AN2604

Migrating from ATmega48P/88P/168P to ATmega48PB/88PB/168PB

Features

The ATmega48PB/88PB/168PB introduces several new features:

- Four extra GPIO pins
  - One pair of GND and VCC removed and replaced with two extra GPIO pins
  - Two pins that previously only had ADC input channels are now multiplexed with GPIO
- USART Start Frame Detection available in all sleep modes
- Analog Comparator output to pin added
- Serial number (Unique Device ID) added

Introduction

This application note acts as a guide to help users of ATmega48P/88P/168P migrating to the newer ATmega48PB/88PB/168PB.

ATmega48PB/88PB/168PB is functionally compatible with ATmega48P/88P/168P. This document will describe how to update the toolchain, developer tools, and IDE.

Always check the latest revision of the corresponding data sheet for the latest and correct characteristics and device details. It is recommended to review the Errata list.

The latest data sheets can be found here:

- ATmega48P/88P/168P - http://www.microchip.com/wwwproducts/en/ATmega168p
- ATmega48PB/88PB/168PB - http://www.microchip.com/wwwproducts/en/ATmega168pb

Table of Contents

1. Hardware Design Compatibility

1.1 Package Types

ATmega48PB/88PB/168PB can function as a drop-in replacement for the 32-pin TQFP package, and the 32-pin VFQFN with the 32-pin MLF package, but there are conditions to follow. See chapter Added/Modified Pin Functionality. For other package types, expect to change the PCB layout when migrating from ATmega48P/88P/168P to ATmega48PB/88PB/168PB. The data sheet includes dimensions and physical drawings of the footprint for each device under "Packaging Information". Below are the different package types compared to the different devices.

ATmega48P/88P/168P is available in the following package types:

- 32-pin TQFP
- 32-pin MLF
- 28-pin VQFN
- 28-pin PDIP

ATmega48PB/88PB/168PB is available in two package types:

- 32-pin TQFP
- 32-pin VFQFN

1.2 Added/Modified Pin Functionality

There are two package types that are compatible with ATmega48P/88P/168P and ATmega48PB/88PB/168PB. This section will compare the pin-out of the TQFP package type. For the other compatible package type, MLF/VFQFN, refer to the data sheet chapters "Ordering Information" and "Packaging Information".

ATmega48PB/88PB/168PB introduces four additional GPIO pins; PORTE [3:0]. The different pins are described in Table 1-1 and the pin-out for each device are shown in Figure 1-1 and Figure 1-2.

The 32-pin MLF/VQFN pin-out can be found in the Pin Configurations section in the ATmega48PB/88PB/168PB data sheet.

Figure 1-1. ATmega48P/88P/168P - 32-Pin TQFP
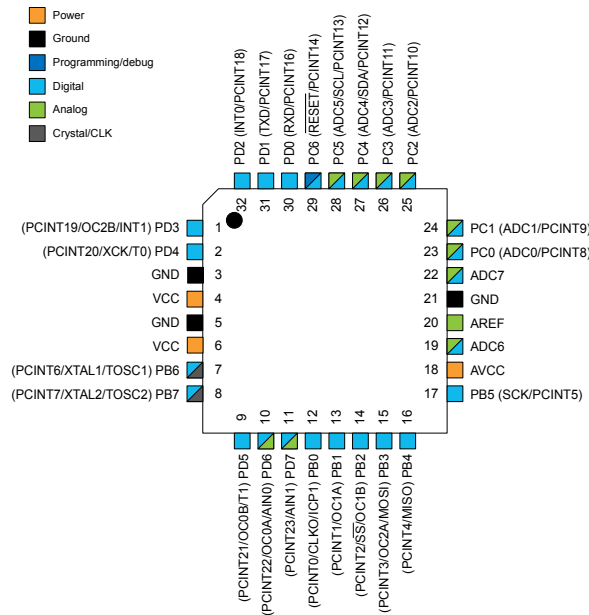
Figure 1-2. ATmega48PB/88PB/168PB - 32-Pin TQFP
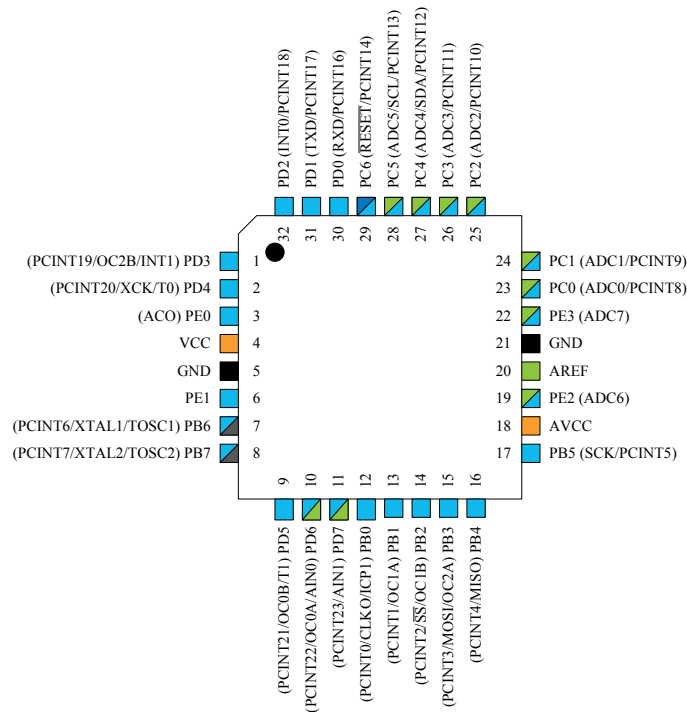
GPIO pins PE2 and PE3 are added to Pin19 and Pin22. PE2 and PE3 are multiplexed with ADC6 and ADC7.

