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**dsPIC33EDV64MC205  
Motor Control Development Board  
User's Guide**

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# dsPIC33EDV64MC205 Motor Control Development Board User's Guide

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NOTES:



# dsPIC33EDV64MC205 MOTOR CONTROL DEVELOPMENT BOARD USER'S GUIDE

## 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 website ([www.microchip.com](http://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 “DSXXXXXXXXA”, where “XXXXXXXX” 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 preface contains general information that will be useful to know before using the dsPIC33EDV64MC205 Motor Control Development Board. Topics discussed in this preface include:

- [Document Layout](#)
- [Conventions Used in this Guide](#)
- [Recommended Reading](#)
- [The Microchip Website](#)
- [Product Change Notification Service](#)
- [Customer Support](#)
- [Document Revision History](#)

### DOCUMENT LAYOUT

The user's guide describes the dsPIC33EDV64MC205 Motor Control Development Board. The document is organized as follows:

- **Chapter 1. “Introduction”** – This chapter introduces the board and provides a brief overview of its features.
- **Chapter 2. “Board Interface”** – This chapter provides information about the board input and output interfaces.
- **Chapter 3. “Hardware”** – This chapter describes the hardware sections of the board.
- **Appendix A. “Board Layout and Schematics”** – This appendix provides board schematics and layout.
- **Appendix B. “Electrical Specifications”** – This appendix summarizes the electrical specifications.
- **Appendix C. “Design Calculation”** – This appendix provides design calculations for certain hardware sections.

## CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

### DOCUMENTATION CONVENTIONS

Description	Represents	Examples
<b>Arial font:</b>		
Italic characters	Referenced books	<i>MPLAB<sup>®</sup> IDE User's Guide</i>
	Emphasized text	...is the <i>only</i> compiler...
Initial caps	A window	the Output window
	A dialog	the Settings dialog
	A menu selection	select Enable Programmer
Quotes	A field name in a window or dialog	"Save project before build"
Underlined, italic text with right angle bracket	A menu path	<u><i>File&gt;Save</i></u>
Bold characters	A dialog button	Click <b>OK</b>
	A tab	Click the <b>Power</b> 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>
<b>Courier New font:</b>		
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	<i>file.o</i> , where <i>file</i> can be any valid filename
Square brackets [ ]	Optional arguments	mcc18 [options] <i>file</i> [options]
Curly braces 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) { ... }

## RECOMMENDED READING

This user's guide describes how to use the dsPIC33EDV64MC205 Motor Control Development Board. The device-specific data sheet contains current information on programming the specific microcontroller or Digital Signal Controller (DSC) devices. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources:

### **MPLAB® XC16 C Compiler User's Guide (DS50002071)**

This user's guide describes how to use the 16-bit MPLAB® XC16 C Compiler. Please visit [www.microchip.com/compilers](http://www.microchip.com/compilers) for more information.

### **MPLAB® X IDE User's Guide (DS50002027)**

This document describes how to set up the MPLAB® X IDE software and use it to create projects and program devices.

### **MPLAB® XC16 Assembler, Linker and Utilities User's Guide (DS50002106)**

This user's guide describes how to use GNU language tools to write code for 16-bit applications.

### **Readme Files**

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

### **dsPIC33EDV64MC205 Data Sheet (DS70005292)**

This document provides device-specific information for the dsPIC33EDV64MC205, 16-Bit Digital Signal Controller with High-Speed PWM, Op Amps, Advanced Analog and MOSFET Driver.

### **dsPIC33 Family Reference Manuals**

Specific Family Reference Manuals (FRMs) are available for each module, which explains the operation of the dsPIC® DSC MCU family architecture and peripheral modules. The specifics of each device family are discussed in their data sheet.

To obtain any of these documents, visit the Microchip website at: [www.microchip.com](http://www.microchip.com).

## THE MICROCHIP WEBSITE

Microchip provides online support via our website at [www.microchip.com](http://www.microchip.com). This website is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the website contains the following information:

- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

## PRODUCT CHANGE NOTIFICATION SERVICE

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To register, access the Microchip website at [www.microchip.com](http://www.microchip.com), click on **Product Change Notification** and follow the registration instructions.

## CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

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

Customers should contact their distributor, representative or FAE for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the website at: <http://support.microchip.com>.

## DOCUMENT REVISION HISTORY

### Revision A (November 2019)

This is the initial released version of the document.



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## Chapter 1. Introduction

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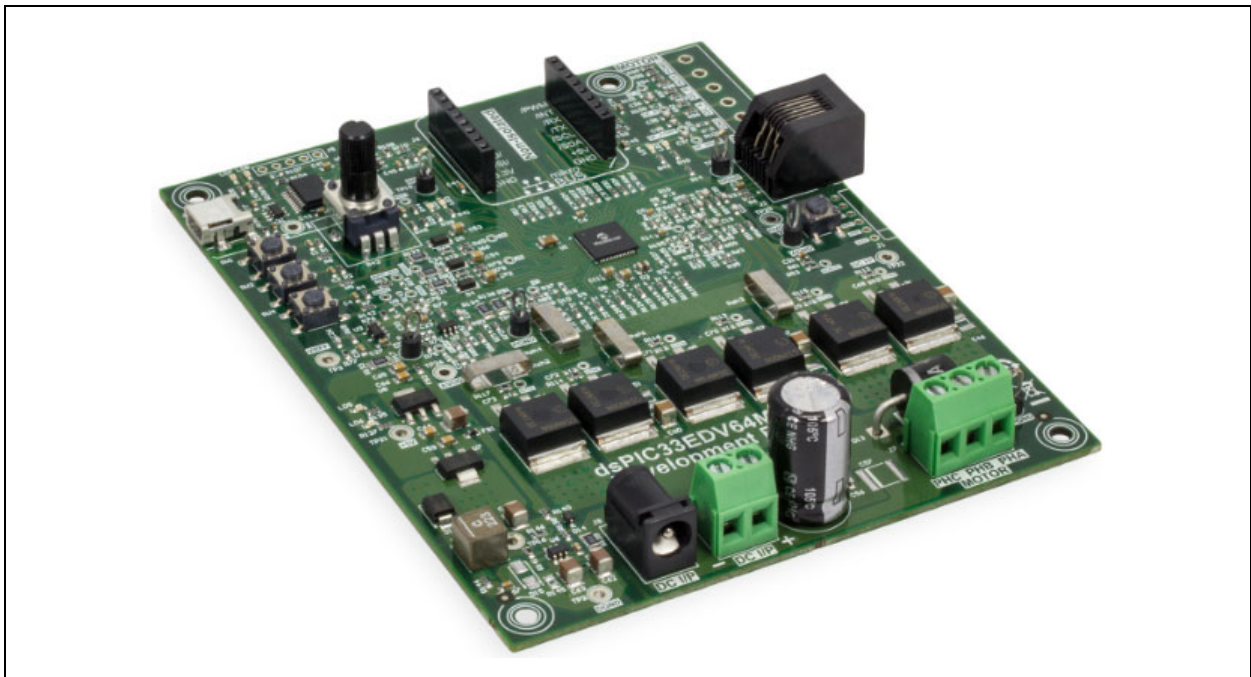
### 1.1 OVERVIEW

The dsPIC33EDV64MC205 Motor Control Development Board is a low-voltage, motor control development board designed to demonstrate the features of the dsPIC33EDV64MC205. This dsPIC<sup>®</sup> DSC is a 16-bit Digital Signal Controller featuring high-speed PWM, op amps, advanced analog and a MOSFET gate driver.

In some instances of the document text, the dsPIC33EDV64MC205 Motor Control Development Board is also referred to as “the development board” to enhance readability.

The development board, shown in [Figure 1-1](#), is targeted to drive a low-voltage three-phase Permanent Magnet Synchronous Motor or Brushless DC motor (PMSM/BLDC motor).

**FIGURE 1-1: dsPIC33EDV64MC205 MOTOR CONTROL DEVELOPMENT BOARD**



### 1.2 FEATURES

Key features of the development board are as follows:

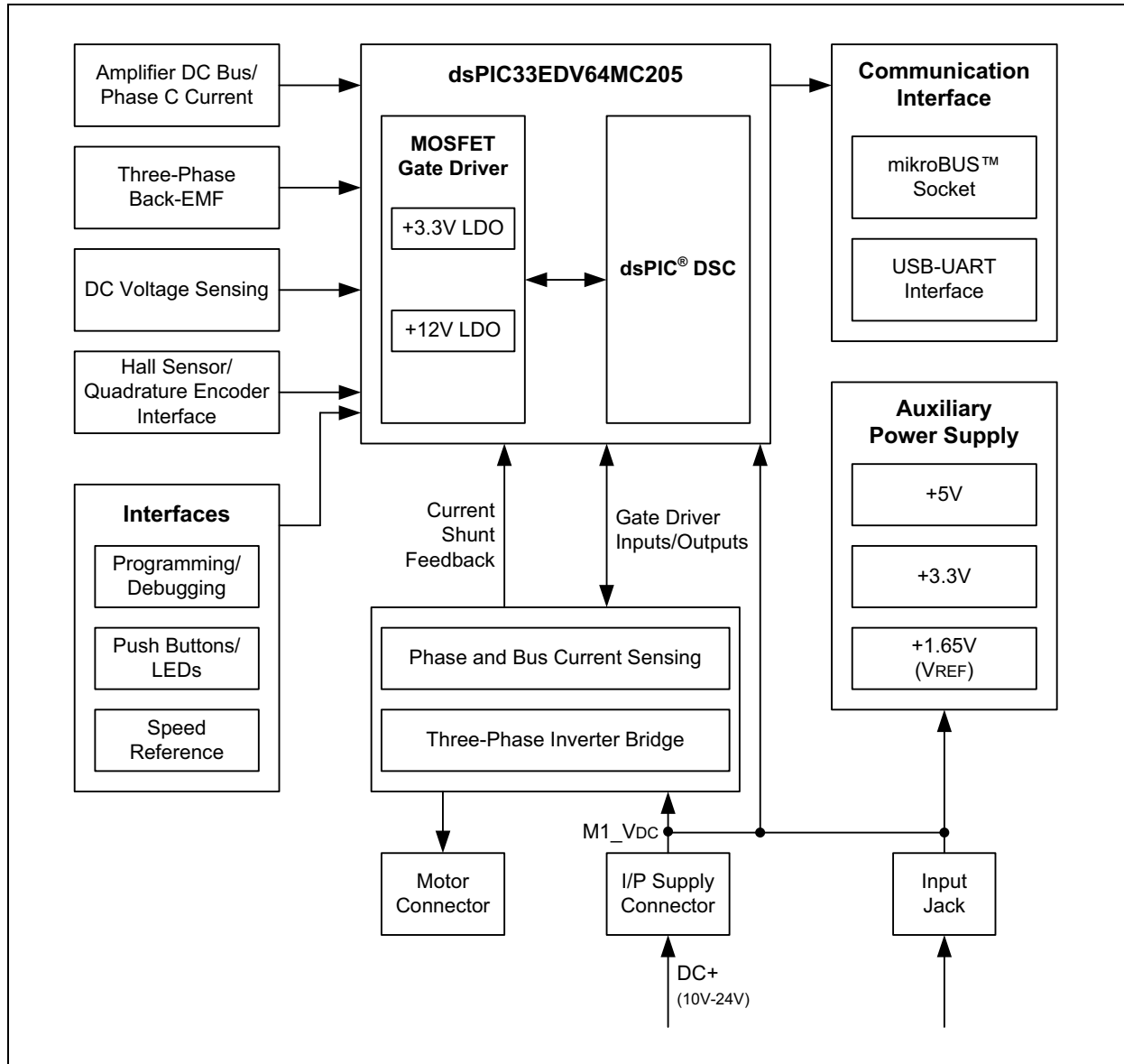
- Three-Phase Motor Control Power Stage with the Following Electrical Specifications:
  - Input DC voltage: 10V to 24 V<sub>DC</sub>
  - Nominal phase RMS current: 10A at +25°C
- Motor Phase Current Sensing to Implement Field-Oriented Control of a PMSM/BLDC Motor
- DC Bus Current Sensing for Overcurrent Protection
- DC Bus Voltage Sensing

- Hall Sensors/Quadrature Encoder Interface to Enable Sensor-Based Motor Control Algorithms
- Debug Serial Interface (USB to UART) Based on Microchip Product MCP2200
- User Interface, such as LEDs, Potentiometer and Push Buttons
- Optional LIN Interface via a MCP2003B MikroElektronika Board ([www.mikroe.com](http://www.mikroe.com)) Plugged on to the mikroBUS™ Socket Provided on the Board
- On-Board Crypto Authentication IC ATECC508A to Allow an IoT-Based Motor Control Application Demo

## 1.3 BLOCK DIAGRAM

The block diagram of the dsPIC33EDV64MC205 Motor Control Development Board is shown in [Figure 1-2](#).

**FIGURE 1-2: BLOCK DIAGRAM OF THE DEVELOPMENT BOARD**



For more information on electrical specifications, refer to [Appendix B. "Electrical Specifications"](#).

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## Chapter 2. Board Interface

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### 2.1 INTRODUCTION

This chapter provides detailed information about the input and output interfaces available on the dsPIC33EDV64MC205 Motor Control Development Board in the following sections:

- [Board Connectors](#)
- [User Interface Hardware](#)

### 2.2 BOARD CONNECTORS

This section summarizes the connectors on the development board. The connectors are intended for:

- Supplying input power to the development board
- Delivering inverter outputs to the motor
- Interfacing motor position sensors, such as Hall sensor/Quadrature Encoder
- Enabling the user to program/debug
- Interfacing a click board™
- Establishing communication with the host PC

The connectors on the development board are shown in [Figure 2-1](#) and summarized in [Table 2-1](#).

FIGURE 2-1: CONNECTORS ON THE DEVELOPMENT BOARD

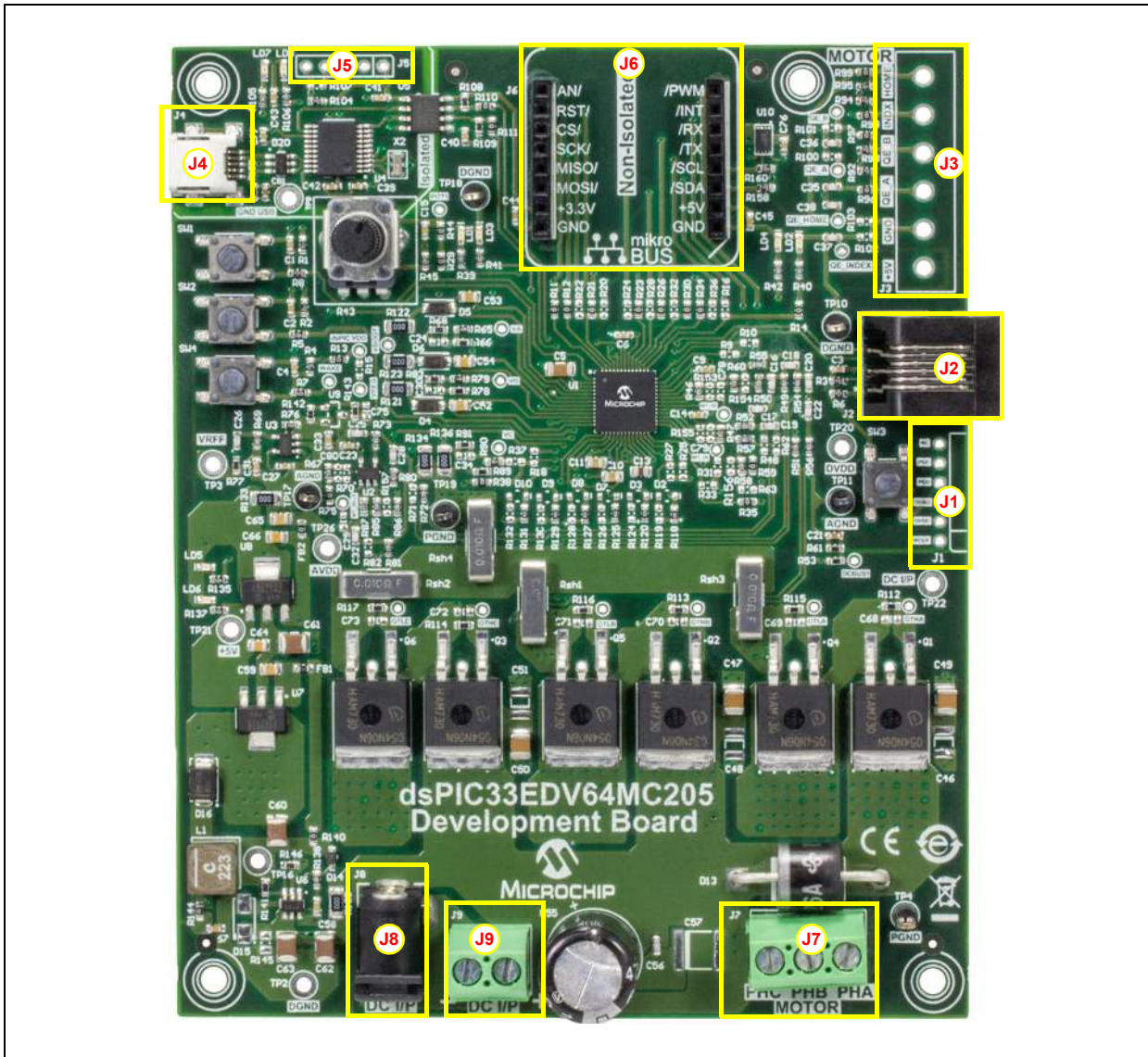


TABLE 2-1: CONNECTORS ON THE DEVELOPMENT BOARD

Connector Designator	No. of Pins	Status	Description
J1	6	Not Populated	ICSP™ connector for programming the dsPIC® DSC
J2	6	Populated	RJ11 connector for programming the dsPIC DSC
J3	6	Not Populated	Hall sensor/Quadrature Encoder Interface connector
J4	5	Populated	Isolated mini-USB port to establish an isolated serial interface with the host PC
J5	5	Not Populated	Isolated UART interface connections
J6	16	Populated	mikroBUS™ socket for interfacing a click board™ with the development board
J7	3	Populated	Connector to deliver three-phase inverter outputs to the motor
J8	2	Populated	Terminal connector to supply DC input to the board
J9	3	Populated	Jack plug to supply DC input to the board

### 2.2.1 ICSP™ Header for Programmer/Debugger Interface (J1)

The 6-pin header J1 can be used for connecting the programmer/debugger, for example, PICKit™ 4, for programming and debugging the dsPIC33EDV64MC205. This is not populated by default. When needed, populate the connector with Part Number 68016-106HLF or similar. The pin details are provided in [Table 2-2](#).

