

Emulating High-Endurance Data EEPROM for PIC10 and PIC12

*Author: Willem J. Smit
Microchip Technology Inc.*

INTRODUCTION

Given Microchip's growing portfolio of microcontrollers, it is self-evident that no two families of microcontrollers are exactly similar in features and specifications. One such feature that is available on select microcontrollers is the ability for users to internally store user data in a nonvolatile manner, such as on internal EEPROM. In order to provide a low-cost solution, some devices exclude internal EEPROM but have the capability to read and write Flash Program Memory (FPM) using self-read/write. This feature allows users to write and read user data to and from any unused portion of FPM in a nonvolatile manner.

It is important to note a few things about FPM to better understand the structures set in place for erase and programming operations.

First, FPM is arranged in rows that consist of a fixed number of 14-bit program memory words. For example, on the PIC10F322, the FPM is broken down into rows consisting of sixteen 14-bit words, which are accessible by an address of XX0h to XXFh.

Second, the FPM can only be erased by a minimum of a row at a time. When erased, the contents are set to all '1's. When writing, only '0's can be written.

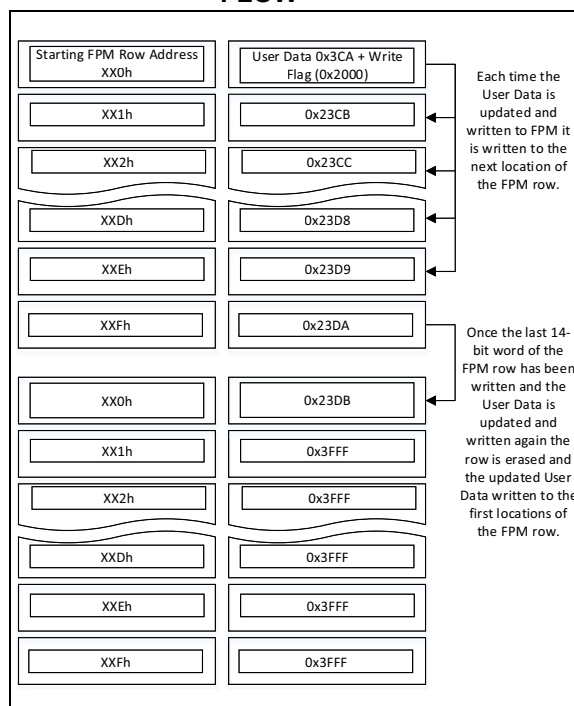
Third, again using the PIC10F322 as an example, Microchip specifies the minimum program Flash memory cell endurance to be 10K erase and write cycles from -40°C to +85°C. Considering each memory cell as 1-bit in the 14-bit FPM word, this application note introduces software library routines, which increase the minimum program FPM cell endurance to a theoretical minimum 160K erase and write cycles, when storing user data in the FPM in rolling-page format (10K FPM cell endurance x 16 rows = 160K FPM cell endurance). Thus, the FPM is brought into the high-endurance range, which is specified as a minimum of 100K erase and write cycles.

OVERVIEW

The supplied software library makes use of a minimum of one row of FPM to store one 12-bit user data value, which is continually updated, requiring a minimum endurance greater than 10K erase and write cycles.

The increased endurance is achieved by incrementing the location of the 12-bit user data by one FPM address location in the row each time a write takes place. Once all sixteen locations within the row have been filled and a new value written, the row is erased and the new value is written to the first 14-bit word location of the same row.

**FIGURE 1: ONE ROW OF FPM
HIGH-ENDURANCE WRITE
FLOW**



IMPLEMENTATION DETAILS

The software library consists of one main function routine:

```
uint16_t ReadWrite_HEFlash(uint8_t
    rw, uint16_t data, uint8_t rowstar-
    taddr)
```

The arguments for the above function are the following:

- “rw” designates if the function will perform a read of the FPM or a write to the FPM
- “rw” = 1 = Write to FPM
- “rw” = 0 = Read of FPM
- “data” is the 12-bit value written by the user
- “rowstartaddr” is the starting address of the FPM row being used. A row’s starting address can be determined by looking at the first nibble starting with the LSB of the FPM addresses. The beginning row address always starting with the first nibble equal to 0x0. For example, 0xE0 to 0xEF is one row, with 0xE0 being the row start address.

