

32-bit RISC Microcontroller

TXZ Family

Reference Manual

12-bit Analog to Digital Converter
(ADC-D)

Revision 1.0

2018-06

TOSHIBA ELECTRONIC DEVICES & STORAGE CORPORATION

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Preface

Related document

| Document name |
|---|
| Exception |
| Clock Control and Operation Mode |
| Product Information |
| Programmable Motor Control Circuit Plus |
| Advanced Programmable Motor Control Circuit |
| Advanced Vector Engine |
| Advanced Vector Engine Plus |

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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Terms and Abbreviations

Some of abbreviations used in this document are as follows:

| | |
|--------|---|
| ADC | Analog to Digital Converter |
| A-PMD | Advanced Programmable Motor Control Circuit |
| A-VE | Advanced Vector Engine |
| A-VE+ | Advanced Vector Engine Plus |
| PMD+ | Programmable Motor Control Circuit Plus |
| TRGSEL | Trigger Selection circuit |

1. Outlines

The 12-bit analog to digital converter (ADC) can convert multiple analog inputs (AINx00 to AINxn) to digital in each unit. The function list is shown as follows.

| Function classification | Function | Operation explanation |
|---------------------------|------------------------------------|--|
| AD conversion | Conversion resolution | 12bits |
| | Conversion time (Note1) | $4.5 \leq AVDD5 \leq 5.5$ [V] 1.0[μ s] at SCLK=120,160[MHz] 1.1[μ s] at SCLK=80[MHz] 1.5[μ s] at SCLK=40[MHz] $2.7 \leq AVDD5 < 4.5$ [V] 2.95[μ s] at SCLK=40[MHz] |
| | Store conversion result | Max 24 conversion result storage registers.(Note1) |
| Start conversion | Start-up by General Purpose Factor | Selectable start-up factor: Software start-up(Continuous conversion, Single conversion) and general purpose trigger. There is a conversion program (Note2) that can perform AD conversions up to 24 with general purpose factor. |
| | Start-up by PMD trigger | Each of the twelve PMD triggers can select and execute one of eight PMD trigger programs (Note2). Each PMD trigger program can perform up to 4 AD conversions at each conversion program. |
| Conversion status | Status flags | Flag showing that the AD conversion is executing. Flag showing that the program is executing (for each trigger). Conversion result storage flag (for each conversion result storage register). Conversion result overrun flag (for each conversion result storage register). |
| Interrupt | - | PMD trigger program completion (2 interrupts). General purpose trigger program completion. Software single conversion program completion. Software continuous conversion program completion. Monitor function interrupt (2 interrupts). |
| Monitor conversion result | AD monitor function | Each ADC unit has 2 channels of monitor function. Selectable conversion result storage register to be monitored. Selectable detection method: Whether the target register value is larger or smaller than the comparison register. Selectable number of detections. Continuous count and accumulated count can be selected. |

Note1: Corresponding contents depend on the product. For details, refer to "Product information" of the reference manual.

Note2: Conversion program can specify conversion channel (analog input) and enable / disable of interrupt. There are multiple programs. Each is started with the start-up factor / trigger.

Figure 1.1 shows the connection relationships with the peripheral functions that are linked with the ADC. The AD conversion can be executed with the PMD trigger synchronized with the motor drive timing of the Programmable Motor Control Circuit Plus or Advanced Programmable Motor Control Circuit (hereafter, abbreviated as PMD) and the general purpose timer trigger. Execution of the OVV protection in PMD and activation of general purpose timer are possible with the AD monitor function.

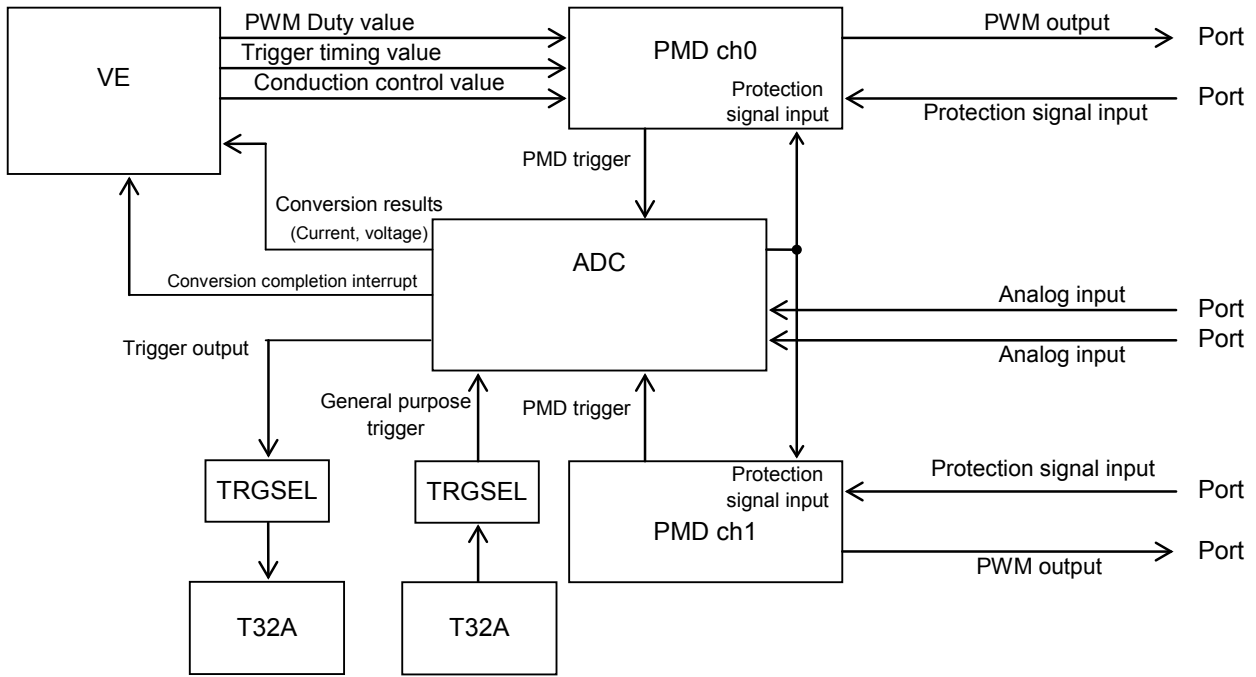


Figure 1.1 Related figure of ADC and another peripheral function

2. Block Diagram

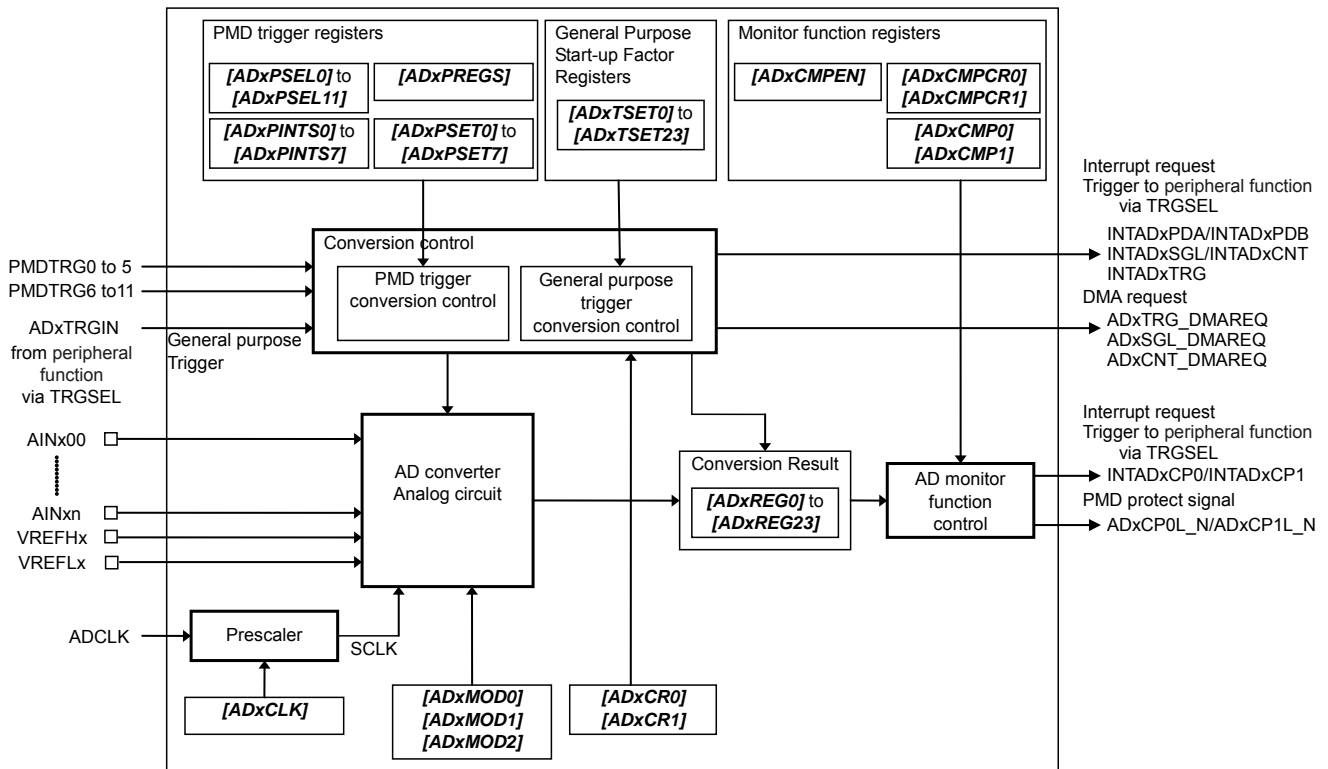


Figure 2.1 ADC Block diagram

Table 2.1 List of Signals

| No | Signal symbol | Signal name | I/O | Related Reference manual |
|----|-----------------|--|--------|----------------------------------|
| 1 | ADCLK | Conversion clock for ADC | Input | Clock Control and Operation Mode |
| 2 | AINx00 to AINxn | Analog input pin | Input | Product Information |
| 3 | VREFHx | Reference power pin for analog | Input | Product Information |
| 4 | VREFLx | Reference GND pin for analog | Input | Product Information |
| 5 | PMDTRG0 to 5 | PMDm PMD trigger 0 to 5 | Input | Product Information |
| 6 | PMDTRG6 to 11 | PMDn PMD trigger 0 to 5 | Input | Product Information |
| 7 | ADxTRGIN | General purpose trigger | Input | Product Information |
| 8 | ADxCP0L_N | Monitor function 0 output for PMD protect function | Output | Product Information |
| 9 | ADxCP1L_N | Monitor function 1 output for PMD protect function | Output | Product Information |
| 10 | INTADxPDA | PMD trigger interrupt A | Output | Exception |
| 11 | INTADxPDB | PMD trigger interrupt B | Output | Exception |
| 12 | INTADxTRG | General purpose trigger interrupt | Output | Exception, Product Information |
| 13 | INTADxSGL | Single conversion interrupt | Output | Exception, Product Information |
| 14 | INTADxCNT | Continuous conversion interrupt | Output | Exception, Product Information |
| 15 | INTADxCP0 | Monitor function 0 interrupt | Output | Exception, Product Information |
| 16 | INTADxCP1 | Monitor function 1 interrupt | Output | Exception, Product Information |
| 17 | ADxTRG_DMAREQ | General purpose trigger DMA request | Output | Product Information |
| 18 | ADxSGL_DMAREQ | Single conversion DMA request | Output | Product Information |
| 19 | ADxCNT_DMAREQ | Continuous conversion DMA request | Output | Product Information |

3. Function and Operation

The ADC is triggered to start the conversion by the software start-up (Software trigger) or the trigger signal from PMD, a timer, and others.

