ATmega328P Automotive

ATmega328P Automotive Silicon Errata and Data Sheet Clarification

Introduction

The ATmega328P Automotive devices you have received conform functionally to the current device data sheet (ww1.microchip.com/downloads/en/DeviceDoc/Atmel-7810-Automotive-Microcontrollers-ATmega328P_Datasheet.pdf), except for the anomalies described in this document. The errata described in this document will likely be addressed in future revisions of the ATmega328P Automotive devices.

Note:

- This document summarizes all the silicon errata issues from all silicon revisions, previous and current

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1. Silicon Issue Summary

Legend

- **-** Erratum is not applicable.
- **X** Erratum is applicable.
- ***** This silicon revision was never released to production.

Peripheral	Short Description	Valid for Silicon Revision	
		Rev. A-C	Rev. D
Device		*	-

2. Silicon Errata Issues

2.1 Errata Details

-	Erratum is not applicable.
X	Erratum is applicable.

3. Data Sheet Clarifications

Note the following typographic corrections and clarifications for the latest version of the device data sheet (ww1.microchip.com/downloads/en/DeviceDoc/Atmel-7810-Automotive-Microcontrollers-ATmega328P_Datasheet.pdf).

Note: Corrections are shown in **bold**. Where possible, the original bold text formatting has been removed for clarity.

3.1 Errata Section in Data Sheet is no Longer Valid

A clarification for the Errata section in the device data sheet has been made.

The errata content has been moved to a separate document, *ATmega328P Automotive Silicon Errata and Data Sheet Clarifications* (this document).

See the *Silicon Errata Issues* section of this document for the latest errata.

3.2 Ordering Information

3.2.1 Ordering Information

A clarification has been made to tables titled ‘Package Type’ for all devices documented in the data sheet:

- A note to the PN row was added informing that the package type can be delivered in two different styles

Package Type	
MA	32-lead, (7x7x1.0 mm) Plastic Thin Quad Flat Package (TQFP)
PN[(1)]	32-pad, (5x5x0.9 mm) body, Lead Pitch 0.50 mm Thin Plastic Quad Flat No-Lead (VQFN)

Note:

1. This package type can be delivered with two different styles in reference numbers ‘C04-21400’ (punched) and ‘C04-21395’ (sawn), as shown in section 3.3.1. PN. For PCB layouts, it is recommended to consider both *recommended land patterns*.

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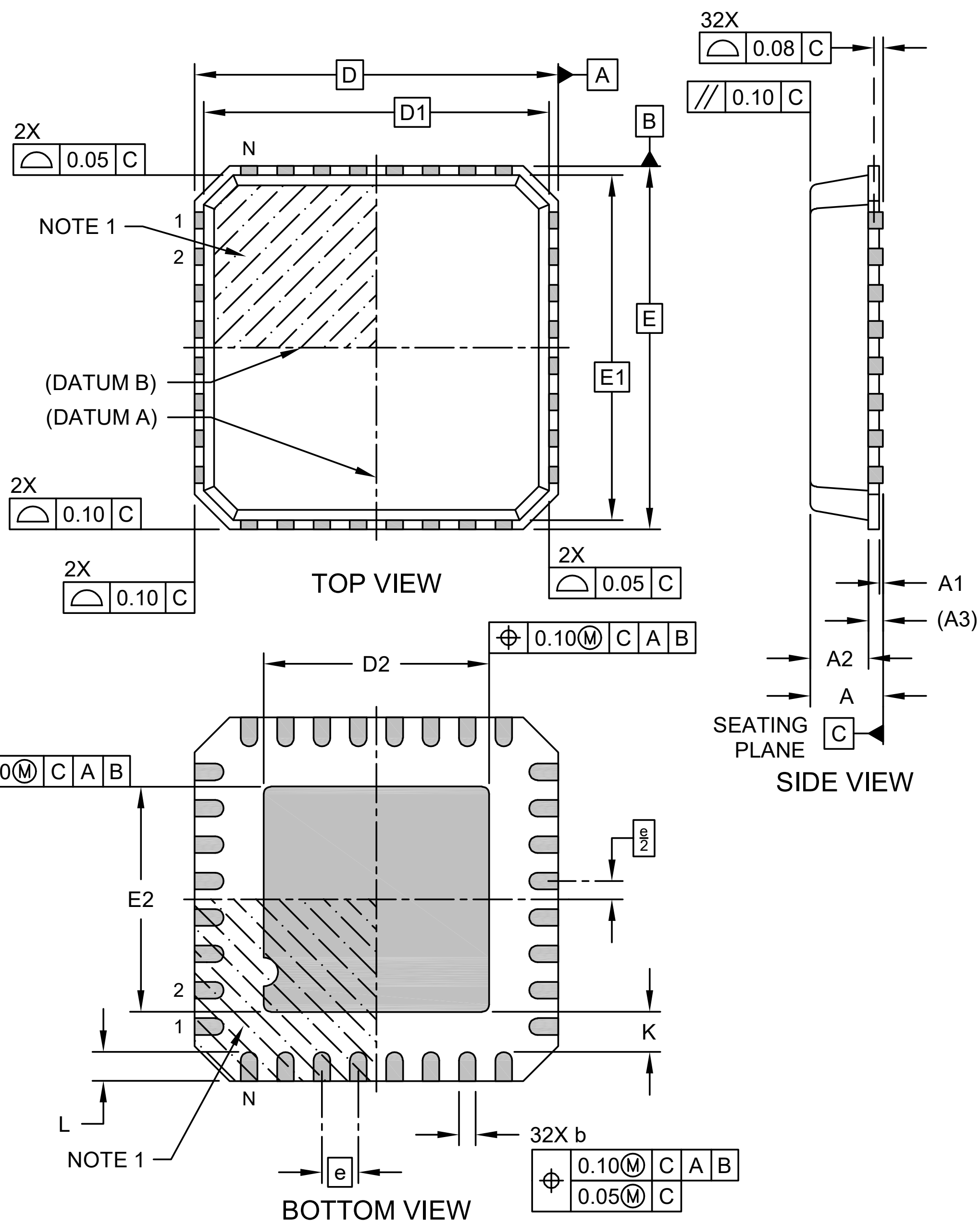
3.3 Packaging Information

