

## Features

- High performance, low power Atmel® AVR® 8-bit microcontroller
- Advanced RISC architecture
  - 131 powerful instructions – most single clock cycle execution
  - 32 × 8 general purpose working registers
  - Fully static operation
  - Up to 20 MIPS throughput at 20MHz
  - On-chip 2-cycle multiplier
- High endurance non-volatile memory segments
  - 4/8/16 Kbytes of in-system self-programmable flash program memory
  - 256/512/512 bytes EEPROM
  - 512/1K/1Kbytes internal SRAM
  - Write/erase cycles: 10,000 flash/100,000 EEPROM
  - Data retention: 20 years at 85°C/100 years at 25°C<sup>(1)</sup>
  - Optional boot code section with independent lock bits
    - In-system programming by on-chip boot program
    - True read-while-write operation
  - Programming lock for software security
- QTouch® library support
  - Capacitive touch buttons, sliders and wheels
  - QTouch and QMatrix acquisition
  - Up to 64 sense channels
- Peripheral features
  - Two 8-bit timer/counters with separate prescaler and compare mode
  - One 16-bit timer/counter with separate prescaler, compare mode, and capture mode
  - Real time counter with separate oscillator
  - Six PWM channels
  - 8-channel 10-bit ADC in TQFP and QFN/MLF package
  - 6-channel 10-bit ADC in PDIP Package
  - Programmable serial USART
  - Master/slave SPI serial interface
  - Byte-oriented 2-wire serial interface (Philips I<sup>2</sup>C compatible)
  - Programmable watchdog timer with separate on-chip oscillator
  - On-chip analog comparator
  - Interrupt and wake-up on pin change
- Special microcontroller features
  - DebugWIRE on-chip debug system
  - Power-on reset and programmable brown-out detection
  - Internal calibrated oscillator
  - External and internal interrupt sources
  - Five sleep modes: Idle, ADC noise reduction, power-save, power-down, and standby
- I/O and packages
  - 23 programmable I/O lines
  - 28-pin PDIP, 32-lead TQFP, 28-pad QFN/MLF and 32-pad QFN/MLF
- Operating voltage:
  - 1.8V - 5.5V for Atmel ATmega48V/88V/168V
  - 2.7V - 5.5V for Atmel ATmega48/88/168
- Temperature range:
  - -40°C to 85°C
- Speed grade:
  - ATmega48V/88V/168V: 0 - 4MHz @ 1.8V - 5.5V, 0 - 10MHz @ 2.7V - 5.5V
  - ATmega48/88/168: 0 - 10MHz @ 2.7V - 5.5V, 0 - 20MHz @ 4.5V - 5.5V
- Low power consumption
  - Active mode:
    - 250µA at 1MHz, 1.8V
    - 15µA at 32kHz, 1.8V (including oscillator)
  - Power-down mode:
    - 0.1µA at 1.8V

Note: 1. See [“Data Retention”](#) on page 7 for details.



## 8-bit Atmel Microcontroller with 4/8/16K Bytes In-System Programmable Flash

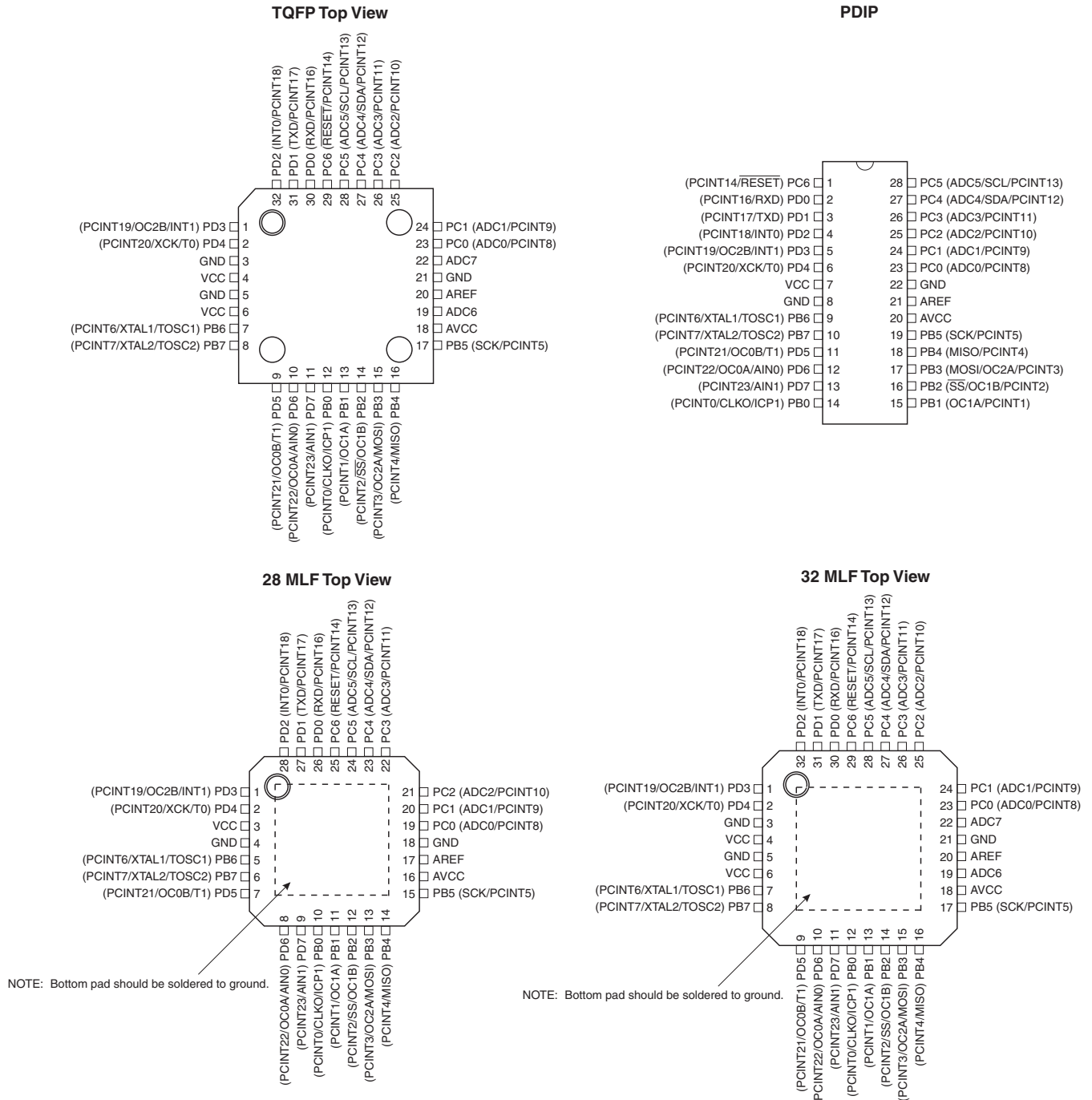
**ATmega48/V**  
**ATmega88/V**  
**ATmega168/V**

## Summary



## 1. Pin configurations

**Figure 1-1.** Pinout Atmel ATmega48/88/1682545TS



## 1.1 Pin descriptions

### 1.1.1 VCC

Digital supply voltage.

### 1.1.2 GND

Ground.

### 1.1.3 Port B (PB7:0) XTAL1/XTAL2/TOSC1/TOSC2

Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Depending on the clock selection fuse settings, PB6 can be used as input to the inverting Oscillator amplifier and input to the internal clock operating circuit.

Depending on the clock selection fuse settings, PB7 can be used as output from the inverting Oscillator amplifier.

If the Internal Calibrated RC Oscillator is used as chip clock source, PB7..6 is used as TOSC2..1 input for the Asynchronous Timer/Counter2 if the AS2 bit in ASSR is set.

The various special features of Port B are elaborated in [“Alternate functions of port B” on page 77](#) and [“System clock and clock options” on page 26](#).

### 1.1.4 Port C (PC5:0)

Port C is a 7-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The PC5..0 output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up resistors are activated. The Port C pins are tri-stated when a reset condition becomes active, even if the clock is not running.

### 1.1.5 PC6/RESET

If the RSTDISBL Fuse is programmed, PC6 is used as an I/O pin. Note that the electrical characteristics of PC6 differ from those of the other pins of Port C.

If the RSTDISBL Fuse is unprogrammed, PC6 is used as a Reset input. A low level on this pin for longer than the minimum pulse length will generate a Reset, even if the clock is not running. The minimum pulse length is given in [Table 28-3 on page 306](#). Shorter pulses are not guaranteed to generate a Reset.

The various special features of Port C are elaborated in [“Alternate functions of port C” on page 80](#).

### 1.1.6 Port D (PD7:0)

Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port D pins that are externally pulled low will source current if the pull-up

resistors are activated. The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not running.

The various special features of Port D are elaborated in [“Alternate functions of port D” on page 83](#).

#### **1.1.7 $AV_{CC}$**

$AV_{CC}$  is the supply voltage pin for the A/D Converter, PC3:0, and ADC7:6. It should be externally connected to  $V_{CC}$ , even if the ADC is not used. If the ADC is used, it should be connected to  $V_{CC}$  through a low-pass filter. Note that PC6..4 use digital supply voltage,  $V_{CC}$ .

#### **1.1.8 AREF**

AREF is the analog reference pin for the A/D Converter.

#### **1.1.9 ADC7:6 (TQFP and QFN/MLF package only)**

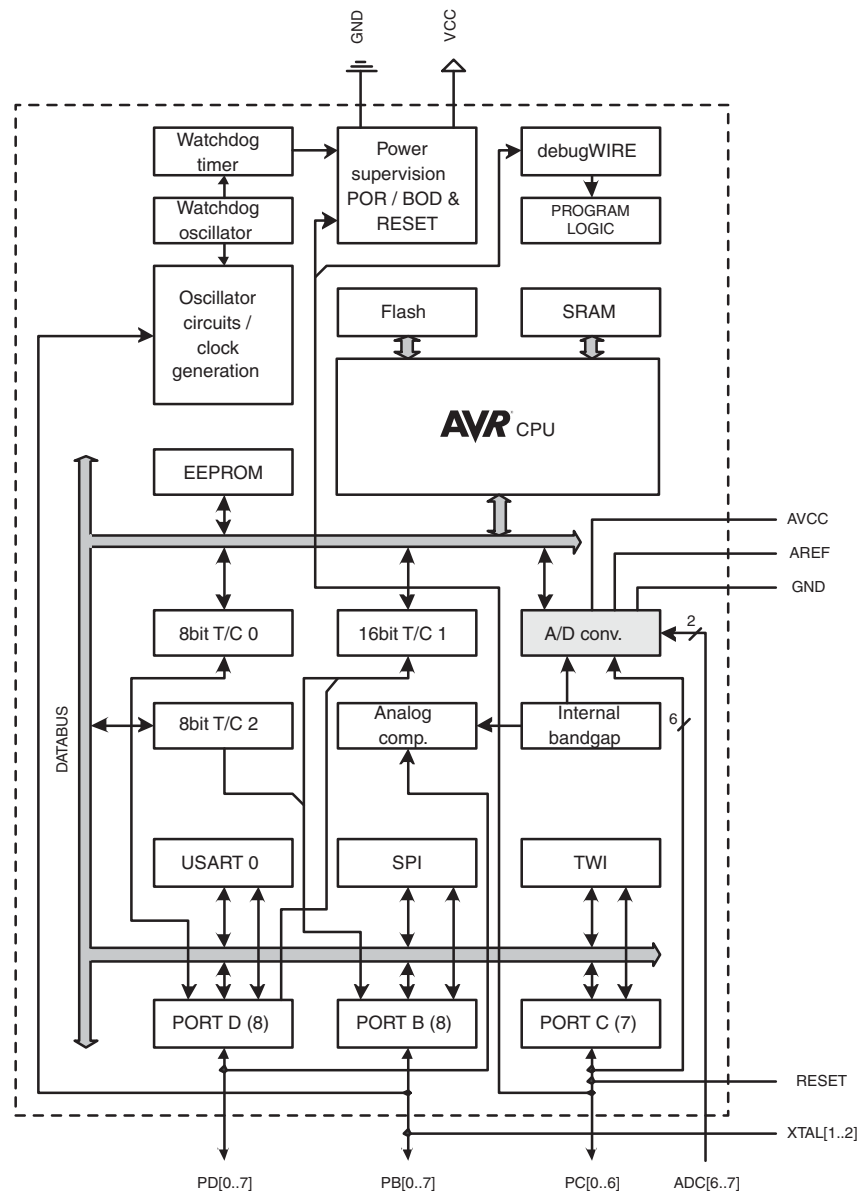
In the TQFP and QFN/MLF package, ADC7:6 serve as analog inputs to the A/D converter. These pins are powered from the analog supply and serve as 10-bit ADC channels.

