PICDEM™ MC Development Board for PIC18FXX31 User's Guide

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Microchip received ISO/TS-16949:2002 quality system certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona and Mountain View, California in October 2003. The Company's quality system processes and procedures are for its PICmicro® 8-bit MCUs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, non-volatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.

Table of Contents

Preface

INTRODUCTION

This chapter contains general information about this manual and contacting customer support.

HIGHLIGHTS

Items discussed in this chapter are:

- About this Guide
- Warranty Registration
- Recommended Reading
- Troubleshooting
- Microchip On-Line Support
- Customer Change Notification Service
- Customer Support

ABOUT THIS GUIDE

Document Layout

This document describes how to use the PICDEM MC Development Board as a development system for Microchip Technology's PIC18F2331/2431/4331/4431 family of enhanced microcontrollers. The manual layout is as follows:

- **Chapter 1: Introduction to the PICDEM™ MC Board** – What the PICDEM MC Board is, what makes it a desirable development tool for motor control, and what features are available.
- **Chapter 2: Getting Started with the PICDEM™ MC Board** – Describes how to connect and begin to use the PICDEM MC Board.
- **Chapter 3: Using the Microchip Motor Control GUI** – Provides a detailed description of PC-based Motor Control GUI and how to use its programmable features.
- **Chapter 4: Creating Motor Control Firmware Projects** – Discusses the basic steps for creating custom applications, or modifying existing applications.
- **Chapter 5: Configuring the PICDEM™ MC Hardware** – Describes how to configure the board for use with various types of AC and DC motors.
- **Chapter 5: Troubleshooting** – Provides information on solving common problems.
- **Appendix A: PICDEM™ MC Technical Information** – Provides the block diagram, detailed schematics and power specifications of the PICDEM MC Board.
- **Appendix B: PICDEM™ MC Software CD** – Provides a summary of the software and documentation on the accompanying CD-ROM.
- **Index** – Cross-reference listing of terms, features and sections of this document.
- **Worldwide Sales and Service** – Gives the address, telephone and fax number for Microchip Technology Inc. sales and service locations throughout the world.

Conventions Used in This Guide

This manual uses the following documentation conventions:

TABLE 1: DOCUMENTATION CONVENTIONS

Description	Represents	Examples
Code (Courier font):		
Plain characters	Sample code Filenames and paths	#define START c:\autoexec.bat
Angle brackets: < >	Variables	<label>, <exp>
Square brackets [ ]	Optional arguments	MPASMWIN [main.asm]
Curly brackets and pipe character: { | }	Choice of mutually exclusive arguments; An OR selection	errorlevel {0|1}
Lower case characters in quotes	Type of data	"filename"
Ellipses...	Used to imply (but not show) additional text that is not relevant to the example	list ["list_option..., "list_option"]
0xnnn	A hexadecimal number where n is a hexadecimal digit	0xFFFF, 0x007A
Italic characters	A variable argument; it can be either a type of data (in lower case characters) or a specific example (in upper case characters).	char isascii (char, *ch*);
Interface (Arial font):		
Underlined, italic text with right arrow	A menu selection from the menu bar	*File > Save*
Bold characters	A window or dialog button to click	**OK**, **Cancel**
Characters in angle brackets < >	A key on the keyboard	<Tab>, <Ctrl-C>
Documents (Arial font):		
Italic characters	Referenced books	*MPLAB IDE User's Guide*

Documentation Updates

All documentation becomes dated, and this user's guide is no exception. Since MPLAB® IDE, MPLAB C1X and other Microchip tools are constantly evolving to meet customer needs, some actual dialogs and/or tool descriptions may differ from those in this document. Please refer to our web site to obtain the latest documentation available.

Documentation Numbering Conventions

Documents are numbered with a "DS" number. The 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 = The document number.

A = The revision level of the document.

WARRANTY REGISTRATION

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

RECOMMENDED READING

This user's guide describes how to use the PICDEM MC Development Board. The data sheets contain current information on programming the specific microcontroller devices.

MPLAB® IDE 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.

MPASM™ User's Guide with MPLINK™ and MPLIB™ (DS33014)

This user's guide describes how to use the Microchip PICmicro® MCU MPASM assembler, the MPLINK object linker and the MPLIB object librarian.

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 (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 Device Data Sheet (DS39616)

This is the definitive reference for Microchip's 28 and 40-pin enhanced motor-control microcontrollers, that are at the heart of the PICDEM MC Development Board.

TROUBLESHOOTING

See Chapter 6 for information on common problems.

MICROCHIP ON-LINE SUPPORT

The Microchip web site provides on-line support at:

http://www.microchip.com

The web site provides a variety of services. Users may download files for the latest development tools, data sheets, application notes, user' guides, articles and sample programs. A variety of Microchip specific business information is also available, including listings of Microchip sales offices and distributors. Other information available on the web site includes:

- Latest Microchip press releases
- Technical support section with FAQs
- Design tips
- Device errata
- Job postings
- Microchip consultant program member listing
- Links to other useful web sites related to Microchip products
- Conferences for products, development systems, technical information and more
- Listing of seminars and events

CUSTOMER CHANGE NOTIFICATION SERVICE

Microchip started the customer notification service to help customers keep current on Microchip products with the least amount of effort. After subscribing, you will receive e-mail notification whenever there is a change, update, revision or errata related to your specified product family or development tool.

Go to the Microchip web site (www.microchip.com) and click on Customer Change Notification, then follow the instructions to register.

The Development Systems product group categories are:

- Compilers
- Emulators
- In-Circuit Debuggers
- MPLAB IDE
- Programmers

Here is a description of these categories:

Compilers – The latest information on Microchip C compilers and other language tools. These include the MPLAB C17, MPLAB C18 and MPLAB C30 C Compilers; MPASM and MPLAB ASM30 assemblers; MPLINK and MPLAB LINK30 linkers; and MPLIB and MPLAB LIB30 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 Microchip in-circuit debuggers. These include the MPLAB ICD and MPLAB ICD 2.

MPLAB – 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 and MPLB SIM30 simulators, MPLAB IDE Project Manager and general editing and debugging features.

Programmers – The latest information on Microchip device programmers. These include the PRO MATE® II device programmer and PICSTART® Plus development programmer.

CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- Distributors
- Local Sales Office
- Field Application Engineers (FAEs)
- Corporate Applications Engineers (CAEs)
- Systems Information and Upgrade Hot Line

Customers should call their distributor or field application engineer (FAE) for support. Local sales offices are also available to help customers. See the last page of this document for a listing of sales offices and locations.

Corporate applications engineers (CAEs) may be contacted at (480) 792-7627.

In addition, there is a Systems Information and Upgrade Information Line. This line provides system users with a list of the latest versions of all of Microchip's development systems software products. This line also provides information on how customers can receive the most current upgrade kits.

The Information Line numbers are:

1-800-755-2345 for U.S. and most of Canada.

1-480-792-7302 for the rest of the world.

Chapter 1. Introduction to the PICDEM™ MC Board

1.1 INTRODUCTION

The PICDEM MC Development Board has been developed for the evaluation and development of both AC and DC motor control applications, utilizing Microchip's family of 28 and 40-pin enhanced microcontrollers. This tool is ideal for beginning motor control designers, as well as those new to the PIC18F2331/2431/4331/4431 family of motor control devices.

The development board provides a complete solution for prototyping motor control applications. Both brushless DC motors (BLDCs) and AC induction motors (ACIMs) can be driven by the board, up to its power handling capacity. Motors can be directly controlled through a simple hardware interface provided on the board itself. The board can be configured in numerous ways, using jumpers and component selection to control a range of motor designs, and can accommodate both AC and DC power inputs. Its isolation design keeps control circuitry separate from power circuitry, allowing users to safely use development, emulation and measurement tools with the board. Finally, the development board can work with a simple graphical interface to provide user-programmable control functions.

1.2 HIGHLIGHTS

This chapter discusses:

- PICDEM MC Board Contents
- Overview of the PICDEM MC Board
- PICDEM MC Board Features
- Microchip Motor Control GUI Software

1.3 PICDEM MC BOARD CONTENTS

The PICDEM MC Board contains the following items:

1. PICDEM MC Board with a Microchip PIC18F4431 microcontroller, preprogrammed with BLDC firmware installed in the main socket.
2. A second PIC18F4431 microcontroller, pre-programmed with 3-phase AC induction motor control firmware.
3. An unprogrammed PIC18F2431 microcontroller.
4. A male-to-female RS-232 serial cable for use in communicating with the board.
5. The Microchip Development Board Software and Documentation CD, containing the Microchip Motor Control GUI, User's Guide and other supporting documents.
6. A warranty registration card.

1.4 OVERVIEW OF THE PICDEM MC BOARD

Electric motors are used widely in many common household products as well as industrial tools. Kitchen appliances such as dishwashers and dryers, hand power tools such as cordless drills, industrial tools like CNC machines, automobiles ... the list of applications where motors can be used is seemingly endless.

The ability to control these motors, both in speed as well as rotation direction, is highly desirable. Until recently, speed-control options were limited to inefficient triac-based controls or costly microcontroller/DSP-based systems. Prototyping new control designs usually meant tailoring a test board and its control firmware to one specific motor architecture. If the design went from using a BLDC motor to an AC induction motor, the motor control system had to be re-designed from scratch.

With the introduction of a low-cost PICDEM Motor Control Development Board based on Microchip's PIC18FXX31 microcontrollers, users can get the variable motor speed with better efficiency, quieter operation and longer system life – all at a lower cost than DSP-based solutions. The PICDEM MC Board gives users the flexibility to drive and control many types of motors. With ready-to-use firmware from Microchip, the development board provides an ideal start to the user in the field of motor control.

1.4.1 Benefits of Using the PICDEM MC Board

The PICDEM MC Development Board gives the motor control developer definite benefits:

LOW-RISK PRODUCT DEVELOPMENT PACKAGE: The PICDEM MC Board is a complete package of hardware and firmware that has been designed to work well as a system. The guesswork of initial hardware and firmware design has been removed, along with the risk; all users need to do is connect a motor and begin customizing their designs.

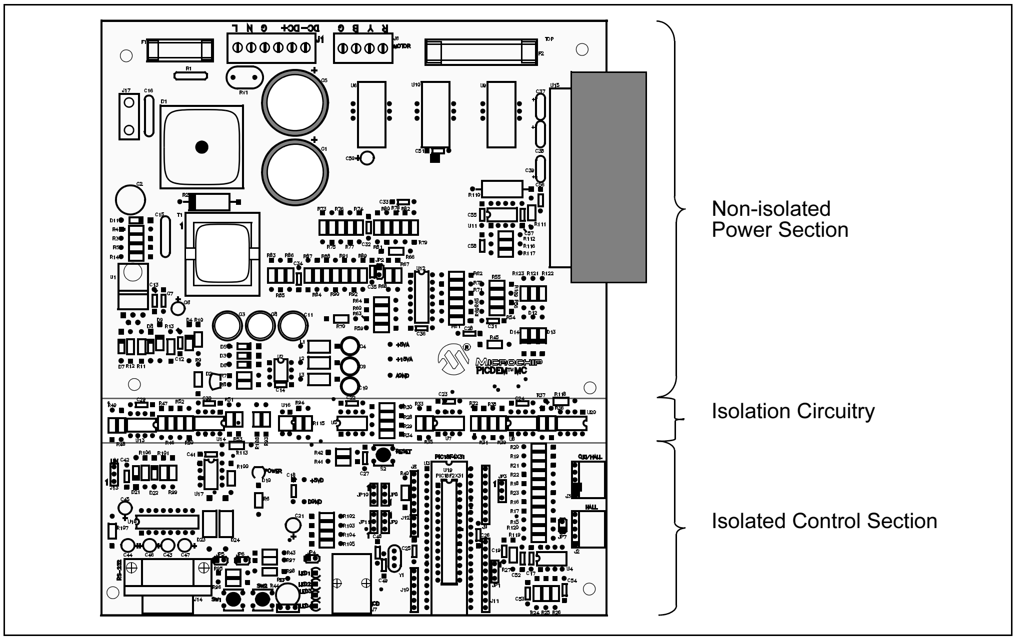
LOWER DEVELOPMENT COST: The complete package means that all necessary hardware is included; there is no need to buy small quantities of components (at premium prices) for prototype applications. The development board is also easy to reuse across many different motor types. By changing the firmware and some jumper settings, the board is ready for the next prototype design. Finally, the voltage-isolated design makes it possible to use Microchip's readily-available line of development tools (i.e., MPLAB ICD 2 and MPLAB ICE) with the board under power, eliminating the need for special testing equipment.

FASTER TIME TO MARKET: All of these features allow developers to rapidly develop and test new motor-control applications, rather than create a new testbed for each new type of motor. It allows users new to motor control to spend time creating applications, instead of experimenting with circuit board layouts. It also lets experienced users test designs quickly, taking advantage of PICmicro based technology to bring their designs to market faster.

1.5 PICDEM MC BOARD FEATURES

In essence, the PICDEM MC Development Board consists of two completely separate systems: a microcontroller-based *control section*, and a *power section* that generates the drive currents that run the motor. The two sections are physically separated at opposite ends of the board, and are linked through optoisolators. The control section of the board is thus referred to as the isolated side of the board. The layout is shown in Figure 1-1.

