value.
  - **"Greater Than":** Compare output is true if period counter is greater than the corresponding compare value.
  - **"Firmware Control"**

The "Firmware Control" implementation provides for a more resource usage model in which the compare mode can be set during runtime. The compare modes may be changed at any time by the WriteCompare1(mode) and WriteCompare2(mode) API calls. These parameters hold only the initial mode written during configuration. If any implementation other than "Firmware Control" is chosen then the hardware is pre-configured and fixed at that configuration at build time. In this case the WriteCompare API's are removed from the compilation and therefore are not available.

CompareValue1/CompareValue2 (uint8/16):

The compare values define the compare output functionality in conjunction with the hardware compare mode options listed above.



The compare values must be greater than 1 and are limited on the high side by the resolution of the PWM. For an 8-bit PWM the compare value has a maximum of 255. Otherwise the compare value has a maximum of 65535. The compare value is also limited by the Period. As the period is decreased the maximum compare values are set to Period -1 to prevent a non-use compare output. The compare values may be changed at any time by the WriteCompare1(comparevalue) and WriteCompare2(comparevalue) API calls. These parameters hold only the initial value written during configuration.

DeadTime (uint8):

The dead time value defines the amount of dead time implemented in the dead-band output signals “ph1” and “ph2” this parameter is only valid when Dead Band is enabled and is limited based on the hardware configuration option defined in the Deadband parameter.

Dead time is only software configurable when the deadband is enabled with a 1-255 range. This data is controlled with the WriteDeadTime(deadtime) and the ReadDeadTime() API calls. When deadband is enabled with the 1-4 range the value set in the configuration is built into the hardware and is not API settable.

Minimum Kill Time (uint8):

The minimum kill time parameter defines the minimum length to be a valid kill signal, of the kill signal necessary when the kill mode parameter is set to “Min Time”.

The min kill time value is controlled with the WriteKillTime(killtime) and ReadKillTime() API Calls and are limited to values of 1-255.

Local Parameters (For API usage)

These parameters are used in the API and not exposed in the GUI; however, these are used in the APIs.

FixedFunctionUsed

Defined as a “1” (true) if the user has chosen to implement the PWM using the fixed function block.

KillModeMinTime

Defined as a “1” (true) if the user has chosen the Kill mode as Min Time. This allows WriteKillTIme and ReadKillTime functions to be included as necessary.

PWMModeCenterAligned

Defined as “1” (true) if the user has chosen the PWM mode as Center Aligned. The ReadCompare and WriteCompare functions are defined differently for this mode than other modes and this parameter is used to add the correct functions and remove the unnecessary functions.

DeadBandUsed

Defined as “1” (true) if the user has chosen to implement Dead Band with a the 1-255 enable mode. This is used to conditionally include WriteDeadTime() and ReadDeadTime() API functions.

DeadBand1_3

Defined as “1” (true) if the user has chosen Dead band with 1-3 counts range. This is used inside of the WriteDeadTime and ReadDeadTime functions for the different operations that must happen to handle the DeadTime.

UseStatus

Defined as 1 when the configuration warrants the usage of a status register. This allows the status register resource to be removed if it is not necessary in the design.

UseControl

Defined as 1 when the configuration warrants the usage of a control register. This allows the control register resource to be removed if it is not necessary in the design.

UseOneCompareMode

Defined as 1 when the configuration warrants only a single compare mode API to be available. This allows the API to be removed as defined by the architecture chosen.

Default Configuration of Parameters

The following are the initial default values for an instantiated PWM:

- Resolution = 8
- PWMMode = Two Outputs
- Period = 255
- Compare1Value = 127
- Compare2Value = 63
- CompareMode1 = Less Than
- CompareMode2 = Less Than
- RunMode = Continuous
- EnableMode = Software Only
- FixedFunction = False

Clock Selection

There is no internal clock in this component. You must attach a clock source.

Placement

Placement of the PWM component is based on the FixedFunction parameter selection for the instance of the component. If FixedFunction = true then the PWM is placed in one of the Fixed Function blocks. If FixedFunction = false then the PWM is placed throughout the UDB array and all placement information is provided to the API through the cyfitter.h file.

Resources

Resolution	Digital Blocks					API Memory (Bytes)		Pins (per External I/O)
	Datapaths	Macro cells	Status Registers	Control Registers	Counter7	Flash	RAM	
8-Bits One-Output & Two Outputs Mode	1	4*	1	1	0			1/2
8-Bits Dual Edged Mode	1	6*	1	1	0			1

Resolution	Digital Blocks					API Memory (Bytes)		Pins (per External I/O)
	Datapaths	Macro cells	Status Registers	Control Registers	Counter7	Flash	RAM	
8-Bits Center Align Mode	1	6*	1	1	0			1
8-Bits Hardware Select Mode								
8-Bits Dither Mode								
16-Bits One Output & Two Outputs Mode	2	X	1	1	0			1/2
Dead-Band 1-3**	+0	+11	+0	+1	+0	+X	+X	+2
Dead-Band 1-255**	+1	+6	+0	+0	+0	+X	+X	+2

* No Dead Band, No Kill Mode & Continuous Run Mode; One or Two Output mode only.

