Order code	Manufacturer code	Description
73-4298	n/a	ATMEGA88V-10PU 8-BIT MICRO 8K DIL-28 (RC

Sales: 01206 751166 **Technical: 01206 835555** **Fax: 01206 7551188**
Sales@rapidelec.co.uk **Tech@rapidelec.co.uk** **www.rapidelectronics.co.uk**

Features

- High Performance, Low Power AVR® 8-Bit Microcontroller
- Advanced RISC Architecture
  - 131 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 20 MIPS Throughput at 20 MHz
  - On-chip 2-cycle Multiplier
- Non-volatile Program and Data Memories
  - 4/8/16K Bytes of In-System Self-Programmable Flash (ATmega48/88/168)
    Endurance: 10,000 Write/Erase Cycles
  - Optional Boot Code Section with Independent Lock Bits
    In-System Programming by On-chip Boot Program
    True Read-While-Write Operation
  - 256/512/512 Bytes EEPROM (ATmega48/88/168)
    Endurance: 100,000 Write/Erase Cycles
  - 512/1K/1K Byte Internal SRAM (ATmega48/88/168)
  - Programming Lock for Software Security
- 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
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - On-chip Analog Comparator
  - Interrupt and Wake-up on Pin Change
- Special Microcontroller Features
  - 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 and 32-pad QFN/MLF
- Operating Voltage:
  - 1.8 - 5.5V for ATmega48V/88V/168V
  - 2.7 - 5.5V for ATmega48/88/168
- Temperature Range:
  - -40°C to 85°C
- Speed Grade:
  - ATmega48V/88V/168V: 0 - 4 MHz @ 1.8 - 5.5V, 0 - 10 MHz @ 2.7 - 5.5V
  - ATmega48/88/168: 0 - 10 MHz @ 2.7 - 5.5V, 0 - 20 MHz @ 4.5 - 5.5V
- Low Power Consumption
  - Active Mode:
    1 MHz, 1.8V: 240µA
    32 kHz, 1.8V: 15µA (including Oscillator)
  - Power-down Mode:
    0.1µA at 1.8V

8-bit AVR® Microcontroller with 8K Bytes In-System Programmable Flash

ATmega48/V
ATmega88/V *
ATmega168/V *

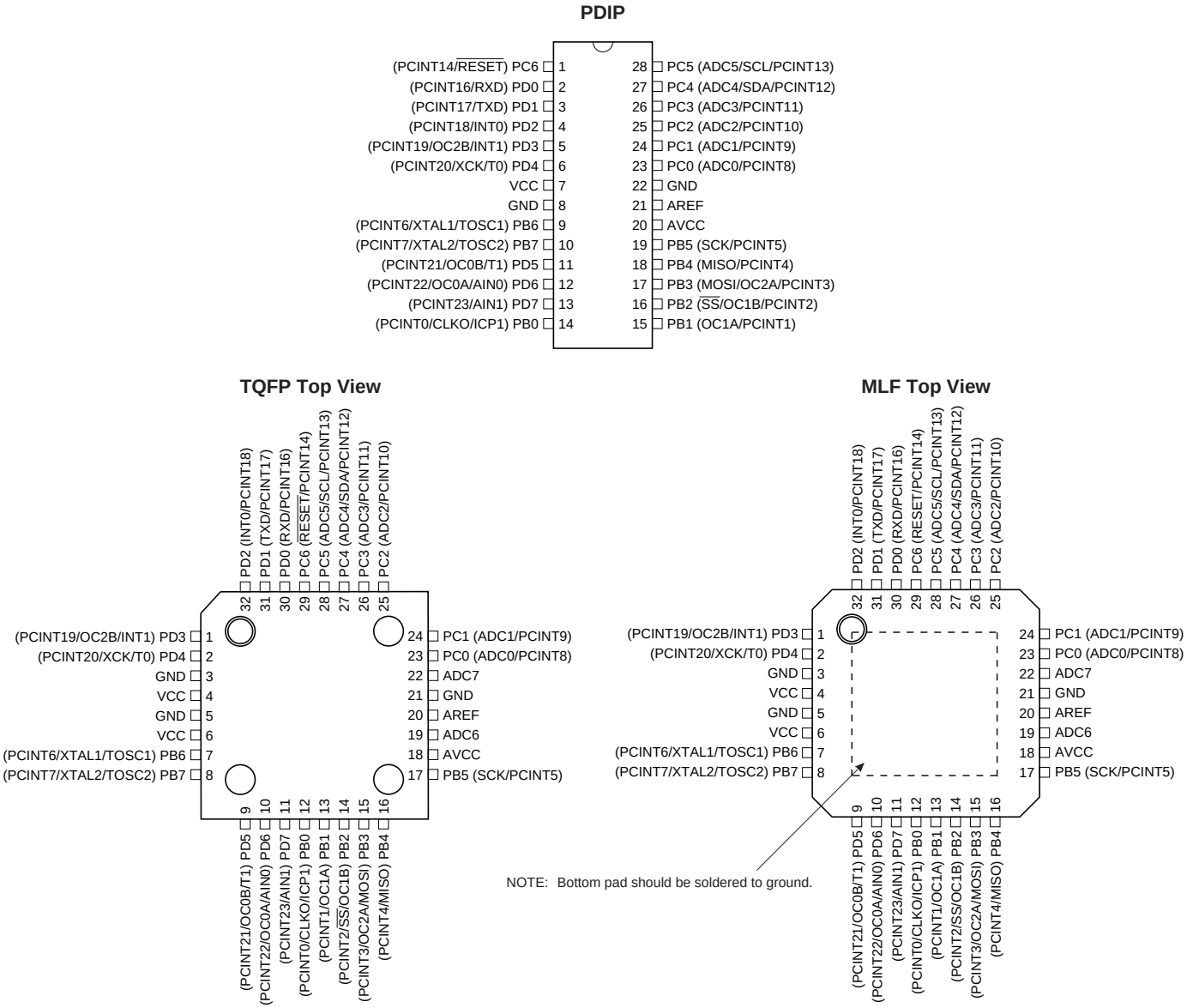
* Preliminary

Summary

Rev. 2545GS–AVR–06/06

1. Pin Configurations

Figure 1-1. Pinout ATmega48/88/168



1.1 Disclaimer

Typical values contained in this datasheet are based on simulations and characterization of other AVR microcontrollers manufactured on the same process technology. Min and Max values will be available after the device is characterized.