FIGURE 1-1: ISOLATION LAYOUT OF THE PICDEM MC BOARD



In its default configuration, the control section uses a PIC18F4431 controller to generate drive waveforms. This is done with an on-chip Power Control PWM module (PCPWM) with six distinct outputs that independently drive three half-bridge circuits. The PCPWM also incorporates programmable dead band interval and fault interrupt protection for a complete power-control implementation. In addition, the controller obtains control commands and motor status information through several analog and digital channels. Analog information from the power section is converted by the on-chip A/D converter for further processing.

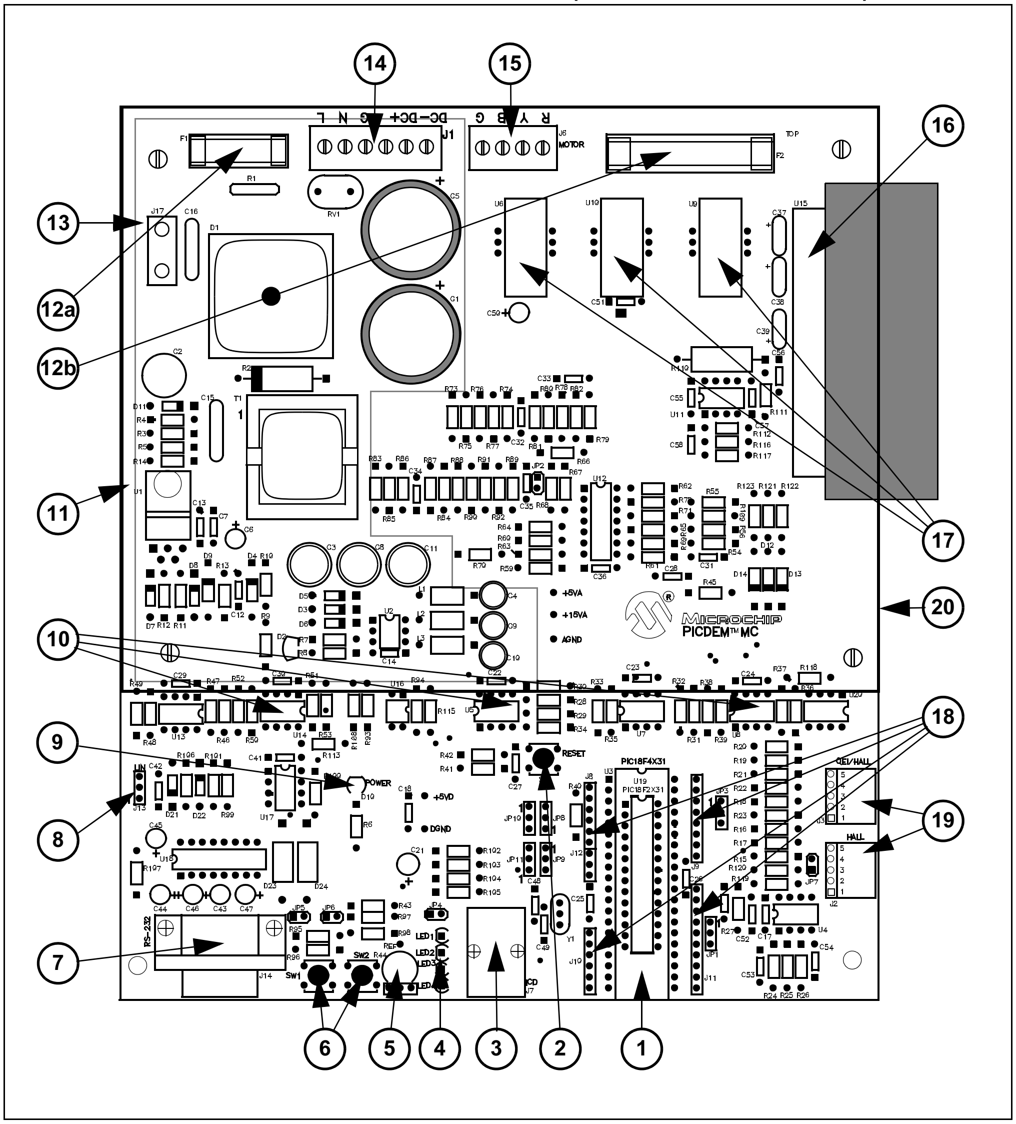
The control section incorporates an external comparator that is used to monitor motor current. Also included are interfaces for both Hall effect and quadrature encoder motion sensors, as well as a serial interface for communication to and control from an external host system.

The power section generates both the motor drive current and the power supply for the entire board. An integrated gate driver/3-phase inverter module (International Rectifier IRAMS10UP60A) takes the waveforms from the PCPWM and boosts them directly to the required drive levels. Motor current is monitored across a shunt resistor connected to the DC return path. Motor current, DC bus voltage and temperature (measured at the power inverter) are sent back to the microcontroller through optoisolators. Conditioning circuits use back EMF measurement to generate commutation signals for sensorless BLDC applications. Additional provisions are made on-board for direct monitoring of motor current, using optional Hall effect transducers.

For on-board power, a flyback power supply circuit provides both isolated and non-isolated voltage to operate the circuitry on both sides of the board. This makes it unnecessary to provide separate external power supplies for the board and the motor.

The overall layout of the board is shown in Figure 1-2.

FIGURE 1-2: THE PICDEM MC BOARD (TOP ASSEMBLY VIEW)



The main features of the board include:

1. **Microcontroller sockets:** The development board has two nested DIP sockets for microcontrollers. As shipped, the outer socket (U3 on the schematic) is populated with a 40-pin PIC18F4431 device. The single microcontroller is responsible for all board functions, including communication through the RS-232 interface. The nested inner socket, designated U19, is a 28-pin DIP socket. It is designed to support an optional PIC18F2X31 microcontroller. The design of the board and the nest sockets dictates that one socket be populated at any given time.
2. **Reset Push Button:** This push button switch is tied to the $\overline{MCLR}$ pin of both 28-pin and 40-pin controller sockets. Pressing the switch causes a hard controller reset.

3. **ICD Connector:** A 6-wire RJ-11 jack is provided as a programming or In-Circuit Debugger interface. The isolated nature of the control section allows users to use development tools, such as MPLAB ICD 2, while the board is under power. See **Section 5.7 “Restoring the Original PICDEM MC Firmware”** for more information on its use.
4. **Monitor LED Bank:** This group of four LEDs is used to indicate both motor and board status. Motor direction, sensor status and fault conditions are indicated by combinations of steady and blinking LEDs. By default, the jumper controlling these LEDs (JP4) is installed, making them functional all the time.
5. **Speed Control Potentiometer:** This analog potentiometer is connected to both microcontroller sockets, and is read by the controller’s ADC. The firmware interprets this input as motor speed.
6. **Control Switches:** Two push button switches are interfaced to the microcontrollers for simple motor control. The provided firmware interprets these switches as commands to start and stop the motor (SW1) or change the direction of its rotation (SW2).
7. **RS-232 (DB9F) Port:** A standard D-shell connector provides a serial connection to control and monitor the development board. Since it uses a standard 232 level shifter, this connector can also be used as a standard serial port for prototype applications.
8. **LIN Interface:** The footprints are provided on the board to add a LIN transceiver and associated circuitry, as well as a 3-pin LINbus connector. The design of the circuit is based on the Microchip MCP201 transceiver. This unpopulated area allows for future development of LIN interfaces for motor control applications. LIN support is not provided in the current versions of the motor control firmware. Component values are provided in the schematic (Figure A-3 in **Appendix A. “PICDEM™ MC Board Technical Information”**.)
9. **Power LED (Red):** This is lit to show that power (from either an AC or DC source) is being supplied to the development board.
10. **Optoisolators:** A total of seven optoisolators (U5, U7, U8, U13, U14, U16 and U20) provide voltage isolation for signals passing between to control and power sections of the board. Other than signals from the current transducers, which are separately isolated, all signal connections between the two sides of the board go through these devices.
11. **Power Supply:** The board incorporates its own power supply (indicated within the border) to handle the power requirements of both the board itself and the motor being driven. The evaluation board can be powered either with a standard 110/230V AC or a DC source. A diode bridge rectifier and DC link capacitor converts supplied AC into DC. The flyback power supply, based on an International Rectifier IRIS4009 integrated switcher, provides +5VD for isolated control circuits, as well as +5VA and +15VA for the non-isolated power circuits. A Metal Oxide Varistor (MOV) across the AC input absorbs voltage spikes, while a negative-temperature coefficient resistor (NTC) protects DC link capacitor against inrush current.
12. **Fuses:** In addition to the protection features described in (11), the AC and DC supplies are separately protected by their own fast-blowing glass cartridge fuses. F1 (12a) protects the board from overcurrent events when the supply current is AC. F2 (12b) protects the board from overcurrent events when using a DC power supply; it also acts as back-up protection from overcurrent events from an AC supply. Removing F2 also isolates the inverter power module from the rest of the board’s circuits.

13. **Voltage Doubler Terminal:** This is an unpopulated location, where users can install a two-terminal connector. Connecting a jumper across this block enables voltage doubling when AC is supplied to the board. This is used whenever the AC supply is less than the motor voltage. Instructions for its use are provided in **Section 5.4.5 "Configuring Voltage Doubling"**.
14. **Power Terminal Strip:** This allows users to connect the board to either a standard 110/230V, single-phase AC source, or a DC power source.
15. **Motor Terminal Strip:** The motor to be driven is connected to this four-terminal strip. Although labelled in the standard lead coding for American 3-phase AC induction motors (R, Y, B and G), all AC and DC motors supported by the board can be connected here. Details are provided in **Section 5.3 "Connecting Different Motor Types"**.
16. **3-phase Inverter Power Module:** The IRAMS10UP60A power module translates the PCPWM outputs from digital logic levels to the power levels required for running the motor. This module provides both the IGBT gate drivers and the inverter in a single package. It also incorporates temperature monitoring inside the package with an integrated NTC thermistor.
17. **Current Transducer Interface:** The footprints are provided to install three Hall effect current transducers and their associated support components. These allow users to directly monitor the current draw for each phase in a 3-phase motor.
18. **Prototype Headers:** Header connectors are provided for users to directly access the microcontroller's I/O port signals. This allows users the option of interfacing the board through a daughter card and risers.
19. **Motion Sensor Inputs:** Two separate five-terminal connectors are provided for connecting either Hall effect sensors (J2) or quadrature encoder sensors (J3). J2 is connected to the controller's interrupt-on-change pins (RC3 through RC5), and is used only with Hall effect sensors. J3 interfaces with the controller's on-chip Quadrature Encoder Interface (QEI) for quadrature encoder sensors, or the Input Capture module for Hall effect sensors. Both jacks provide isolated digital power (+5 VD) and ground. Details on their use is provide in **Section 5.5 "Configuring for Motion Feedback"**.
20. **Top Protective Shield:** As shipped, the PICDEM MC Development Board has a clear acrylic shield installed over the power section (indicated by the outline). It is raised from the PC board by 2-inch standoffs, allowing sufficient room to access the power and motor terminal strips.
    Not shown in this view is the bottom protective shield, which protects the power circuit traces on the bottom of the PC board from shorting out on surfaces they might contact. It is also constructed of clear acrylic sheet, and covers the entire footprint of the board. The shield is separated from the board itself by 1/4-inch standoffs, and incorporates rubber feet for additional isolation.

1.6 MICROCHIP MOTOR CONTROL GUI

Included with the PICDEM MC Board Development Tools CD is the Microchip Motor Control Graphical User Interface (GUI). This PC-based software interface allows users a much greater range of control over motor operation than with the hardware interface in Stand-alone mode. Besides motor speed and direction, users can program motor acceleration/ deceleration and other control factors. They can also create run programs, combining different patterns of motor speed, direction and acceleration/ deceleration. Finally, they can monitor both motor and board operation in real time for conditions such as over current, over voltage and over temperature.

Installation and operation of the motor control software is discussed in Chapter 3.

Chapter 2. Getting Started with the PICDEM™ MC Board

2.1 HIGHLIGHTS

This chapter will cover the following topics:

- Which Mode to Use
- Setting Up the PICDEM MC Board: Stand-alone Mode
- Setting Up the PICDEM MC Board: PC Mode

2.2 WHICH MODE TO USE?

Before setting up the development board, it is necessary to decide which operating mode is appropriate for what you want to do. There are two choices:

- **Stand-alone Mode:** The PICDEM MC Board is connected to a power supply and a motor, but not to a computer. Motor operation is controlled through the two push buttons (start/stop and direction) and the potentiometer (speed). This is a simple demonstration of the board's capability, and is useful for verifying the board's operation. It can also work as a fast "sanity check" of newly-programmed control firmware.
- **PC Mode:** The PICDEM MC Board is also connected to a host computer through a serial interface. In this configuration, motor operation is controlled through a GUI application on the computer; speed cannot be controlled from the potentiometer on the board. The GUI allows more sophisticated motor operation, with controllable acceleration and deceleration, programmable run profiles and real-time monitoring of motor operation.

