XLP 16-Bit Development Kit User's Guide

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XLP 16-BIT DEVELOPMENT KIT 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 "DSXXXXXA", where "XXXXX" 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 on-line help. Select the Help menu, and then Topics to open a list of available on-line help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using the XLP 16-Bit Development Board. 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 XLP 16-Bit Development Board as a development tool to emulate and debug firmware on a target board. The manual layout is as follows:

- **Chapter 1. Introduction to the XLP 16-Bit Board** provides a brief overview of the XLP 16-Bit Development Board, its features and its uses
- **Chapter 2. The XLP Demonstration Application** describes the preprogrammed demonstration program
- **Chapter 3. XLP 16-Bit Development Board Hardware** provides a more detailed description of the XLP 16-bit board's hardware features
- **Appendix A. Development Kit Schematics** provides detailed schematics of the XLP 16-Bit Development Board

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) { ... }`

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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 XLP 16-Bit Development Board. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

Readme for XLP 16-Bit Development Board

For the latest information on using the XLP 16-Bit Development Board, refer to the file, `readme.pdf`, in the "Documentation" subdirectory (inside the "XLP 16-bit Development Board Demo" directory). This file contains update information and known issues that may not be included in this user's guide.

PIC24F16KA102 Family Data Sheet (DS39927)

Consult this document for detailed information on the PIC24F K-series Flash device that is pre-installed in the development kit. Reference information found in this data sheet includes:

- Device memory map
- Device pinout and packaging details
- Device electrical specifications
- List of peripherals included on the device

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 on-line in sections at the Technical Documentation section of the Microchip web site. Refer to these sections for detailed information on PIC24F device operation.

16-Bit MCU and DSC Programmer's Reference Manual (DS70157)

This manual is a software developer's reference for all of Microchip's 16-bit microcontrollers. It describes the instruction set in detail and also provides general information to assist in developing software for PIC24, dsPIC30 and dsPIC33 MCUs.

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- **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 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.
- **Emulators** – The latest information on Microchip in-circuit emulators.This includes the MPLAB ICE 2000 and MPLAB ICE 4000.
- **In-Circuit Debuggers** – The latest information on the Microchip in-circuit debugger, MPLAB ICD 3 and 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, such as the MPLAB PM3 device programmer.

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- 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 (June 2010)

- Revises **Section 2.1 "Initial Setup"** with a simplified installation procedure, reflecting the inclusion of driver software in the software installation package.
- Revises **Section 2.2 "Demonstration Program Operation"** with a modified application description and new application flow diagram for the current revision of the demo application.
- Adds **Section 2.2.1 "Demo Program Configuration"** to describe configuration options in the most current revision of the demo application.
- Revises **Chapter 3. "XLP 16-Bit Development Board Hardware"** with additional information on compatible PICtail Plus daughter boards and a new current measurement cable.
- Corrects the ICD/ICSP™ connectors in Figure A-1 of **Appendix A."Development Kit Schematics"**.
- Other minor typographic corrections throughout.

NOTES:

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Chapter 1. Introduction to the XLP 16-Bit Board

1.1 INTRODUCTION

Thank you for purchasing Microchip Technology's XLP 16-Bit Development Board Kit. The board provides a low-cost, highly configurable development system for Microchip's new line of PIC24F 20 and 28-pin Extreme Low-Power (XLP) microcontrollers, including the PIC24F16KA102 and PIC24FJ64GA102 families.

The XLP 16-bit board permits users to explore and evaluate extreme low-power features, and learn low-power software and hardware techniques. Various headers are available to measure both microcontroller and component power consumption. It is flexible, supporting six different power sources over a wide voltage range. It is highly configurable, equipped with a variety of common peripheral components that can be selectively enabled. Finally, it is expandable through its modular interface, providing for the addition of advanced interfaces and connectivity methods.

As provided, the XLP 16-Bit Development Board functions as a demonstration platform on initial power-up. The included demonstration software takes a temperature measurement, datalogs information to the serial data EEPROM and displays information to a host PC via a USB connection. Additional software is provided to demonstrate low-power techniques and IC interface routines.

1.2 HIGHLIGHTS

The XLP 16-Bit Development Board includes these features:

- Support for both 20-pin and 28-pin versions of both PIC24F J-series and K-series Flash microcontrollers
- Accommodations for six different power source options
- Configurability for a wide range of operating voltages (1.8V to 5.5V)
- Configuration selection jumpers to disable board components
- A hardware switchable option to control power to board components with port pin
- USB connectivity
- Provisions to add RS-232 transceivers (not populated)
- Five user-defined buttons (3 capacitive touch and 2 push buttons)
- Two user-defined LEDs
- Two temperature sensors
- Potentiometer for analog input or High/Low Voltage Detect (HLVD) reference
- Built-in capability for separately measuring microcontroller and component current consumption
- Support for all Microchip compatible programmers and emulators

1.3 WHAT'S IN THE KIT

The XLP 16-Bit Development Board Kit includes the following:

- XLP 16-Bit Development Board with a preprogrammed PIC24F16KA102 microcontroller installed
- USB mini-B cable

1.4 DEVELOPMENT BOARD FEATURES

A layout of the XLP 16-Bit Development Board is shown in Figure 1-1. The board includes these specific features, as indicated in the diagram:

1. Shared footprint 20-pin and 28-pin (300 mil PDIP) sockets for PIC24F microcontrollers, plus associated headers
2. Oscillator circuits (8 MHz and 32.768 kHz) for PIC24F microcontrollers
3. Power supply area (battery holders, external power supply input, LDO regulator and power supply select jumper)
    a) Interface headers for energy harvester demonstration kits
4. IC power control switch (IC PWR)
5. Power LED
6. Adjustable LDO regulator
7. PIC24F on-chip regulator configuration switch and circuitry
8. IC power select jumpers
9. PIC24F Master Clear switch
10. Capacitive touch pads
11. User-defined push buttons
12. Potentiometer
13. User-defined LEDs
14. Serial EEPROM
15. Temperature sensors
16. Capacitive measurement point
17. USB interface (USB/UART transceiver, PIC18F oscillator and USB port)
18. Unpopulated RS-232 options area
19. Programming interfaces:
    a) MPLAB ICD 2 6-wire interface (RJ-11 socket) and separate PIC18 ICSP™ header
    b) PICkit™ programmer 6-pin interface
20. Modular 28-pin riser interface for daughter boards
21. Prototype area with supply voltage and I^2C™ signal access
22. Current measurement jumpers and access point

A more detailed discussion of each feature and its configuration is provided in **Chapter 3. "XLP 16-Bit Development Board Hardware"**.

