

## Features

- High-performance, Low-power 8/16-bit AVR XMEGA Microcontroller
- Non-Volatile Program and Data Memories
  - 64K - 384K Bytes of In-System Self-Programmable Flash
  - 4K - 8K Bytes Boot Section with Independent Lock Bits
  - 2K - 4K Bytes EEPROM
  - 4K - 32K Bytes Internal SRAM
  - External Bus Interface for up to 16M bytes SRAM
  - External Bus Interface for up to 128M bit SDRAM
- Peripheral Features
  - Four-channel DMA Controller with support for external requests
  - Eight-channel Event System
  - Eight 16-bit Timer/Counters
    - Four Timer/Counters with 4 Output Compare or Input Capture channels
    - Four Timer/Counters with 2 Output Compare or Input Capture channels
    - High-Resolution Extension on all Timer/Counters
    - Advanced Waveform Extension on two Timer/Counters
  - Eight USARTs
    - IrDA modulation/demodulation for one USART
  - Four Two-Wire Interfaces with dual address match (<sup>2</sup>C and SMBus compatible)
  - Four SPI (Serial Peripheral Interface) peripherals
  - AES and DES Crypto Engine
  - 16-bit Real Time Counter with separate Oscillator
  - Two Eight-channel, 12-bit, 2 Msps Analog to Digital Converters
  - Two Two-channel, 12-bit, 1 Msps Digital to Analog Converters
  - Four Analog Comparators with Window compare function
  - External Interrupts on all General Purpose I/O pins
  - Programmable Watchdog Timer with Separate On-chip Ultra Low Power Oscillator
- Special Microcontroller Features
  - Power-on Reset and Programmable Brown-out Detection
  - Internal and External Clock Options with PLL and Prescaler
  - Programmable Multi-level Interrupt Controller
  - Sleep Modes: Idle, Power-down, Standby, Power-save, Extended Standby
  - Advanced Programming, Test and Debugging Interfaces
    - JTAG (IEEE 1149.1 Compliant) Interface for programming, test and debugging
    - PDI (Program and Debug Interface) for programming and debugging
- I/O and Packages
  - 78 Programmable I/O Lines
  - 100 - lead TQFP
  - 100 - ball CBGA
- Operating Voltage
  - 1.6 – 3.6V
- Speed performance
  - 0 – 12 MHz @ 1.6 – 3.6V
  - 0 – 32 MHz @ 2.7 – 3.6V

## Typical Applications

- |                      |                   |                                  |
|----------------------|-------------------|----------------------------------|
| • Industrial control | • Climate control | • Hand-held battery applications |
| • Factory automation | • ZigBee          | • Power tools                    |
| • Building control   | • Motor control   | • HVAC                           |
| • Board control      | • Networking      | • Metering                       |
| • White Goods        | • Optical         | • Medical Applications           |



## 8/16-bit **AVR**<sup>®</sup> XMEGA A1 Microcontroller

**ATxmega384A1**  
**ATxmega256A1**  
**ATxmega192A1**  
**ATxmega128A1**  
**ATxmega64A1**

## Preliminary

8067D-AVR-08/08



## 1. Ordering Information

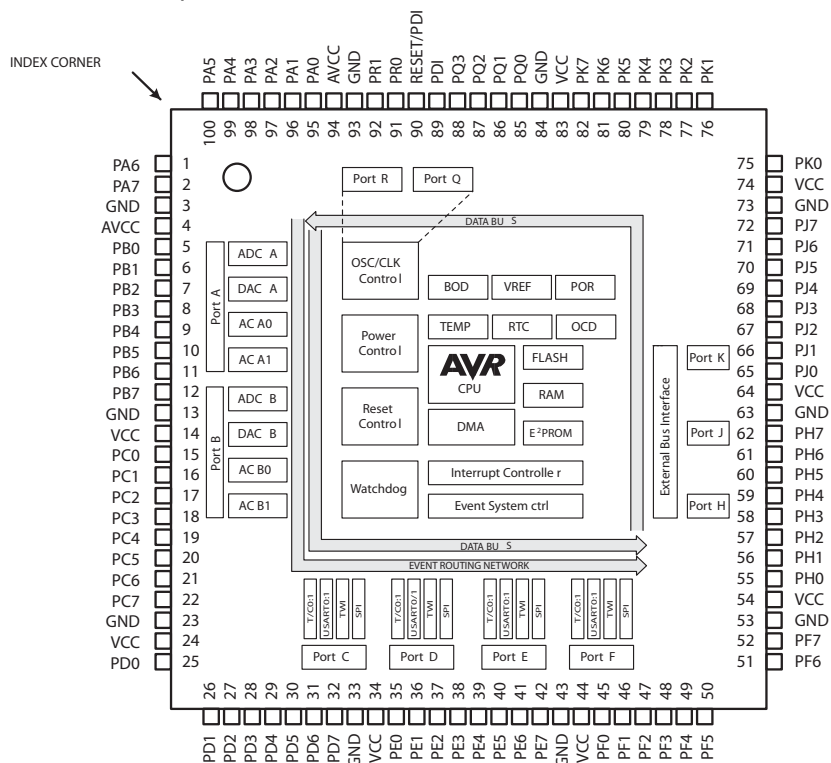
Ordering Code	Flash (B)	E <sup>2</sup> (B)	SRAM (B)	Speed (MHz)	Power Supply	Package <sup>(1)(2)(3)</sup>	Temp
ATxmega384A1-AU	384K + 8K	4K	32K	32	1.6 - 3.6V	100A	-40° - 85°C
ATxmega256A1-AU	256K + 8K	4K	16K	32	1.6 - 3.6V		
ATxmega192A1-AU	192K + 8K	2K	16K	32	1.6 - 3.6V		
ATxmega128A1-AU	128K + 8K	2K	8K	32	1.6 - 3.6V		
ATxmega64A1-AU	64K + 4K	2K	4K	32	1.6 - 3.6V		
ATxmega384A1-CU	384K + 8K	4K	32K	32	1.6 - 3.6V	100C1	
ATxmega256A1-CU	256K + 8K	4K	16K	32	1.6 - 3.6V		
ATxmega192A1-CU	192K + 8K	2K	16K	32	1.6 - 3.6V		
ATxmega128A1-CU	128K + 8K	2K	8K	32	1.6 - 3.6V		
ATxmega64A1-CU	64K + 4K	2K	4K	32	1.6 - 3.6V		

- Notes:
1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information.
  2. Pb-free packaging, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
  3. For packaging information, see ["Packaging information" on page 63](#).

Package Type	
<b>100A</b>	100-lead, 14 x 14 x 1.0 mm, 0.5 mm Lead Pitch, Thin Profile Plastic Quad Flat Package (TQFP)
<b>100C1</b>	100-ball, 9 x 9 x 1.2 mm Body, Ball Pitch 0.88 mm, Chip Ball Grid Array (CBGA)

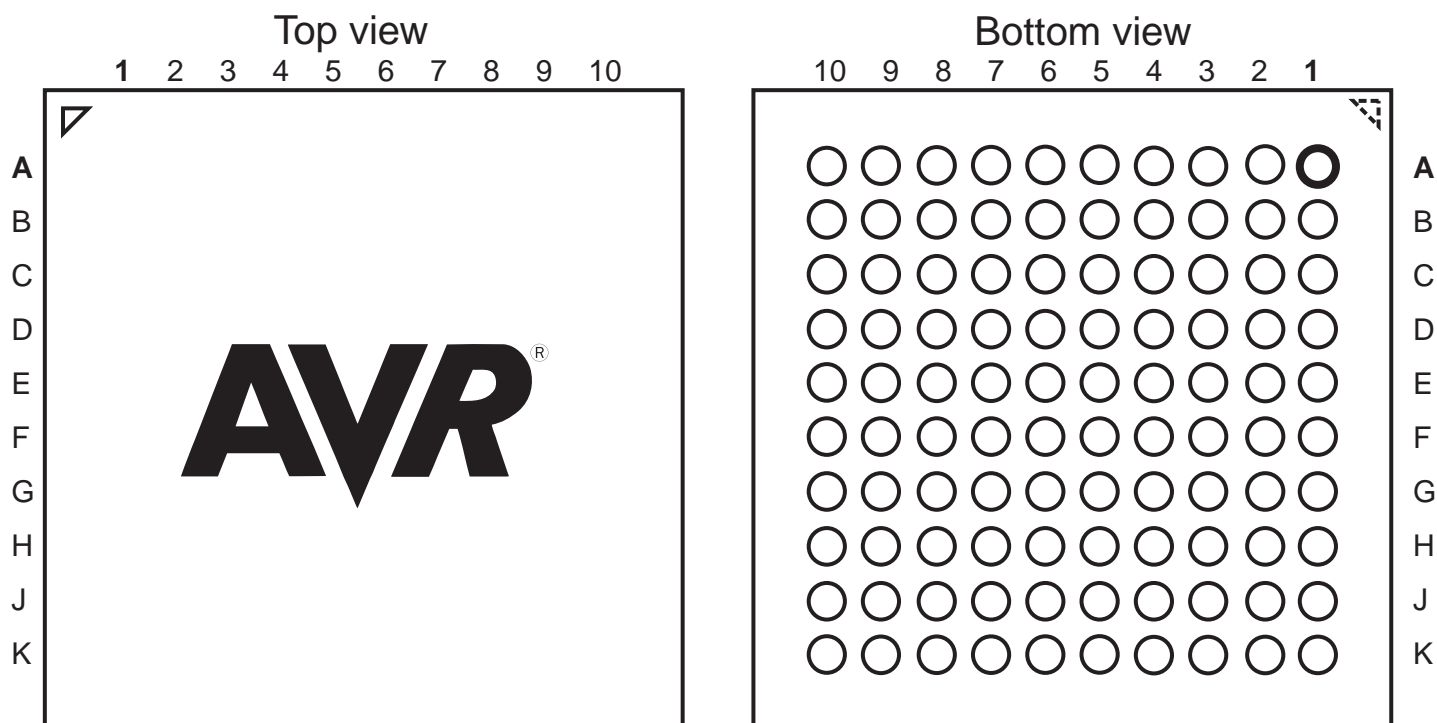
## 2. Pinout/Block Diagram

Figure 2-1. Block diagram and TQFP-pinout.



Note: For full details on pinout and pin functions refer to ["Pinout and Pin Functions" on page 48](#).

**Figure 2-2.** CBGA-pinout



**Table 2-1.** CBGA-pinout

	1	2	3	4	5	6	7	8	9	10
<b>A</b>	PK0	VCC	GND	PJ3	VCC	GND	PH1	GND	VCC	PF7
<b>B</b>	PK3	PK2	PK1	PJ4	PH7	PH4	PH2	PH0	PF6	PF5
<b>C</b>	VCC	PK5	PK4	PJ5	PJ0	PH5	PH3	PF2	PF3	VCC
<b>D</b>	GND	PK6	PK7	PJ6	PJ1	PH6	PF0	PF1	PF4	GND
<b>E</b>	TOSC1/ PQ0	TOSC2/ PQ1	PQ2	PJ7	PJ2	PE7	PE6	PE5	PE4	PE3
<b>F</b>	XTAL1/ PR1	XTAL2/ PR0	RESET/ PDI_CLK	PDI_DATA	PQ3	PC2	PE2	PE1	PE0	VCC
<b>G</b>	GND	PA1	PA4	PB3	PB4	PC1	PC6	PD7	PD6	GND
<b>H</b>	AVCC	PA2	PA5	PB2	PB5	PC0	PC5	PD5	PD4	PD3
<b>J</b>	PA0	PA3	PB0	PB1	PB6	PC3	PC4	PC7	PD2	PD1
<b>K</b>	PA6	PA7	GND	AVCC	PB7	VCC	GND	VCC	GND	PD0

### 3. Overview

The XMEGA A1 is a family of low power, high performance and peripheral rich CMOS 8/16-bit microcontrollers based on the AVR® enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the XMEGA A1 achieves throughputs approaching 1 Million Instructions Per Second (MIPS) per MHz allowing the system designer to optimize power consumption versus processing speed.

The AVR CPU combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction, executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs many times faster than conventional single-accumulator or CISC based microcontrollers.

The XMEGA A1 devices provides the following features: In-System Programmable Flash with Read-While-Write capabilities, Internal EEPROM and SRAM, four-channel DMA Controller, eight-channel Event System, Programmable Multi-level Interrupt Controller, 78 general purpose I/O lines, 16-bit Real Time Counter (RTC), eight flexible 16-bit Timer/Counters with compare modes and PWM, eight USARTs, four Two Wire Serial Interfaces (TWIs), four Serial Peripheral Interfaces (SPIs), AES and DES crypto engine, two 8-channel, 12-bit ADCs with optional differential input with programmable gain, two 2-channel, 12-bit DACs, four analog comparators with window mode, programmable Watchdog Timer with separate Internal Oscillator, accurate internal oscillators with PLL and prescaler and programmable Brown-Out Detection.

The Program and Debug Interface (PDI), a fast 2-pin interface for programming and debugging, is available. The devices also have an IEEE std. 1149.1 compliant JTAG test interface, and this can also be used for On-chip Debug and programming.

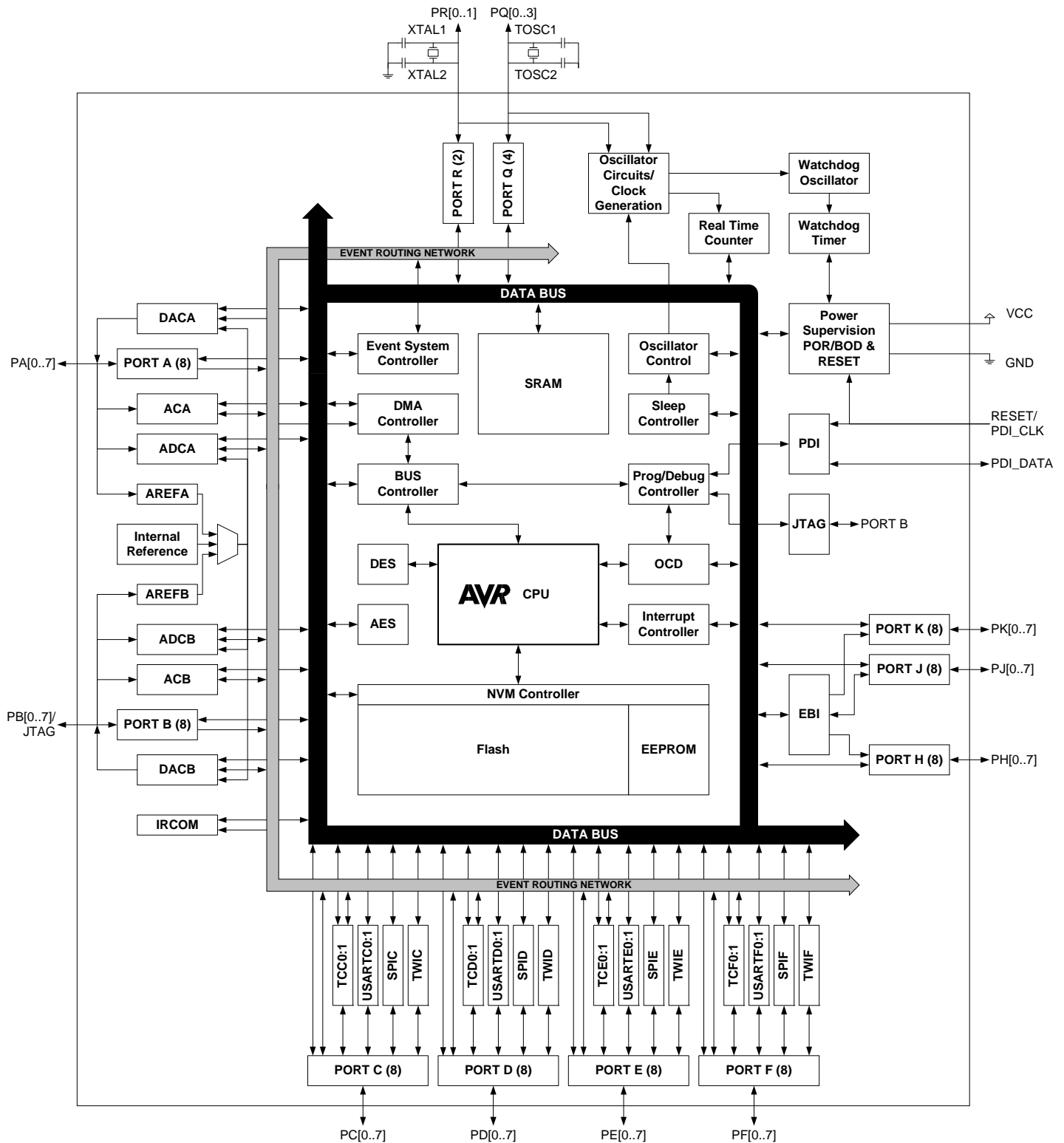
The XMEGA A1 devices have five software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM, DMA Controller, Event System, Interrupt Controller and all peripherals to continue functioning. The Power-down mode saves the SRAM and register contents but stops the oscillators, disabling all other functions until the next TWI or pin-change interrupt, or Reset. In Power-save mode, the asynchronous Real Time Counter continues to run, allowing the application to maintain a timer base while the rest of the device is sleeping. In Standby mode, the Crystal/Resonator Oscillator is kept running while the rest of the device is sleeping. This allows very fast start-up from external crystal combined with low power consumption. In Extended Standby mode, both the main Oscillator and the Asynchronous Timer continue to run. To further reduce power consumption, the peripheral clock to each individual peripheral can optionally be stopped in Active mode and Idle sleep mode.

The device is manufactured using Atmel's high-density nonvolatile memory technology. The program Flash memory can be reprogrammed in-system through the PDI or JTAG. A Bootloader running in the device can use any interface to download the application program to the Flash memory. The Bootloader software in the Boot Flash section will continue to run while the Application Flash section is updated, providing true Read-While-Write operation. By combining an 8/16-bit RISC CPU with In-System Self-Programmable Flash, the Atmel XMEGA A1 is a powerful microcontroller family that provides a highly flexible and cost effective solution for many embedded applications.

The XMEGA A1 devices is supported with a full suite of program and system development tools including: C compilers, macro assemblers, program debugger/simulators, programmers, and evaluation kits.

## 3.1 Block Diagram

Figure 3-1. XMEGA A1 Block Diagram



## **4. Resources**

A comprehensive set of development tools, application notes and datasheets are available for download on <http://www.atmel.com/avr>.

### **4.1 Recommended reading**

- XMEGA A Manual
- XMEGA A Application Notes

This device data sheet only contains part specific information and a short description of each peripheral and module. The XMEGA A Manual describes the modules and peripherals in depth. The XMEGA A application notes contain example code and show applied use of the modules and peripherals.

The XMEGA A Manual and Application Notes are available from <http://www.atmel.com/avr>.

## **5. Disclaimer**

For devices that are not available yet, typical values contained in this datasheet are based on simulations and characterization of other AVR XMEGA microcontrollers manufactured on the same process technology. Min. and Max values will be available after the device is characterized.

