

---

---

**Crystal Selection Guidelines for PL360, ATPL230,  
ATPL250, SAM4CP16B & SAM4CP16C**

---

---

**Introduction**

---

The scope of this application note is to give the design engineer the crystal oscillator requirements for both PLC platforms (G3 & PRIME) and the design guidelines for verifying the clock circuit stage for these Microchip PLC products.

**Features**

---

- Crystal Oscillator Requirements for G3
- Crystal Oscillator Requirements for PRIME
- Guidelines to Verify the Clock Circuit Design
- Clock Circuit Design Example: ATPL250AMB v1 Evaluation Board
- Clock Circuit Design Example: PL360MB v1 Evaluation Board

## Table of Contents

Introduction.....	1
Features.....	1
1. PLC Crystal Oscillator Requirements.....	3
1.1. G3 – ATPL250A & SAM4CP16C.....	3
1.2. PRIME – ATPL230A & SAM4CP16B.....	3
1.3. PL360.....	4
2. Design of the Crystal Oscillator Stage.....	5
2.1. Frequency Tolerance.....	5
2.2. Load Capacitance.....	5
2.3. Drive Level.....	6
3. Clock Circuit Design Example: ATPL250AMB v1 Evaluation Board.....	7
3.1. Crystal Choice.....	7
3.2. Load Capacitance Calculation.....	7
3.3. Series Resistor Calculation.....	8
4. Clock Circuit Design Example: PL360MB v1 Evaluation Board.....	10
4.1. Crystal Choice.....	10
4.2. Load Capacitance Calculation.....	10
4.3. Series Resistor Calculation.....	10
5. Revision History.....	12
5.1. Rev A - 11/2014.....	12
5.2. Rev B - 11/2014.....	12
5.3. Rev C - 05/2015.....	12
5.4. Microchip Rev A - 06/2018.....	12
The Microchip Web Site.....	13
Customer Change Notification Service.....	13
Customer Support.....	13
Microchip Devices Code Protection Feature.....	13
Legal Notice.....	14
Trademarks.....	14
Quality Management System Certified by DNV.....	15
Worldwide Sales and Service.....	16

## 1. PLC Crystal Oscillator Requirements

This section explains the requirements that the designer has to follow in order to choose the correct crystal.

Microchip recommends a crystal oscillator for all the designs; however, if the end user prefers to use another manufacturer, the user will have to fulfill the requirements described in this section and follow all the instructions to design the correct clock circuit described in the section [3. Clock Circuit Design](#)  
Example: [ATPL250AMB v1 Evaluation Board](#).

### 1.1 G3 – ATPL250A & SAM4CP16C

The Microchip G3 PLC devices and crystal oscillator requirements are listed in the next table:

**Table 1-1. Oscillator Requirements for Microchip G3 Devices**

Part Number	Description	Oscillator Requirements	Crystal Recommended by Microchip	
			Manufacturer	Part Number
ATPL250A	G3-PLC modem for Power Line Communications	Frequency: 24MHZ Freq. Tolerance < $\pm 25\text{ppm}$ <sup>(1)</sup>	TXC Corporation	9C-24.000MEEJ-T
SAM4CP16C	Smart Metering platform based on a high performance 32-bit, dual core ARM <sup>®</sup> Cortex-M4 that includes an advanced cryptographic engine and embeds a modem for G3-PLC Power Line Communication		TXC Corporation	7B-24.000MEEQ-T

**Note:**

- As a requirement of G3 specification, the System Clock tolerance, from which transmit frequency and symbol timing are derived, shall be  $\pm 25$  ppm maximum

### 1.2 PRIME – ATPL230A & SAM4CP16B

The Microchip PRIME PLC devices with the crystal oscillator requirements are listed in the next table:

**Table 1-2. Oscillator Requirements for Microchip PRIME Devices**

Part Number	Description	Oscillator Requirements	Crystal Recommended by Microchip	
			Manufacturer	Part Number
ATPL230A	PRIME-PLC modem for Power Line Communications	Frequency: 20MHZ Freq. Tolerance < $\pm 50\text{ppm}$ <sup>(1)</sup>	TXC Corporation	9C-20.000MAAJ-T
SAM4CP16B	Smart Metering platform based on a high performance 32-bit, dual core ARM <sup>®</sup> Cortex-M4 that includes an advanced cryptographic engine and embeds a modem for PRIME-PLC Power Line Communication		Abracon <sup>®</sup> Corporation (LLC)	ABM3C-20.000MHZ-D4Y-T

