dsPIC33CDVL64MC106 and dsPIC33CDV64MC106 Motor Control Development Boards User's Guide

ISBN: 978-1-6683-2272-7

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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 website (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 chapter contains general information that will be useful to know before using the dsPIC33CDVL64MC106 Motor Control Development Board and dsPIC33CDV64MC106 Motor Control Development Board. Items discussed in this chapter include:

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

DOCUMENT LAYOUT

This document describes how to use the dsPIC33CDVL64MC106 Motor Control Development Board and dsPIC33CDV64MC106 Motor Control Development Board. The manual layout is as follows:

- **Chapter 1. "Introduction"** – Introduces the Development Boards.
- **Chapter 2. "Board Interface Description"** – Provides a more detailed description of the input and output interfaces of the Development Boards.
- **Chapter 3. "Hardware Description"** – Provides a detailed description of the hardware features of the Development Boards.
- **Appendix A. "Schematics and Layout"** - Provides the schematics and PCB layout diagrams of the dsPIC33CDVL64MC106 Motor Control Development Board and dsPIC33CDV64MC106 Motor Control Development Board.
- **Appendix B. "Electrical Specifications"** – Provides the electrical specifications for the Development Boards.
- **Appendix C. "Design Details"** – Provides design details of the current amplifier circuits and auxiliary power supply.

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

<table>
<tr><th>Description</th><th>Represents</th><th>Examples</th></tr>
<tr><td colspan="3">Arial font:</td></tr>
<tr><td rowspan="2">Italic characters</td><td>Referenced books</td><td>MPLAB® IDE User's Guide</td></tr>
<tr><td>Emphasized text</td><td>...is the only compiler...</td></tr>
<tr><td rowspan="3">Initial caps</td><td>A window</td><td>the Output window</td></tr>
<tr><td>A dialog</td><td>the Settings dialog</td></tr>
<tr><td>A menu selection</td><td>select Enable Programmer</td></tr>
<tr><td>Quotes</td><td>A field name in a window or dialog</td><td>"Save project before build"</td></tr>
<tr><td>Underlined, italic text with right angle bracket</td><td>A menu path</td><td><u>File>Save</u></td></tr>
<tr><td rowspan="2">Bold characters</td><td>A dialog button</td><td>Click OK</td></tr>
<tr><td>A tab</td><td>Click the Power tab</td></tr>
<tr><td>N'Rnnnn</td><td>A number in verilog format, where N is the total number of digits, R is the radix and n is a digit.</td><td>4'b0010, 2'hF1</td></tr>
<tr><td>Text in angle brackets < ></td><td>A key on the keyboard</td><td>Press <Enter>, <F1></td></tr>
<tr><td colspan="3">Courier New font:</td></tr>
<tr><td rowspan="7">Plain Courier New</td><td>Sample source code</td><td><code>#define START</code></td></tr>
<tr><td>Filenames</td><td><code>autoexec.bat</code></td></tr>
<tr><td>File paths</td><td><code>c:\mcc18\h</code></td></tr>
<tr><td>Keywords</td><td><code>_asm, _endasm, static</code></td></tr>
<tr><td>Command-line options</td><td><code>-Opa+, -Opa-</code></td></tr>
<tr><td>Bit values</td><td><code>0, 1</code></td></tr>
<tr><td>Constants</td><td><code>0xFF, 'A'</code></td></tr>
<tr><td>Italic Courier New</td><td>A variable argument</td><td><code>file.o</code>, where <code>file</code> can be any valid filename</td></tr>
<tr><td>Square brackets [ ]</td><td>Optional arguments</td><td><code>mcc18 [options] file [options]</code></td></tr>
<tr><td>Curly brackets and pipe character: { | }</td><td>Choice of mutually exclusive arguments; an OR selection</td><td><code>errorlevel {0|1}</code></td></tr>
<tr><td rowspan="2">Ellipses...</td><td>Replaces repeated text</td><td><code>var_name [, var_name...]</code></td></tr>
<tr><td>Represents code supplied by user</td><td><code>void main (void)
{ ...
}</code></td></tr>
</table>

