



---

---

## Next-Generation PoE: IEEE<sup>®</sup> 802.3bt White Paper

---

---

*Authors: Eli Ohana  
Shahar Feldman  
Microchip Technology Inc.*

### **FUTURE-PROOFING POWER over ETHERNET (PoE)**

Since the ratification of the first PoE standard in 2003, PoE use has increased dramatically and made headway into new applications. PoE provides huge benefits in relation to ease of installation, saving CAPEX and OPEX costs, and providing a unified and safe power standard for worldwide use.

The main limiting factor affecting PoE use in new applications is the amount of available power. While 15.4W at the power source is sufficient for most IP phones and 802.11a/b/g access points, it is not enough for IP video phones, 802.11n, and pan-tilt-zoom (PTZ) IP cameras. For that reason, the Institute of Electrical and Electronic Engineers, or IEEE, released IEEE 802.3at in 2009, specifying 30W at the PoE source.

Today there is a demand for even higher power to support additional devices connected to the Ethernet network, such as PTZ security cameras, kiosks, POS terminals, thin client, 802.11ac and 802.11ax access points, small cells, and connected LED lighting, all of which can benefit from PoE.

The new IEEE 802.3bt standard increases the maximum PoE power available mainly by utilizing all four pairs of the structured wiring. IEEE 802.3bt extends the power classification information exchanged during initial negotiation to allow meaningful power management capability, enabling support of multiple PoE classes, while also being backward compatible. These enhancements solve the challenge of higher power and more efficient PoE delivery systems.

IEEE 802.3bt Call for Interest (CFI) activity started in early 2013, and the ratification of the standard took place in September 2018. The new standard addresses the existing market needs and is considered a major catalyst to PoE market growth as it facilitates the expansion of PoE use cases by pushing the power limit of Power Sourcing Equipment (PSEs) and Powered Devices (PDs) to 90W and 71.3W respectively.

### **PRE-IEEE 802.3bt PoE STANDARDS**

The IEEE 802.3 Ethernet Working Group has worked on standardizing the delivery of PoE cables since 1999. As one of the leading forces in this activity, Microsemi actively participated and contributed to the first and second PoE CFI in the 802.3 Working Group, and since then, in the standardization of 802.3af-2003, 802.3at-2009, and the 802.3bt Task Force.

The IEEE 802.3af-2003 PoE standard provided up to 15.4W of output power to each device over two pairs of Category 5e (Cat5e) cables. The IEEE 802.3at-2009 standard, also known as PoE+, introduced the "Type 2" PSE/PD capable of supporting 30W output power and 25.5W load power. The latter is mainly an extension of the first standard.

The HDBaseT Alliance standardizes the HDBaseT protocol, which allows extending HDMI links up to 100m over Cat5e or better cables. In 2011, the HDBaseT Alliance created the Power over HDBaseT (PoH) standard that extends the maximum power deliverable to 95W over four pairs.

The following table summarizes the pre-IEEE 802.3bt standards:

**TABLE 1: PRE-IEEE 802.3bt STANDARDS**

Type	Standard	PSE Minimum Input Power	PD Minimum Input Power Ensured	Cable Category	Cable Length	Power Over
Type 1	IEEE® 802.3af	15.4W	12.95W	Cat5e	100m	2 pairs
Type 2	IEEE® 802.3at	30W	25.5W	Cat5e	100m	2 pairs
PoH	PoH	95W	72W-95W <sup>1</sup>	Cat5e/6	100m	4 pairs

**Note 1:** Extended power capability allows PD input power to reach up to 95W if channel length is known.

## WHAT'S NEW IN IEEE 802.3bt

- Introduces Type 3 and Type 4 PSEs/ PDs
- Supporting two PD constructions: Single-Signature PD and Dual-Signature PD
- Working over four pairs
- Additional classes—class 5 to class 8—and improved mutual identification process
- Automatic class functionality
- Extended power capability if channel length is known
- Low standby power support
- 10G-BASE-T with PoE

The following table shows the PoE capabilities on ratification of the IEEE 802.3bt standard.

