

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 16 MIPS Throughput at 16 MHz
 - On-chip 2-cycle Multiplier
- Nonvolatile Program and Data Memories
 - 16K Bytes of In-System Self-Programmable Flash
Endurance: 10,000 Write/Erase Cycles
 - Optional Boot Code Section with Independent Lock Bits
In-System Programming by On-chip Boot Program
True Read-While-Write Operation
 - 512 Bytes EEPROM
Endurance: 100,000 Write/Erase Cycles
 - 1K Byte Internal SRAM
 - 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
 - Four PWM Channels
 - 8-channel, 10-bit ADC
 - 8 Single-ended Channels
 - 7 Differential Channels in TQFP Package Only
 - 2 Differential Channels with Programmable Gain at 1x, 10x, or 200x
 - Byte-oriented Two-wire Serial Interface
 - Programmable Serial USART
 - Master/Slave SPI Serial Interface
 - Programmable Watchdog Timer with Separate On-chip Oscillator
 - On-chip Analog Comparator
- 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, and 44-pad QFN/MLF
- Operating Voltages
 - 2.7 - 5.5V for ATmega16L
 - 4.5 - 5.5V for ATmega16
- Speed Grades
 - 0 - 8 MHz for ATmega16L
 - 0 - 16 MHz for ATmega16
- Power Consumption @ 1 MHz, 3V, and 25°C for ATmega16L
 - Active: 1.1 mA
 - Idle Mode: 0.35 mA
 - Power-down Mode: < 1 µA



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

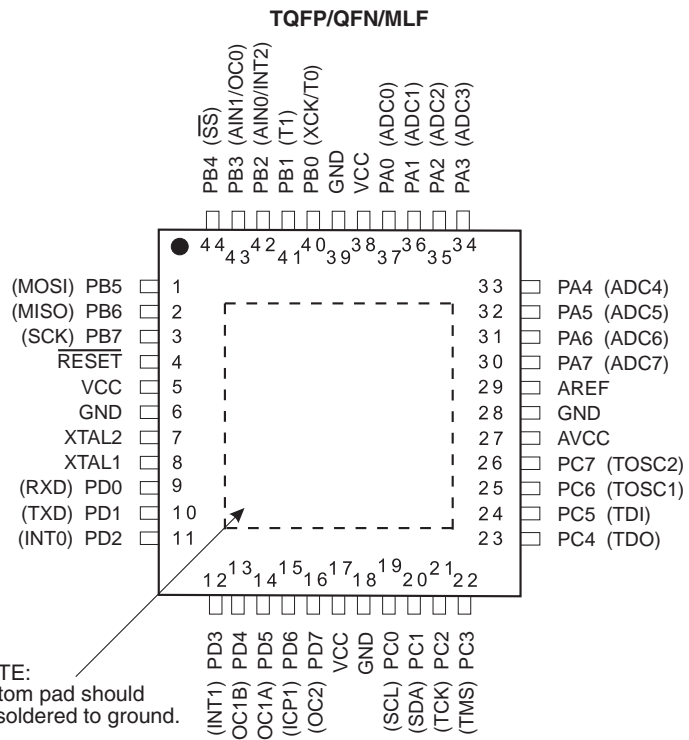
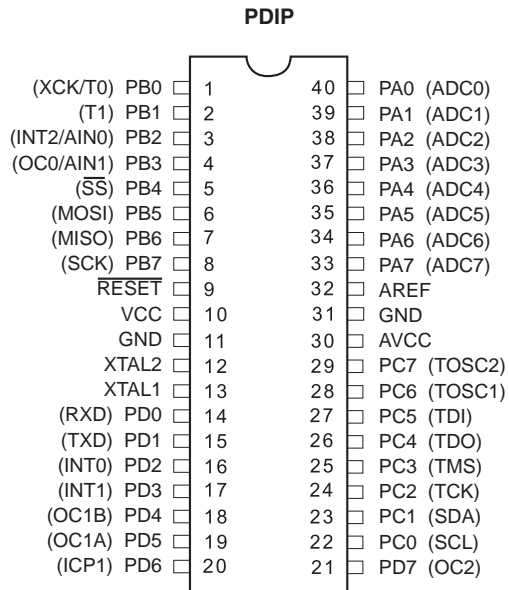
ATmega16
ATmega16L