RECOMMENDED READING

This user's guide describes the dsPIC33CDVL64MC106 Motor Control Development Board and dsPIC33CDV64MC106 Motor Control Development Board. The device-specific data sheets contain additional 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:

"dsPIC33CDVL64MC106 Family Data Sheet" **(DS70005441)**

This document provides device-specific information for the dsPIC33CDVL64MC106 and dsPIC33CDV64MC106. The dsPIC33CDVL64MC106 features a 16-bit Digital Signal Controller, a MOSFET Gate Driver and a LIN Transceiver. The dsPIC33CDV64MC106 features only a Digital Signal Controller and a MOSFET Gate Driver.

"MCP16301 Data Sheet" **(DS20005004)**

This document provides device-specific information about the MCP16301 High-Voltage Input Integrated Switch Step-Down Regulator.

"24LC256 Data Sheet" **(DS20001203)**

This document provides device-specific information about the 24LC256 256-Kbit I^2C CMOS Serial EEPROM.

"MCP1826S Data Sheet" **(DS20002057)**

This document provides device-specific information about the MCP1826S 1000 mA, Low-Voltage, Low Quiescent Current LDO Regulator.

"MCP6024 Data Sheet" **(DS20001685)**

This document provides device-specific information about the MCP6024 10 MHz Rail-to-Rail Input-Output Op Amp.

"MCP651S Data Sheet" **(DS20002146)**

This document provides device-specific information about the MCP651S 50 MHz, 200 µV Op Amp with mCal.

"DSC60XXB Data Sheet" **(DS20006133)**

This document provides device-specific information about the DSC6011JI2B-012.0000 Ultra-Small, Ultra-Low Power 12 MHz MEMS Oscillator.

"ATA663211 Data Sheet" **(DS20006191)**

This document provides device-specific information for the ATA663211 LIN Transceiver.

"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.

AN1299, "Single-Shunt Three-Phase Current Reconstruction Algorithm for Sensorless FOC of a PMSM" **(DS01299)**

AN1078, "Sensorless Field Oriented Control of a PMSM" **(DS01078)**

***AN1292, "Sensorless Field Oriented Control (FOC) for a Permanent Magnet Synchronous Motor (PMSM) Using a PLL Estimator and Field Weakening (FW)"* (DS01292)**

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.

For step-by-step instructions to set up and run a motor control application using the dsPIC33CDVL64MC106 and dsPIC33CDV64MC106 Motor Control Development Boards, refer to the Readme file provided along with the motor control application code.

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.

THE MICROCHIP WEBSITE

Microchip provides online support via our website at 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

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

To register, access the Microchip website at 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 field application engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

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

DOCUMENT REVISION HISTORY

Revision A (April 2021)

- Initial Release of this Document.

Revision B (February 2022)

- Initial Release of this Document.

Revision C (August 2022)

- Updated Table 1-1, Table 2-10 and Table 2-11.
- Updated Figure 1-1, Figure 1-2, Figure 3-9, Figure 3-10, Figure 2-1, Figure 2-2, Figure 2-3, Figure 2-4, Figure 2-5, Figure 2-6, Figure A-1 and Figure A-9.
- Updated **Section 3.2.11.2 "Debug Serial Interface"**.

Revision D (April 2023)

- Updated Figure A-9 through Figure A-16.

NOTES:

Chapter 1. Introduction

1.1 OVERVIEW

The dsPIC33CDVL64MC106 family has two devices: dsPIC33CDVL64MC106 and dsPIC33CDV64MC106. Both devices integrate a 16-bit Digital Signal Controller and a MOSFET Gate Driver. The dsPIC33CDVL64MC106 device also integrates a LIN Transceiver.