**Note:**

1. As a requirement of PRIME specification, the System Clock tolerance, from which transmit frequency and symbol timing are derived, shall be  $\pm 50$  ppm maximum

### 1.3 PL360

The next table shows the crystal oscillator requirements for PL360:

**Table 1-3. Oscillator Requirements for PL360 Devices**

Part Number	Description	Oscillator Requirements	Crystal Recommended by Microchip	
			Manufacturer	Part Number
PL360	PLC modem for Power Line Communications	Frequency: 24MHZ Freq. Tolerance < $\pm 10$ ppm <sup>(1)</sup> <sup>(2)</sup>	Epson	TSX-3225 24.0000MF10Z-C3

**Notes:**

1. As a requirement of G3 specification, the System Clock tolerance, from which transmit frequency and symbol timing are derived, shall be  $\pm 25$  ppm maximum
2. As a requirement of PRIME specification, the System Clock tolerance, from which transmit frequency and symbol timing are derived, shall be  $\pm 50$  ppm maximum

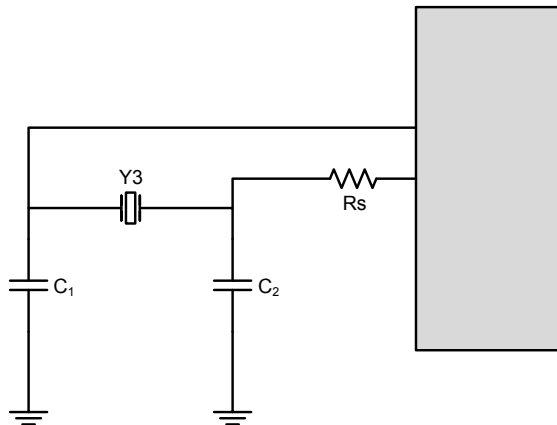


**Important:** For both options (G3 & PRIME) Microchip recommends choosing a crystal with a frequency tolerance below the specification requirement because the total tolerance of a crystal is dependent on production tolerance, temperature stability and age.

## 2. Design of the Crystal Oscillator Stage

The crystal oscillator stage is composed of the following components shown in the [Figure 2-1](#). The design of these components will affect correct crystal operation.

**Figure 2-1. Crystal Oscillator Stage**



Where:

- $C_1$  &  $C_2$  are directly related with the load capacitance. This parameter is specified by the crystal manufacturer and the user has to fulfill this requirement in order to operate at the correct frequency
- $R_S$  is the series resistor. It is very variable and is not usually specified by the manufacturer, so the designer will have to calculate the right value

There are three important parameters to take into account in the oscillator stage design:

### 2.1 Frequency Tolerance

The Frequency Tolerance of a crystal is defined as the initial deviation of the crystal frequency as compared to the absolute at 25°C.

The total tolerance of a crystal is dependent on three factors: production tolerance, temperature stability and age. All of these values are given in [ppm] (parts per million) and can be found in the manufacturer's datasheet.

Therefore, it is important to select a crystal with characteristics to allow achievement of system performance within the limits of the G3 or PRIME specifications.

### 2.2 Load Capacitance

Crystal manufacturers specify a load capacitance ( $C_L$ ) to set the crystal's intended operating frequency. If the designer does not choose the correct load capacitance, the crystal will operate at the wrong frequency.

The design engineer has to select the values of the capacitors  $C_1$  and  $C_2$  (see [Figure 2-1](#)) to match the crystal  $C_L$  using the below equation:

$$C_L = \frac{C_1 \cdot C_2}{C_1 + C_2} + C_S$$

Where:

- $C_L$  is the circuit capacitance that the crystal expects to see to operate at the desired frequency
- $C_1$  and  $C_2$  are the capacitors that the designer has to choose
- $C_S$  is composed by the parasitic capacitance in the PCB and it could be reduced by keeping traces as short as possible

### 2.3 Drive Level

The drive level indicates power consumption by crystal unit while oscillation circuit works. Excessive drive level might cause unexpected change of frequency, crystal damage or shorter device lifetime.