Summary



Pin Configurations

Figure 1. Pinout ATmega16



Disclaimer

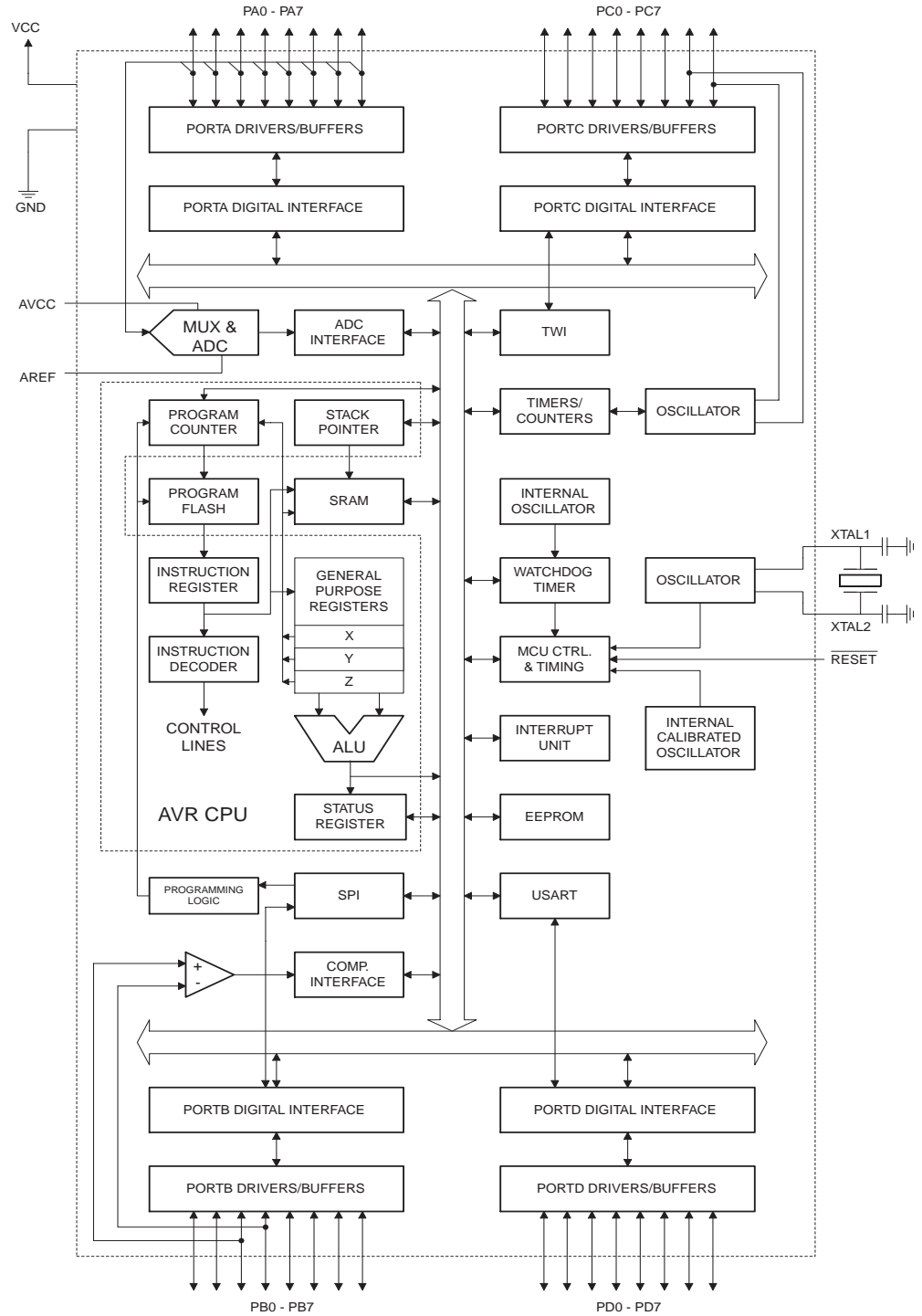
Typical values contained in this datasheet are based on simulations and characterization of other AVR microcontrollers manufactured on the same process technology. Min and Max values will be available after the device is characterized.

Overview

The ATmega16 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 ATmega16 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

Block Diagram

Figure 2. 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 ATmega16 provides the following features: 16K bytes of In-System Programmable Flash Program memory with Read-While-Write capabilities, 512 bytes EEPROM, 1K byte SRAM, 32 general purpose I/O lines, 32 general purpose working registers, a JTAG interface for Boundary-scan, On-chip Debugging support and programming, three flexible Timer/Counters with compare modes, Internal and External Interrupts, a serial programmable USART, a byte oriented Two-wire Serial Interface, an 8-channel, 10-bit ADC with optional differential input stage with programmable gain (TQFP package only), a programmable Watchdog Timer with Internal Oscillator, an SPI serial port, and six software selectable power saving modes. The Idle mode stops the CPU while allowing the USART, Two-wire interface, A/D Converter, 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 External 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 ATmega16 is a powerful microcontroller that provides a highly-flexible and cost-effective solution to many embedded control applications.

The ATmega16 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.

