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What is "[Embedded - Microcontrollers](#)"?

"[Embedded - Microcontrollers](#)" refer to small, integrated circuits designed to perform specific tasks within larger systems. These microcontrollers are essentially compact computers on a single chip, containing a processor core, memory, and programmable input/output peripherals. They are called "embedded" because they are embedded within electronic devices to control various functions, rather than serving as standalone computers. Microcontrollers are crucial in modern electronics, providing the intelligence and control needed for a wide range of applications.

Applications of "[Embedded - Microcontrollers](#)"

Details

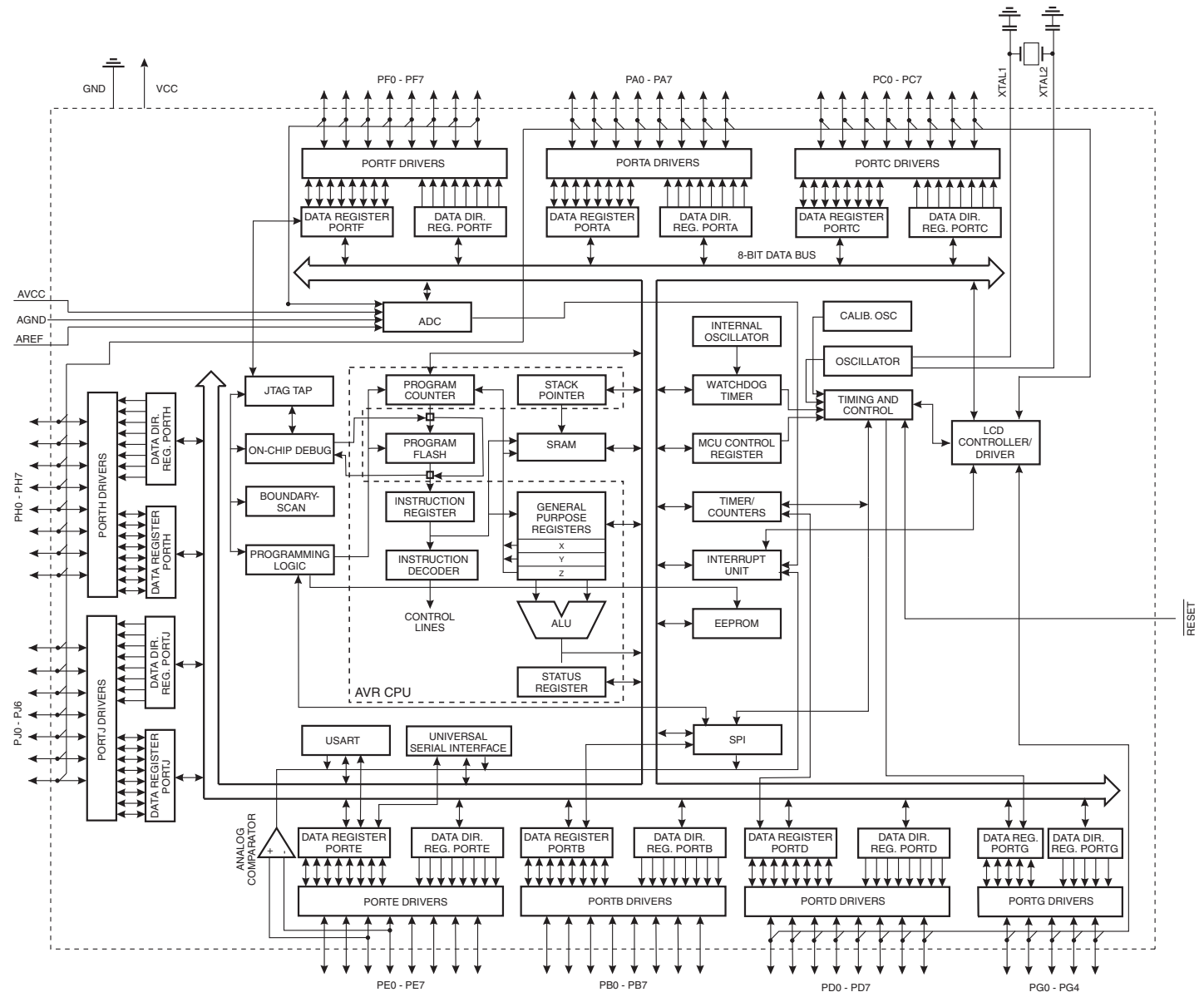
Product Status	Active
Core Processor	AVR
Core Size	8-Bit
Speed	16MHz
Connectivity	SPI, UART/USART, USI
Peripherals	Brown-out Detect/Reset, LCD, POR, PWM, WDT
Number of I/O	54
Program Memory Size	32KB (16K x 16)
Program Memory Type	FLASH
EEPROM Size	1K x 8
RAM Size	2K x 8
Voltage - Supply (Vcc/Vdd)	2.7V ~ 5.5V
Data Converters	A/D 8x10b
Oscillator Type	Internal
Operating Temperature	-40°C ~ 85°C (TA)
Mounting Type	Surface Mount
Package / Case	64-TQFP
Supplier Device Package	64-TQFP (14x14)
Purchase URL	https://www.e-xfl.com/product-detail/microchip-technology/atmega329-16aur

2. Overview

The ATmega329/3290/649/6490 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 ATmega329/3290/649/6490 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 Atmel® 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 Atmel ATmega329/3290/649/6490 provides the following features: 32/64K bytes of In-System Programmable Flash with Read-While-Write capabilities, 1/2K bytes EEPROM, 2/4K byte SRAM, 54/69 general purpose I/O lines, 32 general purpose working registers, a JTAG interface for Boundary-scan, On-chip Debugging support and programming, a complete On-chip LCD controller with internal contrast control, three flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, Universal Serial Interface with Start Condition Detector, an 8-channel, 10-bit ADC, a programmable Watchdog Timer with internal Oscillator, an SPI serial port, and five 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 and the LCD controller continues to run, allowing the user to maintain a timer base and operate the LCD display while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except asynchronous timer, LCD controller and ADC, to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator Oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low-power consumption.

