

## Introduction

The Atmel® picoPower® ATmega328/P 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 ATmega328/P achieves throughputs close to 1MIPS per MHz. This empowers system designer to optimize the device for power consumption versus processing speed.

## Feature

High Performance, Low Power Atmel®AVR® 8-Bit Microcontroller Family

- Advanced RISC Architecture
  - 131 Powerful Instructions
  - Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 20 MIPS Throughput at 20MHz
  - On-chip 2-cycle Multiplier
- High Endurance Non-volatile Memory Segments
  - 32KBytes of In-System Self-Programmable Flash program Memory
  - 1KBytes EEPROM
  - 2KBytes Internal SRAM
  - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
  - Data Retention: 20 years at 85°C/100 years at 25°C<sup>(1)</sup>
  - Optional Boot Code Section with Independent Lock Bits
    - In-System Programming by On-chip Boot Program
    - True Read-While-Write Operation
  - Programming Lock for Software Security
- Atmel® QTouch® Library Support
  - Capacitive Touch Buttons, Sliders and Wheels
  - QTouch and QMatrix® Acquisition
  - Up to 64 sense channels

- Peripheral Features
  - 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
  - Six PWM Channels
  - 8-channel 10-bit ADC in TQFP and QFN/MLF package
    - Temperature Measurement
  - 6-channel 10-bit ADC in PDIP Package
    - Temperature Measurement
  - Two Master/Slave SPI Serial Interface
  - One Programmable Serial USART
  - One Byte-oriented 2-wire Serial Interface (Philips I<sup>2</sup>C compatible)
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - One 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
  - Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended Standby
- I/O and Packages
  - 23 Programmable I/O Lines
  - 28-pin PDIP, 32-lead TQFP, 28-pad QFN/MLF and 32-pad QFN/MLF
- Operating Voltage:
  - 1.8 - 5.5V
- Temperature Range:
  - -40°C to 105°C
- Speed Grade:
  - 0 - 4MHz @ 1.8 - 5.5V
  - 0 - 10MHz @ 2.7 - 5.5V
  - 0 - 20MHz @ 4.5 - 5.5V
- Power Consumption at 1MHz, 1.8V, 25°C
  - Active Mode: 0.2mA
  - Power-down Mode: 0.1µA
  - Power-save Mode: 0.75µA (Including 32kHz RTC)

## Table of Contents

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|                                   |    |
|-----------------------------------|----|
| Introduction.....                 | 1  |
| Feature.....                      | 1  |
| 1. Description.....               | 4  |
| 2. Configuration Summary.....     | 5  |
| 3. Ordering Information .....     | 6  |
| 3.1. ATmega328 .....              | 6  |
| 3.2. ATmega328P .....             | 7  |
| 4. Block Diagram.....             | 8  |
| 5. Pin Configurations.....        | 9  |
| 5.1. Pin-out.....                 | 9  |
| 5.2. Pin Descriptions.....        | 12 |
| 6. I/O Multiplexing.....          | 14 |
| 7. Resources.....                 | 16 |
| 8. Data Retention.....            | 17 |
| 9. About Code Examples.....       | 18 |
| 10. Capacitive Touch Sensing..... | 19 |
| 10.1. QTouch Library.....         | 19 |
| 11. Packaging Information.....    | 20 |
| 11.1. 32-pin 32A.....             | 20 |
| 11.2. 32-pin 32M1-A.....          | 21 |
| 11.3. 28-pin 28M1.....            | 22 |
| 11.4. 28-pin 28P3.....            | 23 |

## 1. Description

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 a 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 ATmega328/P provides the following features: 32Kbytes of In-System Programmable Flash with Read-While-Write capabilities, 1Kbytes EEPROM, 2Kbytes SRAM, 23 general purpose I/O lines, 32 general purpose working registers, Real Time Counter (RTC), three flexible Timer/Counters with compare modes and PWM, 1 serial programmable USARTs , 1 byte-oriented 2-wire Serial Interface (I2C), a 6-channel 10-bit ADC (8 channels in TQFP and QFN/MLF packages) , a programmable Watchdog Timer with internal Oscillator, an SPI serial port, and six software selectable power saving modes. The Idle mode stops the CPU while allowing the 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 continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except asynchronous timer and ADC to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low power consumption. In Extended Standby mode, both the main oscillator and the asynchronous timer continue to run.

Atmel offers the QTouch® library for embedding capacitive touch buttons, sliders and wheels functionality into AVR microcontrollers. The patented charge-transfer signal acquisition offers robust sensing and includes fully debounced reporting of touch keys and includes Adjacent Key Suppression® (AKS™) technology for unambiguous detection of key events. The easy-to-use QTouch Suite toolchain allows you to explore, develop and debug your own touch applications.

The device is manufactured using Atmel's high density non-volatile memory technology. The On-chip ISP Flash allows the program memory to be reprogrammed In-System through an SPI serial interface, by a conventional nonvolatile memory programmer, or by an On-chip Boot program running on the AVR core. The Boot program can use any interface to download the application program in the Application Flash memory. Software in the Boot Flash section will continue to run while the Application Flash section is updated, providing true Read-While-Write operation. By combining an 8-bit RISC CPU with In-System Self-Programmable Flash on a monolithic chip, the Atmel ATmega328/P is a powerful microcontroller that provides a highly flexible and cost effective solution to many embedded control applications.

The ATmega328/P 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. Configuration Summary

| Features  | ATmega328/P   |
|---|---------------|
| Pin Count                                       | 28/32         |
| Flash (Bytes)                                   | 32K           |
| SRAM (Bytes)                                    | 2K            |
| EEPROM (Bytes)                                  | 1K            |
| Interrupt Vector Size (instruction word/vector) | 1/1/2         |
| General Purpose I/O Lines                       | 23            |
| SPI   | 2             |
| TWI (I <sup>2</sup> C)                          | 1             |
| USART   | 1             |
| ADC   | 10-bit 15kSPS |
| ADC Channels                                    | 8             |
| 8-bit Timer/Counters                            | 2             |
| 16-bit Timer/Counters                           | 1             |

and support a real Read-While-Write Self-Programming mechanism. There is a separate Boot Loader Section, and the SPM instruction can only execute from there. In , there is no Read-While-Write support and no separate Boot Loader Section. The SPM instruction can execute from the entire Flash.

