

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
 - 16/32/64K Bytes of In-System Self-programmable Flash program memory
 - 512B/1K/2K Bytes EEPROM
 - 1/2/4K Bytes Internal SRAM
 - Write/Erase Cycles: 10,000 Flash/ 100,000 EEPROM
 - Data retention: 20 years at 85°C/100 years at 25°C
 - 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
- JTAG (IEEE std. 1149.1 Compliant) Interface
 - Boundary-scan Capabilities According to the JTAG Standard
 - Extensive On-chip Debug Support
 - Programming of Flash, EEPROM, Fuses, and Lock Bits through the JTAG Interface
- Peripheral Features
 - Two 8-bit Timer/Counters with Separate Prescalers and Compare Modes
 - 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
Differential mode with selectable gain at 1x, 10x or 200x
 - Byte-oriented Two-wire Serial Interface
 - Two Programmable Serial USART
 - Master/Slave SPI 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 RC 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
 - 32 Programmable I/O Lines
 - 40-pin PDIP, 44-lead TQFP, 44-pad VQFN/QFN/MLF (ATmega164P/324P/644P)
 - 44-pad DRQFN (ATmega164P)
- Operating Voltages
 - 1.8 - 5.5V for ATmega164P/324P/644PV
 - 2.7 - 5.5V for ATmega164P/324P/644P
- Speed Grades
 - ATmega164P/324P/644PV: 0 - 4MHz @ 1.8 - 5.5V, 0 - 10MHz @ 2.7 - 5.5V
 - ATmega164P/324P/644P: 0 - 10MHz @ 2.7 - 5.5V, 0 - 20MHz @ 4.5 - 5.5V
- Power Consumption at 1 MHz, 1.8V, 25°C for ATmega164P/324P/644P
 - Active: 0.4 mA
 - Power-down Mode: 0.1µA
 - Power-save Mode: 0.6µA (Including 32 kHz RTC)



8-bit AVR[®] Microcontroller with 16/32/64K Bytes In-System Programmable Flash

ATmega164P/V
ATmega324P/V
ATmega644P/V

Preliminary

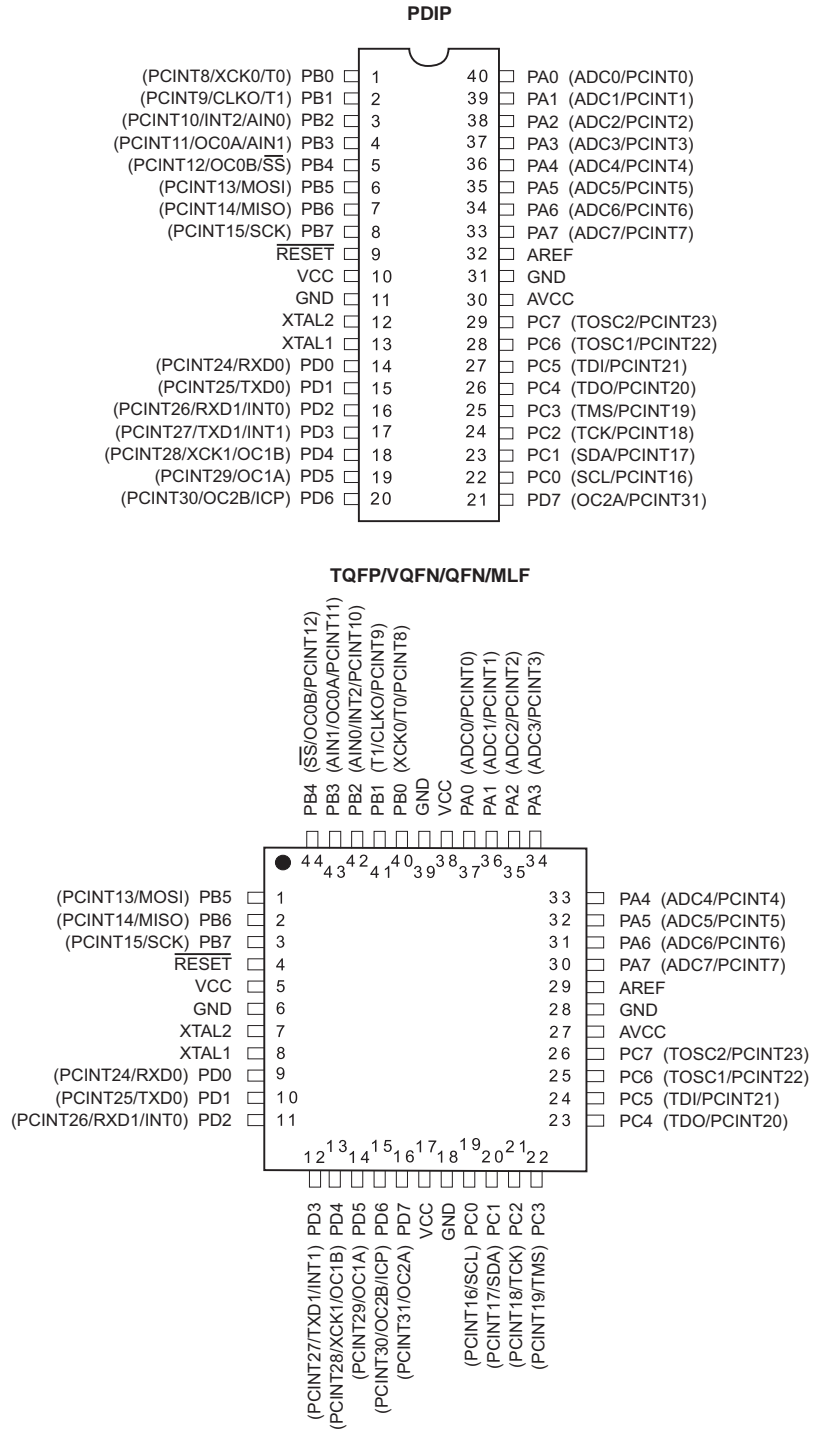
Summary



1. Pin Configurations

1.1 Pinout - PDIP/TQFP/VQFN/QFN/MLF

Figure 1-1. Pinout ATmega164P/324P/644P



Note: The large center pad underneath the VQFN/QFN/MLF package should be soldered to ground on the board to ensure good mechanical stability.