**TABLE 2: PoE CAPABILITIES ON RATIFICATION**

Type	Standard	PSE Minimum Output Power	PD Minimum Input Power	Cable Category	Cable Length	Power Over
Type 1	IEEE® 802.3af	15.4W	12.95W	Cat5e	100m	2 pairs
Type 2	IEEE® 802.3at	30W	25.5W	Cat5e	100m	2 pairs
Type 3	IEEE® 802.3bt	60W	51W-60W <sup>1</sup>	Cat5e	100m	2 or 4 pairs class 0-4 4 pairs class 5-6
Type 4	IEEE® 802.3bt	90W	71W-90W <sup>1</sup>	Cat5e	100m	4 pairs class 7-8

**Note 1:** Extended power capability allows PD input power to reach up to 60W for Type 3 and up to 90W for Type 4 if channel length is known.

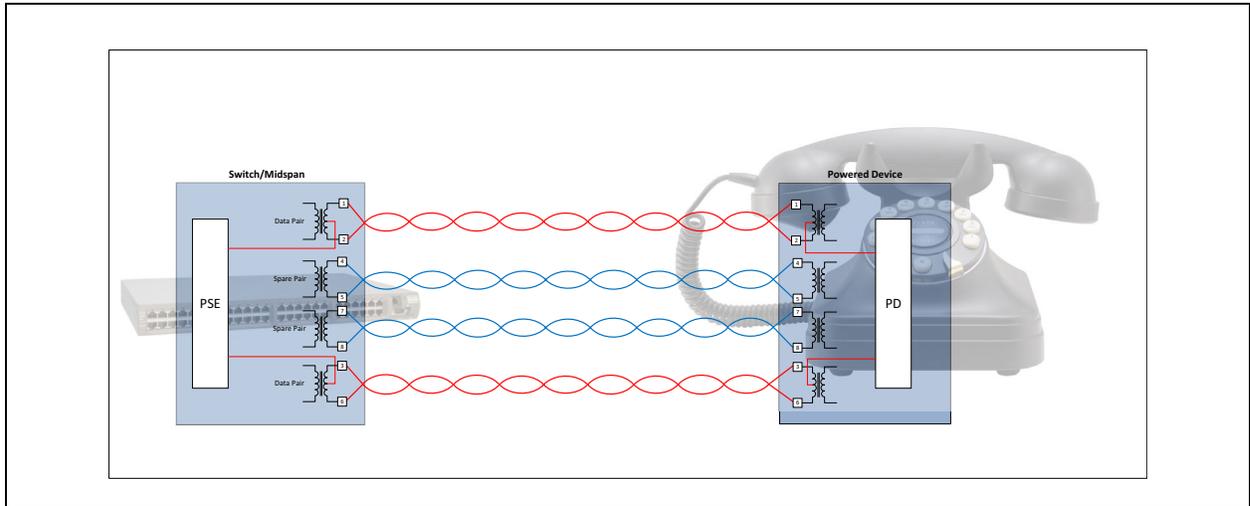
## Maximum Power Per Port

One of the objectives of this standard is to comply with the limited power source and Safety Extra Low Voltage (SELV) requirements as defined in ISO/IEC 60950. However, this compliance means that power cannot exceed 100W per port. Despite this power ceiling, 100W per port is still sufficient for applications previously unsupported under the prior IEEE standards, expanding the potential number of PoE ports deployments.