### 3. Ordering Information

#### 3.1. ATmega328

| Speed [MHz] <sup>(3)</sup> | Power Supply [V] | Ordering Code <sup>(2)</sup>   | Package <sup>(1)</sup>                                 | Operational Range             |
|----------------------------|------------------|--|--|-------------------------------|
| 20                         | 1.8 - 5.5        | ATmega328-AU<br>ATmega328-AUR <sup>(5)</sup><br>ATmega328-MMH <sup>(4)</sup><br>ATmega328-MMHR <sup>(4)(5)</sup><br>ATmega328-MU<br>ATmega328-MUR <sup>(5)</sup><br>ATmega328-PU | 32A<br>32A<br>28M1<br>28M1<br>32M1-A<br>32M1-A<br>28P3 | Industrial<br>(-40°C to 85°C) |

**Note:**

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, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
3. Please refer to *Speed Grades* for Speed vs. V<sub>CC</sub>
4. Tape & Reel.
5. NiPdAu Lead Finish.

| Package Type |  |
|--------------|--|
| 28M1         | 28-pad, 4 x 4 x 1.0 body, Lead Pitch 0.45mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF) |
| 28P3         | 28-lead, 0.300" Wide, Plastic Dual Inline Package (PDIP)   |
| 32M1-A       | 32-pad, 5 x 5 x 1.0 body, Lead Pitch 0.50mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF) |
| 32A          | 32-lead, Thin (1.0mm) Plastic Quad Flat Package (TQFP)   |

### 3.2. ATmega328P

| Speed [MHz] <sup>(3)</sup> | Power Supply [V] | Ordering Code <sup>(2)</sup>      | Package <sup>(1)</sup> | Operational Range              |
|----------------------------|------------------|-----------------------------------|------------------------|--------------------------------|
| 20                         | 1.8 - 5.5        | ATmega328P-AU                     | 32A                    | Industrial<br>(-40°C to 85°C)  |
|                            |                  | ATmega328P-AUR <sup>(5)</sup>     | 32A                    |                                |
|                            |                  | ATmega328P-MMH <sup>(4)</sup>     | 28M1                   |                                |
|                            |                  | ATmega328P-MMHR <sup>(4)(5)</sup> | 28M1                   |                                |
|                            |                  | ATmega328P-MU                     | 32M1-A                 |                                |
|                            |                  | ATmega328P-MUR <sup>(5)</sup>     | 32M1-A                 |                                |
|                            |                  | ATmega328P-PU                     | 28P3                   |                                |
|                            |                  | ATmega328P-AN                     | 32A                    | Industrial<br>(-40°C to 105°C) |
|                            |                  | ATmega328P-ANR <sup>(5)</sup>     | 32A                    |                                |
|                            |                  | ATmega328P-MN                     | 32M1-A                 |                                |
|                            |                  | ATmega328P-MNR <sup>(5)</sup>     | 32M1-A                 |                                |
|                            |                  | ATmega328P-PN                     | 28P3                   |                                |