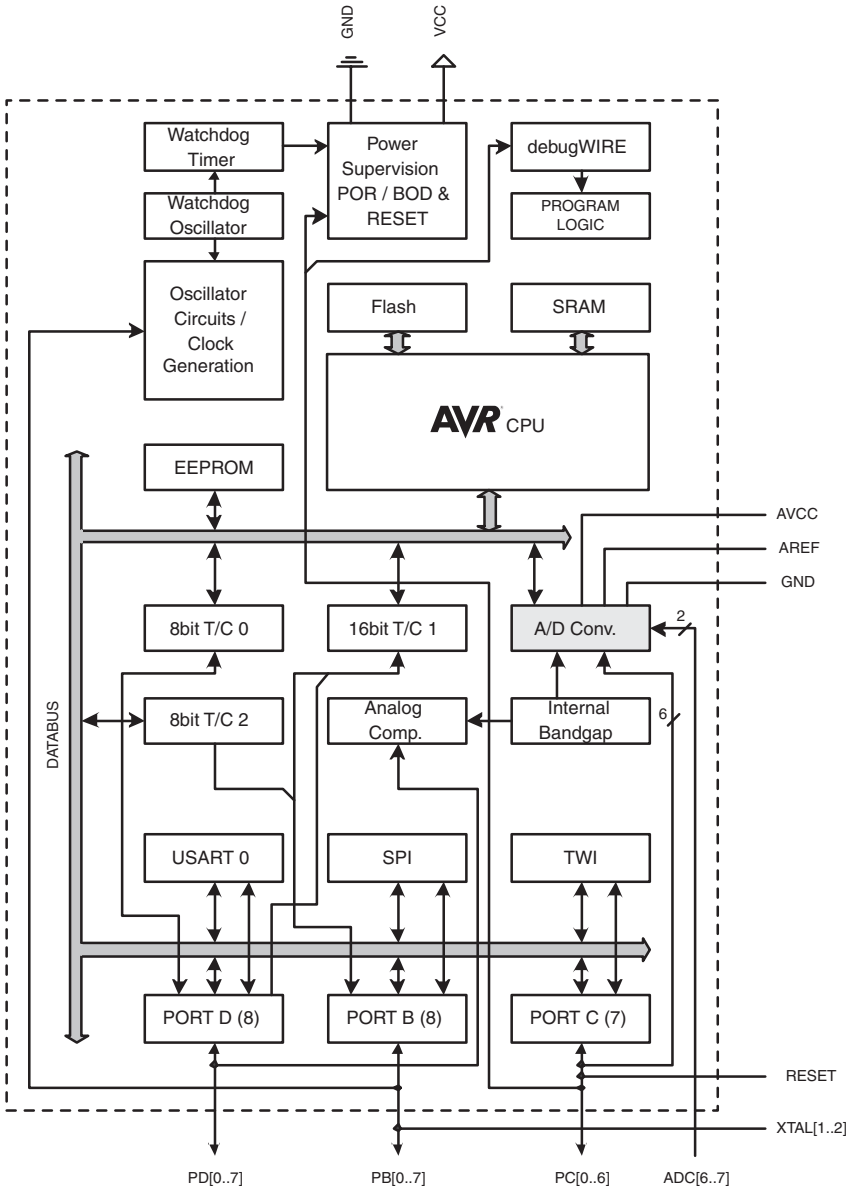
2. Overview

The 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 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.

The device is manufactured using Atmel's 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 ATmega48, ATmega88, and 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	4K Bytes	256 Bytes	512 Bytes	1 instruction word/vector
ATmega88	8K Bytes	512 Bytes	1K Bytes	1 instruction word/vector
ATmega168	16K Bytes	512 Bytes	1K Bytes	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.

2.3 Pin Descriptions

2.3.1 VCC

Digital supply voltage.

2.3.2 GND

Ground.

2.3.3 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 78 and ”System Clock and Clock Options” on page 27.

2.3.4 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.

2.3.5 PC6/$\overline{\text{RESET}}$

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 9-1 on page 46. 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 82.

2.3.6 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 85.

2.3.7 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}.

2.3.8 AREF

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

2.3.9 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.