3.1. Clock Supply

When using ADC, 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]*). Set the AD converter conversion clock enable bit to "1" in Clock supply and stop register for ADC and TRACE (*[CGSPCLKEN]*).

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.

When attempting to stop supplying the clock, make sure to check whether the AD conversion is stopping. Note that when the MCU enters STOP mode, make sure to check whether the AD conversion is stopping as well.

3.2. Conversion Operation by General Purpose Start-up Factor

The factor of the general purpose start-up is the general purpose trigger input or the software start-up factor. The software starts-up the single conversion or the continuous conversion.

3.2.1. Operation

When the conversion is triggered by the general purpose start-up factor, the conversion executes according to the setting in the general purpose start-up factor program register which is prepared for each conversion result register.

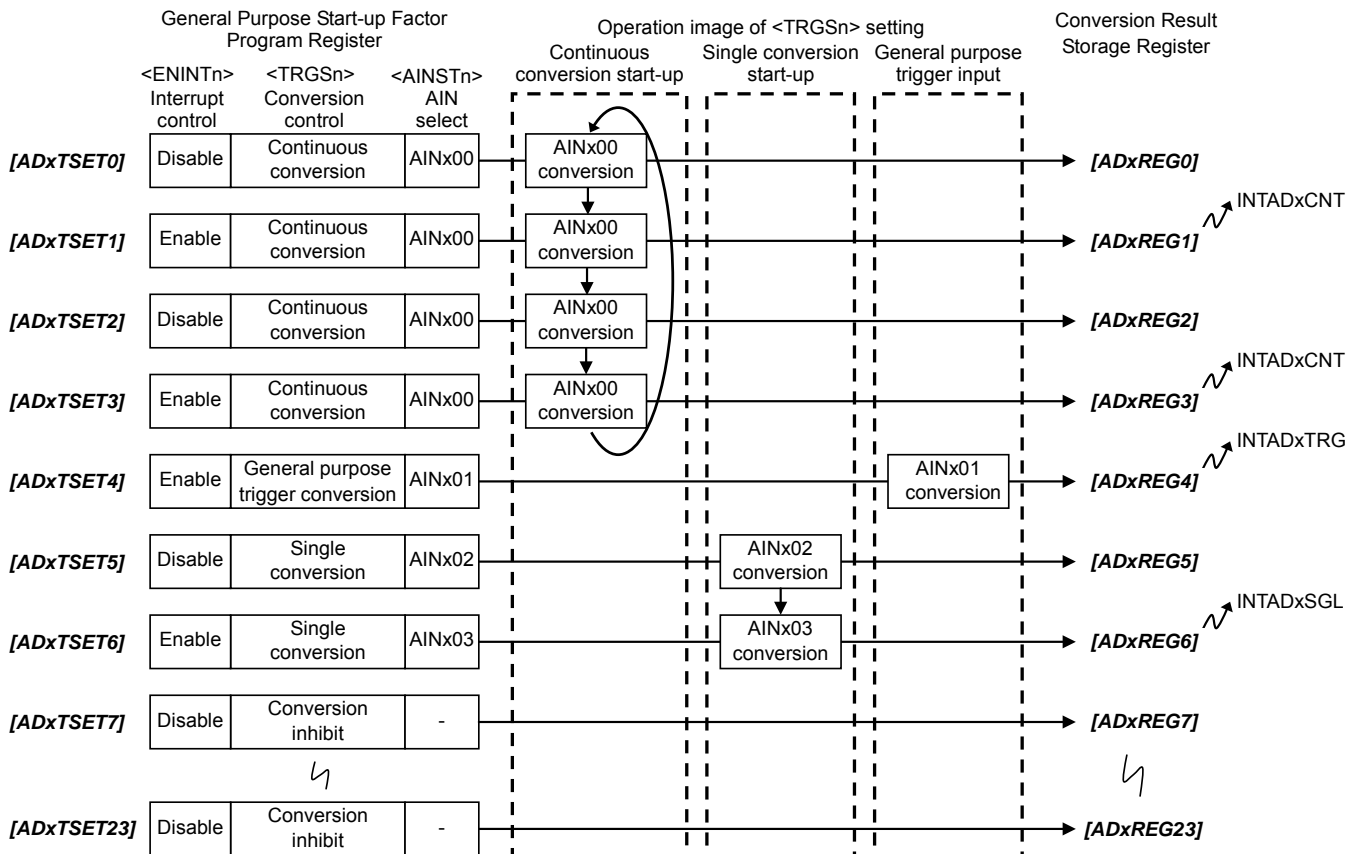


Figure 3.1 General purpose start-up factor and its corresponding operation

The general purpose start-up factor select (Conversion control)<TRGSn>, the AIN select <AINSTn>, and the interrupt enable or disable (Interrupt control)<ENINTn> are programmed to the general purpose start-up factor program register ([ADxTSETn]). When the start-up factor occurs, the specified conversions are executed from the smallest number of the register.

The continuous conversion repeats the specified conversion. The single conversion executes the specified conversion only once. The general purpose trigger conversion executes the specified conversion once when the general purpose trigger is received.

With a general purpose start-up, when the conversion of the interrupt specified by [ADxTSETn]<ENINTn> ends, Different interrupts (INTADxTRG, INTADxSGL, INTADxCNT) are generated for each start-up factor (general purpose trigger conversion, single conversion, continuous conversion).

A DMA request can be generated for each general purpose start-up factor. When a DMA request control ([ADxCRI]<CNTDMEN><SGLDMEN><TRGDMEN>) of the start-up factor that generates the interrupt is set to "1", a DMA request and an interrupt request are generated simultaneously.

Table 3.1 Start-up factor and interrupt / DMA request

| Start-up factor | Interrupt | DMA request |
|--|---|---|
| General purpose trigger conversion | General purpose trigger program completion (INTADxTRG) | General purpose trigger DMA request (ADxTRG_DMAREQ) |
| Single conversion operation (software) | Software single conversion program completion (INTADxSGL) | Single conversion DMA request (ADxSGL_DMAREQ) |
| Continuous conversion operation (software) | Software continuous conversion program completion (INTADxCNT) | Continuous conversion DMA request (ADxCNT_DMAREQ) |

3.2.2. Control Registers

- General purpose start-up factor program register (*[ADxTSET0]* to *[ADxTSET23]*)
The general purpose start-up factor program register is prepared for each conversion result storage register. The AIN select <AINSTn>, the conversion control <TRGSn>, and the interrupt control <ENINTn> are set to *[ADxTSETn]*.
- Mode setting register0(*[ADxMOD0]*)
When using the ADC, set "1" to *[ADxMOD0]*<DACON>. And the interval of 3[μs] are necessary for the stabilization.
- Control register0 (*[ADxCR0]*)
When the AD conversion can be started, after setting, *[ADxCR0]*<ADEN> should be set to "1".
The software single conversion or the software continuous conversion is enabled by setting *[ADxCR0]* <SGL> or <CNT> to "1", respectively. When the continuous conversion should be stopped, <CNT> is set to "0".
- Control register1 (*[ADxCRI]*)
[ADxCRI]<TRGEN> enables the trigger, and then the program start-up is done by the general purpose trigger. The conversion starts when a trigger is received.
[ADxCRI]<SGLDMEN><CNTDMEN><TRGDMEN> are set to "1" to enable the DMA request generation.

Note: *[ADxCRI]* register must be set while *[ADxCR0]*<ADEN>=0.

For start AD conversion by the general purpose start-up factor, please set up as below sequence.

- Single conversion
 - (1) Set interrupt to use INTADxSGL.
 - (2) Set "1" to *[ADxMOD0]*<DACON>, and set "0" to *[ADxMOD0]*<RCUT> (When using multiple units).
 - (3) Wait at least 3[μs].
 - (4) Set *[ADxTSETn]*. AIN selection <AINSTn>= arbitrary, conversion control <TRGSn>=10, interrupt control <ENINTn>=1.
 - (5) To perform the Single conversion using multiple channels, change the AIN selection and set (4) again.
 - (6) Set "1" to *[ADxCR0]*<ADEN>.
 - (7) Set "1" to *[ADxCR0]*<SGL>, starts the conversion.
 - (8) When conversion is complete, INTADxSGL will be generated. Read *[ADxREGn]* in the interrupt service routine.
 - (9) Repeat steps (7) to (8).

- Continuous conversion
 - (1) Set interrupt to use INTADxCNT.
 - (2) Set "1" to $[ADxMOD0]<DACON>$, and set "0" to $[ADxMOD0]<RCUT>$ (When using multiple units).
 - (3) Wait at least 3[μ s].
 - (4) Set $[ADxTSETn]$. AIN selection $<AINSTn>=$ arbitrary, conversion control $<TRGSn>=01$, interrupt control $<ENINTn>=1$.
 - (5) To perform the continuous conversion using multiple channels, change the AIN selection and set (4) again.
 - (6) Set "1" to $[ADxCR0]<ADEN>$.
 - (7) Set "1" to $[ADxCR0]<CNT>$, starts the conversion.
 - (8) When conversion is complete, INTADxCNT will be generated. Read $[ADxREGn]$ in the interrupt service routine.
 - (9) Repeat steps (8).

