

F1 LV Evaluation Platform Motor Control Add-Ons User's Guide

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Preface

NOTICE TO CUSTOMERS

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

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

For the most up-to-date information on development tools, see the MPLAB® IDE online help. Select the Help menu, and then Topics to open a list of available online help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using the F1 LV Evaluation Platform Motor Control Add-ons User's Guide. Items discussed in this chapter include:

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

DOCUMENT LAYOUT

This document describes how to use the F1 LV Evaluation Platform Motor Control Add-ons User's Guide as a development tool to emulate and debug firmware on a target board. The manual layout is as follows:

- **Chapter 1. "F1 LV Evaluation Platform Overview"**
- **Chapter 2. "The BLDC Add-on Board"**
- **Chapter 3. "The Brushed DC Add-on Board"**
- **Chapter 4. "The Bipolar Stepper Add-on Board"**
- **Chapter 5. "The Unipolar Stepper Add-on Board"**
- **Appendix A. "Board Layout and Schematics"**
- **Appendix B. "Conversion Factors"**

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

Description	Represents	Examples
Arial font:		
Italic characters	Referenced books	*MPLAB® IDE User's Guide*
	Emphasized text	...is the *only* compiler...
Initial caps	A window	the Output window
	A dialog	the Settings dialog
	A menu selection	select Enable Programmer
Quotes	A field name in a window or dialog	"Save project before build"
Underlined, italic text with right angle bracket	A menu path	*File>Save*
Bold characters	A dialog button	Click **OK**
	A tab	Click the **Power** tab
N'Rnnnn	A number in verilog format, where N is the total number of digits, R is the radix and n is a digit.	4'b0010, 2'hF1
Text in angle brackets < >	A key on the keyboard	Press <Enter>, <F1>
Courier New font:		
Plain Courier New	Sample source code	`#define START`
	Filenames	`autoexec.bat`
	File paths	`c:\mcc18\h`
	Keywords	`_asm, _endasm, static`
	Command-line options	`-Opa+, -Opa-`
	Bit values	`0, 1`
	Constants	`0xFF, 'A'`
Italic Courier New	A variable argument	*`file`*`.o`, where *`file`* can be any valid filename
Square brackets [ ]	Optional arguments	`mcc18 [options]` *`file`* `[options]`
Curly brackets and pipe character: { | }	Choice of mutually exclusive arguments; an OR selection	`errorlevel {0|1}`
Ellipses...	Replaces repeated text	`var_name [, var_name...]`
	Represents code supplied by user	`void main (void) { ... }`

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WARRANTY REGISTRATION

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

RECOMMENDED READING

This user's guide describes how to use the F1 LV Evaluation Platform Motor Control Add-ons User's Guide. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

Readme for F1 LV Evaluation Platform Motor Control Add-ons User's Guide

For the latest information on using F1 LV Evaluation Platform Motor Control Add-ons User's Guide, read the "`Readme for F1 LV Evaluation Platform Motor Control Add-ons User's Guide.txt`" file (an ASCII text file) in the Readmes 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 Readmes subdirectory of the MPLAB IDE installation directory. The Readme files contain update information and known issues that may not be included in this user's guide.

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- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
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- **Compilers** – The latest information on Microchip C compilers and other language tools. These include the HI-TECH C® C16, 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.
- **In-Circuit Debuggers** – The latest information on the Microchip in-circuit debugger, MPLAB ICD 2, MPLAB ICD 3, PICkit™ 3.
- **MPLAB® IDE** – The latest information on Microchip MPLAB IDE, the Windows® Integrated Development Environment for development systems tools. This list is focused on the MPLAB IDE, MPLAB SIM simulator, MPLAB IDE Project Manager and general editing and debugging features.
- **Programmers** – The latest information on Microchip programmers. These include the MPLAB PM3 device programmers and PICkit™ 3 development programmers.

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- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

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Technical support is available through the web site at: http://support.microchip.com

DOCUMENT REVISION HISTORY

Revision A (March 2012)

- Initial Release of this Document.

NOTES:

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Chapter 1. F1 LV Evaluation Platform Overview

1.1 INTRODUCTION

This user's guide offers a quick start-up and eventual troubleshooting for the motor control add-ons used together with the F1 LV Evaluation Platform. For more details regarding the supported applications, control algorithms, hardware and software support, please visit the reference sections inside this user's guide.

1.2 HARDWARE OVERVIEW

1.2.1 Evaluation Platforms

The F1 Evaluation and F1 LV Evaluation Boards are stand-alone evaluation platforms for investigating the capabilities of the PIC16(L)F1XXX family of devices. F1 is an abbreviation for all PIC® microcontroller devices with the notation "F1" in the device number. All F1 devices are enhanced mid-range devices. Only enhanced mid-range devices have the F1 notation.

There are two development boards for evaluating the F1 devices:

- F1 Evaluation Platform with 44-pin PIC16LF1937 microcontroller
- F1 LV Evaluation Platform with 64-pin PIC16LF1947 microcontroller

This document refers primarily to the F1 LV Evaluation Platform.

The F1 LV Evaluation Platform is the second generation evaluation platform for the enhanced mid-range devices with more I/O pins and expanded capability. For more information about the F1 LV Evaluation Platform refer to DS41614, *"F1 LV Evaluation Platform for Enhanced PIC® Microcontrollers User's Guide*".

1.2.2 Add-on Boards

Four motor control add-on boards are available for use in conjunction with the F1 LV Evaluation Platform. This document describes those boards and the companion control software for evaluating and optimizing motor control. The four motor control boards include:

TABLE 1-1:

Motor Type	ID Shown on Platform LCD	Part Number	F1 LV Eval	F1 Eval
Brushless DC	bldc	DM164130-2	Yes	Yes
Brushed DC	bdc	DM164130-6	Yes	No
Bipolar Stepper	bstp	DM164130-7	Yes	No
Unipolar Stepper	ustp	DM164130-8	Yes	No

The software and hardware interface of the F1 Evaluation Board supports only the BLDC Add-on Board. The software supplied and preloaded on the F1 LV Evaluation Platform supports all four of the add-on boards.

1.2.3 USB Interface

The F1 LV Evaluation Platform includes a USB to serial interface. This provides the capability to control the motors in real time without entering Debug mode. PC control software communicates with the F1 LV Evaluation Platform software to create an integrated motor control evaluation system. The PC software and interface driver are available for free download from the Microchip web site at www.microchip.com/F1Eval.

1.2.4 Add-on Board Power

When using an add-on board, the F1 LV Evaluation Platform power should be supplied from the add-on board. The J6 jumper option makes this connection. There is no jumper option to supply power to the add-on board from the F1 LV Evaluation Platform, because most of the platform power options do not have sufficient capacity. When power is applied to the F1 LV Evaluation Platform through the add-on board, then the UNI/O® memory is detected and read. The F1 LV Evaluation Platform software configures itself to operate the motor identified in the memory. This automatic configuration also applies to the PC control software.

1.2.5 Add-on Board Memory

Every add-on board, with one exception, includes a UNI/O memory device that contains:

- board ID
- board revision
- parameters associated with the motor supplied with the add-on board

When the F1 LV Evaluation Platform senses that an add-on board is attached, the initial display shows the motor type and add-on board revision. Motor speed can be controlled with either the potentiometer on the F1 LV Evaluation Platform or with the PC interface speed control. Additional motor capabilities are available through the PC control interface. These are described in more detail in the sections specific to each motor.

The first generation BLDC boards do not have a UNI/O memory. When the F1 LV Evaluation Platform does not detect a UNI/O memory, it then checks voltages on other selected J3 connections to determine if a BLDC circuit is present. When a BLDC board without UNI/O memory is detected, the motor parameters are then retrieved from the F1 LV Evaluation Platform EEPROM memory. The factory defaults for these parameters match those needed for the motor originally supplied with the BLDC board. If the parameters are modified for another motor, then the *File->RAM->EEPROM* option will save those parameters to the F1 LV Evaluation Platform EEPROM memory in lieu of the UNI/O memory.

The advantage that the UNI/O equipped boards have is that several different add-on boards can each support and remember the settings for a different motor. Various BLDC motors can be accommodated when working with the first generation BLCD Add-on Board, by saving and recalling the motor parameters to and from the PC disc storage with the *File->Save…* and *File->Open…* options.

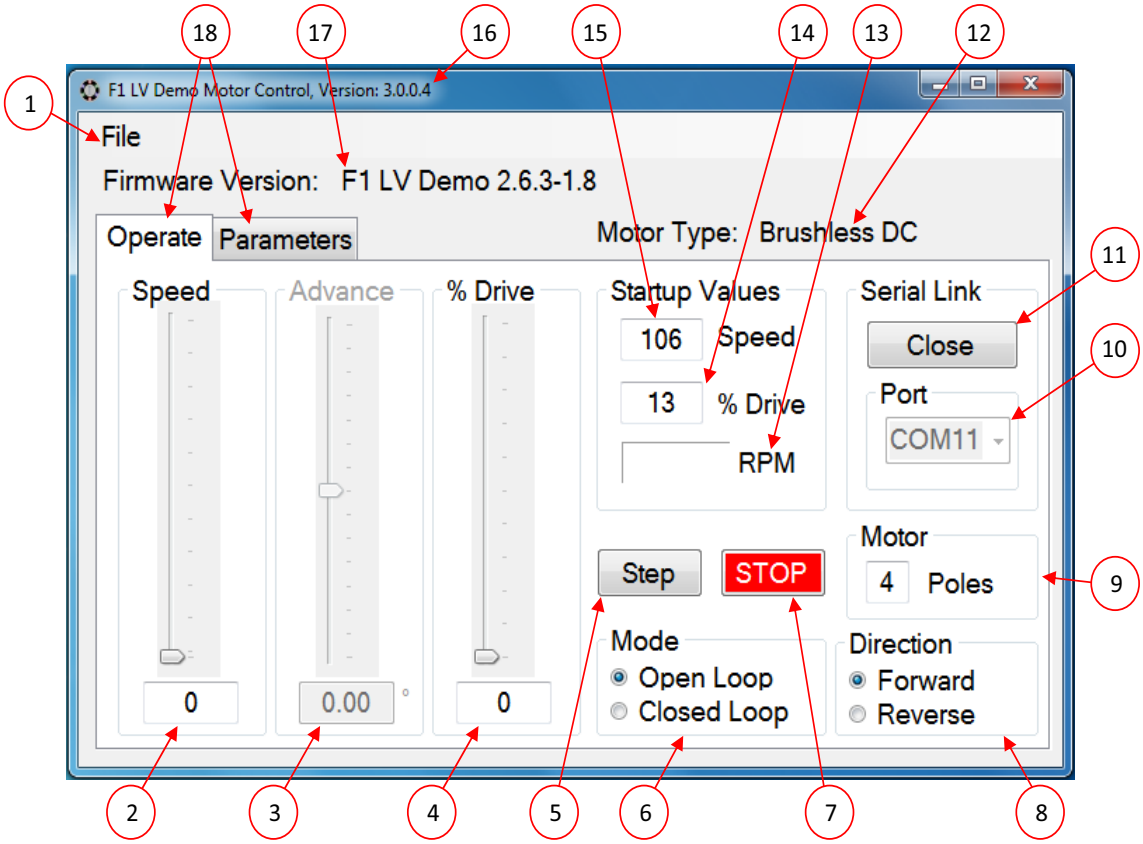
1.3 PC SOFTWARE OVERVIEW

The F1LVDemo software is a Graphical User Interface (GUI) providing control of the motor speed and direction. The GUI also provides access to key parameters of the motor operation. The control parameters vary by motor type. Each parameter and method of optimization are described in detail in the motor sections of this document.

Figure 1-1 and Figure 1-2 show the front panel of the PC control GUI. Features of the control GUI are identified and described below.

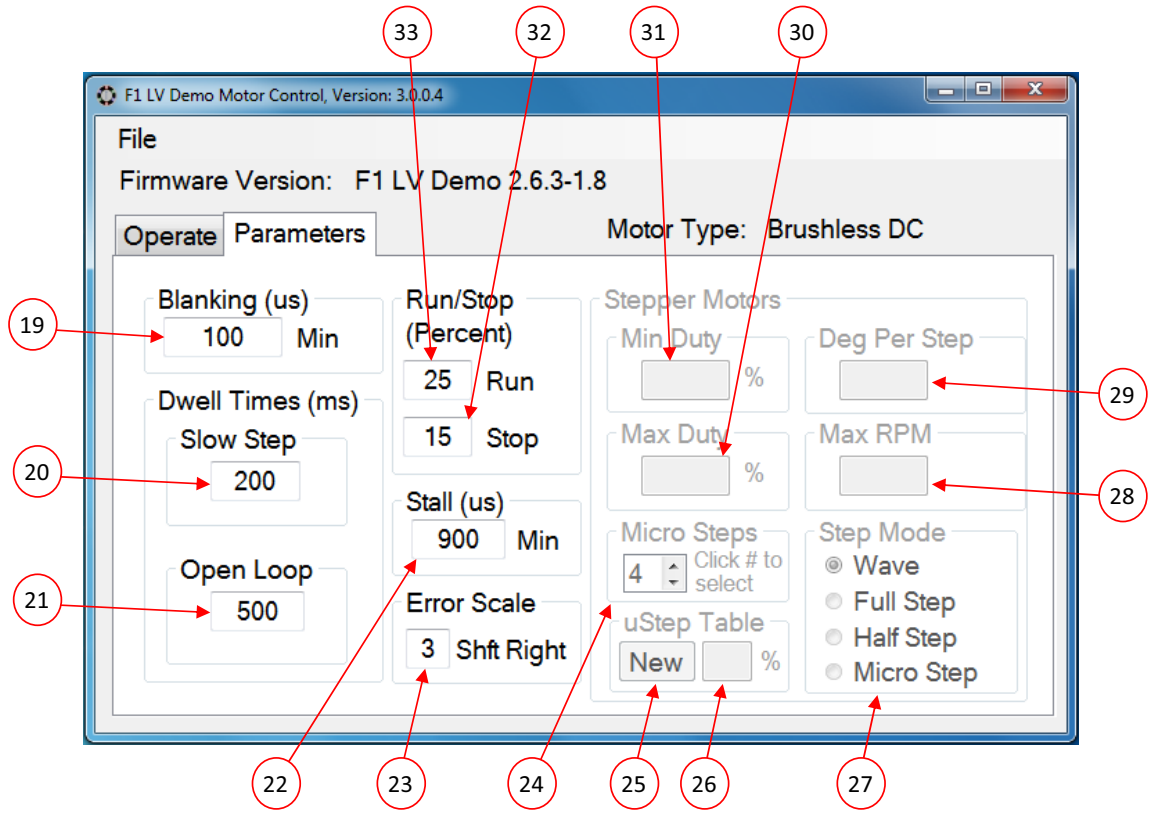
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FIGURE 1-1:



1. Motor Parameters pull-down menu. Save and recall to and from disc.
2. Speed control (relative 0 to 255):
   - Commutation rate in open loop
   - Drive level in closed loop
3. Zero cross advance/retard (BLDC only).
4. Motor drive voltage control (open loop). In BLDC closed loop this control reverts to a balance control.
5. BLDC open-loop single-step button.
6. Open/closed-loop control selection (BLDC and stepper motors only).
7. Panic **STOP** button – Forces drive and commutation to zero.
8. Motor direction selection.
9. Number of motor poles (BLDC only).
10. Serial port selection.
11. Serial link **Open**/**Close** button.
12. Motor type indicator.
13. Motor RPM – click label to update.
14. Initial drive level for start-up.
15. Initial speed setting for start-up.
16. PC Software version.
17. F1 LV Evaluation Platform software version.
18. Run time and static motor parameters tabs.

