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Note the following details of the code protection feature on Microchip devices:

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- 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.

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Object of Declaration: DM240015, MPLAB® Starter Kit for Intelligent.Integrated.Analog

EU Declaration of Conformity
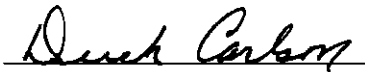
This declaration of conformity is issued by the manufacturer.

The development/evaluation tool is designed to be used for research and development in a laboratory environment. This development/evaluation tool is not a Finished Appliance, nor is it intended for incorporation into Finished Appliances that are made commercially available as single functional units to end users under EU EMC Directive 2004/108/EC and as supported by the European Commission's Guide for the EMC Directive 2004/108/EC (8th February 2010).

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Signed for and on behalf of Microchip Technology Inc. at Chandler, Arizona, USA

Derek Carlson
VP Development Tools

02-MAY-12
Date

NOTES:

MICROCHIP

MPLAB® STARTER KIT FOR INTELLIGENT.INTEGRATED.ANALOG USER'S GUIDE

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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 "DSXXXXXXXXXA", where "XXXXXXXXX" 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 MPLAB Starter Kit for Intelligent.Integrated.Analog. 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
- Revision History

> **Note:** Format limitations do not permit the use of the full Starter Kit name in the page headers in this document. All references to the "MPLAB Starter Kit for PIC24F Integrated Analog" throughout this document are understood to refer to the "MPLAB Starter Kit for Intelligent.Integrated.Analog".

DOCUMENT LAYOUT

This document describes how to use the MPLAB Starter Kit for Intelligent.Integrated.Analog as a development tool to emulate and debug firmware on a target board, as well as how to program devices. The document is organized as follows:

- **Chapter 1. "Introduction to the Starter Kit"** provides a brief overview and hardware description of the Starter Kit.
- **Chapter 2. "The Demonstration Application"** describes the Starter Kit's preprogrammed application.
- **Chapter 3. "Developing New Applications"** describes the important programming and hardware considerations when developing new Starter Kit applications.
- **Chapter 4. "Troubleshooting"** describes common issues and their solutions.
- **Appendix A. "Starter Kit Schematics"** provides detailed schematics for the Starter Kit.
- **Appendix B. "LCD Panel Information"** provides technical details about the custom Microchip LCD panel.
- **Appendix C. "Optional Microphone Amplifier"** describes the optional microphone amplifier for use in voice applications.

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

Description	Represents	Examples
Arial font:		
Italic characters	Referenced books	*MPLAB® IDE User's Guide*
	Emphasized text	...is the *only* 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	*File>Save*
Bold characters	A dialog button	Click **OK**
	A tab	Click the **Power** tab
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	`file`.o, where `file` can be any valid filename
Square brackets [ ]	Optional arguments	`mcc18 [options] file [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) { ... }`

MPLAB® Starter Kit for Intelligent.Integrated.Analog User's Guide

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 MPLAB Starter Kit for Intelligent.Integrated.Analog. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

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.

PIC24F Family Reference Manual

This reference manual explains the operation of the PIC24F microcontroller family architecture and peripheral modules. The specifics of each device family are discussed in the individual family's device data sheet.

This useful manual is online in sections at the Technical Documentation section of the Microchip web site. Refer to these sections for detailed information on PIC24F device operation.

PIC24FJ128GC010 Device Data Sheet (DS30009312) and Flash Programming Specification (DS39970)

Refer to this device data sheet for device-specific information and specifications. Also, refer to the appropriate device flash programming specification for information on instruction sets and firmware development. These files may be found on the Microchip web site or from your local sales office.

MPLAB® XC16 C Compiler User's Guide (DS52071)

This document helps you use Microchip's MPLAB XC16 C compiler to develop your application. MPLAB XC16 is a GNU-based language tool, based on source code from the Free Software Foundation (FSF). For more information about FSF, see www.fsf.org.

MPLAB® X IDE User's Guide (DS52027)

This document describes how to use the MPLAB X IDE, Microchip's latest version of its integrated development environment, as well as the MPLAB Project Manager, MPLAB Editor and MPLAB SIM Simulator. Use these development tools to help you develop and debug application code.