3.3.1 PN

**32-Lead Thin Plastic Quad Flat, No Lead Package (S4B) - 5x5 mm Body [VQFN]
Punch Singulated; 3.10x3.10 mm Exposed Pad**

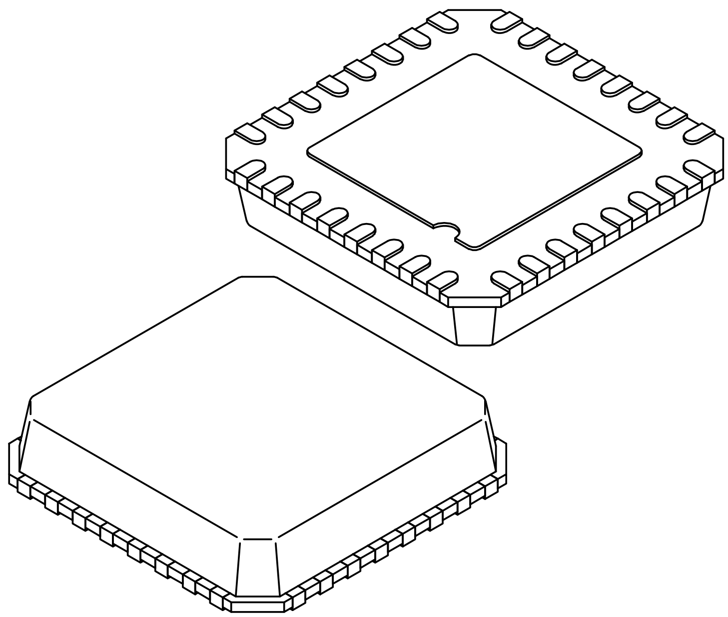
Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Microchip Technology Drawing C04-21400 Rev B Sheet 1 of 2

32-Lead Thin Plastic Quad Flat, No Lead Package (S4B) - 5x5 mm Body [VQFN] Punch Singulated; 3.10x3.10 mm Exposed Pad

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



	Units	MILLIMETERS		
	Dimension Limits	MIN	NOM	MAX
Number of Terminals	N		32	
Pitch	e		0.50 BSC	
Overall Height	A	0.80	0.85	1.00
Standoff	A1	0.00	0.02	0.05
Mold Cap Thickness	A2	-	0.65	0.70
Terminal Thickness	A3		0.20 REF	
Overall Length	D		5.00 BSC	
Mold Cap Length	D1		4.75 BSC	
Exposed Pad Length	D2	2.95	3.10	3.25
Overall Width	E		5.00 BSC	
Mold Cap Width	E1		4.75 BSC	
Exposed Pad Width	E2	2.95	3.10	3.25
Terminal Width	b	0.18	0.23	0.30
Terminal Length	L	0.30	0.40	0.50
Terminal-to-Exposed-Pad	K	0.20	-	-

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is punch singulated
3. Dimensioning and tolerancing per ASME Y14.5M

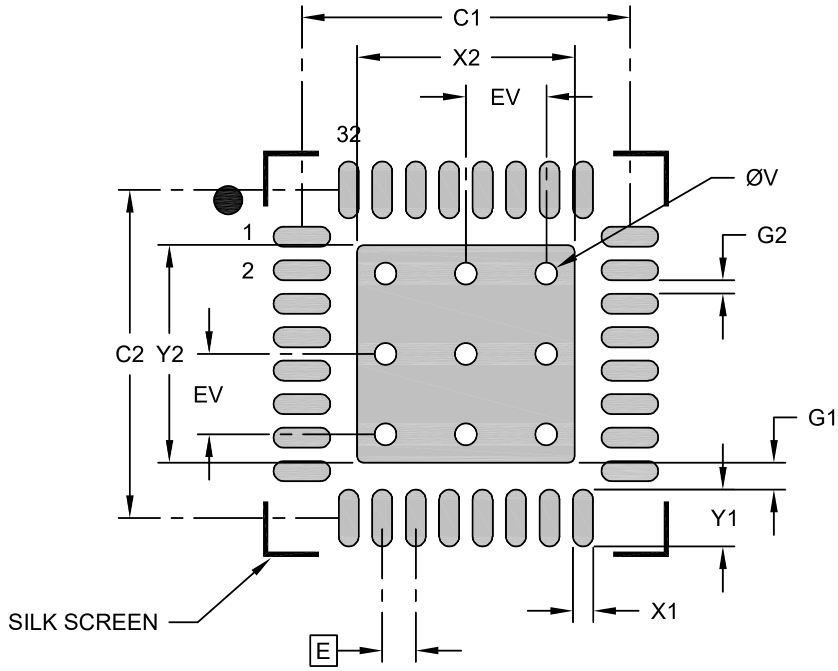
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

   REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-21400 Rev B Sheet 2 of 2

32-Lead Thin Plastic Quad Flat, No Lead Package (S4B) - 5x5 mm Body [VQFN] Punch Singulated; 3.10x3.10 mm Exposed Pad

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



RECOMMENDED LAND PATTERN

	Units	MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E		0.50 BSC	
Optional Center Pad Width	X2			3.25
Optional Center Pad Length	Y2			3.25
Contact Pad Spacing	C1		4.90	
Contact Pad Spacing	C2		4.90	
Contact Pad Width (X32)	X1			0.30
Contact Pad Length (X32)	Y1			0.85
Contact Pad to Center Pad (X32)	G1	0.40		
Contact Pad to Contact Pad (X28)	G2	0.20		
Thermal Via Diameter	V		0.33	
Thermal Via Pitch	EV		1.20	

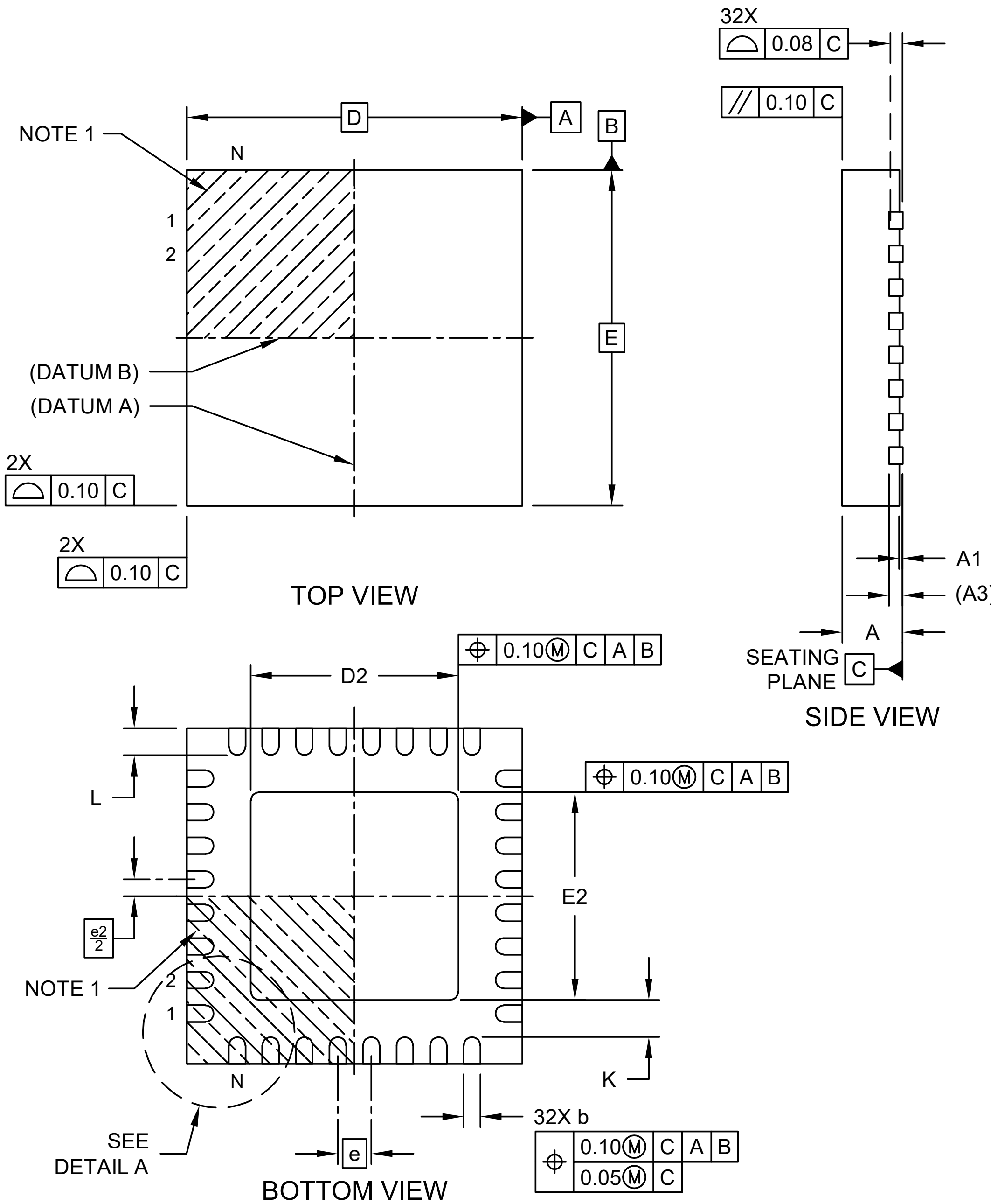
Notes:

1. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
2. For best soldering results, thermal vias, if used, should be filled or tented to avoid solder loss during reflow process

Microchip Technology Drawing C04-23400 Rev B

32-Lead Very Thin Plastic Quad Flat, No Lead Package (UBB) - 5x5x0.9 mm Body [VQFN] With 3.1x3.1 mm Exposed Pad; Atmel Legacy Global Package Code ZMF