FIGURE 1-2:



19. BLDC flyback voltage blanking time.
20. BLDC dwell time at each start-up step.
21. BLDC milliseconds to remain in Open-Loop mode at start-up before closing the loop.
22. BLDC minimum commutation time below which a stall is detected.
23. BLDC error feedback multiplication factor. Each shift divides error by 2.
24. Stepper motor steps in each drive phase when microstepping is selected.
25. Button to invoke new microstep sinusoid drive look-up table.
26. Peak drive level in microstep look-up table.
27. Stepper motor commutation mode selection.
28. Stepper motor maximum RPM commutation rate when speed control is set at maximum.
29. Degrees per step physical attribute of the attached motor.
30. Maximum drive voltage duty cycle applied when speed control is at the maximum RPM. This prevents excessive overdrive of the motor.
31. Stepper motor drive voltage duty cycle applied when speed control is at the lowest run speed above stop.
32. Percent of speed control setting, relative to maximum, below which the motor drive is removed and the motor is stopped.
33. Percent of speed control setting, relative to maximum, above which the motor starts from a stopped state.

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1.4 USING THE F1LVDEMO CONTROL SOFTWARE

1.4.1 Software Updates

The software supplied and preloaded into the F1 LV Evaluation Platform supports all four of the add-on motor control boards. The preloaded software is the latest version available at time of manufacture. Source code including any updates is available for free download from the Microchip web site: www.microchip.com/F1Eval.

All motors can be controlled with the PC-based F1LVDemo control GUI. The F1LVDemo control software is available for free download from the Microchip web site: www.microchip.com/F1Eval.

1.4.2 Serial Link

The F1LVDemo control GUI operates through a USB to serial interface that appears as a standard RS-232 serial port to the PC operating system. The USB interface on the F1 LV Evaluation Platform is an MCP2200 USB to Serial interface device. Ensure that the drivers for this interface are loaded in the PC before making the connection. Interface drivers can be downloaded for free from the MCP2200 product page of the Microchip web site.

1.4.3 Connecting the F1 LV Evaluation Platform to the Add-on Board

Perform the following steps in the order shown to establish the link between the F1LVDemo control software and the F1 LV Evaluation Platform.

1. Connect the desired add-on board to the F1 LV Evaluation Platform J3.
2. Connect the supplied motor to the add-on board.
3. Ensure the following jumpers are in place on the F1 LV Evaluation Platform:
   - J10 – Pot Enable
   - J9 – Temperature Sense Enable
   - J4 – I Sense break
   - J6 – Expansion Board Power
4. Turn the RF2 potentiometer fully counter clockwise.
5. Each add-on board is equipped with a linear 3.3 Volt regulator that supplies power to the F1 LV Evaluation Platform.

Apply 9-12 VDC power to the add-on board. Power can be applied through the black 2.5 mm power jack or directly to the appropriate pins of the add-on board motor connector. The power jack connector is designed to accept 9 VDC, 0.75 amp wall transformer. The center pin is the positive terminal. When power is applied the F1 LV Evaluation Platform LCD will display the motor type and add-on board revision.

At this point the motor can be operated stand-alone with the potentiometer on the F1 LV Evaluation Platform. Additional motor controls are accessible only with the control GUI.

1.4.4 Connecting the F1 LV Evaluation Platform to the PC

6. Connect a USB cable from the PC to the F1 LV Evaluation Platform J2.
7. Execute the F1LVDemo program.
8. Select the communication port associated with the F1 LV Evaluation Platform. This will most likely be the highest numbered communication port in the selection box.
9. The communication port list is built during the F1LVDemo program initialization. If you connect to the board after the program is started, the communication port will not appear in the selection list.

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10. Click the **Open** button. After the link to the F1 LV Evaluation Platform is established, the F1 LV Evaluation Platform software version will be displayed, as well as the detected motor type.

When the link is established, all user accessible motor parameters stored in the add-on board will be retrieved and shown in the corresponding controls of the GUI. Controls not applicable to the detected motor will be disabled and grayed out.

1.4.5 Open Versus Closed Loop

The open-loop and closed-loop selections apply only to brushless DC and stepper motors. In open-loop operation, the motor voltage and speed controls are independent. In closed-loop operation the speed control functions as the control for both the speed and voltage.

Brushless DC is truly a closed-loop operation where the applied voltage is set with the speed control and the motor speed responds automatically to keep the back EMF voltage equal to the applied voltage.

Stepper motor closed-loop operation is technically not closed loop. Both the motor voltage and speed outputs simultaneously follow the single-speed control input as independent open-loop functions of the minimum and maximum speed and drive parameters.

1.4.6 Changing Motor Parameters

To change a motor parameter, type the new value into the corresponding text box. The initial key press clears the previous value and changes the value to red. Red indicates that the value has not been sent to the Platform RAM. When the enter key is pressed the value is immediately sent to the Evaluation Platform RAM and the display returns to the default black. The entry can be terminated without updating the Platform RAM by pressing the Escape key. Changed parameters reside in volatile RAM only. Any Platform Reset will restore the RAM values to those in the Platform EEPROM memory. Unexpected Platform Resets will cause inconsistencies between the parameters displayed in the GUI and those in the Platform RAM. Select the pull-down menu *File->RAM->Display* option to resynchronize the displayed values with those in the Platform RAM.

1.4.7 Saving and Restoring Motor Parameters

Sometimes it is useful to try many different motor setups when optimizing performance. Setups can be saved to disc storage with the pull-down menu *File->Save…* option.

Previously stored setups can be recovered with the pull-down menu *File->Open…* option. Parameters retrieved from disc update both the display and the Platform RAM.

When the optimum setup is determined those parameters can be saved to the Platform nonvolatile memory with the pull-down menu *File->RAM->EEPROM* option. Parameters saved to EEPROM will be restored to RAM on every Platform Reset. The values in the Platform EEPROM can be restored to RAM without a Reset with the pull-down menu *File->EEPROM->RAM* option.

The EEPROM can also be restored to the factory defaults with the pull-down menu *File->Defaults->EEPROM* option. The factory defaults can be altered only by changing the source code and programming the Platform program memory after recompiling the source code.

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1.4.7.1 CATASTROPHIC RECOVERY

In the unlikely event the UNI/O memory becomes erased or damaged, the memory can be completely restored with the *File->Restore->(add-on type)* option. This option should only be used if the add-on board fails the automatic detection process. Take care to select the add-on type corresponding to the attached board. Failure to do so will cause unexpected operation possibly resulting in permanent damage to the add-on board hardware.

1.4.8 Hints for Optimum Performance

The BLDC and stepper motors are interrupt driven. The motor commutation interrupts take precedence over all other operations. All services other than the motor commutation are polled. When the motor is operating at very rapid commutation rates, the time for other services can become severely limited. For most situations, the serial link service is able to keep up with the activity from the PC. However, when a rapid series of commands is coupled with rapid commutations, the serial link can appear to stall. To avoid this situation, use the slider controls for only small and slow changes. Enter numbers directly into the slider text box when a large change to the slider control is desired. If a stalled control condition occurs, try to regain control by clicking on the red **STOP** button. If that does not restore control, the last resort is to press the F1 LV Evaluation Platform **MCLR** button.

1.4.9 Header File Versus GUI Motor Parameters

The default motor parameters are defined in the F1 LV Evaluation Platform source code motor header files. The following table correlates the GUI parameters with the equivalent header file parameters. The conversion factor is the value by which the header file parameter is multiplied to derive the GUI parameter. In all cases, whether in the table or text, parameters expressed as all caps may be found exactly as shown in the header files.

See **Appendix B. “Conversion Factors”** for more information on the parameters and the associated conversion factors.

TABLE 1-2:

Motor Type	GUI Parameter	Header File Parameter	Conversion Factor
BLDC (EBM)	Start-up: Percent Drive	MED_START_DRIVE_PCT	1
	Start-up: Speed (RPM)	START_RPM	1
	Poles	NUM_POLES	1
	Blanking	BLANKING_COUNT_us	1
	Slow Step	TIMEBASE_SLOW_STEP	10
	Open Loop	OPEN_LOOP_ms	1
	Stall	STALL_COUNT_us	1
	Run Percent	LOW_RESTORE_REQUEST_PCT	1
	Stop Percent	LOW_OFF_REQUEST_PCT	1
	Error Scale	ERROR_SCALE	1
BDC (PAN14)	Run Percent	LOW_RESTORE_REQUEST_PCT	1
	Stop Percent	LOW_OFF_REQUEST_PCT	1
Unipolar (42HS03) and Bipolar (39HS) STEPPER	Run Percent	REQUEST_ON	0.392
	Stop Percent	REQUEST_OFF	0.392
	Min. Duty Percent	MIN_DUTY	0.392
	Max. Duty Percent	MAX_DUTY	0.392
	Degrees per Step	MOTOR_STEP_ANGLE	0.1
	Max RPM	MAX_RPM	1
	uStep Table	Bipolar_CCP_Val[] Unipolar_CCP_Val[]	Varies

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Chapter 2. The BLDC Add-on Board

2.1 OVERVIEW

The BLDC add-on (DM164130-2) allows you to drive virtually most sensorless three-phase brushless DC motors used in consumer electronics, ranging from small HVAC applications to complex media reading/writing drives. The add-on is shipped together with the ebm-papst BLDC motor, to which it connects through a ribbon cable to a special connector on the board (J5). Alternatively, any other 5-12V BLDC motor can be used by hooking it up through the J2 connector.

2.1.1 Features

The key features of this board include the following:

Connectors:

- Male 20-pin connector (J1) to match the F1 LV Evaluation Platform
- Generic 6-pin BLDC motor connector (J2)
- 6-pin ebm-papst motor interface (J5)
- 5-12V power supply input connector (J4)

Typical BLDC drive:

- Three P-type and 3 N-type MOSFETs forming three half bridges for the three motor phases
- Six bipolar transistors to command the MOSFETs
- Sensing resistor for current measurement (R15)

Control:

- R21 for adjusting the zero crossing voltage
- R19 for adjusting the over-current Fault detect (software for this function is not implemented).

> **Note:** The function labels on these two controls are reversed on the R2 revision of these boards.

Protection:

- Power fuses (F1, F2)

Power supply:

- 3.3V voltage regulator (U1)

2.1.2 What's Included

The BLDC add-on part number (DM164130-2) contains:

- BLDC Add-on Board designed for the F1 Evaluation Platform
- ebm-papst motor (P/N: VD-3-25.07)
- 28 AWG ribbon cable to match the ebm-papst motor

2.1.3 Reference Documents

This section points you to technical application support.

AN857, *"Brushless DC Motor Control Made Easy"*

AN885, *"Brushless DC (BLDC) Motor Fundamentals"*

AN899, *"Brushless DC Motor Control Using PIC18FXX31 MCUs"*

AN970, *"Using the PIC18F2431 for Sensorless BLDC Motor Control"*

AN1305, *"Sensorless 3-Phase Brushless Motor Control with the PIC16FXXX"*

You can obtain these reference documents from your nearest Microchip sales office (listed in the last page of this document) or by downloading them from the Microchip web site.

2.2 BOARD SETUP

WARNING

The BLDC Motor Control Add-on Board is intended to drive three-phase brushless DC motors. Before connecting the motor, make sure the power rating of the motor is equal to or less than the power rating of the board, as shown in Appendix B. "Conversion Factors". Also, make sure the configuration parameters inside the software or the GUI are correct for the motor you are using. Failure to comply with this warning could lead to malfunction of the board and the motor, and could result in physical harm.
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.

A step-by-step connecting procedure is available in **Section 1.4.3 "Connecting the F1 LV Evaluation Platform to the Add-on Board"**. If using the ebm-papst motor, attach the ribbon cable from the motor at step 2. Also, make sure that POR R4 on the evaluation platform is turned fully CCW.

If using a different motor, connected through J2, please keep in mind to attach each motor phase firmly to the connector. The red connector supplied with the board is designed to accept 22 AWG wire. Bad contacts can damage the add-on and will wear out the motor in time. There is no rule for attaching a specific motor lead to a phase line on the add-on. Keep in mind the correspondences on the software side when testing or measuring directly on that motor phase.

Adjust R21 90 degrees CCW from the mid-point CCW when operating the ebm-papst motor. R21 should be set to its mid-point for other motors.

