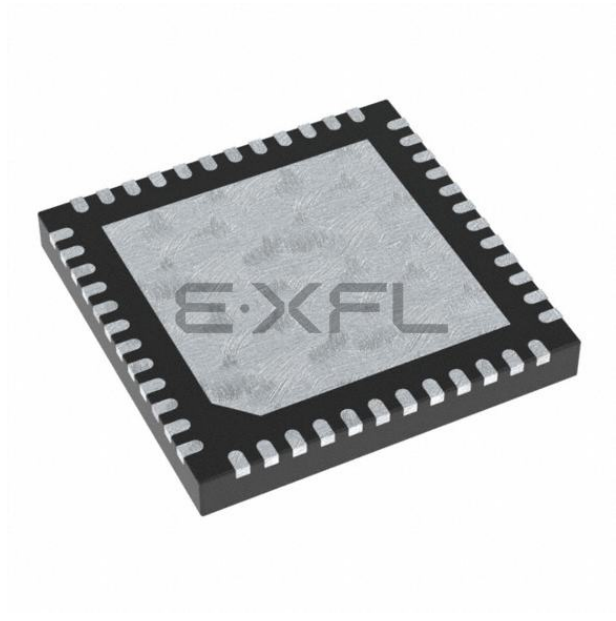

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Applications of "Embedded - Microcontrollers"

Details	
Product Status	Active
Core Processor	ARM® Cortex®-M0+
Core Size	32-Bit Single-Core
Speed	48MHz
Connectivity	I²C, LINbus, SPI, UART/USART
Peripherals	Brown-out Detect/Reset, DMA, POR, WDT
Number of I/O	38
Program Memory Size	256KB (256K x 8)
Program Memory Type	FLASH
EEPROM Size	-
RAM Size	32K x 8
Voltage - Supply (Vcc/Vdd)	2.7V ~ 5.5V
Data Converters	A/D 12x12b
Oscillator Type	Internal
Operating Temperature	-40°C ~ 85°C (TA)
Mounting Type	Surface Mount
Package / Case	48-VFQFN Exposed Pad
Supplier Device Package	48-QFN (7x7)
Purchase URL	https://www.e-xfl.com/product-detail/microchip-technology/atsamc20g18a-mut

6. I/O Multiplexing and Considerations

6.1 Multiplexed Signals

Each pin is by default controlled by the PORT as a general purpose I/O and alternatively it can be assigned to one of the peripheral functions A, B, C, D, E, F, G, H, or I. To enable a peripheral function on a pin, the Peripheral Multiplexer Enable bit in the Pin Configuration register corresponding to that pin (PINCFGn.PMUXEN, n = 0-31) in the PORT must be written to one. The selection of peripheral function A to H is done by writing to the Peripheral Multiplexing Odd and Even bits in the Peripheral Multiplexing register (PMUXn.PMUXE/O) in the PORT.