## Implementing Power Over Four Pairs

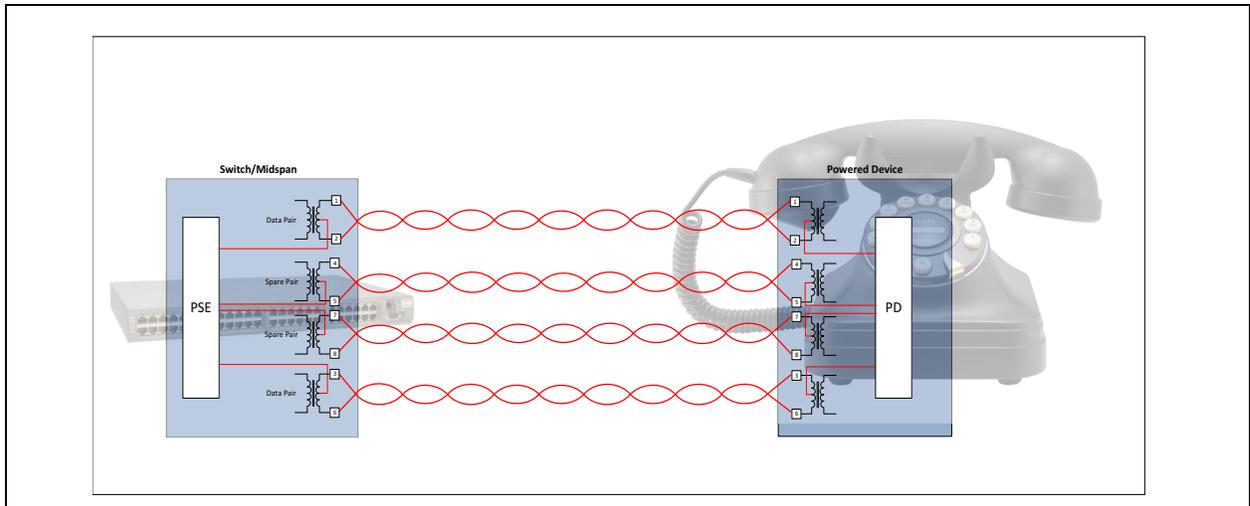
The following illustration (Figure 1) shows a two-pair power connection, with power delivered on the red pair only, while data can be delivered over all four pairs. While the illustration shows power delivery over wires 1, 2, 3, and 6, power can alternatively be delivered over wires 4, 5, 6, and 7 as both options are valid alternatives in the IEEE 802.3 standard.

**FIGURE 1: DATA DELIVERY OVER TWO PAIRS**



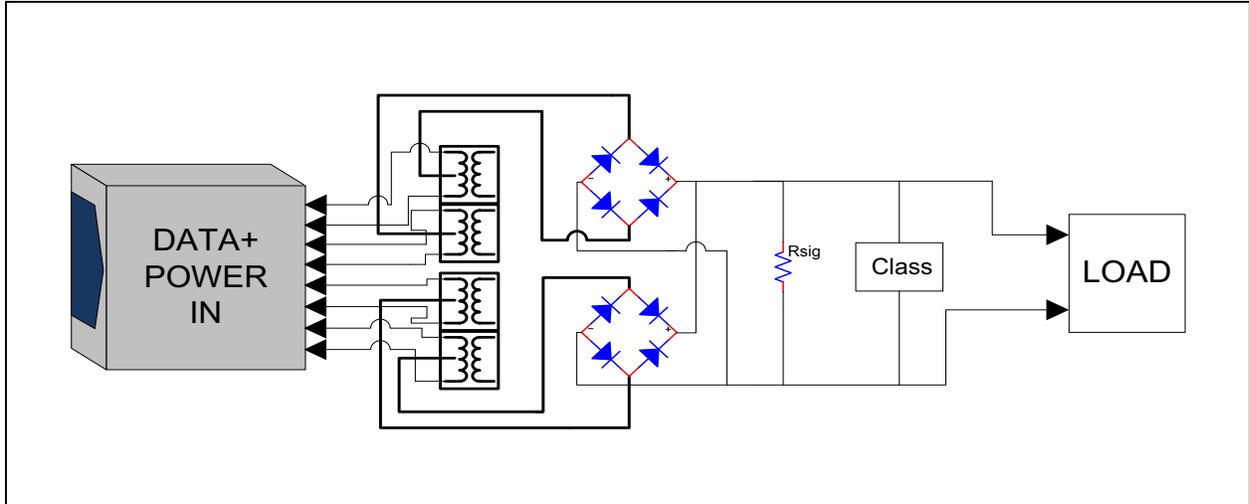
The next illustration (Figure 2) shows a four-pair power connection where power is delivered over all 8 wires.