3. Resources

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

4. 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	191/205
(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	–	218
(0xBC)	TWCR	TWINT	TWEA	TWSTA	TWSTO	TWWC	TWEN	–	TWIE	215
(0xBB)	TWDR	2-wire Serial Interface Data Register								217
(0xBA)	TWAR	TWA6	TWA5	TWA4	TWA3	TWA2	TWA1	TWA0	TWGCE	218
(0xB9)	TWSR	TWS7	TWS6	TWS5	TWS4	TWS3	–	TWPS1	TWPS0	217
(0xB8)	TWBR	2-wire Serial Interface Bit Rate Register								215
(0xB7)	Reserved	–		–	–	–	–	–	–	
(0xB6)	ASSR	–	EXCLK	AS2	TCN2UB	OCR2AUB	OCR2BUB	TCR2AUB	TCR2BUB	158
(0xB5)	Reserved	–	–	–	–	–	–	–	–	
(0xB4)	OCR2B	Timer/Counter2 Output Compare Register B								155
(0xB3)	OCR2A	Timer/Counter2 Output Compare Register A								155
(0xB2)	TCNT2	Timer/Counter2 (8-bit)								155
(0xB1)	TCCR2B	FOC2A	FOC2B	–	–	WGM22	CS22	CS21	CS20	154
(0xB0)	TCCR2A	COM2A1	COM2A0	COM2B1	COM2B0	–	–	WGM21	WGM20	151
(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								134
(0x8A)	OCR1BL	Timer/Counter1 - Output Compare Register B Low Byte								134
(0x89)	OCR1AH	Timer/Counter1 - Output Compare Register A High Byte								134
(0x88)	OCR1AL	Timer/Counter1 - Output Compare Register A Low Byte								134
(0x87)	ICR1H	Timer/Counter1 - Input Capture Register High Byte								135
(0x86)	ICR1L	Timer/Counter1 - Input Capture Register Low Byte								135
(0x85)	TCNT1H	Timer/Counter1 - Counter Register High Byte								134
(0x84)	TCNT1L	Timer/Counter1 - Counter Register Low Byte								134
(0x83)	Reserved	–	–	–	–	–	–	–	–	
(0x82)	TCCR1C	FOC1A	FOC1B	–	–	–	–	–	–	133
(0x81)	TCCR1B	ICNC1	ICES1	–	WGM13	WGM12	CS12	CS11	CS10	132
(0x80)	TCCR1A	COM1A1	COM1A0	COM1B1	COM1B0	–	–	WGM11	WGM10	130
(0x7F)	DIDR1	–	–	–	–	–	–	AIN1D	AIN0D	240
(0x7E)	DIDR0	–	–	ADC5D	ADC4D	ADC3D	ADC2D	ADC1D	ADC0D	256

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	252
(0x7B)	ADCSRB	–	ACME	–	–	–	ADTS2	ADTS1	ADTS0	255
(0x7A)	ADCSRA	ADEN	ADSC	ADATE	ADIF	ADIE	ADPS2	ADPS1	ADPS0	253
(0x79)	ADCH	ADC Data Register High byte								255
(0x78)	ADCL	ADC Data Register Low byte								255
(0x77)	Reserved	–	–	–	–	–	–	–	–	
(0x76)	Reserved	–	–	–	–	–	–	–	–	
(0x75)	Reserved	–	–	–	–	–	–	–	–	
(0x74)	Reserved	–	–	–	–	–	–	–	–	
(0x73)	Reserved	–	–	–	–	–	–	–	–	
(0x72)	Reserved	–	–	–	–	–	–	–	–	
(0x71)	Reserved	–	–	–	–	–	–	–	–	
(0x70)	TIMSK2	–	–	–	–	–	OCIE2B	OCIE2A	TOIE2	156
(0x6F)	TIMSK1	–	–	ICIE1	–	–	OCIE1B	OCIE1A	TOIE1	135
(0x6E)	TIMSK0	–	–	–	–	–	OCIE0B	OCIE0A	TOIE0	106
(0x6D)	PCMSK2	PCINT23	PCINT22	PCINT21	PCINT20	PCINT19	PCINT18	PCINT17	PCINT16	70
(0x6C)	PCMSK1	–	PCINT14	PCINT13	PCINT12	PCINT11	PCINT10	PCINT9	PCINT8	70
(0x6B)	PCMSK0	PCINT7	PCINT6	PCINT5	PCINT4	PCINT3	PCINT2	PCINT1	PCINT0	70
(0x6A)	Reserved	–	–	–	–	–	–	–	–	
(0x69)	EICRA	–	–	–	–	ISC11	ISC10	ISC01	ISC00	67
(0x68)	PCICR	–	–	–	–	–	PCIE2	PCIE1	PCIE0	
(0x67)	Reserved	–	–	–	–	–	–	–	–	
(0x66)	OSCCAL	Oscillator Calibration Register								34
(0x65)	Reserved	–	–	–	–	–	–	–	–	
(0x64)	PRR	PRTWI	PRTIM2	PRTIM0	–	PRTIM1	PRSPI	PRUSART0	PRADC	41
(0x63)	Reserved	–	–	–	–	–	–	–	–	
(0x62)	Reserved	–	–	–	–	–	–	–	–	
(0x61)	CLKPR	CLKPCE	–	–	–	CLKPS3	CLKPS2	CLKPS1	CLKPS0	37
(0x60)	WDTCSR	WDIF	WDIE	WDP3	WDCE	WDE	WDP2	WDP1	WDP0	54
0x3F (0x5F)	SREG	I	T	H	S	V	N	Z	C	11
0x3E (0x5E)	SPH	–	–	–	–	–	(SP10) [5.]	SP9	SP8	13
0x3D (0x5D)	SPL	SP7	SP6	SP5	SP4	SP3	SP2	SP1	SP0	13
0x3C (0x5C)	Reserved	–	–	–	–	–	–	–	–	
0x3B (0x5B)	Reserved	–	–	–	–	–	–	–	–	
0x3A (0x5A)	Reserved	–	–	–	–	–	–	–	–	
0x39 (0x59)	Reserved	–	–	–	–	–	–	–	–	
0x38 (0x58)	Reserved	–	–	–	–	–	–	–	–	
0x37 (0x57)	SPMCSR	SPMIE	(RWWSB)[5.]	–	(RWWSRE)[5.]	BLBSET	PGWRT	PGERS	SELFPRGEN	271
0x36 (0x56)	Reserved	–	–	–	–	–	–	–	–	
0x35 (0x55)	MCUCR	–	–	–	PUD	–	–	IVSEL	IVCE	
0x34 (0x54)	MCUSR	–	–	–	–	WDRF	BORF	EXTRF	PORF	
0x33 (0x53)	SMCR	–	–	–	–	SM2	SM1	SM0	SE	39
0x32 (0x52)	Reserved	–	–	–	–	–	–	–	–	
0x31 (0x51)	Reserved	–	–	–	–	–	–	–	–	
0x30 (0x50)	ACSR	ACD	ACBG	ACO	ACI	ACIE	ACIC	ACIS1	ACIS0	238
0x2F (0x4F)	Reserved	–	–	–	–	–	–	–	–	
0x2E (0x4E)	SPDR	SPI Data Register								168
0x2D (0x4D)	SPSR	SPIF	WCOL	–	–	–	–	–	SPI2X	168
0x2C (0x4C)	SPCR	SPIE	SPE	DORD	MSTR	CPOL	CPHA	SPR1	SPR0	166
0x2B (0x4B)	GPIOR2	General Purpose I/O Register 2								26
0x2A (0x4A)	GPIOR1	General Purpose I/O Register 1								26
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	139/160
0x22 (0x42)	EEARH	(EEPROM Address Register High Byte) [5.]								21
0x21 (0x41)	EEARL	EEPROM Address Register Low Byte								21
0x20 (0x40)	EEDR	EEPROM Data Register								21
0x1F (0x3F)	EECR	–	–	EEPM1	EEPM0	EERIE	EEMPE	EEPE	EERE	21
0x1E (0x3E)	GPIOR0	General Purpose I/O Register 0								26
0x1D (0x3D)	EIMSK	–	–	–	–	–	–	INT1	INT0	68
0x1C (0x3C)	EIFR	–	–	–	–	–	–	INTF1	INTF0	68

