



SECTION 10

CONFIGURABLE TIMER MODULE 4

This section is an overview of CTM4 function. Refer to the [CTM Reference Manual](#) (CTMRM/AD) for a comprehensive discussion of CTM capabilities.

10.1 General

The configurable timer module 4 (CTM4) consists of several submodules which are located on either side of the CTM4 internal submodule bus (SMB). All data and control signals within the CTM4 are passed over this bus. The SMB is connected to the outside world via the bus interface unit submodule (BIUSM), which is connected to the intermodule bus (IMB), and subsequently the CPU32. This configuration allows the CPU32 to access the data and control registers in each CTM4 submodule on the SMB. Three time base buses (TBB1, TBB2 and TBB4), each 16-bits wide, are used to transfer timing information from counters to action submodules. [Figure 10-1](#) shows a block diagram of the CTM4.

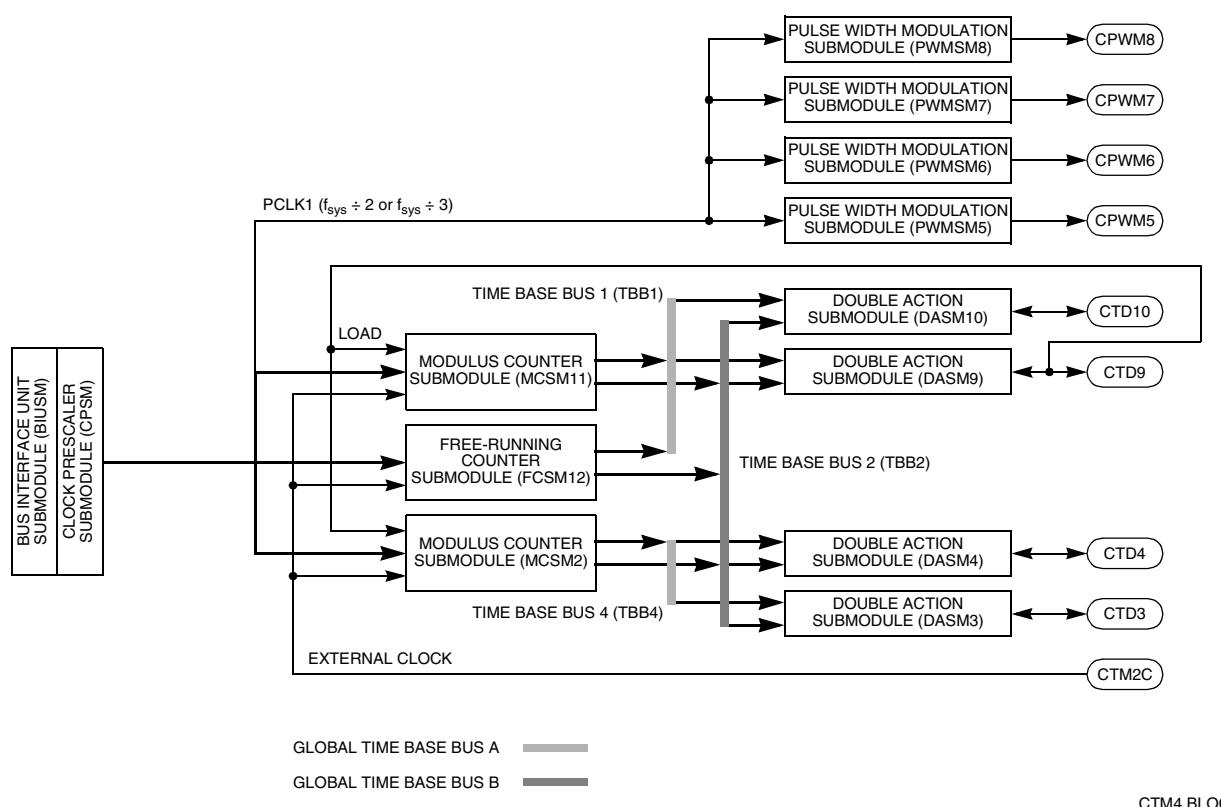


Figure 10-1 CTM4 Block Diagram

The time base buses originate in a counter submodule and are used by the action submodules. Two time base buses are accessible to each submodule.



The bus interface unit submodule (BIUSM) allows all the CTM4 submodules to pass data to and from the IMB via the submodule bus (SMB).

The counter prescaler submodule (CPSM) generates six different clock frequencies which can be used by any counter submodule. This submodule is contained within the BIUSM.

The free-running counter submodule (FCSM) has a 16-bit up counter with an associated clock source selector, selectable time-base bus drivers, writable control registers, readable status bits, and interrupt logic. The CTM4 has one FCSM.

The modulus counter submodule (MCSM) is an enhanced FCSM. A modulus register gives the additional flexibility of recycling the counter at a count other than 64K clock cycles. The CTM4 has two MCSMs.

The double-action submodule (DASM) provides two 16-bit input capture or two 16-bit output compare functions that can occur automatically without software intervention. The CTM4 has four DASMs.

The pulse width modulation submodule (PWMSM) can generate pulse width modulated signals over a wide range of frequencies, independently of other CTM output signals. PWMSMs are not affected by time base bus activity. The CTM4 has four PWMSMs.

10.2 Address Map

The CTM4 address map occupies 256 bytes from address \$YFF400 to \$YFF4FF. All CTM4 registers are accessible only when the CPU32 is in supervisor mode. All reserved addresses return zero when read, and writes have no effect. Refer to [D.7 Configurable Timer Module 4](#) for information concerning CTM4 address map and register bit/field descriptions.

10.3 Time Base Bus System

The CTM4 time base bus system is composed of three 16-bit buses: TBB1, TBB2, and TBB4. These buses are used to transfer timing information from the counter submodules to the action submodules. Two time base buses are available to each submodule. A counter submodule can drive one of the two time base buses to which it is connected. Each action submodule can choose one of the two time base buses to which it is connected as its time base. Control bits within each CTM4 submodule select connection to the appropriate time base bus.

The time base buses are precharge/discharge type buses with wired-OR capability. Therefore, no hardware damage occurs when more than one counter drives the same bus at the same time.

In the CTM4, TBB2 is global and accessible to every submodule. TBB1 and TBB4 are split to form two local time base buses. [Table 10-1](#) shows which time base buses are available to each CTM4 submodule.