** 1-3 Dead Band range and 1-255 Dead-Band Range are mutually exclusive

Application Programming Interface

Application Programming Interface (API) routines allow you to configure the component using software. The following table lists and describes the interface to each function. The subsequent sections cover each function in more detail.

By default, PSoC Creator assigns the instance name "PWM_1" to the first instance of a component in a given design. You can the rename the instance to any unique value that follows the syntactic rules for identifiers. The instance name becomes the prefix of every global function name, variable, and constant symbol. For readability, the instance name used in the following table is "PWM".

Function	Description
void PWM_Start(void)	Enable the PWM operation. Sets the enable bit of the control register for either of the software controlled enable modes.
void PWM_Stop(void)	Disable the PWM operation. Clears the enable bit of the control register for either of the software controlled enable modes.

Function	Description
void PWM_SetInterruptMode(uint8)	Configure the interrupts mask control of the interrupt source status register
uint8 PWM_GetInterruptSource (void)	Returns the mode register defining which events are enabled as interrupt sources.
uint8 PWM_ReadStatusRegister (void)	Returns the current state of the status register
uint8 PWM_ReadControlRegister (void)	Returns the current state of the control register
void PWM_WriteControlRegister (uint8)	Sets the bit-field of the control register
void PWM_SetCompareMode(comparemode)	Writes the compare mode for compare output when set to Dither Mode, Center Align Mode or One Output mode.
void PWM_SetCompareMode1(comparemode)	Writes the compare mode for compare1 output into the control register.
void PWM_SetCompareMode2(comparemode)	Writes the compare mode for compare2 output into the control register.
uint8/16 PWM_ReadCounter(void)	Reads the current counter value (Software Capture)
void PWM_WriteCounter(uint8/uint16)	Writes a new counter value directly to the counter register. This will be implemented for that currently running period and only that period.
void PWM_WritePeriod(uint8/16)	Writes the period value used by the PWM hardware.
uint8/16 PWM_ReadPeriod(void)	Reads the period value used by the PWM hardware.
void PWM_WriteCompare(uint8/16)	Writes the compare value when the instance is defined as Dither Mode, Center Align Mode or One Output Mode.
uint8/16 PWM_ReadCompare(void)	Reads the compare value when the instance is defined as Dither Mode, Center Align Mode or One Output Mode.
void PWM_WriteCompare1(uint8/16)	Writes the compare value for the compare1 output.
uint8/16 PWM_ReadCompare1(void)	Reads the compare value for the compare1 output.
void PWM_WriteCompare2(uint8/16)	Writes the compare value for the compare2 output
uint8/16 PWM_ReadCompare2(void)	Reads the compare value for the compare2 output.
void PWM_WriteDeadTime(uint8)	Writes the dead time value used by the hardware in dead-band implementation.
uint8 PWM_ReadDeadTime(void)	Reads the dead time value used by the hardware in dead-band implementation.
void PWM_WriteKillTime(uint8)	Writes the kill time value used by the hardware when the kill mode is set as “Min Time”
uint8 PWM_ReadkillTime(void)	Reads the kill time value used by the hardware when the kill mode is set as “Min Time”

void PWM_Start(void)

Description: Enable the PWM operation. Sets the enable bit of the control register for either of the software controlled enable modes.

Parameters: None

Return Value: void

Side Effects: Sets the enable bit in the control registers of the PWM. If the Enable Mode is set to hardware only this has no affect on the PWM. If the enable mode is set to Hardware and Software then this will only enable the software portion of this mode and the hardware input must also be enabled to finally enable the PWM.

void PWM_Stop(void)

Description: Disable the PWM operation. Clears the enable bit of the control register for either of the software controlled enable modes.

Parameters: None

Return Value: void

Side Effects: Clears the enable bit in the control registers of the PWM. If the Enable Mode is set to hardware only this has no affect on the PWM. If the enable mode is set to Hardware and Software then this will disable the software portion of this mode and the hardware input will have no further affect on the enable of the PWM.

void PWM_SetInterruptMode(uint8)

Description: Configure the interrupts mask control of the interrupt source status register.

Parameters: interruptSource: uint8 - Bitfield containing the interrupt sources enabled.

Return Value: void

Side Effects: None

uint8 PWM_GetInterruptSource (void)

Description: Returns the mode register defining which events are enabled as interrupt sources.

