



F1 Evaluation Platform for Enhanced PIC[®] Microcontrollers User's Guide

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in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates.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.

Trademarks

The Microchip name and logo, the Microchip logo, dsPIC, KEELOQ, KEELOQ logo, MPLAB, PIC, PICmicro, PICSTART, PIC³² logo, rfPIC and UNI/O are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

FilterLab, Hampshire, HI-TECH C, Linear Active Thermistor, MXDEV, MXLAB, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Analog-for-the-Digital Age, Application Maestro, CodeGuard, dsPICDEM, dsPICDEM.net, dsPICworks, dsSPEAK, ECAN, ECONOMONITOR, FanSense, HI-TIDE, In-Circuit Serial Programming, ICSP, Mindi, MiWi, MPASM, MPLAB Certified logo, MPLIB, MPLINK, mTouch, Omniscient Code Generation, PICC, PICC-18, PICDEM, PICDEM.net, PICKit, PICtail, REAL ICE, rfLAB, Select Mode, Total Endurance, TSHARC, UniWinDriver, WiperLock 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.

All other trademarks mentioned herein are property of their respective companies.

© 2010, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

 Printed on recycled paper.

ISBN: 978-1-60932-512-1

Microchip received ISO/TS-16949:2002 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.

QUALITY MANAGEMENT SYSTEM
CERTIFIED BY DNV
== ISO/TS 16949:2002 ==

Table of Contents

Preface	5
Chapter 1. F1 Evaluation Platform Overview	
1.1 Introduction	11
1.2 Platform Contents	11
1.3 Hardware Features	11
Chapter 2. Getting Started	
2.1 Introduction	13
2.2 Powering the F1 Evaluation Platform	13
2.3 Powering with PICkit™ 3	13
2.4 Powering with the Connector at JP3	14
2.5 Powering with PICkit™ Serial	14
2.6 Powering with the BLDC Expansion Header J3	15
2.7 Default Firmware	15
Chapter 3. Programming the F1 Evaluation Platform	
3.1 Introduction	17
3.2 Programming/Development Tool Support	17
3.3 Hardware Resources	18
Chapter 4. Demo Code	
4.1 Introduction	19
4.2 I ² C™ Demo	19
4.3 LCD Demo	19
4.4 BLDC Demo	19
4.5 Combined Demo	19
Chapter 5. Hardware Libraries and Drivers	
5.1 Introduction	21
5.2 I ² C™ Driver	21
5.3 MCP9800 Driver	21
5.4 RTCC Driver	21
5.5 LCD Driver	21
5.6 Using the I ² C™ Driver	22
5.7 Using the LCD driver	24
5.8 Using the RTCC Driver	26
5.9 Using the MCP9800 Driver	27
Chapter 6. Troubleshooting	
6.1 Introduction	29
6.2 Common Problems	29

F1 Evaluation Platform User’s Guide

Chapter 7. Schematics	
7.1 Introduction	31
Index	39
Worldwide Sales and Service	42

Preface

NOTICE TO CUSTOMERS

All documentation becomes dated, and this manual is no exception. Microchip tools and documentation are constantly evolving to meet customer needs, so some actual dialogs and/or tool descriptions may differ from those in this document. Please refer to our web site (www.microchip.com) to obtain the latest documentation available.

Documents are identified with a “DS” number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is “DSXXXXA”, where “XXXX” is the document number and “A” is the revision level of the document.

For the most up-to-date information on development tools, see the MPLAB® IDE online help. Select the Help menu, and then Topics to open a list of available online help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using the F1 Evaluation Platform User's Guide. Items discussed in this chapter include:

- Document Layout
- Conventions Used in this Guide
- Warranty Registration
- Recommended Reading
- The Microchip Web Site
- Development Systems Customer Change Notification Service
- Customer Support
- Document Revision History

DOCUMENT LAYOUT

This document describes how to use the F1 Evaluation Platform User's Guide as a development tool to emulate and debug firmware on a target board. The manual layout is as follows:

- **Chapter 1. “F1 Evaluation Platform Overview”**
- **Chapter 2. “Getting Started”**
- **Chapter 3. “Programming the F1 Evaluation Platform”**
- **Chapter 4. “Demo Code”**
- **Chapter 5. “Hardware Libraries and Drivers”**
- **Chapter 6. “Troubleshooting”**
- **Chapter 7. “Schematics”**

F1 Evaluation Platform User's Guide

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

Description	Represents	Examples
Arial font:		
Italic characters	Referenced books	<i>MPLAB[®] IDE User's Guide</i>
	Emphasized text	...is the <i>only</i> compiler...
Initial caps	A window	the Output window
	A dialog	the Settings dialog
	A menu selection	select Enable Programmer
Quotes	A field name in a window or dialog	"Save project before build"
Underlined, italic text with right angle bracket	A menu path	<u><i>File>Save</i></u>
Bold characters	A dialog button	Click OK
	A tab	Click the Power tab
N'Rnnnn	A number in verilog format, where N is the total number of digits, R is the radix and n is a digit.	4'b0010, 2'hF1
Text in angle brackets < >	A key on the keyboard	Press <Enter>, <F1>
Courier New font:		
Plain Courier New	Sample source code	#define START
	Filenames	autoexec.bat
	File paths	c:\mcc18\h
	Keywords	_asm, _endasm, static
	Command-line options	-Opa+, -Opa-
	Bit values	0, 1
	Constants	0xFF, 'A'
Italic Courier New	A variable argument	<i>file.o</i> , where <i>file</i> can be any valid filename
Square brackets []	Optional arguments	mcc18 [options] <i>file</i> [options]
Curly brackets and pipe character: { }	Choice of mutually exclusive arguments; an OR selection	errorlevel {0 1}
Ellipses...	Replaces repeated text	var_name [, var_name...]
	Represents code supplied by user	void main (void) { ... }

WARRANTY REGISTRATION

Please complete the enclosed Warranty Registration Card and mail it promptly. Sending in the Warranty Registration Card entitles users to receive new product updates. Interim software releases are available at the Microchip web site.

RECOMMENDED READING

This user's guide describes how to use the F1 Evaluation Platform. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

Readme for F1 Evaluation Platform User's Guide

For the latest information on using F1 Evaluation Platform User's Guide, read the "Readme for F1 Evaluation Platform User's Guide.txt" file (an ASCII text file) in the Readmes subdirectory of the MPLAB IDE installation directory. The Readme file contains update information and known issues that may not be included in this user's guide.

Readme Files

For the latest information on using other tools, read the tool-specific Readme files in the Readmes subdirectory of the MPLAB IDE installation directory. The Readme files contain update information and known issues that may not be included in this user's guide.

F1 Evaluation Platform User's Guide

THE MICROCHIP WEB SITE

Microchip provides online support via our web site at www.microchip.com. This web site is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the web site contains the following information:

- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQs), 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

DEVELOPMENT SYSTEMS CUSTOMER CHANGE NOTIFICATION SERVICE

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

To register, access the Microchip web site at www.microchip.com, click on Customer Change Notification and follow the registration instructions.

The Development Systems product group categories are:

- **Compilers** – The latest information on Microchip C compilers and other language tools. These include the Hitech C16, MPLAB C18 and MPLAB C30 C compilers; MPASM™ and MPLAB ASM30 assemblers; MPLINK™ and MPLAB LINK30 object linkers; and MPLIB™ and MPLAB LIB30 object librarians.
- **In-Circuit Debuggers** – The latest information on the Microchip in-circuit debugger, MPLAB ICD 2, ICD3, PICKit™ 3.
- **MPLAB® IDE** – The latest information on Microchip MPLAB IDE, the Windows® Integrated Development Environment for development systems tools. This list is focused on the MPLAB IDE, MPLAB SIM simulator, MPLAB IDE Project Manager and general editing and debugging features.
- **Programmers** – The latest information on Microchip programmers. These include the MPLAB PM3 device programmers and PICKit™ 3 development programmers.

CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or field application engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the web site at: <http://support.microchip.com>

DOCUMENT REVISION HISTORY

Revision A (October 2009)

- Initial Release of this Document.