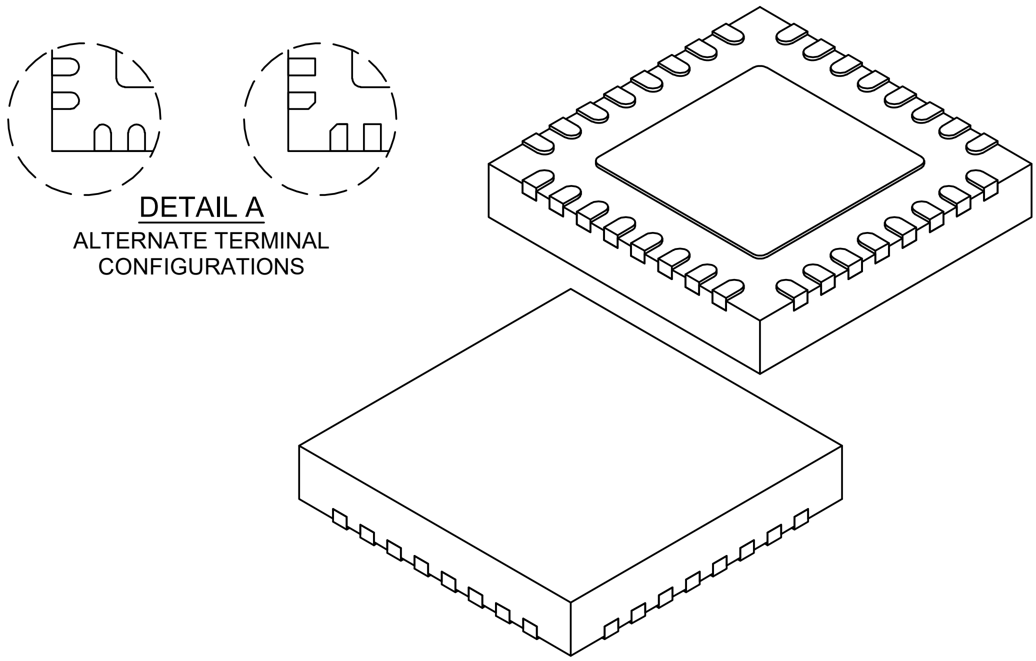
Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Microchip Technology Drawing C04-21395-UBB Rev C Sheet 1 of 2

32-Lead Very Thin Plastic Quad Flat, No Lead Package (UBB) - 5x5x0.9 mm Body [VQFN] With 3.1x3.1 mm Exposed Pad; Atmel Legacy Global Package Code ZMF

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



	Units	MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Terminals	N		32	
Pitch	e		0.50 BSC	
Overall Height	A	0.80	0.85	0.90
Standoff	A1	0.00	0.02	0.05
Terminal Thickness	A3		0.203 REF	
Overall Length	D		5.00 BSC	
Exposed Pad Length	D2	3.00	3.10	3.20
Overall Width	E		5.00 BSC	
Exposed Pad Width	E2	3.00	3.10	3.20
Terminal Width	b	0.18	0.25	0.30
Terminal Length	L	0.30	0.40	0.50
Terminal-to-Exposed-Pad	K	0.20	-	-

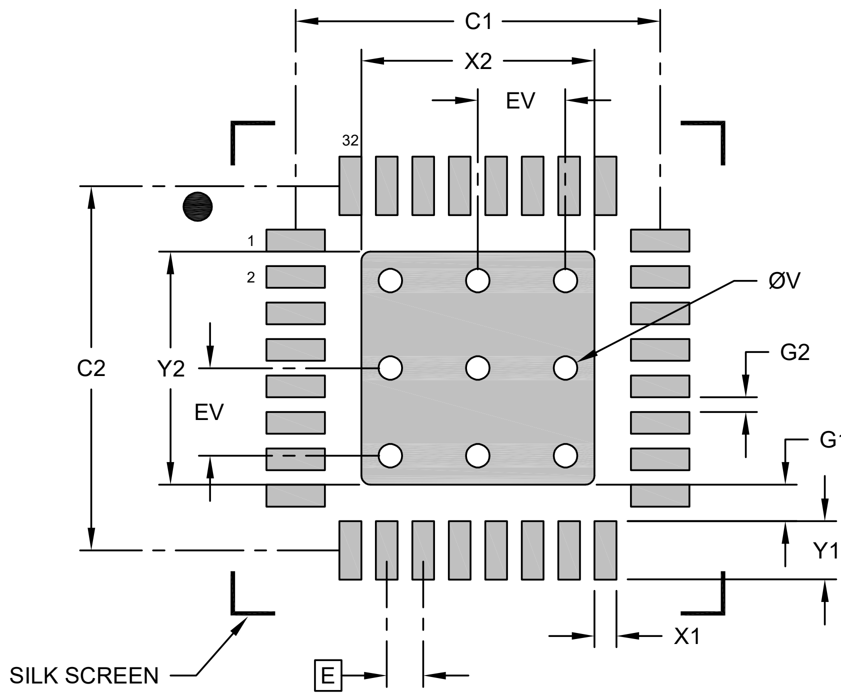
Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is saw singulated
3. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
   REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-21395-UBB Rev C Sheet 2 of 2

32-Lead Very Thin Plastic Quad Flat, No Lead Package (UBB) - 5x5x0.9 mm Body [VQFN] With 3.1x3.1 mm Exposed Pad; Atmel Legacy Global Package Code ZMF