Table 6-1. PORT Function Multiplexing for SAM C21 N

Pin	I/O Pin	Supply	A		B			B[1][2]			C	D	E	F	G	H	I
			EIC	REF	ADC0	ADC1	SDADC	AC	PTC	DAC	SERCOM	SERCOM-ALT	TC	TCC	COM	AC/GCLK	CCL
1	PA00	VDDANA	EXTINT[0]									SERCOM1/PAD[0]	TC2/WO[0]			CMP[2]	
2	PA01	VDDANA	EXTINT[1]									SERCOM1/PAD[1]	TC2/WO[1]			CMP[3]	
3	PC00	VDDANA	EXTINT[8]		AIN[8]												
4	PC01	VDDANA	EXTINT[9]		AIN[9]												
5	PC02	VDDANA	EXTINT[10]		AIN[10]												
6	PC03	VDDIO	EXTINT[11]		AIN[11]						SERCOM7/PAD[0]			TCC2/WO[0]			
7	PA02	VDDANA	EXTINT[2]		AIN[0]			AIN[4]	Y[0]	VOUT							
8	PA03	VDDANA	EXTINT[3]	ADC/VREFA DAC/VREFB	AIN[1]				Y[1]								
9	PB04	VDDANA	EXTINT[4]			AIN[6]		AIN[5]	Y[10]								
10	PB05	VDDANA	EXTINT[5]			AIN[7]		AIN[6]	Y[11]								
13	PB06	VDDIO	EXTINT[6]			AIN[8]	INN[2]	AIN[7]	Y[12]		SERCOM7/PAD[1]						CCL2/IN[6]
14	PB07	VDDIO	EXTINT[7]			AIN[9]	INP[2]		Y[13]		SERCOM7/PAD[3]	SERCOM7/PAD[2]					CCL2/IN[7]
15	PB08	VDDIO	EXTINT[8]		AIN[2]	AIN[4]	INN[1]		Y[14]		SERCOM7/PAD[2]	SERCOM7/PAD[3]	TC4/WO[0]				CCL2/IN[8]
16	PB09	VDDANA	EXTINT[9]		AIN[3]	AIN[5]	INP[1]		Y[15]			SERCOM4/PAD[1]	TC4/WO[1]				CCL2/OUT[2]
17	PA04	VDDANA	EXTINT[4]	SDADC/VREFB	AIN[4]			AIN[0]	Y[2]			SERCOM0/PAD[0]	TC0/WO[0]				CCL0/IN[0]
18	PA05	VDDANA	EXTINT[5]		AIN[5]			AIN[1]	Y[3]			SERCOM0/PAD[1]	TC0/WO[1]				CCL0/IN[1]
19	PA06	VDDANA	EXTINT[6]		AIN[6]		INN[0]	AIN[2]	Y[4]			SERCOM0/PAD[2]	TC1/WO[0]				CCL0/IN[2]
20	PA07	VDDANA	EXTINT[7]		AIN[7]		INP[0]	AIN[3]	Y[5]			SERCOM0/PAD[3]	TC1/WO[1]				CCL0/OUT[0]
21	PC05	VDDANA	EXTINT[13]								SERCOM6/PAD[3]			TCC2/WO[1]			
22	PC06	VDDANA	EXTINT[14]								SERCOM6/PAD[0]						
23	PC07	VDDANA	EXTINT[15]								SERCOM6/PAD[1]						
26	PA08	VDDIO	NMI			AIN[10]			X[0]/Y[16]		SERCOM0/PAD[0]	SERCOM2/PAD[0]	TC0/WO[0]	TCC0/WO[0]			CCL1/IN[3]
27	PA09	VDDIO	EXTINT[9]			AIN[11]			X[1]/Y[17]		SERCOM0/PAD[1]	SERCOM2/PAD[1]	TC0/WO[1]	TCC0/WO[1]			CCL1/IN[4]
28	PA10	VDDIO	EXTINT[10]						X[2]/Y[18]		SERCOM0/PAD[2]	SERCOM2/PAD[2]	TC1/WO[0]	TCC0/WO[2]		GCLK_IO[4]	CCL1/IN[5]
29	PA11	VDDIO	EXTINT[11]						X[3]/Y[19]		SERCOM0/PAD[3]	SERCOM2/PAD[3]	TC1/WO[1]	TCC0/WO[3]		GCLK_IO[5]	CCL1/OUT[1]
30	PB10	VDDIO	EXTINT[10]									SERCOM4/PAD[2]	TC5/WO[0]	TCC0_WO4		GCLK_IO[4]	CCL1/IN[5]
31	PB11	VDDIO	EXTINT[11]									SERCOM4/PAD[3]	TC5/WO[1]	TCC0_WO5		GCLK_IO[5]	CCL1/OUT[1]
32	PB12	VDDIO	EXTINT[12]						X[12]/Y[28]		SERCOM4/PAD[0]		TC4/WO[0]	TCC0_WO6	CAN1/TX	GCLK_IO[6]	
33	PB13	VDDIO	EXTINT[13]						X[13]/Y[29]		SERCOM4/PAD[1]		TC4/WO[1]	TCC0_WO7	CAN1/RX	GCLK_IO[7]	
34	PB14	VDDIO	EXTINT[14]						X[14]/Y[30]		SERCOM4/PAD[2]		TC5/WO[0]		CAN1/TX	GCLK_IO[0]	CCL3/IN[9]
35	PB15	VDDIO	EXTINT[15]						X[15]/Y[31]		SERCOM4/PAD[3]		TC5/WO[1]		CAN1/RX	GCLK_IO[1]	CCL3/IN[10]
38	PC08	VDDIO	EXTINT[0]								SERCOM6/PAD[0]	SERCOM7/PAD[0]					
39	PC09	VDDIO	EXTINT[1]								SERCOM6/PAD[1]	SERCOM7/PAD[1]					
40	PC10	VDDIO	EXTINT[2]								SERCOM6/PAD[2]	SERCOM7/PAD[2]					
41	PC11	VDDIO	EXTINT[3]								SERCOM6/PAD[3]	SERCOM7/PAD[3]					
42	PC12	VDDIO	EXTINT[4]								SERCOM7/PAD[0]						
43	PC13	VDDIO	EXTINT[5]								SERCOM7/PAD[1]						
44	PC14	VDDIO	EXTINT[6]								SERCOM7/PAD[2]						
45	PC15	VDDIO	EXTINT[7]								SERCOM7/PAD[3]						
46	PA12	VDDIO	EXTINT[12]								SERCOM2/PAD[0]	SERCOM4/PAD[0]	TC2/WO[0]	TCC0_WO6		CMP[0]	
47	PA13	VDDIO	EXTINT[13]								SERCOM2/PAD[1]	SERCOM4/PAD[1]	TC2/WO[1]	TCC0_WO7		CMP[1]	
48	PA14	VDDIO	EXTINT[14]								SERCOM2/PAD[2]	SERCOM4/PAD[2]	TC3/WO[0]			GCLK_IO[0]	
49	PA15	VDDIO	EXTINT[15]								SERCOM2/PAD[3]	SERCOM4/PAD[3]	TC3/WO[1]			GCLK_IO[1]	
52	PA16	VDDIO	EXTINT[0]						X[4]/Y[20]		SERCOM1/PAD[0]	SERCOM3/PAD[0]	TC2/WO[0]	TCC1/WO[0]		GCLK_IO[2]	CCL0/IN[0]
53	PA17	VDDIO	EXTINT[1]						X[5]/Y[21]		SERCOM1/PAD[1]	SERCOM3/PAD[1]	TC2/WO[1]	TCC1/WO[1]		GCLK_IO[3]	CCL0/IN[1]
54	PA18	VDDIO	EXTINT[2]						X[6]/Y[22]		SERCOM1/PAD[2]	SERCOM3/PAD[2]	TC3/WO[0]	TCC1/WO[2]		CMP[0]	CCL0/IN[2]
55	PA19	VDDIO	EXTINT[3]						X[7]/Y[23]		SERCOM1/PAD[3]	SERCOM3/PAD[3]	TC3/WO[1]	TCC1/WO[3]		CMP[1]	CCL0/OUT[0]
56	PC16	VDDIO	EXTINT[8]								SERCOM6/PAD[0]						
57	PC17	VDDIO	EXTINT[9]								SERCOM6/PAD[1]						
58	PC18	VDDIO	EXTINT[10]								SERCOM6/PAD[2]						

Bit	31	30	29	28	27	26	25	24
	DATA[31:24]							
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	0	0	0	0	0	0	0	0

Bit	23	22	21	20	19	18	17	16
	DATA[23:16]							
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8
	DATA[15:8]							
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	0	0	0	0	0	0	0	0

Bit	7	6	5	4	3	2	1	0
	DATA[7:0]							
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	0	0	0	0	0	0	0	0

Bits 31:0 – DATA[31:0]: Data
Data register.

13.13.8 Debug Communication Channel 1

Name: DCC1
Offset: 0x0014 [ID-00001c14]
Reset: 0x00000000
Property: -

When the Wake Up Fast bit (DPLLCTRLB.WUF) is set, the wake up fast mode is activated. In this mode the clock gating cell is enabled at the end of the startup time. At this time the final frequency is not stable, as it is still during the acquisition period, but it allows to save several milliseconds. After first acquisition, the Lock Bypass bit (DPLLCTRLB.LBYPASS) indicates if the lock signal is discarded from the control of the clock gater (CG) generating the output clock CLK_DPLL.

