

Chapter 13

Analog-to-Digital Converter (ADC12B16CV1)

Table 13-1. Revision History

Revision Number	Revision Date	Sections Affected	Description of Changes
V01.00	13 Oct. 2005		- Initial version
V01.01	04 Mar. 2008		corrected reference to DJM bit

13.1 Introduction

The ADC12B16C is a 16-channel, 12-bit, multiplexed input successive approximation analog-to-digital converter. Refer to device electrical specifications for ATD accuracy.

13.1.1 Features

- 8-, 10-, or 12-bit resolution.
- Conversion in Stop Mode using internally generated clock
- Automatic return to low power after conversion sequence
- Automatic compare with interrupt for higher than or less/equal than programmable value
- Programmable sample time.
- Left/right justified result data.
- External trigger control.
- Sequence complete interrupt.
- Analog input multiplexer for 16 analog input channels.
- Special conversions for V_{RH} , V_{RL} , $(V_{RL}+V_{RH})/2$.
- 1-to-16 conversion sequence lengths.
- Continuous conversion mode.
- Multiple channel scans.
- Configurable external trigger functionality on any AD channel or any of four additional trigger inputs. The four additional trigger inputs can be chip external or internal. Refer to device specification for availability and connectivity.
- Configurable location for channel wrap around (when converting multiple channels in a sequence).

13.1.2 Modes of Operation

13.1.2.1 Conversion Modes

There is software programmable selection between performing **single** or **continuous conversion** on a **single channel** or **multiple channels**.

13.1.2.2 MCU Operating Modes

- **Stop Mode**
 - **ICLKSTP=0 (in ATDCTL2 register)**
Entering Stop Mode aborts any conversion sequence in progress and if a sequence was aborted restarts it after exiting stop mode. This has the same effect/consequences as starting a conversion sequence with write to ATDCTL5. So after exiting from stop mode with a previously aborted sequence all flags are cleared etc.
 - **ICLKSTP=1 (in ATDCTL2 register)**
A/D conversion sequence seamless continues in Stop Mode based on the internally generated clock ICLK as ATD clock. For conversions during transition from Run to Stop Mode or vice versa the result is not written to the results register, no CCF flag is set and no compare is done. When converting in Stop Mode (ICLKSTP=1) an ATD Stop Recovery time $t_{\text{ATDSTPRCV}}$ is required to switch back to bus clock based ATDCLK when leaving Stop Mode. Do not access ATD registers during this time.
- **Wait Mode**
ADC12B16C behaves same in Run and Wait Mode. For reduced power consumption continuous conversions should be aborted before entering Wait mode.
- **Freeze Mode**
In Freeze Mode the ADC12B16C will either continue or finish or stop converting according to the FRZ1 and FRZ0 bits. This is useful for debugging and emulation.

13.1.3 Block Diagram

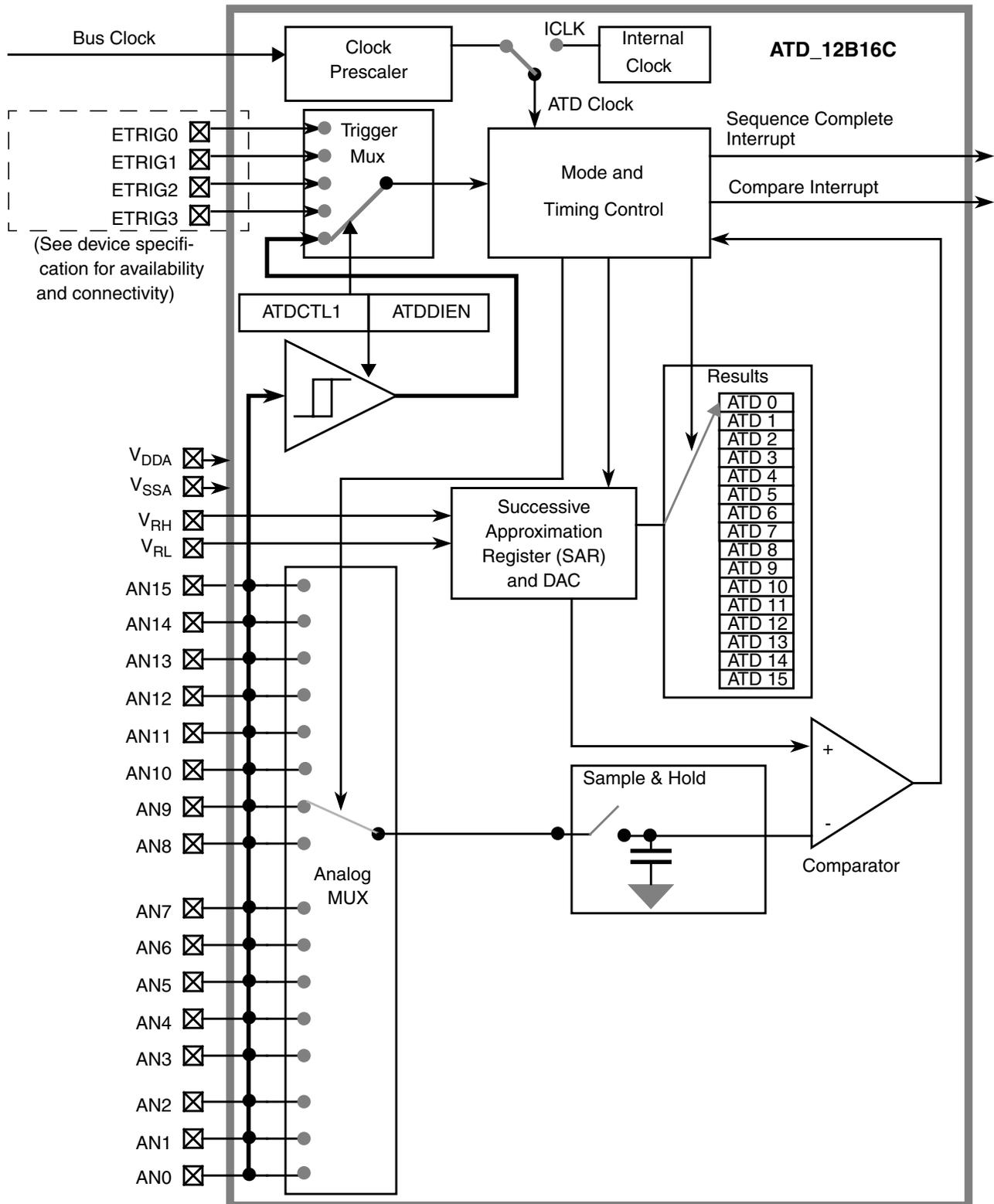


Figure 13-1. ADC12B16C Block Diagram

13.2 Signal Description

This section lists all inputs to the ADC12B16C block.