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E		0.50 BSC	
Center Pad Width	X2			3.20
Center Pad Length	Y2			3.20
Contact Pad Spacing	C1		5.00	
Contact Pad Spacing	C2		5.00	
Contact Pad Width (X32)	X1			0.30
Contact Pad Length (X32)	Y1			0.80
Contact Pad to Center Pad (X32)	G1	0.20		
Contact Pad to Contact Pad (X28)	G2	0.20		
Thermal Via Diameter	V		0.33	
Thermal Via Pitch	EV		1.20	

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

2. For best soldering results, thermal vias, if used, should be filled or tented to avoid solder loss during reflow process

Microchip Technology Drawing C04-23395-UBB Rev C

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3.4 Power Management and Sleep Modes

3.4.1 Sleep Modes

A clarification for the selection of the appropriate sleep modes and their wake-up sources has been made.

The *Figure “Clock Distribution”* presents the different clock systems in the ATmega328P Automotive and their distribution. The figure helps select an appropriate sleep mode. The table below shows the various sleep modes and their wake-up sources BOD disable ability.

Table 3-1. Active Clock Domains and Wake-Up Sources in the Different Sleep Modes

	Active Clock Domains					Oscillators		Wake-Up Sources							
Sleep Mode	clkCPU	clkFLASH	clkIO	clkADC	clkASY	Main Clock Source Enabled	Timer Oscillator Enabled	INT and PCINT	TWI Address Match	Timer2	SPM/EEPROM Ready	ADC	WDT	Other I/O	Software BOD Disable
Idle			X	X	X	X	X[2]	X	X	X	X	X	X	X	
ADC Noise Reduction				X	X	X	X[2]	X	X	X[2]	X	X	X		
Power-Down								X	X				X		X
Power-Save					X		X[2]	X	X	X			X		X
Standby[1]						X		X	X				X		X
Extended Standby					X[2]	X	X[2]	X	X	X			X		X

Notes:

1. Only recommended with an external crystal or resonator selected as the clock source.
2. If Timer/Counter2 is running in Asynchronous mode.

Write the SE bit in the Sleep Mode Control (SMCR) Register to logic one, and execute a SLEEP instruction to enter any six sleep modes. The SM2, SM1, and SM0 bits in the SMCR register select which sleep mode (Idle, ADC Noise Reduction, Power-Down, Power-Save, Standby, or Extended Standby) to be activated by the SLEEP instruction. See *Table “Sleep Mode Select”* for a summary.

If an enabled interrupt occurs while the MCU is in a sleep mode, the MCU wakes up. The MCU is then halted for four cycles in addition to the start-up time, executes the interrupt routine, and resumes execution from the instruction following SLEEP. The register file and SRAM contents are unaltered when the device wakes up from sleep. If a reset occurs during a sleep mode, the MCU wakes up and executes from the Reset Vector.

3.5 16-bit Timer/Counter1 with PWM

3.5.1 Fast PWM Mode in ATmega328P Automotive

A clarification for the description of the COMnx1:0 in the Timer/Counter1 PWM Mode has been made.

The procedure for updating ICR1 differs from updating OCR1A when used for defining the TOP value. The ICR1 register is not double-buffered, meaning that if ICR1 is changed to a low value when the counter is running with none or a low prescaler value, there is a risk that the new ICR1 value written is lower than the current value of TCNT1. Then the result will be that the counter will miss the compare match at the TOP value. The counter will then have to count to the MAX value (0xFFFF) and wrap around starting at 0x0000 before the compare match can occur. The OCR1A register, however, is double-buffered. This feature allows the OCR1A I/O location to be written anytime. When the OCR1A I/O location is written, the written value adds to the OCR1A buffer register. The OCR1A compare

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register will then be updated with the value in the buffer register at the next timer clock cycle TCNT1 matches TOP. The update is done at the same timer clock cycle as the TCNT1 is cleared, and the TOV1 flag is set.

Defining TOP using the ICR1 register works well when using fixed TOP values. By using ICR1, the OCR1A register is free to be used for generating a PWM output on OC1A. However, if the base PWM frequency is actively changed (by changing the TOP value), using the OCR1A as TOP is clearly a better choice due to its double buffer feature.

In fast PWM mode, the compare units allow the generation of PWM waveforms on the OC1x pins. Setting the COM1x1:0 bits to two will produce a non-inverted PWM. Setting the COM1x1:0 to three (see *Table "Compare Output Mode, Fast PWM"*), an inverted PWM output is generated. The actual OC1x value will only be visible on the port pin if the data direction for the port pin is set as output (DDR_OC1x). The PWM waveform is generated by setting (or clearing) the OC1x register at the compare match between OCR1x and TCNT1. Clearing (or setting) the OC1x register at the timer clock cycle, the counter is cleared (changes from TOP to BOTTOM).

