

**32-bit RISC Microcontroller**

# **TXZ Family**

**Reference Manual**

## **Advanced Programmable Motor Control Circuit (A-PMD-A)**

**Revision 2.0**

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**2018-05**

**TOSHIBA ELECTRONIC DEVICES & STORAGE CORPORATION**

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## Preface

### Related document

Document name
Input/Output Ports
Exception
Clock Control and Operation Mode
Product Information
12-bit Analog to Digital Converter
Advanced Vector Engine Plus
Advanced Encoder Input Circuit
Advanced Encoder Input Circuit (32-bit)
32-bit Timer Event Counter

## Conventions

- Numeric formats follow the rules as shown below:
  - Hexadecimal: 0xABC
  - Decimal: 123 or 0d123 – Only when it needs to be explicitly shown that they are decimal numbers.
  - Binary: 0b111 – It is possible to omit the "0b" when the number of bit can be distinctly understood from a sentence.
- "\_N" is added to the end of signal names to indicate low active signals.
- It is called "assert" that a signal moves to its active level, "deassert" to its inactive level.
- When two or more signal names are referred, they are described like as [m: n].  
Example: S[3: 0] shows four signal names S3, S2, S1 and S0 together.
- The characters surrounded by [ ] defines the register.  
Example: [ABCD]
- "n" substitutes suffix number of two or more same kind of registers, fields, and bit names.  
Example: [XYZ1], [XYZ2], [XYZ3] → [XYZn]
- "x" substitutes suffix number or character of units and channels in the Register List.  
In case of unit, "x" means A, B, and C ...  
Example: [ADACR0], [ADBCR0], [ADCCR0] → [ADxCR0]  
In case of channel, "x" means 0, 1, and 2 ...  
Example: [T32A0RUNA], [T32A1RUNA], [T32A2RUNA] → [T32AxRUNA]
- The bit range of a register is written like as [m: n].  
Example: Bit[3: 0] expresses the range of bit 3 to 0.
- The configuration value of a register is expressed by either the hexadecimal number or the binary number.  
Example: [ABCD]<EFG> =0x01 (hexadecimal), [XYZn]<VW> =1 (binary)
- Word and Byte represent the following bit length.
  - Byte: 8 bits
  - Half word: 16 bits
  - Word: 32 bits
  - Double word: 64 bits
- Properties of each bit in a register are expressed as follows:
  - R: Read only
  - W: Write only
  - R/W: Read and Write are possible
- Unless otherwise specified, register access supports only word access.
- The register defined as reserved must not be rewritten. Moreover, do not use the read value.
- The value read from the bit having default value of "-" is unknown.
- When a register containing both of writable bits and read-only bits is written, read-only bits should be written with their default value, In the cases that default is "-", follow the definition of each register.
- Reserved bits of the Write-only register should be written with their default value.  
In the cases that default is "-", follow the definition of each register.
- Do not use read-modified-write processing to the register of a definition which is different by writing and read out.

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respective companies.

## Terms and Abbreviations

Some of abbreviations used in this document are as follows:

ADC	Analog to Digital Converter
A-ENC	Advanced Encoder Input Circuit
A-ENC32	Advanced Encoder Input Circuit (32-bit)
A-PMD	Advanced Programmable Motor Control Circuit
A-VE+	Advanced Vector Engine Plus
PFC	Power Factor Correction
PMD	Programmable Motor Control Circuit
PWM	Pulse Width Modulation
T32A	32-bit Timer Event Counter
VE	Vector Engine



## 1. Outlines

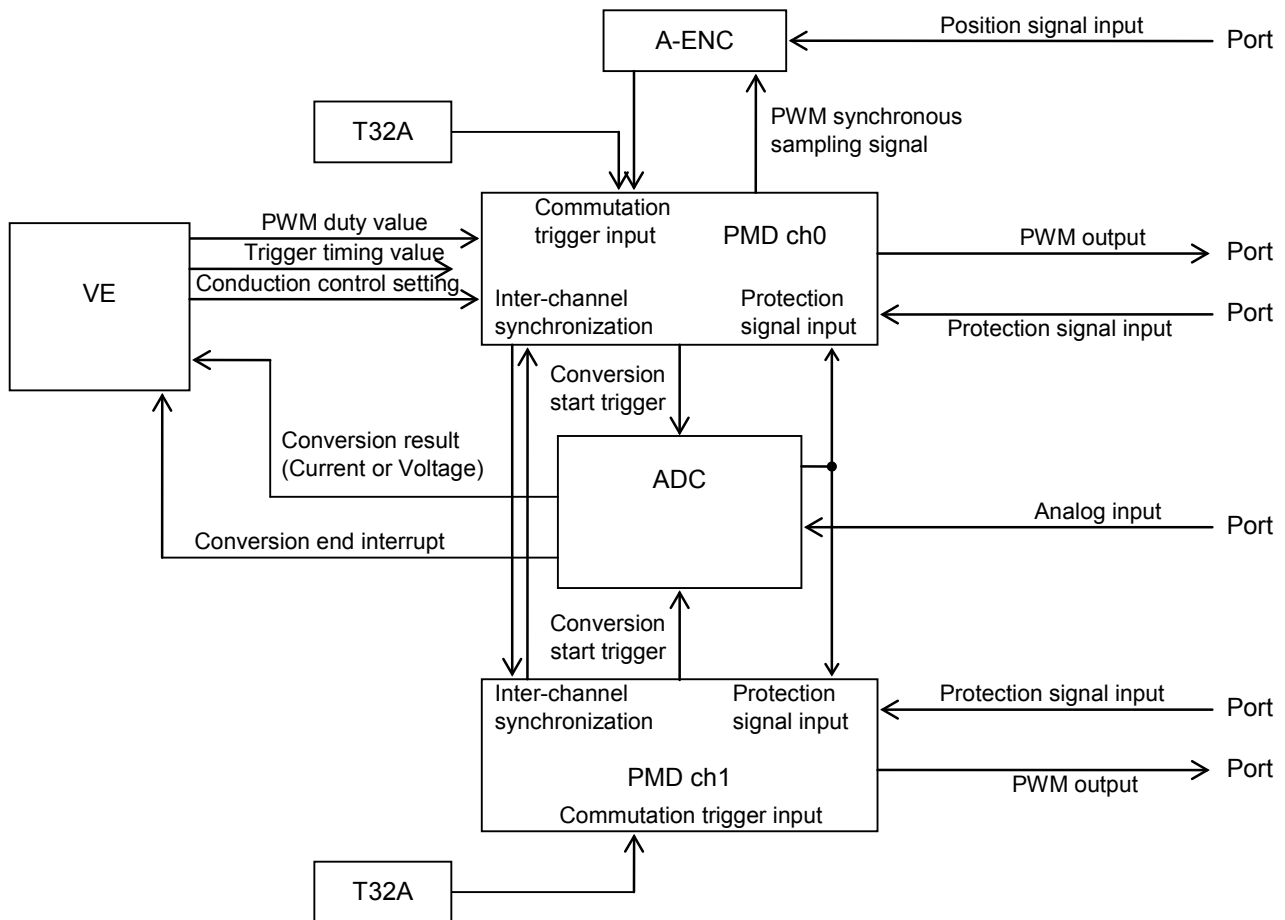
The advanced programmable motor control circuit (hereafter, abbreviated as PMD) can operate as a motor control circuit of 1 channel per unit. The following is a list of functions. The following is a list of functions.

Function Classification	Function	Operation
PWM output	Resolution	The count resolution of PWM carrier: 1/fsys. PWM frequency and duty setting: 15-bit fixed
	PWM carrier generation	The frequency range of the PWM carrier that can be generated is 0.08 to 156.25 kHz (at fsys =80 MHz), and the amplitude is 15-bit width. 4 types of PWM carrier waveform: Triangular waveform, Saw-tooth waveform, Inverse triangular waveform, Inverse saw-tooth waveform. Carrier waveform can be selected for each phase. The phase shift can be done between U and V phases, and between U and W phases in the PWM carriers.
	3-phase PWM wave generation	3-phase PWM is generated by comparing the PWM carrier with the duty setting. 3-phase PWM can be generated by selecting either 3-phase common duty or 3-phase independent duty.
	Conduction control	Each of the U/X, V/Y and W/Z phases can be selected PWM or High/Low output. Upper-phase output or lower-phase output respectively can be set to low-active or high-active. This function has the common PWM carrier waveform and generates independent 3-phase PWM (3-phase complementary PWM).
AD conversion start trigger	Synchronous trigger generation	The AD conversion start trigger can be output at an arbitrary timing synchronized with the PWM carrier.
Protection function	Protection control	Output prohibition function by protection signal input (OFF output or terminal output disabled). 2 types of protect control: EMG, OVV OVV: Port input and ADC monitoring function signal can be selected for protection signal input.
	Dead time control	The dead time control inserts the dead time for preventing short circuit at switching between the upper and lower phases (U/X, V/Y, W/Z). The complementary PWM is output.
Buffer function	-	PWM period, Duty, Synchronous trigger timing, and 6 port output setting are double-buffered or triple-buffered. These setting can be changed during operation. Selectable update timing of execution buffer: Asynchronous, PWM center, PWM end, PWM center/end Selectable update timing of intermediate buffer: Asynchronous, PWM center, PWM end, PWM 1/4, PWM 3/4
Interrupt request	PWM interrupt	PWM interrupt request is generated at a synchronous timing with the PWM wave. Interrupt timing: PWM center or PWM end Interrupt period: Half PWM period, one PWM period, two PWM period, or four PWM period. Decimation control: Synchronous trigger generation and buffer update can be decimated according to interrupt cycle selection.
	EMG interrupt	This interrupt request is generated by the EMG protection of EMG input.
	OVV interrupt	This interrupt request is generated by the OVV protection of OVV input.

Function Classification	Function	Operation
Inter-channel Synchronization Function	PWM enable synchronization	PWM enable can be executed in synchronization with PWM enable of another channel.
	Protection synchronization	EMG protection can be performed in synchronization with EMG protection function of another channel. OVV protection can be performed in synchronization with OVV protection function of another channel.
Debug Output Function	-	The operation timing of motor related peripheral functions can be monitored by port output. - ADC synchronous trigger timing monitor. - Motor control related peripheral functions interrupt generation timing monitor. - ADC conversion timing monitor. - VE task timing monitor.

The PMD realizes 3-phase motor control including Vector control, and 3-phase interleave PFC control when it cooperates with an advanced vector engine plus (hereafter, abbreviated as VE), an analog to digital converter (hereafter, abbreviated as ADC), and an advanced encoder input circuit / advanced encoder input circuit (32-bit) (hereafter, abbreviated as A-ENC).

The pulse width modulation circuit, the conduction control circuit, and the synchronous trigger generation circuit can be controlled by the VE. The synchronous trigger generation circuit can start operating ADC. The conduction control circuit can perform commutation control by trigger input signal from the A-ENC.



**Figure 1.1 Connection diagram of PMD and peripherals**

## 2. Configuration

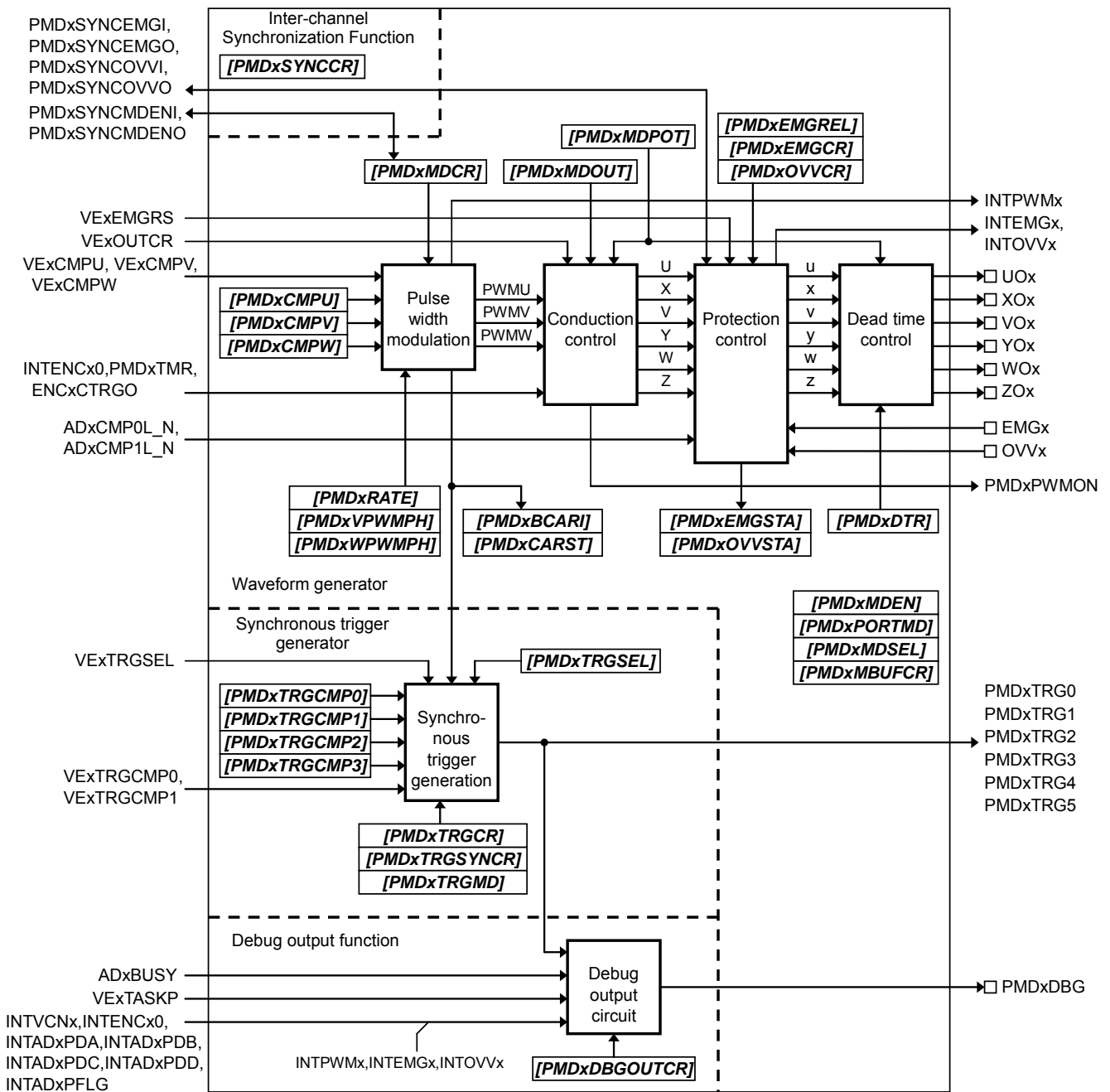


Figure 2.1 Block diagram of PMD circuit

**Table 2.1 List of signals**

No	Signal name		I/O	Related Reference manual
1	UOx	U-phase output pin	Output	Product Information
2	XOx	X-phase output pin	Output	Product Information
3	VOx	V-phase output pin	Output	Product Information
4	YOx	Y-phase output pin	Output	Product Information
5	WOx	W-phase output pin	Output	Product Information
6	ZOx	Z-phase output pin	Output	Product Information
7	EMGx	EMG detection input	Input	Product Information
8	OVVx	OVV detection input	Input	Product Information
9	PMDxDBG	Debug output pin	Output	Product Information
10	PMDxSYNCDENI	Synchronization input for PWM enable	Input	Product Information
11	PMDxSYNCEMGI	Synchronization input for EMG protection	Input	Product Information
12	PMDxSYNCOVVI	Synchronization input for OVV protection	Input	Product Information
13	PMDxSYNCDENO	Synchronization output for PWM enable	Output	Product Information
14	PMDxSYNCEMGO	Synchronization output for EMG protection	Output	Product Information
15	PMDxSYNCOVVO	Synchronization output for OVV protection	Output	Product Information
16	PMDxPWMON	PWM signal for the encoder input	Output	Product Information
17	INTENCx0	Commutation trigger (A-ENC position detection sync)	Input	Product Information
18	PMDxTMR	Commutation trigger (General-purpose timer sync)	Input	Product Information
19	ENCxCTRGO	Commutation trigger (A-ENC MCMP completion sync)	Input	Product Information
20	ADxCMP0L_N	ADC monitor function 0 (OVV detection)	Input	Product Information
21	ADxCMP1L_N	ADC monitor function 1 (OVV detection)	Input	Product Information
22	PMDxTRG0	ADC synchronous trigger output 0	Output	Product Information
23	PMDxTRG1	ADC synchronous trigger output 1	Output	Product Information
24	PMDxTRG2	ADC synchronous trigger output 2	Output	Product Information
25	PMDxTRG3	ADC synchronous trigger output 3	Output	Product Information
26	PMDxTRG4	ADC synchronous trigger output 4	Output	Product Information
27	PMDxTRG5	ADC synchronous trigger output 5	Output	Product Information
28	INTPWMx	PWM interrupt	Output	Exception, Product Information
29	INTEMGx	EMG interrupt	Output	Exception
30	INTOVVx	OVV interrupt	Output	Exception
31	VExCMPU	VE U-phase PWM duty	Input	Product Information
32	VExCMPV	VE V-phase PWM duty	Input	Product Information
33	VExCMPW	VE W-phase PWM duty	Input	Product Information
34	VExTRGCMP0	VE Trigger comparison 0	Input	Product Information
35	VExTRGCMP1	VE Trigger comparison 1	Input	Product Information
36	VExTRGSEL	VE Trigger output selection	Input	Product Information
37	VExOUTCR	VE Conduction control/ Output control	Input	Product Information
38	VExEMGRS	VE EMG release	Input	Product Information
39	ADxBUSY	ADC conversion signal (Debug output)	Input	Product Information
40	INTADxPDA	ADC conversion completion interrupt A (Debug output)	Input	Product Information
41	INTADxPDB	ADC conversion completion interrupt B (Debug output)	Input	Product Information
42	INTADxPDC	ADC conversion completion interrupt C (Debug output)	Input	Product Information
43	INTADxPDD	ADC conversion completion interrupt D (Debug output)	Input	Product Information
44	INTADxPFLG	ADC conversion priority interrupt (Debug output)	Input	Product Information
45	VExTASKP	VE Task transition signal (Debug output)	Input	Product Information
46	INTVCNx	VE interrupt (Debug output)	Input	Product Information
47	INTENCx0	A-ENC interrupt (Debug output)	Input	Product Information

## 3. Function and Operation

PMD circuit consists of a wave generation circuit, a synchronous trigger generation circuit, a debug output function, and an inter-channel synchronization function. The wave generation circuit includes a pulse width modulation circuit, a conduction control circuit, a protection control circuit, and a dead time control circuit.

