



**F1 LV Evaluation Platform for  
Enhanced PIC<sup>®</sup> Microcontrollers  
User's Guide**

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## Preface

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### 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](http://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 LV 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 LV 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 LV Evaluation Platform Overview”**
- **Chapter 2. “Getting Started”**
- **Chapter 3. “Programming the F1 LV Evaluation Platform”**
- **Chapter 4. “Demo Code”**
- **Chapter 5. “Hardware Libraries and Drivers”**
- **Chapter 6. “Troubleshooting”**
- **Chapter 7. “Schematics”**

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## CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

### DOCUMENTATION CONVENTIONS

Description	Represents	Examples
<b>Arial font:</b>		
Italic characters	Referenced books	<i>MPLAB<sup>®</sup> 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&gt;Save</i></u>
Bold characters	A dialog button	Click <b>OK</b>
	A tab	Click the <b>Power</b> 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>
<b>Courier New font:</b>		
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 LV Evaluation Platform. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

### **Readme for F1 LV Evaluation Platform User's Guide**

For the latest information on using F1 LV Evaluation Platform User's Guide, read the "Readme for F1 LV Evaluation Platform User's Guide.txt" file (an ASCII text file) in the Readmes subdirectory of the MPLAB<sup>®</sup> 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.

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## THE MICROCHIP WEB SITE

Microchip provides online support via our web site at [www.microchip.com/F1LVEval](http://www.microchip.com/F1LVEval). 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

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The Development Systems product group categories are:

- **Compilers** – The latest information on Microchip C compilers and other language tools. These include the HI TECH C<sup>®</sup> C16, MPLAB C18 and MPLAB C30 C compilers; MPASM<sup>™</sup> and MPLAB ASM30 assemblers; MPLINK<sup>™</sup> and MPLAB LINK30 object linkers; and MPLIB<sup>™</sup> and MPLAB LIB30 object librarians.
- **In-Circuit Debuggers** – The latest information on the Microchip in-circuit debugger, MPLAB ICD 2, ICD3, PICKit<sup>™</sup> 3.
- **MPLAB<sup>®</sup> IDE** – The latest information on Microchip MPLAB IDE, the Windows<sup>®</sup> 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<sup>™</sup> 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 (November 2011)

- Initial Release of this Document.

# F1 LV Evaluation Platform User's Guide

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NOTES:

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**Chapter 1. F1 LV Evaluation Platform Overview**

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**1.1 INTRODUCTION**

Thank you for choosing the F1 LV Evaluation Platform. This kit allows you to begin development using the PIC16LF1947 microcontroller (MCU).

The PIC16LF1947 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<sup>®</sup> microcontrollers. The F1 LV derivatives feature an enhanced CPU, support for extended amounts of memory, improved peripherals, and XLP low power. The F1 LV Evaluation Platform allows you to evaluate these features for your application in a simple, low-cost platform.

This chapter introduces the F1 LV Evaluation Platform:

- Platform Contents
- Hardware Features

**1.2 PLATFORM CONTENTS**

The F1 LV Evaluation Platform contains the following items:

1. F1 LV Evaluation Platform Demo Board – [www.microchip.com/F1LVEval](http://www.microchip.com/F1LVEval)

**1.3 HARDWARE FEATURES**

The F1 LV Evaluation Platform has the following hardware features:

**1.3.1 PIC16LF1947**

The PIC16LF1947 is a 64-pin full-featured device, including:

1. Enhanced PIC16 instruction set
2. 16K words of Flash memory
3. 1K of RAM
4. 256 bytes of EEPROM
5. 2 CCPs and 3 enhanced CCPs
6. MSSP (I<sup>2</sup>C™, SPI)
7. Enhanced USART
8. 8- and 16-bit timers
9. 32 MHz internal oscillator
10. Low-power 32 kHz crystal oscillator
11. LCD controller
12. LF Operating Range: 1.8-3.6V

**1.3.2 MCP9800 I<sup>2</sup>C™ Temperature Sensor**

The MCP9800 is a low-power, I<sup>2</sup>C temperature sensor with selectable 9 to 12 bits of output resolution.

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## 1.3.3 PICkit™ 3 Programming/Debug Header

The PICkit 3 is a low-cost development tool that allows programming and debugging of the PIC16LF1947 MCU using the PICkit ICSP™ header.

## 1.3.4 MCP2200 USB to Serial Converter

The MCP2200, with the associated driver, makes the F1 LV Evaluation platform appear as a serial port when connected to a PC. The demo code includes utilities to control the various add-on boards through this serial interface.

## 1.3.5 Two Push Buttons, One Potentiometer, 7 LEDs

Simple applications need the basic user interface elements. Two push buttons, one potentiometer and 4 green LEDs are available for any application. The remaining three LEDs are used as indicators, a red LED is used to indicate the board is powered, the remaining two LEDs are green and indicate RX/TX communication through the USB Serial Converter.