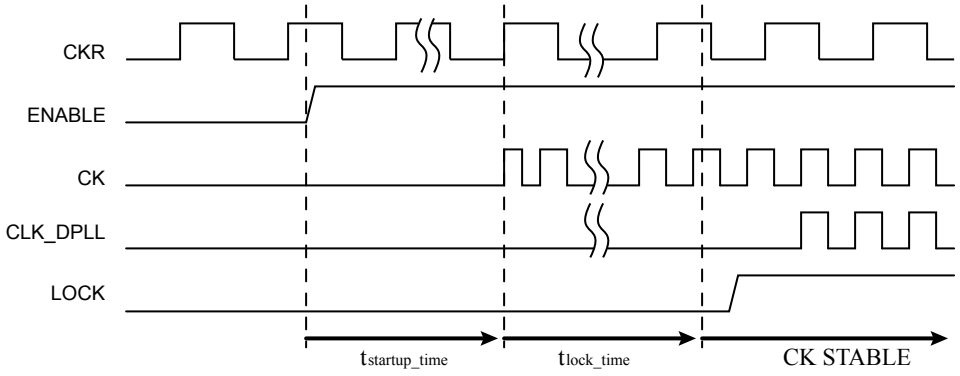
Table 20-3. CLK_DPLL Behavior from Startup to First Edge Detection

WUF	LTIME	CLK_DPLL Behavior
0	0	Normal Mode: First Edge when lock is asserted
0	Not Equal To Zero	Lock Timer Timeout mode: First Edge when the timer down-counts to 0.
1	X	Wake Up Fast Mode: First Edge when CK is active (startup time)

Table 20-4. CLK_DPLL Behavior after First Edge Detection

LBYPASS	CLK_DPLL Behavior
0	Normal Mode: the CLK_DPLL is turned off when lock signal is low.
1	Lock Bypass Mode: the CLK_DPLL is always running, lock is irrelevant.

Figure 20-4. CK and CLK_DPLL Output from DPLL Off Mode to Running Mode



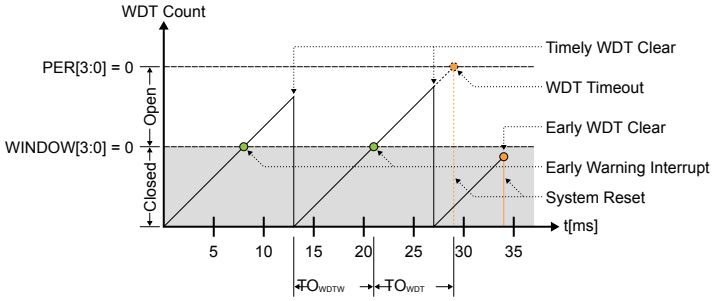
Reference Clock Switching

When a software operation requires reference clock switching, the recommended procedure is to turn the DPLL into the standby mode, modify the DPLLCTRLB.REFCLK to select the desired reference source, and activate the DPLL again.

Output Clock Prescaler

The DPLL controller includes an output prescaler. This prescaler provides three selectable output clocks CK, CKDIV2 and CKDIV4. The Prescaler bit field in the DPLL Prescaler register (DPLLPRESC.PRESC) is used to select a new output clock prescaler. When the prescaler field is modified, the DPLLSYNCBUSY.DPLLPRESC bit is set. It will be cleared by hardware when the synchronization is over.

Figure 23-3. Window-Mode Operation



23.6.3 DMA Operation

Not applicable.

23.6.4 Interrupts

The WDT has the following interrupt source:

- Early Warning (EW): Indicates that the counter is approaching the time-out condition.
  - This interrupt is an asynchronous wake-up source.

Each interrupt source has an interrupt flag associated with it. The interrupt flag in the Interrupt Flag Status and Clear (INTFLAG) register is set when the interrupt condition occurs.

Each interrupt can be individually enabled by writing a '1' to the corresponding bit in the Interrupt Enable Set (INTENSET) register, and disabled by writing a '1' to the corresponding bit in the Interrupt Enable Clear (INTENCLR) register.

An interrupt request is generated when the interrupt flag is set and the corresponding interrupt is enabled. The interrupt request remains active until the interrupt flag is cleared, the interrupt is disabled, or the WDT is reset. See the INTFLAG register description for details on how to clear interrupt flags. All interrupt requests from the peripheral are ORed together on system level to generate one combined interrupt request to the NVIC. The user must read the INTFLAG register to determine which interrupt condition is present.

Note: Interrupts must be globally enabled for interrupt requests to be generated.

Related Links

Nested Vector Interrupt Controller

Overview

Interrupt Line Mapping

PM – Power Manager

Sleep Mode Controller

23.6.5 Events

Not applicable.

23.6.6 Sleep Mode Operation

Related Links

CTRLA

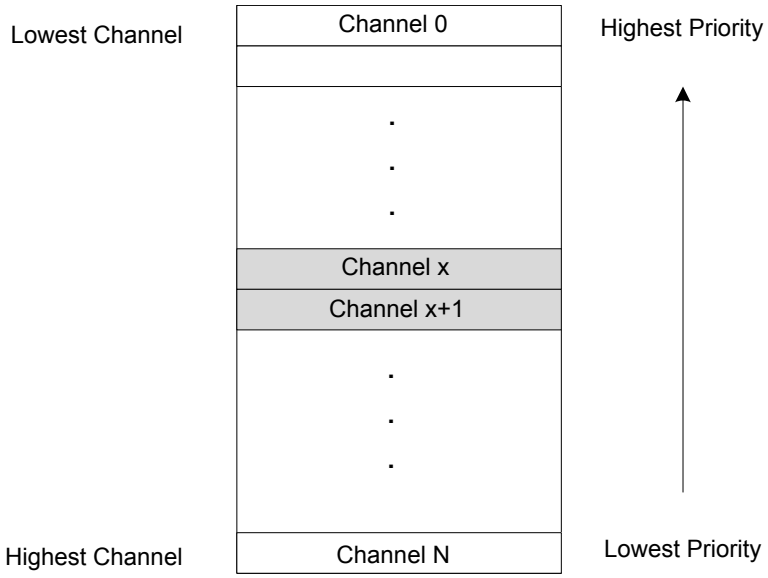
Each DMA channel supports a 4-level priority scheme. The priority level for a channel is configured by writing to the Channel Arbitration Level bit group in the Channel Control B register (CHCTRLB.LVL). As long as all priority levels are enabled, a channel with a higher priority level number will have priority over a channel with a lower priority level number. Each priority level x is enabled by setting the corresponding Priority Level x Enable bit in the Control register (CTRL.LVLENx=1).

Within each priority level the DMAC's arbiter can be configured to prioritize statically or dynamically:

Static Arbitration within a priority level is selected by writing a '0' to the Level x Round-Robin Scheduling Enable bit in the Priority Control 0 register (PRICTRL0.RRLVLENx).

When static arbitration is selected, the arbiter will prioritize a low channel number over a high channel number as shown in the figure below. When using the static arbitration there is a risk of high channel numbers never being granted access as the active channel. This can be avoided using a dynamic arbitration scheme.

Figure 25-5. Static Priority Scheduling



Dynamic Arbitration within a priority level is selected by writing a '1' to PRICTRL0.RRLVLENx.