Since both modes start with the same set-up procedure, we will start by describing the set-up for the Stand-alone mode. Setting up the PC mode involves adding the serial interface to the Stand-alone mode, and is covered later in this chapter.

2.3 SETTING UP THE PICDEM MC BOARD: STAND-ALONE MODE

For evaluating the PICDEM MC Board, the simplest configuration is to use the board by itself, with no computer connection. This setup involves the following:

1. Connecting power to the board
2. Connecting the motor to the board
3. Verifying operation

For the sake of simplicity, we will assume that we are using the development board in its default configuration for BLDC. This means that board jumpers are set in their default settings, and the controller socket (U3) is populated with the PIC18F4431 device that has been pre-programmed with BLDC control firmware. This also assumes the use of a motor with built-in sensors for commutation, spaced at 60°.

If another type of motor is to be used, you may need to change the jumper settings and other hardware configuration changes will be necessary. You will also need to program the microcontroller with different firmware. For more information, refer to **Chapter 4. "Creating Motor Control Firmware Projects"** and **Chapter 5. "Configuring the PICDEM™ MC Board Hardware"**.

2.3.1 Connecting Power

WARNING

When energized, the power produced by the PICDEM MC Board – particularly from the 3-phase inverter – can cause severe equipment damage or personal injury. Always use the proper precautions when working around the board, or power electronic equipment. Whenever possible, use the PICDEM MC Board with the safety shield installed.

1. Remove the board from the box and unwrap the board, set it on a stable, non-conductive surface. For convenience, orient the board so that the side with the controls (SW1 and SW2) is closest to you.
2. Verify that the jumpers are configured for the default settings:
   - The jumpers on JP1 and JP3 are installed between terminals 1 and 2
   - The jumpers on JP4 and JP7 are installed
   - The jumpers for all other jumper locations are removed
3. Locate the power terminal strip J1, at the opposite side of the board from the microcontroller socket. Note that it has provisions for both single-phase AC (L, N and G) and DC (DC+ and DC-) inputs.
4. If an AC power supply is being used, connect the Line, Neutral and Ground lines to the corresponding L, N and G terminals. For DC, connect the positive and negative lines to the DC+ and DC- terminals.

WARNING

Connect either an AC supply OR a DC supply to the PICDEM MC Board – not both at once! Connecting both live AC and DC to the board at the same time may result in permanent damage to the board and/or severe personal injury.

5. Turn on the power. The Power LED (D10) should light. At the same time, the four monitor LEDs (LED1 through LED4) will flash.
6. Turn the potentiometer through its entire range and back. The blink rate of the monitor LEDs will increase as the potentiometer is turned clockwise, and decrease as it is turned counterclockwise. Finish by turning it fully counterclockwise.
7. Turn off the power. Wait for D10 to go out completely before proceeding.

2.3.2 Connecting the Motor

CAUTION

Always verify that the motor being connected matches the firmware to be used. NEVER use AC motor firmware to control a DC motor, or vice versa. Failure to observe these precautions may result in equipment damage or operator injury.

1. Set up the motor. Situate it closely enough to the development board so they can be connected to each other while leaving some slack on the connections. Make certain that the motor is mechanically secured, so that sudden speed and direction changes won't cause it to "walk away".
2. Check the leads coming out of the motor or the terminal block on the motor. For a BLDC, there should be four power leads from the motor: phase A, phase B, phase C and ground (G). They may or not be directly labelled as such; it may be necessary to check the manufacturer's data sheet for the motor to obtain this information.

Note: We are still assuming that this is a default installation. If you are not connecting a BLDC at this point, refer to the Configuration instructions in **Chapter 5. "Configuring the PICDEM™ MC Board Hardware"** for the proper motor configuration before proceeding.

3. Connect the leads or terminals on the motor to the terminals on the development board as follows:

TABLE 2-1: MOTOR-TO-BOARD CONNECTIONS (BRUSHLESS DC MOTORS)

Motor Leads or Terminals	PICDEM MC Board Terminals
A	R
B	Y
C	B
G	G

Note: To avoid electrical interference and erratic operation, be certain to route the motor and power leads as far apart as possible. Do not bundle the leads together.

4. Connect the sensor leads to the terminal block at J3, as shown in Table 2-2.

TABLE 2-2: SENSOR PIN CONFIGURATION FOR J3

Pin	Signal
1	+5 VDC
2	Digital GND
3	INDX/HA
4	QEA/HB
5	QEB/HC

> **Note 1:** As with the winding, the naming of sensor outputs may differ from manufacturer to manufacturer. Always consult the manufacturer's data sheet to verify the sensor output configuration.
>
> **2:** Always be sure to connect the sensors in the order that corresponds to the winding order (sensor A to HA, etc.). This is necessary for the motor to turn in the proper default direction.

5. Check that the potentiometer is turned all the way counter-clockwise before proceeding.

2.3.3 Verifying Operation

With everything properly connected and configured, it's time to verify that everything works.

1. Apply power to the board. As before, D10 should be lit.
2. Press SW1, and slowly turn the potentiometer clockwise. The motor should begin to rotate in its default forward direction.
3. Turn the potentiometer counterclockwise until the motor stops. Press SW2, and slowly turn the potentiometer clockwise. The motor should now rotate in the opposite direction.
4. Slowly turn the potentiometer clockwise. The blink rate of the monitor LEDs <3:1> should increase as before. At the same time, the motor's speed should increase. Turning the potentiometer counterclockwise should cause the LEDs to flash more slowly, while the motor slows down.

2.3.4 Interpreting the Monitor LEDs

The pattern of lighting/blinking of the monitor LEDs is used to indicate both motor operation and the status of the board. It also may change, depending on the motor being driven. A summary of possible patterns is provided in Table 2-3.

LEDs are numbered from top to bottom, bottom being closest to the edge of the board.

TABLE 2-3: MONITOR LEDS AND THEIR MEANING

Motor Type	LED1	LED2	LED3	LED4	Meaning
BLDC	On/Off (1)	On/Off (1)	On/Off (1)	Off	Normal run condition
ACIM	On	On	On	Off	Normal run condition
All motors	(2)	(2)	(2)	On	Motor running, forward
	(2)	(2)	(2)	Off	Motor running, reverse
	Steady Blink	Off	Off	Off	Overvoltage fault
	Off	Steady Blink	Off	Off	Overcurrent fault
	Off	Off	Steady Blink	Off	Overtemperature fault
	Off	Off	Off	Off	No power to board, power supply fault, or LEDs deactivated

Note 1: LEDs flash to indicate sensor events. At high speeds, the LEDs will appear to flicker. At very low speeds or when the rotor is turned manually, the LEDs will blink on and off.

2: State depends on type of motor. Refer to rows for BLDC or ACIM.

2.3.5 Fault States and Resets

The occurrence of any one of the fault conditions (overtemperature, overvoltage or overcurrent) will cause the motor to stop. Once the fault condition has been cleared, the motor can be restarted by pressing SW1 or SW2.

Pressing the Reset button (S2) re-initializes the motor control firmware by forcing a hardware reset of the microcontroller. It is not necessary to perform a reset following a fault condition.

2.4 SETTING UP THE PICDEM MC BOARD: PC MODE

While the Stand-alone mode is useful for simple testing, the PC mode allows more robust motor control. Configuring the PICDEM MC Board for PC mode requires very little additional effort beyond the set up for Stand-alone mode.

2.4.1 Host Computer Requirements

To use the PICDEM MC Board in PC mode, the computer being used must meet the following hardware and software requirements:

- PC-compatible system with an Intel Pentium® class or higher processor, or equivalent, with a minimum clock speed of 133 MHz
- A minimum of 16 MB RAM
- A minimum of 16 MB available hard drive space
- CD-ROM drive (for use with the accompanying CD)
- One available standard serial port, with a matching COM port available through the operating system
- Any 32-bit version of Microsoft Windows® (Windows 98, Windows NT®, Windows 2000 or Windows XP)

2.4.2 Installing the Motor Control GUI

The installation of the host software package is completely automated and does not require any user intervention or configuration once the process is started. The process is identical for all 32-bit Windows operating systems. Users with Windows NT-based desktops (NT 4.0, 2000 and XP) should not need administrative rights to their systems for this installation. Closing all background applications before proceeding is helpful, but not required.

> **Note:** It is possible that some organizations may implement a desktop computer policy sufficiently restrictive to prevent the user from loading any software at all. In theory, this can be done with **any** 32-bit Windows operating system on a network – including Windows 95. If this describes your situation, contact your local Information Services provider for assistance in installing this software.

To install the host software, insert the Software and Documentation CD into the CD-ROM drive. The CD will automatically launch an interface window that allows selection of support software for a range of Microchip development and evaluation boards. From "Development Boards", choose "Motor Control", then "PICDEM_MC", then "GUI".

Alternatively, you can open the CD in Explorer view, and locate the "PICDEM_MC" folder. The GUI setup program is inside the "GUI" folder, inside the "PICDEM_MC" folder.

Double-click on the "`setup.exe`" icon. You will be prompted to read and accept the software licensing agreement. Once you have done this, installation will proceed automatically, and takes 1-2 minutes.

The installation process will install the GUI, as well as any initialization files. By default, all files are installed in the directory `\Program Files\Microchip` under the root level of your hard drive. A short cut for the host software is also installed under Programs from the Start menu (*Programs > Microchip > Motor Control GUI*).

2.4.3 Connecting the PICDEM MC Board

After following the instructions in **Section 2.3 "Setting up the PICDEM MC Board: Stand-alone Mode"** and verifying operation, do the following:

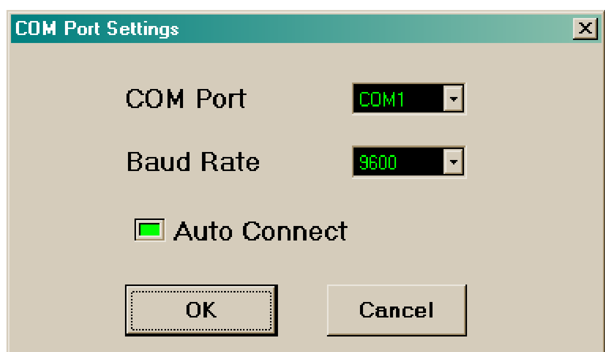
1. Power down the host system. (This isn't strictly necessary, but is always a good safety idea – particularly if it is necessary to re-arrange cables or move the system closer to the board.)
2. Power down the PICDEM MC Board.
3. Connect the serial cable (supplied with the board) to the RS-232 connector on the board, then to the open serial port on your computer.

> **Note:** If the available serial port is a DB25 male connector, you will need to use a DB25F-to-DB9M port adapter, sometimes known as an "external modem adapter". Check with a local electronic parts store or your Information Services provider for additional information.

4. Power up the host system and the PICDEM MC Board.
5. Check the board. The red power LED should light, and the monitor LEDs should all blink. If they don't, check all connections with the power supply and the board. For additional assistance, refer to **Chapter 6 "Troubleshooting"**.
6. Launch the Microchip Motor Control GUI. Click on **COM Setting** in the lower left corner of the window. The COM Port settings dialog (Figure 2-1) appears.

> **Note:** If the COM Port dialog box does not automatically launch, it may also be invoked by clicking on the status bar at the bottom of the Control Panel (see Figure 3-1 for its location).

FIGURE 2-1: COM PORT SETTINGS DIALOG



7. Change the COM port setting to the serial port connected to the PICDEM MC Board. If necessary, change the baud rate to match your requirements (the default rate for the Motor Control GUI is 9600). To enable automatic connection whenever the application is next launched, select "Auto Connect". Click **OK**.
8. Click **Connect** to establish communication with the board.
9. Once communication is established, the message "Connected to PIC18F4431 on COMx at 9600bps" will appear in the message window at the bottom of the control panel. ("x" represents the COM port actually selected; the actual baud rate depends on the setting used.) The connection indicator in the lower left corner of the window should change to solid green.

You are now ready to work with the Motor Control GUI.

NOTES:

Chapter 3. Using the Microchip Motor Control GUI

3.1 HIGHLIGHTS

The items discussed in this chapter are:

- Software Overview
- Starting the Program
- The Control Panel
- The Setup Window

3.2 SOFTWARE OVERVIEW

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

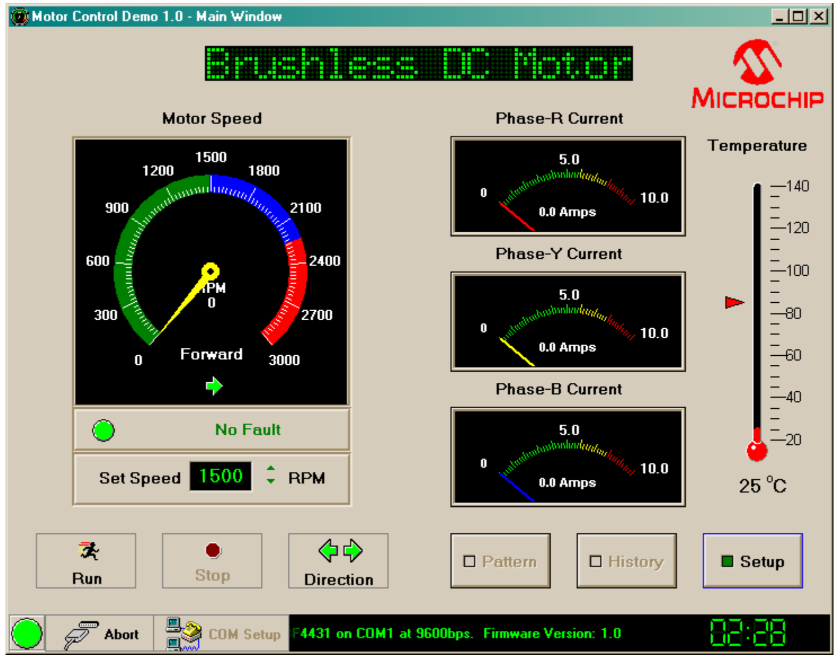
The Motor Control GUI has been designed to communicate with a range of current and planned Microchip motor control kits and applications. A feature of its design is to poll the on-board control firmware on initial communication and automatically configure its options accordingly. As such, some features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

3.3 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 3-1).