Pin Descriptions

VCC	Digital supply voltage.
GND	Ground.
Port A (PA7..PA0)	Port A serves as the analog inputs to the A/D Converter. Port A also serves as an 8-bit bi-directional I/O port, if the A/D Converter is not used. Port pins can provide internal pull-up resistors (selected for each bit). The Port A output buffers have symmetrical drive characteristics with both high sink and source capability. When pins PA0 to PA7 are used as inputs and are externally pulled low, they will source current if the internal 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 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 ATmega16 as listed on page 58.

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. If the JTAG interface is enabled, the pull-up resistors on pins PC5(TDI), PC3(TMS) and PC2(TCK) will be activated even if a reset occurs.

Port C also serves the functions of the JTAG interface and other special features of the ATmega16 as listed on page 61.

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 ATmega16 as listed on page 63.

$\overline{\text{RESET}}$

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 Table 15 on page 38. Shorter pulses are not guaranteed to generate a reset.

XTAL1

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

XTAL2

Output from the inverting Oscillator amplifier.

AVCC

AVCC is the supply voltage pin for Port A and the A/D 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.

AREF

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

Resources

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



Register Summary

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
\$3F (\$5F)	SREG	I	T	H	S	V	N	Z	C	9
\$3E (\$5E)	SPH	–	–	–	–	–	SP10	SP9	SP8	12
\$3D (\$5D)	SPL	SP7	SP6	SP5	SP4	SP3	SP2	SP1	SP0	12
\$3C (\$5C)	OCR0	Timer/Counter0 Output Compare Register								85
\$3B (\$5B)	GICR	INT1	INT0	INT2	–	–	–	IVSEL	IVCE	48, 69
\$3A (\$5A)	GIFR	INTF1	INTF0	INTF2	–	–	–	–	–	70
\$39 (\$59)	TIMSK	OCIE2	TOIE2	TICIE1	OCIE1A	OCIE1B	TOIE1	OCIE0	TOIE0	85, 116, 134
\$38 (\$58)	TIFR	OCF2	TOV2	ICF1	OCF1A	OCF1B	TOV1	OCF0	TOV0	86, 117, 134
\$37 (\$57)	SPMCR	SPMIE	RWWWSB	–	RWWWSRE	BLBSET	PGWRT	PGERS	SPMEN	253
\$36 (\$56)	TWCR	TWINT	TWEA	TWSTA	TWSTO	TWWC	TWEN	–	TWIE	181
\$35 (\$55)	MCUCR	SM2	SE	SM1	SM0	ISC11	ISC10	ISC01	ISC00	32, 68
\$34 (\$54)	MCUCSR	JTD	ISC2	–	JTRF	WDRF	BORF	EXTRF	PORF	41, 69, 232
\$33 (\$53)	TCCR0	FOC0	WGM00	COM01	COM00	WGM01	CS02	CS01	CS00	83
\$32 (\$52)	TCNT0	Timer/Counter0 (8 Bits)								85
\$31 ⁽¹⁾ (\$51) ⁽¹⁾	OSCCAL	Oscillator Calibration Register								30
	OCDR	On-Chip Debug Register								228
\$30 (\$50)	SFIOR	ADTS2	ADTS1	ADTS0	–	ACME	PUD	PSR2	PSR10	57, 88, 135, 202, 222
\$2F (\$4F)	TCCR1A	COM1A1	COM1A0	COM1B1	COM1B0	FOC1A	FOC1B	WGM11	WGM10	111
\$2E (\$4E)	TCCR1B	ICNC1	ICES1	–	WGM13	WGM12	CS12	CS11	CS10	114
\$2D (\$4D)	TCNT1H	Timer/Counter1 – Counter Register High Byte								115
\$2C (\$4C)	TCNT1L	Timer/Counter1 – Counter Register Low Byte								115
\$2B (\$4B)	OCR1AH	Timer/Counter1 – Output Compare Register A High Byte								115
\$2A (\$4A)	OCR1AL	Timer/Counter1 – Output Compare Register A Low Byte								115
\$29 (\$49)	OCR1BH	Timer/Counter1 – Output Compare Register B High Byte								115