The dynamic arbitration scheme in the DMAC is round-robin. With the round-robin scheme, the channel number of the last channel being granted access will have the lowest priority the next time the arbiter has to grant access to a channel within the same priority level, as shown in Figure 25-6. The channel number of the last channel being granted access as the active channel is stored in the Level x Channel Priority Number bit group in the Priority Control 0 register (PRICTRL0.LVLPRIx) for the corresponding priority level.

Bit	31	30	29	28	27	26	25	24
	EXTINT[31:24]							
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	0	0	0	0	0	0	0	0

Bit	23	22	21	20	19	18	17	16
	EXTINT[23:16]							
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8
	EXTINT[15:8]							
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	0	0	0	0	0	0	0	0

Bit	7	6	5	4	3	2	1	0
	EXTINT[7:0]							
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	0	0	0	0	0	0	0	0

Bits 31:0 – EXTINT[31:0]: External Interrupt Enable
The bit x of EXTINT enables the interrupt associated with the EXTINTx pin.

Writing a '0' to bit x has no effect.

Writing a '1' to bit x will clear the External Interrupt Enable bit x, which disables the external interrupt EXTINTx.

Value	Description
0	The external interrupt x is disabled.
1	The external interrupt x is enabled.

26.8.7 Interrupt Enable Set

This register allows the user to enable an interrupt without doing a read-modify-write operation. Changes in this register will also be reflected in the Interrupt Enable Clear (INTENCLR) register.

Name: INTENSET
Offset: 0x10
Reset: 0x00000000
Property: PAC Write-Protection

Value	Name	Description
0x2	CLR	Clear output register of pin on event.
0x3	TGL	Toggle output register of pin on event.

Table 28-5. PORT Event x Pin Identifier (x = [3..0])

Value	Name	Description
0x0	PIN0	Event action to be executed on PIN 0.
0x1	PIN1	Event action to be executed on PIN 1.
...	...	...
0x31	PIN31	Event action to be executed on PIN 31.

28.9.13 Peripheral Multiplexing n

Tip: The I/O pins are assembled in pin groups (”PORT groups”) with up to 32 pins. Group 0 consists of the PA pins, group 1 is for the PB pins, etc. Each pin group has its own PORT registers. For example, the register address offset for the Data Direction (DIR) register for group 0 (PA00 to PA31) is 0x00, and the register address offset for the DIR register for group 1 (PB00 to PB31) is 0x80.

There are up to 16 Peripheral Multiplexing registers in each group, one for every set of two subsequent I/O lines. The n denotes the number of the set of I/O lines.

Name: PMUX
Offset: 0x30 + n*0x01 [n=0..15]
Property: PAC Write-Protection

Bit	7	6	5	4	3	2	1	0
	PMUXO[3:0]				PMUXE[3:0]			
Access	RW	RW	RW	RW	RW	RW	RW	RW
Reset	0	0	0	0	0	0	0	0

Bits 7:4 – PMUXO[3:0]: Peripheral Multiplexing for Odd-Numbered Pin
These bits select the peripheral function for odd-numbered pins (2*n + 1) of a PORT group, if the corresponding PINCFGy.PMUXEN bit is '1'.

Not all possible values for this selection may be valid. For more details, refer to the *I/O Multiplexing and Considerations*.

Sleep Mode Controller

29.6.4 Sleep Mode Operation

The EVSYS can generate interrupts to wake up the device from any sleep mode.

To be able to run in standby, the Run in Standby bit in the Channel register (CHANNELn.RUNSTDBY) must be set to '1'. When the Generic Clock On Demand bit in Channel register (CHANNELn.ONDEMAND) is set to '1' and the event generator is detected, the event channel will request its clock (GCLK_EVSYS_CHANNEL_n). The event latency for a resynchronized channel path will increase by two GCLK_EVSYS_CHANNEL_n clock (i.e., up to five GCLK_EVSYS_CHANNEL_n clock cycles).

A channel will behave differently in different sleep modes regarding to CHANNELn.RUNSTDBY and CHANNELn.ONDEMAND, as shown in the table below:

Table 29-1. Event Channel Sleep Behavior

CHANNELn.ONDEMAND	CHANNELn.RUNSTDBY	Sleep Behavior
0	0	Only run in IDLE sleep mode if an event must be propagated. Disabled in STANDBY sleep mode.
0	1	Always run in IDLE and STANDBY sleep modes.
1	0	Only run in IDLE sleep mode if an event must be propagated. Disabled in STANDBY sleep mode. Two GCLK_EVSYS_n latency added in RESYNC path before the event is propagated internally.
1	1	Always run in IDLE and STANDBY sleep modes. Two GCLK_EVSYS_n latency added in RESYNC path before the event is propagated internally.

29.7 Register Summary

29.7.1 Common Registers

Offset	Name	Bit Pos.								
0x00	CTRLA	7:0								SWRST
0x01..0x0B	Reserved									
0x0C	CHSTATUS	7:0	USRRDY7	USRRDY6	USRRDY5	USRRDY4	USRRDY3	USRRDY2	USRRDY1	USRRDY0
0x0D		15:8					USRRDY11	USRRDY10	USRRDY9	USRRDY8
0x0E		23:16	CHBUSY7	CHBUSY6	CHBUSY5	CHBUSY4	CHBUSY3	CHBUSY2	CHBUSY1	CHBUSY0
0x0F		31:24					CHBUSY11	CHBUSY10	CHBUSY9	CHBUSY8
0x10	INTENCLR	7:0	OVR7	OVR6	OVR5	OVR4	OVR3	OVR2	OVR1	OVR0
0x11		15:8					OVR11	OVR10	OVR9	OVR8
0x12		23:16	EVD7	EVD6	EVD5	EVD4	EVD3	EVD2	EVD1	EVD0
0x13		31:24					EVD11	EVD10	EVD9	EVD8
0x14	INTENSET	7:0	OVR7	OVR6	OVR5	OVR4	OVR3	OVR2	OVR1	OVR0
0x15		15:8					OVR11	OVR10	OVR9	OVR8
0x16		23:16	EVD7	EVD6	EVD5	EVD4	EVD3	EVD2	EVD1	EVD0

Bit	15	14	13	12	11	10	9	8
Access								
Reset								

Bit	7	6	5	4	3	2	1	0
		TXE	COLL	ISF	CTS	BUFOVF	FERR	PERR
Access		R/W	R/W	R/W	R	R/W	R/W	R/W
Reset		0	0	0	0	0	0	0

Bit 6 – TXE: Transmitter Empty
When CTRLA.FORM is set to LIN master mode, this bit is set when any ongoing transmission is complete and TxDATA is empty.