## 2. Overview

The Atmel ATmega48/88/168 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega48/88/168 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

### 2.1 Block diagram

Figure 2-1. Block Diagram



The AVR core 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 up to ten times faster than conventional CISC microcontrollers.

The Atmel ATmega48/88/168 provides the following features: 4K/8K/16K bytes of In-System Programmable Flash with Read-While-Write capabilities, 256/512/512 bytes EEPROM, 512/1K/1K bytes SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, a byte-oriented 2-wire Serial Interface, an SPI serial port, a 6-channel 10-bit ADC (8 channels in TQFP and QFN/MLF packages), a programmable Watchdog Timer with internal Oscillator, and five software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, USART, 2-wire Serial Interface, SPI port, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next interrupt or hardware reset. In Power-save mode, the asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except asynchronous timer and ADC, to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator Oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low power consumption.

Atmel offers the QTouch Library for embedding capacitive touch buttons, sliders and wheels functionality into AVR microcontrollers. The patented charge-transfer signal acquisition offers robust sensing and includes fully debounced reporting of touch keys and includes Adjacent Key Suppression® (AKS®) technology for unambiguous detection of key events. The easy-to-use QTouch Suite toolchain allows you to explore, develop and debug your own touch applications.

The device is manufactured using the Atmel high density non-volatile memory technology. The On-chip ISP Flash allows the program memory to be reprogrammed In-System through an SPI serial interface, by a conventional non-volatile memory programmer, or by an On-chip Boot program running on the AVR core. The Boot program can use any interface to download the application program in the Application Flash memory. 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-bit RISC CPU with In-System Self-Programmable Flash on a monolithic chip, the Atmel ATmega48/88/168 is a powerful microcontroller that provides a highly flexible and cost effective solution to many embedded control applications.

The ATmega48/88/168 AVR is supported with a full suite of program and system development tools including: C Compilers, Macro Assemblers, Program Debugger/Simulators, In-Circuit Emulators, and Evaluation kits.

## 2.2 Comparison between Atmel ATmega48, Atmel ATmega88, and Atmel ATmega168

The ATmega48, ATmega88 and ATmega168 differ only in memory sizes, boot loader support, and interrupt vector sizes. [Table 2-1](#) summarizes the different memory and interrupt vector sizes for the three devices.

**Table 2-1.** Memory size summary.

| Device    | Flash    | EEPROM   | RAM      | Interrupt vector size      |
|-----------|----------|----------|----------|----------------------------|
| ATmega48  | 4Kbytes  | 256Bytes | 512Bytes | 1 instruction word/vector  |
| ATmega88  | 8Kbytes  | 512Bytes | 1Kbytes  | 1 instruction word/vector  |
| ATmega168 | 16Kbytes | 512Bytes | 1Kbytes  | 2 instruction words/vector |

ATmega88 and ATmega168 support a real Read-While-Write Self-Programming mechanism. There is a separate Boot Loader Section, and the SPM instruction can only execute from there. In ATmega48, there is no Read-While-Write support and no separate Boot Loader Section. The SPM instruction can execute from the entire Flash.

### 3. Resources

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

### 4. Data retention

Reliability Qualification results show that the projected data retention failure rate is much less than 1 PPM over 20 years at 85°C or 100 years at 25°C.

### 5. About code examples

This documentation contains simple code examples that briefly show how to use various parts of the device. These code examples assume that the part specific header file is included before compilation. Be aware that not all C compiler vendors include bit definitions in the header files and interrupt handling in C is compiler dependent. Please confirm with the C compiler documentation for more details.

For I/O Registers located in extended I/O map, “IN”, “OUT”, “SBIS”, “SBIC”, “CBI”, and “SBI” instructions must be replaced with instructions that allow access to extended I/O. Typically “LDS” and “STS” combined with “SBR”, “SBRC”, “SBR”, and “CBR”.

### 6. Capacitive touch sensing

The Atmel QTouch Library provides a simple to use solution to realize touch sensitive interfaces on most Atmel AVR microcontrollers. The QTouch Library includes support for the QTouch and QMatrix acquisition methods.

Touch sensing can be added to any application by linking the appropriate Atmel QTouch Library for the AVR Microcontroller. This is done by using a simple set of APIs to define the touch channels and sensors, and then calling the touch sensing API's to retrieve the channel information and determine the touch sensor states.

The QTouch Library is FREE and downloadable from the Atmel website at the following location: [www.atmel.com/qtouchlibrary](http://www.atmel.com/qtouchlibrary). For implementation details and other information, refer to the [Atmel QTouch Library User Guide](#) - also available for download from the Atmel website.

## 7. Register summary

| Address | Name     | Bit 7                        | Bit 6   | Bit 5  | Bit 4 | Bit 3                         | Bit 2           | Bit 1           | Bit 0  | Page    |
|---------|----------|------------------------------|---------|--------|-------|-------------------------------|-----------------|-----------------|--------|---------|
| (0xFF)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xFE)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xFD)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xFC)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xFB)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xFA)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xF9)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xF8)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xF7)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xF6)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xF5)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xF4)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xF3)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xF2)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xF1)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xF0)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xEF)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xEE)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xED)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xEC)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xEB)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xEA)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xE9)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xE8)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xE7)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xE6)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xE5)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xE4)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xE3)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xE2)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xE1)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xE0)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xDF)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xDE)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xDD)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xDC)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xDB)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xDA)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xD9)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xD8)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xD7)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xD6)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xD5)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xD4)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xD3)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xD2)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xD1)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xD0)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xCF)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xCE)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xCD)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xCC)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xCB)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xCA)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xC9)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xC8)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xC7)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xC6)  | UDR0     | USART I/O data register      |         |        |       |                               |                 |                 |        | 189     |
| (0xC5)  | UBRR0H   |                              |         |        |       | USART baud rate register high |                 |                 |        | 193     |
| (0xC4)  | UBRR0L   | USART baud rate register low |         |        |       |                               |                 |                 |        | 193     |
| (0xC3)  | Reserved | –                            | –       | –      | –     | –                             | –               | –               | –      |         |
| (0xC2)  | UCSR0C   | UMSEL01                      | UMSEL00 | UPM01  | UPM00 | USBS0                         | UCSZ01 / UDORD0 | UCSZ00 / UCPHA0 | UCPOL0 | 191/206 |
| (0xC1)  | UCSR0B   | RXCIE0                       | TXCIE0  | UDRIE0 | RXEN0 | TXEN0                         | UCSZ02          | RXB80           | TXB80  | 190     |
| (0xC0)  | UCSR0A   | RXC0                         | TXC0    | UDRE0  | FE0   | DOR0                          | UPE0            | U2X0            | MPCM0  | 189     |

| Address | Name     | Bit 7                                                | Bit 6  | Bit 5  | Bit 4  | Bit 3   | Bit 2   | Bit 1   | Bit 0   | Page |
|---------|----------|------------------------------------------------------|--------|--------|--------|---------|---------|---------|---------|------|
| (0xBF)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xBE)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xBD)  | TWAMR    | TWAM6                                                | TWAM5  | TWAM4  | TWAM3  | TWAM2   | TWAM1   | TWAM0   | –       | 238  |
| (0xBC)  | TWCR     | TWINT                                                | TWEA   | TWSTA  | TWSTO  | TWWC    | TWEN    | –       | TWIE    | 235  |
| (0xBB)  | TWDR     | 2-wire serial interface data register                |        |        |        |         |         |         |         | 237  |
| (0xBA)  | TWAR     | TWA6                                                 | TWA5   | TWA4   | TWA3   | TWA2    | TWA1    | TWA0    | TWGCE   | 238  |
| (0xB9)  | TWSR     | TWS7                                                 | TWS6   | TWS5   | TWS4   | TWS3    | –       | TWPS1   | TWPS0   | 237  |
| (0xB8)  | TWBR     | 2-wire serial interface bit rate register            |        |        |        |         |         |         |         | 235  |
| (0xB7)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xB6)  | ASSR     | –                                                    | EXCLK  | AS2    | TCN2UB | OCR2AUB | OCR2BUB | TCR2AUB | TCR2BUB | 158  |
| (0xB5)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xB4)  | OCR2B    | Timer/Counter2 output compare register B             |        |        |        |         |         |         |         | 157  |
| (0xB3)  | OCR2A    | Timer/Counter2 output compare register A             |        |        |        |         |         |         |         | 156  |
| (0xB2)  | TCNT2    | Timer/Counter2 (8-bit)                               |        |        |        |         |         |         |         | 156  |
| (0xB1)  | TCCR2B   | FOC2A                                                | FOC2B  | –      | –      | WGM22   | CS22    | CS21    | CS20    | 155  |
| (0xB0)  | TCCR2A   | COM2A1                                               | COM2A0 | COM2B1 | COM2B0 | –       | –       | WGM21   | WGM20   | 152  |
| (0xAF)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xAE)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xAD)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xAC)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xAB)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xAA)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xA9)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xA8)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xA7)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xA6)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xA5)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xA4)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xA3)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xA2)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xA1)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0xA0)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x9F)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x9E)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x9D)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x9C)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x9B)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x9A)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x99)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x98)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x97)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x96)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x95)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x94)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x93)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x92)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x91)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x90)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x8F)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x8E)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x8D)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x8C)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x8B)  | OCR1BH   | Timer/Counter1 - output compare register B high byte |        |        |        |         |         |         |         | 133  |
| (0x8A)  | OCR1BL   | Timer/Counter1 - output compare register B low byte  |        |        |        |         |         |         |         | 133  |
| (0x89)  | OCR1AH   | Timer/Counter1 - output compare register A high byte |        |        |        |         |         |         |         | 133  |
| (0x88)  | OCR1AL   | Timer/Counter1 - output compare register A low byte  |        |        |        |         |         |         |         | 133  |
| (0x87)  | ICR1H    | Timer/Counter1 - input capture register high byte    |        |        |        |         |         |         |         | 134  |
| (0x86)  | ICR1L    | Timer/Counter1 - input capture register low byte     |        |        |        |         |         |         |         | 134  |
| (0x85)  | TCNT1H   | Timer/Counter1 - counter register high byte          |        |        |        |         |         |         |         | 133  |
| (0x84)  | TCNT1L   | Timer/Counter1 - counter register low byte           |        |        |        |         |         |         |         | 133  |
| (0x83)  | Reserved | –                                                    | –      | –      | –      | –       | –       | –       | –       |      |
| (0x82)  | TCCR1C   | FOC1A                                                | FOC1B  | –      | –      | –       | –       | –       | –       | 132  |
| (0x81)  | TCCR1B   | ICNC1                                                | ICES1  | –      | WGM13  | WGM12   | CS12    | CS11    | CS10    | 131  |
| (0x80)  | TCCR1A   | COM1A1                                               | COM1A0 | COM1B1 | COM1B0 | –       | –       | WGM11   | WGM10   | 129  |
| (0x7F)  | DIDR1    | –                                                    | –      | –      | –      | –       | –       | AIN1D   | AIN0D   | 242  |
| (0x7E)  | DIDR0    | –                                                    | –      | ADC5D  | ADC4D  | ADC3D   | ADC2D   | ADC1D   | ADC0D   | 258  |