\$28 (\$48)	OCR1BL	Timer/Counter1 – Output Compare Register B Low Byte								115
\$27 (\$47)	ICR1H	Timer/Counter1 – Input Capture Register High Byte								116
\$26 (\$46)	ICR1L	Timer/Counter1 – Input Capture Register Low Byte								116
\$25 (\$45)	TCCR2	FOC2	WGM20	COM21	COM20	WGM21	CS22	CS21	CS20	129
\$24 (\$44)	TCNT2	Timer/Counter2 (8 Bits)								131
\$23 (\$43)	OCR2	Timer/Counter2 Output Compare Register								131
\$22 (\$42)	ASSR	–	–	–	–	AS2	TCN2UB	OCR2UB	TCR2UB	132
\$21 (\$41)	WDTCSR	–	–	–	WDTOE	WDE	WDP2	WDP1	WDP0	43
\$20 ⁽²⁾ (\$40) ⁽²⁾	UBRRH	URSEL	–	–	–	UBRR[11:8]				168
	UCSRC	URSEL	UMSEL	UPM1	UPM0	USBS	UCSZ1	UCSZ0	UCPOL	167
\$1F (\$3F)	EEARH	–	–	–	–	–	–	–	EEAR8	19
\$1E (\$3E)	EEARL	EEPROM Address Register Low Byte								19
\$1D (\$3D)	EEDR	EEPROM Data Register								19
\$1C (\$3C)	EEDCR	–	–	–	–	EERIE	EEMWE	EERE	EERE	19
\$1B (\$3B)	PORTA	PORTA7	PORTA6	PORTA5	PORTA4	PORTA3	PORTA2	PORTA1	PORTA0	66
\$1A (\$3A)	DDRA	DDA7	DDA6	DDA5	DDA4	DDA3	DDA2	DDA1	DDA0	66
\$19 (\$39)	PINA	PINA7	PINA6	PINA5	PINA4	PINA3	PINA2	PINA1	PINA0	66
\$18 (\$38)	PORTB	PORTB7	PORTB6	PORTB5	PORTB4	PORTB3	PORTB2	PORTB1	PORTB0	66
\$17 (\$37)	DDRB	DDB7	DDB6	DDB5	DDB4	DDB3	DDB2	DDB1	DDB0	66
\$16 (\$36)	PINB	PINB7	PINB6	PINB5	PINB4	PINB3	PINB2	PINB1	PINB0	66
\$15 (\$35)	PORTC	PORTC7	PORTC6	PORTC5	PORTC4	PORTC3	PORTC2	PORTC1	PORTC0	67
\$14 (\$34)	DDRC	DDC7	DDC6	DDC5	DDC4	DDC3	DDC2	DDC1	DDC0	67
\$13 (\$33)	PINC	PINC7	PINC6	PINC5	PINC4	PINC3	PINC2	PINC1	PINC0	67
\$12 (\$32)	PORTD	PORTD7	PORTD6	PORTD5	PORTD4	PORTD3	PORTD2	PORTD1	PORTD0	67
\$11 (\$31)	DDRD	DDD7	DDD6	DDD5	DDD4	DDD3	DDD2	DDD1	DDD0	67
\$10 (\$30)	PIND	PIND7	PIND6	PIND5	PIND4	PIND3	PIND2	PIND1	PIND0	67
\$0F (\$2F)	SPDR	SPI Data Register								143
\$0E (\$2E)	SPSR	SPIF	WCOL	–	–	–	–	–	SPI2X	143
\$0D (\$2D)	SPCR	SPIE	SPE	DORD	MSTR	CPOL	CPHA	SPR1	SPR0	141
\$0C (\$2C)	UDR	USART I/O Data Register								164
\$0B (\$2B)	UCSRA	RXC	TXC	UDRE	FE	DOR	PE	U2X	MPCM	165
\$0A (\$2A)	UCSRB	RXCIE	TXCIE	UDRIE	RXEN	TXEN	UCSZ2	RXB8	TXB8	166
\$09 (\$29)	UBRRL	USART Baud Rate Register Low Byte								168
\$08 (\$28)	ACSR	ACD	ACBG	ACO	ACI	ACIE	ACIC	ACIS1	ACIS0	203
\$07 (\$27)	ADMUX	REFS1	REFS0	ADLAR	MUX4	MUX3	MUX2	MUX1	MUX0	218
\$06 (\$26)	ADCSRA	ADEN	ADSC	ADATE	ADIF	ADIE	ADPS2	ADPS1	ADPS0	220
\$05 (\$25)	ADCH	ADC Data Register High Byte								221
\$04 (\$24)	ADCL	ADC Data Register Low Byte								221
\$03 (\$23)	TWDR	Two-wire Serial Interface Data Register								183
\$02 (\$22)	TWAR	TWA6	TWA5	TWA4	TWA3	TWA2	TWA1	TWA0	TWGCE	183

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
\$01 (\$21)	TWSR	TWS7	TWS6	TWS5	TWS4	TWS3	–	TWPS1	TWPS0	182
\$00 (\$20)	TWBR	Two-wire Serial Interface Bit Rate Register								181

- Notes:
1. When the OCDEN Fuse is unprogrammed, the OSCCAL Register is always accessed on this address. Refer to the debugger specific documentation for details on how to use the OCDR Register.
 2. Refer to the USART description for details on how to access UBRRH and UCSRC.
 3. For compatibility with future devices, reserved bits should be written to zero if accessed. Reserved I/O memory addresses should never be written.
 4. 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 \$00 to \$1F only.

