

## Features

- High Performance, Low Power AVR<sup>®</sup> 8-bit Microcontroller
- Advanced RISC Architecture
  - 124 Powerful Instructions - Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 8 MIPS Throughput at 8 MHz
- High Endurance Non-volatile Memory Segments
  - 16K/32K Bytes of In-System Self-Programmable Flash (ATmega16HVB/32HVB)
  - 512/1K Bytes EEPROM
  - 1K/2K Bytes Internal SRAM
  - Write/Erase Cycles 10,000 Flash/100,000 EEPROM
  - Data retention: 20 years at 85°C/100 years at 25°C<sup>(1)</sup>
  - Optional Boot Code Section with Independent Lock Bits
  - In-System Programming by On-chip Boot Program
  - True Read-While-Write Operation
  - Programming Lock for Software Security
- Battery Management Features
  - Two, three or Four Cells in Series
  - High-current Protection (Charge and Discharge)
  - Over-current Protection (Charge and Discharge)
  - Short-circuit Protection (Discharge)
  - High Voltage Outputs to Drive N-Channel Charge/Discharge FETs
  - High Voltage Output to drive P-Channel Precharge FET
  - Integrated Cell Balancing FETs
- Peripheral Features
  - Two configurable 8- or 16-bit Timers with Separate Prescaler, Optional Input Capture (IC), Compare Mode and CTC
  - SPI - Serial Programmable Interface
  - 12-bit Voltage ADC, Six External and One Internal ADC Input
  - High Resolution Coulomb Counter ADC for Current Measurements
  - TWI Serial Interface for SM-Bus
  - Programmable Watchdog Timer
- Special Microcontroller Features
  - debugWIRE On-chip Debug System
  - In-System Programmable via SPI ports
  - Power-on Reset
  - On-chip Voltage Regulator with Short-circuit Monitoring Interface
  - External and Internal Interrupt Sources
  - Sleep Modes: Idle, ADC Noise Reduction, Power-save, and Power-off
- Additional Secure Authentication Features available only under NDA
- Packages
  - 44-lead TSSOP
- Operating Voltage: 4 - 25V
- Maximum Withstand Voltage (High-voltage pins): 35V
- Temperature Range: -40°C to 85°C
- Speed Grade: 1-8 MHz

Note: 1. See "Data Retention" on page 8 for details.



**8-bit AVR<sup>®</sup>  
Microcontroller  
with 16K/32K  
Bytes In-System  
Programmable  
Flash**

**ATmega16HVB  
ATmega32HVB**

**Preliminary**

**Summary**

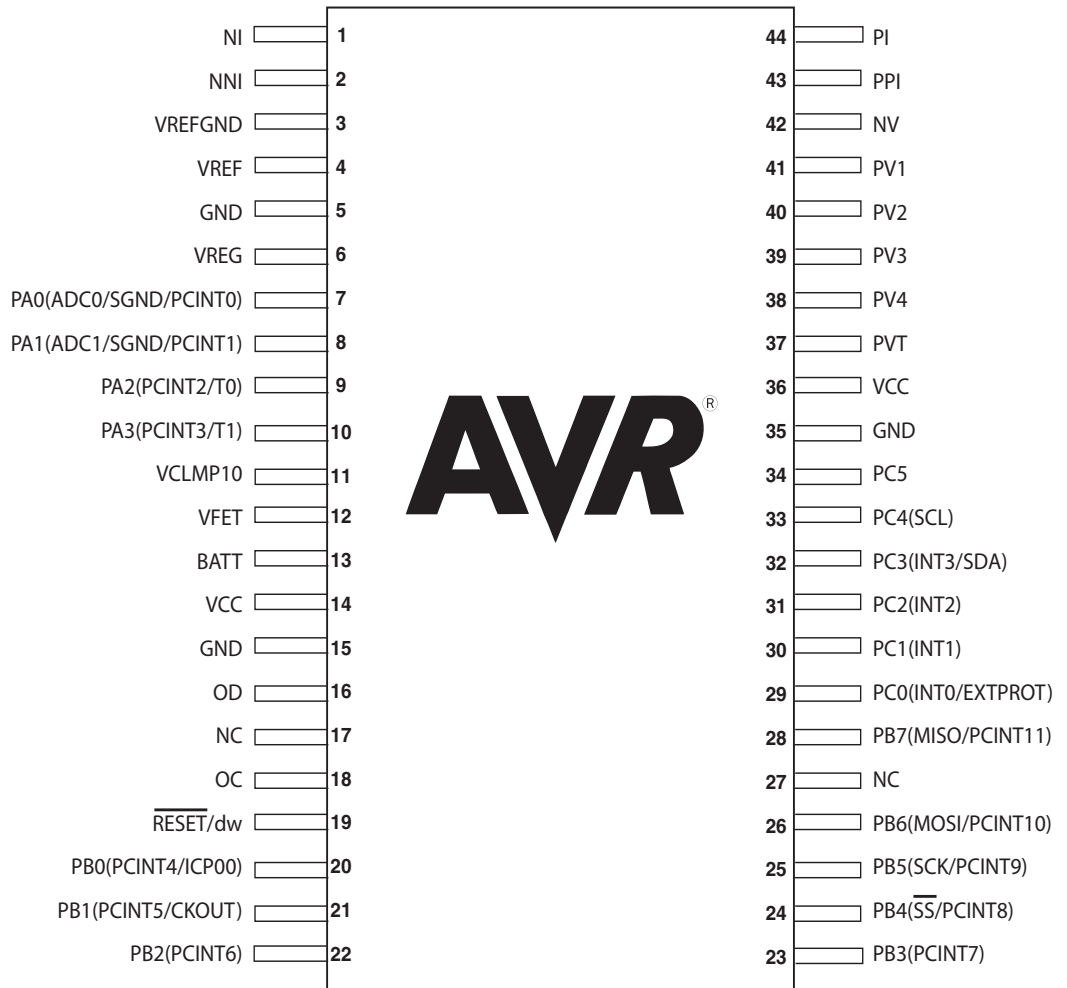
8042A-AVR-07/09



## 1. Pin Configurations

### 1.1 TSSOP

Figure 1-1. TSSOP - pinout ATmega16HVB/32HVB



### 1.2 Pin Descriptions

#### 1.2.1 VFET

High voltage supply pin. This pin is used as supply for the internal voltage regulator, described in "Voltage Regulator" on page 130.

