



**PICDEM™ MC LV
Development Board
User's Guide**

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PICDEM™ MC LV DEVELOPMENT BOARD

Preface

NOTICE TO CUSTOMERS

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

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

For the most up-to-date information on development tools, see the MPLAB® IDE 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 PICDEM™ MC LV Development Board. Items discussed in this chapter include:

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

PICDEM™ MC LV Development Board

DOCUMENT LAYOUT

This document describes how to use the PICDEM MC LV Development Board as a development system for Microchip Technology's PIC18F2331/2431 Microcontrollers (MCUs) and dsPIC30F2010/3010 Digital Signal Controllers (DSCs). The manual layout is as follows:

- **Chapter 1. Introduction to the PICDEM MC LV Development Board** – What the PICDEM MC LV Development Board is, what makes it a desirable development tool for motor control and what features are available. This chapter also includes instructions on how to connect and begin to use the PICDEM MC LV Development Board.
- **Chapter 2. System Level Architecture of the Board** – Provides a block diagram of the board and description of each section.
- **Chapter 3. Getting Started with PIC18FXX31 MCUs** – Provides instructions on how to set up the PICDEM MC LV Development Board using the PIC18FXX31 family devices.
- **Chapter 4. Using the Microchip Motor Control GUI** – Provides a detailed description of PC-based Motor Control GUI and how to use its programmable features.
- **Chapter 5. Creating Motor Control Firmware Projects** – Discusses the basic steps for creating custom applications or modifying existing applications.
- **Chapter 6. Getting Started with dsPIC Digital Signal Controllers** – Describes how to set up and use the PICDEM MC LV Development Board using the dsPIC® family.
- **Chapter 7. Using dsPIC DSCs to Run a Sensorless BLDC Motor** – Describes how to run a BLDC motor, without a Hall effect sensor, using dsPIC devices.
- **Chapter 8. Troubleshooting** – Provides information on solving common problems.
- **Appendix A. Circuit Schematics of the Board** – Provides detailed circuit schematics of the PICDEM MC LV Development Board.
- **Appendix B. Electrical Specifications** – Lists the DC input and output ratings for the PICDEM MC LV Development Board.
- **Appendix C. Jumper Settings** – Provides a detailed list of sensed and sensorless jumper settings for PIC18F MCUs and dsPIC30F DSCs.

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

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

PICDEM™ MC LV Development Board

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

RECOMMENDED READING

This user's guide describes how to use the PICDEM MC LV Development Board. The device-specific data sheets contain current information on programming the specific microcontroller or digital signal controller devices. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

MPLAB® IDE Simulator, Editor User's Guide (DS51025)

Comprehensive guide that describes installation and features of Microchip's MPLAB Integrated Development Environment (IDE), as well as the editor and simulator functions in the MPLAB IDE environment.

Readme for PICDEM MC LV Development Board

For the latest information on using the PICDEM MC LV Development Board, read the *Readme for PICDEM MC LV.txt* file (an ASCII text file) in the *Readme* subdirectory of the MPLAB IDE installation directory. The *Readme* file contains update information and known issues that may not be included in this user's guide.

Readme Files

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

MPASM™ Assembler, MPLINK™ Object Linker, MPLIB™ Object Librarian User's Guide (DS33014)

This user's guide describes how to use the Microchip MPASM Assembler, the MPLINK Object Linker and the MPLIB Object Librarian.

Microchip Technical Library CD-ROM (DS00161)

This CD-ROM contains comprehensive application notes, data sheets and technical briefs for all Microchip products. To obtain this CD, or to download individual documents, visit the Microchip web site (www.microchip.com).

Embedded Control Handbook Update 2000 (DS00711)

This handbook consists of several documents that contain information about microcontroller applications. To obtain these documents, visit the Microchip web site (www.microchip.com).

PICmicro® Mid-Range MCU Family Reference Manual (DS33023) and PICmicro® 18C MCU Family Reference Manual (DS39500)

These manuals explain the general details and operation of the mid-range and advanced MCU family architecture and peripheral modules. They are designed to complement the device data sheets.

PIC18F2331/2431/4331/4431 Data Sheet (DS39616)

This is the definitive reference for Microchip's 28/40/44-pin enhanced Flash micro-controllers with nanoWatt technology, high-performance PWM and A/D, that are at the heart of the PICDEM MC LV Development Board.

dsPIC30F2010 Data Sheet (DS70118)

This is the definitive reference for Microchip's 28-pin, high-performance digital signal controllers.

DEVELOPMENT SYSTEMS CUSTOMER CHANGE NOTIFICATION SERVICE

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

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

The Development Systems product group categories are:

- **Compilers** – The latest information on Microchip C compilers and other language tools. These include the 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 2.
- **MPLAB® IDE** – The latest information on Microchip MPLAB IDE, the Windows® Integrated Development Environment for development systems tools. This list is focused on the MPLAB IDE, MPLAB SIM Simulator, MPLAB IDE Project Manager and general editing and debugging features.
- **Programmers** – The latest information on Microchip programmers. These include the MPLAB PM3 and PRO MATE® II Device Programmers and the PICSTART® Plus and PICKit™ 1 Development Programmers.

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.

PICDEM™ MC LV Development Board

CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support
- Development Systems Information Line

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>

In addition, there is a Development Systems Information Line which lists the latest versions of Microchip's development systems software products. This line also provides information on how customers can receive currently available upgrade kits.

The Development Systems Information Line numbers are:

1-800-755-2345 – United States and most of Canada

1-480-792-7302 – Other International Locations

DOCUMENT REVISION HISTORY

Revision A (May 2005)

- Initial Release of this Document.

Chapter 1. Introduction to the PICDEM MC LV Development Board

1.1 INTRODUCTION

The PICDEM MC LV Development Board is targeted to control Brushless DC (BLDC) motors in sensor or in sensorless operation. This flexible and low-cost board can be configured in different ways to use with Microchip's specialized motor control microcontrollers and digital signal controllers. This low-cost board has the facility to use either the PIC18F2331/2431 or the dsPIC30F2010/3010 devices for control. Low pin count motor control parts, such as the PIC18F1230/1330, can also be configured with daughter boards.

The PICDEM MC LV Development Board is a compact board containing a 3-phase voltage source inverter bridge and control circuitry around the microcontroller. The board comes with a free, ready to use MC-GUI (Motor Control – Graphical User Interface) from Microchip. Using the MC-GUI, the user can easily set and/or change motor parameters. This greatly helps the user in developing customized drive solutions.

1.2 HIGHLIGHTS

This items discussed in this chapter are:

- Motor Control Kit
- Overview of the PICDEM MC LV Development Board
- Board Connectors

1.3 MOTOR CONTROL KIT

The PICDEM MC LV Development Board contains the following items. Before proceeding, make sure that you have each of these items:

- PICDEM MC LV Development Board
- The PICDEM MC LV Development Board CD-ROM with the following applications:
 - PICDEM MC LV Graphical User Interface (MC-GUI)
 - "*PICDEM MC LV Development Board User's Guide*" (this document)
 - Firmware examples using the PIC18F MCUs and dsPIC30F DSCs

1.4 OVERVIEW OF THE PICDEM MC LV DEVELOPMENT BOARD

Brushless DC motors are becoming more popular due to their advantages over other types of motors traditionally used. To learn more about the basics, working principles and control of BLDC motors, refer to Microchip's Application Note *AN885, "Brushless DC (BLDC) Motor Fundamentals"* (DS00885) on Microchip's website (www.microchip.com). You can also visit the specialized web page, www.microchip.com/motor, for technical details on different types of motors and their controls using PIC® microcontrollers and dsPIC® digital signal controllers.