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	$Rd \leftarrow \$FF - Rd$	Z,C,N,V	1
NEG	Rd	Two's Complement	$Rd \leftarrow \$00 - Rd$	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	$Rd \leftarrow Rd \bullet (\$FF - K)$	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	$Rd \leftarrow \$FF$	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	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 $(SREG(s) = 1) PC \leftarrow PC + k + 1$	None	1 / 2
BRBC	s, k	Branch if Status Flag Cleared	if $(SREG(s) = 0) PC \leftarrow PC + k + 1$	None	1 / 2
BREQ	k	Branch if Equal	if $(Z = 1) PC \leftarrow PC + k + 1$	None	1 / 2
BRNE	k	Branch if Not Equal	if $(Z = 0) PC \leftarrow PC + k + 1$	None	1 / 2
BRCS	k	Branch if Carry Set	if $(C = 1) PC \leftarrow PC + k + 1$	None	1 / 2
BRCC	k	Branch if Carry Cleared	if $(C = 0) PC \leftarrow PC + k + 1$	None	1 / 2
BRSH	k	Branch if Same or Higher	if $(C = 0) PC \leftarrow PC + k + 1$	None	1 / 2
BRLO	k	Branch if Lower	if $(C = 1) PC \leftarrow PC + k + 1$	None	1 / 2
BRMI	k	Branch if Minus	if $(N = 1) PC \leftarrow PC + k + 1$	None	1 / 2
BRPL	k	Branch if Plus	if $(N = 0) PC \leftarrow PC + k + 1$	None	1 / 2
BRGE	k	Branch if Greater or Equal, Signed	if $(N \oplus V = 0) PC \leftarrow PC + k + 1$	None	1 / 2
BRLT	k	Branch if Less Than Zero, Signed	if $(N \oplus V = 1) PC \leftarrow PC + k + 1$	None	1 / 2
BRHS	k	Branch if Half Carry Flag Set	if $(H = 1) PC \leftarrow PC + k + 1$	None	1 / 2
BRHC	k	Branch if Half Carry Flag Cleared	if $(H = 0) PC \leftarrow PC + k + 1$	None	1 / 2
BRTS	k	Branch if T Flag Set	if $(T = 1) PC \leftarrow PC + k + 1$	None	1 / 2
BRTC	k	Branch if T Flag Cleared	if $(T = 0) PC \leftarrow PC + k + 1$	None	1 / 2
BRVS	k	Branch if Overflow Flag is Set	if $(V = 1) PC \leftarrow PC + k + 1$	None	1 / 2
BRVC	k	Branch if Overflow Flag is Cleared	if $(V = 0) PC \leftarrow PC + k + 1$	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
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
POP	Rd	Pop Register from Stack	Rd ← STACK	None	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

Mnemonics	Operands	Description	Operation	Flags	#Clocks
CLH		Clear Half Carry Flag in SREG	H ← 0	H	1
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

Ordering Information

Speed (MHz)	Power Supply	Ordering Code	Package	Operation Range		
8	2.7 - 5.5V	ATmega16L-8AC	44A	Commercial (0°C to 70°C)		
		ATmega16L-8PC	40P6			
		ATmega16L-8MC	44M1			
				ATmega16L-8AI	44A	Industrial (-40°C to 85°C)
				ATmega16L-8AU ⁽¹⁾	44A	
				ATmega16L-8PI	40P6	
				ATmega16L-8PU ⁽¹⁾	40P6	
		ATmega16L-8MI	44M1			
		ATmega16L-8MU ⁽¹⁾	44M1			
16	4.5 - 5.5V	ATmega16-16AC	44A	Commercial (0°C to 70°C)		
		ATmega16-16PC	40P6			
		ATmega16-16MC	44M1			
				ATmega16-16AI	44A	Industrial (-40°C to 85°C)
				ATmega16-16AU ⁽¹⁾	44A	
				ATmega16-16PI	40P6	
				ATmega16-16PU ⁽¹⁾	40P6	
				ATmega16-16MI	44M1	
				ATmega16-16MU ⁽¹⁾	44M1	

Note: 1. Pb-free packaging alternative, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.

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, Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)