13.2.1 Detailed Signal Descriptions

13.2.1.1 AN_x (x = 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0)

This pin serves as the analog input Channel *x*. It can also be configured as digital port or external trigger for the ATD conversion.

13.2.1.2 ETRIG3, ETRIG2, ETRIG1, ETRIG0

These inputs can be configured to serve as an external trigger for the ATD conversion.

Refer to device specification for availability and connection of these inputs!

13.2.1.3 V_{RH}, V_{RL}

V_{RH} is the high reference voltage, V_{RL} is the low reference voltage for ATD conversion.

13.2.1.4 V_{DDA}, V_{SSA}

These pins are the power supplies for the analog circuitry of the ADC12B16C block.

13.3 Memory Map and Register Definition

This section provides a detailed description of all registers accessible in the ADC12B16C.

13.3.1 Module Memory Map

Figure 13-2 gives an overview on all ADC12B16C registers.

NOTE

Register Address = Base Address + Address Offset, where the Base Address is defined at the MCU level and the Address Offset is defined at the module level.

Address	Name	Bit 7	6	5	4	3	2	1	Bit 0
0x0000	ATDCTL0	R W Reserved	0	0	0	WRAP3	WRAP2	WRAP1	WRAP0
0x0001	ATDCTL1	R W ETRIGSEL	SRES1	SRES0	SMP_DIS	ETRIGCH3	ETRIGCH2	ETRIGCH1	ETRIGCH0
0x0002	ATDCTL2	R W 0	AFFC	ICLKSTP	ETRIGLE	ETRIGP	ETRIGE	ASCIE	ACMPIE

 = Unimplemented or Reserved

Figure 13-2. ADC12B16C Register Summary (Sheet 1 of 3)

Address	Name		Bit 7	6	5	4	3	2	1	Bit 0
0x0003	ATDCTL3	R W	DJM	S8C	S4C	S2C	S1C	FIFO	FRZ1	FRZ0
0x0004	ATDCTL4	R W	SMP2	SMP1	SMP0	PRS[4:0]				
0x0005	ATDCTL5	R W	0	SC	SCAN	MULT	CD	CC	CB	CA
0x0006	ATDSTAT0	R W	SCF	0	ETORF	FIFOR	CC3	CC2	CC1	CC0
0x0007	Unimplemented	R W	0	0	0	0	0	0	0	0
0x0008	ATDCMPEH	R W	CMPE[15:8]							
0x0009	ATDCMPEL	R W	CMPE[7:0]							
0x000A	ATDSTAT2H	R W	CCF[15:8]							
0x000B	ATDSTAT2L	R W	CCF[7:0]							
0x000C	ATDDIENH	R W	IEN[15:8]							
0x000D	ATDDIENL	R W	IEN[7:0]							
0x000E	ATDCMPHTH	R W	CMPHT[15:8]							
0x000F	ATDCMPHTL	R W	CMPHT[7:0]							
0x0010	ATDDR0	R W	See Section 13.3.2.12.1, "Left Justified Result Data (DJM=0)" and Section 13.3.2.12.2, "Right Justified Result Data (DJM=1)"							
0x0012	ATDDR1	R W	See Section 13.3.2.12.1, "Left Justified Result Data (DJM=0)" and Section 13.3.2.12.2, "Right Justified Result Data (DJM=1)"							
0x0014	ATDDR2	R W	See Section 13.3.2.12.1, "Left Justified Result Data (DJM=0)" and Section 13.3.2.12.2, "Right Justified Result Data (DJM=1)"							
0x0016	ATDDR3	R W	See Section 13.3.2.12.1, "Left Justified Result Data (DJM=0)" and Section 13.3.2.12.2, "Right Justified Result Data (DJM=1)"							
0x0018	ATDDR4	R W	See Section 13.3.2.12.1, "Left Justified Result Data (DJM=0)" and Section 13.3.2.12.2, "Right Justified Result Data (DJM=1)"							
0x001A	ATDDR5	R W	See Section 13.3.2.12.1, "Left Justified Result Data (DJM=0)" and Section 13.3.2.12.2, "Right Justified Result Data (DJM=1)"							
0x001C	ATDDR6	R W	See Section 13.3.2.12.1, "Left Justified Result Data (DJM=0)" and Section 13.3.2.12.2, "Right Justified Result Data (DJM=1)"							
0x001E	ATDDR7	R W	See Section 13.3.2.12.1, "Left Justified Result Data (DJM=0)" and Section 13.3.2.12.2, "Right Justified Result Data (DJM=1)"							
0x0020	ATDDR8	R W	See Section 13.3.2.12.1, "Left Justified Result Data (DJM=0)" and Section 13.3.2.12.2, "Right Justified Result Data (DJM=1)"							
0x0022	ATDDR9	R W	See Section 13.3.2.12.1, "Left Justified Result Data (DJM=0)" and Section 13.3.2.12.2, "Right Justified Result Data (DJM=1)"							

□ = Unimplemented or Reserved

Figure 13-2. ADC12B16C Register Summary (Sheet 2 of 3)

Address	Name	Bit 7	6	5	4	3	2	1	Bit 0
0x0024	ATDDR10	R W	See Section 13.3.2.12.1, "Left Justified Result Data (DJM=0)" and Section 13.3.2.12.2, "Right Justified Result Data (DJM=1)"						
0x0026	ATDDR11	R W	See Section 13.3.2.12.1, "Left Justified Result Data (DJM=0)" and Section 13.3.2.12.2, "Right Justified Result Data (DJM=1)"						
0x0028	ATDDR12	R W	See Section 13.3.2.12.1, "Left Justified Result Data (DJM=0)" and Section 13.3.2.12.2, "Right Justified Result Data (DJM=1)"						
0x002A	ATDDR13	R W	See Section 13.3.2.12.1, "Left Justified Result Data (DJM=0)" and Section 13.3.2.12.2, "Right Justified Result Data (DJM=1)"						
0x002C	ATDDR14	R W	See Section 13.3.2.12.1, "Left Justified Result Data (DJM=0)" and Section 13.3.2.12.2, "Right Justified Result Data (DJM=1)"						
0x002E	ATDDR15	R W	See Section 13.3.2.12.1, "Left Justified Result Data (DJM=0)" and Section 13.3.2.12.2, "Right Justified Result Data (DJM=1)"						

 = Unimplemented or Reserved

Figure 13-2. ADC12B16C Register Summary (Sheet 3 of 3)

13.3.2 Register Descriptions

This section describes in address order all the ADC12B16C registers and their individual bits.

13.3.2.1 ATD Control Register 0 (ATDCTL0)

Writes to this register will abort current conversion sequence.

