

## Features

- High Performance, Low Power AVR<sup>®</sup> 8-Bit Microcontroller
- Advanced RISC Architecture
  - 130 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
- Non-volatile Program and Data Memories
  - In-System Self-Programmable Flash, Endurance: 10,000 Write/Erase Cycles
    - 32K bytes (ATmega329/ATmega3290)
    - 64K bytes (ATmega649/ATmega6490)
  - Optional Boot Code Section with Independent Lock Bits
    - In-System Programming by On-chip Boot Program
    - True Read-While-Write Operation
  - EEPROM, Endurance: 100,000 Write/Erase Cycles
    - 1K bytes (ATmega329/ATmega3290)
    - 2K bytes (ATmega649/ATmega6490)
  - Internal SRAM
    - 2K bytes (ATmega329/ATmega3290)
    - 4K bytes (ATmega649/ATmega6490)
  - 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
  - 4 x 25 Segment LCD Driver (ATmega329/ATmega649)
  - 4 x 40 Segment LCD Driver (ATmega3290/ATmega6490)
  - Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
  - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
  - Real Time Counter with Separate Oscillator
  - Four PWM Channels
  - 8-channel, 10-bit ADC
  - Programmable Serial USART
  - Master/Slave SPI Serial Interface
  - Universal Serial Interface with Start Condition Detector
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - On-chip Analog Comparator
  - Interrupt and Wake-up on Pin Change
- Special Microcontroller Features
  - Power-on Reset and Programmable Brown-out Detection
  - Internal Calibrated Oscillator
  - External and Internal Interrupt Sources
  - Five Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, and Standby
- I/O and Packages
  - 53/68 Programmable I/O Lines
  - 64-lead TQFP, 64-pad QFN/MLF, and 100-lead TQFP
- Speed Grade:
  - ATmega329V/ATmega3290V/ATmega649V/ATmega6490V:  
0 - 4 MHz @ 1.8 - 5.5V, 0 - 8 MHz @ 2.7 - 5.5V
  - ATmega329/3290/649/6490:  
0 - 8 MHz @ 2.7 - 5.5V, 0 - 16 MHz @ 4.5 - 5.5V
- Temperature range:
  - -40°C to 85°C Industrial