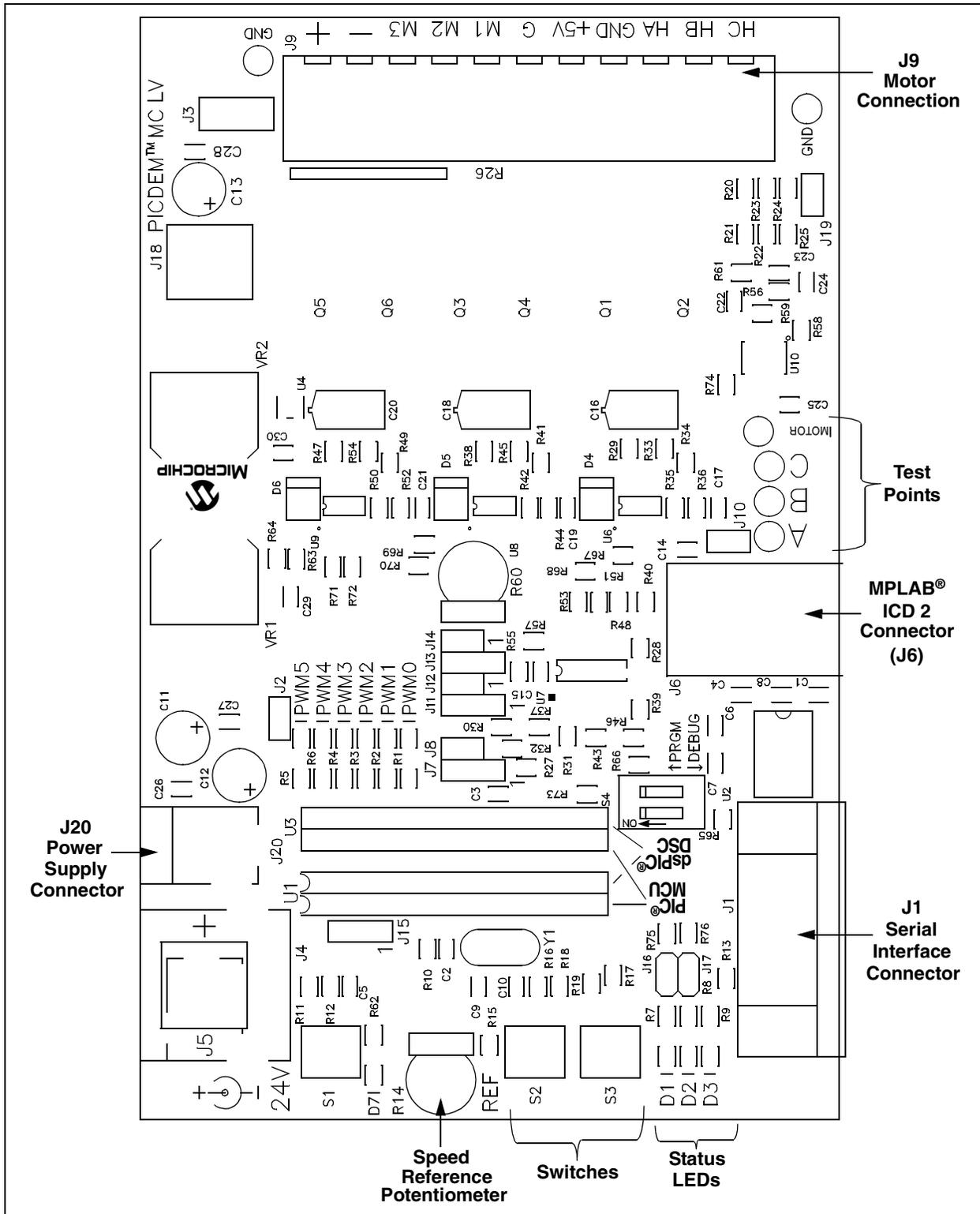
The PICDEM MC LV Development Board supports motors with terminal voltage up to 48V and current up to 4A. Refer to **Appendix B. "Electrical Specifications"** for complete electrical specifications.

PICDEM™ MC LV Development Board

1.5 BOARD CONNECTORS

The PICDEM MC LV Development Board has a PIC18FXX31/dsPIC30F device-based control section and 3-phase power inverters. The board has a power connector (J20), motor connector (J9), ICD 2 connector (J6) and serial interface connector (J1), as shown in Figure 1-1.

FIGURE 1-1: BOARD LAYOUT



1.5.1 Power Connector (J20)

The power connector (J20) has the facility to connect 3 different types of connectors. A barrel connector is mounted on the board when it is shipped. If necessary, the user can replace it with a standard DIN connector or a screw terminal with a 5 mm pitch.

A 24V DC power supply is connected to J20. Use the recommended power supply listed as an accessory (Part Number AC002013) on the Microchip web site (www.microchip.com), or equivalent power supply of your own.

1.5.2 Motor Connector (J9)

The motor connector (J9) has 11 terminals. Table 1-1 shows the functionality of each terminal.

TABLE 1-1: TERMINAL FUNCTIONALITY

Terminal	Function	Special Comments
M1	Motor Winding 1 Connection	
M2	Motor Winding 2 Connection	
M3	Motor Winding 3 Connection	
G	Motor Ground	
HA	Hall Sensor 1 Connection	<i>NOT</i> used for sensorless control
HB	Hall Sensor 2 Connection	<i>NOT</i> used for sensorless control
HC	Hall Sensor 3 Connection	<i>NOT</i> used for sensorless control
+5V	Hall Sensor Power	<i>NOT</i> used for sensorless control
GND	Hall Sensor Power Return	<i>NOT</i> used for sensorless control
+	Positive DC Bus	See Section 2.3.1 “Controller Sockets”
-	Negative DC Bus	See Section 2.3.1 “Controller Sockets”

1.5.3 ICD 2 Connector (J6)

This RJ11 connector is used for programming the part or debugging the firmware using MPLAB® ICD 2. Application-specific functionalities can be added to the existing firmware that is supplied with the board.

1.5.4 Serial Interface (RS-232) Connector (J1)

This connector is used for serial communication, based on the RS-232 protocol, with the external world. When using the PC-based MC-GUI, this connector is used to connect the PC and the board through the RS-232 cable.

PICDEM™ MC LV Development Board

NOTES:

2.3 CONTROL SECTION

Microchip's PIC18F2431/2331 and many versions of the dsPIC30F DSCs have specialized hardware peripherals, like the power control PWM, high-speed ADC, motion control feedback, integrated EEPROM and the power supervisory function, that are required for efficient motor control. The CD supplied along with the PICDEM MC LV Development Board has a variety of programs using both PIC18F and dsPIC30F devices, working in open loop and closed loop, using Hall sensors and in sensorless operation. **Chapter 3. "Getting Started with PIC18FXX31 MCUs"** explains the control algorithm using PIC18F parts and **Chapter 6. "Getting Started with dsPIC Digital Signal Controllers"** explains the control algorithm for dsPIC30F parts.

2.3.1 Controller Sockets

The PICDEM MC LV Development Board has two 28-pin DIP sockets, one each for the PIC18F2331/2431 MCUs and dsPIC30F2010/3010 DSCs. They are offset to each other and marked as the "PIC" and "dsPIC" sockets, respectively. When shipped, a preprogrammed PIC18F2431 is mounted on the "PIC" side of U1. To use the dsPIC device, the user has to remove the PIC18F from the socket and mount the dsPIC DSC on the "dsPIC" side of U3.

Apart from the main controller, the control section has protection circuitry, user interface, Hall sensor interface and Back EMF (BEMF) signal conditioning for sensorless control.

2.3.2 Overcurrent Protection Circuit

A shunt resistor ($R26 = 0.1\Omega$) connected in the DC return path converts the combined three-phase motor current into voltage. This voltage is passed through a low-pass filter and amplified using an op amp circuit with a gain of 11. This amplified voltage is connected to one of the Analog-to-Digital Converter channels (AN0). In addition to this, the amplified voltage is compared to a voltage reference using an op amp comparator. The voltage reference is set using potentiometer R60. Turning the potentiometer clockwise increases the reference and counterclockwise reduces the reference. The range of voltage reference varies from 0V to 3.3V. Based on the motor rated current, the reference can be set. A test point "MOTOR" is given to monitor the motor current on an oscilloscope.

2.3.3 User Interface

On the PICDEM MC LV Development Board, there are switches, LEDs and a potentiometer to use with the GUI interface. Table 2-1 describes each function.

TABLE 2-1: USER INTERFACE

Board Function	Description	Comments
Switch		
S1	Used for resetting the system	
S2 and S3	Various functions	See Chapter 3. "Getting Started with PIC18FXX31 MCUs" and Chapter 6. "Getting Started with dsPIC Digital Signal Controllers" .
LED		
D1, D2, D3	Display status	See Chapter 6. "Getting Started with dsPIC Digital Signal Controllers" and Chapter 3. "Getting Started with PIC18FXX31 MCUs" .
PWM0-PWM5	Display status of PWM0-PWM5	
Potentiometer R14	Motor speed control	Turning the potentiometer clockwise increases the speed and vice versa.

2.3.4 Hall Sensor Interface

Hall sensors on the motor are open-collector outputs. Individual pull-up resistors are provided on the board for each Hall sensor. The Hall sensor signals, HA, HB and HC, are connected to the input capture pins, IC1, IC2 and IC3, respectively.