- General purpose trigger conversion
 - (1) Set interrupt to use INTADxTRG.
 - (2) Set "1" to $[ADxMOD0]<DACON>$, and set "0" to $[ADxMOD0]<RCUT>$ (When using multiple units).
 - (3) Wait at least 3[μ s].
 - (4) Set "1" to $[ADxCRI]<TRGEN>$.
 - (5) Sets which trigger to use for the general purpose trigger (ADxTRGIN). (Note)
 - (6) Set $[ADxTSETn]$. AIN selection $<AINSTn>=$ arbitrary, conversion control $<TRGSn>=11$, interrupt control $<ENINTn>=1$.
 - (7) To activate the general purpose trigger using multiple channels, change the AIN selection and set (6) again.
 - (8) Set "1" to $[ADxCR0]<ADEN>$.
 - (9) When you input a trigger, conversion starts.
 - (10) When conversion is complete, INTADxTRG will be generated. Read $[ADxREGn]$ in the interrupt service routine.
 - (11) Repeat steps (9) to (10).

Note: For details of the signal connected to the general purpose trigger (ADxTRGIN), refer to the reference manual "Product Information".

3.3. Conversion Operation by PMD Trigger

3.3.1. Operation

The conversion is started by the PMDTRGn (n=0 to 11). PMDTRGn are triggered from the PMD. (Note1)(Note2)
 The programmed conversion operation is executed by the PMDTRGn. Each PMDTRGn selects one program from among 9 programs available.
 One program can execute 4-time conversions at maximum. The conversion result is stored to the selected register group in units of 4 registers.
 Either INTADxPDA or INTADxPDB can be generated at the program completion.

Note1: For details of the PMD, refer to "Programmable Motor Control Circuit Plus" or "Advanced Programmable Motor Control Circuit" of the reference manual.

Note2: For the connections of each product, refer to "Product Information" of the reference manual.

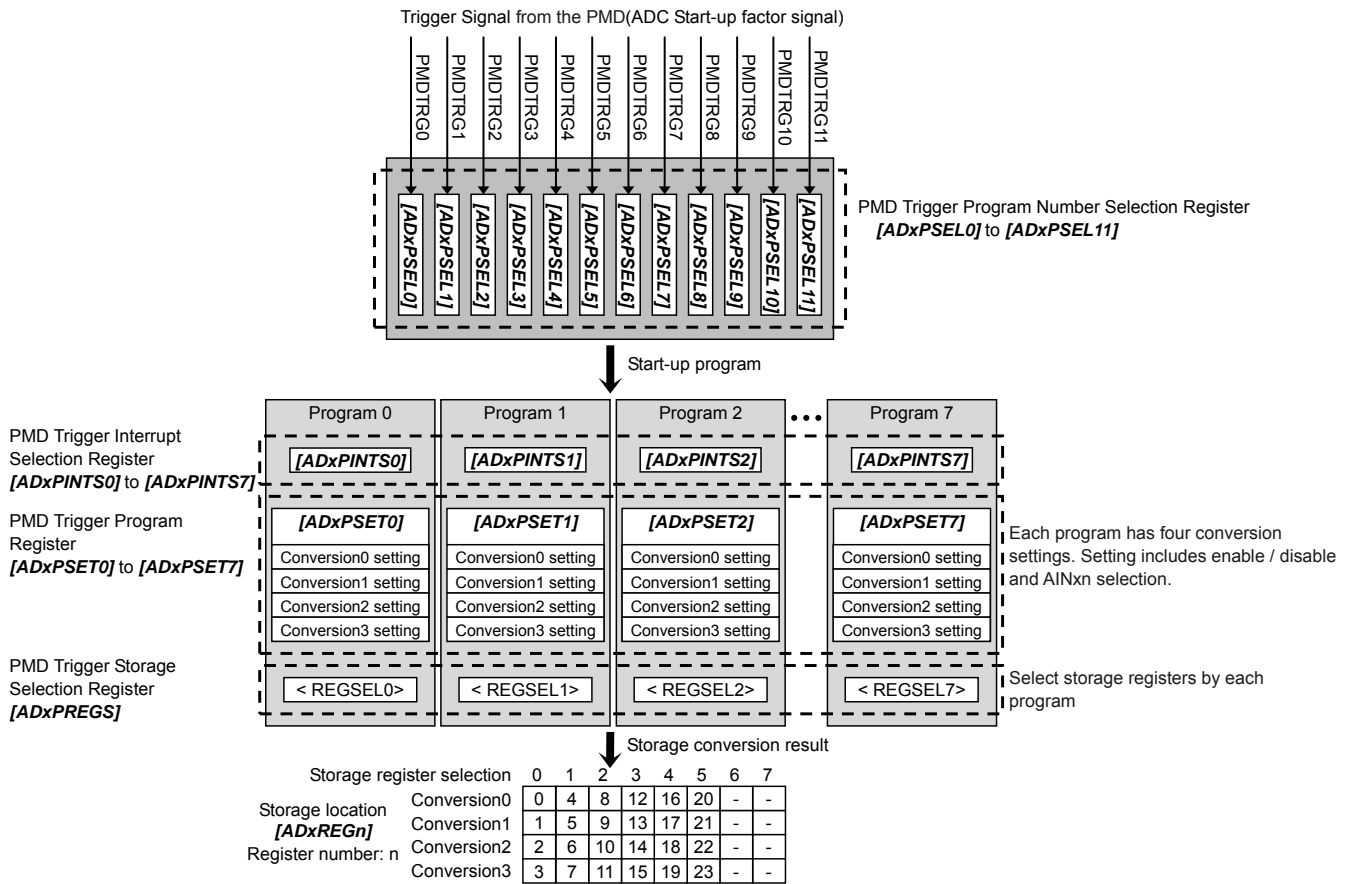


Figure 3.2 PMD start-up factor and its operation

3.3.2. Control Registers

The following registers should be set for the conversion started by the PMD trigger.

- Mode setting register0 (*[ADxMOD0]*)
When using the ADC, set "1" to *[ADxMOD0]<DACON>*. And the interval of 3[μs] are necessary for the stabilization.
- PMD trigger program number selection register (*[ADxPSEL0]* to *[ADxPSEL11]*)
Each register sets the trigger enable/disable and the number of the specified program (0 to 7) for one corresponding trigger out of 12 triggers.
12 registers (*[ADxPSEL0]* to *[ADxPSEL11]*) are prepared for the 12 PMD triggers (PMDTRG0 to PMDTRG11), respectively.
- PMD trigger program register (*[ADxPSET0]* to *[ADxPSET7]*)
These registers are setting for each program. The setting items are the enable or disable of conversion, the analog input channel to be converted, and U/V/W phase for the Advanced Vector Engine Plus (hereafter, abbreviated as VE) notification. Each program can be set to 4-time conversions at maximum.
- PMD trigger interrupt selection register (*[ADxPINTS0]* to *[ADxPINTS7]*)
An interrupt can be generated at the program completion. The PMD trigger interrupt selection register selects the interrupt enable or disable, and the interrupt INTADxPDA or INTADxPDB.
8 registers (*[ADxPINTS0]* to *[ADxPINTS7]*) are prepared for the 8 programs, respectively.
- PMD trigger storage selection register (*[ADxPREGS]*)
The storage destination of the conversion result of each program can be selected. The storage destination is selected from among the group of the conversion result storage register 0 to 3, 4 to 7, 8 to 11, 12 to 15, 16 to 19, and 20 to 23.

Note: When the VE is used, the conversion result storage register 0 to 3 should be used.

- Control register0 (*[ADxCR0]*)
When the AD conversion can be started, after setting, *[ADxCR0]<ADEN>* should be set to "1".

For start AD conversion by PMD trigger, please set up as below sequence.

- (1) Set interrupt to use INTADxPDA or INTADxPDB.
- (2) Set "1" to *[ADxMOD0]<DACON>*, and set "0" to *[ADxMOD0]<RCUT>* (When using multiple units).
- (3) Wait at least 3[μs].
- (4) Set *[ADxPSELn]*. Trigger control *<PENSn>*=1, Program Number *<PMDSn>*= arbitrary.
- (5) Set *[ADxPSETn]*. AIN selection *<AINSPm>*= arbitrary, Phase selection (for Vector Engine) *<UVWISn>* arbitrary, Conversion control *<ENSPn>*=1.
- (6) Set *[ADxPINTSn]*. Interrupt selection *<INTSELn>*=INTADxPDA or INTADxPDB.
- (7) Set *[ADxPREGS]*. Register selection *<REGSELn>*= arbitrary.
- (8) Set "1" to *[ADxCR0]<ADEN>*.
- (9) Conversion starts by the trigger(PMDTRGn) that is PMD generated.
- (10) When conversion program is complete, Interrupt(INTADxPDA or INTADxPDB) will be generated.
Read *[ADxREGn]* to *[ADxREGn+3]* in the interrupt service routine.
- (11) Repeat steps (9) to (10).

3.4. Conversion Stop

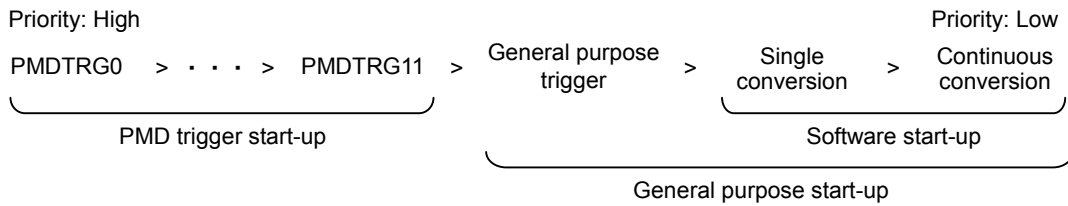
When $[ADxCR0]<ADEN>$ is set to "0", the conversion stops immediately. If the continuous conversion is enabled, $[ADxCR0]<CNT>$ should be also set to "0".

When the conversion stops completely, all bits in $[ADxST]$ become "0". The registers other than $[ADxST]$ keep their data, as well as the conversion result registers. Before the next conversion is enabled, the conversion result registers should be read to clear the corresponding flags.