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

ATmega329/V  
ATmega3290/V  
ATmega649/V  
ATmega6490/V

Preliminary  
Summary

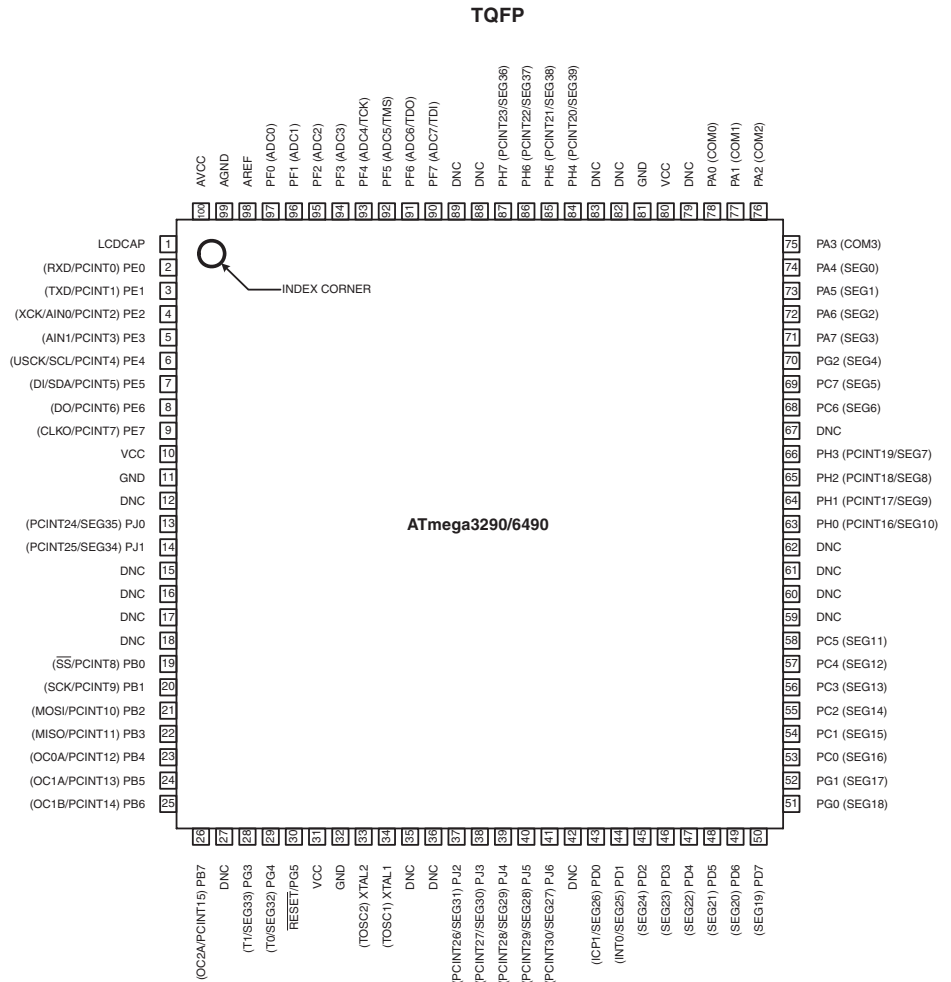


## Features (Continued)

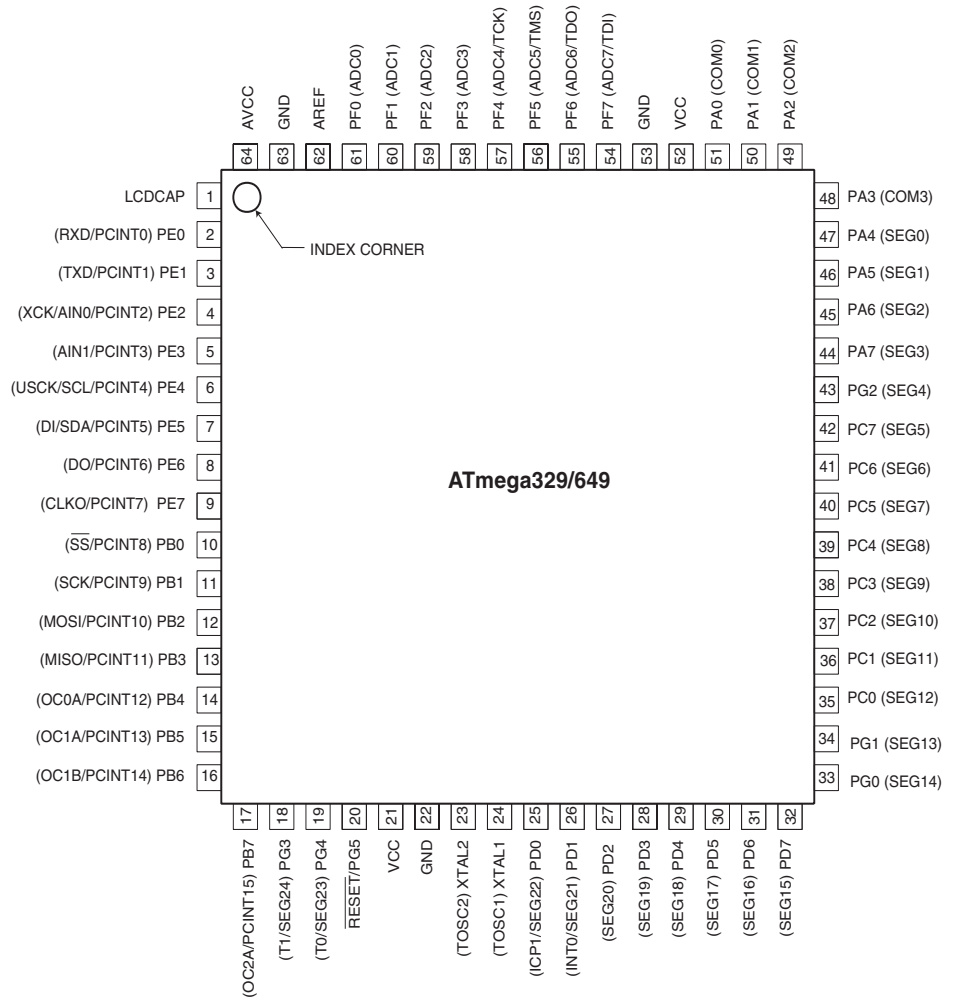
- Ultra-Low Power Consumption
  - Active Mode:
    - 1 MHz, 1.8V: 350  $\mu$ A
    - 32 kHz, 1.8V: 20  $\mu$ A (including Oscillator)
    - 32 kHz, 1.8V: 40  $\mu$ A (including Oscillator and LCD)
  - Power-down Mode:
    - 100 nA at 1.8V

## Pin Configurations

Figure 1. Pinout ATmega3290/6490



**Figure 2.** Pinout ATmega329/649



**Note:** The large center pad underneath the QFN/MLF packages is made of metal and internally connected to GND. It should be soldered or glued to the board to ensure good mechanical stability. If the center pad is left unconnected, the package might loosen from the board.

## Disclaimer

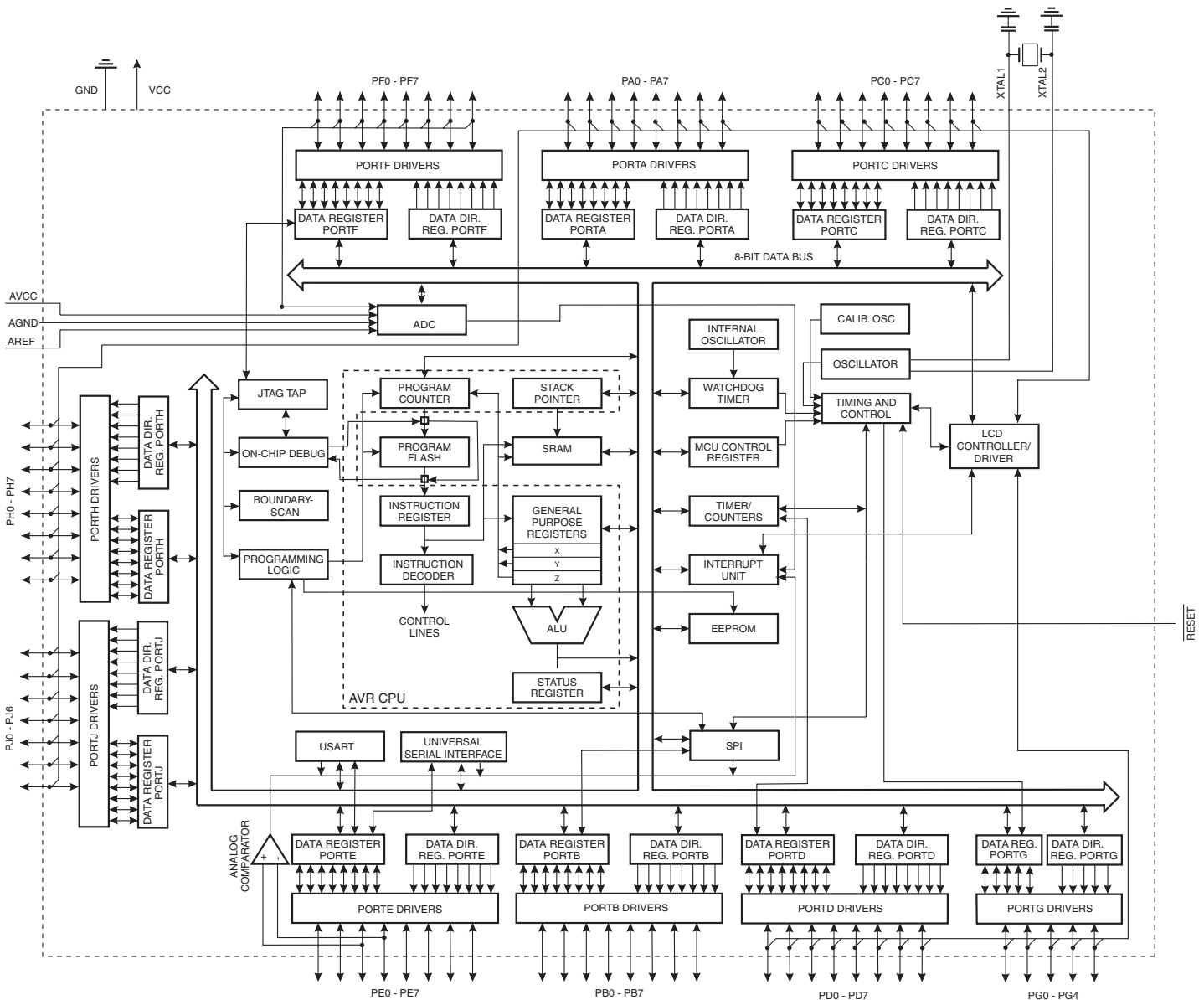
Typical values contained in this datasheet are based on simulations and characterization of other AVR microcontrollers manufactured on the same process technology. Min and Max values will be available after the device is characterized.

