

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
- High Endurance Non-volatile Memory Segments
 - 4/8/16/32K Bytes of In-System Self-Programmable Flash program memory (ATmega48P/88P/168P/328P)
 - 256/512/512/1K Bytes EEPROM (ATmega48P/88P/168P/328P)
 - 512/1K/1K/2K Bytes Internal SRAM (ATmega48P/88P/168P/328P)
 - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
 - Data retention: 20 years at 85°C/100 years at 25°C⁽¹⁾
 - 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
- 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
 - Temperature Measurement
 - 6-channel 10-bit ADC in PDIP Package
 - Temperature Measurement
 - Programmable Serial USART
 - Master/Slave SPI Serial Interface
 - Byte-oriented 2-wire Serial Interface (Philips I²C compatible)
 - 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
 - Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended 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:
 - 1.8 - 5.5V for ATmega48P/88P/168PV
 - 2.7 - 5.5V for ATmega48P/88P/168P
 - 1.8 - 5.5V for ATmega328P
- Temperature Range:
 - -40°C to 85°C
- Speed Grade:
 - ATmega48P/88P/168PV: 0 - 4 MHz @ 1.8 - 5.5V, 0 - 10 MHz @ 2.7 - 5.5V
 - ATmega48P/88P/168P: 0 - 10 MHz @ 2.7 - 5.5V, 0 - 20 MHz @ 4.5 - 5.5V
 - ATmega328P: 0 - 4 MHz @ 1.8 - 5.5V, 0 - 10 MHz @ 2.7 - 5.5V, 0 - 20 MHz @ 4.5 - 5.5V
- Low Power Consumption at 1 MHz, 1.8V, 25°C for ATmega48P/88P/168P:
 - Active Mode: 0.3 mA
 - Power-down Mode: 0.1 µA
 - Power-save Mode: 0.8 µA (Including 32 kHz RTC)