## 6. AVR CPU

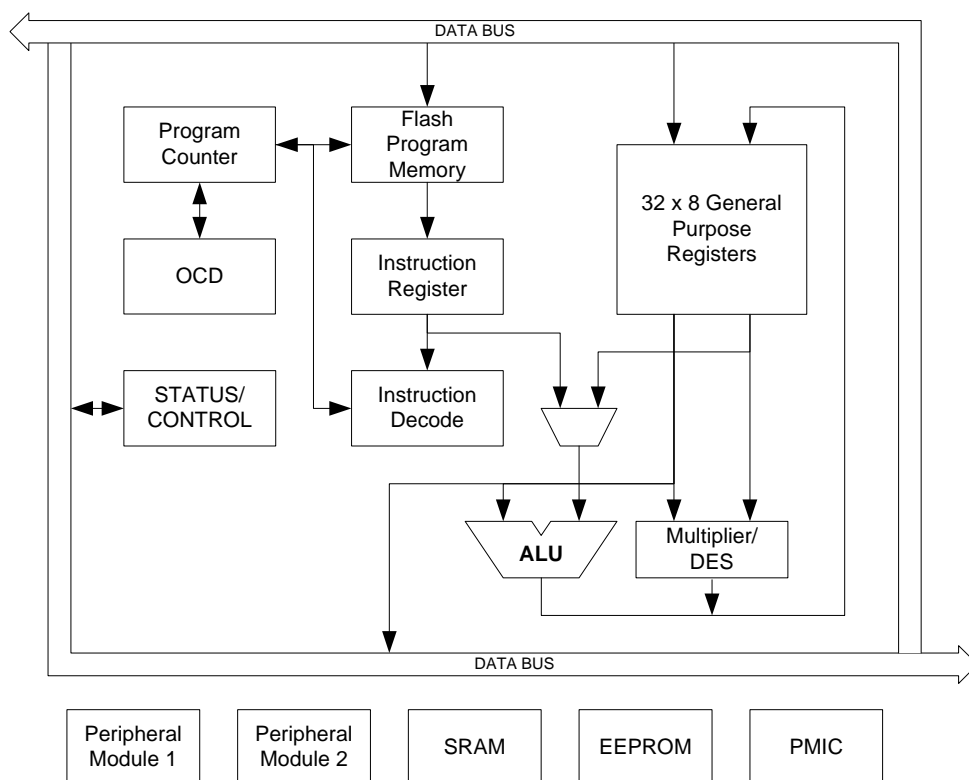
### 6.1 Features

- 8/16-bit high performance AVR RISC Architecture
  - 138 instructions
  - Hardware multiplier
- 32x8-bit registers directly connected to the ALU
- Stack in SRAM
- Stack Pointer accessible in I/O memory space
- Direct addressing of up to 16M Bytes of program and data memory
- True 16/24-bit access to 16/24-bit I/O registers
- Support for 8-, 16- and 32-bit Arithmetic
- Configuration Change Protection of system critical features

### 6.2 Overview

The XMEGA A1 uses the 8/16-bit AVR CPU. The main function of the CPU is program execution. The CPU must therefore be able to access memories, perform calculations and control peripherals. Interrupt handling is described in a separate section. [Figure 6-1 on page 7](#) shows the CPU block diagram.

**Figure 6-1.** CPU block diagram



The AVR uses a Harvard architecture - with separate memories and buses for program and data. Instructions in the program memory are executed with a single level pipeline. While one instruction is being executed, the next instruction is pre-fetched from the program memory. This

concept enables instructions to be executed in every clock cycle. The program memory is In-System Self-Programmable Flash memory.

### **6.3 Register File**

The fast-access Register File contains 32 x 8-bit general purpose working registers with single clock cycle access time. This allows single-cycle Arithmetic Logic Unit (ALU) operation. In a typical ALU cycle, the operation is performed on two Register File operands, and the result is stored back in the Register File.

Six of the 32 registers can be used as three 16-bit address register pointers for data space addressing - enabling efficient address calculations. One of these address pointers can also be used as an address pointer for look up tables in Flash program memory.

### **6.4 ALU - Arithmetic Logic Unit**

The high performance Arithmetic Logic Unit (ALU) supports arithmetic and logic operations between registers or between a constant and a register. Single register operations can also be executed. Within a single clock cycle, arithmetic operations between general purpose registers or between a register and an immediate are executed. After an arithmetic or logic operation, the Status Register is updated to reflect information about the result of the operation.

The ALU operations are divided into three main categories – arithmetic, logical, and bit-functions. Both 8- and 16-bit arithmetic is supported, and the instruction set allows for efficient implementation of 32-bit arithmetic. The ALU also provides a powerful multiplier supporting both signed and unsigned multiplication and fractional format.

### **6.5 Program Flow**

When the device is powered on, the CPU starts to execute instructions from the lowest address in the Flash Program Memory '0'. The Program Counter (PC) addresses the next instruction to be fetched. After a reset, the PC is set to location '0'.

Program flow is provided by conditional and unconditional jump and call instructions, capable of addressing the whole address space directly. Most AVR instructions use a 16-bit word format, while a limited number uses a 32-bit format.

During interrupts and subroutine calls, the return address PC is stored on the Stack. The Stack is effectively allocated in the general data SRAM, and consequently the Stack size is only limited by the total SRAM size and the usage of the SRAM. After reset the Stack Pointer (SP) points to the highest address in the internal SRAM. The SP is read/write accessible in the I/O memory space, enabling easy implementation of multiple stacks or stack areas. The data SRAM can easily be accessed through the five different addressing modes supported in the AVR CPU.



## 7. Memories

### 7.1 Features

- **Flash Program Memory**
  - One linear address space
  - In-System Programmable
  - Self-Programming and Bootloader support
  - Application Section for application code
  - Application Table Section for application code or data storage
  - Boot Section for application code or bootloader code
  - Separate lock bits and protection for all sections
- **Data Memory**
  - One linear address space
  - Single cycle access from CPU
  - SRAM
  - EEPROM
    - Byte or page accessible
    - Optional memory mapping for direct load and store
  - I/O Memory
    - Configuration and Status registers for all peripherals and modules
    - 16-bit accessible General Purpose Register for global variables or flags
  - External Memory support
  - Bus arbitration
    - Safe and deterministic handling of CPU and DMA Controller priority
  - Separate buses for SRAM, EEPROM, I/O Memory and External Memory access
    - Simultaneous bus access for CPU and DMA Controller
- **Calibration Row Memory for factory programmed data**
  - Oscillator calibration bytes
  - Serial number
  - Device ID for each device type
- **User Signature Row**
  - One flash page in size
  - Can be read and written from software
  - Data is kept after Chip Erase

### 7.2 Overview

The AVR architecture has two main memory spaces, the Program Memory and the Data Memory. In addition, the XMEGA A1 features an EEPROM Memory for non-volatile data storage. All three memory spaces are linear and require no paging. The available memory size configurations are shown in [“Ordering Information” on page 2](#). In addition each device has a Flash memory signature row for calibration data, device identification, serial number etc.

Non-volatile memory spaces can be locked for further write or read/write operations. This prevents unrestricted access to the application software.

### 7.3 In-System Programmable Flash Program Memory

The XMEGA A1 devices contains On-chip In-System Programmable Flash memory for program storage, see [Figure 7-1 on page 10](#). Since all AVR instructions are 16- or 32-bits wide, each Flash address location is 16 bits.

The Program Flash memory space is divided into Application and Boot sections. Both sections have dedicated Lock Bits for setting restrictions on write or read/write operations. The Store Program Memory (SPM) instruction must reside in the Boot Section when used to write to the Flash memory.

A third section inside the Application section is referred to as the Application Table section which has separate Lock bits for storage of write or read/write protection. The Application Table section can be used for storing non-volatile data or application software.

**Figure 7-1.** Flash Program Memory (Hexadecimal address)

Word Address									
					0				
					Application Section (384K/256K/192K/128K/64K)				
					...				
2EFFF	/	1EFFF	/	16FFF	/	EFFF	/	77FF	
2F000	/	1F000	/	17000	/	F000	/	7800	Application Table Section (8K/8K/8K/8K/4K)
2FFFF	/	1FFFF	/	17FFF	/	FFFF	/	7FFF	
30000	/	20000	/	18000	/	10000	/	8000	Boot Section (8K/8K/8K/8K/4K)
30FFF	/	20FFF	/	18FFF	/	10FFF	/	87FF	

The Application Table Section and Boot Section can also be used for general application software.

## 7.4 Data Memory

The Data Memory consist of the I/O Memory, EEPROM and SRAM memories, all within one linear address space, see [Figure 7-2 on page 10](#). To simplify development, the memory map for all devices in the family is identical and with empty, reserved memory space for smaller devices.

**Figure 7-2.** Data Memory Map (Hexadecimal address)

Byte Address	ATxmega192A1	Byte Address	ATxmega128A1	Byte Address	ATxmega64A1
0	I/O Registers (4KB)	0	I/O Registers (4KB)	0	I/O Registers (4KB)
FFF		FFF		FFF	
1000	EEPROM (2K)	1000	EEPROM (2K)	1000	EEPROM (2K)
17FF		17FF		17FF	
	RESERVED		RESERVED		RESERVED
2000	Internal SRAM (16K)	2000	Internal SRAM (8K)	2000	Internal SRAM (4K)
5FFF		3FFF		2FFF	
6000	External Memory (0 to 16 MB)	4000	External Memory (0 to 16 MB)	3000	External Memory (0 to 16 MB)
FFFFFF		FFFFFF		FFFFFF	

Byte Address	ATxmega384A1	Byte Address	ATxmega256A1
0	I/O Registers (4KB)	0	I/O Registers (4KB)
FFF		FFF	
1000	EEPROM (4K)	1000	EEPROM (4K)
1FFF		1FFF	
2000	Internal SRAM (32K)	2000	Internal SRAM (16K)
9FFF		5FFF	
10000	External Memory (0 to 16 MB)	6000	External Memory (0 to 16 MB)
FFFFFF		FFFFFF	

## 7.4.1 I/O Memory

All peripherals and modules are addressable through I/O memory locations in the data memory space. All I/O memory locations can be accessed by the Load (LD/LDS/LDD) and Store (ST/STS/STD) instructions, transferring data between the 32 general purpose registers in the CPU and the I/O Memory.

The IN and OUT instructions can address I/O memory locations in the range 0x00 - 0x3F directly.

I/O registers within the address range 0x00 - 0x1F are directly bit-accessible using the SBI and CBI instructions. The value of single bits can be checked by using the SBIS and SBIC instructions on these registers.

The I/O memory address for all peripherals and modules in XMEGA A1 is shown in the [“Peripheral Module Address Map”](#) on page 54.

## 7.4.2 SRAM Data Memory

The XMEGA A1 devices has internal SRAM memory for data storage.

## 7.4.3 EEPROM Data Memory

The XMEGA A1 devices has internal EEPROM memory for non-volatile data storage. It is addressable either in a separate data space or it can be memory mapped into the normal data memory space. The EEPROM memory supports both byte and page access.

#### **7.4.4 EBI - External Bus Interface**

- **Supports SRAM up to**
  - **512K Bytes using 2-port EBI**
  - **16M Bytes using 3-port EBI**
- **Supports SDRAM up to**
  - **128M bit using 3-port EBI**
- **Four software configurable Chip Selects**
- **Software configurable Wait State insertion**
- **Clocked from the Peripheral 2x Clock at up to two times the CPU clock speed**

The External Bus Interface (EBI) is the interface for connecting external peripheral and memory to the data memory space. The XMEGA A1 has 3 ports that can be used for the EBI. It can interface external SRAM, SDRAM, and/or peripherals such as LCD displays and other memory mapped devices.

The address space, and the number of pins used, for the external memory is selectable from 256 bytes (8-bit) and up to 16M bytes (24-bit). Various multiplexing modes for address and data lines can be selected for optimal use of pins when more or less pins is available for the EBI.

Each of the four chip selects has separate configuration, and can be configured for SRAM, SRAM Low Pin Count (LPC) or SDRAM. The data memory address space associated for each chip select is decided by a configurable base address and address size for each chip select.

For SDRAM both 4-bit SDRAM is supported, and SDRAM configurations such as CAS Latency and Refresh rate is configurable in software.

The EBI is clocked from the Peripheral 2x Clock, running up to two times faster than the CPU and supporting speeds of up to 64 MHz.

## 7.5 Calibration Row

The Calibration Row is a separate memory section for factory programmed data. It contains calibration data for functions such as oscillators, device ID, and a factory programmed serial number that is unique for each device. The device ID for the available XMEGA A1 devices is shown in [Table 7-1 on page 13](#). Some of the calibration values will be automatically loaded to the corresponding module or peripheral unit during reset. The Calibration Row can not be written or erased. It can be read from application software and external programming.

**Table 7-1.** Device ID bytes for XMEGA A1 devices.

Device	Device ID bytes		
	Byte 2	Byte 1	Byte 0
ATxmega64A1	4E	96	1E
ATxmega128A1	4C	97	1E
ATxmega192A1	4E	97	1E
ATxmega256A1	46	98	1E
ATxmega384A1	TBD	TBD	TBD

## 7.6 User Signature Row

The User Signature Row is a separate memory section that is fully accessible (read and write) from application software and external programming. The User Signature Row is one flash page in size, and is meant for static user parameter storage, such as calibration data, custom serial numbers, random number seeds etc. This section is not erased by Chip Erase, and requires a dedicated erase command. This ensures parameter storage during multiple program/erase session and On-Chip Debug sessions.

## 7.7 Flash and EEPROM Page Size

The Flash Program Memory and EEPROM data memory is organized in pages. The pages are word accessible for the Flash and byte accessible for the EEPROM.

Table 7-2 on page 14 shows the Flash Program Memory organization. Flash write and erase operations are performed on one page at the time, while reading the Flash is done one byte at the time. For Flash access the Z-pointer (Z[m:n]) is used for addressing. The most significant bits in the address (FPAGE) gives the page number and the least significant address bits (FWORD) gives the word in the page.

**Table 7-2.** Number of words and Pages in the Flash.

Devices	Flash Size (Bytes)	Page Size (words)	FWORD	FPAGE	Application		Boot	
					Size	No of Pages	Size	No of Pages
ATxmega64A1	64K + 4K	128	Z[7:1]	Z[16:8]	64K	256	4K	16
ATxmega128A1	128K + 8K	256	Z[8:1]	Z[17:9]	128K	256	8K	16
ATxmega192A1	192K + 8K	256	Z[8:1]	Z[18:9]	192K	384	8K	16
ATxmega256A1	256K + 8K	256	Z[8:1]	Z[18:9]	256K	512	8K	16
ATxmega384A1	384K + 8K	256	Z[8:1]	Z[19:9]	384K	768	8K	16

Table 7-3 on page 14 shows EEPROM memory organization for the XMEGA A1 devices. EEPROM write and erase operations can be performed one page or one byte at the time, while reading the EEPROM is done one byte at the time. For EEPROM access the NVM Address Register (ADDR[m:n]) is used for addressing. The most significant bits in the address (E2PAGE) gives the page number and the least significant address bits (E2BYTE) gives the byte in the page.

**Table 7-3.** Number of Bytes and Pages in the EEPROM.

Devices	EEPROM Size (Bytes)	Page Size (Bytes)	E2BYTE	E2PAGE	No of Pages
ATxmega64A1	2K	32	ADDR[4:0]	ADDR[10:5]	64
ATxmega128A1	2K	32	ADDR[4:0]	ADDR[10:5]	64
ATxmega192A1	2K	32	ADDR[4:0]	ADDR[10:5]	64
ATxmega256A1	4K	32	ADDR[4:0]	ADDR[11:5]	128
ATxmega384A1	4K	32	ADDR[4:0]	ADDR[11:5]	128

## **8. DMAC - Direct Memory Access Controller**

### **8.1 Features**

- **Allows High-speed data transfer**
  - From memory to peripheral
  - From memory to memory
  - From peripheral to memory
  - From peripheral to peripheral
- **4 Channels**
- **From 1 byte and up to 16M bytes transfers in a single transaction**
- **Multiple addressing modes for source and destination address**
  - Increment
  - Decrement
  - Static
- **1, 2, 4, or 8 byte Burst Transfers**
- **Programmable priority between channels**

### **8.2 Overview**

The XMEGA A1 has a Direct Memory Access (DMA) Controller to move data between memories and peripherals in the data space. The DMA controller uses the same data bus as the CPU to transfer data.

It has 4 channels that can be configured independently. Each DMA channel can perform data transfers in blocks of configurable size from 1 to 64K bytes. A repeat counter can be used to repeat each block transfer for single transactions up to 16M bytes. Each DMA channel can be configured to access the source and destination memory address with incrementing, decrementing or static addressing. The addressing is independent for source and destination address. When the transaction is complete the original source and destination address can automatically be reloaded to be ready for the next transaction.

The DMAC can access all the peripherals through their I/O memory registers, and the DMA may be used for automatic transfer of data to/from communication modules, as well as automatic data retrieval from ADC conversions, data transfer to DAC conversions, or data transfer to or from port pins. A wide range of transfer triggers is available from the peripherals, Event System and software. Each DMA channel has different transfer triggers.

To allow for continuous transfers, two channels can be interlinked so that the second takes over the transfer when the first is finished and vice versa.

The DMA controller can read from memory mapped EEPROM, but it cannot write to the EEPROM or access the Flash.

## 9. Event System

### 9.1 Features

- Inter-peripheral communication and signalling with minimum latency
- CPU and DMA independent operation
- 8 Event Channels allows for up to 8 signals to be routed at the same time
- Events can be generated by
  - Timer/Counters (TCxn)
  - Real Time Counter (RTC)
  - Analog to Digital Converters (ADCx)
  - Analog Comparators (ACx)
  - Ports (PORTx)
  - System Clock (Clk<sub>sys</sub>)
  - Software (CPU)
- Events can be used by
  - Timer/Counters (TCxn)
  - Analog to Digital Converters (ADCx)
  - Digital to Analog Converters (DACx)
  - Ports (PORTx)
  - DMA Controller (DMAC)
  - IR Communication Module (IRCOM)
- The same event can be used by multiple peripherals for synchronized timing
- Advanced Features
  - Manual Event Generation from software (CPU)
  - Quadrature Decoding
  - Digital Filtering
- Functions in Active and Idle mode

### 9.2 Overview

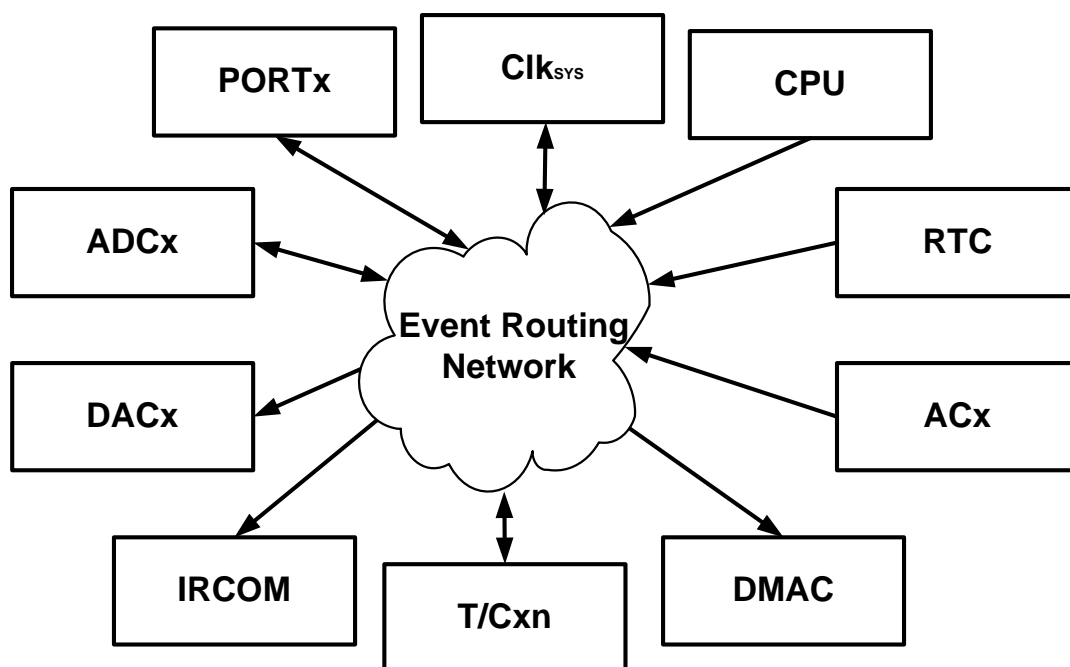
The Event System is a set of features for inter-peripheral communication. It enables the possibility for a change of state in one peripheral to automatically trigger actions in one or more peripherals. What changes in a peripheral that will trigger actions in other peripherals are configurable by software. It is a simple, but powerful system as it allows for autonomous control of peripherals without any use of interrupts, CPU or DMA resources.

The indication of a change in a peripheral is referred to as an event, and is usually the same as the interrupt conditions for that peripheral. Events are passed between peripherals using a dedicated routing network called the Event Routing Network. [Figure 9-1 on page 17](#) shows a basic block diagram of the Event System with the Event Routing Network and the peripherals to which it is connected. This highly flexible system can be used for simple routing of signals, pin functions or for sequencing of events.