## Overview

The 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.

## Block Diagram

Figure 3. 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 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 ATmega329/3290/649/6490 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.



## Comparison between ATmega329, ATmega3290, ATmega649 and ATmega6490

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

**Table 1.** Configuration Summary

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

## Pin Descriptions

**V<sub>CC</sub>**

Digital supply voltage.

**GND**

Ground.

**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.

**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.

**Port C (PC7..PC0)**

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

Port C also serves the functions of special features of the ATmega329/3290/649/6490 as listed on page 71.

**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 ATmega329/3290/649/6490 as listed on page 73.

## Port E (PE7..PE0)

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

Port E also serves the functions of various special features of the ATmega329/3290/649/6490 as listed on page 75.

## Port F (PF7..PF0)

Port F serves as the analog inputs to the A/D Converter.

Port F 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 F output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port F pins that are externally pulled low will source current if the pull-up resistors are activated. The Port F 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 PF7(TDI), PF5(TMS), and PF4(TCK) will be activated even if a reset occurs.

Port F also serves the functions of the JTAG interface.

## 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.

## 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.

## 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.

## 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 16 on page 41. Shorter pulses are not guaranteed to generate a reset.

## XTAL1

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

<b>XTAL2</b>	Output from the inverting Oscillator amplifier.
<b>AVCC</b>	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.
<b>AREF</b>	This is the analog reference pin for the A/D Converter.
<b>LCDCAP</b>	An external capacitor (typical > 470 nF) must be connected to the LCDCAP pin as shown in Figure 99. This capacitor acts as a reservoir for LCD power ( $V_{LCD}$ ). A large capacitance reduces ripple on $V_{LCD}$ but increases the time until $V_{LCD}$ reaches its target value.

## Resources

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



## 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)	<b>LCDDR19</b>	<b>SEG339</b>	<b>SEG338</b>	<b>SEG337</b>	<b>SEG336</b>	<b>SEG335</b>	<b>SEG334</b>	<b>SEG333</b>	<b>SEG332</b>	234
(0xFE)	LCDDR18	<b>SEG331</b>	<b>SEG330</b>	<b>SEG329</b>	<b>SEG328</b>	<b>SEG327</b>	<b>SEG326</b>	<b>SEG325</b>	SEG324	234
(0xFD)	LCDDR17	SEG323	SEG322	SEG321	SEG320	SEG319	SEG318	SEG317	SEG316	234
(0xFC)	LCDDR16	SEG315	SEG314	SEG313	SEG312	SEG311	SEG310	SEG309	SEG308	234
(0xFB)	LCDDR15	SEG307	SEG306	SEG305	SEG304	SEG303	SEG302	SEG301	SEG300	234
(0xFA)	<b>LCDDR14</b>	<b>SEG239</b>	<b>SEG238</b>	<b>SEG237</b>	<b>SEG236</b>	<b>SEG235</b>	<b>SEG234</b>	<b>SEG233</b>	<b>SEG232</b>	234
(0xF9)	LCDDR13	<b>SEG231</b>	<b>SEG230</b>	<b>SEG229</b>	<b>SEG228</b>	<b>SEG227</b>	<b>SEG226</b>	<b>SEG225</b>	SEG224	234
(0xF8)	LCDDR12	SEG223	SEG222	SEG221	SEG220	SEG219	SEG218	SEG217	SEG216	234
(0xF7)	LCDDR11	SEG215	SEG214	SEG213	SEG212	SEG211	SEG210	SEG209	SEG208	234
(0xF6)	LCDDR10	SEG207	SEG206	SEG205	SEG204	SEG203	SEG202	SEG201	SEG200	234
(0xF5)	<b>LCDDR09</b>	<b>SEG139</b>	<b>SEG138</b>	<b>SEG137</b>	<b>SEG136</b>	<b>SEG135</b>	<b>SEG134</b>	<b>SEG133</b>	<b>SEG132</b>	234
(0xF4)	LCDDR08	<b>SEG131</b>	<b>SEG130</b>	<b>SEG129</b>	<b>SEG128</b>	<b>SEG127</b>	<b>SEG126</b>	<b>SEG125</b>	SEG124	234
(0xF3)	LCDDR07	SEG123	SEG122	SEG121	SEG120	SEG119	SEG118	SEG117	SEG116	234
(0xF2)	LCDDR06	SEG115	SEG114	SEG113	SEG112	SEG111	SEG110	SEG109	SEG108	234
(0xF1)	LCDDR05	SEG107	SEG106	SEG105	SEG104	SEG103	SEG102	SEG101	SEG100	234
(0xF0)	<b>LCDDR04</b>	<b>SEG039</b>	<b>SEG038</b>	<b>SEG037</b>	<b>SEG036</b>	<b>SEG035</b>	<b>SEG034</b>	<b>SEG033</b>	<b>SEG032</b>	234
(0xEF)	LCDDR03	<b>SEG031</b>	<b>SEG030</b>	<b>SEG029</b>	<b>SEG028</b>	<b>SEG027</b>	<b>SEG026</b>	<b>SEG025</b>	SEG024	234
(0xEE)	LCDDR02	SEG023	SEG022	SEG021	SEG020	SEG019	SEG018	SEG017	SEG016	234
(0xED)	LCDDR01	SEG015	SEG014	SEG013	SEG012	SEG011	SEG010	SEG009	SEG008	234
(0xEC)	LCDDR00	SEG007	SEG006	SEG005	SEG004	SEG003	SEG002	SEG001	SEG000	234
(0xEB)	Reserved	-	-	-	-	-	-	-	-	
(0xEA)	Reserved	-	-	-	-	-	-	-	-	
(0xE9)	Reserved	-	-	-	-	-	-	-	-	
(0xE8)	Reserved	-	-	-	-	-	-	-	-	
(0xE7)	LCDDCC	LCDDC2	LCDDC1	LCDDC0	-	LCDDC3	LCDDC2	LCDDC1	LCDDC0	233
(0xE6)	LCDDFR	-	LCDDPS2	LCDDPS1	LCDDPS0	-	LCDDC2	LCDDC1	LCDDC0	231
(0xE5)	LCDCRB	LCDCS	LCD2B	LCDMUX1	LCDMUX0	<b>LCDDPM3</b>	LCDDPM2	LCDDPM1	LCDDPM0	229
(0xE4)	LCDCRA	LCDEN	LCDAB	-	LCDIF	LCDIE	-	-	LCDDBL	229
(0xE3)	Reserved	-	-	-	-	-	-	-	-	
(0xE2)	Reserved	-	-	-	-	-	-	-	-	
(0xE1)	Reserved	-	-	-	-	-	-	-	-	
(0xE0)	Reserved	-	-	-	-	-	-	-	-	
(0xDF)	Reserved	-	-	-	-	-	-	-	-	
(0xDE)	Reserved	-	-	-	-	-	-	-	-	
(0xDD)	<b>PORTJ</b>	-	<b>PORTJ6</b>	<b>PORTJ5</b>	<b>PORTJ4</b>	<b>PORTJ3</b>	<b>PORTJ2</b>	<b>PORTJ1</b>	<b>PORTJ0</b>	88
(0xDC)	<b>DDRJ</b>	-	<b>DDJ6</b>	<b>DDJ5</b>	<b>DDJ4</b>	<b>DDJ3</b>	<b>DDJ2</b>	<b>DDJ1</b>	<b>DDJ0</b>	88
(0xDB)	<b>PINJ</b>	-	<b>PINJ6</b>	<b>PINJ5</b>	<b>PINJ4</b>	<b>PINJ3</b>	<b>PINJ2</b>	<b>PINJ1</b>	<b>PINJ0</b>	88
(0xDA)	<b>PORTH</b>	<b>PORTH7</b>	<b>PORTH6</b>	<b>PORTH5</b>	<b>PORTH4</b>	<b>PORTH3</b>	<b>PORTH2</b>	<b>PORTH1</b>	<b>PORTH0</b>	88
(0xD9)	<b>DDRH</b>	<b>DDH7</b>	<b>DDH6</b>	<b>DDH5</b>	<b>DDH4</b>	<b>DDH3</b>	<b>DDH2</b>	<b>DDH1</b>	<b>DDH0</b>	88
(0xD8)	<b>PINH</b>	<b>PINH7</b>	<b>PINH6</b>	<b>PINH5</b>	<b>PINH4</b>	<b>PINH3</b>	<b>PINH2</b>	<b>PINH1</b>	<b>PINH0</b>	88
(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								179
(0xC5)	UBRR0H	USART0 Baud Rate Register High								182
(0xC4)	UBRR0L	USART0 Baud Rate Register Low								182
(0xC3)	Reserved	-	-	-	-	-	-	-	-	



Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
(0xC2)	UCSR0C	-	UMSEL0	UPM01	UPM00	USBS0	UCSZ01	UCSZ00	UCPOL0	181
(0xC1)	UCSR0B	RXCIE0	TXCIE0	UDRIE0	RXEN0	TXEN0	UCSZ02	RXB80	TXB80	180
(0xC0)	UCSR0A	RXC0	TXC0	UDRE0	FE0	DOR0	UPE0	U2X0	MPCM0	179
(0xBF)	Reserved	-	-	-	-	-	-	-	-	
(0xBE)	Reserved	-	-	-	-	-	-	-	-	
(0xBD)	Reserved	-	-	-	-	-	-	-	-	
(0xBC)	Reserved	-	-	-	-	-	-	-	-	
(0xBB)	Reserved	-	-	-	-	-	-	-	-	
(0xBA)	USIDR	USI Data Register								194
(0xB9)	USISR	USISIF	USIOIF	USIPF	USIDC	USICNT3	USICNT2	USICNT1	USICNT0	195
(0xB8)	USICR	USISIE	USIOIE	USIWM1	USIWM0	USICS1	USICS0	USICLK	USITC	196
(0xB7)	Reserved	-	-	-	-	-	-	-	-	
(0xB6)	ASSR	-	-	-	EXCLK	AS2	TCN2UB	OCR2UB	TCR2UB	147
(0xB5)	Reserved	-	-	-	-	-	-	-	-	
(0xB4)	Reserved	-	-	-	-	-	-	-	-	
(0xB3)	OCR2A	Timer/Counter 2 Output Compare Register A								146
(0xB2)	TCNT2	Timer/Counter2								146
(0xB1)	Reserved	-	-	-	-	-	-	-	-	
(0xB0)	TCCR2A	FOC2A	WGM20	COM2A1	COM2A0	WGM21	CS22	CS21	CS20	144
(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								130
(0x8A)	OCR1BL	Timer/Counter1 Output Compare Register B Low								130
(0x89)	OCR1AH	Timer/Counter1 Output Compare Register A High								130
(0x88)	OCR1AL	Timer/Counter1 Output Compare Register A Low								130
(0x87)	ICR1H	Timer/Counter1 Input Capture Register High								130
(0x86)	ICR1L	Timer/Counter1 Input Capture Register Low								130
(0x85)	TCNT1H	Timer/Counter1 High								130
(0x84)	TCNT1L	Timer/Counter1 Low								130

