



Section 1. Introduction

HIGHLIGHTS

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PICmicro MID-RANGE MCU FAMILY

1.1 Introduction

Microchip is the Embedded Control Solutions Company[®]. The company's focus is on products that meet the needs of the embedded control market. We are a leading supplier of:

- 8-bit General Purpose Microcontrollers (PICmicro[™] MCUs)
- Speciality and standard non-volatile memory devices
- Security devices (KEELOQ[®])
- Application specific standard products

Please request a Microchip Product Line Card for a listing of all the interesting products that we have to offer. This literature can be obtained from your local sales office, or downloaded from the Microchip web site (www.microchip.com).

In the past, 8-bit MCU users were fixed on the traditional MCU model for production, a ROM device was required. Microchip has been the leader in changing this perception by showing that OTP devices can give a better lifetime product cost compared to ROM versions.

Microchip has a strength in EPROM technology. That made it the memory technology of choice for the PICmicro MCU's program memory. Microchip has minimized the cost difference between EPROM and ROM memory technology, and therefore Microchip can pass these benefits onto our customers. This is not true for other MCU vendors, and is seen in the price difference between their EPROM and ROM versions.

The growth of Microchip's 8-bit MCU market share is a testament to the PICmicro MCUs ability to meet the needs of many. This growth has made the PICmicro architecture one of the top three architectures available in the general market today. This growth was fueled by the Microchip vision of the benefits of a low cost OTP solution. Some of the benefits for the customer include:

- Quick time to market
- Allows code changes to product, during production run
- No Non-Recurring Engineering (NRE) charges for Mask Revisions
- Ability to easily serialize the product
- Ability to store calibration data, without additional hardware
- Better able to maximize PICmicro MCU inventory
- Less risk, since the same device is used for development as well as for production.

Microchip's PICmicro 8-bit MCUs offer a price/performance ratio that allows them to be considered for any traditional 8-bit MCU application as well as some traditional 4-bit applications (Base-Line family), dedicated logic replacement and low-end DSP applications (High-End family). These features and price-performance mix make PICmicro MCUs an attractive solution for most applications.

1.2 Manual Objective

PICmicro devices are grouped by the size of their Instruction Word. The three current PICmicro families are:

1. Base-Line: 12-bit Instruction Word length
2. Mid-Range: 14-bit Instruction Word length
3. High-End: 16-bit Instruction Word length

This manual focuses on the Mid-Range devices, which are also referred to as the PIC16CXXX MCU family.

The operation of the PIC16CXXX MCU family architecture and peripheral modules is explained, but does not cover the specifics of each device. Therefore, it is not intended to replace the device data sheets, but complement them. In other words, this guide supplies the general details and operation of the PICmicro architecture and peripheral modules, while the data sheets give specific details such as device memory mapping.

Initialization examples are given throughout this manual. These examples sometimes need to be written as device specific as opposed to family generic, though they are valid for most other devices. Some modifications may be required for devices with variations in register file mappings.

Note: The first few Mid-Range devices have minor device variations when compared to this general description. We have tried to describe these variations throughout this manual. Please refer to the specific device data sheet for complete information on the device.

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1.3 Device Structure

Each part of a device can be placed into one of three groups:

1. Core
2. Peripherals
3. Special Features

1.3.1 The Core

The core pertains to the basic features that are required to make the device operate. These include:

- | | |
|--|---------------------|
| 1. Device Oscillator | Revision "DS31002A" |
| 2. Reset logic | Revision "DS31003A" |
| 3. CPU (Central Processing Unit) operation | Revision "DS31005A" |
| 4. ALU (Arithmetic Logical Unit) operation | Revision "DS31005A" |
| 5. Device memory map organization | Revision "DS31006A" |
| 6. Interrupt operation | Revision "DS31008A" |
| 7. Instruction set | Revision "DS31029A" |

1.3.2 Peripherals

Peripherals are the features that add a differentiation from a microprocessor. These ease in interfacing to the external world (such as general purpose I/O, LCD drivers, A/D inputs, and PWM outputs), and internal tasks such as keeping different time bases (such as timers). The peripherals that are discussed are:

- | | |
|---|---------------------|
| 1. General purpose I/O | Revision "DS31009A" |
| 2. Timer0 | Revision "DS31011A" |
| 3. Timer1 | Revision "DS31012A" |
| 4. Timer2 | Revision "DS31013A" |
| 5. Capture, Compare, and PWM (CCP) | Revision "DS31014A" |
| 6. Synchronous Serial Port (SSP) | Revision "DS31015A" |
| 7. Basic Synchronous Serial Port (SSP) | Revision "DS31016A" |
| 8. Master Synchronous Serial Port (MSSP) | Revision "DS31017A" |
| 9. USART (SCI) | Revision "DS31018A" |
| 10. Voltage References | Revision "DS31019A" |
| 11. Comparators | Revision "DS31020A" |
| 12. 8-bit Analog to Digital (A/D) | Revision "DS31021A" |
| 13. Basic 8-bit Analog to Digital (A/D) | Revision "DS31022A" |
| 14. 10-bit Analog to Digital (A/D) | Revision "DS31023A" |
| 15. Slope Analog to Digital (A/D) w/ Thermister | Revision "DS31024A" |
| 16. Liquid Crystal Display (LCD) Drivers | Revision "DS31025A" |
| 17. Parallel Slave Port (PSP) | Revision "DS31010A" |

1.3.3 Special Features

Special features are the unique features that help to do one or more of the following things:

- Decrease system cost
- Increase system reliability
- Increase design flexibility

The Mid-Range PICmicro MCUs offer several features that help achieve these goals. The special features discussed are:

- | | |
|---|---------------------|
| 1. Device Configuration bits | Revision "DS31027A" |
| 2. On-chip Power-on Reset (POR) | Revision "DS31003A" |
| 3. Brown-out Reset (BOR) logic | Revision "DS31003A" |
| 4. Watchdog Timer | Revision "DS31026A" |
| 5. Low power mode (Sleep) | Revision "DS31026A" |
| 6. Internal RC device oscillator | Revision "DS31002A" |
| 7. In-Circuit Serial Programming™ (ICSP™) | Revision "DS31028A" |

1.4 Development Support

Microchip offers a wide range of development tools that allow users to efficiently develop and debug application code. Microchip's development tools can be broken down into four categories:

1. Code generation
2. Software debug
3. Device programmer
4. Product evaluation boards

All tools developed by Microchip operate under the MPLAB™ Integrated Development Environment (IDE), while some third party tools may not. The code generation tools include:

- MPASM
- MPLAB-C
- MP-DriveWay™

These software development programs include device header files. Each header file defines the register names (as shown in the device data sheet) to the specified address or bit location. Using the header files eases code migration, and reduces the tediousness of memorizing a register's address or a bit's position in a register.

<p>Note: Microchip strongly recommends that the supplied header files be used in the source code of your program. This eases code migration as well as increases the quality and depth of the technical support that Microchip can offer.</p>
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Tools which ease in debugging software are:

- PICMASTER® In-Circuit Emulator
- ICEPIC In-Circuit Emulator
- MPLAB-SIM Software Simulator

After generating and debugging the application software, the device will need to be programmed. Microchip offers two levels of programmers:

1. PICSTART® Plus programmer
2. PROMATE® II programmer

Demonstration boards allow the developer of software code to evaluate the capability and suitability of the device to the application. The demo boards offered are:

- PICDEM-1
- PICDEM-2
- PICDEM-3
- PICDEM-14A

A full description of each of Microchip's development tools is discussed in the [“Development Tools”](#) section. As new tools are developed, product briefs and user guides may be obtained from the Microchip web site (www.microchip.com) or from your local Microchip Sales Office.

Code development recommendations and techniques are provided in the [“Code Development”](#) section.

Microchip offers other reference tools to speed the development cycle. These include:

- Application Notes
- Reference Designs
- Microchip web site
- Microchip BBS
- Local Sales Offices with Field Application Support
- Corporate Support Line

Additional avenues of assistance can be found in many Web User Groups including the MIT reflector PIClist. The Microchip web site lists other sites that may be useful references.