Revision B (September 2010)

- Revised Figures 7.1.4, 7.1.5 and 7.1.6

F1 Evaluation Platform User's Guide

NOTES:

Chapter 1. F1 Evaluation Platform Overview

1.1 INTRODUCTION

Thank you for choosing the F1 Evaluation Platform. This kit allows you to begin development using the PIC16LF1937 microcontroller (MCU).

The PIC16LF1937 is the first in a family of enhanced mid-range microcontrollers. These architectural enhancements allow for more memory and faster computation than that of legacy PIC16 microcontrollers.

The PIC16F1 and PIC12F1 family of microcontrollers are a series of 8-bit microcontrollers derived from the popular PIC16 series of 8-bit PIC[®] microcontrollers. The F1 derivatives feature an enhanced CPU, support for extended amounts of memory, improved peripherals, and XLP low power. The F1 Evaluation Platform allows you to evaluate these features for your application in a simple, low-cost platform.

This chapter introduces the F1 Evaluation Platform:

- Platform Contents
- Hardware Features

1.2 PLATFORM CONTENTS

The F1 Evaluation Platform contains the following items:

1. F1 Evaluation Platform Demo Board – www.microchip.com/F1Eval

1.3 HARDWARE FEATURES

The F1 Evaluation Platform has the following hardware features:

1.3.1 PIC16LF1937

The PIC16LF1937 is a 40-pin full-featured device, including:

1. Enhanced PIC16 instruction set
2. 8K Words of Flash memory
3. 512 bytes of RAM
4. 256 bytes of EEPROM
5. 2 CCPs and 3 enhanced CCPs
6. MSSP (I²C[™], SPI)
7. Enhanced USART
8. 8- and 16-bit timers
9. 32 MHz internal oscillator
10. Low-power 32 kHz crystal oscillator and
11. LCD controller.

1.3.2 MCP9800 I²C Temperature Sensor

The MCP9800 is a low-power, I²C temperature sensor with selectable 9 to 12 bits of output resolution.

1.3.3 PICkit™ 3 Programming/Debug Header

The PICkit 3 is a low-cost development tool that allows programming and debugging of the PIC16LF1937 MCU using the PICkit ISCP™ header.

1.3.4 PICkit Serial Communications Header

The PICkit serial is a low-cost development tool that allows I²C, SPI and USART protocols to be monitored and debugged through a simple 6-pin connector.

1.3.5 1 Button, 1 Potentiometer, 4 LEDs

Simple applications need the basic user interface elements. The button, potentiometer and 1 LED are available for any application. The remaining 3 LEDs are shared with the 20-bit motor control expansion connector.

1.3.6 One 3.5 Digit LCD

The 3.5-digit LCD glass supplied on this board is a typical meter-type display with icons for ohms, amps, etc. The PIC16LF1937 makes controlling the LCD very simple.

1.3.7 20-pin Motor Control Expansion Connector

This connector allows the PIC16LF1937 to control an optional Sensorless BLDC add-on board (DM164130-2). The PIC16LF1937 has complete control of 3 phases so other 1, 2, or 3-phase motor topologies can also be controlled.

1.3.8 Current Monitoring Connector

To demonstrate the Extreme Low Power (XLP) features of the PIC16LF1937, a precision ammeter can be connected to the current monitoring connector. This allows your application to be easily optimized for the lowest possible current.

1.3.9 Generous Prototyping Area

Our circuits are not your circuits. A prototyping area has been provided to extend the functionality of this demo board to demonstrate the utility of the PIC16LF1937 in your application.

Chapter 2. Getting Started

2.1 INTRODUCTION

This chapter gives instruction to get your F1 Evaluation Platform powered up and running the default demonstration. The following sections include:

- Powering the F1 Evaluation Platform
- Default Firmware
- Programming the F1 Evaluation Platform with the PICKit™ 3
- Attaching a PICKit Serial (optional)
- Measuring the current consumption

FIGURE 2-1: F1 EVALUATION PLATFORM (DM164130-1)



2.2 POWERING THE F1 EVALUATION PLATFORM

The PIC16LF1937 supplied with your F1 Evaluation Platform requires a supply voltage of 1.8V-3.6V. Voltages above 3.6V will degrade or damage the device. There are four ways to supply the necessary power.

1. Use PICKit 3,
2. Use the power connector at JP3,
3. Use PICKit Serial, or
4. Use the BLDC Expansion Header J3.

2.3 POWERING WITH PICKit™ 3

To power with the PICKit 3, perform the following steps:

1. Make sure a jumper or an ammeter is connected across JP2.
2. If you are using a BLDC expansion, remove the jumper at JP1.

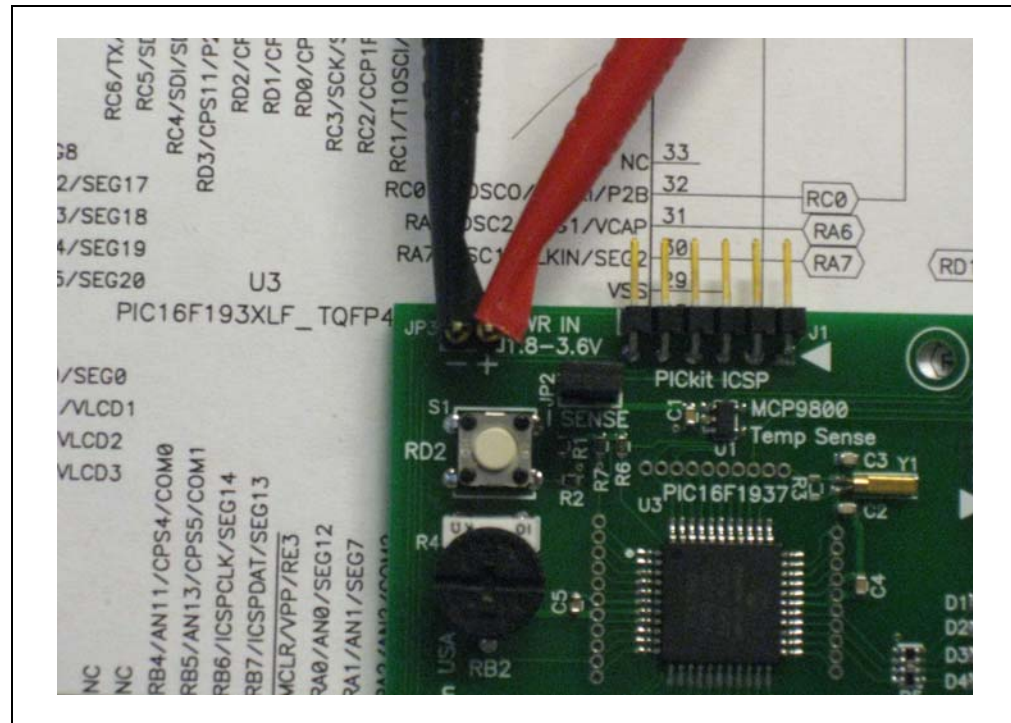
3. Configure the PICKit 3 to supply a voltage between 1.8 and 3.6V. For proper LCD contrast, the supply should be 3.3V.
4. Attach the PICKit 3 to the PICKit ICSP™ connector at the end of the board.
5. Activate the PICKit 3 power output.

2.4 POWERING WITH THE CONNECTOR AT JP3

To power with the connector at JP3, perform the following steps:

1. Make sure a jumper or an ammeter is connected across JP2.
2. If you are using a BLDC expansion, remove the jumper at JP1.
3. Verify the supply voltage to be between 1.8 and 3.6V. For proper LCD contrast, the supply should be 3.3V.
4. Attach the power supply to JP3.
5. Turn on the power supply.

FIGURE 2-2: POWERING WITH THE CONNECTOR AT JP3



2.5 POWERING WITH PICKIT™ SERIAL

To power with the PICkit Serial, perform the following steps:

1. Make sure a jumper or an ammeter is connected across JP2.
2. If you are using a BLDC expansion, remove the jumper at JP1.
3. Configure the PICKit Serial to supply a voltage between 1.8 and 3.6V. For proper LCD contrast, the supply should be 3.3V.
4. Attach the PICKit Serial to the PICKit Serial connector at the top corner of the board.
5. Activate the PICKit Serial power output.