**TABLE 2-2: PIN DESCRIPTION – CONNECTOR J1**

Pin #	Signal Name	Description
1	$\overline{\text{MCLR}}$	Device Master Clear ( $\overline{\text{MCLR}}$ )
2	DVDD	Digital Supply Voltage
3	DGND	Digital Ground
4	PGD	Device Programming Data Line (PGD)
5	PGC	Device Programming Clock Line (PGC)
6	No Connection	—

### 2.2.2 RJ11 Connector for Programmer/Debugger Interface (J2)

The RJ11 connector J2 is provided on the development board to interface the programmer/debugger, for example, MPLAB® ICD 3, REAL ICE™, etc., for programming and debugging the dsPIC33EDV64MC205. [Table 2-3](#) lists the pin connections of J2.

**TABLE 2-3: PIN DESCRIPTION – CONNECTOR J2**

Pin #	Signal Name	Description
1	$\overline{\text{MCLR}}$	Device Master Clear ( $\overline{\text{MCLR}}$ )
2	DVDD	Digital Supply Voltage
3	DGND	Digital Ground
4	PGD	Device Programming Data Line (PGD)
5	PGC	Device Programming Clock Line (PGC)
6	No Connection	—

### 2.2.3 Hall Sensor/Quadrature Encoder Interface (QEI) Connector (J3)

Hall sensors or Quadrature Encoders are used to detect the rotor position. Connector J3 can be used to interface the Hall sensor/Quadrature Encoder of the motor driven by the development board. This is not populated by default. When needed, populate the connector with Part Number ED500/6DS or similar. [Table 2-4](#) shows the pin description of connector J3.

**TABLE 2-4: PIN DESCRIPTION – CONNECTOR J3**

Pin #	Signal Name	Description
1	+5V	Hall Sensors/Quadrature Encoder Power Supply
2	DGND	Digital Ground
3	M1_QE_A	Hall Sensor A/Quadrature Encoder Phase A Feedback of Motor
4	M1_QE_B	Hall Sensor B/Quadrature Encoder Phase B Feedback of Motor
5	M1_QE_INDEX	Hall Sensor C/Quadrature Encoder Index Feedback of Motor
6	M1_QE_HOME	Quadrature Encoder Home Signal Feedback of Motor

## 2.2.4 Isolated USB Interface (J4)

The development board uses an on-board MCP2200 device (see U4 in [Figure A-5](#)) as a bridge between the UART and the USB (see [Table 2-5](#)) for providing a host PC interface.

**Table 2-5: PIN DESCRIPTION – CONNECTOR J4**

Pin #	Signal Name	Description
0	No Connection	Body is Connected to GND_USB
1	+5V_USB	USB Supply +5 Vdc
2	USB_N	USB Data-
3	USB_P	USB Data+
4	No Connection	—
5	GND_USB	USB Ground

## 2.2.5 Isolated UART Interface Header (J5)

An isolated UART interface header J5 is provided for connecting an external UART-USB converter, or accessing UART signals, by disabling the MCP2200 device (see U4 in [Figure A-5](#)). This is not populated by default. When needed, populate the connector with Part Number TSW-10507-S-S or similar. [Table 2-6](#) summarizes the pin functions of connector J5.

**Table 2-6: PIN DESCRIPTION – CONNECTOR J5**

Pin #	Signal Name	Description
1	5V_USB	+5V Supply from External USB-UART Converter
2	MCU_TX	Isolated UART Transmit Pin of dsPIC <sup>®</sup> DSC
3	MCU_RX	Isolated UART Receive Pin of dsPIC DSC
4	GND_USB	Ground Connection Provided by External USB-UART Converter
5	MCP2200_RST	Setting this Pin Low (connecting to Ground) will Disable the MCP2200 (U4)

## 2.2.6 mikroBUS™ Socket for Interfacing Click Board™

The pin mapping between the mikroBUS socket and the dsPIC DSC is summarized in [Table 2-7](#).

**Note 1:** The 'AN' pin of the mikroBUS interface is not connected to any pin of the dsPIC33EDV64MC205. Add or remove specified resistors to establish a connection between a specific pin of the dsPIC33EDV64MC205 with the mikroBUS. For more details, refer to [Table 2-7](#).

For more details, refer to [Section 3.2.12 “mikroBUS™ Interface and Crypto Authentication”](#).

**TABLE 2-7: PIN MAPPING – dsPIC33EDV64MC205 TO mikroBUS™ INTERFACE**

mikroBUS™		dsPIC33EDV64MC205		dsPIC33EDV64MC205 and mikroBUS Interface	
Pin #	Pin Name	Pin #	Pin Function	Resistor Jumper	Default Resistor Jumper Status
1	AN	—	—	NA	No Connection
2	RST	38	RPI24/SDA2/RA8	R9	Not Populated
3	CS	27	PGED3/VREF-/C2IN1-/AN2/RPI32/SS1/CTED2/RB0	R18	Not Populated
		50	RP39/FLT32/INT0/RB7	R20	Not Populated
4	SCK	42	RPI51/SCK1/RC3	R32	Not Populated
5	MISO	41	RPI25/SDI1/RA9	R36	Not Populated
6	MOSI	40	CVREF20/RP20/T1CK/SDO1/RA4	R16	Not Populated
7	+3.3V	—	—	—	Connected to DVDD
8	GND	—	—	—	Connected to DGND
9	GND	—	—	—	Connected to DGND
10	+5V	—	—	—	Connected to +5V
11	SDA	43	RPI52/SDA1/RC4	R28	Not Populated
12	SCL	44	RPI53/SCL1/RC5	R24	Not Populated
13	TX	52	RP41/ASDA1/RB9	R11	Populated
14	RX	51	CVREF10/RP40/ASCL1/T4CK/RB8	R12	Populated
15	INT	50	RP39/FLT32/INT0/RB7	R22	Not Populated
16	PWM	39	RP36/SCL2/RB4	R10	Not Populated

## 2.2.7 Inverter Output Connector (J7)

The development board can drive a three-phase PMSM/BLDC motor. Motor control inverter outputs are available on connector J7. Pin assignments for connector J7 are shown in [Table 2-8](#).

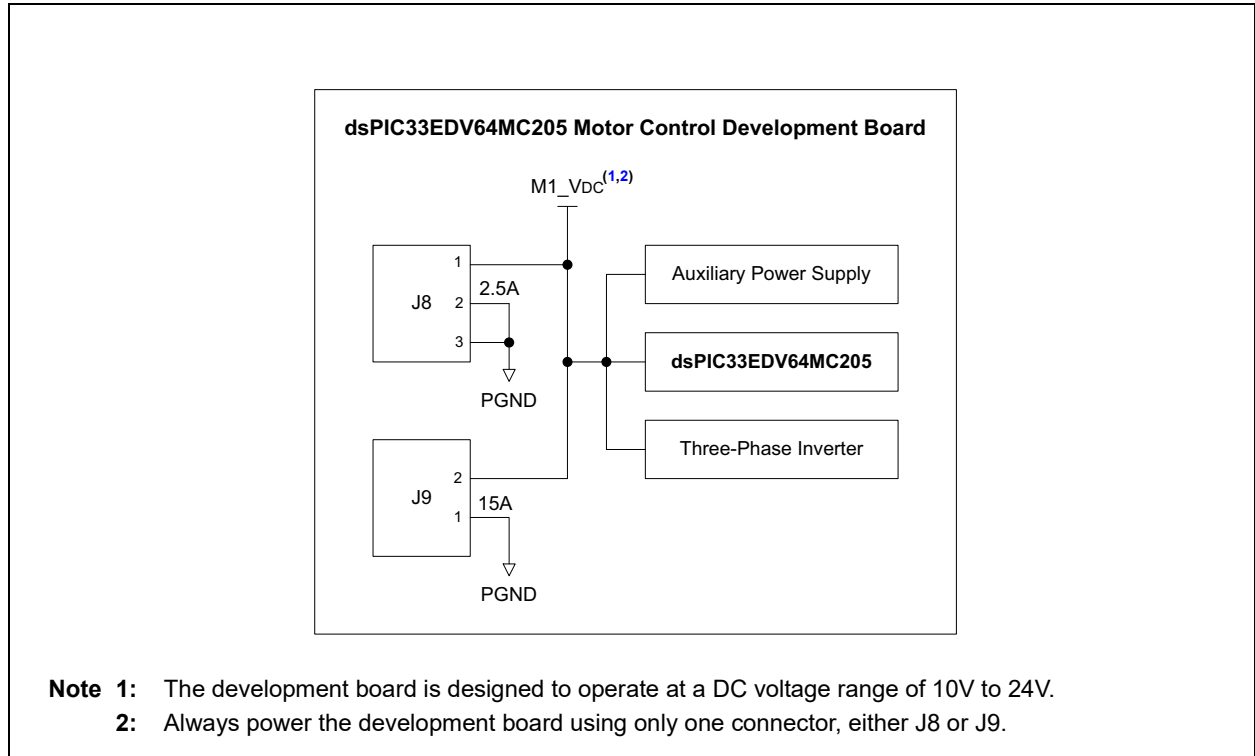
**Table 2-8: PIN DESCRIPTION – CONNECTOR J7**

Pin #	Signal Name	Description
1	PHASE C (PHC)	Phase 3 output of inverter.
2	PHASE B (PHB)	Phase 2 output of inverter.
3	PHASE A (PHA)	Phase 1 output of inverter.

## 2.2.8 Power Supply Connectors (J8, J9)

The dsPIC33EDV64MC205 Motor Control Development Board is designed to operate in a DC voltage range of 10V to 24V. As shown in Figure 2-2, the development board can be powered through either coaxial plug J8 or through terminal connector J9. Connector J8 can carry current up to 2.5A and connector J9 can carry current up to 15A. Table 2-9 and Table 2-10 summarize the pin assignments of connector J8 and J9, respectively.

**FIGURE 2-2: INPUT DC POWER SUPPLY CONNECTIONS**



**Table 2-9: PIN DESCRIPTION – CONNECTOR J8**

Pin #	Signal Name	Description
1	M1_VDC	Positive input of the DC source.
2	PGND	Ground connection of the DC source (PGND).
3	PGND	Ground connection of the DC source.

**Table 2-10: PIN DESCRIPTION – CONNECTOR J9**

Pin #	Signal Name	Description
1	PGND(-)	Ground connection of the DC source (PGND).
2	M1_VDC(+)	Positive input of the DC source.



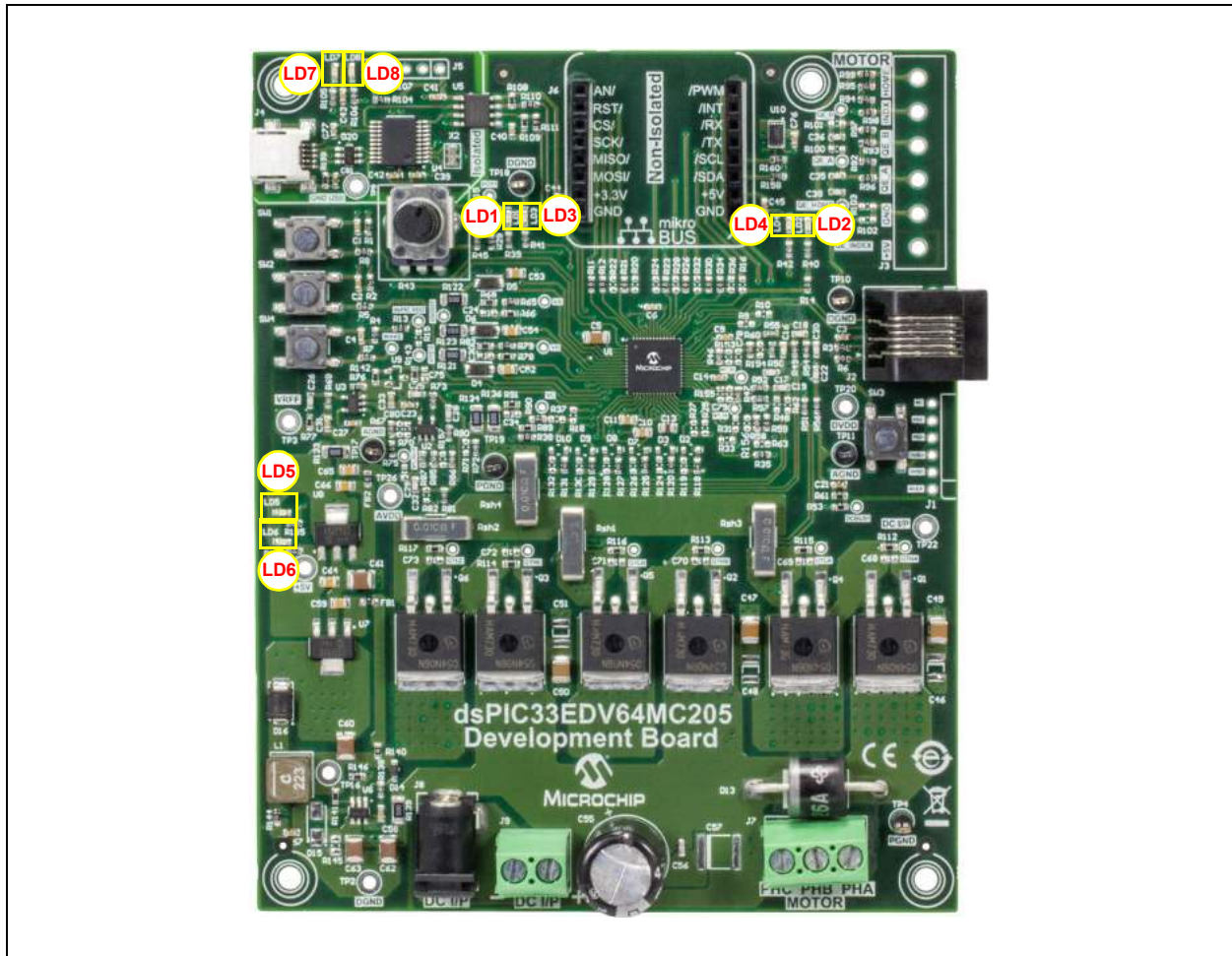
## 2.3 USER INTERFACE HARDWARE

This section describes the LEDs, push buttons, potentiometer and test points available on the development board.

### 2.3.1 LEDs

The LEDs provided on the development board are shown in [Figure 2-3](#) and summarized in [Table 2-11](#).

**FIGURE 2-3: LEDs ON THE DEVELOPMENT BOARD**



**TABLE 2-11: LEDs**

SI. #	Designator	Description
1	LD1	Provided for debugging purposes.
2	LD2	Provided for debugging purposes.
3	LD3	Provided for debugging purposes. This LED is not connected to the dsPIC® port pin by default. This can only be used when the internal FRC is used in the application, and when populating R19 and removing X1 and C8.
4	LD4	Provided for debugging purposes. This LED is not connected to the dsPIC port pin by default. This can only be used when the internal FRC is used in the application, and when populating R19 and removing X1 and C8.
5	LD5	Power-on status indication for auxiliary supply output, DVDD (+3.3V).
6	LD6	Power-on status indication for auxiliary supply output, +5V.
7	LD7	USB transmit activity LED output. <sup>(1)</sup>
8	LD8	USB receive activity LED output. <sup>(1)</sup>

**Note 1:** Refer to the “MCP2200 Family Data Sheet” for more details.

### 2.3.2 Push Buttons

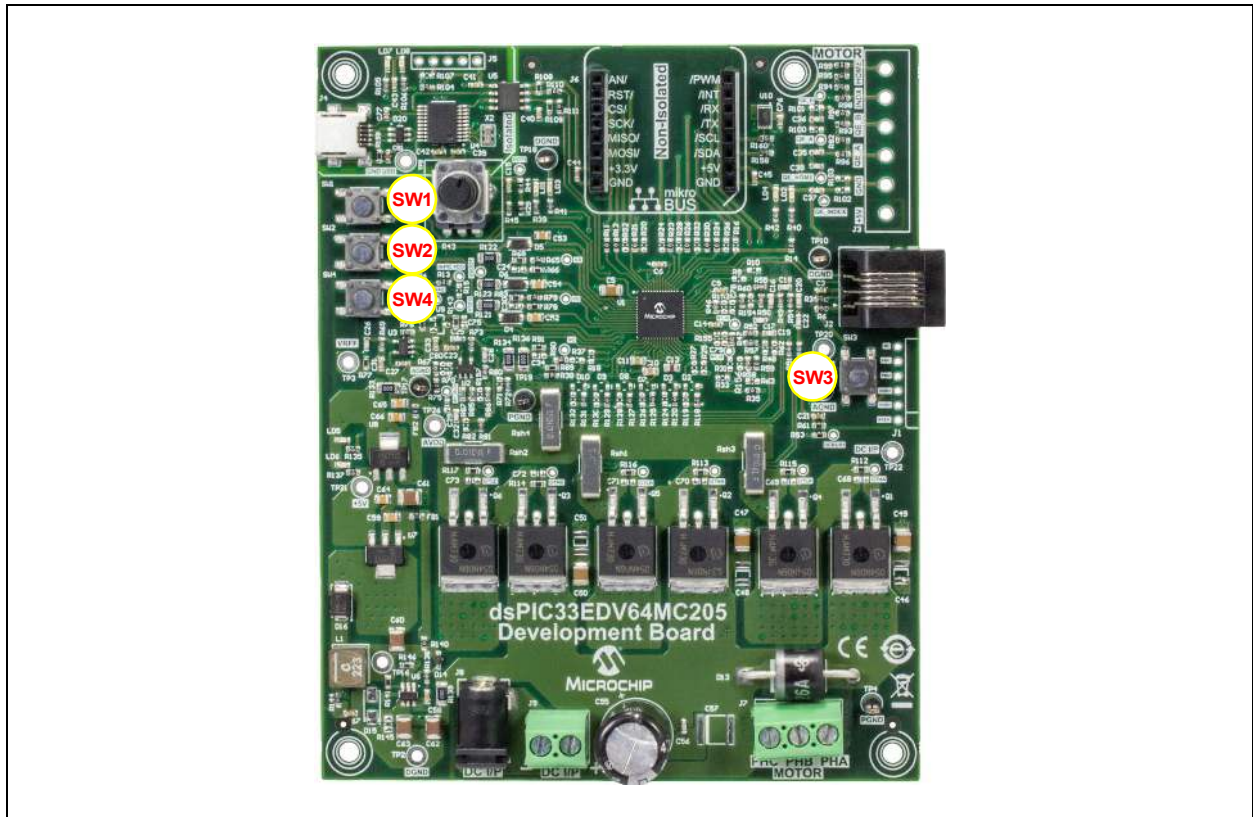
The push buttons provided on the development board are shown in [Figure 2-4](#) and summarized in [Table 2-12](#).