Parameters: None

Return Value: uint8: Bit-Field containing the enabled interrupt sources as defined in the status register bit-field locations

Side Effects: None

uint8 PWM_ReadStatusRegister (void)

Description: Returns the current state of the status register

Parameters: None

Return Value: uint8: Current status register value

Side Effects: Status register bits may be clear on read.

uint8 PWM_ReadControlRegister (void)

Description: Returns the current state of the control register

Parameters: None

Return Value: uint8: Current control register value

Side Effects: None

void PWM_WriteControlRegister (uint8)

Description: Sets the bit-field of the control register

Parameters: uint8: Control register Bit-Field

Return Value: None

Side Effects: None

void PWM_SetCompareMode(comparemode)

Description: Writes the compare mode for compare output when set to Dither Mode, Center Align Mode or One Output mode.

Parameters: comparemode: Compare Mode enumerated type

Return Value: void

Side Effects: None

void PWM_SetCompareMode1(comparemode)

Description: Writes the compare mode for compare1 output into the control register.

Parameters: comparemode: Compare Mode enumerated type

Return Value: void

Side Effects: None

void PWM_SetCompareMode2(comparemode)

Description: Writes the compare mode for compare2 output into the control register.

Parameters: comparemode: Compare mode enumerated type

Return Value: void

Side Effects: None

uint8/16 PWM_ReadCounter(void)

Description: Reads the current counter value. (Software Capture)

Parameters: None

Return Value: uint8/uint16: The current Period Counter value

Side Effects: None

void PWM_WriteCounter(uint8/16)

Description: Writes a new counter value directly to the counter register. This will be implemented for that currently running period and only that period.

Parameters: uint8/uint16: The Period Counter value

Return Value: void

Side Effects: None

void PWM_WritePeriod(uint8/16)

Description: Writes the period value used by the PWM hardware.

Parameters: period: uint8 or 16 depending on resolution, the new period value

Return Value: void

Side Effects: None

uint8/16 PWM_ReadPeriod(void)

Description: Reads the period value used by the PWM hardware.

Parameters: None

Return Value: uint8/16: Period Value

Side Effects: None

void PWM_WriteCompare(uint8/16)

Description: Writes the compare value(s) for the compare output when the PWM mode parameter is set to Dither Mode, Center Aligned Mode or One Output Mode.

Parameters: uint8/16: compare value

Return Value: void

Side Effects: This function is only available if the PWM mode parameter is set to one of the modes described above.

uint8/16 PWM_ReadCompare(void)

Description: Reads the compare value for the compare output when the PWM mode parameter is set to Dither Mode, Center Aligned Mode or One Output Mode.

Parameters: None

Return Value: uint8/uint16: current compare value

Side Effects: This function is only available if the PWM Mode parameter is set to one of the modes described above. Otherwise the ReadCompare1/2 functions must be called.

void PWM_WriteCompare1(uint8/16)

Description: Writes the compare value for the compare1 output.

Parameters: uint8/uint16: new compare value for pwm1

Return Value: void

Side Effects: None

uint8/16 PWM_ReadCompare1(void)

Description: Reads the compare value for the compare1 output.

Parameters: None

Return Value: uint8/uint16: current compare value 1

Side Effects: None

void PWM_WriteCompare2(uint8/16)

Description: Reads the compare value for the compare2 output.

Parameters: uint8/uint16: new compare value for pwm2

Return Value: void

Side Effects: None

uint8/16 PWM_ReadCompare2(void)

Description: Reads the compare value for the compare2 output.

Parameters: None

Return Value: uint8/uint16: the current compare value

Side Effects: None

void PWM_WriteDeadTime(uint8)

Description: Writes the dead time value used by the hardware in dead-band implementation.

Parameters: uint8: Dead Band Counts

Return Value: void

Side Effects: None

uint8 PWM_ReadDeadTime(void)

Description: Reads the dead time value used by the hardware in dead-band implementation.

Parameters: None

Return Value: uint8: The current setting of Dead band Counts

Side Effects: None

void PWM_WriteKillTime(uint8)

Description: Writes the kill time value used by the hardware when the kill mode is set as “Min Time.”

Parameters: uint8: Min Time Kill Counts

Return Value: void

Side Effects: None

uint8 PWM_ReadkillTime(void)

Description:	Reads the kill time value used by the hardware when the kill mode is set as “Min Time.”
Parameters:	None
Return Value:	uint8: The current Min Time Kill Counts
Side Effects:	None

Sample Firmware Source Code

The following is a C language example demonstrating the basic functionality of the PWM component. This example assumes the component has been placed in a design with the default name "PWM_1."

Note If you rename your component you must also edit the example code as appropriate to match the component name you specify.