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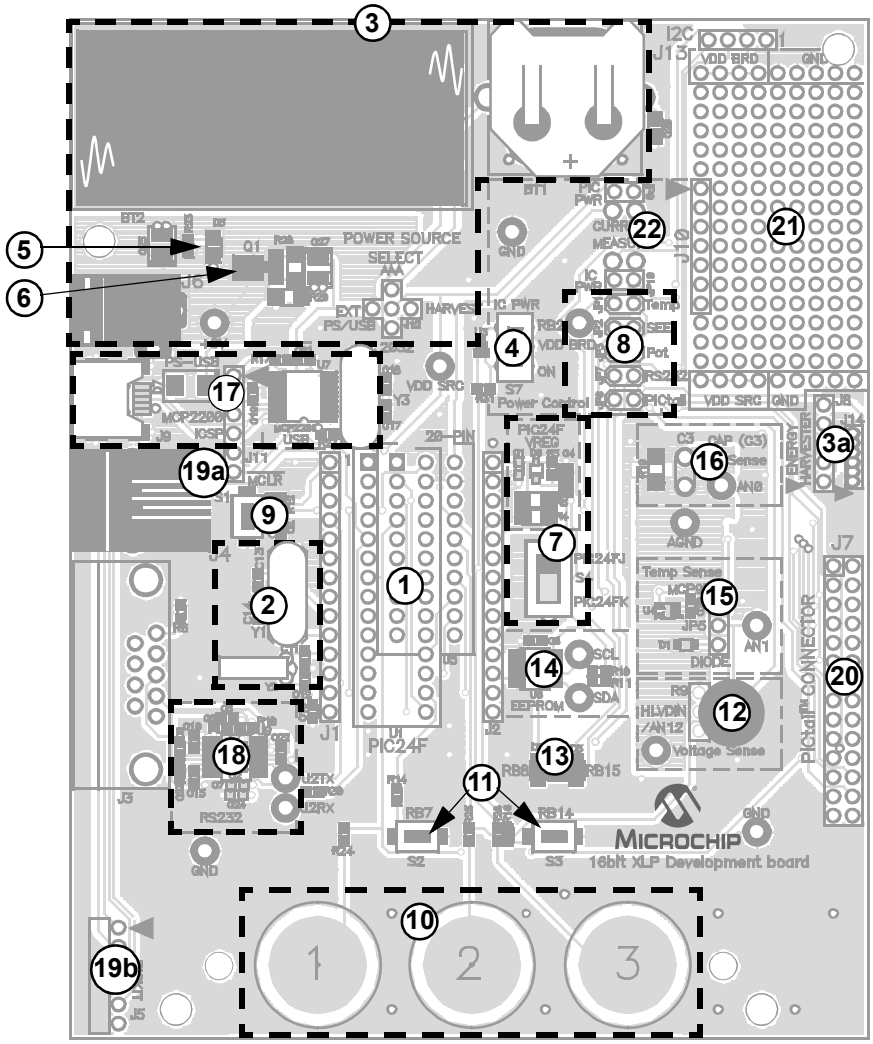
FIGURE 1-1: XLP 16-BIT BOARD COMPONENT LAYOUT



1.5 USING THE DEVELOPMENT BOARD OUT OF THE BOX

Although intended as a development platform, the XLP 16-bit board may also be used directly from the box as a demonstration platform for the preprogrammed PIC24F16KA102 microcontroller.

Refer to **Chapter 2. "The XLP Demonstration Application"** for details on the demonstration code operation.

1.6 DEMONSTRATION PROGRAM

The preprogrammed example code on the PIC24F16KA102 device is available for download from the Microchip web site (www.microchip.com/XLP16BitBoard). All required project files are provided, so that the code may be used as an example or a platform for further development. These may be used with the included PIC24F16KA102 device by programming the device using an MPLAB ICD 2 programmer/debugger, PICkit™ starter kit or any other Microchip programming tool.

In addition, the firmware for the USB-to-serial emulator that is preloaded on the PIC18F14K50 microcontroller, is also provided. Both source code (in C) and compiled code files (in HEX format) are included.

1.7 REFERENCE DOCUMENTS

In addition to the documents listed in the **"Recommended Reading"** section, these documents are also available from Microchip to support the use of the XLP 16-Bit Development Board:

- *"25AA256/25LC256 256K SPI Bus Serial EEPROM"* Data Sheet (DS21822)
- *"MCP9700/9700A/9701/9701A Low-Power Linear Active Thermistor™ ICs"* Data Sheet (DS21942)
- *"PICkit™ 2 Programmer/Debugger User's Guide"* (DS51553)
- *"PICkit™ 3 Programmer/Debugger User's Guide"* (DS51795)
- *"MPLAB® ICD 2 In-Circuit Debugger Quick Start Guide"* (DS51268)
- *"MPLAB® REAL ICE™ In-Circuit Emulator User's Guide"* (DS51616)
- *"Compiled Tips 'n Tricks Guide"* (DS01146)
- *"PIC24F Family Reference Manual",* **Section 11. "Charge Time Measurement Unit (CTMU)"** (DS39724)

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Chapter 2. The XLP Demonstration Application

This chapter describes the demonstration application that is preprogrammed on the PIC24F microcontroller, which shows the use of low-power techniques in a working application. In the process, the application highlights various features of the PIC24F microcontroller family.

2.1 INITIAL SETUP

Although intended as a development platform, the XLP 16-bit board is also designed to be used directly from the box as a demonstration platform. The demonstration firmware preprogrammed into the PIC24F16KA102 microcontroller is ready for immediate use.

The demonstration firmware uses a USB-to-RS-232 converter to communicate with the PC via a standard serial interface. In order to use the board with a PC, a serial terminal program will be required. The open source program, RealTerm, is included with the demo software and can be used to communicate to the board.

2.1.1 Configuring and Connecting the Hardware

To get started with the board, verify that it is properly configured:

1. Verify the PIC24F16KA102 is correctly installed into socket, U1. The notch on the edge of the device package will be toward the top of the board.
2. Verify that S4 is in the "PIC24K" position.
3. Ensure the IC PWR switch is in the "RB2" position.
4. Populate the PIC PWR and IC PWR jumpers.
5. Select "EXT PS/USB" with the power source select jumper.
6. Select the "MCP9700" temperature sensor option with the temp sense jumper.
7. Populate the TEMP, SEE and POT jumpers.

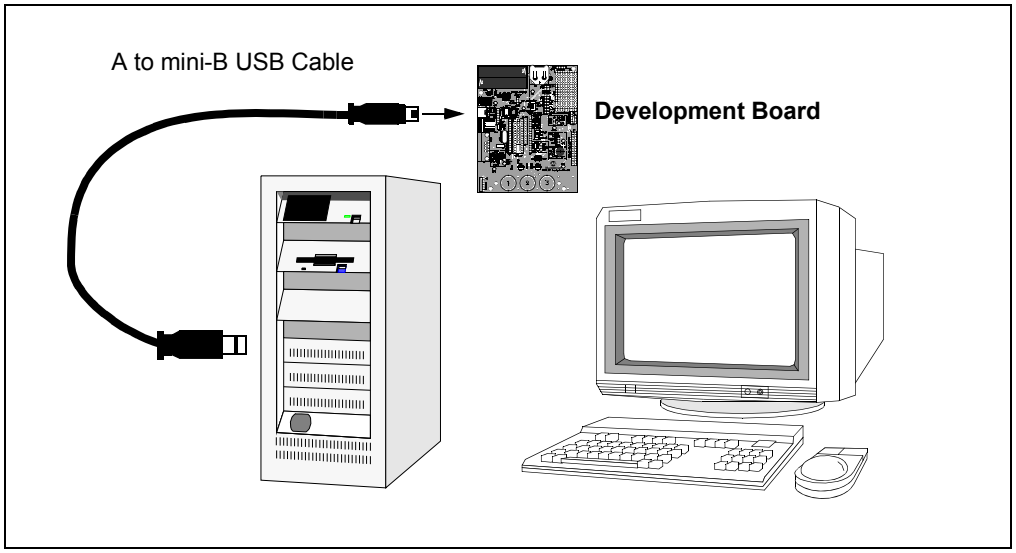
2.1.2 Installing the Software and Driver

Before connecting the board to the PC, install the driver by running the installation file downloaded from the Microchip website. This setup utility will install the source and documentation to the indicated location, and install the USB to RS-232 emulation drivers.

> **Note:** For Windows XP, one or more dialogs may warn that the driver has not been digitally signed. This is normal. Click **OK** to proceed through the dialogs.

After the installation completes, connect the development board to the PC with the provided USB cable (A to mini-B), as shown in Figure 2-1. The drivers will automatically be located and installed by the operating system.

FIGURE 2-1: STARTER KIT SETUP



Once the driver installation finishes, it is necessary to determine the COM port number that has been assigned. To do this in Windows, open Device Manager (from the control panel, click on the **System** applet, select the **Hardware** tab, then click on **Device Manager**). In the default view (Device by Connection), check under "Ports (COM & LPT)" for the newly added COM port. The actual number of the new COM port will vary depending on the hardware configuration of the system prior to driver installation.

2.1.3 Configuring the Serial Terminal

With the board connected and the USB driver installed, the only remaining task is to configure the terminal session. The required COM port settings are:

- Bits per Second: 1,000,000
- Data Bits: 8
- Parity: None
- Stop Bits: 1
- Flow Control: None.

Note:	If the serial terminal software being used does not support this baud rate, it will be necessary to change the default baud rate for the firmware and reprogram the board.

At this point, the terminal is connected to the XLP board and communicating through the emulated serial port. It may be necessary to press S1 (Master Clear) to reset to the PIC24F microcontroller and obtain a display.