2.6 POWERING WITH THE BLDC EXPANSION HEADER J3

The BLDC Expansion hardware contains a 3.3V linear regulator. This allows the 5-12V motor power supply to power the PIC16LF1937. J3 pin 6 is the source for the 3.3V power. To use this power perform the following steps.

1. Make sure a jumper or an ammeter is connected across JP2.
2. Insert the shorting jumper at JP1.
3. Verify that any attached PICkit 3 or PICkit serial is not supplying power.
4. Verify that there is NO power supply or shorting jumper at JP3.
5. Attach the BLDC expansion board.
6. Connect power to the BLDC expansion board.

2.7 DEFAULT FIRMWARE

The default firmware supplied with your F1 Evaluation Board Demo performs the following functions:

1. Blink LEDs
2. Measure the ambient temperature
3. Run a BLDC motor (or try to if no motor is attached)
4. Display time/temperature/pot position/motor RPM on the LCD
5. User interface with a button and pot

For the latest firmware go to www.microchip.com/F1Eval

2.7.1 Blinking LEDs

The 4 LEDs indicate motor phase operation (D<2:4>) and the performance of the primary state machine loop (D1).

2.7.2 Measuring the Ambient Temperature

The MCP9800 is polled when in Temperature Measurement mode. The measured temperature is filtered, scaled to centigrade and displayed on the LCD.

2.7.3 BLDC Motor

One task of the demo code is to drive a BLDC motor attached to the BLDC Expansion Header. The optional BLDC Controller board (DM164130-2) is required to drive the motor. The code performs a series of forced commutation steps to attempt a sensorless motor start. If no back EMF signal is detected, the code repeats the start-up sequence. The LEDs blink at an increasing rate indicating the motor start attempts. If no motor drive hardware is attached, this pattern can repeat or it may detect a BEMF signal in the noise present on the BEMF sense inputs.

2.7.4 LCD Display

The time, temperature, pot position and motor speed are displayed on the LCD. The LCD is a 3.5-digit multimeter display with icons for amps, volts, ohms, etc. The display uses 4 commons and 10 segment drives. The Timer1 oscillator is used to clock the display peripheral and allow the LCD to display data even in Sleep. The LCD peripheral was configured for a Type B waveform for this demo. This mode provides an interrupt when the LCD can be updated. This interrupt is not required for Type A waveforms, but the extra complexity of the interrupt allows the LCD peripheral to be used to provide the real-time clock periodic interrupt. The different waveform types are described in section 21.9 of the PIC16LF193X data sheet (DS41364). Normally, the Timer1 counter would be used, but this timer is required for the BLDC software. Because the LCD is clocked from the 32.768 kHz crystal, the LCDIF operates at a multiple of the crystal frequency, providing a very accurate time base for the real-time clock.

2.7.5 User Interface

Due to the extreme simplicity of this board, only a single button and a single pot are available for user input. These two elements allow the user to cycle through the display elements, change the motor speed and change the time.

Pressing and releasing the button cycles through the 4 display modes:

1. Time
2. Temperature
3. Pot ADC value
4. RPM

Turning the pot will change the motor speed or set the time.

If the display is showing the time, and the button is held down for 3 seconds, turning the pot clockwise will increase the time, and counter clockwise will decrease the time. Placing the pot in the center of the range will leave the time unchanged. A feature that could be added as a simple programming exercise would be to allow the time change to be faster or slower depending upon pot position.

Chapter 3. Programming the F1 Evaluation Platform

3.1 INTRODUCTION

The F1 Evaluation Platform makes extensive use of the onboard peripherals of the PIC16LF1937. This chapter provides guidance concerning the tools used for programming the F1 evaluation board and a map of the board function to I/O pin and pin function.

3.2 PROGRAMMING/DEVELOPMENT TOOL SUPPORT

The following development tools support the F1 Evaluation Platform:

1. PICKit™ 3
2. PICKit™ 2
3. REAL ICE™ in-circuit emulator (with adapter AC164110)

The PICKit™ tools can also power the F1 Evaluation Platform, therefore, no additional hardware is required to get started. The ICSP™ pins of the PIC16LF1937 are dedicated to the PICKit ICSP connector, eliminating interactions between the Evaluation Platform and the programmer/debugger.

If you are developing with the REAL ICE emulator, you will need the AC164110 adaptor, or the high-speed trace adaptor. These adaptors provide the inline 6 pin connector required by the PICKit ICSP programming capability interface. You will also need a power supply, please see **Chapter 2. “Getting Started”** for more on powering the F1 Evaluation Platform.

F1 Evaluation Platform User's Guide

3.3 HARDWARE RESOURCES

TABLE 3-1:

Pin Number	Pin Name	Pin Function Used	Board Function
1	RC7	EUSART RX	PICKit™ Serial Pin 1
2	RD4	Segment 17	LCD Pin 13, S1/S2/m/M
3	RD5	CCP1 Output B	BLDC pin 5, Phase U low drive
4	RD6	CCP1 Output C	BLDC pin 9, Phase V low drive
5	RD7	Segment 20	LCD pin 14, A/V/K/Omega
6	Vss	Vss	Vss
7	Vdd	Vdd	Vdd
8	RB0	Segment 0	LCD pin 5, RC/BATT/-/AC
9	RB1	C12IN3-	BLDC pin 19, Phase V BEMF Zero Cross
10	RB2	AN8	Potentiometer
11	RB3	C12IN2-	BLDC pin 17, Phase U BEMF Zero Cross
14	RB4	COM1	LCD pin 1, Common 1
15	RB5	COM2	LCD pin 2, Common 2
16	RB6	PGC	PICKit 2 ICSP™ pin 5, PGC
17	RB7	PGD	PICKit 2 ICSP pin 4, PGD
18	MCLR	MCLR	PICKit ICSP Pin 1
19	RA0	Segment 12	LCD pin 11, 1A/1F/1E/1D
20	RA1	C12IN1-	BLDC pin 15, Phase W BEMF Zero Cross
21	RA2	COM3	LCD pin 3, Common 3
22	RA3	C1IN+	BLDC pin 16, BEMF Zero Cross Reference
23	RA4	Segment 4	LCD pin 8, 3B/3G/3C/3DP
24	RA5	Segment 5	LCD pin 9, 2A/2F/2E/2D
25	RE0	RE0	LED D4 and BLDC pin 3 Phase W high drive
26	RE1	RE1	LED D3 and BLDC pin 7 Phase U high drive
27	RE2	RE2	LED D2 and BLDC pin 11 Phase V high drive
28	Vdd	Vdd	Vdd
29	Vss	Vss	Vss
30	RA7	Segment 2	LCD pin 7, 3A/3F/3E/3D
31	RA6	Segment 1	LCD pin 6, DH/RH/B-C/4DP
32	RC0	T1OSCO	32.768 kHz Crystal Drive
35	RC1	T1OSCI	32.768 kHz Crystal Drive
36	RC2	CCP1 Output A	BLDC pin 1, Phase W low drive
37	RC3	MSSP SCLK	MCP9800 SCLK and PICKit Serial pin 5
38	RD0	Common 4	LCD pin 4, Common 4
39	RD1	RD1	LED D1
40	RD2	RD2	Button Input
41	RD3	Segment 16	LCD pin 12, 1B/1G/1C/
42	RC4	MSSP SDA	MCP9800 SDA and PICKit Serial pin 4
43	RC5	Segment 10	LCD pin 10, 2B/2G/2C/2DP
44	RC6	EUSART TX	PICKit Serial pin 6

Chapter 4. Demo Code

4.1 INTRODUCTION

The F1 Evaluation Platform demos are located at www.microchip.com/F1Eval. The following demos are available:

1. I²C™ Demo
2. LCD Demo
3. BLDC Demo
4. Combined Demo

This chapter provides an overview to the functions provided by these demos.