**8-bit AVR[®]
Microcontroller
with 4/8/16/32K
Bytes In-System
Programmable
Flash**

**ATmega48P/V
ATmega88P/V
ATmega168P/V
ATmega328P**

Preliminary

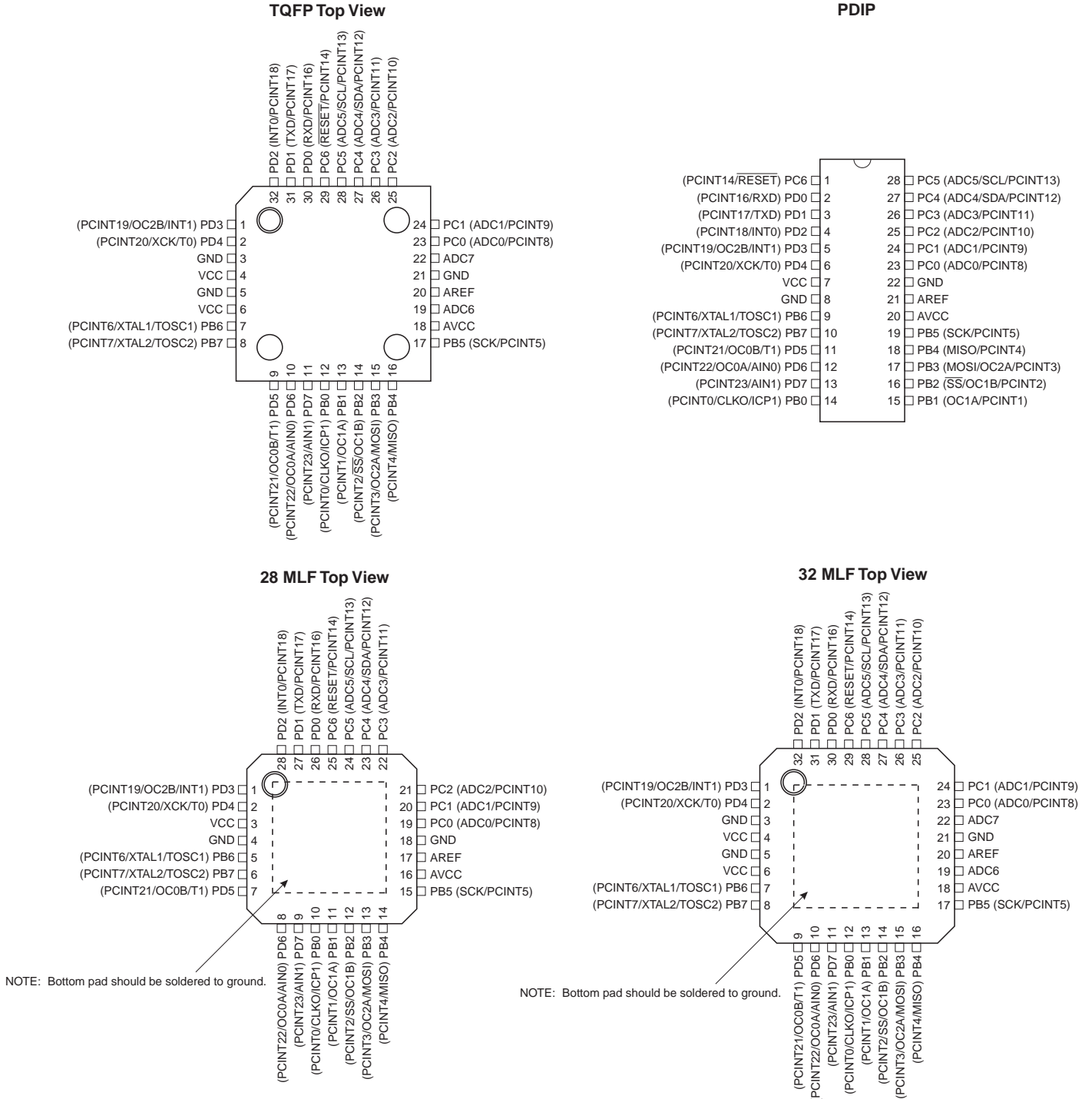
Summary

Rev. 8025FS-AVR-08/08



1. Pin Configurations

Figure 1-1. Pinout ATmega48P/88P/168P/328P



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 82](#) 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/ $\overline{\text{RESET}}$

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 28-3 on page 320](#). 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 85](#).

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 88.

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.

1.2 Disclaimer

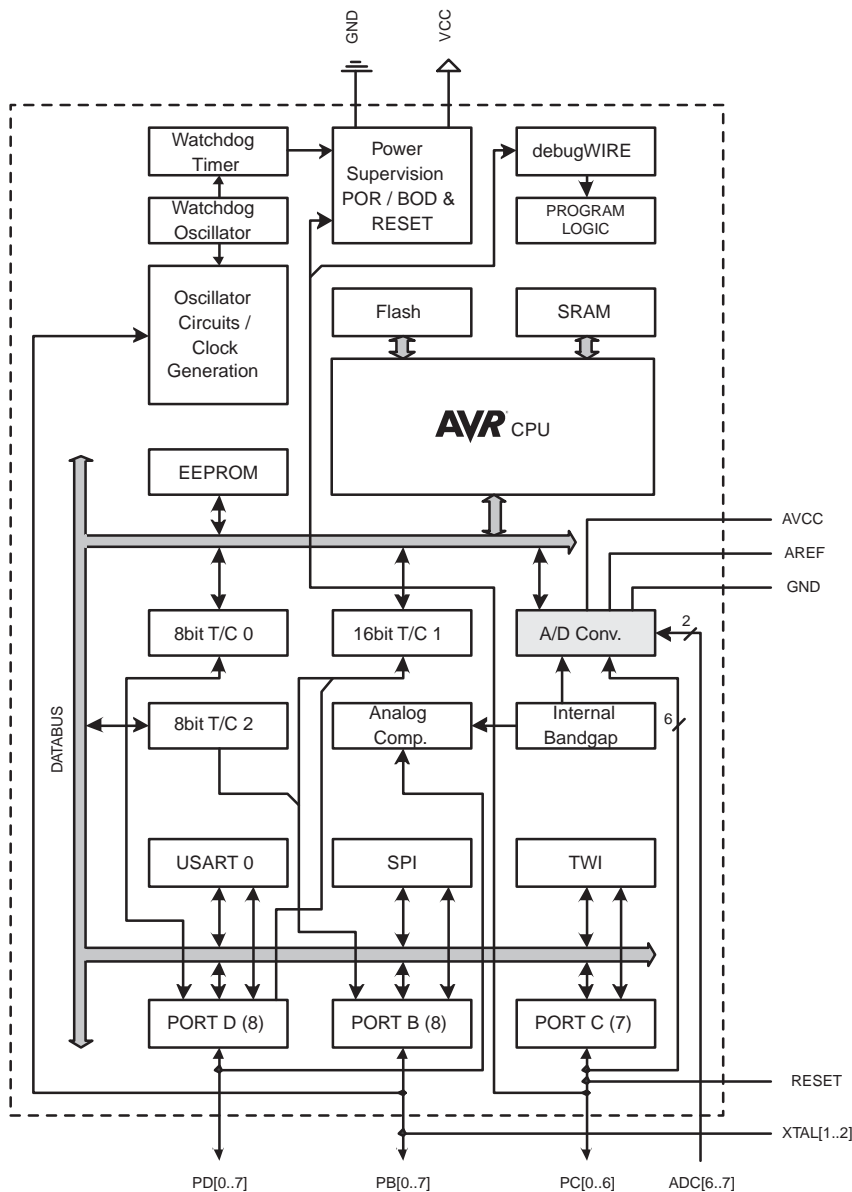
Typical values contained in this datasheet are based on simulations and characterization of other AVR microcontrollers manufactured on the same process technology. Min and Max values will be available after the device is characterized.

2. Overview

The ATmega48P/88P/168P/328P 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 ATmega48P/88P/168P/328P 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 ATmega48P/88P/168P/328P provides the following features: 4K/8K/16K/32K bytes of In-System Programmable Flash with Read-While-Write capabilities, 256/512/512/1K bytes EEPROM, 512/1K/1K/2K 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 ATmega48P/88P/168P/328P is a powerful microcontroller that provides a highly flexible and cost effective solution to many embedded control applications.