There are two Motor Control Development Boards, which are targeted to drive a low-voltage three-phase Permanent Magnet Synchronous Motor (PMSM) or Brushless DC (BLDC) motor using the dsPIC33CDVL64MC106 family of devices. The details of the Development Boards are summarized below:

TABLE 1-1: MOTOR CONTROL DEVELOPMENT BOARDS

Board Name[1]	Part Number	Device Populated on the Development Board	Comments
dsPIC33CDVL64MC106 Motor Control Development Board (Figure 1-1)	EV04R09A	dsPIC33CDVL64MC106	LIN Bus Interface is available. LD4 (Blue) indicates populated device when powered on.
dsPIC33CDV64MC106 Motor Control Development Board (Figure 1-2)	EV14E50A	dsPIC33CDV64MC106	LIN Bus Interface is not available. LD3 (Green) indicates populated device when powered on.

Note 1: This User's Guide is applicable for the Development Boards listed in Table 1-1. They are almost identical, except for the LIN Bus Interface. The differences between them are highlighted in the specific sections of this document.

FIGURE 1-1: dsPIC33CDVL64MC106 MOTOR CONTROL DEVELOPMENT BOARD

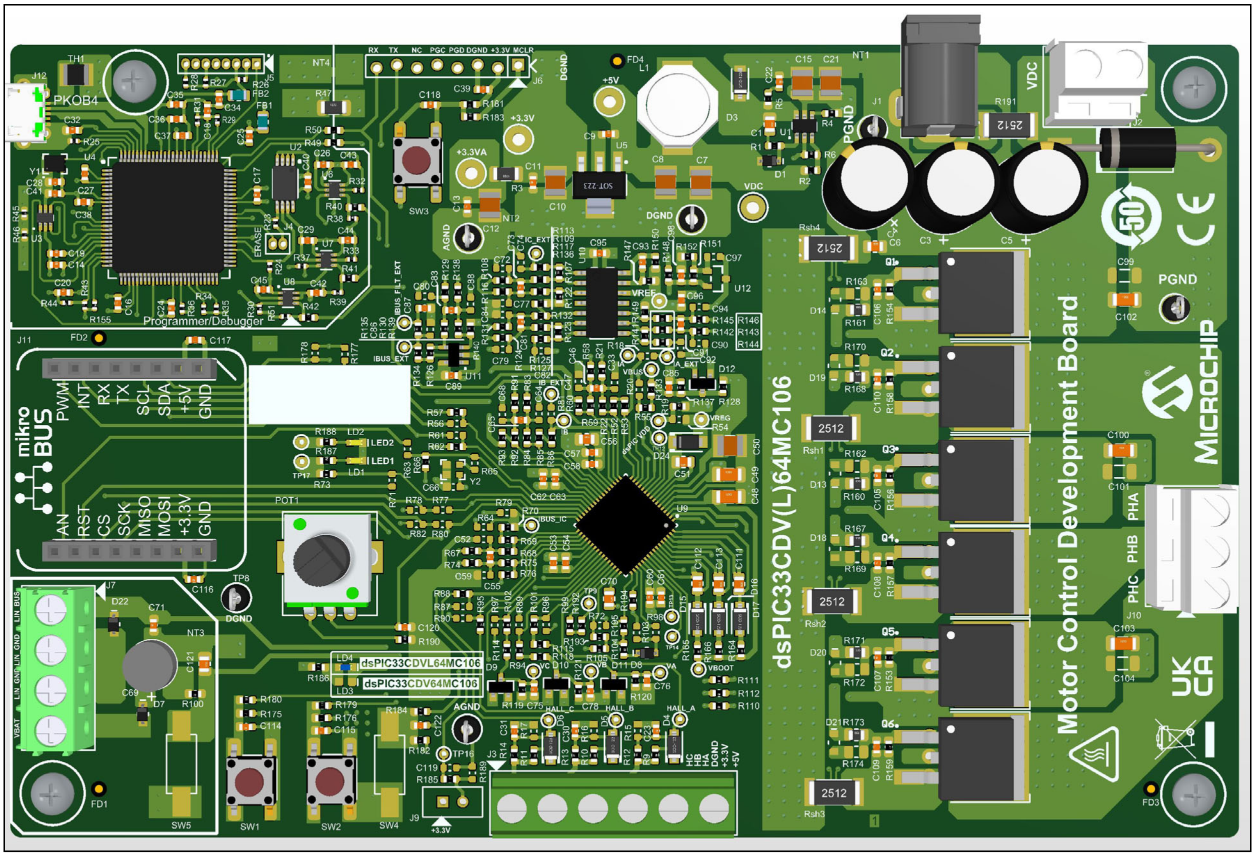
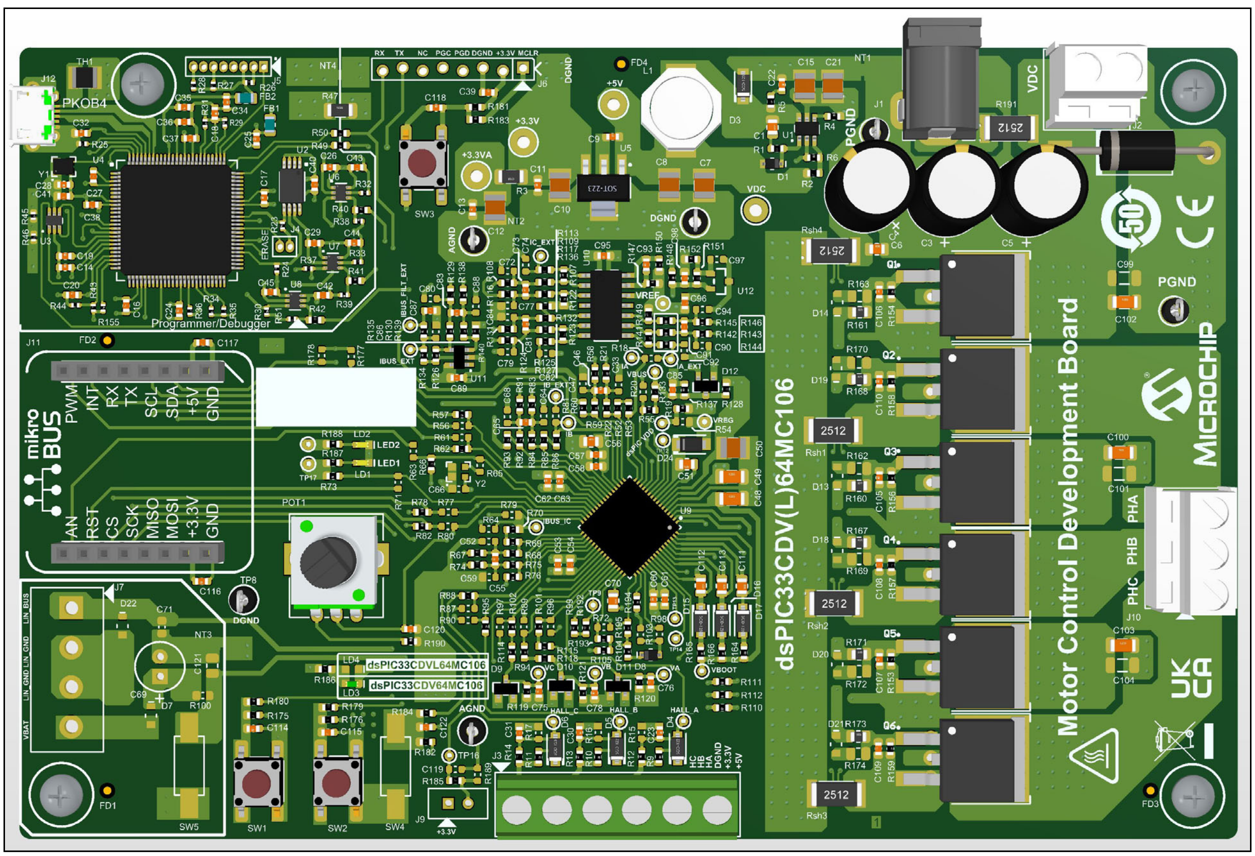