When stopping ADCLK, AD conversion stop processing should be performed. Please confirm that $[ADxST]<ADBF>$ becomes "0" and stop ADCLK.

3.5. Start-up Priority

The start-up factors are prioritized as follows:



If multiple start-up factors occur at the same time, the conversion program with the highest priority start-up factor is executed and other start-up factors are suspended.

Once a PMD trigger conversion program starts to execute, it is never suspended. Even though a higher priority PMD trigger is generated, it can execute after the currently executed conversion program completes.

The situation is different for the conversion programs of the general purpose trigger, the single conversion, and continuous conversion. When a higher priority start-up factor occurs, the current conversion program execution is suspended and the conversion program of the higher priority start-up factor executes. When a lower priority start-up factor occurs, it waits for execution.

The conversion programs of suspended general purpose trigger, single conversion, continuous conversion restarts from suspended conversion when they become executable.

When the start-up factor occurs again during execution of the conversion program of the same start-up factor, the factor is ignored. The execution status of the conversion program can be checked by $[ADxST]<CNTF><SNGF><TRGF><PMDF>$. For the software start-up factors, it should be confirmed whether the corresponding flags are "0". Then, the start-up is certainly executed.

Table 3.2 Operation when the start-up factor occurs during the conversion

| | | Later start-up factor | | | |
|---|--------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| | | PMDTRGm (Note1) | General purpose trigger | Software Single conversion | Software Continuous conversion |
| Current start-up factor during conversion | PMDTRGm (Note1) | Continue current factor (Note2) | Continue current factor (Note3) | Continue current factor (Note3) | Continue current factor (Note3) |
| | General purpose trigger | Start later factor (Note5) | Continue current factor (Note4) | Continue current factor (Note3) | Continue current factor (Note3) |
| | Software Single conversion | Start later factor (Note5) | Start later factor (Note5) | Continue current factor (Note4) | Continue current factor (Note3) |
| | Software Continuous conversion | Start later factor (Note5) | Start later factor (Note5) | Start later factor (Note5) | Continue current factor (Note4) |

Note1: m,n = 0 to 11

Note2: In the case of m = n, The later start-up factor is ignored.
In the case of m < n, the later start-up factor is performed after the current start-up factor is completed.

Note3: The later start-up factor is performed after the current start-up factor is completed.

Note4: The later start-up factor is ignored.

Note5: The current start-up factor is suspended, and the later start-up factor is executed. After the later start-up factor completed, the current start-up factor is restarted.

3.6. AD Monitor Function

The AD monitor function generates an interrupt if the AD conversion result is larger than the set value or smaller. It is possible to detect whether the AD conversion result is within the range of two set values or to detect whether the AD conversion result is out of the range by using this function simultaneously in two channels.

When $[ADxCMPE\text{N}] < \text{CMP0EN} >$ or $< \text{CMP1EN} >$ is set to "1", the corresponding AD monitor function is enabled. The two monitor functions can be enabled simultaneously.

The following description is for $[ADxCMPCR0]$ (The same for $[ADxCMPCR1]$).

$[ADxCMPCR0] < \text{REGS0}[4:0] >$ sets the conversion result storage register which value should be compared. $< \text{ADBIG0} >$ sets the determination condition (larger or smaller). $< \text{CMPCND0} >$ sets the determination count condition. And $< \text{CMPCNT0}[3:0] >$ sets the determination count value.

Whenever a conversion result is stored to the target conversion result storage register, the result is compared (bigger or smaller). If the comparison result is the same as the $< \text{ADBIG0} >$ setting, the determination counter increments.

The determination count condition is either the continuous count or the accumulated count.

The continuous count condition is as follows: when the status set in $< \text{ADBIG0} >$ continues the count times set in $< \text{CMPCNT0}[3:0] >$, the AD monitor function interrupt (INTADxCP0) and the protect signal for the PMD are generated. When it continues exceeding the set-up count number, nothing occurs. If the status is different from the $< \text{ADBIG0} >$ status, the counter is cleared.

The accumulated count condition is as follows: when the count of the status set in $< \text{ADBIG0} >$ is accumulated and the accumulated value reaches the value set in $< \text{CMPCNT0}[3:0] >$, the AD monitor function interrupt (INTADxCP0) and the protect signal for the PMD are generated, and the counter is cleared. Even when the status is different from the status set in $< \text{ADBIG0} >$, the counter value is maintained. When the value in the conversion result storage register specified by the $[ADxCMPCR0]$ register is equal to the value in the conversion result comparison register, the counter does not increment and the AD monitor function interrupt and the trigger are not generated.

Table 3.3 Monitor function and interrupt

| Monitor function | Interrupt |
|---|--|
| Monitor function Setting Register0 ($[ADxCMPCR0]$) | Monitor function 0 Interrupt (INTADxCP0) |
| Monitor function Setting Register1 ($[ADxCMPCR1]$) | Monitor function 1 Interrupt (INTADxCP1) |

When the AD monitor function is used, the overrun flag $[ADxREGn] < \text{ADOVRFn} >$ and the conversion result storage flag $[ADxREGn] < \text{ADRFn} >$ are set because the storage register is not read by the software. So, when the AD monitor function is executing, the flags of the corresponding conversion result storage registers should not be used.

Note: The monitor function registers must be set while $[ADxCR0] < \text{ADEN} > = 0$.

(1) Determination by Continuous count

- Monitor function setting register ($[ADxCMPCR0] = 0x00000200$)
Conversion result storage register (Comparison target): $[ADxREG0]$
Magnitude determination: $[ADxREG0] < ADR0 > > [ADxCMP0] < AD0CMP0 >$
(Larger than the comparison register.)
Determination count condition: Continuous count
Magnitude determination count: 3 counts
- AD conversion result comparison register ($[ADxCMP0] < AD0CMP0 > = 0x888$)
- Monitor function enable register ($[ADxCMPEN] = 0x00000001$)

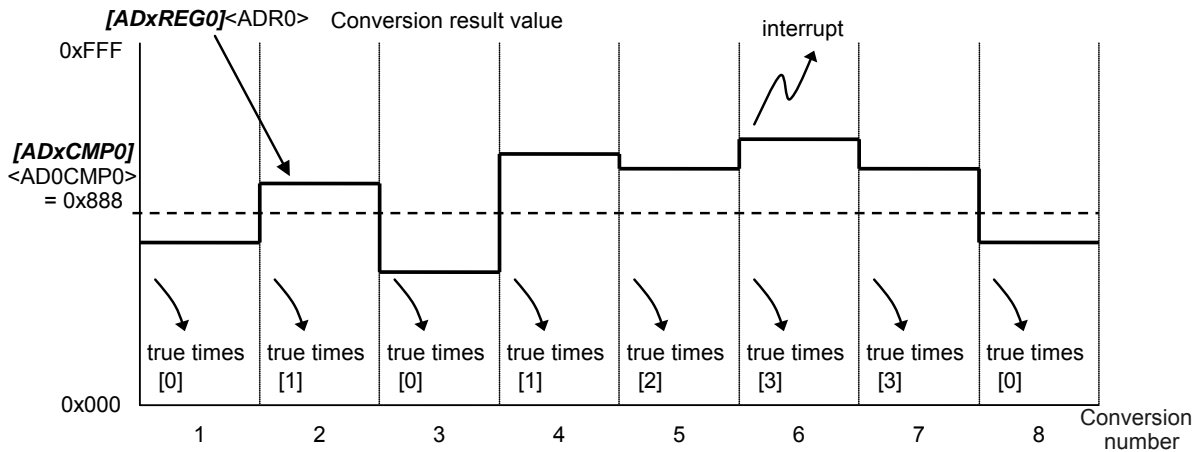


Figure 3.3 AD monitor function (Determination condition: Continuous count)

(2) Determination by Accumulated count

- Monitor function setting register ($[ADxCMPCR0] = 0x00000240$)
Conversion result storage register (Comparison target): $[ADxREG0]$
Magnitude determination: $[ADxREG0] < ADR0 > > [ADxCMP0] < AD0CMP0 >$
(Larger than the comparison register.)
Determination count condition: Accumulated count
Magnitude determination count: 3 counts
- AD conversion result comparison register ($[ADxCMP0] < AD0CMP0 > = 0x888$)
- Monitor function enable register ($[ADxCMPEN] = 0x00000001$)

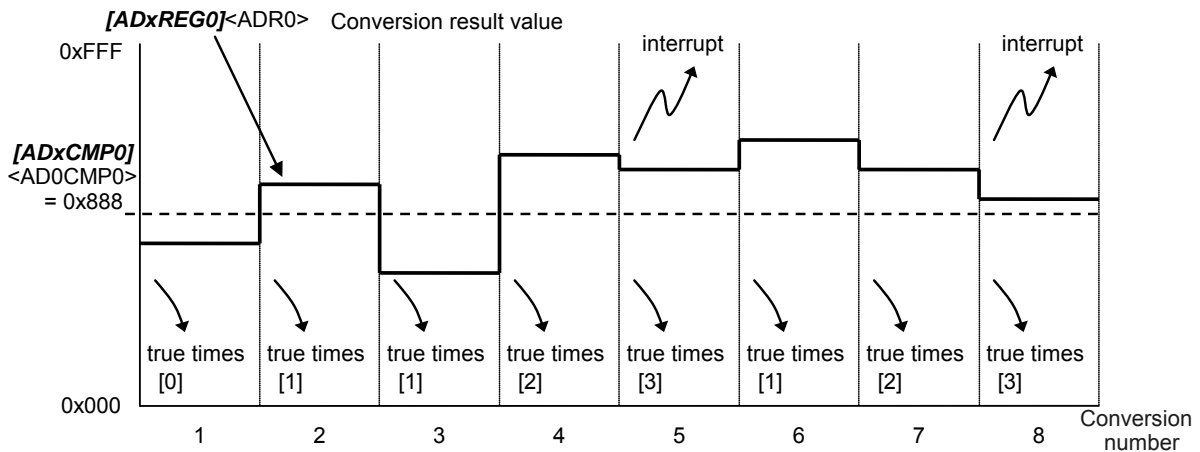


Figure 3.4 AD monitor function (Determination condition: Accumulated count)

3.7. Analog Reference Voltage

Analog reference pins VREFHx and VREFLx in the ADC unit are connected to a High level and a Low level, respectively. When $[ADxMOD0]<RCUT>$ is set to "1", the switch between VREFHx and VREFLx is turned on only during the conversion to reduce the power consumption.