The ATmega48P/88P/168P/328P 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 ATmega48P, ATmega88P, ATmega168P, and ATmega328P

The ATmega48P, ATmega88P, ATmega168P, and ATmega328P 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 |
|------------|-----------|-----------|-----------|-----------------------------|
| ATmega48P | 4K Bytes | 256 Bytes | 512 Bytes | 1 instruction word/vector |
| ATmega88P | 8K Bytes | 512 Bytes | 1K Bytes | 1 instruction word/vector |
| ATmega168P | 16K Bytes | 512 Bytes | 1K Bytes | 2 instruction words/vector |
| ATmega328P | 32K Bytes | 1K Bytes | 2K Bytes | 2 instructions words/vector |

ATmega88P, ATmega168P, and ATmega328P 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 ATmega48P, 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. 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 | | | | | | | | 195 |
| (0xC5) | UBRR0H | USART Baud Rate Register High | | | | | | | | 199 |
| (0xC4) | UBRR0L | USART Baud Rate Register Low | | | | | | | | 199 |
| (0xC3) | Reserved | – | – | – | – | – | – | – | – | |
| (0xC2) | UCSR0C | UMSEL01 | UMSEL00 | UPM01 | UPM00 | USBS0 | UCSZ01 / UDORD0 | UCSZ00 / UCPHA0 | UCPOL0 | 197/212 |
| (0xC1) | UCSR0B | RXCIE0 | TXCIE0 | UDRIE0 | RXEN0 | TXEN0 | UCSZ02 | RXB80 | TXB80 | 196 |
| (0xC0) | UCSR0A | RXC0 | TXC0 | UDRE0 | FE0 | DOR0 | UPE0 | U2X0 | MPCM0 | 195 |

| 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 | – | 245 | |
| (0xBC) | TWCR | TWINT | TWEA | TWSTA | TWSTO | TWWC | TWEN | – | TWIE | 242 | |
| (0xBB) | TWDR | 2-wire Serial Interface Data Register | | | | | | | | | 244 |
| (0xBA) | TWAR | TWA6 | TWA5 | TWA4 | TWA3 | TWA2 | TWA1 | TWA0 | TWGCE | 245 | |
| (0xB9) | TWSR | TWS7 | TWS6 | TWS5 | TWS4 | TWS3 | – | TWPS1 | TWPS0 | 244 | |
| (0xB8) | TWBR | 2-wire Serial Interface Bit Rate Register | | | | | | | | | 242 |
| (0xB7) | Reserved | – | – | – | – | – | – | – | – | | |
| (0xB6) | ASSR | – | EXCLK | AS2 | TCN2UB | OCR2AUB | OCR2BUB | TCR2AUB | TCR2BUB | 164 | |
| (0xB5) | Reserved | – | – | – | – | – | – | – | – | | |
| (0xB4) | OCR2B | Timer/Counter2 Output Compare Register B | | | | | | | | | 162 |
| (0xB3) | OCR2A | Timer/Counter2 Output Compare Register A | | | | | | | | | 162 |
| (0xB2) | TCNT2 | Timer/Counter2 (8-bit) | | | | | | | | | 162 |
| (0xB1) | TCCR2B | FOC2A | FOC2B | – | – | WGM22 | CS22 | CS21 | CS20 | 161 | |
| (0xB0) | TCCR2A | COM2A1 | COM2A0 | COM2B1 | COM2B0 | – | – | WGM21 | WGM20 | 158 | |
| (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 | | | | | | | | | 138 |
| (0x8A) | OCR1BL | Timer/Counter1 - Output Compare Register B Low Byte | | | | | | | | | 138 |
| (0x89) | OCR1AH | Timer/Counter1 - Output Compare Register A High Byte | | | | | | | | | 138 |
| (0x88) | OCR1AL | Timer/Counter1 - Output Compare Register A Low Byte | | | | | | | | | 138 |
| (0x87) | ICR1H | Timer/Counter1 - Input Capture Register High Byte | | | | | | | | | 139 |
| (0x86) | ICR1L | Timer/Counter1 - Input Capture Register Low Byte | | | | | | | | | 139 |
| (0x85) | TCNT1H | Timer/Counter1 - Counter Register High Byte | | | | | | | | | 138 |
| (0x84) | TCNT1L | Timer/Counter1 - Counter Register Low Byte | | | | | | | | | 138 |
| (0x83) | Reserved | – | – | – | – | – | – | – | – | | |
| (0x82) | TCCR1C | FOC1A | FOC1B | – | – | – | – | – | – | 137 | |
| (0x81) | TCCR1B | ICNC1 | ICES1 | – | WGM13 | WGM12 | CS12 | CS11 | CS10 | 136 | |
| (0x80) | TCCR1A | COM1A1 | COM1A0 | COM1B1 | COM1B0 | – | – | WGM11 | WGM10 | 134 | |
| (0x7F) | DIDR1 | – | – | – | – | – | – | AIN1D | AIN0D | 250 | |
| (0x7E) | DIDR0 | – | – | ADC5D | ADC4D | ADC3D | ADC2D | ADC1D | ADC0D | 267 | |



