

PIC18-Q41 Family Product Brief

Introduction

The PIC18-Q41 microcontroller family is available in 14/20-pin devices for real-time control and sensor applications. This analog-focused family features a 12-bit ADC with Computation (ADCC) automating Capacitive Voltage Divider (CVD) techniques for advanced capacitive touch sensing, averaging, filtering, oversampling and threshold comparison, two 8-bit DAC modules and an Operational Amplifier. The family showcases a 16-bit PWM module which provides dual independent outputs on the same time base. Additional features include vectored interrupt controller with fixed latency for handling interrupts, system bus arbiter, Direct Memory Access (DMA) capabilities, UART with support for asynchronous, DMX, DALI and LIN protocols, SPI, I²C, and a programmable 32-bit CRC with Memory Scan. This family also includes memory features such as Memory Access Partition (MAP) to support users in data protection and bootloader applications, and Device Information Area (DIA), which stores factory calibration values to help improve temperature sensor accuracy.

PIC18-Q41 Family Types

Table 1. Devices included in this data sheet

Device	Program Memory Flash (bytes)	Data SRAM (bytes)	Data EEPROM (bytes)	Memory Access Partition/ Device Information Area	I/O Pins/ Peripheral Pin Select	8-Bit Timer with HLT/ 16-Bit Timers	16-Bit Dual PWM/ CCP	Complimentary Waveform Generator	Signal Measurement Timer	Numerically Controlled Oscillator	Configurable Logic Cell	12-Bit ADCC (channels)	8-Bit DAC	Operational Amplifier	Comparator/ Zero-Cross Detect	High-Low Voltage Detect	SPI / I ² C	UART/ UART with Protocol Support	Direct Memory Access (DMA)	Windowed Watchdog Timer	32-Bit CRC with Scanner	Vectored Interrupts	Peripheral Module Disable	Temperature Indicator
PIC18F04Q41	16k	1024	512	Y/Y	12/Y	2/3	3/1	1	1	1	4	11	2	1	2/1	1	2/1	2/1	4	Y	Y	Y	Y	Y
PIC18F05Q41	32k	2048	512	Y/Y	12/Y	2/3	3/1	1	1	1	4	11	2	1	2/1	1	2/1	2/1	4	Y	Y	Y	Y	Y
PIC18F06Q41	64k	4096	512	Y/Y	12/Y	2/3	3/1	1	1	1	4	11	2	1	2/1	1	2/1	2/1	4	Y	Y	Y	Y	Y
PIC18F14Q41	16k	1024	512	Y/Y	18/Y	2/3	3/1	1	1	1	4	17	2	1	2/1	1	2/1	2/1	4	Y	Y	Y	Y	Y
PIC18F15Q41	32k	2048	512	Y/Y	18/Y	2/3	3/1	1	1	1	4	17	2	1	2/1	1	2/1	2/1	4	Y	Y	Y	Y	Y
PIC18F16Q41	64k	4096	512	Y/Y	18/Y	2/3	3/1	1	1	1	4	17	2	1	2/1	1	2/1	2/1	4	Y	Y	Y	Y	Y

Features

- C Compiler Optimized RISC Architecture
- Operating Speed:
 - DC – 64 MHz clock input
 - 62.5 ns minimum instruction cycle
- Four Direct Memory Access (DMA) Controllers:
 - Data transfers to SFR/GPR spaces from either Program Flash Memory, Data EEPROM or SFR/GPR spaces
 - User programmable source and destination sizes
 - Hardware and software triggered data transfers
- Vectored Interrupt Capability:
 - Selectable high/low priority
 - Fixed interrupt latency of three instruction cycles
 - Programmable vector table base address
 - Backwards compatible with previous interrupt capabilities
- 128-Level Deep Hardware Stack
- Low-Current Power-on Reset (POR)
- Configurable Power-up Timer (PWRT)
- Brown-out Reset (BOR)
- Low-Power BOR (LPBOR) Option
- Windowed Watchdog Timer (WWDT):
 - Watchdog Reset on too long or too short interval between watchdog clear events
 - Variable prescaler selection
 - Variable window size selection