Packaging Information

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			

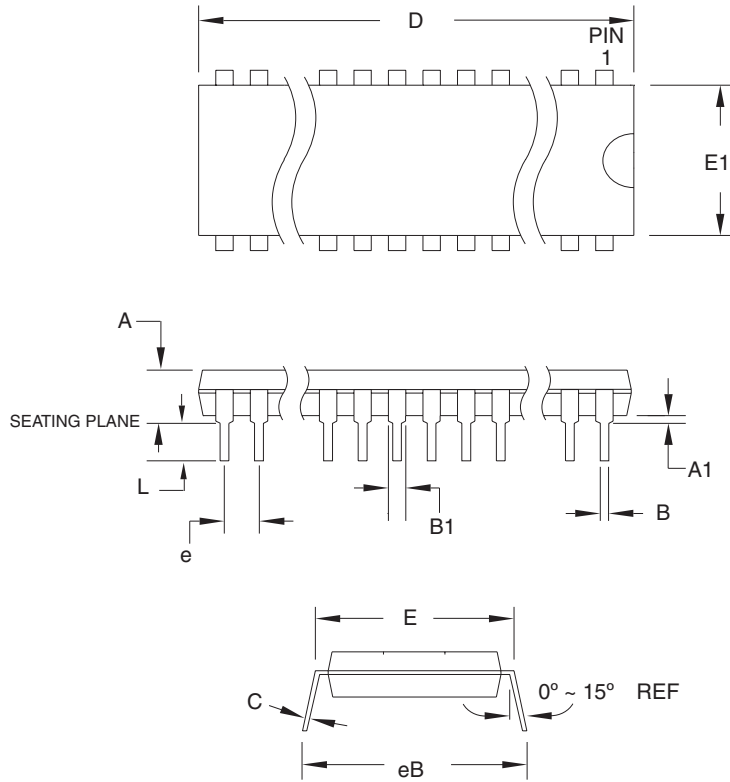
Notes:

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	DRAWING NO.	REV.
		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)	44A	B

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



2325 Orchard Parkway
San Jose, CA 95131

TITLE

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

DRAWING NO.

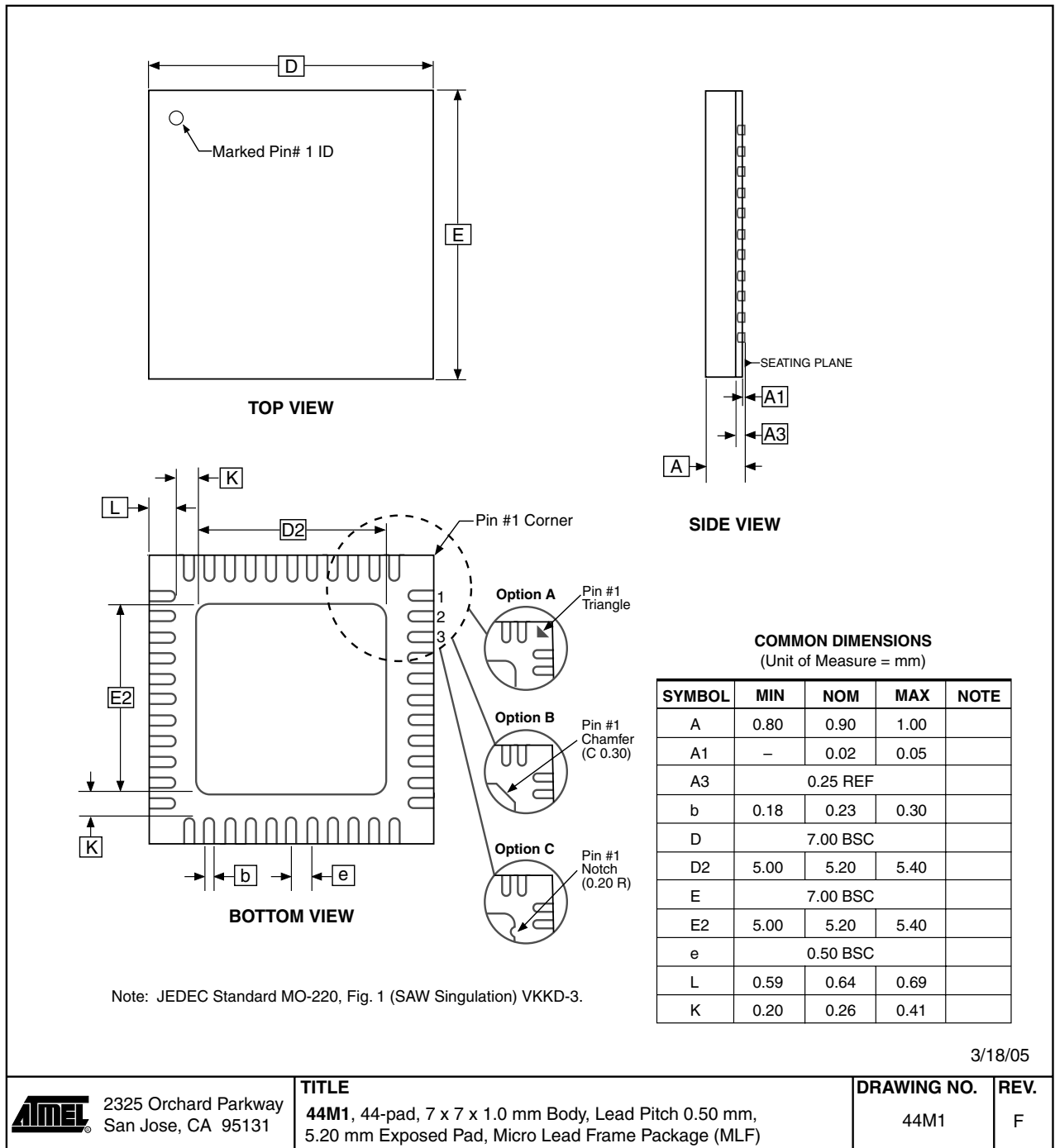
40P6

REV.