Table 10-1 CTM4 Time Base Bus Allocation

Submodule	Global/Local Time Base Bus Allocation		Submodule	Global/Local Time Base Bus Allocation	
	Global Bus A	Global Bus B		Global Bus A	Global Bus B
DASM9	TBB1	TBB2	MCSM 2	TBB4	TBB2
DASM10	TBB1	TBB2	DASM 3	TBB4	TBB2
MCSM 11	TBB1	TBB2	DASM 4	TBB4	TBB2
FCSM 12	TBB1	TBB2			

Each PWMSM has an independent 16-bit counter and 8-bit prescaler clocked by the PCLK1 signal, which is generated by the CPSM. The PWMSMs are not connected to any of the time base buses. Refer to [10.9 Pulse-Width Modulation Submodule \(PWMSM\)](#) for more information.

10.4 Bus Interface Unit Submodule (BIUSM)

The BIUSM connects the SMB to the IMB and allows the CTM4 submodules to communicate with the CPU32. The BIUSM also communicates CTM4 submodule interrupt requests to the IMB, and transfers the interrupt level, arbitration number and vector number to the CPU32 during the interrupt acknowledge cycle.

10.4.1 STOP Effect On the BIUSM

When the CPU32 STOP instruction is executed, only the CPU32 is stopped; the CTM4 continues to operate as normal.

10.4.2 Freeze Effect On the BIUSM

CTM4 response to assertion of the IMB FREEZE signal is controlled by the FRZ bit in the BIUSM configuration register (BIUMCR). Since the BIUSM propagates FREEZE to the CTM4 submodules via the SMB, the setting of FRZ affects all CTM4 submodules.

If the IMB FREEZE signal is asserted and FRZ = 1, all CTM4 submodules freeze. The following conditions apply when the CTM4 is frozen:

- All submodule registers can still be accessed.
- The CPSM, FCSM, MCSM, and PWMSM counters stop counting.
- The IN status bit still reflects the state of the FCSM external clock input pin.
- The IN2 status bit still reflects the state of the MCSM external clock input pin, and the IN1 status bit still reflects the state of the MCSM modulus load input pin.
- DASM capture and compare functions are disabled.
- The DASM IN status bit still reflects the state of its associated pin in the DIS, IPWM, IPM, and IC modes. In the OCB, OCAB, and OPWM modes, IN reflects the state of the DASM output flip flop.

- When configured for OCB, OCAB, or OPWM modes, the state of the DASM output flip-flop will remain unchanged.
- The state of the PWMSM output flip-flop will remain unchanged.



If the IMB FREEZE signal is asserted and FRZ = 0, the freeze condition is ignored, and all CTM4 submodules will continue to operate normally.

10.4.3 LPSTOP Effect on the BIUSM

When the CPU32 LPSTOP instruction is executed, the system clock is stopped. All dependent modules, including the CTM4, are shut down until low-power STOP mode is exited.

10.4.4 BIUSM Registers

The BIUSM contains a module configuration register, a time base register, and a test register. The BIUSM register block occupies the first four register locations in the CTM4 register space. All unused bits and reserved address locations return zero when read. Writes to unused bits and reserved address locations have no effect. Refer to [D.7.1 BIU Module Configuration Register](#), [D.7.2 BIUSM Test Configuration Register](#), and [D.7.3 BIUSM Time Base Register](#) for information concerning BIUSM register and bit descriptions.

10.5 Counter Prescaler Submodule (CPSM)

The counter prescaler submodule (CPSM) is a programmable divider system that provides the CTM4 counters with a choice of six clock signals (PCLK[1:6]) derived from the main MCU system clock. Five of these frequencies are derived from a fixed divider chain. The divide ratio of the last clock frequency is software selectable from a choice of four divide ratios.

The CPSM is part of the BIUSM. [Figure 10-2](#) shows a block diagram of the CPSM.

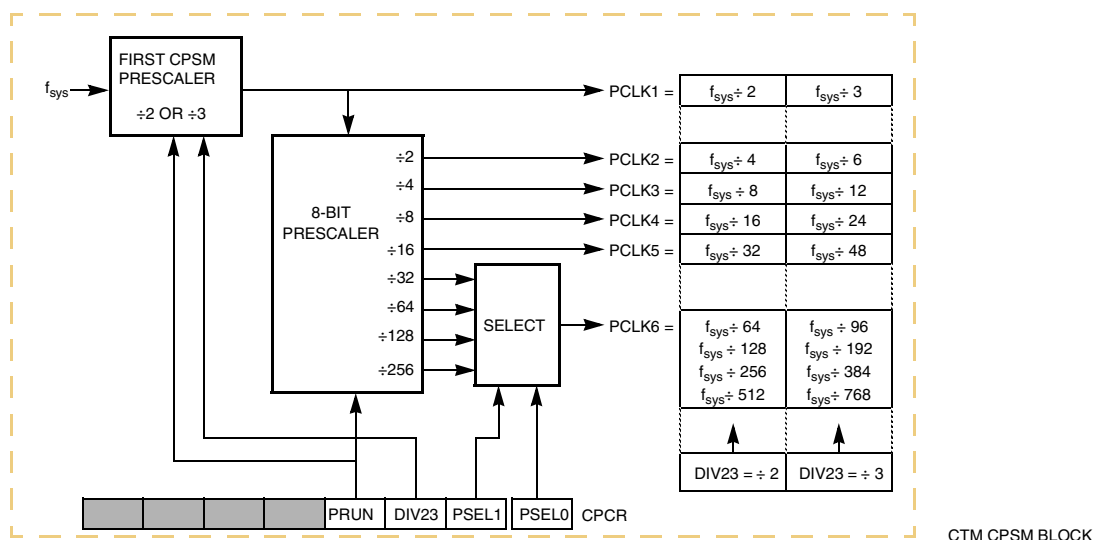


Figure 10-2 CPSM Block Diagram

10.5.1 CPSM Registers

The CPSM contains a control register (CPCR) and a test register (CPTR). All unused bits and reserved address locations return zero when read. Writes to unused bits and reserved address locations have no effect. Refer to [D.7.4 CPSM Control Register](#) and [D.7.5 CPSM Test Register](#) for information concerning CPSM register and bit descriptions.

10.6 Free-Running Counter Submodule (FCSM)

The free-running counter submodule (FCSM) has a 16-bit up counter with an associated clock source selector, selectable time-base bus drivers, control registers, status bits, and interrupt logic. When the 16-bit up counter overflows from \$FFFF to \$0000, an optional overflow interrupt request can be generated. The current state of the 16-bit counter is the primary output of the counter submodules. The user can select which, if any, time base bus is to be driven by the 16-bit counter. A software control register selects whether the clock input to the counter is one of the taps from the prescaler or an input pin. The polarity of the external input pin is also programmable.