2.3 HARDWARE

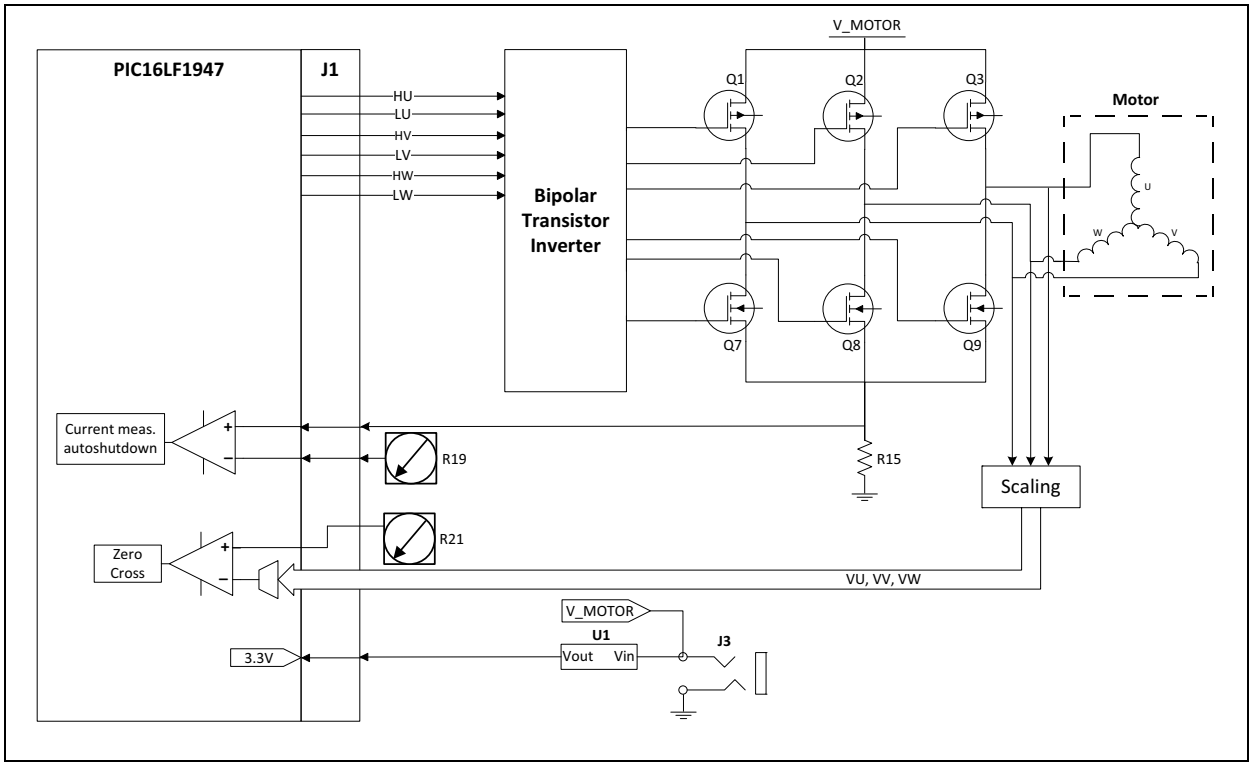
2.3.1 General Architecture

The BLDC add-on uses a typical three half-bridges control configuration suitable for three-phase BLDC motors, using six MOSFETS commanded through six bipolar transistors. Sensorless control is done in the software without any other external components.

Figure 2-1 provides a simplified block diagram of the development board hardware, coupled to the F1 LV Evaluation Platform:

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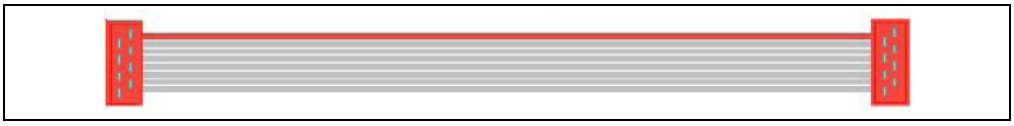
FIGURE 2-1: THE BLDC MOTOR CONTROL ADD-ON ARCHITECTURE



2.3.2 Attaching the Motor

The BLDC add-on kit includes the three-phase 24V ebm-papst motor. This motor can be attached through a dedicated 28AWG 8-wire ribbon cable using connector J5.

FIGURE 2-2: THE EBM-PAPST MOTOR CONNECTOR



However, you can use your own three-phase BLDC motor by attaching its leads to the J2 connector. The red connector supplied with the board is designed to accept 22 AWG wire.

2.3.3 Power-Up

Voltage is supplied through the 2.5 mm jack connector J4, with a maximum rating of +12 VDC. The F1 LV Evaluation Platform should be configured to use expansion board power by inserting the power jumper on J6. See the *"F1 LV Evaluation Platform for Enhanced PIC® Microcontrollers User's Guide"* (DS41614A) for more details.

2.3.4 Power Stage

The BLDC add-on incorporates the classic three half-bridges drive made from P and N-type MOSFETs (for more details, please refer to the BLDC board schematic in **Appendix A. "Board Layout and Schematics"**). The maximum current rating is 8A on each MOSFET. Please keep this in mind when designing your application or modifying the add-on hardware.

The stage contains six PWM (HU, LU, HV, LV, HW, LW) inputs and three back EMF sense outputs (VU, VV, VW). The BLDC motor attaches to the three driver outputs (U, V, W).

Motor current is measured by using the R15 shunt resistor, placed in-between the Power Stage lowside and ground, and connected to the PIC16F1947 through the J1 connector. (Current sensing is not implemented in the F1 LV Evaluation software.)

2.3.5 Protection

Two 5A fuses (F1 and F2) are used to protect your add-on in case of an overcurrent situation in the output drivers. In case one or both of them get burnt, remove power immediately from the board and inspect the add-on for further damage. Do not replace the burnt fuses with other values than the ones provided with the board.

2.3.6 Speed Control

Speed control can be performed through either the Motor Control GUI or the 10K POT R4 located on the F1 LV Evaluation Platform.

2.4 DEMO SOFTWARE

2.4.1 Introduction

The F1 LV Evaluation demonstration program uses a single combined demo. The combined demo source code is organized into sectional code for ease of accommodating several motor types. This chapter provides an overview to the functions provided by the BLDC demo.

The BLDC demo code is designed to operate a sensorless BLDC control. The software can be easily tuned to the needs of your application or motor by changing the parameters on-the-fly, by modifying the motor parameters in the F1LVDemo GUI.

2.4.2 The Motor Control GUI Application

Using the Motor Control Application GUI, you can change the following parameters:

- Motor poles number
- Speed [arbitrary range 0 to 255]
- The timing balance between zero-cross and commutation periods [degrees]
- Phase advance [degrees]
- Start-up speed [arbitrary range 0 to 255]
- Drive voltage [% of full scale]
- The minimum blanking period [us]
- Dwell timings: closed-loop slow stepping [ms] and open loop [ms]
- Run/stop hysteresis drive voltage [% of full scale]
- Minimum motor stalling period [us]
- Error scaling factor [divisor power of 2].

Also, the motor can be run in open/closed loop and forward/reverse.

Clicking on the ‘RPM’ text in the **Operate** tab will display the motor speed in the text box next to it.

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2.4.3 BLDC Parameter Optimization

Brushless motors depend on the software to commutate the motor. The software must determine the rotor position relative to the stator so as to commutate the driver circuitry at specific rotor positions. The rotor position is determined in sensorless motors by voltages induced into the stator by rotor motion. The induced voltage is referred to as back EMF or BEMF. When the rotor is stationary, there is no BEMF from which to determine the rotor position. Starting the motor requires commutating the motor blindly, without the benefit of feedback, to start the rotor in motion fast enough to sense the BEMF, and close the loop on rotor position for commutation.

The motor speed, in response to the applied voltage, varies by motor design. We need to match the initial drive voltage and open-loop commutation rate to the motor to accomplish two objectives:

1. prevent excessive current in the motor
2. start rotation fast enough to sense the BEMF

When the motor is running, the BEMF on the driven pair of stator windings matches the applied voltage. The BEMF on the undriven winding starts at one power rail at the beginning of the commutation period and ends at the other power rail at the end of the commutation period. However, this is only true when the motor is running at the design speed. At any other speed, the BEMF is effectively undetectable. Unfortunately, the motor will not start if we apply a voltage, and then commutate at the rate for which the motor is designed. To start the motor, we need to commutate slower than the design rate and then ramp up to the design speed.

The task of motor optimization is to find a combination of applied voltage and commutation rate for which the motor will start to rotate. From there, the control algorithm will ramp-up the commutation rate to where the BEMF can be sensed. The Motor Control GUI enables us to independently set the applied motor voltage and commutation rate to find a combination that works. Use the following steps to experiment with your motor optimization:

1. Set POT R21 to middle range for your motor or 90 degrees CCW from the middle range for the ebm-papst motor supplied with the BLDC Add-on Board.
2. Select Open-Loop mode.
3. Set the speed control to a nominal rate, such as 100.
4. Slowly increase the % Drive control until the motor starts to turn.
5. Slowly increase the speed control until it is just faster than the motor can go.
6. Slowly reduce the speed control until the motor starts to rotate again.
7. Note the % Drive setting, then enter 0 into the % drive control text box.
8. Re-enter the % drive setting noted in step 6, and observe that the motor starts spinning.
9. Repeat steps 7 and 8 to verify the motor always starts reliably. If it does not, then reduce the speed control slightly and repeat steps 6, 7 and 8.
10. When you are satisfied with the start response obtained by steps 6, 7 and 8, then enter the final speed control value into the Speed Start-up value text box. The equivalent RPM will be displayed.

Note: The displayed RPM value is only accurate if the motor has the number of poles indicated. The number of poles only matters if you want the RPM value to represent the mechanical operation. If you are not sure how many poles your motor has, then you can determine this by leaving the % Drive where it is, setting the speed to zero, and count the number of **Step** button clicks it takes to make one full motor revolution. Divide this number by three, that is the number of poles.

11. Enter the % Drive number into the % Drive start-up value.
12. Click the **Parameters** tab and verify or enter the following nominal values:
    a) Blanking: 100 us
    b) Slow Step: 200 ms.
    c) Open Loop: 500 ms.
    d) Run: % Drive entered in step 13.
    e) Stop: 2 less than Run
    f) Stall: 900 us
    g) Error Scale: 3
13. Click the **Operate** tab and select Closed-Loop mode.
14. Hold your breath, cross your fingers, and slowly increase the speed control to the point where the motor starts. With any luck, your motor will start and immediately lock onto the BEMF feedback to become fully operational in Closed-Loop mode. When that happens, you can increase the speed control to the desired rate. Click on the RPM label to perform one reading of the motor RPM.

Now that you are able to operate the motor in closed loop, at least at slow speed, you need to complete the optimization of the other motor parameters. The following procedures describe each parameter and its adjustment.

2.4.3.1 BLANKING

The blanking interval is required so the BEMF sense does not falsely trigger on the flyback voltage caused by commutation. You can observe this pulse on any motor lead while the motor is running. The flyback pulse voltage occurs immediately following the unmodulated drive period. The width of the flyback pulse varies depending on the inductance of the motor windings and the motor load current. Measure this pulse under worst-case motor operation and set the blanking time to at least the measured time plus some margin. The blanking time must be less than 50% of the minimum commutation period, and ideally much less than that. You may notice during measurement that some modulation pulses immediately following the flyback pulse extend beyond the mid-level of the drive voltage. Treat those pulses as part of the time that must be blanked.

2.4.3.2 SLOW-STEP DWELL TIME

During start-up, the motor windings are energized for a short period to pre-position the rotor. Slow step is the length of time that the windings are energized. Large high inertia motors take longer to reach the position, and therefore need extra time. Experiment and use the shortest time that works.

2.4.3.3 OPEN-LOOP DWELL TIME

The open-loop time is the amount of time that the motor operates in Open-Loop mode before the ramp-up to BEMF detection starts. The open-loop voltage and commutation rate is the same that you entered in the start-up parameters. Small low inertia motors start well going straight from slow step pre-position into the ramp-up to BEMF detection. For those motors you can enter an open-loop time of zero. Larger motors need time to stabilize at the open-loop rate before ramping up. Experiment to find the value that works best for your motor.

2.4.3.4 RUN/STOP PERCENTAGE

The run value should match the start-up drive value to ensure a smooth transition from open loop to ramp-up. Once BEMF lock is obtained, most motors are able to maintain lock below the start-up drive value. Experiment to find the stop value that ensures reliable motor operation at slow speed.

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2.4.3.5 STALL

A motor that stalls may appear to the control algorithm as if it is still running at high speed. Blanking, modulation, and intrinsic motor characteristics all play a part in a false BEMF indication. When this happens, the commutation rate will ramp up to a rate much higher than the motor is able to operate. This feature is used to detect a stall condition. Determine an appropriate stall detection time by measuring the commutation period of the motor at maximum speed. Enter this period minus some margin as the stall period. If the commutation period is ever shorter than the stall period, then the motor will be immediately stopped.

2.4.3.6 ERROR SCALE

The control algorithm compares the actual time from commutation to where the BEMF crosses the mid-drive level. This is referred to as the zero cross event. The zero cross event is expected half way through the commutation period. The error between the expected and actual measured time is scaled down by the error scale factor and added back into the commutation time, thereby forming the closed-loop operation. The error scale value determines the loop gain. Less gain will result in a slower, but more stable response. Conversely, higher gain will result in a faster response, but less stable operation. The error is scaled by performing right shifts on the error value. More shifts means less of the error is getting back into the loop, resulting in less loop gain. The commutation time is a 16-bit integer with a 17^{th} sign bit. Very slow commutation rates will use all 16 bits. BEMF error for slow motors can be large so a correspondingly large error scale can be tolerated. However, as the motor speed increases the commutation time decreases and not all 16 bits are significant. At very high speeds the magnitude of the error is small relative to the full 16-bit number and large error scales cannot be tolerated, because the full error value may be shifted to a value of zero. For most motors, an error scale value of three works well. Again, experiment to see what works best for your particular motor.

2.4.3.7 ADVANCE AND BALANCE CONTROLS

The advance and balance controls should be maintained at zero for normal motor operation. These controls are only used to observe the effects of manipulating the zero crossing event. The advance control advances or retards the zero crossing event. The balance control extends or shortens the commutation time after the zero crossing event. It is interesting to observe on an oscilloscope how the motor reacts to these disturbances.

2.4.3.8 ZERO-CROSSING ADJUSTMENT

A potentiometer, R21, is included on the BLDC Add-on Board for adjusting the zero crossing reference voltage. Most motors require a reference voltage of half the applied motor voltage. However, the winding pattern of some motors results in a nonlinear BEMF response. Such a motor is the ebm-papst motor supplied with the add-on board. This motor has an S-shaped BEMF response and operates best when the zero crossing reference is lower than half the applied motor voltage. If you have difficulty starting the motor, even after going through all the optimization steps, then check the position of R21 and try moving the position slightly more and less than the 90 degree CCW starting position. Once you get the motor operating in closed loop, fine tune the zero crossing reference with R21. This is accomplished by observing the waveform of one of the motor terminals. Adjust R21 so that the rising and falling slopes of the waveform are equal in appearance.

NOTES:

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Chapter 3. The Brushed DC Add-on Board

3.1 GETTING STARTED

3.1.1 Overview

The BDC add-on (DM164130-6) allows you to drive virtually most brushed DC motors used in consumer electronics. The add-on is shipped together with the NMB brushed DC motor (PAN14EE12AA1) mounted on the board. The motor voltage is supplied through jumper J5. Alternatively, any other 5-12V BDC motor can be used by hooking it up through the J4 connector and removing the shorting block from J5.

3.1.2 Features

The key features of this board include the following:

Connectors:

- Male 20-pin connector (J1) to match the F1 LV Evaluation Platform
- Generic 4-pin BLDC motor connector (J4) for 22 AWG wire
- 5-12V power supply input connector (J3)

Typical BDC drive:

- Two N-type and two P-type MOSFETs arranged as an H-bridge
- Four NPN bipolar transistors to command the MOSFETs
- Sensing resistor for current measurement (R15)

Control:

- VREF POT, for general over-current adjustment (over-current detection is not implemented in the demo software).