When CTRLA.FORM is not set to LIN master mode, this bit will always read back as zero.

Writing '0' to this bit has no effect.

Writing '1' to this bit will clear it.

Bit 5 – COLL: Collision Detected
This bit is cleared by writing '1' to the bit or by disabling the receiver.

This bit is set when collision detection is enabled (CTRLB.COLDEN) and a collision is detected.

Writing '0' to this bit has no effect.

Writing '1' to this bit will clear it.

Bit 4 – ISF: Inconsistent Sync Field
This bit is cleared by writing '1' to the bit or by disabling the receiver.

This bit is set when the frame format is set to auto-baud (CTRLA.FORM) and a sync field not equal to 0x55 is received.

Writing '0' to this bit has no effect.

Writing '1' to this bit will clear it.

Bit 3 – CTS: Clear to Send
This bit indicates the current level of the CTS pin when flow control is enabled (CTRLA.TXPO).

Writing '0' to this bit has no effect.

Writing '1' to this bit has no effect.

Bit 2 – BUFOVF: Buffer Overflow
Reading this bit before reading the Data register will indicate the error status of the next character to be read.

This bit is cleared by writing '1' to the bit or by disabling the receiver.

This bit is set when a buffer overflow condition is detected. A buffer overflow occurs when the receive buffer is full, there is a new character waiting in the receive shift register and a new start bit is detected.

Writing '0' to this bit has no effect.

Writing '1' to this bit will clear it.

- Master on Bus (MB)

Each interrupt source has its own interrupt flag. The interrupt flag in the Interrupt Flag Status and Clear register (INTFLAG) will be set when the interrupt condition is meet. Each interrupt can be individually enabled by writing '1' to the corresponding bit in the Interrupt Enable Set register (INTENSET), and disabled by writing '1' to the corresponding bit in the Interrupt Enable Clear register (INTENCLR). An interrupt request is generated when the interrupt flag is set and the corresponding interrupt is enabled. The interrupt request active until the interrupt flag is cleared, the interrupt is disabled or the I^{2}C is reset. See INTFLAG register for details on how to clear interrupt flags.

The I^{2}C has one common interrupt request line for all the interrupt sources. The value of INTFLAG indicates which interrupt is executed. Note that interrupts must be globally enabled for interrupt requests. Refer to *Nested Vector Interrupt Controller* for details.

Related Links

Nested Vector Interrupt Controller

33.6.4.3 Events

Not applicable.

33.6.5 Sleep Mode Operation

I^{2}C Master Operation

The generic clock (GCLK_SERCOMx_CORE) will continue to run in idle sleep mode. If the Run In Standby bit in the Control A register (CTRLA.RUNSTDBY) is '1', the GLK_SERCOMx_CORE will also run in standby sleep mode. Any interrupt can wake up the device.

If CTRLA.RUNSTDBY=0, the GLK_SERCOMx_CORE will be disabled after any ongoing transaction is finished. Any interrupt can wake up the device.

I^{2}C Slave Operation

Writing CTRLA.RUNSTDBY=1 will allow the Address Match interrupt to wake up the device.

When CTRLA.RUNSTDBY=0, all receptions will be dropped.

33.6.6 Synchronization

Due to asynchronicity between the main clock domain and the peripheral clock domains, some registers need to be synchronized when written or read.

The following bits are synchronized when written:

- Software Reset bit in the CTRLA register (CTRLA.SWRST)
- Enable bit in the CTRLA register (CTRLA.ENABLE)
- Write to Bus State bits in the Status register (STATUS.BUSSTATE)
- Address bits in the Address register (ADDR.ADDR) when in master operation.

The following registers are synchronized when written:

- Data (DATA) when in master operation

Required write-synchronization is denoted by the "Write-Synchronized" property in the register description.

Related Links

Register Synchronization

33.7 Register Summary - I2C Slave

Offset	Name	Bit Pos.								
0x00	CTRLA	7:0	RUNSTDBY			MODE[2:0]			ENABLE	SWRST
0x01		15:8								
0x02		23:16	SEXTTOEN		SDAHOLD[1:0]					PINOUT
0x03		31:24		LOWTOUT			SCLSM		SPEED[1:0]	
0x04	CTRLB	7:0								
0x05		15:8	AMODE[1:0]					AACKEN	GCMD	SMEN
0x06		23:16						ACKACT	CMD[1:0]	
0x07		31:24								
0x08 ... 0x13	Reserved									
0x14	INTENCLR	7:0	ERROR					DRDY	AMATCH	PREC
0x15	Reserved									
0x16	INTENSET	7:0	ERROR					DRDY	AMATCH	PREC
0x17	Reserved									
0x18	INTFLAG	7:0	ERROR					DRDY	AMATCH	PREC
0x19	Reserved									
0x1A	STATUS	7:0	CLKHOLD	LOWTOUT		SR	DIR	RXNACK	COLL	BUSERR
0x1B		15:8					LENERR	HS	SEXTTOUT	
0x1C	SYNCBUSY	7:0							ENABLE	SWRST
0x1D		15:8								
0x1E		23:16								
0x1F		31:24								
0x20 ... 0x23	Reserved									
0x24	ADDR	7:0	ADDR[6:0]							GENCEN
0x25		15:8	TENBITEN					ADDR[9:7]		
0x26		23:16	ADDRMASK[6:0]							
0x27		31:24						ADDRMASK[9:7]		
0x28	DATA	7:0	DATA[7:0]							
0x29		15:8								

33.8 Register Description - I2C Slave

Registers can be 8, 16, or 32 bits wide. Atomic 8-, 16- and 32-bit accesses are supported. In addition, the 8-bit quarters and 16-bit halves of a 32-bit register, and the 8-bit halves of a 16-bit register can be accessed directly.