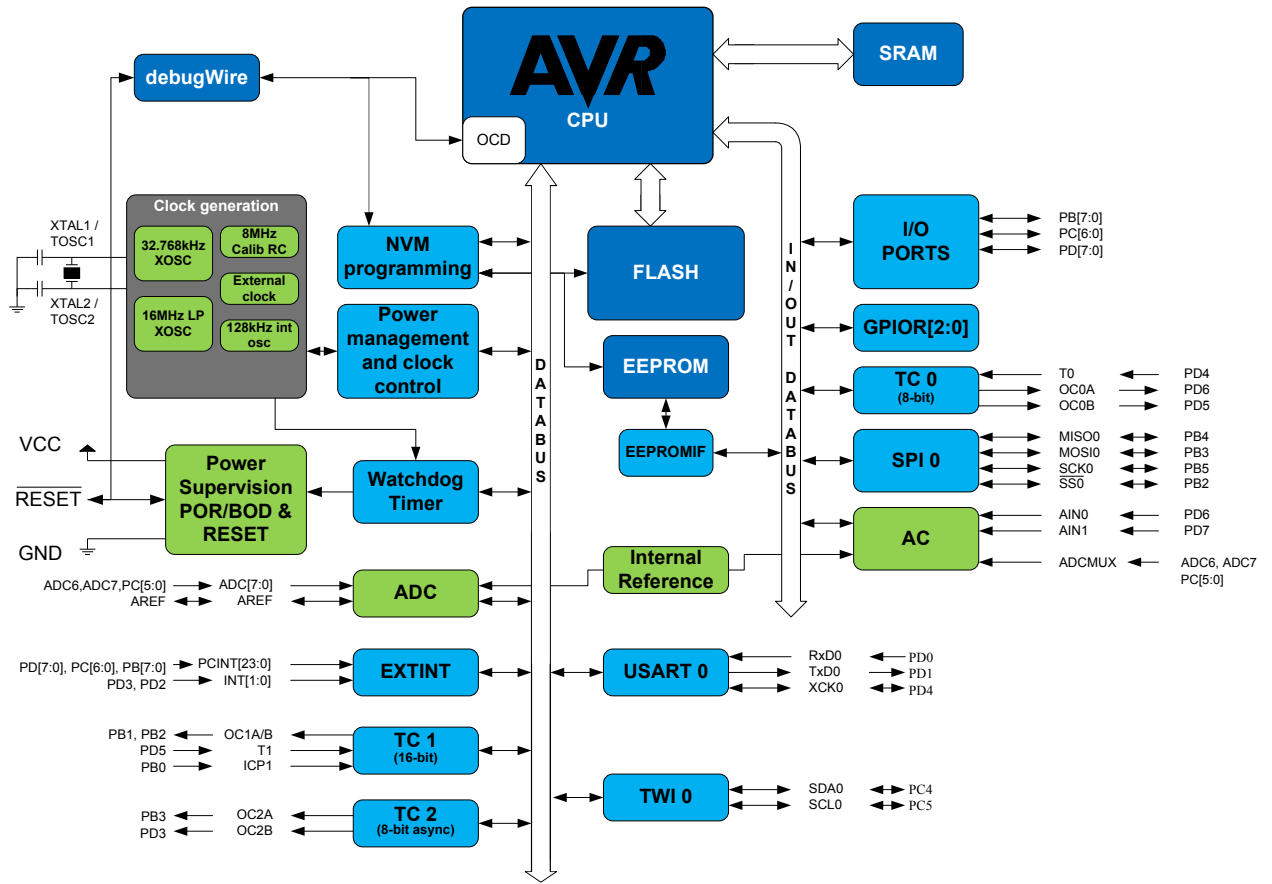
**Note:**

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| Package Type |  |
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| 28P3         | 28-lead, 0.300" Wide, Plastic Dual Inline Package (PDIP)   |
| 32M1-A       | 32-pad, 5 x 5 x 1.0 body, Lead Pitch 0.50mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF) |
| 32A          | 32-lead, Thin (1.0mm) Plastic Quad Flat Package (TQFP)   |

# 4. Block Diagram

Figure 4-1. Block Diagram





## 5. Pin Configurations

### 5.1. Pin-out

Figure 5-1. 28-pin PDIP

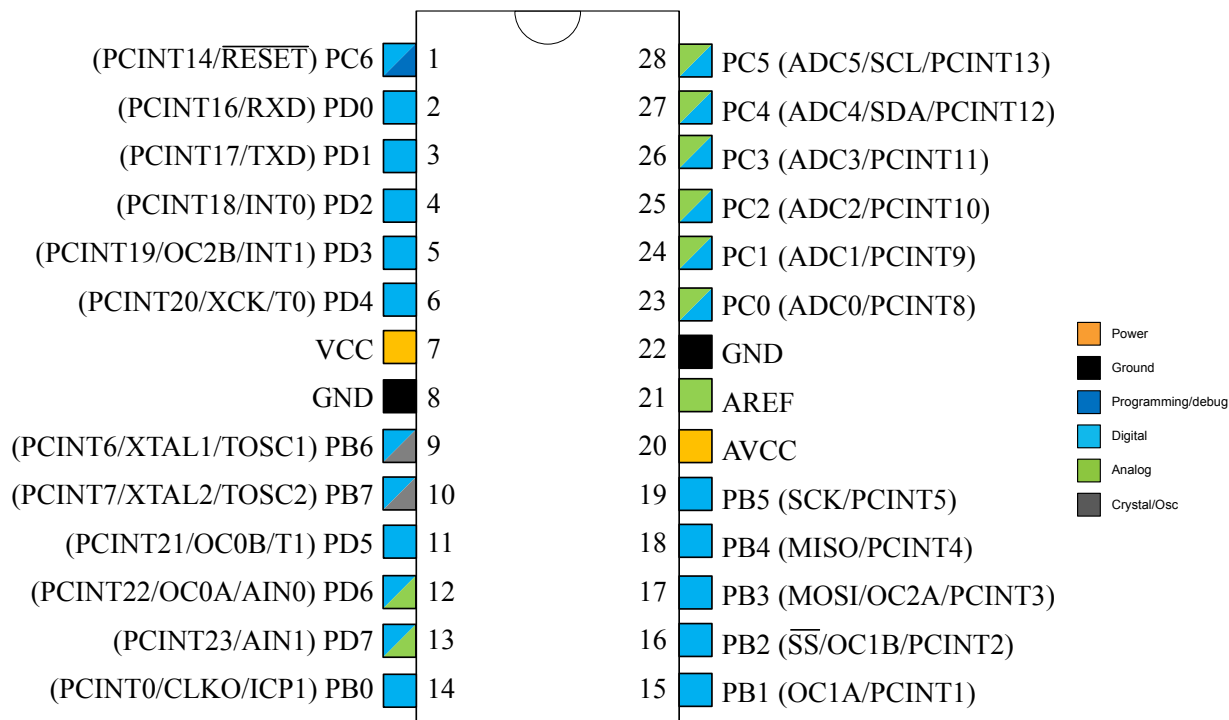
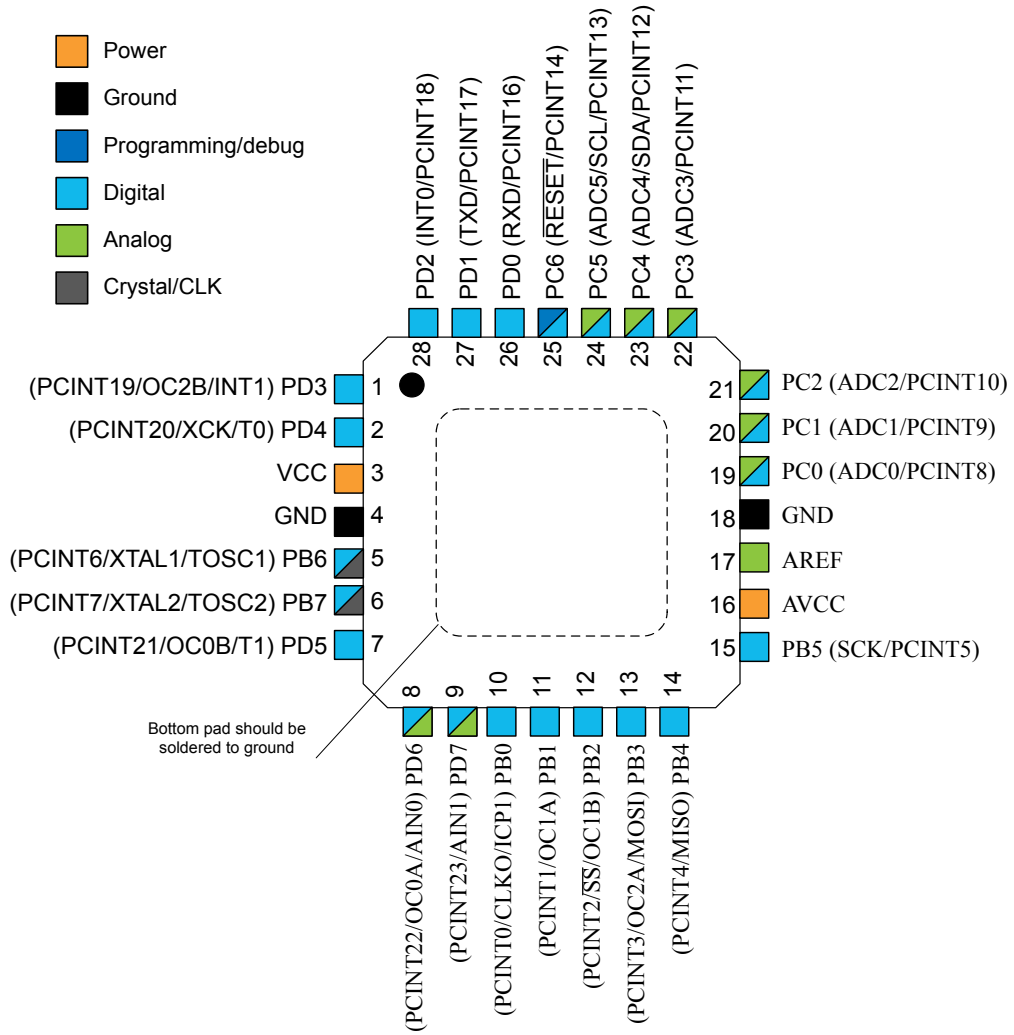