FIGURE 1-2: dsPIC33CDV64MC106 MOTOR CONTROL DEVELOPMENT BOARD



1.2 FEATURES

Key features of the Development Board are as follows:

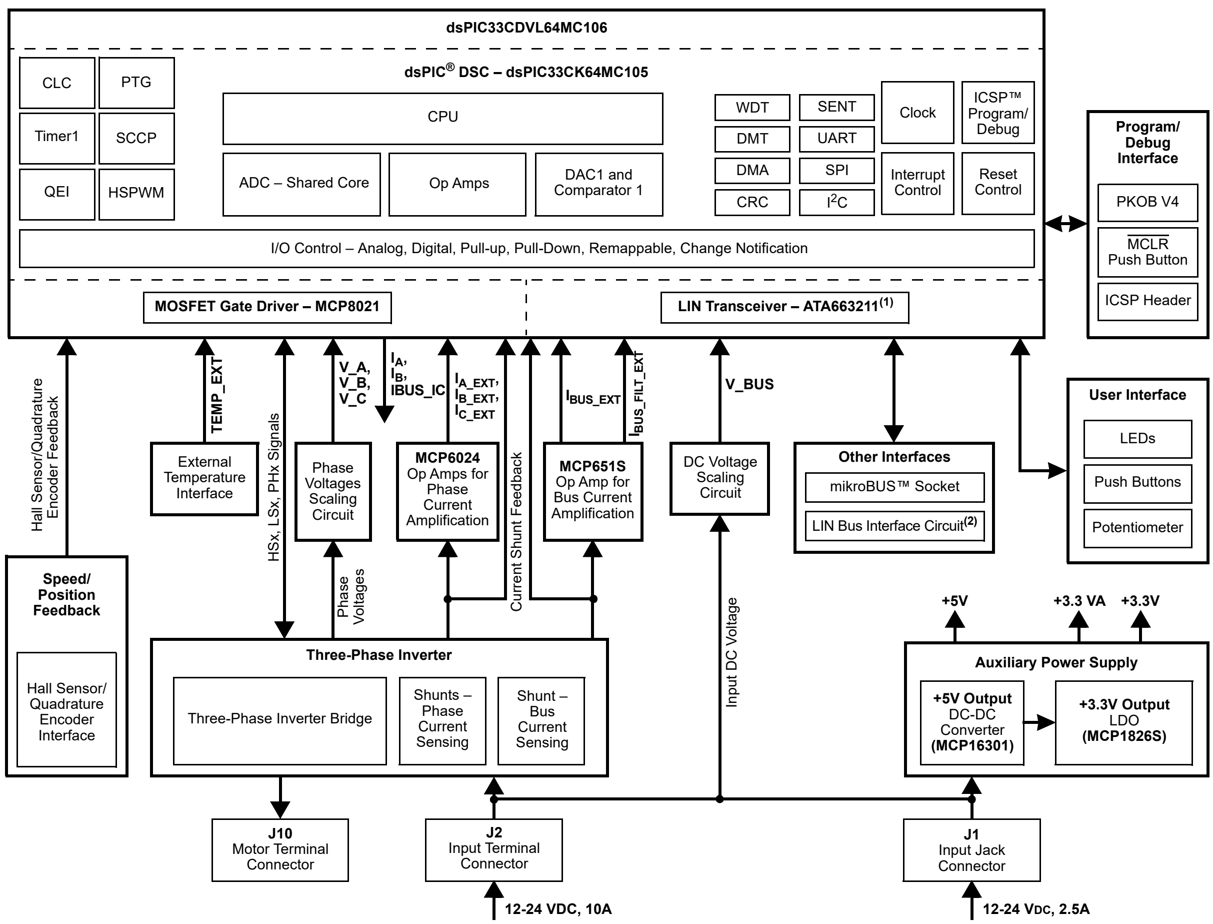
- Three-Phase Motor Control Power Stage with the following Electrical Specifications:
  - Input DC voltage: 12V to 24 V_{DC}
  - Nominal phase RMS current: 10A at +25°C ambient temperature
- Motor Phase Current Feedback to implement Field Oriented Control (FOC) of a PMSM/BLDC Motor
- DC Bus Current Feedback for Overcurrent Protection and to demonstrate Single Shunt Current Reconstruction Algorithm
- DC Bus Voltage Feedback for Overvoltage Protection
- Phase Voltage Feedback to implement Sensorless Trapezoidal Control
- Hall Sensor Interface or Quadrature Encoder Interface (QEI)
- Optional External Temperature Sensor (thermistor) Interface
- PICkit™ On-Board (PKOB4) for Programming and Debugging
- Optional mikroBUS™ Socket to support Connectivity, Sensors and Communication Interfaces by Plugging in mikroBUS Add-On Boards
- LIN Interface (LIN Transceiver is part of the dsPIC33CDVL64MC106)
- User Interface Elements:
  - Two debug LEDs
  - One potentiometer
  - Two push buttons
  - Power-on Status/Device Identification LED
- Auxiliary Power Supply for Powering Circuitry and External Interfaces