In order to count, the FCSM requires the CPSM clock signals to be present. After reset, the FCSM does not count until the prescaler in the CPSM starts running (when the software sets the PRUN bit). This allows all counters in the CTM4 submodules to be synchronized.

The CTM4 has one FCSM. [Figure 10-3](#) shows a block diagram of the FCSM.

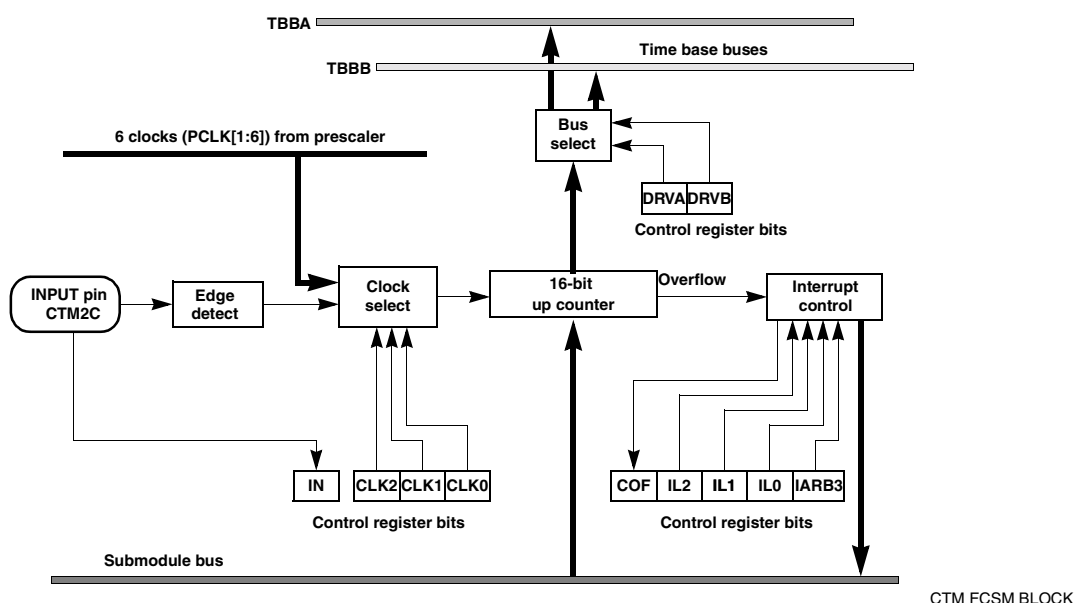


Figure 10-3 FCSM Block Diagram

10.6.1 FCSM Counter

The FCSM counter consists of a 16-bit register and a 16-bit up-counter. Reading the register transfers the contents of the counter to the data bus, while a write to the register loads the counter with a new value. Overflow of the counter is defined to be the transition from \$FFFF to \$0000. An overflow condition sets the counter overflow flag (COF) in the FCSM status/interrupt/control register (FCSMSIC).

NOTE

Reset presets the counter register to \$0000. Writing \$0000 to the counter register while the counter's value is \$FFFF does not set the COF flag and does not generate an interrupt request.

10.6.2 FCSM Clock Sources

The FCSM has eight software selectable counter clock sources, including:

- Six CPSM prescaler outputs (PCLK[1:6])
- Rising edge on CTM2C input
- Falling edge on the CTM2C input

The clock source is selected by the CLK[2:0] bits in FCSMSIC. When the CLK[2:0] bits are being changed, internal circuitry guarantees that spurious edges occurring on the CTM2C pin do not affect the FCSM. The read-only IN bit in FCSMSIC reflects the state of CTM2C. This pin is Schmitt-triggered and is synchronized with the system clock. The maximum allowable frequency for a clock input on CTM2C is $f_{sys}/4$.

10.6.3 FCSM External Event Counting

When an external clock source is selected, the FCSM can act as an event counter simply by counting the number of events occurring on the CTM2C input pin. Alternatively, the FCSM can be programmed to generate an interrupt request when a predefined number of events have been counted. This is done by presetting the counter with the two's complement value of the desired number of events.



10.6.4 FCSM Time Base Bus Driver

The DRVA and DRV B bits in FCSMSIC select the time base bus to be driven. Which of the time base buses is driven depends on where the FCSM is physically placed in any particular CTM implementation. Refer to [Figure 10-1](#) and [Table 10-1](#) for more information.

WARNING

Two time base buses should not be driven at the same time.

10.6.5 FCSM Interrupts

The FCSM can optionally request an interrupt when its counter overflows and the COF bit in FCSMSIC is set. To enable interrupts, set the IL[2:0] field in the FCSMSIC to a non-zero value. The CTM4 compares the CPU32 IP mask value to the priority of the requested interrupt designated by IL[2:0] to determine whether it should contend for arbitration priority. During arbitration, the BIUSM provides the arbitration value specified by IARB[2:0] in BIUMCR and IARB3 in FCSMSIC. If the CTM4 wins arbitration, it responds with a vector number generated by concatenating VECT[7:6] in BIUMCR and the six low-order bits specified by the number of the submodule requesting service. Thus, for FCSM12 in CTM4, six low-order bits would be 12 in decimal, or %001100 in binary.

10.6.6 FCSM Registers

The FCSM contains a status/interrupt/control register and a counter register. All unused bits and reserved address locations return zero when read. Writes to unused bits and reserved address locations have no effect. Refer to [D.7.6 FCSM Status/Interrupt/Control Register](#) and [D.7.7 FCSM Counter Register](#) for information concerning FCSM register and bit descriptions.

10.7 Modulus Counter Submodule (MCSM)

The modulus counter submodule (MCSM) is an enhanced FCSM. The MCSM contains a 16-bit modulus latch, a 16-bit loadable up-counter, counter loading logic, a clock selector, selectable time base bus drivers, and an interrupt interface. A modulus register provides the added flexibility of recycling the counter at a count other than 64K clock cycles. The content of the modulus latch is transferred to the counter when an overflow occurs, or when a user-specified edge transition occurs on a designated modulus load input pin. In addition, a write to the modulus counter simultaneously loads both the counter and the modulus latch with the specified value. The counter then begins incrementing from this new value.

In order to count, the MCSM requires the CPSM clock signals to be present. After reset, the MCSM does not count until the prescaler in the CPSM starts running (when the software sets the PRUN bit). This allows all counters in the CTM4 submodules to be synchronized.



The CTM4 contains two MCSMs. **Figure 10-4** shows a block diagram of the MCSM.