The maximum latency is two CPU clock cycles from when an event is generated in one peripheral, until the actions are triggered in one or more other peripherals.

The Event System is functional in both Active and Idle modes.



**Figure 9-1.** Event system block diagram.

The Event Routing Network can directly connect together ADCs, DACs, Analog Comparators (ACx), I/O ports (PORTx), the Real-time Counter (RTC), Timer/Counters (T/C) and the IR Communication Module (IRCOM). Events can also be generated from software (CPU).

All events from all peripherals are always routed into the Event Routing Network. This consists of eight multiplexers where each can be configured in software to select which event to be routed into that event channel. All eight event channels are connected to the peripherals that can use events, and each of these peripherals can be configured to use events from one or more event channels to automatically trigger a software selectable action.

## 10. System Clock and Clock options

### 10.1 Features

- Fast start-up time
- Safe run-time clock switching
- Internal Oscillators:
  - 32 MHz run-time calibrated RC oscillator
  - 2 MHz run-time calibrated RC oscillator
  - 32 kHz calibrated RC oscillator
  - 32 kHz Ultra Low Power (ULP) oscillator
- External clock options
  - 0.4 - 16 MHz Crystal Oscillator
  - 32 kHz Crystal Oscillator
  - External clock
- PLL with internal and external clock options with 2 to 31x multiplication
- Clock Prescalers with 2 to 2048x division
- Fast peripheral clock running at 2 and 4 times the CPU clock speed
- Automatic Run-Time Calibration of internal oscillators
- Crystal Oscillator failure detection

### 10.2 Overview

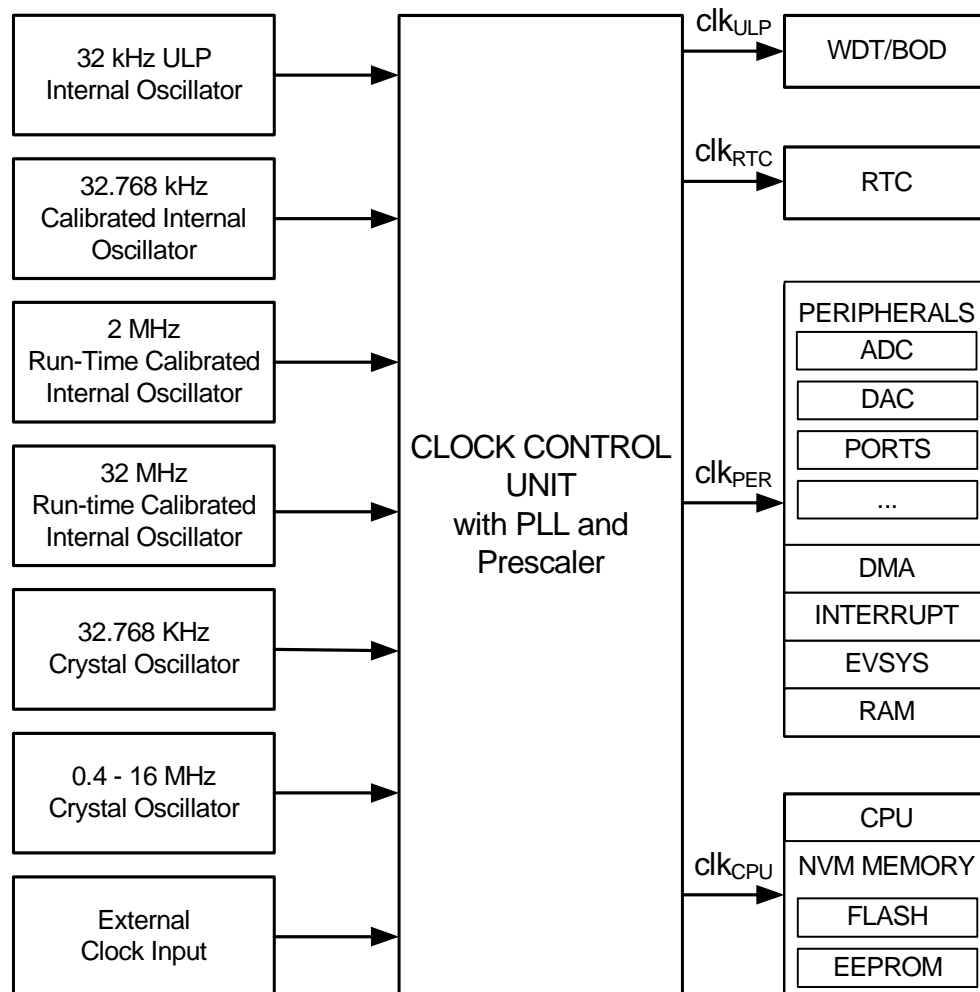
XMEGA A1 has an advanced clock system, supporting a large number of clock sources. It incorporates both integrated oscillators, external crystal oscillators and resonators. A high frequency Phase Locked Loop (PLL) and clock prescalers can be controlled from software to generate a wide range of clock frequencies from the clock source input.

It is possible to switch between clock sources from software during run-time. After reset the device will always start up running from the 2 Mhz internal oscillator.

A calibration feature is available, and can be used for automatic run-time calibration of the internal 2 MHz and 32 MHz oscillators. This reduce frequency drift over voltage and temperature.

A Crystal Oscillator Failure Monitor can be enabled to issue a Non-Maskable Interrupt and switch to internal oscillator if the external oscillator fails. [Figure 10-1 on page 19](#) shows the principal clock system in XMEGA A1.

**Figure 10-1.** Clock system overview



Each clock source is briefly described in the following sub-sections.

## 10.3 Clock Options

### 10.3.1 32 kHz Ultra Low Power Internal Oscillator

The 32 kHz Ultra Low Power (ULP) Internal Oscillator is a very low power consumption clock source. It is used for the Watchdog Timer, Brown-Out Detection and as an asynchronous clock source for the Real Time Counter. This oscillator cannot be used as the system clock source, and it cannot be directly controlled from software.

### 10.3.2 32.768 kHz Calibrated Internal Oscillator

The 32.768 kHz Calibrated Internal Oscillator is a high accuracy clock source that can be used as the system clock source or as an asynchronous clock source for the Real Time Counter. It is calibrated during protection to provide a default frequency which is close to its nominal frequency.

**10.3.3 32.768 kHz Crystal Oscillator**

The 32.768 kHz Crystal Oscillator is a low power driver for an external watch crystal. It can be used as system clock source or as asynchronous clock source for the Real Time Counter.

**10.3.4 0.4 - 16 MHz Crystal Oscillator**

The 0.4 - 16 MHz Crystal Oscillator is a driver intended for driving both external resonators and crystals ranging from 400 kHz to 16 MHz.

**10.3.5 2 MHz Run-time Calibrated Internal Oscillator**

The 2 MHz Run-time Calibrated Internal Oscillator is a high frequency oscillator. It is calibrated during protection to provide a default frequency which is close to its nominal frequency. The oscillator can use the 32 kHz Calibrated Internal Oscillator or the 32 kHz Crystal Oscillator as a source for calibrating the frequency run-time to compensate for temperature and voltage drift hereby optimizing the accuracy of the oscillator.

**10.3.6 32 MHz Run-time Calibrated Internal Oscillator**

The 32 MHz Run-time Calibrated Internal Oscillator is a high frequency oscillator. It is calibrated during protection to provide a default frequency which is close to its nominal frequency. The oscillator can use the 32 kHz Calibrated Internal Oscillator or the 32 kHz Crystal Oscillator as a source for calibrating the frequency run-time to compensate for temperature and voltage drift hereby optimizing the accuracy of the oscillator.

**10.3.7 External Clock input**

The external clock input gives the possibility to connect a clock from an external source.

**10.3.8 PLL with Multiplication factor 2 - 31x**

The PLL provides the possibility of multiplying a frequency by any number from 2 to 31. In combination with the prescalers, this gives a wide range of output frequencies from all clock sources.

## **11. Power Management and Sleep Modes**

### **11.1 Features**

- **5 sleep modes**
  - Idle
  - Power-down
  - Power-save
  - Standby
  - Extended standby
- **Power Reduction registers to disable clocks to unused peripherals**

### **11.2 Overview**

The XMEGA A1 provides various sleep modes tailored to reduce power consumption to a minimum. All sleep modes are available and can be entered from Active mode. In Active mode the CPU is executing application code. The application code decides when and what sleep mode to enter. Interrupts from enabled peripherals and all enabled reset sources can restore the micro-controller from sleep to Active mode.

In addition, Power Reduction registers provide a method to stop the clock to individual peripherals from software. When this is done, the current state of the peripheral is frozen and there is no power consumption from that peripheral. This reduces the power consumption in Active mode and Idle sleep mode.

### **11.3 Sleep Modes**

#### **11.3.1 Idle Mode**

In Idle mode the CPU and Non-Volatile Memory are stopped, but all peripherals including the Interrupt Controller, Event System and DMA Controller are kept running. Interrupt requests from all enabled interrupts will wake the device.

#### **11.3.2 Power-down Mode**

In Power-down mode all system clock sources, and the asynchronous Real Time Counter (RTC) clock source, are stopped. This allows operation of asynchronous modules only. The only interrupts that can wake up the MCU are the Two Wire Interface address match interrupts, and asynchronous port interrupts, e.g pin change.

#### **11.3.3 Power-save Mode**

Power-save mode is identical to Power-down, with one exception: If the RTC is enabled, it will keep running during sleep and the device can also wake up from RTC interrupts.

#### **11.3.4 Standby Mode**

Standby mode is identical to Power-down with the exception that all enabled system clock sources are kept running, while the CPU, Peripheral and RTC clocks are stopped. This reduces the wake-up time when external crystals or resonators are used.

#### **11.3.5 Extended Standby Mode**

Extended Standby mode is identical to Power-save mode with the exception that all enabled system clock sources are kept running while the CPU and Peripheral clocks are stopped. This reduces the wake-up time when external crystals or resonators are used.

## 12. System Control and Reset

### 12.1 Features

- Multiple reset sources for safe operation and device reset
  - Power-On Reset
  - External Reset
  - Watchdog Reset
    - The Watchdog Timer runs from separate, dedicated oscillator
  - Brown-Out Reset
    - Accurate, programmable Brown-Out levels
  - JTAG Reset
  - PDI reset
  - Software reset
- Asynchronous reset
  - No running clock in the device is required for reset
- Reset status register

### 12.2 Resetting the AVR

During reset, all I/O registers are set to their initial values. The SRAM content is not reset. Application execution starts from the Reset Vector. The instruction placed at the Reset Vector should be an Absolute Jump (JMP) instruction to the reset handling routine. By default the Reset Vector address is the lowest Flash program memory address, '0', but it is possible to move the Reset Vector to the first address in the Boot Section.

The I/O ports of the AVR are immediately tri-stated when a reset source goes active.

The reset functionality is asynchronous, so no running clock is required to reset the device.

After the device is reset, the reset source can be determined by the application by reading the Reset Status Register.

### 12.3 Reset Sources

#### 12.3.1 Power-On Reset

The MCU is reset when the supply voltage VCC is below the Power-on Reset threshold voltage.

#### 12.3.2 External Reset

The MCU is reset when a low level is present on the RESET pin.

#### 12.3.3 Watchdog Reset

The MCU is reset when the Watchdog Timer period expires and the Watchdog Reset is enabled. The Watchdog Timer runs from a dedicated oscillator independent of the System Clock. For more details see [“WDT - Watchdog Timer” on page 23](#).

#### 12.3.4 Brown-Out Reset

The MCU is reset when the supply voltage VCC is below the Brown-Out Reset threshold voltage and the Brown-out Detector is enabled. The Brown-out threshold voltage is programmable.

### **12.3.5 JTAG reset**

The MCU is reset as long as there is a logic one in the Reset Register in one of the scan chains of the JTAG system. Refer to IEEE 1149.1 (JTAG) Boundary-scan for details.

### **12.3.6 PDI reset**

The MCU can be reset through the Program and Debug Interface (PDI).

### **12.3.7 Software reset**

The MCU can be reset by the CPU writing to a special I/O register through a timed sequence.

## **12.4 WDT - Watchdog Timer**

### **12.4.1 Features**

- **11 selectable timeout periods, from 8 ms to 8s.**
- **Two operation modes**
  - **Standard mode**
  - **Window mode**
- **Runs from the 1 kHz output of the 32 kHz Ultra Low Power oscillator**
- **Configuration lock to prevent unwanted changes**

### **12.4.2 Overview**

The XMEGA A1 has a Watchdog Timer (WDT). The WDT will run continuously when turned on and if the Watchdog Timer is not reset within a software configurable time-out period, the microcontroller will be reset. The Watchdog Reset (WDR) instruction must be run by software to reset the WDT, and prevent microcontroller reset.

The WDT has a Window mode. In this mode the WDR instruction must be run within a specified period called a window. Application software can set the minimum and maximum limits for this window. If the WDR instruction is not executed inside the window limits, the microcontroller will be reset.

A protection mechanism using a timed write sequence is implemented in order to prevent unwanted enabling, disabling or change of WDT settings.

For maximum safety, the WDT also has an Always-on mode. This mode is enabled by programming a fuse. In Always-on mode, application software can not disable the WDT.

## 13. PMIC - Programmable Multi-level Interrupt Controller

### 13.1 Features

- Separate interrupt vector for each interrupt
- Short, predictable interrupt response time
- Programmable Multi-level Interrupt Controller
  - 3 programmable interrupt levels
  - Selectable priority scheme within low level interrupts (round-robin or fixed)
  - Non-Maskable Interrupts (NMI)
- Interrupt vectors can be moved to the start of the Boot Section

### 13.2 Overview

XMEGA A1 has a Programmable Multi-level Interrupt Controller (PMIC). All peripherals can define three different priority levels for interrupts; high, medium or low. Medium level interrupts may interrupt low level interrupt service routines. High level interrupts may interrupt both low- and medium level interrupt service routines. Low level interrupts have an optional round robin scheme to make sure all interrupts are serviced within a certain amount of time.

The built in oscillator failure detection mechanism can issue a Non-Maskable Interrupt (NMI).

### 13.3 Interrupt vectors

When an interrupt is serviced, the program counter will jump to the interrupt vector address. The interrupt vector is the sum of the peripheral's base interrupt address and the offset address for specific interrupts in each peripheral. The base addresses for the XMEGA A1 devices are shown in [Table 13-1](#). Offset addresses for each interrupt available in the peripheral are described for each peripheral in the XMEGA A manual. For peripherals or modules that have only one interrupt, the interrupt vector is shown in [Table 13-1](#). The program address is the word address.

**Table 13-1.** Reset and Interrupt Vectors

Program Address (Base Address)	Source	Interrupt Description
0x000	RESET	
0x002	OSCF_INT_vect	Crystal Oscillator Failure Interrupt vector (NMI)
0x004	PORTC_INT_base	Port C Interrupt base
0x008	PORTR_INT_base	Port R Interrupt base
0x00C	DMA_INT_base	DMA Controller Interrupt base
0x014	RTC_INT_base	Real Time Counter Interrupt base
0x018	TWIC_INT_base	Two-Wire Interface on Port C Interrupt base
0x01C	TCC0_INT_base	Timer/Counter 0 on port C Interrupt base
0x028	TCC1_INT_base	Timer/Counter 1 on port C Interrupt base
0x030	SPIC_INT_vect	SPI on port C Interrupt vector
0x032	USARTC0_INT_base	USART 0 on port C Interrupt base
0x038	USARTC1_INT_base	USART 1 on port C Interrupt base
0x03E	AES_INT_vect	AES Interrupt vector



Table 13-1. Reset and Interrupt Vectors (Continued)

Program Address (Base Address)	Source	Interrupt Description
0x040	NVM_INT_base	Non-Volatile Memory Interrupt base
0x044	PORTB_INT_base	Port B Interrupt base
0x048	ACB_INT_base	Analog Comparator on Port B Interrupt base
0x04E	ADCB_INT_base	Analog to Digital Converter on Port B Interrupt base
0x056	PORTE_INT_base	Port E Interrupt base
0x05A	TWIE_INT_base	Two-Wire Interface on Port E Interrupt base
0x05E	TCE0_INT_base	Timer/Counter 0 on port E Interrupt base
0x06A	TCE1_INT_base	Timer/Counter 1 on port E Interrupt base
0x072	SPIE_INT_vect	SPI on port E Interrupt vector
0x074	USARTE0_INT_base	USART 0 on port E Interrupt base
0x07A	USARTE1_INT_base	USART 1 on port E Interrupt base
0x080	PORTD_INT_base	Port D Interrupt base
0x084	PORTA_INT_base	Port A Interrupt base
0x088	ACA_INT_base	Analog Comparator on Port A Interrupt base
0x08E	ADCA_INT_base	Analog to Digital Converter on Port A Interrupt base
0x096	TWID_INT_base	Two-Wire Interface on Port D Interrupt base
0x09A	TCD0_INT_base	Timer/Counter 0 on port D Interrupt base
0x0A6	TCD1_INT_base	Timer/Counter 1 on port D Interrupt base
0x0AE	SPID_INT_vector	SPI on port D Interrupt vector
0x0B0	USARTD0_INT_base	USART 0 on port D Interrupt base
0x0B6	USARTD1_INT_base	USART 1 on port D Interrupt base
0x0BC	PORTQ_INT_base	Port Q INT base
0x0C0	PORTH_INT_base	Port H INT base
0x0C4	PORTJ_INT_base	Port J INT base
0x0C8	PORTK_INT_base	Port K INT base
0x0D0	PORTF_INT_base	Port F INT base
0x0D4	TWIF_INT_base	Two-Wire Interface on Port F INT base
0x0D8	TCF0_INT_base	Timer/Counter 0 on port F Interrupt base
0x0E4	TCF1_INT_base	Timer/Counter 1 on port F Interrupt base
0x0EC	SPIF_INT_vector	SPI on port F Interrupt base
0x0EE	USARTF0_INT_base	USART 0 on port F Interrupt base
0x0F4	USARTF1_INT_base	USART 1 on port F Interrupt base

## 14. I/O Ports

### 14.1 Features

- Selectable input and output configuration for each pin individually
- Flexible pin configuration through dedicated Pin Configuration Register
- Synchronous and/or asynchronous input sensing with port interrupts and events
  - Sense both edges
  - Sense rising edges
  - Sense falling edges
  - Sense low level
- Asynchronous wake-up from all input sensing configurations
- Two port interrupts with flexible pin masking
- Highly configurable output driver and pull settings:
  - Totem-pole
  - Pull-up/-down
  - Wired-AND
  - Wired-OR
  - Bus-keeper
  - Inverted I/O
- Optional Slew rate control
- Configuration of multiple pins in a single operation
- Read-Modify-Write (RMW) support
- Toggle/clear/set registers for Output and Direction registers
- Clock output on port pin
- Event Channel 7 output on port pin
- Mapping of port registers (virtual ports) into bit accessible I/O memory space

### 14.2 Overview

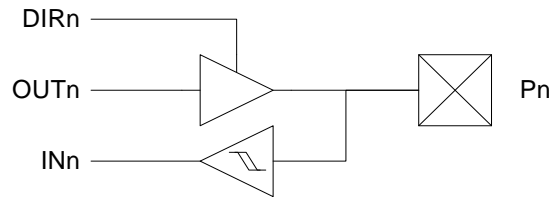
The XMEGA A1 devices have flexible General Purpose I/O Ports. A port consists of up to 8 pins, ranging from pin 0 to pin 7. The ports implement several functions, including synchronous/asynchronous input sensing, pin change interrupts and configurable output settings. All functions are individual per pin, but several pins may be configured in a single operation.

### 14.3 I/O configuration

All port pins (Pn) have programmable output configuration. In addition, all port pins have an inverted I/O function. For an input, this means inverting the signal between the port pin and the pin register. For an output, this means inverting the output signal between the port register and the port pin. The inverted I/O function can be used also when the pin is used for alternate functions. The port pins also have configurable slew rate limitation to reduce electromagnetic emission.