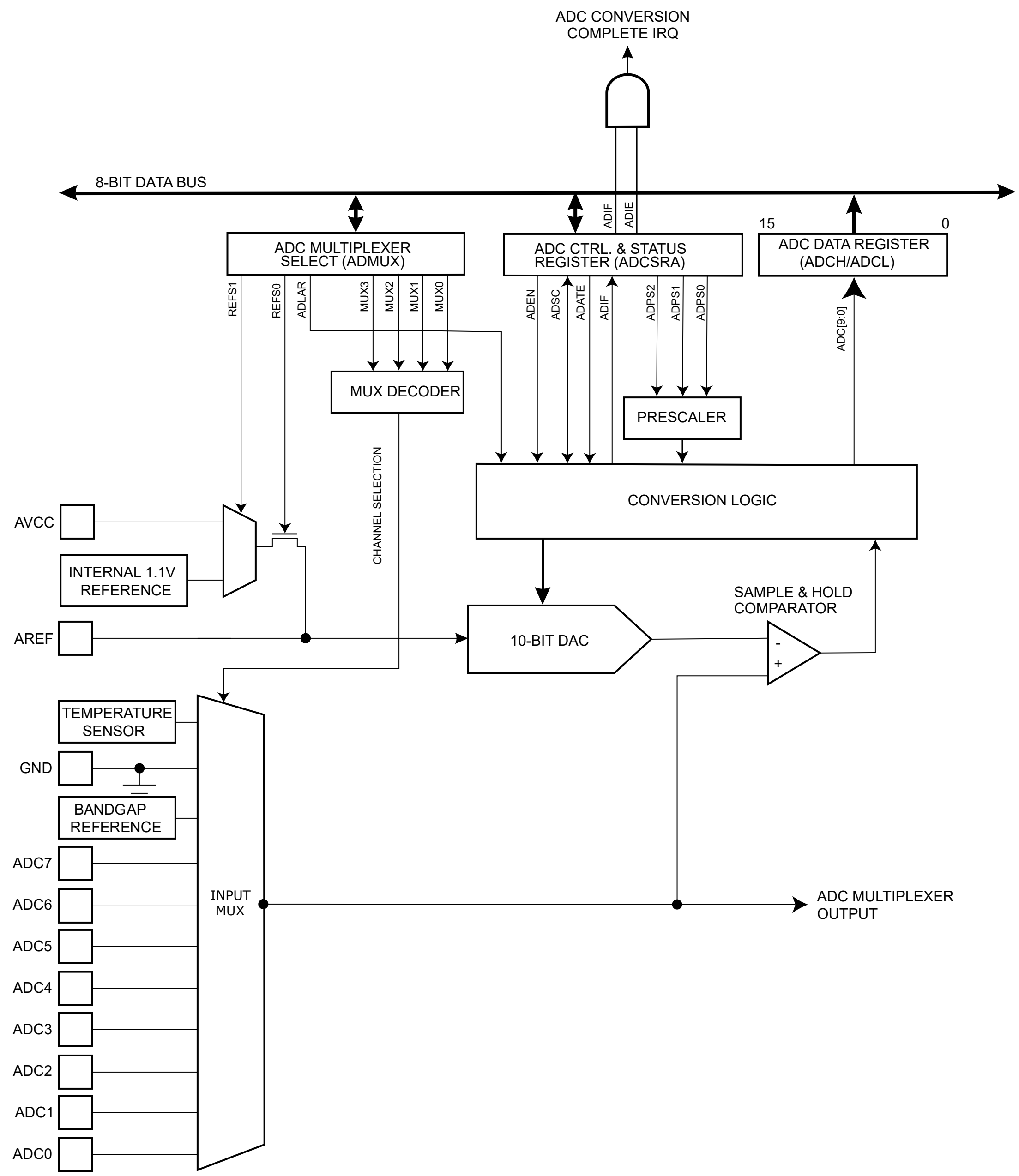
3.6 ADC - Block Diagram

3.6.1 ADC - Analog-to-Digital Converter Block Diagram

A clarification for the Analog-to-Digital Converter (ADC) block diagram has been made.

In the ADC block diagram, ADFR is changed to **ADATE**, and **ADSC is now bidirectional**.

Figure 3-1. Analog-to-Digital Converter Block Schematic Operation



3.7 Interrupts

3.7.1 Interrupt Vectors in ATmega328P Automotive

A clarification for the source names of the Interrupt vectors has been made to comply with the header file naming convention.

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Table 3-2. Reset and Interrupt Vectors in ATmega328P Automotive

Vector No	Program Address(2)	Source	Interrupts definition
1	0x0000(1)	RESET	External pin, Power-on Reset, Brown-out Reset and Watchdog System Reset
2	0x0002	INT0	External Interrupt Request 0
3	0x0004	INT1	External Interrupt Request 1
4	0x0006	PCINT0	Pin Change Interrupt Request 0
5	0x0008	PCINT1	Pin Change Interrupt Request 1
6	0x000A	PCINT2	Pin Change Interrupt Request 2
7	0x000C	WDT	Watchdog Time-out Interrupt
8	0x000E	**TIMER2_COMPA**	Timer/Counter2 Compare Match A
9	0x0010	**TIMER2_COMPB**	Timer/Coutner2 Compare Match B
10	0x0012	**TIMER2_OVF**	Timer/Counter2 Overflow
11	0x0014	**TIMER1_CAPT**	Timer/Counter1 Capture Event
12	0x0016	**TIMER1_COMPA**	Timer/Counter1 Compare Match A
13	0x0018	**TIMER1_COMPB**	Timer/Coutner1 Compare Match B
14	0x001A	**TIMER1_OVF**	Timer/Counter1 Overflow
15	0x001C	**TIMER0_COMPA**	Timer/Counter0 Compare Match A
16	0x001E	**TIMER0_COMPB**	Timer/Coutner0 Compare Match B
17	0x0020	**TIMER0_OVF**	Timer/Counter0 Overflow
18	0x0022	**SPI_STC**	SPI Serial Transfer Complete
19	0x0024	**USART_RX**	USART Rx complete
20	0x0026	**USART_UDRE**	USART Data Register Empty
21	0x0028	**USART_TX**	USART Tx complete
22	0x002A	ADC	ADC Conversion complete
23	0x002C	EE READY	EEPROM Ready
24	0x002E	ANALOG COMP	Analog Comparator
25	0x0030	TWI	Two-wire Serial Interface (I^2C)
26	0x0032	SPM READY	Store Program Memory Ready

