TB087

Using Voltage Supervisors with PICmicro® Microcontroller Systems which Implement In-Circuit Serial Programming™

Author: *Mark Palmer*
Microchip Technology Inc.

INTRODUCTION

Even though many microcontrollers offer an on-chip brown-out function, it may be desirable to use an external voltage supervisor. This may be due to the microcontroller's limited trip point selections or the additional current requirement for enabling the brown-out function. In these cases, an external voltage supervisor device may be preferable.

Many standard microcontrollers are Flash memory devices. This means that the device can be programmed in-circuit. Typically, to enter the in-circuit programming mode, some non-typical state needs to be forced. For PICmicro® microcontrollers, the mode is called In-Circuit Serial Programming™ (ICSP™). A typical microcontroller – ICSP system is shown in Figure 1.

ICSP can be used to program the device after assembly as well as for firmware updates in the field.

In most cases, entering the ICSP mode requires that the $\overline{MCLR}$ pin go from a low voltage (V_{IL}) to the programming high voltage (V_{IHH}). The V_{IHH} is dependent on the PICmicro microcontroller and typically ranges from a minimum of the PICmicro microcontroller's V_{DD} + 3.5V to a maximum of 14V.

> **Note:** Refer to the specific programming specification for the desired PICmicro microcontroller.

As can be expected, these voltages are beyond the maximum voltage specification of the voltage supervisor output pin.

This technical brief will show how the MCP111 and MCP121 may be used in PICmicro microcontroller systems where ICSP is required.

Reset Characteristics

The two main reasons to consider an external voltage supervisor device are:

1. Voltage trip point
2. Operating current

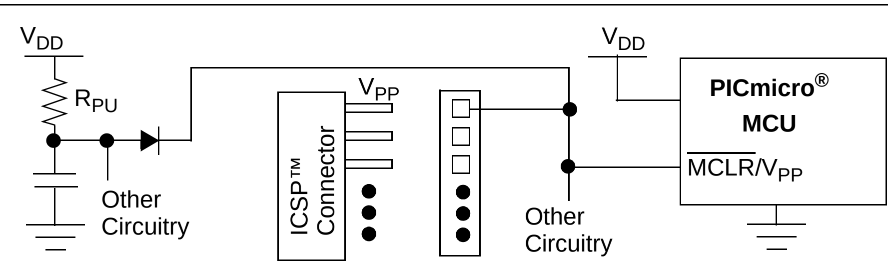
Table 1 shows a voltage trip point and operational current comparison between a couple of PICmicro microcontrollers and either the MCP111 or MCP121. The MCP1X1 offers more voltage trip points and a significantly lower operating current.

TABLE 1: RESET CHARACTERISTICS

Device	Trip Point Voltages (V) (Typ.)	Operating Current (µA) (min./max.)
PIC16F87XA	4.00	—/200 (1)
PIC18F1320	2.72, 4.22, 4.54	19/45 (1)
MCP121	1.90, 2.32, 2.63, 2.93, 3.08, 4.38, 4.63	—/1.75
MCP111	1.90, 2.32, 2.63, 2.90, 2.93, 3.08, 4.38, 4.63	—/1.75 (2)

Note 1: This current added to either device IDD or I_{PD} current.
2: Power-up Timer Active current is 20 µA. This is NOT the typical state.

FIGURE 1: A TYPICAL PICmicro® MICROCONTROLLER SYSTEM WITH ICSP™



A LOOK AT ICSP™ OPERATION

When the application board is assembled, the PICmicro microcontroller can either be blank (unprogrammed) or programmed.

Application boards assembled with blank devices require the ICSP feature. Application boards assembled with programmed devices may or may not require the ICSP feature. This is dependent on whether or not the application board supports firmware upgrades.

Application boards (assembled with programmed devices) that do not support firmware upgrades are not an issue for voltage supervisor devices. This is due to the fact that the MCLR pin does not require an ICSP high voltage (V_{IHH}) to be applied.

Many PICmicro microcontroller applications utilize the ICSP feature of these devices. However, with the ICSP feature, a high voltage (V_{IHH}) is applied to the MCLR pin. Depending on the device used, this maximum voltage on the MCLR pin may be up to 14V. Most devices specify a maximum of 13.5V or below.