Protection:

- 5A power fuses (F1, F2)

Power Supply:

- 3.3V voltage regulator (U1)

Parameter storage:

- 128 x 8 UNI/O® Serial EEPROM (U2)

3.1.3 What's Included

The BDC add-on with part number DM164130-6 contains:

- BDC Add-on Board designed for the F1 Evaluation Platform
- NMB motor (P/N: PAN14EE12AA1)

3.1.4 Reference Documents

This section points you to application technical support.

AN696, *PIC18CXXX/PIC16CXXX DC Servomotor*

AN718, *Brush-DC Servomotor Implementation Using PIC17C756A*

AN893, *Low-Cost Bidirectional Brushed DC Motor Control Using the PIC16F684*

AN905, *Brushed DC Motor Fundamentals*

You can obtain these reference documents from your nearest Microchip sales office (listed in the last page of this document) or by downloading them from the Microchip web site.

3.2 BOARD SETUP

WARNING

Before connecting the motor, make sure the power rating of the motor is equal to or less than the power rating of the board, as shown in Appendix B. "Conversion Factors". Also, make sure the configuration parameters inside the software or the GUI are correct for the motor you are using. Failure to comply with this warning could lead to malfunction of the board and the motor, and could result in physical harm.
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.

A step-by-step connecting procedure is available in **Section 1.4.3 "Connecting the F1 LV Evaluation Platform to the Add-on Board"**. Please make sure that POT R4 on the Evaluation Platform is turned fully CCW.

To connect either the NMB motor (with Jumper J5) or a brushed DC motor of your choice (through terminals V and U of add-on connector J4), keep in mind to attach each motor phase firmly to the connector. Bad contacts can damage the add-on and will wear out the motor in time. There is no rule for attaching a specific motor lead to a phase line on the add-on. Keep in mind the correspondences on the software side when testing or measuring directly on that motor phase.

3.3 HARDWARE

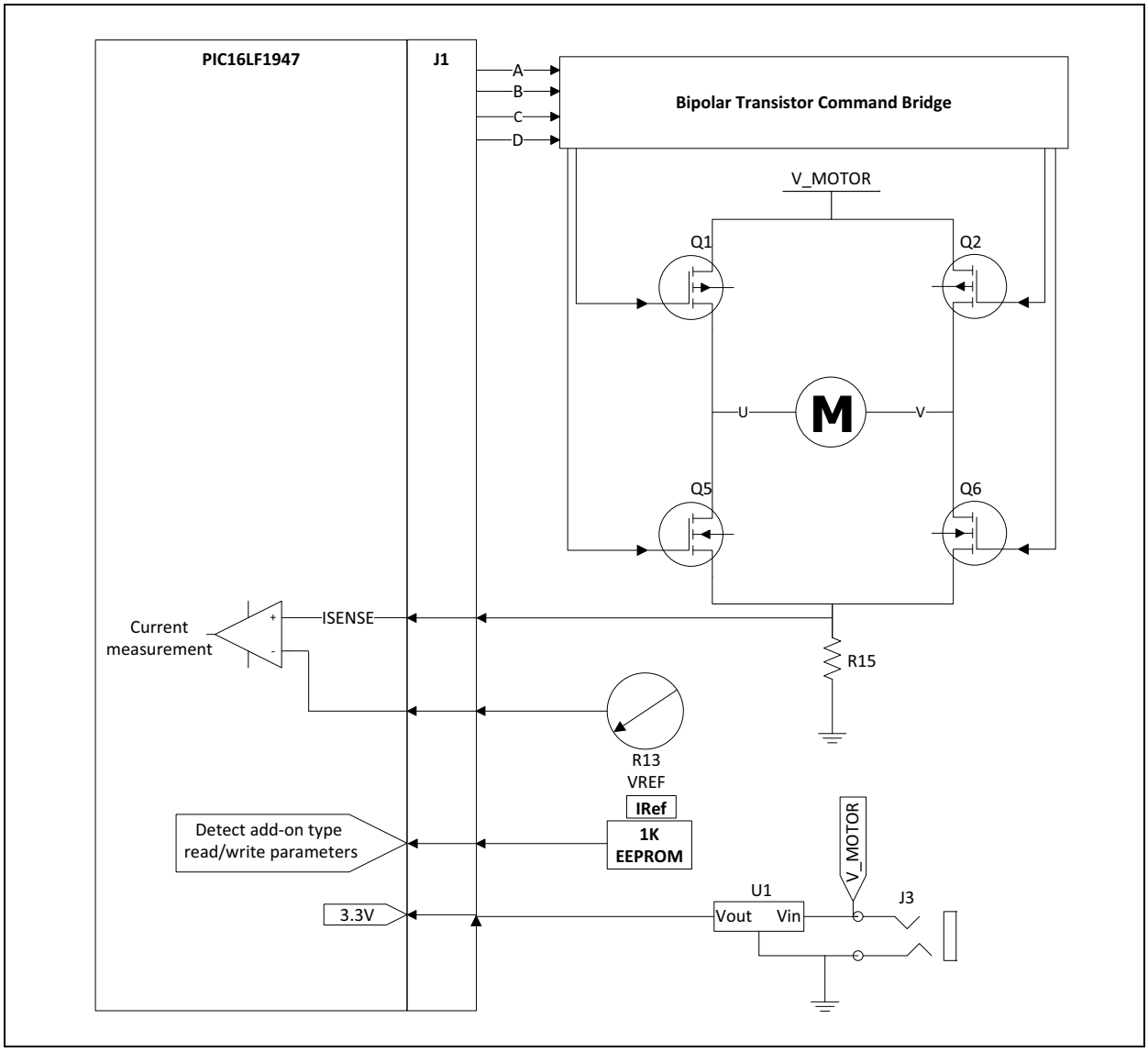
3.3.1 General Architecture

The BDC add-on uses a typical H-bridge control configuration suitable for two-phase BDC motors, using four MOSFETS commanded through four bipolar transistors. The demo software varies the motor speed by pulse-width modulating the H-bridge drive.

Figure 3-1 provides a simplified block diagram of the development board hardware, coupled to the F1 LV Evaluation Platform:

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FIGURE 3-1: THE BDC MOTOR CONTROL ADD-ON ARCHITECTURE



3.3.2 Attaching the Motor

The BDC add-on kit includes a 12V NMB PAN14EE12AA1 motor. This motor is mounted on the board. The voltage is supplied to the motor through jumper J5. To use an alternate motor, remove the shorting block from J5 and attach the two motor leads to lines V and U. The V_MOT and GND connections are for a lab supply and are to be used in lieu of the 2.5 mm power connector.

3.3.3 Power-Up

Voltage is supplied through the 2.5 mm jack connector J3, with a maximum rating of +12VDC. The F1 LV Evaluation Platform must be configured to use expansion board power by inserting the power jumper on J6. See *"F1 LV Evaluation Platform for Enhanced PIC® Microcontrollers User's Guide"* (DS41614) for more details.

3.3.4 Power Stage

The BDC add-on incorporates the classic full H-bridge drive made from two N-type and two P-type MOSFETs. The maximum current rating is 8A on each MOSFET. Please keep this in mind when designing your application or modifying the add-on hardware.

The stage contains four PWM (A, B, C, D) inputs and two driver outputs (VU and VV) to be attached to each terminal of the BDC motor (U, V).

The current on the H-bridge is measured on the R15 shunt resistor, placed in-between the Power Stage lowside and ground, and connected to the PIC16F1947 through the J1 connector.

3.3.5 Protection

Two 5A fuses (F1 and F2) are used to protect your add-on in case of an overcurrent situation in the output drivers. In case one or both of them get burnt, remove power immediately from the board and inspect the add-on for further damage. Do not replace the burnt fuses with other values than the ones provided with the board.

3.3.6 UNI/O® Memory Chip

The UNI/O® memory chip stores the board ID and the application parameters. It is accessed by the Motor Control GUI at start-up in order to recognize which of the four boards is attached to the F1 LV Evaluation Platform, thus loading the appropriate parameters for the add-on used.

3.3.7 Speed Control

Speed control can be performed through either the Motor Control GUI, or the 10K POT R4 found on the F1 LV Evaluation Board.

3.4 DEMO SOFTWARE

3.4.1 Introduction

The F1 LV Evaluation demonstration program uses a single combined demo. The combined demo source code is organized into sectional code for ease of accommodating several motor types. This chapter provides an overview to the functions provided by the BDC demo.

The BDC demo code is designed to operate a brushed DC motor. All that is needed to operate a brushed DC motor is a supply voltage, because brushed DC motors self commutate. The only adjustable parameters for brushed DC motors are the start and stop thresholds. Voltage is applied to the motor when the speed control is greater than the Run percent, and is removed when the speed control is less than the Stop percent.

3.4.2 The Motor Control GUI Application

Using the Motor Control Application GUI, you can change the following parameters:

- Speed [arbitrary range 0 to 255]
- Run/Stop hysteresis drive voltage [% of full scale]

The demo is designed to operate a brushed DC motor in an Open-Loop mode only. Also, the motor can be run either forward or reverse.

Voltage control is the most simple control method for DC motors. It is based on a directly proportional relationship between the applied voltage and speed. Using the Speed slider in the Motor Control GUI or the POT on the F1 Evaluation Platform to adjust speed, you actually adjust the amount of voltage applied to the motor.

The Run/Stop hysteresis is configurable through the Run/Stop input boxes in the **Parameters** tab of the GUI. The Run percentage is the percentage of full-scale control input above which the motor will run. The Stop percentage is the percentage of full-scale control input below which the motor will stop. Separate thresholds allows for hysteresis in the run control.

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Chapter 4. The Bipolar Stepper Add-on Board

4.1 GETTING STARTED

4.1.1 Overview

The bipolar stepper add-on (DM164130-7) allows you to drive common two-phase bipolar stepper motors used in consumer electronics, ranging from CNCs, printers, optical disc drives and small load positioning systems. The add-on is shipped together with the Leadshine 39HS02 bipolar stepper motor pre-wired to plug directly into add-on connector J3. Alternatively, any other 5-12V bipolar stepper motor can be used by hooking it up through the J3 connector.

4.2 FEATURES

The key features of this board include the following:

Connectors:

- Male 20-pin connector (J1) to match the F1 LV Evaluation Platform
- Generic 6-pin bipolar stepper motor connector (J3)
- 5-12V power supply input connector (J2)

Typical Bipolar Stepper drive:

- Four P-type and four N-type MOSFETS comprising two full H-bridges each of which drives one motor phase
- One sensing resistor for current measurement (R3).

Protection:

- 2x5A power fuses (F1, F2)

Power Supply:

- 3.3V voltage regulator (U1)

Parameter storage:

- 1k x 8 UNI/O® Serial EEPROM (U2)

4.2.1 What's Included

The bipolar stepper add-on with part number DM164130-7 contains:

- Bipolar Stepper Add-on Board designed for the F1 Evaluation Platform
- Leadshine motor (P/N: 39HS02)

4.2.2 Reference Documents

This section points you to application technical support.

AN907, *"Stepping Motors Fundamentals"*

AN906, *"Stepper Motor Control Using the PIC16F684"*

AN822, *"Stepper Motor Microstepping with PIC18C452"*

AN1307, *"Stepper Motor Control with dsPIC® DSCs"*

You can obtain these reference documents from your nearest Microchip sales office (listed in the last page of this document) or by downloading them from the Microchip web site.

4.3 GETTING STARTED

WARNING

The Bipolar Motor Control Add-on Board is intended to drive two-phase bipolar stepper motors. Before connecting the motor, make sure the power rating of the motor is equal to or less than the power rating of the board, as shown in Appendix B. "Conversion Factors". Also, make sure the configuration parameters inside the software or the GUI are correct for the motor you are using. Failure to comply with this warning could lead to malfunction of the board and the motor, and could result in physical harm.
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.

A step-by-step connecting procedure is available in **Section 1.4.3 "Connecting the F1 LV Evaluation Platform to the Add-on Board"**. Please make sure that POT R4 on the F1 Evaluation Platform is turned fully CCW.

If using a different motor, connected through J3, please keep in mind to attach each motor terminal firmly to the connector. Bad contacts can damage the add-on and will wear out the motor in time. There is no rule for attaching a specific motor lead to a phase line on the add-on. Keep in mind the correspondences on the software side when testing or measuring directly on that motor phase.

On the F1 LV Evaluation Platform, use push button **RD2** to step through the application menu on the LCD display. To have more control over the motor using a real-time communication tool, please refer to the next section.

4.4 HARDWARE

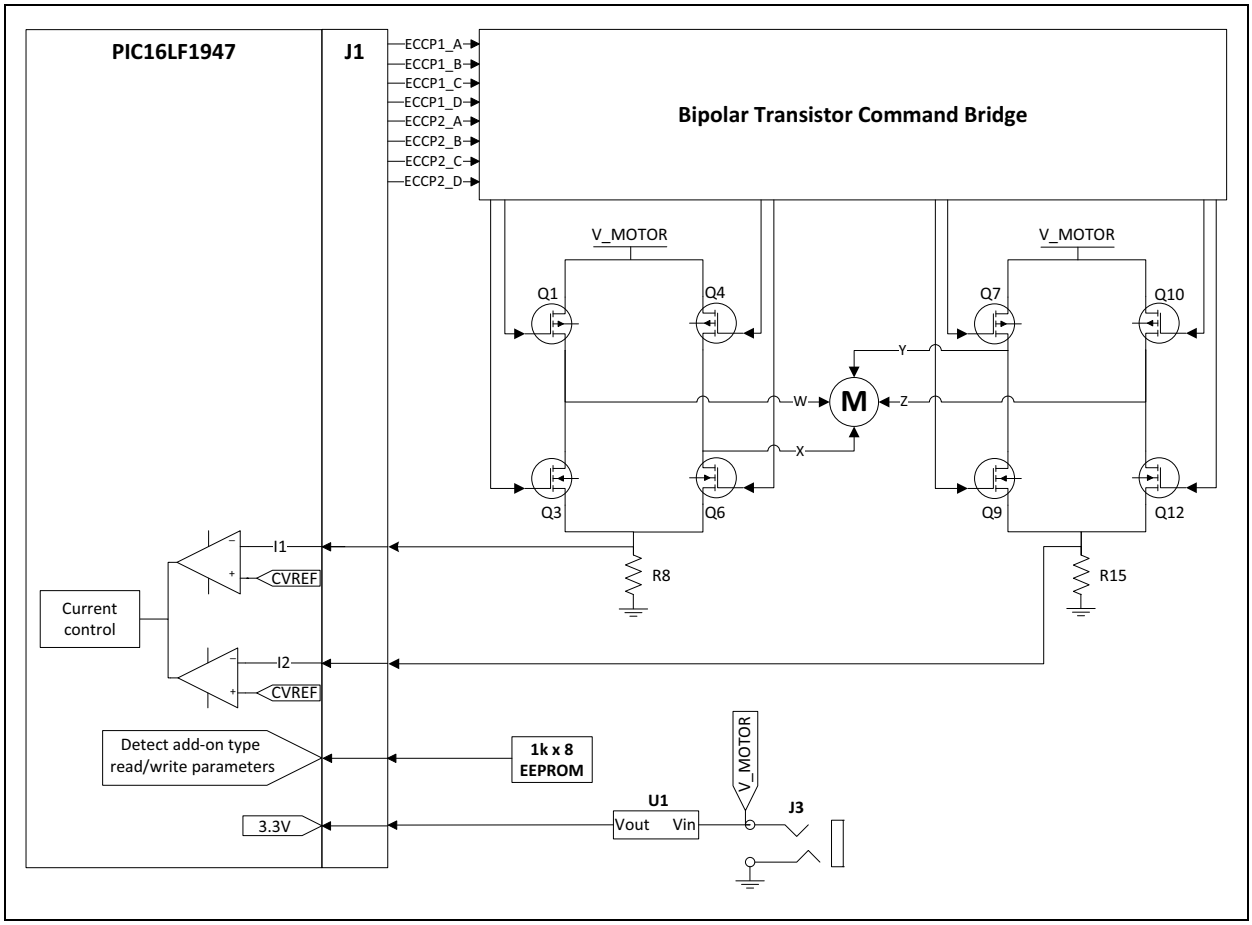
4.4.1 General Architecture

The bipolar stepper add-on uses a simple bipolar stepper drive formed by four independent N-type MOSFETs suitable for two-phase bipolar stepper motors. Open-loop control, closed-loop control, full step, half step, microstepping commutation can be done in the software.