Notes:
1. When the BOOTRST fuse is programmed, the device will jump to the boot loader address at Reset. See "*Boot Loader Support – Read-While-Write Self- Programming*".
2. When setting the IVSEL bit in MCUCR, Interrupt Vectors will be moved to the start of the boot Flash section. The address of each Interrupt Vector will then be the address in this table added to the start address of the boot Flash section.

3.8 Electrical Characteristics

3.8.1 Electrical Characteristics

All DC/AC characteristics in this data sheet are based on characterization of Microchip ATmega328P Automotive AVR® microcontroller manufactured in an automotive process technology.

3.8.1.1 Absolute Maximum Ratings

Stresses beyond those listed under *"Absolute Maximum Ratings"* may cause permanent damage to the device, as this is a stress rating only. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Parameters	Min.	Typ.	Max.	Unit
Operating temperature	–55		+125	°C
Storage temperature	–65		+150	°C
Voltage on any pin except RESET with respect to ground	–0.5		V_{CC} + 0.5	V
Voltage on RESET with respect to ground	–0.5		+13.0	V
Maximum Operating Voltage		6.0		V
DC current per I/O pin		40.0		mA
DC current V_{CC} and GND pins		200.0		mA
Injection current at V_{CC} = 0V		±5.0(1)		mA
Injection current at V_{CC} = 5V		±1.0		mA

Note:
1. Maximum current per port = ±30 mA

3.8.1.2 DC Characteristics

A clarification for Analog Comparator Input Offset Voltage has been made. Two more characteristics in **bold** have been added.

Table 3-3. T_A = –40°C to +125°C, V_{CC} = 2.7V to 5.5V (unless otherwise noted)

Parameter	Condition	Symbol	Min.	Typ.	Max.	Unit
Input low-voltage, except XTAL1 and RESET pin	V_{CC} = 2.7-5.5V	V_{IL}	–0.5		0.3V_{CC}(1)	V
Input high-voltage, except XTAL1 and RESET pins	V_{CC} = 2.7-5.5V	V_{IH}	0.6V_{CC}(2)		V_{CC} + 0.5	V
Input low-voltage, XTAL1 pin	V_{CC} = 2.7-5.5V	V_{IL1}	–0.5		0.1V_{CC}(1)	V
Input high-voltage, XTAL1 pin	V_{CC} = 2.7-5.5V	V_{IH1}	0.7V_{CC}(2)		V_{CC} + 0.5	V
Input low-voltage, RESET pin	V_{CC} = 2.7-5.5V	V_{IL2}	–0.5		0.1V_{CC}(1)	V
Input high-voltage, RESET pin	V_{CC} = 2.7-5.5V	V_{IH2}	0.9V_{CC}(2)		V_{CC} + 0.5	V

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...........continued

Parameter	Condition	Symbol	Min.	Typ.	Max.	Unit
Output low-voltage[(3)]	I_{OL} = 20 mA, V_{CC} = 5V I_{OL} = 5 mA, V_{CC} = 3V	V_{OL}			0.8 0.5	V
Output high- voltage[(4)]	I_{OH} = –20 mA, V_{CC} = 5V I_{OH} = –10 mA, V_{CC} = 3V	V_{OH}	4.1 2.3			V
Input leakage current I/O pin	V_{CC} = 5.5V, pin low (absolute value)	I_{IL}			1	µA
Input leakage current I/O pin	V_{CC} = 5.5V, pin high (absolute value)	I_{IH}			1	µA
Reset pull-up resistor		R_{RST}	30		60	kΩ
I/O pin pull-up resistor		R_{PU}	20		50	kΩ
Analog Comparator Input Offset Voltage	V_{CC} = 5V V_{in} = V_{CC}/2	V_{ACIO}		<10	40	mV
Analog Comparator Input Offset Voltage	**V_{CC} < 3.6V** **V_{in} < 0.5V**	**V_{ACIO}**		**<15**	**60**[(5)]	**mV**
Analog Comparator Input Offset Voltage	**V_{CC} > 3.6V** **V_{in} < 0.5V**	**V_{ACIO}**		**<15**	**500**[(5)]	**mV**
Analog Comparator Input Leakage current	V_{CC} = 5V V_{in} = V_{CC}/2	I_{ACLK}	–50		+50	nA
Analog Comparator Propagation Delay	V_{CC} = 2.7V V_{CC} = 4.0V	t_{ACID}		750 500		ns

Notes:

1. “Max.” means the highest value where the pin is guaranteed to be read as low.
2. “Min.” means the lowest value where the pin is guaranteed to be read as high.
3. Although each I/O port can sink more than the test conditions (20 mA at V_{CC} = 5V, 10 mA at V_{CC} = 3V) under steady-state conditions (non-transient), observe the following:
   a. For ports C0 - C5, the sum of all I_{OL} should not exceed 100 mA.
   b. For ports B0 - B5, D5 - D7, XTAL1 and XTAL2, the sum of all I_{OL} should not exceed 100 mA.
   c. For ports D0 - D4, the sum of all I_{OL} should not exceed 100 mA.