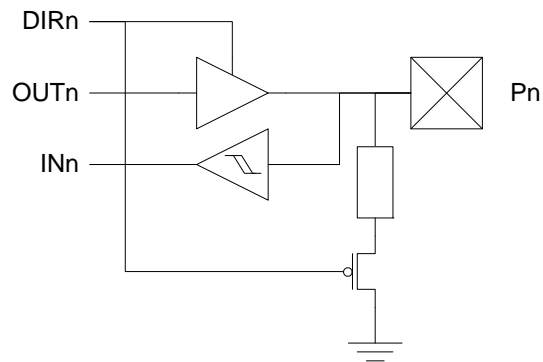
## 14.3.1 Push-pull

**Figure 14-1.** I/O configuration - Totem-pole



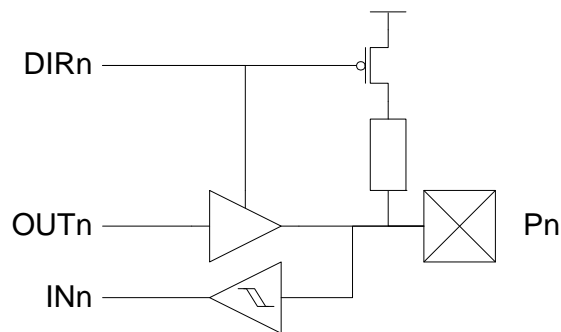
## 14.3.2 Pull-down

**Figure 14-2.** I/O configuration - Totem-pole with pull-down (on input)



## 14.3.3 Pull-up

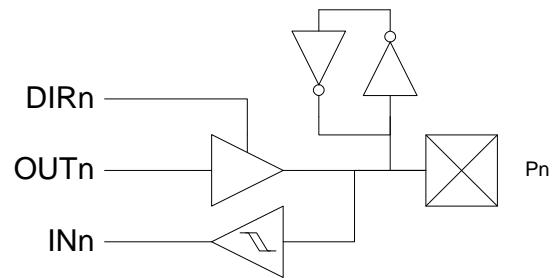
**Figure 14-3.** I/O configuration - Totem-pole with pull-up (on input)



## 14.3.4 Bus-keeper

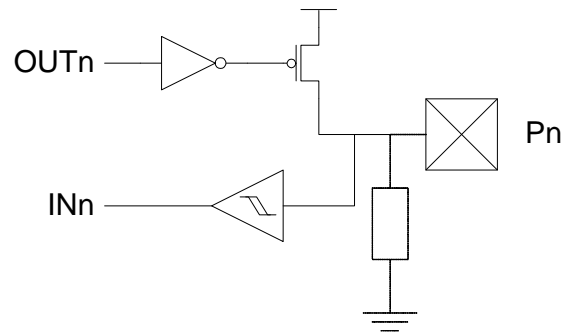
The bus-keeper's weak output produces the same logical level as the last output level. It acts as a pull-up if the last level was '1', and pull-down if the last level was '0'.

**Figure 14-4.** I/O configuration - Totem-pole with bus-keeper

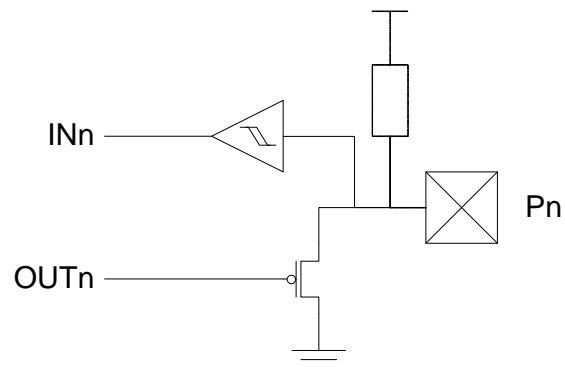


### 14.3.5 Others

**Figure 14-5.** Output configuration - Wired-OR with optional pull-down



**Figure 14-6.** I/O configuration - Wired-AND with optional pull-up

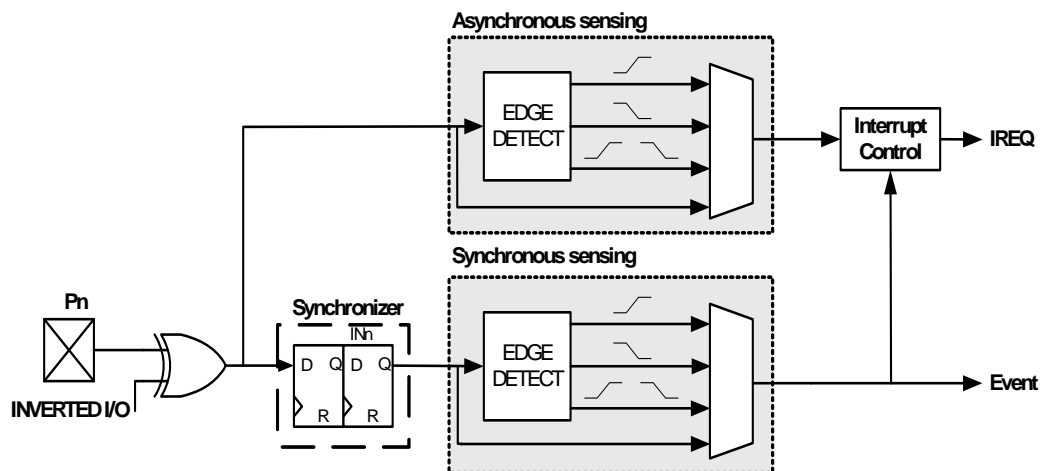


## 14.4 Input sensing

- Sense both edges
- Sense rising edges
- Sense falling edges
- Sense low level

Input sensing is synchronous or asynchronous depending on the enabled clock for the ports, and the configuration is shown in [Figure 14-7 on page 29](#).

**Figure 14-7.** Input sensing system overview



When a pin is configured with inverted I/O the pin value is inverted before the input sensing.

## 14.5 Port Interrupt

Each ports have two interrupts with separate priority and interrupt vector. All pins on the port can be individually selected as source for each of the interrupts. The interrupts are then triggered according to the input sense configuration for each pin configured as source for the interrupt.

## 14.6 Alternate Port Functions

In addition to the input/output functions on all port pins, most pins have alternate functions. This means that other modules or peripherals connected to the port can use the port pins for their functions, such as communication or pulse-width modulation. [“Pinout and Pin Functions” on page 48](#) shows which modules on peripherals that enables alternate functions on a pin, and what alternate functions that is available on a pin.

## 15. T/C - 16-bit Timer/Counter

### 15.1 Features

- **Eight 16-bit Timer/Counters**
  - Four Timer/Counters of type 0
  - Four Timer/Counters of type 1
- **Four Compare or Capture (CC) Channels in Timer/Counter 0**
- **Two Compare or Capture (CC) Channels in Timer/Counter 1**
- **Double Buffered Timer Period Setting**
- **Double Buffered Compare or Capture Channels**
- **Waveform Generation:**
  - Single Slope Pulse Width Modulation
  - Dual Slope Pulse Width Modulation
  - Frequency Generation
- **Input Capture:**
  - Input Capture with Noise Cancelling
  - Frequency capture
  - Pulse width capture
  - 32-bit input capture
- **Event Counter with Direction Control**
- **Timer Overflow and Timer Error Interrupts and Events**
- **One Compare Match or Capture Interrupt and Event per CC Channel**
- **Supports DMA Operation**
- **Hi-Resolution Extension (Hi-Res)**
- **Advanced Waveform Extension (AWEX)**

### 15.2 Overview

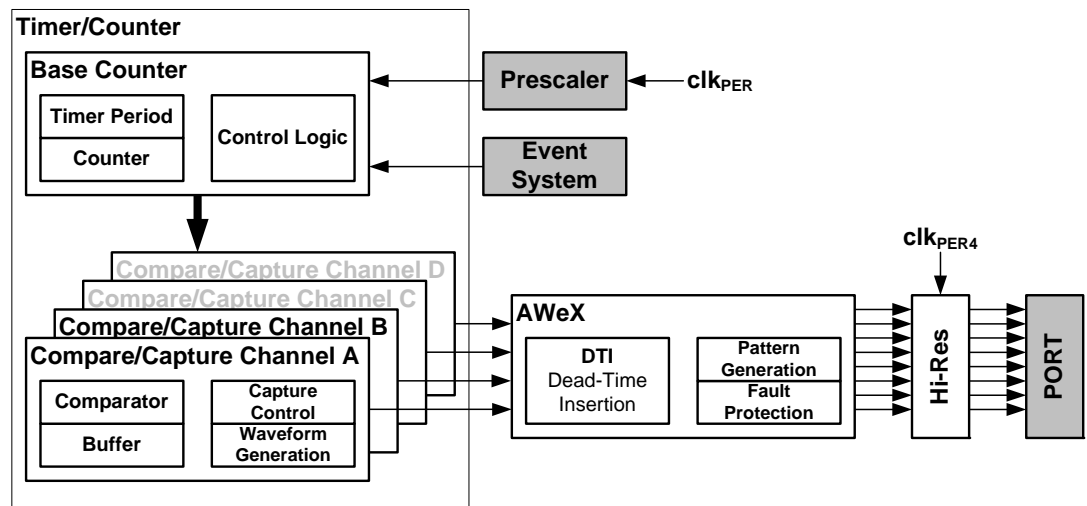
XMEGA A1 has eight Timer/Counters, four Timer/Counter 0 and four Timer/Counter 1. The difference between them is that Timer/Counter 0 has four Compare/Capture channels, while Timer/Counter 1 has two Compare/Capture channels.

The Timer/Counters (T/C) are 16-bit and can count any clock, event or external input in the microcontroller. A programmable prescaler is available to get a useful T/C resolution. Updates of Timer and Compare registers are double buffered to ensure glitch free operation. Single slope PWM, dual slope PWM and frequency generation waveforms can be generated using the Compare Channels.

Through the Event System, any input pin or event in the microcontroller can be used to trigger input capture, hence no dedicated pins is required for this. The input capture has a noise canceler to avoid incorrect capture of the T/C, and can be used to do frequency and pulse width measurements.

A wide range of interrupt or event sources are available, including T/C Overflow, Compare match and Capture for each Compare/Capture channel in the T/C.

PORTC, PORTD, PORTE and PORTF each has one Timer/Counter 0 and one Timer/Counter1. Notation of these Timer/Counters are TCC0 (Time/Counter C0), TCC1, TCD0, TCD1, TCE0, TCE1, TCF0, and TCF1, respectively.

**Figure 15-1.** Overview of a Timer/Counter and closely related peripherals

The Hi-Resolution Extension can be enabled to increase the waveform generation resolution by 2 bits (4x). This is available for all Timer/Counters. See [“Hi-Res - High Resolution Extension” on page 33](#) for more details.

The Advanced Waveform Extension can be enabled to provide extra and more advanced features for the Timer/Counter. This are only available for Timer/Counter 0. See [“AWEX - Advanced Waveform Extension” on page 32](#) for more details.

## 16. AWEX - Advanced Waveform Extension

### 16.1 Features

- Output with complementary output from each Capture channel
- Four Dead Time Insertion (DTI) Units, one for each Capture channel
- 8-bit DTI Resolution
- Separate High and Low Side Dead-Time Setting
- Double Buffered Dead-Time
- Event Controlled Fault Protection
- Single Channel Multiple Output Operation (for BLDC motor control)
- Double Buffered Pattern Generation

### 16.2 Overview

The Advanced Waveform Extension (AWEX) provides extra features to the Timer/Counter in Waveform Generation (WG) modes. The AWEX enables easy and safe implementation of for example, advanced motor control (AC, BLDC, SR, and Stepper) and power control applications.

Any WG output from a Timer/Counter 0 is split into a complimentary pair of outputs when any AWEX feature is enabled. These output pairs go through a Dead-Time Insertion (DTI) unit that enables generation of the non-inverted Low Side (LS) and inverted High Side (HS) of the WG output with dead time insertion between LS and HS switching. The DTI output will override the normal port value according to the port override setting. Optionally the final output can be inverted by using the invert I/O setting for the port pin.

The Pattern Generation unit can be used to generate a synchronized bit pattern on the port it is connected to. In addition, the waveform generator output from Compare Channel A can be distributed to, and override all port pins. When the Pattern Generator unit is enabled, the DTI unit is bypassed.

The Fault Protection unit is connected to the Event System. This enables any event to trigger a fault condition that will disable the AWEX output. Several event channels can be used to trigger fault on several different conditions.

The AWEX is available for TCC0 and TCE0. The notation of these peripherals are AWEXC and AWEXE.



## **17. Hi-Res - High Resolution Extension**

### **17.1 Features**

- **Increases Waveform Generator resolution by 2-bits (4x)**
- **Supports Frequency, single- and dual-slope PWM operation**
- **Supports the AWEX when this is enabled and used for the same Timer/Counter**

### **17.2 Overview**

The Hi-Resolution (Hi-Res) Extension is able to increase the resolution of the waveform generation output by a factor of 4. When enabled for a Timer/Counter, the Fast Peripheral clock running at four times the CPU clock speed will be as input to the Timer/Counter.

The High Resolution Extension can also be used when an AWEX is enabled and used with a Timer/Counter.

XMEGA A1 devices have four Hi-Res Extensions that each can be enabled for each Timer/Counter pair on PORTC, PORTD, PORTE and PORTF. The notation of these peripherals are HIRESC, HIRESD, HIRESE and HIRESF, respectively.

## 18. RTC - 16-bit Real-Time Counter

### 18.1 Features

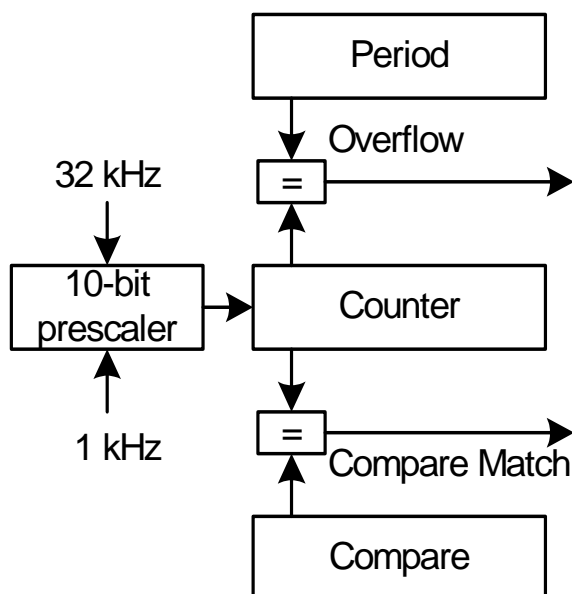
- 16-bit Timer
- Flexible Tick resolution ranging from 1 Hz to 32.768 kHz
- One Compare register
- One Period register
- Clear timer on Overflow or Compare Match
- Overflow or Compare Match event and interrupt generation

### 18.2 Overview

The XMEGA A1 includes a 16-bit Real-time Counter (RTC). The RTC can be clocked from an accurate 32.768 kHz Crystal Oscillator, the 32.768 kHz Calibrated Internal Oscillator, or from the 32 kHz Ultra Low Power Internal Oscillator. The RTC includes both a Period and a Compare register. For details, see [Figure 18-1](#).

A wide range of Resolution and Time-out periods can be configured using the RTC. With a maximum resolution of 30.5  $\mu$ s, time-out periods range up to 2000 seconds. With a resolution of 1 second, the maximum time-out period is over 18 hours (65536 seconds).

**Figure 18-1.** Real Time Counter overview



## 19. TWI - Two-Wire Interface

### 19.1 Features

- Four Identical TWI peripherals
- Simple yet Powerful and Flexible Communication Interface
- Both Master and Slave Operation Supported
- Device can Operate as Transmitter or Receiver
- 7-bit Address Space Allows up to 128 Different Slave Addresses
- Multi-master Arbitration Support
- Up to 400 kHz Data Transfer Speed
- Slew-rate Limited Output Drivers
- Noise Suppression Circuitry Rejects Spikes on Bus Lines
- Fully Programmable Slave Address with General Call Support
- Address Recognition Causes Wake-up when in Sleep Mode
- I<sup>2</sup>C and System Management Bus (SMBus) compatible

### 19.2 Overview

The Two-Wire Interface (TWI) is a bi-directional wired-AND bus with only two lines, the clock (SCL) line and the data (SDA) line. The protocol makes it possible to interconnect up to 128 individually addressable devices. Since it is a multi-master bus, one or more devices capable of taking control of the bus can be connected.

The only external hardware needed to implement the bus is a single pull-up resistor for each of the TWI bus lines. Mechanisms for resolving bus contention are inherent in the TWI protocol.

PORTC, PORTD, PORTE, and PORTF each has one TWI. Notation of these peripherals are TWIC, TWID, TWIE, and TWIF, respectively.

## **20. SPI - Serial Peripheral Interface**

### **20.1 Features**

- Four Identical SPI peripherals
- Full-duplex, Three-wire Synchronous Data Transfer
- Master or Slave Operation
- LSB First or MSB First Data Transfer
- Seven Programmable Bit Rates
- End of Transmission Interrupt Flag
- Write Collision Flag Protection
- Wake-up from Idle Mode
- Double Speed (CK/2) Master SPI Mode

### **20.2 Overview**

The Serial Peripheral Interface (SPI) allows high-speed full-duplex, synchronous data transfer between different devices. Devices can communicate using a master-slave scheme, and data is transferred both to and from the devices simultaneously.

PORTC, PORTD, PORTE, and PORTF each has one SPI. Notation of these peripherals are SPIC, SPID, SPIE, and SPIF, respectively.

## **21. USART**

### **21.1 Features**

- **Eight Identical USART peripherals**
- **Full Duplex Operation (Independent Serial Receive and Transmit Registers)**
- **Asynchronous or Synchronous Operation**
- **Master or Slave Clocked Synchronous Operation**
- **High-resolution Arithmetic Baud Rate Generator**
- **Supports Serial Frames with 5, 6, 7, 8, or 9 Data Bits and 1 or 2 Stop Bits**
- **Odd or Even Parity Generation and Parity Check Supported by Hardware**
- **Data OverRun Detection**
- **Framing Error Detection**
- **Noise Filtering Includes False Start Bit Detection and Digital Low Pass Filter**
- **Three Separate Interrupts on TX Complete, TX Data Register Empty and RX Complete**
- **Multi-processor Communication Mode**
- **Double Speed Asynchronous Communication Mode**
- **Master SPI mode for SPI communication**
- **IrDA support through the IRCOM module**

### **21.2 Overview**

The Universal Synchronous and Asynchronous serial Receiver and Transmitter (USART) is a highly flexible serial communication module. The USART supports full duplex communication, and both asynchronous and clocked synchronous operation. The USART can also be set in Master SPI mode to be used for SPI communication.

Communication is frame based, and the frame format can be customized to support a wide range of standards. The USART is buffered in both direction, enabling continued data transmission without any delay between frames. There are separate interrupt vectors for receive and transmit complete, enabling fully interrupt driven communication. Frame error and buffer overflow are detected in hardware and indicated with separate status flags. Even or odd parity generation and parity check can also be enabled.

One USART can use the IRCOM module to support IrDA 1.4 physical compliant pulse modulation and demodulation for baud rates up to 115.2 kbps.

PORTC, PORTD, PORTE, and PORTF each has two USARTs. Notation of these peripherals are USARTC0, USARTC1, USARTE0, USARTE1, USARTE0, USARTE1, USARTE0, USARTE1, USARTE0, USARTE1, respectively.

## **22. IRCOM - IR Communication Module**

### **22.1 Features**

- Pulse modulation/demodulation for infrared communication
- Compatible to IrDA 1.4 physical for baud rates up to 115.2 kbps
- Selectable pulse modulation scheme
  - 3/16 of baud rate period
  - Fixed pulse period, 8-bit programmable
  - Pulse modulation disabled
- Built in filtering
- Can be connected to and used by one USART at the time

### **22.2 Overview**

XMEGA contains an Infrared Communication Module (IRCOM) for IrDA communication with baud rates up to 115.2 kbps. This supports three modulation schemes: 3/16 of baud rate period, fixed programmable pulse time based on the Peripheral Clock speed, or pulse modulation disabled. There is one IRCOM available which can be connected to any USART to enable infrared pulse coding/decoding for that USART.