1.2 Pinout - DRQFN

Figure 1-2. DRQFN - Pinout ATmega164P

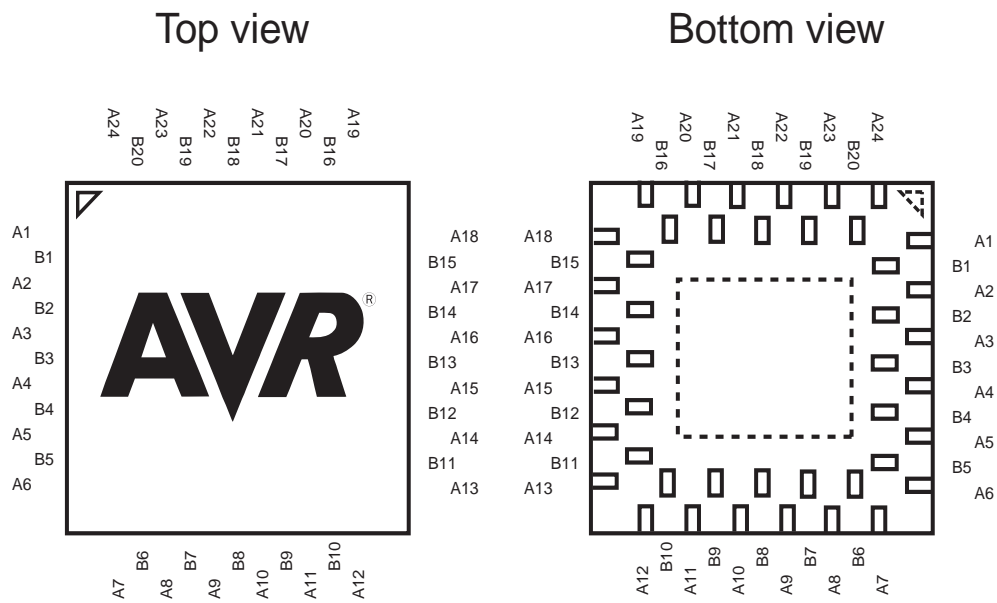


Table 1-1. DRQFN - Pinout ATmega164P/324P

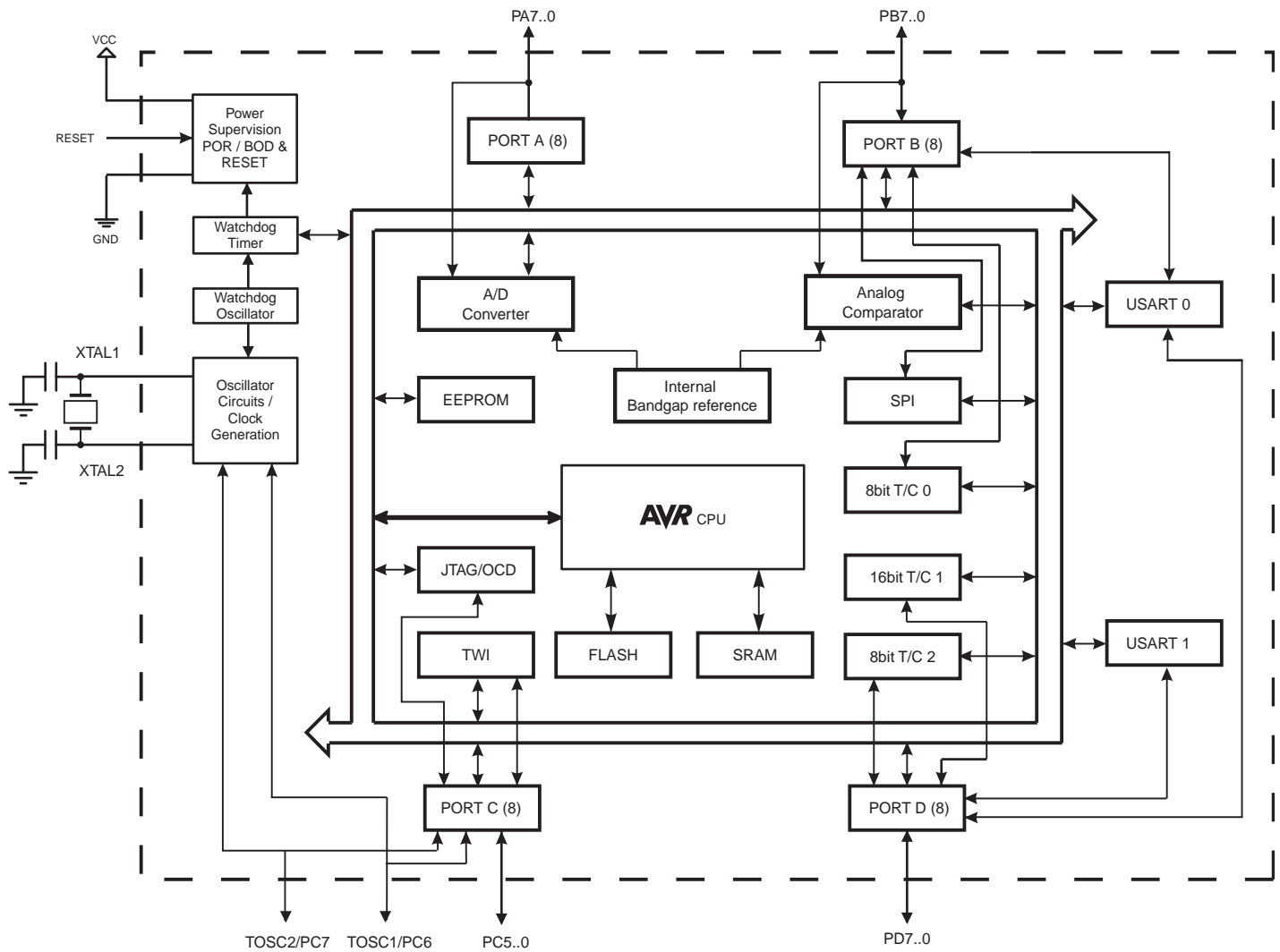
| | | | | | | | |
|-----------|-------|------------|-----|------------|------|------------|-----|
| A1 | PB5 | A7 | PD3 | A13 | PC4 | A19 | PA3 |
| B1 | PB6 | B6 | PD4 | B11 | PC5 | B16 | PA2 |
| A2 | PB7 | A8 | PD5 | A14 | PC6 | A20 | PA1 |
| B2 | RESET | B7 | PD6 | B12 | PC7 | B17 | PA0 |
| A3 | VCC | A9 | PD7 | A15 | AVCC | A21 | VCC |
| B3 | GND | B8 | VCC | B13 | GND | B18 | GND |
| A4 | XTAL2 | A10 | GND | A16 | AREF | A22 | PB0 |
| B4 | XTAL1 | B9 | PC0 | B14 | PA7 | B19 | PB1 |
| A5 | PD0 | A11 | PC1 | A17 | PA6 | A23 | PB2 |
| B5 | PD1 | B10 | PC2 | B15 | PA5 | B20 | PB3 |
| A6 | PD2 | A12 | PC3 | A18 | PA4 | A24 | PB4 |

2. Overview

The ATmega164P/324P/644P 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 ATmega164P/324P/644P 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 ATmega164P/324P/644P provides the following features: 16/32/64K bytes of In-System Programmable Flash with Read-While-Write capabilities, 512B/1K/2K bytes EEPROM, 1/2/4K bytes SRAM, 32 general purpose I/O lines, 32 general purpose working registers, Real Time Counter (RTC), three flexible Timer/Counters with compare modes and PWM, 2 USARTs, a byte oriented 2-wire Serial Interface, a 8-channel, 10-bit ADC with optional differential input stage with programmable gain, programmable Watchdog Timer with Internal Oscillator, an SPI serial port, IEEE std. 1149.1 compliant JTAG test interface, also used for accessing the On-chip Debug system and programming and six software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, 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. In Extended Standby mode, both the main Oscillator and the Asynchronous Timer continue to run.

The device is manufactured using Atmel's high-density nonvolatile memory technology. The On-chip ISP Flash allows the program memory to be reprogrammed in-system through an SPI serial interface, by a conventional nonvolatile 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 ATmega164P/324P/644P is a powerful microcontroller that provides a highly flexible and cost effective solution to many embedded control applications.

The ATmega164P/324P/644P 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 ATmega164P, ATmega324P and ATmega644P

Table 2-1. Differences between ATmega164P and ATmega644P

| Device | Flash | EEPROM | RAM |
|------------|----------|-----------|---------|
| ATmega164P | 16 Kbyte | 512 Bytes | 1 Kbyte |
| ATmega324P | 32 Kbyte | 1 Kbyte | 2 Kbyte |
| ATmega644P | 64 Kbyte | 2 Kbyte | 4 Kbyte |

2.3 Pin Descriptions

2.3.1 VCC

Digital supply voltage.

2.3.2 GND

Ground.

2.3.3 Port A (PA7:PA0)

Port A serves as analog inputs to the Analog-to-digital Converter.