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	156
0x16 (0x36)	TIFR1	–	–	ICF1	–	–	OCF1B	OCF1A	TOV1	136
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	88
0x0A (0x2A)	DDRD	DDD7	DDD6	DDD5	DDD4	DDD3	DDD2	DDD1	DDD0	88
0x09 (0x29)	PIND	PIND7	PIND6	PIND5	PIND4	PIND3	PIND2	PIND1	PIND0	89
0x08 (0x28)	PORTC	–	PORTC6	PORTC5	PORTC4	PORTC3	PORTC2	PORTC1	PORTC0	88
0x07 (0x27)	DDRC	–	DDC6	DDC5	DDC4	DDC3	DDC2	DDC1	DDC0	88
0x06 (0x26)	PINC	–	PINC6	PINC5	PINC4	PINC3	PINC2	PINC1	PINC0	88
0x05 (0x25)	PORTB	PORTB7	PORTB6	PORTB5	PORTB4	PORTB3	PORTB2	PORTB1	PORTB0	88
0x04 (0x24)	DDRB	DDB7	DDB6	DDB5	DDB4	DDB3	DDB2	DDB1	DDB0	88
0x03 (0x23)	PINB	PINB7	PINB6	PINB5	PINB4	PINB3	PINB2	PINB1	PINB0	88
0x02 (0x22)	Reserved	–	–	–	–	–	–	–	–	
0x01 (0x21)	Reserved	–	–	–	–	–	–	–	–	
0x0 (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 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