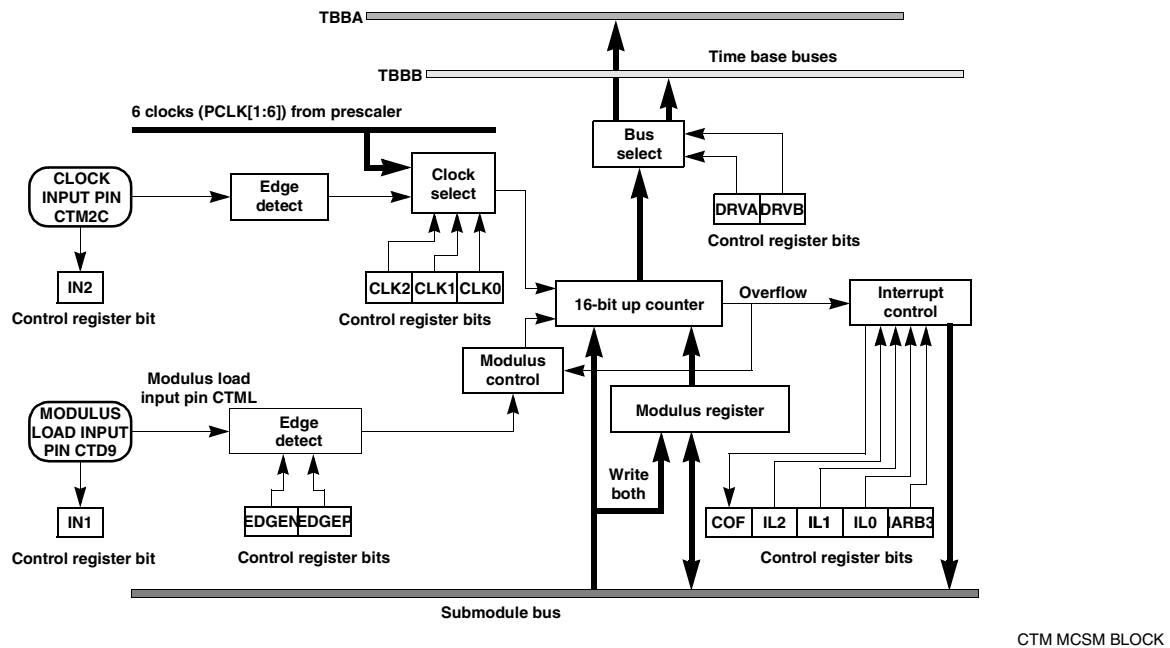


Figure 10-4 MCSM Block Diagram

10.7.1 MCSM Modulus Latch

The 16-bit modulus latch is a read/write register that is used to reload the counter automatically with a predetermined value. The contents of the modulus latch register can be read at any time. Writing to the register loads the modulus latch with the new value. This value is then transferred to the counter register when the next load condition occurs. However, writing to the corresponding counter register loads the modulus latch and the counter register immediately with the new value. The modulus latch register is cleared to \$0000 by reset.

10.7.2 MCSM Counter

The counter is composed of a 16-bit read/write register associated with a 16-bit incrementer. Reading the counter transfers the contents of the counter register to the data bus. Writing to the counter loads the modulus latch and the counter register immediately with the new value.

10.7.2.1 Loading the MCSM Counter Register

The MCSM counter is loaded either by writing to the counter register or by loading it from the modulus latch when a counter overflow occurs. Counter overflow will set the COF bit in the MCSM status/interrupt/control register (MCSMSIC).



NOTE

When the modulus latch is loaded with \$FFFF, the overflow flag is set on every counter clock pulse.

10.7.2.2 Using the MCSM as a Free-Running Counter

Although the MCSM is a modulus counter, it can operate like a free-running counter by loading the modulus register with \$0000.

10.7.3 MCSM Clock Sources

The MCSM has eight software selectable counter clock sources, including:

- Six CPSM prescaler outputs (PCLK[1:6])
- Rising edge on the CTM2C input
- Falling edge on the CTM2C input

The clock source is selected by the CLK[2:0] bits in MCSMSIC. When the CLK[2:0] bits are being changed, internal circuitry guarantees that spurious edges occurring on the CTM2C pin do not affect the MCSM. The read only IN2 bit in MCSMSIC reflects the state of CTM2C. This pin is Schmitt-triggered, and is synchronized with the system clock. The maximum allowable frequency for a clock signal input on CTM2C is $f_{\text{sys}}/4$.

10.7.4 MCSM External Event Counting

When an external clock source is selected, the MCSM can act as an event counter simply by counting the number of events occurring on the CTM2C input pin. Alternatively, the MCSM can be programmed to generate an interrupt when a predefined number of events have been counted. This is done by presetting the counter with the two's complement value of the desired number of events.

10.7.5 MCSM Time Base Bus Driver

The DRVA and DRV B bits in MCSMSIC select the time base bus to be driven. Which of the time base buses is driven depends on where the MCSM is physically placed in any particular CTM implementation. Refer to [Figure 10-1](#) and [Table 10-1](#) for more information.

WARNING

Two time base buses should not be driven at the same time.

10.7.6 MCSM Interrupts

The MCSM can optionally request an interrupt when its counter overflows and the COF bit in MCSMSIC is set. To enable interrupts, set the IL[2:0] field in the MCSMSIC to a non-zero value. The CTM4 compares the CPU32 IP mask value to the priority of

the requested interrupt designated by IL[2:0] to determine whether it should contend for arbitration priority. During arbitration, the BIUSM provides the arbitration value specified by IARB[2:0] in BIUMCR and IARB3 in MCSMSIC. If the CTM4 wins arbitration, it responds with a vector number generated by concatenating VECT[7:6] in BIUMCR and the six low-order bits specified by the number of the submodule requesting service. Thus, for MCSM12 in CTM4, six low-order bits would be 12 in decimal, or %001100 in binary.



10.7.7 MCSM Registers

The MCSM contains a status/interrupt/control register, a counter, and a modulus latch. All unused bits and reserved address locations return zero when read. Writes to unused bits and reserved address locations have no effect. The CTM4 contains three MCSMs, each with its own set of registers. Refer to [D.7.8 MCSM Status/Interrupt/Control Registers](#), [D.7.9 MCSM Counter Registers](#), and [D.7.10 MCSM Modulus Latch Registers](#) for information concerning MCSM register and bit descriptions.