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

Port A also serves the functions of various special features of the ATmega164P/324P/644P as listed on [page 81](#).

2.3.4 Port B (PB7:PB0)

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.

Port B also serves the functions of various special features of the ATmega164P/324P/644P as listed on [page 83](#).

2.3.5 Port C (PC7:PC0)

Port C is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port C 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.

Port C also serves the functions of the JTAG interface, along with special features of the ATmega164P/324P/644P as listed on [page 86](#).

2.3.6 Port D (PD7:PD0)

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.

Port D also serves the functions of various special features of the ATmega164P/324P/644P as listed on [page 88](#).

2.3.7 $\overline{\text{RESET}}$

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 "System and Reset Characteristics" on page 332. Shorter pulses are not guaranteed to generate a reset.

2.3.8 XTAL1

Input to the inverting Oscillator amplifier and input to the internal clock operating circuit.

2.3.9 XTAL2

Output from the inverting Oscillator amplifier.

2.3.10 AVCC

AVCC is the supply voltage pin for Port A and the Analog-to-digital Converter. 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.

2.3.11 AREF

This is the analog reference pin for the Analog-to-digital Converter.

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) | UDR1 | USART1 I/O Data Register | | | | | | | | 190 |
| (0xCD) | UBRR1H | - | - | - | - | USART1 Baud Rate Register High Byte | | | | 194/207 |
| (0xCC) | UBRR1L | USART1 Baud Rate Register Low Byte | | | | | | | | 194/207 |
| (0xCB) | Reserved | - | - | - | - | - | - | - | - | |
| (0xCA) | UCSR1C | UMSEL11 | UMSEL10 | - | - | - | UDORD1 | UCPHA1 | UCPOL1 | 192/206 |
| (0xC9) | UCSR1B | RXCIE1 | TXCIE1 | UDRIE1 | RXEN1 | TXEN1 | UCSZ12 | RXB81 | TXB81 | 191/205 |
| (0xC8) | UCSR1A | RXC1 | TXC1 | UDRE1 | FE1 | DOR1 | UPE1 | U2X1 | MPCM1 | 190/205 |
| (0xC7) | Reserved | - | - | - | - | - | - | - | - | |
| (0xC6) | UDR0 | USART0 I/O Data Register | | | | | | | | 190 |
| (0xC5) | UBRR0H | - | - | - | - | USART0 Baud Rate Register High Byte | | | | 194/207 |
| (0xC4) | UBRR0L | USART0 Baud Rate Register Low Byte | | | | | | | | 194/207 |
| (0xC3) | Reserved | - | - | - | - | - | - | - | - | |
| (0xC2) | UCSR0C | UMSEL01 | UMSEL00 | - | - | - | UDORD0 | UCPHA0 | UCPOL0 | 192/206 |
| (0xC1) | UCSR0B | RXCIE0 | TXCIE0 | UDRIE0 | RXEN0 | TXEN0 | UCSZ02 | RXB80 | TXB80 | 191/205 |

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Page |
|---------|----------|--|--------|--------|--------|---------|---------|---------|---------|---------|
| (0xC0) | UCSR0A | RXC0 | TXC0 | UDRE0 | FE0 | DOR0 | UPE0 | U2X0 | MPCM0 | 190/205 |
| (0xBF) | Reserved | - | - | - | - | - | - | - | - | |
| (0xBE) | Reserved | - | - | - | - | - | - | - | - | |
| (0xBD) | TWAMR | TWAM6 | TWAM5 | TWAM4 | TWAM3 | TWAM2 | TWAM1 | TWAM0 | - | 236 |
| (0xBC) | TWCR | TWINT | TWEA | TWSTA | TWSTO | TWWC | TWEN | - | TWIE | 233 |
| (0xBB) | TWDR | 2-wire Serial Interface Data Register | | | | | | | | 235 |
| (0xBA) | TWAR | TWA6 | TWA5 | TWA4 | TWA3 | TWA2 | TWA1 | TWA0 | TWGCE | 236 |
| (0xB9) | TWSR | TWS7 | TWS6 | TWS5 | TWS4 | TWS3 | - | TWPS1 | TWPS0 | 235 |
| (0xB8) | TWBR | 2-wire Serial Interface Bit Rate Register | | | | | | | | 233 |
| (0xB7) | Reserved | - | - | - | - | - | - | - | - | |
| (0xB6) | ASSR | - | EXCLK | AS2 | TCN2UB | OCR2AUB | OCR2BUB | TCR2AUB | TCR2BUB | 158 |
| (0xB5) | Reserved | - | - | - | - | - | - | - | - | |
| (0xB4) | OCR2B | Timer/Counter2 Output Compare Register B | | | | | | | | 158 |
| (0xB3) | OCR2A | Timer/Counter2 Output Compare Register A | | | | | | | | 158 |
| (0xB2) | TCNT2 | Timer/Counter2 (8 Bit) | | | | | | | | 157 |
| (0xB1) | TCCR2B | FOC2A | FOC2B | - | - | WGM22 | CS22 | CS21 | CS20 | 156 |
| (0xB0) | TCCR2A | COM2A1 | COM2A0 | COM2B1 | COM2B0 | - | - | WGM21 | WGM20 | 153 |
| (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 | | | | | | | | 137 |
| (0x8A) | OCR1BL | Timer/Counter1 - Output Compare Register B Low Byte | | | | | | | | 137 |
| (0x89) | OCR1AH | Timer/Counter1 - Output Compare Register A High Byte | | | | | | | | 137 |
| (0x88) | OCR1AL | Timer/Counter1 - Output Compare Register A Low Byte | | | | | | | | 137 |
| (0x87) | ICR1H | Timer/Counter1 - Input Capture Register High Byte | | | | | | | | 138 |
| (0x86) | ICR1L | Timer/Counter1 - Input Capture Register Low Byte | | | | | | | | 138 |
| (0x85) | TCNT1H | Timer/Counter1 - Counter Register High Byte | | | | | | | | 137 |
| (0x84) | TCNT1L | Timer/Counter1 - Counter Register Low Byte | | | | | | | | 137 |
| (0x83) | Reserved | - | - | - | - | - | - | - | - | |
| (0x82) | TCCR1C | FOC1A | FOC1B | - | - | - | - | - | - | 136 |
| (0x81) | TCCR1B | ICNC1 | ICES1 | - | WGM13 | WGM12 | CS12 | CS11 | CS10 | 135 |
| (0x80) | TCCR1A | COM1A1 | COM1A0 | COM1B1 | COM1B0 | - | - | WGM11 | WGM10 | 133 |
| (0x7F) | DIDR1 | - | - | - | - | - | - | AIN1D | AIN0D | 240 |