   If I_{OL} exceeds the test condition, V_{OL} may exceed the related specification. Pins are not guaranteed to sink a current higher than the listed test condition.
4. Although each I/O port can source more than the test conditions (20 mA at V_{CC} = 5V, 10 mA at V_{CC} = 3V) under steady-state conditions (non-transient), observe the following:
   a. For ports C0 - C5 and D0- D4, the sum of all I_{OH} should not exceed 150 mA.
   b. For ports B0 - B5, D5 - D7, XTAL1 and XTAL2, the sum of all I_{OH} should not exceed 150 mA.

   If I_{OH} exceeds the test condition, V_{OH} may exceed the related specification. Pins are not guaranteed to source a current higher than the listed test condition.
5. These values are based on characterization. The maximum limit is not tested in production and, therefore, cannot be assured.

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Table 3-4. T_A **= –40°C to +125°C,** V_{CC} **= 2.7V to 5.5V (unless otherwise noted)**

Parameter	Condition	Symbol	Min.	Typ.[(2)]	Max.	Units
Power supply current[(1)]	Active 4 MHz, V_{CC} = 3V	I_{CC}		1.5	2.4	mA
	Active 8 MHz, V_{CC} = 5V			5.2	10	mA
	Active 16 MHz, V_{CC} = 5V			9.2	14	mA
	Idle 4 MHz, V_{CC} = 3V			0.25	0.6	mA
	Idle 8 MHz, V_{CC} = 5V			1.0	1.6	mA
	Idle 16 MHz, V_{CC} = 5V			1.9	2.8	mA
Power-down mode[(3)]	WDT enabled, V_{CC} = 3V				44	µA
	WDT enabled, V_{CC} = 5V				66	µA
	WDT disabled, V_{CC} = 3V				40	µA
	WDT disabled, V_{CC} = 5V				60	µA

Notes:

1. Values with Section "*Minimizing Power Consumption*" enabled (0xFF).
2. Typical values at 25°C. Maximum values are test limits in production.
3. The current consumption values include input leakage current.

3.9 Package Marking Information

Legend:	XX...X	Customer-specific information or Microchip part number
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	e3	Pb-free JEDEC® designator for Matte Tin (Sn)

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

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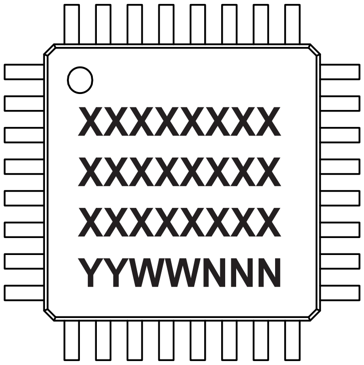
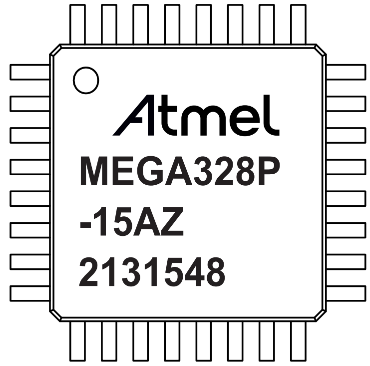
3.9.1 32-Pin TQFP

General

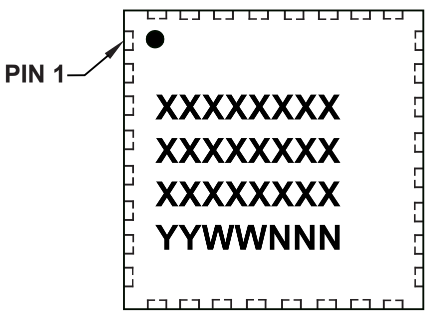


Example

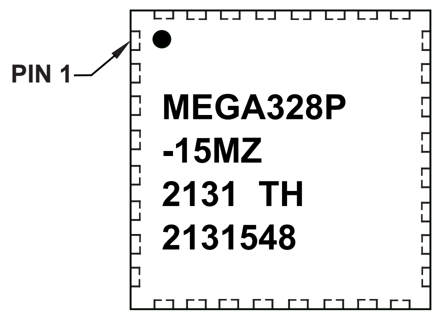


3.9.2 32-Pin VQFN

General



Example



4. Document Revision History

Note: The document revision is independent of the silicon revision.

4.1 Revision History

Doc Rev.	Date	Comments
A	11/2022	Initial release of this document • Errata content moved from the data sheet and restructured to the new document template • Data sheet clarifications added: – Ordering Information: 3.2.1. Ordering Information – Packaging Information: 3.3.1. PN – Power Management and Sleep Modes: 3.4.1. Sleep Modes – 16-bit Timer/Counter1 with PWM: 3.5.1. Fast PWM Mode in ATmega328P Automotive – ADC - Block Diagram: 3.6.1. ADC - Analog-to-Digital Converter Block Diagram – Interrupts: 3.7.1. Interrupt Vectors in ATmega328P Automotive – Electrical Characteristics: 3.8.1.2. DC Characteristics – Package Marking: 3.9. Package Marking Information

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