## 1.3.6 One Custom LCD

The LCD glass supplied on this board is a Microchip custom display with icons for a battery indicator, 4 large numerical digits, 2 small numerical digits, adjustable decimal point, colon for time keeping, 4 function mode (Fx) indicators, 8 segment bar, a three-segment battery power indicator and 1 custom Microchip symbol. The PIC16LF1947 makes controlling the LCD very simple.

## 1.3.7 20-pin Add-on Connector

This connector expands the F1 LV Evaluation Board with optional add-on boards. Currently, there are 4 motor control add-ons planned or in production. The PIC16LF1947 has complete control of 3 phases, so other 1, 2, or 3-phase motor topologies are supported.

## 1.3.8 Current Monitoring Connector

To demonstrate the Extreme Low Power (XLP) features of the PIC16LF1947, 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 PIC16LF1947 in your application.

## 1.3.10 MCP1640 Synchronous Boost Regulator

The MCP1640 is a compact, high-efficiency, fixed frequency, synchronous step-up DC-DC converter. Through the use of this component, the F1 LV Evaluation board has the option of boosting an AAA 1.8V battery to 3.3V, which is then used to power the board and supporting circuitry.

## 1.3.11 MCP1703 LDO Regulator

The MCP1703 is a low-dropout voltage regulator with a 250 mA maximum output. Through the use of this component, the user has the option of powering the F1 LV Evaluation board through the USB Serial Converter connector. The USB supplies 5V, and the MCP1703 reduces this to the operating voltage of 3.3V.

## 1.3.12 User Selectable Power Sources

The F1 LV Evaluation board operates at 3.3V and comes with a flexible range of powering options.

- J5 – (EXT SUPP) The user can power the board from an external power supply connected to the +/- headers.
- J6 – (EXP PWR) The user can power the board from any Add-on board through the expansion connector.
- J7 – (AAA BATT) The user can power the board by inserting a single AAA battery into B1 battery clamp.
- J8 – (USB PWR) The user can power the board by connecting a USB cable to J2 USB SERIAL CONV header.

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NOTES:

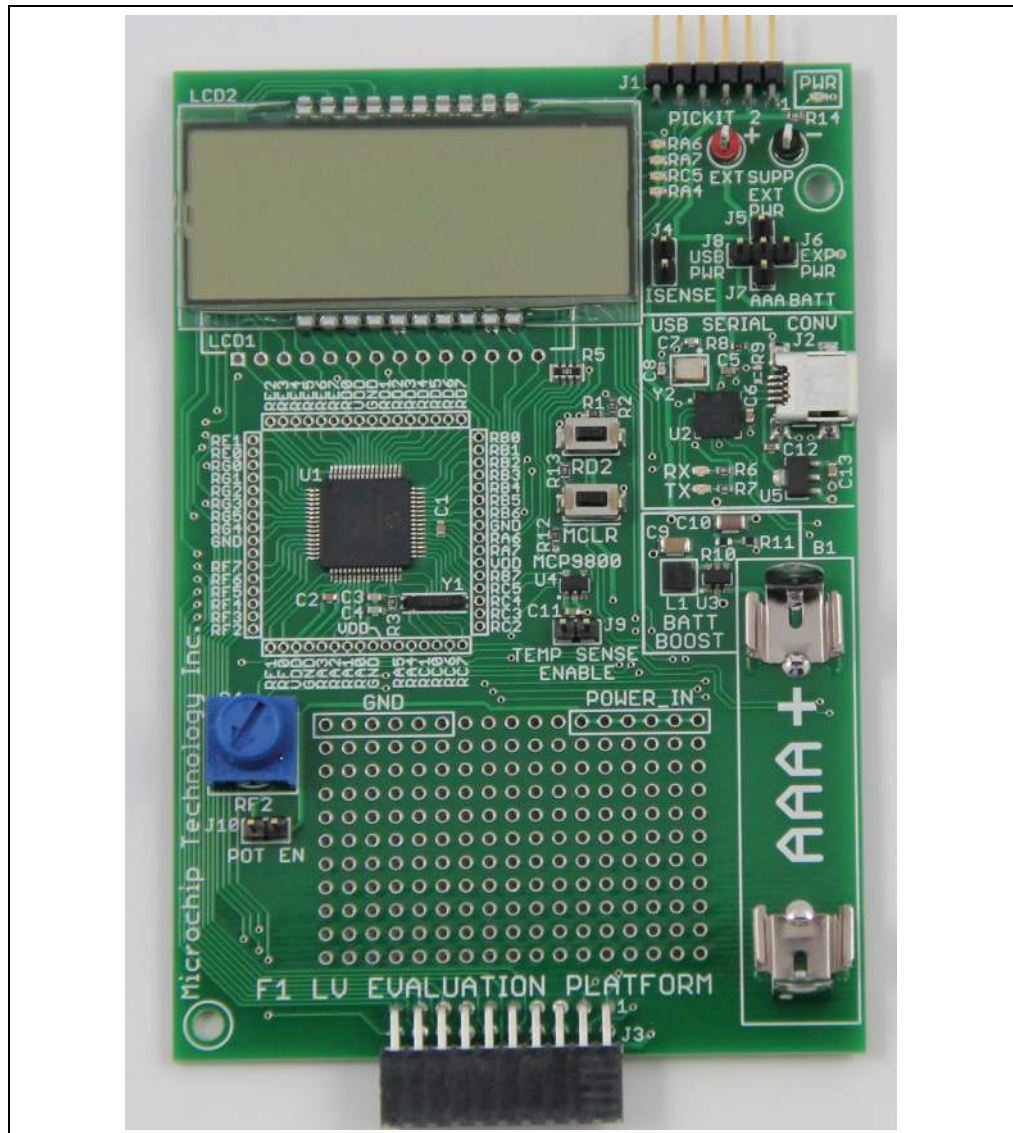
**Chapter 2. Getting Started**

**2.1 INTRODUCTION**

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

- Powering the F1 LV Evaluation Platform
- Default Firmware
- Programming the F1 LV Evaluation Platform with the PICKIT™ 3
- Measuring the current consumption

**FIGURE 2-1: F1 LV EVALUATION PLATFORM**



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## 2.2 POWERING THE F1 LV EVALUATION PLATFORM

The PIC16LF1947 supplied with your F1 LV Evaluation Platform requires a supply voltage of 1.8V-3.6V. Voltages above 3.6V will degrade or damage the device. There are five ways to supply the necessary power.

1. Use PICKit 3

### Select Power Supply Source via cross jumper configuration

2. External Power Source, J5
3. Use the Add-on Expansion Header, J6
4. Use an AAA Battery, J7, or
5. Use USB Cable, J8.

## 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 J4.
2. Configure the PICKit 3 to supply a voltage between 1.8 and 3.6V. For proper LCD contrast, the supply should be 3.3V.
3. Attach the PICKit 3 to the PICKit ICSP™ connector at the end of the board.
4. Activate the PICKit 3 power output.