Memory

- Up to 64 KB of Program Flash Memory
- Up to 4 KB of Data SRAM Memory
- 512 Bytes Data EEPROM
- Memory Access Partition: The Program Flash Memory can be partitioned into:
 - Application Block
 - Boot Block
 - Storage Area Flash (SAF) Block
- Programmable Code Protection and Write Protection
- Device Information Area (DIA) Stores:
 - Temperature indicator factory calibrated data
 - Fixed Voltage Reference measurement data
 - Microchip unique identifier
- Device Characteristics Information (DCI) Area Stores:
 - Program/erase row sizes
 - Pin count details
 - EEPROM size
- Direct, Indirect and Relative Addressing modes

Operating Characteristics

- Operating Voltage Range:

- 1.8V to 5.5V
- Temperature Range:
 - Industrial: -40°C to 85°C
 - Extended: -40°C to 125°C

Power-Saving Functionality

- Doze: CPU and Peripherals Running at Different Cycle Rates (typically CPU is lower)
- Idle: CPU Halted While Peripherals Operate
- Sleep: Lowest Power Consumption
- Peripheral Module Disable (PMD):
 - Ability to selectively disable hardware module to minimize active power consumption of unused peripherals
- Low-Power Mode Features:
 - Sleep: < 1µA typical @ 3V
 - Operating Current:
 - 48µA @ 32 kHz, 3V, typical

Digital Peripherals

- Three 16-Bit Pulse-Width Modulators (PWM):
 - Dual outputs for each PWM module
 - Integrated 16-bit timer/counter
 - Double-buffered user registers for duty cycles
 - Right/Left/Center/Variable aligned modes of operation
 - Multiple clock and Reset signal selections
- Three 16-Bit Timers (TMR0/1/3)
- Two 8-Bit Timers (TMR2/4) with Hardware Limit Timer (HLT)
- Four Configurable Logic Cell (CLC):
 - Integrated combinational and sequential logic
- One Complimentary Waveform Generator (CWG):
 - Rising and falling edge dead-band control
 - Full-bridge, half-bridge, 1-channel drive
 - Multiple signal sources
 - Programmable dead band
 - Fault-shutdown input
- One Capture/Compare/PWM (CCP) module:
 - 16-bit resolution for Capture/Compare modes
 - 10-bit resolution for PWM mode
- One Numerically Controlled Oscillator (NCO):
 - Generates true linear frequency control and increased frequency resolution
 - Input clock up to 64 MHz
- Signal Measurement Timer (SMT):
 - 24-bit timer/counter with prescaler
 - Several modes of operation like Time-of-Flight, Period and Duty Cycle measurement etc.
- Data Signal Modulator (DSM):
 - Multiplex two carrier clocks, with glitch prevention feature
 - Multiple sources for each carrier
- Programmable CRC with Memory Scan:
 - Reliable data/program memory monitoring for Fail-Safe operation (e.g., Class B)

- Calculate 32-bit CRC over any portion of Program Flash Memory
- Three UART modules:
 - One module (UART1) supports LIN master and slave, DMX mode, DALI gear and device protocols
 - Asynchronous UART, RS-232, RS-485 compatible
 - Automatic and user timed BREAK period generation
 - Automatic checksums
 - Programmable 1, 1.5, and two Stop bits
 - Wake-up on BREAK reception
 - DMA compatible
- Two SPI modules:
 - Configurable length bytes
 - Arbitrary length data packets
 - Transmit-without-receive and receive-without-transmit option
 - Transfer byte counter
 - Separate transmit and receive buffers with 2-byte FIFO and DMA capabilities
- One I²C module, SMBus, PMBus™ Compatible:
 - 7-bit and 10-bit addressing modes with address masking modes
 - Dedicated address, transmit and receive buffers and DMA capabilities
 - Bus collision detection with arbitration
 - Bus time-out detection and handling
 - I²C, SMBus 2.0 and SMBus 3.0, and 1.8V input level selections
 - Multi-Master mode, including self-addressing
- Device I/O Port Features:
 - 12 I/O pins (PIC18F04/05/06Q41)
 - 18 I/O pins (PIC18F14/15/16Q41)
 - Individually programmable I/O direction, open-drain, slew rate and weak pull-up control
 - Interrupt-on-change on most pins
 - Three programmable external interrupt pins
- Peripheral Pin Select (PPS):
 - Enables pin mapping of digital I/O