The device is manufactured using Atmel's high density non-volatile memory technology. The On-chip In-System re-Programmable (ISP) Flash allows the program memory to be reprogrammed In-System through an SPI serial interface, by a conventional non-volatile memory programmer, or by an On-chip Boot program running on the AVR core. The Boot program can use any interface to download the application program in the Application Flash memory. Software in the Boot Flash section will continue to run while the Application Flash section is updated, providing true Read-While-Write operation. By combining an 8-bit RISC CPU with In-System Self-Programmable Flash on a monolithic chip, the Atmel ATmega329/3290/649/6490 is a powerful microcontroller that provides a highly flexible and cost effective solution to many embedded control applications.

The Atmel ATmega329/3290/649/6490 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 ATmega329, ATmega3290, ATmega649 and ATmega6490

The ATmega329, ATmega3290, ATmega649, and ATmega6490 differs only in memory sizes, pin count and pinout. [Table 2-1 on page 6](#) summarizes the different configurations for the four devices.

Table 2-1. Configuration Summary

Device	Flash	EEPROM	RAM	LCD Segments	General Purpose I/O Pins
ATmega329	32Kbytes	1Kbytes	2Kbytes	4 x 25	54
ATmega3290	32Kbytes	1K bytes	2Kbytes	4 x 40	69
ATmega649	64Kbytes	2Kbytes	4Kbytes	4 x 25	54
ATmega6490	64Kbytes	2Kbytes	4Kbytes	4 x 40	69

2.3 Pin Descriptions

The following section describes the I/O-pin special functions.

2.3.1 V_{CC}

Digital supply voltage.

2.3.2 GND

Ground.

2.3.3 Port A (PA7..PA0)

Port A is 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 ATmega329/3290/649/6490 as listed on [page 67](#).

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 has better driving capabilities than the other ports.

Port B also serves the functions of various special features of the ATmega329/3290/649/6490 as listed on [page 68](#).

2.3.9 Port G (PG5..PG0)

Port G is a 6-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port G output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port G pins that are externally pulled low will source current if the pull-up resistors are activated. The Port G pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port G also serves the functions of various special features of the ATmega329/3290/649/6490 as listed on [page 75](#).

2.3.10 Port H (PH7..PH0)

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

Port H also serves the functions of various special features of the ATmega3290/6490 as listed on [page 75](#).

2.3.11 Port J (PJ6..PJ0)

Port J is a 7-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port J output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port J pins that are externally pulled low will source current if the pull-up resistors are activated. The Port J pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port J also serves the functions of various special features of the ATmega3290/6490 as listed on [page 75](#).

2.3.12 $\overline{\text{RESET}}$

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 330](#). Shorter pulses are not guaranteed to generate a reset.

2.3.13 XTAL1

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

2.3.14 XTAL2

Output from the inverting Oscillator amplifier.

2.3.15 AVCC

AVCC is the supply voltage pin for Port F 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.

2.3.16 AREF

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

6. Register Summary

Note: Registers with bold type only available in ATmega3290/6490.