2.3.5 Back EMF Signal Conditioning

When a sensorless algorithm is used to control the BLDC motor speed, Back EMF (BEMF) signals are used. Based on zero crossing of BEMF signals, motor commutation is decided in the firmware. The signal conditioning circuit has mainly two blocks: the first is a low-pass filter for each phase voltage and the second is a comparator circuit for determining the zero crosspoint. When using the PIC18F MCU, the jumpers are set to use both of these blocks. The output is connected to the input capture pins, IC1, IC2 and IC3. When a dsPIC30F DSC is used, the low-pass filters are used in the circuit. Using the on-chip Analog-to-Digital Converters, the BEMF zero crosspoint is determined. In order to configure this, the board has 8 jumpers. Refer to **Chapter 3. “Getting Started with PIC18FXX31 MCUs”** and **Chapter 6. “Getting Started with dsPIC Digital Signal Controllers”** for jumper settings for the PIC18F and dsPIC30F, respectively. Also, refer to **Appendix C. “Jumper Settings”** for the complete list of jumper settings. In addition, the silk screen on the non-component side of the board has the jumper settings printed for quick reference.

2.3.6 Temperature Measurement Circuit

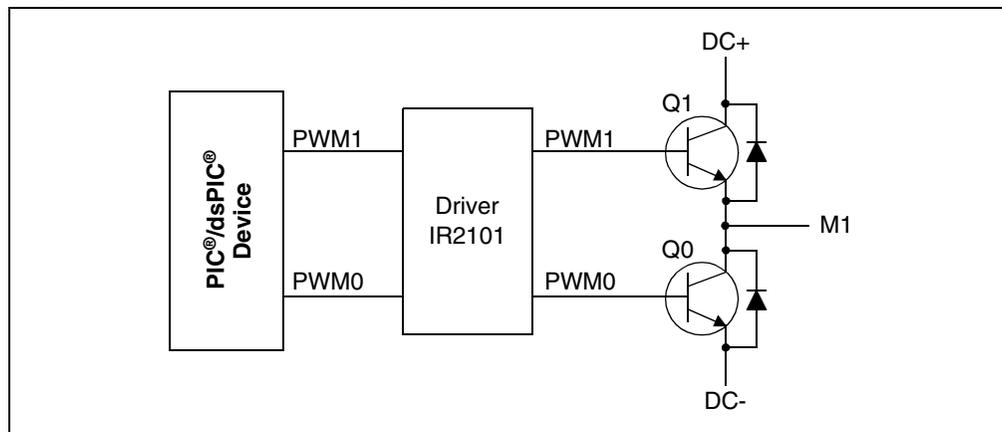
A temperature sensor is placed next to the PCB heat sink near Q5. The sensor, Microchip’s TC74, has an I²C™ interface. It measures the temperature and converts it to a digital value. This value can be read using the I²C protocol. The code on the CD does not include the temperature reading routines. The routines for the Master mode I²C, using the SSP module, can be found on Microchip’s web site.

Note: When using the temperature sensor, jumpers J16 and J17 should be open. When the temperature sensor is used, LEDs D2 and D3 are not available.

2.4 POWER INVERTER SECTION

The inverter section consists of three half-bridge gate drivers and three phase inverter bridges using MOSFETs. Figure 2-2 shows a half-bridge gate driver and half-bridge inverter. This circuit is repeated for each motor phase winding. PWM pairs, PWM0-PWM1, PWM2-PWM3 and PWM4-PWM5, control three half-bridge inverters. The DC bus is either derived from the 24V power supply connected to the input connector J20, or from the ‘+’ and ‘-’ terminals on connector J9.

FIGURE 2-2: HALF-BRIDGE GATE DRIVER AND INVERTER



2.5 POWER SUPPLY

A 24V DC block power supply connected to J20 serves as the main power supply to the board. A +15V power supply is generated for the gate drivers using a 15V regulator (VR2). This 15V regulator is passed through a 5V regulator to drive a +5V power supply to the MCU and the control circuit around the MCU.

2.5.1 Connecting an Alternate Power Supply

The board can support the motors up to the rated voltage of 48V. However, the input power supply that can be connected on J20 is limited to 24V. In such cases, a provision is made to connect a different power supply that powers the DC bus using '+' and '-' terminals on J9. The power jumper J3 that is next to the connector J9 should be opened when a second power supply is connected to J9. This arrangement can also be used if the motor has a lower rated voltage, for example, 12V.

CAUTION

When using a second power supply on '+' and '-' terminals on J9, make sure that jumper J3 is removed. Failure to do this may cause the board to fail or the power supply to fail.

Chapter 3. Getting Started with PIC18FXX31 MCUs

3.1 INTRODUCTION

This chapter provides instructions on how to set up the PICDEM MC LV Development Board using the PIC18FXX31 devices.

WARNING

The PICDEM MC LV Development Board is intended to drive 3-phase BLDC motors. Before connecting the motor, make sure that the power rating of the motor is equal or less than the power rating of the board, as given in Appendix B. “Electrical Specifications”. Also, make sure that the jumper settings are correct for the firmware programmed into the target PIC® MCU mounted on the socket. Failure to comply with this warning could lead to malfunction of the board and/or the motor and could possibly be hazardous to the development staff.

Before beginning the start-up procedure, do a visual check of the board and the motor to be connected for any mechanical damage. If damage is found, **DO NOT** power-up the board. Otherwise, you may further damage the equipment. Immediately contact Microchip’s local office or distributor for information.

3.2 HIGHLIGHTS

This item discussed in this chapter is:

- PICDEM MC LV Development Board Setup

3.3 PICDEM MC LV DEVELOPMENT BOARD SETUP

The following procedure describes how to set up the PICDEM MC LV Development Board to run with a PIC18FXX31 device.

1. Place the PICDEM MC LV Development Board on a sturdy platform.
2. Make sure the PIC18F2331 or the PIC18F2431 is mounted in the “PIC” socket on U1.
3. Connect the 24V power supply to J20.

Note: *DO NOT* connect the motor wires to the board.

LED D7 (red) should turn on. If it does not turn on, check the polarity of the power supply connector. If it is correct and the LED D7 still does not turn on, disconnect power to the board and contact Microchip’s local office or distributor.

4. Determine the algorithm you want to run the motor. The following two options are available:
 - Speed control using Hall sensors
 - Sensorless control
5. Program the part with the desired algorithm. For generating a project and programming using MPLAB® ICD 2, refer to the “MPLAB® ICD 2 In-Circuit Debugger User’s Guide” (DS51331).
6. Disconnect the power supply and complete jumper settings and motor connections as given in the following table. The wire colors mentioned in the brackets are for the Hurst NT Dynamo motor, available from Microchip as an accessory, part number AC300020.

TABLE 3-1: JUMPER SETTINGS

Jumper	Sensored Control	Sensorless Control
J7, J11, J13	Short between 1-2	Short between 1-2
J15	Short between 2-3	Short between 2-3
J8, J12, J14	Open	Short
J10, J16, J17, J19	Short	Short

TABLE 3-2: MOTOR CONNECTIONS

Label on Connector J9	Sensored Control	Sensorless Control
M1	Phase C (red)	Phase C (red)
M2	Phase B (black)	Phase A (white)
M3	Phase A (white)	Phase B (black)
G	Ground (green)	Ground (green)
+5V	Power-on Hall Sensor (red)	No Connection
GND	Power Return for Hall Sensors (black)	No Connection
HA	Hall S1 (white)	No Connection
HB	Hall S2 (brown)	No Connection
HC	Hall S3 (green)	No Connection

- Keep the potentiometer “REF” turned counterclockwise.
- Connect the 24V power supply to the board on J20.

Note: Follow procedures 9 through 13 for manual operation or Stand-Alone mode of the board. For PC operation, or operating the board using the Graphical User Interface, skip to **Chapter 4. “Using the Microchip Motor Control GUI”**.

- Press and release switch S3 once.
- Turn the potentiometer “REF” clockwise, the motor should rotate.
- Each press of S3 toggles the control between Run and Stop conditions.
- To change the direction of rotation, press S2.
- If the motor stops and LED D1 blinks, it indicates that there was an overcurrent Fault. Reduce the speed “REF” and press either S2 or S3 to clear the Fault and resume operation.

Chapter 4. Using the Microchip Motor Control GUI

4.1 HIGHLIGHTS

The items discussed in this chapter are:

- Software Overview
- Starting the Program
- The Main Window (Control Panel)
- The Setup Window

4.2 SOFTWARE OVERVIEW

The Microchip Motor Control GUI provides a convenient computer-based interface for most PICmicro® device-based motor control applications. It is designed to work with a number of electrical designs and motor control paradigms, and provides a wide range of control functions for motor operations. Not only can users set speed and rotation direction, but also program acceleration, deceleration and variable run patterns.