## 23. Crypto Engine

### 23.1 Features

- Data Encryption Standard (DES) CPU instruction
- Advanced Encryption Standard (AES) Crypto module
- DES Instruction
  - Encryption and Decryption
  - Single-cycle DES instruction
  - Encryption/Decryption in 16 clock cycles per 8-byte block
- AES Crypto Module
  - Encryption and Decryption
  - Support 128-bit keys
  - Support XOR data load mode to the State memory for Cipher Block Chaining
  - Encryption/Decryption in 375 clock cycles per 16-byte block

### 23.2 Overview

The Advanced Encryption Standard (AES) and Data Encryption Standard (DES) are two commonly used encryption standards. These are supported through an AES peripheral module and a DES CPU instruction. All communication interfaces and the CPU can optionally use AES and DES encrypted communication and data storage.

DES is supported by a DES instruction in the AVR XMEGA CPU. The 8-byte key and 8-byte data blocks must be loaded into the Register file, and then DES must be executed 16 times to encrypt/decrypt the data block.

The AES Crypto Module encrypts and decrypts 128-bit data blocks with the use of a 128-bit key. The key and data must be loaded into the key and state memory in the module before encryption/decryption is started. It takes 375 peripheral clock cycles before the encryption/decryption is done and decrypted/encrypted data can be read out, and an optional interrupt can be generated. The AES Crypto Module also has DMA support with transfer triggers when encryption/decryption is done and optional auto-start of encryption/decryption when the state memory is fully loaded.

## **24. ADC - 12-bit Analog to Digital Converter**

### **24.1 Features**

- Two ADCs with 12-bit resolution
- 2 Msps sample rate for each ADC
- Signed and Unsigned conversions
- 4 result registers with individual input channel control for each ADC
- 8 single ended inputs for each ADC
- 8x4 differential inputs for each ADC
- Software selectable gain of 2, 4, 8, 16, 32 or 64
- Software selectable resolution of 8- or 12-bit.
- Internal or External Reference selection
- Event triggered conversion for accurate timing
- DMA transfer of conversion results
- Interrupt/Event on compare result

### **24.2 Overview**

XMEGA A1 devices have two Analog to Digital Converters (ADC), see [Figure 24-1 on page 41](#). The two ADC modules can be operated simultaneously, individually or synchronized.

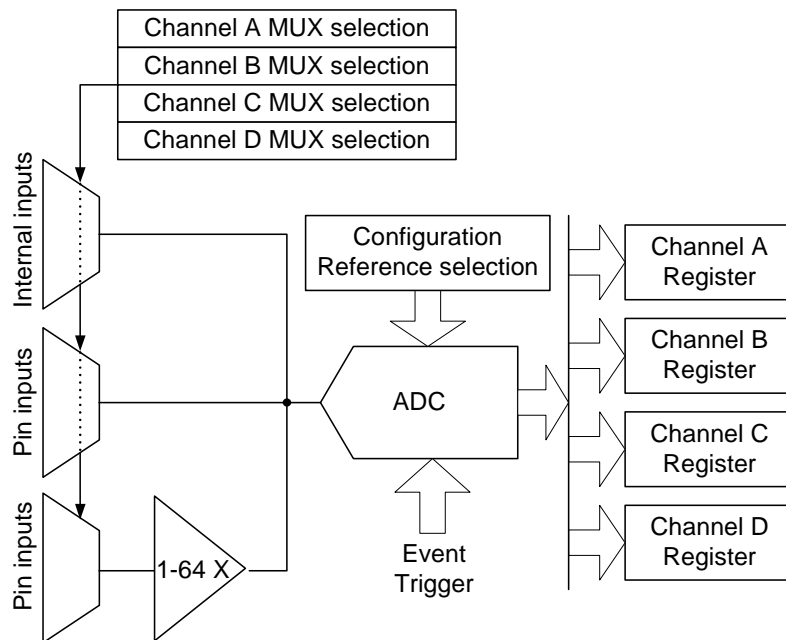
The ADC converts analog voltages to digital values. The ADC has 12-bit resolution and is capable of converting up to 2 million samples per second. The input selection is flexible, and both single-ended and differential measurements can be performed. The ADC can provide both signed and unsigned results, and an optional gain stage is available to increase the dynamic range of the ADC.

It is a Successive Approximation Result (SAR) ADC. A SAR ADC measures one bit of the conversion result at a time. The ADC has a pipeline architecture. This means that a new analog voltage can be sampled and a new ADC measurement started on each ADC clock cycle. Each sample will be converted in the pipeline, where the total sample and conversion time is seven ADC clock cycles for 12-bit result and 5 ADC clock cycles for 8-bit result.

ADC measurements can be started by application software or an incoming event from another peripheral in the device. Four different result registers with individual channel selection (MUX registers) are provided to make it easier for the application to keep track of the data. It is also possible to use DMA to move ADC results directly to memory or peripherals.

Both internal and external analog reference voltages can be used. An accurate internal 1.0V reference is available.



**Figure 24-1.** ADC overview

Each ADC has four MUX selection registers with a corresponding result register. This means that four channels can be sampled within 1.5  $\mu\text{s}$  without any intervention by the application other than starting the conversion. The results will be available in the result registers.

The ADC may be configured for 8- or 12-bit result, reducing the minimum conversion time (propagation delay) from 3.5  $\mu\text{s}$  for 12-bit to 2.5  $\mu\text{s}$  for 8-bit result.

ADC conversion results are provided left- or right adjusted with optional '1' or '0' padding. This eases calculation when the result is represented as a signed integer (signed 16-bit number).

PORTA and PORTB each has one ADC. Notation of these peripherals are ADCA and ADCB, respectively.

## 25. DAC - 12-bit Digital to Analog Converter

### 25.1 Features

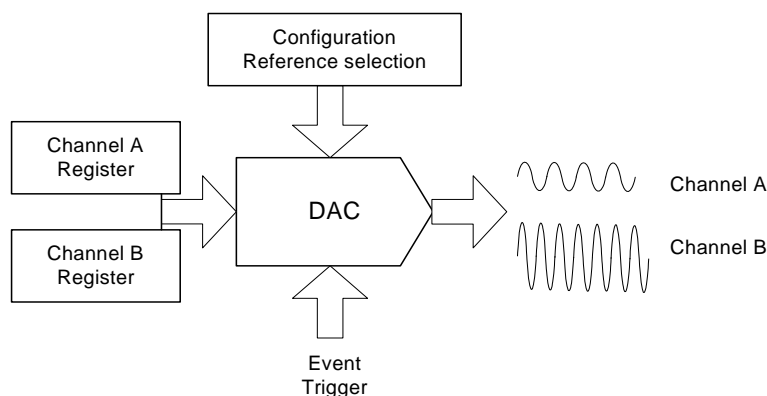
- Two DACs with 12-bit resolution
- Up to 1 Msps conversion rate for each DAC
- Flexible conversion range
- Multiple trigger sources
- 1 continuous output or 2 Sample and Hold (S/H) outputs for each DAC
- Built-in offset and gain calibration
- High drive capabilities
- Low Power Mode

### 25.2 Overview

The XMEGA A1 devices features two 12-bit, 1 Msps DACs with built-in offset and gain calibration, see [Figure 25-1 on page 42](#).

A DAC converts a digital value into an analog signal. The DAC may use an internal 1.1 voltage as the upper limit for conversion, but it is also possible to use the supply voltage or any applied voltage in-between. The external reference input is shared with the ADC reference input.

**Figure 25-1.** DAC overview



Each DAC has one continuous output with high drive capabilities for both resistive and capacitive loads. It is also possible to split the continuous time channel into two Sample and Hold (S/H) channels, each with separate data conversion registers.

A DAC conversion may be started from the application software by writing the data conversion registers. The DAC can also be configured to do conversions triggered by the Event System to have regular timing, independent of the application software. DMA may be used for transferring data from memory locations to DAC data registers.

The DAC has a built-in calibration system to reduce offset and gain error when loading with a calibration value from software.

PORTA and PORTB each has one DAC. Notation of these peripherals are DACA and DACB, respectively.

## 26. AC - Analog Comparator

### 26.1 Features

- Four Analog Comparators
- Selectable Power vs. Speed
- Selectable hysteresis
  - 0, 20 mV, 50 mV
- Analog Comparator output available on pin
- Flexible Input Selection
  - All pins on the port
  - Output from the DAC
  - Bandgap reference voltage.
  - Voltage scaler that can perform a 64-level scaling of the internal VCC voltage.
- Interrupt and event generation on
  - Rising edge
  - Falling edge
  - Toggle
- Window function interrupt and event generation on
  - Signal above window
  - Signal inside window
  - Signal below window

### 26.2 Overview

XMEGA A1 features four Analog Comparators (AC). An Analog Comparator compares two voltages, and the output indicates which input is largest. The Analog Comparator may be configured to give interrupt requests and/or events upon several different combinations of input change.

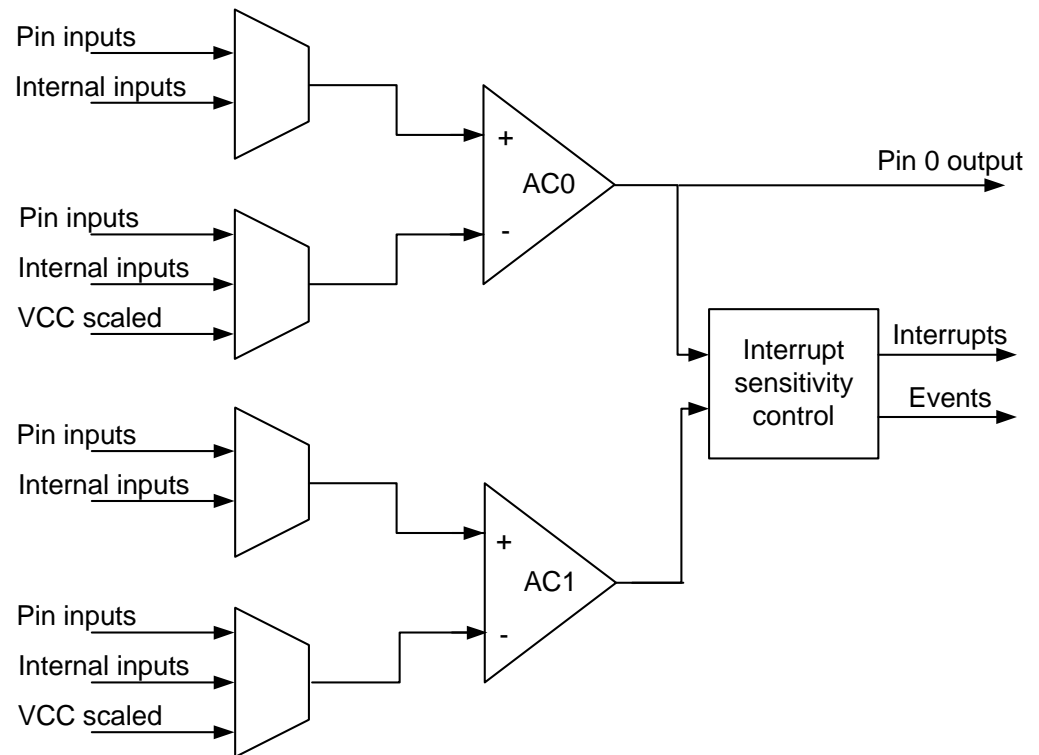
Both hysteresis and propagation delays may be adjusted in order to find the optimal operation for each application.

A wide range of input selection is available, both external pins and several internal signals can be used.

The Analog Comparators are always grouped in pairs (AC0 and AC1) on each analog port. They have identical behavior but separate control registers.

Optionally, the state of the comparator is directly available on a pin.

PORTA and PORTB each has one AC pair. Notations are ACA and ACB, respectively.

**Figure 26-1.** Analog comparator overview

## 26.3 Input Selection

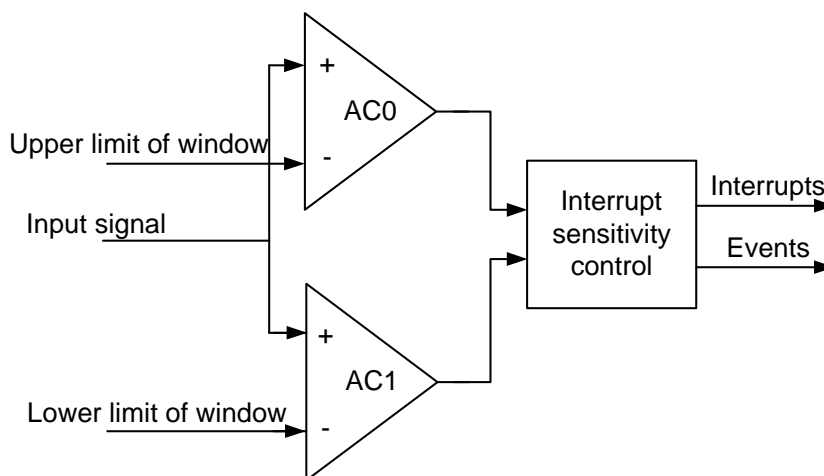
The Analog comparators have a very flexible input selection and the two comparators grouped in a pair may be used to realize a window function. One pair of analog comparators is shown in [Figure 26-1 on page 44](#).

- Input selection from pin
  - Pin 0, 1, 2, 3, 4, 5, 6 selectable to positive input of analog comparator
  - Pin 0, 1, 3, 5, 7 selectable to negative input of analog comparator
- Internal signals available on positive analog comparator inputs
  - Output from 12-bit DAC
- Internal signals available on negative analog comparator inputs
  - 64-level scaler of the VCC, available on negative analog comparator input
  - Bandgap voltage reference
  - Output from 12-bit DAC

## 26.4 Window Function

The window function is realized by connecting the external inputs of the two analog comparators in a pair as shown in [Figure 26-2](#).

**Figure 26-2.** Analog comparator window function



## **27. OCD - On-chip Debug**

### **27.1 Features**

- **Complete Program Flow Control**
  - Go, Stop, Reset, Step into, Step over, Step out, Run-to-Cursor
- **Debugging on C and high-level language source code level**
- **Debugging on Assembler and disassembler level**
- **1 dedicated program address or source level breakpoint for AVR Studio / debugger**
- **4 Hardware Breakpoints**
- **Unlimited Number of User Program Breakpoints**
- **Unlimited Number of User Data Breakpoints, with break on:**
  - Data location read, write or both read and write
  - Data location content equal or not equal to a value
  - Data location content is greater or less than a value
  - Data location content is within or outside a range
  - Bits of a data location are equal or not equal to a value
- **Non-Intrusive Operation**
  - No hardware or software resources in the device are used
- **High Speed Operation**
  - No limitation on debug/programming clock frequency versus system clock frequency

### **27.2 Overview**

The XMEGA A1 has a powerful On-Chip Debug (OCD) system that - in combination with Atmel's development tools - provides all the necessary functions to debug an application. It has support for program and data breakpoints, and can debug an application from C and high level language source code level, as well as assembler and disassembler level. It has full Non-Intrusive Operation and no hardware or software resources in the device are used. The ODC system is accessed through an external debugging tool which connects to the JTAG or PDI physical interfaces. Refer to ["Program and Debug Interfaces"](#) on page 47.

## **28. Program and Debug Interfaces**

### **28.1 Features**

- PDI - Program and Debug Interface (Atmel proprietary 2-pin interface)
- JTAG Interface (IEEE std. 1149.1 compliant)
- Boundary-scan capabilities according to the IEEE Std. 1149.1 (JTAG)
- Access to the OCD system
- Programming of Flash, EEPROM, Fuses and Lock Bits

### **28.2 Overview**

The programming and debug facilities are accessed through the JTAG and PDI physical interfaces. The PDI physical uses one dedicated pin together with the Reset pin, and no general purpose pins are used. JTAG uses four general purpose pins on PORTB.

### **28.3 JTAG interface**

The JTAG physical layer handles the basic low-level serial communication over four I/O lines named TMS, TCK, TDI, and TDO. It complies to the IEEE Std. 1149.1 for test access port and boundary scan.

### **28.4 PDI - Program and Debug Interface**

The PDI is an Atmel proprietary protocol for communication between the microcontroller and Atmel's development tools.

## 29. Pinout and Pin Functions

The pinout of XMEGA A1 is shown in [“Pinout/Block Diagram” on page 2](#). In addition to general I/O functionality, each pin may have several functions. This will depend on which peripheral is enabled and connected to the actual pin. Only one of the alternate pin functions can be used at time.

### 29.1 Alternate Pin Function Description

The tables below shows the notation for all pin functions available and describes its function.

#### 29.1.1 Operation/Power Supply

VCC	Digital supply voltage
AVCC	Analog supply voltage
GND	Ground

#### 29.1.2 Port Interrupt functions

SYNC	Port pin with full synchronous and limited asynchronous interrupt function
ASYN	Port pin with full synchronous and full asynchronous interrupt function

#### 29.1.3 Analog functions

ACn	Analog Comparator input pin n
AC0OUT	Analog Comparator 0 Output
ADCn	Analog to Digital Converter input pin n
DACn	Digital to Analog Converter output pin n
AREF	Analog Reference input pin

#### 29.1.4 EBI functions

An	Address line n	
Dn	Data line n	
$\overline{\text{CSn}}$	Chip Select n	
ALEn	Address Latch Enable pin n	(SRAM)
$\overline{\text{RE}}$	Read Enable	(SRAM)
$\overline{\text{WE}}$	External Data Memory Write	(SRAM /SDRAM)
BAn	Bank Address	(SDRAM)
$\overline{\text{CAS}}$	Column Access Strobe	(SDRAM)
CKE	SDRAM Clock Enable	(SDRAM)
CLK	SDRAM Clock	(SDRAM)
$\overline{\text{DQM}}$	Data Mask Signal/Output Enable	(SDRAM)
$\overline{\text{RAS}}$	Row Access Strobe	(SDRAM)



## 29.1.5 Timer/Counter and AWEX functions

OCnx	Output Compare Channel x for Timer/Counter n
$\overline{\text{OCxn}}$	Inverted Output Compare Channel x for Timer/Counter n

## 29.1.6 Communication functions

SCL	Serial Clock for TWI
SDA	Serial Data for TWI
SCLIN	Serial Clock In for TWI when external driver interface is enabled
SCOUT	Serial Clock Out for TWI when external driver interface is enabled
SDAIN	Serial Data In for TWI when external driver interface is enabled
SDAOUT	Serial Data Out for TWI when external driver interface is enabled
XCKn	Transfer Clock for USART n
RxDn	Receiver Data for USART n
TxDn	Transmitter Data for USART n
$\overline{\text{SS}}$	Slave Select for SPI
MOSI	Master Out Slave In for SPI
MISO	Master In Slave Out for SPI
SCK	Serial Clock for SPI

## 29.1.7 Oscillators, Clock and Event

TOSCn	Timer Oscillator pin n
XTALn	Input/Output for inverting Oscillator pin n
CLKOUT	Peripheral Clock Output
EVOUT	Event Channel 0 Output

## 29.1.8 Debug/System functions

$\overline{\text{RESET}}$	Reset pin
PDI_CLK	Program and Debug Interface Clock pin
PDI_DATA	Program and Debug Interface Data pin
TCK	JTAG Test Clock
TDI	JTAG Test Data In
TDO	JTAG Test Data Out
TMS	JTAG Test Mode Select

## 29.2 Alternate Pin Functions

The tables below show the primary/default function for each pin on a port in the first column, the pin number in the second column, and then all alternate pin functions in the remaining columns. The head row shows what peripheral that enable and use the alternate pin functions.