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
(0xFF)	LCDDR19	SEG339	SEG338	SEG337	SEG336	SEG335	SEG334	SEG333	SEG332	244
(0xFE)	LCDDR18	SEG331	SEG330	SEG329	SEG328	SEG327	SEG326	SEG325	SEG324	244
(0xFD)	LCDDR17	SEG323	SEG322	SEG321	SEG320	SEG319	SEG318	SEG317	SEG316	244
(0xFC)	LCDDR16	SEG315	SEG314	SEG313	SEG312	SEG311	SEG310	SEG309	SEG308	244
(0xFB)	LCDDR15	SEG307	SEG306	SEG305	SEG304	SEG303	SEG302	SEG301	SEG300	244
(0xFA)	LCDDR14	SEG239	SEG238	SEG237	SEG236	SEG235	SEG234	SEG233	SEG232	244
(0xF9)	LCDDR13	SEG231	SEG230	SEG229	SEG228	SEG227	SEG226	SEG225	SEG224	244
(0xF8)	LCDDR12	SEG223	SEG222	SEG221	SEG220	SEG219	SEG218	SEG217	SEG216	244
(0xF7)	LCDDR11	SEG215	SEG214	SEG213	SEG212	SEG211	SEG210	SEG209	SEG208	244
(0xF6)	LCDDR10	SEG207	SEG206	SEG205	SEG204	SEG203	SEG202	SEG201	SEG200	244
(0xF5)	LCDDR09	SEG139	SEG138	SEG137	SEG136	SEG135	SEG134	SEG133	SEG132	244
(0xF4)	LCDDR08	SEG131	SEG130	SEG129	SEG128	SEG127	SEG126	SEG125	SEG124	244
(0xF3)	LCDDR07	SEG123	SEG122	SEG121	SEG120	SEG119	SEG118	SEG117	SEG116	244
(0xF2)	LCDDR06	SEG115	SEG114	SEG113	SEG112	SEG111	SEG110	SEG109	SEG108	244
(0xF1)	LCDDR05	SEG107	SEG106	SEG105	SEG104	SEG103	SEG102	SEG101	SEG100	244
(0xF0)	LCDDR04	SEG039	SEG038	SEG037	SEG036	SEG035	SEG034	SEG033	SEG032	244
(0xEF)	LCDDR03	SEG031	SEG030	SEG029	SEG028	SEG027	SEG026	SEG025	SEG024	244
(0xEE)	LCDDR02	SEG023	SEG022	SEG021	SEG020	SEG019	SEG018	SEG017	SEG016	244
(0xED)	LCDDR01	SEG015	SEG014	SEG013	SEG012	SEG011	SEG010	SEG009	SEG008	244
(0xEC)	LCDDR00	SEG007	SEG006	SEG005	SEG004	SEG003	SEG002	SEG001	SEG000	244
(0xEB)	Reserved	-	-	-	-	-	-	-	-	
(0xEA)	Reserved	-	-	-	-	-	-	-	-	
(0xE9)	Reserved	-	-	-	-	-	-	-	-	
(0xE8)	Reserved	-	-	-	-	-	-	-	-	
(0xE7)	LCDDCR	LCDDC2	LCDDC1	LCDDC0	-	LCDDC3	LCDDC2	LCDDC1	LCDDC0	243
(0xE6)	LCDFRR	-	LCDPS2	LCDPS1	LCDPS0	-	LCDCD2	LCDCD1	LCDCD0	241
(0xE5)	LCDCRB	LDCS	LCD2B	LCDMUX1	LCDMUX0	LCDDPM3	LCDDPM2	LCDDPM1	LCDDPM0	239
(0xE4)	LCDCRA	LCDEN	LCDAB	-	LCDIF	LCDIE	-	-	LCDDBL	239
(0xE3)	Reserved	-	-	-	-	-	-	-	-	
(0xE2)	Reserved	-	-	-	-	-	-	-	-	
(0xE1)	Reserved	-	-	-	-	-	-	-	-	
(0xE0)	Reserved	-	-	-	-	-	-	-	-	
(0xDF)	Reserved	-	-	-	-	-	-	-	-	
(0xDE)	Reserved	-	-	-	-	-	-	-	-	
(0xDD)	PORTJ	-	PORTJ6	PORTJ5	PORTJ4	PORTJ3	PORTJ2	PORTJ1	PORTJ0	90
(0xDC)	DDRJ	-	DDJ6	DDJ5	DDJ4	DDJ3	DDJ2	DDJ1	DDJ0	90
(0xDB)	PINJ	-	PINJ6	PINJ5	PINJ4	PINJ3	PINJ2	PINJ1	PINJ0	90
(0xDA)	PORTH	PORTH7	PORTH6	PORTH5	PORTH4	PORTH3	PORTH2	PORTH1	PORTH0	89
(0xD9)	DDRH	DDH7	DDH6	DDH5	DDH4	DDH3	DDH2	DDH1	DDH0	90
(0xD8)	PINH	PINH7	PINH6	PINH5	PINH4	PINH3	PINH2	PINH1	PINH0	90
(0xD7)	Reserved	-	-	-	-	-	-	-	-	
(0xD6)	Reserved	-	-	-	-	-	-	-	-	
(0xD5)	Reserved	-	-	-	-	-	-	-	-	
(0xD4)	Reserved	-	-	-	-	-	-	-	-	
(0xD3)	Reserved	-	-	-	-	-	-	-	-	
(0xD2)	Reserved	-	-	-	-	-	-	-	-	
(0xD1)	Reserved	-	-	-	-	-	-	-	-	
(0xD0)	Reserved	-	-	-	-	-	-	-	-	
(0xCF)	Reserved	-	-	-	-	-	-	-	-	
(0xCE)	Reserved	-	-	-	-	-	-	-	-	
(0xCD)	Reserved	-	-	-	-	-	-	-	-	
(0xCC)	Reserved	-	-	-	-	-	-	-	-	
(0xCB)	Reserved	-	-	-	-	-	-	-	-	
(0xCA)	Reserved	-	-	-	-	-	-	-	-	
(0xC9)	Reserved	-	-	-	-	-	-	-	-	
(0xC8)	Reserved	-	-	-	-	-	-	-	-	
(0xC7)	Reserved	-	-	-	-	-	-	-	-	
(0xC6)	UDR0	USART0 Data Register								190
(0xC5)	UBRR0H	USART0 Baud Rate Register High								194
(0xC4)	UBRR0L	USART0 Baud Rate Register Low								194

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
(0xC3)	Reserved	-	-	-	-	-	-	-	-	
(0xC2)	UCSR0C	-	UMSEL0	UPM01	UPM00	USBS0	UCSZ01	UCSZ00	UCPOL0	192
(0xC1)	UCSR0B	RXCIE0	TXCIE0	UDRIE0	RXEN0	TXEN0	UCSZ02	RXB80	TXB80	191
(0xC0)	UCSR0A	RXC0	TXC0	UDRE0	FE0	DOR0	UPE0	U2X0	MPCM0	190
(0xBF)	Reserved	-	-	-	-	-	-	-	-	
(0xBE)	Reserved	-	-	-	-	-	-	-	-	
(0xBD)	Reserved	-	-	-	-	-	-	-	-	
(0xBC)	Reserved	-	-	-	-	-	-	-	-	
(0xBB)	Reserved	-	-	-	-	-	-	-	-	
(0xBA)	USIDR	USI Data Register								203
(0xB9)	USISR	USISIF	USIOIF	USIPF	USIDC	USICNT3	USICNT2	USICNT1	USICNT0	203
(0xB8)	USICR	USISIE	USIOIE	USIWM1	USIWM0	USICS1	USICS0	USICK	USITC	204
(0xB7)	Reserved	-	-	-	-	-	-	-	-	
(0xB6)	ASSR	-	-	-	EXCLK	AS2	TCN2UB	OCR2UB	TCR2UB	155
(0xB5)	Reserved	-	-	-	-	-	-	-	-	
(0xB4)	Reserved	-	-	-	-	-	-	-	-	
(0xB3)	OCR2A	Timer/Counter 2 Output Compare Register A								155
(0xB2)	TCNT2	Timer/Counter2								155
(0xB1)	Reserved	-	-	-	-	-	-	-	-	
(0xB0)	TCCR2A	FOC2A	WGM20	COM2A1	COM2A0	WGM21	CS22	CS21	CS20	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								136
(0x8A)	OCR1BL	Timer/Counter1 Output Compare Register B Low								136
(0x89)	OCR1AH	Timer/Counter1 Output Compare Register A High								136
(0x88)	OCR1AL	Timer/Counter1 Output Compare Register A Low								136
(0x87)	ICR1H	Timer/Counter1 Input Capture Register High								137
(0x86)	ICR1L	Timer/Counter1 Input Capture Register Low								137
(0x85)	TCNT1H	Timer/Counter1 High								136