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

FIGURE 3-1: THE CONTROL PANEL VIEW



3.4 THE CONTROL PANEL WINDOW (MAIN WINDOW)

This is the main display for the application. From here, the user can control motor speed and rotation direction in a way that is similar to Stand-alone Mode. The Control Panel also allows users to access to the Setup and Pattern Programming displays.

The 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), this scrolling display indicates the type of motor and control firmware that has been programmed to the PICDEM MC board.
- **Speed/Direction Display:** This 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 with an arrow and text the direction of motor revolution relative to the default direction. Speed for all applications except induction motors in open-loop mode is shown in RPM; for induction motors, the display will reflect the input frequency in Hz.

  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 Display 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 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).

- **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 except induction motors running in open-loop mode; for those, the input is in Hz. Left-clicking on the control, or pressing the <Enter> or <Tab> keys after entering a speed, starts the motor running.
- **Phase Current Display:** This 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 3-1 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 board, the safe operating limit is 6.3A. 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.
- **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 or pressing <Enter> or <Tab> keys on the Speed Set 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 display (described in the following section).

  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 (Figure 2-1); 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 Select** becomes available for configuration.

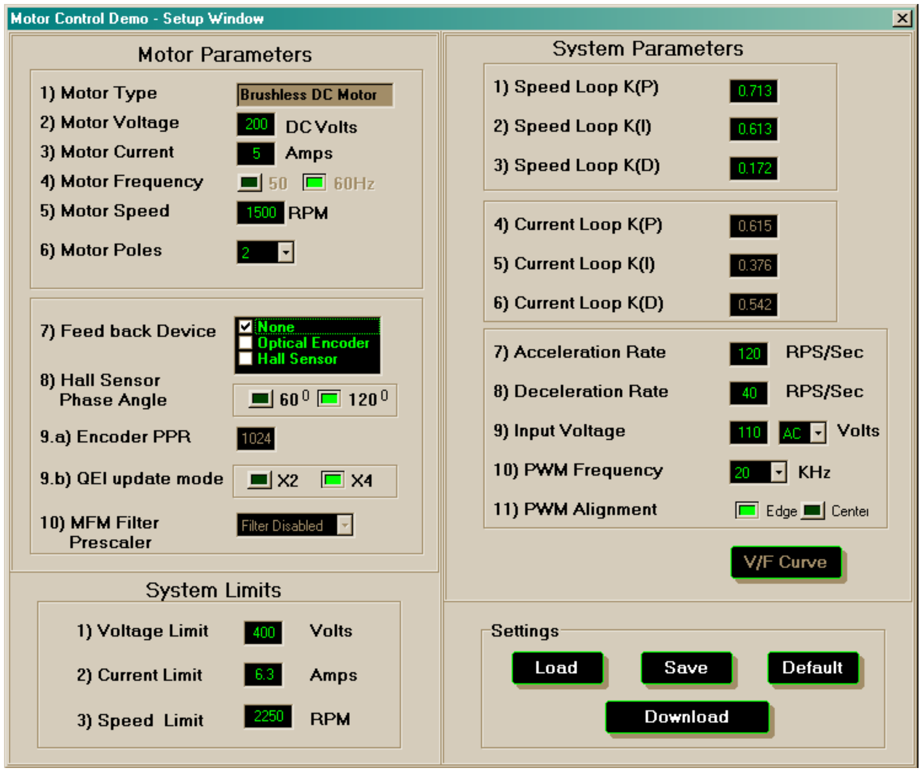
  The indicator at the extreme left shows the status of the serial link. When a link is established, the indicator is solid green. When a connection is being established, the indicator flashes green. Should the link fail, the indicator changes to solid red.

  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.

3.5 THE SETUP WINDOW

FIGURE 3-2: TYPICAL SETUP WINDOW



Clicking on the **Setup** button in the Control Panel launches a second window, the Setup window (Figure 3-2). 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 (control) parameters, 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.

3.5.1 Motor Parameters

These 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 Devices". When Hall effect sensors alone are used, the sensor angle and Motion Feedback Module (MFM) Filter Prescaler 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 may be configured; Hall effect configuration is unavailable. (The use of the QEI update and MFM filter options is discussed in detail in Section 16 of the PIC18FXX31 Data Sheet (DS39616).)

Note that the Hall effect and optical sensors are not mutually exclusive; it is possible for some control methods to use both types at once. In these cases, checking both boxes 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.

3.5.2 System Parameters

The system parameter 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.

3.5.3 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 voltage level (for DC input) or at 1.414 times the input voltage level (for AC).

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 board, this is 6.3A.

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.

3.5.4 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 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 used 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.

> **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.
>
> **2:** Remember that downloading a profile to the PICDEM MC 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.

Chapter 4. Creating Motor Control Firmware Projects

4.1 HIGHLIGHTS

The items discussed in this chapter are:

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

4.2 ABOUT THE INCLUDED APPLICATIONS

The PICDEM MC Development Board comes with two complete firmware solutions. One of them, installed in the board as shipped, is a BLDC control application. It assumes a 3-phase BLDC motor, using Hall effect sensors at a 60-degree spacing. The other application, loaded in the additional PIC18F4431 device, is an ACIM control application. It assumes a 3-phase AC induction motor running in open-loop mode; it uses a VF (constant voltage/frequency ratio) algorithm to regulate speed.

It is possible that neither of these pre-programmed applications fits your requirements. If this is the case, there are other motor control applications that may be useful provided with the Development Tools CD. The CD contains a range of additional motor control applications, including sensorless BLDC control (open-loop and closed-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.

4.3 BEYOND THE INCLUDED APPLICATIONS: CREATING NEW PROJECTS

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

The first step is to create your code in a development environment, such as Microchip's MPLAB IDE. You will need to 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, you can build the project and create the HEX file. Using a device programmer, such as PRO MATE II, you can then load your firmware into one of the supplied PIC18F4431 microcontrollers. Alternately, you can load your firmware directly into the microcontroller installed on the board through the ICD interface. To do this, you will need the MPLAB ICD 2 module.

After the application is loaded, configure the PICDEM MC Board for the motor to be used following the instructions in **Chapter 5. "Configuring the PICDEM™ MC Board Hardware"**. Finally, connect your board to the motor following the directions in **Section 2.3.1 "Connecting Power"** and **Section 2.3.2 "Connecting the Motor"**.

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 your program logic differs significantly from the firmware included with the board, you may not be able to use these modes as described. The "self-test" blinking of the monitor LEDs on power-up may also be disabled.

Chapter 5. Configuring the PICDEM™ MC Board Hardware

5.1 HIGHLIGHTS

This chapter covers the following:

- Jumper and Hardware Locations
- Connecting Different Motor Types
- Configuring the Development Board Options
- Configuring for Motion Feedback
- Current Monitoring Configurations
- Restoring the Original PICDEM MC Firmware

5.2 JUMPER AND HARDWARE LOCATIONS

The PICDEM MC Board can be operated in many different configurations, to accommodate a range of motor types and control applications. Most of these can be implemented without any changes to the board; some options, such as the current transducer measurement system, require the addition of some components. This is described later in this chapter.

Jumpers and other configurable locations are shown in Figure 5-1. A complete listing of their functions is provided in Table 5-1.

FIGURE 5-1: JUMPER AND HARDWARE LOCATIONS

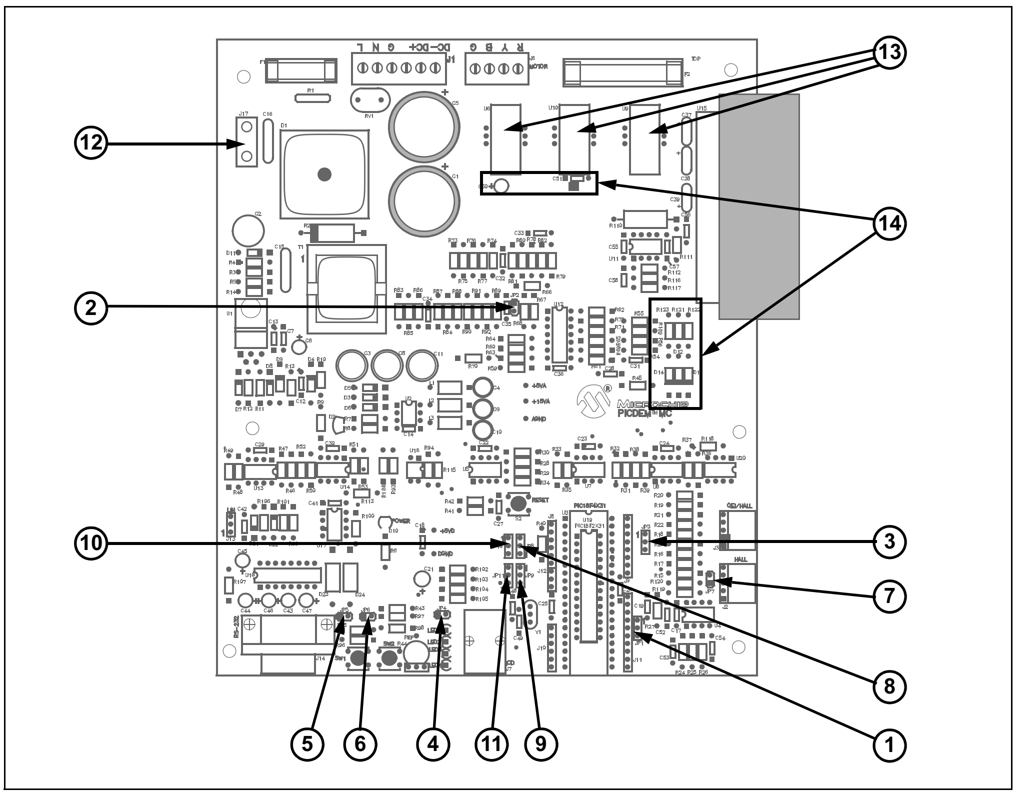


TABLE 5-1: JUMPER AND HARDWARE DESCRIPTIONS

Number	Board ID(s)	Type	Function (Default Setting)
1	JP1	Jumper	Selects PCPWM Fault A input pin (1-2 Bridged)
2	JP2	Jumper	Selects overvoltage limit (Open)
3	JP3	Jumper	Selects PWM4 configuration (1-2 Bridged)
4	JP4	Jumper	Enables monitor LEDs (Bridged)
5	JP5	Jumper	Selects serial port operation (28-pin devices) (Open)
6	JP6	Jumper	
7	JP7	Jumper	Selects current monitor source (Bridged)
8	JP8	Jumper	Enables sensor or back EMF input for motion control (Open) See Sections 5.5.1, 5.5.2 and 5.5.3 for more details.
9	JP9	Jumper	
10	JP10	Jumper	
11	JP11	Jumper	
12	J17	Terminal	Enables AC voltage doubler (Open)
13	U6, U9, U10	Pad	Locations for current transducers (Unpopulated)
14	C50, C51, D12, D13, D14, R121, R122, R123	Pad	Locations for current monitor hardware (Unpopulated)

5.3 CONNECTING DIFFERENT MOTOR TYPES

Everything up to this point has assumed the use of a brushless DC motor (BLDC). As mentioned previously, the PICDEM MC Board can also control many other motor types. To do so, it is necessary to install the proper control firmware and connect the motor correctly. The supported types of motors and their appropriate connections to the PICDEM MC Board are provided in Table 5-2.

TABLE 5-2: PICDEM MC AND MOTOR TERMINAL FOR VARIOUS MOTOR CONFIGURATIONS

Motor Type	3-phase BLDC				Single-phase ACIM				3-phase ACIM			
PICDEM MC Board terminals	R	Y	B	G	R	Y	B	G	R	Y	B	G
Motor terminals	A	B	C	G	L	N	—	G	R	Y	B	G

5.4 CONFIGURING THE DEVELOPMENT BOARD OPTIONS

The PICDEM MC Board can be configured in many ways to take advantage of a range of optional features. Several jumpers, located in various places around the board can be used to implement these features.