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 change 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, assemblers, linkers and other language tools. These include all MPLAB C compilers; all MPLAB assemblers (including MPASM™ Assembler); all MPLAB linkers (including MPLINK™ Object Linker); and all MPLAB librarians (including MPLIB™ Object Librarian).
- **Emulators** – The latest information on Microchip in-circuit emulators.This includes the MPLAB REAL ICE™ and MPLAB ICE 2000 in-circuit emulators.
- **In-Circuit Debuggers** – The latest information on the Microchip in-circuit debuggers. This includes MPLAB ICD 3 in-circuit debuggers and PICkit™ 3 debug express.
- **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 IDE Project Manager, MPLAB Editor and MPLAB SIM Simulator, as well as general editing and debugging features.
- **Programmers** – The latest information on Microchip programmers. These include production programmers, such as MPLAB REAL ICE™ in-circuit emulator, MPLAB ICD 3 in-circuit debugger and MPLAB PM3 device programmers. Also included are non-production development programmers, such as PICSTART® Plus and PICkit 2 and 3.

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://www.microchip.com/support

REVISION HISTORY

Revision A (June 2013)

This is the initial release of this document.

Chapter 1. Introduction to the Starter Kit

Thank you for purchasing the MPLAB Starter Kit for Intelligent.Integrated.Analog. This board is intended to introduce the PIC24FJ128GC010 family of advanced analog microcontrollers and demonstrate its wide range of on-chip analog features.

This chapter introduces the Starter Kit and provides an overview of its features. Topics covered include:

- Overview
- What's in the Kit
- Hardware
- Installing Device Drivers for the Starter Kit

1.1 OVERVIEW

The Starter Kit board includes many analog features to showcase the capabilities of the PIC24FJ128GC010 family. The included 100-pin microcontroller integrates the following analog features:

- A high-speed (10 Msps), 12-bit A/D Converter with multiple input channels
- A high-accuracy, 16-bit Sigma-Delta A/D Converter with two input channels
- Dual 10-bit, voltage output Digital-to-Analog Converters (DACs)
- Two op amps and three comparators
- mTouch™ capacitive sensing

In addition, the Starter Kit board adds external analog and digital sensors, including:

- Ambient light sensor
- Digital temperature sensor
- Microphone
- Headphone/line amplifier (stereo)
- Precision, low-drift voltage reference
- Optional expansion area for a Microchip wireless radio module (MRF24J40A)
- Optional NTC thermistor

The board comes preprogrammed with a menu driven demonstration application that highlights most of the functions on the board. The application can be overwritten with your own software, using the PICkit On Board (PKOB) programmer; no external programmer is needed.

The preprogrammed application operates on a stand-alone basis; other than power from a USB connection, no computer or client-side software is required for the board to operate.