B



44M1



Errata

The revision letter in this section refers to the revision of the ATmega16 device.

ATmega16(L) Rev. I

- **IDCODE masks data from TDI input**

1. **IDCODE masks data from TDI input**

The JTAG instruction IDCODE is not working correctly. Data to succeeding devices are replaced by all-ones during Update-DR.

Problem Fix / Workaround

- If ATmega16 is the only device in the scan chain, the problem is not visible.
- Select the Device ID Register of the ATmega16 by issuing the IDCODE instruction or by entering the Test-Logic-Reset state of the TAP controller to read out the contents of its Device ID Register and possibly data from succeeding devices of the scan chain. Issue the BYPASS instruction to the ATmega16 while reading the Device ID Registers of preceding devices of the boundary scan chain.
- If the Device IDs of all devices in the boundary scan chain must be captured simultaneously, the ATmega16 must be the first device in the chain.

ATmega16(L) Rev. H

- **IDCODE masks data from TDI input**

1. **IDCODE masks data from TDI input**

The JTAG instruction IDCODE is not working correctly. Data to succeeding devices are replaced by all-ones during Update-DR.

Problem Fix / Workaround

- If ATmega16 is the only device in the scan chain, the problem is not visible.
- Select the Device ID Register of the ATmega16 by issuing the IDCODE instruction or by entering the Test-Logic-Reset state of the TAP controller to read out the contents of its Device ID Register and possibly data from succeeding devices of the scan chain. Issue the BYPASS instruction to the ATmega16 while reading the Device ID Registers of preceding devices of the boundary scan chain.
- If the Device IDs of all devices in the boundary scan chain must be captured simultaneously, the ATmega16 must be the first device in the chain.

ATmega16(L) Rev. G

- **IDCODE masks data from TDI input**

1. **IDCODE masks data from TDI input**

The JTAG instruction IDCODE is not working correctly. Data to succeeding devices are replaced by all-ones during Update-DR.

Problem Fix / Workaround

- If ATmega16 is the only device in the scan chain, the problem is not visible.
- Select the Device ID Register of the ATmega16 by issuing the IDCODE instruction or by entering the Test-Logic-Reset state of the TAP controller to read out the contents of its Device ID Register and possibly data from succeeding devices of the scan chain. Issue the BYPASS instruction to the ATmega16 while reading the Device ID Registers of preceding devices of the boundary scan chain.
- If the Device IDs of all devices in the boundary scan chain must be captured simultaneously, the ATmega16 must be the first device in the chain.

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.

Rev. 2466M-04/06

1. Updated typos.
1. Updated “Serial Peripheral Interface – SPI” on page 136.
2. Updated Table 86 on page 222, Table 116 on page 279 ,Table 121 on page 298 and Table 122 on page 300.

Rev. 2466L-06/05

1. Updated note in “Bit Rate Generator Unit” on page 179.
2. Updated values for V_{INT} in “ADC Characteristics” on page 300.
3. Updated “Serial Programming Instruction set” on page 279.
4. Updated USART init C-code example in “USART” on page 145.

Rev. 2466K-04/05

1. Updated “Ordering Information” on page 11.
2. MLF-package alternative changed to “Quad Flat No-Lead/Micro Lead Frame Package QFN/MLF”.
3. Updated “Electrical Characteristics” on page 294.

Rev. 2466J-10/04

1. Updated “Ordering Information” on page 11.

Rev. 2466I-10/04

1. Removed references to analog ground.
2. Updated Table 7 on page 28, Table 15 on page 38, Table 16 on page 42, Table 81 on page 211, Table 116 on page 279, and Table 119 on page 296.
3. Updated “Pinout ATmega16” on page 2.
4. Updated features in “Analog to Digital Converter” on page 205.
5. Updated “Version” on page 230.
6. Updated “Calibration Byte” on page 264.
7. Added “Page Size” on page 265.

Rev. 2466H-12/03

1. Updated “Calibrated Internal RC Oscillator” on page 29.

Rev. 2466G-10/03

1. Removed “Preliminary” from the datasheet.
2. Changed ICP to ICP1 in the datasheet.
3. Updated “JTAG Interface and On-chip Debug System” on page 36.