10.8 Double-Action Submodule (DASM)

The double-action submodule (DASM) allows two 16-bit input capture or two 16-bit output compare functions to occur automatically without software intervention. The input edge detector can be programmed to trigger the capture function on user-specified edges. The output flip flop can be set by one of the output compare functions, and reset by the other one. Interrupt requests can optionally be generated by the input capture and the output compare functions. The user can select one of two incoming time bases for the input capture and output compare functions.

Six operating modes allow the DASM input capture and output compare functions to perform pulse width measurement, period measurement, single pulse generation, and continuous pulse width modulation, as well as standard input capture and output compare. The DASM can also function as a single I/O pin.

DASM operating mode is determined by the mode select field (MODE[3:0]) in the DASM status/interrupt/control register (DASMSIC). [Table 10-2](#) shows the different DASM operating modes.



Table 10-2 DASM Modes of Operation

MODE[3:0]	Mode	Description of Mode
0000	DIS	Disabled — Input pin is high impedance; IN gives state of input pin
0001	IPWM	Input pulse width measurement — Capture on leading edge and the trailing edge of an input pulse
0010	IPM	Input period measurement — Capture two consecutive rising/falling edges
0011	IC	Input capture — Capture when the designated edge is detected
0100	OCB	Output compare, flag set on B compare — Generate leading and trailing edges of an output pulse and set the flag
0101	OCAB	Output compare, flag set on A and B compare — Generate leading and trailing edges of an output pulse and set the flag
0110	—	Reserved
0111	—	Reserved
1xxx	OPWM	Output pulse width modulation — Generate continuous PWM output with 7, 9, 11, 12, 13, 14, 15, or 16 bits of resolution

The DASM is composed of two timing channels (A and B), an output flip-flop, an input edge detector, some control logic and an interrupt interface. All control and status bits are contained in DASMSIC.

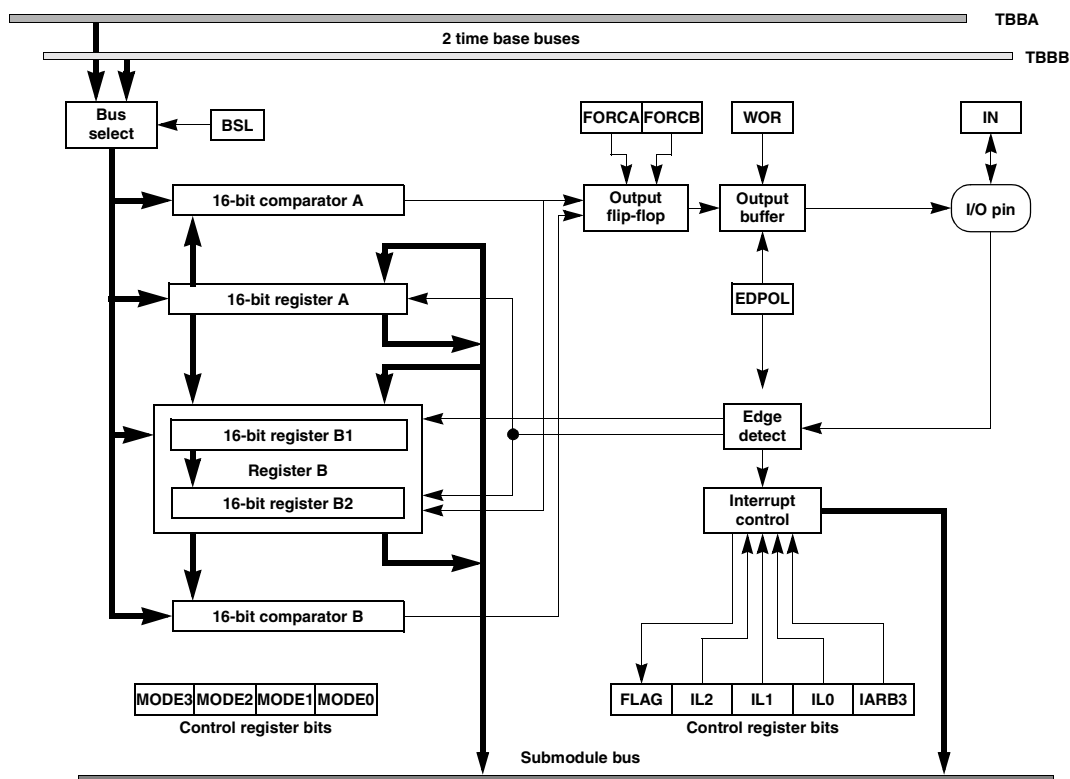
Channel A consists of one 16-bit data register and one 16-bit comparator. To the user, channel B also appears to consist of one 16-bit data register and one 16-bit comparator, though internally, channel B has two data registers (B1 and B2). DASM operating mode determines which register is software accessible. Refer to [Table 10-3](#).

Table 10-3 Channel B Data Register Access

Mode	Data Register
Input Capture (IPWM, IPM, IC)	Registers A and B2 are used to hold the captured values. In these modes, the B1 register is used as a temporary latch for channel B.
Output Compare (OCA, OCAB)	Registers A and B2 are used to define the output pulse. Register B1 is not used in these modes.
Output Pulse Width Modulation Mode (OPWM)	Registers A and B1 are used as primary registers and hidden register B2 is used as a double buffer for channel B.

Register contents are always transferred automatically at the correct time so that the minimum pulse (measured or generated) is just one time base bus count. The A and B data registers are always read/write registers, accessible via the CTM4 submodule bus.

The CTM4 has four DASMs. [Figure 10-5](#) shows a block diagram of the DASM.



CTM DASM BLOCK

Figure 10-5 DASM Block Diagram

10.8.1 DASM Interrupts

The DASM can optionally request an interrupt when the FLAG bit in DASMSIC is set. To enable interrupts, set the IL[2:0] field in DASMSIC to a non-zero value. The CTM4 compares the CPU32 IP mask value to the priority of the requested interrupt designated by IL[2:0] to determine whether it should contend for arbitration priority. During arbitration, the BIUSM provides the arbitration value specified by IARB[2:0] in BIUMCR and IARB3 in DASMSIC. If the CTM4 wins arbitration, it responds with a vector number generated by concatenating VECT[7:6] in BIUMCR and the six low-order bits specified by the number of the submodule requesting service. Thus, for DASM9 in the CTM4, the six low-order bits would be nine in decimal, or %001001 in binary.

10.8.2 DASM Registers

The DASM contains one status/interrupt/control register and two data registers (A and B). All unused bits and reserved address locations return zero when read. Writes to unused bits and reserved address locations have no effect. The CTM4 contains four DASM s, each with its own set of registers. Refer to [D.7.11 DASM Status/Interrupt/Control Registers](#), [D.7.12 DASM Data Register A](#), and [D.7.13 DASM Data Register B](#) for information concerning DASM register and bit descriptions.