Figure 4-1 provides a simplified block diagram of the development board hardware, coupled to the F1 LV Evaluation Platform:

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FIGURE 4-1: THE BIPOLAR STEPPER MOTOR CONTROL ADD-ON ARCHITECTURE



4.4.2 Attaching the Motor

The bipolar stepper add-on kit includes the two-phase Leadshine 39HS02 bipolar stepper motor. The supplied motor is pre-wired to a connector that mates with J3 of the add-on board. The connector is designed to accept 26 AWG wire. Connector terminals 5 and 6, that mate with the board pins 2 and 1 respectively, may be used to wire in a lab supply in lieu of power connector J2. Use of a lab supply with a current monitor is recommended as an aid during parameter optimization.

4.4.3 Power-Up

Power is supplied through either the J2 2.5 mm power jack or the power pins of J3. The default motor parameters assume that the supply voltage is 9 VDC. Changing the supply voltage will require re-optimizing the motor parameters. Monitoring the supply current during optimization is highly recommended to prevent over driving the motor.

The F1 LV Evaluation Platform must be configured to use expansion board power by inserting the power jumper on J6. See the *"F1 LV Evaluation Platform for Enhanced PIC® Microcontrollers User's Guide"* (DS41614).

4.4.4 Power Stage

The unipolar stepper add-on incorporates the classic two H-bridges drive consisting of four N-type and four P-type MOSFETs. The maximum current rating is 8A on each MOSFET. Please keep this in mind when designing your application or modifying the add-on hardware.

The stage contains eight PWM (ECCP1_A, ECCP2_A, ECCP1_B, ECCP2_B, ECCP1_C, ECCP2_C, ECCP1_D, ECCP2_D) inputs and four driver outputs (W, X, Y, Z) to be attached to the bipolar motor terminals. Outputs W and X should be attached to one motor phase, and outputs Y and Z should be attached to the other motor phase.

The current on each phase is measured using the R8 and R15 shunt resistors, placed in-between each H-bridge lowside and ground and connected to the PIC16F1947 through the J1 connector.

4.4.5 Protection

Two 5A fuses (F1 and F2) are used to protect your add-on in case of an overcurrent situation of the supply voltage. In case one or both of them get burnt, remove power immediately from the board and inspect the add-on for further damage. Do not replace the burnt fuses with other values than the ones provided with the board.

4.4.6 UNI/O® Memory Chip

The UNI/O® memory chip stores the board ID and the application parameters. It is accessed by the Motor Control GUI at start-up in order to recognize which of the four motor control add-on boards had been attached to the F1 LV Evaluation Platform, thus loading the appropriate parameters for the add-on used.

4.4.7 Speed Control

Speed control can be performed through either the Motor Control GUI or the 10K POT R4 located on the F1 LV Evaluation Board.

4.4.8 Current Control

The demo software is implemented for control without an actual current feedback. However, by reading the voltage level on shunt resistors R8 or R15, you can implement a software overcurrent protection and perform current control.

For example, a chopper circuit, perhaps the most used method of current control in motor control drives, can be emulated just by using PIC MCU® modules. The PIC16LF1947 has a Fixed Voltage Reference of 1.024V selectable as an input to the internal 5-bit DAC, which in turn can be used by the internal comparators as a reference on the positive inputs. If we select the minimum 1/32 step in the DAC, we obtain a comparator trigger level of 32 mV, which is sufficient to chop the current to the motor in order to maintain it under its maximum rating given by the motor manufacturer (1A in the case of the Leadshine bipolar stepper).

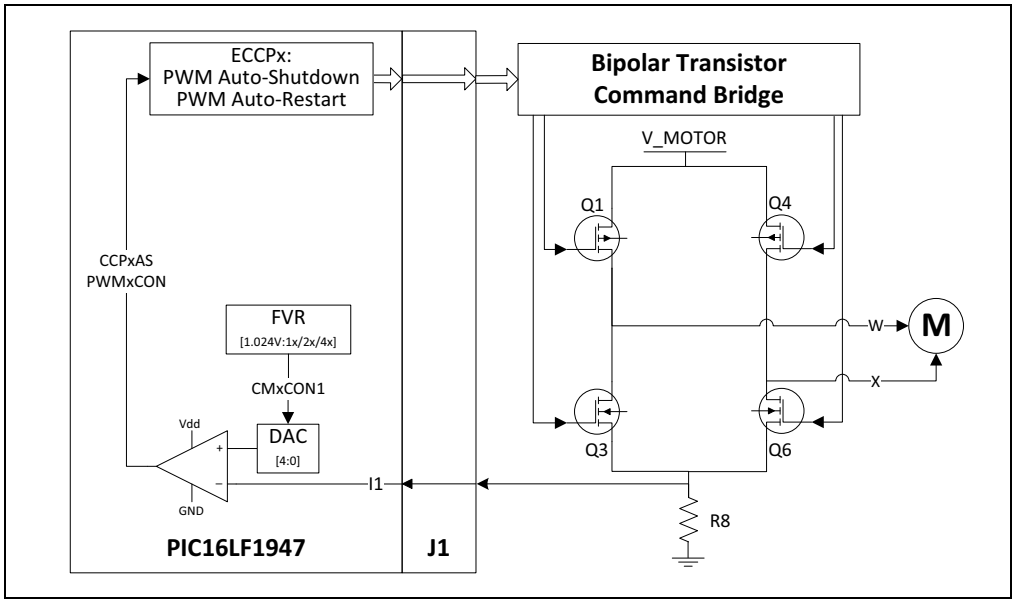
The Enhanced Capture/Compare/PWM modules have built-in features in PWM mode for automatically shutting down the PWM, if the comparators are triggered and auto-restarting the PWM, if certain conditions are met (please consult the PIC16LF1947 data sheet to learn more).

By adjusting the values of the shunt resistors accordingly, you can emulate the chopper circuitry, thus reducing the costs of external components and saving up precious space on your board.

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Figure 4-2 below gives an insight on how to use the PIC MCU modules as part of a current chopper:

FIGURE 4-2: CURRENT CHOPPER CIRCUITRY EMULATED WITH PIC16LF1947 INTERNAL MODULES



4.5 DEMO SOFTWARE

4.5.1 Introduction

The F1 LV evaluation demonstration program uses a single combined demo. The combined demo source code is organized into sectional code for ease of accommodating several motor types. This chapter provides an overview to the functions provided by the bipolar stepper demo.

The bipolar stepper demo code accommodates Full Step, Half Step and Microstep modes of operation. The software can be easily tuned to the needs of your application or motor, by modifying parameters in the Motor Control GUI.

4.5.2 The Motor Control GUI Application

Using the Motor Control Application GUI, you can change the following parameters:

- Speed [arbitrary range 0 to 255]
- Maximum speed [rpm]
- Drive voltage [% of full scale]
- The minimum and maximum PWM duty cycle [% of full scale]
- Motor step angle [degrees]
- Run/Stop hysteresis drive voltage [% of full scale]
- Microstepping granularity [1:4, 1:8, 1:16]
- Microstepping look-up table
- Stepping mode [Wave, Full, Half and Microstep]

Also, the motor can be run in open/closed loop and forward/reverse.

Clicking on the ‘RPM’ text in the **Operate** tab, will display the actual speed in the text box next to it.

4.6 OPTIMIZING STEPPER MOTOR PARAMETERS

4.6.1 Stepper Motor Closed-Loop Drive Overview

Stepper motor closed-loop operation is technically not closed loop. When Closed-Loop mode is selected, then both the motor voltage and speed outputs simultaneously follow the single-speed control input as independent open-loop functions of the minimum and maximum speed and drive parameters. This section describes how to use the GUI to optimize the linked speed and drive functions. First, it's helpful to understand why simultaneous control of speed and voltage is necessary.

It is the nature of stepper motors to be overdriven. In other words, the voltage and current applied to the motor exceeds what is actually needed to rotate the motor. Ideally, the excess drive should be kept to a minimum. When the motor is stationary, the applied voltage needs to be only large enough to keep the motor in position. When there is no external torque applied to the motor, the stationary drive voltage can be as low as zero. In order to rotate the motor, a drive voltage must be applied to the motor coils through drive switches in sequence to progressively rotate the motor to each step position. The PWM duty cycle to the drive switch determines the effective applied voltage. The rate at which the switches are changed is the commutation rate. As the motor speed is increased, it takes more drive voltage and current to maintain speed. If the voltage applied to the motor to maintain the fastest speed were to remain unchanged, then as the motor slowed, the drive current would increase. To minimize excess current, the voltage applied is a function of the commutation rate. For our purposes, the relationship between the applied voltage and commutation rate is linear. The general formula for a linear relationship is:

EQUATION 4-1:

$$Y = mX + b$$

We actually have two linear relationships:

- The relationship between the speed control input and the commutation rate
- The relationship between the speed control input and the PWM duty cycle

The speed control input is an 8-bit number and so has the range from 0 to 255. For any given speed setting, we need to compute both the commutation time and the duty cycle.

For the duty cycle calculation the equation substitutions are as follows:

EQUATION 4-2:

m = DUTY_SCALE

b = MIN_DUTY

X = speed request (0 to 255)

Y = duty cycle value

For the commutation time the equation substitutions are as follows:

EQUATION 4-3:

m = SPEED_SCALING_CONST

b = 0

X = 1/speed request (0 to 255)

Y = Timer 1 counts in each commutation period

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4.6.2 Optimizing DUTY_SCALE and SPEED_SCALING_CONST

The DUTY_SCALE and SPEED_SCALING_CONST are the slope constants of the two equations that determine the drive voltage and commutation rate for any given speed request input. Optimization involves controlling the speed and drive voltage independently to determine the line endpoints. The slope constants can then be calculated from the endpoints.

The purpose of this exercise is to determine the parameters that will limit the drive current over the operating speed range. Therefore, it is necessary to monitor the supply current during optimization. Use the following steps to experiment with your motor optimization:

1. Establish the link between the F1LVDemo application and the F1 LV Evaluation Platform by following the procedure outlined in **Section 1.4.3 "Connecting the F1 LV Evaluation Platform to the Add-on Board"**.
2. In the **Parameters** tab verify that the Deg Per Step value matches that of the motor and change it, if necessary. The supplied Leadshine motor has 1.8 degrees per step.
3. In the **Parameters** tab, select the desired Step mode: Wave, Full, or Half. Microstep is not a valid step mode during optimization.
4. In the **Operate** tab, select Open-Loop mode.
5. Set the Speed slider control to 25.
6. Slowly increase the % Drive slider control until the motor starts rotating smoothly. Observe that the supply current is well below the maximum rating for the motor.
7. Increase the Speed slider until the motor slows or runs erratically.
8. Increase the % Drive until the motor again starts running smoothly.
9. Repeat steps 5 and 6 until no further increase in speed and drive level can be achieved. For example: Upon reaching 100% in the drive level or when increasing the speed causes erratic operation possibly accompanied by increased current draw.
10. When the maximum speed and current is achieved, click on the RPM label and note the RPM indicated. This is the value to be entered in the maximum RPM parameter of the **Parameters** tab.
11. Note the maximum Drive % obtained. This is the value to enter in the Max Duty % parameter of the **Parameters** tab.
12. Press the **STOP** button.
13. Enter the parameters noted in steps 10 and 11. Enter 0 as the Min Duty %.
14. Enter 3 and 2 as the respective initial Run/Stop Percent values. The motor will run when the Drive % value is above the Run value and stop operating when the Drive % value is below the Stop value.
15. Select Closed-Loop mode and try operating the motor with the Speed slider control.
16. If the motor operation changes smoothly over the entire operating range and current stays reasonably constant then optimization is complete.
17. If the motor runs erratically at slow speed then note the drive level at which the motor runs smoothly and enter that value as the Run start value. Enter a value slightly lower than the Run value in the Stop value and repeat steps 15 and 16. The low speed drive can be increased by increasing the Min Duty parameter to equal the Run percent start value.

NOTES:

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Chapter 5. The Unipolar Stepper Add-on Board

5.1 GETTING STARTED

5.1.1 Overview

The unipolar stepper add-on (DM164130-7) allows you to drive common two-phase unipolar stepper motors used in consumer electronics, ranging from CNCs, printers, optical disc drives and small load positioning systems. The add-on is shipped together with the Leadshine 42HS03 unipolar stepper motor pre-wired to plug directly into add-on connector J3. Alternatively, any other 5-12V unipolar stepper motor can be used by hooking it up through the J3 connector.

5.1.2 Features

The key features of this board include the following:

Connectors:

- Male 20-pin connector (J1) to match the F1 LV Evaluation Platform
- Generic 8-pin unipolar stepper motor connector(J3)
- 5-12V power supply input connector (J2)

Typical Unipolar Stepper drive:

- Four N-type MOSFETs, one for each motor winding end
- One sensing resistor for current measurement (R3).