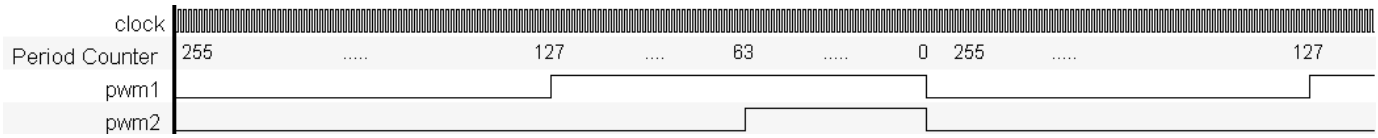
```
#include <device.h>
#include "PWM_1.h"

void main()
{
    Clock_1_Enable();
    PWM_1_Start();
}
```

Functional Description

Fixed Function Block Limitations

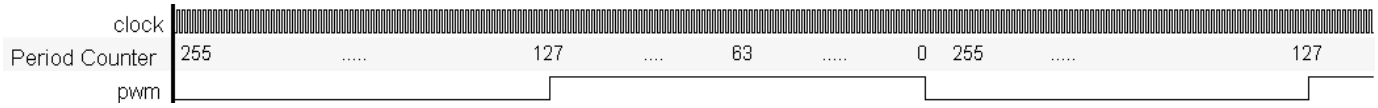
Default Configuration

The default configuration for the PWM is as a two output 8-bit PWM which will create one output with a compare of less than 127 (with a period of 255) and the second output of less than 63 using a 12MHz clock. The following waveform shows the inputs and outputs of the PWM when it is left in the default configuration.



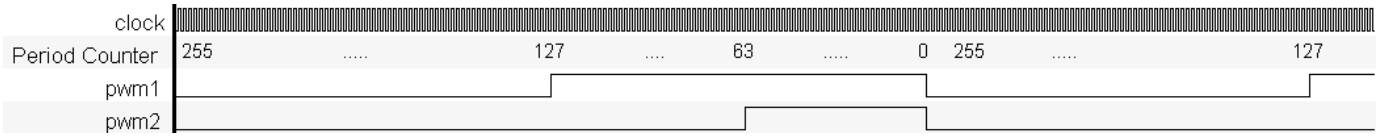
PWM Mode: One Output

A one output PWM has only one output that is controlled by a single compare value and a single compare mode. This waveform can be left aligned with a compare mode of “Greater Than” or “Greater Than Or Equal To” or it can be right aligned with a compare mode of “Less Than” or “Less Than Or Equal To”.



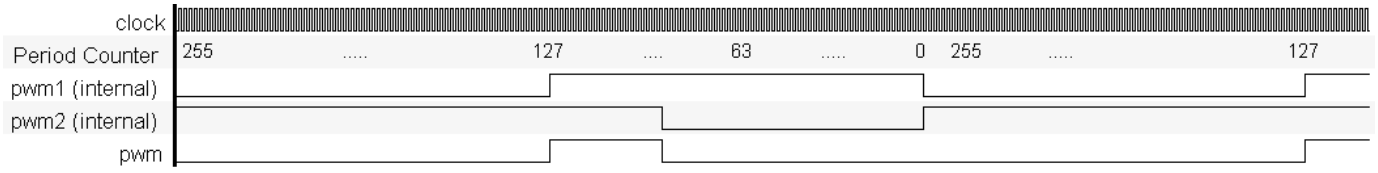
PWM Mode: Two Outputs

The two output PWM is the default configuration as described above. The two pwm output s are defined independently of each other using two compare values and two compare modes. Each of these two outputs can be left aligned or right aligned as described in the one output mode above.



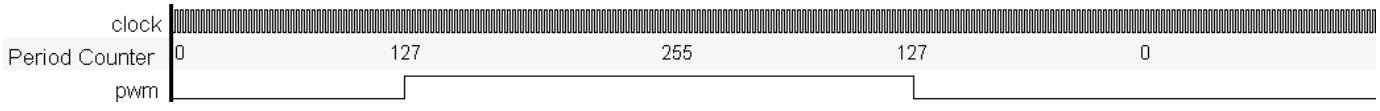
PWM Mode: Dual Edge

A dual edge PWM uses the two compare outputs and two compare modes to generate a single PWM output. The final output is an AND’ing of the two different signals defined by the two compare values and compare modes. This mode requires some understanding by the user of what the different modes will generate. The waveform examples in the parameter editing customizer provide help as to what the final waveform will look like. However the compare values, compare modes and period values are all settable at run-time and changing these values without the understanding of the final configuration can easily create a 0 value output.



PWM Mode: Center Aligned

A center aligned PWM implements the PWM quite differently than all of the other modes described for this PWM. The desired output requires that the period counter start at zero and count up to the period value, and when the period value is reached the counter will start counting back down to zero. In this mode the period value is actually half of the period of the final output. A single compare value and compare mode are available for this functionality.