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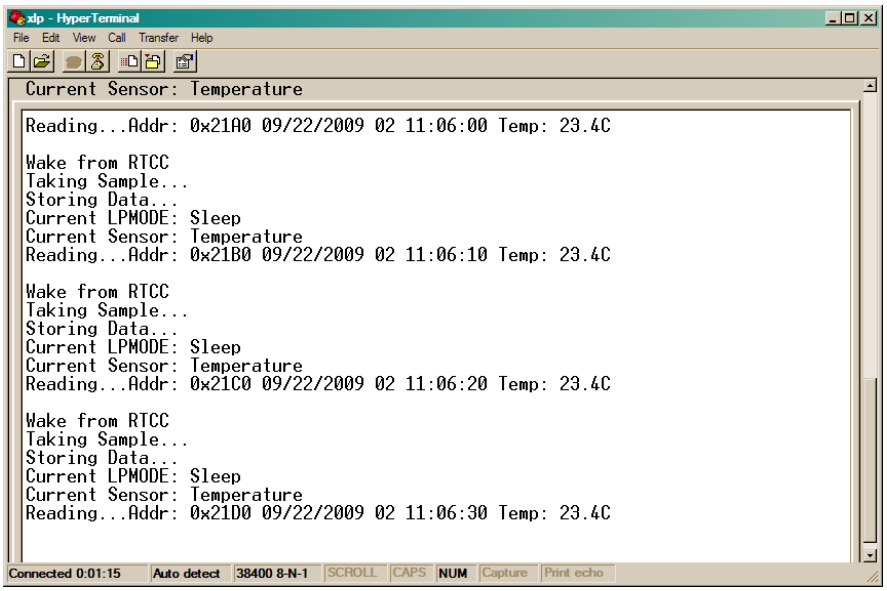
2.2 DEMONSTRATION PROGRAM OPERATION

The demonstration program uses the on-board RS-232 to USB converter to send system status data in serial form to a standard serial terminal (Figure 2-2). It permits the user to select which sensor information is displayed and to choose the microcontroller's Low-Power mode. This permits users to experiment with various low-power and XLP techniques, as well as make direct measurements.The program flow is shown in Figure 2-3.

FIGURE 2-2: SERIAL TERMINAL DISPLAY FOR THE DEMONSTRATION APPLICATION



On power-up, the PIC24F16KA102 device will wake-up every 10 seconds from a Real-Time Clock Calendar (RTCC) interrupt, then re-enter Sleep mode. While awake, the microcontroller takes a temperature measurement using the MCP9700 temperature sensor and writes the information to the serial EEPROM. Status information is displayed, including the wake-up source, Low-Power mode, selected sensor, data EEPROM information and current temperature. In the default POR configuration, the RTCC interrupt is the wake-up source, while the MCP9700 is the active sensor.

Push button switches, S2 and S3, can perform multiple functions depending on the code configuration and how long they are depressed. To minimize power, these switches use internal pull-ups which are disabled in software when not in use.

Pressing S2 forces a sample to be taken immediately on the selected sensor. This information is displayed on the terminal window.

Pressing S3 disables the output to the screen. This permits power measurements without the additional current consumed by the UART. Pressing S3 again enables the UART and permits information to be displayed again.

Pressing and holding S2 for more than two seconds selects the sensor input. Repeated presses cycle between the temperature sensor, potentiometer, capacitive touch pads and all three sensors at once. The display reflects each new sensor selection. When the potentiometer is selected, both V_{DD} and current potentiometer voltages are shown. When the touch pads are selected, their real-time status is displayed. When all three sources are active at once, all of the sensor information is displayed at one time.

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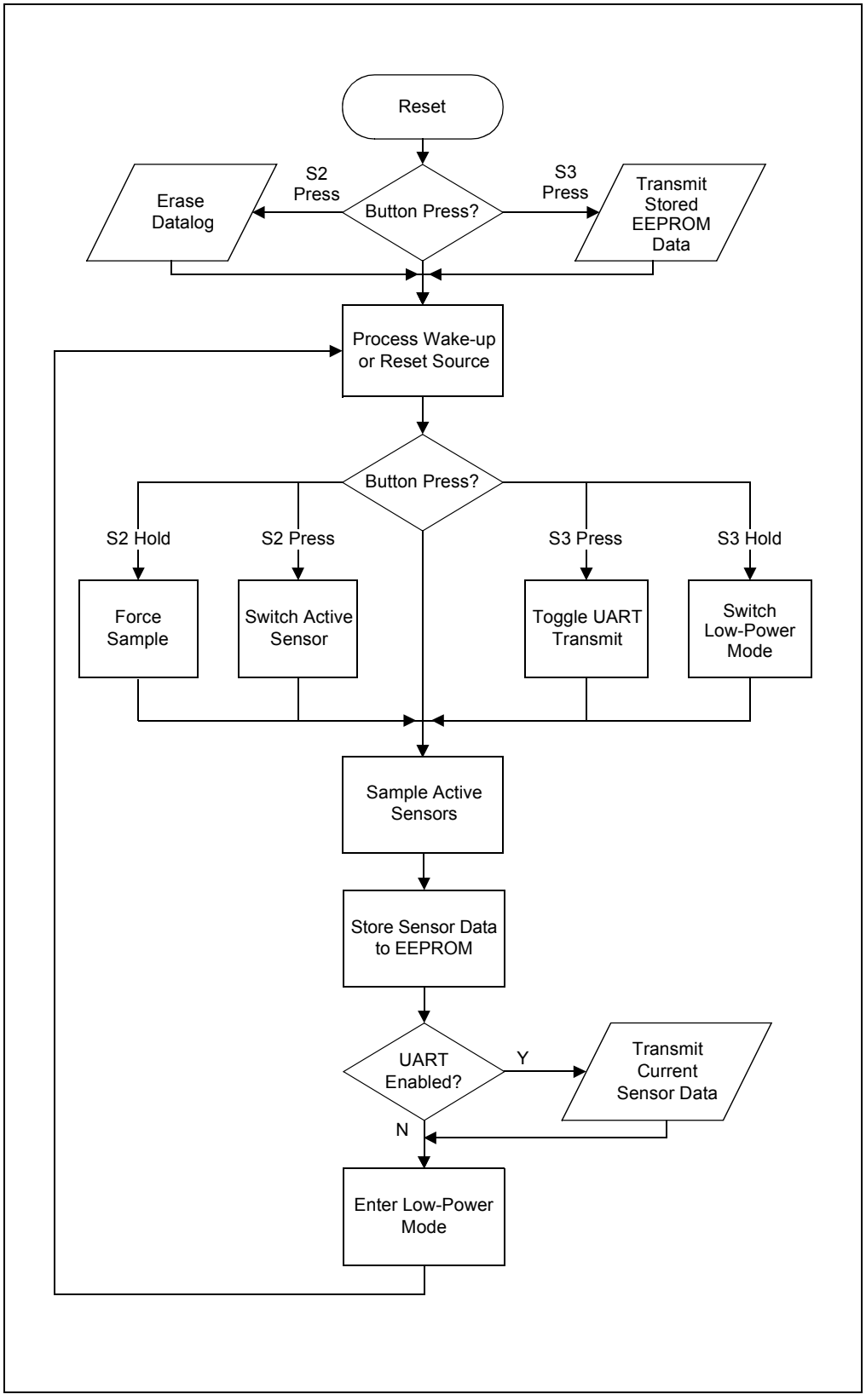
FIGURE 2-3: DEMO APPLICATION SOFTWARE FLOW



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When the capacitive sense pads are active, the device wakes up more often (once per second). In addition, data is only stored to the EEPROM when a capacitive touch event is detected. The same is true when all sensors are active.

Pressing and holding S3 for more than two seconds selects between Sleep, Deep Sleep and Idle modes for the PIC24F microcontroller. In Deep Sleep, most microcontroller functions are disabled to minimize power consumption. The available wake-up sources supported by the XLP 16-Bit Development Board are RTCC interrupt, External Interrupt 0 (INT0) and $\overline{\text{MCLR}}$ Reset. When Idle mode is selected, all peripherals continue to operate; however, program memory is disabled and code execution is stopped to reduce power consumption.