**Table 29-1.** Port A - Alternate functions

PORT A	PIN #	INTERRUPT	ADCA POS	ADCA NEG	ADCA GAINPOS	ADCA GAINNEG	ACA POS	ACA NEG	ACA OUT	DACA	REFA
GND	93										
AVCC	94										
PA0	95	SYNC	ADC0	ADC0	ADC0		AC0	AC0			AREF
PA1	96	SYNC	ADC1	ADC1	ADC1		AC1	AC1			
PA2	97	SYNC/ASYNC	ADC2	ADC2	ADC2		AC2			DAC0	
PA3	98	SYNC	ADC3	ADC3	ADC3		AC3	AC3		DAC1	
PA4	99	SYNC	ADC4		ADC4	ADC4	AC4				
PA5	100	SYNC	ADC5		ADC5	ADC5	AC5	AC5			
PA6	1	SYNC	ADC6		ADC6	ADC6	AC6				
PA7	2	SYNC	ADC7		ADC7	ADC7		AC7	AC0OUT		

**Table 29-2.** Port B - Alternate functions

PORT B	PIN #	INTERRUPT	ADCB POS	ADCB NEG	ADCB GAINPOS	ADCB GAINNEG	ACB POS	ACB NEG	ACB OUT	DACB	REFB	JTAG
GND	3											
VCC	4											
PB0	5	SYNC	ADC0	ADC0	ADC0		AC0	AC0			AREF	
PB1	6	SYNC	ADC1	ADC1	ADC1		AC1	AC1				
PB2	7	SYNC/ASYNC	ADC2	ADC2	ADC2		AC2			DAC0		
PB3	8	SYNC	ADC3	ADC3	ADC3		AC3	AC3		DAC1		
PB4	9	SYNC	ADC4		ADC4	ADC4	AC4					TMS
PB5	10	SYNC	ADC5		ADC5	ADC5	AC5	AC5				TDI
PB6	11	SYNC	ADC6		ADC6	ADC6	AC6					TCK
PB7	12	SYNC	ADC7		ADC7	ADC7		AC7	AC0OUT			TDO

**Table 29-3.** Port C - Alternate functions

PORT C	PIN #	INTERRUPT	TCC0	AWEXC	TCC1	USARTC0	USARTC1	SPIC	TWIC	CLOCKOUT	EVENTOUT
GND	13										
AVCC	14										
PC0	15	SYNC	OC0A	$\overline{OC0A}$					SDA		
PC1	16	SYNC	OC0B	OC0A		XCK0			SCL		
PC2	17	SYNC/ASYNC	OC0C	$\overline{OC0B}$		RXD0					
PC3	18	SYNC	OC0D	OC0B		TXD0					
PC4	19	SYNC		$\overline{OC0C}$	OC1A			$\overline{SS}$			
PC5	20	SYNC		OC0C	OC1B		XCK1	MOSI			
PC6	21	SYNC		$\overline{OC0D}$			RXD1	MISO			
PC7	22	SYNC		OC0D			TXD1	SCK		CLKOUT	EVOUT

**Table 29-4.** Port D - Alternate functions

PORT D	PIN #	INTERRUPT	TCD0	TCD1	USARTD0	USARTD1	SPID	TWID	CLOCKOUT	EVENTOUT
GND	23									
VCC	24									
PD0	25	SYNC	OC0A					SDA		
PD1	26	SYNC	OC0B		XCK0			SCL		
PD2	27	SYNC/ASYNC	OC0C		RXD0					
PD3	28	SYNC	OC0D		TXD0					
PD4	29	SYNC		OC1A			$\overline{SS}$			
PD5	30	SYNC		OC1B		XCK1	MOSI			
PD6	31	SYNC				RXD1	MISO			
PD7	32	SYNC				TXD1	SCK		CLKOUT	EVOUT

**Table 29-5.** Port E - Alternate functions

PORT E	PIN #	INTERRUPT	TCE0	AWEXE	TCE1	USARTE0	USARTE1	SPIE	TWIE	CLOCKOUT	EVENTOUT
GND	33										
VCC	34										
PE0	35	SYNC	OC0A	$\overline{OC0A}$					SDA		
PE1	36	SYNC	OC0B	OC0A		XCK0			SCL		
PE2	37	SYNC/ASYNC	OC0C	$\overline{OC0B}$		RXD0					
PE3	38	SYNC	OC0D	OC0B		TXD0					
PE4	39	SYNC		$\overline{OC0C}$	OC1A			$\overline{SS}$			
PE5	40	SYNC		OC0C	OC1B		XCK1	MOSI			
PE6	41	SYNC		$\overline{OC0D}$			RXD1	MISO			
PE7	42	SYNC		OC0D			TXD1	SCK		CLKOUT	EVOUT

**Table 29-6.** Port F - Alternate functions

PORT F	PIN #	INTERRUPT	TCF0	TCF1	USARTF0	USARTF1	SPIF	TWIF
GND	43							
VCC	44							
PF0	45	SYNC	OC0A					SDA
PF1	46	SYNC	OC0B		XCK0			SCL
PF2	47	SYNC/ASYNC	OC0C		RXD0			
PF3	48	SYNC	OC0D		TXD0			
PF4	49	SYNC		OC1A			$\overline{SS}$	
PF5	50	SYNC		OC1B		XCK1	MOSI	
PF6	51	SYNC				RXD1	MISO	
PF7	52	SYNC				TXD1	SCK	

**Table 29-7.** Port H - Alternate functions

PORT H	PIN #	INTERRUPT	SDRAM 3P	SRAM ALE1	SRAM ALE12	LPC3 ALE1	LPC2 ALE1	LPC2 ALE12
GND	53							
VCC	54							
PH0	55	SYNC	$\overline{WE}$	$\overline{WE}$	$\overline{WE}$	$\overline{WE}$	$\overline{WE}$	$\overline{WE}$
PH1	56	SYNC	$\overline{CAS}$	RE	RE	RE	RE	RE
PH2	57	SYNC/ASYNC	$\overline{RAS}$	ALE1	ALE1	ALE1	ALE1	ALE1
PH3	58	SYNC	$\overline{DQM}$		ALE2			ALE2
PH4	59	SYNC	BA0	$\overline{CS0}/A16$	$\overline{CS0}$	$\overline{CS0}/A16$	$\overline{CS0}$	$\overline{CS0}/A16$
PH5	60	SYNC	BA1	$\overline{CS1}/A17$	$\overline{CS1}$	$\overline{CS1}/A17$	$\overline{CS1}$	$\overline{CS1}/A17$
PH6	61	SYNC	CKE	$\overline{CS2}/A18$	$\overline{CS2}$	$\overline{CS2}/A18$	$\overline{CS2}$	$\overline{CS2}/A18$
PH7	62	SYNC	CLK	$\overline{CS3}/A19$	$\overline{CS3}$	$\overline{CS3}/A19$	$\overline{CS3}$	$\overline{CS3}/A19$

**Table 29-8.** Port J - Alternate functions

PORT J	PIN #	INTERRUPT	SDRAM 3P	SRAM ALE1	SRAM ALE12	LPC3 ALE1	LPC2 ALE1	LPC2 ALE12
GND	63							
VCC	64							
PJ0	65	SYNC	D0	D0	D0	D0/A0	D0/A0	D0/A0/A8
PJ1	66	SYNC	D1	D1	D1	D1/A1	D1/A1	D1/A1/A9
PJ2	67	SYNC/ASYNC	D2	D2	D2	D2/A2	D2/A2	D2/A2/A10
PJ3	68	SYNC	D3	D3	D3	D3/A3	D3/A3	D3/A3/A11
PJ4	69	SYNC	A8	D4	D4	D4/A4	D4/A4	D4/A4/A12
PJ5	70	SYNC	A9	D5	D5	D5/A5	D5/A5	D5/A5/A13
PJ6	71	SYNC	A10	D6	D6	D6/A6	D6/A6	D6/A6/A14
PJ7	72	SYNC	A11	D7	D7	D7/A7	D7/A7	D7/A7/A15

**Table 29-9.** Port K - Alternate functions

PORT K	PIN #	INTERRUPT	SDRAM 3P	SRAM ALE1	SRAM ALE2	LPC3 ALE1
GND	73					
VCC	74					
PK0	75	SYNC	A0	A0/A8	A0/A8/A16	A8
PK1	76	SYNC	A1	A1/A9	A1/A9/A17	A9
PK2	77	SYNC/ASYNC	A2	A2/A10	A2/A10/A18	A10
PK3	78	SYNC	A3	A3/A11	A3/A11/A19	A11
PK4	79	SYNC	A4	A4/A12	A4/A12/A20	A12
PK5	80	SYNC	A5	A5/A13	A5/A13/A21	A13
PK6	81	SYNC	A6	A6/A14	A6/A14/A22	A14
PK7	82	SYNC	A7	A7/A15	A7/A15/A23	A15

**Table 29-10.** Port Q - Alternate functions

PORT Q	PIN #	INTERRUPT	TOSC
VCC	83		
GND	84		
PQ0	85	SYNC	TOSC1
PQ1	86	SYNC	TOSC2
PQ2	87	SYNC/ASYNC	
PQ3	88	SYNC	

**Table 29-11.** Port R- Alternate functions

PORT R	PIN #	INTERRUPT	PDI	XTAL
PDI	89		PDI_DATA	
RESET	90		PDI_CLOCK	
PRO	91	SYNC		XTAL2
PR1	92	SYNC		XTAL1

## 30. Peripheral Module Address Map

The address maps show the base address for each peripheral and module in XMEGA A1. For complete register description and summary for each peripheral module, refer to the XMEGA A Manual.

Base Address	Name	Description
0x0000	GPIO	General Purpose IO Registers
0x0010	VPORT0	Virtual Port 0
0x0014	VPORT1	Virtual Port 1
0x0018	VPORT2	Virtual Port 2
0x001C	VPORT3	Virtual Port 3
0x0030	CPU	CPU
0x0040	CLK	Clock Control
0x0048	SLEEP	Sleep Controller
0x0050	OSC	Oscillator Control
0x0060	DFLLRC32M	DFLL for the 32 MHz Internal RC Oscillator
0x0068	DFLLRC2M	DFLL for the 2 MHz RC Oscillator
0x0070	PR	Power Reduction
0x0078	RST	Reset Controller
0x0080	WDT	Watch-Dog Timer
0x0090	MCU	MCU Control
0x00A0	PMIC	Programmable Multilevel Interrupt Controller
0x00B0	PORTCFG	Port Configuration
0x00C0	AES	AES Module
0x0100	DMA	DMA Controller
0x0180	EVSYS	Event System
0x01C0	NVM	Non Volatile Memory (NVM) Controller
0x0200	ADCA	Analog to Digital Converter on port A
0x0240	ADCB	Analog to Digital Converter on port B
0x0300	DACA	Digital to Analog Converter on port A
0x0320	DACB	Digital to Analog Converter on port B
0x0380	ACA	Analog Comparator pair on port A
0x0390	ACB	Analog Comparator pair on port B
0x0400	RTC	Real Time Counter
0x0440	EBI	External Bus Interface
0x0480	TWIC	Two Wire Interface on port C
0x0490	TWID	Two Wire Interface on port D
0x04A0	TWIE	Two Wire Interface on port E
0x04B0	TWIF	Two Wire Interface on port F
0x0600	PORTA	Port A
0x0620	PORTB	Port B
0x0640	PORTC	Port C
0x0660	PORTD	Port D
0x0680	PORTE	Port E
0x06A0	PORTF	Port F
0x06E0	PORTH	Port H
0x0700	PORTJ	Port J
0x0720	PORTK	Port K
0x07C0	PORTQ	Port Q
0x07E0	PORTR	Port R
0x0800	TCC0	Timer/Counter 0 on port C
0x0840	TCC1	Timer/Counter 1 on port C
0x0880	AWEXC	Advanced Waveform Extension on port C
0x0890	HIRES	High Resolution Extension on port C
0x08A0	USARTC0	USART 0 on port C
0x08B0	USARTC1	USART 1 on port C
0x08C0	SPIC	Serial Peripheral Interface on port C
0x08F8	IRCOM	Infrared Communication Module
0x0900	TCD0	Timer/Counter 0 on port D
0x0940	TCD1	Timer/Counter 1 on port D
0x0990	HIRES	High Resolution Extension on port D
0x09A0	USARTD0	USART 0 on port D
0x09B0	USARTD1	USART 1 on port D
0x09C0	SPID	Serial Peripheral Interface on port D
0x0A00	TCE0	Timer/Counter 0 on port E

Base Address	Name	Description
0x0A40	TCE1	Timer/Counter 1 on port E
0x0A80	AWEXE	Advanced Waveform Extension on port E
0x0A90	HIRESE	High Resolution Extension on port E
0x0AA0	USARTE0	USART 0 on port E
0x0AB0	USARTE1	USART 1 on port E
0x0AC0	SPIE	Serial Peripheral Interface on port E
0x0B00	TCF0	Timer/Counter 0 on port F
0x0B40	TCF1	Timer/Counter 1 on port F
0x0B90	HIRESF	High Resolution Extension on port F
0x0BA0	USARTF0	USART 0 on port F
0x0BB0	USARTF1	USART 1 on port F
0x0BC0	SPIF	Serial Peripheral Interface on port F

## 31. Interrupt Vector Summary.

### 31.1 USART Interrupt vectors

Table 31-1. USART Interrupt vectors

Offset	Source	Interrupt Description
0	RXC	USART Receive Complete Interrupt vector offset
2	DRE	USART Data Register Empty Interrupt vector offset
4	TXC	USART Transmit Complete Interrupt vector offset

### 31.2 Timer/Counter Interrupt vectors

Table 31-2. Timer/Counter Interrupt vectors

Offset	Source	Interrupt Description
0	OVF	Timer/Counter Overflow/Underflow Interrupt vector offset
2	ERR	Timer/Counter Error Interrupt vector offset
4	CCA	Timer/Counter Compare or Capture Channel A Interrupt vector offset
6	CCB	Timer/Counter Compare or Capture Channel B Interrupt vector offset
8	CCC <sup>(1)</sup>	Timer/Counter Compare or Capture Channel C Interrupt vector offset
0x0A	CCD <sup>(1)</sup>	Timer/Counter Compare or Capture Channel D Interrupt vector offset

Note: 1. Only available on Timer/Counter with 4 Compare or Capture channels 16-bit.

### 31.3 SPI Interrupt vectors

Table 31-3. SPI Interrupt vectors

Offset	Source	Interrupt Description
0	SPI	SPI Interrupt vector offset

### 31.4 TWI Interrupt vectors

Table 31-4. TWI Interrupt vectors

Offset	Source	Interrupt Description
0	MASTER	TWI Master Interrupt vector offset
2	SLAVE	TWI Slave Interrupt vector offset



### 31.5 DMA Interrupt vectors

**Table 31-5.** DMA Interrupt vectors

Offset	Source	Interrupt Description
0	CH0	DMA Controller Channel 0 Interrupt vector offset
2	CH1	DMA Controller Channel 1 Interrupt vector offset
4	CH2	DMA Controller Channel 2 Interrupt vector offset
6	CH3	DMA Controller Channel 3 Interrupt vector offset

### 31.6 Crystal Oscillator Failure Interrupt vector

**Table 31-6.** Crystal Oscillator Failure Interrupt vector

Offset	Source	Interrupt Description
0	OSCF	Crystal Oscillator Failure Interrupt vector (NMI) offset

### 31.7 RTC Interrupt vectors

**Table 31-7.** RTC Interrupt vectors

Offset	Source	Interrupt Description
0	COMP	Real Time Counter Compare Match Interrupt vector offset
2	PER	Real Time Counter Period Interrupt vector offset

### 31.8 AES Interrupt vector

**Table 31-8.** AES Interrupt vector

Offset	Source	Interrupt Description
0	AES	AES Interrupt vector offset

### 31.9 NVM Interrupt vectors

**Table 31-9.** NVM Interrupt vectors

Offset	Source	Interrupt Description
0	SPM	Non-Volatile Memory SPM Interrupt level vector offset
2	EE	Non-Volatile Memory EEPROM Interrupt level vector offset

### 31.10 Analog Comparator Interrupt vectors

**Table 31-10.** Analog Comparator Interrupt vectors

Offset	Source	Interrupt Description
0	COMP0	Analog Comparator 0 Interrupt vector offset
2	COMP1	Analog Comparator 1 Interrupt vector offset
4	WINDOW	Analog Comparator Window Interrupt vector offset

### 31.11 ADC Interrupt vectors

**Table 31-11.** Analog to Digital Converter Interrupt vectors

Offset	Source	Interrupt Description
0	CH0	Analog to Digital Converter Channel 0 Interrupt vector offset
2	CH1	Analog to Digital Converter Channel 1 Interrupt vector offset
4	CH2	Analog to Digital Converter Channel 2 Interrupt vector offset
6	CH3	Analog to Digital Converter Channel 3 Interrupt vector offset

### 31.12 PORTS Interrupt vectors

**Table 31-12.** Ports Interrupt vectors

Offset	Source	Interrupt Description
0	INT0	Port Interrupt vector 0 offset
2	INT1	Port Interrupt vector 1 offset

## 32. Instruction Set Summary

Mnemonics	Operands	Description	Operation	Flags	#Clocks
<b>Arithmetic and Logic Instructions</b>					
ADD	Rd, Rr	Add without Carry	$Rd \leftarrow Rd + Rr$	Z,C,N,V,S,H	1
ADC	Rd, Rr	Add with Carry	$Rd \leftarrow Rd + Rr + C$	Z,C,N,V,S,H	1
ADIW	Rd, K	Add Immediate to Word	$Rd \leftarrow Rd + 1:Rd + K$	Z,C,N,V,S	2
SUB	Rd, Rr	Subtract without Carry	$Rd \leftarrow Rd - Rr$	Z,C,N,V,S,H	1
SUBI	Rd, K	Subtract Immediate	$Rd \leftarrow Rd - K$	Z,C,N,V,S,H	1
SBC	Rd, Rr	Subtract with Carry	$Rd \leftarrow Rd - Rr - C$	Z,C,N,V,S,H	1
SBCI	Rd, K	Subtract Immediate with Carry	$Rd \leftarrow Rd - K - C$	Z,C,N,V,S,H	1
SBIW	Rd, K	Subtract Immediate from Word	$Rd + 1:Rd \leftarrow Rd + 1:Rd - K$	Z,C,N,V,S	2
AND	Rd, Rr	Logical AND	$Rd \leftarrow Rd \bullet Rr$	Z,N,V,S	1
ANDI	Rd, K	Logical AND with Immediate	$Rd \leftarrow Rd \bullet K$	Z,N,V,S	1
OR	Rd, Rr	Logical OR	$Rd \leftarrow Rd \vee Rr$	Z,N,V,S	1
ORI	Rd, K	Logical OR with Immediate	$Rd \leftarrow Rd \vee K$	Z,N,V,S	1
EOR	Rd, Rr	Exclusive OR	$Rd \leftarrow Rd \oplus Rr$	Z,N,V,S	1
COM	Rd	One's Complement	$Rd \leftarrow \$FF - Rd$	Z,C,N,V,S	1
NEG	Rd	Two's Complement	$Rd \leftarrow \$00 - Rd$	Z,C,N,V,S,H	1
SBR	Rd,K	Set Bit(s) in Register	$Rd \leftarrow Rd \vee K$	Z,N,V,S	1
CBR	Rd,K	Clear Bit(s) in Register	$Rd \leftarrow Rd \bullet (\$FFh - K)$	Z,N,V,S	1
INC	Rd	Increment	$Rd \leftarrow Rd + 1$	Z,N,V,S	1
DEC	Rd	Decrement	$Rd \leftarrow Rd - 1$	Z,N,V,S	1
TST	Rd	Test for Zero or Minus	$Rd \leftarrow Rd \bullet Rd$	Z,N,V,S	1
CLR	Rd	Clear Register	$Rd \leftarrow Rd \oplus Rd$	Z,N,V,S	1
SER	Rd	Set Register	$Rd \leftarrow \$FF$	None	1
MUL	Rd,Rr	Multiply Unsigned	$R1:R0 \leftarrow Rd \times Rr (UU)$	Z,C	2
MULS	Rd,Rr	Multiply Signed	$R1:R0 \leftarrow Rd \times Rr (SS)$	Z,C	2
MULSU	Rd,Rr	Multiply Signed with Unsigned	$R1:R0 \leftarrow Rd \times Rr (SU)$	Z,C	2
FMUL	Rd,Rr	Fractional Multiply Unsigned	$R1:R0 \leftarrow Rd \times Rr << 1 (UU)$	Z,C	2
FMULS	Rd,Rr	Fractional Multiply Signed	$R1:R0 \leftarrow Rd \times Rr << 1 (SS)$	Z,C	2
FMULSU	Rd,Rr	Fractional Multiply Signed with Unsigned	$R1:R0 \leftarrow Rd \times Rr << 1 (SU)$	Z,C	2
DES	K	Data Encryption	if (H = 0) then R15:R0 $\leftarrow$ Encrypt(R15:R0, K) else if (H = 1) then R15:R0 $\leftarrow$ Decrypt(R15:R0, K)		1/2
<b>Branch Instructions</b>					
RJMP	k	Relative Jump	$PC \leftarrow PC + k + 1$	None	2
IJMP		Indirect Jump to (Z)	$PC(15:0) \leftarrow Z,$ $PC(21:16) \leftarrow 0$	None	2
EIJMP		Extended Indirect Jump to (Z)	$PC(15:0) \leftarrow Z,$ $PC(21:16) \leftarrow EIND$	None	2
JMP	k	Jump	$PC \leftarrow k$	None	3
RCALL	k	Relative Call Subroutine	$PC \leftarrow PC + k + 1$	None	2 / 3 <sup>(1)</sup>
ICALL		Indirect Call to (Z)	$PC(15:0) \leftarrow Z,$ $PC(21:16) \leftarrow 0$	None	2 / 3 <sup>(1)</sup>
EICALL		Extended Indirect Call to (Z)	$PC(15:0) \leftarrow Z,$ $PC(21:16) \leftarrow EIND$	None	3 <sup>(1)</sup>