Note: When using multiple ADC units, do not set the low power operation. (Please use with $[ADxMOD0]<RCUT>=0$.)

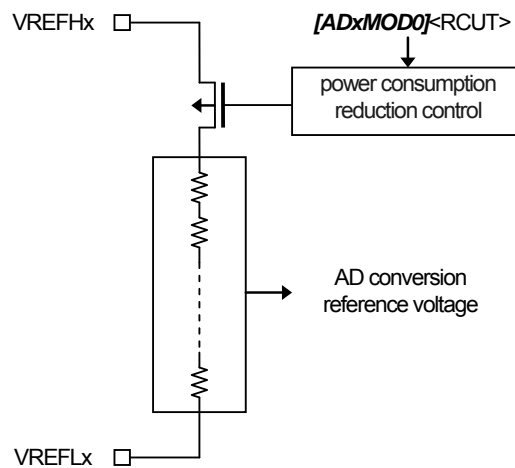


Figure 3.5 Configuration of Analog reference voltage

3.8. Conversion Time

3.8.1. Conversion timing

Figure 3.6 shows the conversion timing.

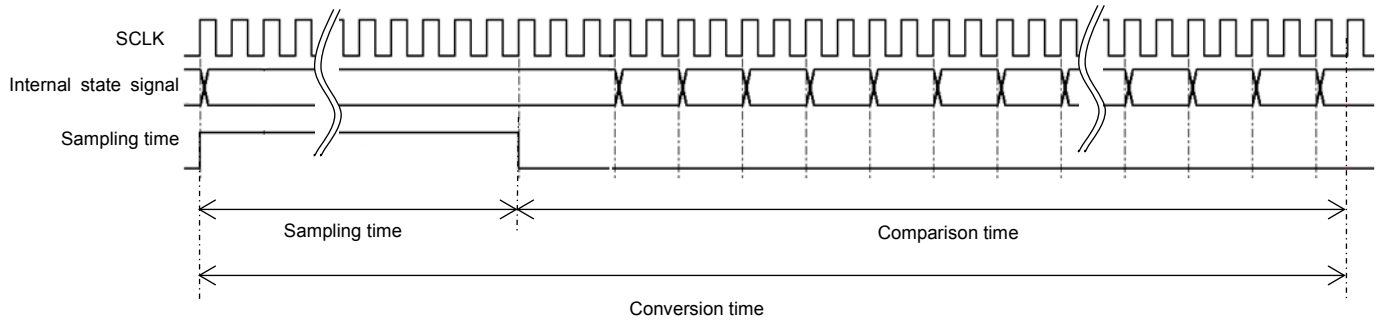


Figure 3.6 Example Conversion timing

4. Registers

4.1. List of Registers

The control registers and their addresses are shown as follows.

| Function | | Channel/Unit | Base address | | |
|------------------------------------|-----|--------------|--------------|------------|------------|
| | | | Type 1 | Type 2 | Type 3 |
| 12-bit Analog to Digital Converter | ADC | unit A | 0x400B8800 | 0x400BA000 | 0x4005A000 |
| | | unit B | 0x400B8C00 | 0x400BA400 | 0x4005A400 |
| | | unit C | - | 0x400BA800 | 0x4005A800 |
| | | unit D | - | 0x400BAC00 | 0x4005AC00 |

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+) |
|---|--------------------|
| Control Register0 | [ADxCR0] 0x0000 |
| Control Register1 | [ADxCR1] 0x0004 |
| Status Register | [ADxST] 0x0008 |
| Conversion Clock Setting Register | [ADxCLK] 0x000C |
| Mode Setting Register0 | [ADxMOD0] 0x0010 |
| Mode Setting Register1 | [ADxMOD1] 0x0014 |
| Mode Setting Register2 | [ADxMOD2] 0x0018 |
| Monitor function Enable Register | [ADxCMPEN] 0x0020 |
| Monitor function Setting Register0 | [ADxCMPCR0] 0x0024 |
| Monitor function Setting Register1 | [ADxCMPCR1] 0x0028 |
| Conversion Result Comparison Register0 | [ADxCMP0] 0x002C |
| Conversion Result Comparison Register1 | [ADxCMP1] 0x0030 |
| PMD Trigger Program Number Selection Register0 | [ADxPSEL0] 0x0040 |
| PMD Trigger Program Number Selection Register1 | [ADxPSEL1] 0x0044 |
| PMD Trigger Program Number Selection Register2 | [ADxPSEL2] 0x0048 |
| PMD Trigger Program Number Selection Register3 | [ADxPSEL3] 0x004C |
| PMD Trigger Program Number Selection Register4 | [ADxPSEL4] 0x0050 |
| PMD Trigger Program Number Selection Register5 | [ADxPSEL5] 0x0054 |
| PMD Trigger Program Number Selection Register6 | [ADxPSEL6] 0x0058 |
| PMD Trigger Program Number Selection Register7 | [ADxPSEL7] 0x005C |
| PMD Trigger Program Number Selection Register8 | [ADxPSEL8] 0x0060 |
| PMD Trigger Program Number Selection Register9 | [ADxPSEL9] 0x0064 |
| PMD Trigger Program Number Selection Register10 | [ADxPSEL10] 0x0068 |
| PMD Trigger Program Number Selection Register11 | [ADxPSEL11] 0x006C |
| PMD Trigger Interrupt Selection Register0 | [ADxPINTS0] 0x0070 |
| PMD Trigger Interrupt Selection Register1 | [ADxPINTS1] 0x0074 |
| PMD Trigger Interrupt Selection Register2 | [ADxPINTS2] 0x0078 |
| PMD Trigger Interrupt Selection Register3 | [ADxPINTS3] 0x007C |
| PMD Trigger Interrupt Selection Register4 | [ADxPINTS4] 0x0080 |
| PMD Trigger Interrupt Selection Register5 | [ADxPINTS5] 0x0084 |
| PMD Trigger Interrupt Selection Register6 | [ADxPINTS6] 0x0088 |
| PMD Trigger Interrupt Selection Register7 | [ADxPINTS7] 0x008C |
| PMD Trigger Storage Selection Register | [ADxPREGS] 0x0090 |
| PMD Trigger Program Register0 | [ADxPSET0] 0x00A0 |
| PMD Trigger Program Register1 | [ADxPSET1] 0x00A4 |
| PMD Trigger Program Register2 | [ADxPSET2] 0x00A8 |
| PMD Trigger Program Register3 | [ADxPSET3] 0x00AC |

| Register Name | | Address (Base+) |
|--|-------------|-----------------|
| PMD Trigger Program Register4 | [ADxPSET4] | 0x00B0 |
| PMD Trigger Program Register5 | [ADxPSET5] | 0x00B4 |
| PMD Trigger Program Register6 | [ADxPSET6] | 0x00B8 |
| PMD Trigger Program Register7 | [ADxPSET7] | 0x00BC |
| General Purpose Start-up Factor Program Register0 | [ADxTSET0] | 0x00C0 |
| General Purpose Start-up Factor Program Register1 | [ADxTSET1] | 0x00C4 |
| General Purpose Start-up Factor Program Register2 | [ADxTSET2] | 0x00C8 |
| General Purpose Start-up Factor Program Register3 | [ADxTSET3] | 0x00CC |
| General Purpose Start-up Factor Program Register4 | [ADxTSET4] | 0x00D0 |
| General Purpose Start-up Factor Program Register5 | [ADxTSET5] | 0x00D4 |
| General Purpose Start-up Factor Program Register6 | [ADxTSET6] | 0x00D8 |
| General Purpose Start-up Factor Program Register7 | [ADxTSET7] | 0x00DC |
| General Purpose Start-up Factor Program Register8 | [ADxTSET8] | 0x00E0 |
| General Purpose Start-up Factor Program Register9 | [ADxTSET9] | 0x00E4 |
| General Purpose Start-up Factor Program Register10 | [ADxTSET10] | 0x00E8 |
| General Purpose Start-up Factor Program Register11 | [ADxTSET11] | 0x00EC |
| General Purpose Start-up Factor Program Register12 | [ADxTSET12] | 0x00F0 |
| General Purpose Start-up Factor Program Register13 | [ADxTSET13] | 0x00F4 |
| General Purpose Start-up Factor Program Register14 | [ADxTSET14] | 0x00F8 |
| General Purpose Start-up Factor Program Register15 | [ADxTSET15] | 0x00FC |
| General Purpose Start-up Factor Program Register16 | [ADxTSET16] | 0x0100 |
| General Purpose Start-up Factor Program Register17 | [ADxTSET17] | 0x0104 |
| General Purpose Start-up Factor Program Register18 | [ADxTSET18] | 0x0108 |
| General Purpose Start-up Factor Program Register19 | [ADxTSET19] | 0x010C |
| General Purpose Start-up Factor Program Register20 | [ADxTSET20] | 0x0110 |
| General Purpose Start-up Factor Program Register21 | [ADxTSET21] | 0x0114 |
| General Purpose Start-up Factor Program Register22 | [ADxTSET22] | 0x0118 |
| General Purpose Start-up Factor Program Register23 | [ADxTSET23] | 0x011C |
| Conversion Result Storage Register0 | [ADxREG0] | 0x0140 |
| Conversion Result Storage Register1 | [ADxREG1] | 0x0144 |
| Conversion Result Storage Register2 | [ADxREG2] | 0x0148 |
| Conversion Result Storage Register3 | [ADxREG3] | 0x014C |
| Conversion Result Storage Register4 | [ADxREG4] | 0x0150 |
| Conversion Result Storage Register5 | [ADxREG5] | 0x0154 |
| Conversion Result Storage Register6 | [ADxREG6] | 0x0158 |
| Conversion Result Storage Register7 | [ADxREG7] | 0x015C |
| Conversion Result Storage Register8 | [ADxREG8] | 0x0160 |
| Conversion Result Storage Register9 | [ADxREG9] | 0x0164 |
| Conversion Result Storage Register10 | [ADxREG10] | 0x0168 |
| Conversion Result Storage Register11 | [ADxREG11] | 0x016C |
| Conversion Result Storage Register12 | [ADxREG12] | 0x0170 |
| Conversion Result Storage Register13 | [ADxREG13] | 0x0174 |
| Conversion Result Storage Register14 | [ADxREG14] | 0x0178 |
| Conversion Result Storage Register15 | [ADxREG15] | 0x017C |
| Conversion Result Storage Register16 | [ADxREG16] | 0x0180 |
| Conversion Result Storage Register17 | [ADxREG17] | 0x0184 |
| Conversion Result Storage Register18 | [ADxREG18] | 0x0188 |
| Conversion Result Storage Register19 | [ADxREG19] | 0x018C |
| Conversion Result Storage Register20 | [ADxREG20] | 0x0190 |
| Conversion Result Storage Register21 | [ADxREG21] | 0x0194 |
| Conversion Result Storage Register22 | [ADxREG22] | 0x0198 |
| Conversion Result Storage Register23 | [ADxREG23] | 0x019C |

Note: Do not access registers that are not assigned by the product (Please refer to "Product Information" of the reference manual.).