- The pulse width modulation circuit generates PWM carrier waveforms and generates independent 3-phase PWM waveforms.
- The conduction control circuit determines the output patterns of the upper and lower phases of U, V, and W phases.
- The protection control circuit stops the outputs in emergency case when EMG or OVV signal is received.
- The dead time control circuit prevents from short-circuit at switching between the upper and lower phases.
- The synchronous trigger generation circuit generates 4 channel synchronous trigger signals to ADC.
- The debug output function outputs the monitoring signal of the operation timing of the peripheral function used for motor control.
- The inter-channel synchronization function synchronizes PWM waveform and protection functions of multiple PMDs.

### 3.1. Clock Supply

When you use PMD, please set an applicable clock enable bit to "1" (clock supply) in Clock supply and stop register A for fsys (*[CGFSYSENA]*, *[CGFSYSMENA]*), Clock supply and stop register B for fsys (*[CGFSYSENB]*, *[CGFSYSMENB]*), and Clock supply and stop register for fc (*[CGFCEN]*).

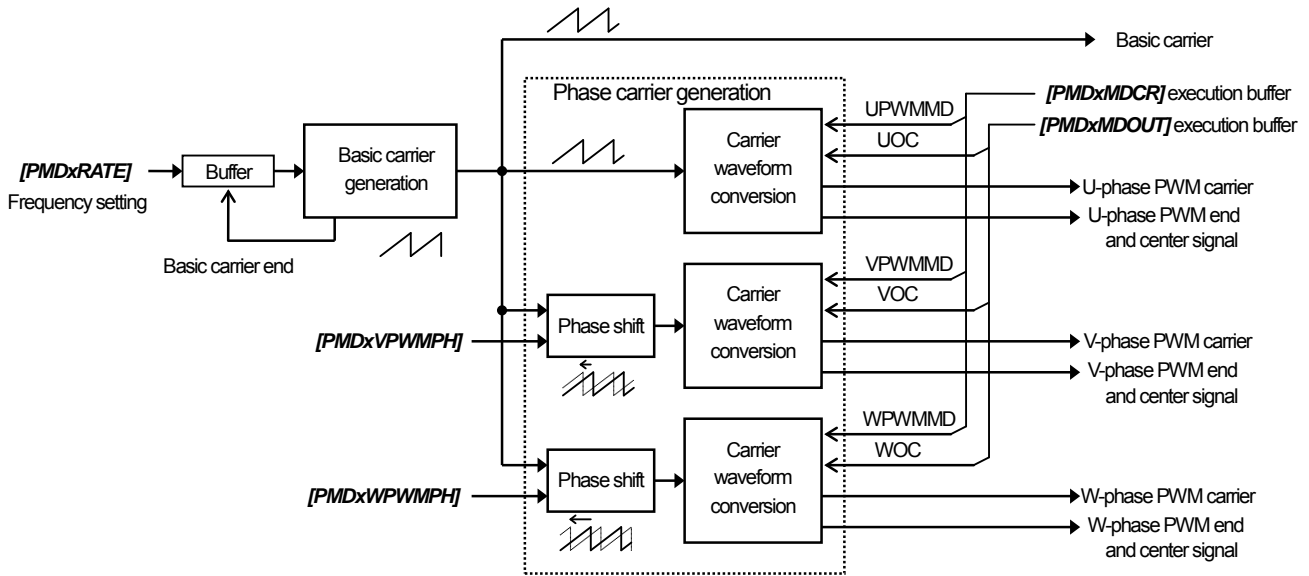
An applicable register and the bit position vary according to a product. Therefore, the register may not exist with the product. Please refer to "Clock Control and Operation Mode" of the reference manual for the details.

### 3.2. Pulse Width Modulation Circuit

The pulse width modulation circuit consists of a PWM carrier generation circuit and 3-phase PWM generation circuit.

#### 3.2.1. PWM Carrier Generation

The PWM carrier generation circuit integrates *[PMDxRATE]* register value to generate a basic carrier (saw-tooth wave), and generates each PWM carrier of 3 phases using the basic carrier.



**Figure 3.1 PWM carrier generation circuit**

- Basic carrier generation

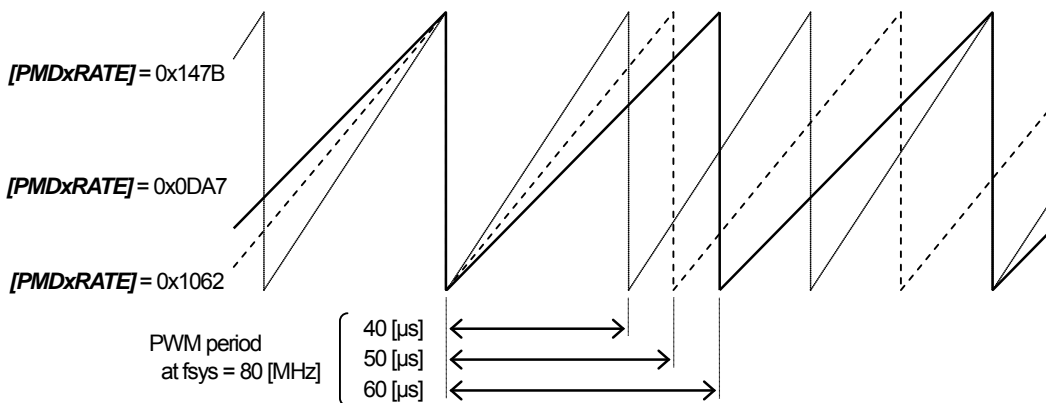
The PWM frequency should be set in `[PMDxRATE]` register. `[PMDxRATE]` register has a double-buffer structure. The execution buffer is updated every basic carrier end (refer to "4.2.7 `[PMDxRATE]` (PWM frequency register)").

The PWM frequency is calculated with the following formula:

$$\text{PWM frequency} = \frac{f_{\text{sys}} [\text{Hz}]}{2^{24} / [\text{PMDxRATE}] \text{ value}}$$

Note: The decimal fraction is rounded off in the denominator.

The amplitude of the basic carrier is the same even when the frequency is changed, as shown in Figure 3.2.



**Figure 3.2 Basic carrier waveform**

- Phase shift

The phase shift can be done between U and V phases, and between U and W phases in the PWM carriers.  $[PMDxVPWMPH]$  and  $[PMDxWPWMPH]$  registers can set the phase differences between U and V phases, and between U and W phases, respectively (refer to Figure 3.3).

The setting value of the phase shift is (the ratio to the PWM period)  $\times 2^{15}$ .

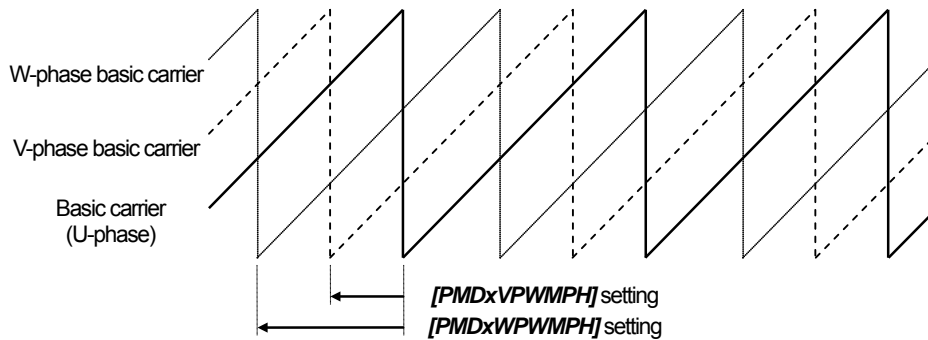


Figure 3.3 Phase shift diagram

- Each phase carrier generation

Each PWM phase carrier can select its waveform using the settings of  $\langle UPWMMD \rangle$ ,  $\langle VPWMMD \rangle$ , and  $\langle WPWMMD \rangle$  in  $[PMDxMDCR]$  register.  $\langle UPWMMD \rangle$ ,  $\langle VPWMMD \rangle$ , and  $\langle WPWMMD \rangle$  fields have a triple-buffer structure. The update timing of the execution buffer is shown in Table 3.1. For the update of the intermediate buffer, refer to "3.7 Buffer Operation".

The waveform of the PWM carrier can be selected from among a saw-tooth wave, a triangular wave, an inverse saw-tooth wave, and an inverse triangular wave (refer to Figure 3.4). And the PWM carrier waveform is inverted if the conduction setting  $[PMDxMDOUT] \langle UOC \rangle / \langle VOC \rangle / \langle WOC \rangle$  is set to "00".

Table 3.1 Update control of execution buffers of  $\langle UPWMMD \rangle$ ,  $\langle VPWMMD \rangle$ , and  $\langle WPWMMD \rangle$

Setting $[PMDxMDPOT] \langle PSYNCS \rangle$	Update Timing
00	Asynchronous with PWM
01	Update at each PWM center
10	Update at each PWM end
11	Update at each PWM end and center

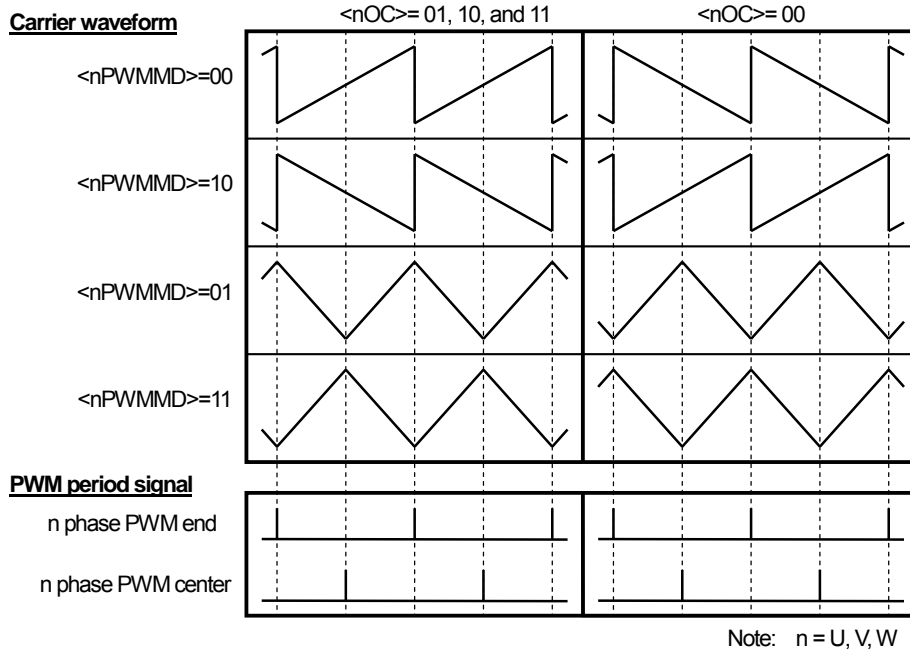


Figure 3.4 Converted carrier waveform output

### 3.2.2. 3 Phase PWM Wave Generation

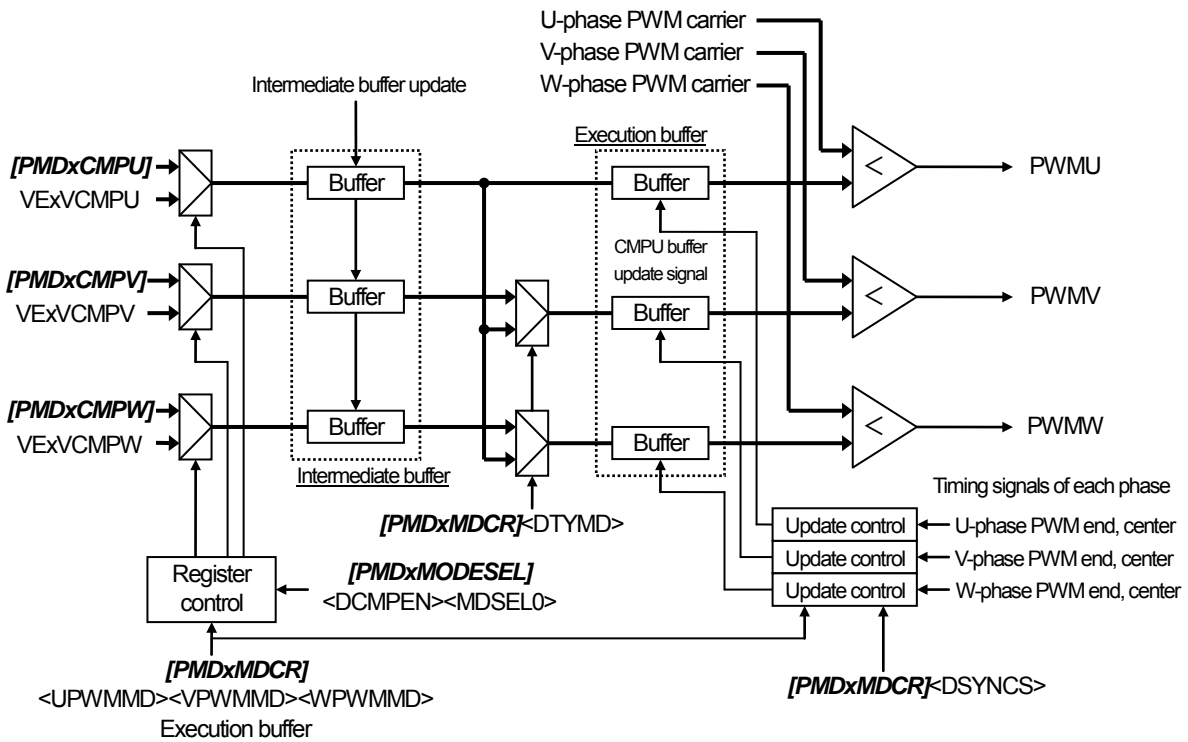


Figure 3.5 Generation circuit of 3-phase PWM waves



- Comparison function

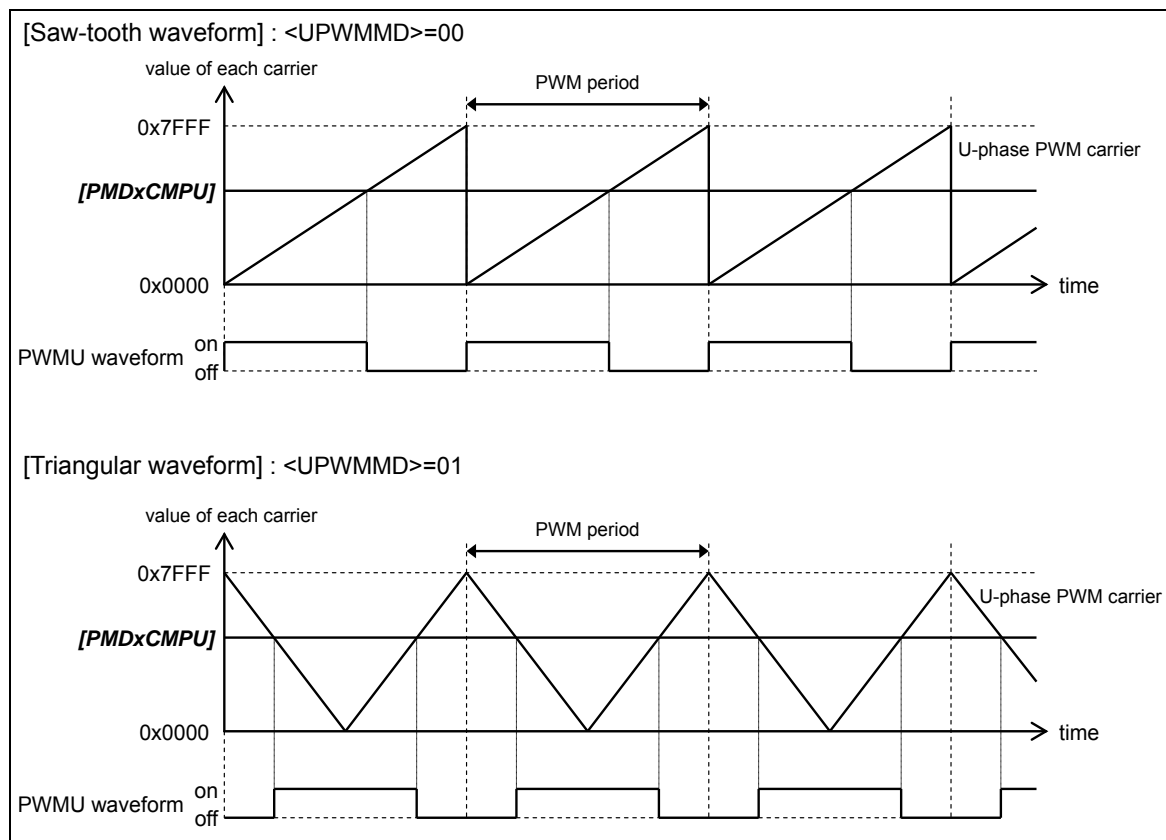
3 comparators compare the magnitudes of 3-phase PWM carries with the values in 3-phase PWM duty comparison registers ( $[PMDxCMPU]$ ,  $[PMDxCMPV]$ , and  $[PMDxCMPW]$ ), respectively, to generate PWM waves which have the expected duties.

Each phase PWM duty comparison register has a triple-buffer structure. The value of each phase PWM duty comparison register is loaded to the execution buffer at a synchronous timing with the PWM period. The update at the half of the PWM period (Load every half period) can be selected (refer to Table 3.2). For the update of the intermediate buffer, refer to "3.7 Buffer Operation".

**Table 3.2 Update control of the execution buffers in  $[PMDxCMPU]$ ,  $[PMDxCMPV]$ , and  $[PMDxCMPW]$**

$[PMDxMDCR]$ setting		Update timing
<DSYNCS>	<INTPRD>	
00	01, 10, 11	Update at each PWM end
	00	Update at each PWM end and center
01	xx	Update at each PWM center
10	xx	Update at each PWM end
11	xx	Update at each PWM end and center

Note: xx: Don't care



**Figure 3.6 PWM waveform**

- Waveform mode

3-phase PWM waveforms can be generated in the following 2 modes by the duty mode selection [*PMDxMDCR*]*<DTYMD>*.