**FIGURE 2: DATA DELIVERY OVER FOUR PAIRS**

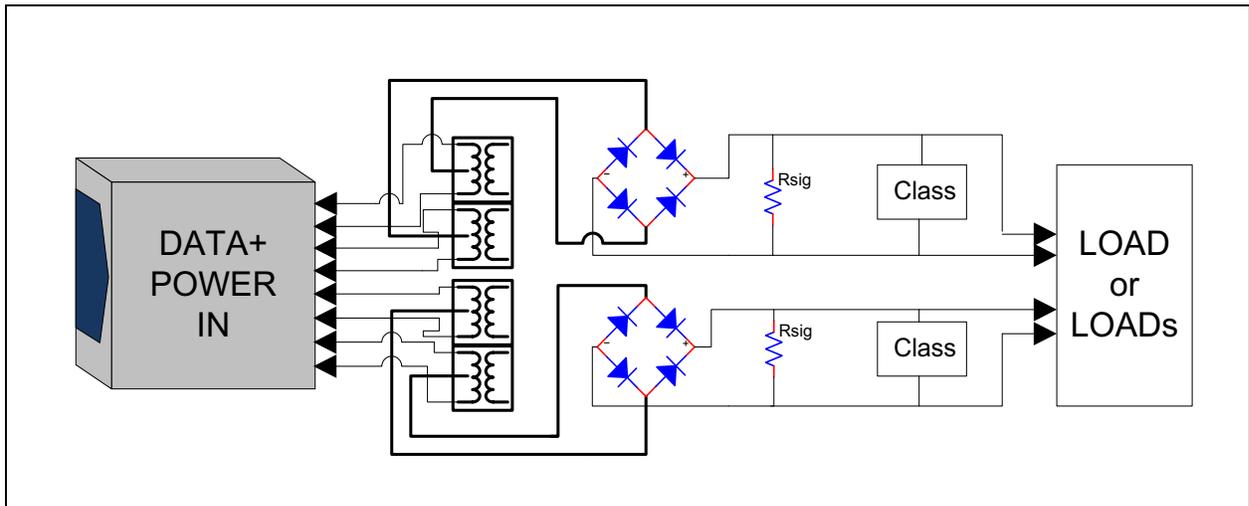


The standard distinguishes between two types of four pair PDs: Single-Signature PD and Dual-Signature PD. General implementation of each alternative is shown in the following illustrations [Figure 3](#) and [Figure 4](#).

**FIGURE 3: SINGLE-SIGNATURE PD**



**FIGURE 4: DUAL-SIGNATURE PD**



An IEEE 802.3bt PSE will identify the PD type and set the power accordingly. According to the application nature, Single-Signature PD or Dual-Signature PD can be implemented. Supporting both architectures is ideal, as it allows more applications to be powered by PoE. Dual-Signature PDs allow supporting two independent loads, each with different power class; e.g. in a surveillance camera built with Dual-Signature PD, one pair may be connected to the camera and the other pair may be connected to the heater.