The maximum drive level is specified by the crystal manufacturer. As the meter will have to operate during long periods of time, the design engineer has to take into account this parameter and choose the correct components that ensure the meter operation lifetime.

The drive level is given by the following formula:

$$Drive\ Level = ESR \times I^2$$

Where:

- ESR is the equivalent series resistor (specified by the crystal manufacturer)
- $I$  is the current flowing through the crystal in RMS. If waveform is sine wave or similar, effective value is calculated by  $I_{p-p}/2\sqrt{2}$

In order to keep the drive level value inside the manufacturer range, it is required to limit the current that flows through the crystal. The total power dissipated by the crystal is proportional to  $R_S$  (see [Figure 2-1](#)), so its value can be modified to obtain a drive level that complies with the requirements.

As the value of  $R_S$  also relates to the safety factor, there is a maximum value of  $R_S$  that maintains a good safety factor and at the same time keeps the drive level below the crystal manufacturer maximum specifications.

### 3. Clock Circuit Design Example: ATPL250AMB v1 Evaluation Board

**Info:** The calculations shown in this section are valid for the ATPL250AMB v1 evaluation board. For other hardware designs, the component values need to be calculated again using the specific characteristics of the new design.

#### 3.1 Crystal Choice

For the evaluation board of the ATPL250A, the selected crystal needs to fulfill the G3 oscillator requirements explained previously (operation frequency of 24MHz and frequency tolerance lower than 25ppm).

The part number selected is the Microchip recommendation and the main features are in the next table:

**Table 3-1. Crystal Oscillator Selected for the ATPL250AMB\_v1 Evaluation Board**

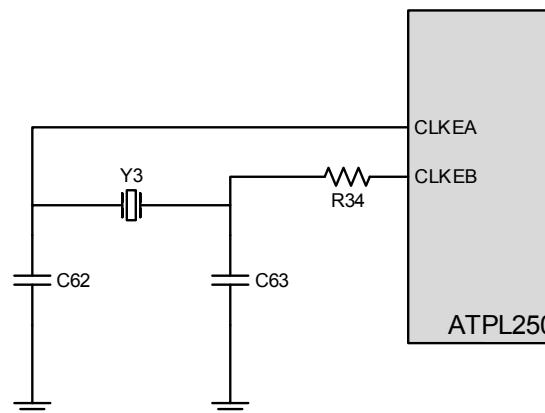
Part Number	Manufacturer	Frequency	Load Capacitance	Frequency Tolerance	ESR	Drive Level
9C-24.000MEEJ-T	<a href="#">TXC Corporation</a>	24MHz	18pF	± 10ppm	30Ω	1~500μW

It is important to remark that this crystal has a frequency tolerance of ± 10ppm, which is lower than the maximum of ± 25ppm required by the G3 specification.

#### 3.2 Load Capacitance Calculation

The load capacitance of the crystal selected is 18pF and the circuit designed for the clock stage is in the next figure:

**Figure 3-1. Clock Circuit in the ATPL250AMB\_v1 Evaluation Board**



This stage is composed by the crystal, two capacitors and a series resistor.

In order to choose the capacitors, we will define both of them with the same value. If we apply this design rule in the Load Capacitance formula explained in the section [2.2 Load Capacitance](#), we have the following:

$$C_{62} = C_{63} (\text{Design condition})$$

$$C_L = \frac{C_{62} \cdot C_{63}}{C_{62} + C_{63}} + C_S = \frac{C_{62}^2}{2C_{62}} + C_S = \frac{C_{62}}{2} + C_S$$

So, taking into account that the Load Capacitance defined by the manufacturer is 18pF, we have:

$$C_L = \frac{C_{62}}{2} + C_S = 18pF \quad \text{where} \quad C_{62} = C_{63}(\text{Design condition})$$

The process to follow now is really simple:

- Calculate the  $C_S$ : In order to make this calculation, we have used a PCB PC software that allows estimation of the capacitance of the traces in the ATPL250AMB\_v1 clock circuit. In addition we have added the parasite capacitance of the ATPL250 pads:

$$C_S = C_{traces} + 2.C_{pads} = 2,4pF(\text{estimated}) + 2,0,8pF = 4pF$$

- With this  $C_S$  value, the resultant capacitor value is:

$$C_L = \frac{C_{62}}{2} + C_S = 18pF \Leftrightarrow C_{62} = C_{63} = 2.(C_L - C_S) = 2.(18pF - 4pF) = 28pF$$

- As the  $C_{traces}$  is an estimated value, the value obtained for  $C_{62}$  &  $C_{63}$  is also estimated. In order to tune this capacitance value and obtain the more accurate frequency, it is necessary to test several capacitance values near the result obtained. With each value tested, it is necessary to measure the crystal frequency in order to obtain the most accurate result possible.



**Tip:** Because the measurement in the crystal terminals is not accurate if the used probe has a parasite capacitance higher than 10pF, it is possible to measure the frequency in the CLKOUT pin of the ATPL2x0A or SAM4CP16x devices in order to avoid measurement errors. Note that in the CLKOUT pin, the frequency will be half of the crystal frequency.

- Once we have tuned the capacitance value obtaining the more accurate frequency fulfilling the G3 requirement of less than  $\pm 25ppm$  the values obtained for the capacitors  $C_{62}$  &  $C_{63}$  are:

$$C_{62} = C_{63} = 27pF$$

### 3.3 Series Resistor Calculation

In this case, we will calculate the value for  $R_{34}$  (see [Figure 3-1](#)) in order to fulfill the drive requirements of the crystal selected (1~500 $\mu$ W).

For that, we will calculate the drive level applying the formula defined in the section [2.3 Drive Level](#) using different values of  $R_{34}$  and taking into account that the ESR of the crystal selected is 30 $\Omega$ .

The method used is as follows:

- Choose a resistor value for the first measurement (The first value chosen for this test was 220 $\Omega$ )
- Use a current probe to calculate the current that is flowing through the crystal. The Current probe used in our measurements is the TCP0030A and it was placed between the crystal and  $R_{34}$  with wirewrap
- Use the formula given in the section [2.3 Drive Level](#) to calculate the drive level
- Check if the drive level is below the maximum value allowed by the crystal manufacturer
- If not, increase the value of  $R_{34}$  and repeat all the steps again

Using several values for the resistor  $R_{34}$ , we obtained the following table:

Table 3-2. Drive Level Measurements with Different Values of  $R_{34}$ 

$R_{34}$ Value	ESR	I <sub>rms</sub>	Maximum Drive Level	Drive Level = ESR x I <sub>rms</sub> <sup>2</sup>
220 $\Omega$	30 $\Omega$	4,66 mA	500 $\mu$ W	651,468 $\mu$ W
430 $\Omega$	30 $\Omega$	4,24 mA	500 $\mu$ W	539,328 $\mu$ W
510 $\Omega$	30 $\Omega$	4,17 mA	500 $\mu$ W	521,667 $\mu$ W
620 $\Omega$	30 $\Omega$	4,01 mA	500 $\mu$ W	482,403 $\mu$ W

The final  $R_{34}$  value chosen for the ATPL250AMB reference design according above calculations is as follows:

$$R_{34} = 620\Omega$$

**Note:** The safety factor obtained with that resistor is 13,8667 which is inside the requirements for a consumer application. Taking that into account, it is not necessary to reduce the value of  $R_{34}$  more as we will deteriorate the safety factor value. Now, it is above 10, so it is a very safe value.

## 4. Clock Circuit Design Example: PL360MB v1 Evaluation Board

**Info:** The calculations shown in this section are valid for the PL360MB v1 evaluation board. For other hardware designs, the component values need to be calculated again using the specific characteristics of the new design.