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
(0x83)	Reserved	-	-	-	-	-	-	-	-	
(0x82)	TCCR1C	FOC1A	FOC1B	-	-	-	-	-	-	129
(0x81)	TCCR1B	ICNC1	ICES1	-	WGM13	WGM12	CS12	CS11	CS10	128
(0x80)	TCCR1A	COM1A1	COM1A0	COM1B1	COM1B0	-	-	WGM11	WGM10	126
(0x7F)	DIDR1	-	-	-	-	-	-	AIN1D	AIN0D	201
(0x7E)	DIDR0	ADC7D	ADC6D	ADC5D	ADC4D	ADC3D	ADC2D	ADC1D	ADC0D	218
(0x7D)	Reserved	-	-	-	-	-	-	-	-	
(0x7C)	ADMUX	REFS1	REFS0	ADLAR	MUX4	MUX3	MUX2	MUX1	MUX0	214
(0x7B)	ADCSRB	-	ACME	-	-	-	ADTS2	ADTS1	ADTS0	199/217
(0x7A)	ADCSRA	ADEN	ADSC	ADATE	ADIF	ADIE	ADPS2	ADPS1	ADPS0	216
(0x79)	ADCH	ADC Data Register High								217
(0x78)	ADCL	ADC Data Register Low								217
(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	149
(0x6F)	TIMSK1	-	-	ICIE1	-	-	OCIE1B	OCIE1A	TOIE1	131
(0x6E)	TIMSK0	-	-	-	-	-	-	OCIE0A	TOIE0	102
(0x6D)	PCMSK2	PCINT23	PCINT22	PCINT21	PCINT20	PCINT19	PCINT18	PCINT17	PCINT16	58
(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]								29
(0x65)	Reserved	-	-	-	-	-	-	-	-	
(0x64)	PRR	-	-	-	PRLCD	PRTIM1	PRSPI	PSUSART0	PRADC	38
(0x63)	Reserved	-	-	-	-	-	-	-	-	
(0x62)	Reserved	-	-	-	-	-	-	-	-	
(0x61)	CLKPR	CLKPCE	-	-	-	CLKPS3	CLKPS2	CLKPS1	CLKPS0	31
(0x60)	WDTCR	-	-	-	WDCE	WDE	WDP2	WDP1	WDP0	46
0x3F (0x5F)	SREG	I	T	H	S	V	N	Z	C	11
0x3E (0x5E)	SPH	Stack Pointer High								13
0x3D (0x5D)	SPL	Stack Pointer Low								13
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	271
0x36 (0x56)	Reserved	-	-	-	-	-	-	-	-	
0x35 (0x55)	MCUCR	JTD	-	-	PUD	-	-	IVSEL	IVCE	52/67/244
0x34 (0x54)	MCUSR	-	-	-	JTRF	WDRF	BORF	EXTRF	PORF	44
0x33 (0x53)	SMCR	-	-	-	-	SM2	SM1	SM0	SE	38
0x32 (0x52)	Reserved	-	-	-	-	-	-	-	-	
0x31 (0x51)	OCDR	IDRD/OCDR7	OCDR6	OCDR5	OCDR4	OCDR3	OCDR2	OCDR1	OCDR0	240
0x30 (0x50)	ACSR	ACD	ACBG	ACO	ACI	ACIE	ACIC	ACIS1	ACIS0	199
0x2F (0x4F)	Reserved	-	-	-	-	-	-	-	-	
0x2E (0x4E)	SPDR	SPI Data Register								159
0x2D (0x4D)	SPSR	SPIF	WCOL	-	-	-	-	-	SPI2X	159
0x2C (0x4C)	SPCR	SPIE	SPE	DORD	MSTR	CPOL	CPHA	SPR1	SPR0	157
0x2B (0x4B)	GPOR2	General Purpose I/O Register								24
0x2A (0x4A)	GPOR1	General Purpose I/O Register								24
0x29 (0x49)	Reserved	-	-	-	-	-	-	-	-	
0x28 (0x48)	Reserved	-	-	-	-	-	-	-	-	
0x27 (0x47)	OCRA	Timer/Counter0 Output Compare A								102
0x26 (0x46)	TCNT0	Timer/Counter0								101
0x25 (0x45)	Reserved	-	-	-	-	-	-	-	-	



Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
0x24 (0x44)	TCCR0A	FOC0A	WGM00	COM0A1	COM0A0	WGM01	CS02	CS01	CS00	99
0x23 (0x43)	GTCCR	TSM	-	-	-	-	-	PSR2	PSR10	104/151
0x22 (0x42)	EEARH	-	-	-	-	-	EEPROM Address Register High			20
0x21 (0x41)	EEARL	EEPROM Address Register Low								20
0x20 (0x40)	EEDR	EEPROM Data Register								20
0x1F (0x3F)	EECR	-	-	-	-	EERIE	EEMWE	EWE	EERE	20
0x1E (0x3E)	GPOR0	General Purpose I/O Register								24
0x1D (0x3D)	EIMSK	PCIE3	PCIE2	PCIE1	PCIE0	-	-	-	INT0	56
0x1C (0x3C)	EIFR	PCIF3	PCIF2	PCIF1	PCIF0	-	-	-	INTF0	57
0x1B (0x3B)	Reserved	-	-	-	-	-	-	-	-	
0x1A (0x3A)	Reserved	-	-	-	-	-	-	-	-	
0x19 (0x39)	Reserved	-	-	-	-	-	-	-	-	
0x18 (0x38)	Reserved	-	-	-	-	-	-	-	-	
0x17 (0x37)	TIFR2	-	-	-	-	-	-	OCF2A	TOV2	149
0x16 (0x36)	TIFR1	-	-	ICF1	-	-	OCF1B	OCF1A	TOV1	131
0x15 (0x35)	TIFR0	-	-	-	-	-	-	OCF0A	TOV0	102
0x14 (0x34)	PORTG	-	-	-	PORTG4	PORTG3	PORTG2	PORTG1	PORTG0	88
0x13 (0x33)	DDRG	-	-	-	DDG4	DDG3	DDG2	DDG1	DDG0	88
0x12 (0x32)	PING	-	-	PING5	PING4	PING3	PING2	PING1	PING0	88
0x11 (0x31)	PORTF	PORTF7	PORTF6	PORTF5	PORTF4	PORTF3	PORTF2	PORTF1	PORTF0	87
0x10 (0x30)	DDRF	DDF7	DDF6	DDF5	DDF4	DDF3	DDF2	DDF1	DDF0	87
0x0F (0x2F)	PINF	PINF7	PINF6	PINF5	PINF4	PINF3	PINF2	PINF1	PINF0	87
0x0E (0x2E)	PORTE	PORTE7	PORTE6	PORTE5	PORTE4	PORTE3	PORTE2	PORTE1	PORTE0	87
0x0D (0x2D)	DDRE	DDE7	DDE6	DDE5	DDE4	DDE3	DDE2	DDE1	DDE0	87
0x0C (0x2C)	PINE	PINE7	PINE6	PINE5	PINE4	PINE3	PINE2	PINE1	PINE0	87
0x0B (0x2B)	PORTD	PORTD7	PORTD6	PORTD5	PORTD4	PORTD3	PORTD2	PORTD1	PORTD0	87
0x0A (0x2A)	DDR	DDD7	DDD6	DDD5	DDD4	DDD3	DDD2	DDD1	DDD0	87
0x09 (0x29)	PIND	PIND7	PIND6	PIND5	PIND4	PIND3	PIND2	PIND1	PIND0	87
0x08 (0x28)	PORTC	PORTC7	PORTC6	PORTC5	PORTC4	PORTC3	PORTC2	PORTC1	PORTC0	86
0x07 (0x27)	DDRC	DDC7	DDC6	DDC5	DDC4	DDC3	DDC2	DDC1	DDC0	86
0x06 (0x26)	PINC	PINC7	PINC6	PINC5	PINC4	PINC3	PINC2	PINC1	PINC0	86
0x05 (0x25)	PORTB	PORTB7	PORTB6	PORTB5	PORTB4	PORTB3	PORTB2	PORTB1	PORTB0	86
0x04 (0x24)	DDRB	DDB7	DDB6	DDB5	DDB4	DDB3	DDB2	DDB1	DDB0	86
0x03 (0x23)	PINB	PINB7	PINB6	PINB5	PINB4	PINB3	PINB2	PINB1	PINB0	86
0x02 (0x22)	PORTA	PORTA7	PORTA6	PORTA5	PORTA4	PORTA3	PORTA2	PORTA1	PORTA0	86
0x01 (0x21)	DDRA	DDA7	DDA6	DDA5	DDA4	DDA3	DDA2	DDA1	DDA0	86
0x00 (0x20)	PINA	PINA7	PINA6	PINA5	PINA4	PINA3	PINA2	PINA1	PINA0	86

- 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 AVR's, 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.

