
Section 19. Dual Comparator Module

HIGHLIGHTS

This section of the manual contains the following major topics:

19.1	Introduction.....	19-2
19.2	Control Register	19-3
19.3	Comparator Operation.....	19-5
19.4	Comparator Reference.....	19-5
19.5	Comparator Response Time	19-5
19.6	Comparator Outputs.....	19-6
19.7	Analog Input Connection Considerations	19-7
19.8	Initialization.....	19-7
19.9	Comparator Interrupts	19-8
19.10	Comparator Operation During Sleep and Idle Modes	19-8
19.11	Effects of a Reset	19-8
19.12	Related Application Notes	19-9
19.13	Revision History	19-10

19.1 INTRODUCTION

The analog dual comparator module contains two comparators that can be configured in a variety of ways. The inputs can be selected from the analog inputs multiplexed with the I/O pins, as well as the on-chip voltage reference (see **Section 20. “Comparator Voltage Reference Module”**). Block diagrams of the various comparator configurations are shown in Figure 19-1.

Note: A comparator module with two analog comparators may also be the scalable comparator module, described in the “PIC24F Family Reference Manual”, **Section 46. “Scalable Comparator Module”** (DS39734). Check the device data sheet to verify which comparator module is included in a particular device.

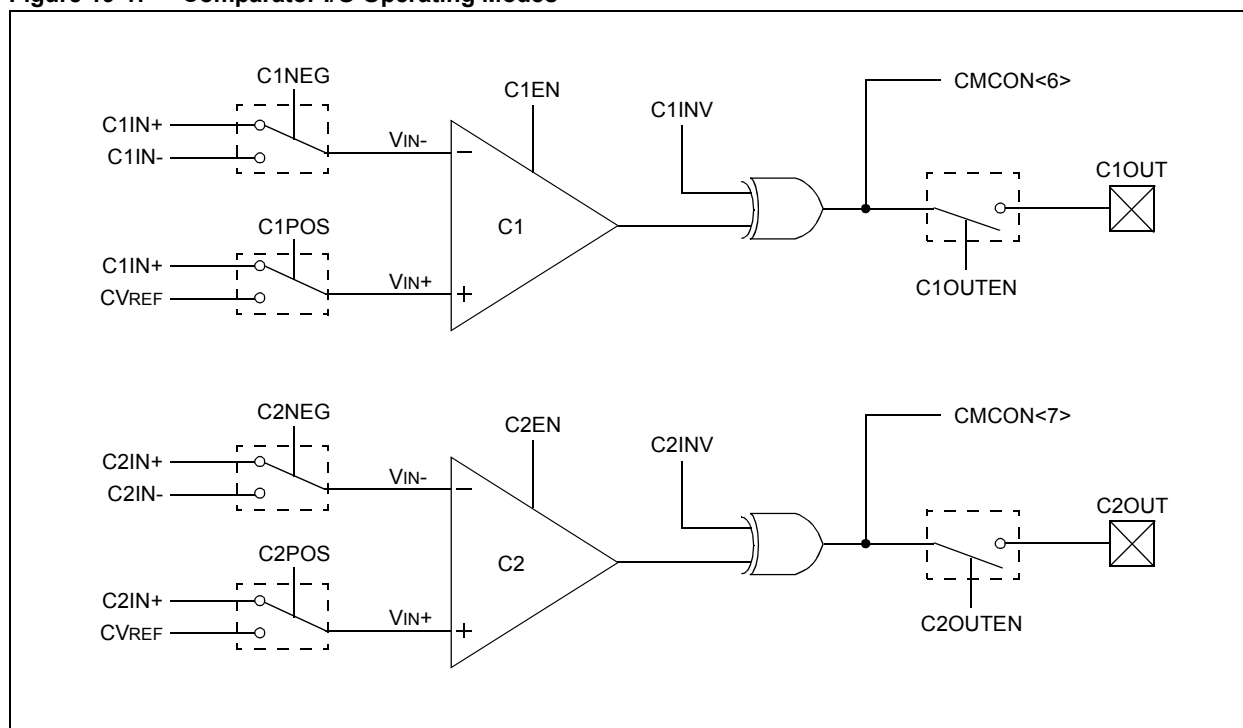
19.1.1 Comparator Configuration

PIC24F devices offer near 100% flexibility in configuration of the comparator module, allowing individual control over many of the options that are fixed on most PIC18 devices. The PIC24F comparator module has individual control over the enables, output inversion, output on I/O pin and input selections. The V_{IN-} pin of each comparator can select from either I/O pin ($CxIN+$ or $CxIN-$) and the V_{IN+} input of the comparator comes from the comparator voltage reference, or the positive I/O pin ($CxIN+$ or $CVREF$). In addition, the PIC24F has 2 individual comparator event control bits. These control bits can be used for detecting when an individual comparator output changes states.

If the Comparator mode is changed, the comparator output level may not be valid for the specified mode change delay.

Note: Comparator interrupts should be disabled during a Comparator mode change; otherwise, a false interrupt may occur.

Figure 19-1: Comparator I/O Operating Modes



19.2 CONTROL REGISTER

