TB055

PS/2® to USB Mouse Translator

Author: *Reston Condit*
Microchip Technology Inc.

OVERVIEW

This technical brief details the translation of a PS/2 mouse to a USB mouse using the PIC16C745/765. The PIC16C745/765 is Microchip's low speed USB microcontroller. All of the USB descriptors for the mouse translator are listed in the tables in Appendix A. A detailed byte-by-byte description is given for each descriptor to assist USB peripheral designers in understanding USB descriptors. For the basics of USB descriptors, refer to TB054: *An Introduction to USB Descriptors with a Gameport to USB Gamepad Translator Example*.

Note: This technical brief is the second in a series of five technical briefs. This series is meant to familiarize developers with USB. For the best understanding of USB, read the briefs in order: TB054, TB055, TB056, TB057, TB058

IMPLEMENTATION

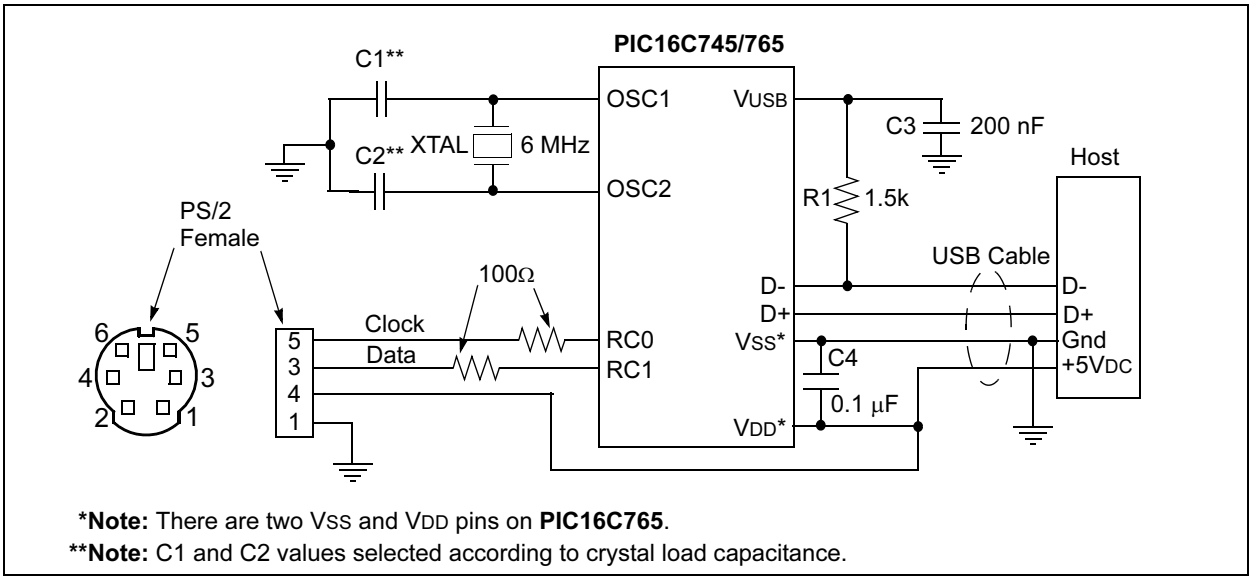
HARDWARE

The PS/2 port is a 6-pin DIN. Only four pins are used:

- Ground
- Power
- Clock
- Data

The power and ground pins are tied directly to VDD and VSS of the microcontroller. The clock and data pins are connected to RC0 and RC1, respectively, via current limiting resistors. The clock is driven by the PS/2 mouse regardless of the direction of the transaction. Figure 1 shows the complete system.

FIGURE 1: PS/2 TO USB MOUSE TRANSLATOR HARDWARE DIAGRAM



***Note:** There are two VSS and VDD pins on **PIC16C765**.

****Note:** C1 and C2 values selected according to crystal load capacitance.

SOFTWARE

PS/2 DATA FORMAT

Before explaining how PS/2 mouse data is translated to USB, it is necessary to touch upon the PS/2 data format. Data is sent via PS/2 one byte at a time regardless of direction, host-to-device or vice-versa. The data has the following form:

- START bit (always low)
- Data byte (Least Significant bit to Most Significant bit)
- PARITY bit (high for an even number of high bits in the data byte and low for an odd number)
- STOP bit (always high)

In the case of host-to-device communication, the STOP bit is immediately followed by an ACK bit (low), which is sent by the device to the host. The bits are read on the falling edge of the clock for device-to-host communication and on the rising edge for host-to-device communication. In the IDLE state, the clock and data lines are held high by the device. See Figure 2 and Figure 3 for device-to-host and host-to-device communication, respectively.