The low operating current (7 mA) of the PIC24FJ128GC010 microcontroller means the entire board can be powered from a USB connection or optionally, by battery. The entire Starter Kit itself draws approximately 25 mA from the USB host when running the demo application; the actual current varies slightly between different segments of the application. In Reduced Power mode, the total current draw for the Starter Kit is 1.7 mA, the majority of which is drawn by the LEDs, with about 150 µA for the microcontroller.
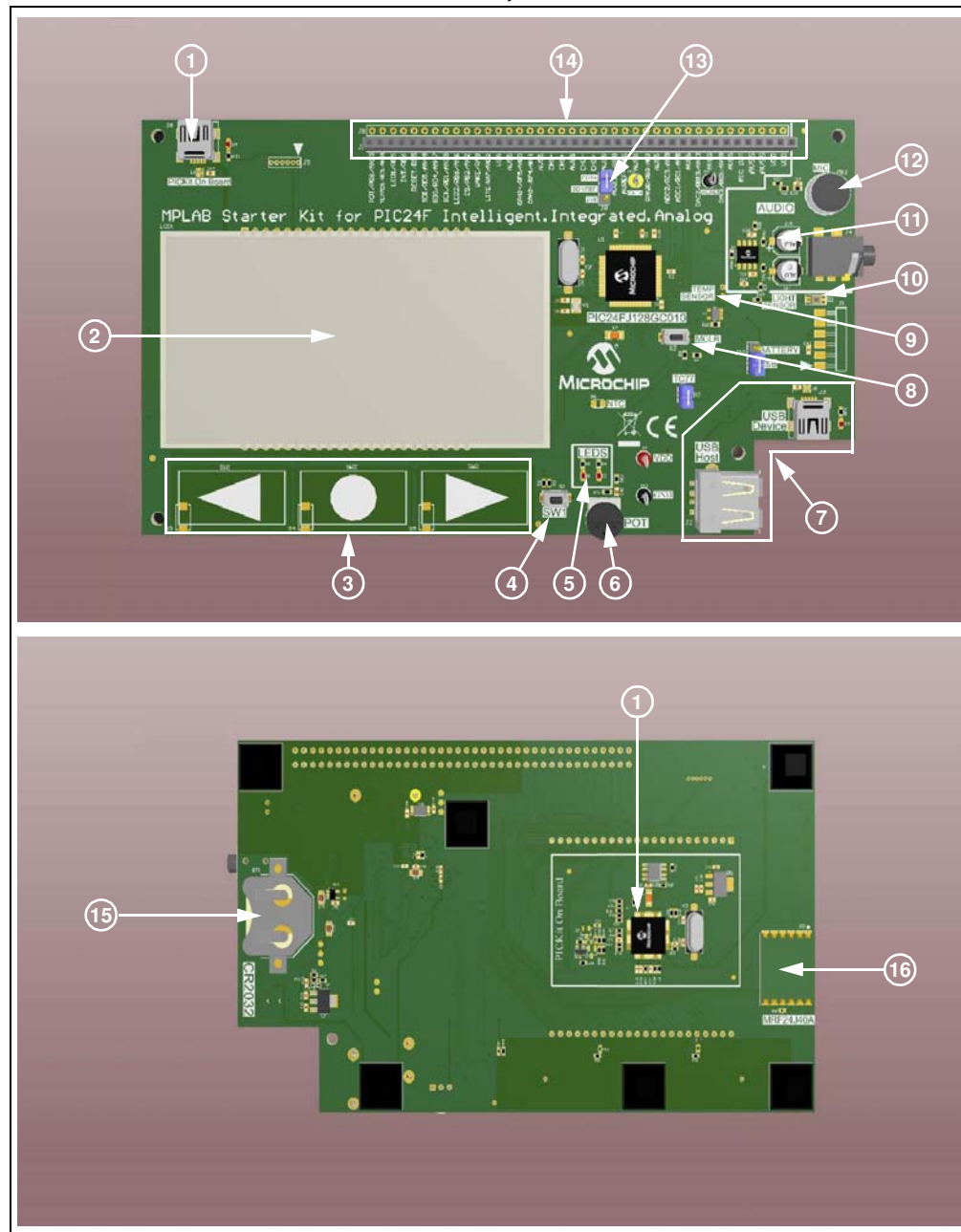
1.2 WHAT'S IN THE KIT

Your MPLAB Starter Kit for Intelligent.Integrated.Analog should contain the following:

• MPLAB Starter Kit board
• USB cable (A to mini-B)
• An insert card with links to the web site for this manual and the demo application

1.3 HARDWARE

Figure 1-1 identifies the major features of the Starter Kit.

FIGURE 1-1: STARTER KIT BOARD, FRONT AND BACK VIEWS

1. **PICkit On Board (PKOB) USB Programmer/Debugger and Connector**

The PKOB is used to program the PIC24FJ128GC010 MCU on the Starter Kit. It connects via USB to MPLAB X, Microchip's programming and debugging environment, and eliminates the need for an external hardware programmer. For more information on loading your own application into the Starter Kit (or reloading the original application), see **Section 3.1 "Reprogramming the Starter Kit Using the PKOB"**.

2. **LCD Display**

This is a custom passive display panel developed exclusively for Microchip Technology. The panel is an STN, positive-sense LCD, organized as a 36-segment by 8-column display. It includes a 37 x 8 dot-matrix array for alphanumeric or special characters and 17 special purpose display icons (useful for many consumer applications) composed of 29 addressable elements.

The LCD panel is directly driven from the I/O pins of the PIC24FJ128GC010 microcontroller; a separate display controller is not required. Multiplexing of the display elements is described in **Appendix B. "LCD Panel Information"**.

3. **mTouch Navigation Touch Pads**

These three navigation buttons are designed into the PCB itself and are configured to respond to the user's body capacitance when touched. Control of the touch sense features are built on the PIC24F microcontroller's on-chip Charge Time Measurement Unit (CTMU) module, which uses a constant-current source to detect changes in the pad's capacitance. A more detailed description of the CTMU module's operation is provided in the *"PIC24F Family Reference Manual",* **"Charge Time Measurement Unit (CTMU)"** (DS39724). Additional information on the mTouch system is available at www.microchip.com/mtouch.