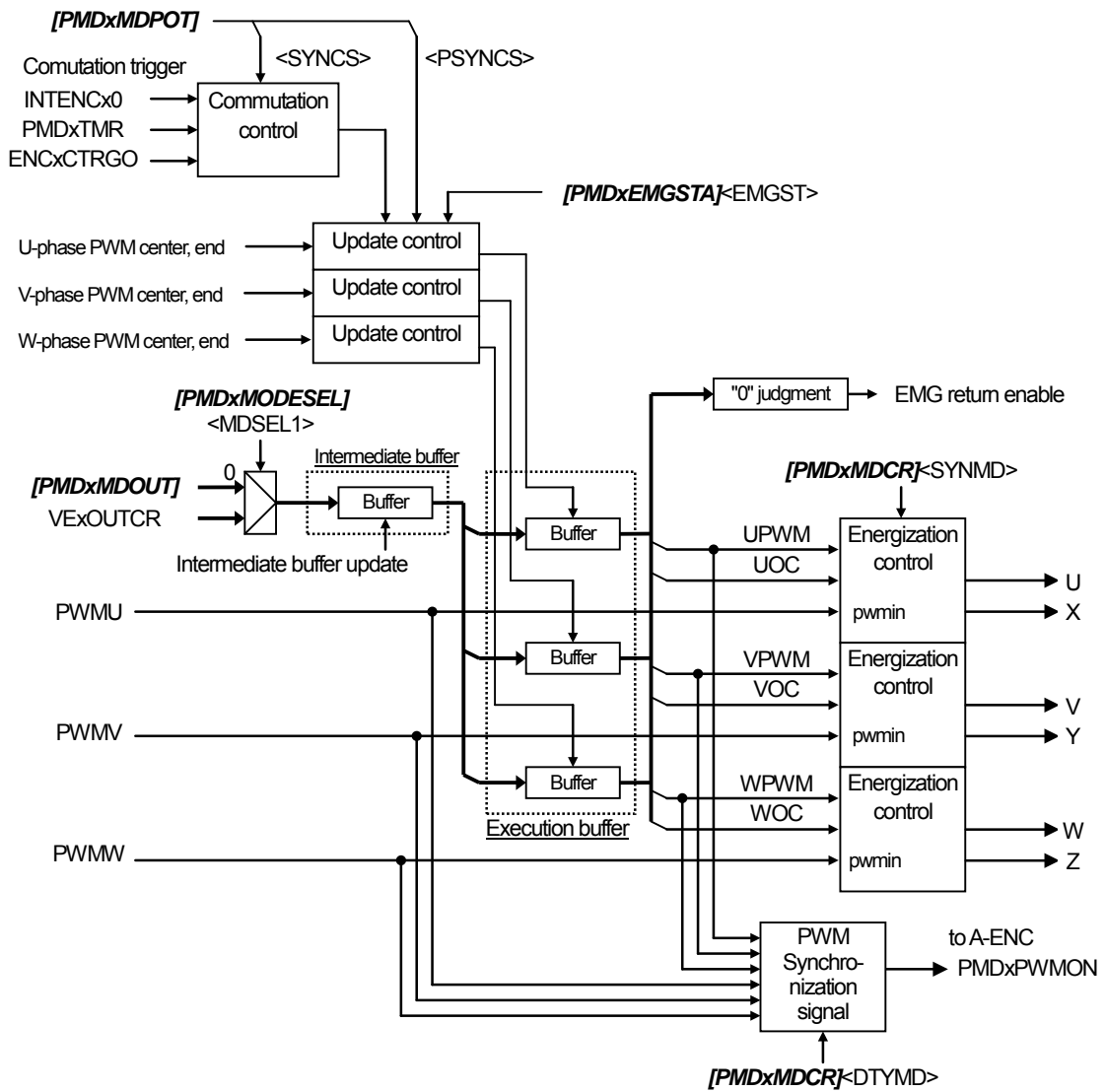
- 3-phase independent duty mode:  
3-phase PWM duty comparison registers are set to different values, respectively. Each PWM wave is generated independently. This mode is used to generate arbitrary driving waves such as sine waves.
- 3-phase common duty mode:  
Only U-phase PWM duty comparison register is used. The register value controls all 3-phase PWM waves. These PWM waves become the same. This mode is used for the pulse control to drive a brushless DC motor.

- Interrupt procedure

The pulse width modulation circuit generates a PWM interrupt request at a synchronous timing with the PWM period. The timing of the interrupt generation can be selected between U-phase PWM end and U-phase PWM center.

The frequency of the PWM interrupt can be selected from among every half of the PWM period, every PWM period, every second PWM period, and every fourth PWM period.

**3.3. Conduction Control Circuit**



**Figure 3.7 Conduction control circuit**

The output ports are controlled by the settings of the PMD conduction control register *[PMDxMDOUT]* /VExOUTCR and the PMD output setting register *[PMDxMDPOT]*. *[PMDxMDOUT]* /VExOUTCR has a triple-buffer structure. The update timing of its execution buffer can be selected between a synchronous timing with PWM period and an asynchronous one. And the update timing which is synchronous with the trigger input can also be set. (For the details of the update timing, refer to Table 3.3.)

Each of 6 port outputs (Upper-phase output, UOx, VOx, and WOx, and Lower-phase output, XOx, YOx, and ZOx) can be set separately to Low active output and High active output by *[PMDxMDPOT]*<POLH> and <POLL>, respectively (Refer to "3.5 Dead time Control Circuit"). And, each phase of U, V, and W can select between PWM output and High/Low level output using *[PMDxMDOUT]* /VExOUTCR <WPWM>, <VPWM>, and <UPWM>, respectively. When PWM output is selected, PWM wave is output, and when High/Low output is selected, High level or Low level is output. The selection of High or Low is done by *[PMDxMDOUT]* /VExOUTCR <WOC>, <VOC>, and <UOC>, respectively. Table 3.4 shows the port outputs determined by the settings of the port output set by *[PMDxMDOUT]* /VExOUTCR and *[PMDxMDPOT]*, and also by the setting of the port output mode set by PMD control register *[PMDxMDCR]*.

And, the conduction control circuit outputs the PWM signal (PMDxPWMON) for PWM synchronous sampling in A-ENC.

**Table 3.3 Update timing of the execution buffer in [PMDxMDOUT]/VExOUTCR**

		[PMDxMDPOT]<PSYNCS> Setting			
		00	01	10	11
[PMDxMDPOT] <SYNCS> Setting	00	Always updated	Each phase PWM center	Each phase PWM end	Each phase PWM end and center
	01	At INTENCx0 generation	When INTENCx0 is generated, at the first each phase PWM center	When INTENCx0 is generated, at the first each phase PWM end	When INTENCx0 is generated, at the first each phase PWM end and center
	10	At PMDxTMR generation	When PMDxTMR is generated, at the first each phase PWM center	When PMDxTMR is generated, at the first each phase PWM end	When PMDxTMR is generated, at the first each phase PWM end and center
	11	At ENCxCTRGO generation	When ENCxCTRGO is generated, at the first each phase PWM center	When ENCxCTRGO is generated, at the first each phase PWM end	When ENCxCTRGO is generated, at the first each phase PWM end and center

Note 1: Asynchronous update is done in PMD disable and EMG protection modes regardless of the settings.

Note 2: When PMD disable ([PMDxMDEN]<PWMEN>=0), the set trigger conditions are cleared.

**Table 3.4 Decode circuit outputs according to [PMDxMDOUT]/VExOUTCR and [PMDxMDCR]<SYNTMD> setting**

[PMDxMDCR]<SYNTMD>=0

		PWM output setting [PMDxMDOUT]<nPWM>			
		0: H/L output		1: PWM output	
		Upper-phase	Lower-phase	Upper-phase	Lower-phase
Conduction setting [PMDxMDOUT] <nOC>	00	Low	Low	PWM	PWM_N
	01	Low	High	Low	PWM
	10	High	Low	PWM	Low
	11	High	High	PWM	PWM_N

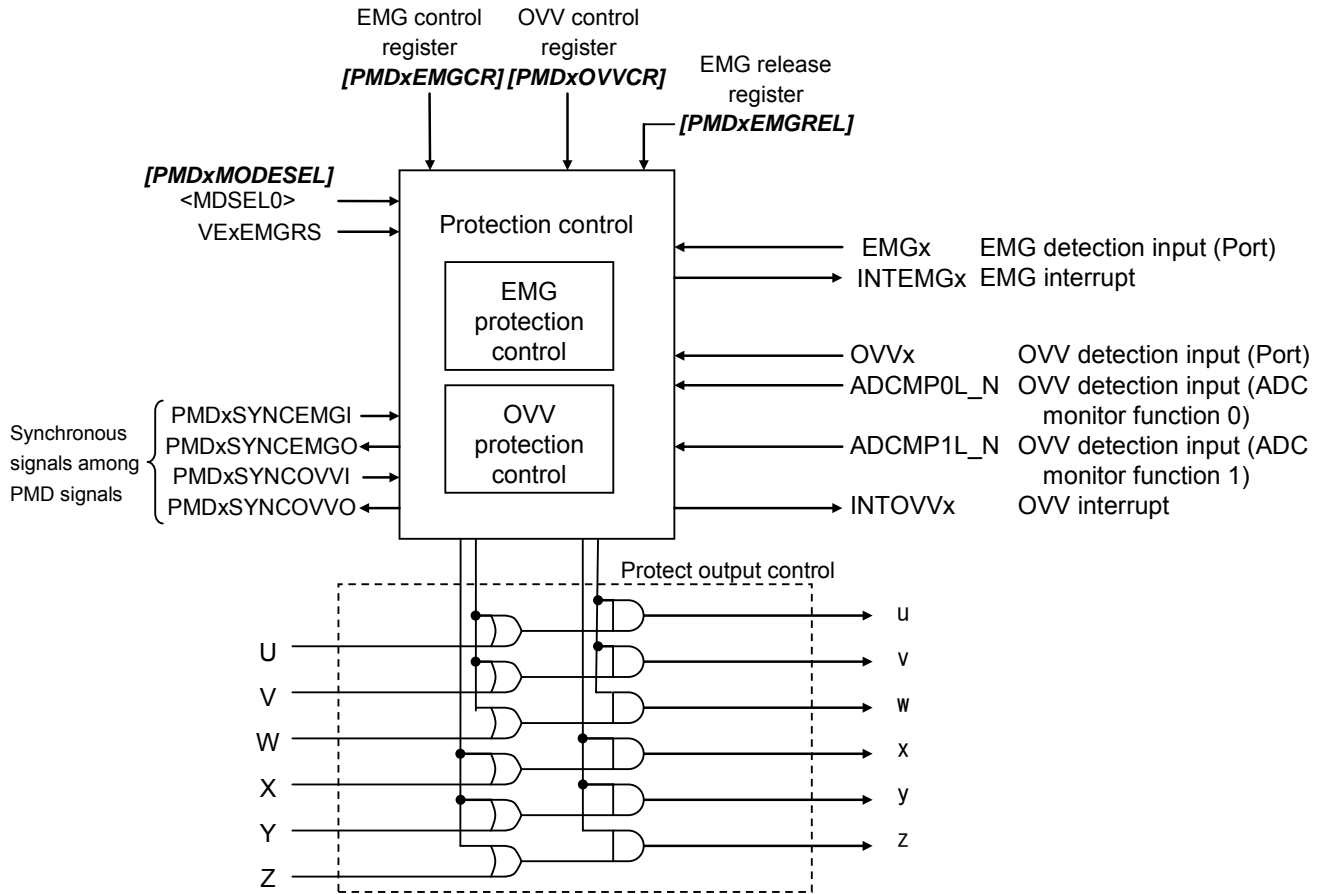
[PMDxMDCR]<SYNTMD>=1

		PWM output setting [PMDxMDOUT]<nPWM>			
		0: H/L output		1: PWM output	
		Upper-phase	Lower-phase	Upper-phase	Lower-phase
Conduction setting [PMDxMDOUT] <nOC>	00	Low	Low	PWM	PWM_N
	01	Low	High	Low	PWM_N
	10	High	Low	PWM	Low
	11	High	High	PWM	PWM_N

Note: n= U, V, W

### 3.4. Protection Control Circuit

The protection control circuit consists of a protection control unit and a protect output control unit.  
The protection control unit consists of EMG protection control and OVV protection control circuits.



**Figure 3.8 Protection control circuit**

### 3.4.1. EMG Protection Control Circuit

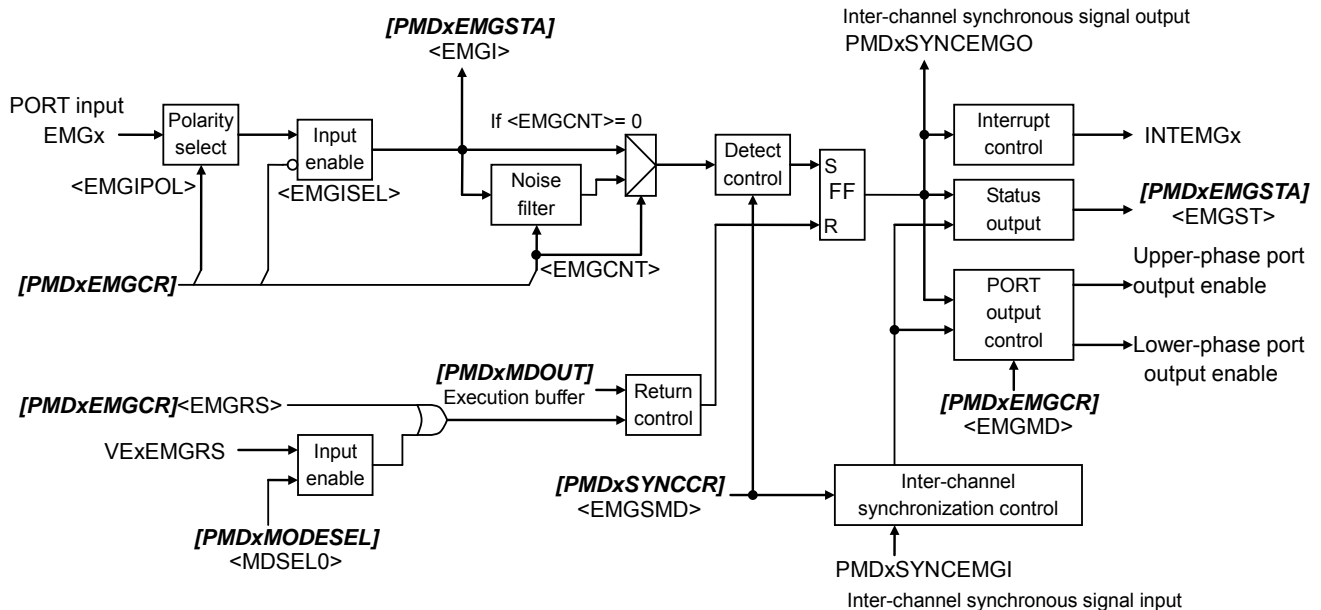


Figure 3.9 EMG protection control circuit

EMG protection control circuit is for emergency stop. The protection is enabled by  $[PMDxEMGCR]\langle EMGEN \rangle = 1$ . When EMG input becomes active, the protection starts operating. The EMG protection is set by EMG control register  $[PMDxEMGCR]$ .

Note: After reset, the EMG protection control circuit is enabled.

- EMG input

EMGx pin is enabled / disabled as EMG input by  $[PMDxEMGCR]\langle EMGISEL \rangle$ . The active level is selected by  $[PMDxEMGCR]\langle EMGIPOL \rangle$  (EMGx input polarity selection).

The noise filter is inserted in the EMG input. The noise detection time is selected with the EMG input detection time setting ( $[PMDxEMGCR]\langle EMGCNT \rangle$ ). When  $\langle EMGCNT \rangle = 0$  setting, the noise filter is bypassed.

Note: If  $\langle EMGCNT \rangle$  and  $\langle EMGIPOL \rangle$  is changed while EMG protection control circuit is enabled, it may become the protection state. Therefore, when these are changed, please execute "Return of the EMG protection".

- EMG protection operation

When EMG input is active for a predetermined period (set by  $\langle EMGCNT \rangle$ ), all 6 PWM outputs can be disabled immediately and EMG interrupt (INTEMGx) is generated. According to the setting of  $[PMDxEMGCR]\langle EMGMD \rangle$ , the external output port status during protection operation is selected from all phase high-impedance, all lower-phase high-impedance / all upper-phase ON, all upper-phase high-impedance / all lower-phase ON.

When  $[PMDxEMGSTA]\langle EMGST \rangle$  is "1", the device is in EMG protection state.

- Return from the EMG protection

If all the port outputs are set to inactive ( $[PMDxMDOUT]/VExOUTCR$  <UPWM>, <VPWM>, <WPWM>, <UOC>, <VOC>, and <WOC> are all "0") in EMG protection state and then  $[PMDxEMGCR]/VExEMGRS$  <EMGRS> is set to "1", the device return from EMG protection state. When, however, EMG input is active, writing "1" to <EMGRS> is ignored. The return procedure should be done after EMG input becomes inactive. It is confirmed with reading  $[PMDxEMGSTA]$ <EMGI>.

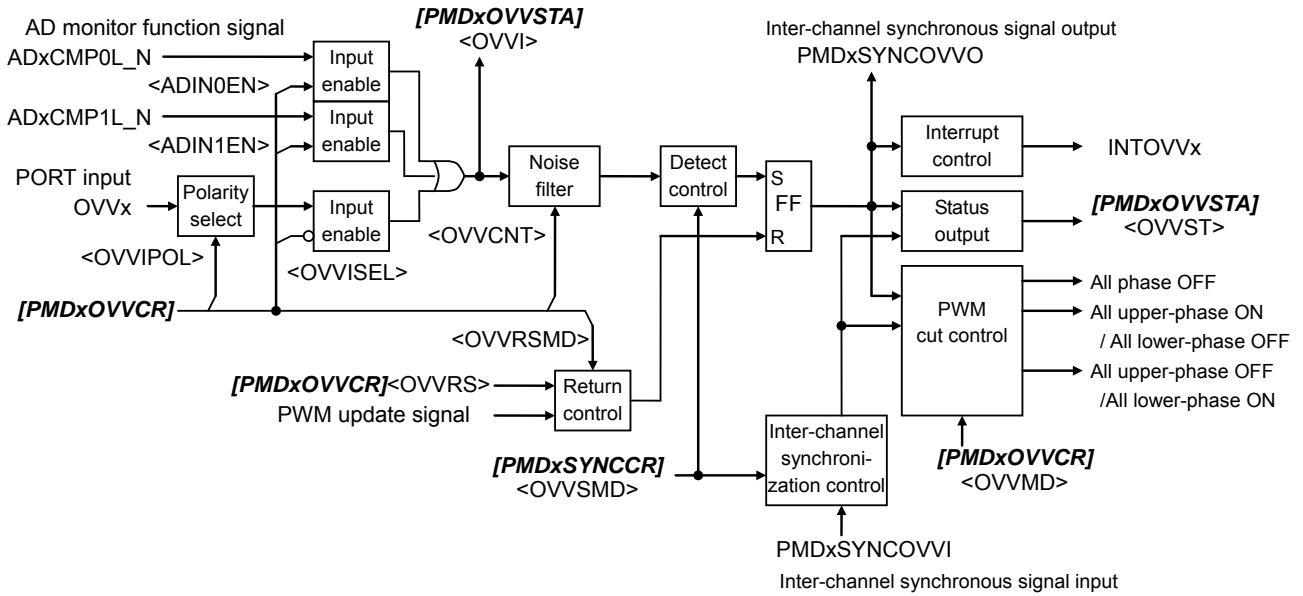
Note: EMG return procedure after the reset deassertion

EMGx pin is shared with a data port. The pin is the data port after the reset deassertion. EMG protection control circuit is enabled at the initial state. So, EMC protection may be active. The return of EMG protection state should be done as follows in the initial sequence:

- (1) EMG function should be selected by the port function register ( $[PxFRn]$ ).
  - (2)  $[PMDxEMGSTA]$ <EMGI> should be read to confirm its value is "1".
  - (3)  $[PMDxMDOUT]/VExOUTCR$  <UPWM>, <VPWM>, <WPWM>, <UOC>, <VOC>, and <WOC> should be set to "0" to set all port outputs to inactive state.
  - (4)  $[PMDxEMGCR]/VExEMGRS$  <EMGRS> should be set to "1" to exit EMG protection state.
- Disable of the EMG protection function

In order to disable EMG function, EMG release register  $[PMDxEMGREL]$  should be set to "0x5A" and "0xA5" in order, then  $[PMDxEMGCR]$ <EMGEN> should be set to "0". These 3 instructions should be executed continuously to prevent from a wrong setting of the disable.