1.5 Device Varieties

Once the functional requirements of the device are specified, some other decisions need to be made. These include:

- Memory technology
- Operating voltage
- Operating temperature range
- Operating frequency
- Packaging

Microchip has a large number of options and option combinations, one of which should fulfill your requirements.

1.5.1 Memory Varieties

Memory technology has no effect on the logical operation of a device. Due to the different processing steps required, some electrical characteristics may vary between devices with the same feature set/pinout but with different memory technologies. An example is the electrical characteristic V_{IL} (Input Low Voltage), which may have some difference between a typical EPROM device and a typical ROM device.

Each device has a variety of frequency ranges and packaging options available. Depending on application and production requirements, the proper device options can be identified using the information in the Product Selection System section at the end of each data sheet. When placing orders, please use the "Product Identification System" at the back of the data sheet to specify the correct part number.

When discussing the functionality of the device, the memory technology and the voltage range do not matter. Microchip offers three program memory types. The memory type is designated in the part number by the first letter(s) after the family affiliation designators.

1. **C**, as in PIC16**C**XXX. These devices have EPROM type memory.
2. **CR**, as in PIC16**CR**XXX. These devices have ROM type memory.
3. **F**, as in PIC16**F**XXX. These devices have Flash type memory.

1.5.1.1 EPROM

Microchip focuses on Erasable Programmable Read Only Memory (EPROM) technology to give the customers flexibility throughout their entire design cycle. With this technology Microchip offers various packaging options as well as services.

1.5.1.2 Read Only Memory (ROM) Devices

Microchip offers a masked Read Only Memory (ROM) version of several of the highest volume parts, thus giving customers a lower cost option for high volume, mature products.

ROM devices do not allow serialization information in the program memory space.

For information on submitting ROM code, please contact your local Microchip sales office.

1.5.1.3 Flash Memory Devices

These devices are electrically erasable, and can therefore be offered in a low cost plastic package. Being electrically erasable, these devices can be both erased and reprogrammed without removal from the circuit. A device will have the same specifications whether it is used for prototype development, pilot programs, or production.

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1.5.2 Operating Voltage Range Options

All Mid-Range PICmicro™ MCUs operate over the standard voltage range. Devices are also offered which operate over an extended voltage range (and reduced frequency range). [Table 1-1](#) shows all possible memory types and voltage range designators for the PIC16CXXX MCU family. The designators are in **bold** typeface.

Table 1-1: Device Memory Type and Voltage Range Designators

Memory Type	Voltage Range	
	Standard	Extended
EPROM	PIC16 C XXX	PIC16 LC XXX
ROM	PIC16 CR XXX	PIC16 LCR XXX
Flash	PIC16 F XXX	PIC16 LF XXX

Note: Not all memory types may be available for a particular device.

As you can see in [Table 1-2](#), Microchip specifies its extended range devices at a more conservative voltage range until device characterization has ensured they will be able to meet the goal of their final design specifications.

Table 1-2: Typical Voltage Ranges for Each Device Type

Typical Voltage Range ⁽¹⁾		EPROM		ROM		Flash	
Standard		C	4.5 - 6.0V	CR	4.5 - 6.0V	F	4.5 - 6.0V
Extended	Before device characterization	LC	3.0 - 6.0V	LCR	3.0 - 6.0V	LF	3.0 - 6.0V
	Final specification ⁽²⁾	LC	2.5 - 6.0V	LCR	2.5 - 6.0V	LF	2.0 - 6.0V

Note 1: Devices fabricated in Microchip's 120K Process Technology will have a maximum limit on V_{DD} of 5.5V. New device data sheets will specify Microchip's technology designation

2: This voltage range depends on the results of device characterization.

1.5.3 Packaging Varieties

Depending on the development phase of your project, one of three package types would be used: The first is a device with an erasure window. Typically these are found in packages with a ceramic body. These devices are used for the development phase, since the device's program memory can be erased and reprogrammed many times.

The second package type is a low cost plastic package. This package type is used in production where device cost is to be kept to a minimum.

Lastly, there is the DIE option. A DIE is an unpackaged device that has been tested. DIEs are used in low cost designs and designs where board space is at a minimum. [Table 1-3](#) shows a quick summary of this.