#### 1.2.2 VCC

Digital supply voltage. Normally connected to VREG.

#### 1.2.3 VREG

Output from the internal Voltage Regulator. Used for external decoupling to ensure stable regulator operation. For details, see "Voltage Regulator" on page 130.

## 1.2.4 VREF

Internal Voltage Reference for external decoupling. For details, see ["Voltage Reference and Temperature Sensor" on page 122](#).

## 1.2.5 VREFGND

Ground for decoupling of Internal Voltage Reference. For details, see ["Voltage Reference and Temperature Sensor" on page 122](#). Do not connect to GND or SGND on PCB.

## 1.2.6 GND

Ground

## 1.2.7 Port A (PA3..PA0)

Port A serves as a low-voltage 4-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). 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 ATmega16HVB/32HVB as listed in ["Alternate Functions of Port A" on page 74](#).

## 1.2.8 Port B (PB7..PB0)

Port B is a low-voltage 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). 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 ATmega16HVB/32HVB as listed in ["Alternate Functions of Port B" on page 75](#).

## 1.2.9 Port C (PC5)

Port C (PC5) is a high voltage Open Drain output port. Port C serves the functions of various special features of the ATmega16HVB/32HVB as listed in ["Alternate Functions of Port C" on page 65](#).

## 1.2.10 Port C (PC4..PC0)

Port C is a 5-bit high voltage Open Drain bi-directional I/O port. Port C serves the functions of various special features of the ATmega16HVB/32HVB as listed in ["Alternate Functions of Port C" on page 65](#).

## 1.2.11 OC/OD

High voltage output to drive Charge/Discharge. For details, see ["FET Driver" on page 145](#).

## 1.2.12 PI/NI

Filtered positive/negative input from external current sense resistor, used to by the Coulomb Counter ADC to measure charge/discharge currents flowing in the battery pack. For details, see ["Coulomb Counter - Dedicated Fuel Gauging Sigma-delta ADC" on page 108](#).

## 1.2.13 PPI/NNI

Unfiltered positive/negative input from external current sense resistor, used by the battery protection circuit, for over-current and short-circuit detection. For details, see ["Battery Protection" on page 133](#).

## 1.2.14 NV/PV1/PV2/PV3/PV4

NV, PV1, PV2, PV3, and PV4 are the inputs for battery cells 1, 2, 3 and 4, used by the Voltage ADC to measure each cell voltage. For details, see ["Voltage ADC – 7-channel General Purpose 12-bit Sigma-Delta ADC" on page 116](#).

## 1.2.15 PVT

Defines the source voltage level for the Charge FET driver. For details, see ["FET Driver" on page 145](#).

## 1.2.16 BATT

Input for detecting when a charger is connected. Defines the source voltage level for the Discharge FET driver. For details, see ["FET Driver" on page 145](#).