4.2. Details of Registers

4.2.1. [ADxCR0] (Control Register0)

| Bit | Bit Symbol | After Reset | Type | Function |
|------|------------|-------------|------|---|
| 31:8 | - | 0 | R | Read as "0" |
| 7 | ADEN | 0 | R/W | ADC control. 0: Disabled. 1: Enabled. When "1" is set, the conversion is enabled. When "0" is set, the conversion stops. |
| 6:2 | - | 0 | R | Read as "0" |
| 1 | SGL | 0 | W | Single conversion control 0: Don't care 1: Conversion start. When "1" is set, the single conversion program starts to execute. If this bit is read, "0" is returned. |
| 0 | CNT | 0 | R/W | Continuous conversion control 0: Disabled. 1: Enabled. When "1" is set, the continuous conversion starts to execute. This bit should be set to "1" when [ADxST]<CNTF> is "0" (a continuous conversion program does not execute). |

4.2.2. [ADxCR1] (Control Register1)

| Bit | Bit Symbol | After Reset | Type | Function |
|------|------------|-------------|------|--|
| 31:7 | - | 0 | R | Read as "0" |
| 6 | CNTDMEN | 0 | R/W | Continuous conversion DMA request control 0: Disabled. 1: Enabled. |
| 5 | SGLDMEN | 0 | R/W | Single conversion DMA request control 0: Disabled. 1: Enabled. |
| 4 | TRGDMEN | 0 | R/W | General purpose trigger DMA request control 0: Disabled. 1: Enabled. |
| 3:1 | - | 0 | R | Read as "0" |
| 0 | TRGEN | 0 | R/W | General purpose trigger start-up control 0: Disabled. 1: Enabled. |

Note: This register must be set while [ADxCR0]<ADEN>=0.

4.2.3. [ADxST] (Status Register)

| Bit | Bit Symbol | After Reset | Type | Function |
|------|------------|-------------|------|---|
| 31:8 | - | 0 | R | Read as "0" |
| 7 | ADBF | 0 | R | AD operation flag 0: Stop (ADCLK can be stopped.) 1: Executing (ADCLK cannot be stopped.) Before ADCLK is stopped, this bit should be confirmed to be "0". |
| 6:4 | - | 0 | R | Read as "0" |
| 3 | CNTF | 0 | R | Continuous conversion program flag 0: Stop 1: Executing When the request is received, this bit becomes "1". When the last conversion result is stored, this bit becomes "0". |
| 2 | SNGF | 0 | R | Single conversion program flag 0: Stop 1: Executing When the request is received, this bit becomes "1". When the last conversion result is stored, this bit becomes "0". |
| 1 | TRGF | 0 | R | General purpose trigger program flag 0: Stop 1: Executing When the request is received, this bit becomes "1". When the last conversion result is stored, this bit becomes "0". |
| 0 | PMDF | 0 | R | PMD trigger program flag 0: Stop 1: Executing When the request is received, this bit becomes "1". When the last conversion result is stored, this bit becomes "0". |

4.2.4. [ADxCLK] (Conversion Clock Setting Register)

| Bit | Bit Symbol | After Reset | Type | Function |
|------|-------------|-------------|------|--|
| 31:7 | - | 0 | R | Read as "0" |
| 6:3 | EXAZ[3:0] | 0000 | R/W | AIN sampling time selection $4.5 \leq AVDD5 \leq 5.5$ [V] AD conversion time 1.0[μ s] at SCLK=160M[Hz]: Write as "0001". AD conversion time 1.0[μ s] at SCLK=120M[Hz]: Write as "0000". AD conversion time 1.1[μ s] at SCLK=80M[Hz]: Write as "0000". AD conversion time 1.5[μ s] at SCLK=40M[Hz]: Write as "0000". $2.7 \leq AVDD5 < 4.5$ [V] AD conversion time 2.95[μ s] at SCLK=40M[Hz]: Write as "0001". |
| 2:0 | VADCLK[2:0] | 000 | R/W | AD prescaler output (SCLK) selection 000: ADCLK/1 001: ADCLK/2 010 to 111: Reserved |

Note: This register must be set while [ADxCR0]<ADEN>=0.

4.2.5. [ADxMOD0] (Mode Setting Register0)

| Bit | Bit Symbol | After Reset | Type | Function |
|------|------------|-------------|------|--|
| 31:2 | - | 0 | R | Read as "0" |
| 1 | RCUT | 1 | R/W | Low power mode selection 0: Normal operation 1: Low power operation (Energized between VREFHx and VREFLx only during the conversion) |
| 0 | DACON | 0 | R/W | DAC control (Note3) 0: OFF 1: ON When the ADC is used, <DACON> should be set to "1". |

Note1: This register must be set while [ADxCR0]<ADEN>=0.

Note2: When using multiple ADC units, do not set the low power operation. (Please use with <RCUT>=0.)

Note3: After [ADxMOD0]<DACON> is set to "1", the interval of 3 [μ s] are necessary for the stabilization.

4.2.6. [ADxMOD1] (Mode Setting Register1)

| Bit | Bit Symbol | After Reset | Type | Function |
|------|------------|-------------|------|--|
| 31:0 | MOD1[31:0] | 0x00004000 | R/W | $4.5 \leq AVDD5 \leq 5.5$ [V] AD conversion time 1.0[μ s] at SCLK=160M[Hz]: Write as "0x00306122" AD conversion time 1.0[μ s] at SCLK=120M[Hz]: Write as "0x00308012" AD conversion time 1.1[μ s] at SCLK=80M[Hz]: Write as "0x00104011" AD conversion time 1.5[μ s] at SCLK=40M[Hz]: Write as "0x00004000" $2.7 \leq AVDD5 < 4.5$ [V] AD conversion time 2.95[μ s] at SCLK=40M[Hz]: Write as "0x0000B001" |

Note: This register must be set while [ADxCR0]<ADEN>=0.

4.2.7. [ADxMOD2] (Mode Setting Register2)

| Bit | Bit Symbol | After Reset | Type | Function |
|------|------------|-------------|------|--|
| 31:0 | MOD2[31:0] | 0x00000000 | R/W | The setting value of this register varies depending on the product. For the setting value, refer to "Product Information" of the reference manual. |

Note: This register must be set while [ADxCR0]<ADEN>=0.

4.2.8. [ADxCMPEN] (Monitor function Enable Register)

| Bit | Bit Symbol | After Reset | Type | Function |
|------|------------|-------------|------|--|
| 31:2 | - | 0 | R | Read as "0" |
| 1 | CMP1EN | 0 | R/W | AD monitor function 1 0: Disabled. 1: Enabled. |
| 0 | CMP0EN | 0 | R/W | AD monitor function 0 0: Disabled. 1: Enabled. |

4.2.9. [ADxCMPCR0] (Monitor function Setting Register0)

| Bit | Bit Symbol | After Reset | Type | Function |
|-------|--------------|-------------|------|--|
| 31:12 | - | 0 | R | Read as "0" |
| 11:8 | CMPCNT0[3:0] | 0000 | R/W | Comparison count 0000: 1 1000: 9 0001: 2 1001: 10 0010: 3 1010: 11 0011: 4 1011: 12 0100: 5 1100: 13 0101: 6 1101: 14 0110: 7 1110: 15 0111: 8 1111: 16 |
| 7 | - | 0 | R | Read as "0" |
| 6 | CMPCND0 | 0 | R/W | Determination condition 0: Continuous count 1: Accumulated count |
| 5 | ADBIG0 | 0 | R/W | Magnitude determination setting 0: Conversion result specified by <REGS0> > [ADxCMP0] (Larger than the comparison register) 1: Conversion result specified by <REGS0> < [ADxCMP0] (Smaller than the comparison register) |
| 4:0 | REGS0[4:0] | 00000 | R/W | Compared conversion result storage register (Note2) 00000: ADxREG0 01000: ADxREG8 10000: ADxREG16 00001: ADxREG1 01001: ADxREG9 10001: ADxREG17 00010: ADxREG2 01010: ADxREG10 10010: ADxREG18 00011: ADxREG3 01011: ADxREG11 10011: ADxREG19 00100: ADxREG4 01100: ADxREG12 10100: ADxREG20 00101: ADxREG5 01101: ADxREG13 10101: ADxREG21 00110: ADxREG6 01110: ADxREG14 10110: ADxREG22 00111: ADxREG7 01111: ADxREG15 10111: ADxREG23 11000 to 11111: Inhibited setting |

Note1: This register must be set while [ADxCMPEN]<CMP0EN>=0.

Note2: The Conversion Result Storage Register which the product does not have is inhibited to be set (Refer to "Product Information" of the reference manual).

4.2.10. [ADxCMPCR1] (Monitor function Setting Register1)

| Bit | Bit Symbol | After Reset | Type | Function |
|-------|--------------|-------------|------|--|
| 31:12 | - | 0 | R | Read as "0" |
| 11:8 | CMPCNT1[3:0] | 0000 | R/W | Comparison count 0000: 1 1000: 9 0001: 2 1001: 10 0010: 3 1010: 11 0011: 4 1011: 12 0100: 5 1100: 13 0101: 6 1101: 14 0110: 7 1110: 15 0111: 8 1111: 16 |
| 7 | - | 0 | R | Read as "0" |
| 6 | CMPCND1 | 0 | R/W | Determination condition 0: Continuous count 1: Accumulated count |
| 5 | ADBIG1 | 0 | R/W | Magnitude determination setting 0: Conversion result specified by <REGS1> > [ADxCMP1] (Larger than the comparison register) 1: Conversion result specified by <REGS1> < [ADxCMP1] (Smaller than the comparison register) |
| 4:0 | REGS1[4:0] | 00000 | R/W | Compared conversion result storage register (Note2) 00000: ADxREG0 01000: ADxREG8 10000: ADxREG16 00001: ADxREG1 01001: ADxREG9 10001: ADxREG17 00010: ADxREG2 01010: ADxREG10 10010: ADxREG18 00011: ADxREG3 01011: ADxREG11 10011: ADxREG19 00100: ADxREG4 01100: ADxREG12 10100: ADxREG20 00101: ADxREG5 01101: ADxREG13 10101: ADxREG21 00110: ADxREG6 01110: ADxREG14 10110: ADxREG22 00111: ADxREG7 01111: ADxREG15 10111: ADxREG23 11000 to 11111: Inhibited setting |

Note1: This register must be set while [ADxCMPEN]<CMP1EN>=0.