This function writes and reads 12 bits of user data to and from the FPM. A write is done by writing the next available/open FPM location (bits <11:0>). Bits <13:12> are used as flags, indicating if a FPM row location has been written or not, as follows:

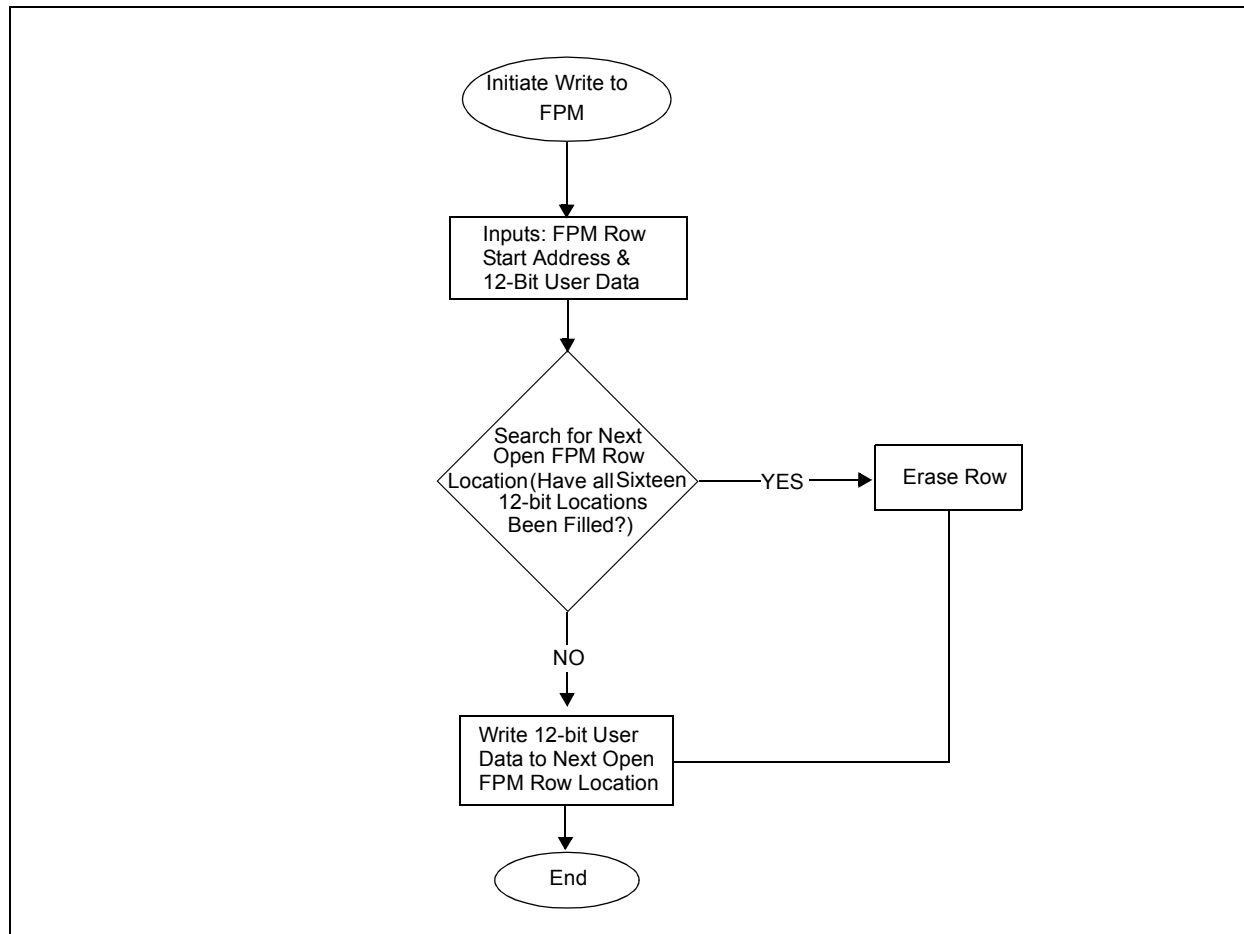
- Bits <13:12> = 0b11 = Open
- Bits <13:12> = 0b10 = Written (Closed)

Write example:

```
ReadWrite_HEFlash(1, 0x3CA, 0xF0)
```

The above function will write a value of 0x3CA to the next available/open FPM location within the row, which has a starting address of 0xF0 (see [Figure 1](#) and [Figure 2](#)).