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
(0x84)	TCNT1L	Timer/Counter1 Low								136
(0x83)	Reserved	-	-	-	-	-	-	-	-	
(0x82)	TCCR1C	FOC1A	FOC1B	-	-	-	-	-	-	135
(0x81)	TCCR1B	ICNC1	ICES1	-	WGM13	WGM12	CS12	CS11	CS10	134
(0x80)	TCCR1A	COM1A1	COM1A0	COM1B1	COM1B0	-	-	WGM11	WGM10	132
(0x7F)	DIDR1	-	-	-	-	-	-	AIN1D	AIN0D	210
(0x7E)	DIDR0	ADC7D	ADC6D	ADC5D	ADC4D	ADC3D	ADC2D	ADC1D	ADC0D	227
(0x7D)	Reserved	-	-	-	-	-	-	-	-	
(0x7C)	ADMUX	REFS1	REFS0	ADLAR	MUX4	MUX3	MUX2	MUX1	MUX0	223
(0x7B)	ADCSRB	-	ACME	-	-	-	ADTS2	ADTS1	ADTS0	209/227
(0x7A)	ADCSRA	ADEN	ADSC	ADATE	ADIF	ADIE	ADPS2	ADPS1	ADPS0	225
(0x79)	ADCH	ADC Data Register High								226
(0x78)	ADCL	ADC Data Register Low								226
(0x77)	Reserved	-	-	-	-	-	-	-	-	
(0x76)	Reserved	-	-	-	-	-	-	-	-	
(0x75)	Reserved	-	-	-	-	-	-	-	-	
(0x74)	Reserved	-	-	-	-	-	-	-	-	
(0x73)	PCMSK3	-	PCINT30	PCINT29	PCINT28	PCINT27	PCINT26	PCINT25	PCINT24	57
(0x72)	Reserved	-	-	-	-	-	-	-	-	
(0x71)	Reserved	-	-	-	-	-	-	-	-	
(0x70)	TIMSK2	-	-	-	-	-	-	OCIE2A	TOIE2	156
(0x6F)	TIMSK1	-	-	ICIE1	-	-	OCIE1B	OCIE1A	TOIE1	137
(0x6E)	TIMSK0	-	-	-	-	-	-	OCIE0A	TOIE0	106
(0x6D)	PCMSK2	PCINT23	PCINT22	PCINT21	PCINT20	PCINT19	PCINT18	PCINT17	PCINT16	57
(0x6C)	PCMSK1	PCINT15	PCINT14	PCINT13	PCINT12	PCINT11	PCINT10	PCINT9	PCINT8	58
(0x6B)	PCMSK0	PCINT7	PCINT6	PCINT5	PCINT4	PCINT3	PCINT2	PCINT1	PCINT0	58
(0x6A)	Reserved	-	-	-	-	-	-	-	-	
(0x69)	EICRA	-	-	-	-	-	-	ISC01	ISC00	55
(0x68)	Reserved	-	-	-	-	-	-	-	-	
(0x67)	Reserved	-	-	-	-	-	-	-	-	
(0x66)	OSCCAL	Oscillator Calibration Register [CAL7..0]								32
(0x65)	Reserved	-	-	-	-	-	-	-	-	
(0x64)	PRR	-	-	-	PRLCD	PRTIM1	PRSPI	PSUSART0	PRADC	40
(0x63)	Reserved	-	-	-	-	-	-	-	-	
(0x62)	Reserved	-	-	-	-	-	-	-	-	
(0x61)	CLKPR	CLKPCE	-	-	-	CLKPS3	CLKPS2	CLKPS1	CLKPS0	33
(0x60)	WDTCR	-	-	-	WDCE	WDE	WDP2	WDP1	WDP0	48
0x3F (0x5F)	SREG	I	T	H	S	V	N	Z	C	12
0x3E (0x5E)	SPH	Stack Pointer High								14
0x3D (0x5D)	SPL	Stack Pointer Low								14
0x3C (0x5C)	Reserved	-	-	-	-	-	-	-	-	
0x3B (0x5B)	Reserved	-	-	-	-	-	-	-	-	
0x3A (0x5A)	Reserved	-	-	-	-	-	-	-	-	
0x39 (0x59)	Reserved	-	-	-	-	-	-	-	-	
0x38 (0x58)	Reserved	-	-	-	-	-	-	-	-	
0x37 (0x57)	SPMCSR	SPMIE	RWWSB	-	RWWSRE	BLBSET	PGWRT	PGERS	SPMEN	291
0x36 (0x56)	Reserved	-	-	-	-	-	-	-	-	
0x35 (0x55)	MCUCR	JTD	-	-	PUD	-	-	IVSEL	IVCE	52/87/254
0x34 (0x54)	MCUSR	-	-	-	JTRF	WDRF	BORF	EXTRF	PORF	47
0x33 (0x53)	SMCR	-	-	-	-	SM2	SM1	SM0	SE	39
0x32 (0x52)	Reserved	-	-	-	-	-	-	-	-	
0x31 (0x51)	OCDR	IDRD/OCDR7	OCDR6	OCDR5	OCDR4	OCDR3	OCDR2	OCDR1	OCDR0	250
0x30 (0x50)	ACSR	ACD	ACBG	ACO	ACI	ACIE	ACIC	ACIS1	ACIS0	209
0x2F (0x4F)	Reserved	-	-	-	-	-	-	-	-	
0x2E (0x4E)	SPDR	SPI Data Register								167
0x2D (0x4D)	SPSR	SPIF	WCOL	-	-	-	-	-	SPI2X	167
0x2C (0x4C)	SPCR	SPIE	SPE	DORD	MSTR	CPOL	CPHA	SPR1	SPR0	165
0x2B (0x4B)	GPIOR2	General Purpose I/O Register								25
0x2A (0x4A)	GPIOR1	General Purpose I/O Register								25
0x29 (0x49)	Reserved	-	-	-	-	-	-	-	-	
0x28 (0x48)	Reserved	-	-	-	-	-	-	-	-	
0x27 (0x47)	OCR0A	Timer/Counter0 Output Compare A								105
0x26 (0x46)	TCNT0	Timer/Counter0								105