The CMCON register (Register 19-1) is used to configure the comparator and present their output status. The C2EN and C1EN bits (CMCON<11:10>) enable or disable the individual comparators.

Comparator input configuration is accomplished with the CxNEG and CxPOS bits (CMCON<3:0>). These determine which of the differential input channels is connected to the non-inverting input, and if either a differential comparator input or the comparator voltage reference is connected to the inverting input. A total of 16 possible configurations are available for both comparators.

The CxOUT bits (CMCON<7:6>) directly report the output state of the comparator, as determined by the relative values of Vin+ and Vin-, and the CxINV bits (CMCON<5:4>). The CxOUTEN bits (CMCON<9:8>) enable the output of the comparator to appear on the corresponding CxOUT pin. The CxEVT pins (CMCON<13:12>) indicate when any change in output state has occurred. These bits are set by hardware and can only be cleared in software.

Register 19-1: CMCON: Comparator Control Register

R/W-0	U-0	R/C-0	R/C-0	R/W-0	R/W-0	R/W-0	R/W-0
CMIDL	—	C2EVT	C1EVT	C2EN	C1EN	C2OUTEN	C1OUTEN
bit 15				bit 8			
R-0	R-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
C2OUT	C1OUT	C2INV	C1INV	C2NEG	C2POS	C1NEG	C1POS
bit 7				bit 0			

Legend:	C = Clearable bit
R = Readable bit	W = Writable bit
-n = Value at POR	'1' = Bit is set
	'0' = Bit is cleared
	x = Bit is unknown

bit 15	CMIDL: Stop in Idle Mode bit 1 = When device enters Idle mode, the module does not generate interrupts; the module is still enabled 0 = Continue normal module operation in Idle mode
bit 14	Unimplemented: Read as '0'
bit 13	C2EVT: Comparator 2 Event bit 1 = Comparator output changed states 0 = Comparator output did not change states
bit 12	C1EVT: Comparator 1 Event bit 1 = Comparator output changed states 0 = Comparator output did not change states
bit 11	C2EN: Comparator 2 Enable bit 1 = Comparator is enabled 0 = Comparator is disabled
bit 10	C1EN: Comparator 1 Enable bit 1 = Comparator is enabled 0 = Comparator is disabled
bit 9	C2OUTEN: Comparator 2 Output Enable bit 1 = Comparator output is driven on the output pad 0 = Comparator output is not driven on the output pad
bit 8	C1OUTEN: Comparator 1 Output Enable bit 1 = Comparator output is driven on the output pad 0 = Comparator output is not driven on the output pad