5.4.1 Disabling the Monitor LEDs

JP4 is a standard jumper. As shipped, JP4 is shorted and the monitor LED bank is enabled. To disable the LEDs, remove the jumper.

5.4.2 Enabling Serial Communications (28-pin Devices Only)

When a 28-pin PIC18F2X31 microcontroller is used with the PICDEM MC Board, jumper positions JP5 and JP6 determine what is connected to pins RC6 and RC7. As shipped, both jumpers are open, which allows the RS-232 serial port to operate normally.

To disable the serial port while using a 28-pin device, install jumpers on both positions. This disables the serial port, but enables the ON/OFF and direction switches (SW1 and SW2) on the board's hardware interface. The potentiometer and the hardware reset switch still work as before.

When a 40-pin microcontroller is used (as in the board's default configuration), JP5 and JP6 should always be removed.

5.4.3 Configuring I/O Assignments (40-pin Devices Only)

The Power Control PWM modules of PIC18F4X31 devices can be configured in many different ways. One unique feature is that the pin multiplexing for certain functions can be changed by the setting of configuration bits. This feature gives users extra flexibility in design.

Specifically, the assignments for the Fault A input and the channel 4 PCPWM output can be located on either of two pins. The default configuration for PIC18F4431 devices is to assign Fault A to pin RC1, with an alternate assignment of RD4. For PWM4, the default assignment is RB5, with an alternate of RD5. Assignments are determined by the PWM4MX and FLTAMX bits at the time of device programming, and cannot be changed unless the device is reprogrammed.

The PICDEM MC Board and the accompanying firmware is designed on the assumption that the default configuration for the PCPWM module will be used. In the course of creating new firmware, however, it may be necessary to use the alternate assignment for one or both functions. This can be accommodated by changing the settings of jumpers JP1 and JP3. Both of these are three-pin jumper locations.

JP1 controls the routing of the Fault A input. The default setting bridges pins 1 and 2, connecting Fault A signals to RC1. Bridging 2 and 3 connects Fault A signals to RD4. Removing the jumper disconnects Fault A entirely.

CAUTION

Fault A is driven by the external current comparator, and is used to trigger overcurrent fault conditions. Removing JP1 disables overcurrent protection, and may cause serious equipment damage.

JP3 controls the routing of the PWM4 output to its matching optoisolator. The default setting bridges pins 1 and 2 and connects RB5 to the isolator. Bridging 2 and 3 connects RD5 instead. Removing the jumper disconnects the PWM4 output entirely, and should only be used for drive configurations that require less than three of the power inverter's half bridges.

Note: When using the original firmware provided with the PICDEM MC Development Board, always leave JP1 and JP3 in their default positions (bridging 1-2). Failure to do this may result in erratic operation or equipment damage.

5.4.4 Configuring Overvoltage Limit

The PICDEM MC Board incorporates constant monitoring of the supply voltage bus to the 3-phase inverter. Over voltage conditions will cause a fault condition and interrupt PCPWM operation.

The over voltage threshold is determined by jumper J2. With the jumper removed (default state), the level is set to approximately 200V DC. When the jumper is installed, the over voltage level is set at approximately 400V DC.

5.4.5 Configuring Voltage Doubling

There may be instances where the rated voltage of the motor exceeds the supply voltage level to the development board. In these cases, users still have the ability to use the motor by enabling the voltage doubler option. This is done by installing a two-terminal block at J17 and connecting a wire jumper across it. When enabled, the DC bus voltage is 2.828 ($2*\sqrt{2}$) times the AC input voltage.

The voltage doubler option should only be used when the board's voltage supply is AC.

WARNING
Do not use the voltage doubler when the AC input to the development board exceeds 140 VRMS. Using the voltage doubler in these circumstances may result in permanent equipment damage and/or serious injury to the user.

5.5 CONFIGURING FOR MOTION FEEDBACK

The PICDEM MC Board can run motors in two broad configurations: *closed-loop* and *open-loop*. Generally, closed-loop implies the use of motion sensors with the motor. Some motors and applications require the use of motion-feedback sensors; an example is brushless DC motors, which require the use of sensors to monitor rotor position for commutation. Other types of motors run well in open-loop mode, perhaps requiring nothing more than a way to measure speed.

Configuration for motion-feedback control depends on the motor's operating configuration. In many cases, connecting the appropriate sensors is all that is required. For sensorless BLDC motors, configuration is determined by jumper settings. JP9 is used for configuration when a 28-pin device is installed.

5.5.1 Configuring for Sensor Operation

The PIC18F4431 microcontroller has on-chip hardware to handle standard quadrature encoder sensor inputs and Hall effect sensor inputs. On the PICDEM MC Board, inputs from these sensors, either internal to the motor or mounted on an external encoder, are connected to the terminal blocks at J3 (quadrature encoder) or J2 (Hall effect). The correct connections for various BLDC motor configurations is shown in Table 5-3.

JP8, 10 and 11 should all be left open. For 40-pin devices, no further configuration is required.

TABLE 5-3: SENSOR CONNECTIONS FOR BLDC MOTOR APPLICATIONS

Control Algorithm Type	Sensors Connected To	
	J2	J3
Open-loop, Hall effect sensors for commutation	Hall effect	—
Closed-loop, Hall effect sensors for speed/feedback	—	Hall effect
Closed-loop, both QEI and Hall effect for commutation	Hall effect	QEI
Sensorless BLDC operation	—	—

5.5.2 Configuring for Sensorless BLDC Operation (40-pin Devices)

The design of BLDC motors normally dictates electronic switching, in order to maintain the proper stator-to-rotor phase relationship. It is possible, however, to closely estimate the rotor's position by measuring the back EMF in the stator windings, then comparing it to a 3-phase neutral point. The PICDEM MC Board includes signal conditioning circuits to process the necessary back EMF information for motor control.

For 40-pin devices, the precise configuration is determined in part by jumper positions JP8, JP10 and JP11. These are all 3-pin jumper locations with three possible settings: bridging 1 and 2, bridging 2 and 3, or open.

To configure the board for sensorless BLDC operation, set jumpers JP8/10/11 to bridge either 1 and 2 or 2 and 3. Bridging 1 and 2 connects the conditioned signals to the interrupt-on-change pins; this allows for effective commutation and open-loop operation, but less precise speed control. Bridging 2 and 3 connects the signals to the on-chip quadrature encoder module; this allows the back EMF signal to simulate closed-loop operation and finer speed control.

Keep in mind that in all cases, jumper configuration is determined by the requirements of the motor control firmware and not the other way around.

5.5.3 Configuring Motion Control for 28-pin Devices

The PIC18F2331 and PIC18F2431 devices offer most of the features of their 40-pin relatives. Because of their smaller pinouts, the multiplexing of features differs slightly. This means that features that are separate on larger parts may share a common pin.

Jumper location JP9 is used in conjunction with the device firmware to determine the mode of operation. Bridging 1 and 2 connects the Index signal from a quadrature encoder to the controller, enabling closed-loop operation with a quadrature encoder. Bridging 2 and 3 connects the phase B current measurement, when 3-phase current transducer measurement is being used. For applications other than sensorless BLDC motors, jumpers JP8/10/11 should be left open.

For sensorless BLDC applications, the specific operating setup dictates two possibilities. If the application is using back EMF information to simulate motion-sensor input for speed control, jumpers JP8/10/11 should all bridge 2-3, while JP9 bridges 1-2. For applications using back EMF to control commutation, JP8/10/11 should bridge 1-2; the setting of JP9 is irrelevant.

As with 40-pin devices, remember that the installed firmware determines the jumper setting, and not the other way around.

5.6 CURRENT MONITORING CONFIGURATIONS

The PICDEM MC Board is designed to accommodate two different forms of drive current monitoring: on-board shunt resistor (default) and on-board current transducers (optional). The mode is selected by installing or removing the jumper at JP7. Selecting the current transducer mode involves other modifications to the board, as noted below.

5.6.1 Shunt Resistor Current Measurement

In the default option for motor current measurement, the output current from the 3-phase inverter is sampled across a low-value, high-wattage resistor (R110). The signal is amplified and compared to a current reference source using a comparator. If the motor current exceeds the reference, a fault signal is sent to the microcontroller. In addition, the signal is also sampled by the ADC; this allows users to define a different trigger condition than the fault signal generated by the comparator.

Shunt resistor measurement is enabled when JP7 is installed (the default setting).

5.6.2 Current Transducer Measurement

In this mode, each lead to the motor is routed through a separate Hall-effect current transducer mounted directly to the board. This option is designed for more direct measurement of current in 3-phase motors. The PICDEM MC Board has been specifically designed to use the LEM LTS 15 transducer, which produces an electrically-isolated output.

Like the shunt resistor mode, a sum signal representing the total motor current is externally compared to a reference value. In contrast to shunt measurement, separate signals for each phase are directly converted to digital values using the microcontroller's ADC. The values are then compared to a reference variable in the control firmware. Each phase is sampled on a separate channels, allowing users to control individual phase currents. Using the external comparator, it is also possible to generate a separate fault condition based on total motor current.

To enable the current transducer mode, the transducers and their associated components must be installed, and other components must be removed. These are not provided with the development board, and must be ordered separately from your parts supplier.

Configuration for the current transducers involves the following:

1. Remove resistors R124, R125 and R126.
2. Remove the short link across the location for D12.
3. Install the transducers in locations U6, U9 and U10.
4. Install the support components for the transducers in their designated locations:
   - D12, D13 and D14 (1N4448 silicon diodes, DO-41 package)
   - R121, R122 and R123 (1 KΩ, 1/4 W resistors)
   - C50 (33 μF, 35V electrolytic capacitor)
   - C51 (0.1 μF ceramic capacitor)
5. Remove the jumper at JP7.

5.7 RESTORING THE ORIGINAL PICDEM MC FIRMWARE

As shipped from the factory, the PIC18F4431 microcontroller installed on the PICDEM MC Board is pre-programmed with BLDC motor control firmware. This code also makes Stand-alone mode possible, and enables serial communication for the PC mode. Similarly, the second PIC18F4431 shipped with the development board is pre-programmed with ACIM control firmware, plus the same core to manage Stand-alone and PC modes.

As users develop their own motor control applications, it is possible that one or both of the controllers will be re-programmed with new firmware. Should it ever become necessary to restore the original firmware, the files have been included on the Microchip Development Tools CD. They are located in the "PICDEM_MC" folder, inside the "Code Examples" folder. Separate folders are provided for ACIM and BLDC applications.

To reprogram the microcontrollers directly with the original firmware, use these HEX files:

- `closed_bldc_hall.hex:` for brushless DC motors (on the installed PIC18F4431)
- `open_VF_3acim.hex:` for AC induction motors (on the optional PIC18F4431)

Users should follow the procedure appropriate for their device programmer and development environment.

5.7.1 Reprogramming via the ICD Connector

The RJ-11 plug at J7 allows users to directly reprogram the microcontroller installed on the PICDEM MC Board. The standard six-wire interface also permits those using the MPLAB ICD 2 development environment and interface hardware to use In-Circuit Debugging, and monitor the microcontrollers and debug code in the actual application. The isolation features of the board make it possible to use MPLAB ICD 2 safely with live applications in development, without fear of damage from high voltages to either the emulator module or the connected host computer.

Chapter 6. Troubleshooting

6.1 HIGHLIGHTS

This chapter discusses the following:

- Common Problems

6.2 COMMON PROBLEMS

1. The Power LED (D10) is not lit

Check the PICDEM MC Board for power:

- For AC input, verify that the wall outlet or power source is working.
- For DC input, verify that the power source is working. Also verify that the polarity is correctly connected from the source to the board.
- Check the fuses (F1 for AC supply, F2 for DC supply) to verify that they have not blown.
- Check that regulated voltage (5V DC on the isolated side, 5V and 15V AC on the non-isolated side) is available at the designated test points.

2. The Motor Control GUI cannot communicate with the board

Check that the board is receiving power (see issue 1, above).

Check the serial cable for proper connections to the board and the computer. Verify that the cable is connected to the correct serial port on the computer. If necessary, verify 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.

Verify that you are using the correct serial port. Check that the COM port selected in the terminal software is actually the physical port that the serial cable is connected to. Verify the baud rate; try choosing a lower rate.

Verify that 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.

3. The motor does not starting turning when SW1 is pressed

Verify that the power supply and motor are connected, and that they are connected correctly. In particular, check that fuse F2 has not blown.

Verify that the motor control firmware matches the type of motor connected to the board.

If using a custom application with the Motor Control GUI, verify that the motor type displayed in the control panel matches the type of motor connected. (It is possible that the application was built using the wrong example firmware). Also verify that the other settings are correct for the motor type.

If the motor uses Hall sensors, verify that they are correctly connected. This is particularly true with BLDC motors, where sensor input is a requirement for proper motor commutation.

In PC mode, check that a speed greater than 0 is entered in the "Enter Speed" text box. Also check that the other motor and system parameters are the correct ones for the motor being used.

In Stand-alone mode, verify that the potentiometer is set somewhere other than fully counterclockwise.

4. The motor trips a fault condition at some point during acceleration.

Try using a slower acceleration rate.