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
0x25 (0x45)	Reserved	-	-	-	-	-	-	-	-	
0x24 (0x44)	TCCR0A	FOC0A	WGM00	COM0A1	COM0A0	WGM01	CS02	CS01	CS00	103
0x23 (0x43)	GTCCR	TSM	-	-	-	-	-	PSR2	PSR10	108/157
0x22 (0x42)	EEARH	-	-	-	-	-	EEPROM Address Register High			22
0x21 (0x41)	EEARL	EEPROM Address Register Low								22
0x20 (0x40)	EEDR	EEPROM Data Register								22
0x1F (0x3F)	EECR	-	-	-	-	EERIE	EEMWE	EWE	EERE	22
0x1E (0x3E)	GPIOR0	General Purpose I/O Register								25
0x1D (0x3D)	EIMSK	PCIE3	PCIE2	PCIE1	PCIE0	-	-	-	INT0	55
0x1C (0x3C)	EIFR	PCIF3	PCIF2	PCIF1	PCIF0	-	-	-	INTF0	56
0x1B (0x3B)	Reserved	-	-	-	-	-	-	-	-	
0x1A (0x3A)	Reserved	-	-	-	-	-	-	-	-	
0x19 (0x39)	Reserved	-	-	-	-	-	-	-	-	
0x18 (0x38)	Reserved	-	-	-	-	-	-	-	-	
0x17 (0x37)	TIFR2	-	-	-	-	-	-	OCF2A	TOV2	157
0x16 (0x36)	TIFR1	-	-	ICF1	-	-	OCF1B	OCF1A	TOV1	138
0x15 (0x35)	TIFR0	-	-	-	-	-	-	OCF0A	TOV0	106
0x14 (0x34)	PORTG	-	-	-	PORTG4	PORTG3	PORTG2	PORTG1	PORTG0	89
0x13 (0x33)	DDRG	-	-	-	DDG4	DDG3	DDG2	DDG1	DDG0	89
0x12 (0x32)	PING	-	-	PING5	PING4	PING3	PING2	PING1	PING0	89
0x11 (0x31)	PORTF	PORTF7	PORTF6	PORTF5	PORTF4	PORTF3	PORTF2	PORTF1	PORTF0	89
0x10 (0x30)	DDRF	DDF7	DDF6	DDF5	DDF4	DDF3	DDF2	DDF1	DDF0	89
0x0F (0x2F)	PINF	PINF7	PINF6	PINF5	PINF4	PINF3	PINF2	PINF1	PINF0	89
0x0E (0x2E)	PORTE	PORTE7	PORTE6	PORTE5	PORTE4	PORTE3	PORTE2	PORTE1	PORTE0	88
0x0D (0x2D)	DDRE	DDE7	DDE6	DDE5	DDE4	DDE3	DDE2	DDE1	DDE0	88
0x0C (0x2C)	PINE	PINE7	PINE6	PINE5	PINE4	PINE3	PINE2	PINE1	PINE0	89
0x0B (0x2B)	PORTD	PORTD7	PORTD6	PORTD5	PORTD4	PORTD3	PORTD2	PORTD1	PORTD0	88
0x0A (0x2A)	DDRD	DDD7	DDD6	DDD5	DDD4	DDD3	DDD2	DDD1	DDD0	88
0x09 (0x29)	PIND	PIND7	PIND6	PIND5	PIND4	PIND3	PIND2	PIND1	PIND0	88
0x08 (0x28)	PORTC	PORTC7	PORTC6	PORTC5	PORTC4	PORTC3	PORTC2	PORTC1	PORTC0	88
0x07 (0x27)	DDRC	DDC7	DDC6	DDC5	DDC4	DDC3	DDC2	DDC1	DDC0	88
0x06 (0x26)	PINC	PINC7	PINC6	PINC5	PINC4	PINC3	PINC2	PINC1	PINC0	88
0x05 (0x25)	PORTB	PORTB7	PORTB6	PORTB5	PORTB4	PORTB3	PORTB2	PORTB1	PORTB0	87
0x04 (0x24)	DDRB	DDB7	DDB6	DDB5	DDB4	DDB3	DDB2	DDB1	DDB0	87
0x03 (0x23)	PINB	PINB7	PINB6	PINB5	PINB4	PINB3	PINB2	PINB1	PINB0	87
0x02 (0x22)	PORTA	PORTA7	PORTA6	PORTA5	PORTA4	PORTA3	PORTA2	PORTA1	PORTA0	87
0x01 (0x21)	DDRA	DDA7	DDA6	DDA5	DDA4	DDA3	DDA2	DDA1	DDA0	87
0x00 (0x20)	PINA	PINA7	PINA6	PINA5	PINA4	PINA3	PINA2	PINA1	PINA0	87

- Note:
- 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 0x00 - 0x1F are directly bit-accessible using the SBI and CBI instructions. In these registers, the value of single bits can be checked by using the SBIS and SBIC instructions.
 - Some of the Status Flags are cleared by writing a logical one to them. Note that, unlike most other AVRs, the CBI and SBI instructions will only operate on the specified bit, and can therefore be used on registers containing such Status Flags. The CBI and SBI instructions work with registers 0x00 to 0x1F only.
 - When using the I/O specific commands IN and OUT, the I/O addresses 0x00 - 0x3F must be used. When addressing I/O Registers as data space using LD and ST instructions, 0x20 must be added to these addresses. The ATmega329/3290/649/6490 is a complex microcontroller with more peripheral units than can be supported within the 64 location reserved in Opcode for the IN and OUT instructions. For the Extended I/O space from 0x60 - 0xFF in SRAM, only the ST/STS/STD and LD/LDS/LDD instructions can be used.