PIC24F Family Reference Manual

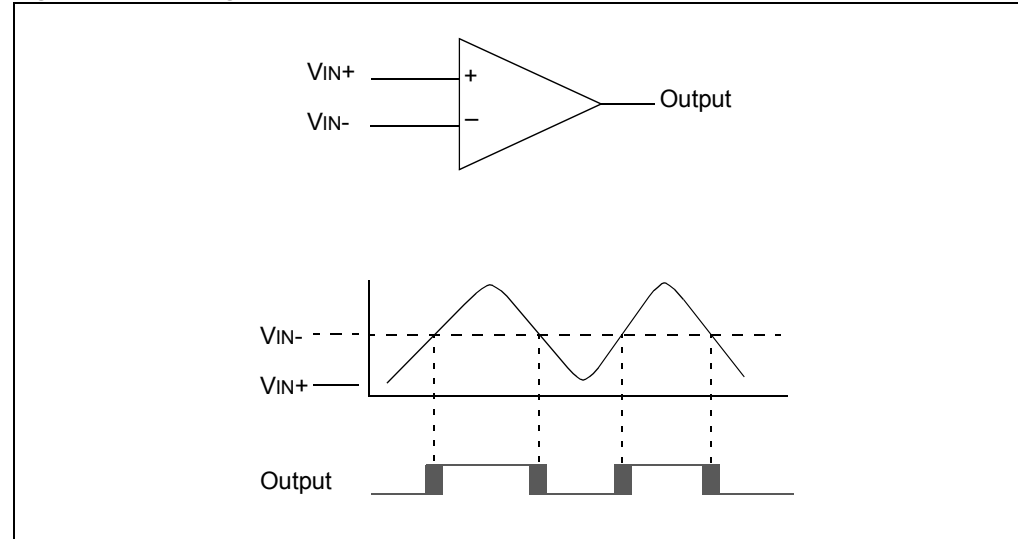
Register 19-1: CMCON: Comparator Control Register (Continued)

bit 7	C2OUT: Comparator 2 Output bit <u>When C2INV = 0:</u> 1 = C2IN+ > C2IN- 0 = C2IN+ < C2IN- <u>When C2INV = 1:</u> 0 = C2IN+ > C2IN- 1 = C2IN+ < C2IN-
bit 6	C1OUT: Comparator 1 Output bit <u>When C1INV = 0:</u> 1 = C1IN+ > C1IN- 0 = C1IN+ < C1IN- <u>When C1INV = 1:</u> 0 = C1IN+ > C1IN- 1 = C1IN+ < C1IN-
bit 5	C2INV: Comparator 2 Output Inversion bit 1 = C2 output is inverted 0 = C2 output is not inverted
bit 4	C1INV: Comparator 1 Output Inversion bit 1 = C1 output is inverted 0 = C1 output is not inverted
bit 3	C2NEG: Comparator 2 Negative Input Configure bit 1 = Input is connected to C2IN+ 0 = Input is connected to C2IN- See Figure 19-1 for the Comparator modes.
bit 2	C2POS: Comparator 2 Positive Input Configure bit 1 = Input is connected to C2IN+ 0 = Input is connected to CVREF See Figure 19-1 for the Comparator modes.
bit 1	C1NEG: Comparator 1 Negative Input Configure bit 1 = Input is connected to C1IN+ 0 = Input is connected to C1IN- See Figure 19-1 for the Comparator modes.
bit 0	C1POS: Comparator 1 Positive Input Configure bit 1 = Input is connected to C1IN+ 0 = Input is connected to CVREF See Figure 19-1 for the Comparator modes.

19.3 COMPARATOR OPERATION

A single comparator is shown in Figure 19-2, along with the relationship between the analog input levels and the digital output. When the analog input at V_{IN+} is less than the analog input V_{IN-} , the output of the comparator is a digital low level. When the analog input at V_{IN+} is greater than the analog input, V_{IN-} , the output of the comparator is a digital high level. The shaded areas of the output of the comparator in Figure 19-2 represent the uncertainty due to input offsets and response time.

Figure 19-2: Single Comparator



19.4 COMPARATOR REFERENCE

Depending on the comparator operating mode, either an external or internal voltage reference may be used. The analog signal present at V_{IN-} is compared to the signal at V_{IN+} and the digital output of the comparator is adjusted accordingly (Figure 19-2).

19.4.1 External Reference Signal

When external voltage references are used, the comparator module can be configured to have the comparators operate from the same, or different, reference sources. However, threshold detector applications may require the same reference.

19.4.2 Internal Reference Signal

The comparator module also allows the selection of an internally generated voltage reference from the comparator voltage reference module. This module is described in more detail in **Section 20. "Comparator Voltage Reference Module"**.

The internal reference is available when $C1POS = 0$, $C2POS = 0$ and the $CVRSS$ bit ($CVRCON<4> = 0$). In this mode, the internal voltage reference is applied to the V_{IN+} pin of both comparators.