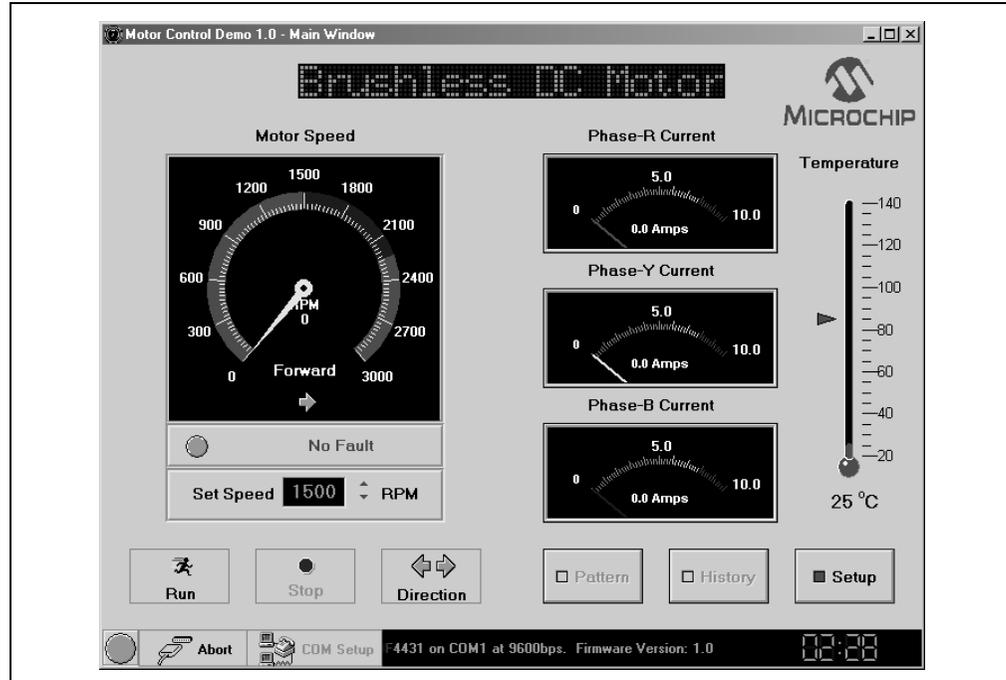
The Motor Control GUI has been designed to communicate with a range of currents and planned Microchip motor control kits and applications. A feature of its design is to poll the on-board control firmware on initial communication and automatically configure its options accordingly. As such, some features discussed here may not be available in certain situations. They are presented here for the sake of completeness.

4.3 STARTING THE PROGRAM

To run the program, select *Programs>Microchip Motor Control Solutions>Motor Control Demo* from the Start menu. Alternatively, double click on the Motor Control GUI shortcut on your desktop. This launches the Main window of the GUI (Figure 4-1).

In this version of the Motor Control GUI, all of the operations are controlled through two windows: the Main window (control panel) and the Setup window. Their operation is described in the following sections.

FIGURE 4-1: THE CONTROL PANEL VIEW



4.4 THE MAIN WINDOW (CONTROL PANEL)

The control panel allows the user to control motor speed and rotation direction in a way that is similar to Stand-Alone mode. It also allows users to access the **Setup** and **Pattern** programming displays.

The control panel's features include:

- **Motor and Control Method Display** – When the motor control firmware is appropriately configured (such as the demonstration applications included with the development kit), the scrolling display indicates the type of motor and control firmware that has been programmed to the PICDEM MC LV Development Board.
- **Speed/Direction Display** – Displays the actual speed of the motor as determined either by sensors, or Back EMF approximation, in both tachometer and digital (text) formats. Below the tachometer is a direction indicator, showing the direction of motor revolution relative to the default direction with an arrow and text. Speed for all applications in Open-Loop mode is shown in RPM.

The full-scale value of the tachometer and the colored zones reflect average safe and hazardous values for the type of motor selected, based on the rated and maximum safe speeds. The full-scale value is determined by the speed limit defined in the Setup window, plus an additional margin. The upper boundary of the green range represents the motor's rated speed. The upper blue boundary is set to scale the maximum safe speed well into the red area; generally, this boundary is halfway between the rated and full-scale speeds. The values may be changed in the Setup window to reflect the actual performance limitations of the motor.

- **Fault Display** – A scrolling text display indicates the state of the Fault conditions monitored by the PICDEM MC LV Development Board. Under normal conditions, it will display a scrolling "No Fault" message and a green indicator. Should a Fault condition occur, the indicator will change to blinking red; the text will also change to red and the message will indicate the specific Fault event(s).

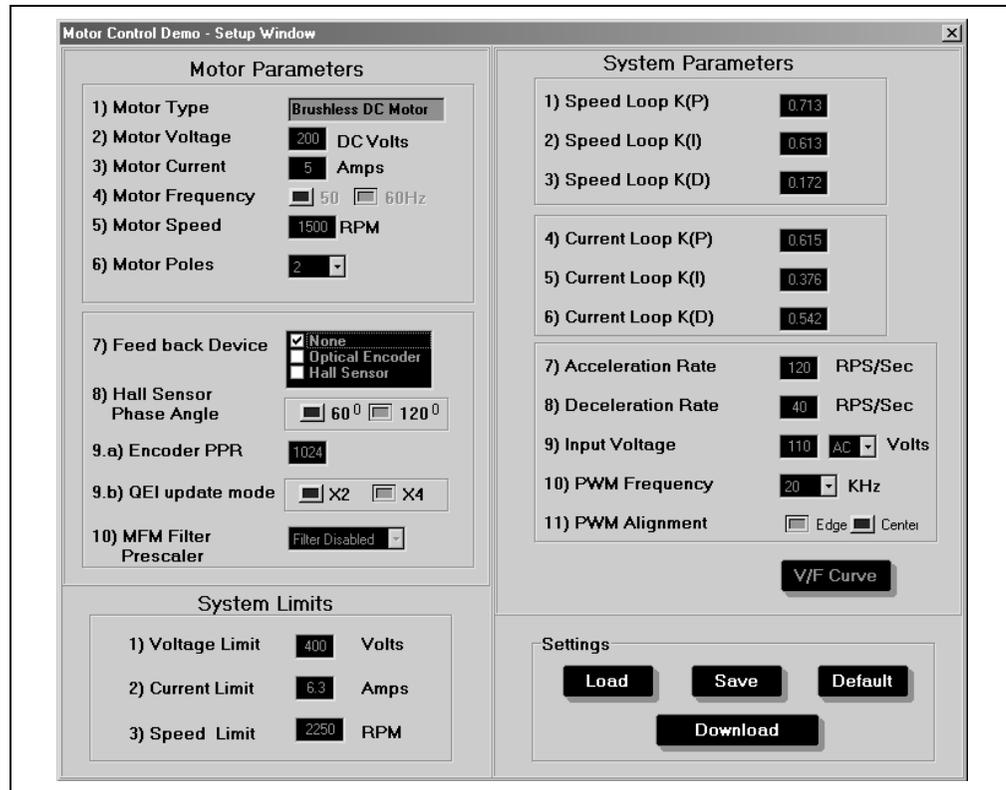
Using the Microchip Motor Control GUI

- **Speed Set Control** – The user can set the target run speed for the motor with this spin box by either direct entry or using the up/down controls. The input is specified in RPM for all applications. Left clicking on the control, or pressing the <Enter> or <Tab> keys after entering a speed, starts the motor running.
- **Phase Current Display** – Displays the current draw for the indicated motor windings in amperes. Information is given in analog gauge and digital (text) format. The number of gauges that are used at any time reflect the motor type and current sensing configuration; for example, using one current transducer will result in one active gauge. The example shown in Figure 4-1 is typical for 3-phase current sensing. As with the speed display, the different color zones represent average safe and hazardous operating ranges based on the capabilities of the development board being used. For the PICDEM MC LV Development Board, the safe operating limit is 6A. The actual safe operating range should be determined from the motor's name plate and data sheet.
- **Temperature Display** – This gives the approximate temperature of the inverter power module in degrees Celsius, as both an analog thermometer and a text value. The arrow at the left of the thermometer indicates the event temperature for overtemperature Faults set in the controller firmware. This display is not implemented in the current version.
- **Control Buttons** – A total of four active motor controls are provided. The first two start and stop the motor, respectively. The motor's current status disables the corresponding button; that is, the **Run** is disabled and the **Stop** button is enabled once the motor is running. Starting the motor by left clicking on the control, or pressing the <Enter> or <Tab> keys on the **Set Speed** control also disables the **Run** button. The third button, **Direction**, toggles the direction of rotation. The **Setup** button at the extreme right launches the Setup window display (described in **Section 4.5 “The Setup Window”**).
Two additional buttons, **Pattern** and **History**, are not implemented in this version of the Motor Control GUI. They will appear shaded.
- **Communication Control** – This area provides user controls for the serial communication link to the board, as well as a real-time status indicator. Clicking **COM Setup** launches the COM Port Setting window; this allows the user to select the serial port and baud rate settings for communicating with the board. By clicking on **Auto Connect**, the Motor Control GUI will automatically attempt to communicate with the board each time the GUI is launched, using the most recently entered COM parameters. Once connected, **COM Setup** becomes unavailable. The **Connect/Abort** button is used to establish or break a serial link with the board. When a link is established, the **Connect** label changes to **Abort** and **COM Setup** becomes unavailable. When the link is broken by clicking on **Abort**, **COM Setup** becomes available for configuration. The indicator at the extreme left shows the status of the serial link. When a link is established, the indicator is solid green. When a connection is being established, the indicator flashes green. Should the link fail, the indicator changes to solid red. Located to the right is a scrolling message display; this shows the current connection status, the device being controlled and the current version of the motor control firmware. A real-time clock based on system clock time is provided at the extreme right of the display.