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

Mnemonics	Operands	Description	Operation	Flags	#Clocks
IN	Rd, P	In Port	$Rd \leftarrow P$	None	1
OUT	P, Rr	Out Port	$P \leftarrow Rr$	None	1
PUSH	Rr	Push Register on Stack	$STACK \leftarrow Rr$	None	2
POP	Rd	Pop Register from Stack	$Rd \leftarrow STACK$	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

8. Ordering Information

8.1 ATmega329

Speed (MHz) ⁽³⁾	Power Supply	Ordering Code ⁽²⁾	Package Type ⁽¹⁾	Operational Range
8	1.8 - 5.5V	ATmega329V-8AU ATmega329V-8AUR ⁽⁴⁾ ATmega329V-8MU ATmega329V-8MUR ⁽⁴⁾	64A 64A 64M1 64M1	Industrial (-40°C to 85°C)
16	2.7 - 5.5V	ATmega329-16AU ATmega329-16AUR ⁽⁴⁾ ATmega329-16MU ATmega329-16MUR ⁽⁴⁾	64A 64A 64M1 64M1	Industrial (-40°C to 85°C)

- 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 alternative, 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 [Figure 28-1 on page 328](#) and [Figure 28-2 on page 328](#).
 4. Tape & Reel

Package Type	
64A	64-lead, 14 x 14 x 1.0 mm, Thin Profile Plastic Quad Flat Package (TQFP)
64M1	64-pad, 9 x 9 x 1.0 mm, Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)
100A	100-lead, 14 x 14 x 1.0 mm, 0.5 mm Lead Pitch, Thin Profile Plastic Quad Flat Package (TQFP)

8.2 ATmega3290

Speed (MHz) ⁽³⁾	Power Supply	Ordering Code ⁽²⁾	Package Type ⁽¹⁾	Operational Range
8	1.8 - 5.5V	ATmega3290V-8AU ATmega3290V-8AUR ⁽⁴⁾	100A 100A	Industrial (-40°C to 85°C)
16	2.7 - 5.5V	ATmega3290-16AU ATmega3290-16AUR ⁽⁴⁾	100A 100A	Industrial (-40°C to 85°C)

- 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 alternative, 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 [Figure 28-1 on page 328](#) and [Figure 28-2 on page 328](#).
 4. Tape & Reel

Package Type	
64A	64-lead, 14 x 14 x 1.0 mm, Thin Profile Plastic Quad Flat Package (TQFP)
64M1	64-pad, 9 x 9 x 1.0 mm, Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)
100A	100-lead, 14 x 14 x 1.0 mm, 0.5 mm Lead Pitch, Thin Profile Plastic Quad Flat Package (TQFP)

8.4 ATmega6490

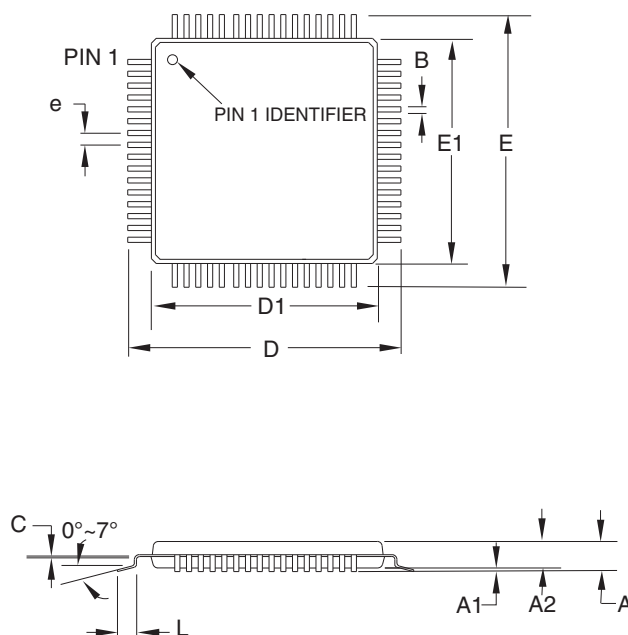
Speed (MHz) ⁽³⁾	Power Supply	Ordering Code ⁽²⁾	Package Type ⁽¹⁾	Operational Range
8	1.8 - 5.5V	ATmega6490V-8AU ATmega6490V-8AUR ⁽⁴⁾	100A 100A	Industrial (-40°C to 85°C)
16	2.7 - 5.5V	ATmega6490-16AU ATmega6490-16AUR ⁽⁴⁾	100A 100A	Industrial (-40°C to 85°C)

- 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 alternative, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
 3. For Speed Grades see [Figure 28-1 on page 328](#) and [Figure 28-2 on page 328](#).
 4. Tape & Reel

Package Type	
64A	64-lead, 14 x 14 x 1.0 mm, Thin Profile Plastic Quad Flat Package (TQFP)
64M1	64-pad, 9 x 9 x 1.0 mm, Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)
100A	100-lead, 14 x 14 x 1.0 mm, 0.5 mm Lead Pitch, Thin Profile Plastic Quad Flat Package (TQFP)

9. Packaging Information

9.1 64A



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	15.75	16.00	16.25	
D1	13.90	14.00	14.10	Note 2
E	15.75	16.00	16.25	
E1	13.90	14.00	14.10	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 AEB.
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.