The push buttons, SW1 and SW2, are provided to control motor operations; for example, starting or stopping the motor, etc. The functions of these push buttons are designated by the motor control application firmware.

**TABLE 2-12: PUSH BUTTONS**

Sl. #	Designator	Description
1	SW1	Push button provided for general purpose.
2	SW2	Push button provided for general purpose.
3	SW3	This push button is tied to the MCLR pin of dsPIC33EDV64MC205. Pressing this button will reset the device.
4	SW4	This push button is tied to the WAKE pin of dsPIC33EDV64MC205. Pressing this button will wake the MOSFET gate driver from Sleep mode. To wake the device from Sleep mode, the WAKE pin must be held low for at least 150 $\mu$ s. Refer to the device data sheet for more details.

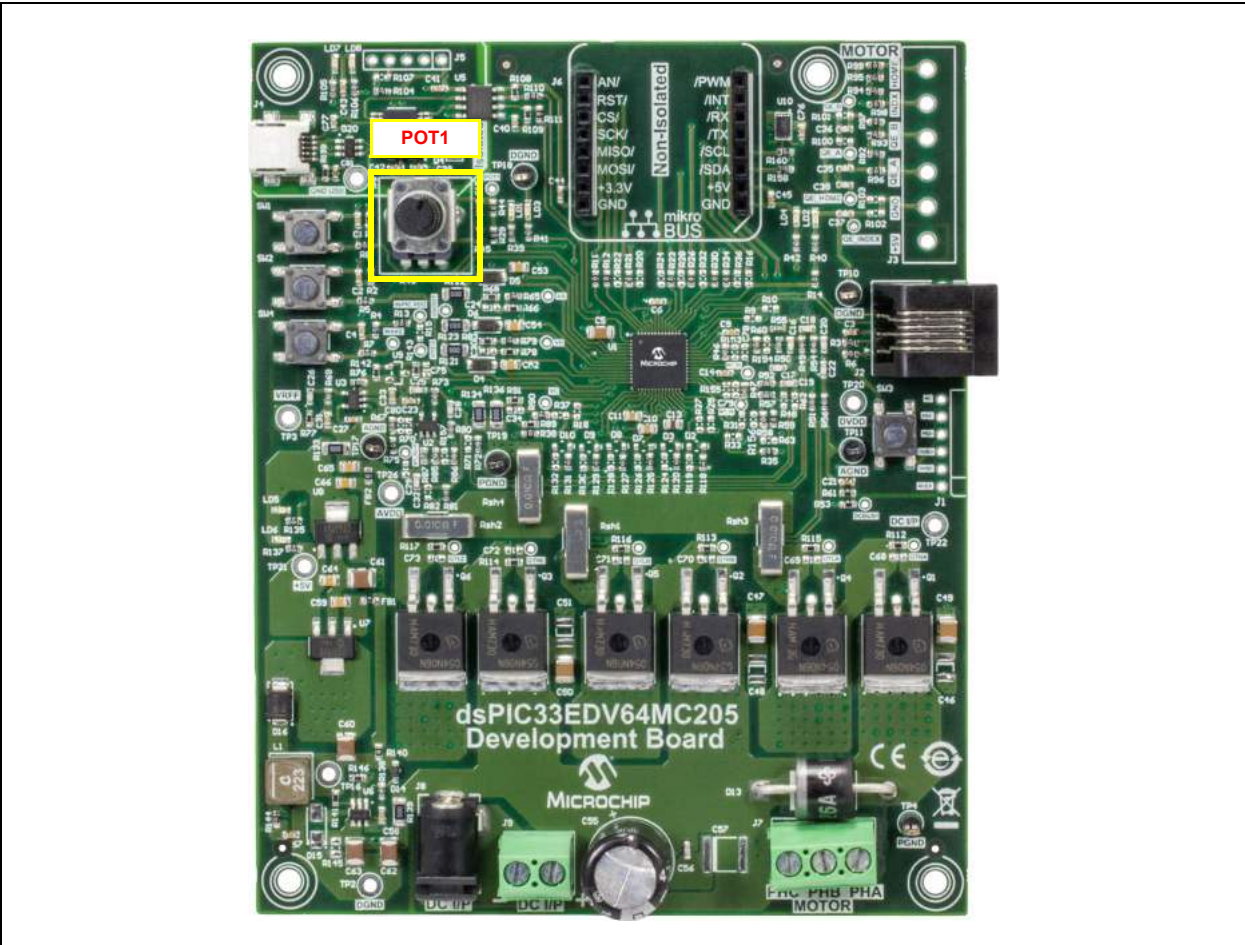
**FIGURE 2-4: PUSH BUTTONS ON THE DEVELOPMENT BOARD**



2.3.3 Potentiometer

The potentiometer on the development board (shown in Figure 2-5) is connected to one of the analog inputs of the device and can be used for setting the speed reference.

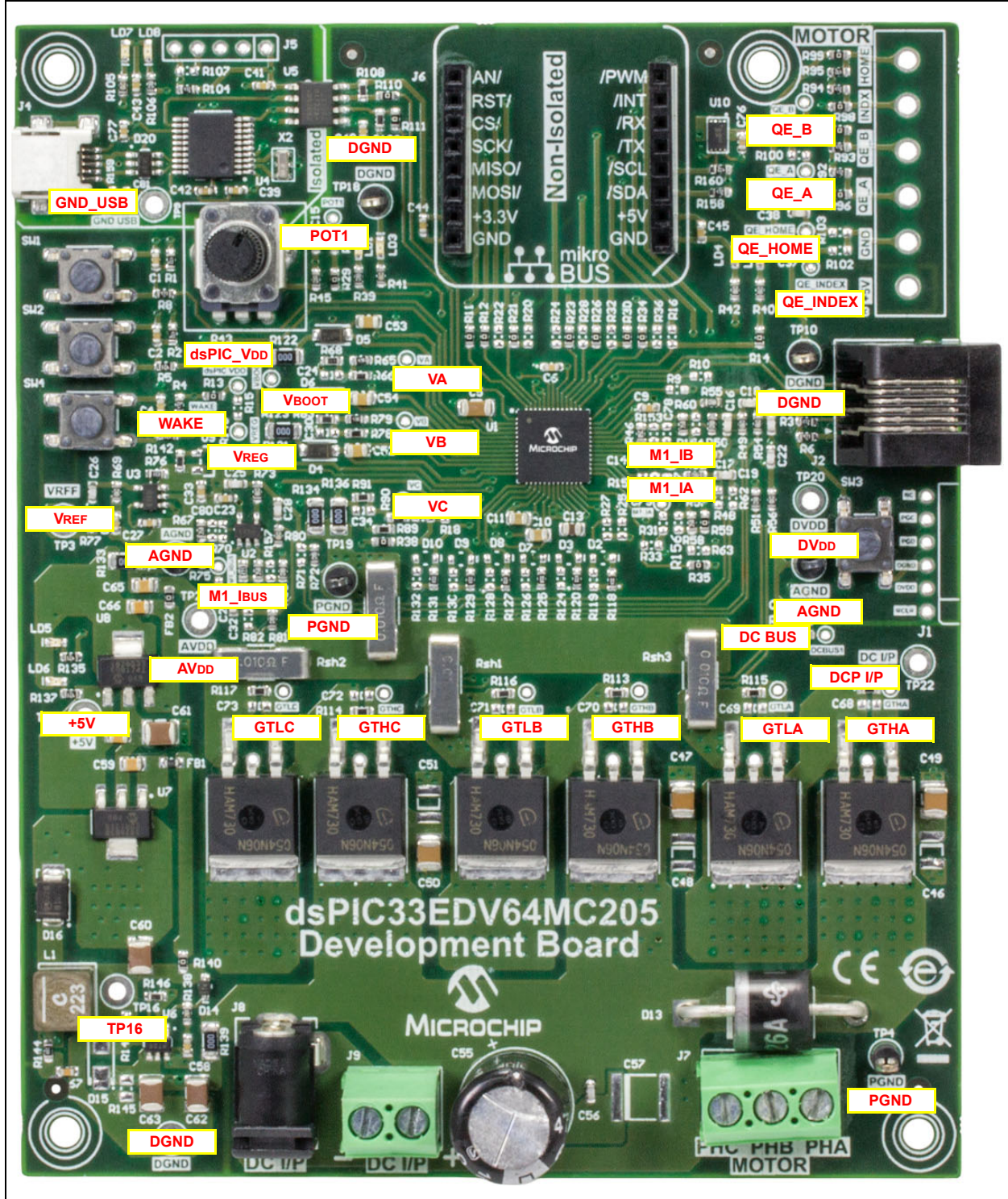
FIGURE 2-5: POTENTIOMETER ON THE DEVELOPMENT BOARD



### 2.3.4 Test Points

There are several test points on the development board to monitor various signals, such as motor feedback voltages, motor currents, auxiliary supply outputs, etc. These test points are marked in [Figure 2-6](#) and summarized in [Table 2-13](#).

FIGURE 2-6: TEST POINTS – dsPIC33EDV64MC205 MOTOR CONTROL DEVELOPMENT BOARD



**TABLE 2-13: BOARD TEST POINTS**

Test Point Number	Signal	Description
TP22	DC I/P (M1_VDC)	DC power supply (10V-24V).
TP4	PGND	Power ground.
TP19	PGND	Power ground.
TP16	—	Intermediate output of auxiliary power supply unit (output of MCP16301 step-down DC-DC converter), see U6 in <a href="#">Figure A-4</a> .
TP21	+5V	+5V power supply output (output of on-board +5V LDO).
TP20	DVDD	+3.3V digital power supply (output of on-board +3.3V LDO).
TP2	DGND	Digital ground.
TP10	DGND	Digital ground.
TP18	DGND	Digital ground.
TP26	AVDD	+3.3V analog power supply.
TP17	AGND	Analog ground.
TP11	AGND	Analog ground.
VREG	VREG	+3.3V output generated by internal LDO of dsPIC33EDV64MC205.
dsPIC_VDD	dsPIC_VDD	+3.3V supply connected to VDD/AVDD of dsPIC33EDV64MC205.
VBOOT	VBOOT	Bootstrap power supply output (+12V) generated by internal LDO of dsPIC33EDV64MC205.
TP3	VREF	+1.65V voltage reference to bias op amp outputs.
M1_IA	M1_IA	Inverter Leg A current feedback (amplified).
M1_IB	M1_IB	Inverter Leg B current feedback (amplified).
M1_IBUS	M1_IBUS	Inverter bus current feedback (amplified).
M1_VA	M1_VA	Phase A back-EMF voltage feedback of motor.
M1_VB	M1_VB	Phase B back-EMF voltage feedback of motor.
M1_VC	M1_VC	Phase C back-EMF voltage feedback of motor.
DCBUS1	M1_VDC	DC bus feedback.
QE_A	M1_QE_A	Hall Sensor A/Quadrature Encoder A feedback of motor.
QE_B	M1_QE_B	Hall Sensor B/Quadrature Encoder B feedback of motor.
QE_INDEX	M1_QE_INDEX	Hall Sensor C/Quadrature Encode Index feedback of motor.
QE_HOME	M1_QE_HOME	Quadrature Encoder Home signal of motor.
GTHA	GTHA	Gate signal from driver to high-side MOSFET of Inverter Leg A.
GTHB	GTHB	Gate signal from driver to high-side MOSFET of Inverter Leg B.
GTHC	GTHC	Gate signal from driver to high-side MOSFET of Inverter Leg C.
GTLA	GTLA	Gate signal from driver to low-side MOSFET of Inverter Leg A.
GTLB	GTLB	Gate signal from driver to low-side MOSFET of Inverter Leg B.
GTLC	GTLC	Gate signal from driver to high-side MOSFET of Inverter Leg C.
WAKE	WAKE	Wake signal to dsPIC33EDV64MC205.
POT1	POT1	Potentiometer used as speed reference.
TP9	GND_USB	USB ground.

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## Chapter 3. Hardware

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### 3.1 INTRODUCTION

This chapter provides a detailed description of the hardware features of the dsPIC33EDV64MC205 Motor Control Development Board. The development board is intended to demonstrate the capability of the dsPIC33EDV64MC205.

The motor control inverter on the development board is controlled by the dsPIC33EDV64MC205 DSC with built-in three-phase gate drivers. Motor phase current signals are amplified by operational amplifiers (op amps) internal to the dsPIC33EDV64MC205 device. The supply to the gate driver is generated by a +12V LDO internal to the dsPIC33EDV64MC205.

The development board incorporates a Hall sensor/Quadrature Encoder interface, sensing circuits to measure DC voltage, bus current and phase currents. In addition, a USB-UART interface, a click board™ interface connector and a crypto authentication IC interface are provided on the board.

The motor control inverter can be operated by using an input voltage in the range of 10V to 24V and can deliver a continuous output phase current of 10A (RMS) in the specified operating range. For more information on electrical specifications, see [Appendix B. “Electrical Specifications”](#).

### 3.2 HARDWARE SECTIONS OF THE DEVELOPMENT BOARD

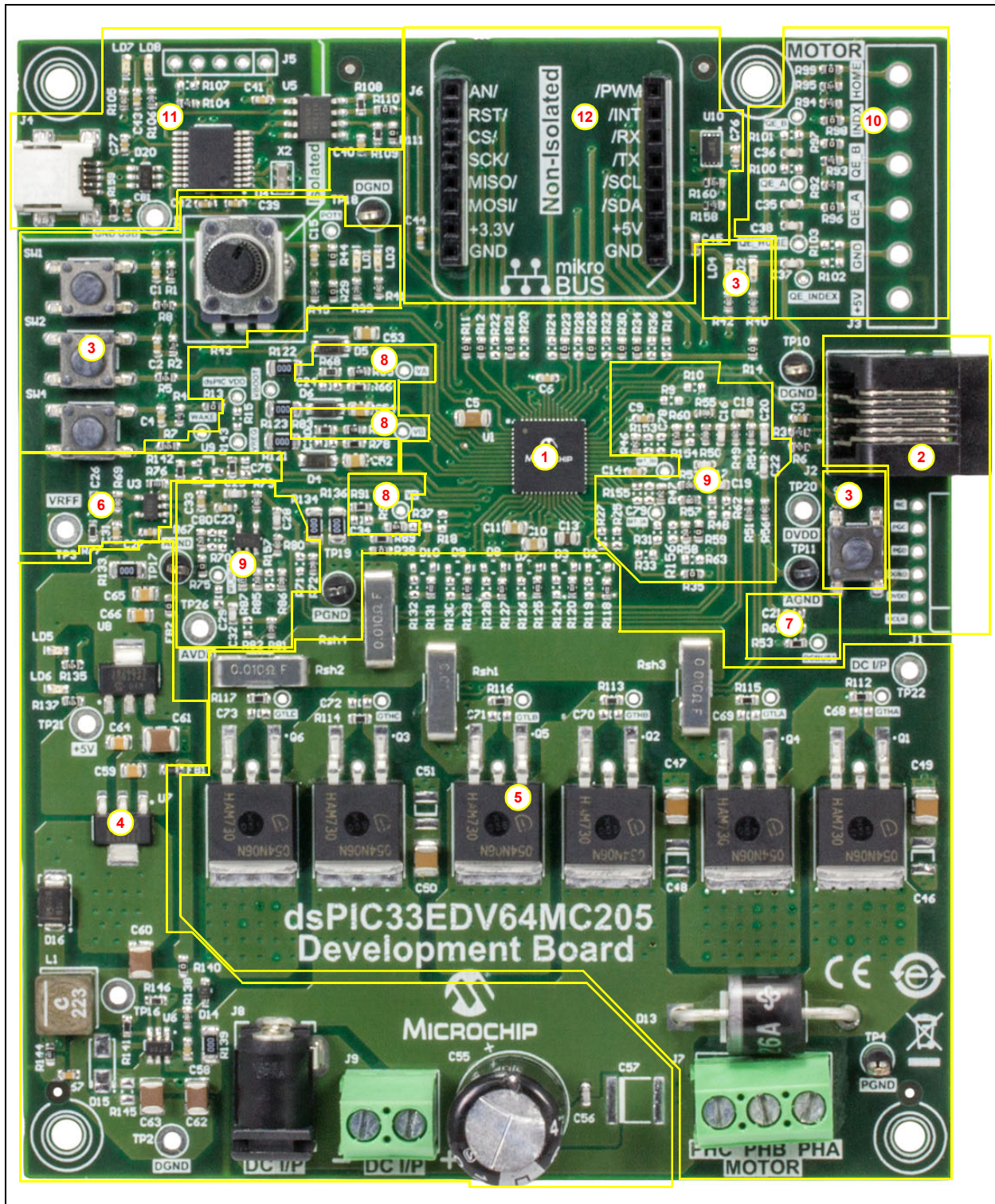
This chapter covers the following hardware sections of the dsPIC33EDV64MC205 Motor Control Development Board:

- [dsPIC33EDV64MC205 and Related Circuit](#)
- [Programmer/Debugger Interface](#)
- [User Interface](#)
- [Power Supply](#)
- [Three-Phase Inverter Bridge](#)
- [Voltage Reference Circuit](#)
- [DC Voltage Sensing](#)
- [Back-EMF Sensing](#)
- [Current Sensing](#)
- [Hall Sensor/Quadrature Encoder Interface](#)
- [Isolated Debug Serial UART Interface](#)
- [mikroBUS™ Interface and Crypto Authentication](#)

[Figure 3-1](#) and [Table 3-1](#) describe the hardware sections of the development board.