The buttons are covered in detail in **Section 2.1 "Start-up Display"**.

4. **SW1 Momentary Push Button**

This is normally an open SPST push button connected to port pin, RD0. Pressing this button brings RD0 to logic low (ground). The demo application uses this switch to toggle Sleep mode, as described in **Section 2.2.9 "Entering Reduced Power (Sleep) Mode"**.

5. **User LEDs**

These two red LEDs are tied to port pins. D1 is tied to RE7 and D2 is tied to RB6. A logical '1' on the port pin will light the corresponding LED. When on, each draws 1 mA of current.

6. **Potentiometer (R7)**

This 10 kΩ trim potentiometer is connected to the analog input pin, AN19. It is configured as a voltage divider between SWITCHED_VDD and ground. See **Section 1.3.1.1 "SWITCHED_VDD Control"** for more information.

7. **USB Host and Device Connectors (J2 and J3)**

Connectors, J2 (USB-A) and J3 (USB mini-B), allow the Starter Kit board to provide USB host and device functionality. These two USB connectors share the microcontroller's single USB port; therefore, only one device can be connected at a time. The preprogrammed application is configured for device functionality only.

When the board is connected through J2, V_{BUS} is used to power the PIC24FJ128GC010 microcontroller (both V_{DD} and SWITCHED_VDD). LED D4 lights when V_{BUS} is detected. The PKOB is not powered.

8. **$\overline{MCLR}$ Push Button (S2)**

Pressing the switch pulls the $\overline{MCLR}$ pin low, causing a Reset for the microcontroller and any application that may be running.

9. Digital Temperature Sensor (U9) and Jumper, JP7

The TC77 is a digital temperature sensor in a SOT-23 package. It uses an SPI interface to communicate to the microcontroller. The TC77 is powered as part of the `SWITCHED_VDD` bus.

When installed (default), jumper, JP7, connects the TC77 chip select to port pin, RE9. If the TC77 is not needed, removing JP7 allows port pin, RE9, to be used as a general purpose I/O resource.

10. Indoor Ambient Light Sensor (Q1)

Q1 is a phototransistor, used to detect indoor ambient light level. The sensor is designed to output a current in the range of 5 µA to 300 µA, as the light flux varies from 10 to 1000 lux. This current flows through R11, causing a voltage of $V_{DD} - (I_{SENSOR}/R11)$ to be applied to analog input pin, AN22. The resulting DC voltage is inversely proportional to the amount of light on the sensor, ranging from 3.3V (dark) to 50 mV (very bright).

The value of R11 (27 kΩ) limits the upper light level to approximately 400 lux. (As a reference, the average ambient light in an office is 300 to 400 lux.)

11. Audio Output Driver and Output Jack (3.5 mm)

The microcontroller's two 10-bit DACs are connected via buffer op amp, U3 (MCP6022), to this jack. DAC1 (port pin, RG9) is connect to the right channel and DAC2 (port pin, RB13) is connected to the left channel. The op amp is configured as a unity gain buffer. The op amp buffer is powered from the `SWITCHED_VDD` bus.

A simple RC filter with a cut point of -3 dB point at 16 kHz is in series with each output. When connecting to a high-impedance input (such as external powered speakers), the 15Ω series resistor has little effect on the amplitude.

> **Note:** Each DAC is capable of driving full-scale levels (i.e., 3.3V p-p). The 15Ω limiting resistor, in series with the outputs, should limit the output to a standard 16Ω headset to approximately 1.5V maximum. However, this level may exceed safe listening levels. When driving headphones, it is recommended that the output level be kept under 200 mV p-p.

12. Electret Microphone

This is a simple, unamplified microphone, which is biased at 1/2 of the `SWITCHED_VDD` voltage (about 1.65V). The output is AC-coupled and brought out to Pin 5 of J7/J8. For voice use, the output will need to be boosted to approximately 20X.

13. Precision Voltage Reference Section Jumper (J9)

The jumper selects the on-board, precision 2.5V voltage reference or an externally applied reference on the CH1+ (default) connection on J7/J8 for use with the Sigma-Delta A/D Converter. The default configuration is V_{DD} as the reference, which is also the default configuration for the preprogrammed demonstration.