2010-10-20



2325 Orchard Parkway
San Jose, CA 95131

TITLE

64A, 64-lead, 14 x 14 mm Body Size, 1.0 mm Body Thickness,
0.8 mm Lead Pitch, Thin Profile Plastic Quad Flat Package (TQFP)

DRAWING NO.

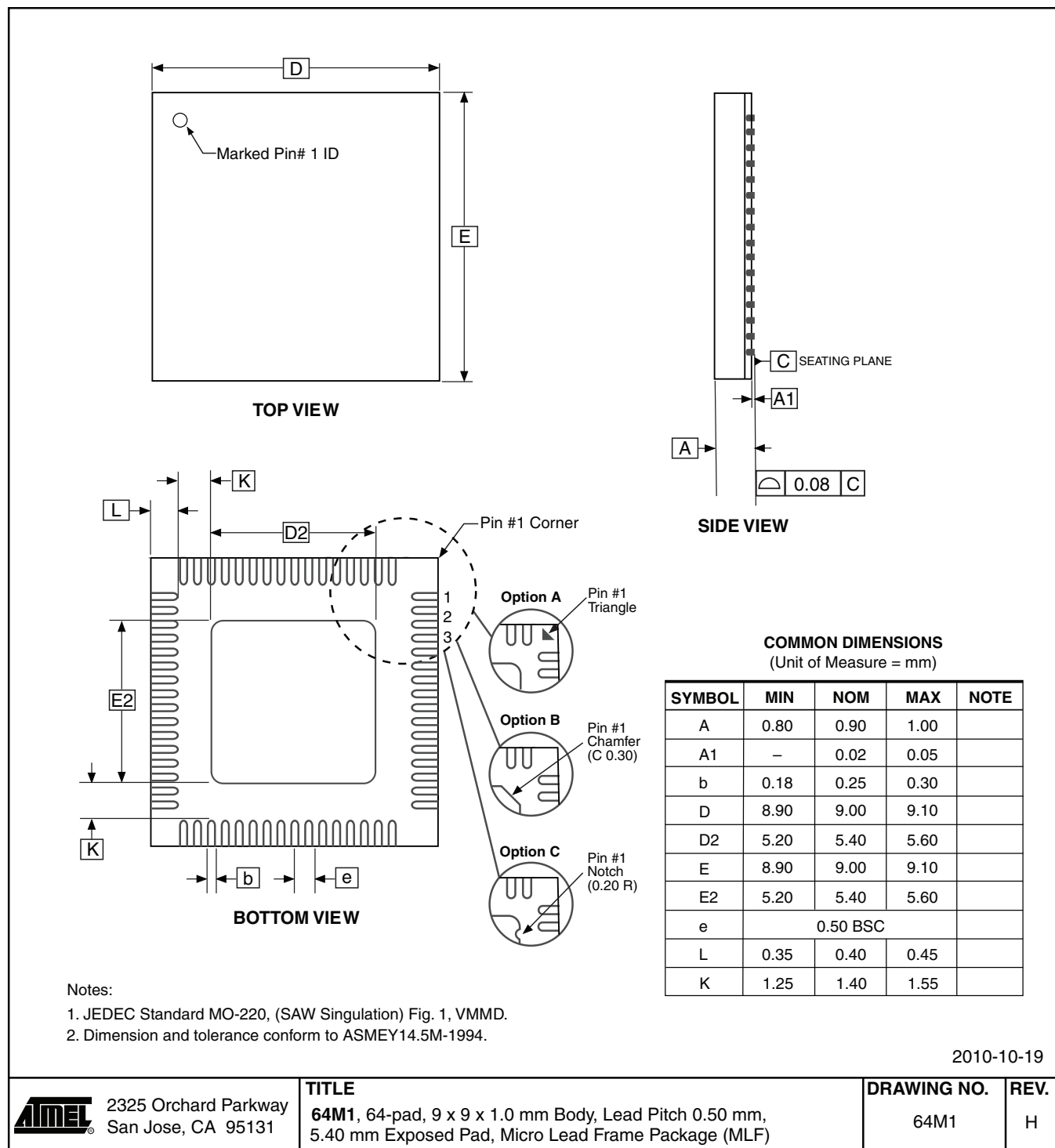
64A

REV.

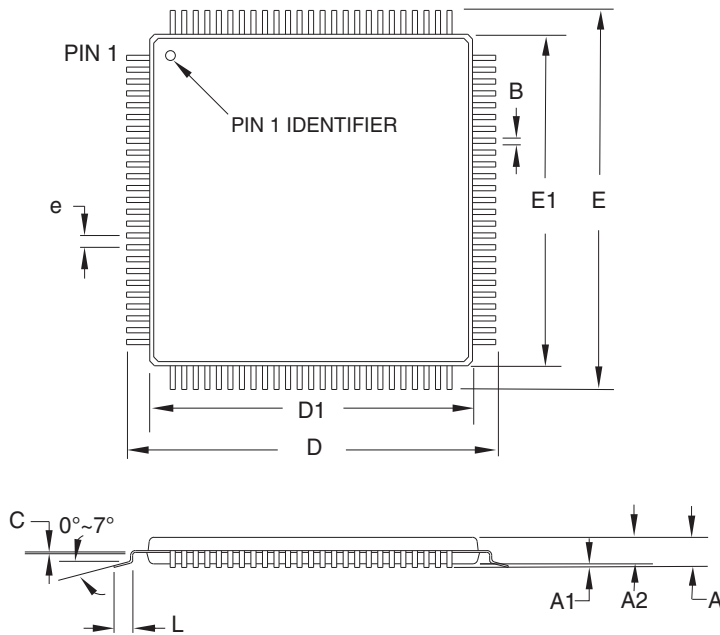
C



9.2 64M1



9.3 100A



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	15.75	16.00	16.25	
D1	13.90	14.00	14.10	Note 2
E	15.75	16.00	16.25	
E1	13.90	14.00	14.10	Note 2
B	0.17	—	0.27	
C	0.09	—	0.20	
L	0.45	—	0.75	
e	0.50 TYP			

Notes:

1. This package conforms to JEDEC reference MS-026, Variation AED.
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 0.08 mm maximum.