Analog Peripherals

- Analog-to-Digital Converter with Computation (ADCC):
 - Up to 17 external channels
 - Up to 140 KSPS
 - Automated math functions on input signals:
 - Averaging, filter calculations, oversampling and threshold comparison
 - Operates in Sleep
 - Four internal analog channels
 - Hardware Capacitive Voltage Divider (CVD) Support:
 - Adjustable sample and hold capacitor array
 - Guard ring digital output drive
 - Automates touch sampling and reduces software size and CPU usage when touch or proximity sensing is required
- Two 8-Bit Digital-to-Analog Converters (DAC):
 - Buffered output available on two I/O pins
 - Internal connections to ADC and Comparators
- Two Comparators (CMP):
 - Four external inputs

- Configurable output polarity
 - External output via Peripheral Pin Select
- One Operational Amplifier:
 - 6 MHz Gain Bandwidth
 - Programmable Gain
 - Internal Gain Resistor Ladder
- Zero-Cross Detect (ZCD):
 - Detect when AC signal on pin crosses ground
- Voltage Reference:
 - Fixed Voltage Reference with 1.024V, 2.048V and 4.096V output levels
 - Internal connections to ADC, Comparator and DAC

Clocking Structure

- High-Precision Internal Oscillator Block (HFINTOSC):
 - Selectable frequencies up to 64 MHz
 - $\pm 1\%$ at calibration
 - Active Clock Tuning of HFINTOSC for better accuracy
- 32 kHz Low-Power Internal Oscillator (LFINTOSC)
- External 32 kHz Crystal Oscillator (SOSC)
- External High-Frequency Oscillator Block:
 - Three crystal/resonator modes
 - Digital Clock Input mode
 - 4x PLL with external sources
- Fail-Safe Clock Monitor:
 - Allows for operational recovery if external clock stops
- Oscillator Start-up Timer (OST):
 - Ensures stability of crystal oscillator sources

Programming/Debug Features

- In-Circuit Serial Programming™ (ICSP™) via Two Pins
- In-Circuit Debug (ICD) with Three Breakpoints via Two Pins
- Debug Integrated On-Chip

Table of Contents

Introduction.....	1
PIC18-Q41 Family Types.....	1
Features.....	2
Memory.....	2
Operating Characteristics.....	2
Power-Saving Functionality.....	3
Digital Peripherals.....	3
Analog Peripherals.....	4
Clocking Structure.....	5
Programming/Debug Features.....	5
1. Packages.....	7
2. Pin Diagrams.....	8
3. Pin Allocation Tables.....	9
The Microchip Website.....	13
Product Change Notification Service.....	13
Customer Support.....	13
Microchip Devices Code Protection Feature.....	13
Legal Notice.....	13
Trademarks.....	14
Quality Management System.....	14
Worldwide Sales and Service.....	15

Packages

Table 2. Packages

Device	14-Pin TSSOP	14-Pin SOIC	20-Pin PDIP	20-Pin SOIC	20-Pin SSOP	20-Pin VQFN
PIC18F04Q41	•	•				
PIC18F05Q41	•	•				
PIC18F06Q41	•	•				
PIC18F14Q41			•	•	•	•
PIC18F15Q41			•	•	•	•
PIC18F16Q41			•	•	•	•

Pin Diagrams

Figure 1.