## Updated Classification Table

**TABLE 3: CLASSIFICATION TABLE**

PD Requested Class	Number of PSE Class Events	Assigned Class	P_Class	P_Class_2P	PD Input Power (Pairset)	PD Input Power (Min)
<b>PSE Connected to a Single-Signature PD</b>						
1	1	1	4W	—	—	3.84W
2	1	2	6.7W	—	—	6.49W
0,3 to 8	1	3	14W	—	—	13W
4 to 8	2 or 3	4	30W	—	—	25.5W
5	4	5	45W	—	—	40W
6 to 8	4	6	60W	—	—	51W
7	5	7	75W	—	—	62W
8	5	8	90W	—	—	71.3W
<b>PSE Connected to a Dual-Signature PD (Classification Per Pairset)</b>						
1	1, 2 or 3	1	—	4W	3.84W	7.68W
2	1, 2 or 3	2	—	6.7W	6.49W	12.98W
3	1, 2 or 3	3	—	14W	13W	26W
4 or 5	1	3	—	14W	14W	26W
4 or 5	2 or 3	4	—	30W	25.5W	51W
5	4	5	—	45W	35.6W	71.2W

### Type 3 and Type 4

As previously mentioned, two additional PSEs and PDs were defined, Type 3 and Type 4. The new types have unique properties that do not exist in Type 1 and Type 2. Additionally, some differences exist between Type 3 and Type 4. The following table summarizes the main features and differences between the four types.

**TABLE 4: SUMMARY OF TYPES 1-4**

Capability	Type 1/Type 2	Type 3	Type 4
V <sub>PSE</sub> (MIN)	44V/50V	50V	52V
PSE Polarity	Flexible	Flexible	Fixed
4P Capable	NO	Class 0-4: Optional Class 5-6 Mandatory	Mandatory
Extended Power	NO	YES	YES
Auto Class	NO	YES	YES
Low MPS	NO	YES	YES
P <sub>PSE</sub> (MAX)	15W/30W	60W	90W-99W
PD Minimum Input Power	12.95W/25.5W	51W <sup>1</sup>	71W <sup>1</sup>
Supported PSE Classes	Class 0-4	Class 1-6	Class 8
Supported PD Classes	Class 0-4	Class 1-6	Class 7-8

**Note 1:** Extended power capability allows PD input power to reach up to 60W for Type 3 and up to 90W for Type 4 if channel length is known.

The new standard introduces an “assigned class” to the PSE system, based on an auto-negotiation between the PSE and PD. The PSE system’s assigned class is determined as the lower power between the PSE available power and the PD requested power. For example, if a PD requests Class 8, but the PSE can support Class 6 only, the assigned class for the overall PSE system will be Class 6.

---

---

## Maintain Power Signature (MPS)

Deploying large numbers of PDs leads to considerable standby power. In the IEEE 802.3af/at standards, minimum power signature of 10 mA was required to keep the port alive. While the IEEE 802.3af/at allows a PD to operate with a minimum on time of 75 ms and a maximum off time of 250 ms duty cycle, it also has to satisfy the AC MPS requirement. This required such PD to show DC resistance below 26.3 K $\Omega$ , which resulted in an overall power consumption of 210 mW when operating with a 54V power supply. This power is multiplied by the number of ports in the system, which results in significant wasted power. For example, in LED lighting applications that use PoE, it is critical to reduce the standby power due to the large number of ports in a typical application. Also, while the light is off, the port should stay on and consume as little as possible. To improve this parameter, the IEEE 802.3bt removes the AC MPS requirement and allows class 5-8 PDs to draw 16 mA with a minimum on time of 7 ms and maximum off time of 310 ms duty cycle which results in less than 20 mW consumed to keep the port alive. This is 10 times better than existing solutions.

## Auto Class

Type 3 and Type 4 PSEs may choose to implement an extension of Physical Layer classification known as auto class. The purpose of auto class is to allow the PSE to determine the actual maximum power drawn by the connected PD and the actual cable length used. PSEs implementing auto class will measure the power consumption of the connected PD throughout a defined period; during this time the PD will consume the maximum power it will ever require. PSEs can set the maximum power output based on the power drawn during auto class plus margin.