4. Updated assembly and C code examples in “Watchdog Timer Control Register – WDTCR” on page 43.
5. Updated Figure 46 on page 103.
6. Updated Table 15 on page 38, Table 82 on page 218 and Table 115 on page 279.
7. Updated “Test Access Port – TAP” on page 223 regarding JTAGEN.
8. Updated description for the JTD bit on page 232.
9. Added note 2 to Figure 126 on page 255.
10. Added a note regarding JTAGEN fuse to Table 105 on page 263.
11. Updated Absolute Maximum Ratings* and DC Characteristics in “Electrical Characteristics” on page 294.
12. Updated “ATmega16 Typical Characteristics” on page 302.
13. Fixed typo for 16 MHz QFN/MLF package in “Ordering Information” on page 11.
14. Added a proposal for solving problems regarding the JTAG instruction IDCODE in “Errata” on page 15.

Rev. 2466F-02/03

1. Added note about masking out unused bits when reading the Program Counter in “Stack Pointer” on page 12.
2. Added Chip Erase as a first step in “Programming the Flash” on page 291 and “Programming the EEPROM” on page 292.
3. Added the section “Unconnected pins” on page 55.
4. Added tips on how to disable the OCD system in “On-chip Debug System” on page 34.
5. Removed reference to the “Multi-purpose Oscillator” application note and “32 kHz Crystal Oscillator” application note, which do not exist.
6. Added information about PWM symmetry for Timer0 and Timer2.
7. Added note in “Filling the Temporary Buffer (Page Loading)” on page 256 about writing to the EEPROM during an SPM Page Load.
8. Removed ADHSM completely.
9. Added Table 73, “TWI Bit Rate Prescaler,” on page 183 to describe the TWPS bits in the “TWI Status Register – TWSR” on page 182.
10. Added section “Default Clock Source” on page 25.

11. Added note about frequency variation when using an external clock. Note added in “External Clock” on page 31. An extra row and a note added in Table 118 on page 296.
12. Various minor TWI corrections.
13. Added “Power Consumption” data in “Features” on page 1.
14. Added section “EEPROM Write During Power-down Sleep Mode” on page 22.
15. Added note about Differential Mode with Auto Triggering in “Prescaling and Conversion Timing” on page 208.
16. Added updated “Packaging Information” on page 12.

Rev. 2466E-10/02

1. Updated “DC Characteristics” on page 294.

Rev. 2466D-09/02

1. Changed all Flash write/erase cycles from 1,000 to 10,000.
2. Updated the following tables: Table 4 on page 26, Table 15 on page 38, Table 42 on page 85, Table 45 on page 112, Table 46 on page 112, Table 59 on page 144, Table 67 on page 168, Table 90 on page 237, Table 102 on page 261, “DC Characteristics” on page 294, Table 119 on page 296, Table 121 on page 298, and Table 122 on page 300.
3. Updated “Errata” on page 15.

Rev. 2466C-03/02

1. Updated typical EEPROM programming time, Table 1 on page 20.
2. Updated typical start-up time in the following tables:
Table 3 on page 25, Table 5 on page 27, Table 6 on page 28, Table 8 on page 29, Table 9 on page 29, and Table 10 on page 30.
3. Updated Table 17 on page 43 with typical WDT Time-out.
4. **Added Some Preliminary Test Limits and Characterization Data.**
Removed some of the TBD's in the following tables and pages:
Table 15 on page 38, Table 16 on page 42, Table 116 on page 272 (table removed in document review #D), “Electrical Characteristics” on page 294, Table 119 on page 296, Table 121 on page 298, and Table 122 on page 300.
5. **Updated TWI Chapter.**
Added the note at the end of the “Bit Rate Generator Unit” on page 179.
6. **Corrected description of ADSC bit in “ADC Control and Status Register A – ADCSRA” on page 220.**
7. **Improved description on how to do a polarity check of the ADC doff results in “ADC Conversion Result” on page 217.**
8. **Added JTAG version number for rev. H in Table 87 on page 230.**

9. Added note regarding OCDEN Fuse below Table 105 on page 263.
10. **Updated Programming Figures:**
Figure 127 on page 265 and Figure 136 on page 277 are updated to also reflect that AVCC must be connected during Programming mode. Figure 131 on page 273 added to illustrate how to program the fuses.
11. Added a note regarding usage of the “PROG_PAGELOAD (\$6)” on page 283 and “PROG_PAGEREAD (\$7)” on page 283.
12. **Removed alternative algorithm for leaving JTAG Programming mode.**
See “Leaving Programming Mode” on page 291.
13. **Added Calibrated RC Oscillator characterization curves in section “ATmega16 Typical Characteristics” on page 302.**
14. **Corrected ordering code for QFN/MLF package (16MHz) in “Ordering Information” on page 11.**
15. **Corrected Table 90, “Scan Signals for the Oscillators⁽¹⁾⁽²⁾⁽³⁾,” on page 237.**



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