Note: Identification of the microcontroller and firmware happens when the Motor Control GUI is launched and the serial link is first established. If the controller and/or firmware is changed, the application may not always see this when the serial link is re-established. Always close and restart the Motor Control GUI when changing the microcontroller or firmware.

4.5 THE SETUP WINDOW

FIGURE 4-2: TYPICAL SETUP WINDOW



Clicking on the **Setup** button in the control panel launches a second window, the Setup window (Figure 4-2). From here, users can define the individual settings for the motor being used. If the appropriate information is included in the firmware, most of the values will auto-populate, or at least be limited to a smaller subset of choices. Features or parameters that are not used will be masked or greyed out.

There are three categories that the user can modify:

- **Motor Parameters**, which define the actual motor and sensor hardware that are used.
- **System Parameters** (control), which define the control variables.
- **System Limits**, which define the hardware maximum ratings.

Controls are also provided to save or recall parameters for later use or restore default settings. Users can download settings to the connected board.

4.5.1 Motor Parameters

These parameters are generally self-explanatory. Information on the motor hardware itself (items 1 through 6) can be found either on the motor's nameplate or in its data sheet. The **Motor Type** field is auto-populated with the motor type identified upon connection.

The configuration for motion feedback sensors is selectively enabled by selecting the appropriate check boxes in **Feedback Device**. When Hall effect sensors alone are used, the **Hall Sensor Phase Angle** and **MFM Filter Prescaler** (Motion Feedback Module) may be configured; the other options are disabled. When optical encoders are enabled, the **Encoder PPR** (Pulses Per Revolution), **QEI update mode** and **MFM Filter Prescaler** may be configured; Hall effect configuration is unavailable. (The use of the **QEI update mode** and **MFM Filter Prescaler** options is discussed in detail in **Section 16 “Motion Feedback Module”** of the *“PIC18F2331/2431/4331/4431 Data Sheet”* (DS39616).

Note: The Hall effect and optical sensors are mutually exclusive; it is not possible for some control methods to use both types at once. In these cases, checking the appropriate box enables all configuration options. Of course, selecting the **None** option in **Feedback Device** disables all sensor configuration options.

For motors with integrated motion feedback sensors, information on the sensor type and arrangement is also found in the motor data sheet. External shaft mounted encoders should also have the required information in their data sheets.

4.5.2 System Parameters

The **System Parameters** options will vary, depending on the motor control principle being used by the firmware.

Proportional-Integral-Derivative (PID) systems are most often employed in closed-loop operation, where constant speed or constant torque is required. Options 1 through 6 will only be available when a PID control algorithm is used.

Acceleration and deceleration are defined as RPS/s for most applications. For induction motors running in open-loop applications, they are defined as Hz/s.

The **Input Voltage** is the actual supply voltage to the board. With the drive voltage level established under **Motor Parameters**, it is used to calculate the limits on the PCPWM duty cycle necessary to generate the drive voltage from the input voltage.

The **PWM Frequency** determines the resolution of the control firmware. The drop-down combo box presents a fixed range of values depending on the firmware application and microcontroller.

Note: The **V/F Curve** control is not available in the current version of the Motor Control GUI.

4.5.3 System Limits

The **System Limits** reflect the maximums of both the motor and the board being used.

Voltage Limit, or the maximum voltage delivered to the motor, is limited at the input DC voltage level.

Current Limit is set at the lesser of the maximum current rating for the motor or the maximum capacity of the board. For the PICDEM MC LV Development Board, this is 4.0A.

Speed Limit is set at the value given in the motor's data sheet, or at a predetermined speed set by the particular motor data file.

CAUTION

Not all motors may be able to run at the maximum speed defined by the Speed Limit parameter. It should be regarded as an upper limit and not the motor's expected maximum speed.

4.5.4 Storing and Using Setting Profiles

Once the parameters for a particular motor are established, it would be nice to preserve them for future use. Users have several options from the Setup window display to do just that.

Clicking on the **Save** button allows the current settings to be stored in a file, while clicking on **Load** selects and loads a file with saved settings. Both commands use the conventional Windows® dialogs for opening and saving files. Setting profiles are saved as motor data files (.mcd extension). Neither of these affects the parameters currently in effect in the on-board firmware.

The **Default** button replaces all of the current settings with the default settings associated with the current motor type. This may be useful for quickly starting over when a set of parameters has been extensively modified and isn't working.

The **Download** button transfers the currently displayed parameters to the on-board firmware. It only changes the parameters and not the control firmware itself.

- | |
|---|
| <p>Note 1: Attempting to load a motor data file that does not match the currently loaded motor and/or control method type will generate an error message.</p> <p>2: Remember that downloading a profile to the PICDEM MC LV Development Board only downloads variable values; it does not download new firmware. Similarly, loading and saving profiles only loads or saves the motor data file to the computer, but does not load or save the file to the on-board firmware.</p> |
|---|

Chapter 5. Creating Motor Control Firmware Projects

5.1 HIGHLIGHTS

The items discussed in this chapter are:

- Included Applications
- Beyond the Included Applications: Creating New Projects

5.2 INCLUDED APPLICATIONS

The PICDEM MC LV Development Board comes with two complete firmware solutions. One of these is the BLDC control application (installed on the board). It assumes a 3-phase BLDC motor using Hall effect sensors at 120-degree spacing application.

It is possible that this preprogrammed application will not meet the project requirements. If so, there are additional motor control applications provided with the PICDEM MC LV Development Board CD. The additional motor control applications include the sensorless BLDC control (open-loop) and Proportional-Integral-Derivative (PID) control algorithms. The applications are provided as ready-to-program HEX files, and as assembler files, with all the necessary support files to create custom projects.

5.3 BEYOND THE INCLUDED APPLICATIONS: CREATING NEW PROJECTS

Even with the provided applications, project requirements may differ. It may be necessary to integrate motor control into your existing code, or you may have a new approach for motor control. In either event, the PICDEM MC LV Development Board can be used to prototype the application.

The first step is to create code in a development environment, such as Microchip's MPLAB® IDE. Add any necessary `.inc` or `.asm` files to the project and set the system and control parameters specific to the application. The best place to get this information is to review the existing firmware applications included on the software CD.

Motor-specific information can be found in the Readme files for the Microchip Motor Control GUI included on the CD.

Once the necessary information is gathered, build the project and create the HEX file. Using a device programmer, such as PRO MATE® II, load your firmware into the supplied PIC18F2431 microcontroller. Alternately, load your firmware directly into the microcontroller installed on the board through the ICD interface.

Note: The operation of the Stand-Alone and PC modes, as described in previous chapters, is an integral part of the motor control firmware. If the program logic differs significantly from the firmware included with the board, it is possible that the modes cannot be used as described. The “self-test” blinking of the monitor LEDs on power-up may also be disabled.

PICDEM™ MC LV Development Board

NOTES:

Chapter 6. Getting Started with dsPIC Digital Signal Controllers

6.1 HIGHLIGHTS

This item discussed in this chapter is:

- Initial Setup

6.2 INITIAL SETUP

The following procedure describes how to set up the PICDEM MC LV Development Board to run with a dsPIC® device.