## 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	Rd,K	Add Immediate to Word	$Rdh:Rdl \leftarrow Rdh:Rdl + K$	Z,C,N,V,S	2
SUB	Rd, Rr	Subtract two Registers	$Rd \leftarrow Rd - Rr$	Z,C,N,V,H	1
SUBI	Rd, K	Subtract Constant from Register	$Rd \leftarrow Rd - K$	Z,C,N,V,H	1
SBC	Rd, Rr	Subtract with Carry two Registers	$Rd \leftarrow Rd - Rr - C$	Z,C,N,V,H	1
SBCI	Rd, K	Subtract with Carry Constant from Reg.	$Rd \leftarrow Rd - K - C$	Z,C,N,V,H	1
SBIW	Rd,K	Subtract Immediate from Word	$Rdh:Rdl \leftarrow Rdh:Rdl - K$	Z,C,N,V,S	2
AND	Rd, Rr	Logical AND Registers	$Rd \leftarrow Rd \bullet Rr$	Z,N,V	1
ANDI	Rd, K	Logical AND Register and Constant	$Rd \leftarrow Rd \bullet K$	Z,N,V	1
OR	Rd, Rr	Logical OR Registers	$Rd \leftarrow Rd \vee Rr$	Z,N,V	1
ORI	Rd, K	Logical OR Register and Constant	$Rd \leftarrow Rd \vee K$	Z,N,V	1
EOR	Rd, Rr	Exclusive OR Registers	$Rd \leftarrow Rd \oplus Rr$	Z,N,V	1
COM	Rd	One's Complement	$Rd \leftarrow 0xFF - Rd$	Z,C,N,V	1
NEG	Rd	Two's Complement	$Rd \leftarrow 0x00 - Rd$	Z,C,N,V,H	1
SBR	Rd,K	Set Bit(s) in Register	$Rd \leftarrow Rd \vee K$	Z,N,V	1
CBR	Rd,K	Clear Bit(s) in Register	$Rd \leftarrow Rd \bullet (0xFF - K)$	Z,N,V	1
INC	Rd	Increment	$Rd \leftarrow Rd + 1$	Z,N,V	1
DEC	Rd	Decrement	$Rd \leftarrow Rd - 1$	Z,N,V	1
TST	Rd	Test for Zero or Minus	$Rd \leftarrow Rd \bullet Rd$	Z,N,V	1
CLR	Rd	Clear Register	$Rd \leftarrow Rd \oplus Rd$	Z,N,V	1
SER	Rd	Set Register	$Rd \leftarrow 0xFF$	None	1
MUL	Rd, Rr	Multiply Unsigned	$R1:R0 \leftarrow Rd \times Rr$	Z,C	2
MULS	Rd, Rr	Multiply Signed	$R1:R0 \leftarrow Rd \times Rr$	Z,C	2
MULSU	Rd, Rr	Multiply Signed with Unsigned	$R1:R0 \leftarrow Rd \times Rr$	Z,C	2
FMUL	Rd, Rr	Fractional Multiply Unsigned	$R1:R0 \leftarrow (Rd \times Rr) \lll 1$	Z,C	2
FMULS	Rd, Rr	Fractional Multiply Signed	$R1:R0 \leftarrow (Rd \times Rr) \lll 1$	Z,C	2
FMULSU	Rd, Rr	Fractional Multiply Signed with Unsigned	$R1:R0 \leftarrow (Rd \times Rr) \lll 1$	Z,C	2
<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

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
OUT	P, Rr	Out Port	P ← Rr	None	1
PUSH	Rr	Push Register on Stack	STACK ← Rr	None	2

Mnemonics	Operands	Description	Operation	Flags	#Clocks
POP	Rd	Pop Register from Stack	Rd ← STACK	None	2
<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



## Ordering Information

### ATmega329

Speed (MHz) <sup>(3)</sup>	Power Supply	Ordering Code	Package Type <sup>(1)</sup>	Operational Range
8	1.8 - 5.5V	ATmega329V-8AI ATmega329V-8AU <sup>(2)</sup> ATmega329V-8MI ATmega329V-8MU <sup>(2)</sup>	64A 64A 64M1 64M1	Industrial (-40°C to 85°C)
16	2.7 - 5.5V	ATmega329-16AI ATmega329-16AU <sup>(2)</sup> ATmega329-16MI ATmega329-16MU <sup>(2)</sup>	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 138 on page 314 and Figure 139 on page 315.

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



## ATmega3290

Speed (MHz) <sup>(3)</sup>	Power Supply	Ordering Code	Package Type <sup>(1)</sup>	Operational Range
8	1.8 - 5.5V	ATmega3290V-8AI ATmega3290V-8AU <sup>(2)</sup>	100A 100A	Industrial (-40°C to 85°C)
16	2.7 - 5.5V	ATmega3290-16AI ATmega3290-16AU <sup>(2)</sup>	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 138 on page 314 and Figure 139 on page 315.

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



## ATmega649

Speed (MHz) <sup>(3)</sup>	Power Supply	Ordering Code	Package Type <sup>(1)</sup>	Operational Range
8	1.8 - 5.5V	ATmega649V-8AI ATmega649V-8AU <sup>(2)</sup> ATmega649V-8MI ATmega649V-8MU <sup>(2)</sup>	64A 64A 64M1 64M1	Industrial (-40°C to 85°C)
16	2.7 - 5.5V	ATmega649-16AI ATmega649-16AU <sup>(2)</sup> ATmega649-16MI ATmega649-16MU <sup>(2)</sup>	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 138 on page 314 and Figure 139 on page 315.