ICSP Requirements

The ICSP requirements for the desired PICmicro microcontroller is shown in that device's programming specification document. For voltage supervisors and voltage detectors, one of the most important specifications is the V_{IHH} specification. The V_{IHH} specification states the voltage requirement on the MCLR pin for the device to be in the ICSP mode. The voltage supervisor open-drain output pin typically would be connected to the MCLR pin.

Table 2 shows the minimum and maximum V_{IHH} specifications for the V_{IHH} voltage on the MCLR pin. Table 2 also shows the Microchip programming specification documents (and the document revision) referenced for this information.

There are only a few devices where the ICSP maximum V_{IHH} specification is greater than 13.5V; they are 14.0V devices.

Note:	Please check the most current revision of the programming specification for the desired device for V_{IHH} and other application requirements.

For these devices (with the 14V maximum V_{IHH}), the maximum voltage on the MCLR pin would then be limited by the MCP111 or MCP121 device, which has a maximum of 13.5V. This should NOT be an issue since the minimum V_{IHH} voltage of these devices is 12.0V and 10.0V (when the device VDD is 5.5V). Therefore, a significant ICSP V_{IHH} voltage window remains (1.5V, worst-case).

TABLE 2: V_{IHH} PROGRAMMING SPECIFICATIONS

VIHH on MCLR				
Min.	**Max.**	**Document**	**Rev**	**Comment**
V_{DD} + 4.0V	12.5V	DS30480, DS39622, DS39643	B, C, A	
12.75V	13.25V	DS20072, DS30139, DS30228, DS30257, DS30261, DS30274, DS30278, DS30298, DS30324, DS30492, DS30555, DS30557, DS30603, DS39028, DS39588, DS40036, DS40037, DS40175	B, I, K, A, D, B, B, D, B, A, B, G, B, E, A, A, A, C	
12.5V	13.5V	DS30190, DS30467, DS41207, DS41208, DS41226, DS41227, DS41228, DS41243	H, A, C, B, D, D, D, A	
10.0V	12.0V	DS39624, DS41237, DS41244	A, A, B	
10.0V	13.5V	DS41196	E	
V_{DD} + 3.5V	13.5V	DS30034, DS39025, DS39589, DS39603, DS39607, DS41191	D, F, B, C, B, C	
9.0V	13.25V	DS30499, DS30500, DS39576, DS39583, DS39592, DS39606, DS70102	B, A, B, B, B, C, D	
12.0V	14.0V	DS30262	E	**Note 1**
V_{DD} + 4.5V	14.0V	DS41156, DS41157, DS41163	D, D, D	**Note 1** **Note 1** **Note 1**
11.0V	13.5V	DS40245	B	
10.0V	13.0V	DS41204	D	

Note 1: **MCP1X1** maximum = 13.5V.

V_{IHH} on the $\overline{MCLR}$ pin

Figure 2 shows a typical microcontroller–voltage supervisor system circuit with this in-line resistance (R_S). R_{PU} is the $\overline{MCLR}$ pull-up resistor, R_S is the in-line resistor to the open-drain output of the voltage supervisor or voltage detector. V_{RS} is the voltage into the $\overline{MCLR}$ pin.

It is recommended that the current into the open-drain output (I_{RS}) be limited to 2 mA, even though characterization was done using a 1 kΩ resistor. This was to allow PICmicro MCU devices with the internal pull-up on the $\overline{MCLR}$ pin to also be used, since the minimum pull-up resistance can be calculated to 12.5 kΩ. This ensures the V_{OL} of the voltage supervisor can meet the requirements of the $\overline{MCLR}$ pin V_{IL}.

WHEN USING THE $\overline{MCLR}$'S INTERNAL PULL-UP RESISTOR

Some PICmicro microcontrollers have an internal pull-up resistor option on their $\overline{MCLR}$ pin.

For example, the PIC16F684 has a typical internal 20 kΩ pull-up on the $\overline{MCLR}$ pin. Looking at the specifications, the minimum pull-up resistance can be calculated to 12.5 kΩ, from the maximum current specification. With the in-line 1 kΩ resistance, the minimum PIC16F684 V_{IL} specification (0.2 x V_{DD}) is not a problem (see VDR calculation from Table 4 and VRS calculation from Table 5).