Pin3 (GND) and Pin6 (VCC) are replaced by PE0 and PE1 respectively. PE0 is multiplexed with ACO.

Application Note

Table 1-1. Pin Functionality Difference

32-Pin TQFP Package	ATmega48P/88P/168P	ATmega48PB/88PB/168PB
Pin3	GND	PE0/ACO
Pin6	VCC	PE1
Pin19	ADC6	ADC6/PE2
Pin22	ADC7	ADC7/PE3

> ⚠ **CAUTION** To use the ATmega48PB/88PB/168PB device as a drop-in replacement for the ATmega48P/88P/168P the following conditions must meet:
> - Pin 3 - If connected to GND, the pin must not be actively driven or ACO must not be enabled.
> - Pin 6 - If connected to VCC, the pin must not be actively driven.

1.3 Alternate Pin Configuration

The alternate pin configurations are:

- **ADC7– Port E, Bit 3**
  PE3 can also be used as ADC input channel 7. ADC input channel 7 uses analog power AVCC.
- **ADC6 – Port E, Bit 2**
  PE2 can also be used as ADC input channel 6. ADC input channel 6 uses analog power AVCC.
- **None – Port E, Bit 1**
  No alternate function.
- **ACO – Port E, Bit 0**
  ACO Analog Compare Output pin is multiplexed with PE0.

2. Code Compatibility

ATmega48P/88P/168P is code compatible with ATmega48PB/88PB/168PB.

To ensure that code designed for ATmega48P/88P/168P executes on the ATmega48PB/88PB/168PB the user must remember to change the device and recompile the code.

A general rule of thumb is that reserved bits should be written to zero if accessed. Reserved I/O memory addresses should never be written.

2.1 Writing Reserved Registers

If code should by accident write to a reserved register, Microchip can not guarantee the behavior of the application.

This chapter describes what to be aware of when using code designed for the ATmega48P/88P/168P on the ATmega48PB/88PB/168PB. If by mistake, the code accesses reserved registers or bit locations, the previous device might still operate as expected. On the newer devices these registers or bits might have specific functions, hence unexpected behavior can be observed.

On the ATmega48P/88P/168P register location 0x4F is reserved as shown in figure Figure 2-1.

Figure 2-1. Extract From the ATmega48P/88P/168P Data Sheet

0x4E	SPDR0	7:0	SPID[7:0]							
0x4F	Reserved									
0x50	ACSR	7:0	ACD	ACBG	ACO	ACI	ACIE	ACIC	ACIS1	ACIS0

On the ATmega48PB/88PB/168PB register location 0x4F is the ACSR0 register. This register contains one bit that controls the analog comparator output to Pin 3, ACOE - Analog Comparator Output Enable, as shown in figure Figure 2-2.