FIGURE 2: HIGH-ENDURANCE FLASH WRITE FLOW CHART



Read example:

```
• buffer = ReadWrite_HEFlash(0, 0x000, 0xF0)
```

The above function will return the last 12-bits value of user data written to the selected FPM row and place the value in “buffer”. In the case of a read, the “data” field is a “don’t care” and will be ignored. If a read is performed and no user data has been written to the FPM, a value of 0xFFFF will be returned (see [Figure 3](#) and [Figure 4](#)).

FIGURE 3: ONE ROW OF FPM HIGH-ENDURANCE READ FLOW

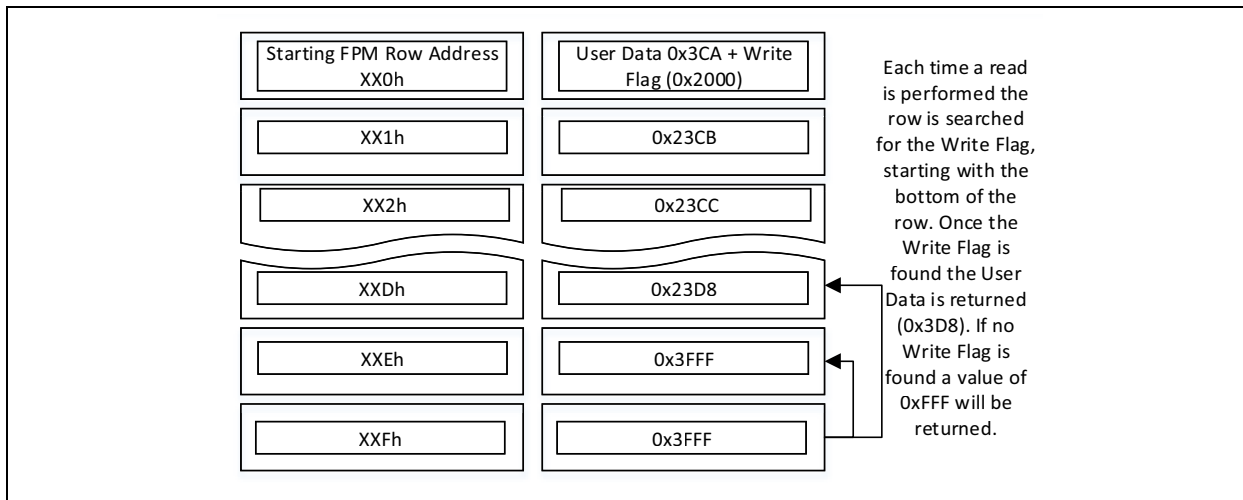
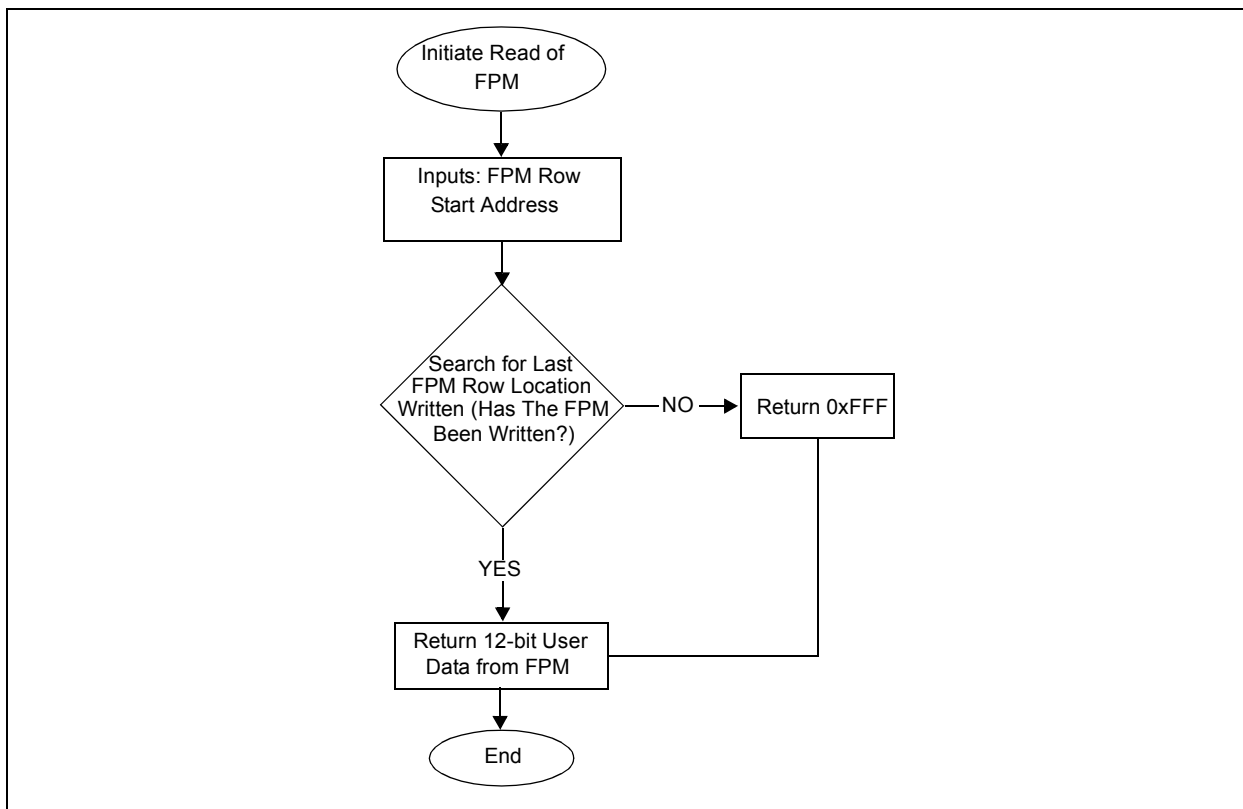