# dsPIC33EDV64MC205 Motor Control Development Board User's Guide

FIGURE 3-1: dsPIC33EDV64MC205 MOTOR CONTROL DEVELOPMENT BOARD HARDWARE SECTIONS





**TABLE 3-1: HARDWARE SECTIONS OF THE DEVELOPMENT BOARD**

Section	Description
1	<a href="#">dsPIC33EDV64MC205 and Related Circuit</a>
2	<a href="#">Programmer/Debugger Interface</a>
3	<a href="#">User Interface</a>
4	<a href="#">Power Supply</a>
5	<a href="#">Three-Phase Inverter Bridge</a>
6	<a href="#">Voltage Reference Circuit</a>
7	<a href="#">DC Voltage Sensing</a>
8	<a href="#">Back-EMF Sensing</a>
9	<a href="#">Current Sensing</a>
10	<a href="#">Hall Sensor/Quadrature Encoder Interface</a>
11	<a href="#">Isolated Debug Serial UART Interface</a>
12	<a href="#">mikroBUS™ Interface and Crypto Authentication</a>

### 3.2.1 dsPIC33EDV64MC205 and Related Circuit

As shown in [Figure 3-2](#), the dsPIC33EDV64MC205 Motor Control Development Board features the dsPIC33EDV64MC205 from Microchip's dsPIC® DSC portfolio. The co-existence of the MOSFET gate driver module and the dsPIC DSC in one device provides a single chip solution for controlling low-voltage PMSM/BLDC motors.

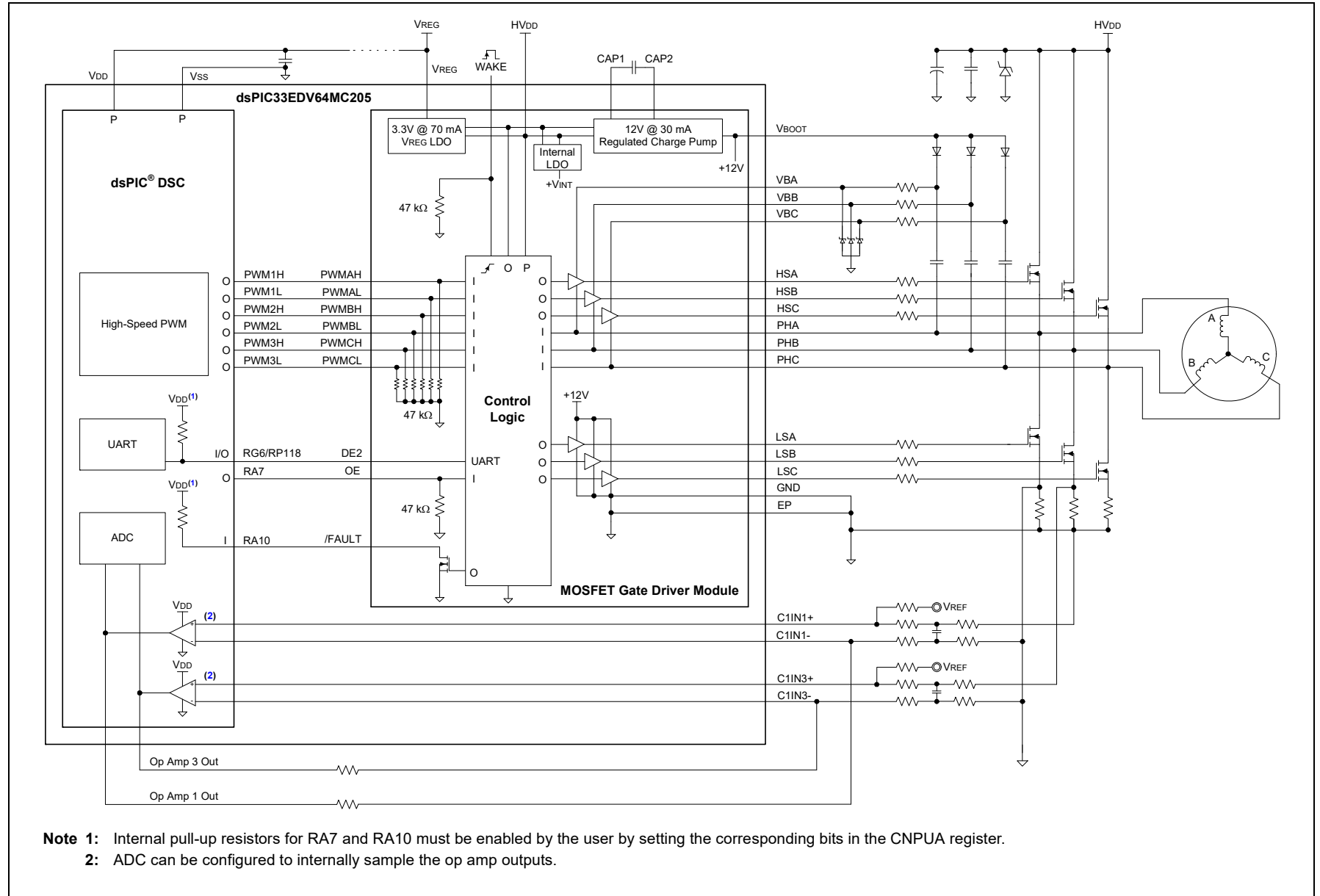
The high-speed PWM outputs of the dsPIC DSC are connected internally to the inputs of the MOSFET gate driver module. The Output Enable (OE), Fault Output (FAULT) from the MOSFET gate driver module and DE2 communication pins are internally connected to the port pins of the dsPIC DSC to create a seamless interface between them. For more information on DE2 communication, refer to the "[dsPIC33EDV64MC205 Data Sheet](#)" (DS70005292).

The MOSFET gate driver module provides several protection features, such as undervoltage, overvoltage, shoot-through and short-circuit protection of the inverter bridge. The DE2 communication link that interfaces between the dsPIC DSC and the MOSFET gate driver module is established by its UART interface. DE2 communication (half-duplex, 9600 baud, 8-bit, no parity, single line communication link) is provided for indicating driver Fault status, driver configuration and setting parameters, such as dead time, blanking time, overcurrent threshold and so on.

The MOSFET gate driver module has two internal LDOs for generating +5V and +3.3V outputs, and a regulated charge pump with a +12V output. In the development board, the +12V output of the charge pump is used for powering the bootstrap circuit. The +12V charge pump can deliver an output current of 30 mA. As the output current of the +12V charge pump is limited to 30 mA, the bootstrap capacitors should be pre-charged prior to turning on the high-side MOSFETs if the low-side MOSFETs are turned off for a longer duration and when the device is powered on. The bootstrap capacitors can be pre-charged by controlling only low-side MOSFETs using PWMs with very short duty cycles. Choose duty cycles such that the output of the +12V charge pump is not falling below +10V during the pre-charge cycle.

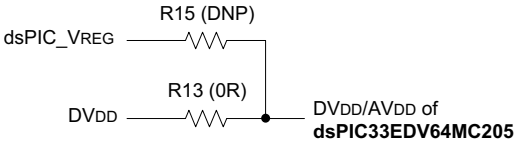
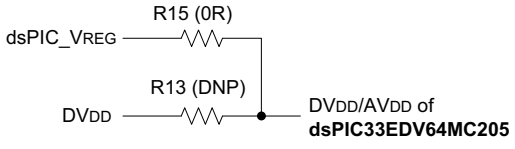
The +5V LDO output is used internally to power the MOSFET gate driver digital logic. The +3.3V LDO output (VREG) can be used to power the dsPIC® DSC or for powering external circuits. The +3.3V LDO can deliver an output current of up to 70 mA at room temperature. At higher temperatures, the output current must be limited to not exceed the power dissipation specification for the device. In the development board, there is a provision to connect the +3.3V LDO to the dsPIC DSC power supply pins (VDD and AVDD). See [Table 3-2](#) for resistor jumper settings to select the required power supply input of the dsPIC DSC internal to the dsPIC33EDV64MC205 device.

**FIGURE 3-2: dsPIC33EDV64MC205 AND RELATED CIRCUITS**



**Note 1:** Internal pull-up resistors for RA7 and RA10 must be enabled by the user by setting the corresponding bits in the CNPUA register.  
**Note 2:** ADC can be configured to internally sample the op amp outputs.

**TABLE 3-2: RESISTOR JUMPER CONFIGURATION – SELECTING POWER SUPPLY INPUT OF dsPIC® DSC**

Resistor Configuration to Power the dsPIC33EDV64MC205 by the On-Board LDO Output of the Auxiliary Power Supply, DVDD <sup>(1)</sup>	Resistor Configuration to Power the dsPIC33EDV64MC205 by the Internal LDO Output of the MOSFET Gate Driver, VREG <sup>(2)</sup>
	

- Note 1:** When internal LDOs are operating, the power dissipation of the dsPIC33EDV64MC205 will increase in proportion to the current drawn from the LDOs. Ensure that the heating is at an acceptable limit.
- Note 2:** The VREG output can only deliver 70 mA of current. Ensure that the current requirement of the dsPIC DSC does not exceed the limit.

### 3.2.2 Programmer/Debugger Interface

The RJ11 connector J2 is provided on the development board to interface the programmer/debugger (for example, MPLAB® ICD 3, REAL ICE™, etc.).

Additionally, a 6-pin ICSP™ programming header J1 is provided for connecting the programmer/debugger (for example, PICkit™ 4).

### 3.2.3 User Interface

The dsPIC33EDV64MC205 Motor Control Development Board user interface has four push buttons, along with a potentiometer and LEDs. The potentiometer can be used for setting speed reference, LEDs are for status indication and the general purpose push buttons (SW1 and SW2) can be used to start and stop the motor, etc. The other two push buttons are designated for specific functions: SW3 is tied to the WAKE pin and SW4 is tied to the MCLR pin of the device to perform wake and Reset functions, respectively.

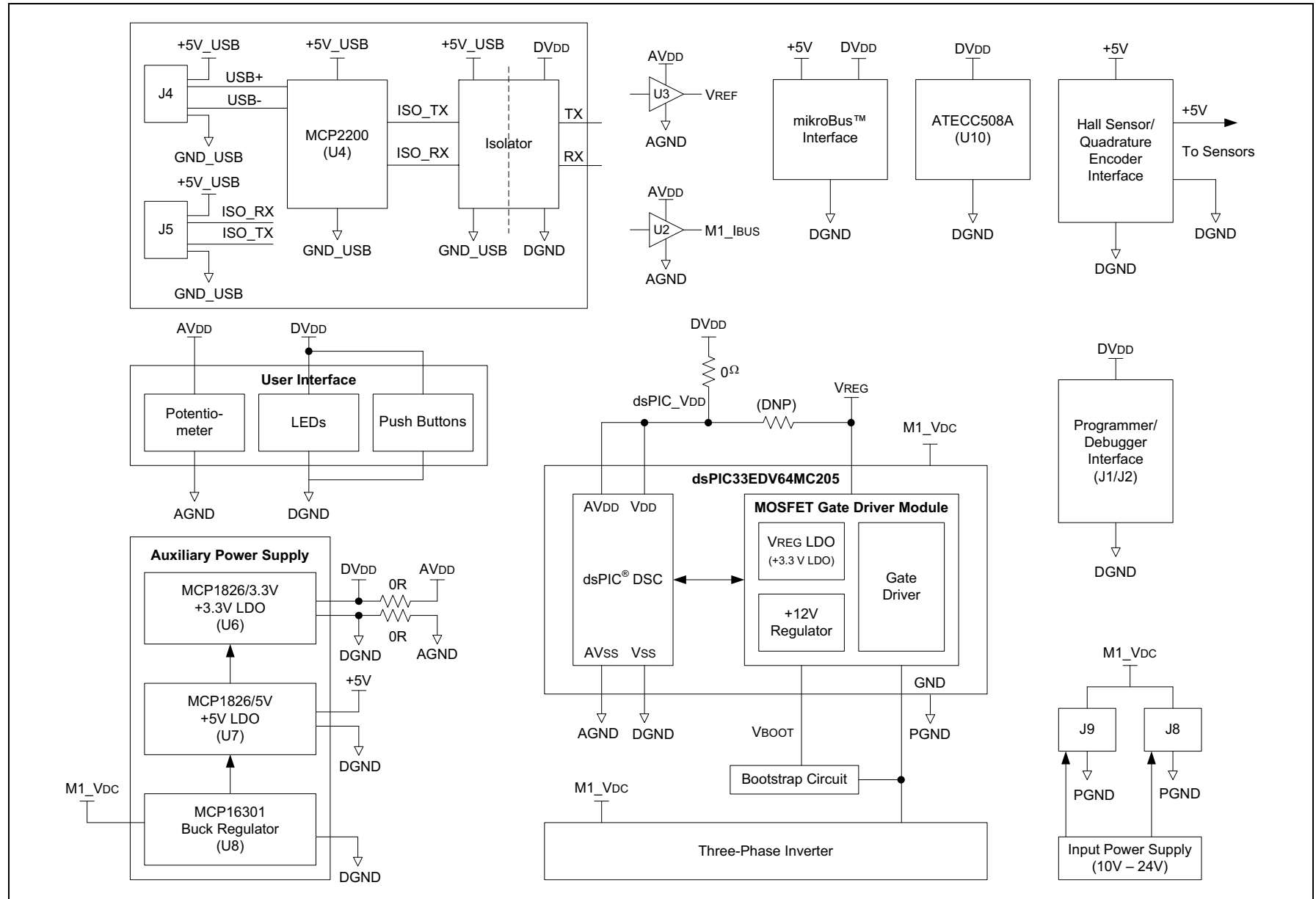
For details, refer to [Section 2.3 “User Interface Hardware”](#).

### 3.2.4 Power Supply

The development board can be powered through connector J8 or J9. The dsPIC33EDV64MC205 is powered by the same power supply as the inverter bridge. The bootstrap circuit used by the high-side gate driver is powered by the VBOOT (i.e., +12V) output generated by the LDO internal to the dsPIC33EDV64MC205. The internal +3.3V LDO, with an output current capability of 70 mA, can be used to power the dsPIC33EDV64MC205. The development board provides a +5V DC output for powering the Hall sensors or Quadrature Encoders.

For more information, refer to [Section C.3 “Auxiliary Power Supply”](#).

**FIGURE 3-3: DEVELOPMENT BOARD POWER SUPPLY INTERCONNECTIONS**



### 3.2.5 Three-Phase Inverter Bridge

The three-phase motor power stage is implemented using six N-channel MOSFETs (IPB054N06N3 G), configured as three half-bridges. A resistor is connected across the gate and source to ensure a soft turn-off of the MOSFET when the gate signal is disconnected. Low-ESR ceramic capacitors are provided across each half-bridge for filtering high-frequency noise, which is generated due to switching. A transient voltage suppressor is connected between the inverter supply and ground for protecting the inverter and driver against voltage transients.

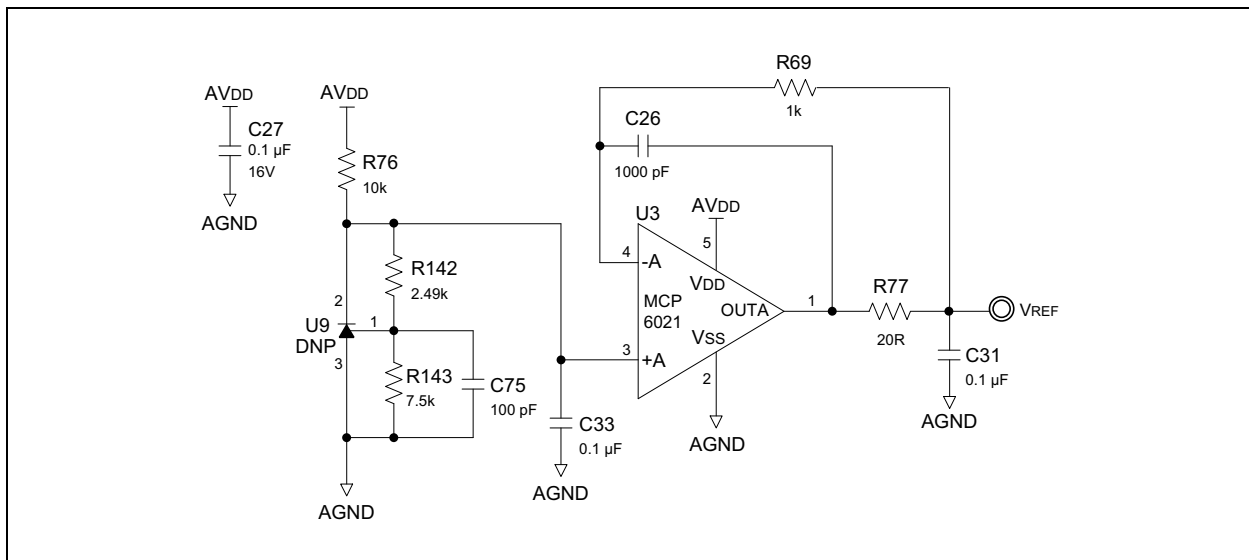
The three-phase gate driver, internal to the dsPIC33EDV64MC205, is used for driving the low-side and high-side MOSFETs of the motor control inverter. The bootstrap circuit (resistor, diode and capacitor), required to drive the high-side MOSFETs, is connected externally to the dsPIC33EDV64MC205. However, the bootstrap circuit is powered by the +12V LDO ( $V_{BOOT} - 30 \text{ mA}$ ) internal to the dsPIC33EDV64MC205.