Mnemonics	Operands	Description	Operation	Flags	#Clocks
CALL	k	call Subroutine	$PC \leftarrow k$	None	3 / 4 <sup>(1)</sup>
RET		Subroutine Return	$PC \leftarrow STACK$	None	4 / 5 <sup>(1)</sup>
RETI		Interrupt Return	$PC \leftarrow STACK$	I	4 / 5 <sup>(1)</sup>
CPSE	Rd,Rr	Compare, Skip if Equal	if (Rd = Rr) $PC \leftarrow PC + 2$ or 3	None	1 / 2 / 3
CP	Rd,Rr	Compare	$Rd - Rr$	Z,C,N,V,S,H	1
CPC	Rd,Rr	Compare with Carry	$Rd - Rr - C$	Z,C,N,V,S,H	1
CPI	Rd,K	Compare with Immediate	$Rd - K$	Z,C,N,V,S,H	1
SBRC	Rr, b	Skip if Bit in Register Cleared	if (Rr(b) = 0) $PC \leftarrow PC + 2$ or 3	None	1 / 2 / 3
SBRS	Rr, b	Skip if Bit in Register Set	if (Rr(b) = 1) $PC \leftarrow PC + 2$ or 3	None	1 / 2 / 3
SBIC	A, b	Skip if Bit in I/O Register Cleared	if (I/O(A,b) = 0) $PC \leftarrow PC + 2$ or 3	None	2 / 3 / 4
SBIS	A, b	Skip if Bit in I/O Register Set	If (I/O(A,b) = 1) $PC \leftarrow PC + 2$ or 3	None	2 / 3 / 4
BRBS	s, k	Branch if Status Flag Set	if (SREG(s) = 1) then $PC \leftarrow PC + k + 1$	None	1 / 2
BRBC	s, k	Branch if Status Flag Cleared	if (SREG(s) = 0) then $PC \leftarrow PC + k + 1$	None	1 / 2
BREQ	k	Branch if Equal	if (Z = 1) then $PC \leftarrow PC + k + 1$	None	1 / 2
BRNE	k	Branch if Not Equal	if (Z = 0) then $PC \leftarrow PC + k + 1$	None	1 / 2
BRCS	k	Branch if Carry Set	if (C = 1) then $PC \leftarrow PC + k + 1$	None	1 / 2
BRCC	k	Branch if Carry Cleared	if (C = 0) then $PC \leftarrow PC + k + 1$	None	1 / 2
BRSH	k	Branch if Same or Higher	if (C = 0) then $PC \leftarrow PC + k + 1$	None	1 / 2
BRLO	k	Branch if Lower	if (C = 1) then $PC \leftarrow PC + k + 1$	None	1 / 2
BRMI	k	Branch if Minus	if (N = 1) then $PC \leftarrow PC + k + 1$	None	1 / 2
BRPL	k	Branch if Plus	if (N = 0) then $PC \leftarrow PC + k + 1$	None	1 / 2
BRGE	k	Branch if Greater or Equal, Signed	if ( $N \oplus V = 0$ ) then $PC \leftarrow PC + k + 1$	None	1 / 2
BRLT	k	Branch if Less Than, Signed	if ( $N \oplus V = 1$ ) then $PC \leftarrow PC + k + 1$	None	1 / 2
BRHS	k	Branch if Half Carry Flag Set	if (H = 1) then $PC \leftarrow PC + k + 1$	None	1 / 2
BRHC	k	Branch if Half Carry Flag Cleared	if (H = 0) then $PC \leftarrow PC + k + 1$	None	1 / 2
BRTS	k	Branch if T Flag Set	if (T = 1) then $PC \leftarrow PC + k + 1$	None	1 / 2
BRTC	k	Branch if T Flag Cleared	if (T = 0) then $PC \leftarrow PC + k + 1$	None	1 / 2
BRVS	k	Branch if Overflow Flag is Set	if (V = 1) then $PC \leftarrow PC + k + 1$	None	1 / 2
BRVC	k	Branch if Overflow Flag is Cleared	if (V = 0) then $PC \leftarrow PC + k + 1$	None	1 / 2
BRIE	k	Branch if Interrupt Enabled	if (I = 1) then $PC \leftarrow PC + k + 1$	None	1 / 2
BRID	k	Branch if Interrupt Disabled	if (I = 0) then $PC \leftarrow PC + k + 1$	None	1 / 2
Data Transfer Instructions					
MOV	Rd, Rr	Copy Register	$Rd \leftarrow Rr$	None	1
MOVW	Rd, Rr	Copy Register Pair	$Rd+1:Rd \leftarrow Rr+1:Rr$	None	1
LDI	Rd, K	Load Immediate	$Rd \leftarrow K$	None	1
LDS	Rd, k	Load Direct from data space	$Rd \leftarrow (k)$	None	2 <sup>(1)(2)</sup>
LD	Rd, X	Load Indirect	$Rd \leftarrow (X)$	None	1 <sup>(1)(2)</sup>
LD	Rd, X+	Load Indirect and Post-Increment	$Rd \leftarrow (X)$ $X \leftarrow X + 1$	None	1 <sup>(1)(2)</sup>
LD	Rd, -X	Load Indirect and Pre-Decrement	$X \leftarrow X - 1$ $Rd \leftarrow (X)$	None	2 <sup>(1)(2)</sup>
LD	Rd, Y	Load Indirect	$Rd \leftarrow (Y)$	None	1 <sup>(1)(2)</sup>
LD	Rd, Y+	Load Indirect and Post-Increment	$Rd \leftarrow (Y)$ $Y \leftarrow Y + 1$	None	1 <sup>(1)(2)</sup>

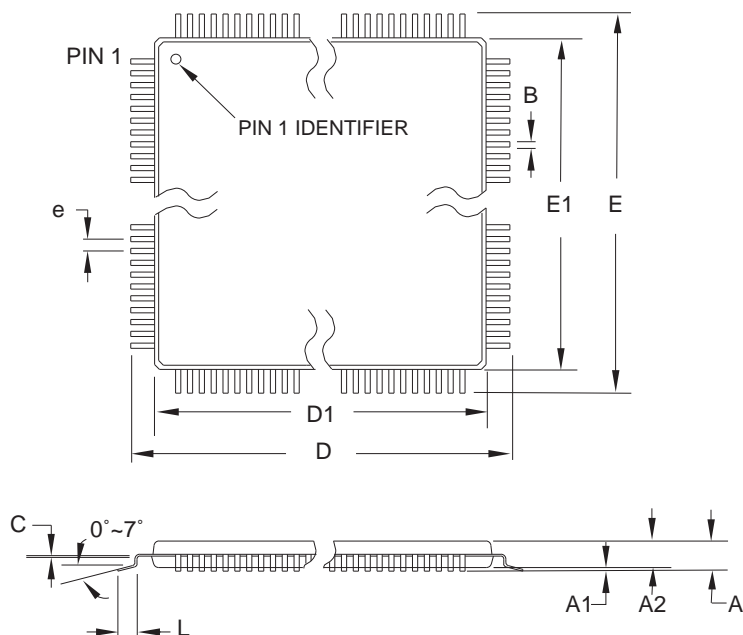
Mnemonics	Operands	Description	Operation	Flags	#Clocks
LD	Rd, -Y	Load Indirect and Pre-Decrement	$Y \leftarrow Y - 1$ $Rd \leftarrow (Y)$	None	2 <sup>(1)(2)</sup>
LDD	Rd, Y+q	Load Indirect with Displacement	$Rd \leftarrow (Y + q)$	None	2 <sup>(1)(2)</sup>
LD	Rd, Z	Load Indirect	$Rd \leftarrow (Z)$	None	1 <sup>(1)(2)</sup>
LD	Rd, Z+	Load Indirect and Post-Increment	$Rd \leftarrow (Z)$ , $Z \leftarrow Z + 1$	None	1 <sup>(1)(2)</sup>
LD	Rd, -Z	Load Indirect and Pre-Decrement	$Z \leftarrow Z - 1$ , $Rd \leftarrow (Z)$	None	2 <sup>(1)(2)</sup>
LDD	Rd, Z+q	Load Indirect with Displacement	$Rd \leftarrow (Z + q)$	None	2 <sup>(1)(2)</sup>
STS	k, Rr	Store Direct to Data Space	$(k) \leftarrow Rr$	None	2 <sup>(1)</sup>
ST	X, Rr	Store Indirect	$(X) \leftarrow Rr$	None	1 <sup>(1)</sup>
ST	X+, Rr	Store Indirect and Post-Increment	$(X) \leftarrow Rr$ , $X \leftarrow X + 1$	None	1 <sup>(1)</sup>
ST	-X, Rr	Store Indirect and Pre-Decrement	$X \leftarrow X - 1$ , $(X) \leftarrow Rr$	None	2 <sup>(1)</sup>
ST	Y, Rr	Store Indirect	$(Y) \leftarrow Rr$	None	1 <sup>(1)</sup>
ST	Y+, Rr	Store Indirect and Post-Increment	$(Y) \leftarrow Rr$ , $Y \leftarrow Y + 1$	None	1 <sup>(1)</sup>
ST	-Y, Rr	Store Indirect and Pre-Decrement	$Y \leftarrow Y - 1$ , $(Y) \leftarrow Rr$	None	2 <sup>(1)</sup>
STD	Y+q, Rr	Store Indirect with Displacement	$(Y + q) \leftarrow Rr$	None	2 <sup>(1)</sup>
ST	Z, Rr	Store Indirect	$(Z) \leftarrow Rr$	None	1 <sup>(1)</sup>
ST	Z+, Rr	Store Indirect and Post-Increment	$(Z) \leftarrow Rr$ , $Z \leftarrow Z + 1$	None	1 <sup>(1)</sup>
ST	-Z, Rr	Store Indirect and Pre-Decrement	$Z \leftarrow Z - 1$	None	2 <sup>(1)</sup>
STD	Z+q, Rr	Store Indirect with Displacement	$(Z + q) \leftarrow Rr$	None	2 <sup>(1)</sup>
LPM		Load Program Memory	$R0 \leftarrow (Z)$	None	3
LPM	Rd, Z	Load Program Memory	$Rd \leftarrow (Z)$	None	3
LPM	Rd, Z+	Load Program Memory and Post-Increment	$Rd \leftarrow (Z)$ , $Z \leftarrow Z + 1$	None	3
ELPM		Extended Load Program Memory	$R0 \leftarrow (RAMPZ:Z)$	None	3
ELPM	Rd, Z	Extended Load Program Memory	$Rd \leftarrow (RAMPZ:Z)$	None	3
ELPM	Rd, Z+	Extended Load Program Memory and Post-Increment	$Rd \leftarrow (RAMPZ:Z)$ , $Z \leftarrow Z + 1$	None	3
SPM		Store Program Memory	$(RAMPZ:Z) \leftarrow R1:R0$	None	-
SPM	Z+	Store Program Memory and Post-Increment by 2	$(RAMPZ:Z) \leftarrow R1:R0$ , $Z \leftarrow Z + 2$	None	-
IN	Rd, A	In From I/O Location	$Rd \leftarrow I/O(A)$	None	1
OUT	A, Rr	Out To I/O Location	$I/O(A) \leftarrow Rr$	None	1
PUSH	Rr	Push Register on Stack	$STACK \leftarrow Rr$	None	1 <sup>(1)</sup>
POP	Rd	Pop Register from Stack	$Rd \leftarrow STACK$	None	2 <sup>(1)</sup>
<b>Bit and Bit-test Instructions</b>					
LSL	Rd	Logical Shift Left	$Rd(n+1) \leftarrow Rd(n)$ , $Rd(0) \leftarrow 0$ , $C \leftarrow Rd(7)$	Z,C,N,V,H	1
LSR	Rd	Logical Shift Right	$Rd(n) \leftarrow Rd(n+1)$ , $Rd(7) \leftarrow 0$ , $C \leftarrow Rd(0)$	Z,C,N,V	1

Mnemonics	Operands	Description	Operation	Flags	#Clocks
ROL	Rd	Rotate Left Through Carry	$Rd(0) \leftarrow C,$ $Rd(n+1) \leftarrow Rd(n),$ $C \leftarrow Rd(7)$	Z,C,N,V,H	1
ROR	Rd	Rotate Right Through Carry	$Rd(7) \leftarrow C,$ $Rd(n) \leftarrow Rd(n+1),$ $C \leftarrow Rd(0)$	Z,C,N,V	1
ASR	Rd	Arithmetic Shift Right	$Rd(n) \leftarrow Rd(n+1), n=0..6$	Z,C,N,V	1
SWAP	Rd	Swap Nibbles	$Rd(3..0) \leftrightarrow Rd(7..4)$	None	1
BSET	s	Flag Set	$SREG(s) \leftarrow 1$	SREG(s)	1
BCLR	s	Flag Clear	$SREG(s) \leftarrow 0$	SREG(s)	1
SBI	A, b	Set Bit in I/O Register	$I/O(A, b) \leftarrow 1$	None	1
CBI	A, b	Clear Bit in I/O Register	$I/O(A, b) \leftarrow 0$	None	1
BST	Rr, b	Bit Store from Register to T	$T \leftarrow Rr(b)$	T	1
BLD	Rd, b	Bit load from T to Register	$Rd(b) \leftarrow T$	None	1
SEC		Set Carry	$C \leftarrow 1$	C	1
CLC		Clear Carry	$C \leftarrow 0$	C	1
SEN		Set Negative Flag	$N \leftarrow 1$	N	1
CLN		Clear Negative Flag	$N \leftarrow 0$	N	1
SEZ		Set Zero Flag	$Z \leftarrow 1$	Z	1
CLZ		Clear Zero Flag	$Z \leftarrow 0$	Z	1
SEI		Global Interrupt Enable	$I \leftarrow 1$	I	1
CLI		Global Interrupt Disable	$I \leftarrow 0$	I	1
SES		Set Signed Test Flag	$S \leftarrow 1$	S	1
CLS		Clear Signed Test Flag	$S \leftarrow 0$	S	1
SEV		Set Two's Complement Overflow	$V \leftarrow 1$	V	1
CLV		Clear Two's Complement Overflow	$V \leftarrow 0$	V	1
SET		Set T in SREG	$T \leftarrow 1$	T	1
CLT		Clear T in SREG	$T \leftarrow 0$	T	1
SEH		Set Half Carry Flag in SREG	$H \leftarrow 1$	H	1
CLH		Clear Half Carry Flag in SREG	$H \leftarrow 0$	H	1
<b>MCU Control Instructions</b>					
BREAK		Break	(See specific descr. for BREAK)	None	1
NOP		No Operation		None	1
SLEEP		Sleep	(see specific descr. for Sleep)	None	1
WDR		Watchdog Reset	(see specific descr. for WDR)	None	1

- Notes:
1. Cycle times for Data memory accesses assume internal memory accesses, and are not valid for accesses via the external RAM interface.
  2. One extra cycle must be added when accessing Internal SRAM.

### 33. Packaging information

#### 33.1 100A




**COMMON DIMENSIONS**  
(Unit of Measure = mm)

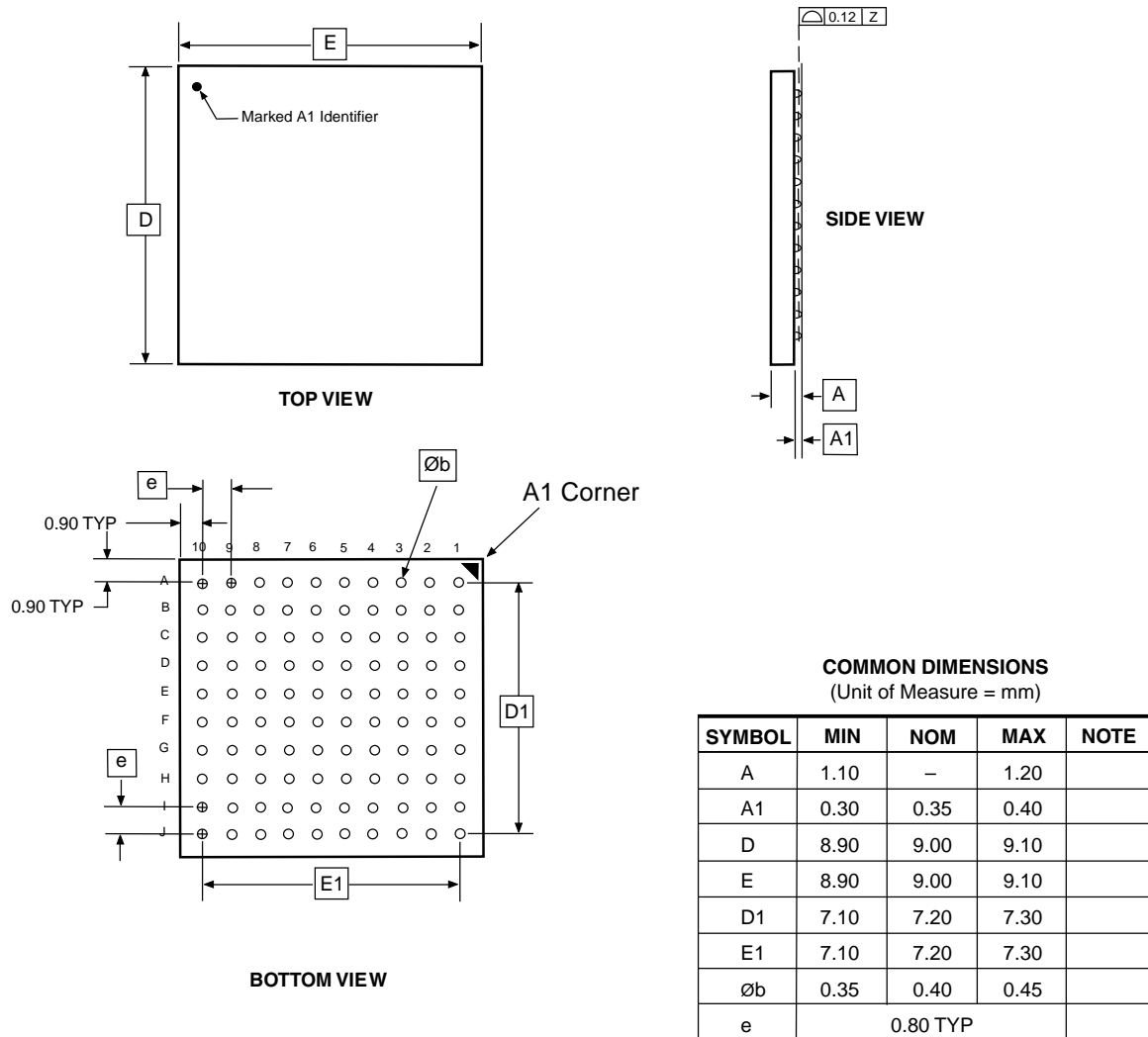
SYMBOL	MIN	NOM	MAX	NOTE
A	–	–	1.20	
A1	0.05	–	0.15	
A2	0.95	1.00	1.05	
D	15.75	16.00	16.25	
D1	13.90	14.00	14.10	Note 2
E	15.75	16.00	16.25	
E1	13.90	14.00	14.10	Note 2
B	0.17	–	0.27	
C	0.09	–	0.20	
L	0.45	–	0.75	
e	0.50 TYP			

- Notes:
1. This package conforms to JEDEC reference MS-026, Variation AED.
  2. Dimensions D1 and E1 do not include mold protrusion. Allowable protrusion is 0.25 mm per side. Dimensions D1 and E1 are maximum plastic body size dimensions including mold mismatch.
  3. Lead coplanarity is 0.08 mm maximum.