Figure 5-2. 28-pin MLF Top View



**Figure 5-3. 32-pin TQFP Top View**

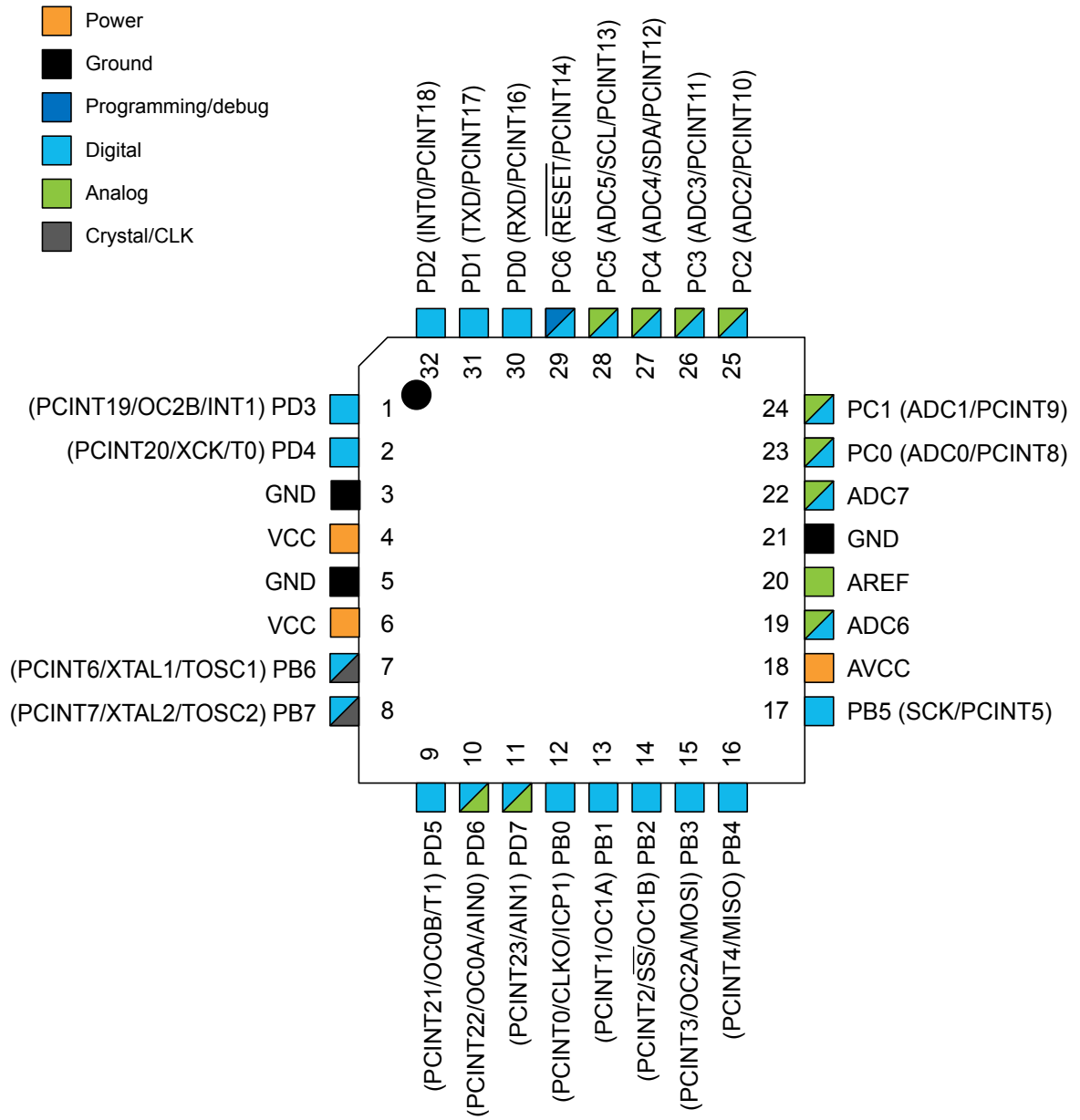
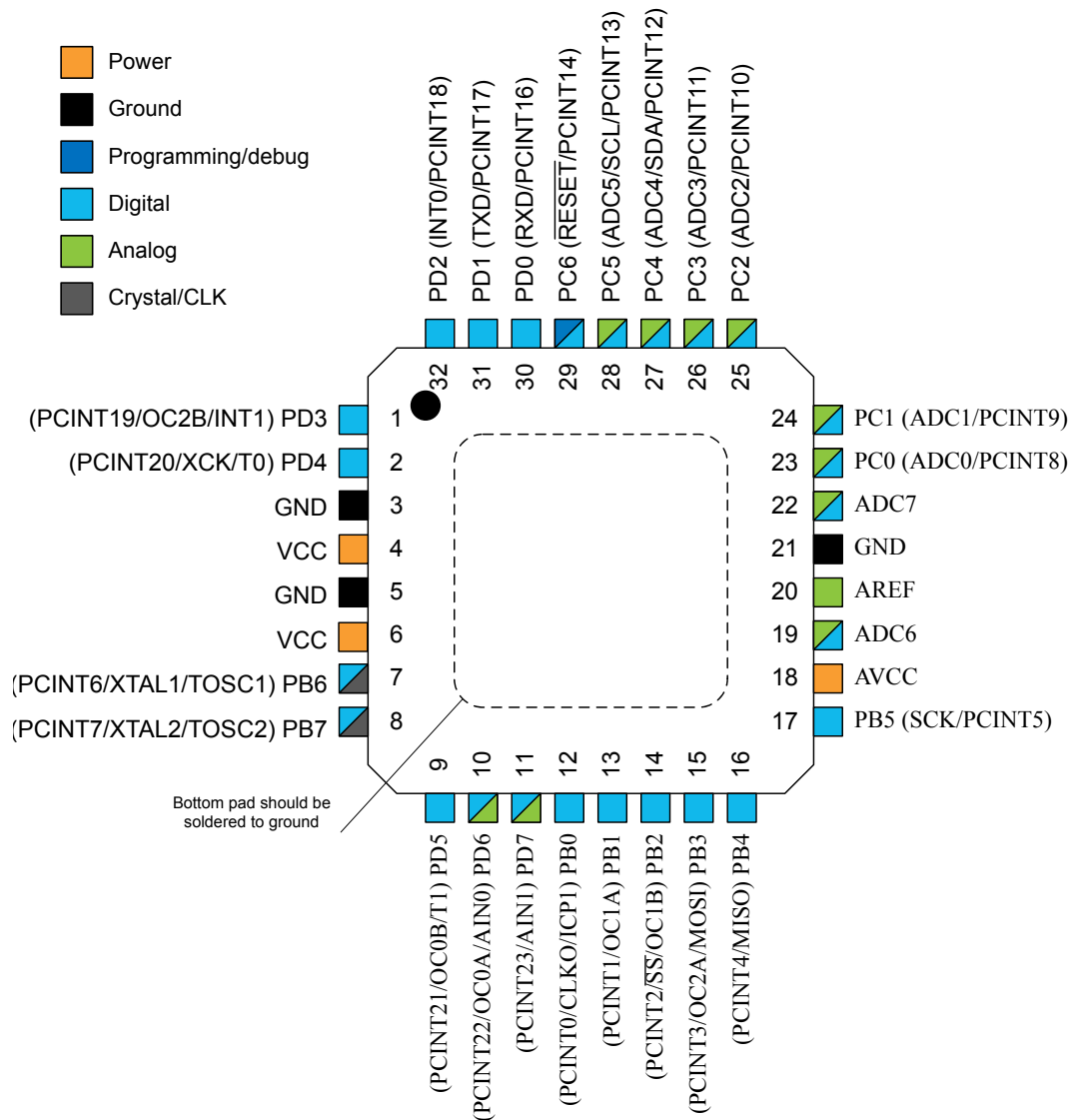