Protection:

- 2x5A power fuses (F1, F2)

Power Supply:

- 3.3V voltage regulator (U1)

Parameter Storage:

- 1k x 8 UNI/O® Serial EEPROM (U2)

5.1.3 What's Included

The unipolar stepper add-on with part number DM164130-7 contains:

- Unipolar Stepper Add-on Board designed for the F1 Evaluation Platform
- Leadshine motor (P/N: 42HS03)

5.1.4 Reference Documents

This section points you to application technical support.

AN907, *"Stepping Motors Fundamentals"*

AN906, *"Stepper Motor Control Using the PIC16F684"*

AN822, *"Stepper Motor Microstepping with PIC18C452"*

AN1307, *"Stepper Motor Control with dsPIC® DSCs"*

You can obtain these reference documents from your nearest Microchip sales office (listed in the last page of this document) or by downloading them from the Microchip web site.

5.2 GETTING STARTED

WARNING

The Unipolar Motor Control Add-on Board is intended to drive 3-phased unipolar stepper motors. Before connecting the motor, make sure the power rating of the motor is equal to or less than the power rating of the board, as shown in Appendix B. "Conversion Factors". Also, make sure the configuration parameters inside the software or the GUI are correct for the motor you are using. Failure to comply with this warning could lead to malfunction of the board and the motor, and could result in physical harm.

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.

A step-by-step connecting procedure is available in **Section 1.4.3 "Connecting the F1 LV Evaluation Platform to the Add-on Board"**. Please make sure that POT R4 on the F1 Evaluation Platform is turned fully CCW.

If using a different motor, connected through J3, please keep in mind to attach each motor phase firmly to the connector. Bad contacts can damage the add-on and, in time, will wear out the motor. There is no rule for attaching a specific motor lead to a phase line on the add-on. Keep in mind the correspondences on the software side when testing or measuring directly on that motor phase.

On the F1 LV Evaluation Platform use push button **RD2** to step through the application menu on the LCD display. To have more control over the motor using a real-time communication tool, please refer to the next section.

5.3 HARDWARE

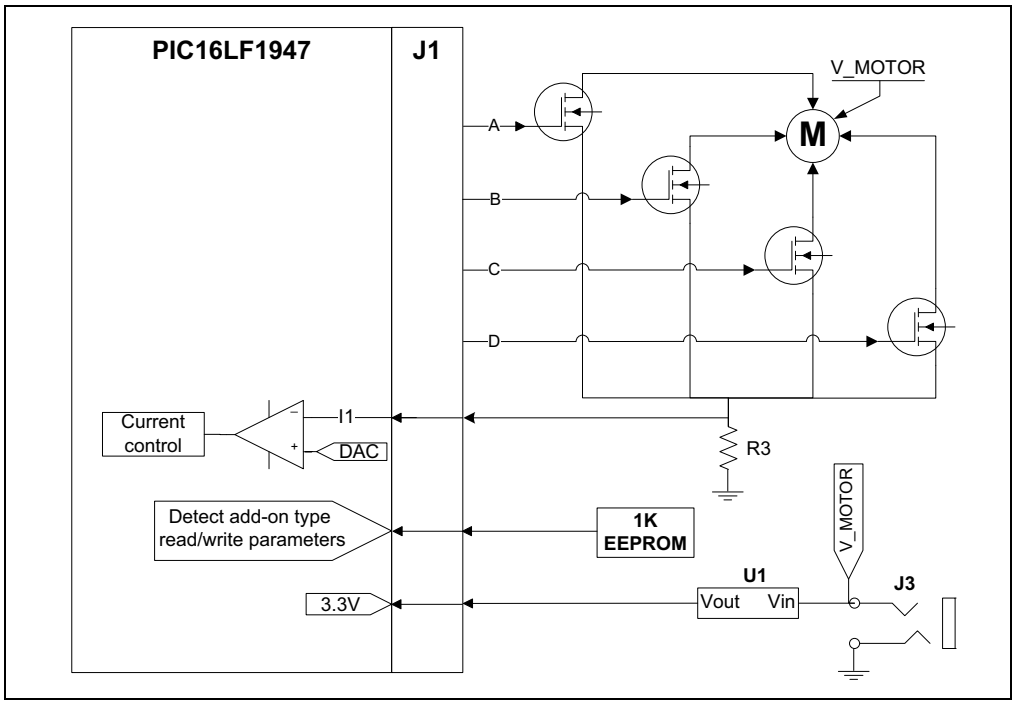
5.3.1 General Architecture

The unipolar stepper add-on uses a simple unipolar stepper drive formed by four independent N-type MOSFETs suitable for two-phase unipolar stepper motors. Open-loop control, closed-loop control, full step, half step, microstepping commutation can be done in the software.

Figure 5-1 provides a simplified block diagram of the development board hardware, coupled to the F1 LV Evaluation Platform:

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FIGURE 5-1: THE UNIPOLAR STEPPER MOTOR CONTROL ADD-ON ARCHITECTURE



5.3.2 Attaching the Motor

The unipolar stepper add-on kit includes the two-phase Leadshine 42HS03 unipolar stepper motor. Since this motor is a hybrid stepper, it can be configured as a unipolar or bipolar stepper motor, by connecting its eight leads in different ways. The motor is supplied pre-wired in the unipolar configuration to a connector that mates with J3 of the add-on board. For bipolar series and parallel connections, please refer to the motor data sheet. The Unipolar Add-on Board, however, supports only the unipolar configuration.

5.3.3 Power-Up

Power is supplied through either the J2 2.5 mm power jack, or the power pins of J3. The default motor parameters assume that the supply voltage is 9 VDC. Changing the supply voltage will require re-optimizing the motor parameters. Monitoring the supply current during optimization is highly recommended to prevent over-driving the motor.

The F1 LV Evaluation Platform must be configured to use expansion board power by inserting the power jumper on J6. See the F1 LV Evaluation Platform User's Guide for more detail.

5.3.4 Power Stage

The unipolar stepper add-on incorporates the classic two H-bridges drive consisting of four N-type and four P-type MOSFETs. The maximum current rating is 8A on each MOSFET. Please keep this in mind when designing your application or modifying the add-on hardware.

The stage contains four PWM (ECCP1_A, ECCP2_A, ECCP1_B, ECCP2_B, ECCP1_C, ECCP2_C, ECCP1_D, ECCP2_D) inputs and four drive outputs (W, X, Y, Z) to be attached to the end of each phase of the unipolar stepper motor.

The current on each phase is measured using the R3 shunt resistor, placed in between the common lowside of all the drivers and ground, and connected to the PIC16F1947 through the J1 connector.

5.3.5 Protection

Two 5A fuses (F1 and F2) are used to protect your add-on in case of an overcurrent situation of the supply voltage. In case one or both of them get burnt, remove power immediately from the board and inspect the add-on for further damage. Do not replace the burnt fuses with other values than the ones provided with the board.

5.3.6 UNI/O® Memory Chip

The UNI/O® memory chip stores the board ID and the application parameters. It is accessed by the Motor Control GUI at start-up in order to recognize which of the four motor control add-on boards had been attached to the F1 LV Evaluation Platform, thus loading the appropriate parameters for the add-on used.

5.3.7 Speed Control

Speed control can be performed through either the Motor Control GUI or the 10K POT R4 located on the F1 LV Evaluation Board.

5.3.8 Current Control

The demo software is intended for control without an actual current feedback. However, by reading the voltage level on shunt resistor R3, you can implement a software overcurrent protection and perform current control.

For example, a chopper circuit, perhaps the most used method of current control in motor control drives, can be emulated just by using PIC MCU modules. The PIC16LF1947 has a Fixed Voltage Reference of 1.024V selectable as an input to the internal 5-bit DAC, which in turn can be used by the internal comparators as a reference on the positive inputs. If we select the minimum 1/32 step in the DAC we obtain a comparator trigger level of 32mV, which is sufficient to chop the current to the motor in order to maintain it under its maximum rating given by the motor manufacturer (1A in the case of the Leadshine unipolar stepper).

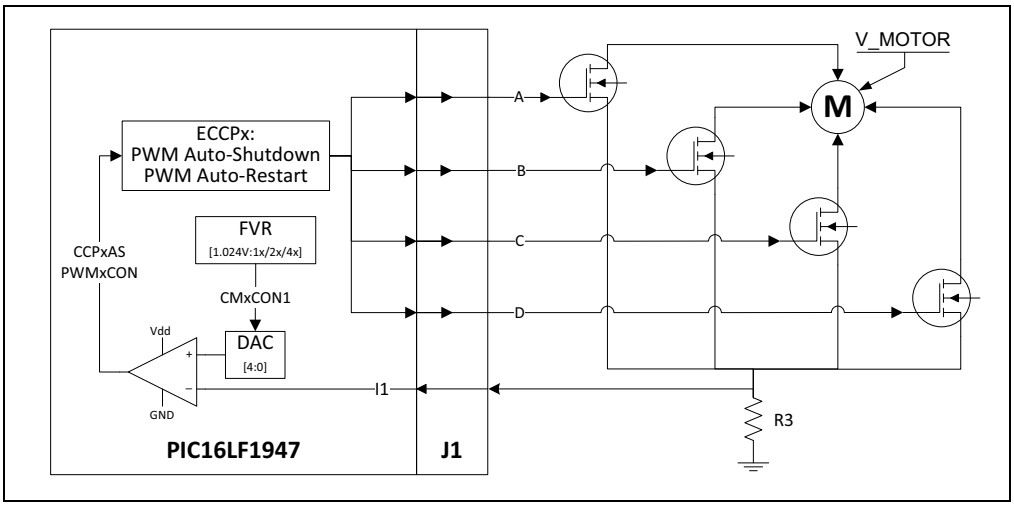
The Enhanced Capture/Compare/PWM modules have built-in features in PWM mode for automatically shutting down the PWM if the comparators are triggered and auto-restarting the PWM if certain conditions are met (please consult the PIC16LF1947 data sheet to learn more).

By adjusting the values of the shunt resistors accordingly, you can emulate the chopper circuitry, thus reducing the costs of external components and saving up precious space on your board.

Figure 5-2 below gives an insight on how to use the PIC MCU modules as parts of a current chopper:

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FIGURE 5-2: CURRENT CHOPPER CIRCUITRY EMULATED WITH PIC16LF1947 INTERNAL MODULES



5.4 DEMO SOFTWARE

5.4.1 Introduction

The F1 LV Evaluation demonstration program uses a single combined demo. The combined demo source code is organized into sectional code for ease of accommodating several motor types. This chapter provides an overview to the functions provided by the unipolar stepper demo.

The unipolar stepper demo code accommodates Full Step, Half Step and Microstep modes of operation. The software can be easily tuned to the needs of your application or motor by modifying parameters in the Motor Control GUI.

5.4.2 The Motor Control GUI Application

Using the Motor Control Application GUI, you can change the following parameters:

- Speed [arbitrary range 0 to 255]
- Maximum speed [rpm]
- Drive voltage [% of full scale]
- The minimum and maximum PWM duty cycle [% of full scale]
- Motor step angle [degrees]
- Run/Stop hysteresis drive voltage [% of full scale]
- Microstepping granularity [1:4, 1:8, 1:16]
- Microstepping look-up table
- Stepping mode [Wave, Full, Half and Microstep]

Also, the motor can be run in open/closed loop and forward/reverse.

Clicking on the ‘RPM’ text in the **Operate** tab, will display the motor speed in the text box next to it.

5.5 OPTIMIZING STEPPER MOTOR PARAMETERS

5.5.1 Stepper Motor Closed-Loop Drive Overview

Stepper motor closed-loop operation is technically not closed loop. When Closed-Loop mode is selected, then both the motor voltage and speed outputs simultaneously follow the single-speed control input as independent open-loop functions of the minimum and maximum speed and drive parameters. This section describes how to use the GUI to optimize the linked speed and drive functions. First, it's helpful to understand why simultaneous control of speed and voltage is necessary.

It is the nature of stepper motors to be overdriven. In other words, the voltage and current applied to the motor exceeds what is actually needed to rotate the motor. Ideally, the excess drive should be kept to a minimum. When the motor is stationary, the applied voltage needs to be only large enough to keep the motor in position. When there is no external torque applied to the motor, the stationary drive voltage can be as low as zero. In order to rotate the motor, a drive voltage must be applied to the motor coils through drive switches in sequence to progressively rotate the motor to each step position. The PWM duty cycle to the drive switch determines the effective applied voltage. The rate at which the switches are changed is the commutation rate. As the motor speed is increased, it takes more drive voltage and current to maintain speed. If the voltage applied to the motor to maintain the fastest speed were to remain unchanged, then as the motor slowed, the drive current would increase. To minimize excess current, the voltage applied is a function of the commutation rate. For our purposes, the relationship between the applied voltage and commutation rate is linear. The general formula for a linear relationship is:

EQUATION 5-1:

$$Y = mX + b$$

We actually have two linear relationships:

- The relationship between the speed control input and the commutation rate
- The relationship between the speed control input and the PWM duty cycle

The speed control input is an 8-bit number and so has the range from 0 to 255. For any given speed setting, we need to compute both the commutation time and the duty cycle.

For the duty cycle calculation the equation substitutions are as follows:

EQUATION 5-2:

m = DUTY_SCALE

b = MIN_DUTY

X = speed request (0 to 255)

Y = duty cycle value

For the commutation time, the equation substitutions are as follows:

EQUATION 5-3:

m = SPEED_SCALING_CONST

b = 0

X = 1/speed request (0 to 255)

Y = Timer 1 counts in each commutation period

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5.5.2 Optimizing DUTY_SCALE and SPEED_SCALING_CONST

The DUTY_SCALE and SPEED_SCALING_CONST are the slope constants of the two equations that determine the drive voltage and commutation rate for any given speed request input. Optimization involves controlling the speed and drive voltage independently to determine the line end points. The slope constants can then be calculated from the end points.