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

## ATmega6490

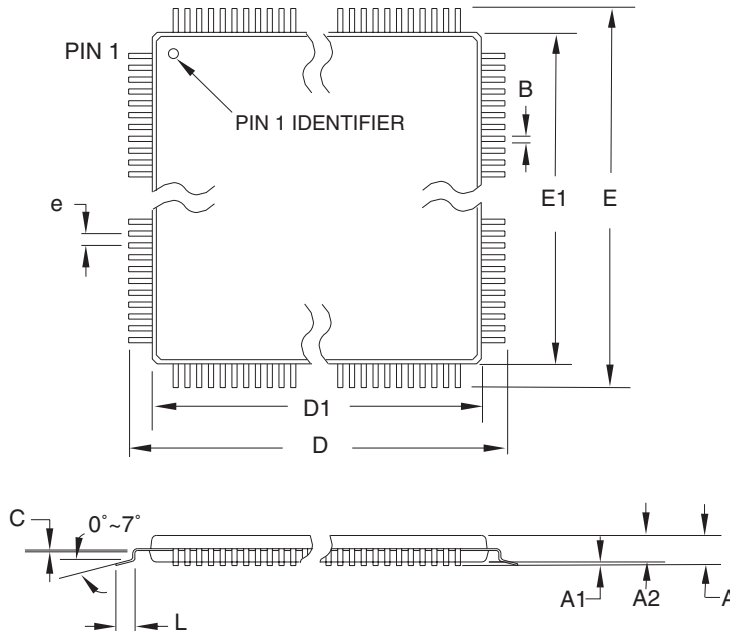
Speed (MHz) <sup>(3)</sup>	Power Supply	Ordering Code	Package Type <sup>(1)</sup>	Operational Range
8	1.8 - 5.5V	ATmega6490V-8AI ATmega6490V-8AU <sup>(2)</sup>	100A 100A	Industrial (-40°C to 85°C)
16	2.7 - 5.5V	ATmega6490-16AI ATmega6490-16AU <sup>(2)</sup>	100A 100A	Industrial (-40°C to 85°C)

- 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 138 on page 314 and Figure 139 on page 315.

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

# Packaging Information

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.

10/5/2001



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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)