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Page |
|-------------|----------|--|---------|---------|----------|-----------------------------------|---------|----------|----------|--------|
| (0x7E) | DIDR0 | ADC7D | ADC6D | ADC5D | ADC4D | ADC3D | ADC2D | ADC1D | ADC0D | 260 |
| (0x7D) | Reserved | - | - | - | - | - | - | - | - | |
| (0x7C) | ADMUX | REFS1 | REFS0 | ADLAR | MUX4 | MUX3 | MUX2 | MUX1 | MUX0 | 256 |
| (0x7B) | ADCSRB | - | ACME | - | - | - | ADTS2 | ADTS1 | ADTS0 | 239 |
| (0x7A) | ADCSRA | ADEN | ADSC | ADATE | ADIF | ADIE | ADPS2 | ADPS1 | ADPS0 | 258 |
| (0x79) | ADCH | ADC Data Register High byte | | | | | | | | 259 |
| (0x78) | ADCL | ADC Data Register Low byte | | | | | | | | 259 |
| (0x77) | Reserved | - | - | - | - | - | - | - | - | |
| (0x76) | Reserved | - | - | - | - | - | - | - | - | |
| (0x75) | Reserved | - | - | - | - | - | - | - | - | |
| (0x74) | Reserved | - | - | - | - | - | - | - | - | |
| (0x73) | PCMSK3 | PCINT31 | PCINT30 | PCINT29 | PCINT28 | PCINT27 | PCINT26 | PCINT25 | PCINT24 | 71 |
| (0x72) | Reserved | - | - | - | - | - | - | - | - | |
| (0x71) | Reserved | - | - | - | - | - | - | - | - | |
| (0x70) | TIMSK2 | - | - | - | - | - | OCIE2B | OCIE2A | TOIE2 | 159 |
| (0x6F) | TIMSK1 | - | - | ICIE1 | - | - | OCIE1B | OCIE1A | TOIE1 | 138 |
| (0x6E) | TIMSK0 | - | - | - | - | - | OCIE0B | OCIE0A | TOIE0 | 110 |
| (0x6D) | PCMSK2 | PCINT23 | PCINT22 | PCINT21 | PCINT20 | PCINT19 | PCINT18 | PCINT17 | PCINT16 | 71 |
| (0x6C) | PCMSK1 | PCINT15 | PCINT14 | PCINT13 | PCINT12 | PCINT11 | PCINT10 | PCINT9 | PCINT8 | 71 |
| (0x6B) | PCMSK0 | PCINT7 | PCINT6 | PCINT5 | PCINT4 | PCINT3 | PCINT2 | PCINT1 | PCINT0 | 72 |
| (0x6A) | Reserved | - | - | - | - | - | - | - | - | |
| (0x69) | EICRA | - | - | ISC21 | ISC20 | ISC11 | ISC10 | ISC01 | ISC00 | 68 |
| (0x68) | PCICR | - | - | - | - | PCIE3 | PCIE2 | PCIE1 | PCIE0 | 70 |
| (0x67) | Reserved | - | - | - | - | - | - | - | - | |
| (0x66) | OSCCAL | Oscillator Calibration Register | | | | | | | | 41 |
| (0x65) | Reserved | - | - | - | - | - | - | - | - | |
| (0x64) | PRR | PRTWI | PRTIM2 | PRTIM0 | PRUSART1 | PRTIM1 | PRSPI | PRUSART0 | PRADC | 49 |
| (0x63) | Reserved | - | - | - | - | - | - | - | - | |
| (0x62) | Reserved | - | - | - | - | - | - | - | - | |
| (0x61) | CLKPR | CLKPCE | - | - | - | CLKPS3 | CLKPS2 | CLKPS1 | CLKPS0 | 41 |
| (0x60) | WDTCR | WDIF | WDIE | WDP3 | WDCE | WDE | WDP2 | WDP1 | WDP0 | 60 |
| 0x3F (0x5F) | SREG | I | T | H | S | V | N | Z | C | 11 |
| 0x3E (0x5E) | SPH | SP15 | SP14 | SP13 | SP12 | SP11 | SP10 | SP9 | SP8 | 12 |
| 0x3D (0x5D) | SPL | SP7 | SP6 | SP5 | SP4 | SP3 | SP2 | SP1 | SP0 | 12 |
| 0x3C (0x5C) | Reserved | - | - | - | - | - | - | - | - | |
| 0x3B (0x5B) | RAMPZ | - | - | - | - | - | - | - | RAMPZ0 | 15 |
| 0x3A (0x5A) | Reserved | - | - | - | - | - | - | - | - | |
| 0x39 (0x59) | Reserved | - | - | - | - | - | - | - | - | |
| 0x38 (0x58) | Reserved | - | - | - | - | - | - | - | - | |
| 0x37 (0x57) | SPMCSR | SPMIE | RWWSB | SIGRD | RWWSRE | BLBSET | PGWRT | PGERS | SPMEN | 292 |
| 0x36 (0x56) | Reserved | - | - | - | - | - | - | - | - | |
| 0x35 (0x55) | MCUCR | JTD | BODS | BODSE | PUD | - | - | IVSEL | IVCE | 92/276 |
| 0x34 (0x54) | MCUSR | - | - | - | JTRF | WDRF | BORF | EXTRF | PORF | 59/276 |
| 0x33 (0x53) | SMCR | - | - | - | - | SM2 | SM1 | SM0 | SE | 48 |
| 0x32 (0x52) | Reserved | - | - | - | - | - | - | - | - | |
| 0x31 (0x51) | OCDR | On-Chip Debug Register | | | | | | | | 266 |
| 0x30 (0x50) | ACSR | ACD | ACBG | ACO | ACI | ACIE | ACIC | ACIS1 | ACIS0 | 258 |
| 0x2F (0x4F) | Reserved | - | - | - | - | - | - | - | - | |
| 0x2E (0x4E) | SPDR | SPI 0 Data Register | | | | | | | | 171 |
| 0x2D (0x4D) | SPSR | SPIF0 | WCOL0 | - | - | - | - | - | SPI2X0 | 170 |
| 0x2C (0x4C) | SPCR | SPIE0 | SPE0 | DORD0 | MSTR0 | CPOL0 | CPHA0 | SPR01 | SPR00 | 169 |
| 0x2B (0x4B) | GPOR2 | General Purpose I/O Register 2 | | | | | | | | 29 |
| 0x2A (0x4A) | GPOR1 | General Purpose I/O Register 1 | | | | | | | | 29 |
| 0x29 (0x49) | Reserved | - | - | - | - | - | - | - | - | |
| 0x28 (0x48) | OCR0B | Timer/Counter0 Output Compare Register B | | | | | | | | 110 |
| 0x27 (0x47) | OCR0A | Timer/Counter0 Output Compare Register A | | | | | | | | 109 |
| 0x26 (0x46) | TCNT0 | Timer/Counter0 (8 Bit) | | | | | | | | 109 |
| 0x25 (0x45) | TCCR0B | FOC0A | FOC0B | - | - | WGM02 | CS02 | CS01 | CS00 | 108 |
| 0x24 (0x44) | TCCR0A | COM0A1 | COM0A0 | COM0B1 | COM0B0 | - | - | WGM01 | WGM00 | 110 |
| 0x23 (0x43) | GTCCR | TSM | - | - | - | - | - | PSRASY | PSR5SYNC | 160 |
| 0x22 (0x42) | EEARH | - | - | - | - | EEPROM Address Register High Byte | | | | 24 |
| 0x21 (0x41) | EEARL | EEPROM Address Register Low Byte | | | | | | | | 24 |
| 0x20 (0x40) | EEDR | EEPROM Data Register | | | | | | | | 24 |
| 0x1F (0x3F) | EEDR | - | - | EEDR1 | EEDR0 | EERIE | EEMPE | EEPE | EERE | 24 |
| 0x1E (0x3E) | GPOR0 | General Purpose I/O Register 0 | | | | | | | | 29 |
| 0x1D (0x3D) | EIMSK | - | - | - | - | - | INT2 | INT1 | INT0 | 69 |