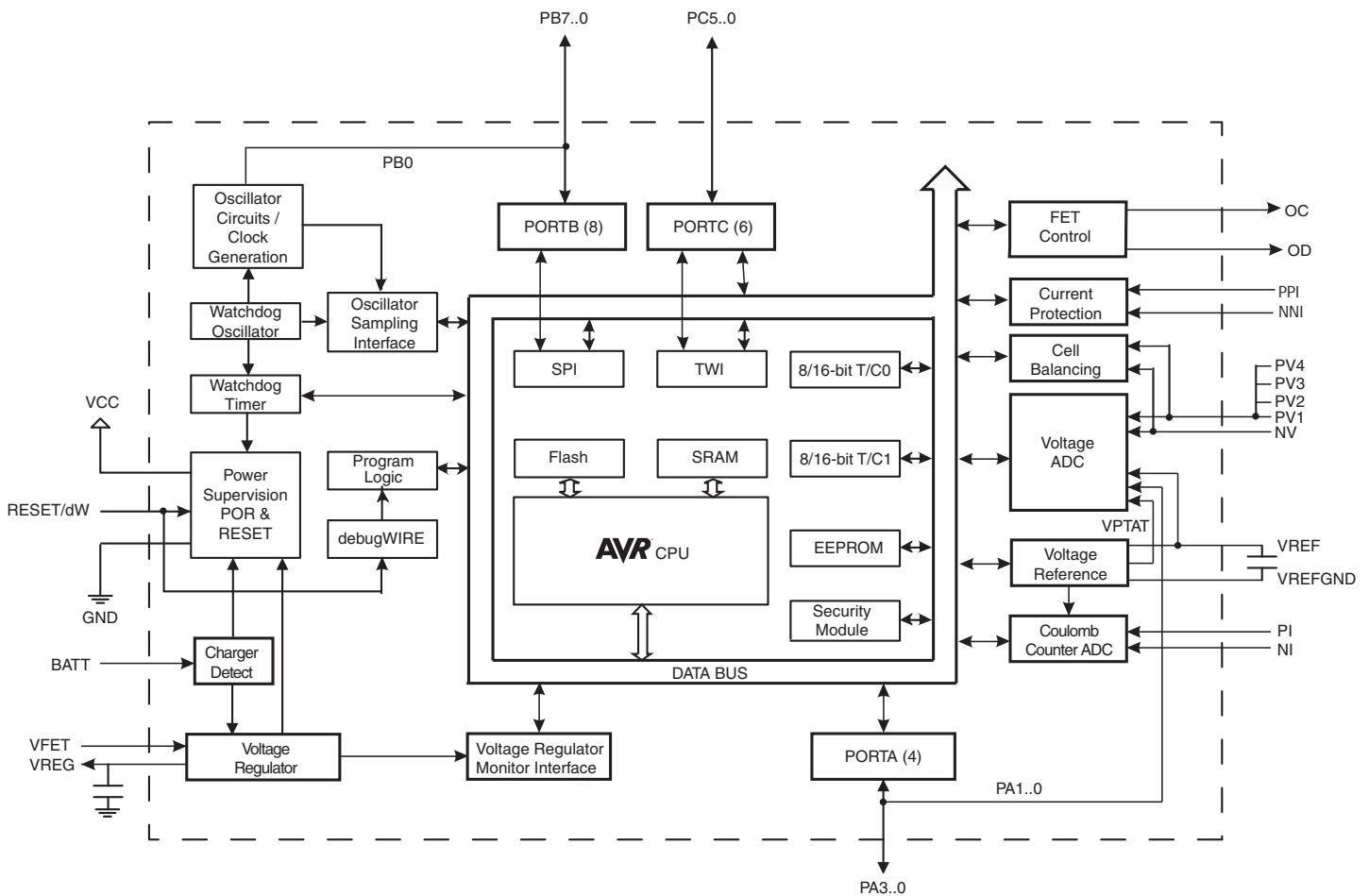
## 1.2.17 $\overline{\text{RESET}}$ /dw

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 11 on page 38. Shorter pulses are not guaranteed to generate a reset. This pin is also used as debugWIRE communication pin.

## 2. Overview

The ATmega16HVB/32HVB is a monitoring and protection circuit for 3 and 4-cell Li-ion applications with focus on high security/authentication, low cost and high utilization of the cell energy. The device contains secure authentication features as well as autonomous battery protection during charging and discharging. The External Protection Input can be used to implement other battery protection mechanisms using external components, e.g. protection against chargers with too high charge voltage can be easily implemented with a few low cost passive components. The feature set makes the ATmega16HVB/32HVB a key component in any system focusing on high security, battery protection, high system utilization and low cost.

Figure 2-1. Block Diagram



ATmega16HVB/32HVB provides the necessary redundancy on-chip to make sure that the battery is protected in critical failure modes. The chip is specifically designed to provide safety for the battery cells in case of pin shorting, loss of power (either caused by battery pack short or  $V_{CC}$

short), illegal charger connection or software runaway. This makes ATmega16HVB/32HVB the ideal 1-chip solution for applications with focus on high safety.

The ATmega16HVB/32HVB features an integrated voltage regulator that operates at a wide range of input voltages, 4 - 25 volts. This voltage is regulated to a constant supply voltage of nominally 3.3 volts for the integrated logic and analog functions. The regulator capabilities, combined with a extremely low power consumption in the power saving modes, greatly enhances the cell energy utilization compared to existing solutions.

The chip utilizes Atmel's patented Deep Under-voltage Recovery (DUVR) mode that supports pre-charging of deeply discharged battery cells without using a separate Pre-charge FET. Optionally, Pre-charge FETs are supported for integration into many existing battery charging schemes.

The battery protection monitors the charge and discharge current to detect illegal conditions and protect the battery from these when required. A 12-bit Voltage ADC allows software to monitor each cell voltage individually with high accuracy. The ADC also provides one internal input channel to measure on-chip temperature and two input channels intended for external thermistors. An 18-bit ADC optimized for Coulomb Counting accumulates charge and discharge currents and reports accumulated current with high resolution and accuracy. It can also be used to provide instantaneous current measurements with 13 bit resolution. Integrated Cell Balancing FETs allow cell balancing algorithms to be implemented in software.

The MCU provides the following features: 16K/32K bytes of In-System Programmable Flash with Read-While-Write capabilities, 512/1K bytes EEPROM, 1K/2K bytes SRAM. 32 general purpose working registers, 12 general purpose I/O lines, 5 general purpose high voltage open drain I/O lines, one general purpose super high voltage open drain output, debugWIRE for On-chip debugging and SPI for In-system Programming, a SM-Bus compliant TWI module, two flexible Timer/Counters with Input Capture and compare modes.

Internal and external interrupts, a 12-bit Sigma Delta ADC for voltage and temperature measurements, a high resolution Sigma Delta ADC for Coulomb Counting and instantaneous current measurements, integrated cell balancing FETs, Additional Secure Authentication Features, an autonomous Battery Protection module, a programmable Watchdog Timer with internal Oscillator, and software selectable power saving modes.

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 device is manufactured using Atmel's high voltage 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 and highly accurate analog front-end in a monolithic chip.

The Atmel ATmega16HVB/32HVB is a powerful microcontroller that provides a highly flexible and cost effective solution. It is part of the AVR Smart Battery family that provides secure

authentication, highly accurate monitoring and autonomous protection for Lithium-ion battery cells.

The ATmega16HVB/32HVB AVR is supported with a full suite of program and system development tools including: C Compilers, Macro Assemblers, Program Debugger/Simulators, and On-chip Debugger.

## 2.1 Comparison Between ATmega16HVB and ATmega32HVB

The ATmega16HVB and ATmega32HVB differ only in memory size for Flash, EEPROM and internal SRAM. [Table 2-1](#) summarizes the different configuration for the two devices.