10.9 Pulse-Width Modulation Submodule (PWMSM)



The PWMSM allows pulse width modulated signals to be generated over a wide range of frequencies, independently of other CTM4 output signals. The output pulse width duty cycle can vary from 0% to 100%, with 16 bits of resolution. The minimum pulse width is twice the MCU system clock period. For example, the minimum pulse width is 95.4 ns when using a 20.97 MHz clock.

The PWMSM is composed of:

- An output flip-flop with output polarity control
- Clock prescaler and selection logic
- A 16-bit up-counter
- Two registers to hold the current and next pulse width values
- Two registers to hold the current and next pulse period values
- A pulse width comparator
- A system state sequencer
- Logic to create 0% and 100% pulses
- Interrupt logic
- A status, interrupt and control register
- A submodule bus interface

The PWMSM includes its own time base counter and does not use the CTM4 time base buses; however, it does use the prescaled clock signal PCLK1 generated by the CPSM. Refer to [10.5 Counter Prescaler Submodule \(CPSM\)](#) and [Figure 10-1](#) for more information. [Figure 10-6](#) shows a block diagram of the PWMSM.

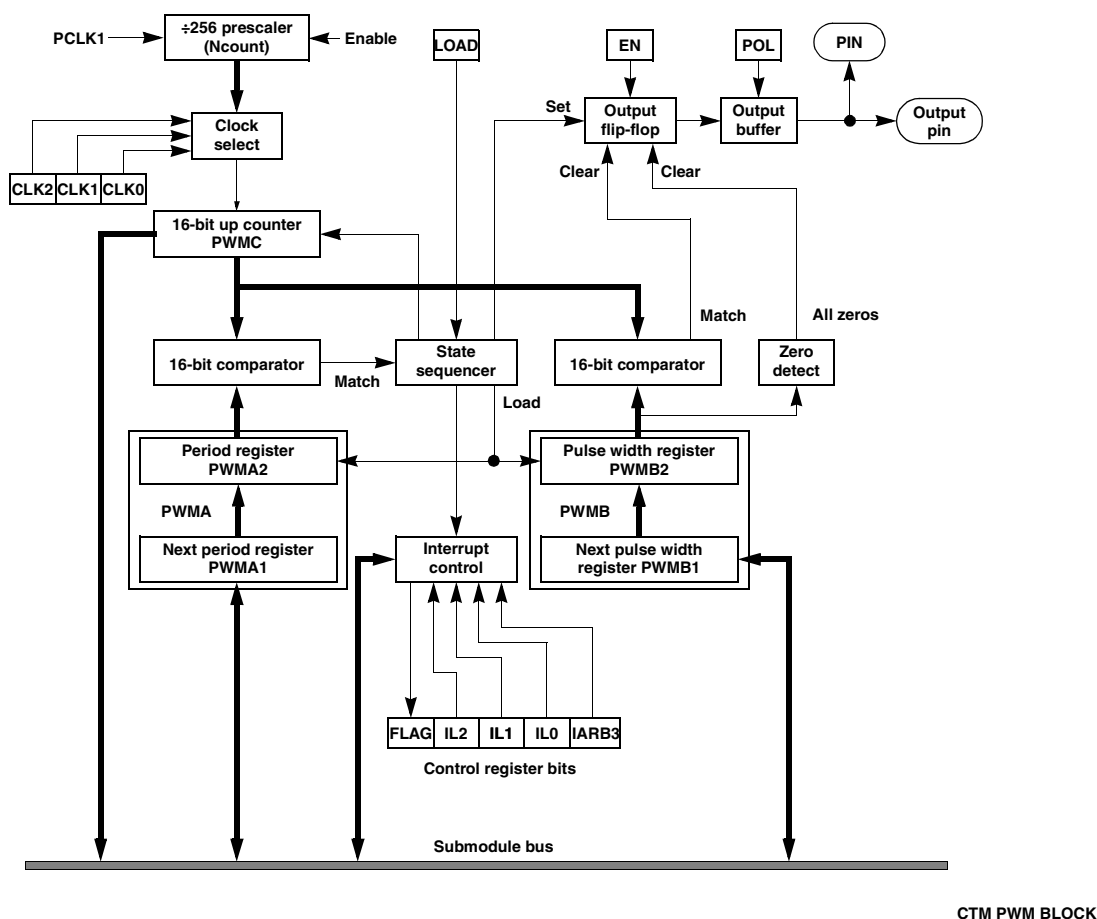


Figure 10-6 Pulse-Width Modulation Submodule Block Diagram

10.9.1 Output Flip-Flop and Pin

The output flip-flop is the basic output mechanism of the PWMSM. Except when the required duty cycle is 0% or 100%, the output flip-flop is set at the beginning of each period and is cleared at the end of the designated pulse width. The polarity of the output pulse is user programmable. The output flip-flop is connected to a buffer that drives the PWMSM's associated output pin. The PWMSM is disabled by clearing the EN bit in the PWMSM status/interrupt/control register (PWMSIC). When the PWMSM is not in use, the output pin can be used as a digital output controlled by the POL bit in PWMSIC.

10.9.2 Clock Selection

The PWMSM contains an 8-bit prescaler that is clocked by the PCLK1 signal ($f_{\text{sys}} \div 2$ or $f_{\text{sys}} \div 3$) from the CPSM. The CLK[2:0] field in PWMSIC selects which of the eight prescaler outputs drives the PWMSM counter. Refer to [Table 10-4](#) for the prescaler output.

**Table 10-4 PWMSM Divide By Options**

CLK2	CLK1	CLK0	PCLK1 = $f_{sys} \div 2$ (CPCR DIV23 = 0)	PCLK1 = $f_{sys} \div 3$ (CPCR DIV23 = 0)
0	0	0	$f_{sys} \div 2$	$f_{sys} \div 3$
0	0	1	$f_{sys} \div 4$	$f_{sys} \div 6$
0	1	0	$f_{sys} \div 8$	$f_{sys} \div 12$
0	1	1	$f_{sys} \div 16$	$f_{sys} \div 24$
1	0	0	$f_{sys} \div 32$	$f_{sys} \div 48$
1	0	1	$f_{sys} \div 64$	$f_{sys} \div 96$
1	1	0	$f_{sys} \div 128$	$f_{sys} \div 192$
1	1	1	$f_{sys} \div 512$	$f_{sys} \div 768$

10.9.3 PWMSM Counter

The 16-bit up counter in the PWMSM provides the time base for the PWM output signal. The counter is held in the \$0001 state after reset or when the PWMSM is disabled. When the PWMSM is enabled, the counter begins counting at the rate selected by CLK[2:0] in PWMSIC. Each time the counter matches the contents of the period register, the counter is preset to \$0001 and starts to count from that value. The counter can be read at any time from the PWMC register without affecting its value. Writing to the counter has no effect.