FIGURE 2: DEVICE-TO-HOST COMMUNICATION (DATA BIT READ ON FALLING EDGE OF CLOCK)

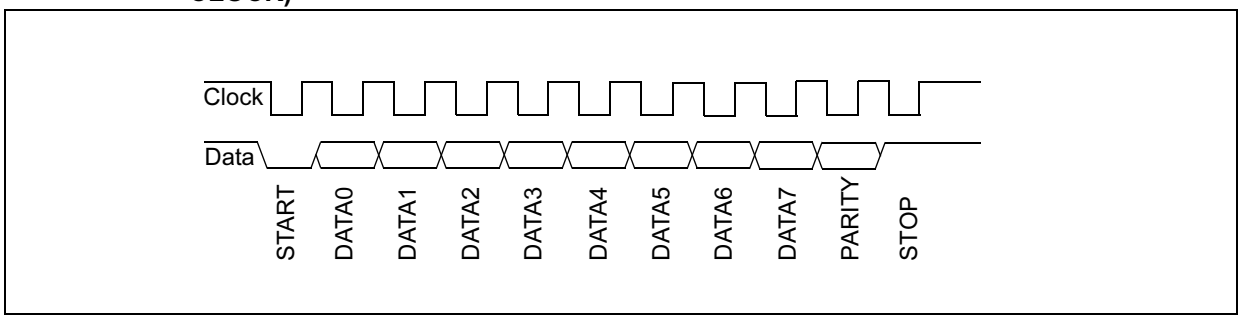
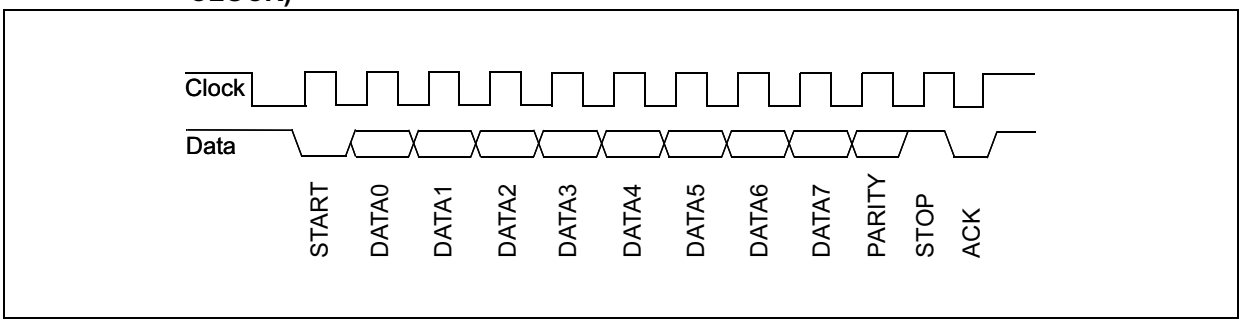


FIGURE 3: HOST-TO-DEVICE COMMUNICATION (DATA BIT READ ON FALLING EDGE OF CLOCK)



INTERRUPT SERVICE ROUTINE

The portion of the firmware that deals with PS/2 reception and translation is entirely interrupt driven. An interrupt is generated when the PS/2 START bit is received from the mouse. At this point, the receive routine is initiated. In addition to this interrupt, every 683 μs, a timer overflow interrupts the normal program flow and implements one state of the mouse state machine. This state machine handles sending bytes to and translating bytes received from the PS/2 mouse. These two interrupts essentially handle everything, except for transferring the translated PS/2 data to the PC via USB.

Tables 1 and 2 show the PS/2 and USB mouse report formats respectively. They are nearly identical so a very short and simple routine translates the PS/2 mouse data format to the USB mouse data format. Table 2 corresponds directly to the report format information described by the report descriptor. The mouse report descriptor is listed in the Appendix A.