Figure 2-2. Extract From the ATmega48PB/88PB/168PB Data Sheet

0x4E	SPDR	7:0	SPID[7:0]							
0x4F	ACSR0	7:0								ACOE
0x50	ACSR	7:0	ACD	ACBG	ACO	ACI	ACIE	ACIC	ACIS [1:0]	

If the ACO is enabled by accident, and ATmega48PB/88PB/168PB is used as a drop-in replacement for ATmega48P/88P/168P, the ACO can potentially try to drive a pin which is connected to GND, and this can lead to unexpected behavior.

2.2 Device Part Pack

To ensure full device support for ATmega48PB/88PB/168PB the latest part pack must be installed. Up-to-date part packs are included in the latest version of Atmel Studio 7.0, or can be manually downloaded if needed:

- In the Atmel Studio 7.0 toolbar, click *Tools -> Device Pack Manager*. In the Device Pack Manager window click and select the latest version under *ATmega_DFP*, then click Install -> Install Selected Packs.
- [Alternative] Go to http://packs.download.atmel.com/ and download the latest *Atmel ATmega Series Device Support*. Install the downloaded file.

3. Ecosystem

The ecosystem for AVR® products includes Atmel Studio 7 Integrated Development Environment, Toolchains for AVR, Programmers, Debuggers, and Starter Kits.

3.1 Integrated Development Environment

3.1.1 Atmel Studio 7

ATmega48PB/88PB/168PB is supported in the latest version of Atmel Studio 7 - a Free IDE for development of C/C++ and assembler code for Atmel microcontrollers.

Studio 4 does not support ATmega48PB/88PB/168PB.

Go to http://www.microchip.com/development-tools/atmel-studio-7 for the latest installer and user guide, and other relevant information.

3.1.2 IAR

ATmega48PB/88PB/168PB is supported in IAR Embedded Workbench® for Atmel AVR® - a commercial C/C++ compiler that is available for 8-bit AVR. Users of IAR™ must ensure their current installed version supports ATmega48PB/88PB/168PB.

There is a 30-day evaluation version as well as a 4 KB code size limited kick-start version available from their website: https://www.iar.com/iar-embedded-workbench/partners/atmel/

3.2 Development Tools

The following developer tool is recommended for ATmega48PB/88PB/168PB:

- Atmel-ICE

Other legacy tools that also support ATmega48PB/88PB/168PB:
- AVR Dragon
- AVR One!
- AVRISP mkII
- JTAGICE mkII
- JTAGICE3
- Power Debugger
- QT600
- STK500
- STK600
- Simulator
- mEDBG

To update the desired tool in Atmel Studio 7: Click Tools → Device Programming in the Atmel Studio 7 Toolbar. When device programming has opened, choose the desired tool, device and interface, and then click Apply. If the tool has an older firmware version, Atmel Studio will prompt you to update the tool firmware version.

Another method: In the Atmel Studio toolbar, click View → Available Atmel Tools. In the Available Atmel Tools window right-click on your Tool and choose Upgrade... in the drop-down menu.

4. New Features

This chapter summarizes the enhancements or added features in ATmega48PB/88PB/168PB compared with ATmega48P/88P/168P.

- USART Start Frame Detection is available in all sleep modes
- Analog Comparator output is available on a pin. (This pin is multiplexed with PE0.)
- Serial Number (Unique Device ID)
- picoPower

4.1 USART

The USART Start Frame Detector can wake up ATmega48PB/88PB/168PB from all sleep modes when it detects a start bit.

When a high-to-low transition is detected on RxDn, the internal 8 MHz oscillator is powered up and the USART clock is enabled. After start-up, the rest of the data frame can be received, provided that the baud rate is slow enough in relation to the internal 8 MHz oscillator start-up time. Start-up time of the internal 8 MHz oscillator varies with supply voltage and temperature.

The USART start frame detection works in both asynchronous and synchronous modes. It is enabled by writing the Start Frame Detection Enable bit (SFDE). If the USART Start Interrupt Enable (RXSIE) bit is set, the USART Receive Start Interrupt is generated immediately when start is detected.

When using the feature without start interrupt, the start detection logic activates the internal 8 MHz oscillator and the USART clock while the frame is being received, only. Other clocks remain stopped until the Receive Complete Interrupt wakes up the MCU.