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Page |
|-------------|----------|--------|--------|--------|--------|--------|--------|--------|--------|------|
| 0x1C (0x3C) | EIFR | - | - | - | - | - | INTF2 | INTF1 | INTF0 | 69 |
| 0x1B (0x3B) | PCIFR | - | - | - | - | PCIF3 | PCIF2 | PCIF1 | PCIF0 | 70 |
| 0x1A (0x3A) | Reserved | - | - | - | - | - | - | - | - | |
| 0x19 (0x39) | Reserved | - | - | - | - | - | - | - | - | |
| 0x18 (0x38) | Reserved | - | - | - | - | - | - | - | - | |
| 0x17 (0x37) | TIFR2 | - | - | - | - | - | OCF2B | OCF2A | TOV2 | 160 |
| 0x16 (0x36) | TIFR1 | - | - | ICF1 | - | - | OCF1B | OCF1A | TOV1 | 139 |
| 0x15 (0x35) | TIFR0 | - | - | - | - | - | OCF0B | OCF0A | TOV0 | 110 |
| 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) | DDRD | DDD7 | DDD6 | DDD5 | DDD4 | DDD3 | DDD2 | DDD1 | DDD0 | 93 |
| 0x09 (0x29) | PIND | PIND7 | PIND6 | PIND5 | PIND4 | PIND3 | PIND2 | PIND1 | PIND0 | 93 |
| 0x08 (0x28) | PORTC | PORTC7 | PORTC6 | PORTC5 | PORTC4 | PORTC3 | PORTC2 | PORTC1 | PORTC0 | 93 |
| 0x07 (0x27) | DDRC | DDC7 | DDC6 | DDC5 | DDC4 | DDC3 | DDC2 | DDC1 | DDC0 | 93 |
| 0x06 (0x26) | PINC | PINC7 | PINC6 | PINC5 | PINC4 | PINC3 | PINC2 | PINC1 | PINC0 | 93 |
| 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) | PORTA | PORTA7 | PORTA6 | PORTA5 | PORTA4 | PORTA3 | PORTA2 | PORTA1 | PORTA0 | 92 |
| 0x01 (0x21) | DDRA | DDA7 | DDA6 | DDA5 | DDA4 | DDA3 | DDA2 | DDA1 | DDA0 | 92 |
| 0x00 (0x20) | PINA | PINA7 | PINA6 | PINA5 | PINA4 | PINA3 | PINA2 | PINA1 | PINA0 | 92 |

- Notes:
- For compatibility with future devices, reserved bits should be written to zero if accessed. Reserved I/O memory addresses should never be written.
 - I/O registers within the address range \$00 - \$1F 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.
 - Some of the status flags are cleared by writing a logical one to them. Note that the CBI and SBI instructions will operate on all bits in the I/O register, writing a one back into any flag read as set, thus clearing the flag. The CBI and SBI instructions work with registers 0x00 to 0x1F only.
 - When using the I/O specific commands IN and OUT, the I/O addresses \$00 - \$3F must be used. When addressing I/O registers as data space using LD and ST instructions, \$20 must be added to these addresses. The ATmega164P/324P/644P 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 \$60 - \$FF, only the ST/STS/STD and LD/LDS/LDD instructions can be used.

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 | RdI,K | Add Immediate to Word | $Rdh:Rdl \leftarrow Rdh:Rdl + K$ | Z,C,N,V,S | 2 |
| SUB | Rd, Rr | Subtract two Registers | $Rd \leftarrow Rd - Rr$ | Z,C,N,V,H | 1 |
| SUBI | Rd, K | Subtract Constant from Register | $Rd \leftarrow Rd - K$ | Z,C,N,V,H | 1 |
| SBC | Rd, Rr | Subtract with Carry two Registers | $Rd \leftarrow Rd - Rr - C$ | Z,C,N,V,H | 1 |
| SBCI | Rd, K | Subtract with Carry Constant from Reg. | $Rd \leftarrow Rd - K - C$ | Z,C,N,V,H | 1 |
| SBIW | RdI,K | Subtract Immediate from Word | $Rdh:Rdl \leftarrow Rdh:Rdl - K$ | Z,C,N,V,S | 2 |
| AND | Rd, Rr | Logical AND Registers | $Rd \leftarrow Rd \bullet Rr$ | Z,N,V | 1 |
| ANDI | Rd, K | Logical AND Register and Constant | $Rd \leftarrow Rd \bullet K$ | Z,N,V | 1 |
| OR | Rd, Rr | Logical OR Registers | $Rd \leftarrow Rd \vee Rr$ | Z,N,V | 1 |
| ORI | Rd, K | Logical OR Register and Constant | $Rd \leftarrow Rd \vee K$ | Z,N,V | 1 |
| EOR | Rd, Rr | Exclusive OR Registers | $Rd \leftarrow Rd \oplus Rr$ | Z,N,V | 1 |
| COM | Rd | One's Complement | $Rd \leftarrow 0xFF - Rd$ | Z,C,N,V | 1 |
| NEG | Rd | Two's Complement | $Rd \leftarrow 0x00 - Rd$ | Z,C,N,V,H | 1 |
| SBR | Rd,K | Set Bit(s) in Register | $Rd \leftarrow Rd \vee K$ | Z,N,V | 1 |
| CBR | Rd,K | Clear Bit(s) in Register | $Rd \leftarrow Rd \bullet (0xFF - K)$ | Z,N,V | 1 |
| INC | Rd | Increment | $Rd \leftarrow Rd + 1$ | Z,N,V | 1 |
| DEC | Rd | Decrement | $Rd \leftarrow Rd - 1$ | Z,N,V | 1 |
| TST | Rd | Test for Zero or Minus | $Rd \leftarrow Rd \bullet Rd$ | Z,N,V | 1 |
| CLR | Rd | Clear Register | $Rd \leftarrow Rd \oplus Rd$ | Z,N,V | 1 |
| SER | Rd | Set Register | $Rd \leftarrow 0xFF$ | None | 1 |
| MUL | Rd, Rr | Multiply Unsigned | $R1:R0 \leftarrow Rd \times Rr$ | Z,C | 2 |
| MULS | Rd, Rr | Multiply Signed | $R1:R0 \leftarrow Rd \times Rr$ | Z,C | 2 |
| MULSU | Rd, Rr | Multiply Signed with Unsigned | $R1:R0 \leftarrow Rd \times Rr$ | Z,C | 2 |
| FMUL | Rd, Rr | Fractional Multiply Unsigned | $R1:R0 \leftarrow (Rd \times Rr) \lll 1$ | Z,C | 2 |
| FMULS | Rd, Rr | Fractional Multiply Signed | $R1:R0 \leftarrow (Rd \times Rr) \lll 1$ | Z,C | 2 |
| FMULSU | Rd, Rr | Fractional Multiply Signed with Unsigned | $R1:R0 \leftarrow (Rd \times Rr) \lll 1$ | Z,C | 2 |
| BRANCH INSTRUCTIONS | | | | | |
| RJMP | k | Relative Jump | $PC \leftarrow PC + k + 1$ | None | 2 |
| IJMP | | Indirect Jump to (Z) | $PC \leftarrow Z$ | None | 2 |
| JMP | k | Direct Jump | $PC \leftarrow k$ | None | 3 |
| RCALL | k | Relative Subroutine Call | $PC \leftarrow PC + k + 1$ | None | 4 |
| ICALL | | Indirect Call to (Z) | $PC \leftarrow Z$ | None | 4 |
| CALL | k | Direct Subroutine Call | $PC \leftarrow k$ | None | 5 |
| RET | | Subroutine Return | $PC \leftarrow STACK$ | None | 5 |
| RETI | | Interrupt Return | $PC \leftarrow STACK$ | I | 5 |
| 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 |

| Mnemonics | Operands | Description | Operation | Flags | #Clocks |
|--------------------------------------|----------|------------------------------------|--|---------|---------|
| BRVC | k | Branch if Overflow Flag is Cleared | if (V = 0) then PC ← PC + k + 1 | None | 1/2 |
| 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 |
| ELPM | | Extended Load Program Memory | R0 ← (RAMPZ:Z) | None | 3 |
| ELPM | Rd, Z | Extended Load Program Memory | Rd ← (Z) | None | 3 |
| ELPM | Rd, Z+ | Extended Load Program Memory | Rd ← (RAMPZ:Z), RAMPZ:Z ← RAMPZ:Z+1 | None | 3 |

| Mnemonics | Operands | Description | Operation | Flags | #Clocks |
|---------------------------------|----------|-------------------------|--|-------|---------|
| 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 |
| 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 |