Module Base + 0x0000

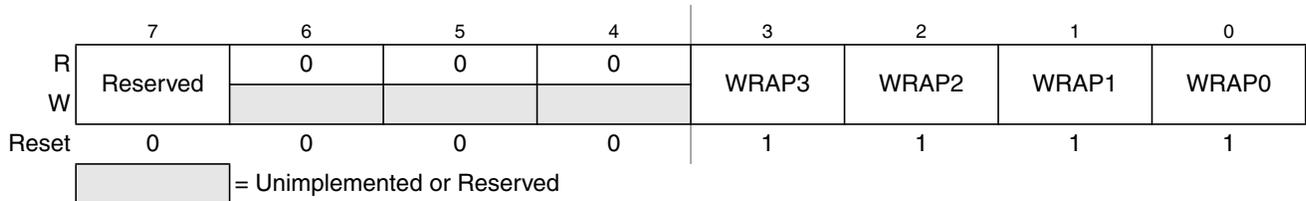


Figure 13-3. ATD Control Register 0 (ATDCTL0)

Read: Anytime

Write: Anytime, in special modes always write 0 to Reserved Bit 7.

Table 13-2. ATDCTL0 Field Descriptions

Field	Description
3-0 WRAP[3-0]	Wrap Around Channel Select Bits — These bits determine the channel for wrap around when doing multi-channel conversions. The coding is summarized in Table 13-3.

Table 13-3. Multi-Channel Wrap Around Coding

WRAP3	WRAP2	WRAP1	WRAP0	Multiple Channel Conversions (MULT = 1) Wraparound to AN0 after Converting
0	0	0	0	Reserved ⁽¹⁾

Table 13-3. Multi-Channel Wrap Around Coding

WRAP3	WRAP2	WRAP1	WRAP0	Multiple Channel Conversions (MULT = 1) Wraparound to AN0 after Converting
0	0	0	1	AN1
0	0	1	0	AN2
0	0	1	1	AN3
0	1	0	0	AN4
0	1	0	1	AN5
0	1	1	0	AN6
0	1	1	1	AN7
1	0	0	0	AN8
1	0	0	1	AN9
1	0	1	0	AN10
1	0	1	1	AN11
1	1	0	0	AN12
1	1	0	1	AN13
1	1	1	0	AN14
1	1	1	1	AN15

1. If only AN0 should be converted use MULT=0.

13.3.2.2 ATD Control Register 1 (ATDCTL1)

Writes to this register will abort current conversion sequence.

Module Base + 0x0001

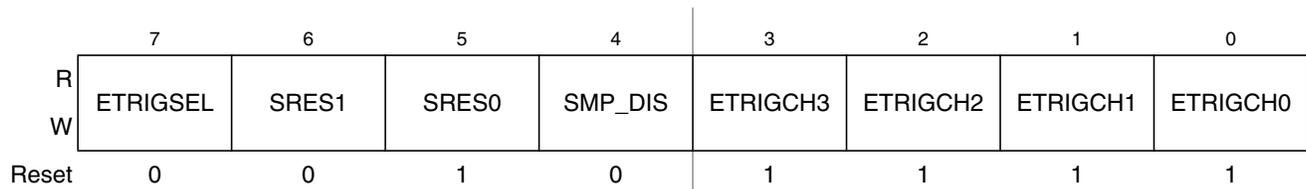


Figure 13-4. ATD Control Register 1 (ATDCTL1)

Read: Anytime

Write: Anytime

Table 13-4. ATDCTL1 Field Descriptions

Field	Description
7 ETRIGSEL	External Trigger Source Select — This bit selects the external trigger source to be either one of the AD channels or one of the ETRIG3-0 inputs. See device specification for availability and connectivity of ETRIG3-0 inputs. If a particular ETRIG3-0 input option is not available, writing a 1 to ETRISEL only sets the bit but has not effect, this means that one of the AD channels (selected by ETRIGCH3-0) is configured as the source for external trigger. The coding is summarized in Table 13-6.
6–5 SRES[1:0]	A/D Resolution Select — These bits select the resolution of A/D conversion results. See Table 13-5 for coding.

Table 13-4. ATDCTL1 Field Descriptions (continued)

Field	Description
4 SMP_DIS	Discharge Before Sampling Bit 0 No discharge before sampling. 1 The internal sample capacitor is discharged before sampling the channel. This adds 2 ATD clock cycles to the sampling time. This can help to detect an open circuit instead of measuring the previous sampled channel.
3–0 ETRIGCH[3:0]	External Trigger Channel Select — These bits select one of the AD channels or one of the ETRIG3-0 inputs as source for the external trigger. The coding is summarized in Table 13-6.

Table 13-5. A/D Resolution Coding

SRES1	SRES0	A/D Resolution
0	0	8-bit data
0	1	10-bit data
1	0	12-bit data
1	1	Reserved

Table 13-6. External Trigger Channel Select Coding

ETRIGSEL	ETRIGCH3	ETRIGCH2	ETRIGCH1	ETRIGCH0	External trigger source is
0	0	0	0	0	AN0
0	0	0	0	1	AN1
0	0	0	1	0	AN2
0	0	0	1	1	AN3
0	0	1	0	0	AN4
0	0	1	0	1	AN5
0	0	1	1	0	AN6
0	0	1	1	1	AN7
0	1	0	0	0	AN8
0	1	0	0	1	AN9
0	1	0	1	0	AN10
0	1	0	1	1	AN11
0	1	1	0	0	AN12
0	1	1	0	1	AN13
0	1	1	1	0	AN14
0	1	1	1	1	AN15
1	0	0	0	0	ETRIG0 ⁽¹⁾
1	0	0	0	1	ETRIG1 ¹
1	0	0	1	0	ETRIG2 ¹
1	0	0	1	1	ETRIG3 ¹
1	0	1	X	X	Reserved
1	1	X	X	X	Reserved

1. Only if ETRIG3-0 input option is available (see device specification), else ETRIGSEL is ignored, that means external trigger source is still on one of the AD channels selected by ETRIGCH3-0

13.3.2.3 ATD Control Register 2 (ATDCTL2)

Writes to this register will abort current conversion sequence.