FIGURE 4: HIGH-ENDURANCE FLASH READ FLOW CHART



Selecting a Row

When selecting a row or rows to write, a few things should be noted:

1. Never attempt to write to a section of FPM occupied by the firmware itself. In addition, areas where the Reset vector and Interrupt vector reside should always be avoided; these are usually located between FPM address 0x0000 and 0x0004.
2. The best way to select an applicable row or rows is to look at the program memory map in MPLAB® X after doing a compile.

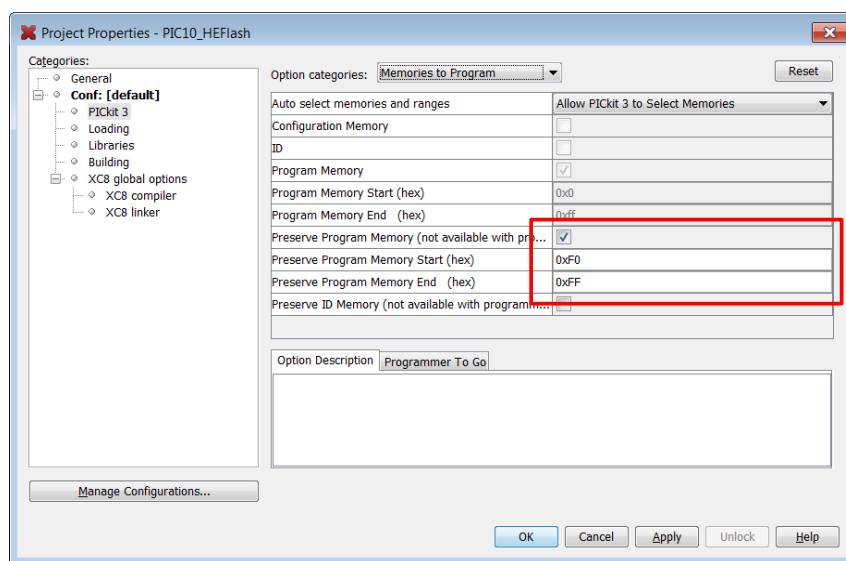
Preserving FPM During Programming Cycles