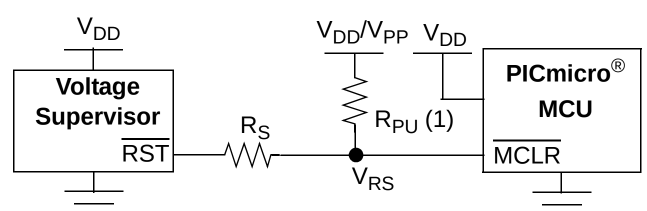
OPEN-DRAIN HIGH VOLTAGE SPECIFICATION

Table 3 shows an example voltage supervisor/voltage detector device data sheet open-drain high voltage (V_{ODH}) specification.

Note:	The device is not specified to constantly maintain the maximum V_{ODH} voltage on the open-drain output pin. This is intended for short ICSP programming cycles.

This specification is specified for a worst-case scenario, where the device V_{DD} is 3V and a V_{PP} of 13.5V. This causes a voltage differential of 10.5V. If the device V_{DD} is 5V, there are less issues since the voltage differential is reduced to 8.5V, decreasing the current into the voltage supervisor open-drain output pin.

FIGURE 2: A TYPICAL PICmicro® MICROCONTROLLER SYSTEM WITH ICSP™ AND AN EXTERNAL VOLTAGE SUPERVISOR



Note 1: Some PICmicro® microcontrollers have a weak pull-up on the $\overline{MCLR}$ pin, so an external pull-up would not be required.

TABLE 3: EXAMPLE DATA SHEET SPECIFICATION

Electrical Specifications: Unless otherwise indicated, all limits are specified for V_{DD} = 1V to 5.5V, R_{PU} = 100 kΩ, T_A = –40°C to +125°C.

Parameters	Sym	Min	Typ	Max	Units	Conditions
Open Drain High Voltage on Output	V_{ODH}	—	—	13.5 (1)	V	V_{DD} = 3.0V, Time voltage > 5.5V applied ≤ 100s, current into pin limited to 2 mA, 25°C operation recommended **Note 1, Note 2**

Note 1: This specification allows this device to be used in PICmicro microcontroller applications that require the ICSP feature (see device-specific programming specifications for voltage requirements). This specification does NOT allow a continuous high voltage to be present on the open-drain output pin (V_{OUT}). The total time that the V_{OUT} pin can be above the maximum device operational voltage (5.5V) is 100s. Current into the V_{OUT} pin should be limited to 2 mA; it is recommended that the device operational temperature be maintained between 0°C to 70°C (25°C preferred). For additional information, please refer to Figure 4.

2: This parameter is established by characterization and not 100% tested.

R_S and R_{PU}

The value of the R_{PU} pull-up resistor and the R_S in-line resistor should be selected to ensure that the voltage supervisor output voltage (V_{OL}) can meet the PICmicro microcontroller $\overline{\text{MCLR}}$ V_{IL} specification.

Figure 3 shows a typical circuit with symbols for each of the components.

Equation 1 shows the equation for the Voltage Divider Ratio (VDR) of the R_S and R_{PU} resistors.

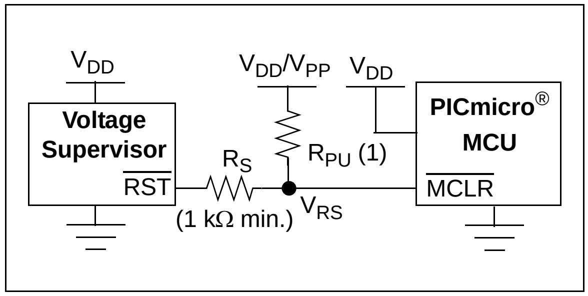
Equation 2 show the equation for calculating the worst case low voltage on the $\overline{\text{MCLR}}$ pin, where V_{OL} is the maximum output low voltage from the MCP1X1 device.

The VRS voltage must not exceed the $\overline{\text{MCLR}}$ VIL specification.

Table 4 shows some values for R_S and the resultant maximum current into the open-drain output pin (I_{RS}). Futhermore, it shows a recommended R_{PU} value for cases when the R_{PU} resistor is external. Given the R_S and the R_{PU}, the VDR is shown.

Table 5 shows values for voltage divider ratios, and how these values relate to the VRS voltage at different system V_{DD} levels.