For low noise and more accurate measurements, the 2.5V precision reference is required. Since the input range of the A/D is V_{SS} to V_{REF}, using the 2.5V reference reduces the converter's input range.

14. Breakout Connectors (J7/J8)

Connectors, J7 and J8, provide a direct interface to select functions of the PIC24FJ128GC010 microcontroller. Connector, J7, is a standard riser and can accept standard 0.025″ square posts. J8 is a parallel connected set of through holes. The mapping of microcontroller pins to riser pins is listed in Table 1-1.

Many of the microcontroller pins are multiplexed with several functions. Refer to **Appendix A. "Starter Kit Schematics"** and the PIC24FJ128GC010 device data sheet if you wish to remap the pins for a custom application.

TABLE 1-1: MAPPING OF BREAKOUT CONNECTOR PINS TO MICROCONTROLLER FUNCTIONS

J7/J8 Pin	Function	Device Pin	J7/J8 Pin	Function	Device Pin
1	V_{DD}	—	21	GND	—
2	V_{DD}	—	22	CH1+ IN	35
3	GND	—	23	CH1- IN	36
4	GND	—	24	GND	—
5	MIC OUT	—	25	OPA2- IN	49
6	GND	—	26	OPA2+ IN	50
7	DAC1 OUT	14	27	GND	—
8	GND	—	28	GND	—
9	DAC2 OUT	42	29	LIGHT OUT	92
10	GND	—	30	WAKE	28
11	1 IN	6	31	$\overline{CS}$ RF	11
12	2 IN	8	32	LED2	26
13	GND	—	33	SCK	76
14	OPA2 OUT	22	34	SDO	81
15	GND	—	35	SDI	82
16	AV_{REF}- IN	24	36	WAKE	28
17	AV_{REF}+ IN	25	37	INT IN	4
18	GND	—	39	LED1	5
19	CH0+ IN	33	39	TC77 CS	19
20	CH0- IN	34	40	POT OUT	12

15. C2032 Battery Holder (BT1)

This allows the Starter Kit (i.e., those portions driven from the PIC24FJ128GC010 microcontroller) to be powered from a single coin cell, as opposed to USB power. Jumper, J10, must also be configured to use the battery power feature.

16. RF Transceiver Footprint (U2)

This 14-pin area is designed to accept an optional Microchip MRF42J40A wireless transceiver, for use with wireless application development. Note that the transceiver requires permanent surface mounting to this area. The preprogrammed demonstration does not support the use of the wireless transceiver.

1.3.1 Power Sources

The Starter Kit can be powered in one of three ways, depending on the usage:

- PKOB USB Connector (J6). This will power the entire MPLAB Starter Kit board, including the PICkit programming circuitry. Jumper, J10, must be placed into the USB position (Pins 2-3), which is the default position. Both power LEDs (D4 and D5) will light.
- USB Device Port (J3). In this mode, only those portions of the board driven by the PIC24FJ128GC010 are functional; the PKOB is not powered. Jumper, J10, must be placed into the USB position (Pins 2-3), which is the default position. Only LED, D4, will light.
- CR2032 Coin Cell (not supplied). Only those portions of the board driven by the PIC24FJ128GC010 microcontroller are functional; the PKOB is not powered. Jumper, J10, must be placed into the BATTERY position (Pins 1-2). While operating from a battery, the USB LEDs do not light.

1.3.1.1 `SWITCHED_VDD` CONTROL

In order to reduce power consumption of the Starter Kit, certain circuits can be powered on or off by the microcontroller. This is controlled by port pin, RA9 (WAKE). Asserting this pin (logic '1') turns VDD on to the following devices:

- MCP6022 headphone buffer (U3)
- Potentiometer (R7)
- TC77 temperature sensor (U8)
- Ambient light sensor (Q1)
- Precision voltage reference (U11)
- Electret Microphone (MK1)
- Optional wireless module (U2) (also is the WAKE function to the module)

When `SWITCHED_VDD` is off, power supply current is reduced approximately 3.5 mA without the wireless module installed. Since the wireless module shares its WAKE pin with the control line for `SWITCHED_VDD`, the module will not be able to go into Sleep mode. Installing the wireless module adds approximately 21 mA of current requirement whenever `SWITCHED_VDD` is asserted.