| Address     | Name     | Bit 7                                            | Bit 6                | Bit 5   | Bit 4                | Bit 3   | Bit 2               | Bit 1    | Bit 0     | Page    |
|-------------|----------|--------------------------------------------------|----------------------|---------|----------------------|---------|---------------------|----------|-----------|---------|
| (0x7D)      | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| (0x7C)      | ADMUX    | REFS1                                            | REFS0                | ADLAR   | –                    | MUX3    | MUX2                | MUX1     | MUX0      | 254     |
| (0x7B)      | ADCSRB   | –                                                | ACME                 | –       | –                    | –       | ADTS2               | ADTS1    | ADTS0     | 257     |
| (0x7A)      | ADCSRA   | ADEN                                             | ADSC                 | ADATE   | ADIF                 | ADIE    | ADPS2               | ADPS1    | ADPS0     | 255     |
| (0x79)      | ADCH     | ADC data register high byte                      |                      |         |                      |         |                     |          |           | 257     |
| (0x78)      | ADCL     | ADC data register low byte                       |                      |         |                      |         |                     |          |           | 257     |
| (0x77)      | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| (0x76)      | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| (0x75)      | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| (0x74)      | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| (0x73)      | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| (0x72)      | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| (0x71)      | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| (0x70)      | TIMSK2   | –                                                | –                    | –       | –                    | –       | OCIE2B              | OCIE2A   | TOIE2     | 157     |
| (0x6F)      | TIMSK1   | –                                                | –                    | ICIE1   | –                    | –       | OCIE1B              | OCIE1A   | TOIE1     | 134     |
| (0x6E)      | TIMSK0   | –                                                | –                    | –       | –                    | –       | OCIE0B              | OCIE0A   | TOIE0     | 105     |
| (0x6D)      | PCMSK2   | PCINT23                                          | PCINT22              | PCINT21 | PCINT20              | PCINT19 | PCINT18             | PCINT17  | PCINT16   | 69      |
| (0x6C)      | PCMSK1   | –                                                | PCINT14              | PCINT13 | PCINT12              | PCINT11 | PCINT10             | PCINT9   | PCINT8    | 69      |
| (0x6B)      | PCMSK0   | PCINT7                                           | PCINT6               | PCINT5  | PCINT4               | PCINT3  | PCINT2              | PCINT1   | PCINT0    | 69      |
| (0x6A)      | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| (0x69)      | EICRA    | –                                                | –                    | –       | –                    | ISC11   | ISC10               | ISC01    | ISC00     | 66      |
| (0x68)      | PCICR    | –                                                | –                    | –       | –                    | –       | PCIE2               | PCIE1    | PCIE0     |         |
| (0x67)      | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| (0x66)      | OSCCAL   | Oscillator calibration register                  |                      |         |                      |         |                     |          |           | 36      |
| (0x65)      | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| (0x64)      | PRR      | PRTWI                                            | PRTIM2               | PRTIM0  | –                    | PRTIM1  | PRSPI               | PRUSART0 | PRADC     | 40      |
| (0x63)      | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| (0x62)      | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| (0x61)      | CLKPR    | CLKPCE                                           | –                    | –       | –                    | CLKPS3  | CLKPS2              | CLKPS1   | CLKPS0    | 36      |
| (0x60)      | WDTCR    | WDIF                                             | WDIE                 | WDP3    | WDCE                 | WDE     | WDP2                | WDP1     | WDP0      | 52      |
| 0x3F (0x5F) | SREG     | I                                                | T                    | H       | S                    | V       | N                   | Z        | C         | 10      |
| 0x3E (0x5E) | SPH      | –                                                | –                    | –       | –                    | –       | (SP10) <sup>5</sup> | SP9      | SP8       | 12      |
| 0x3D (0x5D) | SPL      | SP7                                              | SP6                  | SP5     | SP4                  | SP3     | SP2                 | SP1      | SP0       | 12      |
| 0x3C (0x5C) | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| 0x3B (0x5B) | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| 0x3A (0x5A) | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| 0x39 (0x59) | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| 0x38 (0x58) | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| 0x37 (0x57) | SPMCSR   | SPMIE                                            | (RWWSB) <sup>5</sup> | –       | (RWWSR) <sup>5</sup> | BLBSET  | PGWRT               | PGERS    | SELFPRGEN | 282     |
| 0x36 (0x56) | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| 0x35 (0x55) | MCUCR    | –                                                | –                    | –       | PUD                  | –       | –                   | IVSEL    | IVCE      |         |
| 0x34 (0x54) | MCUSR    | –                                                | –                    | –       | –                    | WDRF    | BORF                | EXTRF    | PORF      |         |
| 0x33 (0x53) | SMCR     | –                                                | –                    | –       | –                    | SM2     | SM1                 | SM0      | SE        | 38      |
| 0x32 (0x52) | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| 0x31 (0x51) | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| 0x30 (0x50) | ACSR     | ACD                                              | ACBG                 | ACO     | ACI                  | ACIE    | ACIC                | ACIS1    | ACIS0     | 241     |
| 0x2F (0x4F) | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| 0x2E (0x4E) | SPDR     | SPI data register                                |                      |         |                      |         |                     |          |           | 169     |
| 0x2D (0x4D) | SPSR     | SPIF                                             | WCOL                 | –       | –                    | –       | –                   | –        | SPI2X     | 168     |
| 0x2C (0x4C) | SPCR     | SPIE                                             | SPE                  | DORD    | MSTR                 | CPOL    | CPHA                | SPR1     | SPR0      | 167     |
| 0x2B (0x4B) | GPOR2    | General purpose I/O register 2                   |                      |         |                      |         |                     |          |           | 25      |
| 0x2A (0x4A) | GPOR1    | General purpose I/O register 1                   |                      |         |                      |         |                     |          |           | 25      |
| 0x29 (0x49) | Reserved | –                                                | –                    | –       | –                    | –       | –                   | –        | –         |         |
| 0x28 (0x48) | OCR0B    | Timer/Counter0 output compare register B         |                      |         |                      |         |                     |          |           |         |
| 0x27 (0x47) | OCR0A    | Timer/Counter0 output compare register A         |                      |         |                      |         |                     |          |           |         |
| 0x26 (0x46) | TCNT0    | Timer/Counter0 (8-bit)                           |                      |         |                      |         |                     |          |           |         |
| 0x25 (0x45) | TCCR0B   | FOC0A                                            | FOC0B                | –       | –                    | WGM02   | CS02                | CS01     | CS00      |         |
| 0x24 (0x44) | TCCR0A   | COM0A1                                           | COM0A0               | COM0B1  | COM0B0               | –       | –                   | WGM01    | WGM00     |         |
| 0x23 (0x43) | GTCCR    | TSM                                              | –                    | –       | –                    | –       | –                   | PSRASY   | PSRSYNC   | 138/159 |
| 0x22 (0x42) | EEARH    | (EEPROM address register high byte) <sup>5</sup> |                      |         |                      |         |                     |          |           | 21      |
| 0x21 (0x41) | EEARL    | EEPROM address register low byte                 |                      |         |                      |         |                     |          |           | 21      |
| 0x20 (0x40) | EEDR     | EEPROM data register                             |                      |         |                      |         |                     |          |           | 21      |
| 0x1F (0x3F) | EEDR     | –                                                | –                    | EEPM1   | EEPM0                | EERIE   | EEMPE               | EEPE     | EERE      | 21      |
| 0x1E (0x3E) | GPOR0    | General purpose I/O register 0                   |                      |         |                      |         |                     |          |           | 25      |
| 0x1D (0x3D) | EIMSK    | –                                                | –                    | –       | –                    | –       | –                   | INT1     | INT0      | 67      |
| 0x1C (0x3C) | EIFR     | –                                                | –                    | –       | –                    | –       | –                   | INTF1    | INTF0     | 67      |

| Address     | Name     | Bit 7  | Bit 6  | Bit 5  | Bit 4  | Bit 3  | Bit 2  | Bit 1  | Bit 0  | Page |
|-------------|----------|--------|--------|--------|--------|--------|--------|--------|--------|------|
| 0x1B (0x3B) | PCIFR    | –      | –      | –      | –      | –      | PCIF2  | PCIF1  | PCIF0  |      |
| 0x1A (0x3A) | Reserved | –      | –      | –      | –      | –      | –      | –      | –      |      |
| 0x19 (0x39) | Reserved | –      | –      | –      | –      | –      | –      | –      | –      |      |
| 0x18 (0x38) | Reserved | –      | –      | –      | –      | –      | –      | –      | –      |      |
| 0x17 (0x37) | TIFR2    | –      | –      | –      | –      | –      | OCF2B  | OCF2A  | TOV2   | 157  |
| 0x16 (0x36) | TIFR1    | –      | –      | ICF1   | –      | –      | OCF1B  | OCF1A  | TOV1   | 135  |
| 0x15 (0x35) | TIFR0    | –      | –      | –      | –      | –      | OCF0B  | OCF0A  | TOV0   |      |
| 0x14 (0x34) | Reserved | –      | –      | –      | –      | –      | –      | –      | –      |      |
| 0x13 (0x33) | Reserved | –      | –      | –      | –      | –      | –      | –      | –      |      |
| 0x12 (0x32) | Reserved | –      | –      | –      | –      | –      | –      | –      | –      |      |
| 0x11 (0x31) | Reserved | –      | –      | –      | –      | –      | –      | –      | –      |      |
| 0x10 (0x30) | Reserved | –      | –      | –      | –      | –      | –      | –      | –      |      |
| 0x0F (0x2F) | Reserved | –      | –      | –      | –      | –      | –      | –      | –      |      |
| 0x0E (0x2E) | Reserved | –      | –      | –      | –      | –      | –      | –      | –      |      |
| 0x0D (0x2D) | Reserved | –      | –      | –      | –      | –      | –      | –      | –      |      |
| 0x0C (0x2C) | Reserved | –      | –      | –      | –      | –      | –      | –      | –      |      |
| 0x0B (0x2B) | PORTD    | PORTD7 | PORTD6 | PORTD5 | PORTD4 | PORTD3 | PORTD2 | PORTD1 | PORTD0 | 87   |
| 0x0A (0x2A) | DDRD     | DDD7   | DDD6   | DDD5   | DDD4   | DDD3   | DDD2   | DDD1   | DDD0   | 87   |
| 0x09 (0x29) | PIND     | PIND7  | PIND6  | PIND5  | PIND4  | PIND3  | PIND2  | PIND1  | PIND0  | 87   |
| 0x08 (0x28) | PORTC    | –      | PORTC6 | PORTC5 | PORTC4 | PORTC3 | PORTC2 | PORTC1 | PORTC0 | 86   |
| 0x07 (0x27) | DDRC     | –      | DDC6   | DDC5   | DDC4   | DDC3   | DDC2   | DDC1   | DDC0   | 86   |
| 0x06 (0x26) | PINC     | –      | PINC6  | PINC5  | PINC4  | PINC3  | PINC2  | PINC1  | PINC0  | 86   |
| 0x05 (0x25) | PORTB    | PORTB7 | PORTB6 | PORTB5 | PORTB4 | PORTB3 | PORTB2 | PORTB1 | PORTB0 | 86   |
| 0x04 (0x24) | DDRB     | DDB7   | DDB6   | DDB5   | DDB4   | DDB3   | DDB2   | DDB1   | DDB0   | 86   |
| 0x03 (0x23) | PINB     | PINB7  | PINB6  | PINB5  | PINB4  | PINB3  | PINB2  | PINB1  | PINB0  | 86   |
| 0x02 (0x22) | Reserved | –      | –      | –      | –      | –      | –      | –      | –      |      |
| 0x01 (0x21) | Reserved | –      | –      | –      | –      | –      | –      | –      | –      |      |
| 0x00 (0x20) | Reserved | –      | –      | –      | –      | –      | –      | –      | –      |      |