The maximum baud rate in synchronous mode depends on the sleep mode the device is woken up from:

- Idle sleep mode: system clock frequency divided by four
- Standby or Power-down: 500 kbps

The maximum baud rate in asynchronous mode depends on the sleep mode the device is woken up from:

- Idle sleep mode: the same as in active mode

Table 4-1. Maximum Total Baud Rate Error in Normal Speed Mode

Baud Rate	Frame Size					
	5	6	7	8	9	10
0 - 28.8 kbps	+6.67 -5.88	+5.79 -5.08	+5.11 -4.48	+4.58 -4.00	+4.14 -3.61	+3.78 -3.30
38.4 kbps	+6.63 -5.88	+5.75 -5.08	+5.08 -4.48	+4.55 -4.00	+4.12 -3.61	+3.76 -3.30
57.6 kbps	+6.10 -5.88	+5.30 -5.08	+4.69 -4.48	+4.20 -4.00	+3.80 -3.61	+3.47 -3.30

Baud Rate	Frame Size					
	5	6	7	8	9	10
76.8 kbps	+5.59 -5.88	+4.85 -5.08	+4.29 -4.48	+3.85 -4.00	+3.48 -3.61	+3.18 -3.30
115.2 kbps	+4.57 -5.88	+3.97 -5.08	+3.51 -4.48	+3.15 -4.00	+2.86 -3.61	+2.61 -3.30

Table 4-2. Maximum Total Baud Rate Error in Double Speed Mode

Baud Rate	Frame Size					
	5	6	7	8	9	10
0 - 57.6 kbps	+5.66 -4.00	+4.92 -3.45	+4.35 -3.03	+3.90 -2.70	+3.53 -2.44	+3.23 -2.22
76.8 kbps	+5.59 -4.00	+4.85 -3.45	+4.29 -3.03	+3.85 -2.70	+3.48 -2.44	+3.18 -2.22
115.2 kbps	+4.57 -4.00	+3.97 -3.45	+3.51 -3.03	+3.15 -2.70	+2.86 -2.44	+2.61 -2.22

4.2 Analog Comparator

The Analog Comparator Output (ACO) can be connected to PE0 if the Analog Comparator Output Enable (ACOE) is written with "1" in the Analog Comparator Control and Status Register C (ACSR0).

4.3 Serial Number

Each ATmega48PB/88PB/168PB has an integrated serial number (also called unique device ID) that can be used to uniquely identify each part.

There are two approaches to get the serial number information.

One way is to read the Signature Row from software. For detailed information, refer to section "Reading the Signature Row from Software" in the latest data sheet.

Table 4-3. Signature Row Addressing

Signature Byte	Z-Pointer Address
Device Signature Byte 1	0x0000
Device Signature Byte 2	0x0002
Device Signature Byte 3	0x0004
RC Oscillator Calibration Byte	0x0001
Serial Number Byte 1	0x000E
Serial Number Byte 0	0x000F
Serial Number Byte 3	0x0010

Signature Byte	Z-Pointer Address
Serial Number Byte 2	0x0011
Serial Number Byte 5	0x0012
Serial Number Byte 4	0x0013
Serial Number Byte 6	0x0015
Serial Number Byte 7	0x0016
Serial Number Byte 8	0x0017

Note:

If the serial number feature is used across several device families the device signature bytes should also be included in the serial number. Extending the serial number to a 12-byte number.

Another way is to read I/O address 0xF0 - 0xF8, as the ATmega48PB/88PB/168PB serial number can be accessed through I/O registers SNOBRx. The serial number is made from concatenating the nine bytes read out from these read-only registers. See sub-chapter SNOBRx - Serial Number Byte 8 to 0 for more detail.