4.2 I²C™ DEMO

The I²C demo reads the current temperature from the on-board MCP9800 I²C temperature sensor. The I²C driver is used to extract the data. The resulting value is converted to a PWM duty cycle and used to control the brightness of the LED D4. LED D1 toggles at approximately 10 ms.

4.3 LCD DEMO

The LCD demo adds button, potentiometer, Real-Time Clock (RTC) and LCD support to the I²C demo. The 32.768 kHz crystal is activated to maintain the Real-Time Clock and to drive the LCD peripheral. An input driver is supplied to manage the button and potentiometer. A state machine now controls the major features of the demo so that the time, temperature and potentiometer value can be displayed on the LCD.

4.4 BLDC DEMO

The BLDC demo controls a sensorless, brushless DC motor connected to the PIC16F1 BLDC Expansion board (DM164130-2). Other motors can also be driven by making appropriate modifications to the motor control parameters in the source code.

Refer to application note AN1305, “*Sensorless 3-Phase Brushless Motor Control with the PIC16FXXX*” for detailed information regarding BLDC motor control.

4.5 COMBINED DEMO

The combined demo combines all the software from all the previous demos to show the power of the PIC16LF1937. In this demo, the BLDC motor is seamlessly controlled while displaying the time, temperature, potentiometer position or motor RPM/10. All drivers are reused from the previous demos. The RTCC is driven from the LCD peripheral.

The combined demo is preprogrammed in the F1 Evaluation Platform.

F1 Evaluation Platform User's Guide

NOTES:

Chapter 5. Hardware Libraries and Drivers

5.1 INTRODUCTION

All of the demo code uses a common set of libraries to provide I²C, real-time clock, MCP9800 and LCD services. These libraries may be useful for other applications so they are documented here. These drivers are located at www.microchip.com/F1Eval.

5.2 I²C™ DRIVER

The I²C driver allows I²C requests to be queued and then handled either by interrupts or by polling. The driver is configured during compilation to support polling or interrupts. The I²C and LCD demos configure the driver for interrupt mode. The Combined demo polls the I²C handler within the MCP9800 driver.

5.3 MCP9800 DRIVER

The MCP9800 driver uses the I²C driver to get the current temperature. The `mcp9800_get_temp` function is fully blocking, so once a request is queued, the driver polls the I²C subsystem until the data is complete. If the I²C driver is operating without interrupts, the `mcp9800_get_temp` function repeatedly calls the `I2C_handler` function to process all the I²C events. If the I²C driver is operating with interrupts, the `mcp9800_get_temp` function simply inserts an `I2C_TRANSACTION_T` into the I²C transaction queue and waits for the transaction to complete.

5.4 RTCC DRIVER

A software RTCC is managed by the supplied RTCC driver. This driver implements the `time()` function required by the C compiler. Time is internally kept as seconds since January 1, 1970. Standard C functions can be used to convert the time to the current date. This driver has two modes. In the first mode, it expects to be called once per second by the Timer1 interrupt. In the second mode, it expects to be called on every LCD mode B frame. This allows the RTCC to keep accurate time even if Timer1 is being used by some other function, such as the BLDC motor driver.

5.5 LCD DRIVER

The LCD driver contains the initialization code required for the LCD peripheral and the mapping code required to control the 3.5-digit LCD supplied with this demo board. It is a good starting point for the LCD driver your unique application will require.

5.6 USING THE I²C™ DRIVER

The supplied software includes an I²C Master mode driver with the following features:

1. Interrupt driven or polled
2. Queued requests
3. Minimum memory requirements
4. Uses Restart to maximize bus bandwidth
5. Multiple atomic I²C transactions allowed at each queue entry
6. Completion flag for each queued block of I²C commands.

5.6.1 I²C Data Structures

Two data structures are defined to simplify interactions with the I²C driver.

5.6.1.1 I2C_RESULTS_T

The I2C_RESULTS_T is an enumerated type with the following enumerations:

TABLE 5-1: I2C_RESULTS_T

I2C_REQUEST_PENDING	Request is in the queue or in process but it is not done.
I2C_REQUEST_COMPLETE	The request is finished successfully.
I2C_REQUEST_STUCK_START	The request was aborted. The start condition did not clear correctly.
I2C_REQUEST_ADDRESS_NO_ACK	The request was aborted. No ACK occurred on the address, so the target device must not exist or is not functioning.
I2C_REQUEST_DATA_NO_ACK	The request was aborted. Not all of the data could be sent because the device did not ACK a byte.
I2C_REQUEST_LOST_STATE	The I ² C state machine had a RAM corruption and the default case caught the failure. This will infinite loop so you should never see it.

The data completion flag for an I²C request is of type I2C_RESULTS_T. This flag will be I2C_REQUEST_PENDING until the request is complete. If the request completed without errors, the value will be I2C_REQUEST_COMPLETE. If there were errors, the value will reflect one of the other 4 error conditions.

5.6.1.2 I2C_T

The I2C_T is a structure representing one transaction on the I²C bus. A transaction contains the following elements:

1. A 7- or 10-bit address. Address type is determined automatically by the driver. R/W mode is implicit in the address and specified by bit 0.
2. An 8-bit baud rate. This is the value placed in SPADD. Predefined constants are included that compute the SPADD value given an FOSC value. Set FOSC with a #define before #including the I2C.h file.
3. A buffer_length. This is the number of bytes available for reading or writing at the supplied data buffer.
4. A Buffer Pointer. Your application will allocate a block of memory for an I²C transaction. Pass a pointer to this block via the Buffer Pointer. The block must remain valid until the transaction is complete (i.e., if you allocate the block as a non-static array within a function, you must not leave the function until the I²C transaction is complete or the array may be reused by a different function).

5.6.2 I²C Function Interface

5.6.2.1 i2c_init

The function `i2c_init` configures the I²C driver and makes it ready to receive transaction in the transaction queue.

FIGURE 5-1:

```
initialize()
{
    i2c_init(I2C_400K);
}
```

5.6.2.2 i2c_insert

The function `i2c_insert` places one complete set of Transaction Request Block (TRB's). TRBs can be bundled into an array of multiple TRBs and inserted as one large request. The driver will ensure that all the TRBs in the list will be processed sequentially with I²C restarts separating them.

FIGURE 5-2:

```
Send_data()
{
    I2C_TRANSACTION_REQUEST_BLOCK trb_list[5];
    I2C_RESULTS flag;
    ... populate the trb's ...

    i2c_insert(5, trb_list, &flag);
}
```

5.6.2.3 i2c_build_write_trb / i2c_build_read_trb

The `i2c_build_write_trb` and `i2c_build_read_trb` functions are helpers to assemble the I2C_TRANSACTION_REQUEST_BLOCKS from passed parameters.

FIGURE 5-3:

```
Send_one_byte()
{
    I2C_TRANSACTION_REQUEST_BLOCK trb_list;
    unsigned char data;
    I2C_RESULTS flag;

    data_block = .. my data byte ..

    i2c_build_write_trb(&trb_list, ADDRESS, 1, &data, i2c_200K);

    i2c_insert(1, &trb, &flag);
}
```

5.6.2.4 i2c_write_block / i2c_read_block

The `i2c_write_block` and `i2c_read_block` functions are helpers that assemble a TRB, insert it into the queue and wait for the transaction to complete.

FIGURE 5-4:

```
Send_one_byte()
{
    unsigned char data;
    i2c_write_block(ADDRESS, 1, &data, i2c_200K);
}
```

5.6.2.5 i2c_handler

The `i2c_handler` function must be called for each I²C state to be handled. This function can be placed into the Interrupt Service Routine for your application or, you can simply poll it often. If the `i2c_write_block` or `i2c_read_block` functions are used when the driver is configured for polling, then this function will repeatedly be called until the transaction completes.

FIGURE 5-5:

```
Interrupt_service_routine()
{
    i2c_handler();
}
```

5.7 USING THE LCD DRIVER

The supplied LCD driver configures the LCD module for the I/O pins used by the F1 Evaluation Platform. Icon definitions are provided to simplify the software. A BCD to 7-segment display mapping function is also provided to further simplify control of the LCD glass. For more information concerning the LCD peripheral, please consult the LCD chapter in the PIC16LF1937 data sheet (DS41364).