Figure 5-4. 32-pin MLF Top View



## 5.2. Pin Descriptions

### 5.2.1. VCC

Digital supply voltage.

### 5.2.2. GND

Ground.

### 5.2.3. Port B (PB[7:0]) XTAL1/XTAL2/TOSC1/TOSC2

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.

Depending on the clock selection fuse settings, PB6 can be used as input to the inverting Oscillator amplifier and input to the internal clock operating circuit.

Depending on the clock selection fuse settings, PB7 can be used as output from the inverting Oscillator amplifier.

If the Internal Calibrated RC Oscillator is used as chip clock source, PB[7:6] is used as TOSC[2:1] input for the Asynchronous Timer/Counter2 if the AS2 bit in ASSR is set.

#### 5.2.4. Port C (PC[5:0])

Port C is a 7-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The PC[5:0] 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.

#### 5.2.5. PC6/RESET

If the RSTDISBL Fuse is programmed, PC6 is used as an I/O pin. Note that the electrical characteristics of PC6 differ from those of the other pins of Port C.

If the RSTDISBL Fuse is unprogrammed, PC6 is used as a 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. Shorter pulses are not guaranteed to generate a Reset.

The various special features of Port C are elaborated in the *Alternate Functions of Port C* section.

#### 5.2.6. Port D (PD[7:0])

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.

#### 5.2.7. AV<sub>CC</sub>

AV<sub>CC</sub> is the supply voltage pin for the A/D Converter, PC[3:0], and PE[3:2]. It should be externally connected to V<sub>CC</sub>, even if the ADC is not used. If the ADC is used, it should be connected to V<sub>CC</sub> through a low-pass filter. Note that PC[6:4] use digital supply voltage, V<sub>CC</sub>.

#### 5.2.8. AREF

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

#### 5.2.9. ADC[7:6] (TQFP and VFQFN Package Only)

In the TQFP and VFQFN package, ADC[7:6] serve as analog inputs to the A/D converter. These pins are powered from the analog supply and serve as 10-bit ADC channels.

## 6. I/O Multiplexing

Each pin is by default controlled by the PORT as a general purpose I/O and alternatively it can be assigned to one of the peripheral functions.

The following table describes the peripheral signals multiplexed to the PORT I/O pins.