TABLE 1: PS/2 MOUSE REPORT

Byte	Bit	Description
3	7	MSB of Y Data
	6-1	Y Data
	0	LSB of Y Data
2	7	MSB of X Data
	6-1	X Data
	0	LSB of X Data
1	7	Y Data Overflow, 1 = overflow
	6	X Data Overflow, 1 = overflow
	5	Y Data Sign, 1 = negative
	4	X Data Sign, 1 = negative
	3	Reserved
	2	Reserved
	1	Right Button Status, 1 = pressed
	0	Left Button Status, 1 = pressed

TABLE 2: USB MOUSE REPORT

Byte	Bit	Description
3	7	MSB of Y Data
	6-1	Y Data
	0	LSB of Y Data
2	7	MSB of X Data
	6-1	X Data
	0	LSB of X Data
1	7	Reserved
	6	Reserved
	5	Reserved
	4	Reserved
	3	Reserved
	2	Third Button Status, 1 = pressed
	1	Right Button Status, 1 = pressed
	0	Left Button Status, 1 = pressed

MAIN LOOP

The main loop of the firmware sends USB mouse data to the host. This is done with the use of the `PutEP1` function. `PutEP1` loads the EP1 IN buffer with the USB mouse data. Special function register `BC1IAL` is the address pointer to the EP1 IN buffer. After the bytes are loaded into the buffer, the `UOWN` bit (`BD1IST<7>`) is set so that the SIE will send the bytes to the host the next time the host polls the device.

A closer look at the source code and endpoint descriptor reveals that `PutEP1` sends four bytes to the host instead of three -- the number of bytes specified in the report descriptor. If only three bytes are sent, the mouse will never move the cursor. The reason for this stems from the fact that a mouse is a boot device. Since the mouse is such a commonly used peripheral, the host requires a standard length report of four bytes. Therefore, in the mouse example, a null fourth byte is sent with the three data bytes.

REFERENCES

1. USB Specification, Version 1.1: Chapter 9 (located at www.usb.org)
2. Device Class Definition for Human Interface Devices (located at www.usb.org)
3. HID Usage Tables (located at www.usb.org)
4. USB Firmware User's Guide (located in USB Support Firmware zip file at www.microchip.com)
5. USB Complete, *Second Edition,* Jan Axelson; Lakeview Research, 2001 (www.lvr.com)
6. TB054: *An Introduction to USB Descriptors with a Gameport to USB Gamepad Translator*
7. TB056: *Demonstrating the Set_Report Request with a PS/2 to USB Keyboard Translator Example*
8. TB057: *USB Combination Devices Demonstrated by a Combination Mouse and Gamepad device*
9. TB058: *Demonstrating the Soft Detact Function with a PS/2 to USB Translator Example*

APPENDIX A:

Chapter 9 of the USB Specification, V 1.10, defines the standard descriptors (Device, Configuration, Interface, Endpoint, and String Descriptors.) The HID Class Definition defines the HID descriptors (HID and Report.)

TABLE 3: DEVICE DESCRIPTOR

Offset	Field	Size	Description	Value for Mouse
0	bLength	1	Size of descriptor in bytes	0x12
1	bDescriptorType	1	Descriptor Type (DEVICE = 1)	0x01
2	bcdUSB	2	USB Specification release (Ver 1.10 = 0x0110)	0x0110
4	bDeviceClass	1	Class code (this field is zero if every interface specifies its own class information)	0x00
5	bDeviceSubClass	1	Subclass code (if the Class code is zero this must be zero)	0x00
6	bDeviceProtocol	1	Protocol code (zero if it does not use a class-specific protocols on a device level)	0x00
7	bMaxPacketSize0	1	Maximum packet size (eight for low speed)	0x08
8	idVendor	2	Vendor ID (assigned by the USB-IF)	0x04D8
10	idProduct	2	Product ID (assigned by the manufacture)	0x0001
12	bcdDevice	2	Device release number in binary-coded decimal	0x0441
14	iManufacturer	1	Index of string descriptor describing manufacturer (String 1 is “Microchip”)	0x01
15	iProduct	1	Index of string descriptor describing product (String 2 is “PIC16C745/765 USB Mouse”)	0x02
16	iSerialNumber	1	Index of string descriptor describing the serial number (none)	0x00
17	bNumConfigurations	1	Number of possible configurations	0x01