| 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 | 263 |
| (0x7B) | ADCSRB | – | ACME | – | – | – | ADTS2 | ADTS1 | ADTS0 | 266 |
| (0x7A) | ADCSRA | ADEN | ADSC | ADATE | ADIF | ADIE | ADPS2 | ADPS1 | ADPS0 | 264 |
| (0x79) | ADCH | ADC Data Register High byte | | | | | | | | 266 |
| (0x78) | ADCL | ADC Data Register Low byte | | | | | | | | 266 |
| (0x77) | Reserved | – | – | – | – | – | – | – | – | |
| (0x76) | Reserved | – | – | – | – | – | – | – | – | |
| (0x75) | Reserved | – | – | – | – | – | – | – | – | |
| (0x74) | Reserved | – | – | – | – | – | – | – | – | |
| (0x73) | Reserved | – | – | – | – | – | – | – | – | |
| (0x72) | Reserved | – | – | – | – | – | – | – | – | |
| (0x71) | Reserved | – | – | – | – | – | – | – | – | |
| (0x70) | TIMSK2 | – | – | – | – | – | OCIE2B | OCIE2A | TOIE2 | 163 |
| (0x6F) | TIMSK1 | – | – | ICIE1 | – | – | OCIE1B | OCIE1A | TOIE1 | 139 |
| (0x6E) | TIMSK0 | – | – | – | – | – | OCIE0B | OCIE0A | TOIE0 | 111 |
| (0x6D) | PCMSK2 | PCINT23 | PCINT22 | PCINT21 | PCINT20 | PCINT19 | PCINT18 | PCINT17 | PCINT16 | 74 |
| (0x6C) | PCMSK1 | – | PCINT14 | PCINT13 | PCINT12 | PCINT11 | PCINT10 | PCINT9 | PCINT8 | 74 |
| (0x6B) | PCMSK0 | PCINT7 | PCINT6 | PCINT5 | PCINT4 | PCINT3 | PCINT2 | PCINT1 | PCINT0 | 74 |
| (0x6A) | Reserved | – | – | – | – | – | – | – | – | |
| (0x69) | EICRA | – | – | – | – | ISC11 | ISC10 | ISC01 | ISC00 | 71 |
| (0x68) | PCICR | – | – | – | – | – | PCIE2 | PCIE1 | PCIE0 | |
| (0x67) | Reserved | – | – | – | – | – | – | – | – | |
| (0x66) | OSCCAL | Oscillator Calibration Register | | | | | | | | 37 |
| (0x65) | Reserved | – | – | – | – | – | – | – | – | |
| (0x64) | PRR | PRTWI | PRTIM2 | PRTIM0 | – | PRTIM1 | PRSPI | PRUSART0 | PRADC | 42 |
| (0x63) | Reserved | – | – | – | – | – | – | – | – | |
| (0x62) | Reserved | – | – | – | – | – | – | – | – | |
| (0x61) | CLKPR | CLKPCE | – | – | – | CLKPS3 | CLKPS2 | CLKPS1 | CLKPS0 | 37 |
| (0x60) | WDTCR | WDIF | WDIE | WDP3 | WDCE | WDE | WDP2 | WDP1 | WDP0 | 54 |
| 0x3F (0x5F) | SREG | I | T | H | S | V | N | Z | C | 9 |
| 0x3E (0x5E) | SPH | – | – | – | – | – | (SP10) ⁵ | 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) ⁵ | – | (RWWRE) ⁵ | BLBSET | PGWRT | PGERS | SELFPRGEN | 293 |
| 0x36 (0x56) | Reserved | – | – | – | – | – | – | – | – | |
| 0x35 (0x55) | MCUCR | – | BODS | BODSE | PUD | – | – | IVSEL | IVCE | 44/68/92 |
| 0x34 (0x54) | MCUSR | – | – | – | – | WDRF | BORF | EXTRF | PORF | 54 |
| 0x33 (0x53) | SMCR | – | – | – | – | SM2 | SM1 | SM0 | SE | 40 |
| 0x32 (0x52) | Reserved | – | – | – | – | – | – | – | – | |
| 0x31 (0x51) | Reserved | – | – | – | – | – | – | – | – | |
| 0x30 (0x50) | ACSR | ACD | ACBG | ACO | ACI | ACIE | ACIC | ACIS1 | ACIS0 | 248 |
| 0x2F (0x4F) | Reserved | – | – | – | – | – | – | – | – | |
| 0x2E (0x4E) | SPDR | SPI Data Register | | | | | | | | 175 |
| 0x2D (0x4D) | SPSR | SPIF | WCOL | – | – | – | – | – | SPI2X | 174 |
| 0x2C (0x4C) | SPCR | SPIE | SPE | DORD | MSTR | CPOL | CPHA | SPR1 | SPR0 | 173 |
| 0x2B (0x4B) | GPIOR2 | General Purpose I/O Register 2 | | | | | | | | 25 |
| 0x2A (0x4A) | GPIOR1 | 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 | 143/165 |
| 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) | EEDR | – | – | EEDR1 | EEDR0 | EERIE | EEMPE | EEPE | EERE | 21 |
| 0x1E (0x3E) | GPIOR0 | General Purpose I/O Register 0 | | | | | | | | 25 |
| 0x1D (0x3D) | EIMSK | – | – | – | – | – | – | INT1 | INT0 | 72 |
| 0x1C (0x3C) | EIFR | – | – | – | – | – | – | INTF1 | INTF0 | 72 |