**Table 6-1. PORT Function Multiplexing**

| (32-pin MLF/TQFP) Pin# | (28-pin MLF) Pin# | (28-pin PIPD) Pin# | PAD             | EXTINT | PCINT   | ADC/AC | OSC             | T/C #0 | T/C #1 | USART 0 | I2C 0 | SPI 0 |
|------------------------|-------------------|--------------------|-----------------|--------|---------|--------|-----------------|--------|--------|---------|-------|-------|
| 1                      | 1                 | 5                  | PD[3]           | INT1   | PCINT19 |        |                 | OC2B   |        |         |       |       |
| 2                      | 2                 | 6                  | PD[4]           |        | PCINT20 |        |                 | T0     |        | XCK0    |       |       |
| 4                      | 3                 | 7                  | VCC             |        |         |        |                 |        |        |         |       |       |
| 3                      | 4                 | 8                  | GND             |        |         |        |                 |        |        |         |       |       |
| 6                      | -                 | -                  | VCC             |        |         |        |                 |        |        |         |       |       |
| 5                      | -                 | -                  | GND             |        |         |        |                 |        |        |         |       |       |
| 7                      | 5                 | 9                  | PB[6]           |        | PCINT6  |        | XTAL1/<br>TOSC1 |        |        |         |       |       |
| 8                      | 6                 | 10                 | PB[7]           |        | PCINT7  |        | XTAL2/<br>TOSC2 |        |        |         |       |       |
| 9                      | 7                 | 11                 | PD[5]           |        | PCINT21 |        |                 | OC0B   | T1     |         |       |       |
| 10                     | 8                 | 12                 | PD[6]           |        | PCINT22 | AIN0   |                 | OC0A   |        |         |       |       |
| 11                     | 9                 | 13                 | PD[7]           |        | PCINT23 | AIN1   |                 |        |        |         |       |       |
| 12                     | 10                | 14                 | PB[0]           |        | PCINT0  |        | CLKO            | ICP1   |        |         |       |       |
| 13                     | 11                | 15                 | PB[1]           |        | PCINT1  |        |                 | OC1A   |        |         |       |       |
| 14                     | 12                | 16                 | PB[2]           |        | PCINT2  |        |                 | OC1B   |        |         |       | SS0   |
| 15                     | 13                | 17                 | PB[3]           |        | PCINT3  |        |                 | OC2A   |        |         |       | MOSI0 |
| 16                     | 14                | 18                 | PB[4]           |        | PCINT4  |        |                 |        |        |         |       | MISO0 |
| 17                     | 15                | 19                 | PB[5]           |        | PCINT5  |        |                 |        |        |         |       | SCK0  |
| 18                     | 16                | 20                 | AVCC            |        |         |        |                 |        |        |         |       |       |
| 19                     | -                 | -                  | ADC6            |        |         | ADC6   |                 |        |        |         |       |       |
| 20                     | 17                | 21                 | AREF            |        |         |        |                 |        |        |         |       |       |
| 21                     | 18                | 22                 | GND             |        |         |        |                 |        |        |         |       |       |
| 22                     | -                 | -                  | ADC7            |        |         | ADC7   |                 |        |        |         |       |       |
| 23                     | 19                | 13                 | PC[0]           |        | PCINT8  | ADC0   |                 |        |        |         |       |       |
| 24                     | 20                | 24                 | PC[1]           |        | PCINT9  | ADC1   |                 |        |        |         |       |       |
| 25                     | 21                | 25                 | PC[2]           |        | PCINT10 | ADC2   |                 |        |        |         |       |       |
| 26                     | 22                | 26                 | PC[3]           |        | PCINT11 | ADC3   |                 |        |        |         |       |       |
| 27                     | 23                | 27                 | PC[4]           |        | PCINT12 | ADC4   |                 |        |        |         |       | SDA0  |
| 28                     | 24                | 28                 | PC[5]           |        | PCINT13 | ADC5   |                 |        |        |         |       | SCL0  |
| 29                     | 25                | 1                  | PC[6]/<br>RESET |        | PCINT14 |        |                 |        |        |         |       |       |

| (32-pin MLF/TQFP) Pin# | (28-pin MLF) Pin# | (28-pin PIPD) Pin# | PAD   | EXTINT | PCINT   | ADC/AC | OSC | T/C #0 | T/C #1 | USART 0 | I2C 0 | SPI 0 |
|------------------------|-------------------|--------------------|-------|--------|---------|--------|-----|--------|--------|---------|-------|-------|
| 30                     | 26                | 2                  | PD[0] |        | PCINT16 |        |     |        |        | RXD0    |       |       |
| 31                     | 27                | 3                  | PD[1] |        | PCINT17 |        |     |        |        | TXD0    |       |       |
| 32                     | 28                | 4                  | PD[2] | INT0   | PCINT18 |        |     |        |        |         |       |       |

## 7. Resources

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



## 8. Data Retention

Reliability Qualification results show that the projected data retention failure rate is much less than 1 PPM over 20 years at 85°C.

## 9. About Code Examples

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

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

## 10. Capacitive Touch Sensing

### 10.1. QTouch Library

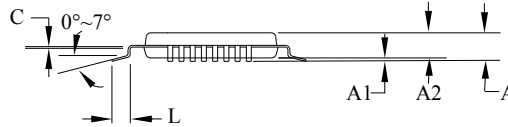
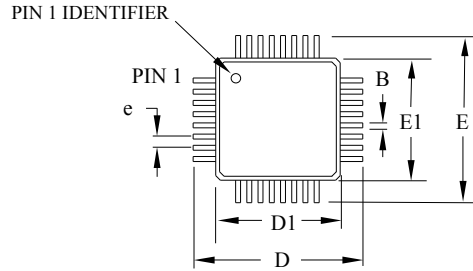
The Atmel® QTouch® Library provides a simple to use solution to realize touch sensitive interfaces on most Atmel AVR® microcontrollers. The QTouch Library includes support for the Atmel QTouch and Atmel QMatrix® acquisition methods.

Touch sensing can be added to any application by linking the appropriate Atmel QTouch Library for the AVR Microcontroller. This is done by using a simple set of APIs to define the touch channels and sensors, and then calling the touch sensing API's to retrieve the channel information and determine the touch sensor states.

The QTouch Library is FREE and downloadable from the Atmel website at the following location: <http://www.atmel.com/technologies/touch/>. For implementation details and other information, refer to the [Atmel QTouch Library User Guide](#) - also available for download from the Atmel website.