**Table 2-1.** Configuration summary

Device	Flash	EEPROM	SRAM
ATmega16HVB	16K	512	1K
ATmega32HVB	32K	1K	2K

## 3. About

### 3.1 Disclaimer

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

### 3.2 Resources

A comprehensive set of development tools, application notes and datasheets are available for download on <http://www.atmel.com/avr.n1>

### 3.3 Code Examples

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

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

### 3.4 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.



## 4. Register Summary

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page		
(0xFF)	Reserved	-	-	-	-	-	-	-	-			
(0xFE)	BPPLR	-	-	-	-	-	-	BPPLE	BPPL	138		
(0xFD)	BPCR	-	-	EPID	SCD	DOCD	COCD	DHCD	CHCD	139		
(0xFC)	BPHCTR	-	-	HCPT[5:0]								140
(0xFB)	BPOCTR	-	-	OCPT[5:0]								140
(0xFA)	BPSCTR	-	SCPT[6:0]									140
(0xF9)	BPCHCD					CHCDL[7:0]						143
(0xF8)	BPDHCD					DHCDL[7:0]						142
(0xF7)	BPCOCD					COCDL[7:0]						142
(0xF6)	BPDOCD					DOCDL[7:0]						141
(0xF5)	BPSCD					SCDL[7:0]						141
(0xF4)	Reserved	-	-	-	-	-	-	-	-			
(0xF3)	BPIFR	-	-	-	SCIF	DOCIF	COCIF	DHCIF	CHCIF	144		
(0xF2)	BPIMSK	-	-	-	SCIE	DOCIE	COCIE	DHCIE	CHCIE	143		
(0xF1)	CBCR	-	-	-	-	CBE4	CBE3	CBE2	CBE1	151		
(0xF0)	FCSR	-	-	-	-	DUVRD	CPS	DFE	CFE	148		
(0xEF)	Reserved	-	-	-	-	-	-	-	-			
(0xEE)	Reserved	-	-	-	-	-	-	-	-			
(0xED)	Reserved	-	-	-	-	-	-	-	-			
(0xEC)	Reserved	-	-	-	-	-	-	-	-			
(0xEB)	Reserved	-	-	-	-	-	-	-	-			
(0xEA)	CADRDC	CADRDC[7:0]									115	
(0xE9)	CADRCC	CADRCC[7:0]									114	
(0xE8)	CADCSRC	-	-	-	-	-	-	-	CADVSE	113		
(0xE7)	CADCSRB	-	CADACIE	CADRCIE	CADICIE	-	CADACIF	CADRCIF	CADICIF	112		
(0xE6)	CADCSRA	CADEN	CADPOL	CADUB	CADAS[1:0]		CADSI[1:0]		CADSE	111		
(0xE5)	CADICH	CADIC[15:8]									113	
(0xE4)	CADICL	CADIC[7:0]									113	
(0xE3)	CADAC3	CADAC[31:24]									114	
(0xE2)	CADAC2	CADAC[23:16]									114	
(0xE1)	CADAC1	CADAC[15:8]									114	
(0xE0)	CADAC0	CADAC[7:0]									114	
(0xDF)	Reserved	-	-	-	-	-	-	-	-			
(0xDE)	Reserved	-	-	-	-	-	-	-	-			
(0xDD)	Reserved	-	-	-	-	-	-	-	-			
(0xDC)	Reserved	-	-	-	-	-	-	-	-			
(0xDB)	Reserved	-	-	-	-	-	-	-	-			
(0xDA)	Reserved	-	-	-	-	-	-	-	-			
(0xD9)	Reserved	-	-	-	-	-	-	-	-			
(0xD8)	Reserved	-	-	-	-	-	-	-	-			
(0xD7)	Reserved	-	-	-	-	-	-	-	-			
(0xD6)	Reserved	-	-	-	-	-	-	-	-			
(0xD5)	Reserved	-	-	-	-	-	-	-	-			
(0xD4)	CHGDCSR	-	-	-	BATTVPV	CHGDISC1	CHGDISC1	CHGDIF	CHGDIE	129		
(0xD3)	Reserved	-	-	-	-	-	-	-	-			
(0xD2)	BGCSR	-	-	BGD	BGSCDE	-	-	BGSCDIF	BGSCDIE	125		
(0xD1)	BGCRR	BGCRR[7:0]									124	
(0xD0)	BGCCR	-	-	BGCC[5:0]							9	
(0xCF)	Reserved	-	-	-	-	-	-	-	-			
(0xCE)	Reserved	-	-	-	-	-	-	-	-			
(0xCD)	Reserved	-	-	-	-	-	-	-	-			
(0xCC)	Reserved	-	-	-	-	-	-	-	-			
(0xCB)	Reserved	-	-	-	-	-	-	-	-			
(0xCA)	Reserved	-	-	-	-	-	-	-	-			
(0xC9)	Reserved	-	-	-	-	-	-	-	-			
(0xC8)	ROCR	ROCS	-	-	ROCD	-	-	ROCWIF	ROCWIE	132		
(0xC7)	Reserved	-	-	-	-	-	-	-	-			
(0xC6)	Reserved	-	-	-	-	-	-	-	-			
(0xC5)	Reserved	-	-	-	-	-	-	-	-			
(0xC4)	Reserved	-	-	-	-	-	-	-	-			
(0xC3)	Reserved	-	-	-	-	-	-	-	-			
(0xC2)	Reserved	-	-	-	-	-	-	-	-			
(0xC1)	Reserved	-	-	-	-	-	-	-	-			
(0xC0)	Reserved	-	-	-	-	-	-	-	-			