1.4 INSTALLING DEVICE DRIVERS FOR THE STARTER KIT

The USB mode firmware requires the generic Microsoft® WinUSB driver (`winusb.dll`) to be in the directory, `C:\\windows\system32`. This driver should already be installed on computers running Microsoft Windows. When the Starter Kit board is attached for the first time, a notification window that drivers are being installed may briefly appear.

When the drivers are properly installed, the Starter Kit will appear as a USB COM port when plugged into the USB device port (J3).

Chapter 2. The Demonstration Application

This chapter describes the preprogrammed demonstration on the Starter Kit. The application is essentially free-standing and does not require a host application running on a computer. The board can be powered from either USB mini-B connector (J3 or J6).

2.1   START-UP DISPLAY

The application displays a 24-hour clock (`hh:mm`, with flashing colon). The Microchip logo icon appears in the lower right corner of the LCD; LED, D4, is also lit. If this is not correct, try unplugging and replugging the USB cable. Refer to **Chapter 4. "Troubleshooting"** for more information.

The three mTouch touch pads are used by the demo code for data entry and navigation:

- Left Arrow (◄): Decrement current display value or go to the previous demo
- Circle (●): Enter data or select the next submenu
- Right Arrow (▶): Increase current display value or go to the next demo

The mTouch software included in the application waits a preset time to verify the pad has been touched. When the software decodes a "finger down" event, the red LED, D1, will light. When the finger is lifted off the pad, the LED is turned off and the demo application executes the action. Tapping the pad for less than the programmed time (about 100 ms) will not cause a press to be detected.

2.2   SECTIONS OF THE DEMO

The demo application is divided into several foreground sections, with each dedicated to showing a unique function of the microcontroller. In addition to these, the demo application runs a continuous background process to export data over the USB port.

The sections are organized as a closed-loop menu, meaning they will repeat once the end is reached if the ▶ key is pressed. The sections are ordered as follows:

- Clock
- Sigma-Delta A/D
- Pipelined A/D (also includes the ambient light sensor)
- Stereo DAC
- Temperature Sensor (external TC77 sensor)
- LCD Test
- Audio Input (microphone)

Some sections (like setting the clock) have submenus, which are selected using the ● pad. Detailed information on each section follows.

2.2.1 Clock Demo

The 24-hour clock is the home page for the demo. This is a 24-hour clock with a blinking colon for seconds. The clock uses the on-board 32 kHz Secondary Oscillator (SOSC) for an accurate time base.

To set the clock to the proper time:

1. Press ● when the LCD is displaying the clock.
2. The display shows, `hh:mm`, where 'hh' is the current hour and 'mm' is the current minute. The first hours digit begins to blink, indicating that is the current digit to set.
3. Press the ◀ pad to decrement the hours digit or press ▶ to increment the digit. Since this is a 24-hour setting, the digits cycle through 0 > 1 > 2 > 0... .
4. When the correct digit is shown, press ● to save it. The current digit stops blinking and the next digit begins to blink.
5. Repeat Steps 2 through 4 for each of the remaining digits until the display is showing the correct time.

Note that there is no back key to return to a previous digit. If you make an error after pressing the ● key, you have to start over.

2.2.2 Sigma-Delta A/D Demo

This section demonstrates the Sigma-Delta A/D Converter. For more information on this module and its feature set, refer to the *"PIC24F Family Reference Manual", "***16-Bit Sigma-Delta A/D Converter"** (DS30687).

Pressing the ▶ pad from the clock demo causes the LCD to momentarily display, "`SD ADC CH:DATA`". "`CH:DATA`" is the display format of the A/D result, where "`CH`" is the Sigma-Delta A/D channel and "`DATA`" is a 16-bit signed hexadecimal value. Positive values are in the range of 0000h to 7FFFh. Due to a slight offset voltage, the display may indicate a small negative voltage (FFC0h to FFFFh). If the CH+/CH- inputs are swapped, the display will show negative values (a range of 8000h to 0000h).

The demo uses CH1 to read an externally applied voltage with SV_DD (3.3V) as the A/D voltage reference. The precision 2.5V reference can be used if the demo application is modified (or replaced with custom code) to use CH1+ as the reference and measurements are taken with the CH0 channel.