TABLE 4: CONFIGURATION DESCRIPTOR

Offset	Field	Size	Description	Value for Mouse
0	bLength	1	Size of descriptor in bytes	0x09
1	bDescriptorType	1	Descriptor Type (CONFIGURATION = 2)	0x02
2	bTotalLength	2	Total length of data returned for this configuration (For the mouse example this is the combined length of the configuration, interface, HID, and endpoint descriptors)	0x0022
4	bNumInterfaces	1	Number of interfaces supported by this configuration	0x01
5	bConfigurationValue	1	Value to use as an argument to the Set Configuration() request to select this configuration	0x01
6	iConfiguration	1	Index of string descriptor describing this configuration (String 4 is “Cfg1”)	0x04
7	bmAttributes	1	Configuration characteristics Bit 7: Always one Bit 6: Self-powered Bit 5: Remote Wake-up Bits 4..0: Zero	0xA0
8	bMaxPower	1	Maximum power consumption expressed in 2 mA units (in this case 50 = 100 ma)	0x32

TABLE 5: INTERFACE DESCRIPTOR

Offset	Field	Size	Description	Value for Mouse
0	bLength	1	Size of descriptor in bytes	0x09
1	bDescriptorType	1	Descriptor Type (INTERFACE = 4)	0x04
2	bInterfaceNumber	1	Number of this interface (zero based array)	0x00
3	bAlternateSetting	1	Value used to select this alternate setting for the interface identified in the prior field (there is no alternate setting for this mouse)	0x00
4	bNumEndpoints	1	Number of endpoints used by this interface	0x01
5	bInterfaceClass	1	Class code (assigned by the USB-IF)	0x03
6	bInterfaceSubClass	1	Subclass code (bootdevice = 1)	0x01
7	bInterfaceSubProtocol	1	Protocol code (mouse = 2)	0x02
8	iInterface	1	Index of string descriptor describing this interface (String 5 is “EP1 IN“)	0x05

TABLE 6: HUMAN INTERFACE DEVICE (HID) DESCRIPTOR

Offset	Field	Size	Description	Value for Mouse
0	bLength	1	Size of descriptor in bytes	0x09
1	bDescriptorType	1	Descriptor Type (HID = 21)	0x21
2	bcdHID	2	HID Class Specification release (Ver 1.00 = 0x0100)	0x0100
4	bCountryCode	1	Country code of localized hardware	0x00
5	bNumDescriptors	1	Number of HID class descriptors	0x01
6	bDescriptorType	1	Type of class descriptor (REPORT = 22)	0x22
7	bDescriptorLength	2	Total size of report descriptor	0x0032

TABLE 7: ENDPOINT DESCRIPTOR

Offset	Field	Size	Description	Value for Mouse
0	bLength	1	Size of descriptor in bytes	0x07
1	bDescriptorType	1	Descriptor Type (ENDPOINT = 5)	0x05
2	bEndpointAddress	1	Endpoint characteristics Bits 3...0: Always one Bits 6...4: Self-powered Bit 7: Remote Wake-up 0 = OUT endpoint 1 = IN endpoint	0x81
3	bmAttributes	1	Endpoint's attributes Bits 1...0: Transfer Type 00 = Control 01 = Isochronous 10 = Bulk 11 = Interrupt Bits 7...2: Always zero for low speed	0x03
4	wMaxPacketSize	2	Maximum packet size Bits 10...0: Maximum packet size in bytes Bits 12...11: Number of additional transaction opportunities per microframe 00 = None 01 = 1 additional 10 = 2 additional 11 = Reserved	0x0004
6	bInterval	1	Interval for polling endpoint for data transfer (in 1 ms increments for low speed devices)	0x0A