- Note:
1. For compatibility with future devices, reserved bits should be written to zero if accessed. Reserved I/O memory addresses should never be written.
  2. I/O Registers within the address range 0x00 - 0x1F are directly bit-accessible using the SBI and CBI instructions. In these registers, the value of single bits can be checked by using the SBIS and SBIC instructions.
  3. Some of the Status Flags are cleared by writing a logical one to them. Note that, unlike most other AVRs, the CBI and SBI instructions will only operate on the specified bit, and can therefore be used on registers containing such Status Flags. The CBI and SBI instructions work with registers 0x00 to 0x1F only.
  4. When using the I/O specific commands IN and OUT, the I/O addresses 0x00 - 0x3F must be used. When addressing I/O Registers as data space using LD and ST instructions, 0x20 must be added to these addresses. The Atmel ATmega48/88/168 is a complex microcontroller with more peripheral units than can be supported within the 64 location reserved in Opcode for the IN and OUT instructions. For the Extended I/O space from 0x60 - 0xFF in SRAM, only the ST/STS/STD and LD/LDS/LDD instructions can be used.
  5. Only valid for ATmega88/168

## 8. Instruction set summary

| Mnemonics                                | Operands | Description                              | Operation                                             | Flags         | #Clocks |
|------------------------------------------|----------|------------------------------------------|-------------------------------------------------------|---------------|---------|
| <b>ARITHMETIC AND LOGIC INSTRUCTIONS</b> |          |                                          |                                                       |               |         |
| ADD                                      | Rd, Rr   | Add two registers                        | $Rd \leftarrow Rd + Rr$                               | Z, C, N, V, H | 1       |
| ADC                                      | Rd, Rr   | Add with carry two registers             | $Rd \leftarrow Rd + Rr + C$                           | Z, C, N, V, H | 1       |
| ADIW                                     | RdI, K   | Add immediate to word                    | $Rdh:Rdl \leftarrow Rdh:Rdl + K$                      | Z, C, N, V, S | 2       |
| SUB                                      | Rd, Rr   | Subtract two registers                   | $Rd \leftarrow Rd - Rr$                               | Z, C, N, V, H | 1       |
| SUBI                                     | Rd, K    | Subtract constant from register          | $Rd \leftarrow Rd - K$                                | Z, C, N, V, H | 1       |
| SBC                                      | Rd, Rr   | Subtract with carry two registers        | $Rd \leftarrow Rd - Rr - C$                           | Z, C, N, V, H | 1       |
| SBCI                                     | Rd, K    | Subtract with carry constant from reg.   | $Rd \leftarrow Rd - K - C$                            | Z, C, N, V, H | 1       |
| SBIW                                     | RdI, K   | Subtract immediate from Word             | $Rdh:Rdl \leftarrow Rdh:Rdl - K$                      | Z, C, N, V, S | 2       |
| AND                                      | Rd, Rr   | Logical AND registers                    | $Rd \leftarrow Rd \bullet Rr$                         | Z, N, V       | 1       |
| ANDI                                     | Rd, K    | Logical AND register and constant        | $Rd \leftarrow Rd \bullet K$                          | Z, N, V       | 1       |
| OR                                       | Rd, Rr   | Logical OR registers                     | $Rd \leftarrow Rd \vee Rr$                            | Z, N, V       | 1       |
| ORI                                      | Rd, K    | Logical OR register and constant         | $Rd \leftarrow Rd \vee K$                             | Z, N, V       | 1       |
| EOR                                      | Rd, Rr   | Exclusive OR registers                   | $Rd \leftarrow Rd \oplus Rr$                          | Z, N, V       | 1       |
| COM                                      | Rd       | One's complement                         | $Rd \leftarrow 0xFF - Rd$                             | Z, C, N, V    | 1       |
| NEG                                      | Rd       | Two's complement                         | $Rd \leftarrow 0x00 - Rd$                             | Z, C, N, V, H | 1       |
| SBR                                      | Rd, K    | Set bit(s) in register                   | $Rd \leftarrow Rd \vee K$                             | Z, N, V       | 1       |
| CBR                                      | Rd, K    | Clear bit(s) in register                 | $Rd \leftarrow Rd \bullet (0xFF - K)$                 | Z, N, V       | 1       |
| INC                                      | Rd       | Increment                                | $Rd \leftarrow Rd + 1$                                | Z, N, V       | 1       |
| DEC                                      | Rd       | Decrement                                | $Rd \leftarrow Rd - 1$                                | Z, N, V       | 1       |
| TST                                      | Rd       | Test for zero or minus                   | $Rd \leftarrow Rd \bullet Rd$                         | Z, N, V       | 1       |
| CLR                                      | Rd       | Clear register                           | $Rd \leftarrow Rd \oplus Rd$                          | Z, N, V       | 1       |
| SER                                      | Rd       | Set register                             | $Rd \leftarrow 0xFF$                                  | None          | 1       |
| MUL                                      | Rd, Rr   | Multiply unsigned                        | $R1:R0 \leftarrow Rd \times Rr$                       | Z, C          | 2       |
| MULS                                     | Rd, Rr   | Multiply signed                          | $R1:R0 \leftarrow Rd \times Rr$                       | Z, C          | 2       |
| MULSU                                    | Rd, Rr   | Multiply signed with unsigned            | $R1:R0 \leftarrow Rd \times Rr$                       | Z, C          | 2       |
| FMUL                                     | Rd, Rr   | Fractional multiply unsigned             | $R1:R0 \leftarrow (Rd \times Rr) \lll 1$              | Z, C          | 2       |
| FMULS                                    | Rd, Rr   | Fractional multiply signed               | $R1:R0 \leftarrow (Rd \times Rr) \lll 1$              | Z, C          | 2       |
| FMULSU                                   | Rd, Rr   | Fractional multiply signed with unsigned | $R1:R0 \leftarrow (Rd \times Rr) \lll 1$              | Z, C          | 2       |
| <b>BRANCH INSTRUCTIONS</b>               |          |                                          |                                                       |               |         |
| RJMP                                     | k        | Relative jump                            | $PC \leftarrow PC + k + 1$                            | None          | 2       |
| JMP                                      |          | Indirect jump to (Z)                     | $PC \leftarrow Z$                                     | None          | 2       |
| JMP <sup>(1)</sup>                       | k        | Direct jump                              | $PC \leftarrow k$                                     | None          | 3       |
| RCALL                                    | k        | Relative subroutine call                 | $PC \leftarrow PC + k + 1$                            | None          | 3       |
| ICALL                                    |          | Indirect call to (Z)                     | $PC \leftarrow Z$                                     | None          | 3       |
| CALL <sup>(1)</sup>                      | k        | Direct subroutine call                   | $PC \leftarrow k$                                     | None          | 4       |
| RET                                      |          | Subroutine return                        | $PC \leftarrow STACK$                                 | None          | 4       |
| RETI                                     |          | Interrupt return                         | $PC \leftarrow STACK$                                 | I             | 4       |
| 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, N, V, C, H | 1       |
| CPC                                      | Rd, Rr   | Compare with carry                       | $Rd - Rr - C$                                         | Z, N, V, C, H | 1       |
| CPI                                      | Rd, K    | Compare register with immediate          | $Rd - K$                                              | Z, N, V, C, 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 is set           | if $(Rr(b)=1)$ $PC \leftarrow PC + 2$ or 3            | None          | 1/2/3   |
| SBIC                                     | P, b     | Skip if bit in I/O register cleared      | if $(P(b)=0)$ $PC \leftarrow PC + 2$ or 3             | None          | 1/2/3   |
| SBIS                                     | P, b     | Skip if bit in I/O register is set       | if $(P(b)=1)$ $PC \leftarrow PC + 2$ or 3             | None          | 1/2/3   |
| 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 zero, 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     |

| Mnemonics                            | Operands | Description                      | Operation                                | Flags      | #Clocks |
|--------------------------------------|----------|----------------------------------|------------------------------------------|------------|---------|
| BRIE                                 | k        | Branch if interrupt enabled      | if (I = 1) then PC ← PC + k + 1          | None       | 1/2     |
| BRID                                 | k        | Branch if interrupt disabled     | if (I = 0) then PC ← PC + k + 1          | None       | 1/2     |
| <b>BIT AND BIT-TEST INSTRUCTIONS</b> |          |                                  |                                          |            |         |
| SBI                                  | P,b      | Set bit in I/O register          | I/O(P,b) ← 1                             | None       | 2       |
| CBI                                  | P,b      | Clear bit in I/O register        | I/O(P,b) ← 0                             | None       | 2       |
| LSL                                  | Rd       | Logical shift left               | Rd(n+1) ← Rd(n), Rd(0) ← 0               | Z, C, N, V | 1       |
| LSR                                  | Rd       | Logical shift right              | Rd(n) ← Rd(n+1), Rd(7) ← 0               | Z, C, N, V | 1       |
| ROL                                  | Rd       | Rotate left through carry        | Rd(0) ← C, Rd(n+1) ← Rd(n), C ← Rd(7)    | Z, C, N, V | 1       |
| ROR                                  | Rd       | Rotate right through carry       | Rd(7) ← C, Rd(n) ← Rd(n+1), C ← Rd(0)    | Z, C, N, V | 1       |
| ASR                                  | Rd       | Arithmetic shift right           | Rd(n) ← Rd(n+1), n=0..6                  | Z, C, N, V | 1       |
| SWAP                                 | Rd       | Swap nibbles                     | Rd(3..0) ← Rd(7..4), Rd(7..4) ← Rd(3..0) | None       | 1       |
| BSET                                 | s        | Flag set                         | SREG(s) ← 1                              | SREG(s)    | 1       |
| BCLR                                 | s        | Flag clear                       | SREG(s) ← 0                              | SREG(s)    | 1       |
| BST                                  | Rr, b    | Bit store from register to T     | T ← Rr(b)                                | T          | 1       |
| BLD                                  | Rd, b    | Bit load from T to register      | Rd(b) ← T                                | None       | 1       |
| SEC                                  |          | Set carry                        | C ← 1                                    | C          | 1       |
| CLC                                  |          | Clear carry                      | C ← 0                                    | C          | 1       |
| SEN                                  |          | Set negative flag                | N ← 1                                    | N          | 1       |
| CLN                                  |          | Clear negative flag              | N ← 0                                    | N          | 1       |
| SEZ                                  |          | Set zero flag                    | Z ← 1                                    | Z          | 1       |
| CLZ                                  |          | Clear zero flag                  | Z ← 0                                    | Z          | 1       |
| SEI                                  |          | Global interrupt enable          | I ← 1                                    | I          | 1       |
| CLI                                  |          | Global interrupt disable         | I ← 0                                    | I          | 1       |
| SES                                  |          | Set signed test flag             | S ← 1                                    | S          | 1       |
| CLS                                  |          | Clear signed test flag           | S ← 0                                    | S          | 1       |
| SEV                                  |          | Set Twos complement overflow     | V ← 1                                    | V          | 1       |
| CLV                                  |          | Clear Twos complement overflow   | V ← 0                                    | V          | 1       |
| SET                                  |          | Set T in SREG                    | T ← 1                                    | T          | 1       |
| CLT                                  |          | Clear T in SREG                  | T ← 0                                    | T          | 1       |
| SEH                                  |          | Set half carry flag in SREG      | H ← 1                                    | H          | 1       |
| CLH                                  |          | Clear half carry flag in SREG    | H ← 0                                    | H          | 1       |
| <b>DATA TRANSFER INSTRUCTIONS</b>    |          |                                  |                                          |            |         |
| MOV                                  | Rd, Rr   | Move between registers           | Rd ← Rr                                  | None       | 1       |
| MOVW                                 | Rd, Rr   | Copy register Word               | Rd+1:Rd ← Rr+1:Rr                        | None       | 1       |
| LDI                                  | Rd, K    | Load immediate                   | Rd ← K                                   | None       | 1       |
| LD                                   | Rd, X    | Load indirect                    | Rd ← (X)                                 | None       | 2       |
| LD                                   | Rd, X+   | Load indirect and post-inc.      | Rd ← (X), X ← X + 1                      | None       | 2       |
| LD                                   | Rd, -X   | Load indirect and pre-dec.       | X ← X - 1, Rd ← (X)                      | None       | 2       |
| LD                                   | Rd, Y    | Load indirect                    | Rd ← (Y)                                 | None       | 2       |
| LD                                   | Rd, Y+   | Load indirect and post-inc.      | Rd ← (Y), Y ← Y + 1                      | None       | 2       |
| LD                                   | Rd, -Y   | Load indirect and pre-dec.       | Y ← Y - 1, Rd ← (Y)                      | None       | 2       |
| LDD                                  | Rd, Y+q  | Load indirect with displacement  | Rd ← (Y + q)                             | None       | 2       |
| LD                                   | Rd, Z    | Load indirect                    | Rd ← (Z)                                 | None       | 2       |
| LD                                   | Rd, Z+   | Load indirect and post-inc.      | Rd ← (Z), Z ← Z + 1                      | None       | 2       |
| LD                                   | Rd, -Z   | Load indirect and pre-dec.       | Z ← Z - 1, Rd ← (Z)                      | None       | 2       |
| LDD                                  | Rd, Z+q  | Load indirect with displacement  | Rd ← (Z + q)                             | None       | 2       |
| LDS                                  | Rd, k    | Load direct from SRAM            | Rd ← (k)                                 | None       | 2       |
| ST                                   | X, Rr    | Store indirect                   | (X) ← Rr                                 | None       | 2       |
| ST                                   | X+, Rr   | Store indirect and post-inc.     | (X) ← Rr, X ← X + 1                      | None       | 2       |
| ST                                   | -X, Rr   | Store indirect and pre-dec.      | X ← X - 1, (X) ← Rr                      | None       | 2       |
| ST                                   | Y, Rr    | Store indirect                   | (Y) ← Rr                                 | None       | 2       |
| ST                                   | Y+, Rr   | Store indirect and post-inc.     | (Y) ← Rr, Y ← Y + 1                      | None       | 2       |
| ST                                   | -Y, Rr   | Store indirect and pre-dec.      | Y ← Y - 1, (Y) ← Rr                      | None       | 2       |
| STD                                  | Y+q, Rr  | Store indirect with displacement | (Y + q) ← Rr                             | None       | 2       |
| ST                                   | Z, Rr    | Store indirect                   | (Z) ← Rr                                 | None       | 2       |
| ST                                   | Z+, Rr   | Store indirect and post-inc.     | (Z) ← Rr, Z ← Z + 1                      | None       | 2       |
| ST                                   | -Z, Rr   | Store indirect and pre-dec.      | Z ← Z - 1, (Z) ← Rr                      | None       | 2       |
| STD                                  | Z+q, Rr  | Store indirect with displacement | (Z + q) ← Rr                             | None       | 2       |
| STS                                  | k, Rr    | Store direct to SRAM             | (k) ← Rr                                 | None       | 2       |
| LPM                                  |          | Load program memory              | R0 ← (Z)                                 | None       | 3       |
| LPM                                  | Rd, Z    | Load program memory              | Rd ← (Z)                                 | None       | 3       |
| LPM                                  | Rd, Z+   | Load program memory and post-inc | Rd ← (Z), Z ← Z + 1                      | None       | 3       |
| SPM                                  |          | Store program memory             | (Z) ← R1:R0                              | None       | -       |
| IN                                   | Rd, P    | In port                          | Rd ← P                                   | None       | 1       |
| OUT                                  | P, Rr    | Out port                         | P ← Rr                                   | None       | 1       |
| PUSH                                 | Rr       | Push register on stack           | STACK ← Rr                               | None       | 2       |