2010-10-20



2325 Orchard Parkway
San Jose, CA 95131

TITLE

100A, 100-lead, 14 x 14 mm Body Size, 1.0 mm Body Thickness,
0.5 mm Lead Pitch, Thin Profile Plastic Quad Flat Package (TQFP)

DRAWING NO.

100A

REV.

D

10. Errata

10.1 ATmega329

10.1.1 ATmega329 rev. C

- Interrupts may be lost when writing the timer registers in the asynchronous timer

1. Interrupts may be lost when writing the timer registers in the asynchronous timer

The interrupt will be lost if a timer register that is synchronous timer clock is written when the asynchronous Timer/Counter register (TCNTx) is 0x00.

Problem Fix/Workaround

Always check that the asynchronous Timer/Counter register neither have the value 0xFF nor 0x00 before writing to the asynchronous Timer Control Register (TCCR_x), asynchronous Timer Counter Register (TCNT_x), or asynchronous Output Compare Register (OCR_x).

10.1.2 ATmega329 rev. B

Not sampled.

10.1.3 ATmega329 rev. A

- LCD contrast voltage too high
- Interrupts may be lost when writing the timer registers in the asynchronous timer

1. LCD contrast voltage too high

When the LCD is active and using low power waveform, the LCD contrast voltage can be too high. This occurs when V_{CC} is higher than V_{LCD} , and when using low LCD drivetime.

Problem Fix/Workaround

There are several possible workarounds:

- Use normal waveform instead of low power waveform
- Use drivetime of 375 μ s or longer

2. Interrupts may be lost when writing the timer registers in the asynchronous timer

The interrupt will be lost if a timer register that is synchronous timer clock is written when the asynchronous Timer/Counter register (TCNTx) is 0x00.

Problem Fix/Workaround

Always check that the asynchronous Timer/Counter register neither have the value 0xFF nor 0x00 before writing to the asynchronous Timer Control Register (TCCR_x), asynchronous Timer Counter Register (TCNT_x), or asynchronous Output Compare Register (OCR_x).

10.2 ATmega3290

10.2.1 ATmega3290 rev. C

- Interrupts may be lost when writing the timer registers in the asynchronous timer

1. Interrupts may be lost when writing the timer registers in the asynchronous timer

The interrupt will be lost if a timer register that is synchronous timer clock is written when the asynchronous Timer/Counter register (TCNTx) is 0x00.

Problem Fix/Workaround

Always check that the asynchronous Timer/Counter register neither have the value 0xFF nor 0x00 before writing to the asynchronous Timer Control Register (TCCR_x), asynchronous Timer Counter Register (TCNT_x), or asynchronous Output Compare Register (OCR_x).

10.2.2 ATmega3290 rev. B

Not sampled.

10.2.3 ATmega3290 rev. A

- LCD contrast voltage too high
- Interrupts may be lost when writing the timer registers in the asynchronous timer

1. LCD contrast voltage too high

When the LCD is active and using low power waveform, the LCD contrast voltage can be too high. This occurs when V_{CC} is higher than V_{LCD} , and when using low LCD drivetime.

Problem Fix/Workaround

There are several possible workarounds:

- Use normal waveform instead of low power waveform
- Use drivetime of 375 μ s or longer

2. Interrupts may be lost when writing the timer registers in the asynchronous timer

The interrupt will be lost if a timer register that is synchronous timer clock is written when the asynchronous Timer/Counter register (TCNT_x) is 0x00.

Problem Fix/Workaround

Always check that the asynchronous Timer/Counter register neither have the value 0xFF nor 0x00 before writing to the asynchronous Timer Control Register (TCCR_x), asynchronous Timer Counter Register (TCNT_x), or asynchronous Output Compare Register (OCR_x).

11. Datasheet Revision History

Please note that the referring page numbers in this section are referring to this document. The referring revision in this section are referring to the document revision.

11.1 Rev. 2552K – 04/11

1. Removed “Preliminary” from the front page.
2. Removed “Disclaimer Section” from the datasheet.
3. Updated [Table 28-5 on page 330](#) “BODLEVEL Fuse Coding(1)” .
4. Updated [Table 28-8 on page 334](#) “LCD Controller Characteristics” .
5. Updated “[Ordering Information](#)” on page 372 to include “Tape & Reel” devices. The “AI” and “MI” devices removed.
6. Updated “[Errata](#)” on page 379.
7. Updated the datasheet according to the Atmel new brand style guide, including the last page.

11.2 Rev. 2552J – 08/07

1. Updated “[Features](#)” on page 1.
2. Added “[Data Retention](#)” on page 9.
3. Updated “[Serial Programming Algorithm](#)” on page 309.
4. Updated “[Speed Grades](#)” on page 328.
5. Updated “[System and Reset Characteristics](#)” on page 330.
6. Moved Register Descriptions to the end of each chapter.

11.3 Rev. 2552I – 04/07

1. Updated date in backpage
2. Updated column in [Table 28-5 on page 330](#).

11.4 Rev. 2552H – 11/06

1. Updated [Table 28-7 on page 333](#).
2. Updated note in [Table 28-7 on page 333](#) and [Table 28-2 on page 329](#).

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