Because of the limited number of wake-up sources available in Deep Sleep mode, S3 can not wake the microcontroller. However, S1 ($\overline{\text{MCLR}}$ Reset) and S2 (connected to INT0) can wake up the device. The RTCC interrupt will continue to periodically wake-up the microcontroller every 10 seconds. The display indicates which wake-up source is used to exit Deep Sleep mode.

Note: While the capacitive touch pads are enabled, the demo application will enter Sleep mode instead of Deep Sleep; this permits the touch pads to remain active and exit the Low-Power mode.

Holding S2 while resetting the device resets the datalog, restarting the EEPROM address counter at 00h.

Holding S3 while resetting the device outputs the EEPROM contents via the UART. The output consists of a data log of time-stamps from the RTCC and the sensor measurements taken at that time.

2.2.1 Demo Program Configuration

The demonstration software has a number of configuration options to allow it to be used in a number of low-power applications. These are implemented in the application source code using `#ifdef` statements.

There are two projects which share configuration options:

- The XLP16Demo project, which implements the full functionality of the board for a typical low-power application powered by a battery.
- The XLPEHDemo project, customized for use with an Energy Harvester as a power supply.

Eight configuration options are available:

- `USE_PWRCTL` enables the control of power to external circuits dynamically via an I/O pin driving the gate of a FET. This allows the code to disable power consuming external devices when they are not in use, such as when the device is asleep. With this define, the firmware dynamically enables and disables external devices as they are used.
- `USE_PWRCTL_ONESHOT` is an alternative to `USE_PWRCTL`. This option enables and disables external devices only once per loop. External devices are powered on when the microcontroller wakes from Sleep and powered off after completing the loop, but before entering Sleep. This option is provided for low-power applications which have restrictions on the peak current available, as dynamic power control of the external devices can cause undesired current spikes.
- `USE_BUTTON_HOLD` enables the firmware to detect when a user presses and holds S2 or S3 for a specific amount of time. The held-button detection algorithm is implemented to consume as little power as possible. However, due to the length of time required to detect a button press and release, it may consume too much power for some applications. These applications can disable held-button detection to maintain minimal power consumption.

- USE_CAPTOUCH enables the capacitive touch sensing algorithm. Effective cap touch sensing requires a fast response time (about 100 ms), which can drain too much power for some applications. This setting allows capacitive touch sensing to be disabled so that it is not used as part of the Sensor mode cycle.
- USE_HARVESTER enables energy harvester State-of-Charge monitoring. When enabled, the firmware tracks the charge state of the energy harvester and attempts to manage available power to prevent fully discharging the battery.
- DEFAULT_MODE sets the default Low-Power mode, selecting between Sleep, Deep Sleep and Idle modes. If held-button detection is enabled, the Low-Power mode can be changed at run time; otherwise, the selected mode is always used.
- DEFAULT_SENSOR sets the default sensor, selecting between temperature, potentiometer voltage, capacitive touch sensors and all sensors. If held-button detection is enabled, the sensor can be changed at run time; otherwise, the selected sensor is always used.
- DEFAULT_TX sets the default transmitter setting. If true, the demo will have UART transmissions enabled by default. If false, they are disabled. The state of the transmitter can always be changed at run time by pressing S3.

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Chapter 3. XLP 16-Bit Development Board Hardware

3.1 INTRODUCTION

This chapter provides a more detailed description of the hardware features of the XLP 16-Bit Development Board.

3.2 HARDWARE FEATURES

The key features of the XLP 16-bit board are listed below. They are represented in the order given in **Section 1.4 "Development Board Features"** and Figure 1-1.

3.2.1 PIC24F Processor Support

The XLP 16-bit board has been designed to accommodate PIC24F microcontrollers in both 20-pin and 28-pin 300 mil PDIP packages. All pin signals on both sockets are also available for external monitoring on the 14-pin headers (J1 and J2), located on either side of the sockets.

3.2.1.1 FEATURE AVAILABILITY BY PIC24F DEVICE FAMILY

The high degree of pin compatibility between PIC24F device families makes it possible for the XLP 16-Bit Development Board to support many low pin count devices. However, there are a few minor pinout differences between families that make it difficult to create a universal board. Of all of the board's features described in this chapter, only three are not universally available to all PIC24F microcontrollers. These are summarized in Table 3-1, with details provided in subsequent sections. Any feature that is not listed here is implemented uniformly for all PIC24F device families that are supported by the development board.

TABLE 3-1: FEATURES THAT ARE NOT UNIVERSALLY AVAILABLE

PIC24F Device Family	Board Feature		
	Potentiometer	D3 (Yellow)	28-Pin Modular Connector
28-pin J-series	**(Note 1)**	**N**	Y
28-pin K-series	Y	Y	Y
20-pin K-series	Y	Y	**N**

Note 1: Functions as an A/D potentiometer only on these devices, and as an A/D and HVLD reference potentiometer on all others.

3.2.2 PIC24F Oscillator Options

The installed microcontroller has two separate oscillator circuits connected. The main oscillator uses an 8 MHz crystal (Y1) and functions as the primary oscillator. A second circuit, using a 32.768 kHz crystal (Y2), functions as the Timer1 oscillator, and serves as the source for the RTCC and secondary oscillator.

3.2.3 Power Sources

The XLP 16-bit board can use any one of six power options for full operation:

1. Bus power via the USB connector (J9). This provides a nominal 5V power source, regulated to approximately 3.3V for the microcontroller and board components, through a Schottky diode and Low Dropout (LDO) regulator circuit (D7, Q1). The green power LED (D5) is illuminated when this power source is used and bus power is present.
2. An unregulated supply of 9 VDC nominal (range of 5V to 12V) is supplied to J6. For default functionality, a center hot power supply with a current capability of 100 mA is sufficient. A larger power supply can be used, up to 700 mA, and may be needed to support PICtail accessories. This voltage is fed into the on-board regulator. The green power LED is illuminated when this power source is used and power is present.

Note 1: The XLP 16-Bit Development Kit does not include a power supply. If an external supply is needed, use Microchip part number AC162039.

2: The regulated power supply options are provided for easier development. Power consumption by a regulator circuit is not included in board power measurement.

3. Two AAA batteries (not included) installed in BT2. The output voltage is not regulated by the LDO, so the microcontroller and board run at the voltage provided by the battery pair. To minimize current consumption, the power LED is not illuminated for this power source.
4. A CR2032 coin cell battery (not included) installed in BT1. As with the AAA battery option, the microcontroller and board run directly from the 3V nominal battery voltage and the power LED is not illuminated.
5. Two headers (one 5-pin, one 6-pin 0.05" pitch) are provided to connect with external energy harvesting development systems. The headers are industry standard sizes commonly used with energy harvesting applications. If you plan to use an energy harvesting system, verify pin compatibility before proceeding.
6. An external, regulated DC power supply connected to the VDD SRC and one of the GND test points. Voltage is supplied to board and microcontroller without voltage drops or voltage regulation; therefore, supply voltage must meet the voltage requirements for the installed PIC24F device. The power LED does not illuminate in this configuration.
   The installed PIC24F16KA102 operates between 1.8V to 3.6V. Refer to the appropriate device data sheet for other devices.

A four-way jumper block, POWER SOURCE SELECT (J12), selects the power supply option. The available options are USB/EXT PWR, AAA, 2032 and HARVEST (methods 1 through 5, above). The default configuration (as shipped) is USB Power mode. The jumper block does not control external power applied directly to the board (method 6), since the test point is located in the circuit after the block.

3.2.3.1 COMPONENT POWER SWITCH

The component power switch, IC PWR (S7), allows for software-enabled control of power by the PIC24F device to many of the board components. When the switch is in the "RB2" position, the RB2 port pin can control power to components using a P channel FET switch (U3). This permits experimentation with a popular technique to reduce an application's power consumption and extend battery life.

When the switch is in the "ON" position, component power is selected only by the corresponding component select jumper. See **Section 3.2.4 "Component Select Jumpers"** for additional information.