An example of how to read out the serial number is given below:
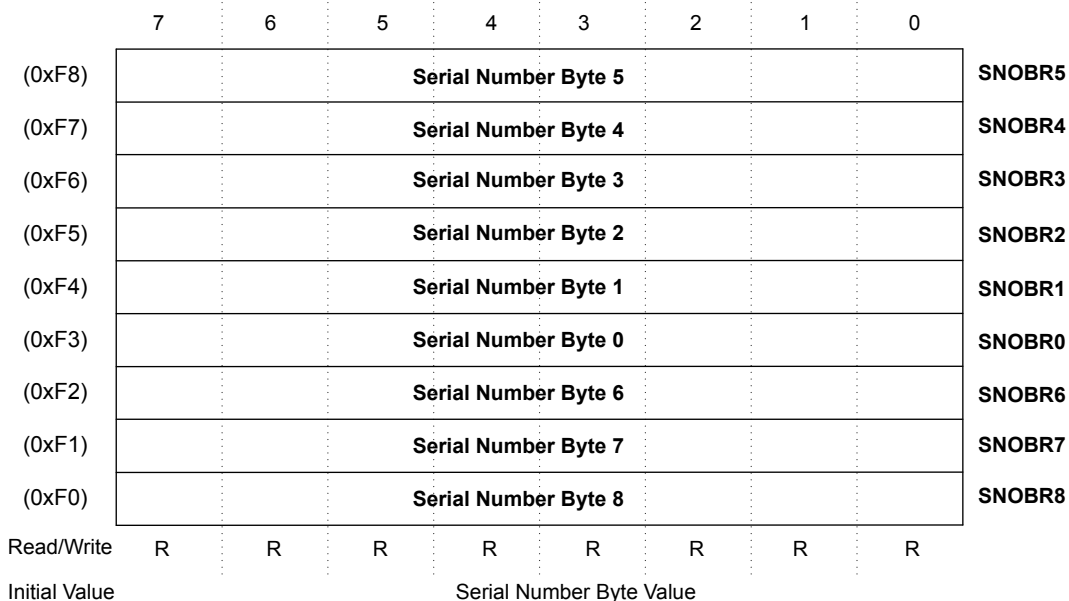
C Code Example

```
uint8_t serial_num[9] = {0};

for(uint8_t i = 0; i < 9; i++){
    serial_num[i] = *((uint8_t *) &DEVID0+i);
}
```

4.3.1   SNOBRx - Serial Number Byte 8 to 0

	7	6	5	4	3	2	1	0	
(0xF8)				Serial Number Byte 5					SNOBR5
(0xF7)				Serial Number Byte 4					SNOBR4
(0xF6)				Serial Number Byte 3					SNOBR3
(0xF5)				Serial Number Byte 2					SNOBR2
(0xF4)				Serial Number Byte 1					SNOBR1
(0xF3)				Serial Number Byte 0					SNOBR0
(0xF2)				Serial Number Byte 6					SNOBR6
(0xF1)				Serial Number Byte 7					SNOBR7
(0xF0)				Serial Number Byte 8					SNOBR8
Read/Write	R	R	R	R	R	R	R	R	
Initial Value				Serial Number Byte Value					

5. Updated Features

5.1 Signature Bytes

All AVR microcontrollers have a three-byte signature code, which identifies the device. This code can be read in both serial and parallel mode, also when the device is locked. The three bytes reside in a separate address space. For the device signature bytes, there are differences between ATmega48P/88P/168P and ATmega48PB/88PB/168PB, see the table below for more detail.

Table 5-1. Device ID

Part	Signature Bytes Address		
	0x000	0x001	0x002
ATmega48P/PV	0x1E	0x92	0x0A
ATmega48PB	0x1E	0x92	0x10
ATmega88P/PV	0x1E	0x93	0x0F
ATmega88PB	0x1E	0x93	0x16
ATmega168P/PV	0x1E	0x94	0x0B
ATmega168PB	0x1E	0x94	0x15

5.2 Full Swing Oscillator

The ATmega48P/88P/168P device includes a full swing crystal oscillator as a clock source option, which can be selected by configuring the flash fuse. In the new ATmega48PB/88PB/168PB, the full swing crystal oscillator is removed. Refer to the "Clock Sources" chapter in the device data sheet.

Table 5-2. Full Swing Oscillator Removed from ATmega48PB/88PB/168PB

Device Function	ATmega48P/88P/168P	ATmega48PB/88PB/168PB
Full swing crystal oscillator	Yes	No

5.3 Characteristics

This chapter will compare the biggest changes in electrical- and typical characteristics. For the most up-to-date- and other numbers refer to the latest data sheet of the device.

The latest data sheets can be found here:

- ATmega48PB/88PB/168PB - http://www.microchip.com/wwwproducts/en/ATmega168pb
- ATmega48P/88P/168P - http://www.microchip.com/wwwproducts/en/ATmega168p

Table 5-3. Typical Wait Delay Before Writing the Next Flash or EEPROM Location

Symbol	ATmega48P/88P/168P	ATmega48PB/88PB/168PB	Units
t_{WD_FLASH}	4.5	2.6	ms
t_{WD_EEPROM}	3.6	3.6	ms

Symbol	ATmega48P/88P/168P	ATmega48PB/88PB/168PB	Units
t_{WD_ERASE}	9.0	10.5	ms
t_{WD_FUSE}	-	4.5	ms