## Extended Power

The af and at standards define the minimum power that the PSE should source and the maximum power that the PD should expect to receive. There is some amount of power that is budgeted for dissipation on the cables in the worst-case scenario of 100m cables. Following that approach means that for a PSE sourcing 90W output, the PD should expect only 71W while 19W are budgeted for 100m cable power loss. However, is that always the case? What if the PSE and the PD are in close proximity? If the actual cable power loss is much lower, can we free up this power for the system use? The idea of the extended power feature is to allow the PD (or the PSE) to use the maximum available power based on the cable's true total resistance. Once the PD measures the cable resistance, it can calculate the power that will be lost on the cable and benefit from a higher power consumption. Note that this feature was first introduced and implemented as part of the PoH standard and is now supported as an optional feature for Type 3 and Type 4 PSE and PD.

## Backward Compatibility

Although new features have been added, higher power is supported and some algorithms changed to ensure interoperability. The idea is that the system will work with legacy Type 1 and Type 2 devices. It should work automatically, as long as the PSE is capable (in terms of power) of supporting the PD and both are standard compliant. Should the PD require higher power (IEEE 802.3bt PD) and the PSE cannot support it (IEEE 802.3af/at PSE), the PD will either remain off or it will turn on and consume only the power available from the PSE.

For the latest information, see <http://www.microsemi.com/designsupport/poe-and-poh-technology#resource>.

## IEEE 802.3bt: ENABLING NEW APPLICATIONS

Support for higher power with PoE opens more opportunities. It enables new markets and widens PoE's scope to existing markets that require higher power in applications such as:

- Smart buildings with enterprise IoT (connected LED lighting)
- Safe cities (PTZ cameras)
- Kiosks
- Point of Sale (POS) terminals
- Thin clients
- Access points
- Small cells

---

---

## SUMMARY

The new IEEE 802.3bt standard enables delivery of 90W over four pairs of Cat5e cables and above. Such PoE level is expected to be the maximum level defined, as higher levels may not be safe for the existing cabling and connectors deployed in today's infrastructures. The standard will replace all existing pre-standard solutions that deliver 60W/75W/95W today, such as UPoE or 4PPoE.

Microchip is an innovator and thought leader in PoE technology and a major contributor to 802.3af, 802.3at, 802.3bt IEEE standards. Microchip is committed to providing PoE ICs and PoE Systems that comply with the new IEEE 802.3bt standard.

For more information about PoE Systems, or to find the solution to power your application, see <http://www.microsemi.com/products/poe-systems/poe-systems>.

For more information about PoE PSE ICs, or to find the solution to power your application, see <http://www.microsemi.com/product-directory/power-over-ethernet/850-poe-pse-manager>.

For more information about PoE PD ICs, or to find the solution to power your application, see <http://www.microsemi.com/product-directory/power-over-ethernet/847-poe-pd-front-end-wpwm-controller>.

## REVISION HISTORY

**TABLE 5: REVISION HISTORY**

Date	Section/Figure/Entry	Correction
2016	Document	Microsemi initial document release
March 2019	Document	<ul style="list-style-type: none"><li>• Converted to Microchip format and assigned document number DS00002992A</li><li>• Changes made to reflect Microchip's editing standards</li><li>• Included Microchip back matter</li></ul>

---

---

## THE MICROCHIP WEBSITE

Microchip provides online support via our WWW site at [www.microchip.com](http://www.microchip.com). This website is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the website 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 website at [www.microchip.com](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 website at: <http://microchip.com/support>**

---

**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 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.

© 2019, Microchip Technology Incorporated, All Rights Reserved.