# 11. Packaging Information

## 11.1. 32-pin 32A



**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      | 8.75     | 9.00 | 9.25 |        |
| D1     | 6.90     | 7.00 | 7.10 | Note 2 |
| E      | 8.75     | 9.00 | 9.25 |        |
| E1     | 6.90     | 7.00 | 7.10 | Note 2 |
| B      | 0.30     | –    | 0.45 |        |
| C      | 0.09     | –    | 0.20 |        |
| L      | 0.45     | –    | 0.75 |        |
| e      | 0.80 TYP |      |      |        |

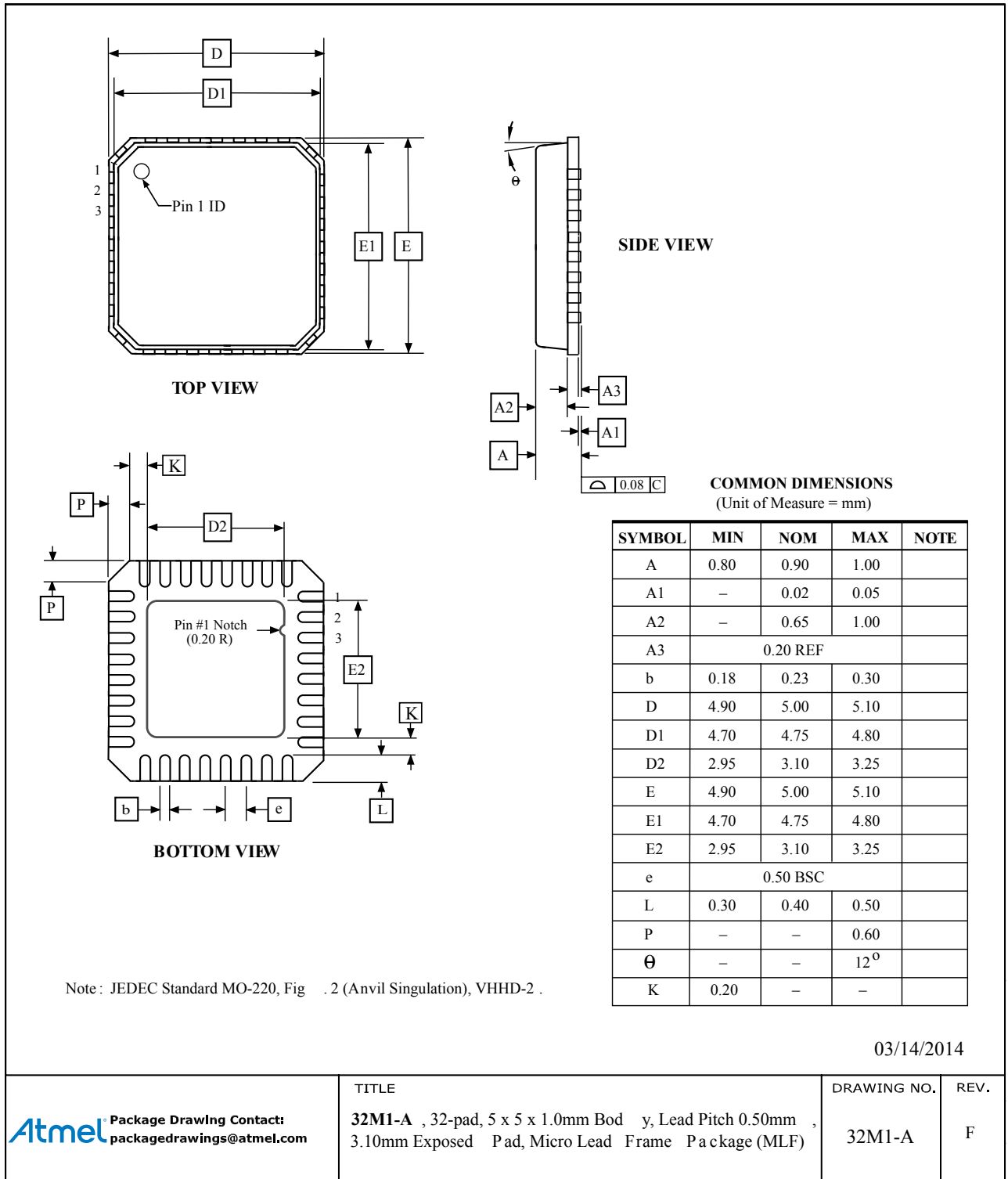
**Notes:**

1. This package conforms to JEDEC reference MS-026, Variation ABA.
2. Dimensions D1 and E1 do not include mold protrusion. Allowable protrusion is 0.25mm per side. Dimensions D1 and E1 are maximum plastic body size dimensions including mold mismatch.
3. Lead coplanarity is 0.10mm maximum.