Note2: The Conversion Result Storage Register which the product does not have is inhibited to be set (Refer to "Product Information" of the reference manual).

4.2.11. [ADxCMP0] (Conversion Result Comparison Register0)

| Bit | Bit Symbol | After Reset | Type | Function |
|-------|---------------|-------------|------|---|
| 31:16 | - | 0 | R | Read as "0" |
| 15:4 | AD0CMP0[11:0] | 0x000 | R/W | AD conversion result comparison value storage The value compared with the AD conversion result is set. |
| 3:0 | - | 0 | R | Read as "0" |

Note: This register must be set while [ADxCMPEN]<CMP0EN>=0.

4.2.12. [ADxCMP1] (Conversion Result Comparison Register1)

| Bit | Bit Symbol | After Reset | Type | Function |
|-------|---------------|-------------|------|---|
| 31:16 | - | 0 | R | Read as "0" |
| 15:4 | AD0CMP1[11:0] | 0x000 | R/W | AD conversion result comparison value storage The value compared with the AD conversion result is set. |
| 3:0 | - | 0 | R | Read as "0" |

Note: This register must be set while [ADxCMPEN]<CMP1EN>=0.

4.2.13. PMD Trigger Control Registers

4.2.13.1. [ADxPSEL0] (PMD Trigger Program Number Selection Register0)

The following is an example of [ADxPSEL0]. [ADxPSEL1] to [ADxPSEL11] have the same configuration.

| Bit | Bit Symbol | After Reset | Type | Function |
|------|------------|-------------|------|--|
| 31:8 | - | 0 | R | Read as "0" |
| 7 | PENS0 | 0 | R/W | PMDTRG0 trigger control (Note2) 0: Disabled. 1: Enabled. |
| 6:3 | - | 0 | R | Read as "0" |
| 2:0 | PMDS0[2:0] | 000 | R/W | Program number selection 000: Program 0 001: Program 1 010: Program 2 011: Program 3 100: Program 4 101: Program 5 110: Program 6 111: Program 7 |

Note1: This register must be set while [ADxCR0]<ADEN>=0.

Note2: For detail of PMD, please refer to "Programmable Motor Control Circuit Plus" or "Advanced Programmable Motor Control Circuit" of reference manual.

4.2.13.2. [ADxPINTS0] (PMD Trigger Interrupt Selection Register0)

The following is an example of [ADxPINTS0]. [ADxPINTS1] to [ADxPINTS7] have the same configuration.

| Bit | Bit Symbol | After Reset | Type | Function |
|------|--------------|-------------|------|---|
| 31:2 | - | 0 | R | Read as "0" |
| 1:0 | INTSEL0[1:0] | 00 | R/W | Interrupt selection 00: No interrupts. 01: INTADxPDA 10: INTADxPDB 11: Reserved This field selects an interrupt for the program 0. |

Note: This register must be set while [ADxCR0]<ADEN>=0.

4.2.13.3. [ADxPREGS] (PMD Trigger Storage Selection Register)

| Bit | Bit Symbol | After Reset | Type | Function |
|-------|--------------|-------------|------|--|
| 31 | - | 0 | R | Read as "0" |
| 30:28 | REGSEL7[2:0] | 000 | R/W | Program 7 conversion result storage register selection (Note2) 000: ADxREG0 to 3 100: ADxREG16 to 19 001: ADxREG4 to 7 101: ADxREG20 to 23 010: ADxREG8 to 11 110: Inhibited setting. 011: ADxREG12 to 15 111: Inhibited setting. |
| 27 | - | 0 | R | Read as "0" |
| 26:24 | REGSEL6[2:0] | 000 | R/W | Program 6 conversion result storage register selection (Note2) 000: ADxREG0 to 3 100: ADxREG16 to 19 001: ADxREG4 to 7 101: ADxREG20 to 23 010: ADxREG8 to 11 110: Inhibited setting. 011: ADxREG12 to 15 111: Inhibited setting. |
| 23 | - | 0 | R | Read as "0" |
| 22:20 | REGSEL5[2:0] | 000 | R/W | Program 5 conversion result storage register selection (Note2) 000: ADxREG0 to 3 100: ADxREG16 to 19 001: ADxREG4 to 7 101: ADxREG20 to 23 010: ADxREG8 to 11 110: Inhibited setting. 011: ADxREG12 to 15 111: Inhibited setting. |
| 19 | - | 0 | R | Read as "0" |
| 18:16 | REGSEL4[2:0] | 000 | R/W | Program 4 conversion result storage register selection (Note2) 000: ADxREG0 to 3 100: ADxREG16 to 19 001: ADxREG4 to 7 101: ADxREG20 to 23 010: ADxREG8 to 11 110: Inhibited setting. 011: ADxREG12 to 15 111: Inhibited setting. |
| 15 | - | 0 | R | Read as "0" |
| 14:12 | REGSEL3[2:0] | 000 | R/W | Program 3 conversion result storage register selection (Note2) 000: ADxREG0 to 3 100: ADxREG16 to 19 001: ADxREG4 to 7 101: ADxREG20 to 23 010: ADxREG8 to 11 110: Inhibited setting. 011: ADxREG12 to 15 111: Inhibited setting. |
| 11 | - | 0 | R | Read as "0" |
| 10:8 | REGSEL2[2:0] | 000 | R/W | Program 2 conversion result storage register selection (Note2) 000: ADxREG0 to 3 100: ADxREG16 to 19 001: ADxREG4 to 7 101: ADxREG20 to 23 010: ADxREG8 to 11 110: Inhibited setting. 011: ADxREG12 to 15 111: Inhibited setting. |
| 7 | - | 0 | R | Read as "0" |
| 6:4 | REGSEL1[2:0] | 000 | R/W | Program 1 conversion result storage register selection (Note2) 000: ADxREG0 to 3 100: ADxREG16 to 19 001: ADxREG4 to 7 101: ADxREG20 to 23 010: ADxREG8 to 11 110: Inhibited setting. 011: ADxREG12 to 15 111: Inhibited setting. |
| 3 | - | 0 | R | Read as "0" |
| 2:0 | REGSEL0[2:0] | 000 | R/W | Program 0 conversion result storage register selection (Note2) 000: ADxREG0 to 3 100: ADxREG16 to 19 001: ADxREG4 to 7 101: ADxREG20 to 23 010: ADxREG8 to 11 110: Inhibited setting. 011: ADxREG12 to 15 111: Inhibited setting. |

Note1: This register must be set while [ADxCR0]<ADEN>=0.

Note2: The Conversion Result Storage Register which the product does not have is inhibited to be set (Refer to "Product Information" of the reference manual).

4.2.13.4. [ADxPSET0] (PMD Trigger Program Register0)

The following is an example of [ADxPSET0]. [ADxPSET1] to [ADxPSET7] have the same configuration.

| Bit | Bit Symbol | After Reset | Type | Function |
|-------|--------------|-------------|------|--|
| 31 | ENSP03 | 0 | R/W | Conversion 3 setting: Conversion control 0: Disabled. 1: Enabled. |
| 30:29 | UVWIS03[1:0] | 00 | R/W | Conversion 3 setting: Phase select (for Vector Engine) 00: Not specified 01: U 10: V 11: W |
| 28:24 | AINSP03[4:0] | 00000 | R/W | Conversion 3 setting: AIN selection(Note2) 00000: AINx00 01000: AINx08 10000: AINx16 00001: AINx01 01001: AINx09 10001: AINx17 00010: AINx02 01010: AINx10 10010: AINx18 00011: AINx03 01011: AINx11 10011: AINx19 00100: AINx04 01100: AINx12 10100: AINx20 00101: AINx05 01101: AINx13 10101: AINx21 00110: AINx06 01110: AINx14 10110: AINx22 00111: AINx07 01111: AINx15 10111: AINx23 11000 to 11111: Inhibited setting |
| 23 | ENSP02 | 0 | R/W | Conversion 2 setting: Conversion control 0: Disabled. 1: Enabled. |
| 22:21 | UVWIS02[1:0] | 00 | R/W | Conversion 2 setting: Phase select (for Vector Engine) 00: Not specified 01: U 10: V 11: W |
| 20:16 | AINSP02[4:0] | 00000 | R/W | Conversion 2 setting: AIN selection (Note2) 00000: AINx00 01000: AINx08 10000: AINx16 00001: AINx01 01001: AINx09 10001: AINx17 00010: AINx02 01010: AINx10 10010: AINx18 00011: AINx03 01011: AINx11 10011: AINx19 00100: AINx04 01100: AINx12 10100: AINx20 00101: AINx05 01101: AINx13 10101: AINx21 00110: AINx06 01110: AINx14 10110: AINx22 00111: AINx07 01111: AINx15 10111: AINx23 11000 to 11111: Inhibited setting |
| 15 | ENSP01 | 0 | R/W | Conversion 1 setting: Conversion control 0: Disabled. 1: Enabled. |
| 14:13 | UVWIS01[1:0] | 00 | R/W | Conversion 1 setting: Phase select (for Vector Engine) 00: Not specified 01: U 10: V 11: W |
| 12:8 | AINSP01[4:0] | 00000 | R/W | Conversion 1 setting: AIN selection(Note2) 00000: AINx00 01000: AINx08 10000: AINx16 00001: AINx01 01001: AINx09 10001: AINx17 00010: AINx02 01010: AINx10 10010: AINx18 00011: AINx03 01011: AINx11 10011: AINx19 00100: AINx04 01100: AINx12 10100: AINx20 00101: AINx05 01101: AINx13 10101: AINx21 00110: AINx06 01110: AINx14 10110: AINx22 00111: AINx07 01111: AINx15 10111: AINx23 11000 to 11111: Inhibited setting |

| Bit | Bit Symbol | After Reset | Type | Function |
|-----|--------------|-------------|------|---|
| 7 | ENSP00 | 0 | R/W | Conversion 0 setting: Conversion control 0: Disabled. 1: Enabled. |
| 6:5 | UVWIS00[1:0] | 00 | R/W | Conversion 0 setting: Phase select (for Vector Engine) 00: Not specified 01: U 10: V 11: W |
| 4:0 | AINSP00[4:0] | 00000 | R/W | Conversion 0 setting: AIN selection(Note2) 00000: AINx00 01000: AINx08 10000: AINx16 00001: AINx01 01001: AINx09 10001: AINx17 00010: AINx02 01010: AINx10 10010: AINx18 00011: AINx03 01011: AINx11 10011: AINx19 00100: AINx04 01100: AINx12 10100: AINx20 00101: AINx05 01101: AINx13 10101: AINx21 00110: AINx06 01110: AINx14 10110: AINx22 00111: AINx07 01111: AINx15 10111: AINx23 11000 to 11111: Inhibited setting |

Note1: This register must be set while $[ADxCR0] \langle ADEN \rangle = 0$.