Module Base + 0x0002

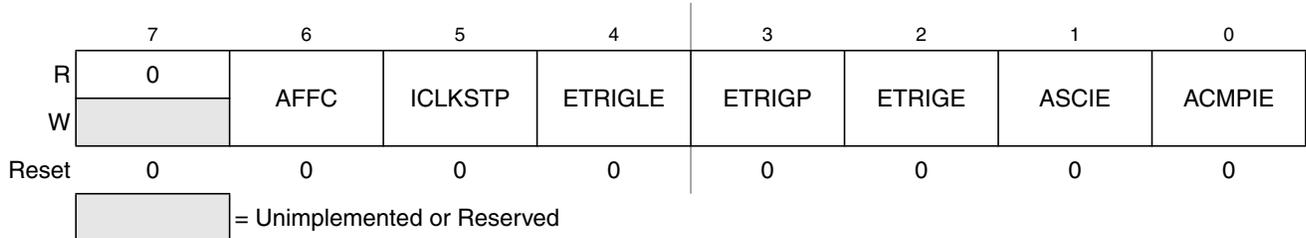


Figure 13-5. ATD Control Register 2 (ATDCTL2)

Read: Anytime

Write: Anytime

Table 13-7. ATDCTL2 Field Descriptions

Field	Description
6 AFFC	ATD Fast Flag Clear All 0 ATD flag clearing done by write 1 to respective CCF[n] flag. 1 Changes all ATD conversion complete flags to a fast clear sequence. For compare disabled (CMPE[n]=0) a read access to the result register will cause the associated CCF[n] flag to clear automatically. For compare enabled (CMPE[n]=1) a write access to the result register will cause the associated CCF[n] flag to clear automatically.
5 ICLKSTP	Internal Clock in Stop Mode Bit — This bit enables A/D conversions in stop mode. When going into stop mode and ICLKSTP=1 the ATD conversion clock is automatically switched to the internally generated clock ICLK. Current conversion sequence will seamless continue. Conversion speed will change from prescaled bus frequency to the ICLK frequency (see ATD Electrical Characteristics in device description). The prescaler bits PRS4-0 in ATDCTL4 have no effect on the ICLK frequency. For conversions during stop mode the automatic compare interrupt or the sequence complete interrupt can be used to inform software handler about changing A/D values. External trigger will not work while converting in stop mode. For conversions during transition from Run to Stop Mode or vice versa the result is not written to the results register, no CCF flag is set and no compare is done. When converting in Stop Mode (ICLKSTP=1) an ATD Stop Recovery time $t_{ATDSTPRCV}$ is required to switch back to bus clock based ATDCLK when leaving Stop Mode. Do not access ATD registers during this time. 0 If A/D conversion sequence is ongoing when going into stop mode, the actual conversion sequence will be aborted and automatically restarted when exiting stop mode. 1 A/D continues to convert in stop mode using internally generated clock (ICLK)
4 ETRIGLE	External Trigger Level/Edge Control — This bit controls the sensitivity of the external trigger signal. See Table 13-8 for details.
3 ETRIGP	External Trigger Polarity — This bit controls the polarity of the external trigger signal. See Table 13-8 for details.
2 ETRIGE	External Trigger Mode Enable — This bit enables the external trigger on one of the AD channels or one of the ETRIG3-0 inputs as described in Table 13-6 . If external trigger source is one of the AD channels, the digital input buffer of this channel is enabled. The external trigger allows to synchronize the start of conversion with external events. External trigger will not work while converting in stop mode. 0 Disable external trigger 1 Enable external trigger

Table 13-7. ATDCTL2 Field Descriptions (continued)

Field	Description
1 ASCIE	ATD Sequence Complete Interrupt Enable 0 ATD Sequence Complete interrupt requests are disabled. 1 ATD Sequence Complete interrupt will be requested whenever SCF=1 is set.
0 ACMPIE	ATD Compare Interrupt Enable — If automatic compare is enabled for conversion <i>n</i> (CMPE[<i>n</i>]=1 in ATDCMPE register) this bit enables the compare interrupt. If the CCF[<i>n</i>] flag is set (showing a successful compare for conversion <i>n</i>), the compare interrupt is triggered. 0 ATD Compare interrupt requests are disabled. 1 For the conversions in a sequence for which automatic compare is enabled (CMPE[<i>n</i>]=1), ATD Compare Interrupt will be requested whenever any of the respective CCF flags is set.

Table 13-8. External Trigger Configurations

ETRIGLE	ETRIGP	External Trigger Sensitivity
0	0	Falling edge
0	1	Rising edge
1	0	Low level
1	1	High level

13.3.2.4 ATD Control Register 3 (ATDCTL3)

Writes to this register will abort current conversion sequence.

Module Base + 0x0003

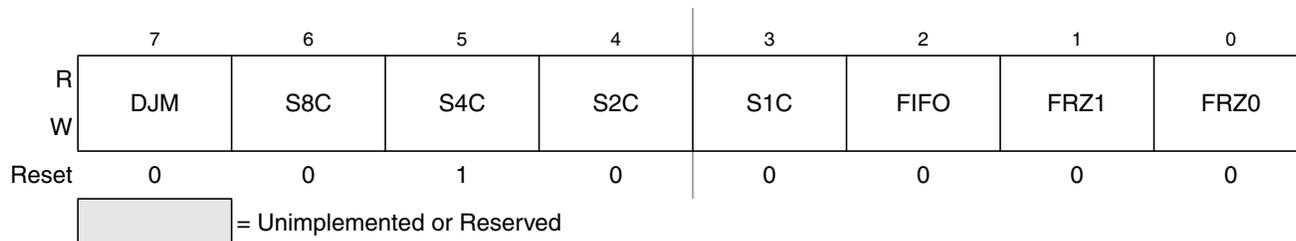


Figure 13-6. ATD Control Register 3 (ATDCTL3)

Read: Anytime

Write: Anytime

Field	Description
7 DJM	Result Register Data Justification — Result data format is always unsigned. This bit controls justification of conversion data in the result registers. 0 Left justified data in the result registers. 1 Right justified data in the result registers. Table 13-10 gives examples ATD results for an input signal range between 0 and 5.12 Volts.

Table 13-9. ATDCTL3 Field Descriptions

Field	Description
6–3 S8C, S4C, S2C, S1C	Conversion Sequence Length — These bits control the number of conversions per sequence. Table 13-11 shows all combinations. At reset, S4C is set to 1 (sequence length is 4). This is to maintain software continuity to HC12 family.
2 FIFO	<p>Result Register FIFO Mode — If this bit is zero (non-FIFO mode), the A/D conversion results map into the result registers based on the conversion sequence; the result of the first conversion appears in the first result register (ATDDR0), the second result in the second result register (ATDDR1), and so on.</p> <p>If this bit is one (FIFO mode) the conversion counter is not reset at the beginning or ending of a conversion sequence; sequential conversion results are placed in consecutive result registers. In a continuously scanning conversion sequence, the result register counter will wrap around when it reaches the end of the result register file. The conversion counter value (CC3-0 in ATDSTAT0) can be used to determine where in the result register file, the current conversion result will be placed.</p> <p>Aborting a conversion or starting a new conversion clears the conversion counter even if FIFO=1. So the first result of a new conversion sequence, started by writing to ATDCTL5, will always be placed in the first result register (ATDDDR0). Intended usage of FIFO mode is continuous conversion (SCAN=1) or triggered conversion (ETRIG=1).</p> <p>Which result registers hold valid data can be tracked using the conversion complete flags. Fast flag clear mode may or may not be useful in a particular application to track valid data.</p> <p>If this bit is one, automatic compare of result registers is always disabled, that is ADC12B16C will behave as if ACMPIE and all CPME[n] were zero.</p> <p>0 Conversion results are placed in the corresponding result register up to the selected sequence length. 1 Conversion results are placed in consecutive result registers (wrap around at end).</p>
1–0 FRZ[1:0]	Background Debug Freeze Enable — When debugging an application, it is useful in many cases to have the ATD pause when a breakpoint (Freeze Mode) is encountered. These 2 bits determine how the ATD will respond to a breakpoint as shown in Table 13-12 . Leakage onto the storage node and comparator reference capacitors may compromise the accuracy of an immediately frozen conversion depending on the length of the freeze period.