| Mnemonics                       | Operands | Description             | Operation                                | Flags | #Clocks |
|---------------------------------|----------|-------------------------|------------------------------------------|-------|---------|
| POP                             | Rd       | Pop register from stack | Rd ← STACK                               | None  | 2       |
| <b>MCU CONTROL INSTRUCTIONS</b> |          |                         |                                          |       |         |
| NOP                             |          | No operation            |                                          | None  | 1       |
| SLEEP                           |          | Sleep                   | (See specific descr. for sleep function) | None  | 1       |
| WDR                             |          | Watchdog reset          | (See specific descr. for WDR/timer)      | None  | 1       |
| BREAK                           |          | Break                   | For on-chip debug only                   | None  | N/A     |

Note: 1. These instructions are only available in Atmel ATmega168.

## 9. Ordering information

### 9.1 Atmel ATmega48

| Speed (MHz)       | Power supply | Ordering code <sup>(2)</sup>                                                                                                                                                                                                                         | Package <sup>(1)</sup>                                                 | Operational range             |
|-------------------|--------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|-------------------------------|
| 10 <sup>(3)</sup> | 1.8V - 5.5V  | ATmega48V-10AUR <sup>(5)</sup><br>ATmega48V-10MUR <sup>(5)</sup><br>ATmega48V-10AU<br>ATmega48V-10MMU<br>ATmega48V-10MMUR <sup>(5)</sup><br>ATmega48V-10MMH <sup>(4)</sup><br>ATmega48V-10MMHR <sup>(4)(5)</sup><br>ATmega48V-10MU<br>ATmega48V-10PU | 32A<br>32M1-A<br>32A<br>28M1<br>28M1<br>28M1<br>28M1<br>32M1-A<br>28P3 | Industrial<br>(-40°C to 85°C) |
| 20 <sup>(3)</sup> | 2.7V - 5.5V  | ATmega48-20AUR <sup>(5)</sup><br>ATmega48-20MUR <sup>(5)</sup><br>ATmega48-20AU<br>ATmega48-20MMU<br>ATmega48-20MMUR <sup>(5)</sup><br>ATmega48-20MMH <sup>(4)</sup><br>ATmega48-20MMHR <sup>(4)(5)</sup><br>ATmega48-20MU<br>ATmega48-20PU          | 32A<br>32M1-A<br>32A<br>28M1<br>28M1<br>28M1<br>28M1<br>32M1-A<br>28P3 | Industrial<br>(-40°C to 85°C) |

- Note:
1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
  2. Pb-free packaging alternative, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
  3. See [Figure 28-1 on page 304](#) and [Figure 28-2 on page 304](#).
  4. NiPdAu lead finish.
  5. Tape & Reel.

| Package type  |                                                                                                  |
|---------------|--------------------------------------------------------------------------------------------------|
| <b>32A</b>    | 32-lead, thin (1.0mm) plastic quad flat package (TQFP)                                           |
| <b>28M1</b>   | 28-pad, 4 × 4 × 1.0 body, lead pitch 0.45mm quad flat no-lead/micro lead frame package (QFN/MLF) |
| <b>32M1-A</b> | 32-pad, 5 × 5 × 1.0 body, lead pitch 0.50mm quad flat no-lead/micro lead frame package (QFN/MLF) |
| <b>28P3</b>   | 28-lead, 0.300" wide, plastic dual inline package (PDIP)                                         |

## 9.2 Atmel ATmega88

| Speed (MHz)       | Power supply | Ordering code <sup>(2)</sup>                                                                                           | Package <sup>(1)</sup>                 | Operational range             |
|-------------------|--------------|------------------------------------------------------------------------------------------------------------------------|----------------------------------------|-------------------------------|
| 10 <sup>(3)</sup> | 1.8V - 5.5V  | ATmega88V-10AUR <sup>(4)</sup><br>ATmega88V-10MUR <sup>(4)</sup><br>ATmega88V-10AU<br>ATmega88V-10MU<br>ATmega88V-10PU | 32A<br>32M1-A<br>32A<br>32M1-A<br>28P3 | Industrial<br>(-40°C to 85°C) |
| 20 <sup>(3)</sup> | 2.7V - 5.5V  | ATmega88-20AUR <sup>(4)</sup><br>ATmega88-20MUR <sup>(4)</sup><br>ATmega88-20AU<br>ATmega88-20MU<br>ATmega88-20PU      | 32A<br>32M1-A<br>32A<br>32M1-A<br>28P3 | Industrial<br>(-40°C to 85°C) |

- Note:
1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
  2. Pb-free packaging alternative, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
  3. See [Figure 28-1 on page 304](#) and [Figure 28-2 on page 304](#).
  4. Tape & reel

| Package type  |                                                                                                  |
|---------------|--------------------------------------------------------------------------------------------------|
| <b>32A</b>    | 32-lead, thin (1.0mm) plastic quad flat package (TQFP)                                           |
| <b>32M1-A</b> | 32-pad, 5 × 5 × 1.0 body, lead pitch 0.50mm quad flat no-lead/micro lead frame package (QFN/MLF) |
| <b>28P3</b>   | 28-lead, 0.300" wide, plastic dual inline package (PDIP)                                         |

### 9.3 Atmel ATmega168

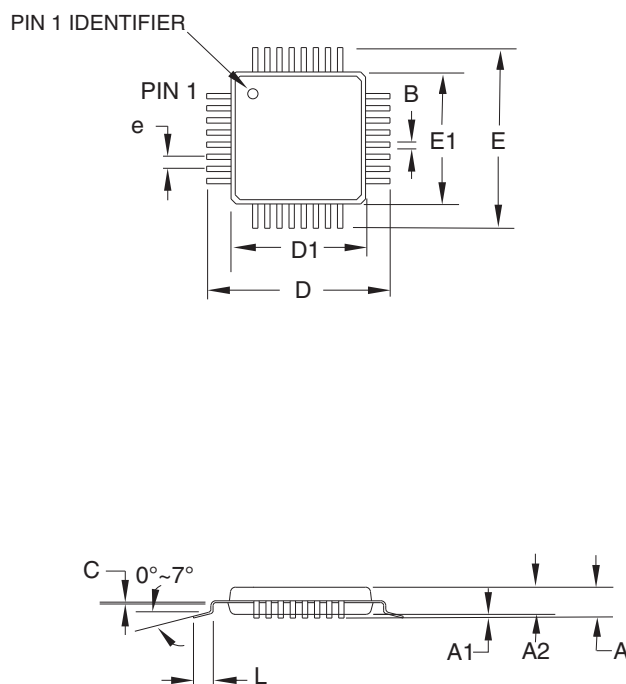
| Speed (MHz) <sup>(3)</sup> | Power supply | Ordering code <sup>(2)</sup>                                                                                                | Package <sup>(1)</sup>                 | Operational range             |
|----------------------------|--------------|-----------------------------------------------------------------------------------------------------------------------------|----------------------------------------|-------------------------------|
| 10                         | 1.8V - 5.5V  | ATmega168V-10AUR <sup>(4)</sup><br>ATmega168V-10MUR <sup>(4)</sup><br>ATmega168V-10AU<br>ATmega168V-10MU<br>ATmega168V-10PU | 32A<br>32M1-A<br>32A<br>32M1-A<br>28P3 | Industrial<br>(-40°C to 85°C) |
| 20                         | 2.7V - 5.5V  | ATmega168-20AUR <sup>(4)</sup><br>ATmega168-20MUR <sup>(4)</sup><br>ATmega168-20AU<br>ATmega168-20MU<br>ATmega168-20PU      | 32A<br>32M1-A<br>32A<br>32M1-A<br>28P3 | Industrial<br>(-40°C to 85°C) |

- Note:
1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
  2. Pb-free packaging alternative, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
  3. See [Figure 28-1 on page 304](#) and [Figure 28-2 on page 304](#).
  4. Tape & reel

| Package type  |                                                                                                  |
|---------------|--------------------------------------------------------------------------------------------------|
| <b>32A</b>    | 32-lead, thin (1.0mm) plastic quad flat package (TQFP)                                           |
| <b>32M1-A</b> | 32-pad, 5 × 5 × 1.0 body, lead pitch 0.50mm quad flat no-lead/micro lead frame package (QFN/MLF) |
| <b>28P3</b>   | 28-lead, 0.300" wide, plastic dual inline package (PDIP)                                         |

## 10. Packaging Information

### 10.1 32A



**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      | 8.75     | 9.00 | 9.25 |        |
| D1     | 6.90     | 7.00 | 7.10 | Note 2 |
| E      | 8.75     | 9.00 | 9.25 |        |
| E1     | 6.90     | 7.00 | 7.10 | Note 2 |
| B      | 0.30     | —    | 0.45 |        |
| C      | 0.09     | —    | 0.20 |        |
| L      | 0.45     | —    | 0.75 |        |
| e      | 0.80 TYP |      |      |        |

**Notes:**

1. This package conforms to JEDEC reference MS-026, Variation ABA.
2. Dimensions D1 and E1 do not include mold protrusion. Allowable protrusion is 0.25mm per side. Dimensions D1 and E1 are maximum plastic body size dimensions including mold mismatch.
3. Lead coplanarity is 0.10mm maximum.