PWM Mode: Hardware Select

A hardware select PWM is implemented as a two output PWM where the implementation has two independent compare values and compare modes and a hardware input “cmp_sel” selects which of the two input is the final pwm output. This allows the user to switch between two pre-configured values as necessary without modifying the parameters.

PWM Mode: Dither

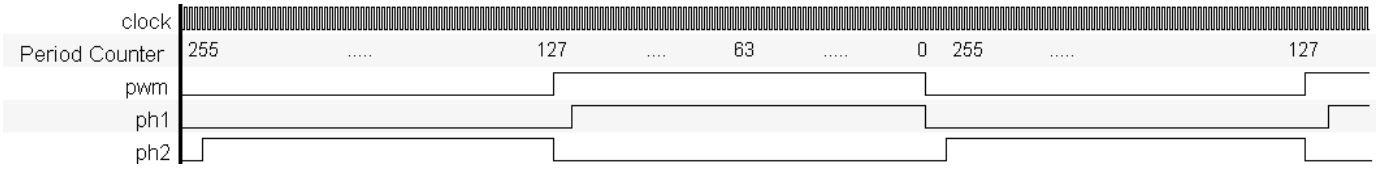
Dither mode PWM is implemented as a hardware select mode PWM with the caveat that the first and compare values have a difference of 1 and both compare modes are identical. There is also a built-in state machine controlling the hardware select. In this mode the “cmp_sel” input is not available to the user. The user may control the offset as 0.00, 0.25, 0.50 and 0.75 with the parameter field visible in this mode. If the offset is configured as 0.00 then the output is always the compare1 output. When set to .25 the output is compare1 for 3 cycles and compare1 + 1 for a single cycle.

Dither Mode	Cycle 0	Cycle 1	Cycle 2	Cycle 3
0.00	Compare1	Compare1	Compare1	Compare1
0.25	Compare1 + 1	Compare1	Compare1	Compare1
0.50	Compare1	Compare1 + 1	Compare1	Compare1 + 1
0.75	Compare1 + 1	Compare1 + 1	Compare1 + 1	Compare 1

Dead-Band

Dead-Band is an add-on option to any of the PWM modes described above. When dead-band is enabled two new outputs ph1 and ph2 (phase1 and phase2) become visible on the symbol. The dead-band outputs work on a single PWM output. In all modes except two output mode the dead-band outputs are related to the single PWM output. In two output mode the dead-band is only implemented on the pwm1 output. In all Dead-Band modes the original output is available as well as the ph1 and ph2 outputs.

Dead-Band can be configured as having a range of 1-4 clock cycles for dead-band time or 1-256. The 1-4 cycle range is provided to reduce resource usage by implementing the counter in PLD’s instead of using a full datapath. When the 1-256 range Dead-Band is selected a full datapath and the necessary logic are used from the UDB array.



Kill Modes

Like dead-band, kill mode is an add-on function that does not interrupt the implementation of the pwm internally. This add-on is placed at the outputs of the PWM and manipulates only the final output signals. When Dead-Band is not implemented the kill operation disables the PWM outputs by pulling them low. If Dead-Band is implemented then the kill operation disables the ph1 and ph2 outputs by pulling ph1 low and ph2 high.

Kill Mode: Asynchronous

In Asynchronous kill mode the outputs are disabled while the kill input is active (high) and the outputs are re-enabled as soon as the kill input goes inactive.

Kill Mode: Single Cycle

In single Cycle kill mode the outputs are disabled while the kill input is active (high) and the outputs are re-enabled at the beginning of the next period.

Kill Mode: Latched

In Latched Kill mode the outputs are disabled when the kill input goes high and the outputs are re-enabled after the PWM has been reset.

Kill Mode: Min Time

In Min-Time kill mode the outputs are disabled while the kill input is active (high) and the outputs are re-enabled after the minimum time has elapsed if the kill input is no longer active. For this mode the user defines the minimum kill time in the number of clock counts 1-255. The API necessary for controlling the min-kill time counts is only available if this kill mode is selected.

Run Mode: Continuous

Continuous run-mode is the default configuration of the PWM. This mode allows the PWM to run forever while enabled. So long as the PWM is enabled the output will cycle through period after period implementing the specified pulse width output.

Run Mode: One Shot Single

One Shot-Single run mode will run the PWM for a single period on a valid trigger event. The trigger input is necessary for this mode as it is the hardware signal to the control logic. One shot will not re-arm the trigger until after the period has elapsed and the trigger is reset.