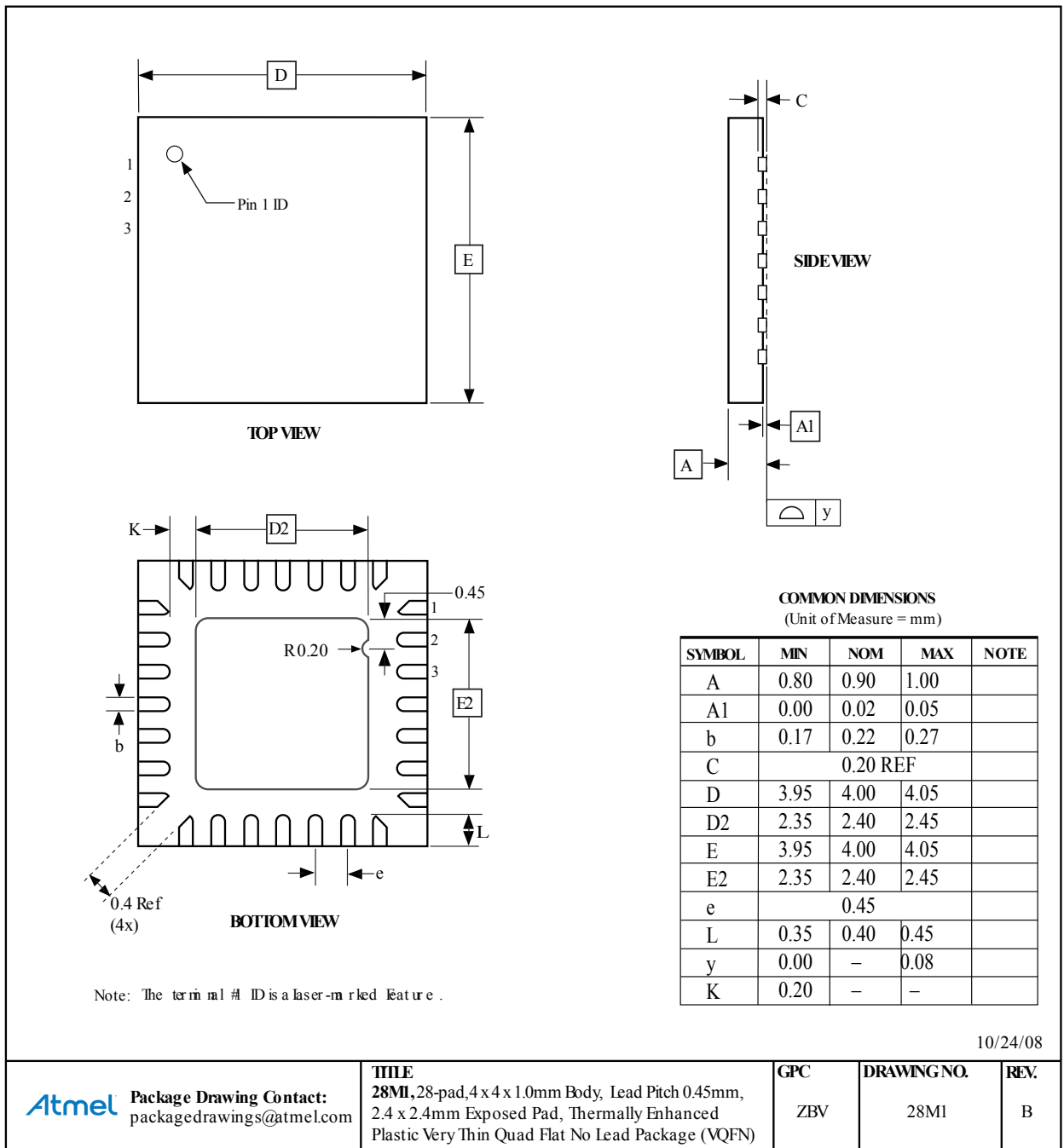
2010-10-20

|  |  |                    |             |
|--|--|--------------------|-------------|
|  | <b>TITLE</b>   | <b>DRAWING NO.</b> | <b>REV.</b> |
|  | 32A, 32-lead, 7 x 7mm body size, 1.0mm body thickness, 0.8mm lead pitch, thin profile plastic quad flat package (TQFP) | 32A                | C           |

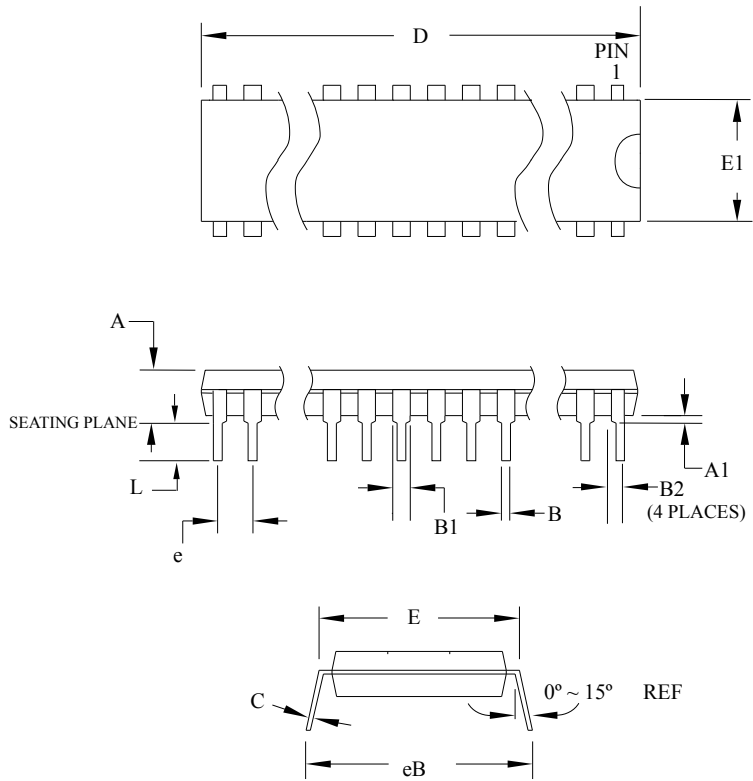
## 11.2. 32-pin 32M1-A



### 11.3. 28-pin 28M1



# 11.4. 28-pin 28P3



**COMMON DIMENSIONS**  
(Unit of Measure = mm)

| SYMBOL | MIN       | NOM | MAX    | NOTE   |
|--------|-----------|-----|--------|--------|
| A      | -         | -   | 4.5724 |        |
| A1     | 0.508     | -   | -      |        |
| D      | 34.544    | -   | 34.798 | Note 1 |
| E      | 7.620     | -   | 8.255  |        |
| E1     | 7.112     | -   | 7.493  | Note 1 |
| B      | 0.381     | -   | 0.533  |        |
| B1     | 1.143     | -   | 1.397  |        |
| B2     | 0.762     | -   | 1.143  |        |
| L      | 3.175     | -   | 3.429  |        |
| C      | 0.203     | -   | 0.356  |        |
| eB     | -         | -   | 10.160 |        |
| e      | 2.540 TYP |     |        |        |

Note: 1. Dimensions D and E1 do not include mold Flash or Protrusion.  
Mold Flash or Protrusion shall not exceed 0.25mm (0.010").

09/28/01

|  |  |                    |             |
|--|--|--------------------|-------------|
| 2325 Orchard Parkway<br>San Jose, CA 95131 | <b>TITLE</b><br><b>28P3</b> , 28-lead (0.300"/7.62mm Wide) Plastic Dual<br>Inline Package (PDIP) | <b>DRAWING NO.</b> | <b>REV.</b> |
|  |  | 28P3               | B           |

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