2010-10-20



2325 Orchard Parkway  
San Jose, CA 95131

**TITLE**

**32A**, 32-lead, 7 x 7mm Body Size, 1.0mm Body Thickness,  
0.8 mm Lead Pitch, Thin Profile Plastic Quad Flat Package (TQFP)

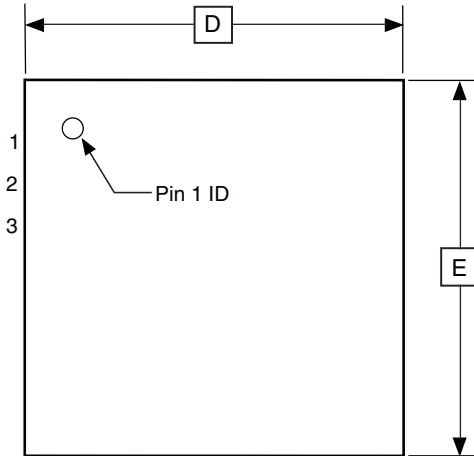
**DRAWING NO.**

32A

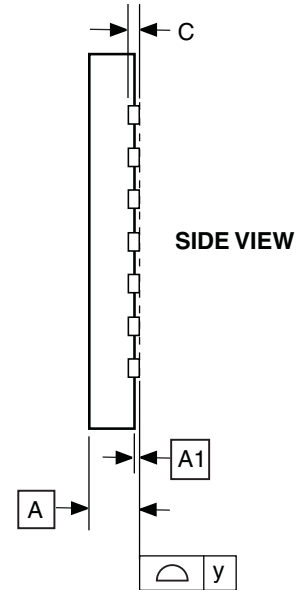
**REV.**

C

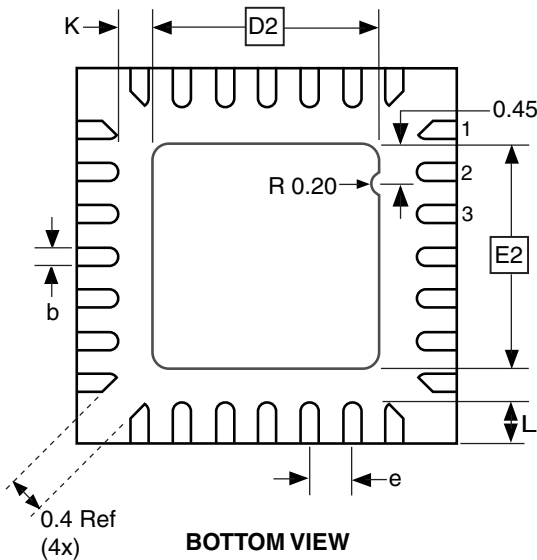
## 10.2 28M1



TOP VIEW



SIDE VIEW



BOTTOM VIEW

COMMON DIMENSIONS  
(Unit of Measure = mm)

| SYMBOL | MIN      | NOM  | MAX  | NOTE |
|--------|----------|------|------|------|
| A      | 0.80     | 0.90 | 1.00 |      |
| A1     | 0.00     | 0.02 | 0.05 |      |
| b      | 0.17     | 0.22 | 0.27 |      |
| C      | 0.20 REF |      |      |      |
| D      | 3.95     | 4.00 | 4.05 |      |
| D2     | 2.35     | 2.40 | 2.45 |      |
| E      | 3.95     | 4.00 | 4.05 |      |
| E2     | 2.35     | 2.40 | 2.45 |      |
| e      | 0.45     |      |      |      |
| L      | 0.35     | 0.40 | 0.45 |      |
| y      | 0.00     | —    | 0.08 |      |
| K      | 0.20     | —    | —    |      |

Note: The terminal #1 ID is a Laser-marked Feature.

10/24/08



Package Drawing Contact:  
packagedrawings@atmel.com

### TITLE

**28M1**, 28-pad, 4 x 4 x 1.0mm Body, Lead Pitch 0.45mm,  
2.4 x 2.4mm Exposed Pad, Thermally Enhanced  
Plastic Very Thin Quad Flat No Lead Package (VQFN)

### GPC

ZBV

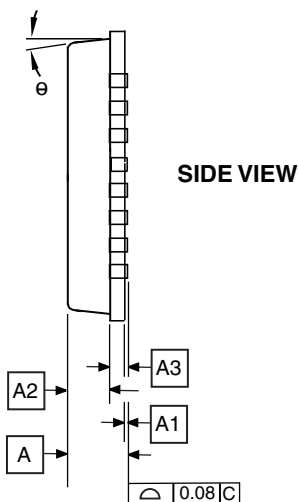
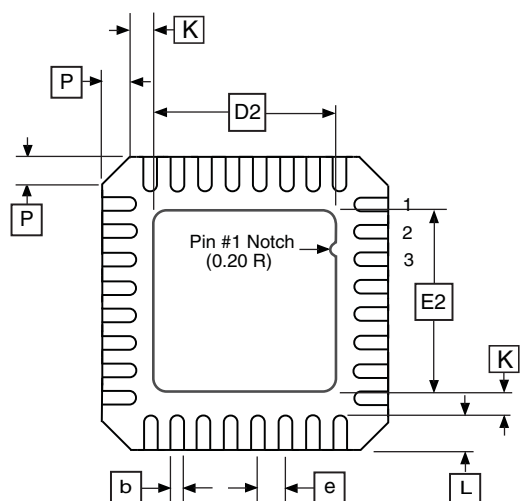
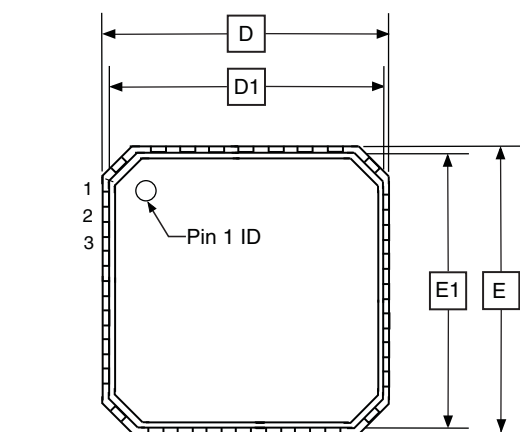
### DRAWING NO.

28M1

### REV.

B

## 10.3 32M1-A



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

| SYMBOL | MIN      | NOM  | MAX  | NOTE |
|--------|----------|------|------|------|
| A      | 0.80     | 0.90 | 1.00 |      |
| A1     | —        | 0.02 | 0.05 |      |
| A2     | —        | 0.65 | 1.00 |      |
| A3     | 0.20 REF |      |      |      |
| b      | 0.18     | 0.23 | 0.30 |      |
| D      | 4.90     | 5.00 | 5.10 |      |
| D1     | 4.70     | 4.75 | 4.80 |      |
| D2     | 2.95     | 3.10 | 3.25 |      |
| E      | 4.90     | 5.00 | 5.10 |      |
| E1     | 4.70     | 4.75 | 4.80 |      |
| E2     | 2.95     | 3.10 | 3.25 |      |
| e      | 0.50 BSC |      |      |      |
| L      | 0.30     | 0.40 | 0.50 |      |
| P      | —        | —    | 0.60 |      |
| Θ      | —        | —    | 12°  |      |
| K      | 0.20     | —    | —    |      |

Note: JEDEC Standard MO-220, Fig. 2 (Anvil Singulation), VHHD-2.

5/25/06



2325 Orchard Parkway  
San Jose, CA 95131

### TITLE

**32M1-A**, 32-pad, 5 x 5 x 1.0mm Body, Lead Pitch 0.50mm,  
3.10mm Exposed Pad, Micro Lead Frame Package (MLF)

### DRAWING NO.

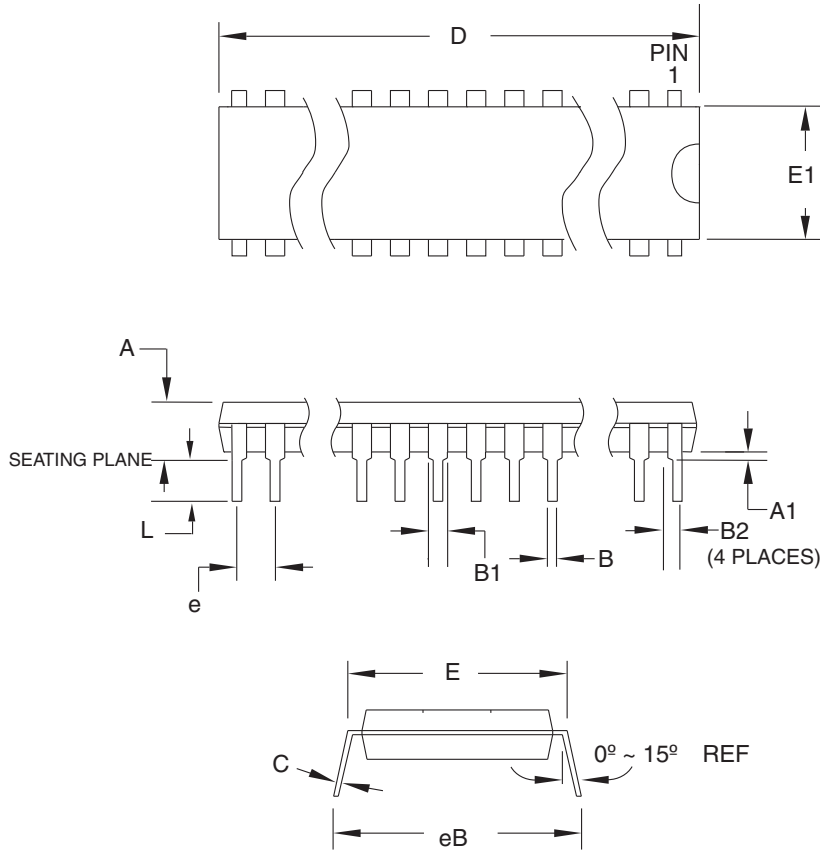
32M1-A

### REV.

E



## 10.4 28P3



Note: 1. Dimensions  $D$  and  $E1$  do not include mold Flash or Protrusion.  
Mold Flash or Protrusion shall not exceed 0.25mm (0.010").

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

| SYMBOL | MIN       | NOM | MAX    | NOTE   |
|--------|-----------|-----|--------|--------|
| A      | —         | —   | 4.5724 |        |
| A1     | 0.508     | —   | —      |        |
| D      | 34.544    | —   | 34.798 | Note 1 |
| E      | 7.620     | —   | 8.255  |        |
| E1     | 7.112     | —   | 7.493  | Note 1 |
| B      | 0.381     | —   | 0.533  |        |
| B1     | 1.143     | —   | 1.397  |        |
| B2     | 0.762     | —   | 1.143  |        |
| L      | 3.175     | —   | 3.429  |        |
| C      | 0.203     | —   | 0.356  |        |
| eB     | —         | —   | 10.160 |        |
| e      | 2.540 TYP |     |        |        |

09/28/01



2325 Orchard Parkway  
San Jose, CA 95131

### TITLE

**28P3**, 28-lead (0.300"/7.62mm Wide) Plastic Dual  
Inline Package (PDIP)

### DRAWING NO.

28P3

### REV.

B

## 11. Errata

### 11.1 Errata Atmel ATmega48

The revision letter in this section refers to the revision of the ATmega48 device.