14-Pin SOIC

14-Pin TSSOP

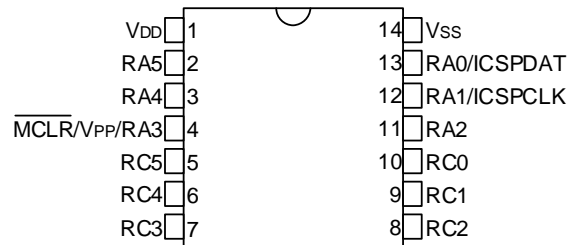


Figure 2.

20-Pin PDIP

20-Pin SOIC

20-Pin SSOP

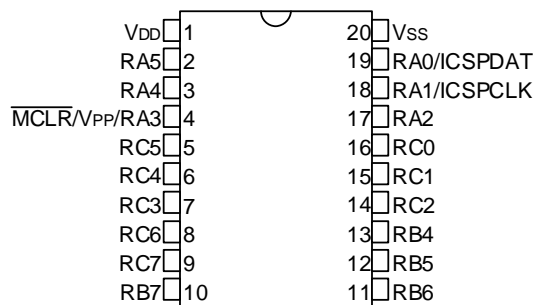
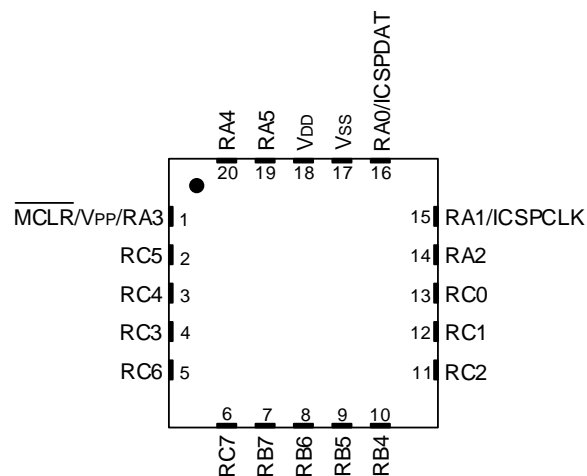


Figure 3.

20-Pin VQFN



Note: It is recommended that the exposed bottom pad be connected to V_{SS} , however, it must not be the only V_{SS} connection to the device.

Pin Allocation Tables

Table 3. 14-Pin Allocation Table

I/O	14-Pin SOIC/ICSSOP	A/D	Reference	Operational Amplifier	Comparator	ZCD	Timers/SMT	16-Bit PWM/CCP	CWG	CLC	SPI	I ² C	UART	DSM	IOC	Interrupts	Basic
RA0	13	ANA0	DAC1OUT1	OPA1IN3+ OPA1IN3-	C1IN0+	—	—	—	—	—	SS2(1)	—	—	—	IOCA0	—	ICDDAT ICSPDAT
RA1	12	ANA1	VREF+ (ADC) VREF+ (DAC1) VREF+ (DAC2)	—	C1IN0- C2IN0-	—	—	—	—	—	—	—	—	MDSRC(1)	IOCA1	—	ICDCLK ICSPCLK
RA2	11	ANA2	VREF- (ADC) VREF- (DAC1) VREF- (DAC2) DAC1OUT2	OPA1IN2+ OPA1IN2-	—	ZCDIN	T0CKI(1)	—	CWGIN(1)	—	—	—	—	—	IOCA2	INT0(1)	—
RA3	4	—	—	—	—	—	—	—	—	—	—	—	—	—	IOCA3	—	MCLR VPP
RA4	3	ANA4	—	—	—	—	T1G(1)	—	—	CLCIN3(1)	—	—	RX3(1)	—	IOCA4	INT1(1)	CLKOUT SOSCO OSC2
RA5	2	ANA5	—	—	—	—	T1CKI(1) T2IN(1) SMT1WIN(1)	PWM1ERS(1)	—	—	—	—	CTS3(1)	—	IOCA5	INT2(1)	CLKIN SOSCI OSC1
RC0	10	ANC0	—	OPA1IN0+	C2IN0+	—	SMT1SIG(1)	—	—	—	SCK1(1)	SCL1(3,4)	—	—	IOCC0	—	—
RC1	9	ANC1	—	OPA1IN0-	C1IN1- C2IN1-	—	T4IN(1)	PWM2ERS(1)	—	CLCIN2(1)	SDI1(1)	SDA1(3,4)	RX2(1)	—	IOCC1	—	—
RC2	8	ANC2 ADACT(1)	—	OPA1OUT	C1IN2- C2IN2-	—	—	PWM3ERS(1)	—	—	—	—	CTS2(1)	MDCARL(1)	IOCC2	—	—
RC3	7	ANC3	—	OPA1IN1+ OPA1IN1-	C1IN3- C2IN3-	—	—	PWMIN2(1)	—	CLCIN0(1)	SS1(1)	—	—	—	IOCC3	—	—
RC4	6	ANC4	—	—	—	—	T3G(1)	—	—	CLCIN1(1)	SCK2(1)	—	CTS1(1)	—	IOCC4	—	—
RC5	5	ANC5	—	—	—	—	T3CKI(1)	CCP1IN(1) PWMIN1(1)	—	—	SDI2(1)	—	RX1(1)	MDCARH(1)	IOCC5	—	—
VDD	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	VDD
VSS	14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	VSS