The input amplifier for the Sigma-Delta A/D is differential; that is, you can apply a differential voltage across the two inputs. This is why swapping the inputs in the demo generates a negative value. The amplifier has different gain settings but in the demo, it is set for a gain of 1.

It is also possible to make a single-ended measurement with the Sigma-Delta A/D Converter by applying a voltage to one terminal, while the other is the ground reference. To do this, with using SV_DD as a reference:

1. Set jumper, J9, to the CH1+ position.
2. Connect an external jumper wire between CH1- (J7, Pin 23) and AV_SS (any of the GND pins on J7).
3. Connect the voltage to be measured to CH1+ (J7, Pin 22). The voltage must be in the range of 0V to 3.3V.

2.2.3 Pipeline A/D Demo

This section of the demo uses the 12-bit Pipeline A/D Converter. For more information on this module and its operation, refer to the *"PIC24F Family Reference Manual"*, **"12-Bit, High-Speed Pipeline A/D Converter"** (DS30686).

The Pipeline A/D demo uses two analog input channels of the Pipeline A/D Converter to display a pair of bar graphs. The bar graphs extend, left-to-right, across the LCD. The top bar is the reading of the potentiometer, R7 (AN19), and the lower bar graph is the ambient light sensor, Q1 (AN22). Turning the thumb wheel counterclockwise, or covering the light sensor, reduces the corresponding bar.

While in this demo, pressing the ● pad advances through a sequence of display options. On the first touch, the display shows, "`19:xxxx`", where "`xxxx`" is the hexadecimal value from the A/D of the potentiometer's current setting (range, 0 to 0FFFh).

Pressing ● again displays, "`22:yyyy`", where "`yyyy`" is the hexadecimal value from the A/D of the light sensor; the value increases with less light.

Pressing ● again displays, "`8:zzzz`", to display the converted value on AN8 (Pin 11 on JP7/8), where "`zzzz`" is the hexadecimal value of the voltage. If a voltage is not present, and AN8 is not tied to V_{SS}, this value will be random.

Pressing ● once more returns to the original display.

The data from the potentiometer, light sensor and AN8 are output over the USB port, as described in **Section 2.2.8 "Background Data Transmission"**, via the background data transmission process.

2.2.4 Stereo DAC Demo

This section generates three audio sine waves, one octave apart. The demo application calculates a 512-point sine wave and stores the 10-bit values for each point in RAM. Timer4 is used to transfer (via the DMA bus) the RAM buffer to the DAC Output registers. The output frequency is calculated, on-the-fly, as a passed parameter in Hz. The frequencies of the three tones generated are: 110 Hz, 220 Hz and 440 Hz (A_2, A_3 and A_4 or middle A).

The raw DAC output is passed through the 16 kHz low-pass filters and to the headphone jack.The maximum voltage generated by the demo is 800 mV p-p.

Pressing the ● key steps through the three different frequencies.

> **Note:** Do not use excessive volume with this part of the demo. The maximum output (800 mV p-p) may produce an audio output in excess of safe listening levels.

2.2.5 TC77 Temperature Sensor Demo

This section uses the TC77 temperature sensor (U8) to obtain the ambient temperature. This sensor transfers data to the microcontroller via the SPI bus. The chip select is provided by the port pin, RE9, and is routed via jumper, JP7.

By default, the demo displays the board's current temperature in degrees Centigrade. Pressing ● converts the reading to Fahrenheit. The LCD displays the thermometer icon and the appropriate temperature unit icon.

2.2.6 LCD Test Demo

This section of the demo displays all the available graphic icons and sequentially flashes each one while showing their name in the dot-matrix portion of the LCD. This demo repeats continuously until another portion is selected. There is no submenu.

2.2.7   Audio/Microphone Demo

This section uses a bar graph display to represent the output of the unamplified electret microphone. The 12-bit Pipeline A/D Converter is used to measure the amplitude of the output signal.

To use this section, it is necessary to first connect MIC OUT (J7/J8, Pin 5) to ADC1 IN (Pin 11) with a jumper wire (22 gauge recommended). The display bar graph increases (extends to the right) as the amplitude of the input signal increases. As the microphone's output is low, it is necessary to directly tap on it or blow into it to get a response.