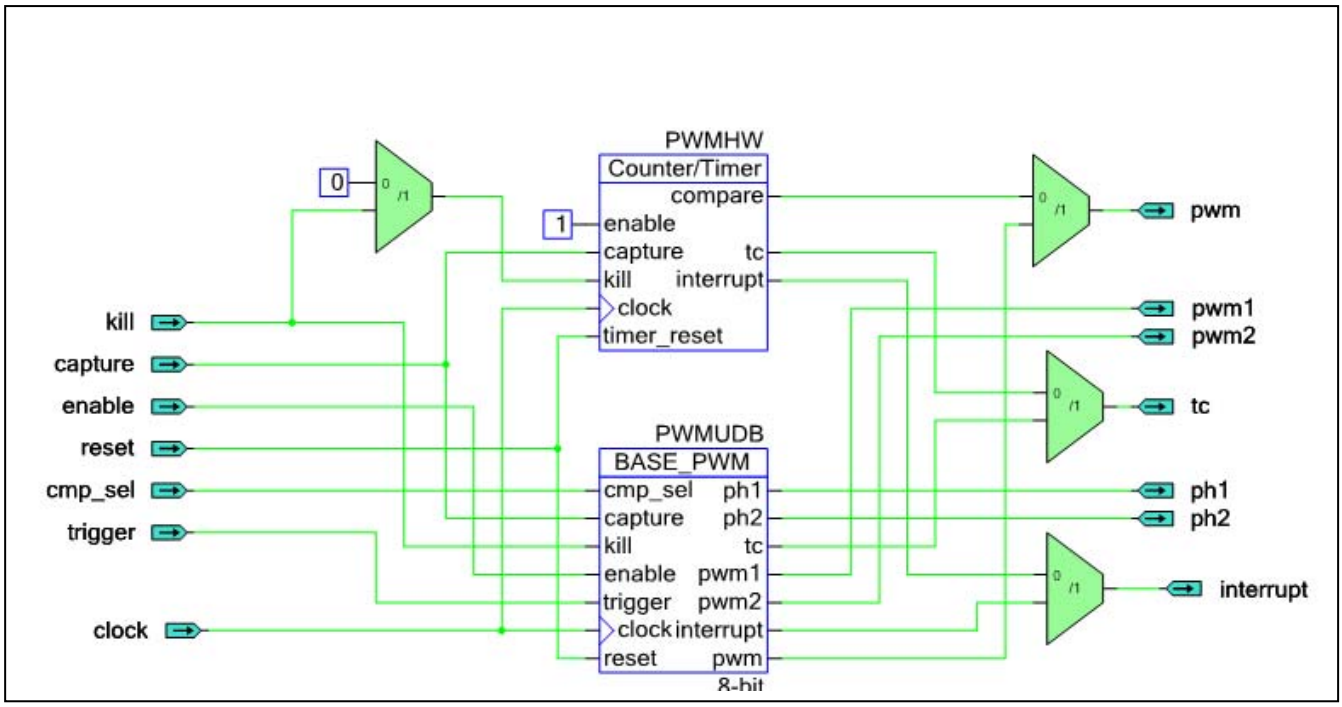
Run Mode: One Shot Multi

One Shot-Multi run mode will run the PWM for a single period on a valid trigger event and will continue running so long as the trigger is active. The trigger input is also necessary for this mode as it was for the One Shot-Single mode.

Block Diagram and Configuration

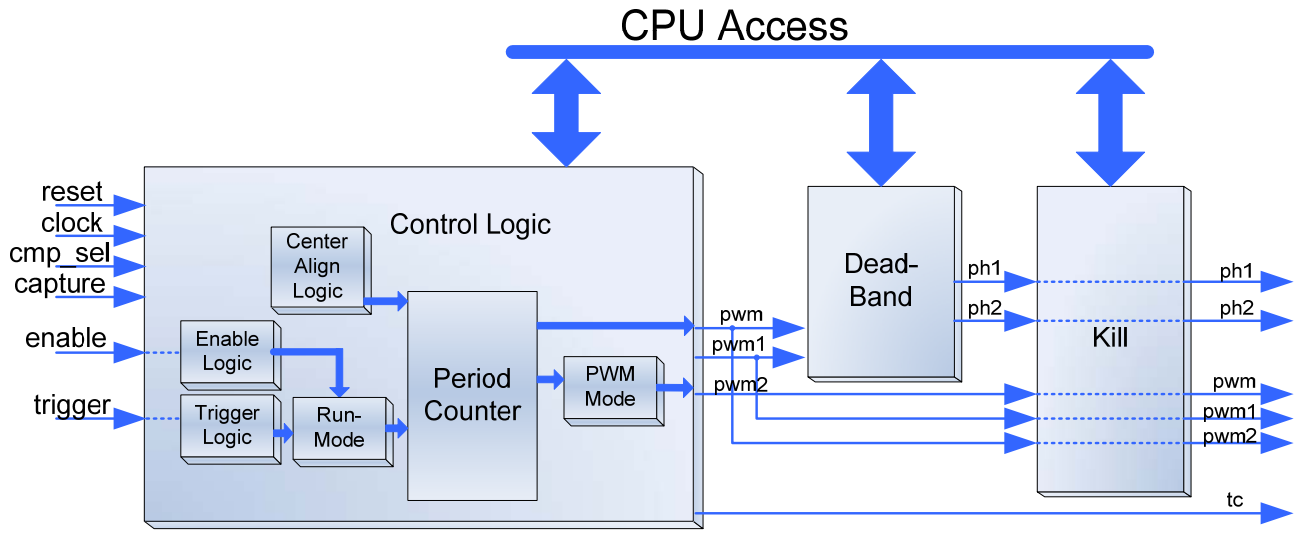
The PWM may be implemented using a fixed function block or using UDB components. An advance parameter “Implementation” allows you to specify the block that you expect this component to be placed in. The Fixed function implementation will consume one of the Timer/Counter/PWM blocks. In either the fixed function or UDB configuration all of the registers and API are consolidated to give a single entity look and feel. The API is described above and the registers are described here to define the overall implementation of the PWM.