5.7.1 LCD Data Structures

5.7.1.1 BCD_TYPE

To simplify BCD to the 7-segment display mapping, a BCD segment data type has been provided. This data type is simply four 4-bit fields representing digits 0, 1, 2 and 3.

FIGURE 5-6:

```
typedef union
{
    UINT16 val;
    struct
    {
        unsigned digit0 : 4;
        unsigned digit1 : 4;
        unsigned digit2 : 4;
        unsigned digit3 : 4;
    };
} BCD_TYPE;
```

Simply place the number you want displayed in each digit position and call `lcd_display_digits`. Digit 3 is the Most Significant $\frac{1}{2}$ digit of the 3.5-digit LCD glass. Therefore, the largest value displayable is 1FFF assuming hexadecimal digits or 1999 for decimal digits.

5.7.2 LCD Function Interface

5.7.2.1 lcd_init

This function configures the LCD peripheral for this board and this glass. Type B waveforms are used to allow the LCD peripheral to be used for the real-time clock function. The Timer1 oscillator is configured as the LCD clock source.

FIGURE 5-7:

```
System_initialize()
{
    lcd_init();
}
```

5.7.2.2 lcd_display_digits

This function accepts a BCD_TYPE variable and maps each digit to the correct segments. Mapping the segments is done in two stages. First, the digit is converted to the correct 7-segment mapping. Then, the 7-segment mapping is converted to the actual glass segments with a long series of “if-else” statements. This function will need extensive work in the “if-else” statements for applications driving different glass.

FIGURE 5-8:

```
void display_int(int t)
{
    BCD_TYPE bcd;

    bcd.digit0 = t % 10;
    t /= 10;
    bcd.digit1 = t % 10;
    t /= 10;
    bcd.digit2 = t % 10;
    t /= 10;
    bcd.digit3 = t % 10;
    lcd_display_digits(bcd);
}
```

5.7.2.3 lcd_display_on / lcd_display_off

These two functions simply turn the LCD peripheral off. The Timer1 oscillator is left running. One use for these functions is to implement display blinking.

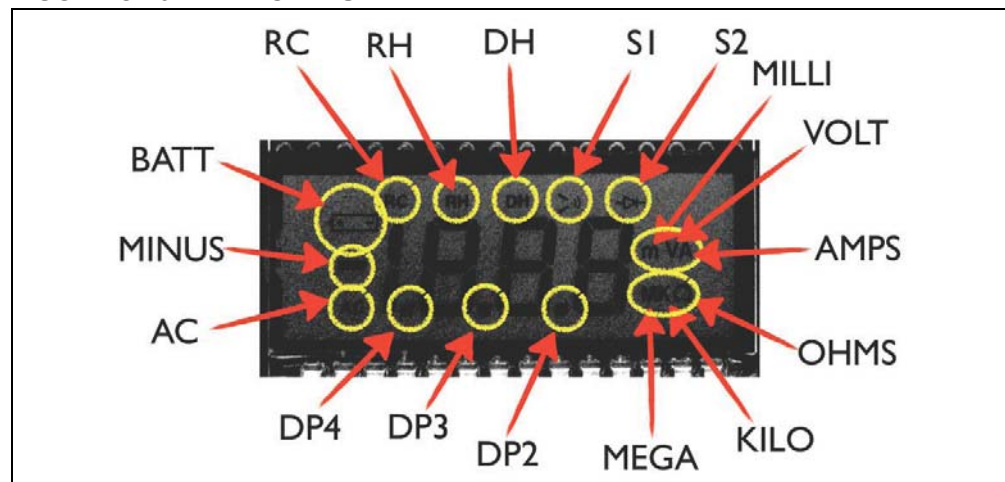
FIGURE 5-9:

```
void update_blinking()
{
    if(time(0) % 2) // if an odd number of seconds
    {
        lcd_display_on();
    }
    else
    {
        lcd_display_off();
    }
}
```

F1 Evaluation Platform User's Guide

5.7.3 LCD Segment Definitions

FIGURE 5-10: LCD DISPLAY



There are many segments present on the F1 Evaluation Platform LCD. To access these segments, simply set the supplied #defines to '1' or '0'.

FIGURE 5-11:

```
void display_volts(int v)
{
    display_int(v);
    DP3 = 0;
    DP2 = 0;
    S1 = 0;
    S2 = 0;
    AMPS = 0;
    VOLT = 1;
    KILO = 0;
    OHMS = 0;
    if (v < 0)
        MINUS = 1;
    else
        MINUS = 0;
}
```

5.8 USING THE RTCC DRIVER

The RTC driver simply keeps track of seconds. The power-up initial value is '0', however a function (`rtcc_set`) is provided to change that value. To keep the seconds up-to-date, the function, `rtcc_handler`, must be called more frequently than the defined value of `CLOCKS_PER_SECOND`. There are two options for the RTCC driver. The first option is to use the Timer1 counter to provide a 1 Hz interrupt (`CLOCKS_PER_SECOND = 1`). The second option is to use the LCD write-allowed interrupt flag to provide a 128 Hz event (`CLOCKS_PER_SECOND = 128`). The two choices are selected by defining `use_lcdif` or undefining `use_lcdif`.

5.8.1 RTCC Function Interface

5.8.1.1 `rtcc_init`

Initialize the RTCC function including Timer1, if required.

FIGURE 5-12:

```
System_initialization()
{
    rtcc_init();
}
```

5.8.1.2 rtcc_handler

The `rtcc_handler` function must be called frequently to keep the internal seconds counter accurate.

FIGURE 5-13:

```
System_interrupt_service_routine()
{
    If(TMR1IF & TMR1IE)
    {
        TMR1IF = 0;
        rtcc_handler();
    }
}
```

5.8.1.3 rtcc_set

After system initialization, the seconds counter is cleared to '0'. The standard C libraries equate 0 seconds to Midnight, Jan 1, 1970. That time has expired a long time ago, so a new time in seconds can be configured with `rtcc_set()`.

FIGURE 5-14:

```
#include <time.h>
Time_set() // set the time & date to 1 second after midnight, July 4, 2009
{
    struct tm time_str;
    time_t unix_time;
    time_str.tm_year = 2009; // the year
    time_str.tm_mon = 7;    // the month
    time_str.tm_mday = 4;   // the day of the month
    time_str.tm_hour = 0;   // the hour (0-23)
    time_str.tm_min = 0;    // the minutes
    time_str.tm_sec = 1;    // the seconds
    time_str.tm_isdst = -1; // daylight savings time modifier

    unix_time = mktime(&time_str);
    rtcc_set(unix_time);
}
```

5.8.1.4 time

The standard C libraries require the application to supply the `time` function. This function returns the current `time_t` value or loads a supplied `time_t` value. The interrupts are saved and restored to make this function safe for use with interrupt driven code.

5.9 USING THE MCP9800 DRIVER

The MCP9800 is an I²C temperature sensor. The MCP9800 driver provides a simple interface to the features in the sensor.

5.9.1 MCP9800 Function Interface

5.9.1.1 mcp9800_init

This function configures the MCP9800 for 12-bit temperature, Continuous Conversion mode. In this mode, the temperature is always ready to be read from the I²C interface.

FIGURE 5-15:

```
System_init()
{
    i2c_init();
    mcp9800_init();
}
```

5.9.1.2 mcp9800_get_temp

This function reads the current temperature and scales the result to degrees C * 10. (24.3C is returned 243)

FIGURE 5-16:

```
Thermostat()
{
    int temperature;
    temperature = mcp9800_get_temp();
    if(temperature > 260)
    {
        turn_on_air_conditioner();
    }
}
```

Chapter 6. Troubleshooting

6.1 INTRODUCTION

There may come a time when you need to determine why your F1 Evaluation Platform is not performing correctly. This chapter lists a few of the problems that can prevent proper operation.

6.2 COMMON PROBLEMS

6.2.1 The board will not power up

Make sure there is no shorting jumper at JP3. Then, go back and review **Chapter 2. "Getting Started"** of this manual.