**Note:** When powering from the PICKit 3, all power supply jumpers (J5 - J8) should be removed.

**FIGURE 2-2: POWERING FROM PICKit™ 3**



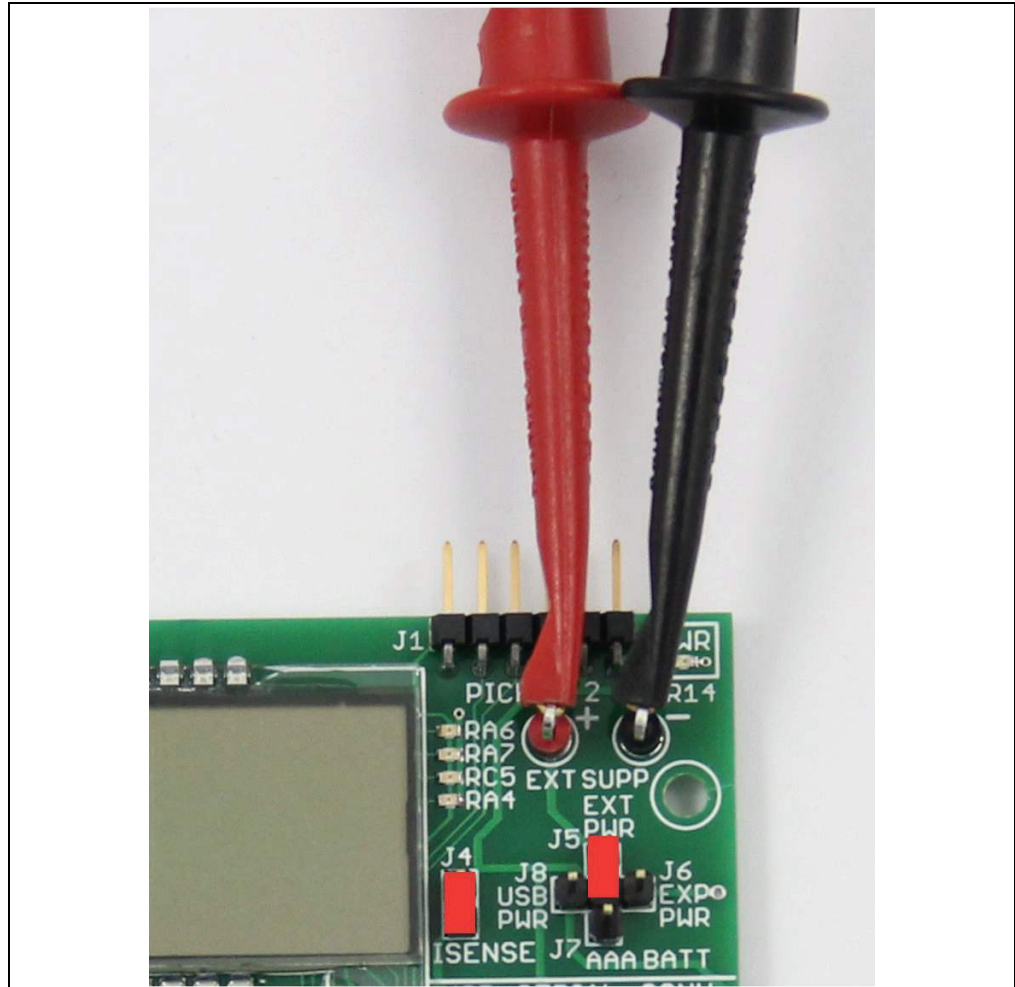


## 2.4 POWERING FROM EXTERNAL POWER SUPPLY

To power from an external power supply, perform the following steps:

1. Make sure a jumper or an ammeter is connected across J4.
2. Connect VREF+ to EXT SUPP (+), connect VREF- to EXT SUPP(-).
3. Verify the supply voltage to be between 1.8 and 3.6V. For proper LCD contrast, the supply should be 3.3V.
4. Populate EXT PWR jumper, J5.
5. Turn on the power supply.

**FIGURE 2-3: POWERING WITH EXTERNAL POWER SUPPLY**



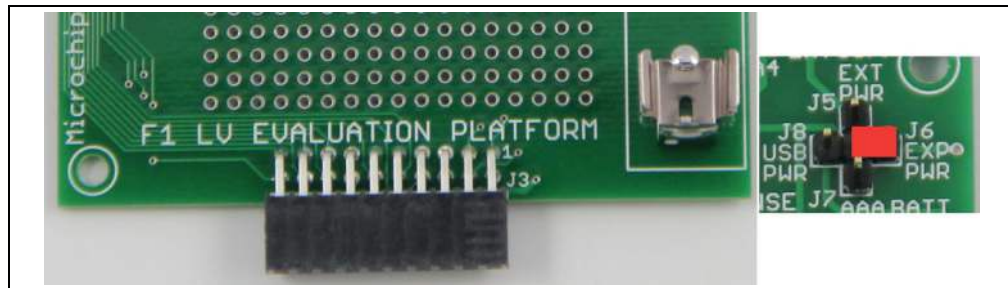
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## 2.5 POWERING WITH THE ADD-ON EXPANSION HEADER J3

The add-on expansion hardware will supply the F1 LV Evaluation board with 3.3V DC through use of a linear regulator. This allows the 5-12V motor power supply to power the PIC16LF1947. 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 J4.
2. Verify that any attached PICKit 3 is not supplying power.
3. Populate the EXP PWR jumper, J6.
4. Attach the add-on expansion board.
5. Connect power to the add-on expansion board.