FIGURE 3: VOLTAGE SUPERVISOR CIRCUIT



EQUATION 1: VOLTAGE DIVIDER RATIO (VDR)

$$VDR = \frac{R_S}{R_S + R_{PU}}$$

EQUATION 2: VRS

$$V_{RS} = ((V_{DD} - V_{OL}) \times VDR) + V_{OL}$$

TABLE 4: R_S AND R_{PU}

R_S (kΩ)	R_{PU} (kΩ)	I_{RS} (1) (mA)	VDR	Comment
1	12.5 (2)	10.5	0.0741	
5.25	63	2	0.0769	Recommended I_{RS}

Note 1: When V_{DD} = 3V and V_{IHH} = 13.5V

2: This in the minimum $\overline{\text{MCLR}}$ pin internal pull-up resistance.

TABLE 5: VDR, V_{RS} CALCULATIONS

VDR	V_{RS}		Comment (1)
	V_{DD} = 3.0V	V_{DD} = 5.5V	
0.0741	0.592	0.778V	
0.0769	0.6	0.792	Max VDR for V_{DD} = 3.0V
0.1219	—	1.022	Max VDR for V_{DD} = 4.5V ($\overline{\text{MCLR}}$ VIL = 0.9V)
0.1304	—	1.065	Max VDR for V_{DD} = 5.0V ($\overline{\text{MCLR}}$ VIL = 1.0V)
0.1373	—	1.1V	Max V_{RS} for V_{DD} = 5.5V

Note 1: When $\overline{\text{MCLR}}$ VIL = 0.2 V_{DD}

MCP111 and MCP121 Open-Drain High Voltage Characterization

Figure 4 shows the characterization curve of the current into the voltage supervisor devices (MCP111 and MCP121) as the voltage on the open-drain pin is increased. This characterization was done with a 1 kΩ in-line resistance to limit current into the device. This low current will not damage the structure of the output pin. We suggest that the lower the voltage on the output pin, the better. However, there should not be any issues with a limited time duration (100 sec.) at 13.5V (through the 1 kΩ resistor).

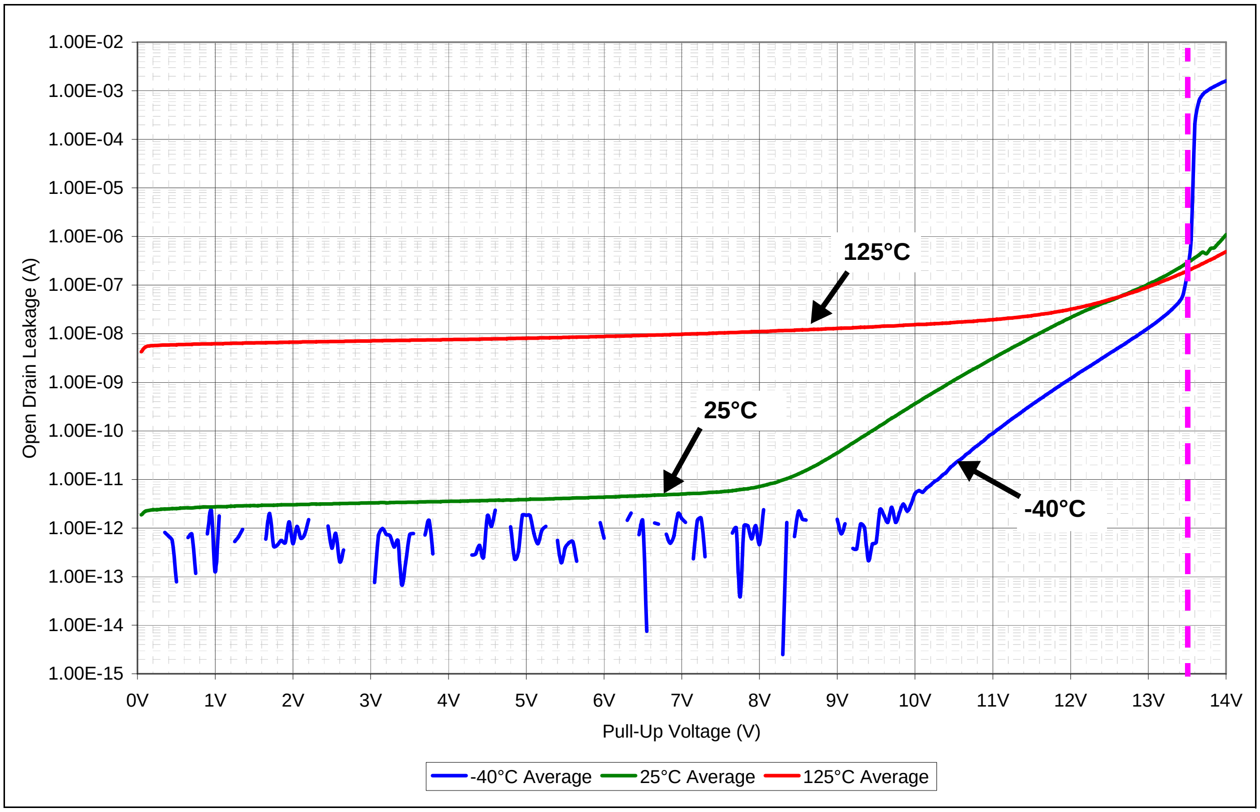
The majority of programming specifications for the PICmicro microcontrollers recommend a programming temperature of 25°C. Only at low temperature, and voltages above 13.5V, does this pin current start to rise, leveling off at the mA range.