**3.4.2. OVV Protection Control Circuit**



**Figure 3.10 OVV protection control circuit**

The OVV protection control circuit is enabled by  $[PMDxOVVCR]<OVVEN>=1$ . When OVV input becomes active, the protection starts operating. This protection is set by OVV control register ( $[PMDxOVVCR]$ ).

- OVV input

OVVx pin and ADC monitor function signals (ADxCMP0L\_N / ADxCMP1L\_N) are enabled / disabled as OVV input by  $[PMDxOVVCR]<OVVISEL>/<ADIN0EN>/<ADIN1EN>$ , respectively. The active level is selected by <OVVIPOL> in OVVx input (Port) polarity selection register.

The noise filter is inserted in the OVV input. The noise detection time is selected with the OVV input detection time setting ( $[PMDxOVVCR]<OVVCNT>$ ).

Note: If <OVVCNT> and <OVVIPOL> is changed while OVV protection control circuit is enabled, it may become the protection state. Therefore, when these are changed, please execute "Return of the OVV protection".

- OVV protection operation

OVV protection control circuit fixes 6 port outputs in the conduction control block to High level or Low level, when OVV input is active for a predetermined period (set by <OVVCNT>). And OVV interrupt (INTOVVx) is generated.  $[PMDxOVVCR]<OVVMD>$  setting selects from among all lower-phase OFF/all upper-phase ON, all upper-phase OFF/all lower-phase ON, and all phase OFF.

When  $[PMDxOVVSTA]<OVVST>$  is "1", the device is in OVV protection state.



- Return from the OVV protection

When  $[PMDxOVVCR]<OVVRS>$  is set to "1", the device returns from OVV protection state. When, however, OVV input is active, writing "1" to  $<OVVRS>$  is ignored. The return procedure should be done after OVV input becomes inactive. It is confirmed with reading  $[PMDxOVVSTA]<OVVI>$ .

When OVV return operation selection  $<OVVRSMD>=0$ , the auto return is enabled. After OVV input becomes inactive, the return is done at the synchronous timing with U-phase PWM period (the state of the port can be checked by reading  $[PMDxOVVSTA]<OVVI>$ ). The device returns automatically from OVV protection state at U-phase PWM end. When, however, half PWM period interrupt is set, the timing is the PWM end and center.

- Disable of the OVV protection control circuit

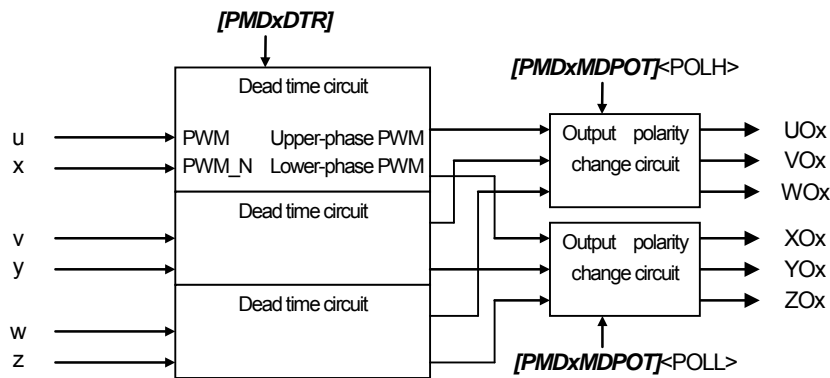
In order to disable OVV function, EMG release register  $[PMDxEMGREL]$  should be set to "0x5A" and "0xA5" in order, then  $[PMDxOVVCR]<OVVEN>$  should be set to "0". These 3 instructions should be executed continuously to prevent the OVV protection control circuit from being inadvertently disabled.

### 3.4.3. Protection control when using the debug tool

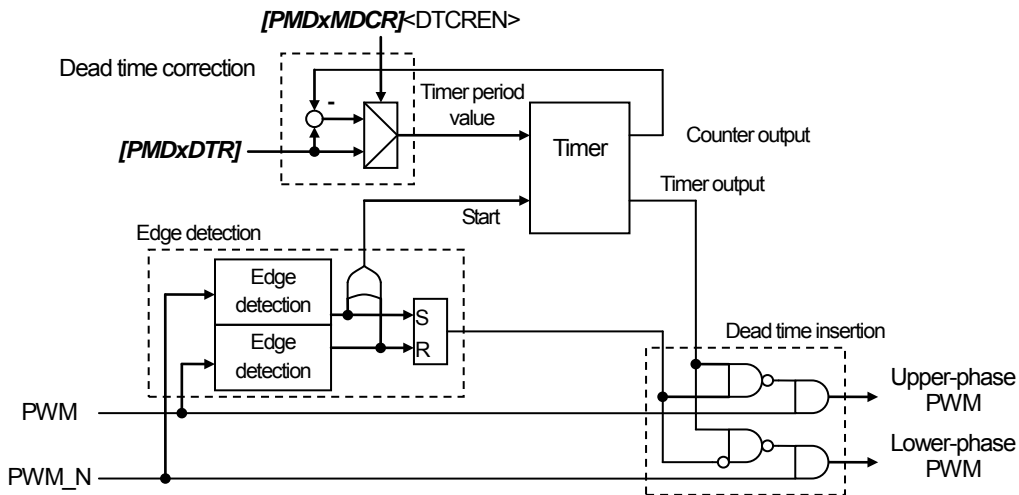
When using the debug tool, PMD output ports can be disabled when PMD is stopped by the debug halt. However, when the EMG occurs, port outputs are controlled depending by setting the  $[PMDxEMGCR]<EMGMMD[1:0]>$ .

In the debug halt, whether the port output becomes high-impedance or PMD output is selected by  $[PMDxPORTMD]<PORTMD>$  setting.

### 3.5. Dead time Control Circuit



**Figure 3.11 Dead time control circuit**



**Figure 3.12 Dead time circuit**

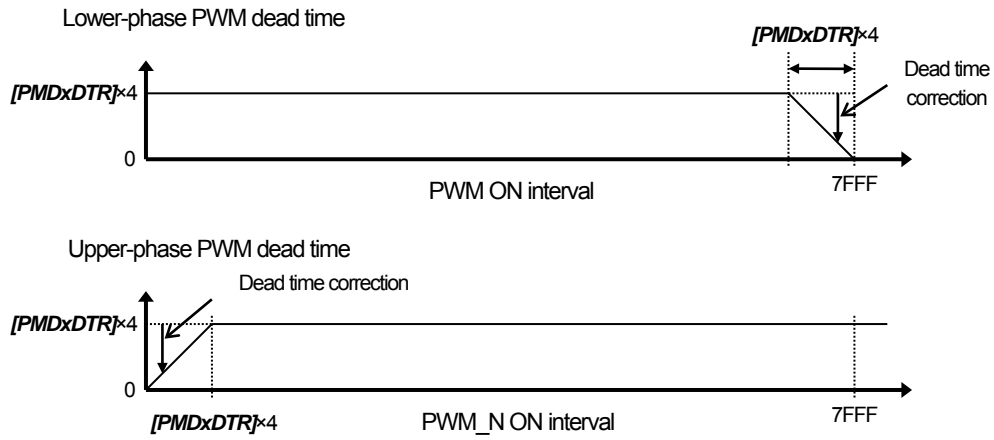
The dead time control circuit consists of a dead time circuit and an output polarity change circuit. The dead time circuit includes an edge detection block, a timer block, a dead time insertion block, and a dead time correction block (refer to Figure 3.12).

The dead time circuit delays ON timing to prevent from the short-circuit between the upper-phase and the lower-phase for U, V, and W phases, when both the upper-phase and the lower-phase invert their signals at the same time. The unit of the delay time is  $4/f_{\text{sys}}$  (50 ns at 80 MHz, 10-bit resolution). The delay time is set to the dead time register  $[PMDxDTR]$ .

The output polarity change circuit can select High-active or Low-active for Upper-phase output (UOx, VOx, and WOx) and Lower-phase output (XOx, YOx, and ZOx) independently. The selection is done by PMD output setting register  $[PMDxMDPOT]<POLH>$  and  $<POLL>$ , respectively.

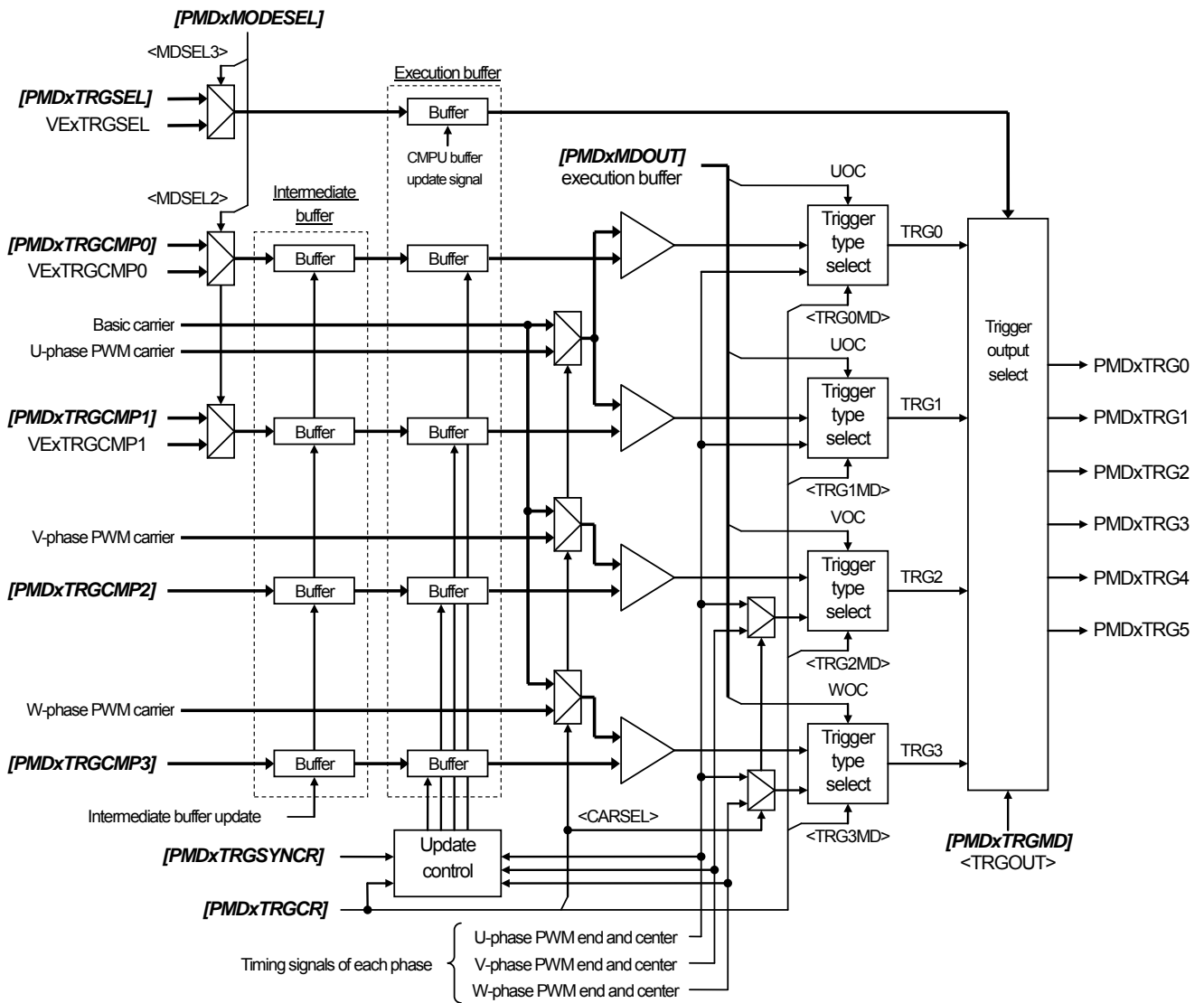
The dead time correction circuit operates as follows: When  $[PMDxMDCR]<DTCREN>$  is set to "1" and one of Upper-phase PWM and Lower-phase PWM has 0 ON time, the delay time of the other PWM is shortened. If PWM output changes to OFF during the dead time interval, the dead time correction function shortens the delay time of the opposite phase by the remaining dead time interval ("Dead time register setting value" - "ON interval"). That is, when Upper-phase PWM output changes to OFF during the dead time interval, the delay time of Lower-phase PWM is shortened. When Lower-phase PWM output changes to OFF during the dead time interval,

the delay time of Upper-phase PWM is shortened. The delay time is corrected near 100% duty of Upper-phase PWM or near 0% duty of Lower-phase PWM, as shown in Figure 3.13.



**Figure 3.13 Dead time correction**

### 3.6. Synchronous Trigger Generation Circuit



**Figure 3.14 Synchronous trigger generation circuit**

The synchronous trigger generation circuit generates 4 trigger signals (TRG0 to TRG3) which are synchronous with each phase PWM carrier and are used to sample ADC data. If VE mode is selected by *[PMDxMODESEL]* <MSEL3>, *[PMDxTRGCMP0]* and *[PMDxTRGCMP1]* are changed to VE register outputs VExTRGCMP0 and VExTRGCMP1, respectively.

The trigger timing can be selected from among the followings:

- (1) Coincident time in the first half of a triangular wave carrier (Note1)(Note2)
- (2) Coincident time in the second half of a triangular wave carrier (Note1)(Note2)
- (3) Coincident times in the first and second halves of a triangular wave carrier (Note1)(Note2)
- (4) PWM end of the basic carrier or each phase carrier (Note2)(Note3)
- (5) PWM center of the basic carrier or each phase carrier (Note2)(Note3)
- (6) PWM center and end of the basic carrier or each phase carrier (Note2)(Note3)

- Note1: Coincidence of the basic carrier or each phase carrier and  $[PMDxTRGCMPn]$  value.
- Note2: When saw-tooth wave ( $[PMDxMDCR]<UPWMMD>/<VPWMMD>/<WPWMMD>= 00, 10$ )  
There is no distinction between the first half and the second half.  
The trigger does not occur at the PWM center and it occurs at the PWM end.
- Note3: When comparing the basic carrier, it becomes U-phase PWM center / end timing.

Trigger compare registers are triple-buffer configuration. The execution buffer update timing is shown in the table below. For the update timing of the intermediate buffer, refer to "3.7 Buffer Operation".

**Table 3.5 Buffer update timing of Trigger comparison register**

$[PMDxTRGSYNCR]$ <TSYNCS> Setting	$[PMDxTRGCR]$ <TRGnMD> Setting	$[PMDxTRGCMPn]$ Register Buffer Update Timing
00	000	Immediate update
	001	Update at each phase PWM end (Note1)
	010	Update at each phase PWM center (Note1)(Note2)
	011	Update at each phase PWM end and center (Note1)(Note2)
	1xx	Immediate update
01	xxx	Update at each phase PWM center (Note1)(Note2)
10	xxx	Update at each phase PWM end (Note1)
11	xxx	Update at each phase PWM end and center (Note1)(Note2)

- Note 1: When comparing the basic carrier, it becomes U-phase PWM center / end timing.
- Note 2: When PWM carrier is a saw-tooth wave ( $[PMDxMDCR]<UPWMMD>/<VPWMMD>/<WPWMMD>= 00$  or  $10$ ), the update is done at the PWM end.
- Note 3: xxx: Don't care
- Note 4: When  $[PMDxMDEN]<PWMEN>=0$ , the immediate update is done regardless of the setting.

In the trigger output mode setting register ( $[PMDxTRGMD]<TRGOUT>=1$ ), the TRG0 signal (set by  $[PMDxTRGCMP0]/VExTRGCMP0$  and  $[PMDxTRGCR]<TRG0MD>$ ) is output to the ADC synchronous trigger (PMDxTRG0 to 5) which is set in the trigger output selection register  $[PMDxTRGSEL]/VExTRGSEL$ .

**Table 3.6 Trigger output pattern**

$[PMDxTRGMD]$ <TRGOUT> Setting	$[PMDxTRGCMPn]$ Comparison Register	$[PMDxTRGSEL]$ Setting	Trigger Output
<TRGOUT>=0	$[PMDxTRGCMP0]$	x	PMDxTRG0
	$[PMDxTRGCMP1]$		PMDxTRG1
	$[PMDxTRGCMP2]$		PMDxTRG2
	$[PMDxTRGCMP3]$		PMDxTRG3
<TRGOUT>=1	$[PMDxTRGCMP0]$	0	PMDxTRG0
		1	PMDxTRG1
		2	PMDxTRG2
		3	PMDxTRG3
		4	PMDxTRG4
	5	PMDxTRG5	
	$[PMDxTRGCMP1]$	x	No triggers are output.
$[PMDxTRGCMP2]$	x	No triggers are output.	
$[PMDxTRGCMP3]$	x	No triggers are output.	

Note: x: don't care

If the trigger output is enabled in EMG protection state,  $[PMDxTRGMD]<EMGTGE>$  should be set to "1".