The two hardware implementations you chose are selected from a top level schematic as shown below:



This configuration allows for either the Fixed Function block or the UDB implementation to be selected and the routing of the I/O are handled in the background to give this single component look and feel. The UDB implementation is described in the following block diagram.

Figure 3 UDB Implementation



Registers

Status

The status register is a read only register which contains the various status bits defined for the PWM. The value of this register is available with the PWM_ReadStatusRegister() function call. The interrupt output signal (interrupt) is generated from an ORing of the masked bit-fields within this register. You can set the mask using the PWM_SetInterruptMode() function call and upon receiving an interrupt you can retrieve the interrupt source by reading the Status register with the PWM_GetInterruptSource() function call. The Status register is a clear on read register so the interrupt source is held until either of the ReadStatusRegister() or GetInterruptSource() function is called. The PWM_GetInterruptSource() API will handle which interrupts are enabled to provide an accurate report of what the actual source of the interrupt was. All operations on the status register must use the following defines for the bit-fields as these bit-fields may be moved around within the status register during place and route.

There are several bit-fields masks defined for the status register. Any of these bit-fields may be included as an interrupt source. The #defines are available in the generated header file (.h) as follows:

PWM_STATUS_TC

Status of the terminal count output. This bit goes high when the terminal count output is high.

PWM_STATUS_CMP1

Status of the pwm1 compare value as it relates to the period counter. This bit goes high when the comparison output is high.

PWM_STATUS_CMP2

Status of the pwm2 compare value as it relates to the period counter. This bit goes high when the comparison output is high.

Control

The Control register allows you to control the general operation of the PWM. This register is written with the PWM_WriteControlRegister() function call and read with the PWM_ReadControlRegister(). When reading or writing the control register you must use the bit-field definitions as defined in the header (.h) file. The #defines for the control register are as follows:

PWM_CTRL_ENABLE

The enable bit controls software enabling of the PWM operation. The PWM has a configurable enable mode defined at build time. If the Enable mode parameter is set to “Input Only” then the functionality of this bit is none. However in either of the other modes the PWM does not decrement if this bit is not set high. Normal operation requires that this bit is set and held high during all operation of the PWM.

PWM_CTRL_CMPMODE1_MASK

The Compare mode control is a 3-bit field used to define the expected compare output operation for the pwm1 output. This bit-field will be 3 consecutive bits in the control register and all operations on this bit-field must use the #defines associated with the compare modes available. These are:

PWM_1_B_PWM_CM_LESSTHAN

PWM_1_B_PWM_CM_LESSTHANOREQUAL

PWM_1_B_PWM_CM_EQUAL

PWM_1_B_PWM_CM_GREATERTHAN

PWM_1_B_PWM_CM_GREATERTHANOREQUAL

This bit-field is configured at initialization with the compare mode defined in the CompareMode1 parameter and may be modified with the SetCompareMode() or SetCompareMode1() API call.

PWM_CTRL_CMPMODE2_MASK

The Compare mode control is a 3-bit field used to define the expected compare output operation for the pwm2 output. This bit-field will be 3 consecutive bits in the control register and all operations on this bit-field must use the #defines associated with the compare modes available. These are:

PWM_1_B_PWM_CM_LESSTHAN

PWM_1_B_PWM_CM_LESSTHANOREQUAL

PWM_1_B_PWM_CM_EQUAL

PWM_1_B_PWM_CM_GREATERTHAN

PWM_1_B_PWM_CM_GREATERTHANOREQUAL

This bit-field is configured at initialization with the compare mode defined in the CompareMode2 parameter and may be modified with the SetCompareMode2() API call.

Period (8 or 16-bit based on Resolution)

The period register contains the period value set by the user through the PWM_WritePeriod() function call and defined by the Period parameter at initialization. The PWM_ReadPeriod() function may be used to find the current value of this register. The Period register has no affect on the PWM until a terminal count is reached at which time the period counter is reloaded with this value.