If the motor still causes a fault during acceleration, it may be that the motor type is not supported by the firmware or the PICDEM MC Board itself. Verify the motor type against the firmware used. Also compare the motor's faceplate ratings against the electrical specification of the board, as provided in **Section A.4 "PICDEM MC Development Board Electrical Specifications"**.

Appendix A. PICDEM™ MC Board Technical Information

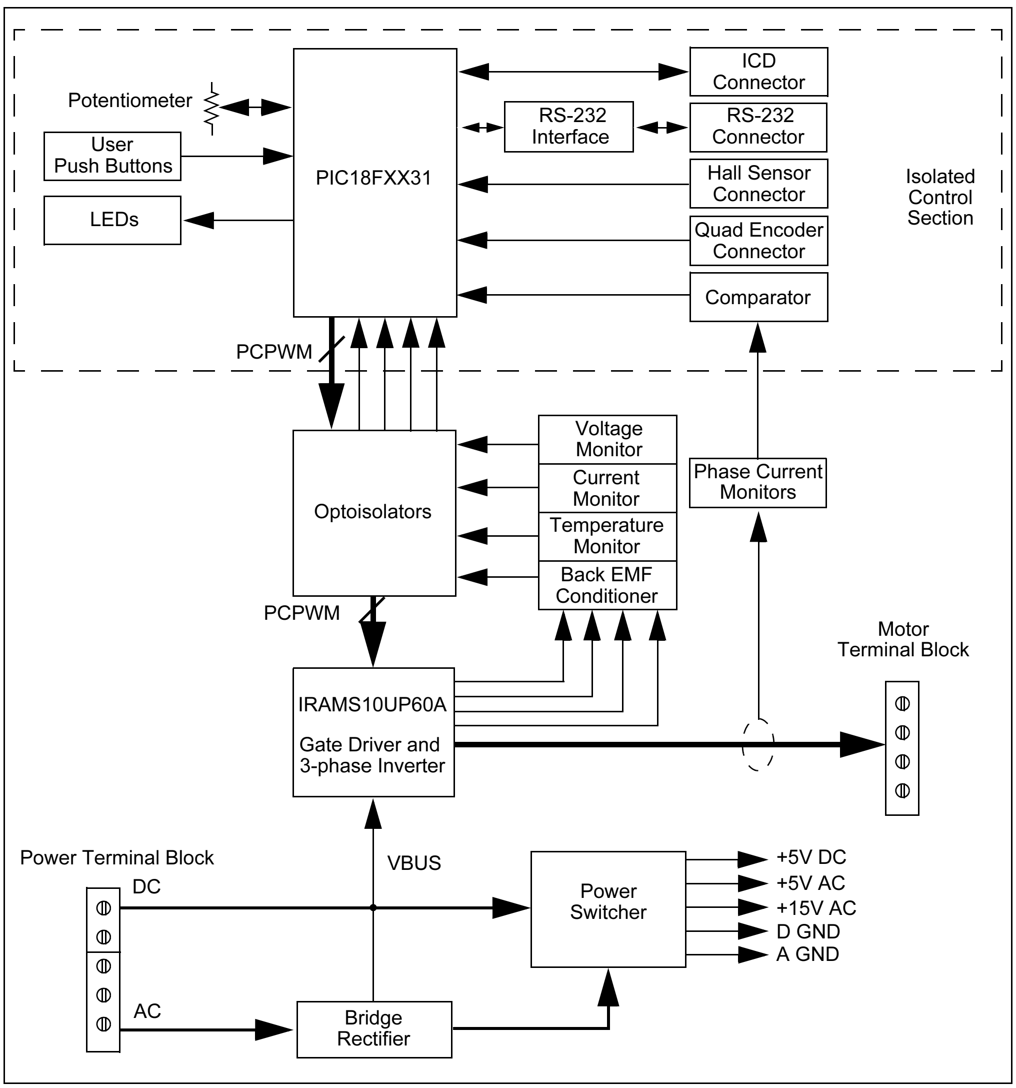
A.1 HIGHLIGHTS

This chapter will cover the following topics:

- PICDEM MC Block Diagram
- PICDEM MC Development Board Schematics
- PICDEM MC Development Board Electrical Specifications
- Recommended Motors for Use with the PICDEM MC Board

A.2 PICDEM MC BLOCK DIAGRAM

FIGURE A-1: PICDEM MC DEVELOPMENT BOARD FUNCTIONAL BLOCK DIAGRAM



A.3 PICDEM MC DEVELOPMENT BOARD SCHEMATICS

FIGURE A-2: BOARD SCHEMATIC, PART 1 (PIC18F4X31 MICROCONTROLLER, PCPWM ISOLATORS, CURRENT COMPARATOR AND ASSOCIATED PARTS)

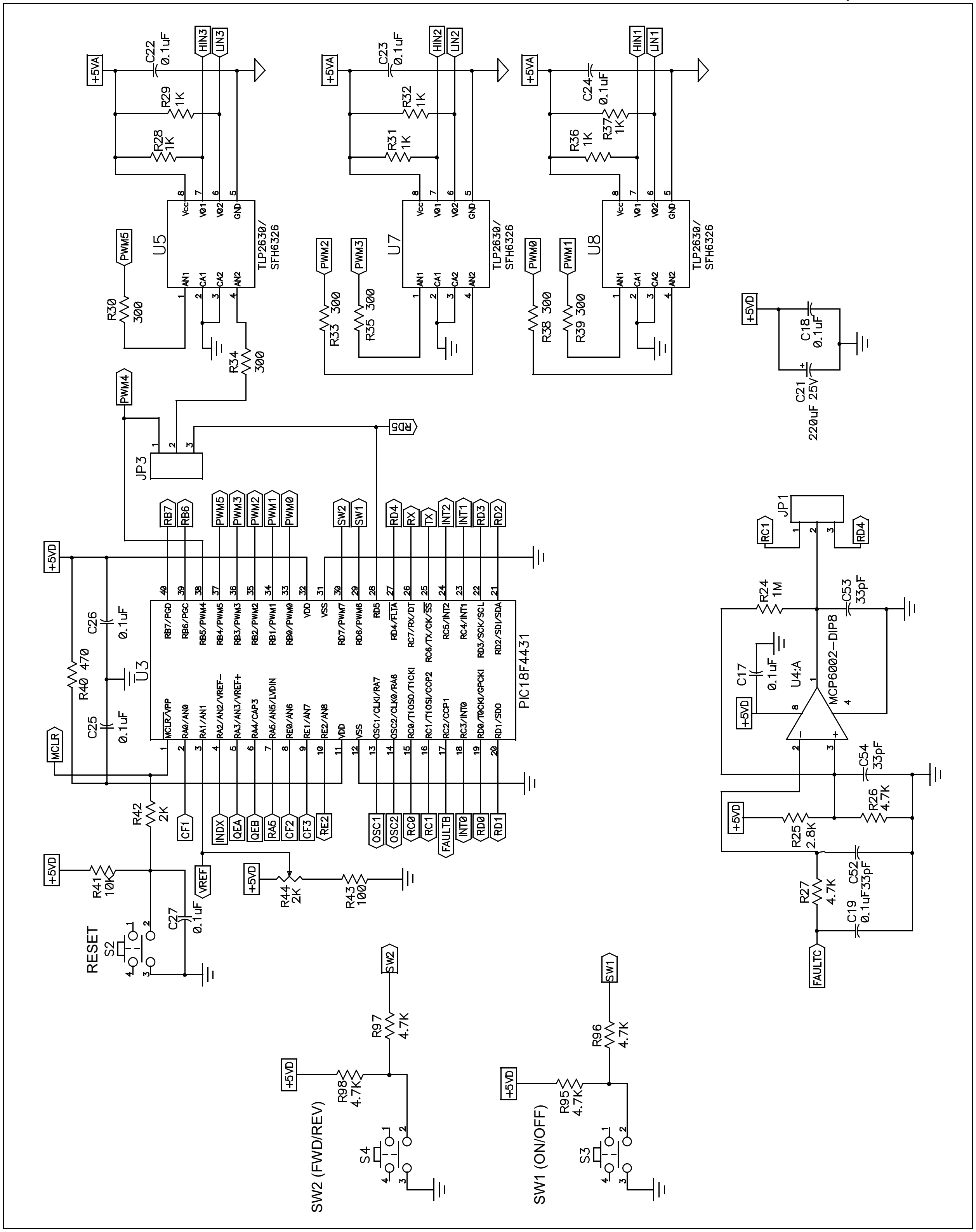


FIGURE A-3: BOARD SCHEMATIC, PART 2 (PIC18F2X31 MICROCONTROLLER SOCKET, USART, CLOCK OSCILLATOR NETWORK AND OPTIONAL LIN INTERFACE)

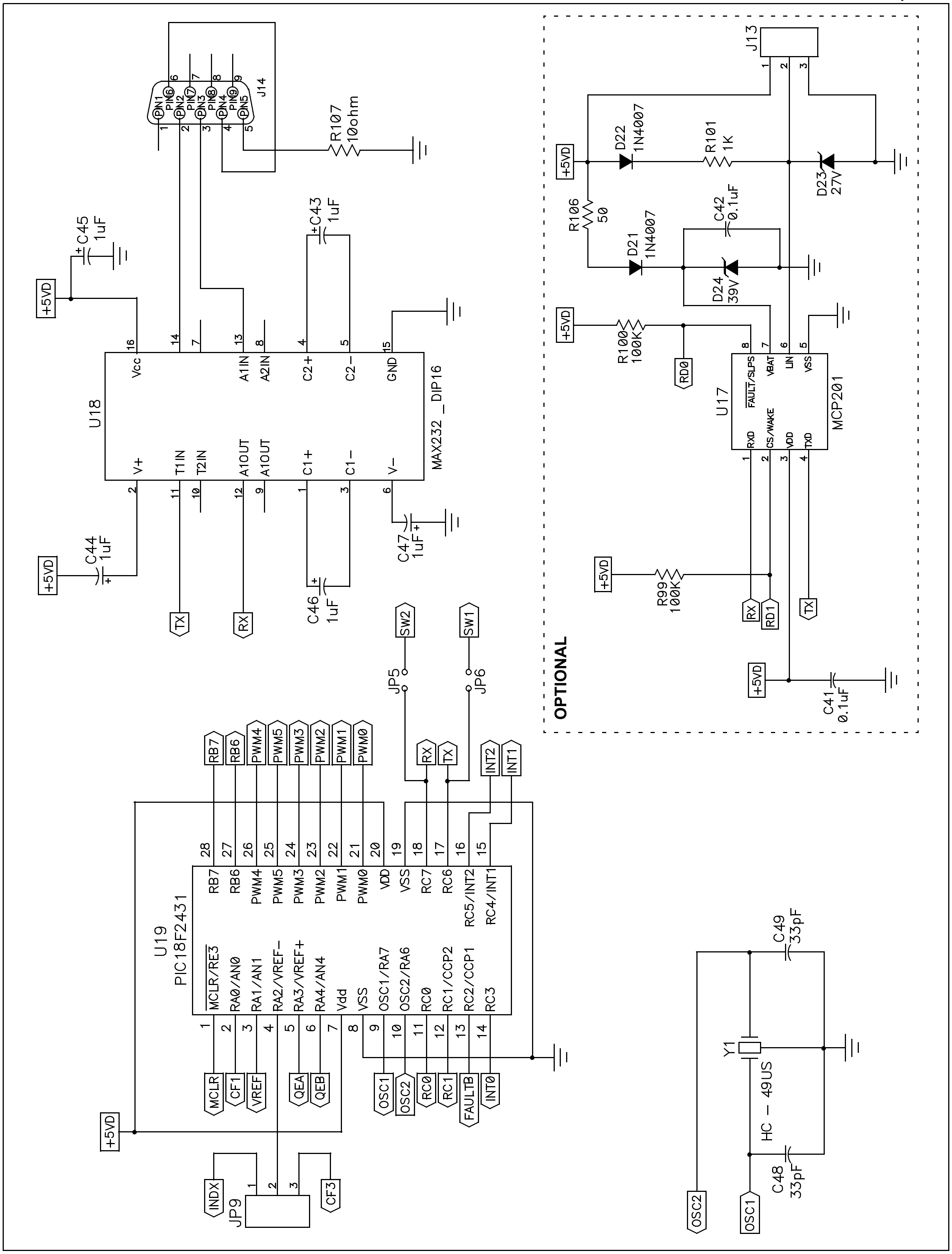


FIGURE A-4: BOARD SCHEMATIC, PART 3 (SENSOR AND MICROCONTROLLER HEADER CONNECTORS, MONITOR LEDS)