Table 13-9. ATDCTL3 Field Descriptions (continued)

Table 13-10. Examples of ideal decimal ATD Results

Input Signal $V_{RL} = 0$ Volts $V_{RH} = 5.12$ Volts	8-Bit Codes (resolution=20mV)	10-Bit Codes (resolution=5mV)	12-Bit Codes (transfer curve has 1.25mV offset) (resolution=1.25mV)
5.120 Volts	255	1023	4095
...
0.022	1	4	17
0.020	1	4	16
0.018	1	4	14
0.016	1	3	12
0.014	1	3	11
0.012	1	2	9
0.010	1	2	8
0.008	0	2	6
0.006	0	1	4
0.004	0	1	3
0.003	0	0	2
0.002	0	0	1
0.000	0	0	0

Table 13-11. Conversion Sequence Length Coding

S8C	S4C	S2C	S1C	Number of Conversions per Sequence
0	0	0	0	16
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	0	0	0	8
1	0	0	1	9
1	0	1	0	10
1	0	1	1	11
1	1	0	0	12
1	1	0	1	13
1	1	1	0	14
1	1	1	1	15

Table 13-12. ATD Behavior in Freeze Mode (Breakpoint)

FRZ1	FRZ0	Behavior in Freeze Mode
0	0	Continue conversion
0	1	Reserved
1	0	Finish current conversion, then freeze
1	1	Freeze Immediately

13.3.2.5 ATD Control Register 4 (ATDCTL4)

Writes to this register will abort current conversion sequence.

Module Base + 0x0004

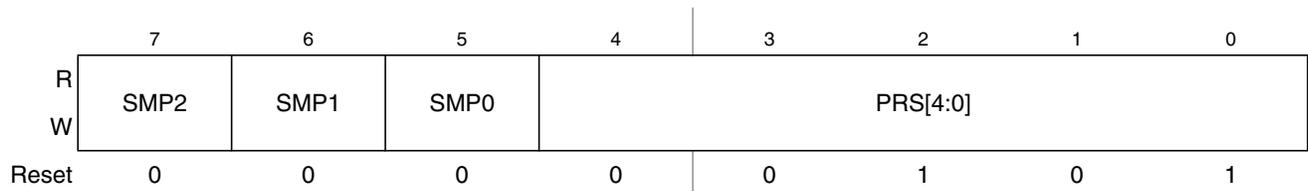


Figure 13-7. ATD Control Register 4 (ATDCTL4)

Read: Anytime

Write: Anytime

Table 13-13. ATDCTL4 Field Descriptions

Field	Description
7–5 SMP[2:0]	Sample Time Select — These three bits select the length of the sample time in units of ATD conversion clock cycles. Note that the ATD conversion clock period is itself a function of the prescaler value (bits PRS4-0). Table 13-14 lists the available sample time lengths.
4–0 PRS[4:0]	ATD Clock Prescaler — These 5 bits are the binary prescaler value PRS. The ATD conversion clock frequency is calculated as follows: $f_{\text{ATDCLK}} = \frac{f_{\text{BUS}}}{2 \times (\text{PRS} + 1)}$ Refer to Device Specification for allowed frequency range of f_{ATDCLK} .

Table 13-14. Sample Time Select

SMP2	SMP1	SMP0	Sample Time in Number of ATD Clock Cycles
0	0	0	4
0	0	1	6
0	1	0	8
0	1	1	10
1	0	0	12
1	0	1	16
1	1	0	20
1	1	1	24

13.3.2.6 ATD Control Register 5 (ATDCTL5)

Writes to this register will abort current conversion sequence and start a new conversion sequence. If external trigger is enabled (ETRIGE=1) an initial write to ATDCTL5 is required to allow starting of a conversion sequence which will then occur on each trigger event. Start of conversion means the beginning of the sampling phase.

Module Base + 0x0005

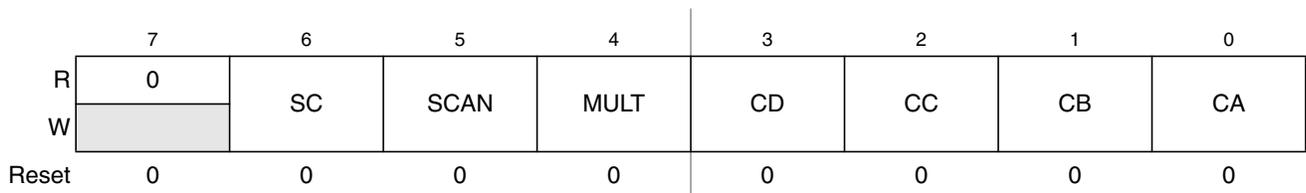


Figure 13-8. ATD Control Register 5 (ATDCTL5)

Read: Anytime

Write: Anytime

Table 13-15. ATDCTL5 Field Descriptions

Field	Description
6 SC	<p>Special Channel Conversion Bit — If this bit is set, then special channel conversion can be selected using CD, CC, CB and CA of ATDCTL5. Table 13-16 lists the coding.</p> <p>0 Special channel conversions disabled 1 Special channel conversions enabled</p>
5 SCAN	<p>Continuous Conversion Sequence Mode — This bit selects whether conversion sequences are performed continuously or only once. If external trigger is enabled (ETRIGE=1) setting this bit has no effect, that means external trigger always starts a single conversion sequence.</p> <p>0 Single conversion sequence 1 Continuous conversion sequences (scan mode)</p>
4 MULT	<p>Multi-Channel Sample Mode — When MULT is 0, the ATD sequence controller samples only from the specified analog input channel for an entire conversion sequence. The analog channel is selected by channel selection code (control bits CD/CC/CB/CA located in ATDCTL5). When MULT is 1, the ATD sequence controller samples across channels. The number of channels sampled is determined by the sequence length value (S8C, S4C, S2C, S1C). The first analog channel examined is determined by channel selection code (CD, CC, CB, CA control bits); subsequent channels sampled in the sequence are determined by incrementing the channel selection code or wrapping around to AN0 (channel 0).</p> <p>0 Sample only one channel 1 Sample across several channels</p>
3–0 CD, CC, CB, CA	<p>Analog Input Channel Select Code — These bits select the analog input channel(s) whose signals are sampled and converted to digital codes. Table 13-16 lists the coding used to select the various analog input channels.</p> <p>In the case of single channel conversions (MULT=0), this selection code specifies the channel to be examined.</p> <p>In the case of multiple channel conversions (MULT=1), this selection code specifies the first channel to be examined in the conversion sequence. Subsequent channels are determined by incrementing the channel selection code or wrapping around to AN0 (after converting the channel defined by the Wrap Around Channel Select Bits WRAP3-0 in ATDCTL0). In case of starting with a channel number higher than the one defined by WRAP3-0 the first wrap around will be AN15 to AN0.</p>