#### 11.1.1 Rev. D

- **Interrupts may be lost when writing the timer registers in the asynchronous timer**

##### 1. **Interrupts may be lost when writing the timer registers in the asynchronous timer**

The interrupt will be lost if a timer register that is synchronous timer clock is written when the asynchronous Timer/Counter register (TCNTx) is 0x00.

##### **Problem fix/workaround**

Always check that the asynchronous Timer/Counter register neither have the value 0xFF nor 0x00 before writing to the asynchronous Timer Control Register (TCCR<sub>x</sub>), asynchronous Timer Counter Register (TCNT<sub>x</sub>), or asynchronous Output Compare Register (OCR<sub>x</sub>).

#### 11.1.2 Rev. C

- **Reading EEPROM when system clock frequency is below 900kHz may not work**
- **Interrupts may be lost when writing the timer registers in the asynchronous timer**

##### 1. **Reading EEPROM when system clock frequency is below 900kHz may not work**

Reading Data from the EEPROM at system clock frequency below 900kHz may result in wrong data read.

##### **Problem fix/workaround**

Avoid using the EEPROM at clock frequency below 900kHz.

##### 2. **Interrupts may be lost when writing the timer registers in the asynchronous timer**

The interrupt will be lost if a timer register that is synchronous timer clock is written when the asynchronous Timer/Counter register (TCNT<sub>x</sub>) is 0x00.

##### **Problem fix/workaround**

Always check that the asynchronous Timer/Counter register neither have the value 0xFF nor 0x00 before writing to the asynchronous Timer Control Register (TCCR<sub>x</sub>), asynchronous Timer Counter Register (TCNT<sub>x</sub>), or asynchronous Output Compare Register (OCR<sub>x</sub>).

#### 11.1.3 Rev. B

- **Interrupts may be lost when writing the timer registers in the asynchronous timer**

##### 1. **Interrupts may be lost when writing the timer registers in the asynchronous timer**

The interrupt will be lost if a timer register that is synchronous timer clock is written when the asynchronous Timer/Counter register (TCNT<sub>x</sub>) is 0x00.

##### **Problem fix/workaround**

Always check that the asynchronous Timer/Counter register neither have the value 0xFF nor 0x00 before writing to the asynchronous Timer Control Register (TCCR<sub>x</sub>), asynchronous Timer Counter Register (TCNT<sub>x</sub>), or asynchronous Output Compare Register (OCR<sub>x</sub>).

#### 11.1.4 Rev A

- **Part may hang in reset**
- **Wrong values read after erase only operation**
- **Watchdog timer interrupt disabled**
- **Start-up time with crystal oscillator is higher than expected**
- **High power consumption in power-down with external clock**
- **Asynchronous oscillator does not stop in power-down**
- **Interrupts may be lost when writing the timer registers in the asynchronous timer**

##### 1. **Part may hang in reset**

Some parts may get stuck in a reset state when a reset signal is applied when the internal reset state-machine is in a specific state. The internal reset state-machine is in this state for approximately 10ns immediately before the part wakes up after a reset, and in a 10ns window when altering the system clock prescaler. The problem is most often seen during In-System Programming of the device. There are theoretical possibilities of this happening also in run-mode. The following three cases can trigger the device to get stuck in a reset-state:

- Two succeeding resets are applied where the second reset occurs in the 10ns window before the device is out of the reset-state caused by the first reset.
- A reset is applied in a 10ns window while the system clock prescaler value is updated by software.
- Leaving SPI-programming mode generates an internal reset signal that can trigger this case.

The two first cases can occur during normal operating mode, while the last case occurs only during programming of the device.

##### **Problem fix/workaround**

The first case can be avoided during run-mode by ensuring that only one reset source is active. If an external reset push button is used, the reset start-up time should be selected such that the reset line is fully debounced during the start-up time.

The second case can be avoided by not using the system clock prescaler.

The third case occurs during In-System programming only. It is most frequently seen when using the internal RC at maximum frequency.

If the device gets stuck in the reset-state, turn power off, then on again to get the device out of this state.

##### 2. **Wrong values read after erase only operation**

At supply voltages below 2.7V, an EEPROM location that is erased by the Erase Only operation may read as programmed (0x00).

##### **Problem fix/workaround**

If it is necessary to read an EEPROM location after Erase Only, use an Atomic Write operation with 0xFF as data in order to erase a location. In any case, the Write Only operation can be used as intended. Thus no special considerations are needed as long as the erased location is not read before it is programmed.

### 3. Watchdog timer interrupt disabled

If the watchdog timer interrupt flag is not cleared before a new timeout occurs, the watchdog will be disabled, and the interrupt flag will automatically be cleared. This is only applicable in interrupt only mode. If the Watchdog is configured to reset the device in the watchdog time-out following an interrupt, the device works correctly.

#### Problem fix/workaround

Make sure there is enough time to always service the first timeout event before a new watchdog timeout occurs. This is done by selecting a long enough time-out period.

### 4. Start-up time with crystal oscillator is higher than expected

The clock counting part of the start-up time is about two times higher than expected for all start-up periods when running on an external Crystal. This applies only when waking up by reset. Wake-up from power down is not affected. For most settings, the clock counting parts is a small fraction of the overall start-up time, and thus, the problem can be ignored. The exception is when using a very low frequency crystal like for instance a 32kHz clock crystal.

#### Problem fix/workaround

No known workaround.

### 5. High power consumption in power-down with external clock

The power consumption in power down with an active external clock is about 10 times higher than when using internal RC or external oscillators.

#### Problem fix/workaround

Stop the external clock when the device is in power down.

### 6. Asynchronous oscillator does not stop in power-down

The Asynchronous oscillator does not stop when entering power down mode. This leads to higher power consumption than expected.

#### Problem fix/workaround

Manually disable the asynchronous timer before entering power down.

### 7. Interrupts may be lost when writing the timer registers in the asynchronous timer

The interrupt will be lost if a timer register that is synchronous timer clock is written when the asynchronous Timer/Counter register (TCNTx) is 0x00.

#### Problem fix/workaround

Always check that the asynchronous Timer/Counter register neither have the value 0xFF nor 0x00 before writing to the asynchronous Timer Control Register (TCCRx), asynchronous Timer Counter Register (TCNTx), or asynchronous Output Compare Register (OCRx).

## 11.2 Errata Atmel ATmega88

The revision letter in this section refers to the revision of the ATmega88 device.

### 11.2.1 Rev. D

- **Interrupts may be lost when writing the timer registers in the asynchronous timer**

#### 1. **Interrupts may be lost when writing the timer registers in the asynchronous timer**

The interrupt will be lost if a timer register that is synchronous timer clock is written when the asynchronous Timer/Counter register (TCNTx) is 0x00.

##### **Problem fix/workaround**

Always check that the asynchronous Timer/Counter register neither have the value 0xFF nor 0x00 before writing to the asynchronous Timer Control Register (TCCRx), asynchronous Timer Counter Register (TCNTx), or asynchronous Output Compare Register (OCRx).

### 11.2.2 Rev. B/C

Not sampled.

### 11.2.3 Rev. A

- **Writing to EEPROM does not work at low operating voltages**
- **Part may hang in reset**
- **Interrupts may be lost when writing the timer registers in the asynchronous timer**

#### 1. **Writing to EEPROM does not work at low operating voltages**

Writing to the EEPROM does not work at low voltages.

##### **Problem fix/workaround**

Do not write the EEPROM at voltages below 4.5 Volts.  
This will be corrected in rev. B.

#### 2. **Part may hang in reset**

Some parts may get stuck in a reset state when a reset signal is applied when the internal reset state-machine is in a specific state. The internal reset state-machine is in this state for approximately 10ns immediately before the part wakes up after a reset, and in a 10ns window when altering the system clock prescaler. The problem is most often seen during In-System Programming of the device. There are theoretical possibilities of this happening also in run-mode. The following three cases can trigger the device to get stuck in a reset-state:

- Two succeeding resets are applied where the second reset occurs in the 10ns window before the device is out of the reset-state caused by the first reset.
- A reset is applied in a 10ns window while the system clock prescaler value is updated by software.
- Leaving SPI-programming mode generates an internal reset signal that can trigger this case.

The two first cases can occur during normal operating mode, while the last case occurs only during programming of the device.

## Problem fix/workaround

The first case can be avoided during run-mode by ensuring that only one reset source is active. If an external reset push button is used, the reset start-up time should be selected such that the reset line is fully debounced during the start-up time.

The second case can be avoided by not using the system clock prescaler.

The third case occurs during In-System programming only. It is most frequently seen when using the internal RC at maximum frequency.

If the device gets stuck in the reset-state, turn power off, then on again to get the device out of this state.

### 3. Interrupts may be lost when writing the timer registers in the asynchronous timer

The interrupt will be lost if a timer register that is synchronous timer clock is written when the asynchronous Timer/Counter register (TCNTx) is 0x00.

## Problem fix/workaround

Always check that the asynchronous Timer/Counter register neither have the value 0xFF nor 0x00 before writing to the asynchronous Timer Control Register (TCCRx), asynchronous Timer Counter Register (TCNTx), or asynchronous Output Compare Register (OCRx).

## 11.3 Errata Atmel ATmega168

The revision letter in this section refers to the revision of the ATmega168 device.

### 11.3.1 Rev C

#### • Interrupts may be lost when writing the timer registers in the asynchronous timer

#### 1. Interrupts may be lost when writing the timer registers in the asynchronous timer

The interrupt will be lost if a timer register that is synchronous timer clock is written when the asynchronous Timer/Counter register (TCNTx) is 0x00.

## Problem fix/workaround

Always check that the asynchronous Timer/Counter register neither have the value 0xFF nor 0x00 before writing to the asynchronous Timer Control Register (TCCRx), asynchronous Timer Counter Register (TCNTx), or asynchronous Output Compare Register (OCRx).

### 11.3.2 Rev B

- Part may hang in reset
- Interrupts may be lost when writing the timer registers in the asynchronous timer

#### 1. Part may hang in reset

Some parts may get stuck in a reset state when a reset signal is applied when the internal reset state-machine is in a specific state. The internal reset state-machine is in this state for approximately 10ns immediately before the part wakes up after a reset, and in a 10ns window when altering the system clock prescaler. The problem is most often seen during In-System Programming of the device. There are theoretical possibilities of this happening also in run-mode. The following three cases can trigger the device to get stuck in a reset-state:

- Two succeeding resets are applied where the second reset occurs in the 10ns window before the device is out of the reset-state caused by the first reset.

- A reset is applied in a 10ns window while the system clock prescaler value is updated by software.
- Leaving SPI-programming mode generates an internal reset signal that can trigger this case.

The two first cases can occur during normal operating mode, while the last case occurs only during programming of the device.

#### **Problem fix/workaround**

The first case can be avoided during run-mode by ensuring that only one reset source is active. If an external reset push button is used, the reset start-up time should be selected such that the reset line is fully debounced during the start-up time.

The second case can be avoided by not using the system clock prescaler.

The third case occurs during In-System programming only. It is most frequently seen when using the internal RC at maximum frequency.

If the device gets stuck in the reset-state, turn power off, then on again to get the device out of this state.

### **2. Interrupts may be lost when writing the timer registers in the asynchronous timer**

The interrupt will be lost if a timer register that is synchronous timer clock is written when the asynchronous Timer/Counter register (TCNTx) is 0x00.

#### **Problem fix/workaround**

Always check that the asynchronous Timer/Counter register neither have the value 0xFF nor 0x00 before writing to the asynchronous Timer Control Register (TCCRx), asynchronous Timer Counter Register (TCNTx), or asynchronous Output Compare Register (OCRx).

## **11.3.3 Rev A**

- **Wrong values read after erase only operation**
- **Part may hang in reset**
- **Interrupts may be lost when writing the timer registers in the asynchronous timer**

### **1. Wrong values read after erase only operation**

At supply voltages below 2.7V, an EEPROM location that is erased by the Erase Only operation may read as programmed (0x00).