The output of the three-phase inverter bridge is available on connector J7.

### 3.2.6 Voltage Reference Circuit

The Reference Voltage ( $V_{REF}$ ) is generated on the dsPIC33EDV64MC205 Motor Control Development Board; it is half the analog supply voltage ( $AV_{DD}$ ), that is, approximately +1.65V. This is used for providing a DC voltage shift on the op amp output, allowing positive and negative current swings as a single supply amplifier is used for current amplification. The reference circuit is built around an MCP6021 op amp (see [Figure 3-4](#)). The resistors, R76, R142 and R143, form the voltage divider circuit and generate a voltage equal to half of the Analog Voltage ( $AV_{DD}$ ). The op amp U3 (MCP6021) is used as a buffer. The resistors, R69, R77 and C26, form a compensation circuit to drive capacitive loads, where C26 acts as a high-frequency feedback path and R69 is used as a feedback path for low-frequency signals.

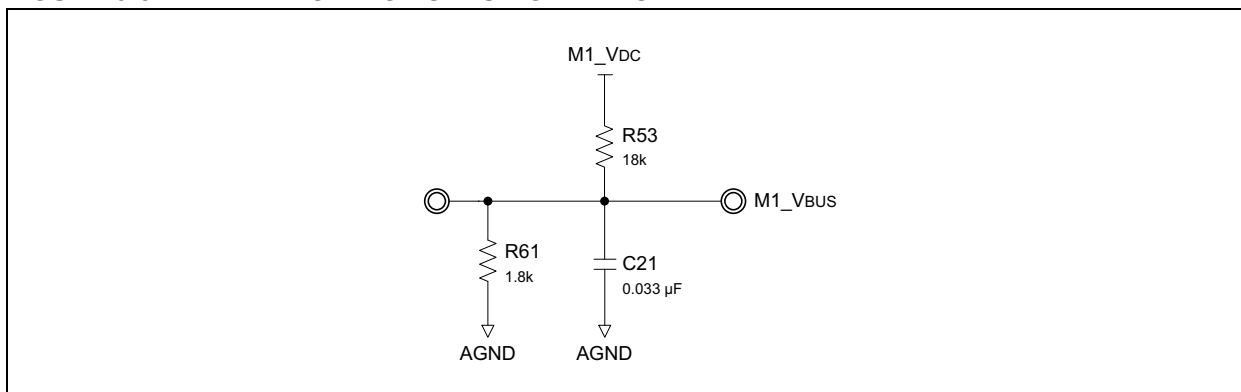
**FIGURE 3-4: VOLTAGE REFERENCE CIRCUIT**



## 3.2.7 DC Voltage Sensing

A voltage sensing network is provided to scale down the DC supply voltage powering the inverter to connect it to an analog channel of the dsPIC<sup>®</sup> DSC for voltage measurement. The voltage divider network, formed by resistors R53 and R61, divides the DC input voltage at a voltage scaling ratio of 1:11 (see [Figure 3-7](#)). The voltage divider network output (M1\_VBUS) is connected to the analog input pin (Pin #26) of the dsPIC33EDV64MC205.

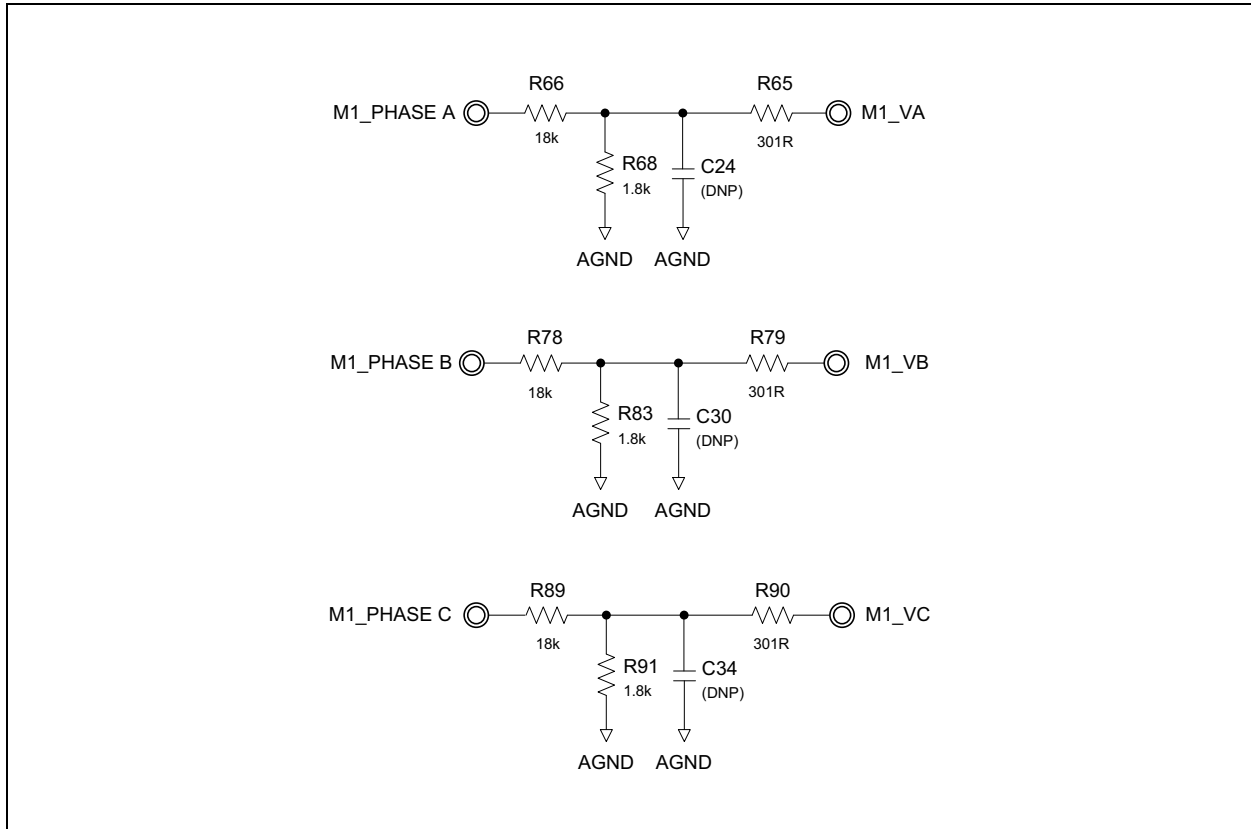
**FIGURE 3-5: DC VOLTAGE SENSING NETWORK**



### 3.2.8 Back-EMF Sensing

The PMSM/BLDC motor can be commutated by monitoring back-EMF signals. The motor back-EMF is scaled down by voltage dividers. The capacitors can be added at the divider outputs to filter noise. The scaled back-EMF signals can be connected to analog input pins of the dsPIC33EDV64MC205 by populating zero ohm jumpers provided on the development board.

**FIGURE 3-6: BACK-EMF SENSING NETWORK**



**Note:** Phase current signals and phase voltage (back-EMF) signals cannot be connected to the dsPIC33EDV64MC205 simultaneously. [Table 3-3](#) summarizes the resistor jumper settings for connecting back-EMF signals to the dsPIC33EDV64MC205.

# dsPIC33EDV64MC205 Motor Control Development Board User's Guide

**TABLE 3-3: RESISTOR JUMPER SETTINGS TO CONNECT BACK-EMF SIGNALS TO dsPIC33EDV64MC205**

Back-EMF Signal	Pin # <sup>(1)</sup>	Pin Function <sup>(1)</sup>	Populate <sup>(2)</sup>	Remove <sup>(2)</sup>	Remarks
Back-EMF Signal Motor Phase A (M1_VA)	33	AN6/C4IN1+/ OA3OUT/ OCFB/RC0	R25	R27/R46/R153/C78  Also disables Amplifier 3 (OA3) of dsPIC33EDV64MC205	Disconnects dsPIC33EDV64MC205 Pin #35 and OA3 amplifier feedback network
	25	AN0/OA2OUT/ RA0	R27	R29/R25	Disconnects potentiometer (POT1) and connection to dsPIC33EDV64MC205 Pin #33
Back-EMF Signal Motor Phase B (M1_VB)	28	PGEC3/VREF+/ AN3/RPI33/SS1/ OA1OUT/ CTED1/RB1	R31	R33/R47/R155/C79  Also disables Amplifier 2 (OA1) of dsPIC33EDV64MC205	Disconnects dsPIC33EDV64MC205 Pin #26 and OA1 amplifier feedback network
	26	AN1/C2IN1+/ RA1	R33	R31/R35	Disconnects dsPIC33EDV64MC205 Pin #28 and SC bus voltage sense signal (M1_VBUS)
Back-EMF Signal Motor Phase C (M1_VC)	27	PGED3/VREF-/ C2IN1-/AN2/ RPI32/SS1/ CTED2/RB0	R37	R38/R18	Disconnects bus current signal (M1_IBUS) and mikroBUS™ signal (CS)

**Note 1:** Pin number and function of dsPIC33EDV64MC205.

**Note 2:** Resistors to be populated or removed to connect back-EMF signals to the dsPIC33EDV64MC205.



### 3.2.9 Current Sensing

Field-Oriented Control (FOC) requires the motor phase current of the PMSM/BLDC motor. In the dsPIC33EDV64MC205 Motor Control Development Board, shunt resistors are provided in each inverter leg to determine the amount of current flowing through the motor phases. An additional shunt resistor is provided for sensing the bus current as this information is necessary for overcurrent protection. Motor phase currents can also be reconstructed from the DC bus current information by appropriately sampling currents during the PWM switching period. A noninverting differential amplifier is used for amplifying the voltage drop across the shunt resistors. The amplifier output voltage is shifted by +1.65V ( $V_{REF}$ ) to allow positive and negative current swings. The voltage offset of the bus current sensing circuit can be modified by the resistor divider (R86 and R87) provided in the noninverting input of the bus current amplifier. The Common-mode and Differential-mode filters are added to the op amp input pins for noise filtering. It is also possible to add filters at the output of the DC bus current amplifier (U2).

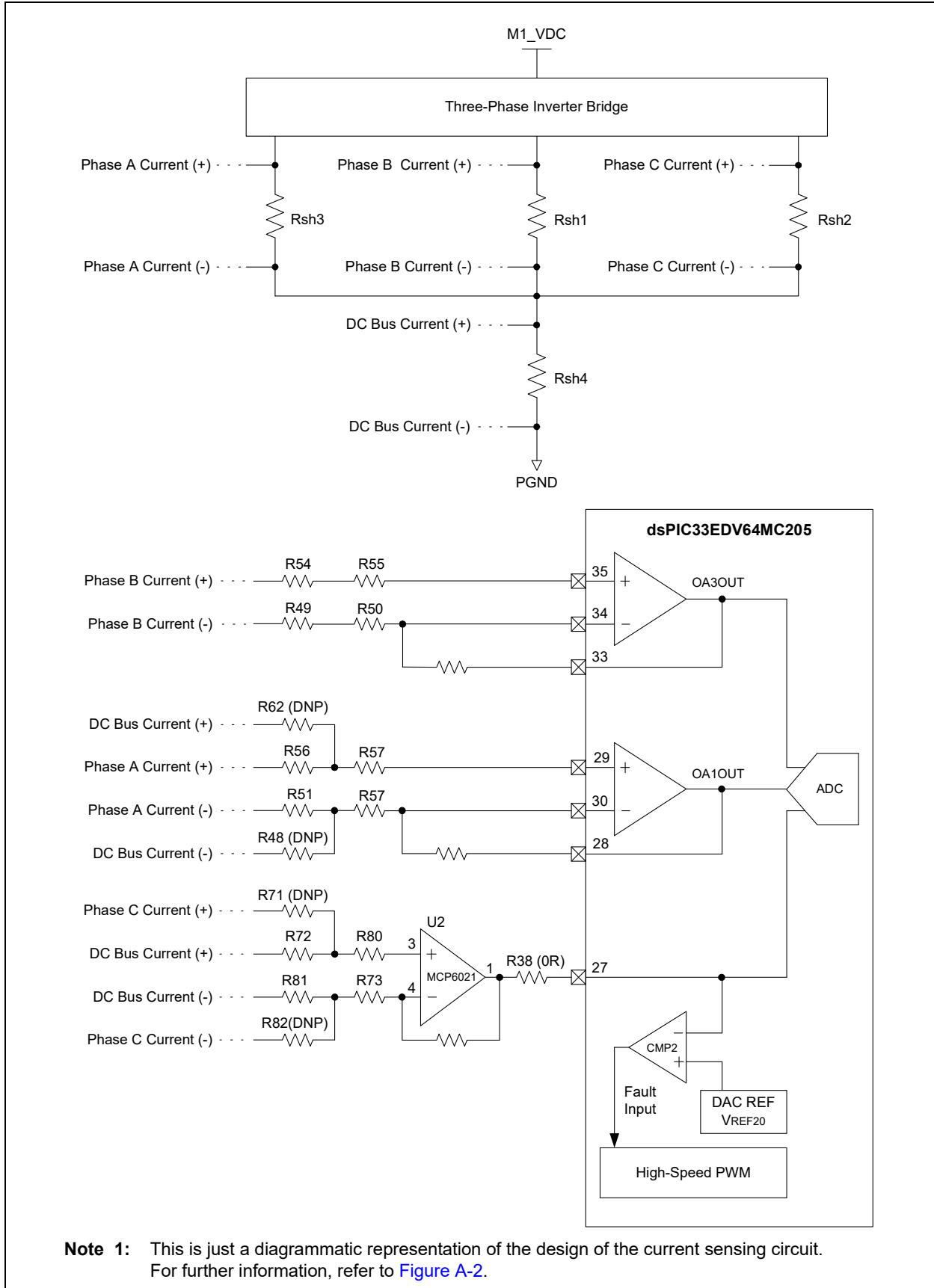
As shown in [Figure 3-7](#), op amps, OA1 and OA3, that are internal to dsPIC33EDV64MC205 are used for Phase A and Phase B current amplification. The dsPIC33EDV64MC205 internal amplifier, OA1, can be configured to sense DC bus current instead of Phase A current by populating the input resistors appropriately.

The op amp, MCP6021 (U2), is added for DC bus current amplification. This amplifier can be configured to sense Phase C current by populating the appropriate input resistors. The Common-mode and Differential-mode filters are provided at the input pins of the op amp U2 used for DC bus current amplification. When the 'Single-Shunt Three-Phase Current Reconstruction Algorithm' is implemented, the capacitors, C25 and C32, can be removed to reduce filter delays to minimize the critical time window needed to sample bus current to reconstruct the phase currents. The output of this amplifier, U2 (M1\_IBUS), is connected to one of the analog inputs (Pin #27) of the dsPIC33EDV64MC205. This pin also connects to the internal Comparator 2 negative input (C2IN1-). The Comparator 2 positive input is configured to use the internal DAC output to set the overcurrent threshold. The Comparator 2 output (CMP2) generates an active-low output when overcurrent is detected. This comparator output is available to the high-speed PWM module as a Fault input. If the high-speed PWM module Fault is enabled and CMP2 is selected as an active-low Fault source, during an overcurrent Fault condition, the motor control PWMs will be disabled, thus protecting the MOSFETs.

The gain of the amplifier used for phase current and bus current sensing are set for sensing 4.4A peak current by default. The gain of the amplifier can be changed as required by the application.

For more information refer to [C.2 "Current Sensing Circuit"](#).

**FIGURE 3-7: CURRENT SENSE CONFIGURATION<sup>(1)</sup>**



### 3.2.10 Hall Sensor/Quadrature Encoder Interface

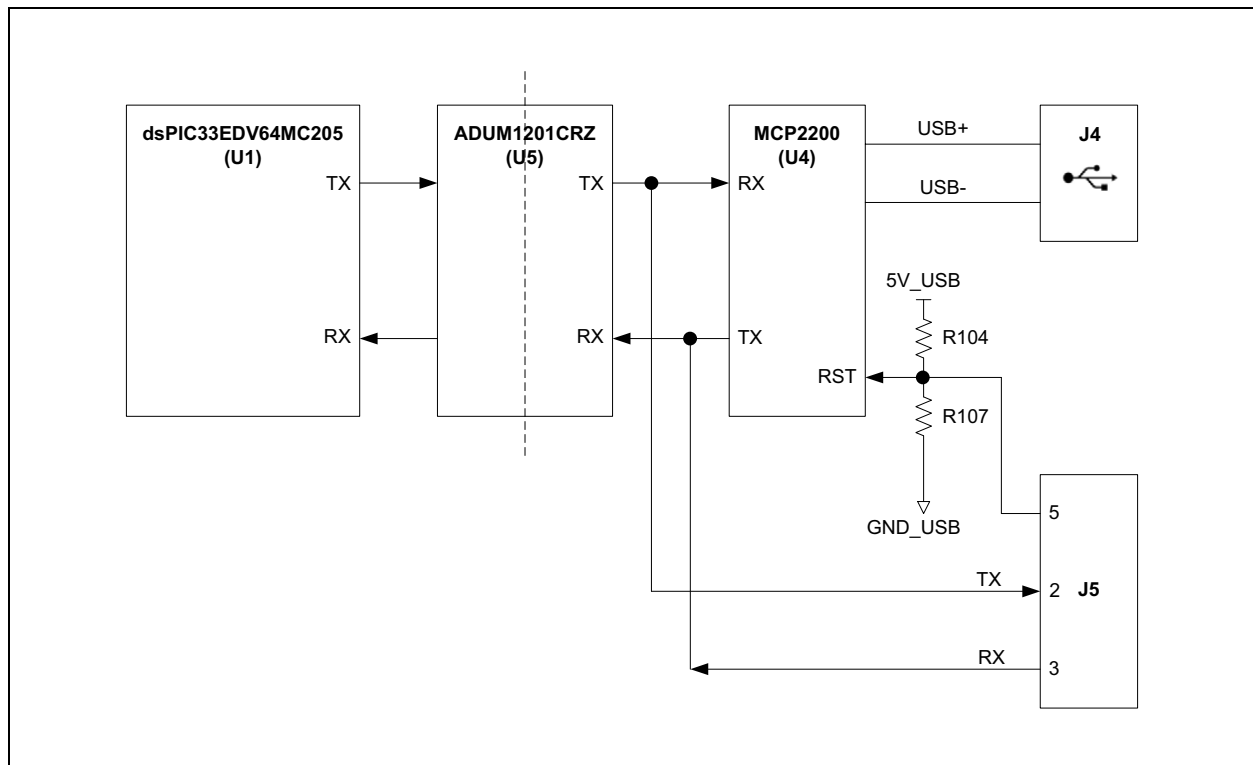
The PMSM/BLDC motor control applications can read rotor position and speed information from Hall sensors or encoders. The Hall sensors can be powered by the +5V supply output available through the interface connector terminals. The Hall sensor/Quadrature Encoder Interface circuit supports either open-collector or push-pull output sensors. A capacitor is added to each signal output to reduce noise. The circuit is configured to interface with open-collector output sensors by default. However, a voltage divider circuit is provided at each signal to scale down the signal level from +5V to +3.3V when sensors with a push-pull output are interfaced. When interfacing sensors with a push-pull output, remove the pull-up resistors as well.