7. Ordering Information

7.1 ATmega164P

| Speed (MHz) ⁽³⁾ | Power Supply | Ordering Code | Package ⁽¹⁾ | Operational Range |
|----------------------------|--------------|----------------------------------|------------------------|-------------------------------|
| 10 | 1.8 - 5.5V | ATmega164PV-10AU ⁽²⁾ | 44A | Industrial (-40°C to 85°C) |
| | | ATmega164PV-10PU ⁽²⁾ | 40P6 | |
| | | ATmega164PV-10MU ⁽²⁾ | 44M1 | |
| | | ATmega164PV-10MCU ⁽²⁾ | 44MC | |
| 20 | 2.7 - 5.5V | ATmega164P-20AU ⁽²⁾ | 44A | |
| | | ATmega164P-20PU ⁽²⁾ | 40P6 | |
| | | ATmega164P-20MU ⁽²⁾ | 44M1 | |
| | | ATmega164P-20MCU ⁽²⁾ | 44MC | |

- Notes:
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. For Speed vs. V_{CC} see ["Speed Grades" on page 330](#).

| Package Type | |
|--------------|--|
| 44A | 44-lead, Thin (1.0 mm) Plastic Gull Wing Quad Flat Package (TQFP) |
| 40P6 | 40-pin, 0.600" Wide, Plastic Dual Inline Package (PDIP) |
| 44M1 | 44-pad, 7 x 7 x 1.0 mm body, lead pitch 0.50 mm, Thermally Enhanced Plastic Very Thin Quad Flat No-Lead (VQFN) |
| 44MC | 44-lead (2-row Staggered), 5 x 5 x 1.0 mm body, 2.60 x 2.60 mm Exposed Pad, Quad Flat No-Lead Package (QFN) |

7.2 ATmega324P

| Speed (MHz) ⁽³⁾ | Power Supply | Ordering Code | Package ⁽¹⁾ | Operational Range |
|----------------------------|--------------|---------------------------------|------------------------|-------------------------------|
| 10 | 1.8 - 5.5V | ATmega324PV-10AU ⁽²⁾ | 44A | Industrial (-40°C to 85°C) |
| | | ATmega324PV-10PU ⁽²⁾ | 40P6 | |
| | | ATmega324PV-10MU ⁽²⁾ | 44M1 | |
| 20 | 2.7 - 5.5V | ATmega324P-20AU ⁽²⁾ | 44A | |
| | | ATmega324P-20PU ⁽²⁾ | 40P6 | |
| | | ATmega324P-20MU ⁽²⁾ | 44M1 | |

- Notes:
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. For Speed vs. V_{CC} see "[Speed Grades](#)" on page 330.

| Package Type | |
|--------------|--|
| 44A | 44-lead, Thin (1.0 mm) Plastic Gull Wing Quad Flat Package (TQFP) |
| 40P6 | 40-pin, 0.600" Wide, Plastic Dual Inline Package (PDIP) |
| 44M1 | 44-pad, 7 x 7 x 1.0 mm body, lead pitch 0.50 mm, Thermally Enhanced Plastic Very Thin Quad Flat No-Lead (VQFN) |

7.3 ATmega644P

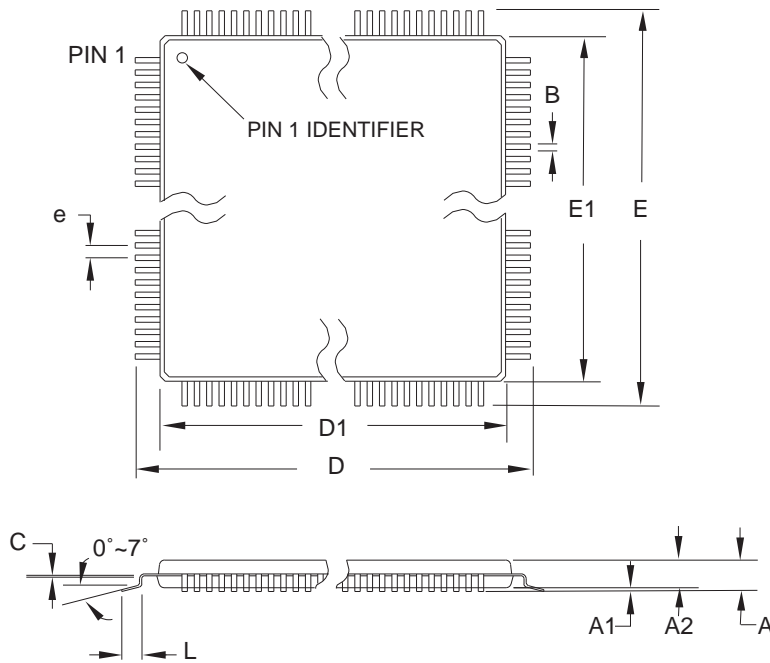
| Speed (MHz) ⁽³⁾ | Power Supply | Ordering Code | Package ⁽¹⁾ | Operational Range |
|----------------------------|--------------|---------------------------------|------------------------|-------------------------------|
| 10 | 1.8 - 5.5V | ATmega644PV-10AU ⁽²⁾ | 44A | Industrial (-40°C to 85°C) |
| | | ATmega644PV-10PU ⁽²⁾ | 40P6 | |
| | | ATmega644PV-10MU ⁽²⁾ | 44M1 | |
| 20 | 2.7 - 5.5V | ATmega644P-20AU ⁽²⁾ | 44A | Industrial (-40°C to 85°C) |
| | | ATmega644P-20PU ⁽²⁾ | 40P6 | |
| | | ATmega644P-20MU ⁽²⁾ | 44M1 | |

- Notes:
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. For Speed vs. V_{CC} see "[Speed Grades](#)" on page 330.

| Package Type | |
|--------------|--|
| 44A | 44-lead, Thin (1.0 mm) Plastic Gull Wing Quad Flat Package (TQFP) |
| 40P6 | 40-pin, 0.600" Wide, Plastic Dual Inline Package (PDIP) |
| 44M1 | 44-pad, 7 x 7 x 1.0 mm body, lead pitch 0.50 mm, Thermally Enhanced Plastic Very Thin Quad Flat No-Lead (VQFN) |

8. Packaging Information

8.1 44A



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 | 11.75 | 12.00 | 12.25 | |
| D1 | 9.90 | 10.00 | 10.10 | Note 2 |
| E | 11.75 | 12.00 | 12.25 | |
| E1 | 9.90 | 10.00 | 10.10 | 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 ACB.
 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

44A, 44-lead, 10 x 10 mm Body Size, 1.0 mm Body Thickness,
0.8 mm Lead Pitch, Thin Profile Plastic Quad Flat Package (TQFP)