**FIGURE 2-4: EXPANSION SLOT POWER**

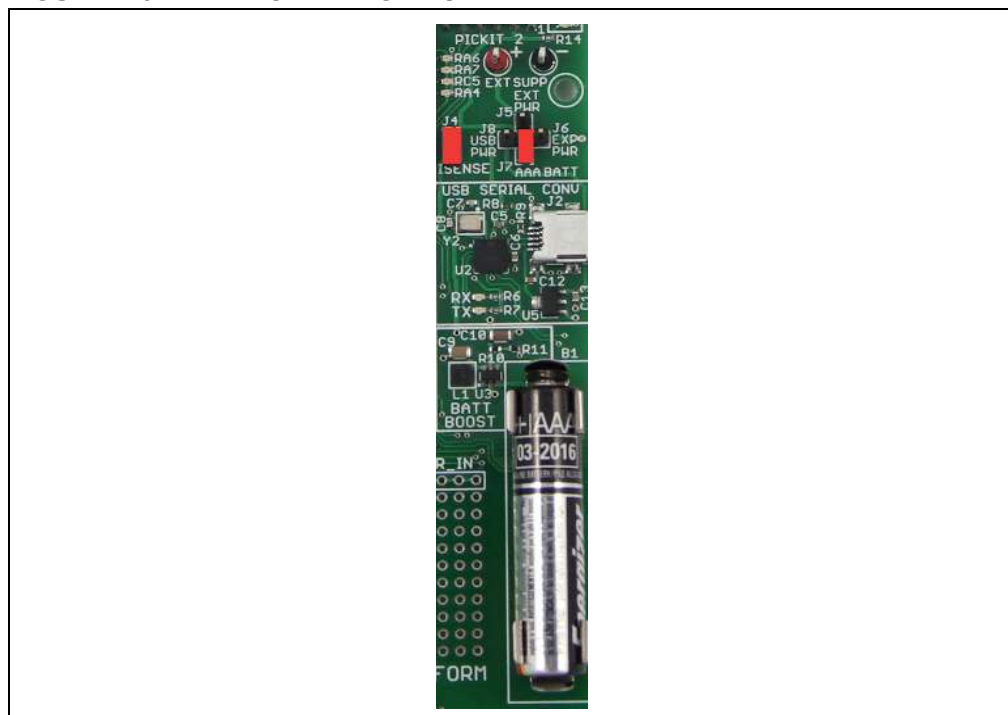


## 2.6 POWERING WITH A AAA BATTERY

To power with a single AAA battery, the MCP1640 Boost Regulator is used to take the supplied 1.8V and convert it to 3.3V.

1. Make sure the jumper or an ammeter is connected across J4.
2. Insert AAA battery into B1 battery clip.
3. Populate AAA BATT jumper, J7.

**FIGURE 2-5: POWERING FROM BATTERY**





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## 2.8.3 Add-on Motor Expansion

A main task of the demo code is to allow the user to connect any of the expansion add-on motor boards and have the PIC16LF1947 determine the motor type and adjust the drive accordingly. The code provided with the F1 LV Evaluation board works with the following add-on boards:

- BLDC (DM164130-2)
- BDC (DM164130-6)
- Unipolar Stepper (DM164130-7)
- Bipolar Stepper (DM164130-8)

## 2.8.4 LCD Display

The time, temperature, pot position and motor speed are displayed on the LCD. The LCD is a display with multipurpose icons. The display uses 4 commons and 28 segment drives. The Timer1 oscillator is used to clock the display peripheral and allow the LCD to display data even in Sleep. Normally, the Timer1 counter would be used to drive the display, but this timer is required for the BLDC software. This requires configuring the LCD peripheral for a Type B waveform for this demo. The Type B waveform requires coordinating LCD updates when the peripheral is ready. The BLDC Interrupt requirements preclude using the built-in LCD interrupt for update coordination, therefore, the LCD interrupt is polled as part of the main loop. Type A waveforms can update the display without the extra coordination complexity. The different waveform types are described in section 21.9 of the PIC16LF1947 data sheet (DS41414). 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.

## 2.8.5 User Interface

Due to the extreme simplicity of this board, only a single button and a single pot are available for user input. A MCLR button is also present for the demonstration, this will function as a master clear switch. 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 following display modes:

1. Add-on Motor Indicator
2. Setable AM/PM Clock
3. 24-hr clock with seconds
4. Temperature (C)
5. Temperature (F)
6. POT ADC Value
7. Motor RPM (BLDC and stepper motors only)

By holding down the RD2 button during the Setable Clock mode, the minutes will begin to increment. The minutes will increment from 0-9; when the minutes increment past 9, the minutes will begin to increase by factors of 10. When incrementing reaches an hour, the hours will begin to increment and the minutes will stay at 00. The AM/PM indicator will automatically change accordingly. To set the clock, first set the hours and release the button. Then, set the tens of minutes and release the button. Finally, set the seconds. To synchronize the seconds, increment the minutes one final time at the instant the time reference advances to the next minute.

Turning the pot will change the motor speed.

When an expansion board is present, the F1 LV Evaluation code will automatically detect the add-on type and modify the motor drive accordingly.

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## Chapter 3. Programming the F1 LV Evaluation Platform

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### 3.1 INTRODUCTION

The F1 LV Evaluation Platform makes extensive use of the on-board peripherals of the PIC16LF1947. This chapter provides guidance concerning the tools used for programming the F1 LV 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 LV Evaluation Platform:

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

The PICKit™ or ICD 3 tools can also power the F1 LV Evaluation Platform, therefore, no additional hardware is required to get started. The ICSP pins of the PIC16LF1947 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 ICD, 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 LV Evaluation Platform.