.....continued

I/O	14-Pin SOLIC/SSOP	A/D	Reference	Operational Amplifier	Comparator	ZCD	Timers/SMT	16-Bit PWM/CCP	CWG	CLC	SPI	I ² C	UART	DSM	IOC	Interrupts	Basic
OUT(2)	—	ADCGRDA ADCGRDB	—	C1OUT C2OUT	—	—	TMR0	PWM11 PWM12 PWM21 PWM22 PWM31 PWM32 CCP1	CWG1A CWG1B CWG1C CWG1D	CLC1OUT CLC2OUT CLC3OUT CLC4OUT	SS1 SCK1 SD01 SS2 SCK2 SDO2	SDA1 SCL1	DTR1 RTS1 TX1 DTR2 RTS2 TX2 DTR3 RTS3 TX3	DSM1	—	—	—

Note:

1. This is a PPS re-mappable input signal. The input function may be moved from the default location shown to one of several other PORTx pins.
2. All digital output signals shown in these rows are PPS re-mappable. These signals may be mapped to output onto one of several PORTx pin options.
3. This is a bidirectional signal. For normal module operation, the firmware should map this signal to the same pin in both the PPS input and PPS output registers.
4. These pins are configured for I²C logic levels; The SCLx/SDAx signals may be assigned to any of these pins. PPS assignments to the other pins (e.g., RB1) will operate, but input logic levels will be standard TTL/ST as selected by the INLVL register, instead of the I²C specific or SMBus input buffer thresholds.
5. A 0.1 uF bypass capacitor to V_{SS} is required on the V_{DD} pin.