10.9.4 PWMSM Period Registers and Comparator

The period section of the PWMSM consists of two 16-bit period registers (PWMA1 and PWMA2) and one 16-bit comparator. PWMA2 holds the current PWM period value, and PWMA1 holds the next PWM period value. The next period of the output PWM signal is established by writing a value into PWMA1. PWMA2 acts as a double buffer for PWMA1, allowing the contents of PWMA1 to be changed at any time without affecting the period of the current output signal. PWMA2 is not user accessible. PWMA1 can be read or written at any time. The new value in PWMA1 is transferred to PWMA2 on the next full cycle of the PWM output or when a one is written to the LOAD bit in PWMSIC.

The comparator continuously compares the contents of PWMA2 with the value in the PWMSM counter. When a match occurs, the state sequencer sets the output flip-flop and resets the counter to \$0001.

Period values \$0000 and \$0001 are special cases. When PWMA2 contains \$0000, an output period of 65536 PWM clock periods is generated.

When PWMA2 contains \$0001, a period match occurs on every PWM clock period. The counter never increments beyond \$0001, and the output level never changes.

NOTE

Values of \$0002 in the period register (PWMA2) and \$0001 in the pulse width register (PWMB2) result in the maximum possible output frequency for a given PWM counter clock frequency.



10.9.5 PWMSM Pulse-Width Registers and Comparator

The pulse width section of the PWMSM consists of two 16-bit pulse width registers (PWMB1 and PWMB2) and one 16-bit comparator. PWMB2 holds the current PWM pulse width value, and PWMB1 holds the next PWM pulse width value. The next pulse width of the output PWM signal is established by writing a value into PWMB1. PWMB2 acts as a double buffer for PWMB1, allowing the contents of PWMB1 to be changed at any time without affecting the pulse width of the current output signal. PWMB2 is not user accessible. PWMB1 can be read or written at any time. The new value in PWMB1 is transferred to PWMB2 on the next full cycle of the output or when a one is written to the LOAD bit in PWMSIC.

The comparator continuously compares the contents of PWMB2 with the counter. When a match occurs, the output flip-flop is cleared. This pulse width match completes the pulse width, however, it does not affect the counter.

The PWM output pulse may be as short as one PWM counter clock period (PWMB2 = \$0001). It may be as long as one PWM clock period less than the PWM period. For example, a pulse width equal to 65535 PWM clock periods can be obtained by setting PWMB2 to \$FFFF and PWMA2 to \$0000.

10.9.6 PWMSM Coherency

Access to PWMSM registers can be accomplished with 16-bit transfers in most cases. The PWMSM treats a 32-bit access as two 16-bit accesses, except when the access is a write to the period and pulse width registers. A single long word write can set both PWMA1 and PWMB1 because they occupy subsequent memory addresses. If the write can be completed within the current PWM period, there is no visible effect on the output signal. New values loaded into PWMA1 and PWMB1 will be transferred into PWMA2 and PWMB2 at the start of the next period. If the write coincides with the end of the current PWM period, the transfer of values from PWMA1 and PWMB1 into PWMA2 and PWMB2 will be suppressed until the end of the next period. This prevents undesired glitches on the output signal. During the period that is output before the suppressed transfer completes, the current values in PWMA2 and PWMB2 are used.

10.9.7 PWMSM Interrupts

The FLAG bit in PWMSIC is set when a new PWM period begins and indicates that the period and pulse width registers (PWMA1 and PWMB1) may be updated with new values for the next output period. The PWMSM can optionally request an interrupt when FLAG is set. To enable interrupts, set the IL[2:0] field in PWMSIC to a non-zero value. The CTM4 compares the CPU32 IP mask value to the priority of the requested interrupt designated by IL[2:0] to determine whether it should contend for arbitration priority.

During arbitration, the BIUSM provides the arbitration value specified by IARB[2:0] in BIUMCR and IARB3 in PWMSIC. If the CTM4 wins arbitration, it responds with a vector number generated by concatenating VECT[7:6] in BIUMCR and the six low-order bits specified by the number of the submodule requesting service. Thus, for PWMSM8 in the CTM4, the six low-order bits would be eight in decimal, or %00100 in binary.



10.9.8 PWM Frequency

The relationship between the PWM output frequency (f_{PWM}) and the MCU system clock frequency (f_{sys}) is given by the following equation:

$$f_{\text{PWM}} = \frac{f_{\text{sys}}}{N_{\text{CLOCK}} \cdot N_{\text{PERIOD}}}$$

where N_{CLOCK} is the divide ratio specified by the CLK[2:0] field in PWMSIC and N_{PERIOD} is the period specified by PWMA1.

The minimum PWM output frequency achievable with a specified number of bits of resolution for a given system clock frequency is:

$$\text{Minimum } f_{\text{PWM}} = \frac{f_{\text{sys}}}{256 N_{\text{CPSM}} \cdot 2^{\text{Bits of Resolution}}}$$

where N_{CPSM} is the CPSM divide ratio of two or three.

Similarly, the maximum PWM output frequency achievable with a specified number of bits of resolution for a given system clock frequency is:

$$\text{Maximum } f_{\text{PWM}} = \frac{f_{\text{sys}}}{N_{\text{CPSM}} \cdot 2^{\text{Bits of Resolution}}}$$

Tables 10-5 and **10-6** summarize the minimum pulse widths and frequency ranges available from the PWMSM based on the CPSM system clock divide ratio and a system clock frequency of 20.97 MHz.