FIGURE 4: REPORT DESCRIPTOR

```
0x05, 0x01  usage page (generic desktop      Choose the usage page "mouse" is on
0x09, 0x02  usage (mouse)                    Device is a mouse
0xA1, 0x01  collection (application)         This collection encompasses the report format
0x09, 0x01  usage (pointer)                  Choose the key code usage page
0xA1, 0x00  collection (physical)            Physical collection
0x05, 0x09  usage page (buttons)             Choose the “button” usage page
0x19, 0x01  usage minimum (1)                There are three buttons
0x29, 0x03  usage maximum (3)
0x15, 0x00  logical minimum (0)              Each button is represented by one bit
0x25, 0x01  logical maximum (1)
0x95, 0x03  report count (3)                 Three reports, one bit each
0x75, 0x01  report size (1)
0x81, 0x02  input (data, variable, absolute) Defined bits above are data bits
0x95, 0x01  report count (1)                 One report, five bits in length
0x75, 0x05  report size (5)
0x81, 0x01  input (constant)                 Bit stuff to fill byte
0x05, 0x01  usage page (generic desktop)     Choose the usage pare “X” and “Y” are on
0x09, 0x30  usage (X)                        X direction of pointer
0x09, 0x31  usage (Y)                        Y direction of pointer
0x15, 0x81  logical minimum (-127)           Range of report data is -127 to 127
0x25, 0x7F  logical maximum (127)
0x75, 0x08  report size (8)                  Two reports, eight bits each
0x95, 0x03  report count (2)
0x81, 0x06  input (data, variable, absolute) Defined bits above are data bits
0xC0        end collection                   End physical collection
0xC0        end collection                   End application collection
```

APPENDIX B: SOURCE CODE

Due to the length of the source code for the PS/2 to USB Mouse Translator, the source code is available separately. The complete source code is available as a single WinZip archive file, `tb055sc.zip`, which may be downloaded from the Microchip corporate Web site at:

www.microchip.com

Note the following details of the code protection feature on PICmicro® MCUs.

- The PICmicro family meets the specifications contained in the Microchip Data Sheet.
- Microchip believes that its family of PICmicro microcontrollers is one of the most secure products 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 PICmicro microcontroller in a manner outside the operating specifications contained in the data sheet. The person doing so may be 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 product.

If you have any further questions about this matter, please contact the local sales office nearest to you.

DNV Certification, Inc. USA — ANSI-RAB QMS ACCREDITED — DNV MSC The Netherlands Accredited by the RvA — DNV — ISO 9001 / QS-9000 REGISTERED FIRM

Microchip received QS-9000 quality system certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona in July 1999 and Mountain View, California in March 2002. The Company’s quality system processes and procedures are QS-9000 compliant for its PICmicro® 8-bit MCUs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, non-volatile memory and analog products. In addition, Microchip’s quality system for the design and manufacture of development systems is ISO 9001 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: 480-792-7627
Web Address: http://www.microchip.com

Rocky Mountain
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7966 Fax: 480-792-4338

Atlanta
500 Sugar Mill Road, Suite 200B
Atlanta, GA 30350
Tel: 770-640-0034 Fax: 770-640-0307

Boston
2 Lan Drive, Suite 120
Westford, MA 01886
Tel: 978-692-3848 Fax: 978-692-3821

Chicago
333 Pierce Road, Suite 180
Itasca, IL 60143
Tel: 630-285-0071 Fax: 630-285-0075

Dallas
4570 Westgrove Drive, Suite 160
Addison, TX 75001
Tel: 972-818-7423 Fax: 972-818-2924

Detroit
Tri-Atria Office Building
32255 Northwestern Highway, Suite 190
Farmington Hills, MI 48334
Tel: 248-538-2250 Fax: 248-538-2260

Kokomo
2767 S. Albright Road
Kokomo, Indiana 46902
Tel: 765-864-8360 Fax: 765-864-8387

Los Angeles
18201 Von Karman, Suite 1090
Irvine, CA 92612
Tel: 949-263-1888 Fax: 949-263-1338

San Jose
Microchip Technology Inc.
2107 North First Street, Suite 590
San Jose, CA 95131
Tel: 408-436-7950 Fax: 408-436-7955

Toronto
6285 Northam Drive, Suite 108
Mississauga, Ontario L4V 1X5, Canada
Tel: 905-673-0699 Fax: 905-673-6509

ASIA/PACIFIC

Australia
Microchip Technology Australia Pty Ltd
Suite 22, 41 Rawson Street
Epping 2121, NSW
Australia
Tel: 61-2-9868-6733 Fax: 61-2-9868-6755