Table 13-16. Analog Input Channel Select Coding

SC	CD	CC	CB	CA	Analog Input Channel
0	0	0	0	0	AN0
	0	0	0	1	AN1
	0	0	1	0	AN2
	0	0	1	1	AN3
	0	1	0	0	AN4
	0	1	0	1	AN5
	0	1	1	0	AN6
	0	1	1	1	AN7
	1	0	0	0	AN8
	1	0	0	1	AN9
	1	0	1	0	AN10
	1	0	1	1	AN11
	1	1	0	0	AN12
	1	1	0	1	AN13
	1	1	1	0	AN14
1	1	1	1	AN15	
1	0	0	0	0	Reserved
	0	0	0	1	Reserved
	0	0	1	X	Reserved
	0	1	0	0	V_{RH}
	0	1	0	1	V_{RL}
	0	1	1	0	$(V_{RH}+V_{RL}) / 2$
	0	1	1	1	Reserved
	1	X	X	X	Reserved

13.3.2.7 ATD Status Register 0 (ATDSTAT0)

This register contains the Sequence Complete Flag, overrun flags for external trigger and FIFO mode, and the conversion counter.

Module Base + 0x0006

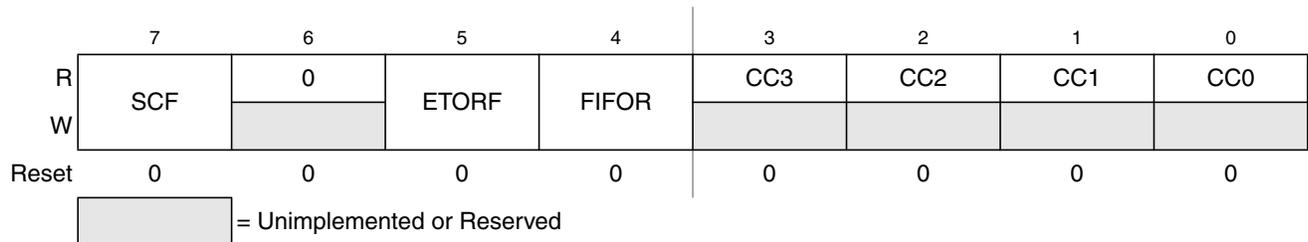


Figure 13-9. ATD Status Register 0 (ATDSTAT0)

Read: Anytime

Write: Anytime (No effect on (CC3, CC2, CC1, CC0))

Table 13-17. ATDSTAT0 Field Descriptions

Field	Description
7 SCF	<p>Sequence Complete Flag — This flag is set upon completion of a conversion sequence. If conversion sequences are continuously performed (SCAN=1), the flag is set after each one is completed. This flag is cleared when one of the following occurs:</p> <ul style="list-style-type: none"> A) Write “1” to SCF B) Write to ATDCTL5 (a new conversion sequence is started) C) If AFFC=1 and read of a result register <p>0 Conversion sequence not completed 1 Conversion sequence has completed</p>
5 ETORF	<p>External Trigger Overrun Flag — While in edge trigger mode (ETRIGLE=0), if additional active edges are detected while a conversion sequence is in process the overrun flag is set. This flag is cleared when one of the following occurs:</p> <ul style="list-style-type: none"> A) Write “1” to ETORF B) Write to ATDCTL0,1,2,3,4, ATDCMPE or ATDCMPHT (a conversion sequence is aborted) C) Write to ATDCTL5 (a new conversion sequence is started) <p>0 No External trigger over run error has occurred 1 External trigger over run error has occurred</p>
4 FIFOR	<p>Result Register Over Run Flag — This bit indicates that a result register has been written to before its associated conversion complete flag (CCF) has been cleared. This flag is most useful when using the FIFO mode because the flag potentially indicates that result registers are out of sync with the input channels. However, it is also practical for non-FIFO modes, and indicates that a result register has been over written before it has been read (i.e. the old data has been lost). This flag is cleared when one of the following occurs:</p> <ul style="list-style-type: none"> A) Write “1” to FIFOR B) Write to ATDCTL0,1,2,3,4, ATDCMPE or ATDCMPHT (a conversion sequence is aborted) C) Write to ATDCTL5 (a new conversion sequence is started) <p>0 No over run has occurred 1 Overrun condition exists (result register has been written while associated CCFx flag was still set)</p>
3–0 CC[3:0]	<p>Conversion Counter — These 4 read-only bits are the binary value of the conversion counter. The conversion counter points to the result register that will receive the result of the current conversion. E.g. CC3=0, CC2=1, CC1=1, CC0=0 indicates that the result of the current conversion will be in ATD Result Register 6. If in non-FIFO mode (FIFO=0) the conversion counter is initialized to zero at the begin and end of the conversion sequence. If in FIFO mode (FIFO=1) the register counter is not initialized. The conversion counters wraps around when its maximum value is reached.</p> <p>Aborting a conversion or starting a new conversion clears the conversion counter even if FIFO=1.</p>

13.3.2.8 ATD Compare Enable Register (ATDCMPE)

Writes to this register will abort current conversion sequence.