## 3.7. Buffer Operation

The buffer configuration of a register has a single-buffer, double-buffer, and triple-buffer.

*[PMDxRATE]* register is a double-buffer one. *[PMDxMDOUT]*, *[PMDxCMPU]*, *[PMDxCMPV]*, *[PMDxCMPW]*, *[PMDxTRGCMP0]*, *[PMDxTRGCMP1]*, *[PMDxTRGCMP2]*, *[PMDxTRGCMP3]*, and *[PMDxTRGSEL]* registers, and *[PMDxMDCR]*<UPWMMD>, <VPWMMD>, and <WPWMMD> have triple-buffer. The other registers are single-buffer ones. The double-buffer structure has a register stage and an execution buffer stage. And the triple-buffer structure has an intermediate buffer stage between the register stage and the execution stage.

The register stage can be read or written. Some registers can be selected from PMD registers or VE registers by the setting of *[PMDxMODESEL]* register.

The intermediate stage can be updated at the timing selected by *[PMDxMBUFCTR]*<BUFCTR>. When <BUFCTR>=000, the intermediate stage is bypassed.

The update timing of the execution buffer stage can be set per register independently. For the details of the setting, refer to each register description.

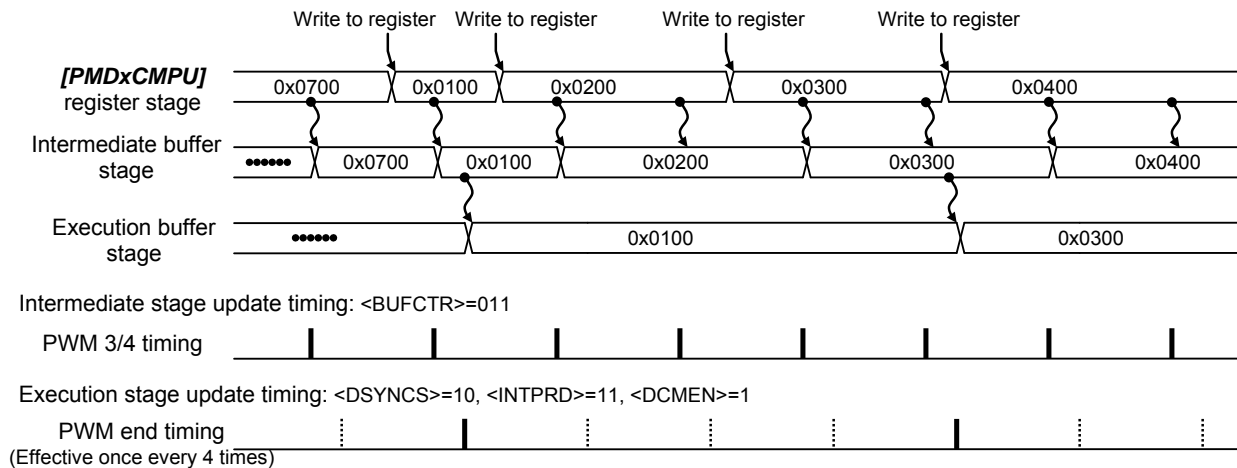


Figure 3.15 Triple-buffer update timing example of *[PMDxCMPU]* register

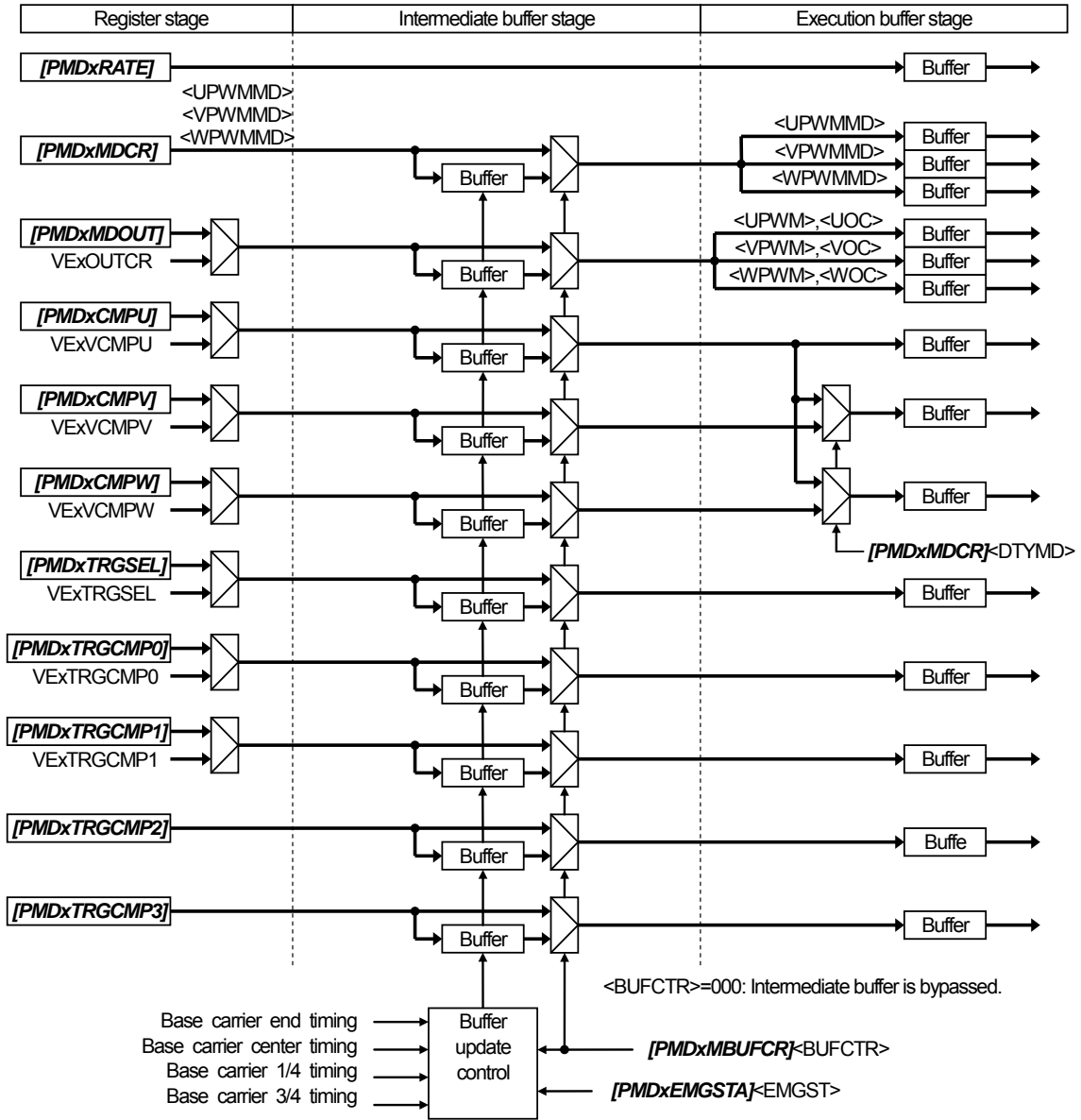


Figure 3.16 Register buffer configuration

### 3.8. Decimation of Execution Buffer Update Timing and Synchronous Trigger Output Timing

The update of the execution buffer and the trigger output usually occurs once in a PWM period. When the interrupt period is selected to two PWM periods or more, the update timing of the execution buffer and the ADC synchronous trigger output can be decimated.

When  $[PMDxMDCR] \langle INTPRD \rangle = 10$  or  $11$ , the decimation control can be enabled by the setting  $[PMDxMDCR] \langle DCMEN \rangle$  to "1".

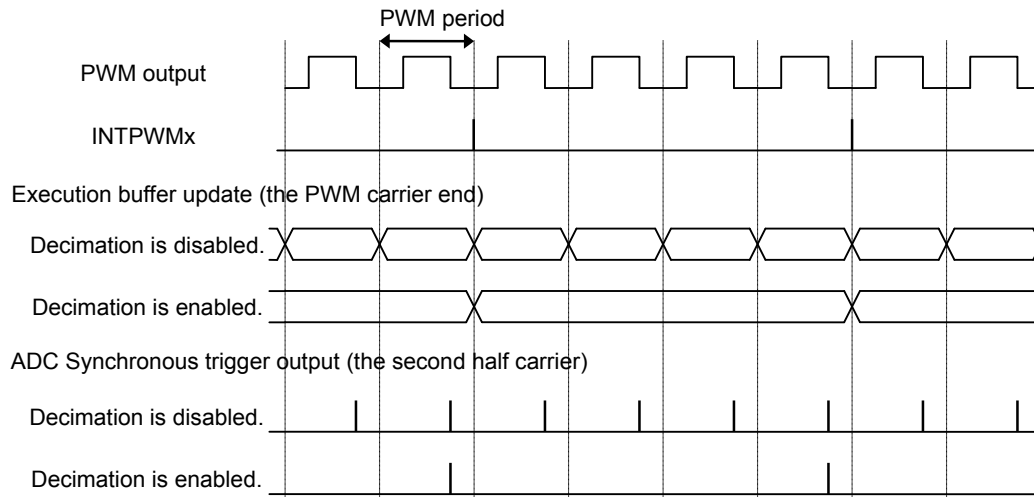


Figure 3.17 Timing example of Decimation control (in the case of  $\langle INTPRD \rangle = 11$ )



### 3.9. Inter-channel Synchronization Function

Multiple PMD circuits can be operated synchronously. There are 3 kinds of synchronization, as shown below. The channels which operate in the slave mode should be enabled to do the synchronization function. The channel which operates in the master mode or operates alone should not be enabled.

Note: When all channels are enabled for synchronization, the function cannot operate. Only the channel to be operated as a slave should be enabled for synchronization.

- PWM enable synchronization

The enable or disable of the synchronization is set by  $[PMDxSYNCCR]<PWMSMD>$ . When the enable is set, the enable or disable is controlled by  $[PMDxMDEN]<PWMEN>$  in the master channel.

- EMG protection synchronization

The enable or disable of the synchronization, and the synchronous mode are set by  $[PMDxSYNCCR]<EMGSMD>$ . EMG protection synchronization has two synchronous modes.

- Synchronization mode 1  
EMG detection in a slave channel is ignored. EMG detection in a master channel sets the slave channel to EMG protection state. The return of the protection is done by the master channel.  
EMG interrupt is generated only in the master channel.
- Synchronization mode 2  
EMG detection can be done on both master channel and slave channel. The slave channel enters EMG protection state when either the master or the slave detects EMG. The return of the protection is done by the channel which detected EMG.  
EMG interrupt is generated only in the channel which detects EMG.

- OVV protection synchronization

The enable or disable of the synchronization, and the synchronous mode are set by  $[PMDxSYNCCR]<OVVSMD>$ . OVV protection synchronization has two synchronous modes.

- Synchronization mode 1  
OVV detection in a slave channel is ignored. OVV detection in a master channel sets the slave channel to OVV protection state. The return of the protection can be done only by the master channel.  
OVV interrupt is generated only in the master channel.
- Synchronization mode 2  
OVV detection can be done on both master channel and slave channel. The slave channel enters OVV protection state when either the master or the slave detects OVV. The return of the protection is done by the channel which detected OVV.  
OVV interrupt is generated only in the channel which detects OVV.

### 3.10. Debug Output Function

The debug output function generates a monitor signal and outputs it. The monitor signal is selected from among the signals in the PMD, ADC, VE, and A-ENC circuits. In a mode other than the ADC conversion timing monitor mode, the debug output toggles every time a permitted signal is input.

The initial value of debug output can be set by  $[PMDxDBGOUTCR]<INIFF>$  (Note). The  $<INIFF>$  setting is reflected by disabling debug output ( $[PMDxDBGOUTCR]<DBGEN>=0$ ).

Note: Initial value cannot be set with ADC conversion timing monitor mode.

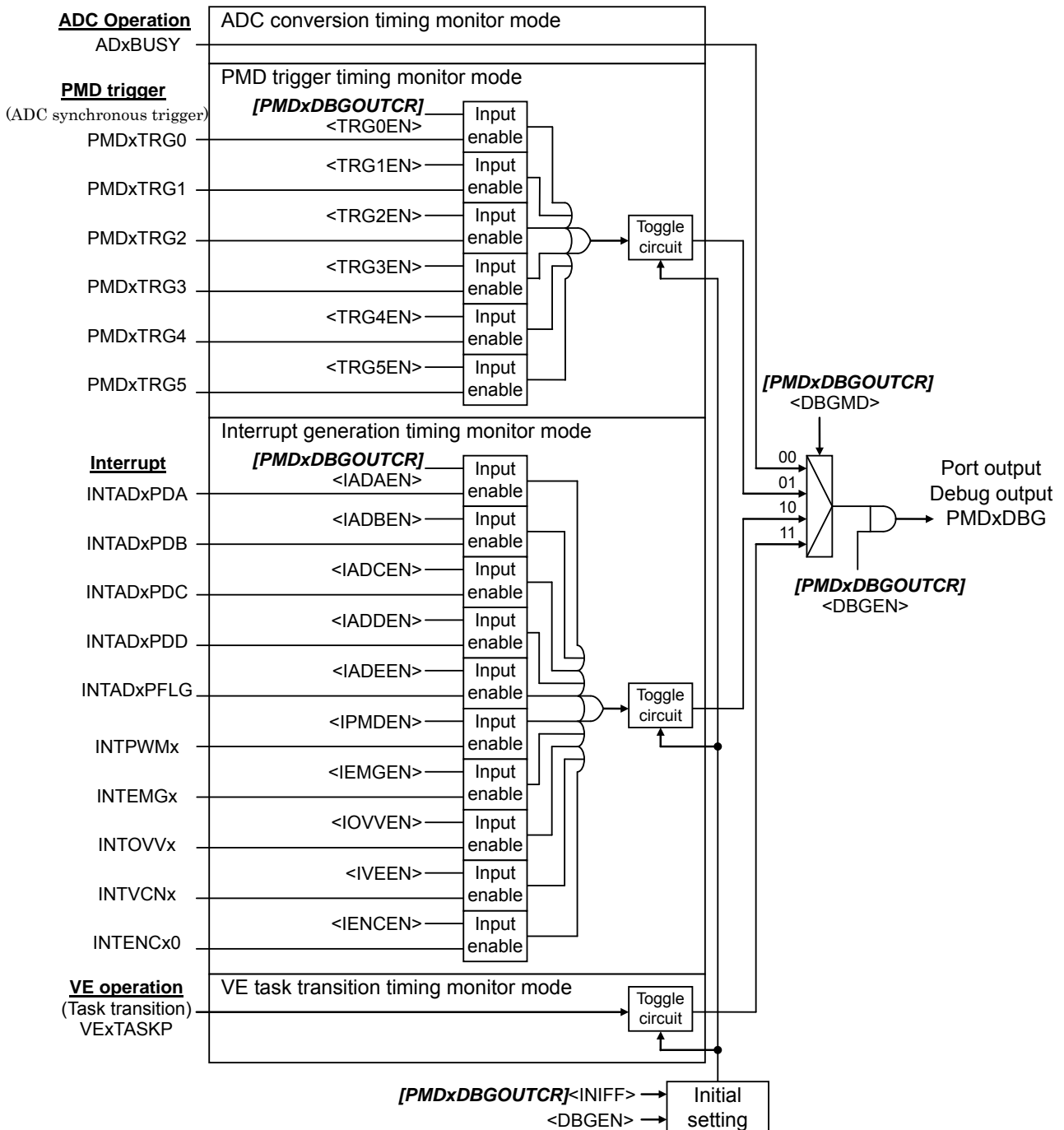


Figure 3.18 Debug output circuit

## 4. Registers

### 4.1. List of Registers

The control registers and their addresses are shown as follows.

Peripheral Function		Channel/Unit	Base Address		
			TYPE1	TYPE2	TYPE3
Advanced programmable motor control circuit	A-PMD	ch0	0x400F6000	0x400E9000	0x40089000
		ch1	0x400F6100	0x400E9400	0x40089400
		ch2	0x400F6200	0x400E9800	0x40089800
		ch3	0x400F6300	0x400E9C00	0x40089C00

Note: The channel/unit and base address type are different by products. Please refer to "Product Information" of the reference manual for the details.

Register Name	Address (Base+)
PMD enable register	[PMDxMDEN] 0x0000
Port output mode register	[PMDxPORTMD] 0x0004
PMD control register	[PMDxMDCR] 0x0008
PWM carrier status register	[PMDxCARSTA] 0x000C
Basic carrier register	[PMDxBCARI] 0x0010
PWM frequency register	[PMDxRATE] 0x0014
PWM duty comparison U register	[PMDxCMPU] 0x0018
PWM duty comparison V register	[PMDxCMPV] 0x001C
PWM duty comparison W register	[PMDxCMPW] 0x0020
Mode selection register	[PMDxMODESEL] 0x0024
PMD conduction control register	[PMDxMDOUT] 0x0028
PMD output setting register	[PMDxMDPOT] 0x002C
EMG release register	[PMDxEMGREL] 0x0030
EMG control register	[PMDxEMGCR] 0x0034
EMG status register	[PMDxEMGSTA] 0x0038
OVV control register	[PMDxOVVCR] 0x003C
OVV status register	[PMDxOVVSTA] 0x0040
Dead time register	[PMDxDTR] 0x0044
Trigger comparison 0 register	[PMDxTRGCMP0] 0x0048
Trigger comparison 1 register	[PMDxTRGCMP1] 0x004C
Trigger comparison 2 register	[PMDxTRGCMP2] 0x0050
Trigger comparison 3 register	[PMDxTRGCMP3] 0x0054
Trigger control register	[PMDxTRGCR] 0x0058
Trigger output mode setting register	[PMDxTRGMD] 0x005C
Trigger output selection register	[PMDxTRGSEL] 0x0060
Trigger update timing setting register	[PMDxTRGSYNCR] 0x0064
V-phase phase difference register	[PMDxVPWMPH] 0x0068
W-phase phase difference register	[PMDxWPWMPH] 0x006C
Intermediate buffer control register	[PMDxMBUFCR] 0x0070
Synchronization control register	[PMDxSYNCCR] 0x0074
Debug output control register	[PMDxDBGOUTCR] 0x0078

## 4.2. Details of Registers

### 4.2.1. [PMDxMDEN] (PMD enable register)

Bit	Bit Symbol	After Reset	Type	Description
31:1	-	0	R	Read as "0"
0	PWMEN	0	R/W	Wave composition function is enabled or disabled. 0: Disabled. 1: Enabled.

Note 1: When the port is set to the function output (PWM output), the port output is disabled (High-impedance) at <PWMEN>=0.