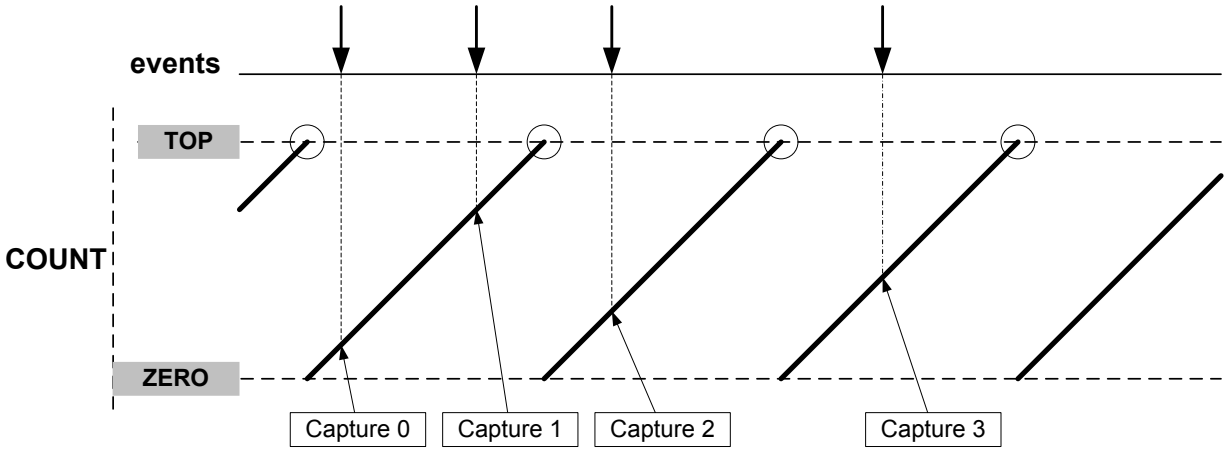
Some registers are optionally write-protected by the Peripheral Access Controller (PAC). Optional PAC write-protection is denoted by the "PAC Write-Protection" property in each individual register description. For details, refer to Register Access Protection.

Some registers are synchronized when read and/or written. Synchronization is denoted by the "Write-Synchronized" or the "Read-Synchronized" property in each individual register description. For details, refer to Synchronization.

Event Capture Action

The compare/capture channels can be used as input capture channels to capture events from the Event System or from the corresponding IO pin, and give them a timestamp. The following figure shows four capture events for one capture channel.

Figure 35-12. Input Capture Timing



The TC can detect capture overflow of the input capture channels: When a new capture event is detected while the Capture Interrupt flag (INTFLAG.MCx) is still set, the new timestamp will not be stored and INTFLAG.ERR will be set.

Period and Pulse-Width (PPW) Capture Action

The TC can perform two input captures and restart the counter on one of the edges. This enables the TC to measure the pulse width and period and to characterize the frequency *f* and duty cycle of an input signal:

$$f = \frac{1}{T}$$

$$\mathrm{dutyCycle} = \frac{t_p}{T}$$

Name: STATUS
Offset: 0x0B
Reset: 0x01
Property: Read-Synchronized

Bit	7	6	5	4	3	2	1	0
				CCBUFVx	PERBUFV		SLAVE	STOP
Access				R/W	R/W		R	R
Reset				0	0		0	1

Bit 4 – CCBUFVx: Channel x Compare or Capture Buffer Valid
For a compare channel x, the bit x is set when a new value is written to the corresponding CCBUFx register.

The bit x is cleared by writing a '1' to it when CTRLB.LUPD is set, or it is cleared automatically by hardware on UPDATE condition.

For a capture channel x, the bit x is set when a valid capture value is stored in the CCBUFx register. The bit x is cleared automatically when the CCx register is read.

Bit 3 – PERBUFV: Period Buffer Valid
This bit is set when a new value is written to the PERBUF register. The bit is cleared by writing '1' to the corresponding location when CTRLB.LUPD is set, or automatically cleared by hardware on UPDATE condition. This bit is available only in 8-bit mode and will always read zero in 16- and 32-bit modes.

Bit 1 – SLAVE: Slave Status Flag
This bit is only available in 32-bit mode on the slave TC (i.e., TC1 and/or TC3). The bit is set when the associated master TC (TC0 and TC2, respectively) is set to run in 32-bit mode.

Bit 0 – STOP: Stop Status Flag
This bit is set when the TC is disabled, on a Stop command, or on an overflow/underflow condition when the One-Shot bit in the Control B Set register (CTRLBSET.ONESHOT) is '1'.

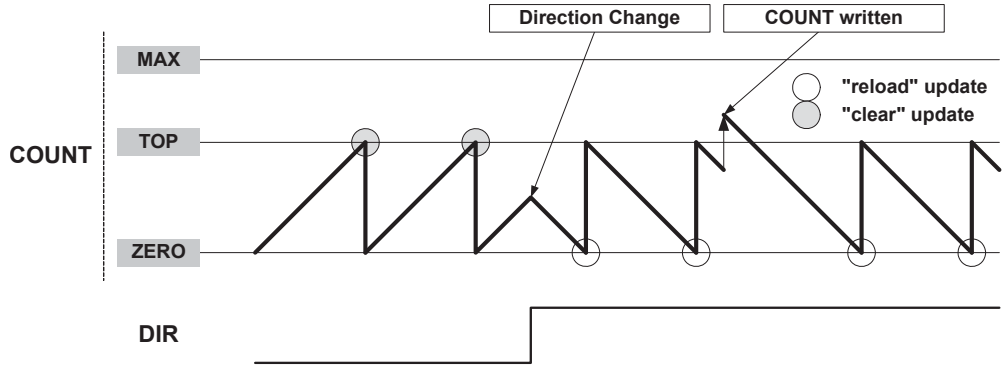
Value	Description
0	Counter is running.
1	Counter is stopped.

35.7.1.9 Waveform Generation Control

Name: WAVE
Offset: 0x0C
Reset: 0x00
Property: PAC Write-Protection, Enable-Protected

INTFLAG.OVF can be used to trigger an interrupt, a DMA request, or an event. An overflow/underflow occurrence (i.e. a compare match with TOP/ZERO) will stop counting if the One-Shot bit in the Control B register is set (CTRLBSET.ONESHOT).

Figure 36-3. Counter Operation



It is possible to change the counter value (by writing directly in the COUNT register) even when the counter is running. The COUNT value will always be ZERO or TOP, depending on direction set by CTRLBSET.DIR or CTRLBCLR.DIR, when starting the TCC, unless a different value has been written to it, or the TCC has been stopped at a value other than ZERO. The write access has higher priority than count, clear, or reload. The direction of the counter can also be changed during normal operation. See also Figure 36-3.

Stop Command

A stop command can be issued from software by using TCC Command bits in Control B Set register (CTRLBSET.CMD=0x2, STOP).

Pause Event Action

A pause command can be issued when the stop event action is configured in the Input Event Action 1 bits in Event Control register (EVCTRL.EVACT1=0x3, STOP).

Re-Trigger Command and Event Action

A re-trigger command can be issued from software by using TCC Command bits in Control B Set register (CTRLBSET.CMD=0x1, RETRIGGER), or from event when the re-trigger event action is configured in the Input Event 0/1 Action bits in Event Control register (EVCTRL.EVACTn=0x1, RETRIGGER).