| 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 | 163 |
| 0x16 (0x36) | TIFR1 | – | – | ICF1 | – | – | OCF1B | OCF1A | TOV1 | 140 |
| 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 | 93 |
| 0x0A (0x2A) | DDR | DDD7 | DDD6 | DDD5 | DDD4 | DDD3 | DDD2 | DDD1 | DDD0 | 93 |
| 0x09 (0x29) | PIND | PIND7 | PIND6 | PIND5 | PIND4 | PIND3 | PIND2 | PIND1 | PIND0 | 93 |
| 0x08 (0x28) | PORTC | – | PORTC6 | PORTC5 | PORTC4 | PORTC3 | PORTC2 | PORTC1 | PORTC0 | 92 |
| 0x07 (0x27) | DDRC | – | DDC6 | DDC5 | DDC4 | DDC3 | DDC2 | DDC1 | DDC0 | 92 |
| 0x06 (0x26) | PINC | – | PINC6 | PINC5 | PINC4 | PINC3 | PINC2 | PINC1 | PINC0 | 92 |
| 0x05 (0x25) | PORTB | PORTB7 | PORTB6 | PORTB5 | PORTB4 | PORTB3 | PORTB2 | PORTB1 | PORTB0 | 92 |
| 0x04 (0x24) | DDRB | DDB7 | DDB6 | DDB5 | DDB4 | DDB3 | DDB2 | DDB1 | DDB0 | 92 |
| 0x03 (0x23) | PINB | PINB7 | PINB6 | PINB5 | PINB4 | PINB3 | PINB2 | PINB1 | PINB0 | 92 |
| 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 ATmega48P/88P/168P/328P 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 ATmega88P/168P.

6. Instruction Set Summary

| Mnemonics | Operands | Description | Operation | Flags | #Clocks |
|--|----------|--|---|---------------|---------|
| ARITHMETIC AND LOGIC INSTRUCTIONS | | | | | |
| 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 | Rd,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 | Rd,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 |
| BRANCH INSTRUCTIONS | | | | | |
| RJMP | k | Relative Jump | $PC \leftarrow PC + k + 1$ | None | 2 |
| IJMP | | Indirect Jump to (Z) | $PC \leftarrow Z$ | None | 2 |
| JMP ⁽¹⁾ | 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 ⁽¹⁾ | 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 |
| 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 ATmega168P and ATmega328P.



7. Ordering Information

7.1 ATmega48P

| Speed (MHz) | Power Supply | Ordering Code ⁽²⁾ | Package ⁽¹⁾ | Operational Range |
|-------------------|--------------|---|-------------------------------|-------------------------------|
| 10 ⁽³⁾ | 1.8 - 5.5 | ATmega48PV-10AU ATmega48PV-10MMU ATmega48PV-10MU ATmega48PV-10PU | 32A 28M1 32M1-A 28P3 | Industrial (-40°C to 85°C) |
| 20 ⁽³⁾ | 2.7 - 5.5 | ATmega48P-20AU ATmega48P-20MMU ATmega48P-20MU ATmega48P-20PU | 32A 28M1 32M1-A 28P3 | 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 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 317](#) and [Figure 28-2 on page 318](#).

| Package Type | |
|---------------|---|
| 32A | 32-lead, Thin (1.0 mm) Plastic Quad Flat Package (TQFP) |
| 28M1 | 28-pad, 4 x 4 x 1.0 body, Lead Pitch 0.45 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF) |
| 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) |
| 28P3 | 28-lead, 0.300" Wide, Plastic Dual Inline Package (PDIP) |



7.2 ATmega88P

| Speed (MHz) | Power Supply | Ordering Code ⁽²⁾ | Package ⁽¹⁾ | Operational Range |
|-------------------|--------------|---|------------------------|-------------------------------|
| 10 ⁽³⁾ | 1.8 - 5.5 | ATmega88PV-10AU ATmega88PV-10MU ATmega88PV-10PU | 32A 32M1-A 28P3 | Industrial (-40°C to 85°C) |
| 20 ⁽³⁾ | 2.7 - 5.5 | ATmega88P-20AU ATmega88P-20MU ATmega88P-20PU | 32A 32M1-A 28P3 | 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 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 317](#) and [Figure 28-2 on page 318](#).

| 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) |

7.3 ATmega168P

| Speed (MHz) ⁽³⁾ | Power Supply | Ordering Code ⁽²⁾ | Package ⁽¹⁾ | Operational Range |
|----------------------------|--------------|--|------------------------|-------------------------------|
| 10 | 1.8 - 5.5 | ATmega168PV-10AU ATmega168PV-10MU ATmega168PV-10PU | 32A 32M1-A 28P3 | Industrial (-40°C to 85°C) |
| 20 | 2.7 - 5.5 | ATmega168P-20AU ATmega168P-20MU ATmega168P-20PU | 32A 32M1-A 28P3 | 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 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 317](#) and [Figure 28-2 on page 318](#).