Note 2: <PWMEN>=1 should be set after initial settings other than <PWMEN> like an output polarity are set.

Note 3: At synchronous operation (Slave mode), this bit is valid only in the master channel, not in the slave channel.

### 4.2.2. [PMDxPORTMD] (Port output mode register)

Bit	Bit Symbol	After Reset	Type	Description
31:2	-	0	R	Read as "0"
1:0	PORTMD[1:0]	00	R/W	Setting of the port control at debug halt 00: Upper-phase High-impedance / Lower-phase High-impedance 01: Upper-phase High-impedance / Lower-phase PMD output 10: Upper-phase PMD output / Lower-phase High-impedance 11: Upper-phase PMD output / Lower-phase PMD output This field sets the port outputs of Upper-phases (UOx/VOx/WOx) and Lower-phases (XOx/YOx/ZOx) at occurrence of debug halt while the port is set to the function output (PWM output). At occurrence of debug halt while "High-impedance" is selected, the port output is disabled (High-impedance). Otherwise, the output follows PMD output.

Note 1: The output is disabled (High-impedance) at [PMDxMDEN]<PWMEN>=0, regardless of <PORTMD> setting.

Note 2: The port control is done by the setting of [PMDxEMGCR]<EMGMD> at EMG input mode, too.

Note 3: For the input/output port setting, refer to "Input/Output Ports" of the reference manual.

### 4.2.3. [PMDxMODESEL] (Mode selection register)

Bit	Bit Symbol	After Reset	Type	Description
31:8	-	0	R	Read as "0"
7	DCMPEN	0	R/W	Enable of auto change between VE register and PMD register (Note1)(Note2) 0: Register change is disabled. (Only <MDESEL0> setting register can be used) 1: Register change is enabled. (Two registers are changed between the first half and the second half of PWM period.) This is valid in <MDESEL0>=1. This is valid when all phase triangular wave carriers are selected ([PMDxMDCR]<UPWMMMD>/<VPWMMMD>/<WPWMMMD>= 01, 11).
6:4	-	0	R	Read as "0"
3	MDESEL3	0	R/W	Mode selection 3 0: Bus mode (PMD register is used: [PMDxTRGSEL]). 1: VE mode (VE register is used: [VExTRGSEL]). TRGSEL register selection.
2	MDESEL2	0	R/W	Mode selection 2 0: Bus mode (PMD registers are used: [PMDxTRGCMP0] and [PMDxTRGCMP1]). 1: VE mode (VE registers are used: [VExTRGCMP0] and [VExTRGCMP1]). TRGCMP0 and TRGCMP1 register selection.
1	MDESEL1	0	R/W	Mode selection 1 0: Bus mode (PMD register is used: [PMDxMDOUT]). 1: VE mode (VE register is used: [VExOUTCR]). [PMDxMDOUT] /VEOUTCR register selection.
0	MDESEL0	0	R/W	Mode selection 0 0: Bus mode (PMD registers are used: [PMDxCMPU], [PMDxCMPV] and [PMDxCMPW]). 1: VE mode (VE registers are used: the selection of [VExCMPU], [VExCMPV], and [VExCMPW] registers, and [VExEMGRS] register enable setting.)

Note1: When the change is enabled, the triple-buffer disable should be set ([PMDxMBUF CR] =0).

Note2: When register change is enabled(<DCMPEN>=1), set [VExEN] register and [VExREPTIME] register of VE to "0x00000001" for use the VE register ([VExCMPU], [VExCMPV], and [VExCMPW]).

Note3: For the details of VE, refer to "Advanced Vector Engine Plus" of the reference manual.

## 4.2.4. [PMDxMDCR] (PMD control register)

Bit	Bit Symbol	After Reset	Type	Description
31:16	-	0	R	Read as "0"
15:14	WPWMMD[1:0]	00	R/W	W-phase PWM carrier wave selection (Note 1)(Note 2)(Note 3)(Note 4) 00: Saw-tooth wave (Edge PWM ) 01: Triangle wave (Center PWM ) 10: Reversed saw-tooth wave (Edge PWM ) 11: Reversed triangular wave (Center PWM )
13:12	VPWMMD[1:0]	00	R/W	V-phase PWM carrier wave selection (Note 1)(Note 2)(Note 3)(Note 4) 00: Saw-tooth wave (Edge PWM ) 01: Triangle wave (Center PWM ) 10: Reversed saw-tooth wave (Edge PWM ) 11: Reversed triangular wave (Center PWM )
11:10	UPWMMD[1:0]	00	R/W	U-phase PWM carrier wave selection (Note 1)(Note 2)(Note 3)(Note 4) 00: Saw-tooth wave (Edge PWM ) 01: Triangle wave (Center PWM ) 10: Reversed saw-tooth wave (Edge PWM ) 11: Reversed triangular wave (Center PWM )
9:8	DSYNCS[1:0]	00	R/W	Update timing of the execution buffer in PWM duty comparison register (Note 6)(Note 8) 00: The timing depends on the interrupt period setting (INTPRD). (Refer to Table 3.2.) When the half period interrupt request is selected (<INTPRD>=00), the update is done at each phase PWM end and center. Otherwise, at PWM end. 01: Update at each phase PWM center. 10: Update at each phase PWM end. 11: Update at each phase PWM end and center.
7	DTCREN	0	R/W	Dead time correction enable 0: Disabled. 1: Enabled.
6	DCMEN	0	R/W	Decimation control of the execution buffer update and the synchronous trigger output When 2 period interrupt or 4 period interrupt is selected (<INTPRD>= 10 or 11), the decimation control is enabled for the update timing of the execution buffer and the synchronous trigger output. 0: Disabled. 1: Enabled. The target buffers are [PMDxCMPU]/[PMDxCMPV]/[PMDxCMPW], [PMDxTRGCMP0]/[PMDxTRGCMP1]/[PMDxTRGCMP2]/[PMDxTRGCMP3], [PMDxTRGSEL], [PMDxMDOUT], and [PMDxMDCR]<UPWMMD>/<VPWMMD>/<WPWMMD>.
5	SYNTMD	0	R/W	Port output mode setting This bit controls the port output with the combination of [PMDxMDOUT] <UOC>/<VOC>/<WOC>/<UPWM>/<VPWM>/<WPWM>, [PMDxMDPOT] <POLH>/<POLL>, and <SYNTMD> (Refer to Table 3.4).
4	DTYMD	0	R/W	Duty mode selection 0: Common for 3 phases. 1: Independent for each phase. The duty setting is selected between the independent setting ([PMDxCMPU]/[PMDxCMPV]/[PMDxCMPW]) or the common setting for 3 phases ([PMDxCMPU]).
3	PINT	0	R/W	PWM interrupt request timing selection (Note 6)(Note 7) 0: Interrupt request is generated at U-phase PWM center. 1: Interrupt request is generated at U-phase PWM end.

Bit	Bit Symbol	After Reset	Type	Description
2:1	INTPRD[1:0]	00	R/W	PWM interrupt request period selection 00: Request at every PWM half period (Note 5) 01: Request at every PWM 1 period 10: Request at every PWM 2 periods 11: Request at every PWM 4 periods The frequency of PWM interrupt request is selected from among half PWM period, 1 PWM period, 2 PWM periods, and 4 PWM periods. Execution buffer update timing and trigger output can be decimated out according to interrupt request period selection. (refer to "3.8 Decimation of Execution Buffer Update Timing and Synchronous Trigger Output Timing".)
0	-	0	R	Read as "0"

- Note 1: The update can be done while PWM counter is operating owing to the triple-buffer structure.
- Note 2: The update timing of the execution buffer is shown in "Table 3.1 Update control of execution buffers of <UPWMMD>, <VPWMMD>, and <WPWMMD>".
- Note 3: For the update timing of the intermediate buffer, refer to "3.7 Buffer Operation".
- Note 4: When this field is read, the value of the register stage (the data set through the bus) returns.
- Note 5: It is valid when the triangular wave carrier is selected (<UPWMMD>/<VPWMMD>/<WPWMMD>= 01, 11).
- Note 6: When the saw-tooth wave carrier is selected (<UPWMMD>/<VPWMMD>/<WPWMMD>= 00, 10), the update is done at the PWM end, regardless of the setting.
- Note 7: When the interrupt period is a half period (<INTPRD>=00), the update is done at both the PWM end and center.
- Note 8: When  $[PMDxMDEN] <PWMEN> = 0$ , the asynchronous update is done regardless of the setting.

#### 4.2.5. [PMDxCARSTA] (PWM carrier status register)

Bit	Bit Symbol	After Reset	Type	Description
31:3	-	0	R	Read as "0"
2	PMMWST	0	R	W-phase PWM carrier state 0: First half W-phase PWM period 1: Second half W-phase PWM period
1	PMMVST	0	R	V-phase PWM carrier state 0: First half V-phase PWM period 1: Second half V-phase PWM period
0	PMMUST	0	R	U-phase PWM carrier state 0: First half U-phase PWM period 1: Second half U-phase PWM period

#### 4.2.6. [PMDxBCARI] (Basic carrier register)

Bit	Bit Symbol	After Reset	Type	Description
31:15	-	0	R	Read as "0"
14:0	BCARI[14:0]	0x0000	R	Read of the basic carrier Counter value resolution is 1/fsys (12.5 ns at fsys =80 MHz). The carrier value at PMD disable ([PMDxMDEN]<PWMEN>=0) is [PMDxRATE] / 2 <sup>10</sup> .

#### 4.2.7. [PMDxRATE] (PWM frequency register)

Bit	Bit Symbol	After Reset	Type	Description
31:15	-	0	R	Read as "0"
14:0	RATE[14:0]	0x0000	R/W	PWM frequency setting RATE ≥ 0x0010 PWM frequency = fsys x <RATE> value / 2 <sup>24</sup> The setting value is calculated with the following formula: (PWM frequency) / fsys x 2 <sup>24</sup>

Note 1: When a value less than "0x0010" is set, it is automatically replaced with "0x0010" (the register stores the setting value).

Note 2: The byte write (upper 8 bits ([15:8]) and lower 8 bits ([7:0]) are written separately) should not be done. When the byte write is done, the operation cannot be guaranteed.

Note 3: [PMDxRATE] register can be updated while the PWM counter is operating, because it has a double-buffer structure.

Note 4: The update timing of the execution buffer is the basic carrier end timing. When, however, [PMDxMDEN]<PWMEN>=0 or [PMDxMDPOT]<PSYNCS>=00, the update is done at any time.

Note 5: When this field is read, the value of the register stage (the data set through the bus) returns.



## 4.2.8. PWM duty comparison register

### 4.2.8.1. [PMDxCMPU] (PWM duty comparison U register)

Bit	Bit Symbol	After Reset	Type	Description
31:16	-	0	R	Read as "0"
15:0	CMPU[15:0]	0x0000	R/W	U-phase PWM duty ratio setting 0x0000 to 0x8000 Determines U-phase PWM duty ratio. U-phase PWM carrier is compared with the execution buffer value to output the PWM which has the setting duty ratio.

Note 1: For  $\langle \text{CMPU} \rangle \geq 0x8000$ , the duty ratio is 100 %.

Note 2: When the compare register value which is updated through the bus is loaded to the execution buffer, [PMDxMODESEL]-MDSEL0 should be set to "0" to be Bus mode (default).

Note 3: The byte write (upper 8 bits ([15:8]) and lower 8 bits ([7:0]) are written separately) should not be done. When the byte write is done, the operation cannot be guaranteed.

Note 4: [PMDxCMPU] register can be updated while the PWM counter is operating, because it has a triple-buffer structure.

Note 5: For the update timing of the execution buffer, refer to "Table 3.2 Update control of the execution buffers in [PMDxCMPU], [PMDxCMPV], and [PMDxCMPW]".

Note 6: For the update timing of the intermediate buffer, refer to "3.7 Buffer Operation".

Note 7: When this field is read, the value of the register stage (the data set through the bus) returns.

### 4.2.8.2. [PMDxCMPV] (PWM duty comparison V register)

Bit	Bit Symbol	After Reset	Type	Description
31:16	-	0	R	Read as "0"
15:0	CMPV[15:0]	0x0000	R/W	V-phase PWM duty ratio setting 0x0000 to 0x8000 Determines V-phase PWM duty ratio. V-phase PWM carrier is compared with the execution buffer value to output the PWM which has the setting duty ratio.

Note 1: For  $\langle \text{CMPV} \rangle \geq 0x8000$ , the duty ratio is 100 %.

Note 2: When the compare register value which is updated through the bus is loaded to the execution buffer, [PMDxMODESEL]-MDSEL0 should be set to "0" to be Bus mode (default).

Note 3: The byte write (upper 8 bits ([15:8]) and lower 8 bits ([7:0]) are written separately) should not be done. When the byte write is done, the operation cannot be guaranteed.

Note 4: [PMDxCMPV] register can be updated while the PWM counter is operating, because it has a triple-buffer structure.

Note 5: For the update timing of the execution buffer, refer to "Table 3.2 Update control of the execution buffers in [PMDxCMPU], [PMDxCMPV], and [PMDxCMPW]".

Note 6: For the update timing of the intermediate buffer, refer to "3.7 Buffer Operation".

Note 7: When this field is read, the value of the register stage (the data set through the bus) returns.

### 4.2.8.3. [PMDxCMPW] (PWM duty comparison W register)

Bit	Bit Symbol	After Reset	Type	Description
31:16	-	0	R	Read as "0"
15:0	CMPW[15:0]	0x0000	R/W	W-phase PWM duty ratio setting 0x0000 to 0x8000 Determines W-phase PWM duty ratio. W-phase PWM carrier is compared with the execution buffer value to output the PWM which has the setting duty ratio.

Note 1: For <CMPW> ≥ 0x8000, the duty ratio is 100 %.

Note 2: When the compare register value which is updated through the bus is loaded to the execution buffer, [PMDxMODESEL]<MDESEL0> should be set to "0" to be Bus mode (default).

Note 3: The byte write (upper 8 bits ([15:8]) and lower 8 bits ([7:0]) are written separately) should not be done. When the byte write is done, the operation cannot be guaranteed.

Note 4: [PMDxCMPW] register can be updated while the PWM counter is operating, because it has a triple-buffer structure.

Note 5: For the update timing of the execution buffer, refer to "Table 3.2 Update control of the execution buffers in [PMDxCMPU], [PMDxCMPV], and [PMDxCMPW]".

Note 6: For the update timing of the intermediate buffer, refer to "3.7 Buffer Operation".

Note 7: When this field is read, the value of the register stage (the data set through the bus) returns.

### 4.2.9. PWM carrier phase difference register

#### 4.2.9.1. [PMDxVPWMPH] (V-phase phase difference register)

Bit	Bit Symbol	After Reset	Type	Description
31:15	-	0	R	Read as "0"
14:0	VPWMPH[14:0]	0x0000	R/W	V-phase PWM carrier phase difference setting 0x0000 to 0x7FFF The phase difference from the basic carrier is set.

Note: The byte write (upper 8 bits ([15:8]) and lower 8 bits ([7:0]) are written separately) should not be done. When the byte write is done, the operation cannot be guaranteed.

#### 4.2.9.2. [PMDxWPWMPH] (W-phase phase difference register)

Bit	Bit Symbol	After Reset	Type	Description
31:15	-	0	R	Read as "0"
14:0	WPWMPH[14:0]	0x0000	R/W	W-phase PWM carrier phase difference setting 0x0000 to 0x7FFF The phase difference from the basic carrier is set.

Note: The byte write (upper 8 bits ([15:8]) and lower 8 bits ([7:0]) are written separately) should not be done. When the byte write is done, the operation cannot be guaranteed.

## 4.2.10. [PMDxMDPOT] (PMD output setting register)

Bit	Bit Symbol	After Reset	Type	Description
31:10	-	0	R	Read as "0"
9:8	SYNCS[1:0]	00	R/W	<p>[PMDxMDOUT] /VExOUTCR setting transfer timing selection (the trigger synchronization setting)</p> <p>00: Asynchronous.            01: INTENCx0: At A-ENCx interrupt request generation. (Note6)            10: PMDxTMR: At General purpose timer interrupt request generation. (Note6)            11: ENCXCTRGO: At A-ENCx MCMP validity generation. (Note6)</p> <p>The update timing of the conduction control register buffer is selected. (Note 2)(Note 3)(Note5)</p>
7:4	-	0	R	Read as "0"
3	POLH	0	R/W	<p>Selection of the output polarity of the upper-phase outputs (UOx, VOx, and WOx).</p> <p>0: Low active.            1: High active.</p>
2	POLL	0	R/W	<p>Selection of the output polarity of the lower-phase outputs (XOx, YOx, and ZOx).</p> <p>0: Low active            1: High active.</p>
1:0	PSYNCS[1:0]	00	R/W	<p>Selection of the update timing of the execution buffer in [PMDxMDOUT] /VExOUTCR and [PMDxMDCR]&lt;UPWMMD&gt;/&lt;VPWMMD&gt;/&lt;WPWMMD&gt;.</p> <p>00: Asynchronous with PWM.            01: Each phase PWM center            10: Each phase PWM end            11: Each phase PWM end and center</p> <p>The update timing of the conduction control register buffer is selected. (Note 2)(Note 3)(Note 4)(Note5)</p>

Note 1: This register should be set during [PMDxMDEN]<PWMEN>=0.

Note 2: The update timing of the execution buffer in [PMDxMDOUT] /VExOUTCR is determined by the combination of <PSYNCS> setting and <SYNCS> setting. (Refer to "Table 3.3 Update timing of the execution buffer in [PMDxMDOUT] /VExOUTCR".)

Note 3: When PMD disable ([PMDxMDEN]<PWMEN>=0) or EMG protection state, the update timing is an asynchronous one regardless of the setting.

Note 4: When PWM carrier is a saw-tooth wave ([PMDxMDCR]<UPWMMD>/<VPWMMD>/<WPWMMD>=00 or 10), setting except "00" is PWM end update.

Note 5: By setting <SYNCS>=0 and <PSYNCS>=0, the value of the [PMDxMDOUT] /VExOUTCR register is immediately reflected in the port output.

Note 6: The connection destination depend on the product. For details, refer to "Product Information" of the reference manual.