WARNING

- Note 1:** The PICDEM MC LV Development Board is intended to drive the 3-phase BLDC motor. Before connecting the motor, make sure that the power rating of the motor is equal or less than the power rating of the board, as shown in **Appendix B. “Electrical Specifications”**. Also, make sure the jumper settings are correct for the firmware programmed into the target dsPIC device mounted on the socket. Failure to comply with this warning could lead to malfunction of the board, the motor and could be hazardous to the development staff.
- 2:** Before beginning the start-up procedure, complete a visual check of the board and the motor for connectivity and mechanical damage. If damage is found, DO NOT power-up the board. Otherwise, you may further damage the equipment. Contact Microchip’s local office or distributor immediately.

1. Place the PICDEM MC LV Development Board on a sturdy platform/surface.
2. Confirm that a dsPIC30F2010, dsPIC30F3010 or dsPIC30F4012 is mounted in the “dsPIC” marked U3 socket.
3. Connect the 24V power supply to J5. DO NOT connect the motor wires to the board. LED D7 (red) should turn on. If it does not turn on, check the polarity of the power supply connector. If it is correct and LED D7 does not turn on, disconnect the power to the board and contact Microchip’s local office or distributor.
4. Two Application Notes are available for information on running BLDC Motors using dsPIC devices:

AN957, “Sensored BLDC Motor Control Using dsPIC30F2010” (DS00957)

AN992, “Sensorless BLDC Motor Control Using dsPIC30F2010” (DS00992)

AN957 and AN992 have been developed using the PICDEM MC LV Development Board. The code available with these Application Notes can be downloaded from the Microchip web site (www.microchip.com) and will work with the BLDC motor provided in the application kit. To generate a project and program using MPLAB® ICD 2 In-Circuit Debugger, refer to the “MPLAB® ICD 2 In-Circuit Debugger User’s Guide” (DS51331).

WARNING

- Note 1:** When programming the dsPIC device on the PICDEM MC LV Development Board, the two DIP switches must be in the PRGM position. This will ensure the programming pins are connected to the programmer. If the user has generated independent code, the user must select EMUC2/EMUD2 pins for emulation in the MPLAB Configuration menu. These alternate pins will then be programmed and will be used for the debugging or run phase.
- 2:** After programming the dsPIC device, the user can disconnect the programmer from the ICD 2 plug J6 and run the device in Stand-Alone mode. Alternatively, if the ICD 2 is being used in the Emulator mode, then the DIP switches have to be switched to the DEBUG position. Then, the EMUC2/EMUD2 pins will be connected to the ICD 2, and assuming the configuration was done as described above, the user will be able to run the firmware using the ICD 2 as an emulator.

5. Disconnect the power supply and ensure that the jumper settings and motor connection match Table 6-1 and Table 6-2 respectively.

TABLE 6-1: JUMPER SETTINGS

Jumper	Sensored Control	Sensorless Control
J7, J11, J13	Open	Short between 2-3
J15	Don't care	Don't care
J8, J10, J12, J14	Open	Open
J19	Short	Open
J16, J17	Short	Short

TABLE 6-2: MOTOR CONNECTIONS

Label on Connector J9	Sensored Control	Sensorless Control
M1	Phase C (red)	Phase C (red)
M2	Phase B (black)	Phase A (white)
M3	Phase A (white)	Phase B (black)
G	Ground (green)	Ground (green)
+5V	Power-on Hall Sensor (red)	No Connection
Return (symbol)	Power Return for Hall Sensor (black)	No Connection
HA	Hall S1 (white)	No Connection
HB	Hall S2 (brown)	No Connection
HC	Hall S3 (green)	No Connection

6. Keep the potentiometer "REF" on the 50% or center position. Turn the pot marked "R60" to the full clockwise position.
7. Connect the 24V power supply to the board. The red LED D7 will turn on.
8. To start the motor, press S2.
9. To increase the speed of the motor, turn the potentiometer marked "REF" clockwise.
10. If the motor stops, press S2 once to reset the process and repeat steps 9-11.
11. The debug information will be relayed via the serial port. Connect Hyperterminal at 19200 baud to view the speed of the motor, or any Fault which occurs during the execution of the code.

Chapter 7. Using dsPIC DSCs to Run a Sensorless BLDC Motor

7.1 INTRODUCTION

The PICDEM MC LV Development Board can be used to run a BLDC motor without a Hall effect sensor. To find out more and get a full description of the application, refer to Application Note AN992, “Sensorless BLDC Motor Control Using dsPIC30F2010” (DS00992). For jumper settings and details on how to connect the motor, refer to **Chapter 6. “Getting Started with dsPIC Digital Signal Controllers”**.

In this chapter, we will briefly explain how a sensorless BLDC motor application is run using a dsPIC device and describe how to adjust some of the parameters in order to make specific BLDC motors run. For more details on the hardware and firmware specifications, refer to Application Notes AN901, “Using the dsPIC30F for Sensorless BLDC Control” (DS00901) and AN992, “Sensorless BLDC Motor Control Using dsPIC30F2010” (DS00992). These Application Notes can be found on the Microchip web site (www.microchip.com).

7.2 HIGHLIGHTS

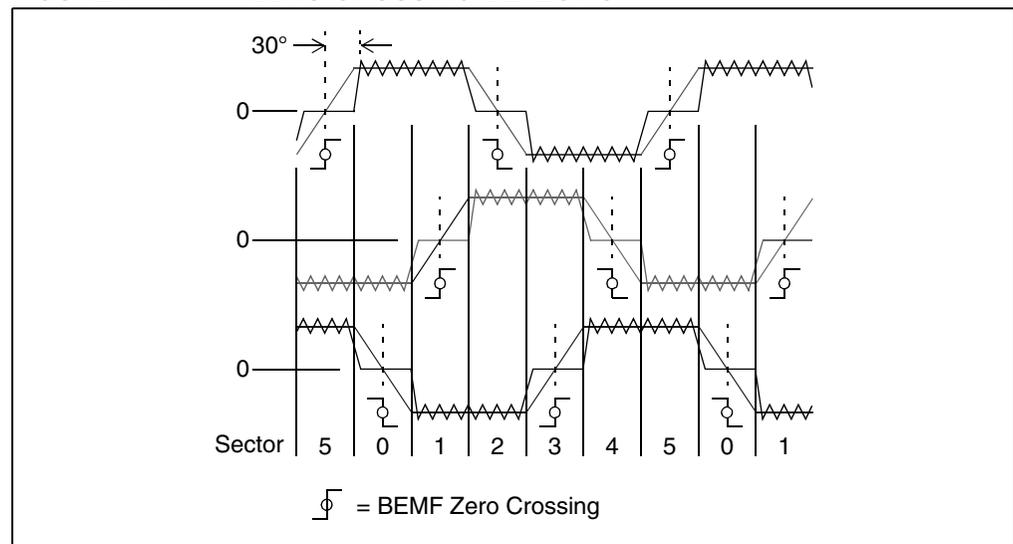
This items discussed in this chapter are:

- Sensorless Control of a BLDC Motor
- Using the PICDEM MC LV Development Board for Higher Motor Voltage
- Using the PICDEM MC LV Development Board for Lower Motor Voltage

7.3 SENSORLESS CONTROL OF A BLDC MOTOR

To run a BLDC motor without sensors, it is important to sense the rotor magnet position with reference to the windings on the stator. In order to do this properly, the Back EMF on the unexcited winding is monitored. As the motor is spun, the voltage waveform on the three winding phases will be seen, as shown in an idealized manner in Figure 7-1.