19.5 COMPARATOR RESPONSE TIME

Response time is the maximum time, after selecting a new reference voltage or input source, before the comparator output has a valid level. If the internal reference is changed, the maximum delay of the internal voltage reference must be considered when using the comparator outputs. Otherwise, the maximum delay of the comparators should be used.

19.6 COMPARATOR OUTPUTS

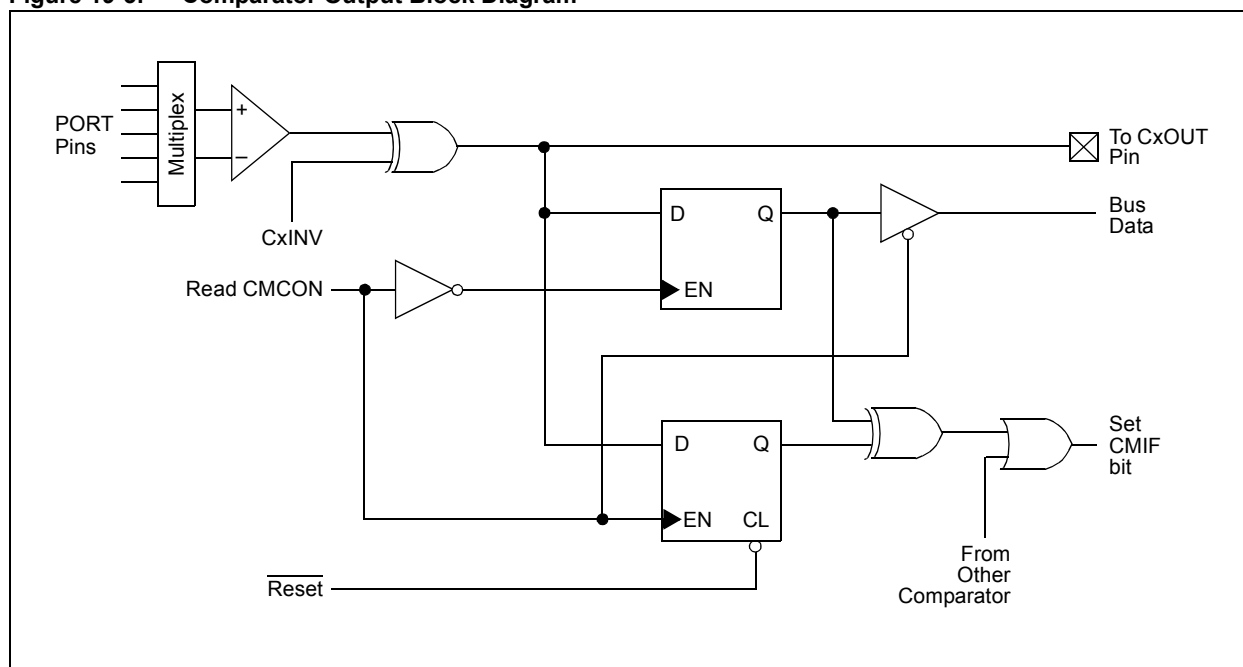
The comparator outputs are read through the CMCON register. These bits are read-only. The comparator outputs may also be directly output to the I/O pins via C1OUT and C2OUT. When enabled, multiplexers in the output path of the I/O pins will switch and the output of each pin will be the unsynchronized output of the comparator. The uncertainty of each of the comparators is related to the input offset voltage and the response time given in the specifications. Figure 19-3 shows the comparator output block diagram.

The associated TRIS bits will still function as an output enable/disable for the I/O pins while in this mode.

The polarity of the comparator outputs can be changed using the C2INV and C1INV bits (CMCON<5:4>).

- Note 1:** When reading the PORT register, all pins configured as analog inputs will read as '0's. Pins configured as digital inputs will convert an analog input according to the Schmitt Trigger input specification.
- 2:** Analog levels on any pin defined as a digital input may cause the input buffer to consume more current than is specified.