## 4.2.11. [PMDxMDOUT] (PMD conduction control register)

Bit	Bit Symbol	After Reset	Type	Description
31:11	-	0	R	Read as "0"
10	WPWM	0	R/W	W-phase PWM output setting 0: H/L output 1: PWM output The port output is controlled by the combination of this bit, <WOC>, <WPWM>, [PMDxMDPOT]<POLH>/<POLL>, and [PMDxMDCR] <SYNTMD>. (Refer to Table 3.4.)
9	VPWM	0	R/W	V-phase PWM output setting 0: H/L output 1: PWM output The port output is controlled by the combination of this bit, <VOC>, <VPWM>, [PMDxMDPOT]<POLH>/<POLL>, and [PMDxMDCR] <SYNTMD>. (Refer to Table 3.4.)
8	UPWM	0	R/W	U-phase PWM output setting 0: H/L output 1: PWM output The port output is controlled by the combination of this bit, <UOC>, <UPWM>, [PMDxMDPOT]<POLH>/<POLL>, and [PMDxMDCR] <SYNTMD>. (Refer to Table 3.4.)
7:6	-	0	R	Read as "0"
5:4	WOC[1:0]	00	R/W	W-phase conduction control setting The port output is controlled by the combination of this bit, <WOC>, <WPWM>, [PMDxMDPOT]<POLH>/<POLL>, and [PMDxMDCR] <SYNTMD>. (Refer to Table 3.4.) When <WOC>=00, W-phase carrier wave is reversed.
3:2	VOC[1:0]	00	R/W	V-phase conduction control setting The port output is controlled by the combination of this bit, <VOC>, <VPWM>, [PMDxMDPOT]<POLH>/<POLL>, and [PMDxMDCR] <SYNTMD>. (Refer to Table 3.4.) When <VOC>=00, V-phase carrier wave is reversed.
1:0	UOC[1:0]	00	R/W	U-phase conduction control setting The port output is controlled by the combination of this bit, <UOC>, <UPWM>, [PMDxMDPOT]<POLH>/<POLL>, and [PMDxMDCR] <SYNTMD>. (Refer to Table 3.4.) When <UOC>=00, U-phase carrier wave is reversed.

Note 1: When [PMDxMDOUT] / VExOUTCR value which is updated through the bus is loaded to the execution buffer, [PMDxMODESEL] <MDSEL0> should be set to "0" to be Bus mode (default).

Note 2: The byte write (upper 8 bits ([15:8]) and lower 8 bits ([7:0]) are written separately) should not be done. When the byte write is done, the operation cannot be guaranteed.

Note 3: The conduction control register can be updated while the PWM counter is operating, because it has a triple-buffer structure.

Note 4: For the update timing of the execution buffer, refer to "Table 3.3 Update timing of the execution buffer in [PMDxMDOUT] / VExOUTCR".

Note 5: For the update timing of the intermediate buffer, refer to "3.7 Buffer Operation".

Note 6: When this register is read, the value of the register stage (the data set through the bus) returns.

## 4.2.12. [PMDxEMGCR] (EMG control register)

Bit	Bit Symbol	After Reset	Type	Description
31:16	-	0	R	Read as "0"
15:13	-	000	R/W	Write as "000"
12:8	EMGCNT[4:0]	00000	R/W	EMG input detection time (Note1) 00000 to 11111 (When "00000" is set, the noise filter is bypassed.) The noise reduction time is set for detected abnormal input signal. The noise reduction time is calculated with the following formula: <EMGCNT> × 16/fsys
7	EMGIPOL	0	R/W	EMGx pin polarity selection (Note1) 0: Low active. 1: High active
6	-	0	R	Read as "0"
5	INHEN	1	R/W	PMD enable or disable in Debug halt 0: Disabled. 1: Enabled (Initial state). When debug halt signal is input, this bit selects either to stop PMD, or not.
4:3	EMGMD[1:0]	11	R/W	EMG protection mode selection (Note2) 00: All phase High-impedance 01: All upper-phase ON/All lower-phase High-impedance 10: All upper-phase High-impedance/All lower-phase ON 11: All phase High-impedance Note: ON: PWM output continues. This field sets the port outputs of the upper phases (UOx, VOx, and WOx) and the lower phases (XOx, YOx, and ZOx).
2	EMGISEL	0	R/W	EMGx pin input disable 0: Port input is enabled. 1: Port input is disabled. EMGx pin input signal is disabled to input the protection control circuit.
1	EMGRS	0	W	Return from EMG protection state 0: Don't care 1: Return from the protection state [PMDxMDOUT]/VExOUTCR register should be set to "0x000". Then, [PMDxEMGSTA]<EMGI> becomes "1". If <EMGRS> is set to "1", the device exits EMG protection state. Read as "0".
0	EMGEN	1	R/W	EMG protection control circuit enable or disable setting 0: Disabled. 1: Enabled (Initial state) When EMG protection control circuit is disabled, EMG release register [PMDxEMGREL] should be set to "0x5A" and "0xA5" in order, then <EMGEN> should be set to "0". (3 instructions should be executed continuously.)

Note 1: If <EMGCNT> and <EMGIPOL> is changed while EMG protection control circuit is enabled, it may become the protection state. Therefore, when these are changed, please return from the EMG protected state by the following procedure.

- (1) [PMDxEMGSTA]<EMGI> should be read to confirm its value is "1".
- (2) [PMDxMDOUT]/VExOUTCR <UPWM>, <VPWM>, <WPWM>, <UOC>, <VOC>, and <WOC> should be set to "0" to set all port outputs to inactive state.
- (3) [PMDxEMGCR]/VExEMGRS <EMGRS> should be set to "1" to exit EMG protection.

Note 2: <EMGMD> protection mode setting is prioritized when OVV and EMG occur at the same time.

### 4.2.13. [PMDxEMGSTA] (EMG status register)

Bit	Bit Symbol	After Reset	Type	Description
31:2	-	0	R	Read as "0"
1	EMGI	Undefined.	R	EMG input state 0: Active input. 1: Inactive input. When an active signal among the enabled EMG input signals is input, this bit is set to "0".
0	EMGST	0	R	EMG protection state 0: Normal operation 1: Protection state EMG protection status can be checked by reading this bit.

### 4.2.14. [PMDxEMGREL] (EMG release register)

Bit	Bit Symbol	After Reset	Type	Description
31:8	-	0	R	Read as "0"
7:0	EMGREL[7:0]	0x00	W	EMG/OVV disable code The setting of "0x5A" and "0xA5" in order disables EMG function or OVV function. After the disable code is written, [PMDxEMGCR]<EMGEN>=0 or [PMDxOVVCR]<OVVEN>=0 should be set continuously.

Note: The disable code should be written for EMG function and OVV function separately.

## 4.2.15. [PMDxOVVCR] (OVV control register)

Bit	Bit Symbol	After Reset	Type	Description
31:16	-	0	R	Read as "0"
15	OVVRSMD	0	R/W	OVV exit operation selection 0: Automatic return from the protection state or return by the setting of <OVVRS>=1. The automatic return timing is synchronous with U-phase PWM carrier after OVV input becomes inactive. 1: Return from the protection state by the setting of <OVVRS>=1.
14:13	-	0	R	Read as "0"
12:8	OVVCNT[4:0]	00000	R/W	OVV input detection time 00001 to 11111 (When "00000" is set, the stored data becomes "00001".) The noise reduction time for OVV input is set. The noise reduction time is calculated with the following formula: $\text{<OVVCNT>} \times 16/\text{fsys}$ Please set with OVV disabled state (<OVVEN>=0).
7	OVVIPOL	0	R/W	OVVx pin polarity selection 0: Low active. 1: High active.
6	ADIN1EN	0	R/W	ADC monitor function 1 input enable (Note 1) 0: Input disabled. 1: Input enabled. Signal input from ADC monitor function 1 is selected to be enabled or disabled. The comparison result of ADC monitor function 1 can be used as OVV input (when OVV protection is enabled).
5	ADIN0EN	0	R/W	ADC monitor function 0 input enable (Note 1) 0: Input disabled. 1: Input enabled. Signal input from ADC monitor function 0 is selected to be enabled or disabled. The comparison result of ADC monitor function 0 can be used as OVV input (when OVV protection is enabled).
4:3	OVVMD[1:0]	00	R/W	OVV protection mode selection (Note 2) 00: No output restrictions. 01: All upper-phase ON/All lower-phase OFF 10: All upper-phase OFF/All lower-phase ON 11: All phase OFF This field sets the upper-phase (UOx, VOx, and WOx) and the lower-phase (XOx, VOx, and ZOx) outputs to ON or OFF when OVV occurs. ON means the fixed active output, and OFF, the fixed inactive output. Active or Inactive is set to [PMDxMDPOT]<POLL> and <POLH>.
2	OVVISEL	0	R/W	OVVx input selection 0: Port input enabled. 1: Port input disabled. OVV signal input to the protection control circuit is disabled to input from the port.
1	OVVRS	0	W	Return from OVV protection state 0: Don't care 1: Return from the protection state Read as "0". The return should be done after confirming that [PMDxOVVSTA]<OVVI> becomes "1".

Bit	Bit Symbol	After Reset	Type	Description
0	OVVEN	0	R/W	OVV protection control circuit enable or disable 0: Disabled. 1: Enabled. When OVV protection control circuit is disabled, EMG release register <b>[PMDxEMGREL]</b> should be set to "0x5A" and "0xA5" in order, then <OVVEN> should be set to "0". (3 instructions should be executed continuously.)

Note 1: For the details of ADC monitor function, refer to "AD Monitor Function" in "12-bit Analog to Digital Converter" of the reference manual.

Note 2: **[PMDxEMGCR]**<EMGMD> protection mode setting is prioritized when OVV and EMG occur at the same time.

#### 4.2.16. **[PMDxOVVSTA]** (OVV status register)

Bit	Bit Symbol	After Reset	Type	Description
31:2	-	0	R	Read as "0"
1	OVVI	Undefined.	R	OVV input state 0: Active input. 1: Inactive input. When an active signal among the enabled OVV input signals is input, this bit is set to "0".
0	OVVST	0	R	OVV protection state 0: Normal operation 1: Protection state OVV protection status can be checked by reading this bit.

#### 4.2.17. **[PMDxDTR]** (Dead time register)

Bit	Bit Symbol	After Reset	Type	Description
31:10	-	0	R	Read as "0"
9:0	DTR[9:0]	0x000	R/W	Dead time is set. 0x000 to 0x3FF The dead time is calculated with the following formula: <DTR> setting value × 4/fsys

Note: This register should be set during **[PMDxMDEN]**<PWMEN>=0.



## 4.2.18. Trigger comparison register

### 4.2.18.1. [PMDxTRGCMP0] (Trigger comparison 0 register)

Bit	Bit Symbol	After Reset	Type	Description
31:15	-	0	R	Read as "0"
14:0	TRGCMP0[14:0]	0x0000	R/W	Trigger output comparison register Setting range: 0x0000 to 0x7FFF This register value is compared with the basic carrier or U-phase carrier to generate a trigger signal (TRG0).

Note 1: When the comparison register value which is updated through the bus is loaded to the execution buffer, **[PMDxMODESEL]<MSEL2>** should be set to "0" to be Bus mode (default).

Note 2: The byte write (upper 8 bits ([15:8]) and lower 8 bits ([7:0]) are written separately) should not be done. When the byte write is done, the operation cannot be guaranteed.

Note 3: The trigger comparison register can be updated while the PWM counter is operating, because it has a triple-buffer structure.

Note 4: For the update timing of the execution buffer, refer to "Table 3.5 Buffer update timing of Trigger comparison register".

Note 5: For the update timing of the intermediate buffer, refer to "3.7 Buffer Operation".

Note 6: When this field is read, the value of the register stage (the data set through the bus) returns.

### 4.2.18.2. [PMDxTRGCMP1] (Trigger comparison 1 register)

Bit	Bit Symbol	After Reset	Type	Description
31:15	-	0	R	Read as "0"
14:0	TRGCMP1[14:0]	0x0000	R/W	Trigger output comparison register Setting range: 0x0000 to 0x7FFF This register value is compared with the basic carrier or U-phase carrier to generate a trigger signal (TRG1).

Note 1: When the comparison register value which is updated through the bus is loaded to the execution buffer, **[PMDxMODESEL]<MSEL2>** should be set to "0" to be Bus mode (default).

Note 2: The byte write (upper 8 bits ([15:8]) and lower 8 bits ([7:0]) are written separately) should not be done. When the byte write is done, the operation cannot be guaranteed.

Note 3: The trigger comparison register can be updated while the PWM counter is operating, because it has a triple-buffer structure.

Note 4: For the update timing of the execution buffer, refer to "Table 3.5 Buffer update timing of Trigger comparison register".

Note 5: For the update timing of the intermediate buffer, refer to "3.7 Buffer Operation".

Note 6: When this field is read, the value of the register stage (the data set through the bus) returns.

### 4.2.18.3. [PMDxTRGCMP2] (Trigger comparison 2 register)

Bit	Bit Symbol	After Reset	Type	Description
31:15	-	0	R	Read as "0"
14:0	TRGCMP2[14:0]	0x0000	R/W	Trigger output comparison register Setting range: 0x0000 to 0x7FFF This register value is compared with the basic carrier or V-phase carrier to generate a trigger signal (TRG2).

Note 1: The byte write (upper 8 bits ([15:8]) and lower 8 bits ([7:0]) are written separately) should not be done. When the byte write is done, the operation cannot be guaranteed.

Note 2: The trigger comparison register can be updated while the PWM counter is operating, because it has a triple-buffer structure.

Note 3: For the update timing of the execution buffer, refer to "Table 3.5 Buffer update timing of Trigger comparison register".

Note 4: For the update timing of the intermediate buffer, refer to "3.7 Buffer Operation".

Note 5: When this field is read, the value of the register stage (the data set through the bus) returns.

### 4.2.18.4. [PMDxTRGCMP3] (Trigger comparison 3 register)

Bit	Bit Symbol	After Reset	Type	Description
31:15	-	0	R	Read as "0"
14:0	TRGCMP3[14:0]	0x0000	R/W	Trigger output comparison register Setting range: 0x0000 to 0x7FFF This register value is compared with the basic carrier or W-phase carrier to generate a trigger signal (TRG3).

Note 1: The byte write (upper 8 bits ([15:8]) and lower 8 bits ([7:0]) are written separately) should not be done. When the byte write is done, the operation cannot be guaranteed.

Note 2: The trigger comparison register can be updated while the PWM counter is operating, because it has a triple-buffer structure.

Note 3: For the update timing of the execution buffer, refer to "Table 3.5 Buffer update timing of Trigger comparison register".

Note 4: For the update timing of the intermediate buffer, refer to "3.7 Buffer Operation".

Note 5: When this field is read, the value of the register stage (the data set through the bus) returns.

## 4.2.19. [PMDxTRGCR] (Trigger control register)

Bit	Bit Symbol	After Reset	Type	Description
31:17	-	0	R	Read as "0"
16	CARSEL	0	R/W	Comparison carrier selection 0: Comparison with the base carrier [PMDxTRGCMP0] to [PMDxTRGCMP3] are compared with the basic carrier. 1: Comparison with each phase carrier [PMDxTRGCMP0] and [PMDxTRGCMP1] are compared with U-phase carrier. [PMDxTRGCMP2] is compared with V-phase carrier. [PMDxTRGCMP3] is compared with W-phase carrier.
15	TRG3BE	0	R/W	Asynchronous update enable of the execution buffer in [PMDxTRGCMP3] (Note1) 0: Synchronous update (Note2) 1: Asynchronous update (the update is done immediately after the data write.)
14:12	TRG3MD[2:0]	000	R/W	[PMDxTRGCMP3] mode setting This field selects the coincidence mode of the trigger output. (Note3) 000: Trigger output is disabled. 001: Trigger is output at the coincidence in the first half of the triangular carrier. 010: Trigger is output at the coincidence in the second half of the triangular carrier. 011: Trigger is output at the coincidence in the first and second halves of the triangular carrier. 100: Trigger is output at PWM end timing. 101: Trigger is output at PWM center timing. 110: Trigger is output at PWM end and center timings. 111: Trigger output is disabled.
11	TRG2BE	0	R/W	Asynchronous update enable for the execution buffer in [PMDxTRGCMP2] (Note1) 0: Synchronous update (Note2) 1: Asynchronous update (the update is done immediately after the data write.)
10:8	TRG2MD[2:0]	000	R/W	[PMDxTRGCMP2] mode setting This field selects the coincidence mode of the trigger output. (Note3) 000: Trigger output is disabled. 001: Trigger is output at the coincidence in the first half of the triangular carrier. 010: Trigger is output at the coincidence in the second half of the triangular carrier. 011: Trigger is output at the coincidence in the first and second halves of the triangular carrier. 100: Trigger is output at PWM end timing. 101: Trigger is output at PWM center timing. 110: Trigger is output at PWM end and center timings. 111: Trigger output is disabled.
7	TRG1BE	0	R/W	Asynchronous update enable for the execution buffer in [PMDxTRGCMP1] (Note1) 0: Synchronous update (Note2) 1: Asynchronous update (the update is done immediately after the data write.)

Bit	Bit Symbol	After Reset	Type	Description
6:4	TRG1MD[2:0]	000	R/W	<p><b>[PMDxTRGCMP1]</b> mode setting</p> <p>This field selects the coincidence mode of the trigger output. (Note3)</p> <p>000: Trigger output is disabled.</p> <p>001: Trigger is output at the coincidence in the first half of the triangular carrier.</p> <p>010: Trigger is output at the coincidence in the second half of the triangular carrier.</p> <p>011: Trigger is output at the coincidence in the first and second halves of the triangular carrier.</p> <p>100: Trigger is output at PWM end timing.</p> <p>101: Trigger is output at PWM center timing.</p> <p>110: Trigger is output at PWM end and center timings.</p> <p>111: Trigger output is disabled.</p>
3	TRG0BE	0	R/W	<p>Asynchronous update enable for the execution buffer in <b>[PMDxTRGCMP0]</b> (Note1)</p> <p>0: Synchronous update (Note2)</p> <p>1: Asynchronous update (the update is done immediately after the data write.)</p>
2:0	TRG0MD[2:0]	000	R/W	<p><b>[PMDxTRGCMP0]</b> mode setting</p> <p>This field selects the coincidence mode of the trigger output. (Note3)</p> <p>000: Trigger output is disabled.</p> <p>001: Trigger is output at the coincidence in the first half of the triangular carrier.</p> <p>010: Trigger is output at the coincidence in the second half of the triangular carrier.</p> <p>011: Trigger is output at the coincidence in the first and second halves of the triangular carrier.</p> <p>100: Trigger is output at PWM end timing.</p> <p>101: Trigger is output at PWM center timing.</p> <p>110: Trigger is output at PWM end and center timings.</p> <p>111: Trigger output is disabled.</p>

Note 1: When  $[PMDxMDEN] < PWMEN > = 0$ , the asynchronous update is done regardless of the setting.

Note 2: For the update timing, refer to "Table 3.5 Buffer update timing of Trigger comparison register".