The purpose of this exercise is to determine the parameters that will limit the drive current over the operating speed range. Therefore, it is necessary to monitor the supply current during optimization. Use the following steps to experiment with your motor optimization:

1. Establish the link between the F1LVDemo application and the F1 LV Evaluation Platform by following the procedure outlined in **Section 1.4.3 "Connecting the F1 LV Evaluation Platform to the Add-on Board"**.
2. In the **Parameters** tab verify that the Deg Per Step value matches that of the motor and change it, if necessary. The supplied Leadshine motor has 1.8 degrees per step.
3. In the **Parameters** tab, select the desired Step mode: Wave, Full, or Half. Microstep is not a valid step mode during optimization.
4. In the **Operate** tab, select Open-Loop mode.
5. Set the Speed slider control to 25.
6. Slowly increase the % Drive slider control until the motor starts rotating smoothly. Observe that the supply current is well below the maximum rating for the motor.
7. Increase the Speed slider until the motor slows or runs erratically.
8. Increase the % Drive until the motor again starts running smoothly.
9. Repeat steps 5 and 6 until no further increase in speed and drive level can be achieved. For example: Upon reaching 100% in the drive level or when increasing the speed causes erratic operation possibly accompanied by increased current draw.
10. When the maximum speed and current is achieved, then click on the RPM label and note the RPM indicated. This is the value to be entered in the Max RPM parameter of the **Parameters** tab.
11. Note the maximum Drive % obtained. This is the value to enter in the Max Duty % parameter of the **Parameters** tab.
12. Press the **STOP** button.
13. Enter the Parameters noted in steps 10 and 11. Enter 0 as the Min Duty %.
14. Enter 3 and 2 as the respective initial Run/Stop Percent values. The motor will run when the Drive % value is above the Run value and stop operating when the Drive % value is below the Stop value.
15. Select Closed-Loop mode and try operating the motor with the Speed slider control.
16. If the motor operation changes smoothly over the entire operating range and current stays reasonably constant then optimization is complete.
17. If the motor runs erratically at slow speed then note the drive level at which the motor runs smoothly and enter that value as the Run start value. Enter a value slightly lower than the Run value in the Stop value and repeat steps 15 and 16. The low speed drive can be increased by increasing the Min Duty parameter to equal the Run percent start value.

NOTES:

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Appendix A. Board Layout and Schematics

A.1 INTRODUCTION

This appendix contains the F1 LV board layout and schematics.

FIGURE A-1: F1 UNIPOLAR STEPPER MOTOR ADD-ON (SHEET 1 OF 5)

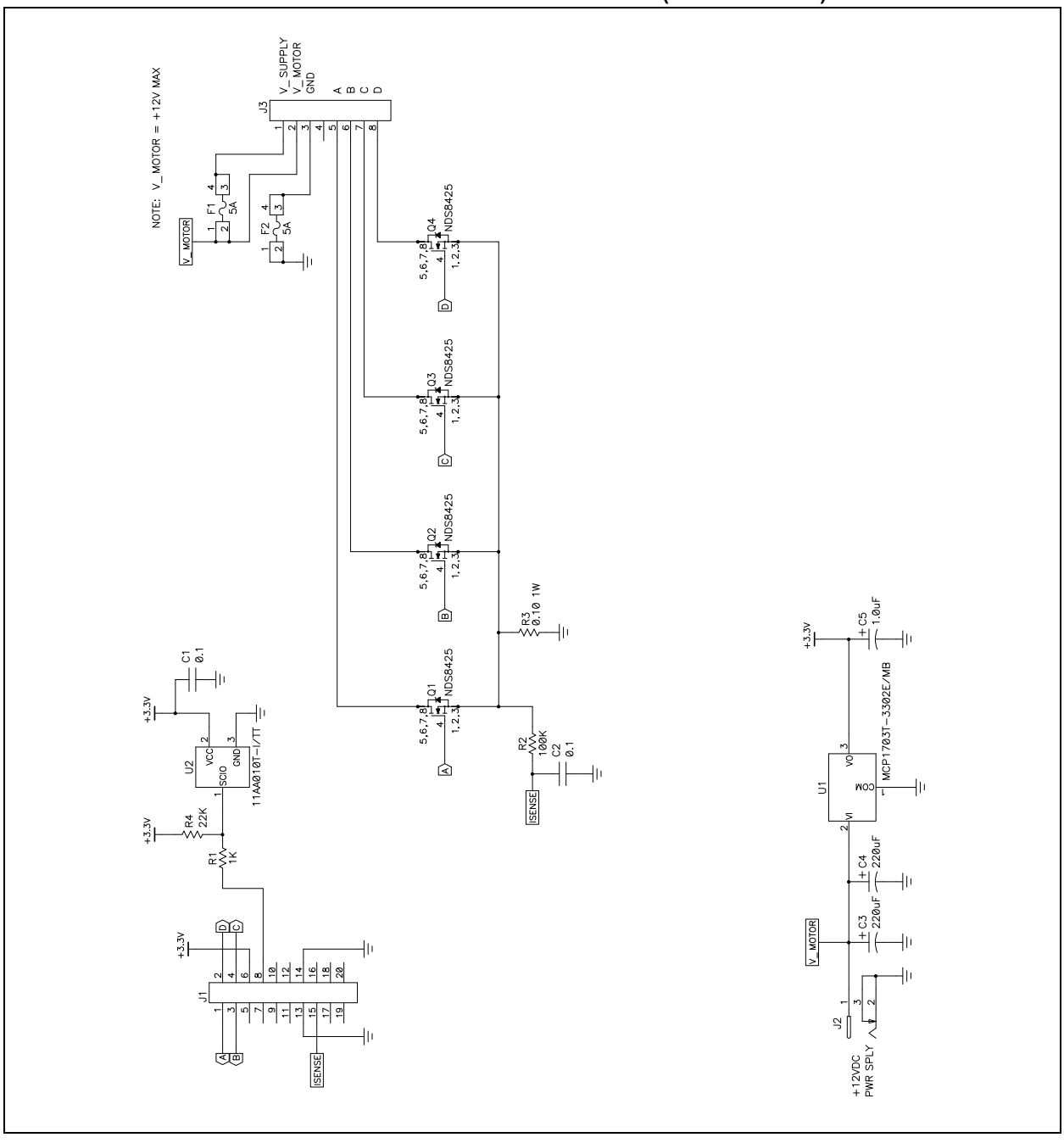
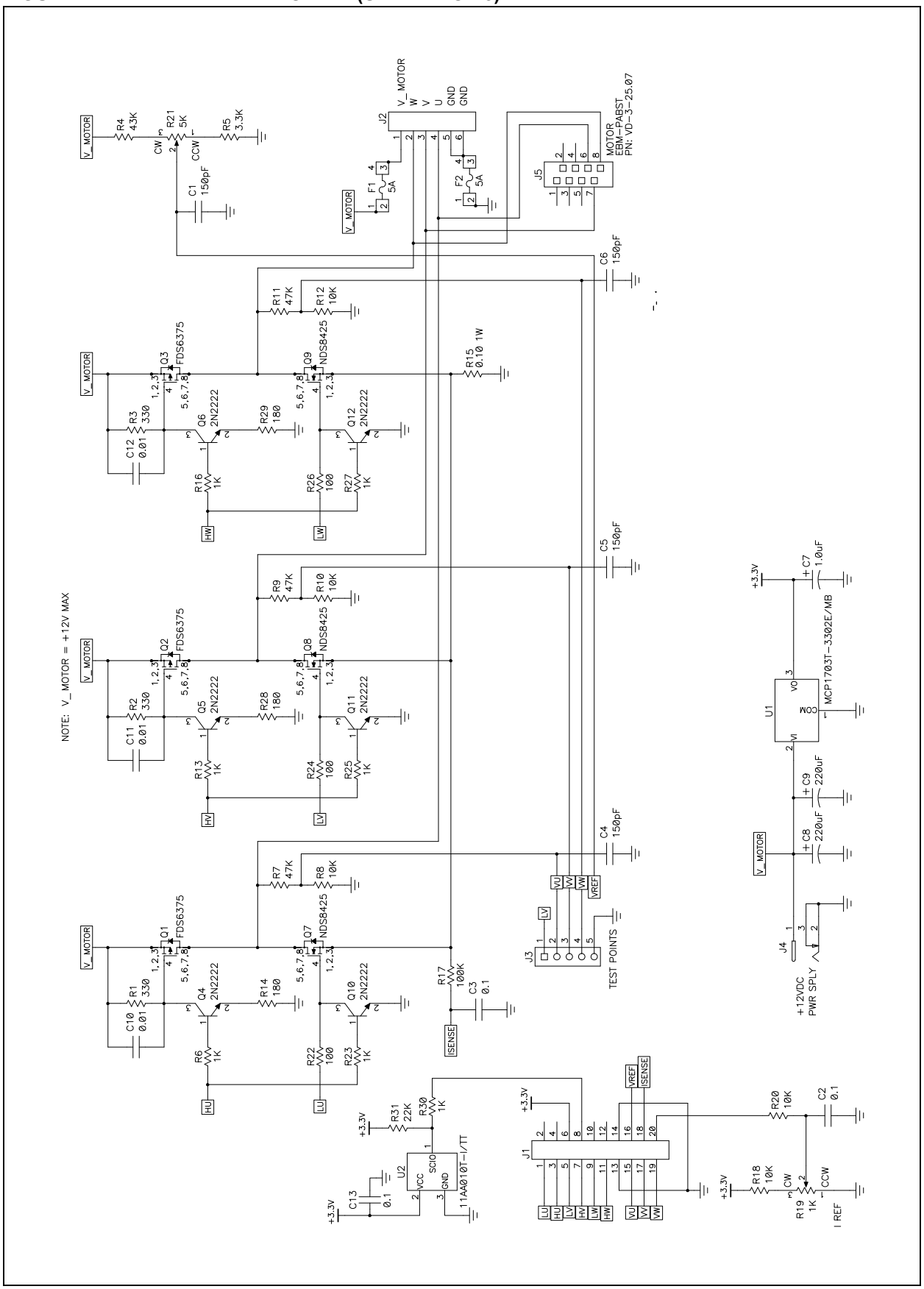


FIGURE A-2: BLDC ADD-ON BD (SHEET 2 OF 5)



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FIGURE A-3: F1 BIPOLAR STEPPER MOTOR ADD-ON (SHEET 3 OF 5)