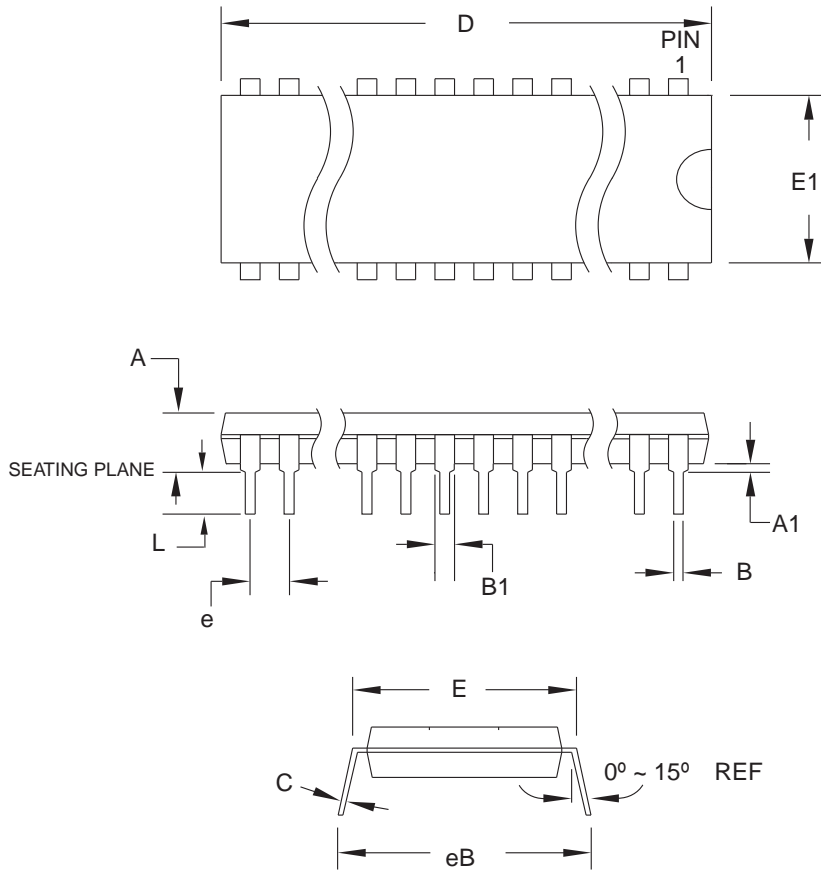
DRAWING NO.

44A

REV.

B

8.2 40P6



COMMON DIMENSIONS
(Unit of Measure = mm)

| SYMBOL | MIN | NOM | MAX | NOTE |
|--------|-----------|-----|--------|--------|
| A | – | – | 4.826 | |
| A1 | 0.381 | – | – | |
| D | 52.070 | – | 52.578 | Note 2 |
| E | 15.240 | – | 15.875 | |
| E1 | 13.462 | – | 13.970 | Note 2 |
| B | 0.356 | – | 0.559 | |
| B1 | 1.041 | – | 1.651 | |
| L | 3.048 | – | 3.556 | |
| C | 0.203 | – | 0.381 | |
| eB | 15.494 | – | 17.526 | |
| e | 2.540 TYP | | | |

- Notes: 1. This package conforms to JEDEC reference MS-011, Variation AC.
 2. 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

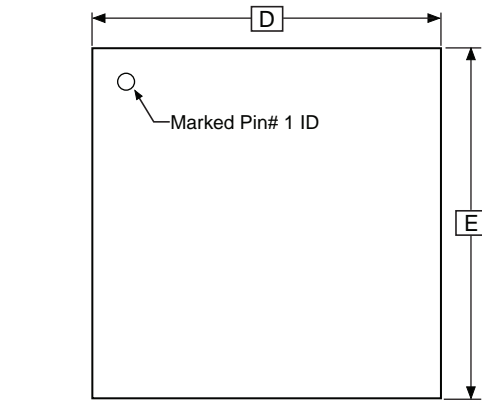
ATMEL 2325 Orchard Parkway
San Jose, CA 95131

TITLE
40P6, 40-lead (0.600"/15.24 mm Wide) Plastic Dual
 Inline Package (PDIP)

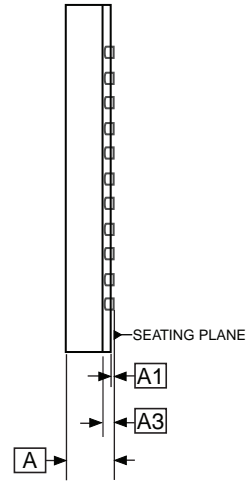
DRAWING NO.
40P6

REV.
B

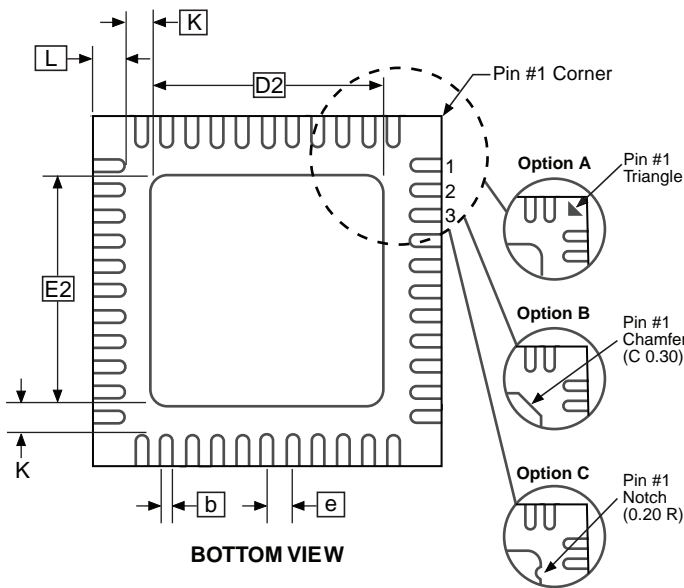
8.3 44M1



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 | |
| A3 | 0.20 REF | | | |
| b | 0.18 | 0.23 | 0.30 | |
| D | 6.90 | 7.00 | 7.10 | |
| D2 | 5.00 | 5.20 | 5.40 | |
| E | 6.90 | 7.00 | 7.10 | |
| E2 | 5.00 | 5.20 | 5.40 | |
| e | 0.50 BSC | | | |
| L | 0.59 | 0.64 | 0.69 | |
| K | 0.20 | 0.26 | 0.41 | |

Note: JEDEC Standard MO-220, Fig. 1 (SAW Singulation) VKKD-3.

9/26/08



Package Drawing Contact:
packagedrawings@atmel.com

TITLE
44M1, 44-pad, 7 x 7 x 1.0 mm Body, Lead Pitch 0.50 mm, 5.20 mm Exposed Pad, Thermally Enhanced Plastic Very Thin Quad Flat No Lead Package (VQFN)