#### **Problem fix/workaround**

If it is necessary to read an EEPROM location after Erase Only, use an Atomic Write operation with 0xFF as data in order to erase a location. In any case, the Write Only operation can be used as intended. Thus no special considerations are needed as long as the erased location is not read before it is programmed.

### **2. Part may hang in reset**

Some parts may get stuck in a reset state when a reset signal is applied when the internal reset state-machine is in a specific state. The internal reset state-machine is in this state for approximately 10ns immediately before the part wakes up after a reset, and in a 10ns window when altering the system clock prescaler. The problem is most often seen during In-System Programming of the device. There are theoretical possibilities of this happening also in run-mode. The following three cases can trigger the device to get stuck in a reset-state:

- Two succeeding resets are applied where the second reset occurs in the 10ns window before the device is out of the reset-state caused by the first reset.
- A reset is applied in a 10ns window while the system clock prescaler value is updated by software.
- Leaving SPI-programming mode generates an internal reset signal that can trigger this case.

The two first cases can occur during normal operating mode, while the last case occurs only during programming of the device.

#### **Problem fix/workaround**

The first case can be avoided during run-mode by ensuring that only one reset source is active. If an external reset push button is used, the reset start-up time should be selected such that the reset line is fully debounced during the start-up time.

The second case can be avoided by not using the system clock prescaler.

The third case occurs during In-System programming only. It is most frequently seen when using the internal RC at maximum frequency.

If the device gets stuck in the reset-state, turn power off, then on again to get the device out of this state.

## **2. Interrupts may be lost when writing the timer registers in the asynchronous timer**

The interrupt will be lost if a timer register that is synchronous timer clock is written when the asynchronous Timer/Counter register (TCNTx) is 0x00.

#### **Problem fix/workaround**

Always check that the asynchronous Timer/Counter register neither have the value 0xFF nor 0x00 before writing to the asynchronous Timer Control Register (TCCR<sub>x</sub>), asynchronous Timer Counter Register (TCNT<sub>x</sub>), or asynchronous Output Compare Register (OCR<sub>x</sub>).

## 12. Datasheet Revision History

Please note that the referring page numbers in this section are referred to this document. The referring revision in this section are referring to the document revision.

### 12.1 Rev. 2545T-04/11

1. Ordering information has been updated by removing AI and MI and added AUR and MUR (tape & reel).
2. Added and corrected cross references and short-cuts.
3. Document updated according to new Atmel standard.
4. QTouch Library Support Features

### 12.2 Rev. 2545S-07/10

1. Note 6 and Note 7 in [Table 28-5, "2-wire serial bus requirements.,"](#) on page 307 have been removed.
2. Document updated according to Atmel standard.

### 12.3 Rev. 2545R-07/09

1. Updated ["Errata" on page 22.](#)
2. Updated the last page with the Atmel new addresses.

### 12.4 Rev. 2545Q-06/09

1. Removed the heading "About". The subsections of this section is now separate sections, "Resources", "Data Retention" and "About Code Examples"
2. Updated ["Ordering information" on page 15.](#)

### 12.5 Rev. 2545P-02/09

1. Removed Power-off slope rate from [Table 28-3 on page 306.](#)

**12.6 Rev. 2545O-02/09**

1. Changed minimum Power-on Reset Threshold Voltage (falling) to 0.05V in [Table 28-3 on page 306](#).
2. Removed section “Power-on slope rate” from [“System and reset characteristics” on page 306](#).

**12.7 Rev. 2545N-01/09**

1. Updated [“Features” on page 1](#) and added the note “Not recommended for new designs”.
2. Merged the sections Resources, Data Retention and About Code Examples under one common section, [“Resources” on page 7](#).
3. Updated [Figure 8-4 on page 34](#).
4. Updated [“System clock prescaler” on page 35](#).
5. Updated [“Alternate functions of port B” on page 77](#).
6. Added section [“” on page 306](#).
7. Updated [“Pin thresholds and hysteresis” on page 329](#).

**12.8 Rev. 2545M-09/07**

1. Added [“Data retention” on page 7](#).
2. Updated [“ADC characteristics” on page 310](#).
3. [“Preliminary” removed through the datasheet](#).

**12.9 Rev. 2545L-08/07**

1. Updated [“Features” on page 1](#).
2. Updated code example in [“MCUCR – MCU control register” on page 63](#).
3. Updated [“System and reset characteristics” on page 306](#).
4. Updated Note in [Table 8-3 on page 29](#), [Table 8-5 on page 30](#), [Table 8-8 on page 33](#), [Table 8-10 on page 33](#).

**12.10 Rev. 2545K-04/07**

1. Updated [“Interrupts” on page 55](#).
2. Updated [“Errata Atmel ATmega48” on page 22](#).
3. Changed description in [“Analog-to-digital converter” on page 243](#).

## 12.11 Rev. 2545J-12/06

1. Updated “Features” on page 1.
2. Updated Table 1-1 on page 2.
3. Updated “Ordering information” on page 15.
4. Updated “Packaging Information” on page 18.

## 12.12 Rev. 2545I-11/06

1. Updated “Features” on page 1.
2. Updated Features in “2-wire serial interface” on page 208.
3. Fixed typos in Table 28-3 on page 306.

## 12.13 Rev. 2545H-10/06

1. Updated typos.
2. Updated “Features” on page 1.
3. Updated “Calibrated internal RC oscillator” on page 32.
4. Updated “System control and reset” on page 44.
5. Updated “Brown-out detection” on page 46.
6. Updated “Fast PWM mode” on page 120.
7. Updated bit description in “TCCR1C – Timer/Counter1 control register C” on page 132.
8. Updated code example in “SPI – Serial peripheral interface” on page 160.
9. Updated Table 14-3 on page 100, Table 14-6 on page 101, Table 14-8 on page 102, Table 15-2 on page 129, Table 15-3 on page 130, Table 15-4 on page 131, Table 17-3 on page 153, Table 17-6 on page 154, Table 17-8 on page 155, and Table 27-5 on page 286.
10. Added Note to Table 25-1 on page 264, Table 26-5 on page 278, and Table 27-17 on page 299.
11. Updated “Setting the boot loader lock bits by SPM” on page 276.
12. Updated “Signature bytes” on page 287
13. Updated “Electrical characteristics” on page 302.
14. Updated “Errata” on page 22.

## 12.14 Rev. 2545G-06/06

1. Added Addresses in Registers.
2. Updated “Calibrated internal RC oscillator” on page 32.
3. Updated Table 8-12 on page 34, Table 9-1 on page 38, Table 10-1 on page 53, Table 13-3 on page 77.
4. Updated “ADC noise reduction mode” on page 39.
5. Updated note for Table 9-2 on page 42.
6. Updated “Bit 2 - PRSPI: Power reduction serial peripheral interface” on page 43.
7. Updated “TCCR0B – Timer/counter control register B” on page 103.

8. Updated “Fast PWM mode” on page 120.
9. Updated “Asynchronous operation of Timer/Counter2” on page 150.
10. Updated “SPI – Serial peripheral interface” on page 160.
11. Updated “UCSRnA – USART MSPIM control and status register n A” on page 205.
12. Updated note in “Bit rate generator unit” on page 215.
13. Updated “Bit 6 – ACBG: Analog comparator bandgap select” on page 241.
14. Updated Features in “Analog-to-digital converter” on page 243.
15. Updated “Prescaling and conversion timing” on page 246.
16. Updated “Limitations of debugWIRE” on page 260.
17. Added Table 28-1 on page 305.
18. Updated Figure 15-7 on page 121, Figure 29-45 on page 338.
19. Updated rev. A in “Errata Atmel ATmega48” on page 22.
20. Added rev. C and D in “Errata Atmel ATmega48” on page 22.

### **12.15 Rev. 2545F-05/05**

1. Added Section 3. “Resources” on page 7
2. Update Section 8.6 “Calibrated internal RC oscillator” on page 32.
3. Updated Section 27.8.3 “Serial programming instruction set” on page 299.
4. Table notes in Section 28.2 “DC characteristics” on page 302 updated.
5. Updated Section 10. “Errata” on page 22.

### **12.16 Rev. 2545E-02/05**

1. MLF-package alternative changed to “Quad Flat No-Lead/Micro Lead Frame Package QFN/MLF”.
2. Updated “EECR – The EEPROM control register” on page 21.
3. Updated “Calibrated internal RC oscillator” on page 32.
4. Updated “External clock” on page 34.
5. Updated Table 28-3 on page 306, Table 28-6 on page 308, Table 28-2 on page 305 and Table 27-16 on page 299
6. Added “Pin change interrupt timing” on page 65
7. Updated “8-bit timer/counter block diagram.” on page 89.
8. Updated “SPMCSR – Store program memory control and status register” on page 266.
9. Updated “Enter programming mode” on page 290.
10. Updated “DC characteristics” on page 302.
11. Updated “Ordering information” on page 15.
12. Updated “Errata Atmel ATmega88” on page 25 and “Errata Atmel ATmega168” on page 27.

## 12.17 Rev. 2545D-07/04

1. Updated instructions used with WDTCSR in relevant code examples.
2. Updated [Table 8-5 on page 30](#), [Table 28-4 on page 306](#), [Table 26-9 on page 281](#), and [Table 26-11 on page 282](#).
3. Updated [“System clock prescaler” on page 35](#).
4. Moved [“TIMSK2 – Timer/Counter2 interrupt mask register” on page 157](#) and [“TIFR2 – Timer/Counter2 interrupt flag register” on page 157](#) to [“Register description” on page 152](#).
5. Updated cross-reference in [“Electrical interconnection” on page 209](#).
6. Updated equation in [“Bit rate generator unit” on page 215](#).
7. Added [“Page size” on page 288](#).
8. Updated [“Serial programming algorithm” on page 298](#).
9. Updated Ordering Information for [“Atmel ATmega168” on page 17](#).
10. Updated [“Errata Atmel ATmega88” on page 25](#) and [“Errata Atmel ATmega168” on page 27](#).
11. Updated equation in [“Bit rate generator unit” on page 215](#).

## 12.18 Rev. 2545C-04/04

1. Speed Grades changed: 12MHz to 10MHz and 24MHz to 20MHz
2. Updated [“Speed grades” on page 304](#).
3. Updated [“Ordering information” on page 15](#).
4. Updated [“Errata Atmel ATmega88” on page 25](#).

## 12.19 Rev. 2545B-01/04

1. Added PDIP to [“I/O and Packages”](#), updated [“Speed Grade”](#) and Power Consumption Estimates in [11. “Features” on page 1](#).
2. Updated [“Stack pointer” on page 12](#) with RAMEND as recommended Stack Pointer value.
3. Added section [“Power reduction register” on page 40](#) and a note regarding the use of the PRR bits to 2-wire, Timer/Counters, USART, Analog Comparator and ADC sections.
4. Updated [“Watchdog timer” on page 48](#).
5. Updated [Figure 15-2 on page 129](#) and [Table 15-3 on page 130](#).
6. Extra Compare Match Interrupt OCF2B added to features in section [“8-bit Timer/Counter2 with PWM and asynchronous operation” on page 139](#)
7. Updated [Table 9-1 on page 38](#), [Table 23-5 on page 258](#), [Table 27-4 to Table 27-7 on page 285 to 287](#) and [Table 23-1 on page 248](#). Added note 2 to [Table 27-1 on page 284](#). Fixed typo in [Table 12-1 on page 66](#).
8. Updated whole [“Typical characteristics” on page 314](#).
9. Added item 2 to 5 in [“Errata Atmel ATmega48” on page 22](#).

10. Renamed the following bits:
  - SPMEN to SELFPRGEN
  - PSR2 to PSRASY
  - PSR10 to PSRSYNC
  - Watchdog Reset to Watchdog System Reset
11. Updated C code examples containing old IAR syntax.
12. Updated BLBSET description in [“SPMCSR – Store program memory control and status register” on page 282.](#)

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