When the command is detected during counting operation, the counter will be reloaded or cleared, depending on the counting direction (CTRLBSET.DIR or CTRLBCLR.DIR). The Re-Trigger bit in the Interrupt Flag Status and Clear register will be set (INTFLAG.TRG). It is also possible to generate an event by writing a '1' to the Re-Trigger Event Output Enable bit in the Event Control register (EVCTRL.TRGEO). If the re-trigger command is detected when the counter is stopped, the counter will resume counting operation from the value in COUNT.

Note:
When a re-trigger event action is configured in the Event Action bits in the Event Control register (EVCTRL.EVACTn=0x1, RETRIGGER), enabling the counter will not start the counter. The counter will start on the next incoming event and restart on corresponding following event.

Start Event Action

The start action can be selected in the Event Control register (EVCTRL.EVACT0=0x3, START) and can start the counting operation when previously stopped. The event has no effect if the counter is already

Name: PERBUF
Offset: 0x6C [ID-00002e48]
Reset: 0xFFFFFFFF
Property: Write-Synchronized, Read-Synchronized

Bit	31	30	29	28	27	26	25	24
Access								
Reset								

Bit	23	22	21	20	19	18	17	16
	PERBUF[17:10]							
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	1	1	1	1	1	1	1	1

Bit	15	14	13	12	11	10	9	8
	PERBUF[9:2]							
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	1	1	1	1	1	1	1	1

Bit	7	6	5	4	3	2	1	0
	PERBUF[1:0]		DITHERBUF[5:0]					
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	1	1	1	1	1	1	1	1

Bits 23:6 – PERBUF[17:0]: Period Buffer Value
These bits hold the value of the period buffer register. The value is copied to PER register on UPDATE condition.

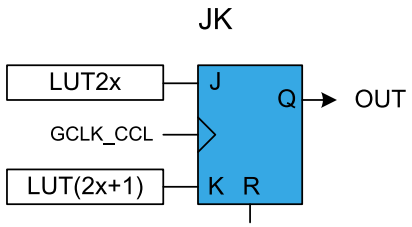
Note: When the TCC is configured as 16-bit timer/counter, the excess bits are read zero.

Note: This bit field occupies the MSB of the register, [23:m]. m is dependent on the Resolution bit in the Control A register (CTRLA.RESOLUTION):

CTRLA.RESOLUTION	Bits [23:m]
0x0 - NONE	23:0
0x1 - DITH4	23:4
0x2 - DITH5	23:5
0x3 - DITH6	23:6 (depicted)

Bits 5:0 – DITHERBUF[5:0]: Dithering Buffer Cycle Number
These bits represent the PER.DITHER bits buffer. When the double buffering is enabled, the value of this bit field is copied to the PER.DITHER bits on an UPDATE condition.
Note: This bit field consists of the n LSB of the register. n is dependent on the value of the Resolution bits in the Control A register (CTRLA.RESOLUTION):

Figure 37-15. JK Flip Flop



When the even LUT is disabled (LUTCTRL0.ENABLE=0 / LUTCTRL2.ENABLE=0), the flip-flop is asynchronously cleared. The reset command (R) is kept enabled for one APB clock cycle. In all other cases, the flip-flop output (OUT) is refreshed on rising edge of the GCLK_CCL, as shown in Table 37-3.

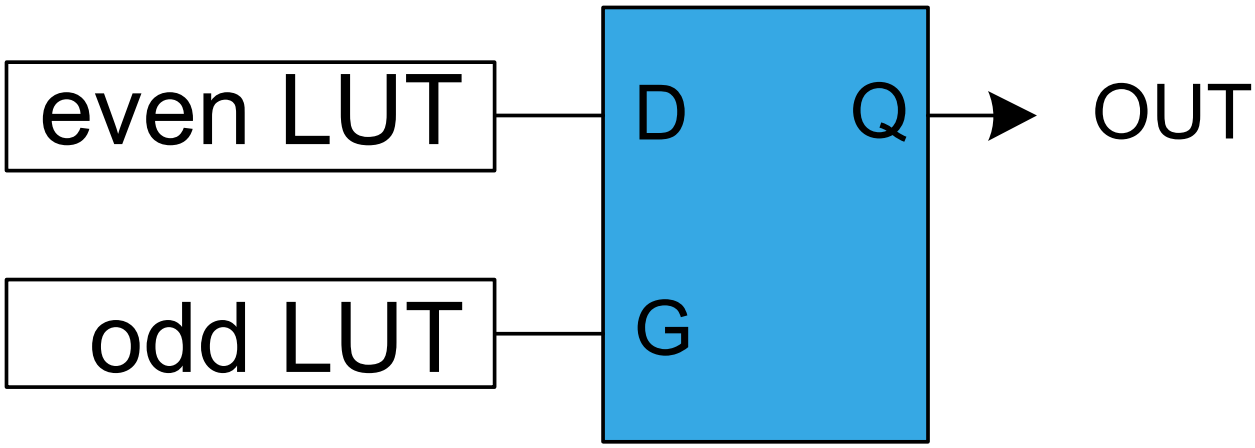
Table 37-3. JK Characteristics

R	J	K	OUT
1	X	X	Clear
0	0	0	Hold state (no change)
0	0	1	Clear
0	1	0	Set
0	1	1	Toggle

Gated D-Latch (DLATCH)

When the DLATCH is selected, the D-input is driven by the even LUT output (LUT0 and LUT2), and the G-input is driven by the odd LUT output (LUT1 and LUT3), as shown in Figure 37-14.

Figure 37-16. D-Latch



When the even LUT is disabled (LUTCTRL0.ENABLE=0 / LUTCTRL2.ENABLE=0), the latch output will be cleared. The G-input is forced enabled for one more APB clock cycle, and the D-input to zero. In all other cases, the latch output (OUT) is refreshed as shown in Table 37-4.

Number of Accumulated Samples	AVGCTRL. SAMPLENUM	Number of Automatic Right Shifts	Final Result Precision	Automatic Division Factor
4	0x2	0	14 bits	0
8	0x3	0	15 bits	0
16	0x4	0	16 bits	0
32	0x5	1	16 bits	2
64	0x6	2	16 bits	4
128	0x7	3	16 bits	8
256	0x8	4	16 bits	16
512	0x9	5	16 bits	32
1024	0xA	6	16 bits	64
Reserved	0xB –0xF		12 bits	0

38.6.2.10 Averaging

Averaging is a feature that increases the sample accuracy, at the cost of a reduced sampling rate. This feature is suitable when operating in noisy conditions.