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## 3.3 HARDWARE RESOURCES

TABLE 3-1: HARDWARE RESOURCES

Pin Number	PORT ID	I/O	Use	Name	Description
1	RE1	0		RE1	J3 – Pin 10
2	RE0	0		RE0	J3 – Pin 12
3	RG0	0		P3A	Low Side Drive C; J3 – Pin 9
4	RG1	I	LCD	SEG43	S1/S2/S3/S4
5	RG2	I	LCD	SEG44	T1/T2/T3/T4
6	RG3	0		R3	J3 – Pin 8
7	RG5	I		MCLR/VPP	MCLR
8	RG4	0		RG4	J3 – Pin 2
9				Vss	Supply Return
10	NC			NC	Pin tied to VDD
11	RF7	I	AN5	C12IN3-	BEMF A; J3 – Pin 15
12	RF6	I	AN1	C1IN+	BEMF Reference; J3 – Pin 16
13	RF5	I	AN10	C12IN1-	BEMF C; J3 – Pin 19
14	RF4	I	AN9	C2IN+	Current Sense Reference; J3 – Pin 18
15	RF3	I	AN8	C12IN2-	BEMF B; J3 – Pin 17
16	RF2	0		RF2	C1OUT
17	RF1	I	LCD	SEG19	S5/S6/S7/S8
18	RF0	I	AN16	C12IN0-	Current Sense; J3 – Pin 20
19				AVDD	Power Supply
20				AVSS	Supply Return
21	RA3	I	AN3	RA3	Battery Voltage
22	RA2	I	LCD	SEG34	6A/6D/6E/6F
23	RA1	I	LCD	SEG18	5B/5C/5G/P5
24	RA0	I	LCD	SEG33	5A/5D/5E/5F
25				Vss	Supply Return
26				VDD	Power Supply
27	RA5	I	AN4	RA5	Speed Control Input (New Layout)
28	RA4	0		RA4	LED [D4]
29	RC1	I		RC1	T1OSCI
30	RC0	0		RC0	T1OSCO
31	RC6	0		TX1	Serial Transmit
32	RC7	I		RX1	Serial Receive
33	RC2	0		P1A	Low Side Drive B; J3 – Pin 1
34	RC3	I		SCK1	I <sup>2</sup> C™ Clock
35	RC4	I		SDA1	I <sup>2</sup> C Data
36	RC5	0		RC5	Phase C LED, LED [D3]
37	RB7	0		RGD	ICSP™ Data (TestPoint 1)
38				VDD	Power Supply
39	RA7	0		RA7	Phase B LED; LED [D2]
40	RA6	0		RA6	Phase A LED; LED [D1]
41				Vss	Supply Return
42	RB6	0		PGC	ICSP Clock (TestPoint 1)
43	RB5	I	LCD	SEG29	F2/6B/6C/6G

# Programming the F1 LV Evaluation Platform

**TABLE 3-1: HARDWARE RESOURCES (CONTINUED)**

44	RB4	I	LCD	SEG11	F1/F3/F4/P6
45	RB3	I	LCD	SEG10	4B/4C/4G/P4
46	RB2	I	LCD	SEG9	4A/4D/4E/4F
47	RB1	I	LCD	SEG8	3B/3C/3G/P3
48	RB0	I	LCD	SEG30	3A/3D/3E/3F
49	RD7	I	LCD	SEG7	2B/2C/2G/P2
50	RD6	0		P1B	High Side Drive A; J3 – Pin 3
51	RD5	0		RD5	J3 – Pin 4
52	RD4	0		P3B	High Side Drive C; J3 – Pin 11
53	RD3	I	LCD	SEG3	2A/2D/2E/2F
54	RD2	I		RD2	Push Button
55	RD1	I	LCD	SEG1	1B/1C/1G/1P
56				Vss	Supply Return
57				VDD	Power Supply
58	RD0	I	LCD	SEG0	1A/1D/1E/1F
59	RE7	0		P2A	Low Side Drive B; J3 – Pin 5
60	RE6	I	LCD	COM3	COM4
61	RE5	I	LCD	COM2	COM3
62	RE4	I	LCD	COM1	COM2
63	RE3	I	LCD	COM0	COM1
64	RE2	0		P2B	High Side Drive B; J3 – Pin 7

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## Chapter 4. Demo Code

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### 4.1 INTRODUCTION

The F1 LV Evaluation Platform demo is located at [www.microchip.com/F1LVEval](http://www.microchip.com/F1LVEval). The F1 LV Evaluation demonstration program uses a single Combined Demo. The Combined Demo source code is organized into sectional code for ease of portability:

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

### 4.2 SERVICE DRIVERS

Multiple services drivers are utilized during this demo for operation. For user ease, these drivers have been separated for easy portability.

- The I<sup>2</sup>C driver is used by the MCP9800 driver to read the current temperature from the on-board MCP9800 I<sup>2</sup>C temperature sensor.
- Using the LCD and RTCC drivers, the LCD is used for display of the clock, temperature, motor status and motor type.
- The UNI/O<sup>®</sup> driver is used to read from each add-on board which motor type is being attached, and which firmware should be used.

### 4.3 COMBINED DEMO

The combined demo combines all the software from all the previous demos to show the power of the PIC16LF1947. In this demo, the user can attach any of the (4) add-on motor boards for use. The F1 LV Evaluation Board will auto-detect the type of motor add-on used and automatically configure accordingly for use. All drivers are reused from the previous demos. The RTCC is driven from the LCD peripheral.