5. Instruction Set Summary

Mnemonics	Operands	Description	Operation	Flags	#Clocks
ARITHMETIC AND LOGIC INSTRUCTIONS					
ADD	Rd, Rr	Add two Registers	Rd ← Rd + Rr	Z,C,N,V,H	1
ADC	Rd, Rr	Add with Carry two Registers	Rd ← Rd + Rr + C	Z,C,N,V,H	1
ADIW	Rdl,K	Add Immediate to Word	Rdh:Rdl ← Rdh:Rdl + K	Z,C,N,V,S	2
SUB	Rd, Rr	Subtract two Registers	Rd ← Rd - Rr	Z,C,N,V,H	1
SUBI	Rd, K	Subtract Constant from Register	Rd ← Rd - K	Z,C,N,V,H	1
SBC	Rd, Rr	Subtract with Carry two Registers	Rd ← Rd - Rr - C	Z,C,N,V,H	1
SBCI	Rd, K	Subtract with Carry Constant from Reg.	Rd ← Rd - K - C	Z,C,N,V,H	1
SBIW	Rdl,K	Subtract Immediate from Word	Rdh:Rdl ← Rdh:Rdl - K	Z,C,N,V,S	2
AND	Rd, Rr	Logical AND Registers	Rd ← Rd • Rr	Z,N,V	1
ANDI	Rd, K	Logical AND Register and Constant	Rd ← Rd • K	Z,N,V	1
OR	Rd, Rr	Logical OR Registers	Rd ← Rd v Rr	Z,N,V	1
ORI	Rd, K	Logical OR Register and Constant	Rd ← Rd v K	Z,N,V	1
EOR	Rd, Rr	Exclusive OR Registers	Rd ← Rd ⊕ Rr	Z,N,V	1
COM	Rd	One's Complement	Rd ← 0xFF – Rd	Z,C,N,V	1
NEG	Rd	Two's Complement	Rd ← 0x00 – Rd	Z,C,N,V,H	1
SBR	Rd,K	Set Bit(s) in Register	Rd ← Rd v K	Z,N,V	1
CBR	Rd,K	Clear Bit(s) in Register	Rd ← Rd • (0xFF - K)	Z,N,V	1
INC	Rd	Increment	Rd ← Rd + 1	Z,N,V	1
DEC	Rd	Decrement	Rd ← Rd – 1	Z,N,V	1
TST	Rd	Test for Zero or Minus	Rd ← Rd • Rd	Z,N,V	1
CLR	Rd	Clear Register	Rd ← Rd ⊕ Rd	Z,N,V	1
SER	Rd	Set Register	Rd ← 0xFF	None	1
MUL	Rd, Rr	Multiply Unsigned	R1:R0 ← Rd x Rr	Z,C	2
MULS	Rd, Rr	Multiply Signed	R1:R0 ← Rd x Rr	Z,C	2
MULSU	Rd, Rr	Multiply Signed with Unsigned	R1:R0 ← Rd x Rr	Z,C	2
FMUL	Rd, Rr	Fractional Multiply Unsigned	R1:R0 ← (Rd x Rr) << 1	Z,C	2
FMULS	Rd, Rr	Fractional Multiply Signed	R1:R0 ← (Rd x Rr) << 1	Z,C	2
FMULSU	Rd, Rr	Fractional Multiply Signed with Unsigned	R1:R0 ← (Rd x Rr) << 1	Z,C	2
BRANCH INSTRUCTIONS					
RJMP	k	Relative Jump	PC ← PC + k + 1	None	2
IJMP		Indirect Jump to (Z)	PC ← Z	None	2
JMP[1]	k	Direct Jump	PC ← k	None	3
RCALL	k	Relative Subroutine Call	PC ← PC + k + 1	None	3
ICALL		Indirect Call to (Z)	PC ← Z	None	3
CALL[1]	k	Direct Subroutine Call	PC ← k	None	4
RET		Subroutine Return	PC ← STACK	None	4
RETI		Interrupt Return	PC ← STACK	I	4
CPSE	Rd,Rr	Compare, Skip if Equal	if (Rd = Rr) PC ← 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 ← PC + 2 or 3	None	1/2/3
SBRS	Rr, b	Skip if Bit in Register is Set	if (Rr(b)=1) PC ← PC + 2 or 3	None	1/2/3
SBIC	P, b	Skip if Bit in I/O Register Cleared	if (P(b)=0) PC ← 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 ← PC + 2 or 3	None	1/2/3
BRBS	s, k	Branch if Status Flag Set	if (SREG(s) = 1) then PC←PC+k + 1	None	1/2
BRBC	s, k	Branch if Status Flag Cleared	if (SREG(s) = 0) then PC←PC+k + 1	None	1/2
BREQ	k	Branch if Equal	if (Z = 1) then PC ← PC + k + 1	None	1/2
BRNE	k	Branch if Not Equal	if (Z = 0) then PC ← PC + k + 1	None	1/2
BRCS	k	Branch if Carry Set	if (C = 1) then PC ← PC + k + 1	None	1/2
BRCC	k	Branch if Carry Cleared	if (C = 0) then PC ← PC + k + 1	None	1/2
BRSH	k	Branch if Same or Higher	if (C = 0) then PC ← PC + k + 1	None	1/2
BRLO	k	Branch if Lower	if (C = 1) then PC ← PC + k + 1	None	1/2
BRMI	k	Branch if Minus	if (N = 1) then PC ← PC + k + 1	None	1/2
BRPL	k	Branch if Plus	if (N = 0) then PC ← PC + k + 1	None	1/2
BRGE	k	Branch if Greater or Equal, Signed	if (N ⊕ V= 0) then PC ← PC + k + 1	None	1/2
BRLT	k	Branch if Less Than Zero, Signed	if (N ⊕ V= 1) then PC ← PC + k + 1	None	1/2
BRHS	k	Branch if Half Carry Flag Set	if (H = 1) then PC ← PC + k + 1	None	1/2
BRHC	k	Branch if Half Carry Flag Cleared	if (H = 0) then PC ← PC + k + 1	None	1/2
BRTS	k	Branch if T Flag Set	if (T = 1) then PC ← PC + k + 1	None	1/2
BRTC	k	Branch if T Flag Cleared	if (T = 0) then PC ← PC + k + 1	None	1/2
BRVS	k	Branch if Overflow Flag is Set	if (V = 1) then PC ← PC + k + 1	None	1/2
BRVC	k	Branch if Overflow Flag is Cleared	if (V = 0) then PC ← 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
BIT AND BIT-TEST INSTRUCTIONS					
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
DATA TRANSFER INSTRUCTIONS					
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
MCU CONTROL INSTRUCTIONS					
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 ATmega168.

6. Ordering Information

6.1 ATmega48

Speed (MHz)	Power Supply	Ordering Code	Package[1]	Operational Range
10[3]	1.8 - 5.5	ATmega48V-10AI ATmega48V-10PI ATmega48V-10MI ATmega48V-10AU[2] ATmega48V-10PU[2] ATmega48V-10MU[2]	32A 28P3 32M1-A 32A 28P3 32M1-A	Industrial (-40°C to 85°C)
20[3]	2.7 - 5.5	ATmega48-20AI ATmega48-20PI ATmega48-20MI ATmega48-20AU[2] ATmega48-20PU[2] ATmega48-20MU[2]	32A 28P3 32M1-A 32A 28P3 32M1-A	Industrial (-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 27-2 on page 305 and Figure 27-3 on page 305.