### 3.2.11 Isolated Debug Serial UART Interface

The isolated serial USB to UART interface can be used to establish communication between the host PC and the dsPIC33EDV64MC205 device. The dsPIC33EDV64MC205 Motor Control Development Board uses an on-board MCP2200 as a bridge between the UART and USB. The MCP2200 is a USB 2.0 to UART protocol converter with GPIO from Microchip's 'Interfacing and Networking' product portfolio. For a detailed description and the "MCP2200 Data Sheet" (DS20002228), visit Microchip's website ([www.microchip.com](http://www.microchip.com)).

The UART TX and RX signals from the dsPIC33EDV64MC205 are isolated by the two-channel isolator, ADUM1201CRZ, and then connected to the RX and TX pins of the MCP2200, respectively. The USB outputs (USB+, USB-) are connected to the mini-USB header J4, provided to interface with the host PC. See Figure 3-8 for the isolated debug serial UART interface interconnection provided on the development board. An ESD protection diode array is provided on USB data lines. The USB-UART connection setup can support a baud rate of up to 1 Mbps.

FIGURE 3-8: ISOLATED DEBUG SERIAL UART INTERFACE



There is an additional header, J5, which is provided on the development board to allow interfacing of any other USB-UART serial converters. As shown in [Figure 3-8](#), isolated UART TX and RX signals from dsPIC33EDV64MC205 are connected to J5 (Pins #2 and #3). When interfacing an external USB to UART converter through connector J5, disable the on-board MCP2200 by holding its RST pin low. This can be done by connecting Pin Number 5 of the J5 connector to USB\_GND or removing resistor R104 and populating R107.

Collateral documents, such as the USB driver, information related to driver installation and how to access ports, etc., for operating systems such as Linux<sup>®</sup>, Mac<sup>®</sup> and Windows<sup>®</sup> operating systems are available at Microchip's website (<http://www.microchip.com/MCP2200>). In the Windows OS, after successful driver installation, the device will appear as a 'COMx' port object to which standard terminal programs can open, read and write data.

The MPLAB X IDE hosts two plug-ins, which allow real-time diagnostics through interaction with an external host PC. These include:

- X2C-Scope from the Linz Center of Mechatronics GmbH for use with the X2C-Scope plug-in for MPLAB X IDE.
- RTDM from Microchip for use with the MPLAB Data Monitor and Control Interface (DMCI) plug-in.

### 3.2.12 mikroBUS™ Interface and Crypto Authentication

The mikroBUS interface connectors are provided to add one of the available click boards to the dsPIC33EDV64MC205 Development Board. The primary intention of adding this interface is to allow LIN connectivity through a MikroElektronica™ MCP2003B board ([www.mikroe.com](http://www.mikroe.com)). However, users can interface other click boards if connection requirements are satisfied.

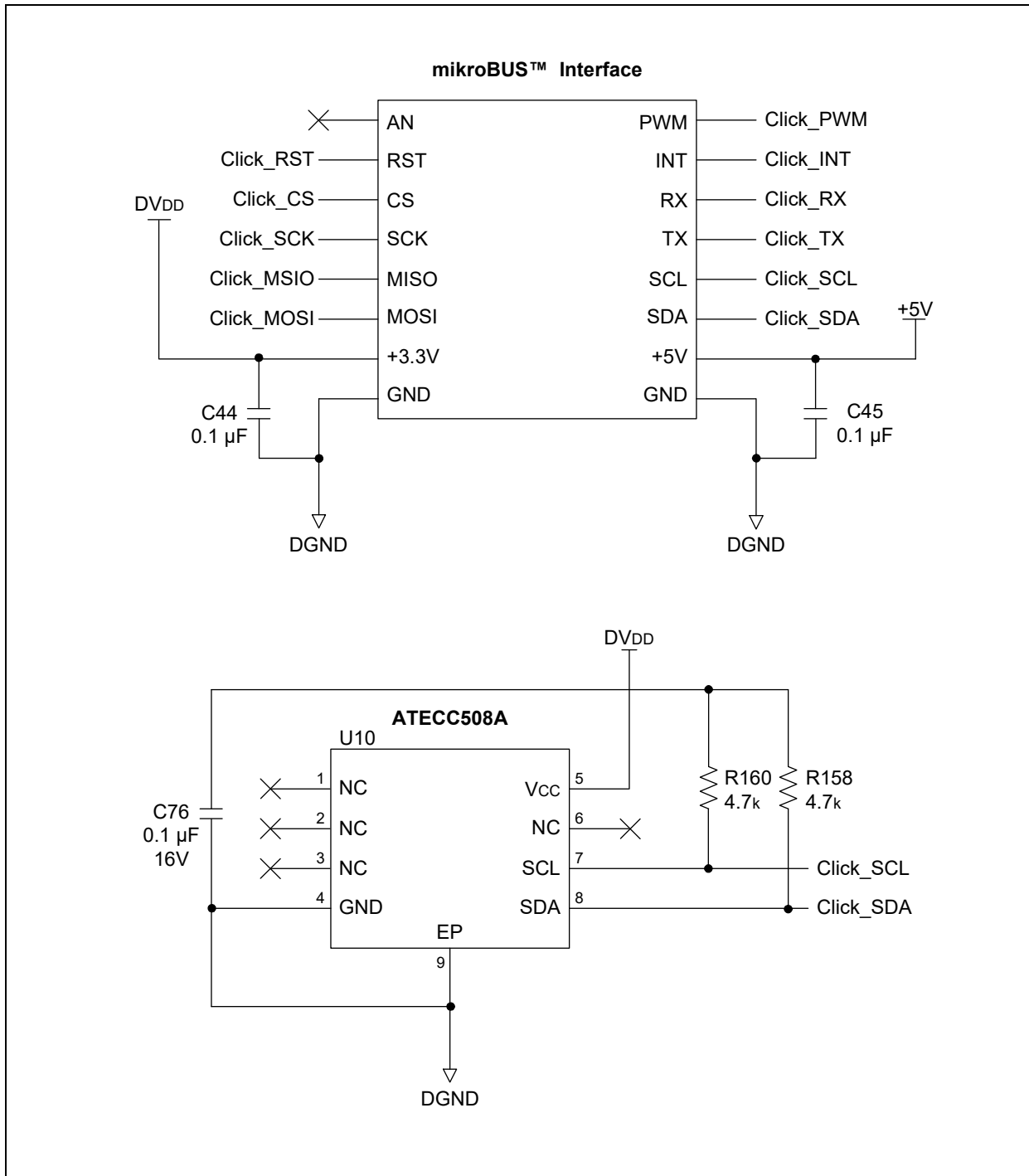
**Note 1:** The 'AN' pin of the mikroBUS interface is not connected to any pin of the dsPIC33EDV64MC205. Refer to [Table 3-4](#) for pin mapping between dsPIC33EDV64MC205 to the mikroBUS interface. Add or remove specified resistors to establish connection between specific pins of the dsPIC33EDV64MC205 device with the mikroBUS interface.

**TABLE 3-4: PIN MAPPING – dsPIC33EDV64MC205 TO mikroBUS™ INTERFACE**

mikroBUS™		dsPIC33EDV64MC205		To Interface dsPIC33EDV64MC205 with Specific Pin of mikroBUS		Remarks
Pin #	Pin Name	Pin #	Pin Function	Populate	Remove if Populated	
1	AN	—	—	N/A	N/A	No connection
2	RST	38	RPI24/SDA2/RA8	R9	R111	Disconnects isolated UART interface TX
3	CS	27	PGED3/VREF-/C2IN1-/AN2/RPI32/SS1/CTED2/RB0	R18	R20/R37/R38	Disconnects M1_IBUS/M1_VC and connection to dsPIC33EDV64MC205 Pin #50
		50	RP39/FLT32/INT0/RB7	R20	R18/R21/R22	Disconnects LED1 and connection to mikroBUS interface INT signal
4	SCK	42	RPI51/SCK1/RC3	R32	R30	Disconnects M1_QE_INDEX (Quadrature Encoder Index signal)
5	MISO	41	RPI25/SDI1/RA9	R36	R34	Disconnects M1_QE_HOME (Quadrature Encoder Home signal)
6	MOSI	40	CVREF20/RP20/T1CK/SDO1/RA4	R16	R14	Disconnects LED2
11	SDA	43	RPI52/SDA1/RC4	R28	R26	Disconnects M1_QE_B (Quadrature Encoder Input B)
12	SCL	44	RPI53/SCL1/RC5	R24	R23	Disconnects M1_QE_A (Quadrature Encoder Input A)
13	TX	52	RP41/ASDA1/RB9	R11	—	Direct connection (default)
14	RX	51	CVREF10/RP40/ASCL1/T4CK/RB8	R12	—	Direct connection (default)
15	INT	50	RP39/FLT32/INT0/RB7	R22	R21/R20	Disconnects LED1 and connection to mikroBUS interface CS signal
16	PWM	39	RP36/SCL2/RB4	R10	R110	Disconnects isolated UART interface TX

To create a secured IoT-based motor control application demo, a crypto authentication device, ATECC508A from the Microchip product portfolio, is added on the development board. This device can be interfaced with the dsPIC33EDV64MC205 through the I<sup>2</sup>C interface. The same I<sup>2</sup>C communication lines of the dsPIC33EDV64MC205 are connected to the mikroBUS interface connector, allowing this to be configured as a secured node of the I<sup>2</sup>C network (see Figure 3-9). The mikroBUS interface is not isolated from the input supply connected to the development board.

**FIGURE 3-9: mikroBUS™ INTERFACE AND CRYPTO AUTHENTICATION CIRCUIT**



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## Appendix A. Board Layout and Schematics

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### A.1 INTRODUCTION

This chapter provides detailed technical information on the dsPIC33EDV64MC205 Motor Control Development Board.

### A.2 BOARD LAYOUT AND SCHEMATICS

The following are the schematics and layout of the development board:

- [Figure A-1](#): dsPIC33EDV64MC205 Motor Control Development Board Schematic (Sheet 1 of 5)
- [Figure A-2](#): dsPIC33EDV64MC205 Motor Control Development Board Schematic (Sheet 2 of 5)
- [Figure A-3](#): dsPIC33EDV64MC205 Motor Control Development Board Schematic (Sheet 3 of 5)
- [Figure A-4](#): dsPIC33EDV64MC205 Motor Control Development Board Schematic (Sheet 4 of 5)
- [Figure A-5](#): dsPIC33EDV64MC205 Motor Control Development Board Schematic (Sheet 5 of 5)
- [Figure A-6](#): dsPIC33EDV64MC205 Motor Control Development Board Layout (Top View)
- [Figure A-7](#): dsPIC33EDV64MC205 Motor Control Development Board Layout (Bottom View)

FIGURE A-1: dsPIC33EDV64MC205 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATIC REV. 1.0 (SHEET 1 OF 5)

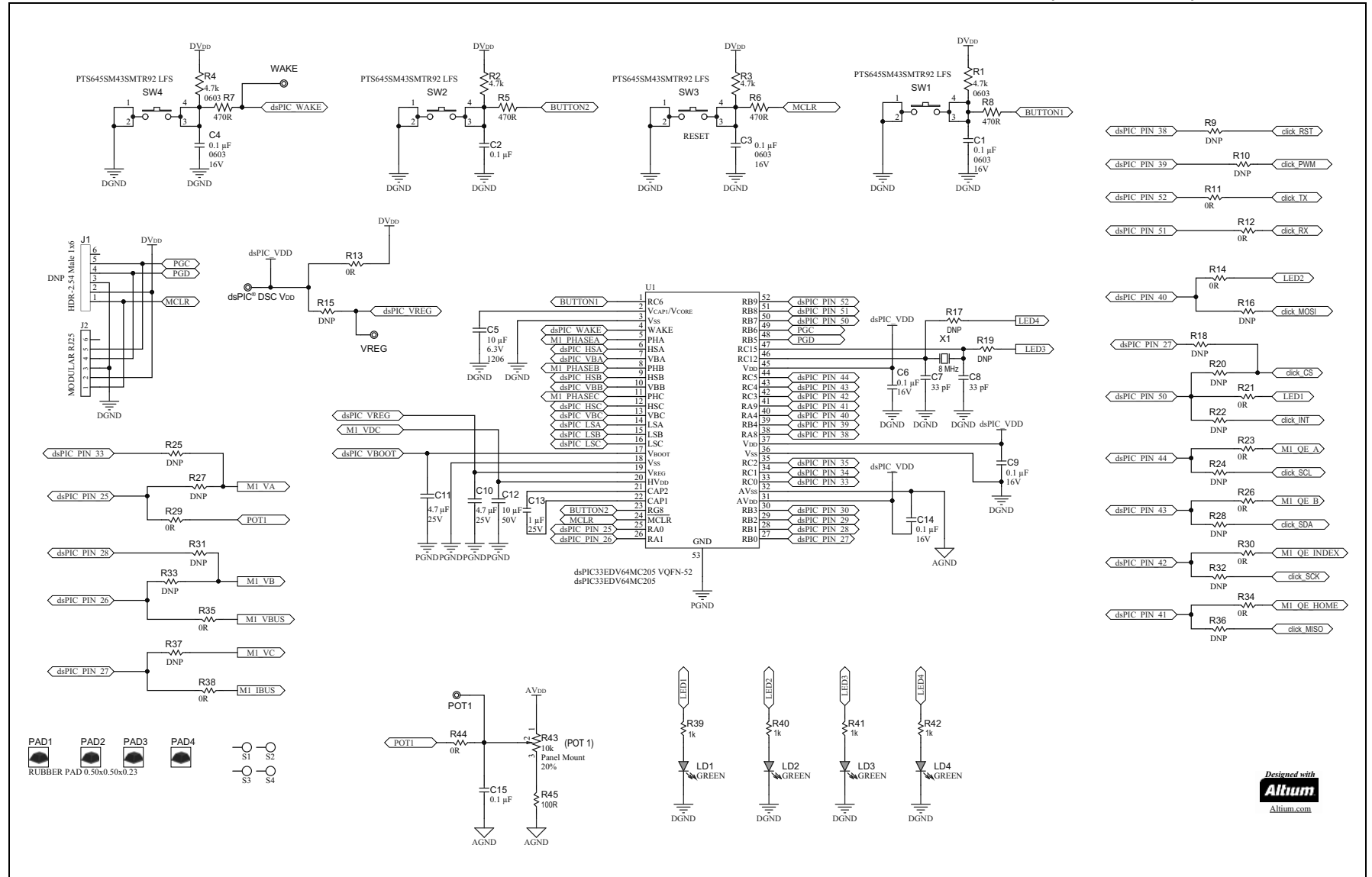




FIGURE A-2: dsPIC33EDV64MC205 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATIC REV. 1.0 (SHEET 2 OF 5)