Read: Anytime

Write: Anytime

Module Base + 0x0008

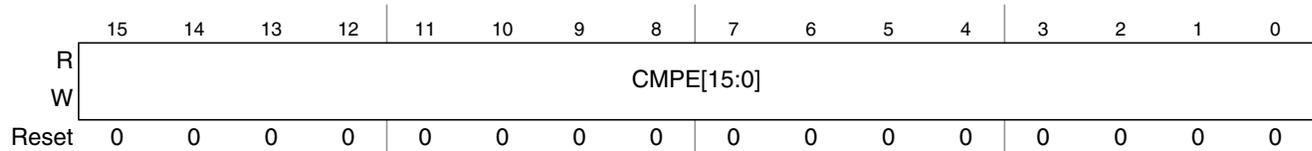


Figure 13-10. ATD Compare Enable Register (ATDCMPE)

Table 13-18. ATDCMPE Field Descriptions

Field	Description
15–0 CMPE[15:0]	<p>Compare Enable for Conversion Number n ($n= 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0$) of a Sequence</p> <p>— These bits enable automatic compare of conversion results individually for conversions of a sequence. The sense of each comparison is determined by the CMPHT[n] bit in the ATDCMPHT register.</p> <p>For each conversion number with CMPE[n]=1 do the following:</p> <ol style="list-style-type: none"> 1) Write compare value to ATDDRn result register 2) Write compare operator with CMPHT[n] in ATDCPMHT register <p>CCF[n] in ATDSTAT2 register will flag individual success of any comparison.</p> <p>0 No automatic compare 1 Automatic compare of results for conversion n of a sequence is enabled.</p>

13.3.2.9 ATD Status Register 2 (ATDSTAT2)

This read-only register contains the Conversion Complete Flags CCF[15:0].

Module Base + 0x000A

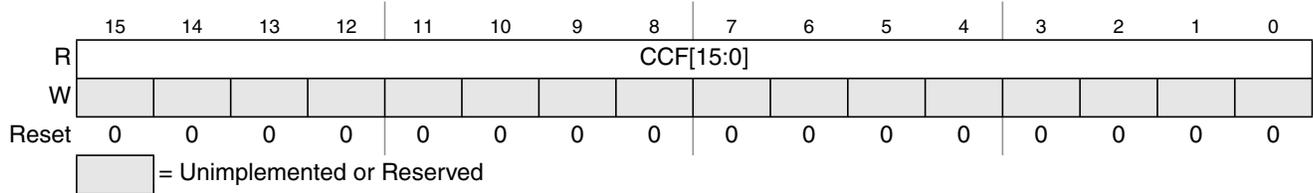


Figure 13-11. ATD Status Register 2 (ATDSTAT2)

Read: Anytime

Write: Anytime, no effect

Table 13-19. ATDSTAT2 Field Descriptions

Field	Description
15–0 CCF[15:0]	<p>Conversion Complete Flag n ($n= 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0$) — A conversion complete flag is set at the end of each conversion in a sequence. The flags are associated with the conversion position in a sequence (and also the result register number). Therefore in non-fifo mode, CCF[8] is set when the ninth conversion in a sequence is complete and the result is available in result register ATDDR8; CCF[9] is set when the tenth conversion in a sequence is complete and the result is available in ATDDR9, and so forth.</p> <p>If automatic compare of conversion results is enabled (CMPE[n]=1 in ATDCMPE), the conversion complete flag is only set if comparison with ATDDRn is true and if ACMPIE=1 a compare interrupt will be requested. In this case, as the ATDDRn result register is used to hold the compare value, the result will not be stored there at the end of the conversion but is lost.</p> <p>A flag CCF[n] is cleared when one of the following occurs:</p> <ul style="list-style-type: none"> A) Write to ATDCTL5 (a new conversion sequence is started) B) If AFFC=0, write “1” to CCF[n] C) If AFFC=1 and CMPE[n]=0, read of result register ATDDRn D) If AFFC=1 and CMPE[n]=1, write to result register ATDDRn <p>In case of a concurrent set and clear on CCF[n]: The clearing by method A) will overwrite the set. The clearing by methods B) or C) or D) will be overwritten by the set.</p> <ul style="list-style-type: none"> 0 Conversion number n not completed or successfully compared 1 If (CMPE[n]=0): Conversion number n has completed. Result is ready in ATDDRn. <p>If (CMPE[n]=1): Compare for conversion result number n with compare value in ATDDRn, using compare operator CMPGT[n] is true. (No result available in ATDDRn)</p>

13.3.2.10 ATD Input Enable Register (ATDDIEN)

Module Base + 0x000C

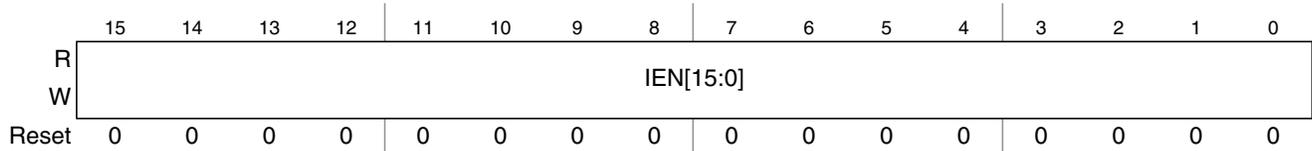


Figure 13-12. ATD Input Enable Register (ATDDIEN)

Read: Anytime

Write: Anytime

Table 13-20. ATDDIEN Field Descriptions

Field	Description
15–0 IEN[15:0]	<p>ATD Digital Input Enable on channel x ($x= 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0$) — This bit controls the digital input buffer from the analog input pin (ANx) to the digital data register.</p> <p>0 Disable digital input buffer to ANx pin 1 Enable digital input buffer on ANx pin.</p> <p>Note: Setting this bit will enable the corresponding digital input buffer continuously. If this bit is set while simultaneously using it as an analog port, there is potentially increased power consumption because the digital input buffer maybe in the linear region.</p>

13.3.2.11 ATD Compare Higher Than Register (ATDCMPHT)

Writes to this register will abort current conversion sequence.

Read: Anytime

Write: Anytime

Module Base + 0x000E

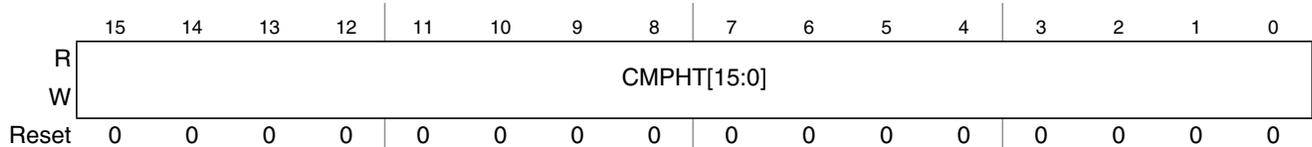


Figure 13-13. ATD Compare Higher Than Register (ATDCMPHT)

Table 13-21. ATDCMPHT Field Descriptions

Field	Description
15–0 CMPHT[15:0]	<p>Compare Operation Higher Than Enable for conversion number n ($n= 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0$) of a Sequence — This bit selects the operator for comparison of conversion results.</p> <p>0 If result of conversion n is lower or same than compare value in ATDDRn, this is flagged in ATDSTAT2 1 If result of conversion n is higher than compare value in ATDDRn, this is flagged in ATDSTAT2</p>

13.3.2.12 ATD Conversion Result Registers (ATDDR n)

The A/D conversion results are stored in 16 result registers. Results are always in unsigned data representation. Left and right justification is selected using the DJM control bit in ATDCTL3.