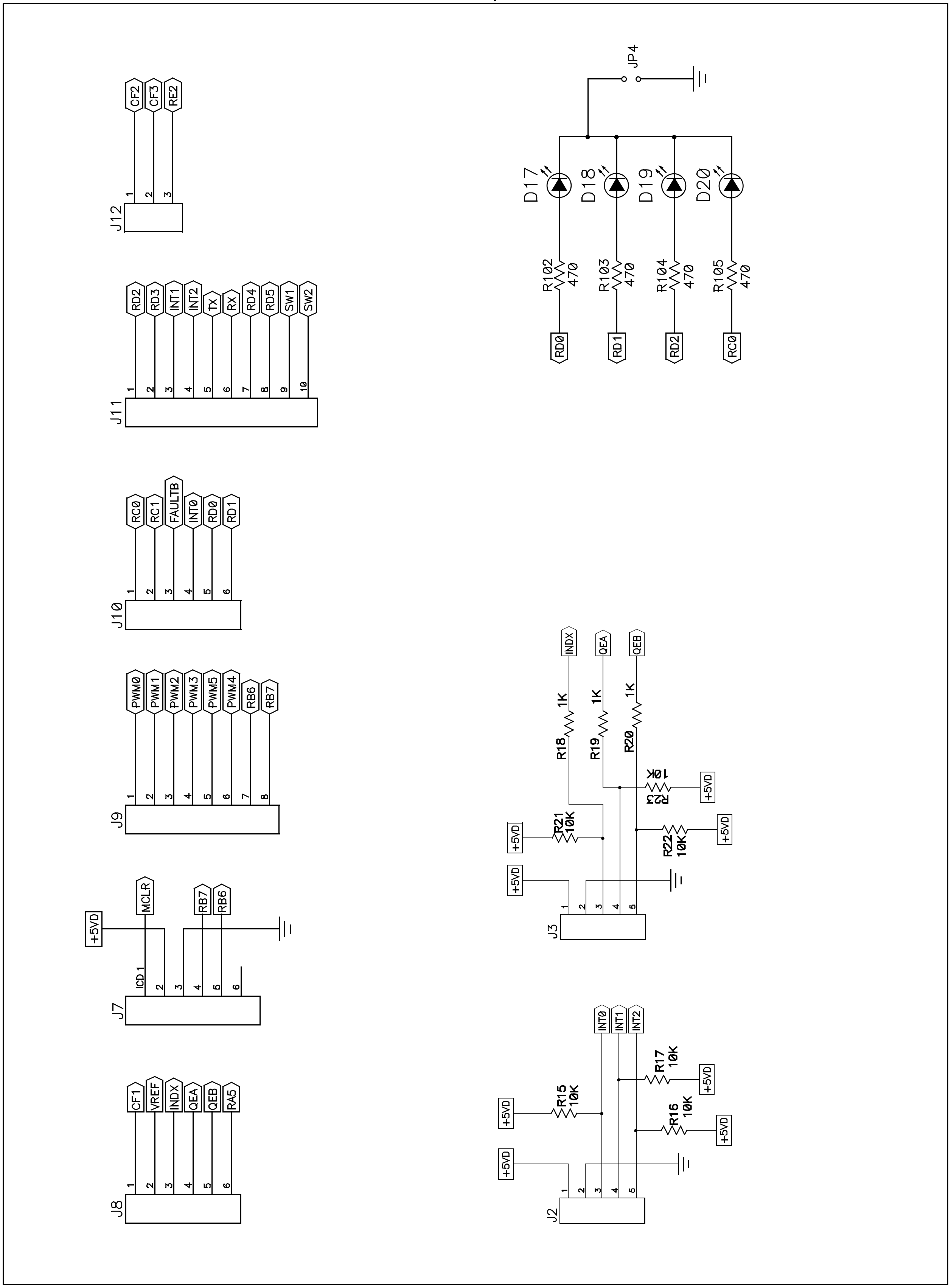


FIGURE A-5: BOARD SCHEMATIC, PART 4 (SIGNAL CONDITIONER FOR SENSORLESS BLDC OPERATION)

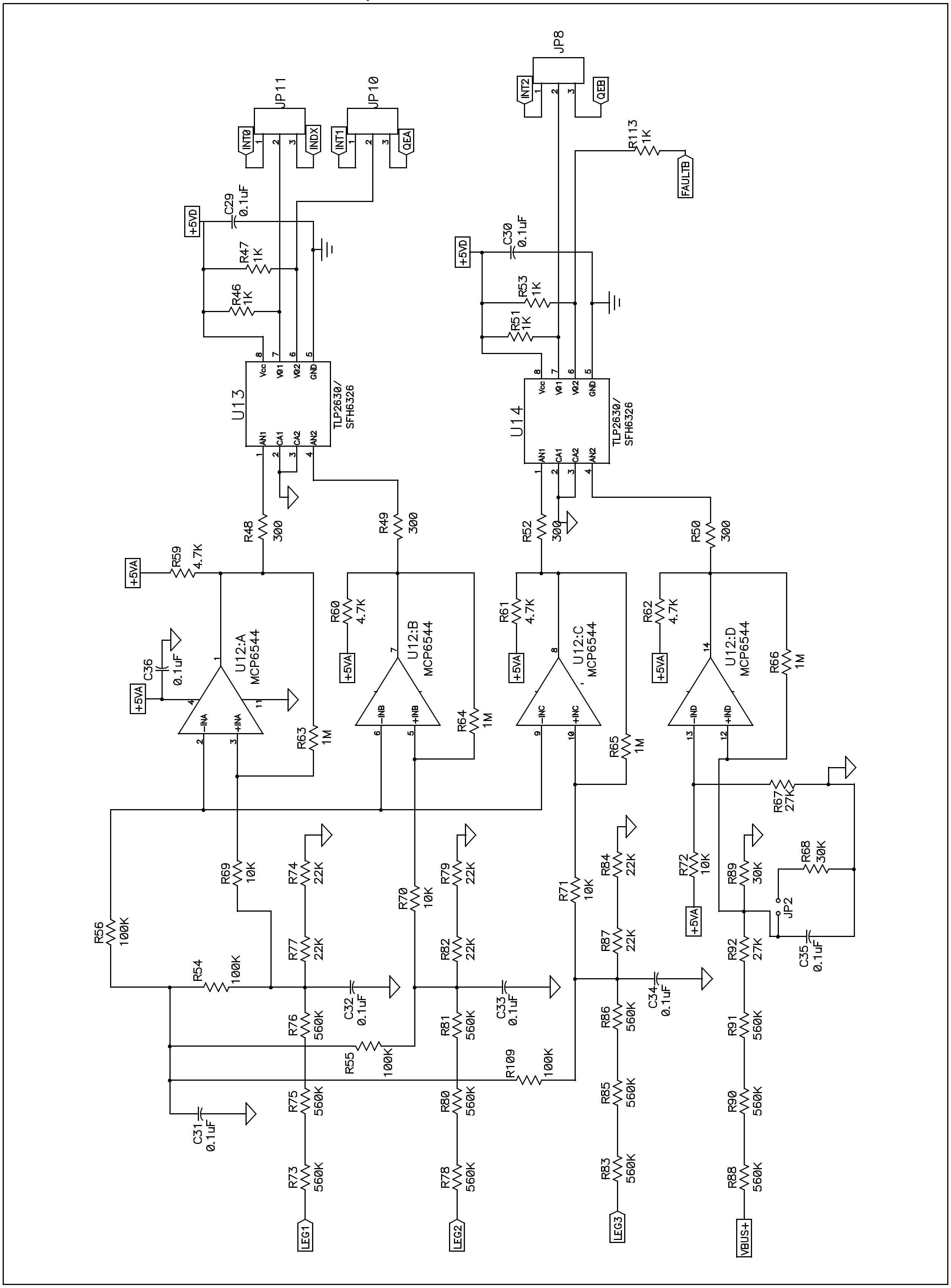


FIGURE A-6: BOARD SCHEMATIC, PART 5 (3-PHASE INVERTER POWER MODULE AND SHUNT CURRENT MEASUREMENT)

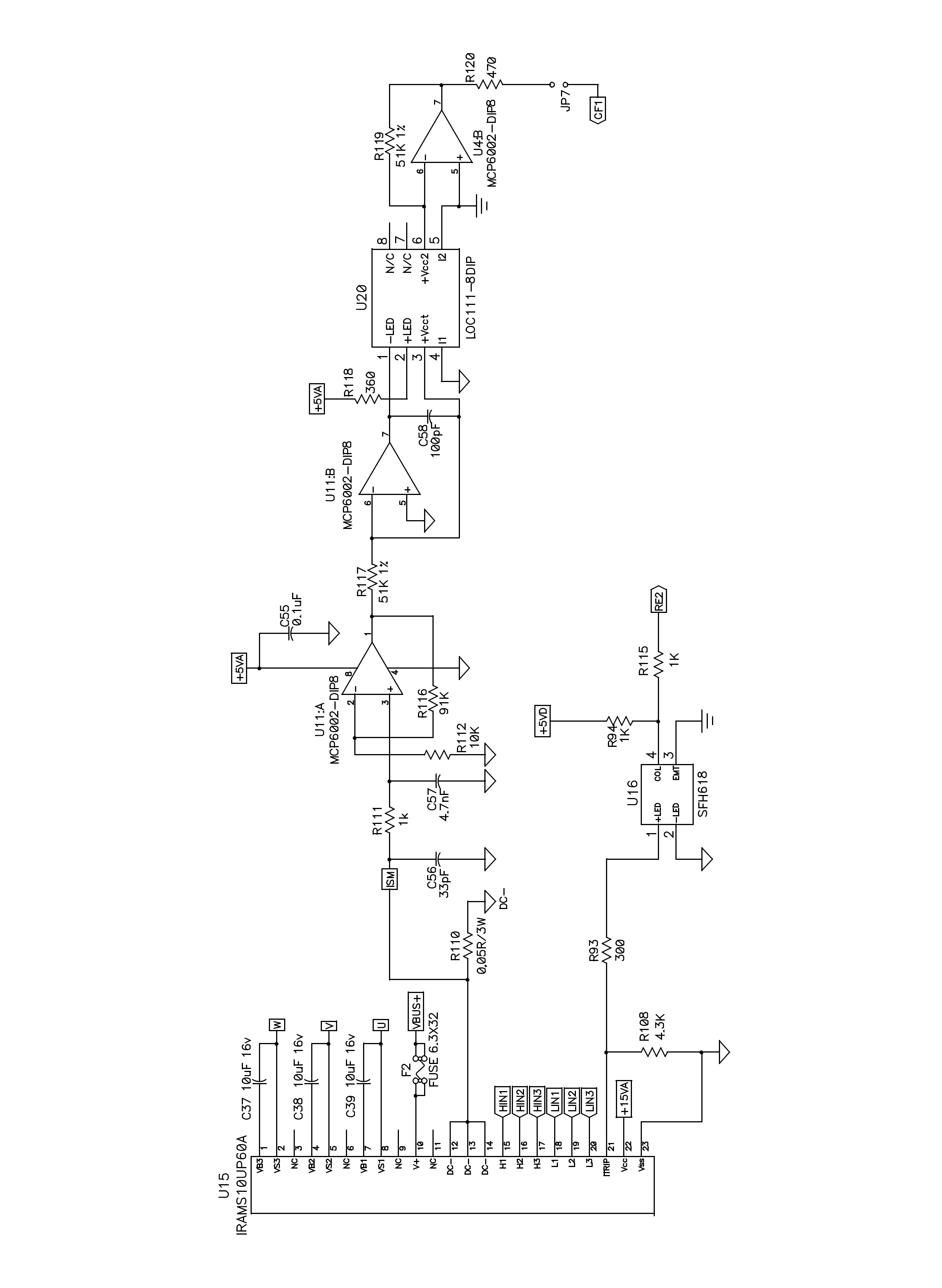


FIGURE A-7: BOARD SCHEMATIC, PART 6 (MOTOR TERMINAL BLOCK AND OPTIONAL CURRENT TRANSDUCER CIRCUITRY)