| 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) |



7.4 ATmega328P

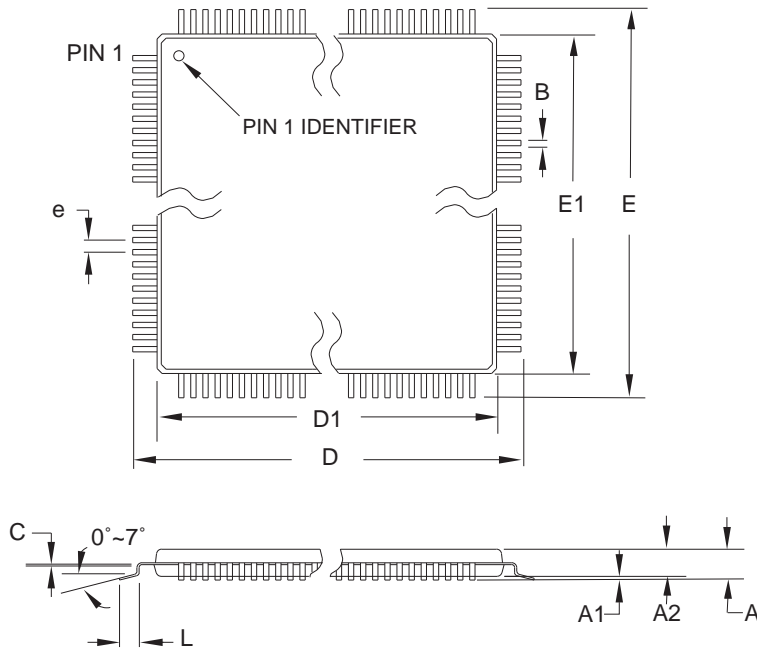
| Speed (MHz) ⁽³⁾ | Power Supply | Ordering Code ⁽²⁾ | Package ⁽¹⁾ | Operational Range |
|----------------------------|--------------|--|------------------------|-------------------------------|
| 20 | 1.8 - 5.5 | ATmega328P- AU ATmega328P- MU ATmega328P- PU | 32A 32M1-A 28P3 | Industrial (-40°C to 85°C) |

- 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 complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
 3. See [Figure 28-3 on page 318](#).

| 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) |

8. Packaging Information

8.1 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



2325 Orchard Parkway
San Jose, CA 95131

TITLE

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)

DRAWING NO.