The combined demo is preprogrammed in the F1 LV Evaluation Platform.

### 4.4 MOTOR CONTROL GUI APPLICATION

The F1 LV Evaluation Platform is developed to connect through the MCP2200 to the user's computer emulating a serial port. The GUI is capable of detecting which F1 LV add-on board is being used. Through the application, the user is capable of exploring the many options made with these motor types.

The GUI is capable of detecting and displaying which firmware version is being used through the F1 LV Evaluation Platform, and also which add-on board is connected. The features of the GUI in use with the F1 LV Evaluation Platform with its add-on boards is discussed in the Add-on User's Guide.

### 4.5 BLDC DEMO

The BLDC demo controls a sensorless, brushless DC motor connected to the PIC16F1 BLDC Expansion board (DM164130-2). Motors of the same type, but other than the motor supplied, can also be driven by making appropriate modifications to the motor control parameters.

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

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## 4.6 BDC DEMO

The BDC demo controls a brushed DC motor connected to the PIC16F1 BDC Expansion board (DM164130-6). Motors of the same type, but other than the motor supplied, can also be driven by making appropriate modifications to the motor control parameters.

## 4.7 UNIPOLAR STEPPER DEMO

The Unipolar Stepper Demo controls a Unipolar stepper motor connected to the PIC16F1 Unipolar Expansion board (DM164130-8). Motors of the same type, but other than the motor supplied, can also be driven by making appropriate modifications to the motor control parameters.

## 4.8 BIPOLAR STEPPER DEMO

The Bipolar Stepper Demo controls a Unipolar stepper motor connected to the PIC16F1 Bipolar Expansion board (DM164130-7). Motors of the same type, but other than the motor supplied, can also be driven by making appropriate modifications to the motor control parameters.

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## Chapter 5. Hardware Libraries and Drivers

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### 5.1 INTRODUCTION

The demo code uses a common set of libraries to provide I<sup>2</sup>C, 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/F1LVEval](http://www.microchip.com/F1LVEval).

### 5.2 I<sup>2</sup>C™ DRIVER

The I<sup>2</sup>C driver allows I<sup>2</sup>C 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 I<sup>2</sup>C and LCD demos configure the driver for interrupt mode. The Combined Demo polls the I<sup>2</sup>C handler within the MCP9800 driver.

### 5.3 MCP9800 DRIVER

The MCP9800 driver uses the I<sup>2</sup>C driver to get the current temperature. The `mcp9800_get_temp` function is fully blocking, so once a request is queued, the driver polls the I<sup>2</sup>C subsystem until the data is complete. If the I<sup>2</sup>C driver is operating without interrupts, the `mcp9800_get_temp` function repeatedly calls the `I2C_handler` function to process all the I<sup>2</sup>C events. If the I<sup>2</sup>C driver is operating with interrupts, the `mcp9800_get_temp` function simply inserts an `I2C_TRANSACTION_T` into the I<sup>2</sup>C 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 LCD supplied with this demo board. It is a good starting point for the LCD driver your unique application will require.

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## 5.6 USING THE I<sup>2</sup>C™ DRIVER

The supplied software includes an I<sup>2</sup>C 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 I<sup>2</sup>C transactions allowed at each queue entry
6. Completion flag for each queued block of I<sup>2</sup>C commands.

### 5.6.1 I<sup>2</sup>C Data Structures

Two data structures are defined to simplify interactions with the I<sup>2</sup>C driver.

#### 5.6.1.1 I2C\_RESULTS

The I2C\_RESULTS 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 <sup>2</sup> 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 I<sup>2</sup>C request is of type I2C\_RESULTS. 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\_TRANSACTION\_REQUEST\_BLOCK

The I2C\_TRANSACTION\_REQUEST\_BLOCK is a structure representing one transaction on the I<sup>2</sup>C 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 I<sup>2</sup>C 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 I<sup>2</sup>C transaction is complete or the array may be reused by a different function).

## 5.6.2 I<sup>2</sup>C Function Interface

### 5.6.2.1 i2c\_init

The function `i2c_init` configures the I<sup>2</sup>C driver and makes it ready to receive transaction in the transaction queue.

**FIGURE 5-1:**

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

### 5.6.2.2 i2c\_insert

The function `i2c_insert` places one complete set of Transaction Request Block (TRBs). 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 I<sup>2</sup>C 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.

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**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 I<sup>2</sup>C 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 LV 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 PIC16LF1947 data sheet (DS41414).