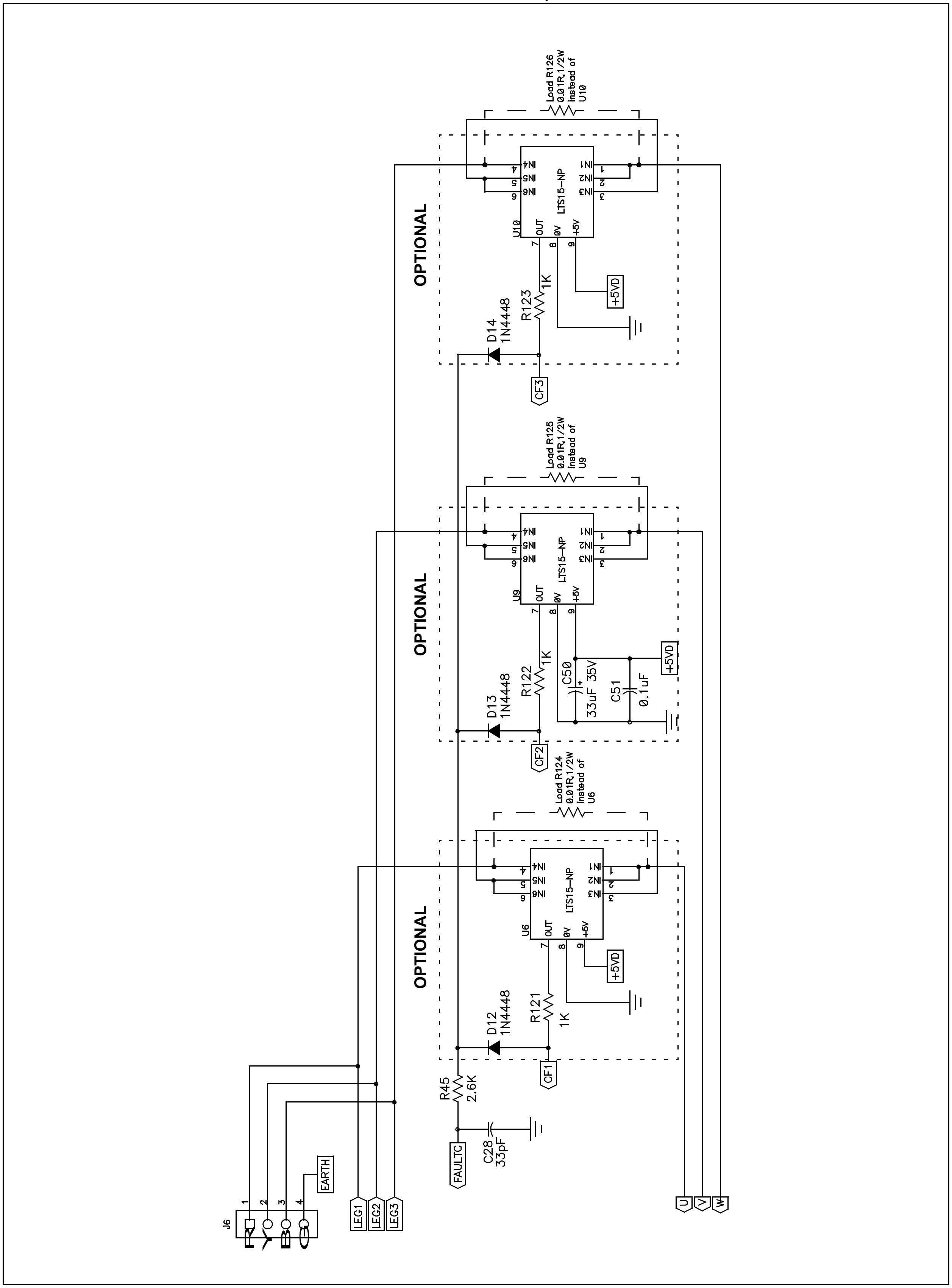


FIGURE A-8: BOARD SCHEMATIC, PART 7 (POWER SUPPLY)

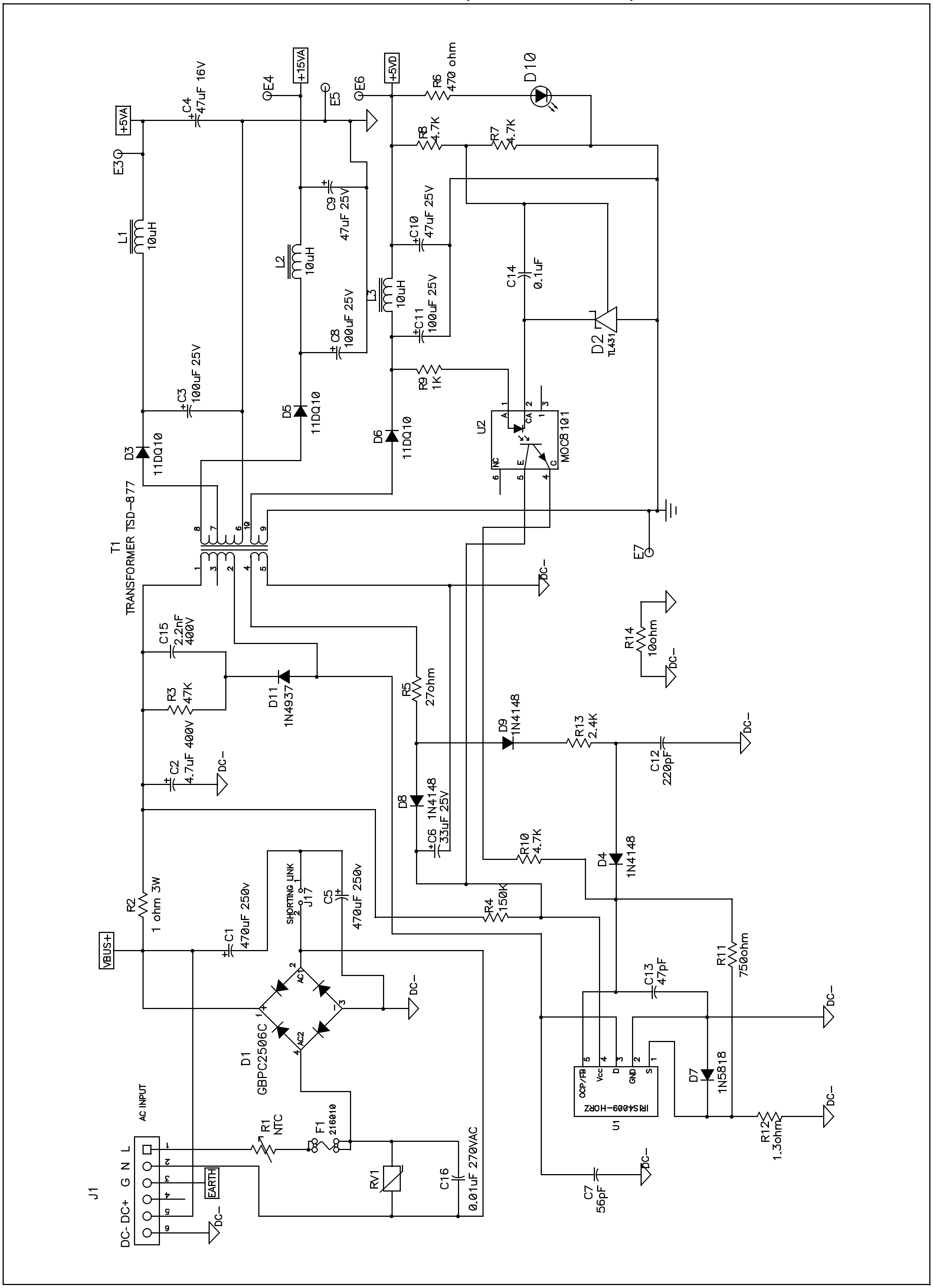


TABLE A-1: SIGNALS USED IN THE PICDEM MC SCHEMATIC

Signal Name	Function
+15VA	Non-isolated DC supply voltage for power components.
+5VD	Isolated supply voltage for digital components.
CF1, CF2 or CF3	Current feedback signal from designated motor phase winding. CF can also represent total motor current when current transducer measurement is used.
DC-	DC bus return path.
FAULTB	PCPWM fault signal input (over voltage).
FAULTC	Fault signal input from comparator (overcurrent).
HIN1, HIN2 or HIN3	Upper leg input for designated phase to 3-phase inverter (isolated signal).
INDX	Index position signal to QEI inputs on microcontroller.
INT0, INT1 or INT2	Hall effect sensor signal to interrupt-on-change inputs on microcontroller.
LEG1, LEG2 or LEG3	Current transducer signal for designated motor winding phase.
LIN1, LIN2 or LIN3	Lower leg input for designated phase to 3-phase inverter (isolated signal).
$\overline{\text{MCLR}}$	Microcontroller hardware reset.
PWM0 through PWM5	PCPWM waveform outputs from microcontroller.
QEA, QEB	Quadrature encoder sensor signals to QEI inputs on microcontroller.
RAn, RBn, RCn, RDn or REn	Bit n of the designated port of the microcontroller.
RX and TX	RS-232 serial receive and transmit.
SW1, SW2	Push button input from designated switch to microcontroller.
U, V, W	Drive-level output from inverter power module to motor.
V_{BUS}+	DC high voltage to inverter power module.
V_{REF}	External reference voltage for overcurrent detect.

TABLE A-2: MOTION-CONTROL SENSOR PIN CONFIGURATION

Hall Effect Input (J2)		Quadrature/Hall Effect Input (J3)	
Pin	Signal	Pin	Signal
1	+5 VDC	1	+5 VDC
2	Digital GND	2	Digital GND
3	HA	3	INDX/HA
4	HB	4	QEA/HB
5	HC	5	QEB/HC

A.4 PICDEM MC DEVELOPMENT BOARD ELECTRICAL SPECIFICATIONS

TABLE A-3: PICDEM MC BOARD INPUT VOLTAGE RATINGS

Parameter	Specification				Note
	Min	Typ	Max	Unit	
Supply Voltage: AC	85	—	270	VRMS	Single-phase
Supply Frequency	—	50–60	—	Hz	
Supply Voltage: DC	100	—	350	V	
Standby Current	—	42	—	mA	115 VAC supply
Standby Power	—	5.0	7.0	W	115 VAC supply

TABLE A-4: PICDEM MC BOARD INPUT PROTECTION RATINGS

Parameter	Specification				Note
	Min	Typ	Max	Unit	
Fuse F1					
Breakdown Voltage	—	250		VRMS	
Current	—	6.3	—	A	
Fuse F2					
Breakdown Voltage	—	400	—	VDC	
Current	—	6.3	—	A	
Varistor MOV1					BC Component part no. 2322-594-2716. See data sheet for details.
Continuous Voltage	—	—	275	VRMS	
	—	—	350	VDC	
NTC R1					Ametherm part no. SL22-2R018. See data sheet for details.
Resistance (25°C)	—	2	—	Ω	
Steady-state current	—	—	18	A	

TABLE A-5: POWER SUPPLY RATINGS

Parameter	Specification				Note
	Min	Typ	Max	Unit	
Breakdown Voltage	650	—	—	VDC	For IRIS4009 integrated switcher. See data sheet for details.
Isolated Power Supply (+5VD)					
Output Voltage	—	5	—	VDC	
Current	—	1	—	A	
Non-isolated Power Supply (+5VA)					
Output Voltage	—	5	—	VDC	
Current	—	0.6	—	A	
Non-isolated Power Supply (+15VA)					
Output Voltage	—	15	—	VDC	
Current	—	0.6	—	A	

TABLE A-6: INVERTER POWER MODULE RATINGS

<table>
<tr><th rowspan="2" colspan="2">Parameter</th><th colspan="4">Specification</th><th rowspan="2">Note</th></tr>
<tr><th>Min</th><th>Typ</th><th>Max</th><th>Unit</th></tr>
<tr><td colspan="2">Breakdown Voltage</td><td>650</td><td>—</td><td>—</td><td>VDC</td><td rowspan="3">IR part no. IRAMS10UP60A. See data sheet for details.</td></tr>
<tr><td rowspan="2">RMS Phase Current</td><td>25°C</td><td>—</td><td>—</td><td>10</td><td>A</td></tr>
<tr><td>100°C</td><td>—</td><td>—</td><td>5</td><td>A</td></tr>
</table>

TABLE A-7: PICDEM MC BOARD DEFAULT PROTECTION SETTING

Parameter	Value	Unit	Note
Overvoltage Limit	200	VDC	
Overcurrent Limit	6.3	A	
Overtemperature Limit	110	°C	Reflects IGBT junction temperature

A.5 RECOMMENDED MOTORS FOR USE WITH THE PICDEM MC BOARD

While the PICDEM MC Development Board can be used with any of the previously described motor types (subject to the board's power-handling capabilities, of course), there are several specific motors that have proved particularly useful in the development of the PICDEM MC Board. These may serve as a starting point for developing your own motor-driven applications.

For 3-phase AC induction motors:

- Leeson model C4T34FB2C
  (Catalog # 100905.00)
  208/230 VAC, 1.8A
  Power rating: 1/2 HP
  For more information: **www.leeson.com**
- Dayton model 2N103R
  208/220 VAC, 1.0A
  Power rating: 1/2 HP
  For more information: **www.grainger.com**

For brushless DC motors:

- Bodine Electric model 22B4BEBL
  130 VDC
  Power rating: 1/8 HP
- Bodine Electric model 34B4BEBL
  24 VDC
  Power rating: 1/4 HP
  For more information on these motors: **www.bodine-electric.com**

NOTES:

Appendix B. PICDEM™ MC Software on the CD

B.1 HIGHLIGHTS

This chapter summarizes the firmware and software for the PICDEM MC Development Board on the Microchip Software and Documentation CD.

B.2 WHAT'S ON THE CD

The Software and Documentation CD contains the most current software and firmware for all of Microchip's demonstration and evaluation kits. The files for the PICDEM MC Board are located in the folder "PICDEM_MC".

Included with the files for the development board are:

Microchip Motor Control GUI

The entire utility is contained in the self-extracting installer file `setup.exe`. Executing this file will install the motor control application described in Chapter 3.

PICDEM MC Firmware

The firmware for the PICDEM MC Development Board is located in the Firmware folder. The device-specific files are located in the subfolders for the specific type of motor application. In addition to the Hex files for device programming, assembly language source files are provided for creating custom projects.

All necessary project, header and linker files are also included, so that users with MPLAB IDE may begin to create custom projects immediately.

Note:	The MPLAB Integrated Development Environment software is not included with the PICDEM MC Development Board. Users who do not have MPLAB IDE may download it without charge from the Microchip web site (www.microchip.com).

PICDEM™ MC User's Guide

This single file is the electronic version of this development board manual, provided in Adobe® Acrobat® format.

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