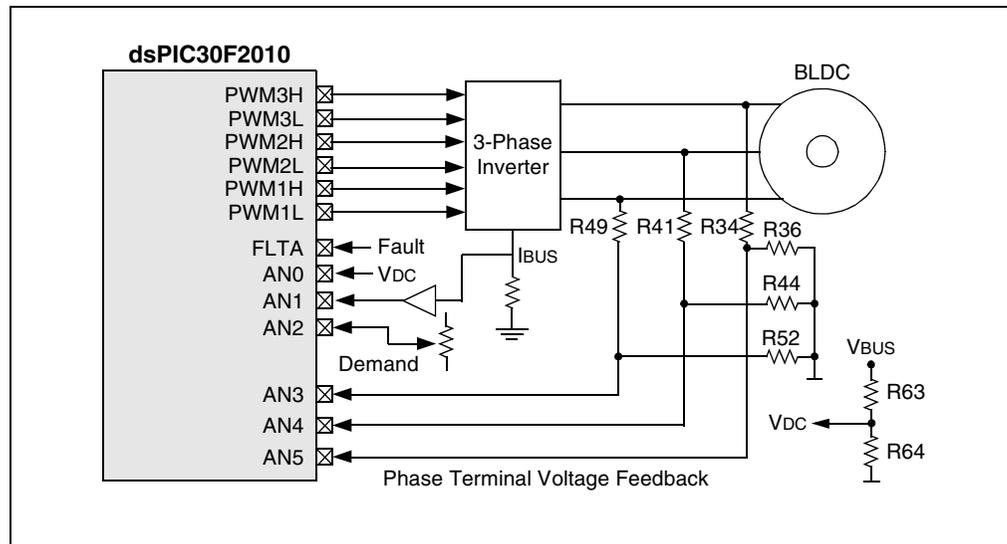
FIGURE 7-1: ZERO-CROSSING DETECTION



PICDEM™ MC LV Development Board

There are 6 sectors, each 60 degrees wide, which accumulate to give one 360 degree electrical revolution of the motor. In each sector, two windings are excited: one with a high voltage and the other with a low voltage. The third winding is not excited. As the rotor rotates from one sector to another, a new set of windings is excited. The sequence of excitation in each sector is provided by the motor manufacturer. The winding in each sector that is not excited will be influenced by the Back EMF voltage. This voltage is not high or low, but a falling or rising voltage level, going symmetrically from a high-to-low or a low-to-high. It crosses the center, or star point voltage, at about 30 degrees before the next commutation point of the rotor. This center, or star point voltage, is also referred to as the zero-crossing voltage. Its value is exactly half the voltage applied to the excited windings of the motor. The dsPIC device uses its fast ADC to sense the zero-cross point. Having sensed the zero-cross point, it can predict the time required for the next commutation phase. The zero-cross sensing and drive of the motor is shown in Figure 7-2.

FIGURE 7-2: HARDWARE BLOCK DIAGRAM



The PWM signals drive three MOSFET drivers (IR2101s), which in turn, drive the 3-phase bridge inverter connected to the 3 motor windings (see **Appendix A. “Circuit Schematics of the Board”**). The motor windings are driven with 24V. This voltage is scaled down to about 1.8V full scale when sensed by the ADC inputs of the dsPIC device. The scaling for each winding is done by resistor pairs, R34/R36, R41/R44 and R49/R52 (see **Appendix A. “Circuit Schematics of the Board”**). The bus voltage is sensed and scaled down by resistor pair, R63/R64.

Note: All the resistor pairs should have the same value for a given motor voltage. The resistor pairs used on the PICDEM MC LV Development Board give a full-scale value of about 2.4V and so, the zero-cross voltage is about 1.2V. This is based on a motor voltage of 24V.

7.4 USING THE PICDEM MC LV DEVELOPMENT BOARD FOR HIGHER MOTOR VOLTAGE

The PICDEM MC LV Development Board can be used to drive a motor at a voltage higher than 24V, but not exceeding 36V. The new high voltage can be supplied to the system at the Plus (+) and Minus (-) terminals on J9. For the sensorless algorithm to work, the user will have to modify the resistor pairs to drive the same full-scale (2.4V) and zero-cross (1.2V) voltages (see **Section 7.3 “Sensorless Control of a BLDC Motor”**). Do not exceed the input voltage of the 15V regulator (VR2), which is typically about 36V. Since the voltage drop across VR2 will increase substantially, make sure to provide additional heat sinking for VR2.

7.5 USING THE PICDEM MC LV DEVELOPMENT BOARD FOR LOWER MOTOR VOLTAGE

The PICDEM MC LV Development Board can be used to drive a motor at a voltage lower than 24V, but not below 10V. This voltage can be supplied to the system at the Plus (+) and Minus (-) terminals on J9. Since the 15V regulator will no longer be used to drive the MOSFET drivers, J18 should be provided with a shorting jumper. This jumper connects the Plus (+) voltage directly to the MOSFET drivers. For the sensorless algorithm to work, the user will have to modify the resistor pairs to derive the same full-scale (2.4V) and zero-crossing (1.2V) voltages (see **Section 7.3 “Sensorless Control of a BLDC Motor”**). Make sure not to exceed the maximum input voltage of the MOSFET drivers, U6, U8 and U9. This voltage is typically 20V.

PICDEM™ MC LV Development Board

NOTES:

Chapter 8. Troubleshooting

8.1 HIGHLIGHTS

This item discussed in this chapter is:

- Common Problems

8.2 COMMON PROBLEMS

8.2.1 The Power LED D7 is Not Lit

Check the PICDEM MC LV Development Board for power:

- Check the power supply and make sure it is connected to the board.
- Check the power cable and make sure it is plugged into the outlet.
- Check and verify that the power source is working properly.
- If using a power supply other than the one supplied by Microchip, check the power supply polarity.
- Disconnect the power to the board. Using an ohmmeter, check for any short circuits between the power (VDD) and return path (VSS). If a short exists, do not proceed any further. Contact Microchip's local office or distributor.
- Disconnect power and motor connections from the board. Using an ohmmeter, check for any short circuits between the motor terminals, M1-M2, M1-M3 and M2-M3. If a short does exist, do not proceed any further. Contact Microchip's local office or distributor.

8.2.2 The Motor Control GUI Cannot Communicate with the Board

- Check the PICDEM MC LV Development Board and make sure it is receiving power.
- Check the serial cable for proper connections to the board and the computer.
- Verify the cable is connected to the correct serial port on the computer. If necessary, check the serial cable by swapping in another cable that is known to be good.
- Verify, through Windows® Device Manager (accessed through the system applet in the Control Panel), that the selected COM port is recognized by the operating system and is working.
- Confirm that the correct serial port is being used. Check that the COM port selected in the terminal software is actually the physical port the serial cable is connected to.
- Verify the baud rate; try choosing a lower rate.
- Check the monitor LEDs flash briefly on Reset or power-up of the board.
- If all other settings and connections are correct, try resetting the board and restarting the Motor Control GUI.

8.2.3 The Motor Does Not Start When S2 or S3 is Pressed

Verify the power supply and motor connections:

- Verify that the power supply is connected to the board and is in working condition.
- Verify that the controller is in the correct socket; PIC18F on the “PIC” socket and DSC on the “dsPIC” socket.
- Make sure the jumper settings are correct for the type of control selected.
- Verify that the motor connections on J9 are making proper contact.
- Check that the speed reference potentiometer (R14) has a sufficient level. Turn the potentiometer clockwise slowly and check for motor rotation.
- Check for overcurrent condition. If the motor has overloaded or the Fault detection circuit detects overcurrent, check LED D1. If it is blinking continuously, reset the system by pressing S1. Also, check for potentiometer R60 for correct current threshold level for the selected motor type. Rotate counterclockwise to increase the current threshold level.

8.2.4 A Fault Condition Occurs While Accelerating the Motor

Try using a lower acceleration rate:

- If the motor still causes a Fault condition, check the motor power rating. It should be within the board power rating specified.
- Check the potentiometer R60 level. Set R60 for the correct current threshold level for the selected motor type. Rotate counterclockwise to increase the current threshold level.
- Check for correct socket selection and jumper selections for the type of control used.
- If using an alternative power supply for the motor, from the control power supply, check for its current rating. The power supply should have equal or more current capability than the motor used.