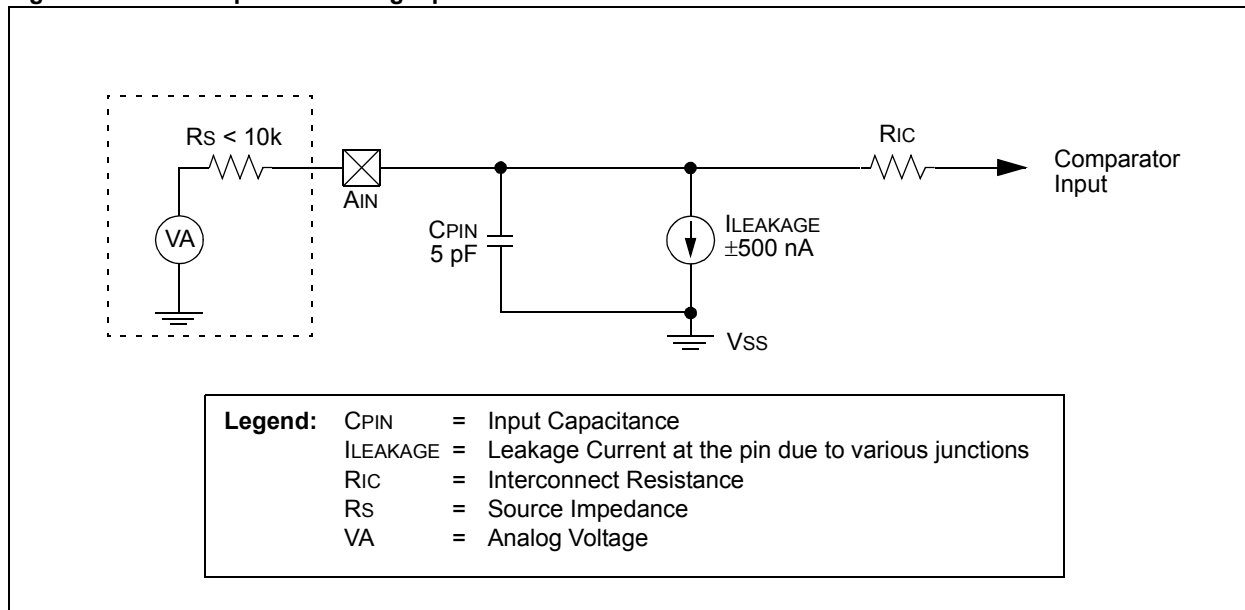
Figure 19-3: Comparator Output Block Diagram



19.7 ANALOG INPUT CONNECTION CONSIDERATIONS

A simplified circuit for an analog input is shown in Figure 19-4. A maximum source impedance of 10 k Ω is recommended for the analog sources. Any external component connected to an analog input pin, such as a capacitor or a Zener diode, should have very little leakage current.

Figure 19-4: Comparator Analog Input Model



19.8 INITIALIZATION

This initialization sequence configures the comparator module as two independent comparators with outputs enabled and the Comparator 1 output inverted. The comparator voltage reference module is configured for output enable and set for 0.25 * VDD. Example 19-1 shows a program sequence to configure the voltage reference and comparator module. The delay used in this example is based off of an 8 MHz oscillator.

Example 19-1: Comparator Configuration

```
CMCON      = 0x0F10;           //Initialize Comparator Module

CVRCON     = 0x00C0;           //Initialize Voltage Reference Module

CMCONbits.C1EVT = 0;           //Clear Comparator 1 Event
CMCONbits.C2EVT = 0;           //Clear Comparator 2 Event

asm volatile("repeat #40");     //Delay 10us
Nop();
```

19.9 COMPARATOR INTERRUPTS

The Comparator Interrupt Flag, CMIF (IFS1<2>), is set whenever there is a change in the output value of either comparator. Software can read C1EVT and C2EVT to determine the actual change that occurred. Since it is also possible to write a '1' to this register, a simulated interrupt may be initiated. The CMIF and CxEVT bits must be reset by clearing them in software.

If the CMIE bit (IEC1<2>) is cleared, the interrupt is not enabled, though the CMIF bit will still be set if an interrupt condition occurs.

Note: If a change in the CMCON register (C1OUT or C2OUT) should occur when a read operation is being executed (start of the Q2 cycle), then the CMIF (IFS1<2>) interrupt flag may not get set.