6. Additional reading and related documents

- AVR095: Migrating between ATmega48, ATmega88 and ATmega168
- AVR512: Migration from ATmega48/88/168 to ATmega48P/88P/168P
- AVR528: Migrating from ATmega48P/88P/168P to ATmega48PA/88P/168PA
- AVR532: Migrating from ATmega48/88/168 to ATmega48A/88A/168A

- AN2519: AVR Microcontroller Hardware Design Considerations
- AT12615: Getting Started with ATmega48PB/88PB/ 168PB
- AVR040: EMC Design Considerations
- AVR053: Calibration of the internal RC oscillator
- AVR140: ATmega48/88/168 family run-time calibration of the Internal RC oscillator for LIN applications
- AVR910: In-System Programming
- AVR4013: picoPower Basics
- AVR4100: Selecting and testing 32kHz crystal oscillators for AVR microcontrollers
- AVR42787: AVR Software User Guide

Additional documents can be found here: http://www.microchip.com/wwwproducts/en/ATmega168pb

Or our webpage at www.microchip.com

7. Revision History

Doc. Rev.	Date	Comments
A	12/2017	Initial document release

The Microchip Web Site

Microchip provides online support via our web site at http://www.microchip.com/. This web site is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the web site contains the following information:

- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQ), technical support requests, online discussion groups, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

Customer Change Notification Service

Microchip's customer notification service helps keep customers current on Microchip products. Subscribers will receive e-mail notification whenever there are changes, updates, revisions or errata related to a specified product family or development tool of interest.

To register, access the Microchip web site at http://www.microchip.com/. Under "Support", click on "Customer Change Notification" and follow the registration instructions.

Customer Support

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or Field Application Engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the web site at: http://www.microchip.com/support

Microchip Devices Code Protection Feature

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.

- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Legal Notice

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

Trademarks

The Microchip name and logo, the Microchip logo, AnyRate, AVR, AVR logo, AVR Freaks, BeaconThings, BitCloud, CryptoMemory, CryptoRF, dsPIC, FlashFlex, flexPWR, Heldo, JukeBlox, KeeLoq, KeeLoq logo, Kleer, LANCheck, LINK MD, maXStylus, maXTouch, MediaLB, megaAVR, MOST, MOST logo, MPLAB, OptoLyzer, PIC, picoPower, PICSTART, PIC32 logo, Prochip Designer, QTouch, RightTouch, SAM-BA, SpyNIC, SST, SST Logo, SuperFlash, tinyAVR, UNI/O, and XMEGA are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

ClockWorks, The Embedded Control Solutions Company, EtherSynch, Hyper Speed Control, HyperLight Load, IntelliMOS, mTouch, Precision Edge, and Quiet-Wire are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Adjacent Key Suppression, AKS, Analog-for-the-Digital Age, Any Capacitor, AnyIn, AnyOut, BodyCom, chipKIT, chipKIT logo, CodeGuard, CryptoAuthentication, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, EtherGREEN, In-Circuit Serial Programming, ICSP, Inter-Chip Connectivity, JitterBlocker, KleerNet, KleerNet logo, Mindi, MiWi, motorBench, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICkit, PICtail, PureSilicon, QMatrix, RightTouch logo, REAL ICE, Ripple Blocker, SAM-ICE, Serial Quad I/O, SMART-I.S., SQI, SuperSwitcher, SuperSwitcher II, Total Endurance, TSHARC, USBCheck, VariSense, ViewSpan, WiperLock, Wireless DNA, and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

Silicon Storage Technology is a registered trademark of Microchip Technology Inc. in other countries.

GestIC is a registered trademark of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

Quality Management System Certified by DNV

ISO/TS 16949

Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.