Package Type	
32A	32-lead, Thin (1.0 mm) Plastic Quad Flat Package (TQFP)
28P3	28-lead, 0.300” Wide, Plastic Dual Inline Package (PDIP)
32M1-A	32-pad, 5 x 5 x 1.0 body, Lead Pitch 0.50 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)

6.2 ATmega88

Speed (MHz)	Power Supply	Ordering Code	Package[1]	Operational Range
10[3]	1.8 - 5.5	ATmega88V-10AI ATmega88V-10PI ATmega88V-10MI ATmega88V-10AU[2] ATmega88V-10PU[2] ATmega88V-10MU[2]	32A 28P3 32M1-A 32A 28P3 32M1-A	Industrial (-40°C to 85°C)
20[3]	2.7 - 5.5	ATmega88-20AI ATmega88-20PI ATmega88-20MI ATmega88-20AU[2] ATmega88-20PU[2] ATmega88-20MU[2]	32A 28P3 32M1-A 32A 28P3 32M1-A	Industrial (-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 27-2 on page 305 and Figure 27-3 on page 305.

Package Type	
32A	32-lead, Thin (1.0 mm) Plastic Quad Flat Package (TQFP)
28P3	28-lead, 0.300” Wide, Plastic Dual Inline Package (PDIP)
32M1-A	32-pad, 5 x 5 x 1.0 body, Lead Pitch 0.50 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)

6.3 ATmega168

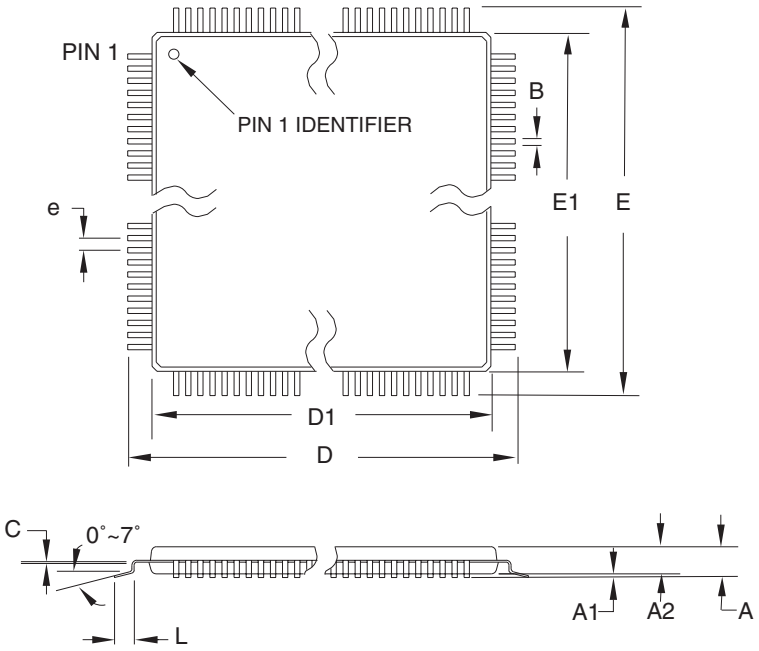
Speed (MHz)[3]	Power Supply	Ordering Code	Package[1]	Operational Range
10	1.8 - 5.5	ATmega168V-10AI ATmega168V-10PI ATmega168V-10MI ATmega168V-10AU[2] ATmega168V-10PU[2] ATmega168V-10MU[2]	32A 28P3 32M1-A 32A 28P3 32M1-A	Industrial (-40°C to 85°C)
20	2.7 - 5.5	ATmega168-20AI ATmega168-20PI ATmega168-20MI ATmega168-20AU[2] ATmega168-20PU[2] ATmega168-20MU[2]	32A 28P3 32M1-A 32A 28P3 32M1-A	Industrial (-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 27-2 on page 305 and Figure 27-3 on page 305.

Package Type	
32A	32-lead, Thin (1.0 mm) Plastic Quad Flat Package (TQFP)
28P3	28-lead, 0.300” Wide, Plastic Dual Inline Package (PDIP)
32M1-A	32-pad, 5 x 5 x 1.0 body, Lead Pitch 0.50 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)

7. Packaging Information

7.1 32A



COMMON DIMENSIONS
(Unit of Measure = mm)

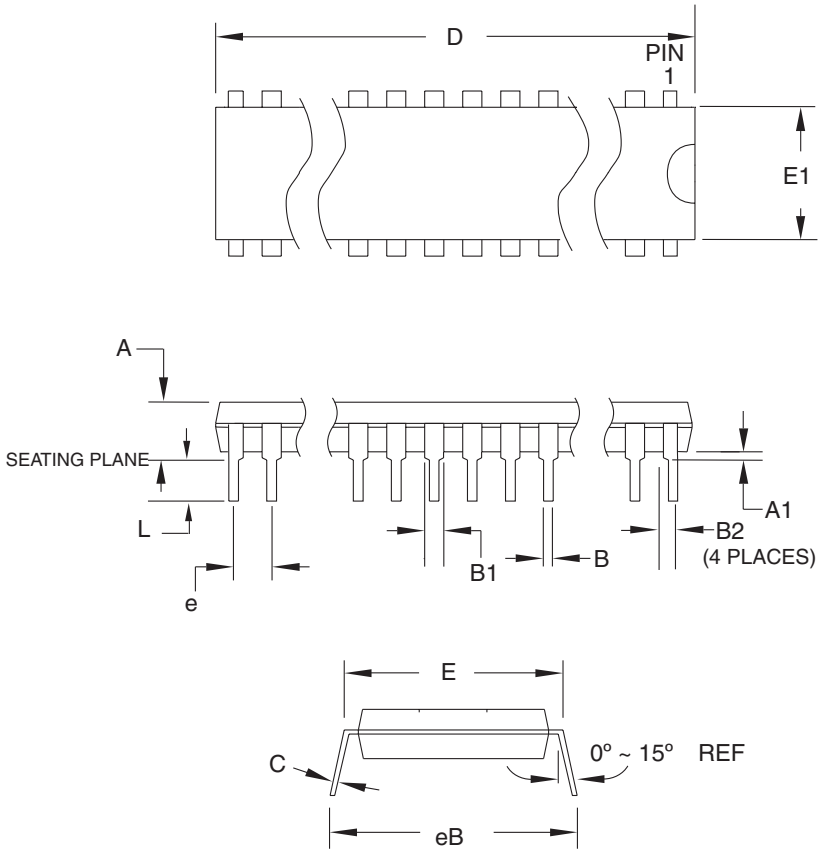
SYMBOL	MIN	NOM	MAX	NOTE
A	–	–	1.20	
A1	0.05	–	0.15	
A2	0.95	1.00	1.05	
D	8.75	9.00	9.25	
D1	6.90	7.00	7.10	Note 2
E	8.75	9.00	9.25	
E1	6.90	7.00	7.10	Note 2
B	0.30	–	0.45	
C	0.09	–	0.20	
L	0.45	–	0.75	
e	0.80 TYP			