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3.2.3.2 POWER LED

The green power LED (D9) illuminates when power is supplied from either the external 9V power supply or the USB connector.

3.2.3.3 ADJUSTABLE SUPPLY VOLTAGES

The LDO regulator (Q1) is adjustable, and can support a wide voltage range for both board component and microcontrollers. It can be configured between 1.8V to 5.5V by changing the values of the voltage divider formed by R28 and R29. Typical values are listed in Table 3-2. The equation relating the resistor values to target V_{DD} is provided in Figure A-3 of **Section Appendix A. "Development Kit Schematics"**. As shipped, the LDO is configured to supply 3.3V.

The typical drop of the LDO is approximately 1.75V. Ensure the fixed power supply or USB supply voltage exceeds the desired microcontroller voltage by at least this amount.

Note:	Always verify that the voltage selected on the LDO meets the V_{DD} specification of the installed PIC24F device.

The performance of the MCP9700 and the LEDs is diminished at 1.8V operation. If RS-232 communication is needed at 1.8V, populate the LTC2801 and associated components. See **Section 3.2.14 "RS-232 Serial Port Options"** for more information.

TABLE 3-2: RESISTOR VALUES FOR R28/R29 VOLTAGE DIVIDER

Component	Target V_{DD}		
	1.8V	**3.3V**	**5.0V**
R28	150 Ω	120 Ω	75 Ω
R29	450 Ω	200 Ω	33 Ω

3.2.3.4 ON-CHIP REGULATOR CONFIGURATIONS (PIC24F J-SERIES)

The XLP 16-bit board supports multiple regulator configurations for PIC24F devices with an internal voltage regulator. A slider switch (S4) allows the user to configure the board for either J-series or K-series Flash devices. With switch, S4, in the "PIC24FJ" position, the microcontroller's internal voltage regulator is enabled by connecting a pull-down resistor to the DISVREG pin and a 10 µF capacitor to the V_{CAP} pin.

For PIC24F J-series devices, additional power savings can be achieved by disabling the regulator. Three methods are supported by making several component changes to the "PIC24F VREG" section of the PCB:

- Separate power supply for V_{DD} and V_{DDCORE}
- V_{DDCORE} and V_{DD} connected together
- V_{DDCORE} connected through a zener diode to V_{DD}

The required component changes are summarized in Table 3-3.

TABLE 3-3: COMPONENT CHANGES FOR DISABLING ON-CHIP REGULATOR

J-series Regulator Option	Component Placement and Value					
	R3	**R4**	**R5**	**C4**	**D6**	**V_{CAP} Test Point**
Split V_{DD} and V_{DDCORE}	NP	NP	1 kΩ	NP	NP	V_{DDCORE}
Same V_{DD} and V_{DDCORE}	0Ω				NP	N/C
V_{DDCORE} Zener diode	NP				P	N/C

Legend: NP = Not Populated; P = Populated

3.2.4 Component Select Jumpers

A bank of jumpers is available to selectively enable various board components. These jumpers, located in the "Power Control" block on the board, permit the user to perform customized power management analysis and configure the board more closely to the user's application. By removing the jumper for a component, power is disconnected to the designated IC and supporting circuitry, eliminating power consumption to these components. See **Section 3.3.2 "Component Power Measurement"** for more information on power monitoring.

When the IC PWR switch is set to the "RB2" position, the component select jumpers determine which components are under software control. Any component not selected by its corresponding jumper remains disabled.

Component select jumpers are implemented for:

- Serial EEPROM (JP2)
- Modular expansion header (JP6)
- MCP9700 thermistor (JP1)
- ADC/HLVD potentiometer (JP3)

An additional jumper (JP7) selects power for the unpopulated RS-232 serial circuitry. See **Section 3.2.14 "RS-232 Serial Port Options"** for more information.

3.2.5 Master Clear Reset ($\overline{MCLR}$) Switch

The $\overline{MCLR}$ switch (S1) is an active-low switch with a pull-up. It resets the PIC24F microcontroller in either socket. It does not reset the PIC18F14K50 microcontroller used for USB communication. Therefore, USB communication is not affected by this switch.

3.2.6 Capacitive Touch Pads

Three capacitive touch pads, based on the Charge Time Measurement Unit (CTMU), are available. They are multiplexed to three separate analog channels (Table 3-4).

In many capacitive touch applications, an overlay is used to protect the PCB. Mounting holes are provided to secure overlay materials for evaluation.

The low pin count devices, supported by the XLP 16-bit board, require that the touch pads be multiplexed with other board components. Specifically, CT2 is multiplexed with the temperature sensor circuitry, while CT3 is shared with the "Cap Sense" socket with the C3 designator. To avoid interference with the pads, observe the modifications noted in Table 3-4.

TABLE 3-4: CAPACITIVE TOUCH PAD ANALOG INPUT ASSIGNMENTS

Cap Touch Button	Analog Input	Note
1	AN5	
2	AN1	Remove JP5
3	AN0	Unpopulate C3 socket

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3.2.7 User-Defined Switches

Two push button switches (S2 and S3) are provided for user-defined digital inputs. They are connected to the I/O pins shown in Table 3-5. When pressed, they pull the respective port pin to ground. Using these switches requires the corresponding pin's internal weak pull-ups be enabled. When the switches are not required, the pull-ups can be disabled; this adds the ability to reduce power consumption in software.

TABLE 3-5: PUSH BUTTON SWITCH INPUT ASSIGNMENTS

Switch	Input Ports		Note
	28-Pin	20-Pin	
S2	RB7/INT0	RA6/CN8	Internal weak pull-ups required
S3	RB14/CN12	N/C	

3.2.8 Potentiometer

A 100 kΩ potentiometer (R9) is connected to AN12 for all PIC24F devices. It can be adjusted from VDD to VSS to provide an analog input voltage to the A/D Converter.

On PIC24F K-series Flash devices, the potentiometer also provides a reference voltage for the High-Low Voltage Detect (HLVD) module. HLVD is not implemented on J-series Flash devices.

3.2.9 User-Defined LEDs

The board features one yellow and one red LED (D2 and D3) that can serve as user-defined outputs. D2 is connected to the RB8 port pin for all PIC24F devices. D3 is connected to RB15 on K-series Flash devices only. Ensure the correct device family is selected on switch, S4.

3.2.10 Serial EEPROM

A 24AA256 256 KB (32 Kbytes x 8) serial EEPROM (U6) is connected to I2C1 for both PIC24F 20-pin and 28-pin devices. It is used to demonstrate I^2C™ bus operation. It is included for nonvolatile firmware storage, in addition to the internal data EEPROM of the PIC24F16KA102. The SDA and SCl signals for the I^2C bus are available to the user at test points near U6 and at take-off points adjacent to the prototype area.

3.2.11 Temperature Measurement Options

The XLP 16-bit board features two different temperature sensing options. An MCP9700 analog output thermistor (U4) is connected to a PIC® MCU A/D Converter input (AN1). The thermistor's output voltage has a linear correlation to the temperature.

The thermistor is disconnected from the microcontroller by removing jumper, JP5. To use I/O pins efficiently, the thermistor is multiplexed with Capacitive Touch Pad 3. Avoid contact with this pad during temperature measurements to minimize effect on temperature measurement accuracy.

The XLP 16-bit board also implements a conventional junction diode connected to an analog input to demonstrate low-cost temperature sensing. The Charge Time Measurement Unit (CTMU) provides a specified current to the diode; an A/D conversion determines the voltage across the diode. This voltage has a linear correlation to the diode's temperature. For more information on this solution, refer to *TB3016,* "*Using the PIC® MCU CTMU for Temperature Measurement*" (DS93016) for more information.

The XLP 16-bit demonstration software implements both the MCP9700 and diode CTMU measurement solutions via a compile-time option. By default, the MCP9700 is used. Note that when switching to the diode temperature measurement, it may be necessary to calibrate the measurement by changing the diode calibration constants to account for part-to-part variation in the diode.