Table 1-3: Typical Package Uses

Package Type	Typical Usage
Windowed	Development Mode
Plastic	Production
DIE	Special Applications, such as those which require minimum board space

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1.5.3.4 UV Erasable Devices

The UV erasable version of EPROM program memory devices is optimal for prototype development and pilot programs.

These devices can be erased and reprogrammed to any of the configuration modes. Third party programmers are also available; refer to Microchip's *Third Party Guide* (DS00104) for a list of sources.

The amount of time required to completely erase a UV erasable device depends on: the wavelength of the light, its intensity, distance from UV source, the process technology of the device (how small are the memory cells).

<p>Note: Fluorescent lights and sunlight both emit ultraviolet light at the erasure wavelength. Leaving a UV erasable device's window uncovered could cause, over time, the devices memory cells to become erased. The erasure time for a fluorescent light is about three years, while sunlight requires only about one week. To prevent the memory cells from losing data, an opaque label should be placed over the erasure window.</p>

1.5.3.5 One-Time-Programmable (OTP) Devices

The availability of OTP devices is especially useful for customers expecting code changes and updates.

OTP devices, packaged in plastic packages, permit the user to program them once. In addition to the program and data EPROM memories, the configuration bits must be programmed.

1.5.3.6 Flash Devices

A Flash device allows its memory to be changed by an electric charge. This means that the system can be designed so that programming may be performed in-circuit. Since no window is required, the lower cost plastic packages can be used for these devices.

1.5.3.7 EEPROM Devices

An EEPROM device allows its memory to be erased by an electric charge. This means that the system can be designed so that erasure and reprogramming may be performed in-circuit. Since no window is required, the lower cost plastic packages can be used for these devices.

1.5.3.8 ROM Devices

ROM devices have their program memory fixed at the time of the silicon manufacture. Since the program memory cannot be changed, the device can be housed in the lower cost plastic package.

1.5.3.9 DIE

The DIE option allows the board size to become as small as physically possible. The DIE Support document (DS30258) explains general information about using and designing with DIE. There are also individual specification sheets that detail DIE specific information. Manufacturing with DIE requires special knowledge and equipment. This means that the number of manufacturing houses that support DIE will be limited. If you decide to use the DIE option, please research your manufacturing sites to ensure that they will be able to meet the specialized requirements of DIE use.

1.5.3.10 Specialized Services

For OTP customers with established code, Microchip offers two specialized services. These two services, Quick Turn Production Programming and Serialized Quick Turn Production Programming, that allow customers to shorten their manufacturing cycle time.

1.5.3.11 Quick Turn Production (QTP) Programming

Microchip offers this programming service for factory production orders. This service is made available for users who choose not to program a medium to high quantity of units and whose code patterns have stabilized. The devices are identical to the OTP devices but with all EPROM locations and configuration options already programmed by the factory. Certain code and prototype verification procedures apply before production shipments are available. Please contact your local Microchip sales office for more details.

1.5.3.12 Serialized Quick Turn Production (SQTPSM) Programming

Microchip offers a this unique programming service where a few user-defined locations in each device are programmed with different serial numbers. The serial numbers may be random, pseudo-random or sequential.

Serial programming allows each device to have a unique number which can serve as an entry-code, password or ID number.

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1.6 Style and Symbol Conventions

Throughout this document, certain style and font format changes are used. Most format changes imply a distinction should be made for the emphasized text. The MCU industry has many symbols and non-conventional word definitions/abbreviations. Table 1-4 provides a description for many of the conventions contained in this document. A glossary is provided in the “Glossary” section, which contains more word and abbreviation definitions that are used throughout this manual.

1.6.1 Document Conventions

Table 1-4 defines some of the symbols and terms used throughout this manual.