Table 4. 20-Pin Allocation Table

I/O	20-Pin PDIP/SOIC/TSSOP	20-Pin VQFN	A/D	Reference	Operational Amplifier	Comparator	ZCD	Timers/SMT	16-Bit PWM/CCP	CWG	CLC	SPI	I ² C	UART	DSM	IOC	Interrupts	Basic
RA0	19	16	ANA0	DAC1OUT1	OPA1IN3+ OPA1IN3-	C1IN0+	—	—	—	—	—	—	—	—	—	IOCA0	—	ICDDAT ICSPDAT
RA1	18	15	ANA1	VREF+ (ADC) VREF+ (DAC1) VREF+ (DAC2)	—	C1IN0- C2IN0-	—	—	—	—	—	SS2(1)	—	—	MDSRC(1)	IOCA1	—	ICDCLK ICSPCLK
RA2	17	14	ANA2	VREF- (ADC) VREF- (DAC1) VREF- (DAC2) DAC1OUT2	OPA1IN2+ OPA1IN2-	—	ZCDIN	—	—	CWGIN(1)	CLCIN0(1)	—	—	—	—	IOCA2	—	—
RA3	4	1	—	—	—	—	—	—	—	—	—	—	—	—	—	IOCA3	—	MCLR Vpp
RA4	3	20	ANA4	—	—	—	—	T1G(1) SMT1SIG(1)	—	—	—	—	—	—	—	IOCA4	—	CLKOUT SOSCO OSC2
RA5	2	19	ANA5	—	—	—	—	T2IN(1) SMT1WIN(1)	PWM1ERS(1)	—	—	—	—	—	—	IOCA5	—	CLKIN SOSCI OSC1
RB4	13	10	ANB4	—	OPA1IN0-	—	—	—	—	—	CLCIN2(1)	SDI1(1)	SDA1(3,4)	—	—	IOCB4	—	—
RB5	12	9	ANB5	—	OPA1IN0+	—	—	—	—	—	CLCIN3(1)	SDI2(1)	—	RX1(1)	—	IOCB5	—	—
RB6	11	8	ANB6	—	—	—	—	—	—	—	—	SCK1(1)	SCL1(3,4)	—	—	IOCB6	—	—
RB7	10	7	ANB7	—	—	—	—	—	—	—	—	SCK2(1)	—	CTS1(1)	—	IOCB7	—	—
RC0	16	13	ANC0	—	—	C2IN0+	—	—	—	—	—	—	—	—	—	IOCC0	INT0(1)	—
RC1	15	12	ANC1	—	—	C1IN1- C2IN1-	—	T4IN(1)	PWM2ERS(1)	—	—	—	—	—	—	IOCC1	INT1(1)	—
RC2	14	11	ANC2 ADACT(1)	—	OPA1OUT	C1IN2- C2IN2-	—	—	PWM3ERS(1)	—	—	—	—	—	—	IOCC2	INT2(1)	—
RC3	7	4	ANC3	—	OPA1IN1+ OPA1IN1-	C1IN3- C2IN3-	—	—	PWMIN2(1)	—	CLCIN1(1)	—	—	—	—	IOCC3	—	—
RC4	6	3	ANC4	—	—	—	—	T3G(1)	—	—	—	—	—	—	—	IOCC4	—	—
RC5	5	2	ANC5	—	—	—	—	T3CKI(1) T0CKI(1)	CCP1IN(1) PWMIN1(1)	—	—	—	—	—	—	IOCC5	—	—
RC6	8	5	ANC6	—	—	—	—	T1CKI(1)	—	—	—	—	—	—	—	IOCC6	—	—
RC7	9	6	ANC7	—	—	—	—	—	—	—	—	—	—	—	—	IOCC7	—	—
VDD	1	18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	VDD
VSS	20	17	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	VSS

.....continued

I/O	20-Pin PDIP/SOIC/TSSOP	20-Pin VQFN	A/D	Reference	Operational Amplifier	Comparator	ZCD	Timers/SMT	16-Bit PWM/CCP	CWG	CLC	SPI	I ² C	UART	DSM	IOC	Interrupts	Basic
OUT(2)	—	—	ADCGRDA ADCGRDB	—	C1OUT C2OUT	—	—	TMR0	PWM11 PWM12 PWM21 PWM22 PWM31 PWM32 CCP1	CWG1A CWG1B CWG1C CWG1D	CLC1OUT CLC2OUT CLC3OUT CLC4OUT	SS1 SCK1 SD01 SS2 SCK2 SDO2	SDA1 SCL1	DTR1 RTS1 TX1 DTR2 RTS2 TX2 DTR3 RTS3 TX3	DSM1	—	—	—

Note:

1. This is a PPS re-mappable input signal. The input function may be moved from the default location shown to one of several other PORTx pins.
2. All digital output signals shown in these rows are PPS re-mappable. These signals may be mapped to output onto one of several PORTx pin options.
3. This is a bidirectional signal. For normal module operation, the firmware should map this signal to the same pin in both the PPS input and PPS output registers.
4. These pins are configured for I²C logic levels; The SCLx/SDAx signals may be assigned to any of these pins. PPS assignments to the other pins (e.g., RB1) will operate, but input logic levels will be standard TTL/ST as selected by the INLVL register, instead of the I²C specific or SMBus input buffer thresholds.
5. A 0.1 uF bypass capacitor to V_{SS} is required on the V_{DD} pin.