3.2.12 Capacitive Sense Socket

The socket, labeled "Cap Sense", permits the easy connection of a capacitive load to the input of the Charge Time Measurement Unit (CTMU). It connects to analog input, AN0, for 28-pin devices and AN10 for 20-pin devices. It can be used to demonstrate CTMU measurements for capacitance, time and voltage. For additional information on measuring capacitance with the CTMU, refer to **Section 11. "Charge Time Measurement Unit (CTMU)"** (DS39724) of the "*PIC24F Family Reference Manual*".

3.2.13 USB Connectivity

The 16-bit XLP board includes a PIC18F14K50 USB microcontroller (U2) which provides USB connectivity and UART-to-USB protocol translation. The PIC18F14K50 is hard-wired to the PIC24F RX and TX pins, and communicates with the PIC24F device through its UART. The USB UART translation software is available in the USB stack release.

The PIC18F14K50 is clocked independently from the PIC24F microcontroller. It uses its own 12 MHz crystal (Y3).

3.2.14 RS-232 Serial Port Options

The XLP 16-bit board supports two types of RS-232 transceivers and associated support circuitry through a standard DB9 connector. This port is configured as a DCE device and can be connected to a PC using a straight-through cable. Hardware flow control is not supported. As shipped, the serial port circuitry and DB9 connector are not populated; instead, USB is used to communicate to the host PC.

By supporting two transceivers, the user can choose between a low-cost solution based on the MAX3221 (3.0V to 5.5V) or a wide voltage range (1.8V to 5.5V) solution using the LTC2801. For operation at the low end of the board's V_{DD} range (1.8V to 2.0V), the MAX2331 is below its minimum specified operating voltage. It is recommended that the LTC2801 circuit be populated in this circumstance.

The PIC24F microcontroller's TX and RX pins are also connected to the PIC18F14K50 RX and TX pins, and are used to convert the UART communication to USB. When the RS-232 option is implemented, remove the zero ohm resistor, R27, to avoid contention with the PIC18F14K50.

3.2.15 Modular Expansion Connector

The XLP 16-bit board implements a 28-pin modular expansion interface (J7). Although physically similar to the PICtail™ interface available on many Microchip demo and development boards, it does not implement the full range of signals supported by the PICtail interface. The connector pin assignments for J7 are shown in **Appendix A. "Development Kit Schematics"**.

The XLP board's interface allows the board to provide basic generic functionality to select PICtail modules (listed below), and also be forward compatible with new PICtail technologies. The user will need to review new modules as they become available to determine their compatibility with the XLP 16-bit board.

In order to use the software for compatible PICtail modules, the pin assignments defined in software will need to be remapped to those implemented in the interface. This typically requires minor changes to the header file (`.h`) of the software stack.

Note 1: The 100 kΩ potentiometer is multiplexed with pin 19 of the connector. It is recommended to turn the potentiometer to its highest resistance setting to minimize the load on that pin's signal.

2: Due to the limited availability of I/O ports on 20-pin PIC24F devices, the modular expansion interface does not support these devices.

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3.2.15.1 COMPATIBLE PICtail DAUGHTER BOARDS

At the time of the writing of this user's guide, the following PICtail daughter boards were compatible with the XLP 16-Bit Development Board through the modular interface:

- PICtail Daughter Board for SD and MMC (Microchip part number AC164122)
- Speech Playback Daughter Board (Microchip part number AC163027-4)
- MRF49XA PICtail Plus Daughter Cards (Microchip part numbers AC164137-1 and -2)
- MRF24J40 PICtail Plus Daughter Cards (Microchip part numbers AC164134-1 and -2)

Future PICtail daughter boards may also be compatible with the interface. It is up to users to evaluate any new boards that they may wish to use for signal compatibility.

3.2.16 Programming Interfaces

Two options for on-board programming of the PIC24F microcontroller are provided. Both are compatible with all of the microcontrollers supported by the XLP development board.

The RJ-11 socket (J4) supports the standard 6-wire connector for Microchip's MPLAB ICD 2 in-circuit programmer/debugger module. Connector, J5, is a standard 6-pin PICkit® 2 programmer interface. This provides a second low-cost programming option in addition to MPLAB ICD 2.

In addition, the PIC18F14K50 USB microcontroller may be programmed separately from the PIC24F device. A dedicated 6-pin interface (J11), located adjacent to the RJ-11 interface, is used for the PIC18 device.

3.2.17 Prototype Area

To assist in the development and testing of application hardware, the XLP board includes a 15 x 9 prototype area for the installation of the user's custom circuitry. Sources for board power (both V_{DD_SRC} and V_{DD_BRD}) and ground are located adjacent to the area. In addition, the SDA and SCL signals for the I^2C lines between the PIC24F microcontroller and the serial EEPROM have been provided at the unpopulated header (J13), adjacent to the prototype area. This allows users to experiment with a multi-device I^2C bus in their application.

3.3 CURRENT MEASUREMENT

One of the great advantages of the XLP 16-bit board is its provisions for in-circuit current measurement. Using simple techniques and equipment, users can experiment directly with low-power hardware and software techniques, then directly measure their current consumption without introducing measurement induced artifacts. This provides a fast method of directly validating power-saving strategies. To make measurements more useful, the development board allows for the measurement of microcontroller current draw and non-microcontroller component current separately.

3.3.1 PIC24F Current Measurement

To measure current consumed by the PIC24F microcontroller, the PIC PWR jumper (JP9) can be removed and a current measurement cable connected to its pins. This allows the user to empirically evaluate the microcontroller's various low-power features. Since JP9 interrupts the microcontroller's V_{DD} path, always be certain to re-install the jumper when measurements are not being taken.

To avoid starving the microcontroller's current supply and causing low-power conditions, it may be necessary to switch the ammeter to a higher current range during programming and full-power operation. When the microcontroller is operating in a low-power state, switching to a low range will produce a more accurate measurement.

As an alternative, two through-hole sockets, marked CURRENT MEASURE, have also been placed in the microcontroller's V_{DD} path. Using an appropriately sized resistor will create a voltage drop corresponding to the current being consumed by the microcontroller; this can, in turn, be measured with an oscilloscope. To do this:

1. Calculate the size of the resistor required to produce the voltage drop using the V_{DD} and estimated current consumption (found in the electrical specifications of the device data sheet).
2. Connect the resistor across the through-hole sockets.
3. Connect the scope's probes across the terminals of JP9.
4. With the appropriate power supply connected and the scope configured for Differential Voltage mode, remove the PIC® MCU PWR jumper. (This sequence provides continuous microcontroller power and avoids a spurious BOR or POR event.)

The resulting waveform will be a scalar representation of the current consumed by the PIC24F device. This technique is especially useful for evaluating microcontroller power over a time interval.

Note: Since the resistor is placed in series with the PIC MCU V_{DD} pin, the resulting voltage drop may affect power calculations. Ensure calculations are based on *actual* V_{DD}, instead of the supplied board voltage.

3.3.2 Component Power Measurement

The IC PWR jumper (JP10) allows the user to measure the current consumed by the various board components. It also permits the user to experiment with low-power techniques on a variety of commonly used components.

Current measurements taken at JP10 exclude current consumption from the microcontroller, ICSP™ header and the USB interface. Therefore, communications with a host PC and emulator/programmer connections do not need to be accounted for in determining an accurate current measurement, as they are not included in the first place. Since JP10 interrupts the V_{DD} path to the board's other components, always be certain to re-install the jumper when measurements are not being taken.

3.3.3 Ammeter Tool Header

The XLP 16-bit board includes a special 7-pin header (J10) for current measurement. The PIC MCU PWR and IC PWR jumpers (JP9 and JP10) ensure continuity of power when connecting or disconnecting a current measurement device. Microchip provides an optional XLP Current Measurement Cable (part number AC002023) as a convenient way of connecting the header to an ammeter.