Table 1-4: Document Conventions

Symbol or Term	Description
set	To force a bit/register to a value of logic ‘1’.
clear	To force a bit/register to a value of logic ‘0’.
reset	1) To force a register/bit to its default state. 2) A condition in which the device places itself after a device reset occurs. Some bits will be forced to ‘0’ (such as interrupt enable bits), while others will be forced to ‘1’ (such as the I/O data direction bits).
0xnn or nnh	Designates the number ‘nn’ in the hexadecimal number system. These conventions are used in the code examples.
B’bbbbbbbb’	Designates the number ‘bbbbbbbb’ in the binary number system. This convention is used in the text and in figures and tables.
R-M-W	Read - Modify - Write. This is when a register or port is read, then the value is modified, and that value is then written back to the register or port. This action can occur from a single instruction (such as bit set file, BSF) or a sequence of instructions.
: (colon)	Used to specify a range, or the concatenation of registers / bits / pins. An example is TMR1H:TMR1L is the concatenation of two 8-bit registers to form a 16-bit timer value, while SSPM3:SSPM0 are 4-bits used to specify the mode of the SSP module. Concatenation order (left-right) usually specifies a positional relationship (MSb to LSb, higher to lower).
< >	Specifies bit(s) locations in a particular register. An example is SSPCON<SSPM3:SSPM0> (or SSPCON<3:0>) specifies the register and associated bits or bit positions.
Courier Font	Used for code examples, binary numbers, and for Instruction Mnemonics in the text.
Times Font	Used for equations and variables.
Times, Bold Font Italics	Used in explanatory text for items called out from a graphic/equation/example.
Note	Notes present information that we wish to reemphasize, either to help you avoid a common pitfall, or make you aware of operating differences between some device family members. A Note is always in a shaded box (as below), unless used in a table, where it is at the bottom of the table (as in this table). Note: This is a note in a note box.
Caution ⁽¹⁾	A caution statement describes a situation that could potentially damage software or equipment.
Warning ⁽¹⁾	A warning statement describes a situation that could potentially cause personnel harm.

Note 1: The information in a caution or a warning is provided for your protection. Please read each caution and warning carefully.

1.6.2 Electrical Specifications

Throughout this manual there will be references to electrical specification parameter numbers. A parameter number represents a unique set of characteristics and conditions that is consistent between every data sheet, though the actual parameter value may vary from device to device.

The “**Electrical Specifications**” section shows all the specifications that are documented for all devices. No one device has all these specifications. This section is intended to let you know the types of parameters that Microchip specifies. The value of each specification is device dependent, though we strongly attempt to keep them consistent across all devices.

Table 1-5: Electrical Specification Parameter Numbering Convention

Parameter Number Format	Comment
Dxxx	DC Specification
Axxx	DC Specification for Analog peripherals
xxx	Timing (AC) Specification
PDxxx	Device Programming DC Specification
Pxxx	Device Programming Timing (AC) Specification

Legend: xxx: represents a number.

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1.7 Related Documents

Microchip, as well as other sources, offers additional documentation which can aid in your development with PICmicro MCUs. These lists contain the most common documentation but other documents may also be available. Please check the Microchip web site (www.microchip.com) for the latest published technical documentation.

1.7.1 Microchip Documentation

The following documents are available from Microchip. Many of these documents provide application specific information that give actual examples of using, programming and designing with PICmicro MCUs.

1. **MPASM User's Guide (DS33014)**
This document explains how to use Microchip's MPASM assembler.
2. **MPLAB™-C Compiler User's Guide (DS51014)**
This document explains how to use Microchip's MPLAB-C C compiler.
3. **MPLAB User's Guide (DS51025)**
This document explains how to use Microchip's MPLAB Integrated Development Environment.
4. **MPLAB Editor User's Guide (DS30420)**
This document explains how to use Microchip's MPLAB built-in editor.
5. **PICMASTER® User's Guide (DS30421)**
This document explains how to use Microchip's PICMASTER In-Circuit Emulator.
6. **MPSIM User's Guide (DS30027)**
This document explains how to use Microchip's MPLAB Simulator.
7. **PRO MATE® User's Guide (DS30082)**
This document explains how to use Microchip's PRO MATE universal programmer.
8. **PICSTART®-Plus User's Guide (DS51028)**
This document explains how to use Microchip's PICSTART-Plus low-cost universal programmer.
9. **fuzzyTECH®-MP User's Guide (DS30389)**
This document explains how to use the fuzzyTECH-MP fuzzy logic code generator.
10. **MP-DriveWay™ User's Guide (DS51027)**
This document explains how to use the MP-DriveWay code generator.
11. **fuzzyTECH-MP Fuzzy Logic Handbook (DS30238)**
This document explains the basics of fuzzyTECH-MP fuzzy.
12. **Embedded Control Handbook Volume I (DS00092)**
This document contains a plethora of application notes. This is useful for insight on how to use the device (or parts of it) as well as getting started on your particular application due to the availability of extensive code files.
13. **Embedded Control Handbook Volume II (DS00167)**
This document contains the Math Libraries for PICmicro MCUs.
14. **In-Circuit Serial Programming Guide™ (DS30277)**
This document discusses implementing In-Circuit Serial Programming.
15. **PICDEM-1 User's Guide (DS351079)**
This document explains how to use Microchip's PICDEM-1 demo board.
16. **PICDEM-2 User's Guide (DS30374)**
This document explains how to use Microchip's PICDEM-2 demo board.
17. **PICDEM-3 User's Guide (DS33015)**
This document explains how to use Microchip's PICDEM-3 demo board.
18. **Third Party Guide (DS00104)**
This document lists Microchip's third parties, as well as various consultants.
19. **DIE Support (DS30258)**
This document gives information on using Microchip products in DIE form.