### 4.1 Crystal Choice

The part number selected is the Microchip recommendation and the main features are shown in the next table:

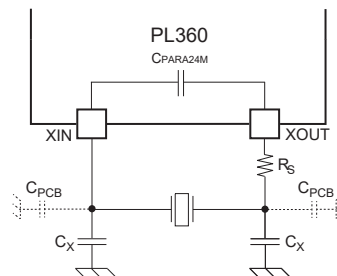
**Table 4-1. Crystal Oscillator Selected for the PL360MB\_v1 Evaluation Board**

Part Number	Manufacturer	Frequency	Load Capacitance	Frequency Tolerance	ESR	Drive Level
TSX-3225 24.0000MF10Z-C3	Epson	24MHz	18pF	± 10ppm	40Ω	1~100μW

### 4.2 Load Capacitance Calculation

The typical PL360 oscillator external circuit is shown in the next figure:

**Figure 4-1. PL360 Crystal Oscillator Circuit**



The value of  $C_X$  is defined in the Crystal Oscillator section of the PL360 datasheet, and is as follows:

$$C_X = 2 \times (C_{XTAL} - C_{PARA24M} - C_{PCB} / 2)$$

Where  $C_{XTAL}$  is the load capacitance of the crystal,  $C_{PARA24M}$  is the internal parasitic impedance of the oscillator, typically 0.7pF and  $C_{PCB}$  is the ground referenced parasitic capacitance of the PCB on XIN and XOUT tracks.

Assuming  $C_{PCB} = 2\text{pF}$  for the PCB traces, the  $C_X$  calculation is:

$$C_X = 2 \times (18 - 0.7 - 2/2) = 33\text{pF}$$

### 4.3 Series Resistor Calculation

The Crystal Oscillator section of the *PL360 datasheet* recommends a maximum Equivalent Series Resistor (ESR) of 100 Ω. Since the selected crystal already has an ESR of 40 Ω, the initial value of  $R_S$  can be 0 Ω.

Under those conditions, using a current probe to calculate the power that is being dissipated in the crystal, we obtained the following results:

Table 4-2. Drive Level Measurements with  $R_S = 0$ 

$R_S$ Value	ESR	Measured $I_{rms}$	Drive Level = $ESR \times I_{rms}^2$	Crystal Maximum
0 $\Omega$	40 $\Omega$	1,3 mA	70 $\mu W$	100 $\mu W$

In conclusion, the measured current and resultant drive level are below the recommended maximum value specified by the crystal manufacturer, so that the value of  $R_S$  can be left equal to 0  $\Omega$ .

## 5. Revision History

**Note:** Revisions 5.1-5.3 (Rev A-C) refer to Atmel document number 43084. With the 06/2018 revision, the document was converted to Microchip format and assigned DS number 00002716, beginning with Rev A.

### 5.1 Rev A - 11/2014

Document	Initial document release, Atmel document number 43084.
----------	--

### 5.2 Rev B - 11/2014

Document	First document revision.
----------	--------------------------

### 5.3 Rev C - 05/2015

<a href="#">2.3 Drive Level</a>	Updated this section.
<a href="#">3.3 Series Resistor Calculation</a>	Updated this section.

### 5.4 Microchip Rev A - 06/2018

Document	<ul style="list-style-type: none"><li>• Converted to Microchip format with new document number DS00002716.</li><li>• Added PL360 requirements and example calculations.</li></ul>
----------	---

---

## 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, BitCloud, chipKIT, chipKIT logo, CryptoMemory, CryptoRF, dsPIC, FlashFlex, flexPWR, Heldo, JukeBlox, KeeLoq, Klear, LANCheck, LINK MD, maXStylus, maXTouch, MediaLB, megaAVR, MOST, MOST logo, MPLAB, OptoLyzer, PIC, picoPower, PICSTART, PIC32 logo, Prochip Designer, QTouch, 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, CodeGuard, CryptoAuthentication, CryptoAutomotive, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, EtherGREEN, In-Circuit Serial Programming, ICSP, INICnet, Inter-Chip Connectivity, JitterBlocker, KlearNet, KlearNet logo, memBrain, Mindi, MiWi, motorBench, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICKit, PICtail, PowerSmart, PureSilicon, QMatrix, 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.

© 2018, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

ISBN: 978-1-5224-3184-8

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