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Appendix A. Development Kit Schematics

The following schematic diagrams are included in this appendix:

- Figure A-1: Microcontroller Sockets/Headers and Associated Components
- Figure A-2: USB/Serial Interface, EEPROM, Temperature Sensors and 28-Pin Interface
- Figure A-3: Power Circuit and Selector Jumpers
- Figure A-4: Unpopulated Circuits (RS-232 and I^2C Header)

FIGURE A-1: DEVELOPMENT BOARD SCHEMATIC, SHEET 1: MICROCONTROLLER SOCKETS/HEADERS AND ASSOCIATED COMPONENTS

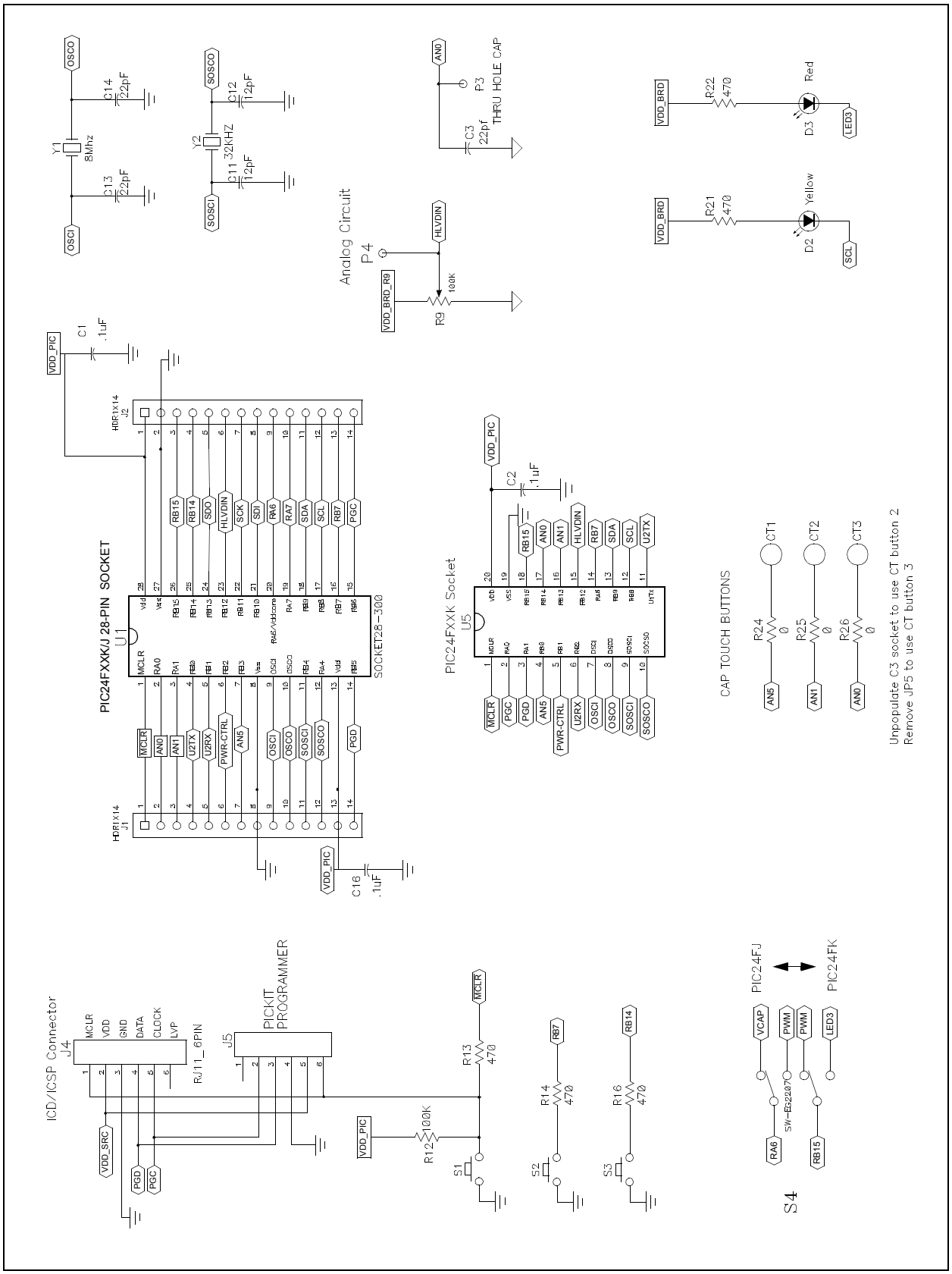

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FIGURE A-2: DEVELOPMENT BOARD SCHEMATIC, SHEET 2: USB/SERIAL INTERFACE, EEPROM, TEMPERATURE SENSORS AND 28-PIN INTERFACE