1.7.2 Third Party Documentation

There are several documents available from third party sources around the world. Microchip does not review these documents for technical accuracy, however they may be a helpful source for understanding the operation of Microchip MCU devices. This is not necessarily a complete list, but are the documents that we were aware of at the time of printing. For more information on how to contact some of these sources, as well as any new sources that we become aware of, please visit the Microchip web site.

DOCUMENT	LANGUAGE
The PIC16C5X Microcontroller: A Practical Approach to Embedded Control Bill Rigby/ Terry Dalby, Tecksystems Inc. 0-9654740-0-3.....	English
Easy PIC'n David Benson, Square 1 Electronics 0-9654162-0-8.....	English
A Beginners Guide to the Microchip PIC® Nigel Gardner, Bluebird Electronics 1-899013-01-6.....	English
PIC Microcontroller Operation and Applications DN de Beer, Cape Technikon	English
Digital Systems and Programmable Interface Controllers WP Verburg, Pretoria Technikon	English
Mikroprozessor PIC16C5X Michael Rose, Hüthig 3-7785-2169-1.....	German
Mikroprozessor PIC17C42 Michael Rose, Hüthig 3-7785-2170-5.....	German
Les Microcontrolleurs PIC et mise en oeuvre Christian Tavernier, Dunod 2-10-002647-X	French
Micontrolleurs PIC a structure RISC C.F. Urbain, Publitrone 2-86661-058-X	French
New Possibilities with the Microchip PIC RIGA	Russian

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DOCUMENT	LANGUAGE
PIC16C5X/71/84 Development and Design, Part 1 United Tech Electronic Co. Ltd 957-21-0807-7	Chinese
PIC16C5X/71/84 Development and Design, Part 2 United Tech Electronic Co. Ltd 957-21-1152-3	Chinese
PIC16C5X/71/84 Development and Design, Part 3 United Tech Electronic Co. Ltd 957-21-1187-6	Chinese
PIC16C5X/71/84 Development and Design, Part 4 United Tech Electronic Co. Ltd 957-21-1251-1	Chinese
PIC16C5X/71/84 Development and Design, Part 5 United Tech Electronic Co. Ltd 957-21-1257-0	Chinese
PIC16C84 MCU Architecture and Software Development ICC Company 957-8716-79-6	Chinese

1.8 Related Application Notes

This section lists application notes that are related to this section of the manual. These application notes may not be written specifically for the PIC16CXXX Mid-Range MCU family (that is they may be written for the Base-Line, or the High-End families), but the concepts are pertinent, and could be used (with modification and possible limitations). The current application notes related to an introduction to Microchip's PICmicro MCUs are:

Title	Application Note #
A Comparison of Low End 8-bit Microcontrollers	AN520
PIC16C54A EMI Results	AN577
Continuous Improvement	AN503
Improving the Susceptibility of an Application to ESD	AN595
Plastic Packaging and the Effects of Surface Mount Soldering Techniques	AN598

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1.9 Revision History

Revision A

This is the initial released revision of Microchip's PICmicro MCUs Introduction.