Note 3: When  $[PMDxMDCR] < UPWMMD > / < VPWMMD > / < WPWMMD > = 00, 10$  (Saw-tooth wave);

- There is no distinction between the first half and the second half, regardless of the setting value, "001", "010", or "011".
- Trigger does not occur at the PWM center. Either "100", "101", or "110" is selected, it occurs output at the PWM end.

#### 4.2.20. **[PMDxTRGSYNCR]** (Trigger update timing setting register)

Bit	Bit Symbol	After Reset	Type	Description
31:2	-	0	R	Read as "0"
1:0	TSYNCS[1:0]	00	R/W	<p>Update timing setting for the execution buffer in the trigger comparison register</p> <p>00: Each phase PWM end or center timing selected by <math>[PMDxTRGCR] &lt; TRGnMD &gt;</math> (n= 0 to 3).</p> <p>01: Each phase PWM center timing</p> <p>10: Each phase PWM end timing</p> <p>11: Each phase PWM end and center timings</p>

Note 1: For the update timing, refer to "Table 3.5 Buffer update timing of Trigger comparison register".

Note 2: When  $[PMDxMDEN] < PWMEN > = 0$ , the asynchronous update is done regardless of the setting.

### 4.2.21. [PMDxTRGMD] (Trigger output mode setting register)

Bit	Bit Symbol	After Reset	Type	Description
31:2	-	0	R	Read as "0"
1	TRGOUT	0	R/W	Trigger output mode 0: Trigger fixed output 1: Trigger selected output In the trigger fixed output mode, the triggers PMDxTRG0 to PMDxTRG3 are output at coincidence of [PMDxTRGCMP0] to [PMDxTRGCMP3]. PMDxTRG4 and PMDxTRG5 are not output. In the trigger selected output mode, the output signal of [PMDxTRGCMP0] is issued to one of PMDxTRG0 to PMDxTRG5. The trigger output is selected by the trigger output selection register. (Note)
0	EMGTGE	0	R/W	Output enable setting in EMG protection state 0: Trigger output is disabled during the protection state. 1: Trigger output is enabled during the protection state. This bit selects enable or disable of the trigger output during EMG protection state.

Note: For the trigger output pattern at the trigger selected output (<TRGOUT>=1), refer to "Table 3.6 Trigger output pattern".

### 4.2.22. [PMDxTRGSEL] (Trigger output selection register)

Bit	Bit Symbol	After Reset	Type	Description
31:3	-	0	R	Read as "0"
2:0	TRGSEL[2:0]	000	R/W	Trigger output port selection 000: Output from PMDxTRG0 001: Output from PMDxTRG1 010: Output from PMDxTRG2 011: Output from PMDxTRG3 100: Output from PMDxTRG4 101: Output from PMDxTRG5 110: Trigger is not output. 111: Trigger is not output. This field is valid at the trigger selection output enable ([PMDxTRGMD] <TRGOUT>=1), and selects the output trigger which is set by [PMDxTRGCMP0]. (Refer to Table 3.6.)

Note 1: When the comparison register value which is updated through the bus is loaded to the execution buffer, [PMDxMODESEL]<MDESEL3> should be set to "0" to be Bus mode (default).

Note 2: The trigger output register can be updated while the PWM counter is operating, because it has a triple-buffer structure.

Note 3: The update timing of the execution buffer is the same as U-phase comparison register ([PMDxCMPU]).

Note 4: For the update timing of the intermediate buffer, refer to "3.7 Buffer Operation".

Note 5: When this field is read, the value of the register stage (the data set through the bus) returns.

Note 6: When PMD disable ([PMDxMDEN]<PWMEN>=0), the update timing is an asynchronous one.

### 4.2.23. [PMDxMBUFCR] (Intermediate buffer control register)

Bit	Bit Symbol	After Reset	Type	Description
31:3	-	0	R	Read as "0"
2:0	BUFCR[2:0]	000	R/W	Intermediate buffer update control 000: Intermediate buffer is disabled (the buffer is bypassed). 001: PWM period update (U-phase PWM end timing) 010: PWM period update (U-phase PWM center timing) 011: PWM period update (U-phase PWM 3/4 timing) 100: PWM period update (U-phase PWM 1/4 timing) 101: PWM half period update (U-phase PWM end and center timings) 110: PWM half period update (U-phase PWM 1/4 and 3/4 timings) 111: Reserved

Note 1: When PMD disable ([PMDxMDEN]<PWMEN>=0) and in EMG protection state, the update timing is an asynchronous one regardless of the setting.

Note 2: When the auto change is enabled for PWM duty comparison register ([PMDxMODESEL]<DCMPEN>=1), the intermediate register should be disabled.

### 4.2.24. [PMDxSYNCCR] (Synchronization control register)

Bit	Bit Symbol	After Reset	Type	Description
31:8	-	0	R	Read as "0"
7:6	OVVSMD[1:0]	00	R/W	OVV synchronous operation setting 00 and 01: Synchronous operation is disabled. 10: Synchronous operation is enabled (Self channel OVV detection is disabled). 11: Synchronous operation is enabled (Self channel OVV detection is enabled). This field is valid when [PMDxOVVCR]<OVVEN>=1.
5:4	EMGSMD[1:0]	00	R/W	EMG synchronous operation setting 00 and 01: Synchronous operation is disabled. 10: Synchronous operation is enabled (Self channel EMG detection is disabled). 11: Synchronous operation is enabled (Self channel EMG detection is enabled). This field is valid when [PMDxEMGCR]<EMGEN>=1.
3:1	-	0	R	Read as "0"
0	PWMSMD	0	R/W	PWM synchronous operation setting 0: Synchronous operation is disabled. 1: Synchronous operation is enabled. When this bit is set to enable, [PMDxMDEN]<PWMEN> setting becomes invalid.

Note 1: When all channels are enabled for synchronization, the function cannot operate. Only the channel to be operated as a slave should be enabled for synchronization.

Note 2: For the details of the channels that can operate synchronously, refer to "Product Information" in the reference manual.

## 4.2.25. [PMDxDBGOUTCR] (Debug output control register)

Bit	Bit Symbol	After Reset	Type	Description
31	INIFF	0	R/W	PMDxDBG output initial state setting 0: "0" is output. 1: "1" is output. When <DBGEN>=0, PMDxDBG output is updated to the setting value. This setting cannot be used in ADC conversion timing monitor (<DBGMD>=00).
30:22	-	0	R	Read as "0"
21	TRG5EN	0	R/W	PMD trigger 5 monitor enable setting 0: PMDxTRG5 is disabled. 1: PMDxTRG5 is enabled. This bit is valid at <DBGMD>=01.
20	TRG4EN	0	R/W	PMD trigger 4 monitor enable setting 0: PMDxTRG4 is disabled. 1: PMDxTRG4 is enabled. This bit is valid at <DBGMD>=01.
19	TRG3EN	0	R/W	PMD trigger 3 monitor enable setting 0: PMDxTRG3 is disabled. 1: PMDxTRG3 is enabled. This bit is valid at <DBGMD>=01.
18	TRG2EN	0	R/W	PMD trigger 2 monitor enable setting 0: PMDxTRG2 is disabled. 1: PMDxTRG2 is enabled. This bit is valid at <DBGMD>=01.
17	TRG1EN	0	R/W	PMD trigger 1 monitor enable setting 0: PMDxTRG1 is disabled. 1: PMDxTRG1 is enabled. This bit is valid at <DBGMD>=01.
16	TRG0EN	0	R/W	PMD trigger 0 monitor enable setting 0: PMDxTRG0 is disabled. 1: PMDxTRG0 is enabled. This bit is valid at <DBGMD>=01.
15:13	-	0	R	Read as "0"
12	IENCEN	0	R/W	A-ENC interrupt monitor enable setting 0: INTENCx0 is disabled. 1: INTENCx0 is enabled. This bit is valid at <DBGMD>=10.
11	IVEEN	0	R/W	VE interrupt monitor enable setting 0: INTVCNx is disabled. 1: INTVCNx is enabled. This bit is valid at <DBGMD>=10.
10	IOVVEN	0	R/W	PMD interrupt monitor enable setting 0: INTOVVx is disabled. 1: INTOVVx is enabled. This bit is valid at <DBGMD>=10.
9	IEMGEN	0	R/W	PMD interrupt monitor enable setting 0: INTEMGx is disabled. 1: INTEMGx is enabled. This bit is valid at <DBGMD>=10.

Bit	Bit Symbol	After Reset	Type	Description
8	IPMDEN	0	R/W	PMD interrupt monitor enable setting 0: INTPWMx is disabled. 1: INTPWMx is enabled. This bit is valid at <DBGMD>=10.
7	IADEEN	0	R/W	ADC interrupt monitor enable setting 0: INTADxPFLG is disabled. 1: INTADxPFLG is enabled. This bit is valid at <DBGMD>=10.
6	IADDEN	0	R/W	ADC interrupt monitor enable setting 0: INTADxPDD is disabled. 1: INTADxPDD is enabled. This bit is valid at <DBGMD>=10.
5	IADCEN	0	R/W	ADC interrupt monitor enable setting 0: INTADxPDC is disabled. 1: INTADxPDC is enabled. This bit is valid at <DBGMD>=10.
4	IADBEN	0	R/W	ADC interrupt monitor enable setting 0: INTADxPDB is disabled. 1: INTADxPDB is enabled. This bit is valid at <DBGMD>=10.
3	IADAEN	0	R/W	ADC interrupt monitor enable setting 0: INTADxPDA is disabled. 1: INTADxPDA is enabled. This bit is valid at <DBGMD>=10.
2:1	DBGMD[1:0]	0	R/W	Debug mode selection 00: ADC conversion timing monitor 01: PMD trigger timing monitor 10: Interrupt generation timing monitor 11: VE task transition timing monitor
0	DBGGEN	0	R/W	Debug output enable setting 0: Debug output is disabled. 1: Debug output is enabled.



## 5. Precaution for Use

- When PMD cooperate with ADC, please refer to "12-bit Analog to Digital Converter" of the reference manual together.
- The byte write of registers is disabled regardless of whether PWM is operating or stopped.
- *[PMDxBCARI]* value has changed during PWM operation. Therefore, the byte read of *[PMDxBCARI]* should not be done. Read should be done with Word or Half-word unit.
- The following registers have the double-buffer or triple-buffer structure. The data written to these registers is transferred to the subsequent stage buffer at each update timing (depending on the setting).
  - *[PMDxCMPU]*, *[PMDxCMPV]*, *[PMDxCMPW]*
  - *[PMDxMDOUT]*
  - *[PMDxRATE]*
  - *[PMDxMDCR]*<UPWMMD>, <VPWMMD>, <WPWMMD>
  - *[PMDxTRGCMP0]* to *[PMDxTRGCMP3]*
  - *[PMDxTRGSEL]*
- Be sure to release processing from the EMG protection state before using the PMD.
- The EMG protection control circuit is enabled after reset. If it is not used, prohibit it with the following procedure.
  - (1) *[PMDxEMGREL]* should be set to "0x5A"
  - (2) *[PMDxEMGREL]* should be set to "0xA5"
  - (3) *[PMDxEMGCR]*<EMGEN> should be set to "0"

Note: These 3 instructions must be executed consecutively.

- When attempting to stop supplying the clock, make sure to check whether the PMD is stopping. Note that when the MCU enters STOP1/STOP2 mode, make sure to check whether the PMD is stopping as well.

## 6. Revision History

**Table 6.1 Revision history**

Revision	Date	Description
1.0	2017-11-01	First release
2.0	2018-05-09	<ul style="list-style-type: none"> <li>- The entire document dead-time→dead time pin name: UO,VO,WO,XO,YO,ZO→UOx,VOx,WOx,XOx,YOx,ZOx</li> <li>- Related document Arrange documents Added: Advanced Encoder Input Circuit Advanced Encoder Input Circuit (32-bit), 32-bit Timer Event Counter Modified: Vector Engen → Vector Engine</li> <li>- Terms and Abbreviations Added: A-ENC32, T32A</li> <li>- 1.Outlines Protection function in table: Deleted "EMG:Port input and..." Added in p10: "/ advanced encoder input circuit (32-bit)" "hereafter, abbreviated as" Figure 1.1 Deleted COMP</li> <li>- 2. Configuration Figure 2.1, Table 2.1: Deleted CMPA/CMPB/CMPC</li> <li>- 3.1.Clock Supply Modified register name</li> <li>- 3.2.1. PWM Carrier Generation Figure 3.1 &lt;nPWMMMD&gt;→nPWMMMD,&lt;nOC&gt;→nOC Each phase carrier generation: &lt;nOC&gt;→ &lt;UOC&gt;/&lt;VOC&gt;/&lt;WOC&gt;</li> <li>- Figure 3.5 &lt;UPWMMMD&gt;&lt;VPWMMMD&gt;&lt;WPWMMMD&gt;→ &lt;UPWMMMD&gt;&lt;VPWMMMD&gt;&lt;WPWMMMD&gt; Execution buffer</li> <li>- 3.3. Conduction Control Circuit Figure 3.7: &lt;EMGST&gt;→ <b>[PMDxEMGSTA]</b>&lt;EMGST&gt; Deleted "Timing signals of each phase" 2nd line: VExOUTCR register → VExOUTCR Table 3.3 Note2: If→When, Deleted " is set"</li> <li>- Figure 3.8, Figure 3.9 Deleted CMPA/CMPB/CMPC</li> <li>- 3.4.1.EMG Protection Control Circuit 1st term:Deleted CMPA/CMPB/CMPC and &lt;CPAEN&gt;/&lt;CPBEN&gt;/&lt;CPCEN&gt; 3rd term title: "Return of the EMG"→"Return from the EMG" EMG pin → EMGx pin 4th term: "and next, "0xA5". Then" → "and "0xA5" in order, then"</li> <li>- 3.4.2.OVV Protection Control Circuit 2nd term: INTOVV→INTOVVx 3rd term title: "Return of the OVV"→"Return from the OVV" 4th term: "and next, "0xA5". Then" → "and "0xA5" in order, then"</li> <li>- Figure 3.11 output polarity change → output polarity change circuit</li> <li>- 3.6. Synchronous Trigger Generation Circuit Figure 3.14 &lt;UOC&gt;→UOC, &lt;VOC&gt;→VOC, &lt;WOC&gt;→WOC p30 Note2: &lt;nPWMMMD&gt;→&lt;UPWMMMD&gt;/&lt;VPWMMMD&gt;/&lt;WPWMMMD&gt; Table 3.5 Note3: x→xxx Modified "In the trigger output mode setting register..."</li> <li>- 3.3.Buffer Operation Deleted in 11th line: " is set" Figure 3.16 EMGST→ <b>[PMDxEMGSTA]</b>&lt;EMGST&gt;</li> <li>- 3.8. Decimation of Execution Buffer... Modified: synchronous trigger → ADC synchronous trigger Deleted in 4th line: " is set"</li> <li>- "Inter-channel Synchronization Function" Chapter change: "4."→"3.9."</li> <li>- "Debug Output Function " Chapter change: "5."→"3.10." 2nd line: AD conversion timing →ADC conversion timing Note: timing monitor → timing monitor mode</li> <li>- 4.1. List of Registers Table of Base Address: Deleted "Function Name" cell Added TYPE3 column</li> <li>- 4.2.2. Description: Tool break→debug halt</li> <li>- 4.2.3. DCPEN/Description: &lt;nPWMMMD&gt;→ &lt;UPWMMMD&gt;/&lt;VPWMMMD&gt;/&lt;WPWMMMD&gt;</li> </ul>

Revision	Date	Description
		<p>Added Note2, Note3</p> <p>- 4.2.4. DCMEN/Description: Deleted "Note: "  <del>[PMDxCMPn] → [PMDxCMPU]/[PMDxCMPV]/[PMDxCMPW]  [PMDxTRGCMPn] →  [PMDxTRGCMP0]/[PMDxTRGCMP1]/[PMDxTRGCMP2]/[PMDxTRGCMP3]  &lt;nPWMMMD&gt; → &lt;UPWMMMD&gt;/&lt;VPWMMMD&gt;/&lt;WPWMMMD&gt;</del>  SYNTMD/Description: &lt;nOC&gt; → &lt;UOC&gt;/&lt;VOC&gt;/&lt;WOC&gt;  &lt;nPWM&gt; → &lt;UPWM&gt;/&lt;VPWM&gt;/&lt;WPWM&gt;</p> <p>DTYMD/Description: CMPU → [PMDxCMPU], CMPV → [PMDxCMPV],  CMPW → [PMDxCMPW]</p> <p>INTPRD/Description 7th line: 2 → 2 PWM periods  Corrected from 8th line</p> <p>Note5, Note6: &lt;nPWMMMD&gt; → &lt;UPWMMMD&gt;/&lt;VPWMMMD&gt;/&lt;WPWMMMD&gt;  Deleted "(n=U,V,W)"</p> <p>Note8: Deleted " is set"</p> <p>- 4.2.6. After Reset: 0 → 0x0000  Description: 12.5 ns at fsys =80 MHz → 1/fsys (12.5 ns at fsys =80 MHz)</p> <p>- 4.2.8.1. Description: set → setting</p> <p>- 4.2.8.2. Description: the V-phase → V-phase</p> <p>- 4.2.8.3. Description: the W-phase → W-phase</p> <p>- 4.2.10. SYNCS/Description: A-ENC → A-ENCx  Note7 → Note6, Note6 → Note5</p> <p>PSYNCS/Description: Deleted "(Note6)"</p> <p>- 4.2.11. WOC, VOC, UOC/Description: Deleted "Note: "</p> <p>- 4.2.12. Bit15 to 13: Changed "-"(Reserverd)  EMGCNT/Description: Changed hexadecimal notation to binary notation  EMGIPOL/Description: Deleted "Please set with EMG disabled state.... "  INHEN/Description: PMD stop signal is input from the tool  → debug halt signal is input  EMGISEL/Description: protection circuit → protection control circuit</p> <p>- 4.2.15. OVVCNT/Description:  Changed hexadecimal notation to binary notation  ADIN1EN/Description: disable → disabled  OVVISEL/Description: protection circuit → protection control circuit  Note1: Added "of the reference manual"</p> <p>- 4.2.19. Note1, Note3: Deleted " is set"</p> <p>- 4.2.20. Note1: Added " For the update timing,"  Note2: Deleted " is set"</p> <p>- 4.2.22. Description: "Table 3.6 Trigger...." → Table 3.6</p> <p>- 4.2.25. INIFF/Description: Deleted " is set"</p> <p>- 5. Precaution for Use Last term: STOP → STOP1/STOP2</p>

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