The user, in the Interrupt Service Routine, can clear the interrupt by clearing CMIF. See **Section 8. "Interrupts"** in this manual for more information.

19.10 COMPARATOR OPERATION DURING SLEEP AND IDLE MODES

19.10.1 Comparator Operation During Sleep

When a comparator is active and the device is placed in Sleep mode, the comparator remains active and the interrupt is functional, if enabled. This interrupt will wake-up the device from Sleep mode, when enabled. Each operational comparator will consume additional current, as shown in the comparator specifications. To minimize power consumption while in Sleep mode, turn off the comparators, CxEN = 0 (CMCON<11:10>), before entering Sleep. If the device wakes up from Sleep, the contents of the CMCON register are not affected. See **Section 10. "Power-Saving Features"** in this manual for additional information on Sleep.

19.10.2 Comparator Operation During Idle

When a comparator is active and the device is placed in Idle mode, the comparator remains active and interrupts are generated, if enabled, and CMIDL = 0 (CMCON<15>). If it is desired for the comparators to operate in Idle mode without generating interrupts, configure CMIDL = 1 (CMCON<15>). See **Section 10. "Power-Saving Features"** in this manual for more information on Idle.

19.11 EFFECTS OF A RESET

A device Reset forces the CMCON register to its Reset state, causing the comparator modules to be turned off (CxEN = 0). However, the input pins multiplexed with analog input sources are configured as analog inputs, by default, on device Reset. The I/O configuration for these pins is determined by the setting of the ADxPCFG register. Therefore, device current is minimized when analog inputs are present at Reset time.

19.12 RELATED APPLICATION NOTES

This section lists application notes that are related to this section of the manual. These application notes may not be written specifically for the PIC24F device family, but the concepts are pertinent and could be used with modification and possible limitations. The current application notes related to the Comparator module are:

Title	Application Note #
Resistance and Capacitance Meter Using a PIC16C622	AN611
Make a Delta-Sigma Converter Using a Microcontroller's Analog Comparator Module	AN700
A Comparator Based Slope ADC	AN863
Oscillator Circuits for RTD Temperature Sensors	AN895
Temperature Measurement Circuits for Embedded Applications	AN929
Analog Sensor Conditioning Circuits – An Overview	AN990

Note: Please visit the Microchip web site (www.microchip.com) for additional application notes and code examples for the PIC24F family of devices.
--

19.13 REVISION HISTORY

Revision A (June 2006)

This is the initial released revision of this document.

Revision B (March 2010)

Renamed as “Dual Comparator Module”, to distinguish from the recently introduced **Section 46. “Scalable Comparator Module”** (DS39734).

Reorganized all topics to reflect the order used in **Section 46. “Scalable Comparator Module”**.
Replaced the text of **Section 19.2 “Control Register”** with a new version, to provide a clearer explanation of the register.

Revised Figure 19-3 to correct the “Read CMCON” circuit input.

Revised Figure 19-4 with an updated input model.

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.

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.

Trademarks

The Microchip name and logo, the Microchip logo, dsPIC, KEELOQ, KEELOQ logo, MPLAB, PIC, PICmicro, PICSTART, PIC³² logo, rfPIC and UNI/O are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.


FilterLab, Hampshire, HI-TECH C, Linear Active Thermistor, MXDEV, MXLAB, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Analog-for-the-Digital Age, Application Maestro, CodeGuard, dsPICDEM, dsPICDEM.net, dsPICworks, dsSPEAK, ECAN, ECONOMONITOR, FanSense, HI-TIDE, In-Circuit Serial Programming, ICSP, Mindi, MiWi, MPASM, MPLAB Certified logo, MPLIB, MPLINK, mTouch, Octopus, Omniscient Code Generation, PICC, PICC-18, PICDEM, PICDEM.net, PICkit, PICTail, REAL ICE, rLAB, Select Mode, Total Endurance, TSHARC, UniWinDriver, WiperLock 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.

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

© 2010, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

 Printed on recycled paper.

ISBN: 978-1-60932-146-8

Microchip received ISO/TS-16949:2002 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.