The Microchip Website

Microchip provides online support via our website at <http://www.microchip.com/>. This website is used to make files and information easily available to customers. Some of the content available includes:

- **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 (FAQs), technical support requests, online discussion groups, Microchip design partner 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

Product Change Notification Service

Microchip's product change notification service helps keep customers current on Microchip products. Subscribers will receive email notification whenever there are changes, updates, revisions or errata related to a specified product family or development tool of interest.

To register, go to <http://www.microchip.com/pcn> and follow the registration instructions.

Customer Support

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Embedded Solutions Engineer (ESE)
- Technical Support

Customers should contact their distributor, representative or ESE for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in this document.

Technical support is available through the website 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, Adaptec, AnyRate, AVR, AVR logo, AVR Freaks, BesTime, BitCloud, chipKIT, chipKIT logo, CryptoMemory, CryptoRF, dsPIC, FlashFlex, flexPWR, HELDO, IGLOO, JukeBlox, KeeLoq, Kleer, LANCheck, LinkMD, maXStylus, maXTouch, MediaLB, megaAVR, Microsemi, Microsemi logo, MOST, MOST logo, MPLAB, OptoLyzer, PackeTime, PIC, picoPower, PICSTART, PIC32 logo, PolarFire, Prochip Designer, QTouch, SAM-BA, SenGenuity, SpyNIC, SST, SST Logo, SuperFlash, Symmetricom, SyncServer, Tachyon, TempTrackr, TimeSource, tinyAVR, UNI/O, Vectron, and XMEGA are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

APT, ClockWorks, The Embedded Control Solutions Company, EtherSynch, FlashTec, Hyper Speed Control, HyperLight Load, IntelliMOS, Libero, motorBench, mTouch, Powermite 3, Precision Edge, ProASIC, ProASIC Plus, ProASIC Plus logo, Quiet-Wire, SmartFusion, SyncWorld, Temux, TimeCesium, TimeHub, TimePictra, TimeProvider, Vite, WinPath, and ZL 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, BlueSky, 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, KleerNet, KleerNet logo, memBrain, Mindi, MiWi, 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.

The Adaptec logo, Frequency on Demand, Silicon Storage Technology, and Symmcom are registered trademarks 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.

© 2020, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

ISBN: 978-1-5224-5688-9

Quality Management System

For information regarding Microchip's Quality Management Systems, please visit <http://www.microchip.com/quality>.