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page	
(0xBF)	Reserved	–	–	–	–	–	–	–	–		
(0xBE)	TWBCSR	TWBCIF	TWBCIE	–	–	–	TWBDT1	TWBDT0	TWBCIP	183	
(0xBD)	TWAMR	TWAM[6:0]							–	–	183
(0xBC)	TWCR	TWINT	TWEA	TWSTA	TWSTO	TWWC	TWEN	–	TWIE	180	
(0xBB)	TWDR	2-wire Serial Interface Data Register									182
(0xBA)	TWAR	TWA[6:0]							–	TWGCE	182
(0xB9)	TWSR	TWS[7:3]					–	–	TWPS1	TWPS0	181
(0xB8)	TWBR	2-wire Serial Interface Bit Rate Register									180
(0xB7)	Reserved	–	–	–	–	–	–	–	–		
(0xB6)	Reserved	–	–	–	–	–	–	–	–		
(0xB5)	Reserved	–	–	–	–	–	–	–	–		
(0xB4)	Reserved	–	–	–	–	–	–	–	–		
(0xB3)	Reserved	–	–	–	–	–	–	–	–		
(0xB2)	Reserved	–	–	–	–	–	–	–	–		
(0xB1)	Reserved	–	–	–	–	–	–	–	–		
(0xB0)	Reserved	–	–	–	–	–	–	–	–		
(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)	Reserved	–	–	–	–	–	–	–	–		
(0x8A)	Reserved	–	–	–	–	–	–	–	–		
(0x89)	OCR1B	Timer/Counter1 – Output Compare Register B									95
(0x88)	OCR1A	Timer/Counter1 – Output Compare Register A									95
(0x87)	Reserved	–	–	–	–	–	–	–	–		
(0x86)	Reserved	–	–	–	–	–	–	–	–		
(0x85)	TCNT1H	Timer/Counter1 (8 Bit) High Byte									95
(0x84)	TCNT1L	Timer/Counter1 (8 Bit) Low Byte									95
(0x83)	Reserved	–	–	–	–	–	–	–	–		
(0x82)	Reserved	–	–	–	–	–	–	–	–		
(0x81)	TCCR1B	–	–	–	–	–	CS12	CS11	CS10	81	
(0x80)	TCCR1A	TCW1	ICEN1	ICNC1	ICES1	ICS1	–	–	WGM10	94	
(0x7F)	Reserved	–	–	–	–	–	–	–	–		
(0x7E)	DIDR0	–	–	–	–	–	–	PA1DID	PA0DID	121	



Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
(0x7D)	Reserved	–	–	–	–	–	–	–	–	
(0x7C)	VADMUX	–	–	–	–	VADMUX[3:0]				119
(0x7B)	Reserved	–	–	–	–	–	–	–	–	
(0x7A)	VADCSR	–	–	–	–	VADEN	VADSC	VADCCIF	VADCCIE	119
(0x79)	VADCH	–	–	–	–	VADC Data Register High byte				120
(0x78)	VADCL	VADC Data Register Low byte								120
(0x77)	Reserved	–	–	–	–	–	–	–	–	
(0x76)	Reserved	–	–	–	–	–	–	–	–	
(0x75)	Reserved	–	–	–	–	–	–	–	–	
(0x74)	Reserved	–	–	–	–	–	–	–	–	
(0x73)	Reserved	–	–	–	–	–	–	–	–	
(0x72)	Reserved	–	–	–	–	–	–	–	–	
(0x71)	Reserved	–	–	–	–	–	–	–	–	
(0x70)	Reserved	–	–	–	–	–	–	–	–	
(0x6F)	TIMSK1	–	–	–	–	ICIE1	OCIE1B	OCIE1A	TOIE1	96
(0x6E)	TIMSK0	–	–	–	–	ICIE0	OCIE0B	OCIE0A	TOIE0	96
(0x6D)	Reserved	–	–	–	–	–	–	–	–	
(0x6C)	PCMSK1	PCINT[15:8]								60
(0x6B)	PCMSK0	–	–	–	–	PCINT[3:0]				61
(0x6A)	Reserved	–	–	–	–	–	–	–	–	
(0x69)	EICRA	ISC31	ISC30	ISC21	ISC20	ISC11	ISC10	ISC01	ISC00	58
(0x68)	PCICR	–	–	–	–	–	–	PCIE1	PCIE0	60
(0x67)	Reserved	–	–	–	–	–	–	–	–	
(0x66)	FOSCCAL	Fast Oscillator Calibration Register								32
(0x65)	Reserved	–	–	–	–	–	–	–	–	
(0x64)	PRR0	–	PRTWI	PRVRM	–	PRSPI	PRTIM1	PRTIM0	PRVADC	40
(0x63)	Reserved	–	–	–	–	–	–	–	–	
(0x62)	Reserved	–	–	–	–	–	–	–	–	
(0x61)	CLKPR	CLKPCE	–	–	–	–	–	CLKPS1	CLKPS0	32
(0x60)	WDTCR	WDIF	WDIE	WDP3	WDCE	WDE	WDP2	WDP1	WDP0	49
0x3F (0x5F)	SREG	I	T	H	S	V	N	Z	C	10
0x3E (0x5E)	SPH	SP15	SP14	SP13	SP12	SP11	SP10	SP9	SP8	13
0x3D (0x5D)	SPL	SP7	SP6	SP5	SP4	SP3	SP2	SP1	SP0	13
0x3C (0x5C)	Reserved	–	–	–	–	–	–	–	–	
0x3B (0x5B)	Reserved	–	–	–	–	–	–	–	–	
0x3A (0x5A)	Reserved	–	–	–	–	–	–	–	–	
0x39 (0x59)	Reserved	–	–	–	–	–	–	–	–	
0x38 (0x58)	Reserved	–	–	–	–	–	–	–	–	
0x37 (0x57)	SPMCSR	SPMIE	RWWSB	SIGRD	CTPB	RFLB	PGWRT	PGERS	SPMEN	202
0x36 (0x56)	Reserved	–	–	–	–	–	–	–	–	
0x35 (0x55)	MCUCR	–	–	CKOE	PUD	–	–	IVSEL	IVCE	78/32
0x34 (0x54)	MCUSR	–	–	–	OCDRF	WDRF	BODRF	EXTRF	PORF	49
0x33 (0x53)	SMCR	–	–	–	–	SM[2:0]		–	SE	39
0x32 (0x52)	Reserved	–	–	–	–	–	–	–	–	
0x31 (0x51)	DWDR	debugWIRE Data Register								186
0x30 (0x50)	Reserved	–	–	–	–	–	–	–	–	
0x2F (0x4F)	Reserved	–	–	–	–	–	–	–	–	
0x2E (0x4E)	SPDR	SPI Data Register								107
0x2D (0x4D)	SPSR	SPIF	WCOL	–	–	–	–	–	SPI2X	106
0x2C (0x4C)	SPCR	SPIE	SPE	DORD	MSTR	CPOL	CPHA	SPR1	SPR0	105
0x2B (0x4B)	GPIOR2	General Purpose I/O Register 2								24
0x2A (0x4A)	GPIOR1	General Purpose I/O Register 1								24
0x29 (0x49)	OCR0B	Timer/Counter0 Output Compare Register B								95
0x28 (0x48)	OCR0A	Timer/Counter0 Output Compare Register A								95
0x27 (0x47)	TCNT0H	Timer/Counter0 (8 Bit) High Byte								95
0x26 (0x46)	TCNT0L	Timer/Counter0 (8 Bit) Low Byte								95
0x25 (0x45)	TCCR0B	–	–	–	–	–	CS02	CS01	CS00	81
0x24 (0x44)	TCCR0A	TCW0	ICEN0	ICNC0	ICES0	ICS0	–	–	WGM00	94
0x23 (0x43)	GTCCR	TSM	–	–	–	–	–	–	PSRSYNC	
0x22 (0x42)	EEARH	–	–	–	–	–	–	EEPROM High byte		20
0x21 (0x41)	EEARL	EEPROM Address Register Low Byte								20
0x20 (0x40)	EEDR	EEPROM Data Register								20
0x1F (0x3F)	EECR	–	–	EEMP1	EEMP0	EERIE	EEMPE	EEPE	EERE	21
0x1E (0x3E)	GPIOR0	General Purpose I/O Register 0								24
0x1D (0x3D)	EIMSK	–	–	–	–	INT3	INT2	INT1	INT0	59
0x1C (0x3C)	EIFR	–	–	–	–	INTF3	INTF2	INTF1	INTF0	59



Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
0x1B (0x3B)	PCIFR	–	–	–	–	–	–	PCIF1	PCIF0	60
0x1A (0x3A)	Reserved	–	–	–	–	–	–	–	–	
0x19 (0x39)	Reserved	–	–	–	–	–	–	–	–	
0x18 (0x38)	Reserved	–	–	–	–	–	–	–	–	
0x17 (0x37)	OSICSR	–	–	–	OSISELO	–	–	OSIST	OSIEN	33
0x16 (0x36)	TIFR1	–	–	–	–	ICF1	OCF1B	OCF1A	TOV1	96
0x15 (0x35)	TIFR0	–	–	–	–	ICF0	OCF0B	OCF0A	TOV0	96
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)	Reserved	–	–	–	–	–	–	–	–	
0x0A (0x2A)	Reserved	–	–	–	–	–	–	–	–	
0x09 (0x29)	Reserved	–	–	–	–	–	–	–	–	
0x08 (0x28)	PORTC	–	–	PORTC5	PORTC4	PORTC3	PORTC2	PORTC1	PORTC0	66
0x07 (0x27)	Reserved	–	–	–	–	–	–	–	–	
0x06 (0x26)	PINC	–	–	–	PINC4	PINC3	PINC2	PINC1	PINC0	66
0x05 (0x25)	PORTB	PORTB7	PORTB6	PORTB5	PORTB4	PORTB3	PORTB2	PORTB1	PORTB0	78
0x04 (0x24)	DDRB	DDB7	DDB6	DDB5	DDB4	DDB3	DDB2	DDB1	DDB0	78
0x03 (0x23)	PINB	PINB7	PINB6	PINB5	PINB4	PINB3	PINB2	PINB1	PINB0	78
0x02 (0x22)	PORTA	–	–	–	–	PORTA3	PORTA2	PORTA1	PORTA0	78
0x01 (0x21)	DDRA	–	–	–	–	DDA3	DDA2	DDA1	DDA0	78
0x00 (0x20)	PINA	–	–	–	–	PINA3	PINA2	PINA1	PINA0	78

- Notes:
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 \$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.
  3. 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.
  4. 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 ATmega16HVB/32HVB 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 in SRAM, only the ST/STS/STD and LD/LDS/LDD instructions can be used.

## 5. Instruction Set Summary

Mnemonics	Operands	Description	Operation	Flags	#Clocks
<b>ARITHMETIC AND LOGIC INSTRUCTIONS</b>					
ADD	Rd, Rr	Add two Registers	$Rd \leftarrow Rd + Rr$	Z,C,N,V,H	1
ADC	Rd, Rr	Add with Carry two Registers	$Rd \leftarrow Rd + Rr + C$	Z,C,N,V,H	1
ADIW	RdI,K	Add Immediate to Word	$Rdh:Rdl \leftarrow Rdh:Rdl + K$	Z,C,N,V,S	2
SUB	Rd, Rr	Subtract two Registers	$Rd \leftarrow Rd - Rr$	Z,C,N,V,H	1
SUBI	Rd, K	Subtract Constant from Register	$Rd \leftarrow Rd - K$	Z,C,N,V,H	1
SBC	Rd, Rr	Subtract with Carry two Registers	$Rd \leftarrow Rd - Rr - C$	Z,C,N,V,H	1
SBCI	Rd, K	Subtract with Carry Constant from Reg.	$Rd \leftarrow Rd - K - C$	Z,C,N,V,H	1
SBIW	RdI,K	Subtract Immediate from Word	$Rdh:Rdl \leftarrow Rdh:Rdl - K$	Z,C,N,V,S	2
AND	Rd, Rr	Logical AND Registers	$Rd \leftarrow Rd \cdot Rr$	Z,N,V	1
ANDI	Rd, K	Logical AND Register and Constant	$Rd \leftarrow Rd \cdot K$	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	$Rd \leftarrow Rd \cdot (0xFF - K)$	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	$Rd \leftarrow Rd \cdot Rd$	Z,N,V	1
CLR	Rd	Clear Register	$Rd \leftarrow Rd \oplus Rd$	Z,N,V	1
SER	Rd	Set Register	$Rd \leftarrow 0xFF$	None	1
MUL	Rd, Rr	Multiply Unsigned	$R1:R0 \leftarrow Rd \times Rr$	Z,C	2
MULS	Rd, Rr	Multiply Signed	$R1:R0 \leftarrow Rd \times Rr$	Z,C	2
MULSU	Rd, Rr	Multiply Signed with Unsigned	$R1:R0 \leftarrow Rd \times Rr$	Z,C	2
FMUL	Rd, Rr	Fractional Multiply Unsigned	$R1:R0 \leftarrow (Rd \times Rr) \lll 1$	Z,C	2
FMULS	Rd, Rr	Fractional Multiply Signed	$R1:R0 \leftarrow (Rd \times Rr) \lll 1$	Z,C	2
FMULSU	Rd, Rr	Fractional Multiply Signed with Unsigned	$R1:R0 \leftarrow (Rd \times Rr) \lll 1$	Z,C	2
<b>BRANCH INSTRUCTIONS</b>					
RJMP	k	Relative Jump	$PC \leftarrow PC + k + 1$	None	2
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	3
ICALL		Indirect Call to (Z)	$PC \leftarrow Z$	None	3
CALL	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