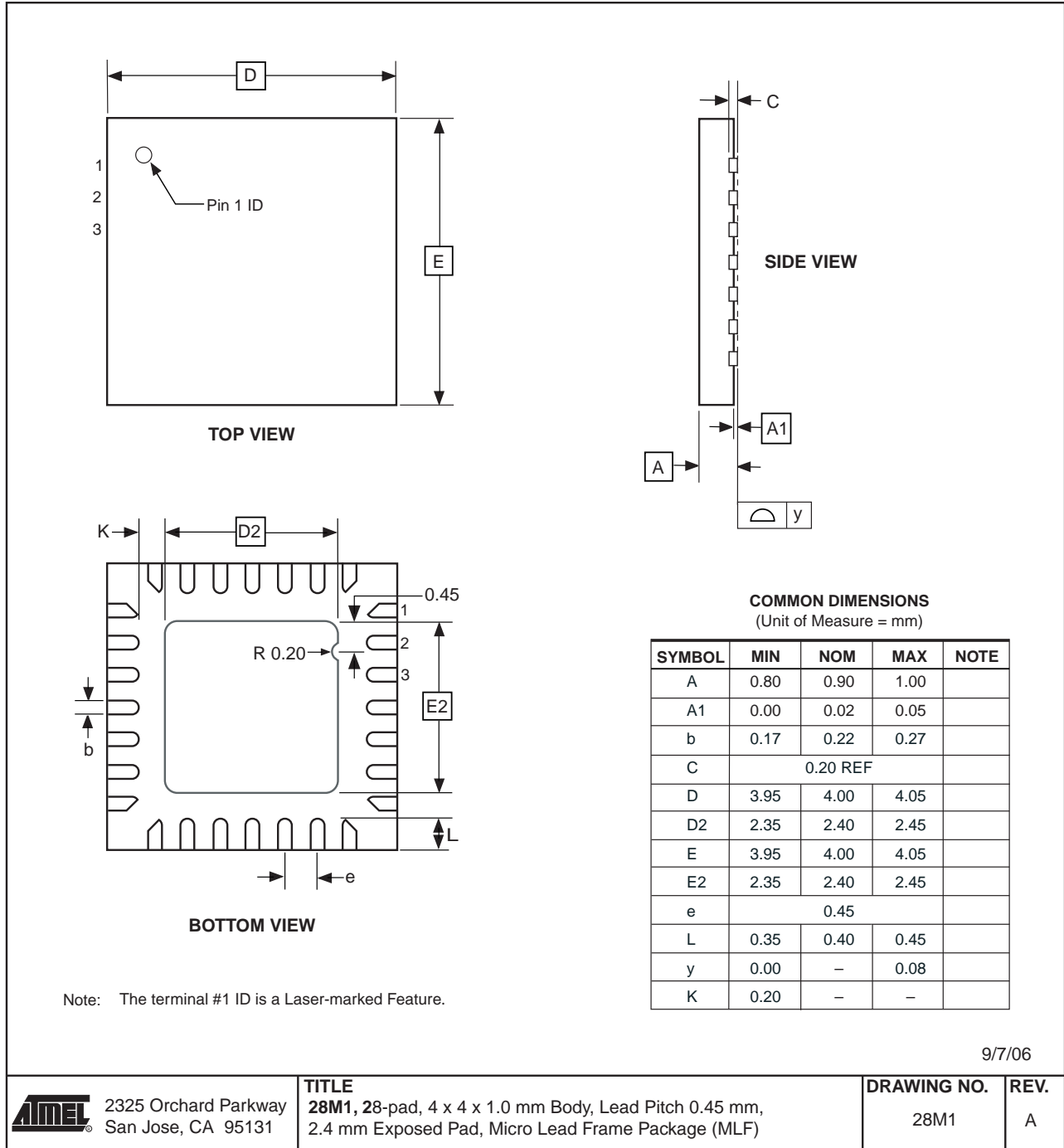
32A

REV.

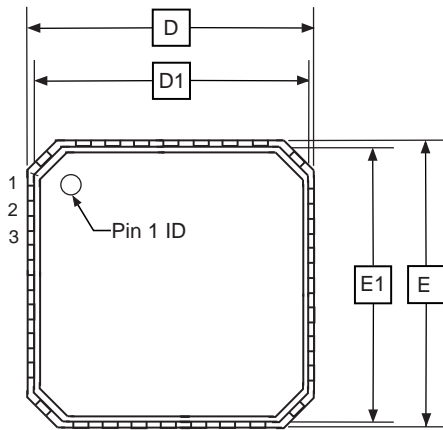
B



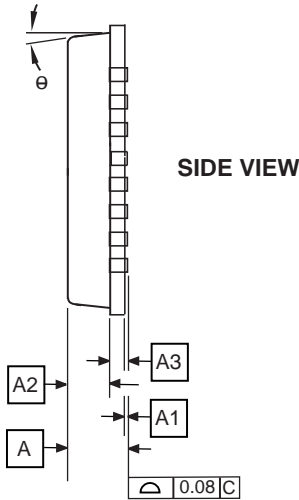
8.2 28M1



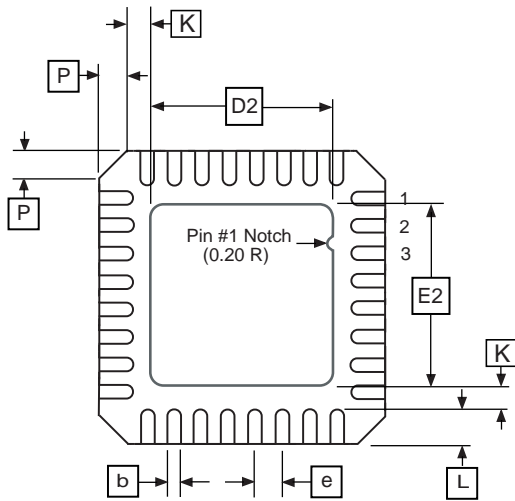
8.3 32M1-A



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 | – | 0.02 | 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 1.0 mm Body, Lead Pitch 0.50 mm,
3.10 mm Exposed Pad, Micro Lead Frame Package (MLF)

DRAWING NO.

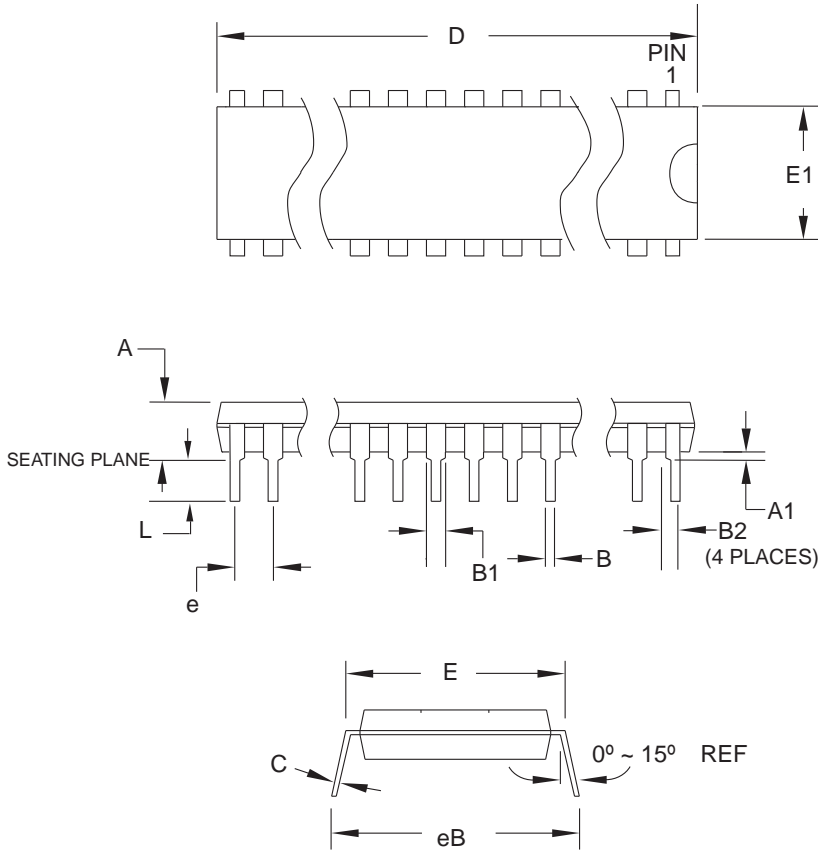
32M1-A

REV.