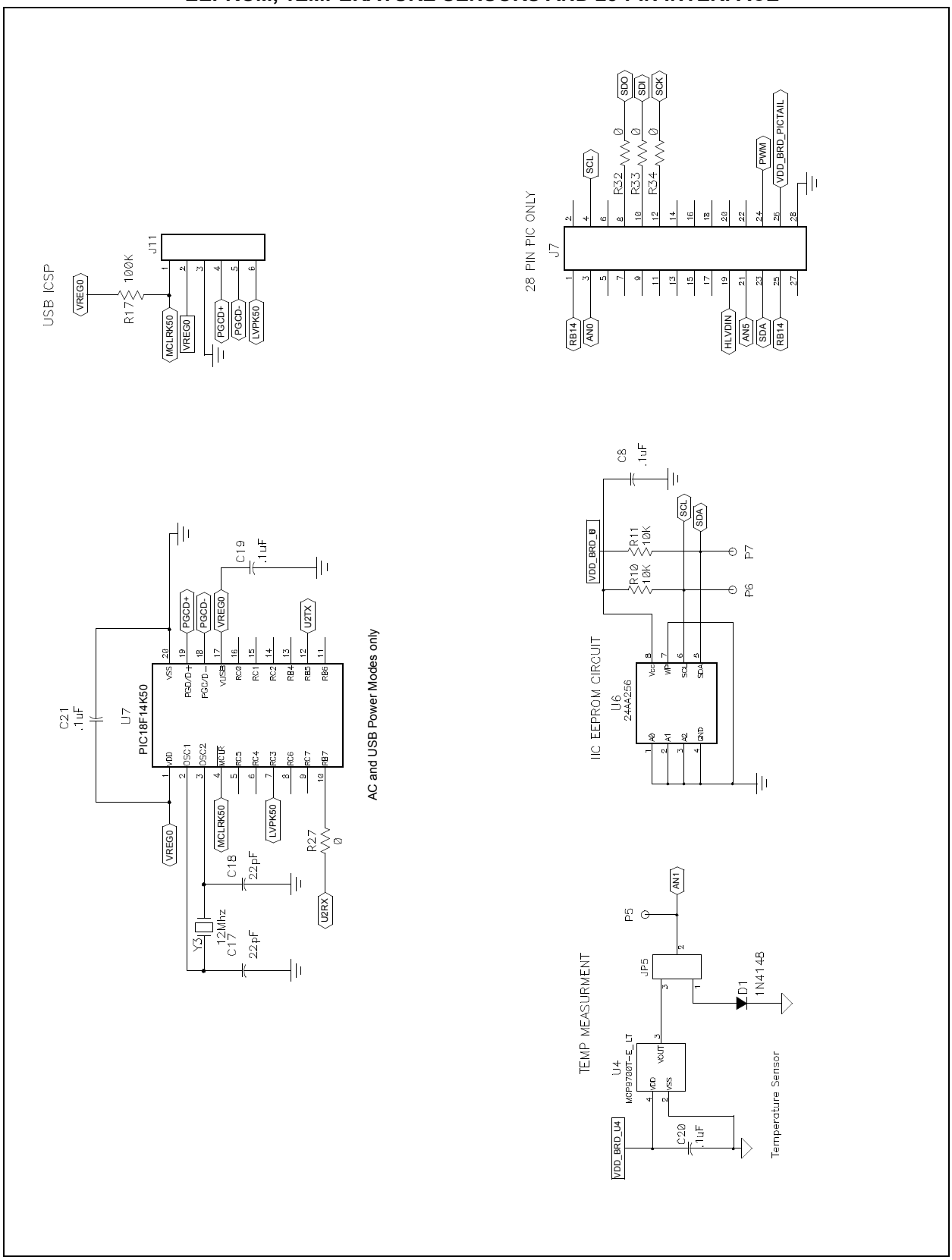

FIGURE A-3: DEVELOPMENT BOARD SCHEMATIC, SHEET 3: POWER CIRCUIT AND SELECTOR JUMPERS

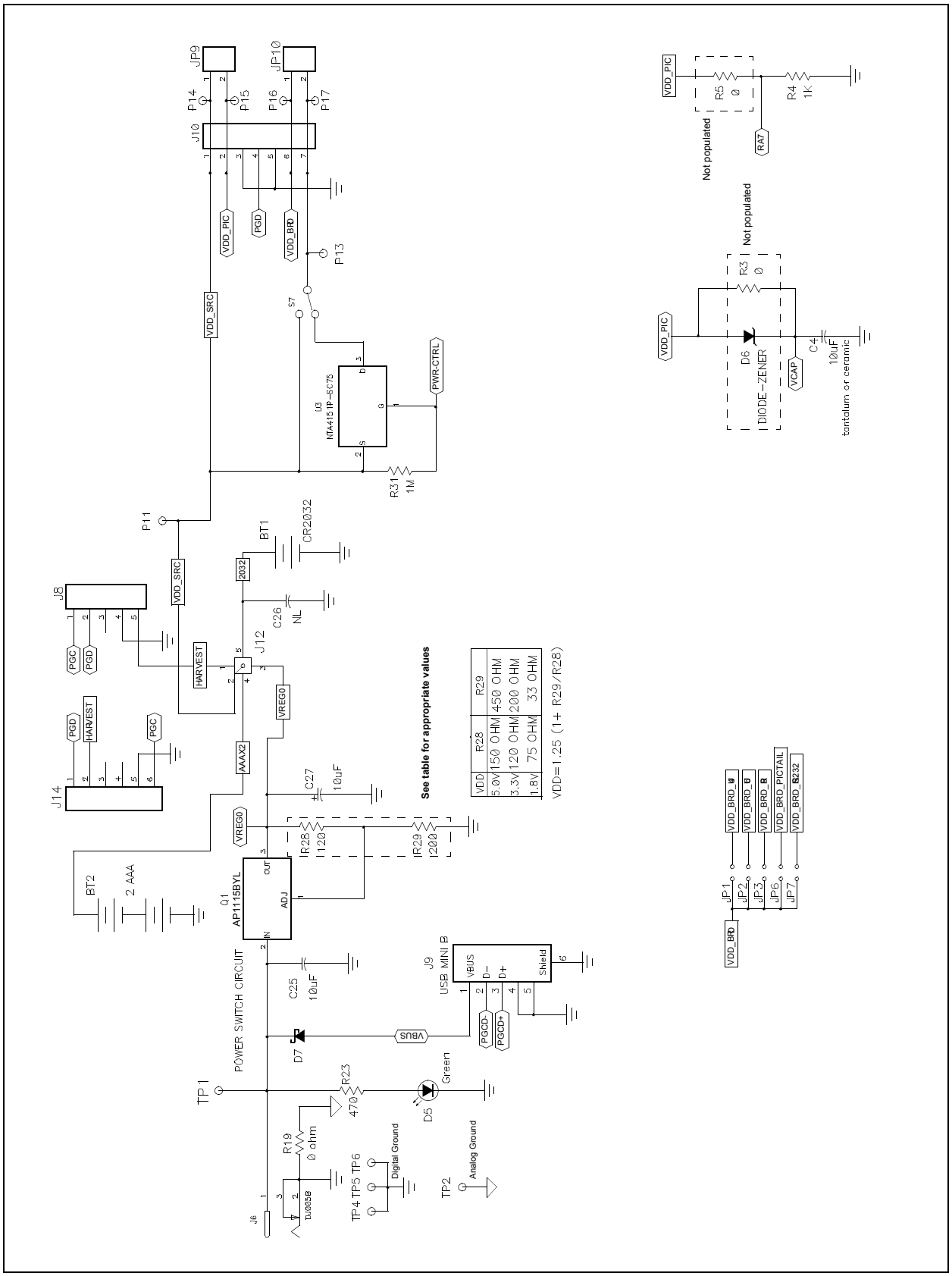

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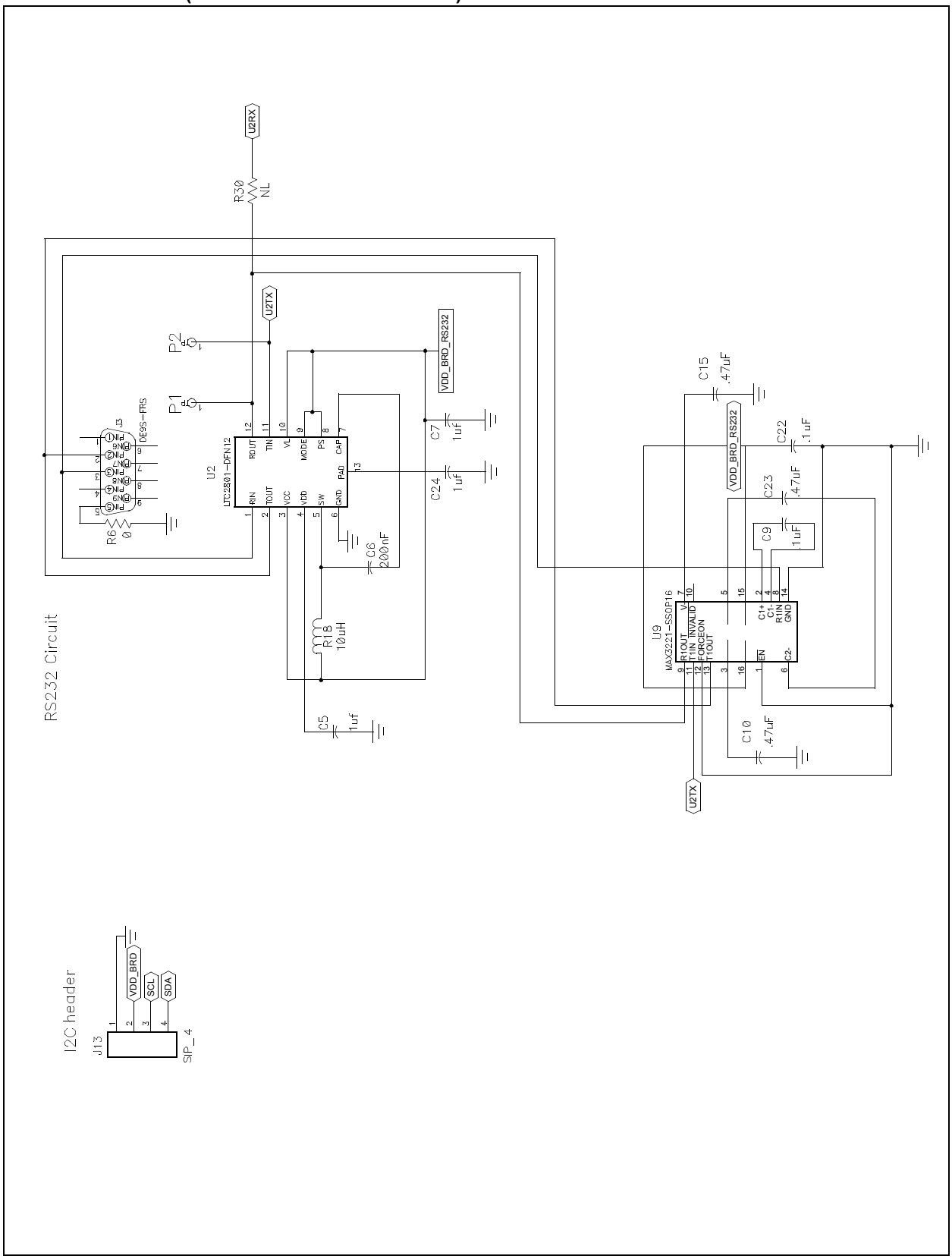
FIGURE A-4: DEVELOPMENT BOARD SCHEMATIC, SHEET 4: UNPOPULATED CIRCUITS (RS-232 AND I²C™ HEADER)



NOTES:

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

China - Beijing
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Fax: 86-10-8528-2104

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Fax: 86-28-8665-7889

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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
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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
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Fax: 86-756-3210049

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Fax: 91-80-3090-4123

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Fax: 91-11-4160-8632

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