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 0.25 mm per side. Dimensions D1 and E1 are maximum plastic body size dimensions including mold mismatch.
3. Lead coplanarity is 0.10 mm maximum.

10/5/2001

	TITLE	DRAWING NO.	REV.
2325 Orchard Parkway San Jose, CA 95131	**32A,** 32-lead, 7 x 7 mm Body Size, 1.0 mm Body Thickness, 0.8 mm Lead Pitch, Thin Profile Plastic Quad Flat Package (TQFP)	32A	B

7.2 28P3



COMMON DIMENSIONS
(Unit of Measure = mm)

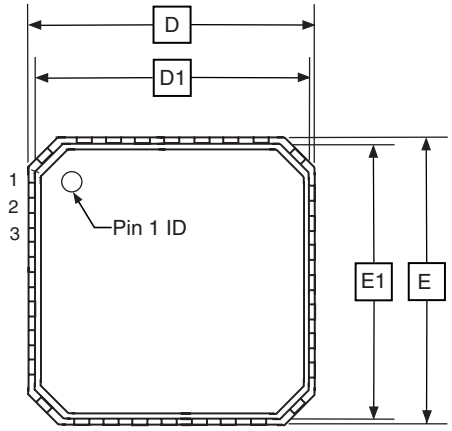
SYMBOL	MIN	NOM	MAX	NOTE
A	–	–	4.5724	
A1	0.508	–	–	
D	34.544	–	34.798	Note 1
E	7.620	–	8.255	
E1	7.112	–	7.493	Note 1
B	0.381	–	0.533	
B1	1.143	–	1.397	
B2	0.762	–	1.143	
L	3.175	–	3.429	
C	0.203	–	0.356	
eB	–	–	10.160	
e	2.540 TYP			

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

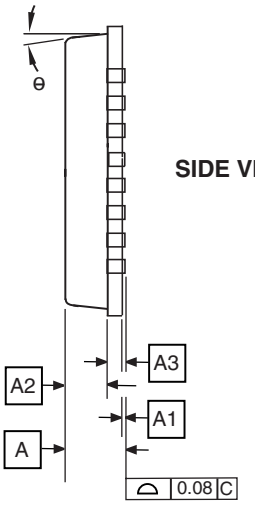
09/28/01

	TITLE	DRAWING NO.	REV.
2325 Orchard Parkway San Jose, CA 95131	**28P3**, 28-lead (0.300"/7.62 mm Wide) Plastic Dual Inline Package (PDIP)	28P3	B

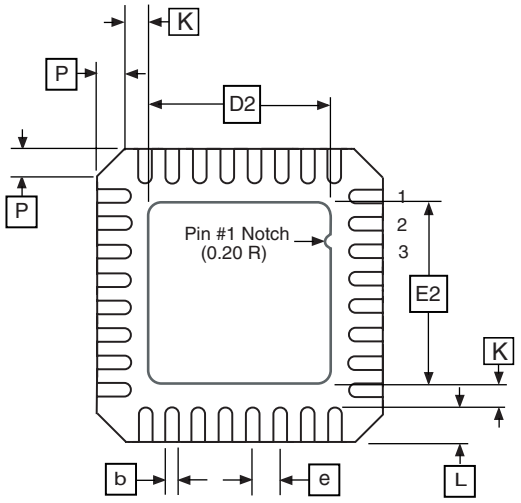
7.3 32M1-A



TOP VIEW



SIDE VIEW



BOTTOM VIEW

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

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^{o}	
K	0.20	–	–	

5/25/06

	TITLE	DRAWING NO.	REV.
2325 Orchard Parkway San Jose, CA 95131	**32M1-A**, 32-pad, 5 x 5 x 1.0 mm Body, Lead Pitch 0.50 mm, 3.10 mm Exposed Pad, Micro Lead Frame Package (MLF)	32M1-A	E

8. Errata

8.1 Errata ATmega48

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

8.1.1 Rev. B

No errata.

8.1.2 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**

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 10 ns immediately before the part wakes up after a reset, and in a 10 ns 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 10 ns 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 2.7 V, 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 2 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 32 kHz 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.

8.2 Errata ATmega88

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

8.2.1 Rev. D

No errata.

8.2.2 Rev. B/C

Not sampled.