Note2: The AIN which the product does not have is inhibited to be set (Refer to "Product Information" of the reference manual).

4.2.14. [ADxTSET0] (General Purpose Start-up Factor Program Register0)

The following is an example of [ADxTSET0]. [ADxTSET1] to [ADxTSET23] have the same configuration.

| Bit | Bit Symbol | After Reset | Type | Function |
|------|-------------|-------------|------|---|
| 31:8 | - | 0 | R | Read as "0" |
| 7 | ENINT0 | 0 | R/W | Conversion Result Storage Register0 setting: Interrupt control 0: Disabled. 1: Enabled. |
| 6:5 | TRGS0[1:0] | 00 | R/W | Conversion Result Storage Register0 setting: Conversion control 00: Conversion is inhibited. 01: Continuous conversion. 10: Single conversion. 11: General purpose trigger conversion. |
| 4:0 | AINST0[4:0] | 00000 | R/W | Conversion Result Storage Register0 setting: AIN selection (Note2) 00000: AINx00 01000: AINx08 10000: AINx16 00001: AINx01 01001: AINx09 10001: AINx17 00010: AINx02 01010: AINx10 10010: AINx18 00011: AINx03 01011: AINx11 10011: AINx19 00100: AINx04 01100: AINx12 10100: AINx20 00101: AINx05 01101: AINx13 10101: AINx21 00110: AINx06 01110: AINx14 10110: AINx22 00111: AINx07 01111: AINx15 10111: AINx23 11000 to 11111: Inhibited setting |

Note1: This register must be set while [ADxCR0]<ADEN>=0.

Note2: The AIN which the product does not have is inhibited to be set (Refer to "Product Information" of the reference manual).

4.2.15. [ADxREG0] (Conversion Result Storage Register0)

The following is an example of [ADxREG0]. [ADxREG1] to [ADxREG23] have the same configuration.

| Bit | Bit Symbol | After Reset | Type | Function |
|-------|--------------|-------------|------|---|
| 31:30 | - | 0 | R | Read as "0" |
| 29 | ADOVRF_M0 | 0 | R | Mirror bit of overrun flag <ADOVRF0> |
| 28 | ADRF_M0 | 0 | R | Mirror bit of AD conversion result storage flag <ADRF0> |
| 27:16 | ADR_M0[11:0] | 0x000 | R | Mirror bit of AD conversion result <ADR0>. The AD conversion result is read from the lower 12 bits in the upper half word of [ADxREG0] register. |
| 15:4 | ADR0[11:0] | 0x000 | R | AD conversion result is stored. The AD conversion result is read from the upper 12 bits in the lower half word of [ADxREG0] register. |
| 3:2 | - | 0 | R | Read as "0" |
| 1 | ADOVRF0 | 0 | R | Overrun flag 0: Not occurred. 1: Occurred. This flag is set to "1", when an AD conversion result is overwritten before the [ADxREG0] register is read. This flag is cleared to "0" when it is read. |
| 0 | ADRF0 | 0 | R | AD conversion result storage flag 0: No conversion results are stored. 1: A conversion result is stored. This flag is set to "1" when an AD conversion value is stored. This flag is cleared to "0" when it is read. |

5. Usage Example

5.1. Single conversion

The single conversion is started by software and enable more than one conversion.

In the following setting example, the conversion results of the two analog inputs (AINx02, AINx03) are saved in two result storage registers (*[ADxREG4]*, *[ADxREG5]*), and a single conversion interrupt INTADxSGL is generated at the end of second conversion.

- Initial setting

- *[ADxMOD0]* = 0x00000001
DAC ON: <DAON>=1
Normal operation: <RCUT>=0
- *[ADxCLK]* = 0x00000008
Conversion Clock setting: Conversion time 1.0[μs] at ADCLK=SCLK=160[MHz]
- *[ADxMOD1]* = 0x00306122
MODE setting 1: Conversion time 1.0[μs] at ADCLK=SCLK=160[MHz]
- *[ADxMOD2]* = 0x00000000

Note: The setting value varies depending on the product. For the setting value, refer to "Product Information" of the reference manual.

- Conversion program setting

- *[ADxTSET4]* = 0x00000042
Single conversion: <TRGS4>=10
AINx02: <AINST4>=00010
Disable interrupt output: <ENINT4>=0
- *[ADxTSET5]* = 0x000000C3
Single conversion: <TRGS5>=10
AINx03: <AINST5>=00011
Enable interrupt output: <ENINT5>=1

- Conversion start setting

- *[ADxCRI]* = 0x00000000
Disable DMA request
- *[ADxCR0]* = 0x00000082
Enable ADC: <ADEN>=1
Disable continuous conversion: <CNT>=0
Enable single conversion: <SGL>=1 ;Conversion start

5.2. PMD trigger conversion

5.2.1. PMD (3-shunt), ADC × 1

The following shows the connection diagram in which PMD channel 0 and ADC unit A are used in 3-shunt.

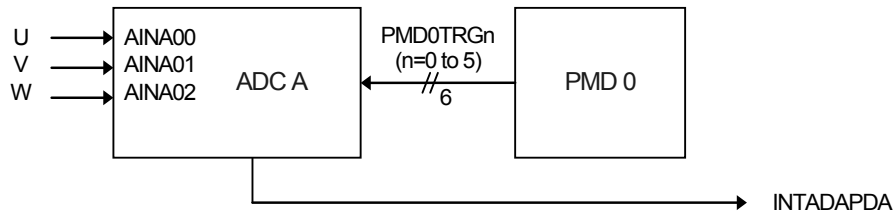


Figure 5.1 3-shunt example

The setting example for the ADC is as follows in this case:

Table 5.1 ADC setting in 3-shunt

| Program | 0 | 1 | 2 | 3 | 4 | 5 |
|---------|-----------|-----------|-----------|-----------|-----------|-----------|
| Reg0 | U | V | W | V | W | U |
| Reg1 | V | W | U | U | V | W |
| INT | INTADAPDA | INTADAPDA | INTADAPDA | INTADAPDA | INTADAPDA | INTADAPDA |

The 6 trigger inputs PMD0TRG0 to 5 are assigned to the programs 0 to 5 by *[ADAPSEL0]* to *[ADAPSEL5]*.

Reg0 and Reg1 in the table represent *[ADAPSETn][7:0]* and *[ADAPSETn][15:8]* (n: Program number), respectively. U, V, and W in the table are the motor phases. The corresponding AIN input should be selected for each phase.

When the trigger is received, the AD conversion starts and the execution is done in the order of Reg0 and Reg1. Each conversion result is stored to the conversion result storage register, and the INTADAPDA interrupt is generated.

5.2.2. PMD (1-shunt), ADC × 1

The following shows the connection diagram in which PMD channel 0 and ADC unit A are used in 1-shunt.

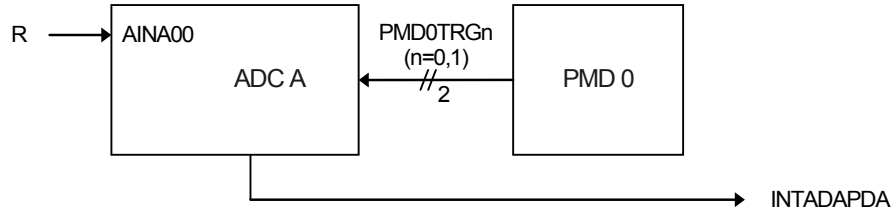


Figure 5.2 1-shunt example

The setting example for the ADC is as follows in this case:

Table 5.2 ADC unit A in 1-shunt

| Trigger | PMD0 | PMD0 |
|---------|------|-----------|
| | 0 | 1 |
| Program | 0 | 1 |
| Reg0 | R | - |
| Reg1 | - | R |
| INT | - | INTADAPDA |

The two trigger signals from PMD0 are assigned to the program numbers, respectively.

Reg0 and Reg1 in the table represent $[ADAPSETn][7:0]$ and $[ADAPSETn][15:8]$ (n: Program number), respectively. R in the table is a resistor. It is connected to the corresponding AIN.

When the trigger is received, ADC unit A starts and the conversion result is stored to the conversion result storage register0 and 1. The conversion executes in the order of the program0 and 1. The INTADAPDA interrupt is generated at the conversion completion.

6. Precaution

- The AD conversion result may have some variation due to the fluctuation of the power supply and surrounding noises. The data of the output pins should not be changed during AD conversion to prevent from degrading the AD conversion accuracy. The AD conversion accuracy may degrade if the signal on the shared pin with the AD input/output changes or other output pin changes its output during the AD conversion. In the above case, the AD conversion result should be acquired with the mean value of multiple conversion results and other countermeasures.

- Measures should be taken to prevent digital noise from mixing into the analog power supply pins(AVDD5, AVSS) and the reference voltage pins(VREFHx, VREFLx) of the ADC.
 - Insert a bypass capacitor between AVDD5 and AVSS pins, the VREFHx and VREFLx pins. Place the capacitor as close to the terminal as possible.

7. Revision History

Table 7.1 Revision History

| Revision | Date | Description |
|----------|------------|---------------|
| 1.0 | 2018-06-19 | First release |

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