GPC

ZWS

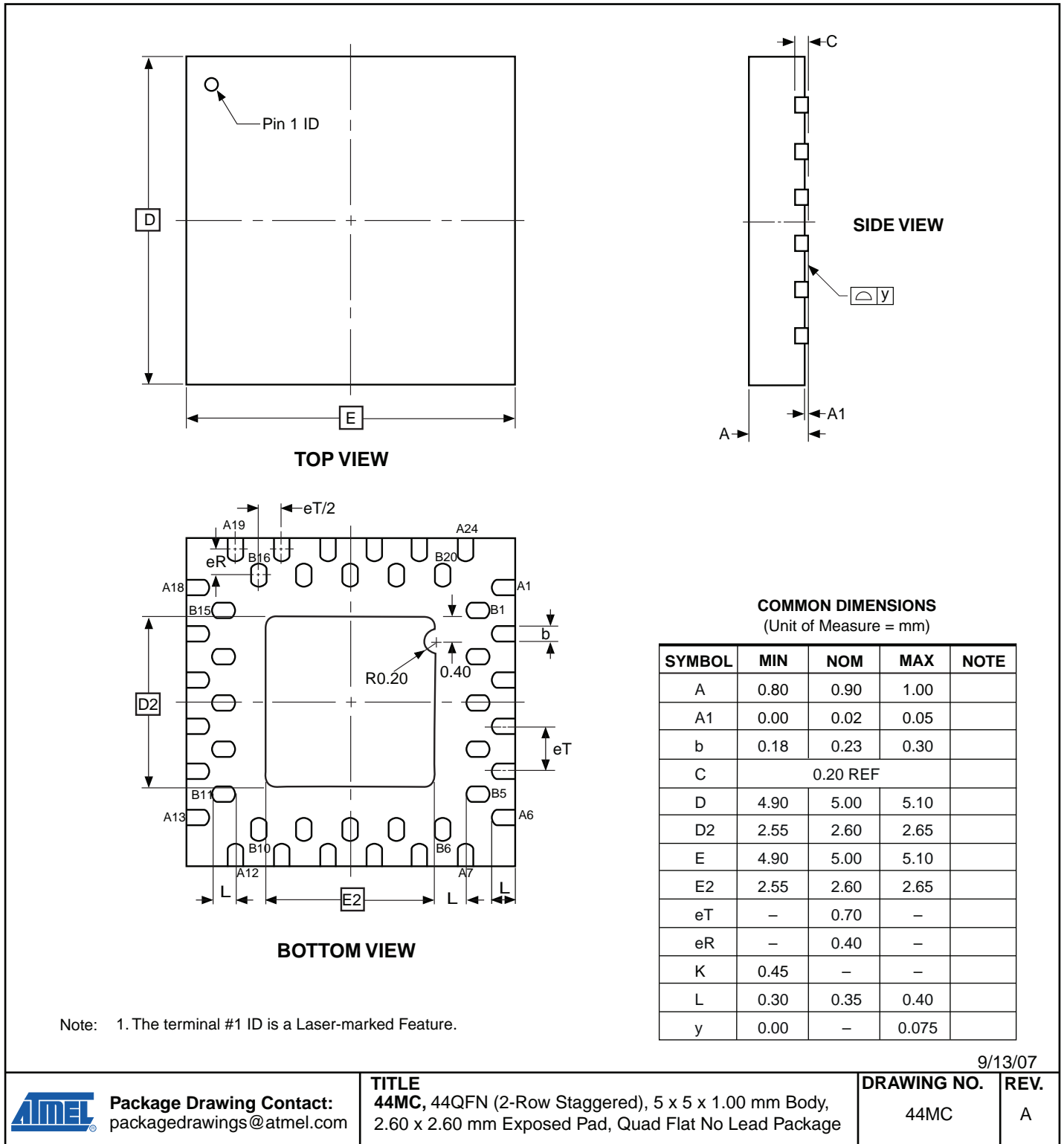
DRAWING NO.

44M1

REV.

H

8.4 44MC





9. Errata

9.1 ATmega164P

9.1.1 Rev. A

No known Errata.

9.2 ATmega324P

9.2.1 Rev. A

No known Errata.

9.3 ATmega644P

9.3.1 Rev. A

Not sampled.

9.3.2 Rev. B

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. 8011K- 09/08

1. Updated "Features" on page 1, "Pin Configurations" on page 2 and "Ordering Information" on page 15 according to the updated 44M1 package drawing.
2. Updated V_{OL} in the table of "DC Characteristics" on page 326.
3. Updated t_{RST} and t_{BOD} unites in the table of "System and Reset Characteristics" on page 332.
4. Updated typical values for ATmega324P and ATmega644P in the tables of "DC Characteristics" on page 326.
5. Replaced the package drawing "44M1" on page 426 by a rev H update.

10.2 Rev. 8011J- 09/08

1. Updated ATmega644P "Errata" on page 428.

10.3 Rev. 8011I- 05/08

1. Updated description in "AVCC" on page 7.
2. Updated "Stack Pointer" on page 14.
3. Updated Data Memory Map addresses, Figure 7-2 on page 21.
4. Updated description of use of external capacitors in "Low Frequency Crystal Oscillator" on page 35.
5. Updated typo in "Alternate Functions of Port C" on page 86.
6. Updated bit description in "TWSR – TWI Status Register" on page 235.
7. Updated typo in "Programming via the JTAG Interface" on page 313.
8. Updated conditions for V_{OL} in the table of "DC Characteristics" on page 326.
9. Updated "External Clock Drive" on page 331.
10. Updated conditions for V_{INT2} in Table 27-11 (Single Ended channels) in "ADC Characteristics" on page 336.
11. Updated Minimum Reference Voltage in Table 27-12 (Differential channels) in "ADC Characteristics" on page 336.
12. Updated bit bit field typos in "Register Summary" on page 414.

10.4 Rev. 8011H- 04/08

1. Added 44-pad DRQFN pinout for ATmega164P in "Pinout - DRQFN" on page 3.
2. Added note to "Address Match Unit" on page 215.
3. Updated ATmega164P "Ordering Information" on page 421.
4. Added 44-lead QFN (44MC) to "Packaging Information" on page 424.

10.5 Rev. 8011G- 08/07

1. Updated "Features" on page 1
2. Added "Data Retention" on page 9.
3. Updated "SPH and SPL – Stack Pointer High and Stack pointer Low" on page 15.
4. LCD reference removed from table note in "Sleep Modes" on page 43.
5. Updated code example in "Bit 0 – IVCE: Interrupt Vector Change Enable" on page 66.
6. Removed reference to External Memory Interface in "Alternate Functions of Port A" on page 81.
7. Updated "Data Reception – The USART Receiver" on page 181.
8. Updated "ADCSR – ADC Control and Status Register B" on page 239.
9. Updated overview in "ADC - Analog-to-digital Converter" on page 241.
10. Added "ATmega644P Typical Characteristic" on page 389.
11. Updated Figure 28-31 on page 355, Figure 28-32 on page 356, Figure 28-33 on page 356
12. Updated notes in Table 8-3 on page 33, Table 8-8 on page 36, Table 8-9 on page 37, and Table 8-11 on page 38.
13. Updated Table 13-7 on page 85, Table 13-8 on page 85, Table 13-10 on page 87, Table 13-11 on page 88, Table 13-14 on page 91, Table 27-1 on page 328, Table 27-2 on page 328, Table 27-5 on page 331, Table 27-9 on page 333, and Table 27-12 on page 337
14. Updated "ATmega324P DC Characteristics" on page 328 and "ATmega644P DC Characteristics" on page 329.
15. Updated Table 27-7 on page 332 and Table 8-13 on page 38.

10.6 Rev. 8011F- 04/07

1. Updated "Watchdog Timer Configuration" on page 60.

10.7 Rev. 8011E - 04/07

1. Updated "GTCCR – General Timer/Counter Control Register" on page 160.
2. Updated "EECR – The EEPROM Control Register" on page 24.

10.8 Rev. 8011D - 02/07

1. Updated "Pinout ATmega164P/324P/644P" on page 2.
2. Updated "Power-down Mode" on page 45.
3. Updated note in Table 12-1 on page 69.
4. Updated Table 24-1 on page 273.
5. Updated "Boot Size Configuration⁽¹⁾" on page 290.
6. Updated V_{OL} limits in "DC Characteristics" on page 326.
7. Updated note 3 and 4 in "DC Characteristics" on page 326.
8. Added note to "ATmega164P DC Characteristics" on page 328.
9. Added note to "ATmega324P DC Characteristics" on page 328.
10. Updated Figure 28-13 on page 346 and Figure 28-60 on page 371.

10.9 Rev. 8011C - 10/06

1. Updated "DC Characteristics" on page 326.

10.10 Rev. 8011B - 09/06

1. Updated "DC Characteristics" on page 326.

10.11 Rev. 8011A - 08/06

1. Initial revision.



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