## 5. Instruction Set Summary (Continued)

Mnemonics	Operands	Description	Operation	Flags	#Clocks
BRIE	k	Branch if Interrupt Enabled	if (I = 1) then PC ← PC + k + 1	None	1/2
BRID	k	Branch if Interrupt Disabled	if (I = 0) then PC ← PC + k + 1	None	1/2
<b>BIT AND BIT-TEST INSTRUCTIONS</b>					
SBI	P,b	Set Bit in I/O Register	I/O(P,b) ← 1	None	2
CBI	P,b	Clear Bit in I/O Register	I/O(P,b) ← 0	None	2
LSL	Rd	Logical Shift Left	Rd(n+1) ← Rd(n), Rd(0) ← 0	Z,C,N,V	1
LSR	Rd	Logical Shift Right	Rd(n) ← Rd(n+1), Rd(7) ← 0	Z,C,N,V	1
ROL	Rd	Rotate Left Through Carry	Rd(0) ← C, Rd(n+1) ← Rd(n), C ← Rd(7)	Z,C,N,V	1
ROR	Rd	Rotate Right Through Carry	Rd(7) ← C, Rd(n) ← Rd(n+1), C ← Rd(0)	Z,C,N,V	1
ASR	Rd	Arithmetic Shift Right	Rd(n) ← Rd(n+1), n=0..6	Z,C,N,V	1
SWAP	Rd	Swap Nibbles	Rd(3..0) ← Rd(7..4), Rd(7..4) ← Rd(3..0)	None	1
BSET	s	Flag Set	SREG(s) ← 1	SREG(s)	1
BCLR	s	Flag Clear	SREG(s) ← 0	SREG(s)	1
BST	Rr, b	Bit Store from Register to T	T ← Rr(b)	T	1
BLD	Rd, b	Bit load from T to Register	Rd(b) ← T	None	1
SEC		Set Carry	C ← 1	C	1
CLC		Clear Carry	C ← 0	C	1
SEN		Set Negative Flag	N ← 1	N	1
CLN		Clear Negative Flag	N ← 0	N	1
SEZ		Set Zero Flag	Z ← 1	Z	1
CLZ		Clear Zero Flag	Z ← 0	Z	1
SEI		Global Interrupt Enable	I ← 1	I	1
CLI		Global Interrupt Disable	I ← 0	I	1
SES		Set Signed Test Flag	S ← 1	S	1
CLS		Clear Signed Test Flag	S ← 0	S	1
SEV		Set Twos Complement Overflow	V ← 1	V	1
CLV		Clear Twos Complement Overflow	V ← 0	V	1
SET		Set T in SREG	T ← 1	T	1
CLT		Clear T in SREG	T ← 0	T	1
SEH		Set Half Carry Flag in SREG	H ← 1	H	1
CLH		Clear Half Carry Flag in SREG	H ← 0	H	1
<b>DATA TRANSFER INSTRUCTIONS</b>					
MOV	Rd, Rr	Move Between Registers	Rd ← Rr	None	1
MOVW	Rd, Rr	Copy Register Word	Rd+1:Rd ← Rr+1:Rr	None	1
LDI	Rd, K	Load Immediate	Rd ← K	None	1
LD	Rd, X	Load Indirect	Rd ← (X)	None	2
LD	Rd, X+	Load Indirect and Post-Inc.	Rd ← (X), X ← X + 1	None	2
LD	Rd, -X	Load Indirect and Pre-Dec.	X ← X - 1, Rd ← (X)	None	2
LD	Rd, Y	Load Indirect	Rd ← (Y)	None	2
LD	Rd, Y+	Load Indirect and Post-Inc.	Rd ← (Y), Y ← Y + 1	None	2
LD	Rd, -Y	Load Indirect and Pre-Dec.	Y ← Y - 1, Rd ← (Y)	None	2
LDD	Rd, Y+q	Load Indirect with Displacement	Rd ← (Y + q)	None	2
LD	Rd, Z	Load Indirect	Rd ← (Z)	None	2
LD	Rd, Z+	Load Indirect and Post-Inc.	Rd ← (Z), Z ← Z+1	None	2
LD	Rd, -Z	Load Indirect and Pre-Dec.	Z ← Z - 1, Rd ← (Z)	None	2
LDD	Rd, Z+q	Load Indirect with Displacement	Rd ← (Z + q)	None	2
LDS	Rd, k	Load Direct from SRAM	Rd ← (k)	None	2
ST	X, Rr	Store Indirect	(X) ← Rr	None	2
ST	X+, Rr	Store Indirect and Post-Inc.	(X) ← Rr, X ← X + 1	None	2
ST	-X, Rr	Store Indirect and Pre-Dec.	X ← X - 1, (X) ← Rr	None	2
ST	Y, Rr	Store Indirect	(Y) ← Rr	None	2
ST	Y+, Rr	Store Indirect and Post-Inc.	(Y) ← Rr, Y ← Y + 1	None	2
ST	-Y, Rr	Store Indirect and Pre-Dec.	Y ← Y - 1, (Y) ← Rr	None	2
STD	Y+q, Rr	Store Indirect with Displacement	(Y + q) ← Rr	None	2
ST	Z, Rr	Store Indirect	(Z) ← Rr	None	2
ST	Z+, Rr	Store Indirect and Post-Inc.	(Z) ← Rr, Z ← Z + 1	None	2
ST	-Z, Rr	Store Indirect and Pre-Dec.	Z ← Z - 1, (Z) ← Rr	None	2
STD	Z+q, Rr	Store Indirect with Displacement	(Z + q) ← Rr	None	2
STS	k, Rr	Store Direct to SRAM	(k) ← Rr	None	2
LPM		Load Program Memory	R0 ← (Z)	None	3
LPM	Rd, Z	Load Program Memory	Rd ← (Z)	None	3
LPM	Rd, Z+	Load Program Memory and Post-Inc	Rd ← (Z), Z ← Z+1	None	3
SPM		Store Program Memory	(Z) ← R1:R0	None	-
IN	Rd, P	In Port	Rd ← P	None	1