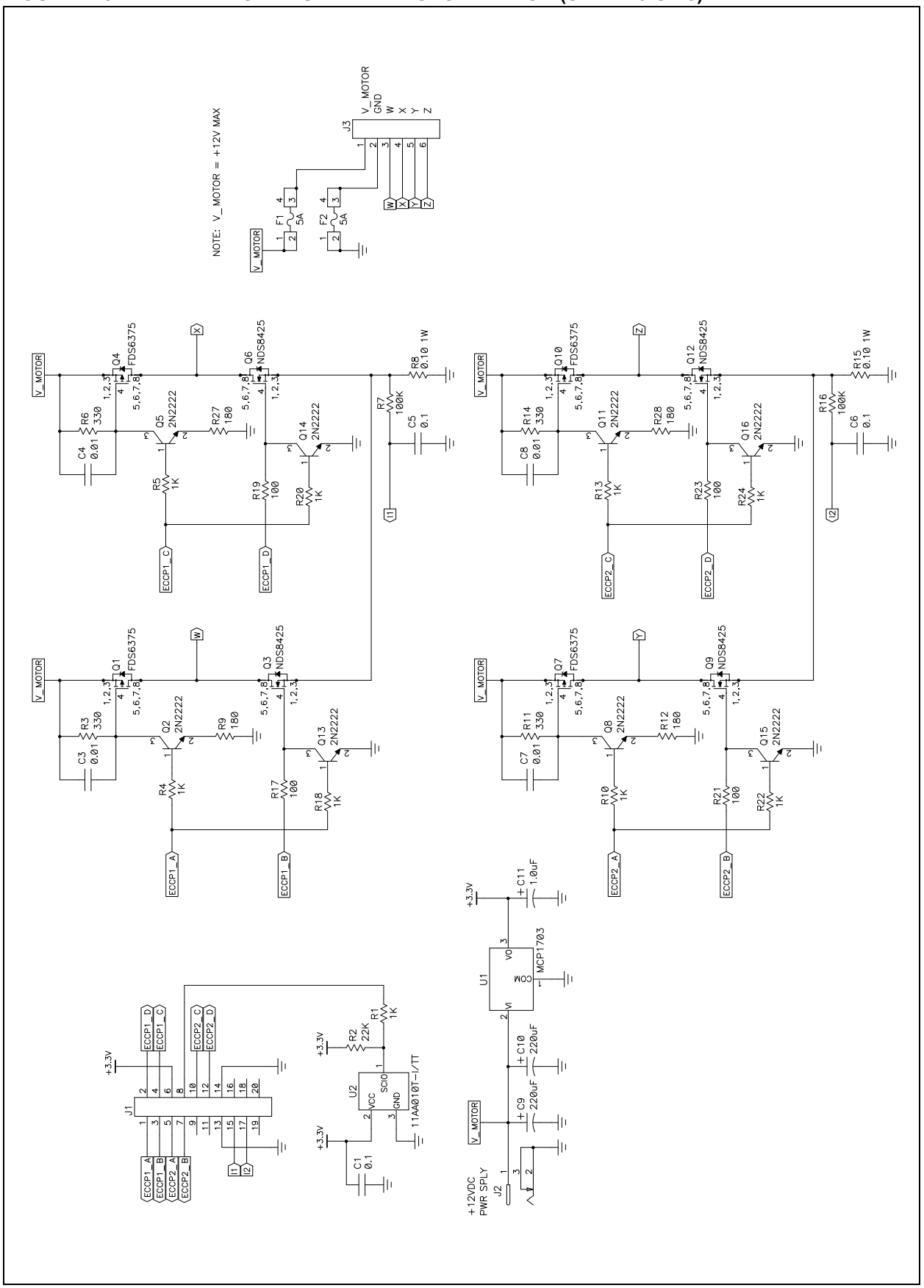
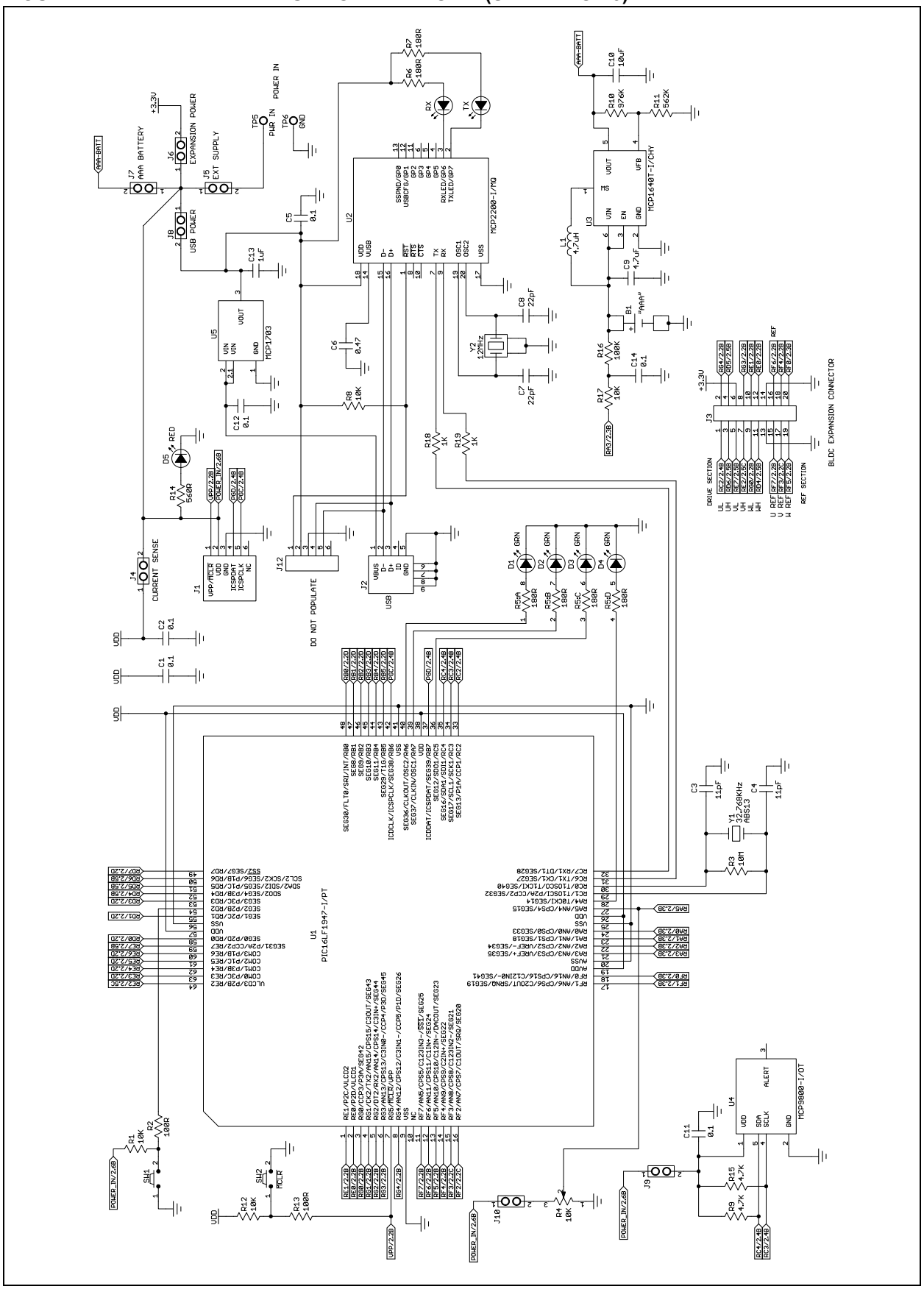
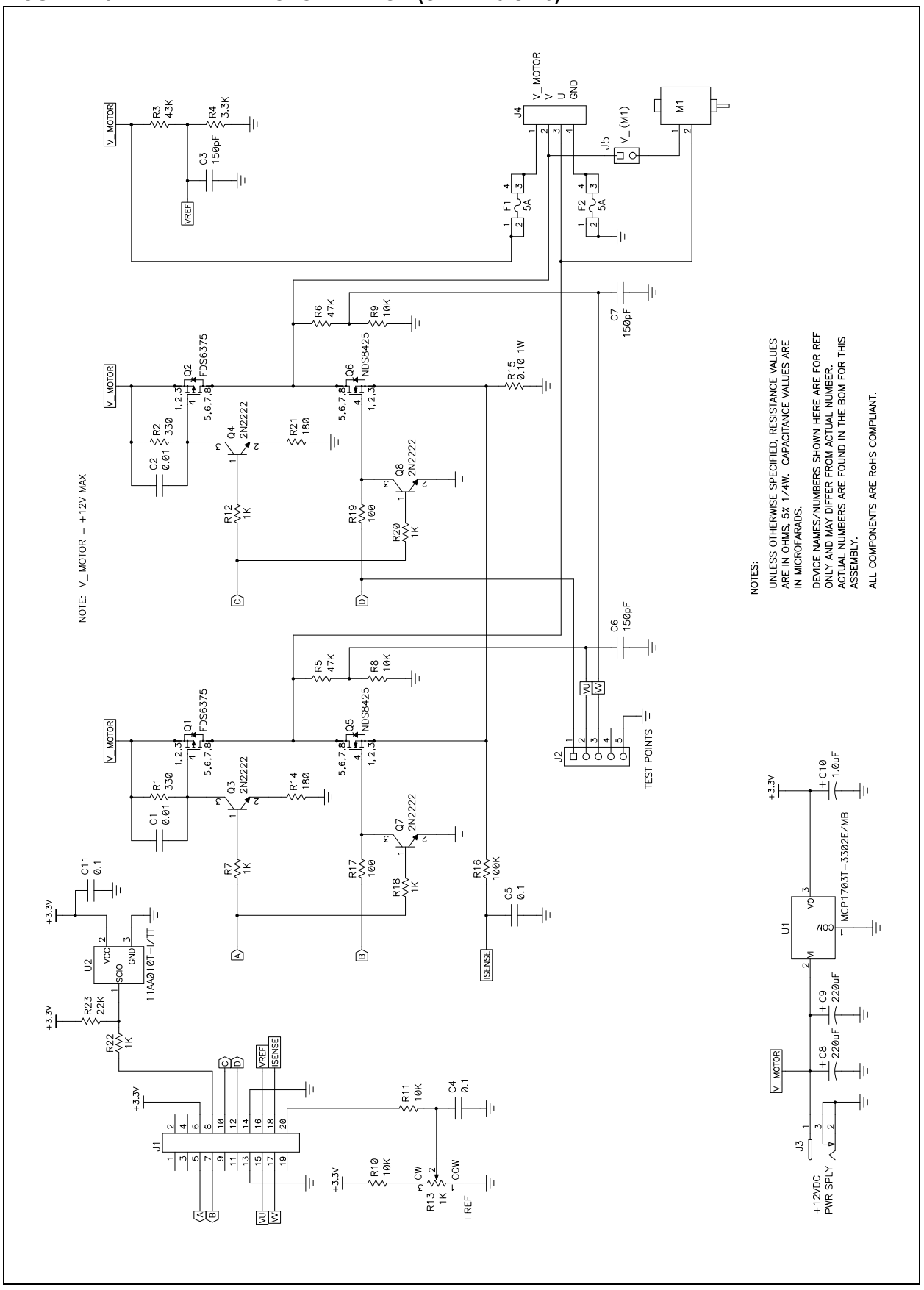


FIGURE A-4: F1 FV EVALUATION PLATFORM (SHEET 4 OF 5)



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FIGURE A-5: F1 BDC MOTOR ADD-ON (SHEET 5 OF 5)



NOTES:

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Appendix B. Conversion Factors

B.1 SYSTEM CONSTANTS

Many of the conversion factors are based on operating parameters of the PIC® microcontroller. Those parameters are determined at compile time and are assumed to be fixed. The fixed parameters and their associated values are as follows:

TABLE B-1:

Parameter	Value
FOSC	32 MHz
System Frequency	FOSC/4
Timer 1 Prescale	8
Timer 1 Frequency	System Frequency/Timer 1 Prescale
Timer 2 Prescale	4
Timer 2 Frequency	System Frequency/Timer 2 Prescale
BLDC Phases	3
Max. Speed Request	255

B.2 START-UP: SPEED

The start-up commutation speed is the initial commutation period expressed as Timer1 counts. The number entered in the Speed box is the inverse (16-bit number negative) of initial commutation period divided by 256 (upper 8 bits of a 16-bit number). The use of the inverse can be explained as follows: Because it is natural to think of small values as slow and large values as fast, the open-loop speed control starts at 0 and tops out at 255. The commutation time counter, however, operates on the inverse of the Speed Control value, because long commutation times result in slower speeds than short commutation times. The RPM derived from the commutation period is computed as follows:

EQUATION B-1:

$$\text{Commutation Period} = 65536 - (\text{Speed Control Value} * 256)$$

$$\text{RPM} = 60 * \text{Timer1 Frequency} / (\text{NumberOfPoles} * \text{BLDC Phases} * \text{Commutation Period})$$

B.3 SLOW STEP

The slow-step dwell time is measured in TimeBaseManager() time-ticks which are derived from Timer0. The TimeBaseManager() sets time-elapsed flags at every 10 millisecond time-tick. The various routines monitor the TimeBaseManager() flags to determine when to perform their service. Divide the Slow-Step time by the TimeBaseManager() time-tick to determine the TIMEBASE_SLOW_STEP count.

EQUATION B-2:

$$\text{TIMEBASE_SLOW_STEP} = \text{Slow Step Time (ms)} * \text{TimeBaseManager() time-tick}$$

B.4 STEPPER RUN AND STOP PERCENTAGES

The Run and Stop thresholds in the stepper motor include files are expressed as raw speed request numbers. The speed request is an 8-bit unsigned integer entered either from the Analog-to-Digital conversion of the potentiometer voltage, or specified directly from the PC controller through the serial input. The maximum speed request is the maximum value of a byte or 255. The conversion factor to convert the raw speed request to a percentage is 100 divided by the maximum speed request number.

EQUATION B-3:

Request Percent = Raw Request Value * 100 / Maximum Request Value

Request Percent = Raw Request Value * 100 / 255

B.5 DEGREES PER STEP

The assembler works only with integer math. Therefore, the header files specify all values as integers. In order to maintain the full resolution of floating point numbers, floating point values are multiplied by factors of 10 so they can be expressed as integer values. Motor step angles are multiplied by 10 to achieve the desired step angle resolution of 0.1 degree.

EQUATION B-4:

MOTOR_STEP_ANGLE = Degrees per step * 10

Degrees per step = MOTOR_STEP_ANGLE * 0.1

B.6 STEPPER: MIN AND MAX DUTY PERCENT

The mininum and maximum duty cycle percentages are based on the maximum duty cycle value of 255. For all drive modes, except microstepping, the 8-bit duty cycle value is translated to the 10 bits required for the PWM by the LinearSpeedProfile look-up table. The MIN_DUTY and MAX_DUTY header file parameters are specified as inputs to the look-up table. In other words, a MAX_DUTY parameter of 255 equates to 100% duty cycle.

EQUATION B-5:

Min Duty Percent = MIN_DUTY * 100 / 255

Max Duty Percent = MAX_DUTY * 100 / 255

B.7 CONSTANTS DERIVED FROM STEPPER PARAMETERS

The stepper motor parameter optimization section introduced two constants not shown in the GUI parameters. Both constants are computed from the other parameters at compile time and saved for use during execution. In fact, the parameters that define these two constants are not accessible during program execution. Only the constants are necessary.

B.7.1 DUTY_SCALE Constant

The DUTY_CYCLE constant is multiplied by 256 for use in the scaling computation. The final result of the scaling multiplication is therefore 256 times larger than needed. This maintains the 8-bit resolution for the parameter and forgoes the need for floating point calculations during execution. Final reduction of the multiplication is simply a matter of using the Most Significant Byte of the result. The DUTY_CYCLE constant is defined as follows:

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EQUATION B-6:

$$DUTY_CYCLE = (MAX_DUTY - MIN_DUTY + 1) * 256 / Max\ Speed\ Request$$

The 256 factor in the numerator is the multiplier which scales the result up by one byte width. Max Speed Request normalizes the constant to the speed request range. Notice that Max Speed Request is 255, which is approximately equal to the 256 multiplier. The difference is insignificant, so the 256 multiplier cancels out the Max Speed Request, allowing the DUTY_CYCLE to be stored as an 8-bit integer.

B.7.2 SPEED_SCALING_CONST Constant

The SPEED_SCALING_CONST is used to convert the speed request to the number of Timer1 counts in one commutation period. The SPEED_SCALING_CONST is a function of:

- Timer1 frequency
- Motor degrees per step
- Maximum speed request
- Maximum motor speed when the maximum drive voltage is applied

EQUATION B-7:

$$SPEED_SCALING_CONST = Timer\ 1\ Frequency * Max\ Speed\ Request * Motor\ Degrees\ Per\ Step * 60 / 360 * Max\ RPM$$
$$SPEED_SCALING_CONST = Timer\ 1\ Frequency * Motor\ Degrees\ Per\ Step * 255 / (6 * Max\ RPM)$$

The SPEED_SCALING_CONST is stored as a 32-bit integer.

B.8 USTEP TABLE

In order to understand the microstep drive table values, you must first understand how the PWM period duty cycle is generated: The output drive goes active at the beginning of the PWM period, and is forced inactive part way through the period by the value of a timer. The ratio of the active time relative to the PWM period is the duty cycle.

The PWM period is determined by the Timer2 frequency and PR2 register. Timer2 counts up to the value of PR2 then resets. The active drive period is determined by the 8-bit value in CCPR1L plus two more bits in CCP1CON. Two Least Significant bits of Timer2 extend beyond the 8-bit Timer2 register (TMR2), and are used to compare with the two CCP1CON bits mentioned. The CCP output drive is active from when Timer2 resets until the count reaches CCPR1L. The output drive remains inactive for the remainder of the counts until Timer2 resets at the value of PR2.

The longest PWM period, for which there are 256 TMR2 counts, is achieved when PR2 is the maximum value. All 8 bits can be resolved for the duty cycle when PR2 is set to the maximum. There are two additional Least Significant resolution bits in the CCP1CON register, DCB0 and DCB1, which extend the duty cycle resolution to a maximum of 10 bits. Frequencies higher than the lowest require a PR2 value less than the maximum. Anything less than the maximum value in PR2 will reduce the duty cycle resolution.

In our system, the PWM frequency is 16 kHz. The PR2 value to achieve this is 0x7D or 125 decimal. Actually, PR2 is set to 0x7C so that a 100% duty cycle is achieved when 0x7D is placed in the CCPR1L register. All values up to 0x7C can be expressed with 7 bits. Those 7 bits plus the two Least significant bits in the CCP1CON register yield a 9-bit duty cycle resolution. We use only the Most Significant 8 bits of the 9, because it reduces the size and complexity of the microstepping look-up tables. Considering that the maximum 7-bit PR2 value for 16 kHz operation is 125, then the 8-bit maximum value (7 bits for CCPR1L and 1 bit for DCB1) is 250.

During microstepping, the LinearSpeedProfile look-up table is not used: The drive values go directly from the microstep table into the CCP duty cycle registers without any additional scaling. The microstepping tables consist of pre-scaled sine wave data for one quarter of a full cycle. The factory default scaling factor for the two types of stepper motors is 100% for the bipolar (250 maximum), and 50% for the unipolar (125 maximum). No scaling information about the table values residing in the Platform memory is available to the GUI, therefore the “uStep %” box is blank. You have only the option of generating a new table based on the scaling factor entered in the “uStep %” box. When you generate a new microstep table, then the values are immediately placed in the Platform RAM and will be lost at the next Reset. To make the new table values endure Resets replace the EEPROM values with the new table values by selecting the pull-down *File->RAM->EEPROM* option after creating the new table.

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