E



8.4 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



2325 Orchard Parkway
San Jose, CA 95131

TITLE

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

DRAWING NO.

28P3

REV.

B

9. Errata

9.1 Errata ATmega48P

The revision letter in this section refers to the revision of the ATmega48P device.

9.1.1 Rev. B

No known errata.

9.1.2 Rev. A

Not Sampled.

9.2 Errata ATmega88P

The revision letter in this section refers to the revision of the ATmega88P device.

9.2.1 Rev. A

No known errata.

9.3 Errata ATmega168P

The revision letter in this section refers to the revision of the ATmega168P device.

9.3.1 Rev A

No known errata.

9.4 Errata ATmega328P

The revision letter in this section refers to the revision of the ATmega328P device.

9.4.1 Rev B

- **Unstable 32 kHz Oscillator**

1. **Unstable 32 kHz Oscillator**

The 32 kHz oscillator does not work as system clock.

The 32 kHz oscillator used as asynchronous timer is inaccurate.

Problem Fix/ Workaround

None

9.4.2 Rev A

No known errata.

10. 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.

10.1 Rev. 2545F-08/08

1. Updated "ATmega328P Typical Characteristics" on page 401 with Power-save numbers.
2. Added ATmega328P "Standby Supply Current" on page 408.

10.2 Rev. 2545E-08/08

1. Updated description of "Stack Pointer" on page 12.
2. Updated description of use of external capacitors in "Low Frequency Crystal Oscillator" on page 32.
3. Updated Table 8-9 in "Low Frequency Crystal Oscillator" on page 32.
4. Added note to "Address Match Unit" on page 222.
5. Added section "Reading the Signature Row from Software" on page 286.
6. Updated "Program And Data Memory Lock Bits" on page 295 to include ATmega328P in the description.
7. Added "ATmega328P DC Characteristics" on page 317.
8. Updated "Speed Grades" on page 317 for ATmega328P.
9. Removed note 6 and 7 from the table "2-wire Serial Interface Characteristics" on page 323.
10. Added figure "Minimum Reset Pulse width vs. V_{CC} ." on page 352 for ATmega48P.
11. Added figure "Minimum Reset Pulse width vs. V_{CC} ." on page 376 for ATmega88P.
12. Added figure "Minimum Reset Pulse width vs. V_{CC} ." on page 400 for ATmega168P.
13. Added "ATmega328P Typical Characteristics" on page 401.
14. Updated Ordering Information for "ATmega328P" on page 18.

10.3 Rev. 2545D-03/08

1. Updated figures in "Speed Grades" on page 317.
2. Updated note in Table 28-4 in "System and Reset Characteristics" on page 320.
3. Ordering codes for "ATmega328P" on page 18 updated.
 - ATmega328P is offered in 20 MHz option only.
4. Added Errata for ATmega328P rev. B, "Errata ATmega328P" on page 23.

10.4 Rev. 2545C-01/08

1. Power-save Maximum values removed from "ATmega48P DC Characteristics" on page 315, "ATmega88P DC Characteristics" on page 316, and "ATmega168P DC Characteristics" on page 316.

10.5 Rev. 2545B-01/08

1. Updated "Features" on page 1.
2. Added "Data Retention" on page 7.
3. Updated Table 8-2 on page 28.
4. Removed "Low-frequency Crystal Oscillator Internal Load Capacitance" table from "Low Frequency Crystal Oscillator" on page 32.
5. Removed JTD bit from "MCUCR – MCU Control Register" on page 44.
6. Updated typical and general program setup for Reset and Interrupt Vector Addresses in "Interrupt Vectors in ATmega168P" on page 62 and "Interrupt Vectors in ATmega328P" on page 65.
7. Updated Interrupt Vectors Start Address in Table 11-5 on page 63 and Table 11-7 on page 66.
8. Updated "Temperature Measurement" on page 262.
9. Updated ATmega328P "Fuse Bits" on page 296.
10. Removed V_{OL3}/V_{OH3} rows from "DC Characteristics" on page 314.
11. Updated condition for V_{OL} in "DC Characteristics" on page 314.
Updated max value for V_{IL2} in "DC Characteristics" on page 314.
12. Added "ATmega48P DC Characteristics" on page 315, "ATmega88P DC Characteristics" on page 316, and "ATmega168P DC Characteristics" on page 316.
13. Updated "System and Reset Characteristics" on page 320.
14. Added "ATmega48P Typical Characteristics" on page 329, "ATmega88P Typical Characteristics" on page 353, and "ATmega168P Typical Characteristics" on page 377.
15. Updated note in "Instruction Set Summary" on page 12.

10.6 Rev. 2545A-07/07

1. Initial revision.



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