Worldwide Sales and Service

AMERICAS	ASIA/PACIFIC	ASIA/PACIFIC	EUROPE
<p>Corporate Office 2355 West Chandler Blvd. Chandler, AZ 85224-6199 Tel: 480-792-7200 Tel: 480-792-7277 Technical Support: http://www.microchip.com/support Web Address: http://www.microchip.com</p> <p>Atlanta Duluth, GA Tel: 678-957-9614 Fax: 678-957-1455</p> <p>Austin, TX Tel: 512-257-3370</p> <p>Boston Westborough, MA Tel: 774-760-0087 Fax: 774-760-0088</p> <p>Chicago Itasca, IL Tel: 630-285-0071 Fax: 630-285-0075</p> <p>Dallas Addison, TX Tel: 972-818-7423 Fax: 972-818-2924</p> <p>Detroit Novi, MI Tel: 248-848-4000</p> <p>Houston, TX Tel: 281-894-5983</p> <p>Indianapolis Noblesville, IN Tel: 317-773-8323 Fax: 317-773-5453 Tel: 317-536-2380</p> <p>Los Angeles Mission Viejo, CA Tel: 949-462-9523 Fax: 949-462-9608 Tel: 951-273-7800</p> <p>Raleigh, NC Tel: 919-844-7510</p> <p>New York, NY Tel: 631-435-6000</p> <p>San Jose, CA Tel: 408-735-9110 Tel: 408-436-4270</p> <p>Canada - Toronto Tel: 905-695-1980 Fax: 905-695-2078</p>	<p>Australia - Sydney Tel: 61-2-9868-6733</p> <p>China - Beijing Tel: 86-10-8569-7000</p> <p>China - Chengdu Tel: 86-28-8665-5511</p> <p>China - Chongqing Tel: 86-23-8980-9588</p> <p>China - Dongguan Tel: 86-769-8702-9880</p> <p>China - Guangzhou Tel: 86-20-8755-8029</p> <p>China - Hangzhou Tel: 86-571-8792-8115</p> <p>China - Hong Kong SAR Tel: 852-2943-5100</p> <p>China - Nanjing Tel: 86-25-8473-2460</p> <p>China - Qingdao Tel: 86-532-8502-7355</p> <p>China - Shanghai Tel: 86-21-3326-8000</p> <p>China - Shenyang Tel: 86-24-2334-2829</p> <p>China - Shenzhen Tel: 86-755-8864-2200</p> <p>China - Suzhou Tel: 86-186-6233-1526</p> <p>China - Wuhan Tel: 86-27-5980-5300</p> <p>China - Xian Tel: 86-29-8833-7252</p> <p>China - Xiamen Tel: 86-592-2388138</p> <p>China - Zhuhai Tel: 86-756-3210040</p>	<p>India - Bangalore Tel: 91-80-3090-4444</p> <p>India - New Delhi Tel: 91-11-4160-8631</p> <p>India - Pune Tel: 91-20-4121-0141</p> <p>Japan - Osaka Tel: 81-6-6152-7160</p> <p>Japan - Tokyo Tel: 81-3-6880-3770</p> <p>Korea - Daegu Tel: 82-53-744-4301</p> <p>Korea - Seoul Tel: 82-2-554-7200</p> <p>Malaysia - Kuala Lumpur Tel: 60-3-7651-7906</p> <p>Malaysia - Penang Tel: 60-4-227-8870</p> <p>Philippines - Manila Tel: 63-2-634-9065</p> <p>Singapore Tel: 65-6334-8870</p> <p>Taiwan - Hsin Chu Tel: 886-3-577-8366</p> <p>Taiwan - Kaohsiung Tel: 886-7-213-7830</p> <p>Taiwan - Taipei Tel: 886-2-2508-8600</p> <p>Thailand - Bangkok Tel: 66-2-694-1351</p> <p>Vietnam - Ho Chi Minh Tel: 84-28-5448-2100</p>	<p>Austria - Wels Tel: 43-7242-2244-39 Fax: 43-7242-2244-393</p> <p>Denmark - Copenhagen Tel: 45-4450-2828 Fax: 45-4485-2829</p> <p>Finland - Espoo Tel: 358-9-4520-820</p> <p>France - Paris Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79</p> <p>Germany - Garching Tel: 49-8931-9700</p> <p>Germany - Haan Tel: 49-2129-3766400</p> <p>Germany - Heilbronn Tel: 49-7131-72400</p> <p>Germany - Karlsruhe Tel: 49-721-625370</p> <p>Germany - Munich Tel: 49-89-627-144-0 Fax: 49-89-627-144-44</p> <p>Germany - Rosenheim Tel: 49-8031-354-560</p> <p>Israel - Ra'anana Tel: 972-9-744-7705</p> <p>Italy - Milan Tel: 39-0331-742611 Fax: 39-0331-466781</p> <p>Italy - Padova Tel: 39-049-7625286</p> <p>Netherlands - Drunen Tel: 31-416-690399 Fax: 31-416-690340</p> <p>Norway - Trondheim Tel: 47-72884388</p> <p>Poland - Warsaw Tel: 48-22-3325737</p> <p>Romania - Bucharest Tel: 40-21-407-87-50</p> <p>Spain - Madrid Tel: 34-91-708-08-90 Fax: 34-91-708-08-91</p> <p>Sweden - Gothenberg Tel: 46-31-704-60-40</p> <p>Sweden - Stockholm Tel: 46-8-5090-4654</p> <p>UK - Wokingham Tel: 44-118-921-5800 Fax: 44-118-921-5820</p>