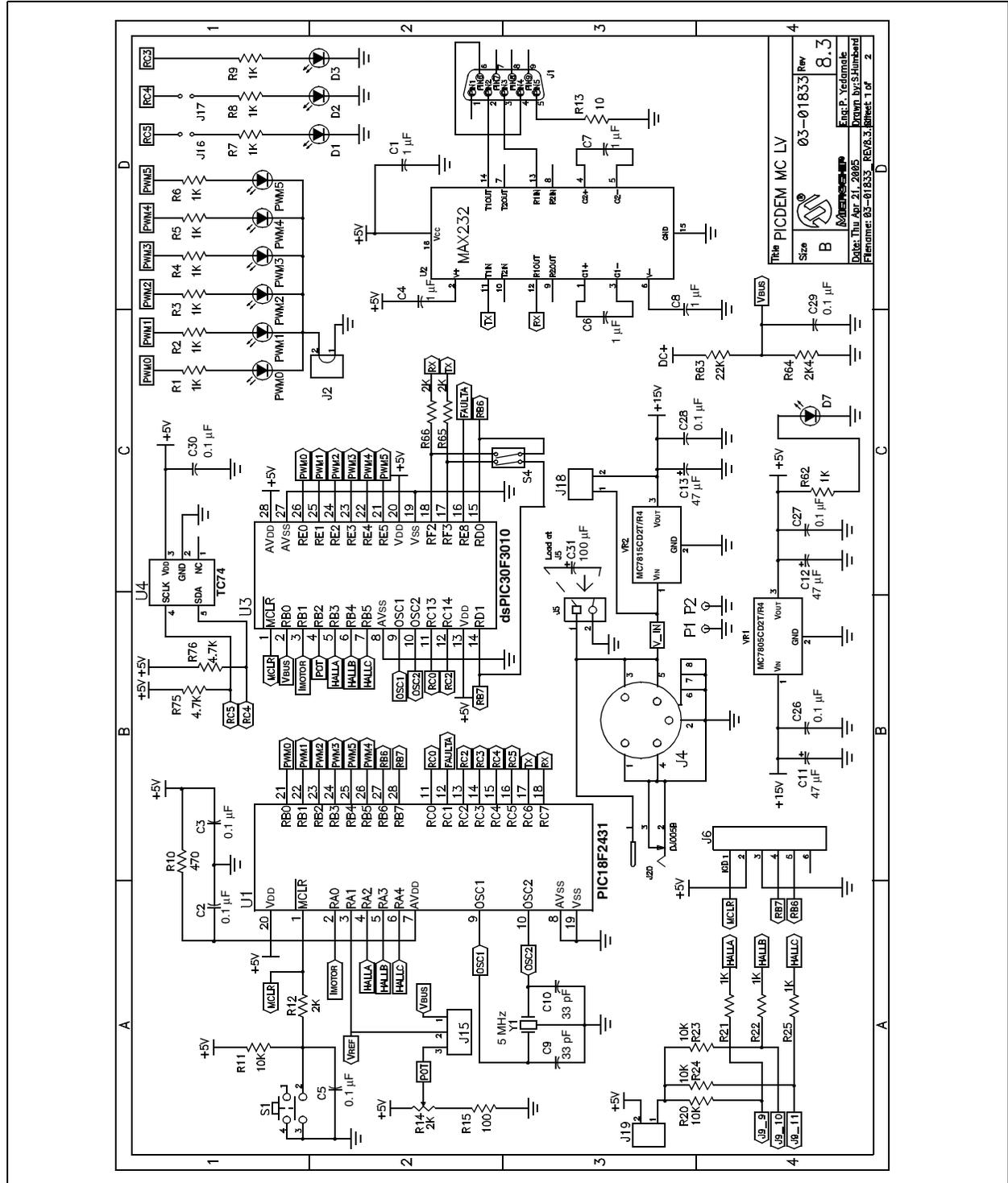
8.2.5 A Fault Condition Occurs When the Motor is Loaded

Check the motor power rating:

- The motor power rating should be within the board power rating specified.
- Check the potentiometer R60 level. Set R60 for the correct current threshold level for the selected motor type. Rotate counterclockwise to increase the current threshold level.
- If using an alternative power supply for the motor, from the control power supply, check for its current rating. The power supply should have equal or more current capability than the motor used.

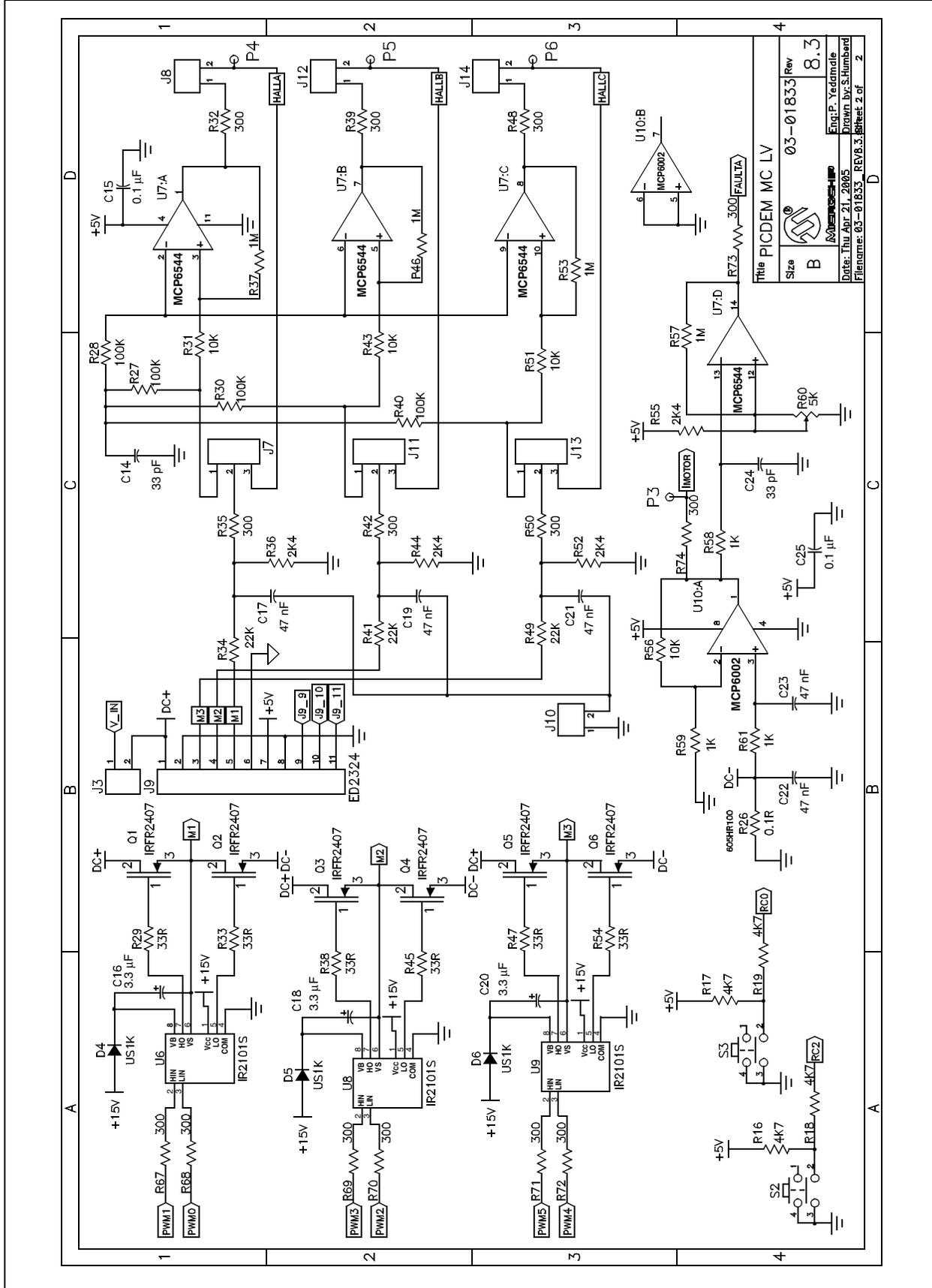
Appendix A. Circuit Schematics of the Board

FIGURE A-1: CIRCUIT SCHEMATIC (SHEET 1 OF 2)



PICDEM™ MC LV Development Board

FIGURE A-2: CIRCUIT SCHEMATIC (SHEET 2 OF 2)



Appendix B. Electrical Specifications

TABLE B-1: DC INPUT RATING

Parameter	Min	Typical	Max	Unit	Note
Supply Voltage	15	24	—	V	DC input on J5
Supply Voltage	12	—	48	V	DC input between '+' and '-' on J9 (open jumper J3)
Standby Current	—	30	—	mA	With 24V DC supply
Standby Power	—	0.72	—	Watts	With 24V DC supply

TABLE B-2: OUTPUT RATING

Parameter	Min	Typical	Max	Unit	Note
Voltage	—	24	48	V _{DC}	Voltage is based on the DC bus voltage
Current	—	2.5	4	A	
Power Rating	—	60	120	Watt	

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Appendix C. Jumper Settings

TABLE C-1: JUMPER SETTINGS

Jumper	Sensored Control Using PIC18F MCU	Sensorless Control Using PIC18F MCU	Sensored Control Using dsPIC30F DSC	Sensorless Control Using dsPIC30F DSC
J7 (3 pin)	Short between 1-2	Short between 1-2	All Open	Short between 2-3
J8 (2 pin)	Open	Short	Open	Open
J10 (2 pin)	Short	Short	Open	Open
J11 (3 pin)	Short between 1-2	Short between 1-2	All Open	Short between 2-3
J12 (2 pin)	Open	Short	Open	Open
J13 (3 pin)	Short between 1-2	Short between 1-2	All Open	Short between 2-3
J14 (2 pin)	Open	Short	Open	Open
J15 (3 pin)	Short between 2-3	Short between 2-3	Don't care	Don't care
J16 (2 pin)	Short	Short	Short	Short
J17 (2 pin)	Short	Short	Short	Short
J19 (2 pin)	Short	Short	Short	Open

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