The on-board electret microphone is biased at 1.6 VDC and is unamplified. To use the microphone for voice recording, it will be necessary to add an amplifier. An appropriate design would be an AC-coupled amplifier, with approximately 20X gain, and with an output DC-biased to 1.6V (the microphone's normal bias level) at midscale. An example of a suitable design is provided in **Appendix C. "Optional Microphone Amplifier"**.

2.2.8   Background Data Transmission

As the foreground demo application runs, a separate background process is also executing. This process sequentially converts the input from three different analog inputs into a digital value and exports this data over USB as a virtual COM (serial) port. The Pipeline A/D demo must be selected for data to be output on the USB port. The data is output in three hexadecimal words, representing the potentiometer value, the light sensor value and the signal on AN8. The process repeats the conversions and exports the most current values continuously.

The data from this process can be read from the virtual COM port by using any available serial terminal emulator.

2.2.9   Entering Reduced Power (Sleep) Mode

During any foreground section of the application, pressing SW1 places the micro-controller in Sleep mode. While in this mode, execution of the demo is paused while the display returns to the 24-hour clock demo. Also, two "**z**"s are added to the LCD display. The background transmission of data over the virtual COM port also pauses. The microcontroller wakes, once every minute, allowing the time display to be updated, after which the microcontroller returns to Sleep mode.

Pressing SW1 again ends Sleep Mode. The "**z**"s on the display are removed and the clock display's colon resumes blinking.

2.3 OTHER HARDWARE RESOURCES ON THE STARTER KIT

Connector, J2, is configured as a USB host. As it is connected in parallel with the USB device port connector, J2 cannot be used while J3 is in use.

A footprint (R5) is provided on the board for an add-on thermistor. The footprint is designed to accommodate an NTC thermistor in an 0805 package size. Typical values are 10 kΩ and 47 kΩ. The CTMU can source a current to the NTC and read the resulting voltage using the 12-bit Pipeline A/D Converter. This feature is not implemented in the supplied demo software. For more information, refer to Microchip Application Note, *AN1375, "See What You Can Do with the CTMU"* (DS01375).

If touch sensing is not desired, the function of the touch pads can be replaced with push button (or other momentary contact) switches. Spaces are provided for switches, S3, S4 and S5, as well as corresponding (unpopulated) pull-up resistors, R12, R52 and R54. Note that installing these components does not automatically disable touch sense functionality.

The footprint for U2 has been designed to directly solder mount one of Microchip Technology's wireless transceiver modules. Although the MRF24J40A (2.4 GHz, IEEE 802.15.4) wireless transceiver is specified elsewhere in this manual, in theory, any pin-compatible Microchip wireless transceiver module can be used.

The unpopulated footprints for J1 and J5 are provided in the event that additional programming and emulation interfaces are required. J1 provides a 6-pin interface to the Starter Kit for use as a ICSP™ compatible emulator product (Microchip MPLAB ICD 3 programmer, the PICkit 3 programmer or the MPLAB REAL ICE emulator). It can also be used as an alternative method for directly programming the PIC2FJ128GC010 microcontroller via In-Circuit Serial Programming™ (ICSP™). J5 provides a standard 5/6-pin interface to the PKOB and can be used to update its firmware.

NOTES:

Chapter 3. Developing New Applications

The MPLAB Starter Kit for Intelligent.Integrated.Analog may be used with MPLAB®
IDE, the free Integrated Development Environment available on Microchip's web site.
MPLAB IDE allows the starter kit to be used as an in-circuit debugger as well as a pro-
grammer for the featured device.

In-circuit debugging allows you to run, examine and modify your program for the device
embedded in the Starter Kit hardware. This greatly assists you in debugging your
firmware and hardware together.

Working through the PICkit On Board (PKOB), the Starter Kit interacts with the
MPLAB IDE application to run, stop and single-step through programs. Breakpoints
can be set and the processor can be reset. Once the processor is stopped, the
register's contents can be examined and modified.

3.1   REPROGRAMMING THE STARTER KIT USING THE PKOB

When the Starter Kit is connected from your computer to the PICkit On Board USB
connector (J6), MPLAB recognizes it as a valid programmer and debugger. In
MPLAB IDE 8.x, the drop-down menu will show "Starter Kit on Board" as the correct
name (Figure 3-1).

FIGURE 3-1:   SELECTING THE PKOB IN EARLIER VERSIONS OF MPLAB® IDE