During program cycles, via MPLAB X by default, the whole FPM on the device is erased. If a user requires user data already written to FPM to be preserved during the programming cycle in MPLAB X, this can be done in the following way:

- Open Project Properties
- Select the programmer being used in the left hand column (e.g., PICKit™ 3, REAL ICE™, ICD3)
- Check the Preserve Program Memory box
- Enter the range of the rows selected for High-Endurance Flash Emulation in the Preserve Program Memory Start and Stop box

Figure 5 shows how to preserve FPM location 0x0F through 0xFF.

FIGURE 5: MPLAB X FPM PRESERVATION



Software License Agreement

The software supplied herewith by Microchip Technology Incorporated (the "Company") is intended and supplied to you, the Company's customer, for use solely and exclusively with products manufactured by the Company.

The software is owned by the Company and/or its supplier, and is protected under applicable copyright laws. All rights are reserved. Any use in violation of the foregoing restrictions may subject the user to criminal sanctions under applicable laws, as well as to civil liability for the breach of the terms and conditions of this license.

THIS SOFTWARE IS PROVIDED IN AN "AS IS" CONDITION. NO WARRANTIES, WHETHER EXPRESS, IMPLIED OR STATUTORY, INCLUDING, BUT NOT LIMITED TO, IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE APPLY TO THIS SOFTWARE. THE COMPANY SHALL NOT, IN ANY CIRCUMSTANCES, BE LIABLE FOR SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES, FOR ANY REASON WHATSOEVER.

EXAMPLE 1: PIC10_PIC12_EHEDEEPROM.C (EMULATING HIGH ENDURANCE DATA EPPROM)

```
uint16_t ReadWrite_HEFlash(uint8_t rw,
uint16_t data, uint8_t rowstartaddr) {
    uint8_t addr;
    Save_INTERRUPT();
    if (rw == 1) {
        addr = rowstartaddr;
    } else {
        addr = (rowstartaddr + 0xF);
    }
    uint8_t cnt;
    //CHECK FOR NEXT AVAILABLE WORD LOCATION
    for (cnt = 0x10; cnt != 0x0; cnt--) {
        Read_FLASH(addr); //Read FLASH
        if (rw == 1) { //SEARCH FOR NEXT OPEN LOCATION
            if (PMDATH == 0x3F) { //IF NEXT ROW IS AVAILABLE
                PMDAT = data; //PLACE USER DATA IN PMDAT TO BE WRITTEN TO FLASH
                asm("bsf PMDATH, 5"); //SET FPM FREE FLAG (FPM LOCATION HAS BEEN WRITTEN)
                asm("bcf PMDATH, 4");
                Write_FLASH(); //Write TO FLASH
                break;
            }
            addr++;
            //CHECK IF THE ROW HAS EXPIRED
            if (cnt <= 0x1) {
                //THE ROW HAS EXPIRED IT WILL NOW BE ERASED
                PMCON1 = 0b00010100; //CLEAR PM1CON & FREE = 1, WREN = 1
                PMADR = rowstartaddr;
                Unlock_FLASH();
                //Write USER DATA
                PMDAT = data; //PLACE USER DATA IN PMDAT TO BE WRITTEN TO FLASH
                asm("bsf PMDATH, 5"); //SET FPM FREE FLAG (FPM LOCATION HAS BEEN WRITTEN)
                asm("bcf PMDATH, 4");
                Write_FLASH(); //Write TO FLASH
            }
        } else { //SEARCH FOR LAST WRITTEN LOCATION
            if ((PMDATH & 0x20) && (PMDATH != 0x3F)) { //CHECK FPM FREE FLAG
                data = (PMDAT & 0xFFFF); //RETURN DATA FROM LAST WRITTEN LOCATION
                break;
            }
        }
    }
}
```