### 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`.

## 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();
    }
}
```

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## 5.7.3 LCD Segment Definitions

FIGURE 5-10: LCD DISPLAY

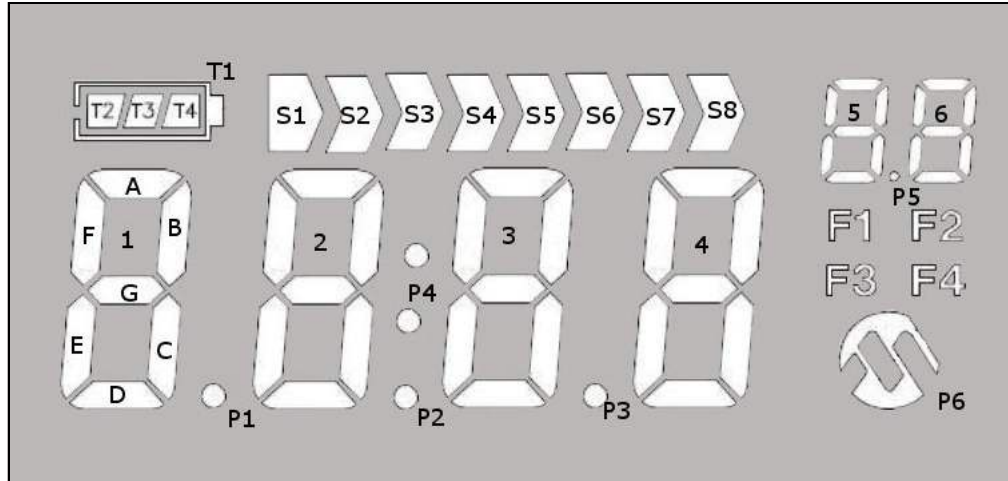


TABLE 5-2:

PIN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
COM1	1A	1B	2A	2B	3A	3B	4A	4B	F1	F2	6D	PS	5D	S8	S1	T1	COM1			
COM2	1F	1G	2F	2G	3F	3G	4F	4G	F3	6C	6E	5C	5E	S7	S2	T3		COM2		
COM3	1E	1C	2E	2C	3E	3C	4E	4C	F4	6G	6F	5G	SF	S6	S3	T2			COM3	
COM4	1D	P1	2D	P2	3D	P3	4D	P4	P6	6B	6A	5B	5A	S5	S4	T4				COM4

There are many segments present on the F1 LV 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()`.

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**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 I<sup>2</sup>C 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 I<sup>2</sup>C 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

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### 6.1 INTRODUCTION

There may come a time when you need to determine why your F1 LV 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 the power supply jumper is populating the proper pins. Confirm the ISENSE, J4, jumper is populated or an ammeter is connected. 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 LV 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 PIC16LF1947.
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 PIC16LF1947 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.

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## **Chapter 7. Schematics**

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### **7.1 INTRODUCTION**

To help understand the features of the F1 LV Evaluation Platform, the schematics are included here.









## 7.1.4 F1 LV Evaluation Platform Schematic (4 of 4)

**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  N Controlled Impedance

Cu weight external layers  1oz

Cu weight internal layers

Finished overall thickness  .062 in. +/-  .006

If multilayer, use Black Oxide on inner layers.  
Brown Oxide is optional.

**FINISH:**  Immersion Gold  
 Immersion Tin

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

If edge connector fingers are present, plate with Nickel/Gold ≥ 20 microinches Gold

**SOLDERMASK:** DYNACHEM EPIC 200 LPI or equiv.  
**SOLDERMASK COLOR:** GREEN  
**SILKSCREEN COLOR:** WHITE

**ARTWORK SET NO.:**  05-02202  REV  C

All holes to be located by the NC drill file.  
Indicate Country where PCB was fabricated on the side indicated.  
Any deviation from the above specs must be approved by Microchip.

The schematic shows a rectangular PCB layout with dimensions: 4.300 (width), 2.800 (height), 3.750 (top offset), 2.950 (right offset), 0.150 (bottom offset), and 0.150 (right offset). A central square area is labeled 'MARK MFR ID FAR SIDE'. A rectangular area is labeled 'SILKSCREEN "/>

Symbol	Hole Diameter	Quantity	Plated	Tol +/-
+	0.0308 HLL ( 0.0308 mto	224	YES	R005
X	0.2030 HLL ( 0.2030 mto	6	YES	R005
□	0.2030 HLL ( 0.2030 mto	6	YES	R005
○	0.2030 HLL ( 0.2030 mto	2	NO	R005
×	0.2030 HLL ( 0.2030 mto	5	YES	R005
◇	0.2030 HLL ( 0.2030 mto	2	NO	R005
▽	0.2030 HLL ( 0.2030 mto	035	YES	R005
△	0.2030 HLL ( 0.2030 mto	7	YES	R005
★	0.2030 HLL ( 0.2030 mto	1	YES	R005

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