10/5/2001

 2325 Orchard Parkway San Jose, CA 95131	<b>TITLE</b> <b>100A</b> , 100-lead, 14 x 14 mm Body Size, 1.0 mm Body Thickness, 0.5 mm Lead Pitch, Thin Profile Plastic Quad Flat Package (TQFP)	<b>DRAWING NO.</b>	<b>REV.</b>
		100A	C

## 33.2 100C1



5/25/06



2325 Orchard Parkway  
San Jose, CA 95131

### TITLE

**100C1**, 100-ball, 9 x 9 x 1.2 mm Body, Ball Pitch 0.80 mm  
Chip Array BGA Package (CBGA)

### DRAWING NO.

100C1

### REV.

A





## 34. Electrical Characteristics - TBD

### 34.1 Absolute Maximum Ratings\*

Operating Temperature.....	-55°C to +125°C
Storage Temperature .....	-65°C to +150°C
Voltage on any Pin with respect to Ground...-	0.5V to $V_{CC}+0.5V$
Maximum Operating Voltage .....	3.6V
DC Current per I/O Pin .....	20.0 mA
DC Current $V_{CC}$ and GND Pins.....	200.0 mA

**\*NOTICE:** Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

### 34.2 DC Characteristics

$T_A = -40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ ,  $V_{CC} = 1.6V$  to  $3.6V$  (unless otherwise noted)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
$V_{IL}$	Input Low Voltage	$V_{CC} = 3.3V$	-0.5		$0.3V_{CC}$	V
		$V_{CC} = 2.7V$ ,	-0.5		$0.3V_{CC}$	V
		$V_{CC} = 1.8V$ ,	-0.5		$0.3V_{CC}$	V
$V_{IH}$	Input High Voltage	$V_{CC} = 3.3V$ ,	$0.7V_{CC}$		$V_{CC}+0.5$	V
		$V_{CC} = 2.7V$ ,	$0.7V_{CC}$		$V_{CC}+0.5$	V
		$V_{CC} = 1.8V$ ,	$0.7V_{CC}$		$V_{CC}+0.5$	V
$I_{OL}$	Output Sink Current	$V_{CC} = 3.3V$ , $V_{OL} = 0.2V_{CC}$		20		mA
		$V_{CC} = 2.7V$ , $V_{OL} = 0.2V_{CC}$		17		mA
		$V_{CC} = 1.8V$ , $V_{OL} = 0.2V_{CC}$		10		mA
$I_{OH}$	Output Source Current	$V_{CC} = 3.3V$ , $V_{OH} = 0.8V_{CC}$		10		mA
		$V_{CC} = 2.7V$ , $V_{OH} = 0.8V_{CC}$		7		mA
		$V_{CC} = 1.8V$ , $V_{OH} = 0.8V_{CC}$		3		mA
$I_{IL}$	Input Leakage Current I/O Pin			<0.001		$\mu A$
$I_{IH}$	Input Leakage Current I/O Pin			<0.001		$\mu A$
$R_{RST}$	Reset Pull-up Resistor			20		$k\Omega$
$R_{PU}$	I/O Pin Pull-up Resistor			20		$k\Omega$

$T_A = -40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ ,  $V_{CC} = 1.6\text{V}$  to  $3.6\text{V}$  (unless otherwise noted)

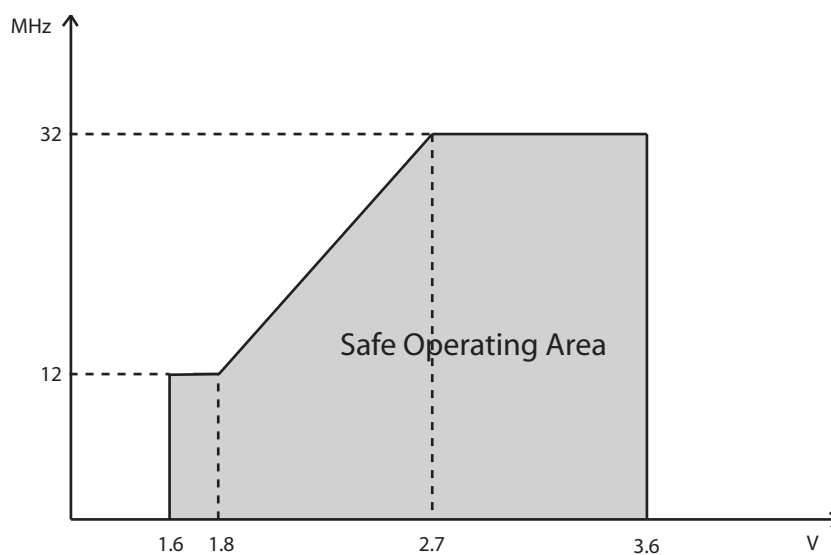
Symbol	Parameter	Condition			Min.	Typ.	Max.	Units
I <sub>CC</sub>	Power Supply Current	Active	1 MHz, Ext. Clock All PRR set	V <sub>CC</sub> = 1.8V		350		μA
				V <sub>CC</sub> = 2.7V		650		
				V <sub>CC</sub> = 3.3V		880		
			2 MHz V <sub>CC</sub> = 1.8V All PRR Set	Internal RC		720		
				Ext. Clock		670		
			32 MHz, V <sub>CC</sub> = 2.7V All PRR Set	Internal RC		TBD		
				Ext. Clock		16		
			32 MHz, V <sub>CC</sub> = 3.3V All PRR Set	Internal RC		TBD		
				Ext. Clock		21		
		Idle	1 MHz, Ext. Clock All PRR set	V <sub>CC</sub> = 1.8V		130		μA
				V <sub>CC</sub> = 2.7V		220		
				V <sub>CC</sub> = 3.3V		290		
			2 MHz V <sub>CC</sub> = 1.8V All PRR Set	Internal RC		310		
				Ext. Clock		260		
			32 MHz, V <sub>CC</sub> = 2.7V All PRR Set	Internal RC		TBD		
				Ext. Clock		7		
			32 MHz, V <sub>CC</sub> = 3.3V All PRR Set	Internal RC		TBD		
				Ext. Clock		9.2		
	Power-down mode	All Functions Disabled		V <sub>CC</sub> = 1.8V		0.1		μA
		ULP, WDT, Sampled BOD Enabled	V <sub>CC</sub> = 1.8V		1.1			
			V <sub>CC</sub> = 3.3V		1.5			
	Power-save mode	ULP, RTC,WDT, BOD Enabled,	V <sub>CC</sub> = 1.8V		1.1		μA	
			V <sub>CC</sub> = 3.3V		1.5			
		RTC Enabled, 1 kHz from Low Power TOSC32	V <sub>CC</sub> = 1.8V		650		nA	
			V <sub>CC</sub> = 3.3V		650			

Note: 1. "Max" means the highest value where the pin is guaranteed to be read as low  
2. "Min" means the lowest value where the pin is guaranteed to be read as high

### 34.3 Speed

The maximum frequency of the XMEGA A1 devices is depending on  $V_{CC}$ . As shown in [Figure 34-1 on page 67](#) the Frequency vs.  $V_{CC}$  curve is linear between  $1.8V < V_{CC} < 2.7V$ .

**Figure 34-1.** Maximum Frequency vs.  $V_{CC}$



### 34.4 ADC Characteristics – TBD

**Table 34-1.** ADC Characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Units
	Resolution		8	12	12	LSB
	Integral Non-Linearity (INL)			TBD		LSB
	Differential Non-Linearity (DNL)			TBD		LSB
	Gain Error			TBD		LSB
	Offset Error			TBD		LSB
	Conversion Time	8-bit Result	2.5			μs
		12-bit Result	3.5			μs
	ADC Clock Frequency		100		2000	kHz
AVCC	DC Supply Voltage		1.6		3.6	V
	Source Impedance	2 Msps sample rate		3		kΩ
	Start-up time			TBD		μs
AVCC	Analog Supply Voltage		$V_{CC} - 0.3$		$V_{CC} + 0.3$	V

**Table 34-2.** ADC Gain Stage Characteristics

Symbol	Parameter	Condition		Min	Typ	Max	Units
	Input Capacitance				TBD		pF
	Offset Error	1X Gain, VCC = 3.3V	AREF = Int. 1.0V		-5		LSB
			AREF = Ext. 2.5V		-3		
		2X Gain, VCC = 3.3V	AREF = Int. 1.0V		-5		
			AREF = Ext. 2.5V		-3		
		4X Gain, VCC = 3.3V	AREF = Int. 1.0V		-5		
			AREF = Ext. 2.5V		-2.5		
		8X Gain, VCC = 3.3V	AREF = Int. 1.0V		-5		
			AREF = Ext. 2.5V		-2		
		16X Gain, VCC = 3.3V	AREF = Int. 1.0V		-4		
			AREF = Ext. 2.5V		-1.5		
		32X Gain, VCC = 3.3V	AREF = Int. 1.0V		-3		
			AREF = Ext. 2.5V		0		
		64X Gain, VCC = 3.3V	AREF = Int. 1.0V		3		
			AREF = Ext. 2.5V		5		

**Table 34-2. ADC Gain Stage Characteristics (Continued)**

Symbol	Parameter	Condition		Min	Typ	Max	Units
	Gain Error	1X Gain, VCC = 3.3V	AREF = Int. 1.0V		TBD		LSB
			AREF = Ext. 2.5V		TBD		
		2X Gain, VCC = 3.3V	AREF = Int. 1.0V		TBD		
			AREF = Ext. 2.5V		TBD		
		4X Gain, VCC = 3.3V	AREF = Int. 1.0V		TBD		
			AREF = Ext. 2.5V		TBD		
		8X Gain, VCC = 3.3V	AREF = Int. 1.0V		TBD		
			AREF = Ext. 2.5V		TBD		
		16X Gain, VCC = 3.3V	AREF = Int. 1.0V		TBD		
			AREF = Ext. 2.5V		TBD		
		32X Gain, VCC = 3.3V	AREF = Int. 1.0V		TBD		
			AREF = Ext. 2.5V		TBD		
		64X Gain, VCC = 3.3V	AREF = Int. 1.0V		TBD		
			AREF = Ext. 2.5V		TBD		
	Signal-to-Noise Ratio (SNR)	1X Gain, VCC = 3.3V	AREF = Int. 1.0V		76.3		dB
			AREF = Ext. 1.7V		75.7		
			AREF = Ext. 2.5V		74.6		
		2X Gain, VCC = 3.3V	AREF = Int. 1.0V		71.2		
			AREF = Ext. 1.7V		72.2		
			AREF = Ext. 2.5V		71.6		
		4X Gain, VCC = 3.3V	AREF = Int. 1.0V		64.8		
			AREF = Ext. 1.7V		66.8		
			AREF = Ext. 2.5V		67.7		
		8X Gain, VCC = 3.3V	AREF = Int. 1.0V		57.1		
			AREF = Ext. 1.7V		59.3		
			AREF = Ext. 2.5V		60.8		
		16X Gain, VCC = 3.3V	AREF = Int. 1.0V		48.2		
			AREF = Ext. 1.7V		50.5		
			AREF = Ext. 2.5V		52.2		
		32X Gain, VCC = 3.3V	AREF = Int. 1.0V		39.3		
			AREF = Ext. 1.7V		41.6		
			AREF = Ext. 2.5V		43.2		
		64X Gain, VCC = 3.3V	AREF = Int. 1.0V		30.2		
			AREF = Ext. 1.7V		32.4		
			AREF = Ext. 2.5V		34.3		

**Table 34-2.** ADC Gain Stage Characteristics (Continued)

Symbol	Parameter	Condition	Min	Typ	Max	Units
	Signal Range			TBD		V
	DC Supply Current			TBD		mA
	Start-up time			TBD		# clk cycles

## 34.5 DAC Characteristics – TBD

**Table 34-3.** DAC Characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Units
	Resolution		12		12	LSB
	Integral Non-Linearity (INL)			TBD		LSB
	Differential Non-Linearity (DNL)			TBD		LSB
	Gain Error			TBD		LSB
	Offset Error			TBD		LSB
	Calibrated Gain/Offset Error			TBD		LSB
	Output Range			TBD		V
	Output Settling Time			TBD		μs
	Output Capacitance			TBD		nF
	Output Resistance			TBD		kΩ
	Reference Input Voltage			TBD		V
	Reference Input Capacitance			TBD		pF
	Reference Input Resistance			TBD		kΩ
	Current Consumption			TBD		mA
	Start-up time			TBD		μs

## 34.6 Analog Comparator Characteristics – TBD

**Table 34-4.** Analog Comparator Characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Units
	Offset			0.5		mV
	Hysteresis	No, High Speed mode		0		
		No, Low Power mode		0		mV
		Small, High Speed mode		3		mV
		Small, Low Power mode		3		mV
		Large, High Speed mode		25		mV
		Large, Low Power mode		30		mV
	Propagation Delay	High Speed mode		50		ns
		Low power mode		130		

**Table 34-4.** Analog Comparator Characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Units
	Current Consumption	High Speed mode		TBD		$\mu\text{A}$
		Low power mode		TBD		
	Start-up time			TBD		$\mu\text{s}$

## **35. Typical Characteristics - TBD**



## 36. Errata

### 36.1 ATxmega128A1 rev. G

#### 1. Bootloader Section in Flash is non-functional

The Bootloader Section is non-functional, and bootloader or application code cannot reside in this part of the Flash.

##### Problem fix/Workaround

None, do not use the Bootloader Section.

#### 2. Bandgap voltage input for the ACs cannot be changed when used for both ACs simultaneously

If the Bandgap voltage is selected as input for one Analog Comparator (AC) and then selected/deselected as input for the another AC, the first comparator will be affected for up to 1  $\mu$ s and could potentially give a wrong comparison result.

##### Problem fix/Workaround

If the Bandgap is required for both ACs simultaneously, configure the input selection for both ACs before enabling any of them.

#### 3. DAC is nonlinear and inaccurate when reference is above 2.4V

Using the DAC with a reference voltage above 2.4V give inaccurate output when converting codes that give below 0.75V output:

- $\pm 20$  LSB for continuous mode
- $\pm 200$  LSB for Sample and Hold mode

##### Problem fix/Workaround

None, avoid using a voltage reference above 2.4V.

#### 4. ADC gain stage output range is limited to 2.6 V.

The amplified output of the ADC gain stage will never go above 2.6V, hence the differential input will only give correct output when below 2.6V/gain. For the available gain settings, this gives a differential input range of:

- 1X gain: 2.6V
- 2X gain: 1.3V
- 4X gain: 0.65V
- 8X gain: 325 mV
- 16X gain: 163 mV
- 32X gain: 82 mV
- 64X gain: 41 mV

##### Problem fix/Workaround

Keep the amplified voltage output from the ADC gain stage below 2.6V in order to get a correct result, or keep ADC voltage reference is below 2.6V.

**5. The ADC has up to  $\pm 2$  LSB inaccuracy**

The ADC will have up to  $\pm 2$  LSB inaccuracy, visible as a saw-tooth pattern on the input voltage/ output value transfer function of the ADC. The inaccuracy increases with increasing voltage reference reaching  $\pm 2$  LSB with 3V reference.

**Problem fix/Workaround**

None, the actual ADC resolution will be reduced with up to  $\pm 2$  LSB.

**6. TWI, a general address call will match independent of the R/W-bit value.**

When the TWI is in Slave mode and a general address call is issued on the bus, the TWI Slave will get an address match regardless of the R/W-bit (ADDR[0] bit) value in the Slave Address Register.

**Problem fix/Workaround**

Use software to check the R/W-bit on general call address match.

**7. TWI, the minimum I<sup>2</sup>C SCL low time could be violated in Master Read mode**

When the TWI is in Master Read mode and issuing a Repeated Start on the bus, this will immediately release the SCL line even if one complete SCL low period has not passed. This means that the minimum SCL low time in the I<sup>2</sup>C specification could be violated.

**Problem fix/Workaround**

If this causes a potential problem in the application, software must ensure that the Repeated Start is never issued before one SCL low time has passed.

**8. Setting HIRE PR bit makes PWM output unavailable**

Setting the HIRE Power Reduction (PR) bit for PORTx will make any Frequency or PWM output for the corresponding Timer/Counters (TCx0 and TCx1) unavailable on the pin.

**Problem fix/Workaround**

Do not write the HIRE PR bit on PORTx when frequency or PWM output from TCx0/1 is used.

**9. EEPROM erase and write does not work with all System Clock sources**

When doing EEPROM erase or Write operations with other clock sources than the 2 MHz RCOSC, Flash will be read wrongly for one or two clock cycles at the end of the EEPROM operation.

**Problem fix/Workaround**

Alt 1: Use the internal 2 MHz RCOSC when doing erase or write operations on EEPROM.

Alt 2: Ensure to be in sleep mode while completing erase or write on EEPROM. After starting erase or write operations on EEPROM, other interrupts should be disabled and the device put to sleep.

## 37. Datasheet Revision History

### 37.1 8067D – 08/08

1. Updated [“Ordering Information”](#) on page 2.
2. Updated CBGA pinout in [“Pinout/Block Diagram”](#) on page 2
3. Updated [“Peripheral Module Address Map”](#) on page 54.
4. Inserted [“Interrupt Vector Summary.”](#) on page 56.

### 37.2 8067C – 06/08

1. Updated the Front page and [“Features”](#) on page 1.
2. Updated the [“DC Characteristics”](#) on page 65.
3. Updated [Figure 3-1](#) on page 5.
4. Added [“Flash and EEPROM Page Size”](#) on page 14.
5. Updated [Table 34-2](#) on page 68 with new data: Gain Error, Offset Error and Signal -to-Noise Ratio (SNR).
6. Updated Errata [“ATxmega128A1 rev. G”](#) on page 73.

### 37.3 8067B – 05/08

1. Updated [“Pinout/Block Diagram”](#) on page 2 and [“Pinout and Pin Functions”](#) on page 48.
2. Added XMEGA A1 Block Diagram, [Figure 3-1](#) on page 5.
3. Updated [“Overview”](#) on page 4 included the XMEGA A1 explanation text on page 6.
4. Updated AVR CPU [“Features”](#) on page 7.
5. Updated Event System block diagram, [Figure 9-1](#) on page 17.
6. Updated [“PMIC - Programmable Multi-level Interrupt Controller”](#) on page 24.
7. Updated [“AC - Analog Comparator”](#) on page 43.
8. Updated [“Alternate Pin Function Description”](#) on page 48.
9. Updated [“Alternate Pin Functions”](#) on page 50.
10. Updated [“Typical Characteristics - TBD”](#) on page 72.
11. Updated [“Ordering Information”](#) on page 2.
12. Updated [“Overview”](#) on page 4.
13. Updated [Figure 6-1](#) on page 7.

14. Inserted a new [Figure 15-1 on page 31](#).
15. Updated Speed grades in [“Speed” on page 67](#).
16. Added a new ATxmega384A1 device in [“Features” on page 1](#), updated [“Ordering Information” on page 2](#) and [“Memories” on page 9](#).
17. Replaced the [Figure 3-1 on page 5](#) by a new XMEGA A1 detailed block diagram.
18. Inserted Errata [“ATxmega128A1 rev. G” on page 73](#).

## **37.4 8067A – 02/08**

1. Initial revision.

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