6.2.2 LCD is blank, but everything else works

The demo code in supplied with the F1 Evaluation Platform uses the Timer1 oscillator to drive the LCD. If the Timer1 oscillator is not oscillating, the LCD will remain blank. Here are some steps to assure that the Timer1 oscillator is working properly.

1. Clean and dry the board especially around the components at the top right corner of the PIC16LF1937.
2. Make sure no foreign material is shorting the crystal leads.
3. If you are using the RC0 and RC1 pins for some other function, you should modify `lcd_init` to reconfigure the LCD peripheral for a different clock source.

The Timer1 oscillator of the PIC16LF1937 is a very low-power design that can be easily disrupted by stray leakage. In an actual application, Microchip recommends that the crystal circuit be conformal coated to prevent leakage. Please review Application Note AN1288, "*Design Practices for Low-Power External Oscillators*" for more information.

6.2.3 The motor spins, but then stops

The BLDC start-up algorithm could be having trouble finding the BEMF zero-crossing signal required to synchronize the motor commutation.

If you have attached the BLDC add-on board and you are using the supplied BLDC motor, then the pot labeled `iRef` needs to be turned completely counter clockwise to assure that a good BEMF zero-crossing signal is detected by the PIC16LF1937.

If you are using a different motor, you need to adjust the zero-crossing threshold to match the requirements of the motor. For more information, consult the documentation supplied with the BLDC add-on board.

F1 Evaluation Platform User's Guide

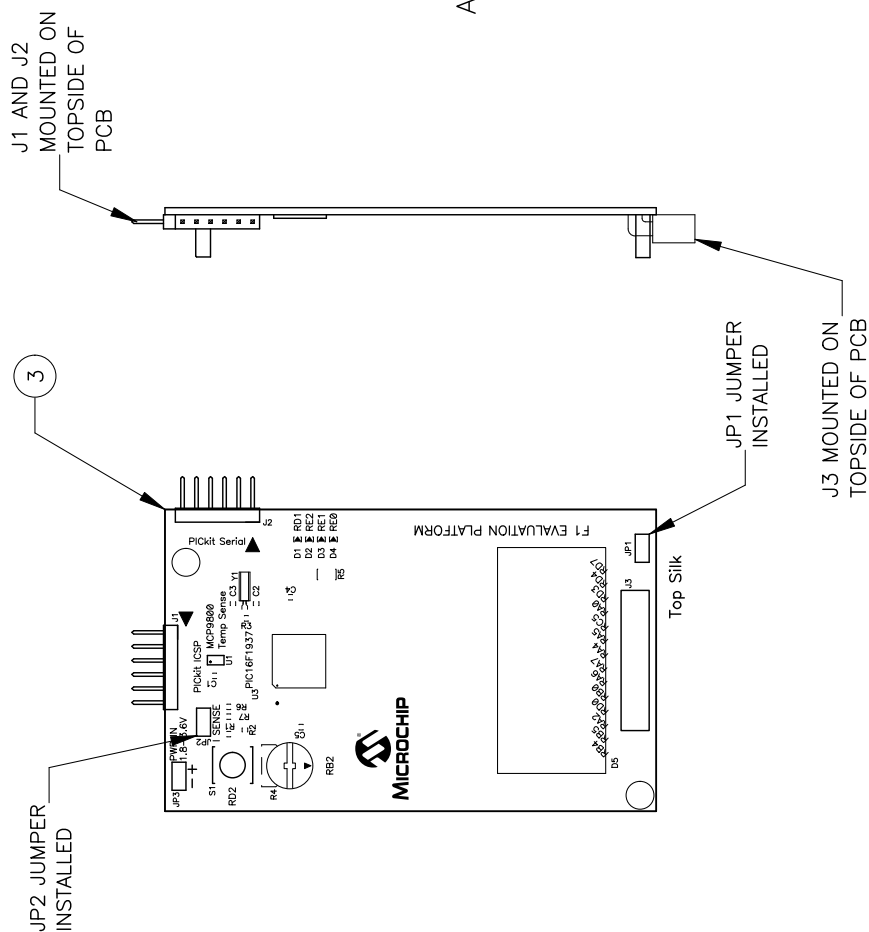
NOTES:

Chapter 7. Schematics

7.1 INTRODUCTION

To help understand the features of the F1 Evaluation Platform and the BLDC add-on board, the schematics are included here.

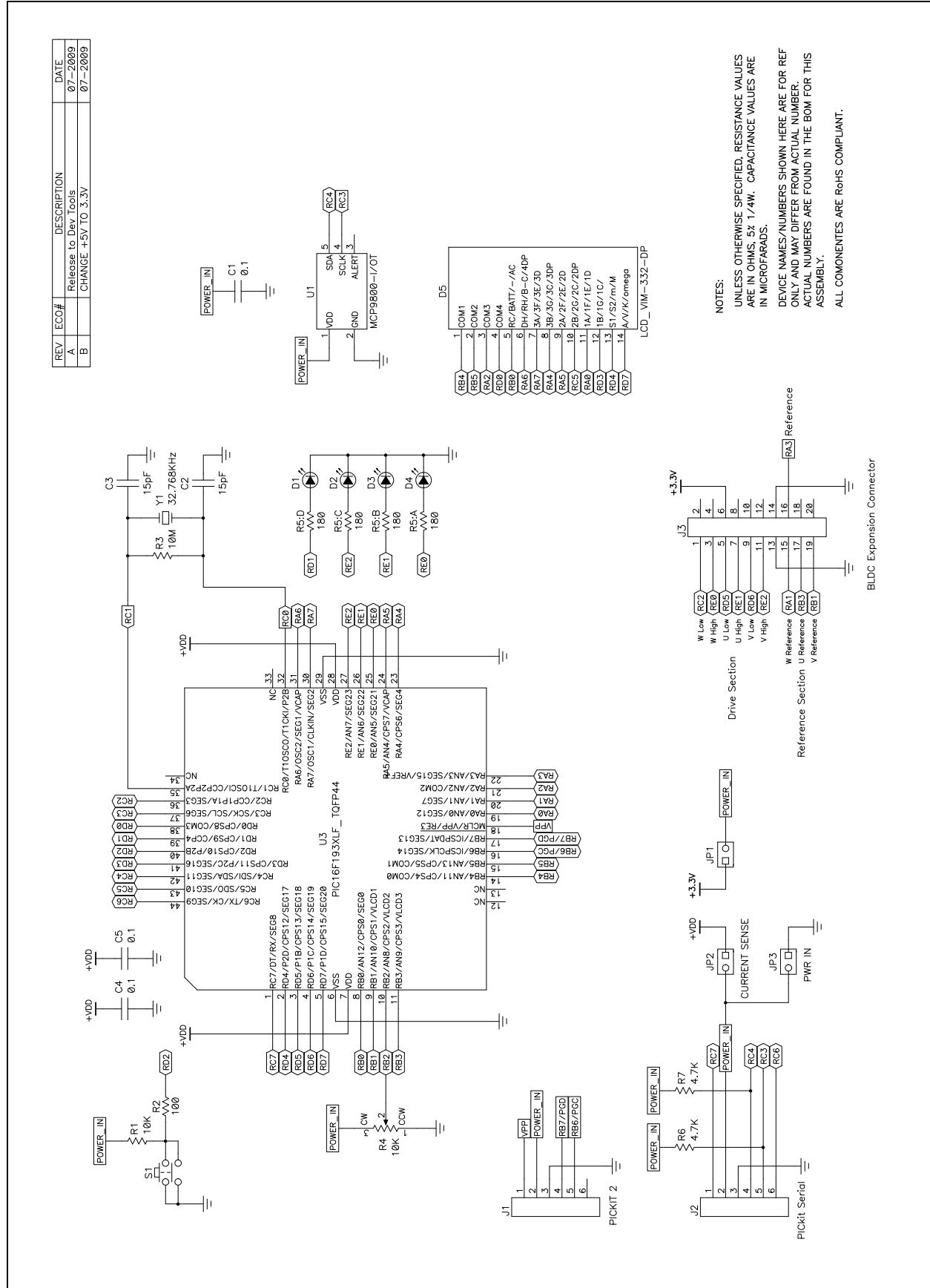
7.1.1 F1 Evaluation Platform Schematic (1 of 3)



ASSEMBLY NOTES: UNLESS OTHERWISE SPECIFIED

1. ALL COMPONENTS ARE RoHS COMPLIANT.
2. ALL THROUGH HOLE COMPONENTS MOUNTED ON THE TOP SIDE.
3. ALL COMPONENTS SHALL BE MOUNTED FLUSH TO THE BOARD.
4. ALL UNUSED COMPONENT PADS SHALL BE FREE OF SOLDER.
5. ALL LEADS SHALL BE TRIMMED TO A MAXIMUM LENGTH OF: N/A
6. MAXIMUM COMPONENT HEIGHT NOT TO EXCEED: N/A
7. THESE COMPONENTS REQUIRE SOCKETS: NONE.
8. UNPOPULATED COMPONENTS: SEE BILL OF MATERIALS.
9. FINISHED BOARD SHALL BE FREE OF ALL RESIDUES.