ISBN: 978-1-5224-4270-7

**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.*



# MICROCHIP

## 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](http://www.microchip.com)

#### Atlanta

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

#### Austin, TX

Tel: 512-257-3370

#### Boston

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

#### Chicago

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

#### Dallas

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

#### Detroit

Novi, MI  
Tel: 248-848-4000

#### Houston, TX

Tel: 281-894-5983

#### Indianapolis

Noblesville, IN  
Tel: 317-773-8323  
Fax: 317-773-5453  
Tel: 317-536-2380

#### Los Angeles

Mission Viejo, CA  
Tel: 949-462-9523  
Fax: 949-462-9608  
Tel: 951-273-7800

#### Raleigh, NC

Tel: 919-844-7510

#### New York, NY

Tel: 631-435-6000

#### San Jose, CA

Tel: 408-735-9110  
Tel: 408-436-4270

#### Canada - Toronto

Tel: 905-695-1980  
Fax: 905-695-2078

### ASIA/PACIFIC

**Australia - Sydney**  
Tel: 61-2-9868-6733

**China - Beijing**  
Tel: 86-10-8569-7000

**China - Chengdu**  
Tel: 86-28-8665-5511

**China - Chongqing**  
Tel: 86-23-8980-9588

**China - Dongguan**  
Tel: 86-769-8702-9880

**China - Guangzhou**  
Tel: 86-20-8755-8029

**China - Hangzhou**  
Tel: 86-571-8792-8115

**China - Hong Kong SAR**  
Tel: 852-2943-5100

**China - Nanjing**  
Tel: 86-25-8473-2460

**China - Qingdao**  
Tel: 86-532-8502-7355

**China - Shanghai**  
Tel: 86-21-3326-8000

**China - Shenyang**  
Tel: 86-24-2334-2829

**China - Shenzhen**  
Tel: 86-755-8864-2200

**China - Suzhou**  
Tel: 86-186-6233-1526

**China - Wuhan**  
Tel: 86-27-5980-5300

**China - Xian**  
Tel: 86-29-8833-7252

**China - Xiamen**  
Tel: 86-592-2388138

**China - Zhuhai**  
Tel: 86-756-3210040

### ASIA/PACIFIC

**India - Bangalore**  
Tel: 91-80-3090-4444

**India - New Delhi**  
Tel: 91-11-4160-8631

**India - Pune**  
Tel: 91-20-4121-0141

**Japan - Osaka**  
Tel: 81-6-6152-7160

**Japan - Tokyo**  
Tel: 81-3-6880-3770

**Korea - Daegu**  
Tel: 82-53-744-4301

**Korea - Seoul**  
Tel: 82-2-554-7200

**Malaysia - Kuala Lumpur**  
Tel: 60-3-7651-7906

**Malaysia - Penang**  
Tel: 60-4-227-8870

**Philippines - Manila**  
Tel: 63-2-634-9065

**Singapore**  
Tel: 65-6334-8870

**Taiwan - Hsin Chu**  
Tel: 886-3-577-8366

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

**Taiwan - Taipei**  
Tel: 886-2-2508-8600

**Thailand - Bangkok**  
Tel: 66-2-694-1351

**Vietnam - Ho Chi Minh**  
Tel: 84-28-5448-2100

### EUROPE

**Austria - Wels**  
Tel: 43-7242-2244-39  
Fax: 43-7242-2244-393

**Denmark - Copenhagen**  
Tel: 45-4450-2828  
Fax: 45-4485-2829

**Finland - Espoo**  
Tel: 358-9-4520-820

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

**Germany - Garching**  
Tel: 49-8931-9700

**Germany - Haan**  
Tel: 49-2129-3766400

**Germany - Heilbronn**  
Tel: 49-7131-67-3636

**Germany - Karlsruhe**  
Tel: 49-721-625370

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

**Germany - Rosenheim**  
Tel: 49-8031-354-560

**Israel - Ra'anana**  
Tel: 972-9-744-7705

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

**Italy - Padova**  
Tel: 39-049-7625286

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

**Norway - Trondheim**  
Tel: 47-7288-4388

**Poland - Warsaw**  
Tel: 48-22-3325737

**Romania - Bucharest**  
Tel: 40-21-407-87-50

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

**Sweden - Gothenberg**  
Tel: 46-31-704-60-40

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

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