Although this curve shows that the device can support operation at -40°C at 13.5V, it is recommended that the device be operated as close as possible to 25°C. Also, the lower the voltage, the better, since this adds to the "safety margin" for your system.

Based on the design of the device and the characterization data, here are the recommended operating rules:

1. Minimize the voltage differential between the device V_{DD} and the V_{PP} voltage.
   - a V_{DD} = 5.0V and V_{PP} = 13.0V (8V delta) is much better than a V_{DD} = 3.0V and V_{PP} = 13.5V (10.5V delta)
2. Maximize size of current limiting resistor (R_S).
   - an R_S = 10 kΩ is better than an R_S = 1 kΩ.
3. Apply the high voltage at warmer temperatures.
4. Limit time at high voltage.

FIGURE 4: EXAMPLE VOLTAGE SUPERVISOR OUTPUT PIN CURRENT VS. VOLTAGE GRAPH



OTHER MICROCHIP VOLTAGE SUPERVISOR DEVICES

Other Microchip voltage supervisor devices with an open-drain output have not yet been evaluated for their ability to support the ICSP V_{IHH} voltage requirements on their open-drain output pin.

Devices that have a push-pull output (or those open-drain devices that have an internal pull-up resistor) are not suitable due to the high currents that can occur when the internal semiconductor devices become forward-biased. These high currents can lead to the device being damaged after programming (immediate or long-term reliability).

Figure 5 shows an alternate circuit that can be used with any voltage supervisor device. There are two drawbacks for these types of circuit implementations. First is the additional cost of the Schottky diode (with a low voltage drop, ~ 0.3V). Second is the additional current consumption.

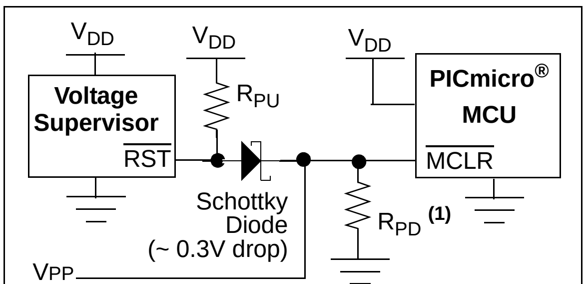
The operation of the circuit is as follows:

When the $\overline{RST}$ pin is not driven low, the Schottky diode will "block" the VPP voltage from the $\overline{RST}$ pin (so the voltage on the $\overline{RST}$ pin does not violate the device specifications). When the V_{PP} signal is disconnected (open), the R_{PU} will pull up the voltage on the $\overline{MCLR}$ pin to above it's V_{IH} level.

When the $\overline{RST}$ pin is driven low (and the VPP signal is disconnected), the Schottky diode will block the $\overline{RST}$ pin's V_{OL} from the $\overline{MCLR}$ pin. The $\overline{MCLR}$ pin will essentially be floating. So something needs to ensure that the voltage level on the $\overline{MCLR}$ pin does not exceed the $\overline{MCLR}$ pin's V_{IL} specification. This could be attributed to either the leakage characteristics of the Schottky diode, or an external pull-down resistor.