China - Beijing
Microchip Technology Consulting (Shanghai) Co., Ltd., Beijing Liaison Office
Unit 915
Bei Hai Wan Tai Bldg.
No. 6 Chaoyangmen Beidajie
Beijing, 100027, No. China
Tel: 86-10-85282100 Fax: 86-10-85282104

China - Chengdu
Microchip Technology Consulting (Shanghai) Co., Ltd., Chengdu Liaison Office
Rm. 2401, 24th Floor,
Ming Xing Financial Tower
No. 88 TIDU Street
Chengdu 610016, China
Tel: 86-28-86766200 Fax: 86-28-86766599

China - Fuzhou
Microchip Technology Consulting (Shanghai) Co., Ltd., Fuzhou Liaison Office
Unit 28F, World Trade Plaza
No. 71 Wusi Road
Fuzhou 350001, China
Tel: 86-591-7503506 Fax: 86-591-7503521

China - Shanghai
Microchip Technology Consulting (Shanghai) Co., Ltd.
Room 701, Bldg. B
Far East International Plaza
No. 317 Xian Xia Road
Shanghai, 200051
Tel: 86-21-6275-5700 Fax: 86-21-6275-5060

China - Shenzhen
Microchip Technology Consulting (Shanghai) Co., Ltd., Shenzhen Liaison Office
Rm. 1315, 13/F, Shenzhen Kerry Centre,
Renminnan Lu
Shenzhen 518001, China
Tel: 86-755-82350361 Fax: 86-755-82366086

China - Hong Kong SAR
Microchip Technology Hongkong Ltd.
Unit 901-6, Tower 2, Metroplaza
223 Hing Fong Road
Kwai Fong, N.T., Hong Kong
Tel: 852-2401-1200 Fax: 852-2401-3431

India
Microchip Technology Inc.
India Liaison Office
Divyasree Chambers
1 Floor, Wing A (A3/A4)
No. 11, O'Shaugnessey Road
Bangalore, 560 025, India
Tel: 91-80-2290061 Fax: 91-80-2290062

Japan
Microchip Technology Japan K.K.
Benex S-1 6F
3-18-20, Shinyokohama
Kohoku-Ku, Yokohama-shi
Kanagawa, 222-0033, Japan
Tel: 81-45-471- 6166 Fax: 81-45-471-6122

Korea
Microchip Technology Korea
168-1, Youngbo Bldg. 3 Floor
Samsung-Dong, Kangnam-Ku
Seoul, Korea 135-882
Tel: 82-2-554-7200 Fax: 82-2-558-5934

Singapore
Microchip Technology Singapore Pte Ltd.
200 Middle Road
#07-02 Prime Centre
Singapore, 188980
Tel: 65-6334-8870 Fax: 65-6334-8850

Taiwan
Microchip Technology (Barbados) Inc.,
Taiwan Branch
11F-3, No. 207
Tung Hua North Road
Taipei, 105, Taiwan
Tel: 886-2-2717-7175 Fax: 886-2-2545-0139

EUROPE

Austria
Microchip Technology Austria GmbH
Durisolstrasse 2
A-4600 Wels
Austria
Tel: 43-7242-2244-399
Fax: 43-7242-2244-393

Denmark
Microchip Technology Nordic ApS
Regus Business Centre
Lautrup hoj 1-3
Ballerup DK-2750 Denmark
Tel: 45 4420 9895 Fax: 45 4420 9910

France
Microchip Technology SARL
Parc d'Activite du Moulin de Massy
43 Rue du Saule Trapu
Batiment A - ler Etage
91300 Massy, France
Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79

Germany
Microchip Technology GmbH
Steinheilstrasse 10
D-85737 Ismaning, Germany
Tel: 49-89-627-144 0 Fax: 49-89-627-144-44

Italy
Microchip Technology SRL
Centro Direzionale Colleoni
Palazzo Taurus 1 V. Le Colleoni 1
20041 Agrate Brianza
Milan, Italy
Tel: 39-039-65791-1 Fax: 39-039-6899883

United Kingdom
Microchip Ltd.
505 Eskdale Road
Winnersh Triangle
Wokingham
Berkshire, England RG41 5TU
Tel: 44 118 921 5869 Fax: 44-118 921-5820

10/18/02