8.2.3 Rev. A

- **Writing to EEPROM does not work at low Operating Voltages**
- **Part may hang in reset**

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 10 ns immediately before the part wakes up after a reset, and in a 10 ns 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 10 ns 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.

8.3 Errata ATmega168

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

8.3.1 Rev C

No errata.

8.3.2 Rev B

- **Part may hang in reset**

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 10 ns immediately before the part wakes up after a reset, and in a 10 ns 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 10 ns 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.

8.3.3 Rev A

- **Wrong values read after Erase Only operation**
- **Part may hang in reset**

1. Wrong values read after Erase Only operation

At supply voltages below 2.7 V, 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 10 ns immediately before the part wakes up after a reset, and in a 10 ns 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 10 ns 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.

9. 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.

9.1 Rev. 2545G-06/06

1. Added Addresses in Registers.
2. Updated "Calibrated Internal RC Oscillator" on page 33.
3. Updated Table 7-12 on page 35, Table 8-1 on page 39, Table 9-5 on page 54, Table 12-3 on page 78.
4. Updated "ADC Noise Reduction Mode" on page 40.
5. Updated note for Table 8-2 on page 43.
6. Updatad "Bit 2 - PRSPI: Power Reduction Serial Peripheral Interface" on page 44.
7. Updated "TCCR0B – Timer/Counter Control Register B" on page 104.
8. Updated "Fast PWM Mode" on page 121.
9. Updated "Asynchronous Operation of Timer/Counter2" on page 157.
10. Updated "SPI – Serial Peripheral Interface" on page 161.
11. Updated "UCSRnA – USART MSPIM Control and Status Register n A" on page 204.
12. Updated note in "Bit Rate Generator Unit" on page 213.
13. Updated "Bit 6 – ACBG: Analog Comparator Bandgap Select" on page 239.
14. Updated Features in "Analog-to-Digital Converter" on page 241.
15. Updated "Prescaling and Conversion Timing" on page 244.
16. Updated "Limitations of debugWIRE" on page 258.
17. Added Table 27-5 on page 309.
18. Updated Figure 14-7 on page 122, Figure 28-44 on page 333.
19. Updated rev. A in "Errata ATmega48" on page 350.
20. Added rev. C and D in "Errata ATmega48" on page 350.

9.2 Rev. 2545F-05/05

1. Added Section 3. "Resources" on page 6
2. Update Section 7.6 "Calibrated Internal RC Oscillator" on page 33.
3. Updated Section 26.8.3 "Serial Programming Instruction set" on page 299.
4. Table notes in Section 27.2 "DC Characteristics ATmega48/88/168*" on page 302 updated.
5. Updated Section 8. "Errata" on page 20.

9.3 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 33.
4. Updated "External Clock" on page 35.

5. Updated Table 9-1 on page 46, Table 27-3 on page 307, Table 27-1 on page 304and Table 26-16 on page 299
6. Added "Pin Change Interrupt Timing" on page 66
7. Updated "8-bit Timer/Counter Block Diagram" on page 90.
8. Updated "SPMCSR – Store Program Memory Control and Status Register" on page 261.
9. Updated "Enter Programming Mode" on page 288.
10. Updated "DC Characteristics ATmega48/88/168*" on page 302.
11. Updated "Ordering Information" on page 14.
12. Updated "Errata ATmega88" on page 21 and "Errata ATmega168" on page 22.

9.4 Rev. 2545D-07/04

1. Updated instructions used with WDTCSR in relevant code examples.
2. Updated Table 7-5 on page 31, Table 9-2 on page 48, Table 25-9 on page 280, and Table 25-11 on page 281.
3. Updated "System Clock Prescaler" on page 36.
4. Moved "TIMSK2 – Timer/Counter2 Interrupt Mask Register" and "TIFR2 – Timer/Counter2 Interrupt Flag Register" to "8-bit Timer/Counter Register Description" on page 151.
5. Updated cross-reference in "Electrical Interconnection" on page 208.
6. Updated equation in "Bit Rate Generator Unit" on page 213.
7. Added "Page Size" on page 286.
8. Updated "Serial Programming Algorithm" on page 298.
9. Updated Ordering Information for "ATmega168" on page 16.
10. Updated "Errata ATmega88" on page 21 and "Errata ATmega168" on page 22.
11. Updated equation in "Bit Rate Generator Unit" on page 213.

9.5 Rev. 2545C-04/04

1. Speed Grades changed: 12MHz to 10MHz and 24MHz to 20MHz
2. Updated "Maximum Speed vs. V_{CC}" on page 304.
3. Updated "Ordering Information" on page 14.
4. Updated "Errata ATmega88" on page 21.

9.6 Rev. 2545B-01/04

1. Added PDIP to "I/O and Packages", updated "Speed Grade" and Power Consumption Estimates in 9."Features" on page 1.
2. Updated "Stack Pointer" on page 13 with RAMEND as recommended Stack Pointer value.
3. Added section "Power Reduction Register" on page 41 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 51.

5. Updated Figure 14-2 on page 130 and Table 14-3 on page 131.
6. Extra Compare Match Interrupt OCF2B added to features in section "8-bit Timer/Counter2 with PWM and Asynchronous Operation" on page 140
7. Updated Table 8-1 on page 39, Table 22-5 on page 256, Table 26-4 to Table 26-7 on page 283 to 285 and Table 22-1 on page 246. Added note 2 to Table 26-1 on page 282. Fixed typo in Table 11-1 on page 67.
8. Updated whole "ATmega48/88/168 Typical Characteristics – Preliminary Data" on page 310.
9. Added item 2 to 5 in "Errata ATmega48" on page 20.
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 271.

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