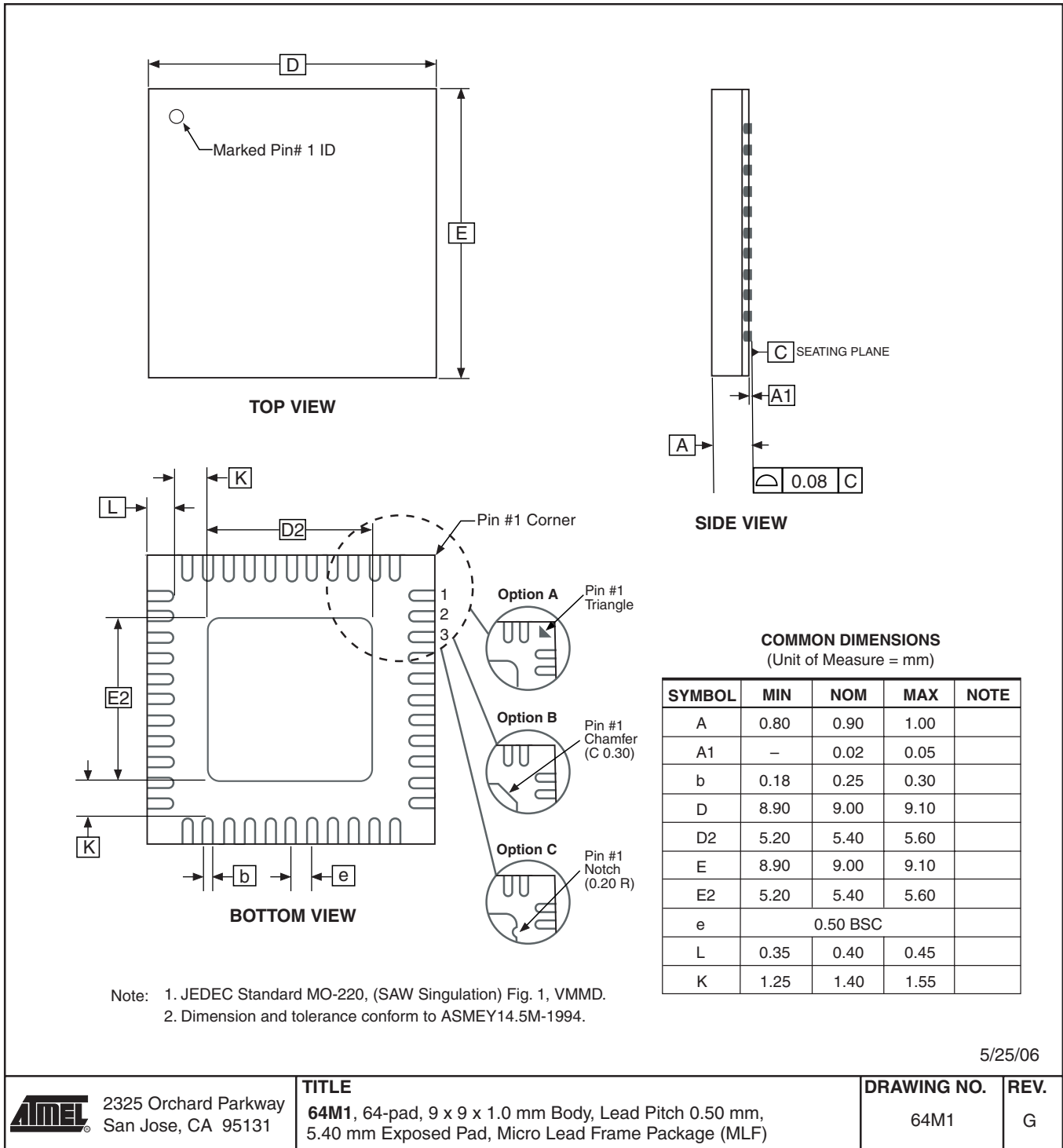
**DRAWING NO.**

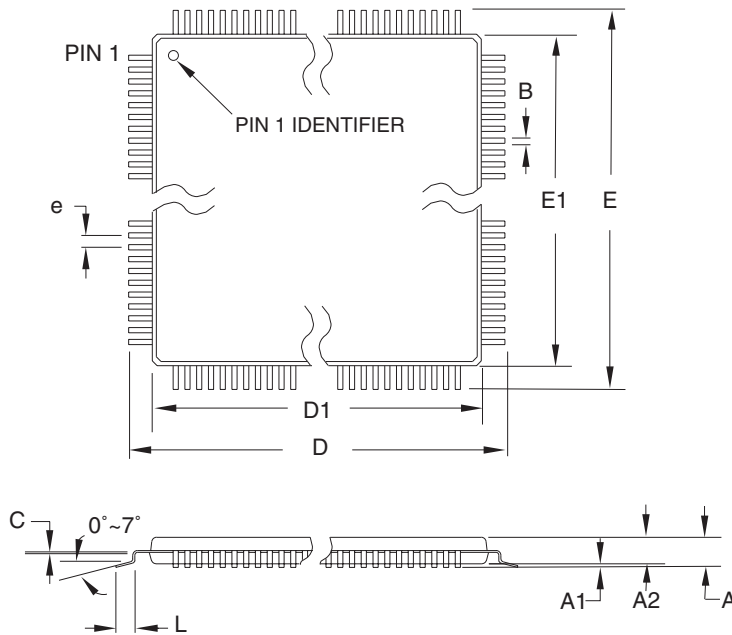
64A

**REV.**

B

## 64M1





**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.

10/5/2001

2325 Orchard Parkway San Jose, CA 95131	<b>TITLE</b>	<b>DRAWING NO.</b>	<b>REV.</b>
	<b>100A</b> , 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)	100A	C

## Errata

### 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

If one of the timer registers which is synchronized to the asynchronous timer2 clock is written in the cycle before a overflow interrupt occurs, the interrupt may be lost.

##### **Problem Fix/Workaround**

Always check that the Timer2 Timer/Counter register, TCNT2, does not have the value 0xFF before writing the Timer2 Control Register, TCCR2, or Output Compare Register, OCR2.

### ATmega329 rev. B

Not sampled.

### 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  $\mu$ s or longer

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

If one of the timer registers which is synchronized to the asynchronous timer2 clock is written in the cycle before a overflow interrupt occurs, the interrupt may be lost.

##### **Problem Fix/Workaround**

Always check that the Timer2 Timer/Counter register, TCNT2, does not have the value 0xFF before writing the Timer2 Control Register, TCCR2, or Output Compare Register, OCR2.

## 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**

If one of the timer registers which is synchronized to the asynchronous timer2 clock is written in the cycle before a overflow interrupt occurs, the interrupt may be lost.

### **Problem Fix/Workaround**

Always check that the Timer2 Timer/Counter register, TCNT2, does not have the value 0xFF before writing the Timer2 Control Register, TCCR2, or Output Compare Register, OCR2.

## ATmega3290 rev. B

Not sampled.

## 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  $\mu$ s or longer

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

If one of the timer registers which is synchronized to the asynchronous timer2 clock is written in the cycle before a overflow interrupt occurs, the interrupt may be lost.

### **Problem Fix/Workaround**

Always check that the Timer2 Timer/Counter register, TCNT2, does not have the value 0xFF before writing the Timer2 Control Register, TCCR2, or Output Compare Register, OCR2.



## ATmega649 rev. A

- **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**

If one of the timer registers which is synchronized to the asynchronous timer2 clock is written in the cycle before a overflow interrupt occurs, the interrupt may be lost.

**Problem Fix/Wortkaround**

Always check that the Timer2 Timer/Counter register, TCNT2, does not have the value 0xFF before writing the Timer2 Control Register, TCCR2, or Output Compare Register, OCR2.

## ATmega6490 rev. A

- **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**

If one of the timer registers which is synchronized to the asynchronous timer2 clock is written in the cycle before a overflow interrupt occurs, the interrupt may be lost.

**Problem Fix/Wortkaround**

Always check that the Timer2 Timer/Counter register, TCNT2, does not have the value 0xFF before writing the Timer2 Control Register, TCCR2, or Output Compare Register, OCR2.

## 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.

### Rev. 2552H – 11/06

1. Updated Table 141 on page 318.
2. Updated note in Table 141 on page 318 and Table 143 on page 319.

### Rev. 2552G – 07/06

1. Updated Table 55 on page 100, Table 57 on page 100, Table 62 on page 127, Table 64 on page 128, Table 64 on page 128, Table 67 on page 144 and Table 69 on page 145.
2. Updated “Fast PWM Mode” on page 118.
3. Updated Features in “USI – Universal Serial Interface” on page 187.
4. Added “Clock speed considerations.” on page 194.
5. “Errata” on page 364.

### Rev. 2552F – 06/06

1. Updated “Calibrated Internal RC Oscillator” on page 28.
2. Updated “OSCCAL – Oscillator Calibration Register” on page 29
3. Added Table 143 on page 319.

### Rev. 2552E – 04/06

1. Updated “Calibrated Internal RC Oscillator” on page 28.

### Rev. 2552D – 03/06

1. Updated “Errata” on page 364.

### Rev. 2552C – 03/06

1. Added “Resources” on page 8.
2. Added Addresses in Registers.
3. Updated number of General Purpose I/O pins.
4. Updated code example in “Bit 0 – IVCE: Interrupt Vector Change Enable” on page 52.
5. Updated Introduction in “I/O-Ports” on page 59.
6. Updated “SPI – Serial Peripheral Interface” on page 152.
7. Updated “Bit 6 – ACBG: Analog Comparator Bandgap Select” on page 201.
8. Updated Features in “Analog to Digital Converter” on page 203.
9. Updated “Prescaling and Conversion Timing” on page 206.
10. Updated features in “LCD Controller” on page 220.
11. Updated “ATmega329/3290/649/6490 Boot Loader Parameters” on page 280.
12. Updated “DC Characteristics” on page 310.
13. Updated “LCD Controller Characteristics – Preliminary Data – TBD” on page 319.

## Rev. 2552B – 05/05

1. MLF-package alternative changed to “Quad Flat No-Lead/Micro Lead Frame Package QFN/MLF”.
2. Added “Pin Change Interrupt Timing” on page 54.
3. Updated Table 104 on page 233, Table 105 on page 234 and Table 137 on page 299.
4. Added Figure 131 on page 300.
5. Updated Figure 92 on page 211 and Figure 124 on page 292.
6. Updated algorithm “Enter Programming Mode” on page 287.
7. Added “Supply Current of I/O modules” on page 325.
8. Updated “Ordering Information” on page 357.

## Rev. 2552A –11/04

1. Initial version.



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