Averaging is done by accumulating m samples, as described in Accumulation, and dividing the result by m. The averaged result is available in the RESULT register. The number of samples to be accumulated is specified by writing to AVGCTRL.SAMPLENUM as shown in Table 38-2.

The division is obtained by a combination of the automatic right shift described above, and an additional right shift that must be specified by writing to the Adjusting Result/Division Coefficient field in AVGCTRL (AVGCTRL.ADJRES), as described in Table 38-2.

Note: To perform the averaging of two or more samples, the Conversion Result Resolution field in the Control C register (CTRLC.RESSEL) must be set.

Averaging AVGCTRL.SAMPLENUM samples will reduce the un-averaged sampling rate by a factor $\frac{1}{\text{AVGCTRL.SAMPLENUM}}$.

When the averaged result is available, the INTFLAG.RESRDY bit will be set.

Table 38-2. Averaging

Number of Accumulated Samples	AVGCTRL. SAMPLENUM	Intermediate Result Precision	Number of Automatic Right Shifts	Division Factor	AVGCTRL.ADJRES	Total Number of Right Shifts	Final Result Precision	Automatic Division Factor
1	0x0	12 bits	0	1	0x0		12 bits	0
2	0x1	13	0	2	0x1	1	12 bits	0
4	0x2	14	0	4	0x2	2	12 bits	0
8	0x3	15	0	8	0x3	3	12 bits	0
16	0x4	16	0	16	0x4	4	12 bits	0
32	0x5	17	1	16	0x4	5	12 bits	2

Register Synchronization

41.7 Register Summary

Offset	Name	Bit Pos.								
0x00	CTRLA	7:0		RUNSTDBY					ENABLE	SWRST
0x01	CTRLB	7:0	REFSEL[1:0]		DITHER		VPD	LEFTADJ	IOEN	EOEN
0x02	EVCTRL	7:0						INVEI	EMPTYEO	STARTEI
0x03	Reserved									
0x04	INTENCLR	7:0							EMPTY	UNDERRUN
0x05	INTENSET	7:0							EMPTY	UNDERRUN
0x06	INTFLAG	7:0							EMPTY	UNDERRUN
0x07	STATUS	7:0								READY
0x08	DATA	7:0	DATA[7:0]							
0x09		15:8	DATA[15:8]							
0x0A ... 0x0B	Reserved									
0x0C	DATABUF	7:0	DATABUF[7:0]							
0x0D		15:8	DATABUF[15:8]							
0x0E ... 0x0F	Reserved									
0x10	SYNCBUSY	7:0					DATABUF	DATA	ENABLE	SWRST
0x11		15:8								
0x12		23:16								
0x13		31:24								
0x14 ... 0x17	Reserved									
0x18	DBGCTRL	7:0								DBGRUN

41.8 Register Description

Registers can be 8, 16, or 32 bits wide. Atomic 8-, 16- and 32-bit accesses are supported. In addition, the 8-bit quarters and 16-bit halves of a 32-bit register, and the 8-bit halves of a 16-bit register can be accessed directly.

Some registers are optionally write-protected by the Peripheral Access Controller (PAC). Optional PAC write-protection is denoted by the "PAC Write-Protection" property in each individual register description. For details, refer to Register Access Protection.

Some registers are synchronized when read and/or written. Synchronization is denoted by the "Write-Synchronized" or the "Read-Synchronized" property in each individual register description. For details, refer to Synchronization.

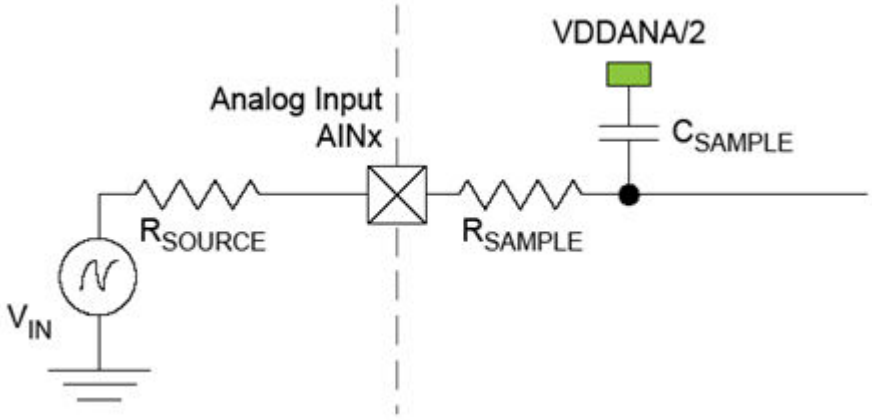
Some registers are enable-protected, meaning they can only be written when the peripheral is disabled. Enable-protection is denoted by the "Enable-Protected" property in each individual register description.

41.8.1 Control A

Symbol	Parameters	Conditions	Min	Typ	Max	Unit
Vcmin	Input common mode voltage	CTRLC.R2R=1	0.2	-	VREF-0.2	V
		CTRLC.R2R=0	VREF/2-0.2	-	VREF/2+0.2	V
CSAMPLE	Input sampling capacitance		-	1.6	4.5	pF
RSAMPLE	Input sampling on-resistance	For a sampling rate at 1 Msps	-	1000	1715	Ω
Rref	Reference input source resistance		0	-	1000	kΩ

1. These values are based on simulation. These values are not covered by test limits in production or characterization.

Figure 45-4. ADC Analog Input AINx



The minimum sampling time $t_{samplehold}$ for a given R_{source} can be found using this formula:

$$t_{samplehold} \geq \left(R_{sample} + R_{source}\right) \times C_{sample} \times \left(n + 2\right) \times \ln\left(2\right)$$

For 12-bit accuracy:

$$t_{samplehold} \geq \left(R_{sample} + R_{source}\right) \times C_{sample} \times 9.7$$

where $t_{samplehold} \geq \frac{1}{2 \times f_{ADC}}$.

Table 45-19. Differential Mode(1)

Symbol	Parameter	Conditions		Measurement			Unit
				Min	Typ	Max	
ENOB(2)	Effective Number of bits	Fadc = 500 ksps	Vddana=5.0V Vref=Vddana	10.0	10.7	11	bits
			Vddana=2.7V Vref=2.0V	10.3	10.5	10.9	
		Fadc = 1 Msps	Vddana=5.0V Vref=Vddana	10.5	10.8	11.1	
			Vddana=2.7V Vref=2.0V	9.9	10.0	10.6	
TUE	Total Unadjusted Error	Fadc = 500 ksps	Vddana=5.0V Vref=Vddana	-	7.8	17.0	LSB