If automatic compare of conversions results is enabled (CMPE[n]=1 in ATDCMPE), these registers must be written with the compare values in left or right justified format depending on the actual value of the DJM bit. In this case, as the ATDDR n register is used to hold the compare value, the result will not be stored there at the end of the conversion but is lost.

Read: Anytime

Write: Anytime

NOTE

For conversions not using automatic compare, results are stored in the result registers after each conversion. In this case avoid writing to ATDDR n except for initial values, because an A/D result might be overwritten.

13.3.2.12.1 Left Justified Result Data (DJM=0)

Module Base +

0x0010 = ATDDR0, 0x0012 = ATDDR1, 0x0014 = ATDDR2, 0x0016 = ATDDR3

0x0018 = ATDDR4, 0x001A = ATDDR5, 0x001C = ATDDR6, 0x001E = ATDDR7

0x0020 = ATDDR8, 0x0022 = ATDDR9, 0x0024 = ATDDR10, 0x0026 = ATDDR11

0x0028 = ATDDR12, 0x002A = ATDDR13, 0x002C = ATDDR14, 0x002E = ATDDR15

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	0	0	0	0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 13-14. Left justified ATD conversion result register (ATDDR n)

13.3.2.12.2 Right Justified Result Data (DJM=1)

Module Base +

0x0010 = ATDDR0, 0x0012 = ATDDR1, 0x0014 = ATDDR2, 0x0016 = ATDDR3

0x0018 = ATDDR4, 0x001A = ATDDR5, 0x001C = ATDDR6, 0x001E = ATDDR7

0x0020 = ATDDR8, 0x0022 = ATDDR9, 0x0024 = ATDDR10, 0x0026 = ATDDR11

0x0028 = ATDDR12, 0x002A = ATDDR13, 0x002C = ATDDR14, 0x002E = ATDDR15

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0	0	0	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 13-15. Right justified ATD conversion result register (ATDDR n)

Table 13-16 shows how depending on the A/D resolution the conversion result is transferred to the ATD result registers. Compare is always done using all 12 bits of both the conversion result and the compare value in ATDDR n .

Table 13-22. Conversion result mapping to ATDDRn

A/D resolution	DJM	conversion result mapping to ATDDRn
8-bit data	0	Bit[11:4] = result, Bit[3:0]=0000
8-bit data	1	Bit[7:0] = result, Bit[11:8]=0000
10-bit data	0	Bit[11:2] = result, Bit[1:0]=00
10-bit data	1	Bit[9:0] = result, Bit[11:10]=00
12-bit data	X	Bit[11:0] = result

13.4 Functional Description

The ADC12B16C is structured into an analog sub-block and a digital sub-block.

13.4.1 Analog Sub-Block

The analog sub-block contains all analog electronics required to perform a single conversion. Separate power supplies V_{DDA} and V_{SSA} allow to isolate noise of other MCU circuitry from the analog sub-block.

13.4.1.1 Sample and Hold Machine

The Sample and Hold (S/H) Machine accepts analog signals from the external world and stores them as capacitor charge on a storage node.

During the sample process the analog input connects directly to the storage node.

The input analog signals are unipolar and must fall within the potential range of V_{SSA} to V_{DDA} .

During the hold process the analog input is disconnected from the storage node.

13.4.1.2 Analog Input Multiplexer

The analog input multiplexer connects one of the 16 external analog input channels to the sample and hold machine.

13.4.1.3 Analog-to-Digital (A/D) Machine

The A/D Machine performs analog to digital conversions. The resolution is program selectable at either 8 or 10 or 12 bits. The A/D machine uses a successive approximation architecture. It functions by comparing the stored analog sample potential with a series of digitally generated analog potentials. By following a binary search algorithm, the A/D machine locates the approximating potential that is nearest to the sampled potential.

When not converting the A/D machine is automatically powered down.

Only analog input signals within the potential range of V_{RL} to V_{RH} (A/D reference potentials) will result in a non-railed digital output code.

13.4.2 Digital Sub-Block

This subsection explains some of the digital features in more detail. See [Section 13.3.2, “Register Descriptions”](#) for all details.

13.4.2.1 External Trigger Input

The external trigger feature allows the user to synchronize ATD conversions to the external environment events rather than relying on software to signal the ATD module when ATD conversions are to take place. The external trigger signal (out of reset ATD channel 15, configurable in ATDCTL1) is programmable to be edge or level sensitive with polarity control. [Table 13-23](#) gives a brief description of the different combinations of control bits and their effect on the external trigger function.

Table 13-23. External Trigger Control Bits

ETRIGLE	ETRIGP	ETRIGE	SCAN	Description
X	X	0	0	Ignores external trigger. Performs one conversion sequence and stops.
X	X	0	1	Ignores external trigger. Performs continuous conversion sequences.
0	0	1	X	Falling edge triggered. Performs one conversion sequence per trigger.
0	1	1	X	Rising edge triggered. Performs one conversion sequence per trigger.
1	0	1	X	Trigger active low. Performs continuous conversions while trigger is active.
1	1	1	X	Trigger active high. Performs continuous conversions while trigger is active.

During a conversion, if additional active edges are detected the overrun error flag ETORF is set.

In either level or edge triggered modes, the first conversion begins when the trigger is received.

Once ETRIGE is enabled, conversions cannot be started by a write to ATDCTL5, but rather must be triggered externally.

If the level mode is active and the external trigger both de-asserts and re-asserts itself during a conversion sequence, this does not constitute an overrun. Therefore, the flag is not set. If the trigger is left asserted in level mode while a sequence is completing, another sequence will be triggered immediately.

13.4.2.2 General-Purpose Digital Port Operation

The input channel pins can be multiplexed between analog and digital data. As analog inputs, they are multiplexed and sampled as analog channels to the A/D converter. The analog/digital multiplex operation is performed in the input pads. The input pad is always connected to the analog input channels of the ADC12B16C. The input pad signal is buffered to the digital port registers. This buffer can be turned on or off with the ATDDIEN register. This is important so that the buffer does not draw excess current when analog potentials are presented at its input.

13.5 Resets

At reset the ADC12B16C is in a power down state. The reset state of each individual bit is listed within the Register Description section (see [Section 13.3.2, “Register Descriptions”](#)) which details the registers and their bit-field.

13.6 Interrupts

The interrupts requested by the ADC12B16C are listed in [Table 13-24](#). Refer to MCU specification for related vector address and priority.

Table 13-24. ATD Interrupt Vectors

Interrupt Source	CCR Mask	Local Enable
Sequence Complete Interrupt	1 bit	ASCIE in ATDCTL2
Compare Interrupt	1 bit	ACMPIE in ATDCTL2

See [Section 13.3.2, “Register Descriptions”](#) for further details.