7.1.2 F1 Evaluation Platform Schematic (2 of 3)



F1 Evaluation Platform User's Guide

7.1.3 F1 Evaluation Platform Schematic (3 of 3)

REV

B

DESCRIPTION

PRELIMINARY

DATE

AUG 09

NOTES:

This PCB to be manufactured to meet all acceptance levels of a CLASS 2 PCB per ANSI/IPC-A-600G.

MATERIAL: Isola PCL370HR FR-4 or Equivalent.

☐ Multilayer ☐ 2 Layers ☐ Controlled Impedance

Cu weight external layers ☐ 1 OZ

Cu weight internal layers ☐

Finished overall thickness ☐ 0.062 inch $\pm$ 0.005

If board is multilayer, use black oxide on inner layers. Brown oxide is optional.

FINISH:

☐ Immersion Gold

☐ Edge connector fingers shall be plated with Nickel/Gold, $\geq$ 20 microinches gold.

☐ FLASH Gold

☐ Immersion Tin

☒ Soldermask over bare copper (SMOBC) with Hot-Air Leveled Solder.

Soldermask — DYNACHEM EPIC 200 LPI or equivalent.

Soldermask color: GREEN

Silkscreen color: White

SILKSCREEN

"MADE IN USA"

FAR SIDE

SEE NOTES

MARK MFR ID

FAR SIDE

3.500

3.235

0.115

0.115

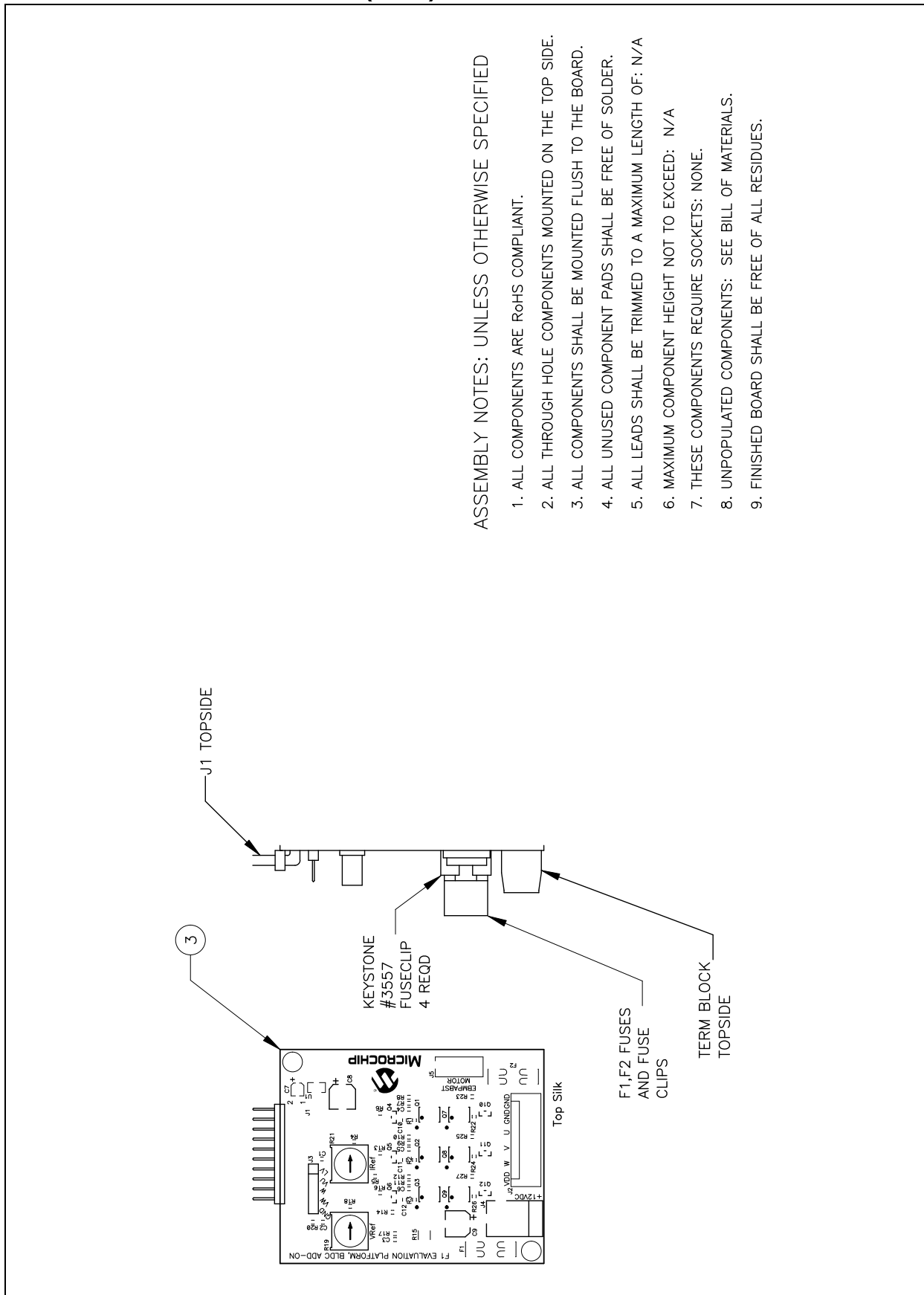
1.660

2.150

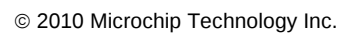
Drill Table

Hole Dia (inch)	Symbol	Quantity	Plated	Tol (+/-)
0.012	+	37	Yes	+0.002 -0.005
0.024	X	40	Yes	0.003
0.031	Y	3	Yes	0.003
0.038	T	222	Yes	0.003
0.042	⊗	42	Yes	0.003
0.120	⊗	2	No	0.005

7.1.4 BLDC Add-On Schematic (1 of 3)



7.1.5 BLDC Add-On Schematic (2 of 3)



7.1.6 BLDC Add-On Schematic (3 of 3)

NOTES:

This PCB to be manufactured to meet all acceptance levels of a CLASS 2 PCB per ANSI/IPC-A-600G.

MATERIAL: Isola PCL370HR FR-4 or Equivalent.

☐ Multilayer ☐ 2 Layers ☐ Controlled Impedance

Cu weight external layers ☐ 1 OZ

Cu weight internal layers ☐

Finished overall thickness ☐ .062 inch $\pm$.005

If board is multilayer, use black oxide on inner layers. Brown oxide is optional.

FINISH: ☐ Immersion Gold

☐ Edge connector fingers shall be plated with Nickel/Gold, ≥ 20 microinches gold.

☐ FLASH Gold

☐ Immersion Tin

☒ Soldermask over bare copper (SMOBC) with Hot-Air Leveled Solder.

Soldermask – DYNACHEM EPIC 200 LPI or equivalent.