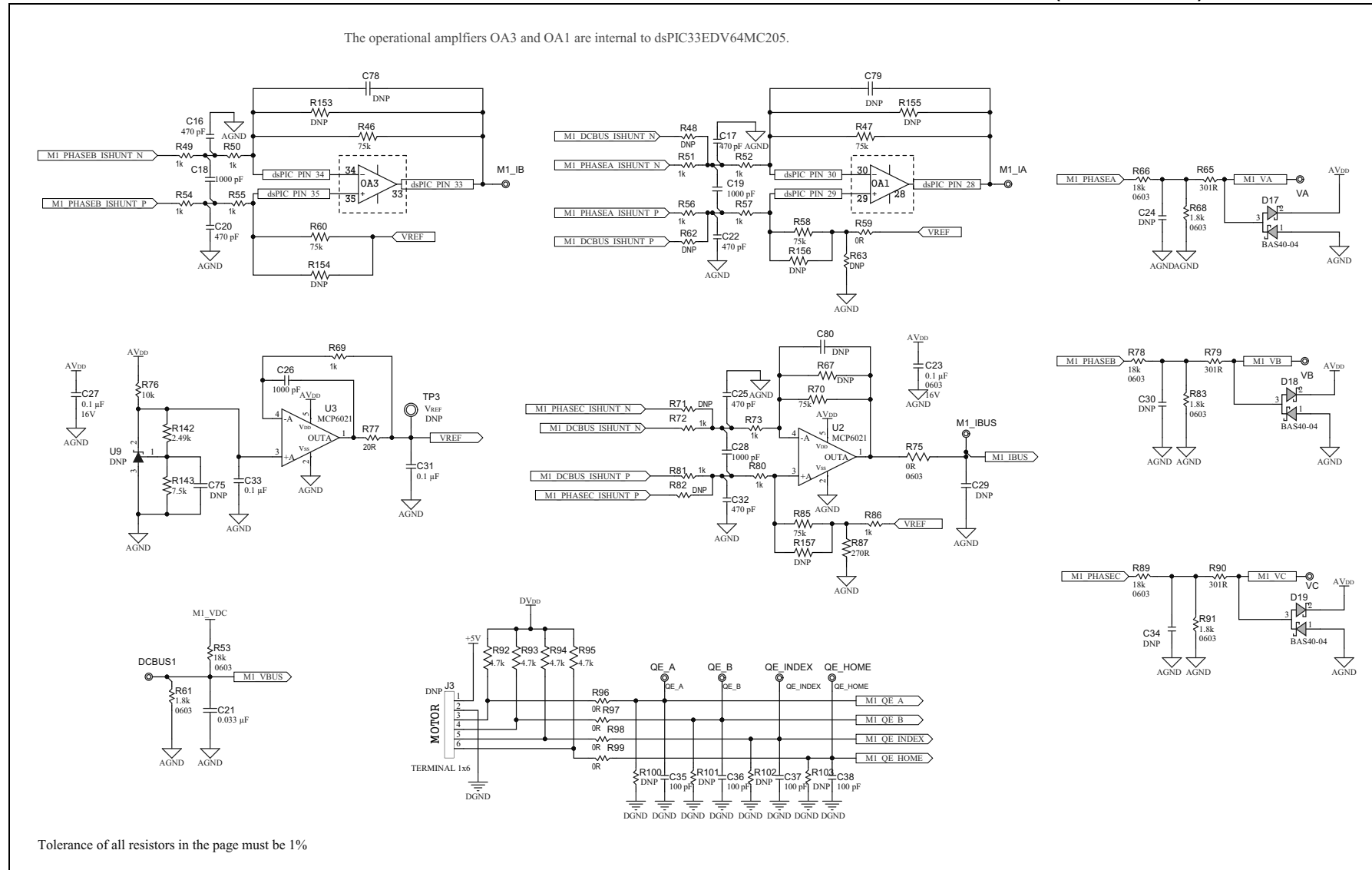


FIGURE A-3: dsPIC33EDV64MC205 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATIC REV. 1.0 (SHEET 3 OF 5)

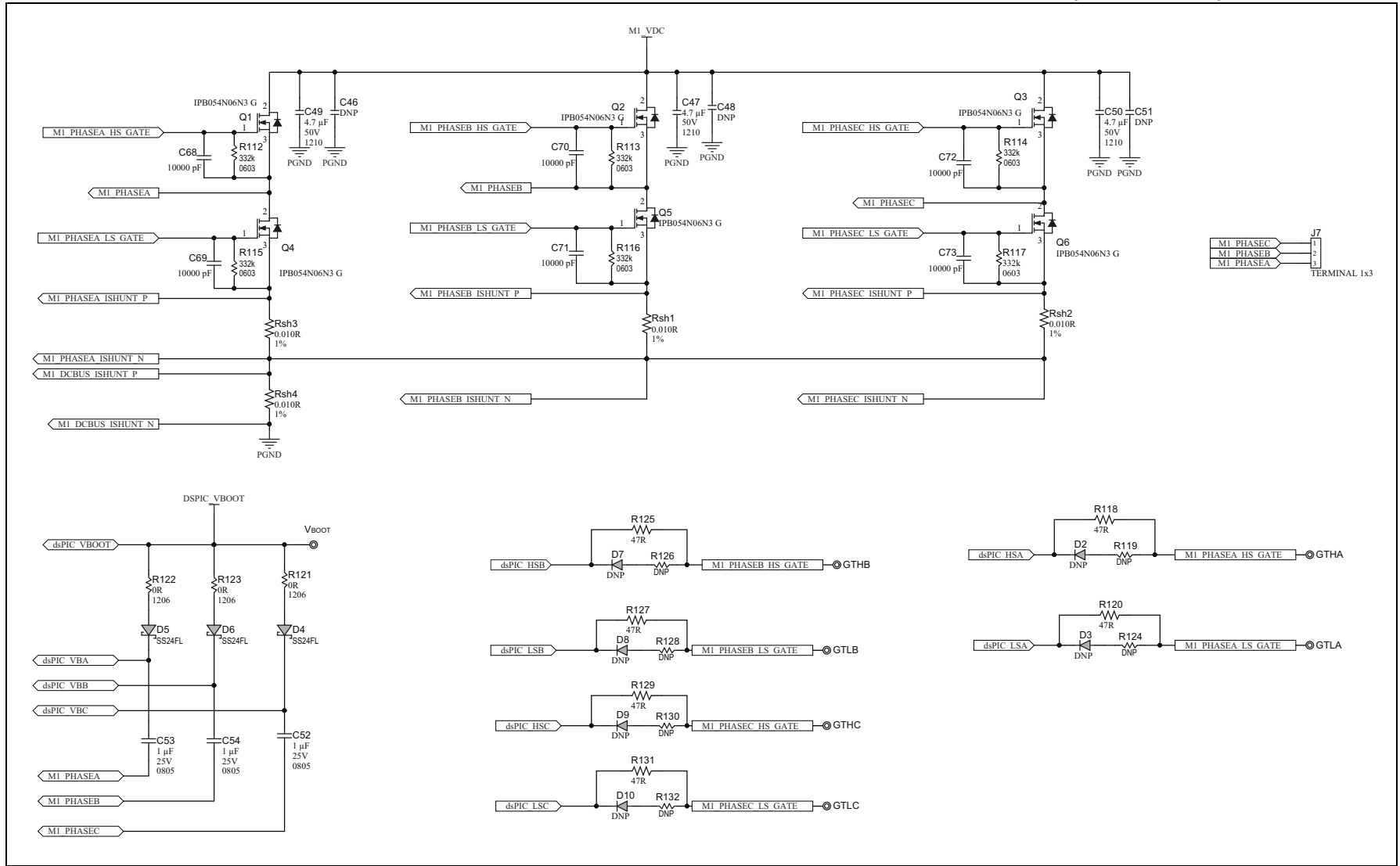


FIGURE A-4: dsPIC33EDV64MC205 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATIC REV. 1.0 (SHEET 4 OF 5)

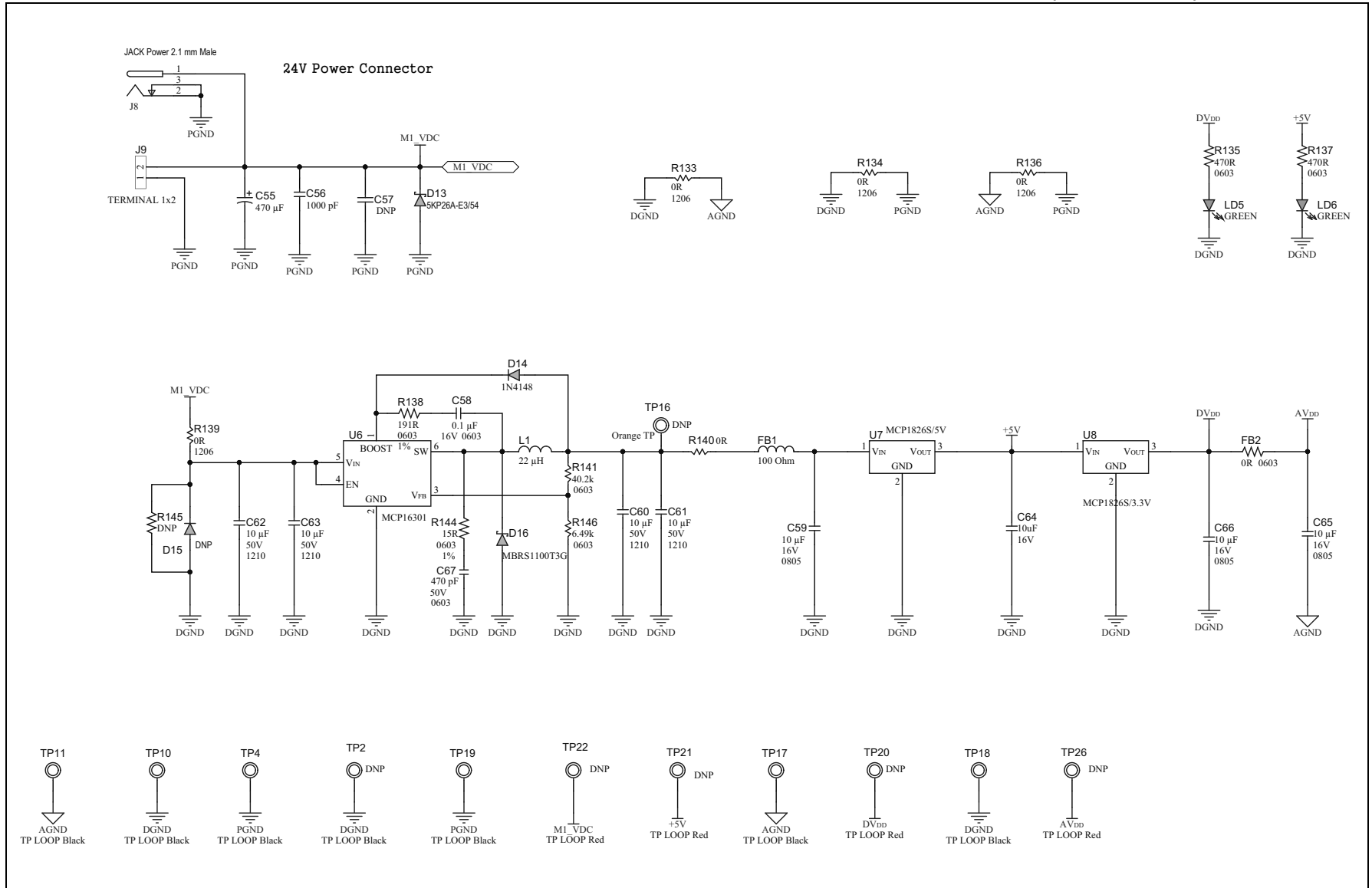


FIGURE A-5: dsPIC33EDV64MC205 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATIC REV. 1.0 (SHEET 5 OF 5)

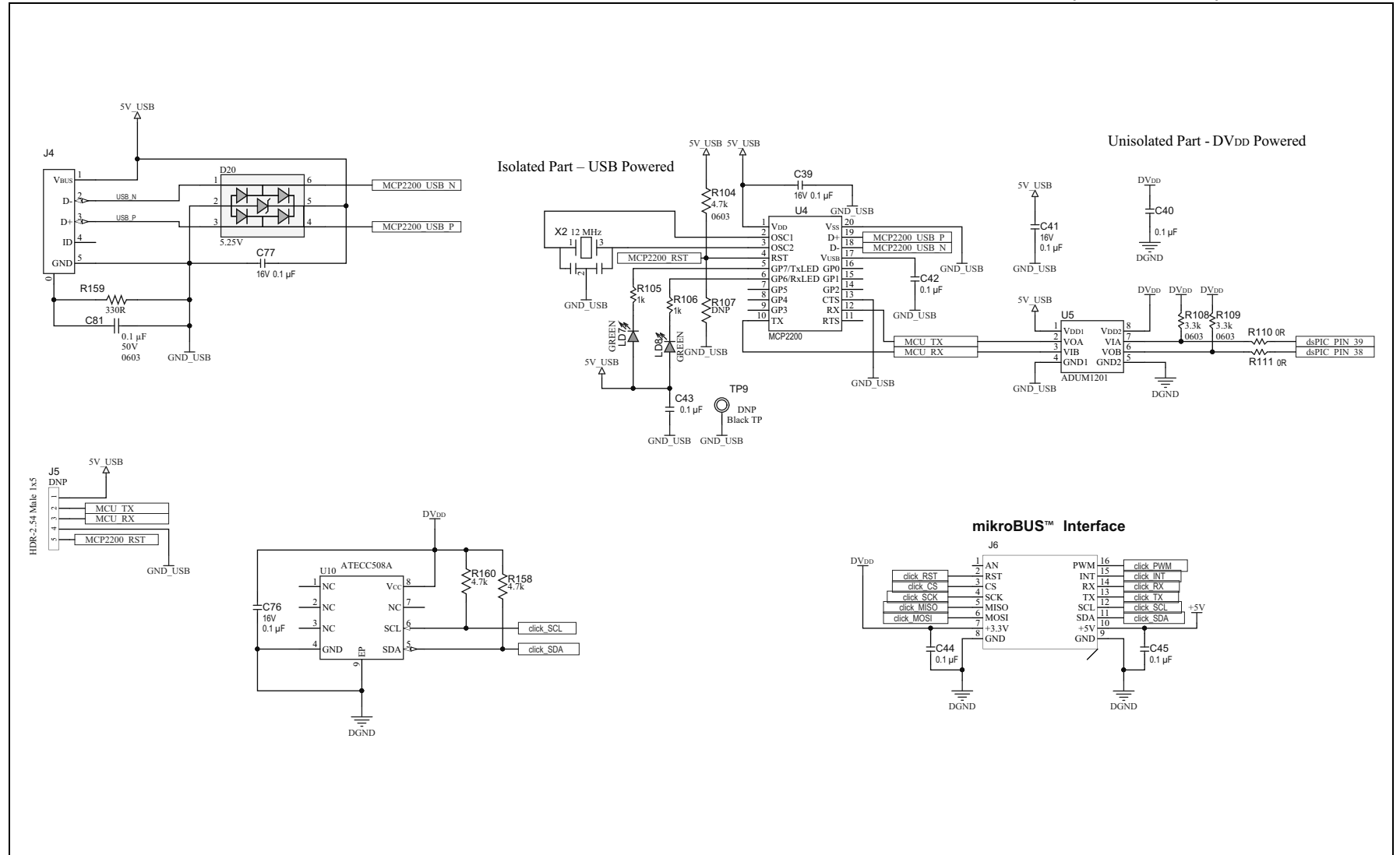


FIGURE A-6: dsPIC33EDV64MC205 MOTOR CONTROL DEVELOPMENT BOARD LAYOUT (TOP VIEW)

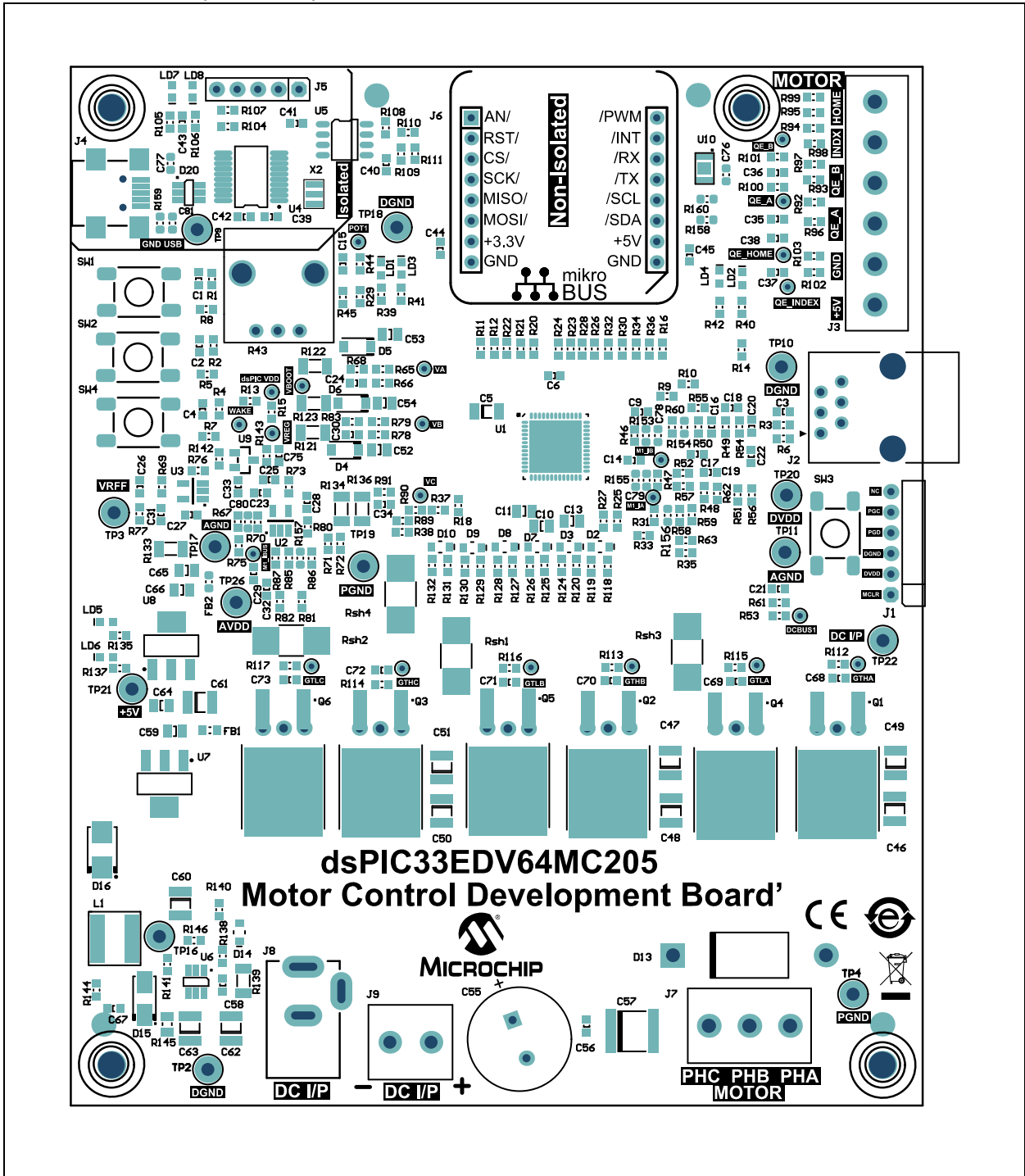
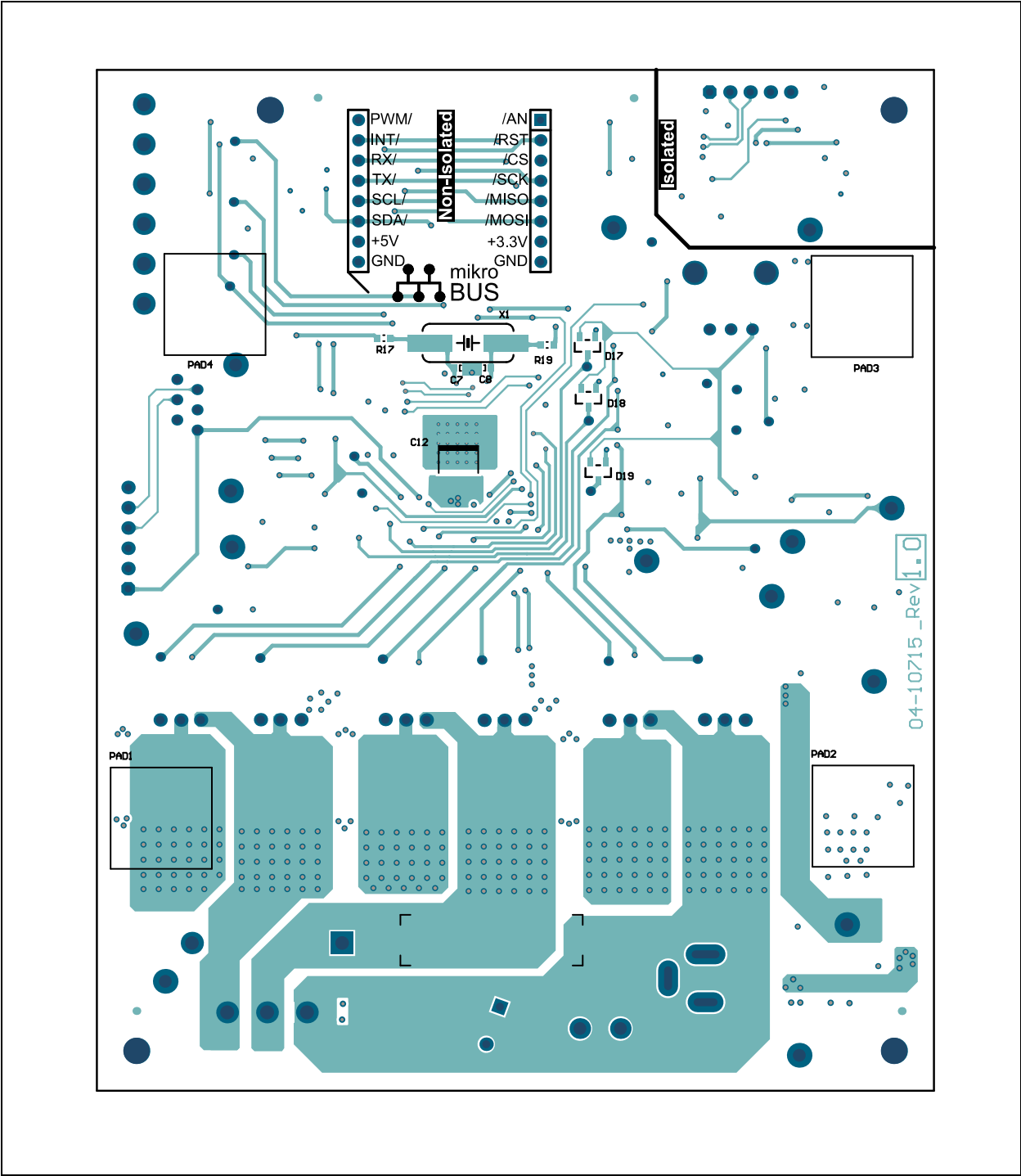