PIC10_PIC12_EHEDEEPROM.C (EMULATING HIGH ENDURANCE DATA EPPROM) (CONTINUED)

```

    }
    addr--;
    }
    INTCON = SaveInt;
    }
    return data ;
    }

void Save_INTERRUPT(void) {
    SaveInt = INTCON; //save interrupt status

    GIE = 0; //Disable ints so required sequences will execute properly
}

void Read_FLASH(uint8_t address) {
    PMADR = address;
    PMCON1 = 0b00000001; //RD = 1 Read PROGRAM FLASH
    while (RD);
}

void Unlock_FLASH(void) {
    PMCON2 = 0x55; //FLASH Write/ERASE Unlock SEQUENCE
    PMCON2 = 0xAA;
    WR = 1;
    while (WR);
    WREN = 0; //INHIBITS PROGRAMMING AND ERASING OF PROGRAM FLASH
}

void Write_FLASH(void) {
    //PMCON1 = 0b00100100; //LOAD PROGRAM MEMORY Write LATCHES
    //Unlock_FLASH();
    PMCON1 = 0b00000100; //Write PROGRAM Write LATCHES TO PROGRAM MEMORY
    Unlock_FLASH();
}

```

Interrupts

Special attention should be paid if interrupts are used in the application. When interrupts are being used in the main user code, "save_INTERRUPT();" and "INTCON = SaveInt;" should be on uncommented in LPC_HEFlash.C.

This will cause the device to disable all interrupts during read and write high-endurance FPM cycles, as well as saving the state of the INTCON register before a read or write cycle and restoring it afterwards. The interrupts are disabled to avoid an interrupt occurring during a read or write cycle and resulting in FPM data corruption.

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, FlashFlex, KEELOQ, KEELOQ logo, MPLAB, PIC, PICmicro, PICSTART, PIC³² logo, rPIC, SST, SST Logo, SuperFlash 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, MTP, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

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

Analog-for-the-Digital Age, Application Maestro, BodyCom, chipKIT, chipKIT logo, CodeGuard, dsPICDEM, dsPICDEM.net, dsPICworks, dsSPEAK, ECAN, ECONOMONITOR, FanSense, HI-TIDE, In-Circuit Serial Programming, ICSP, Mindi, MiWi, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, mTouch, Omniclient Code Generation, PICC, PICC-18, PICDEM, PICDEM.net, PICkit, PICTail, REAL ICE, rLAB, Select Mode, SQL, Serial Quad I/O, Total Endurance, TSHARC, UniWinDriver, WiperLock, ZENA and Z-Scale 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.

GestIC and ULPP are registered trademarks 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.

© 2014, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

 Printed on recycled paper.

ISBN: 978-1-63276-188-0

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

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

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

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

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

New York, NY
Tel: 631-435-6000

San Jose, CA
Tel: 408-735-9110

Canada - Toronto
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: 852-2943-5100
Fax: 852-2401-3431

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

China - Beijing
Tel: 86-10-8569-7000
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 - Hangzhou
Tel: 86-571-8792-8115
Fax: 86-571-8792-8116

China - Hong Kong SAR
Tel: 852-2943-5100
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: 86-755-8864-2200
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: 91-20-3019-1500

Japan - Osaka
Tel: 81-6-6152-7160
Fax: 81-6-6152-9310

Japan - Tokyo
Tel: 81-3-6880-3770
Fax: 81-3-6880-3771

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: 886-3-5778-366
Fax: 886-3-5770-955

Taiwan - Kaohsiung
Tel: 886-7-213-7830

Taiwan - Taipei
Tel: 886-2-2508-8600
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 - Dusseldorf
Tel: 49-2129-3766400

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

Germany - Pforzheim
Tel: 49-7231-424750

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

Italy - Venice
Tel: 39-049-7625286

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

Poland - Warsaw
Tel: 48-22-3325737

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

Sweden - Stockholm
Tel: 46-8-5090-4654

UK - Wokingham
Tel: 44-118-921-5800
Fax: 44-118-921-5820