QUALITY MANAGEMENT SYSTEM
CERTIFIED BY DNV
== ISO/TS 16949:2002 ==



WORLDWIDE SALES AND SERVICE

AMERICAS

Corporate Office

2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
<http://support.microchip.com>
Web Address:
www.microchip.com

Atlanta

Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Boston

Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago

Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Cleveland

Independence, OH
Tel: 216-447-0464
Fax: 216-447-0643

Dallas

Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit

Farmington Hills, MI
Tel: 248-538-2250
Fax: 248-538-2260

Kokomo

Kokomo, IN
Tel: 765-864-8360
Fax: 765-864-8387

Los Angeles

Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608

Santa Clara

Santa Clara, CA
Tel: 408-961-6444
Fax: 408-961-6445

Toronto

Mississauga, Ontario,
Canada
Tel: 905-673-0699
Fax: 905-673-6509

ASIA/PACIFIC

Asia Pacific Office

Suites 3707-14, 37th Floor
Tower 6, The Gateway
Harbour City, Kowloon
Hong Kong
Tel: 852-2401-1200
Fax: 852-2401-3431

Australia - Sydney

Tel: 61-2-9868-6733
Fax: 61-2-9868-6755

China - Beijing

Tel: 86-10-8528-2100
Fax: 86-10-8528-2104

China - Chengdu

Tel: 86-28-8665-5511
Fax: 86-28-8665-7889

China - Chongqing

Tel: 86-23-8980-9588
Fax: 86-23-8980-9500

China - Hong Kong SAR

Tel: 852-2401-1200
Fax: 852-2401-3431

China - Nanjing

Tel: 86-25-8473-2460
Fax: 86-25-8473-2470

China - Qingdao

Tel: 86-532-8502-7355
Fax: 86-532-8502-7205

China - Shanghai

Tel: 86-21-5407-5533
Fax: 86-21-5407-5066

China - Shenyang

Tel: 86-24-2334-2829
Fax: 86-24-2334-2393

China - Shenzhen

Tel: 86-755-8203-2660
Fax: 86-755-8203-1760

China - Wuhan

Tel: 86-27-5980-5300
Fax: 86-27-5980-5118

China - Xian

Tel: 86-29-8833-7252
Fax: 86-29-8833-7256

China - Xiamen

Tel: 86-592-2388138
Fax: 86-592-2388130

China - Zhuhai

Tel: 86-756-3210040
Fax: 86-756-3210049

ASIA/PACIFIC

India - Bangalore

Tel: 91-80-3090-4444
Fax: 91-80-3090-4123

India - New Delhi

Tel: 91-11-4160-8631
Fax: 91-11-4160-8632

India - Pune

Tel: 91-20-2566-1512
Fax: 91-20-2566-1513

Japan - Yokohama

Tel: 81-45-471- 6166
Fax: 81-45-471-6122

Korea - Daegu

Tel: 82-53-744-4301
Fax: 82-53-744-4302

Korea - Seoul

Tel: 82-2-554-7200
Fax: 82-2-558-5932 or
82-2-558-5934

Malaysia - Kuala Lumpur

Tel: 60-3-6201-9857
Fax: 60-3-6201-9859

Malaysia - Penang

Tel: 60-4-227-8870
Fax: 60-4-227-4068

Philippines - Manila

Tel: 63-2-634-9065
Fax: 63-2-634-9069

Singapore

Tel: 65-6334-8870
Fax: 65-6334-8850

Taiwan - Hsin Chu

Tel: 886-3-6578-300
Fax: 886-3-6578-370

Taiwan - Kaohsiung

Tel: 886-7-536-4818
Fax: 886-7-536-4803

Taiwan - Taipei

Tel: 886-2-2500-6610
Fax: 886-2-2508-0102

Thailand - Bangkok

Tel: 66-2-694-1351
Fax: 66-2-694-1350

EUROPE

Austria - Wels

Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen

Tel: 45-4450-2828
Fax: 45-4485-2829

France - Paris

Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Munich

Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Italy - Milan

Tel: 39-0331-742611
Fax: 39-0331-466781

Netherlands - Drunen

Tel: 31-416-690399
Fax: 31-416-690340

Spain - Madrid

Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

UK - Wokingham

Tel: 44-118-921-5869
Fax: 44-118-921-5820