Compare1/Compare2 (8 or 16-bit based on Resolution)

The compare registers contains the compare values used to determine the state of the pwm or pwm1 and pwm2 outputs (dependant upon PWM Mode parameter) . The pwm/pwm1 and pwm2 outputs are based on how these registers compare to the period counter value in relation to the compare modes defined in the control register.

Period Counter (8 or 16-bit based on Resolution)

The period counter register contains the counter value throughout the operation of the PWM. During basic operation this register is decrementing by 1 while the PWM is enabled and on each rising edge of the clock input. The contents of this register may be read at any time by the user with the PWM_ReadCounter() function call. When the terminal count is reached this register is reloaded with the period value you define in the period register through the PWM_WritePeriod() function call or during initialization with the Period parameter.

The pwm, pwm1 and pwm2 outputs are based on the relationship between the value held in this register and the value defined in the compare registers through the PWM_WriteCompare() function calls or during initialization with the CompareValue parameters

Conditional Compilation Information

The PWM API requires several conditional compile definitions to handle the multiple configurations it must support. It is required that the API conditionally compile on the Resolution chosen, the Implementation chosen between the Fixed Function block or the UDB blocks, dead band modes, kill modes, and PWM modes. The conditions defined are based on the parameters FixedFunction, Resolution, DeadBand, KillMode and PWMMode. The API should never use these parameters directly but should use the defines listed below.

PWM_Resolution

The resolution define is assigned to the Resolution value at build time. It is used throughout the API to compile in the correct data width types for the API functions relying on this information.

PWM_UsingFixedFunction

The Using Fixed Function define is used mostly in the header file to make the correct register assignments as the registers provided in the fixed function block are different than those used when the PWM is implemented in UDB's.

PWM_DeadBandMode

The deadband mode define is used to conditionally compile in WriteDeadTime() and ReadDeadTime() API.

PWM_KillModeMinTime

The kill mode min time define is used to conditionally compile in WriteKillTime() and ReadKillTime() API.

PWM_KillMode

The Kill Mode define is used to define the register access point for the Kill Mode Min Time register if Kill Mode is min time.

PWM_PWMMode

The PWM mode define is used to include the correct WriteCompare() and ReadCompare() API functions as necessary for the mode in use.

PWM_PWMModeIsCenterAligned

The PWM mode is center aligned define is used to redefine the period register address. Center aligned is quite different from other modes in implementation and requires usage of different registers for operation that must be handled in the Header file.

PWM_DeadBandUsed

The deadband used define controls conditionally compiling the WriteDeadTime() and ReadDeadTime() API.

PWM_DeadBand2_4

The deadband 2-4 define controls conditionally compiling the implementation within the WriteDeadTime() and ReadDeadTime() API.

PWM_UseStatus

The Use Status is used to remove the status register if the design warrants in the verilog and to conditionally compile out the status register definitions and API's in the header and C files.

PWM_UseControl

The Use Control is used to remove the Control register if the design warrants in the verilog and to conditionally compile out the status register definitions and API's in the header and C files.

PWM_UseOneCompareMode

The use one compare mode is used to conditionally compile in and out the expected API calls necessary for 1 or 2 compare mode PWM mode functions.

PWM_MinimumKillTime

Provides the initial minimum kill time programmed into the min-time datapath when the Kill mode is set to Minimum Kill Time.

PWM_EnableMode

Provides condition compilation abilities to remove the API provided for specific Enable Modes.

Constants

There are several constants defined for the status and control registers as well as some of the enumerated types. Most of these are described above for the Control and Status Register. However there are more constants needed in the header file to make all of this happen. Each of the register definitions requires either a pointer into the register data or a register address. Because of multiple Endianness` of the compilers it is required that the CY_GET_REGX and CY_SET_REGX macros are used for register accesses greater than 8-bits. These macro's require the use of the _PTR definition for each of the registers.

It is also required that the control and status register bits be allowed to be placed and routed by the fitter engine in that we must have constants that define the placement of the bits. For each of the status and control register bits there is an associated _SHIFT value which defines the bit's offset within the register. These are used in the header file to define the final bit mask as an _MASK definition (The _MASK extension is only added to bit-fields greater than a single bit, all single bit values drop the _MASK extension).

The fixed function block has some limitations compared to the UDB implementations because it is designed with limited configurability.

DC and AC Electrical Characteristics

5.0V/3.3V DC and AC Electrical Characteristics

Parameter	Typical	Min	Max	Units	Conditions and Notes
Input					
Input Voltage Range	---		Vss to Vdd	V	
Input Capacitance	---		---	pF	
Input Impedance	---		---	Ω	
Maximum Clock Rate	---		67	MHz	