Table 10-5 PWM Pulse and Frequency Ranges (in Hz) Using ÷ 2 Option (20.97 MHz)

f_{sys} Divide Ratio	Minimum Pulse Width	Bits of Resolution															
		16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
÷ 2	0.095 μs	160	320	640	1280	2560	5120	10239	20479	40957	81914	164K	328K	655K	1311K	2621K	5243K
÷ 4	0.191 μs	80	160	320	640	1280	2560	5120	10239	20479	40957	81914	164K	328K	655K	1311K	2621K
÷ 8	0.381 μs	40	80	160	320	640	1280	2560	5120	10239	20479	40957	81914	164K	328K	655K	1311K
÷ 16	0.763 μs	20	40	80	160	320	640	1280	2560	5120	10239	20479	40957	81914	164K	328K	655K
÷ 32	1.53 μs	10	20	40	80	160	320	640	1280	2560	5120	10239	20479	40957	81914	164K	328K
÷ 64	3.05 μs	5	10	20	40	80	160	320	640	1280	2560	5120	10239	20479	40957	81914	164K
÷ 128	6.10 μs	2.5	5	10	20	40	80	160	320	640	1280	2560	5120	10239	20479	40957	81914
÷ 512	24.42 μs	0.6	1.3	2.5	5	10	20	40	80	160	320	640	1280	2560	5120	10239	20479



Table 10-6 PWM Pulse and Frequency Ranges (in Hz) Using ÷ 3 Option (20.97 MHz)

f _{sys} Divide Ratio	Minimum Pulse Width	Bits of Resolution															
		16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
÷ 3	0.179 μs	107	224	427	853	1707	3413	6826	13652	27305	54609	109K	218K	437K	874K	1748K	3495K
÷ 6	0.358 μs	53	107	224	427	853	1707	3413	6826	13652	27305	54609	109K	218K	437K	874K	1748K
÷ 12	0.715 μs	27	53	107	224	427	853	1707	3413	6826	13652	27305	54609	109K	218K	437K	874K
÷ 24	1.431 μs	13	27	53	107	224	427	853	1707	3413	6826	13652	27305	54609	109K	218K	437K
÷ 48	2.861 μs	7	13	27	53	107	224	427	853	1707	3413	6826	13652	27305	54609	109K	218K
÷ 96	5.722 μs	3	7	13	27	53	107	224	427	853	1707	3413	6826	13652	27305	54609	109K
÷ 192	11.44 μs	2	3	7	13	27	53	107	224	427	853	1707	3413	6826	13652	27305	54609
÷ 768	45.78 μs	0.4	0.8	2	3	7	13	27	53	107	224	427	853	1707	3413	6826	13652

10.9.9 PWM Pulse Width

The shortest output pulse width (t_{PWMIN}) that can be obtained is given by the following equation:

$$t_{PWMIN} = \frac{N_{CLOCK}}{f_{sys}}$$

The maximum output pulse width (t_{PWMAX}) that can be obtained is given by the following equation:

$$t_{PWMAX} = \frac{N_{CLOCK} \cdot (N_{PERIOD} - 1)}{f_{sys}}$$

10.9.10 PWM Period and Pulse Width Register Values

The value loaded into PWMA1 to obtain a given period is:

$$PWMA1 = \frac{f_{sys}}{N_{CLOCK} \cdot f_{PWM}}$$

The value loaded into PWMB1 to obtain a given duty cycle is:

$$PWMB1 = \frac{1}{t_{PWMIN} \cdot f_{PWM}} = \frac{\text{Duty Cycle \%}}{100} \cdot PWMA1$$

10.9.10.1 PWM Duty Cycle Boundary Cases

PWM duty cycles 0% and 100% are special boundary cases (zero pulse width and infinite pulse width) that are defined by the “always clear” and “always set” states of the output flip-flop.

A zero width pulse is generated by setting PWMB2 to \$0000. The output is a true steady state signal. An infinite width pulse is generated by setting PWMB2 equal to or greater than the period value in PWMA2. In both cases, the state of the output pin will remain unchanged at the polarity defined by the POL bit in PWMSIC.

NOTE

A duty cycle of 100% is not possible when the output period is set to 65536 PWM clock periods (which occurs when PWMB2 is set to \$0000). In this case, the maximum duty cycle is 99.998% ($100 \times 65535/65536$).

Even when the duty cycle is 0% or 100%, the PWMSM counter continues to count.



10.9.11 PWMSM Registers

The PWMSM contains a status/interrupt/control register, a period register, a pulse width register, and a counter register. All unused bits and reserved address locations return zero when read. Writes to unused bits and reserved address locations have no effect. The CTM4 contains four PWMSMs, each with its own set of registers. Refer to [D.7.14 PWM Status/Interrupt/Control Register](#), [D.7.15 PWM Period Register](#), [D.7.16 PWM Pulse Width Register](#), and [D.7.17 PWM Counter Register](#) for information concerning PWMSM register and bit descriptions.

10.10 CTM4 Interrupts

The CTM4 is able to generate as many as eleven requests for interrupt service. Each submodule capable of requesting an interrupt can do so on any of seven levels. Submodules that can request interrupt service have a 3-bit level number and a 1-bit arbitration number that is user-initialized.

The 3-bit level number selects which of seven interrupt signals on the IMB are driven by that submodule to generate an interrupt request. Of the four priority bits provided by the IMB to the CTM4 for interrupt arbitration, one of them comes from the chosen submodule, and the BIUSM provides the other three. Thus, the CTM4 can respond with two of the 15 possible arbitration numbers.

During the IMB arbitration process, the BIUSM manages the separate arbitration among the CTM4 submodules to determine which submodule should respond. The CTM4 has a fixed hardware prioritization scheme for all submodules. When two or more submodules have an interrupt request pending at the level being arbitrated on the IMB, the submodule with the lowest number (also the lowest status/interrupt/control register address) is given the highest priority to respond.

If the CTM4 wins arbitration, it responds with a vector number generated by concatenating VECT[7:6] in BIUMCR and the six low-order bits specified by the number of the submodule requesting service. [Table 10-7](#) shows the allocation of CTM4 submodule numbers and interrupt vector numbers.



Table 10-7 CTM4 Interrupt Priority and Vector/Pin Allocation

Submodule Name	Submodule Number	Submodule Base Address	Submodule Binary Vector Number
BIUSM	0	\$YFF400 ¹	None
CPSM	1	\$YFF408	None
MCSM2	2	\$YFF410	xx000010 ²
DASM3	3	\$YFF418	xx000011
DASM4	4	\$YFF420	xx000100
PWSM5	5	\$YFF428	xx000101
PWSM6	6	\$YFF430	xx000110
PWSM7	7	\$YFF438	xx000111
PWSM8	8	\$YFF440	xx001000
DASM9	9	\$YFF448	xx001001
DASM10	10	\$YFF450	xx001010
MCSM11	11	\$YFF458	xx001011
FCSM12	12	\$YFF460	xx001100

NOTES:

1. Y = M111, where M is the state of the MM bit in SIMCR (Y = \$7 or \$F).
2. "xx" represents VECT[7:6] in the BIUSM module configuration register.