## 5. Instruction Set Summary (Continued)

Mnemonics	Operands	Description	Operation	Flags	#Clocks
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
<b>MCU CONTROL INSTRUCTIONS</b>					
NOP		No Operation		None	1
SLEEP		Sleep	(see specific descr. for Sleep function)	None	1
WDR		Watchdog Reset	(see specific descr. for WDR/timer)	None	1
BREAK		Break	For On-chip Debug Only	None	N/A

## 6. Ordering Information

### 6.1 ATmega16HVB

Speed (MHz)	Power Supply	Ordering Code	Package	Operation Range
1 - 8 MHz	4 - 25V	ATMEGA16HVB-8X3	44X1	-40°C to 85°C

Package Type	
44X1	44-lead, 4.4 mm Body Width, Plastic Thin Shrink Small Outline Package (TSSOP)



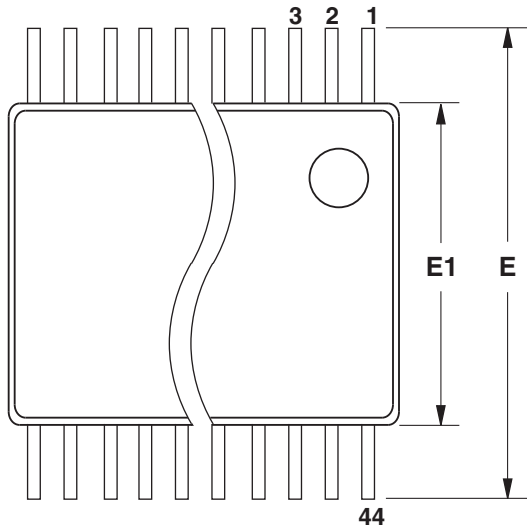
## 6.2 ATmega32HVB

Speed (MHz)	Power Supply	Ordering Code	Package	Operation Range
1 - 8 MHz	4 - 25V	ATMEGA32HVB-8X3	44X1	-40°C to 85°C

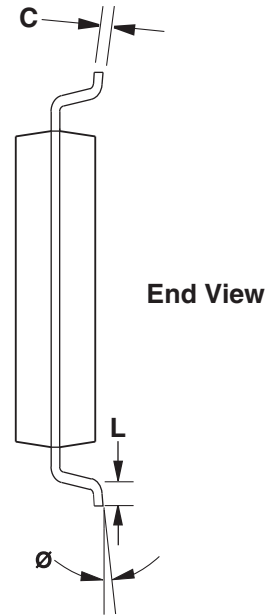
Package Type	
<b>44X1</b>	44-lead, 4.4 mm Body Width, Plastic Thin Shrink Small Outline Package (TSSOP)

## 7. Packaging Information

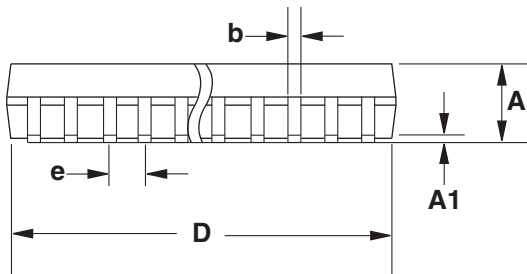
### 7.1 44X1



Top View



End View



Side View

COMMON DIMENSIONS  
(Unit of Measure = mm)

SYMBOL	MIN	NOM	MAX	NOTE
A	–	–	1.20	
A1	0.05	–	0.15	
b	0.17	–	0.27	
C	0.09	–	0.20	
D	10.90	11.00	11.10	
E1	4.30	4.40	4.50	
E	6.20	6.40	6.60	
e	0.50 TYP			
L	0.50	0.60	0.70	
ø	0°	–	8°	

Note: These drawings are for general information only. Refer to JEDEC Drawing MO-153BE.

5/16/07



2325 Orchard Parkway  
San Jose, CA 95131

**TITLE**  
44X1, 44-lead, 4.4 mm Body Width, Plastic Thin Shrink  
Small Outline Package (TSSOP)

**DRAWING NO.**  
44X1

**REV.**  
A

## 8. Errata

### 8.1 ATmega16HVB

#### 8.1.1 Rev. A

No known errata.

### 8.2 ATmega32HVB

#### 8.2.1 Rev. A

No known errata.

## **9. Revision history**

### **9.1 Rev A 08/09**

1. Initial revision





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