Soldermask color: GREEN

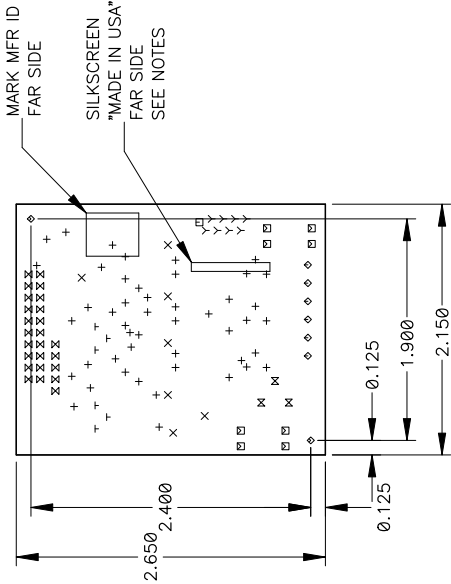
Silkscreen color: White

All holes to be located by the coordinates from the NC drill data provided.

Use artwork set No. ☐ 05-02153 ☐ REV ☐ E

Indicate country where PCB was fabricated on the side indicated.

Any alternatives to the above specifications must be approved by Microchip.



Drill Table					Tol (+/-)	
Hole Dia (inch)	Symbol	Quantity	Plated			
0.016	+	47	Yes		0.003	
0.020	X	7	Yes		0.003	
0.032	Y	8	Yes		0.003	
0.038	T	6	Yes		0.003	
0.042	Z	25	Yes		0.003	
0.048	M	3	Yes		0.003	
0.059	□	1	No		0.003	
0.060	◇	6	Yes		0.003	
0.067	▣	8	Yes		0.003	
0.120	◇	2	No		0.005	

F1 Evaluation Platform User's Guide

NOTES:

Index

Numerics

2C Demo	19
3.5-digit LCD	12

A

AC164110	17
Ammeter	14

B

BEMF Zero crossing signal	29
BLDC Demo	19
BLDC expansion	14
BLDC motor	15

C

C12IN3-	18
CCP1 Output A	18
CCP1 Output B	18
CCP1 Output C	18
Centigrade	15
COM1	18
COM2	18
COM3	18
Combined Demo	19
Common Problems	29
Customer Notification Service	8
Customer Support	9

D

Documentation	
Conventions	6
Layout	5

E

Enhanced midrange microcontrollers	11
EUSART RX	18

F

F1 Evaluation Platform	11
F1 Evaluation Platform Schematic	32

H

Hardware Features	11
16-bit timers	11
32-MHz internal oscillator	11
CCPs	11
EEPROM	11
Enhanced USART	11
LCD controller	11
RAM	11
Hardware Libraries & Drivers	21

I

ICSP pins	17
Internet Address	8

L

LCD Demo	19
LCD Display	16
LCD Function Interface	25
lcd_display_digits	25
lcd_display_on / lcd_display_off	25
lcd_init	25
Linear regulator	15

M

MCLR	18
MCP9800	11
Temperature sensor	11
Microchip Internet Web Site	8
MSSP SCLK	18
MSSP SDA	18

P

PGC	18
PGD	18
PIC [®] microcontrollers	11
PIC16 series	11
PIC16F1 Evaluation Kit	11
PIC16F1 family	11
PIC16LF1937	11
PICKit ICSP [™] programming capability interface	17
PICKit Serial	14
PICKit Serial connector	14
PICKit Serial power output	14
PICKit [™] 2	17
PICKit [™] 3	17
Platform Contents	11
F1 Evaluation Platform Demo Board	11
Powering with PICKit 3	13
JP1	13
JP2	13
PICKit ICSP connector	14
Voltage	14
Programming and debugging	12

F1 Evaluation Platform User's Guide

R

RD1	18
RD2	18
RE0	18
RE1	18
RE2	18
Reading, Recommended.....	7
Readme.....	7
REAL ICE™ in-circuit emulator	17

S

Segment 17	18
Sensorless BLCD add-on board.....	12
Supply voltage.....	13

T

T1OSCI	18
T1OSCO	18

U

User Interface	16
Pot ADC value	16
RPM	16
Temperature	16
Time	16

W

Warranty Registration.....	7
WWW Address.....	8

X

XLP low power	11
---------------------	----

NOTES:



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://support.microchip.com>
Web Address:
www.microchip.com

Atlanta

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

Boston

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

Chicago

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

Cleveland

Independence, OH
Tel: 216-447-0464
Fax: 216-447-0643

Dallas

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

Detroit

Farmington Hills, MI
Tel: 248-538-2250
Fax: 248-538-2260

Kokomo

Kokomo, IN
Tel: 765-864-8360
Fax: 765-864-8387

Los Angeles

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

Santa Clara

Santa Clara, CA
Tel: 408-961-6444
Fax: 408-961-6445

Toronto

Mississauga, Ontario,
Canada
Tel: 905-673-0699
Fax: 905-673-6509

ASIA/PACIFIC

Asia Pacific Office

Suites 3707-14, 37th Floor
Tower 6, The Gateway
Harbour City, Kowloon
Hong Kong
Tel: 852-2401-1200
Fax: 852-2401-3431

Australia - Sydney

Tel: 61-2-9868-6733
Fax: 61-2-9868-6755

China - Beijing

Tel: 86-10-8528-2100
Fax: 86-10-8528-2104

China - Chengdu

Tel: 86-28-8665-5511
Fax: 86-28-8665-7889

China - Chongqing

Tel: 86-23-8980-9588
Fax: 86-23-8980-9500

China - Hong Kong SAR

Tel: 852-2401-1200
Fax: 852-2401-3431

China - Nanjing

Tel: 86-25-8473-2460
Fax: 86-25-8473-2470

China - Qingdao

Tel: 86-532-8502-7355
Fax: 86-532-8502-7205

China - Shanghai

Tel: 86-21-5407-5533
Fax: 86-21-5407-5066

China - Shenyang

Tel: 86-24-2334-2829
Fax: 86-24-2334-2393

China - Shenzhen

Tel: 86-755-8203-2660
Fax: 86-755-8203-1760

China - Wuhan

Tel: 86-27-5980-5300
Fax: 86-27-5980-5118

China - Xian

Tel: 86-29-8833-7252
Fax: 86-29-8833-7256

China - Xiamen

Tel: 86-592-2388138
Fax: 86-592-2388130

China - Zhuhai

Tel: 86-756-3210040
Fax: 86-756-3210049

ASIA/PACIFIC

India - Bangalore

Tel: 91-80-3090-4444
Fax: 91-80-3090-4123

India - New Delhi

Tel: 91-11-4160-8631
Fax: 91-11-4160-8632

India - Pune

Tel: 91-20-2566-1512
Fax: 91-20-2566-1513

Japan - Yokohama

Tel: 81-45-471- 6166
Fax: 81-45-471-6122

Korea - Daegu

Tel: 82-53-744-4301
Fax: 82-53-744-4302

Korea - Seoul

Tel: 82-2-554-7200
Fax: 82-2-558-5932 or
82-2-558-5934

Malaysia - Kuala Lumpur

Tel: 60-3-6201-9857
Fax: 60-3-6201-9859

Malaysia - Penang

Tel: 60-4-227-8870
Fax: 60-4-227-4068

Philippines - Manila

Tel: 63-2-634-9065
Fax: 63-2-634-9069

Singapore

Tel: 65-6334-8870
Fax: 65-6334-8850

Taiwan - Hsin Chu

Tel: 886-3-6578-300
Fax: 886-3-6578-370

Taiwan - Kaohsiung

Tel: 886-7-213-7830
Fax: 886-7-330-9305

Taiwan - Taipei

Tel: 886-2-2500-6610
Fax: 886-2-2508-0102

Thailand - Bangkok

Tel: 66-2-694-1351
Fax: 66-2-694-1350

EUROPE

Austria - Wels

Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen

Tel: 45-4450-2828
Fax: 45-4485-2829

France - Paris

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

Germany - Munich

Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Italy - Milan

Tel: 39-0331-742611
Fax: 39-0331-466781

Netherlands - Drunen

Tel: 31-416-690399
Fax: 31-416-690340

Spain - Madrid

Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

UK - Wokingham

Tel: 44-118-921-5869
Fax: 44-118-921-5820