FIGURE A-7: dsPIC33EDV64MC205 MOTOR CONTROL DEVELOPMENT BOARD LAYOUT (BOTTOM VIEW)



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## Appendix B. Electrical Specifications

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### B.1 INTRODUCTION

This chapter provides the electrical specifications for the dsPIC33EDV64MC205 Motor Control Development Board (see [Table B-1](#)).

**TABLE B-1: ELECTRICAL SPECIFICATIONS**

Parameter	Operating Range
Input DC Voltage	10V-24V
Maximum Input Current through Connector J8	2.5A
Maximum Input Current through Connector J9	15A
Continuous Output Current per Phase @ +25°C	10A (RMS)

At an ambient temperature (+25°C), the development board remains within thermal limits when operating with continuous output currents of up to 10A (RMS) while operating in the permissible voltage range.

NOTES:



## Appendix C. Design Calculation

### C.1 INTRODUCTION

This chapter provides design details of the:

- [Current Sensing Circuit](#)
- [Auxiliary Power Supply](#)

### C.2 CURRENT SENSING CIRCUIT

Circuits used for sensing motor phase currents and DC bus current are shown in [Figure C-1](#).

**FIGURE C-1: CURRENT SENSING CIRCUIT CONFIGURATION**

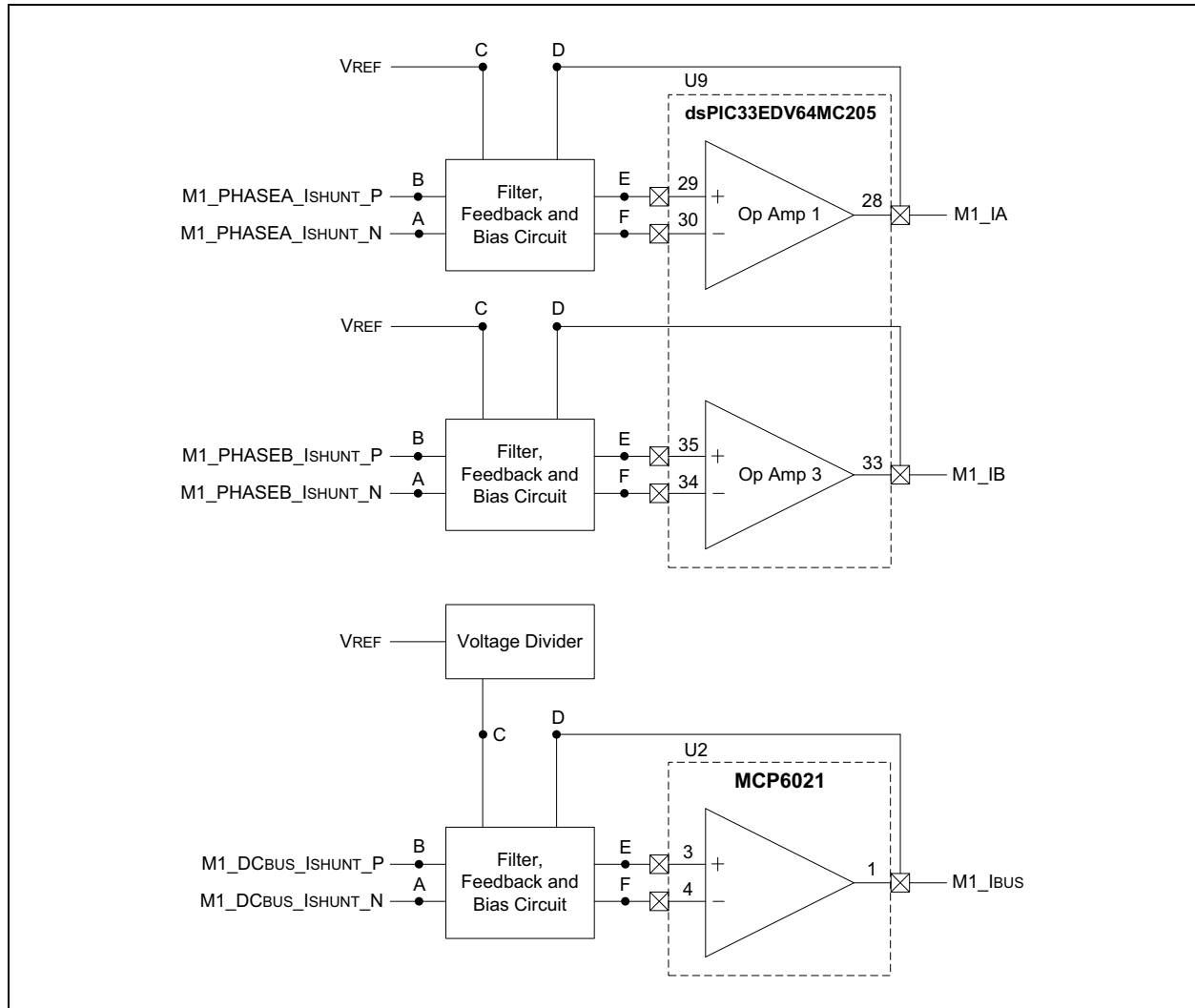
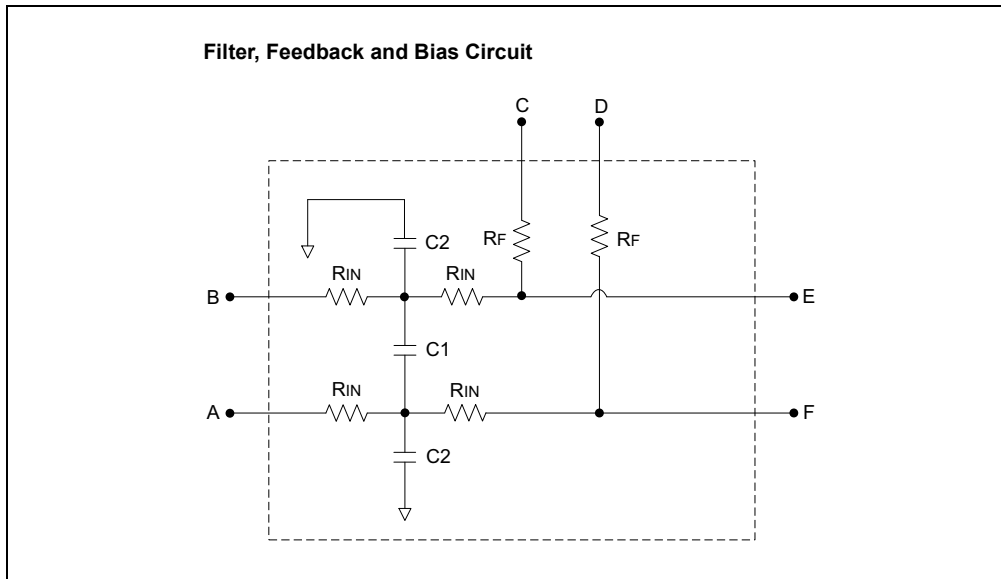


Figure C-2 shows the amplifier gain setting.

**FIGURE C-2: AMPLIFIER GAIN SETTING**



Equation C-1 provides the amplifier gain setting calculations. Equation C-2 and Equation C-3 show the cutoff frequency calculations using a differential-mode filter and a common-mode filter, respectively.

**EQUATION C-1: AMPLIFIER GAIN**

$$\text{Differential Amplifier Gain} = \frac{R_f}{(2 \times R_{in})}$$

**EQUATION C-2: CUTOFF FREQUENCY DIFFERENTIAL-MODE FILTER**

$$\text{Differential mode } f_{-3dB} \cong \frac{1}{2\pi(2 \times R_{in})\left(\frac{C2}{2} + C1\right)}$$

**EQUATION C-3: CUTOFF FREQUENCY COMMON-MODE FILTER**

$$\text{Common mode } f_{-3dB} \cong \frac{1}{2\pi(R_{in})(C2)}$$

## C.3 AUXILIARY POWER SUPPLY

The power supply circuit is designed in the following two stages:

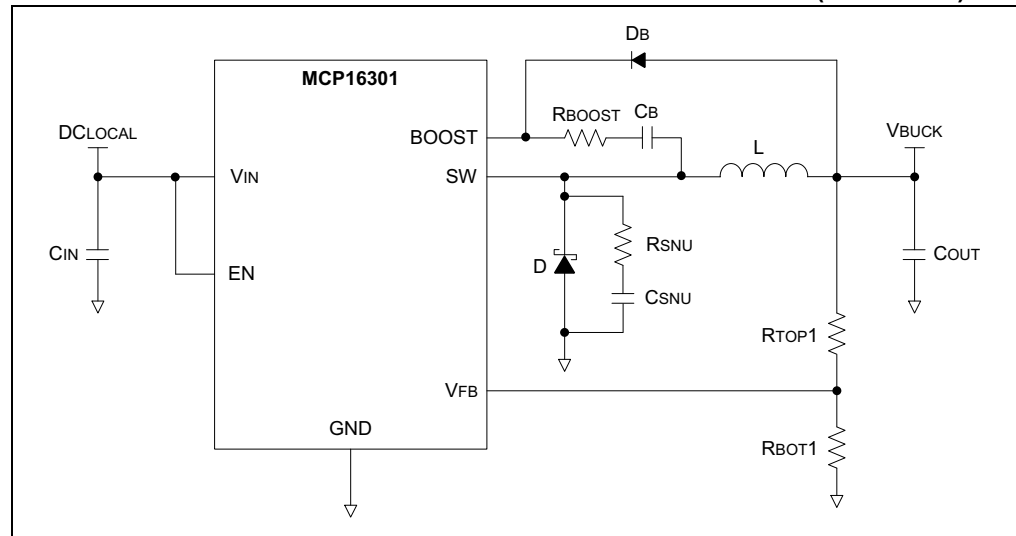
1. [First Stage of Auxiliary Power Supply](#)
2. [Second Stage of Auxiliary Power Supply](#)

### C.3.1 First Stage of Auxiliary Power Supply

The first stage of the power supply is a synchronous step-down converter (see [Figure C-3](#)). The first stage power supply has the following specifications:

- Input Voltage = 9V-26.4V
- Output Voltage ( $V_{BUCK}$ ) = 5.6V

**FIGURE C-3: FIRST STAGE OF POWER SUPPLY CIRCUIT (MCP16301)**



The component values used in this circuit are listed in [Table C-1](#), and were chosen using [Equation C-4](#) with  $V_{FB} = 0.8V$  and  $K = 0.22V/\mu H$  (see [Note 1](#) in [Table C-1](#)).

**EQUATION C-4:**

$$R_{TOP1} = R_{BOT1} \times \left( \frac{V_{BUCK}}{V_{FB}} - 1 \right)$$

$$K = V_{BUCK} / L$$

**TABLE C-1: FIRST STAGE POWER SUPPLY COMPONENT VALUES**

Designator	Power Supply 1
RTOP1	R141 = 40.2 kΩ
RBOT1	R146 = 6.49 kΩ
L	L1 = 22 μH <sup>(1)</sup>
CB	C58 = 0.1 μF <sup>(1)</sup>
CIN	C62 = C63 = 10 μF <sup>(1)</sup>
COUT	C60 = C61 = 10 μF <sup>(1)</sup>
VBUCK	5.6V

**Note 1:** These components are selected based on recommendations from the “MCP16301/H High-Voltage Input Integrated Switch Step-Down Regulator Data Sheet” (DS20005004).

A low forward drop Schottky diode is used for free-wheeling diode D. The average diode current is calculated using [Equation C-5](#). Based on these calculations, a MBRS1100T3G Schottky diode is selected.

### EQUATION C-5:

$$I_{D(AVG)} = \left(1 - \frac{V_{BUCK}}{DCLOCAL}\right) \times I_{OUT}$$

A standard 1N4148 ultra-fast diode for boost diode DB was selected based on recommendations from the “MCP16301/H High-Voltage Input Integrated Switch Step-Down Regulator Data Sheet” (DS20005004). For more information about the snubber circuits, RSNU and CSNU, and series boost resistor, RBOOST, refer to AN1466, “Reduction of the High-Frequency Switching Noise in the MCP16301 High-Voltage Buck Converter” (DS01466) application note.

### C.3.2 Second Stage of Auxiliary Power Supply

The second stage of the power supply has the following specifications:

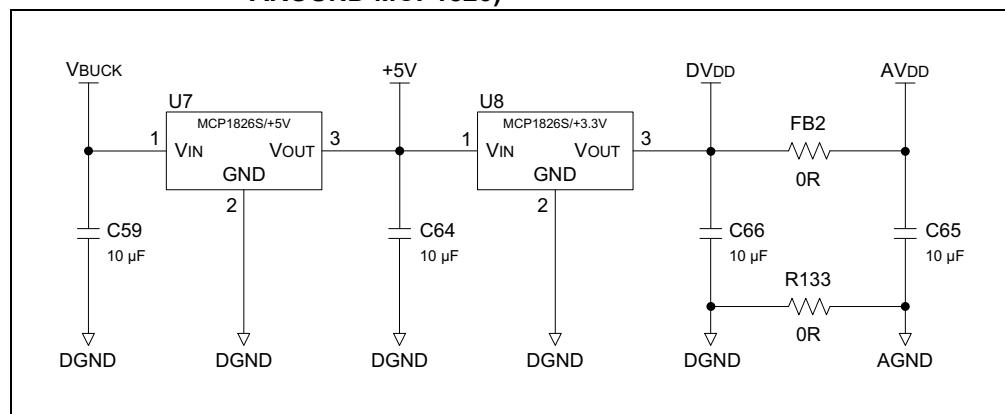
- Input Voltage ( $V_{BUCK}$ ) = +5.6V
- Output Voltage 1 (+5V) = +5V
- Output Voltage 2 (DVDD/AVDD) = +3.3V

Two LDOs are used for generating the +5V and +3.3V outputs. As shown in [Figure C-3](#), the input of the +5V LDO (MCP1826/+5V) is  $V_{BUCK}$ , which is the output of the first stage of the auxiliary power supply.

The input of the +3.3V LDO is the output of the +5V LDO.

As shown in [Figure C-4](#), AVDD and DVDD are +3.3V, and resistor FB2 is used as a net tie for separating the analog and digital circuits during the layout stage.

**FIGURE C-4: SECOND STAGE POWER SUPPLY (APPLICATION CIRCUIT AROUND MCP1826)**



Input and output capacitors of the LDOs are selected based on the recommendations from the “MCP1826/MCP1826S 1000 mA, Low-Voltage, Low Quiescent Current LDO Regulator Data Sheet” (DS22057).

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**NOTES:**



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