The selection of the R_{PU} and R_{PD} resistor values should ensure that both the $\overline{MCLR}$ V_{IH} and V_{IL} specifications can be met (R_{PD} ~= 10* R_{PU}).

FIGURE 5: ALTERNATE VOLTAGE SUPERVISOR CIRCUIT



Note 1: This pull-down resistor may or may not be required. That depends on the leakage characteristics of the Schottky diode. If required, the R_{PD} value must be selected to ensure the $\overline{MCLR}$ pin V_{IH} and V_{IL} specifications are met (R_{PD} ~= 10*R_{PU}).

OTHER MANUFACTURER'S DEVICES

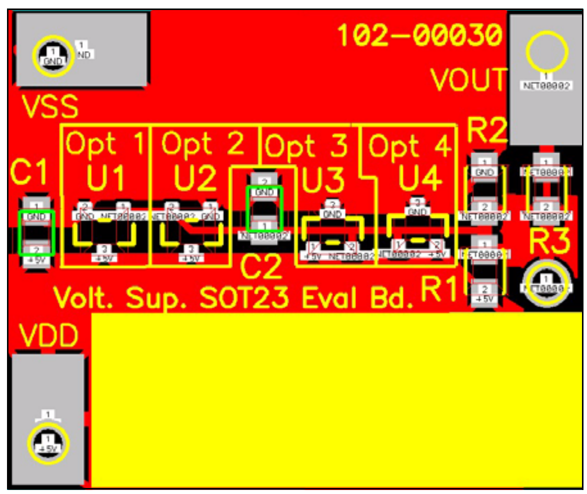
After inspecting many other competitor's voltage supervisor/voltage detector data sheets, it did not appear that their open-drain outputs are specified to support the V_{IHH} voltage requirements of the PICmicro microcontroller ICSP feature.

When using a voltage supervisor or voltage detector, ensure that the device's specifications meet the ICSP operation conditions of your application. Failure to do so may result in damage to the voltage supervisor or voltage detector (immediate or long-term reliability).

QUICK EVALUATIONS

Microchip offers a SOT-23-3 evaluation board (Part Number: VSUPEV). This board can be purchased via the Microchip web site and allows the voltage supervisor and in-line resistor to be installed and then connected to the PICmicro MCU circuit. When installing the in-line resistor (R3, see Figure 6), be sure to cut the default trace that shorts out this component. Additional information can be found in the *"Voltage Supervisor SOT23 Evaluation Board User's Guide"*, DS51510.

FIGURE 6: SOT-23-3 EVALUATION BOARD – VSUPEV



SUMMARY

This technical brief has shown how Microchip's MCP111 or MCP121 can be interfaced to devices that require a temporary high voltage on one of their pins. This is particularly relevant to applications using the In-Circuit Serial Programming (ICSP) feature with one of Microchip Technology's PICmicro microcontrollers.

Not all applications require the use of an external voltage supervisor solution. But if they do, ensure that a device is selected that is specified to allow the high voltage required by ICSP.

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.

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

Microchip received ISO/TS-16949:2002 quality system certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona and Mountain View, California in October 2003. The Company's quality system processes and procedures are for its PICmicro® 8-bit MCUs, 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

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
Alpharetta, GA
Tel: 770-640-0034
Fax: 770-640-0307

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
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

San Jose
Mountain View, CA
Tel: 650-215-1444
Fax: 650-961-0286

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

ASIA/PACIFIC

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: 86-28-8676-6200
Fax: 86-28-8676-6599

China - Fuzhou
Tel: 86-591-8750-3506
Fax: 86-591-8750-3521

China - Hong Kong SAR
Tel: 852-2401-1200
Fax: 852-2401-3431

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 - Shunde
Tel: 86-757-2839-5507
Fax: 86-757-2839-5571

China - Qingdao
Tel: 86-532-502-7355
Fax: 86-532-502-7205

ASIA/PACIFIC

India - Bangalore
Tel: 91-80-2229-0061
Fax: 91-80-2229-0062

India - New Delhi
Tel: 91-11-5160-8631
Fax: 91-11-5160-8632

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

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

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

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

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

Taiwan - Hsinchu
Tel: 886-3-572-9526
Fax: 886-3-572-6459

EUROPE

Austria - Weis
Tel: 43-7242-2244-399
Fax: 43-7242-2244-393

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

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

Germany - Ismaning
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

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

03/01/05