Worldwide Sales and Service

AMERICAS	ASIA/PACIFIC	ASIA/PACIFIC	EUROPE
Corporate Office 2355 West Chandler Blvd. Chandler, AZ 85224-6199 Tel: 480-792-7200 Fax: 480-792-7277 Technical Support: http://www.microchip.com/ support Web Address: www.microchip.com **Atlanta** Duluth, GA Tel: 678-957-9614 Fax: 678-957-1455 **Austin, TX** Tel: 512-257-3370 **Boston** Westborough, MA Tel: 774-760-0087 Fax: 774-760-0088 **Chicago** Itasca, IL Tel: 630-285-0071 Fax: 630-285-0075 **Dallas** Addison, TX Tel: 972-818-7423 Fax: 972-818-2924 **Detroit** Novi, MI Tel: 248-848-4000 **Houston, TX** Tel: 281-894-5983 **Indianapolis** Noblesville, IN Tel: 317-773-8323 Fax: 317-773-5453 Tel: 317-536-2380 **Los Angeles** Mission Viejo, CA Tel: 949-462-9523 Fax: 949-462-9608 Tel: 951-273-7800 **Raleigh, NC** Tel: 919-844-7510 **New York, NY** Tel: 631-435-6000 **San Jose, CA** Tel: 408-735-9110 Tel: 408-436-4270 **Canada - Toronto** Tel: 905-695-1980 Fax: 905-695-2078	**Australia - Sydney** Tel: 61-2-9868-6733 **China - Beijing** Tel: 86-10-8569-7000 **China - Chengdu** Tel: 86-28-8665-5511 **China - Chongqing** Tel: 86-23-8980-9588 **China - Dongguan** Tel: 86-769-8702-9880 **China - Guangzhou** Tel: 86-20-8755-8029 **China - Hangzhou** Tel: 86-571-8792-8115 **China - Hong Kong SAR** Tel: 852-2943-5100 **China - Nanjing** Tel: 86-25-8473-2460 **China - Qingdao** Tel: 86-532-8502-7355 **China - Shanghai** Tel: 86-21-3326-8000 **China - Shenyang** Tel: 86-24-2334-2829 **China - Shenzhen** Tel: 86-755-8864-2200 **China - Suzhou** Tel: 86-186-6233-1526 **China - Wuhan** Tel: 86-27-5980-5300 **China - Xian** Tel: 86-29-8833-7252 **China - Xiamen** Tel: 86-592-2388138 **China - Zhuhai** Tel: 86-756-3210040	**India - Bangalore** Tel: 91-80-3090-4444 **India - New Delhi** Tel: 91-11-4160-8631 **India - Pune** Tel: 91-20-4121-0141 **Japan - Osaka** Tel: 81-6-6152-7160 **Japan - Tokyo** Tel: 81-3-6880- 3770 **Korea - Daegu** Tel: 82-53-744-4301 **Korea - Seoul** Tel: 82-2-554-7200 **Malaysia - Kuala Lumpur** Tel: 60-3-7651-7906 **Malaysia - Penang** Tel: 60-4-227-8870 **Philippines - Manila** Tel: 63-2-634-9065 **Singapore** Tel: 65-6334-8870 **Taiwan - Hsin Chu** Tel: 886-3-577-8366 **Taiwan - Kaohsiung** Tel: 886-7-213-7830 **Taiwan - Taipei** Tel: 886-2-2508-8600 **Thailand - Bangkok** Tel: 66-2-694-1351 **Vietnam - Ho Chi Minh** Tel: 84-28-5448-2100	**Austria - Wels** Tel: 43-7242-2244-39 Fax: 43-7242-2244-393 **Denmark - Copenhagen** Tel: 45-4450-2828 Fax: 45-4485-2829 **Finland - Espoo** Tel: 358-9-4520-820 **France - Paris** Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79 **Germany - Garching** Tel: 49-8931-9700 **Germany - Haan** Tel: 49-2129-3766400 **Germany - Heilbronn** Tel: 49-7131-67-3636 **Germany - Karlsruhe** Tel: 49-721-625370 **Germany - Munich** Tel: 49-89-627-144-0 Fax: 49-89-627-144-44 **Germany - Rosenheim** Tel: 49-8031-354-560 **Israel - Ra'anana** Tel: 972-9-744-7705 **Italy - Milan** Tel: 39-0331-742611 Fax: 39-0331-466781 **Italy - Padova** Tel: 39-049-7625286 **Netherlands - Drunen** Tel: 31-416-690399 Fax: 31-416-690340 **Norway - Trondheim** Tel: 47-7289-7561 **Poland - Warsaw** Tel: 48-22-3325737 **Romania - Bucharest** Tel: 40-21-407-87-50 **Spain - Madrid** Tel: 34-91-708-08-90 Fax: 34-91-708-08-91 **Sweden - Gothenberg** Tel: 46-31-704-60-40 **Sweden - Stockholm** Tel: 46-8-5090-4654 **UK - Wokingham** Tel: 44-118-921-5800 Fax: 44-118-921-5820