Note: LIN Bus Interface circuit is unpopulated in the dsPIC33CDV64MC106 Motor Control Development Board.

1.3 BLOCK DIAGRAM

The block diagram of the dsPIC33CDVL64MC106 Motor Control Development Board is shown in Figure 1-3. For more information on electrical specifications, refer to **Appendix B. "Electrical Specifications"**.

FIGURE 1-3: BLOCK DIAGRAM – dsPIC33CDVL64MC106 MOTOR CONTROL DEVELOPMENT BOARD



Note 1: Only applies to the device with a LIN Transceiver module (dsPIC33CDVL64MC106).

2: LIN Bus Interface circuit is unpopulated in the dsPIC33CDV64MC106 Motor Control Development Board.

1.4 MICROCHIP PRODUCTS USED IN THE DEVELOPMENT BOARD

The Development Board uses many Microchip products to implement its features. The Microchip products used in the design are summarized in Table 1-2.

TABLE 1-2: MICROCHIP PRODUCTS USED IN THE dsPIC33CDVL64MC106 MOTOR CONTROL DEVELOPMENT BOARD

Part Number	Description	Circuit Designator	Circuit Section
MCP16301	High-Voltage Input Integrated Switch Step-Down Regulator	U1	**Section 3.2.2 "Power Supply"**
24LC256	256K I^2C CMOS Serial EEPROM	U2	**Section 3.2.11 "Programmer/Debugger Interface"**
ATSAME70N21B	High-Performance 32-Bit ARM Cortex®-M7 Processor with Floating Point Unit (FPU).	U4	**Section 3.2.11 "Programmer/Debugger Interface"**
MCP1826ST-330	1000 mA, Low-Voltage, Low Quiescent Current LDO Regulator	U5	**Section 3.2.2 "Power Supply"**
dsPIC33CDVL64MC106 (1)	SiP Module with 16-Bit Digital Signal Controller, MOSFET Driver and LIN Transceiver	U9	**Section 3.2.1 "dsPIC33CDVL64MC106 and Auxiliary Circuits"**
dsPIC33CDV64MC106 (2)	SiP Module with 16-Bit Digital Signal Controller and MOS-FET Gate Driver	U9	**Section 3.2.1 "dsPIC33CDVL64MC106 and Auxiliary Circuits"**
MCP6024	Rail-to-Rail Input/Output, 10 MHz Op Amps	U10	**Section 3.2.4 "Current Sensing Circuits"**
MCP651S	50 MHz High Slew Rate Low Offset Op Amp with mCal.	U11	**Section 3.2.4 "Current Sensing Circuits"**
DSC6011JI2B-012.000	Ultra-Small, Ultra-Low Power MEMS Oscillator (DSC60XXB)	Y1	**Section 3.2.11 "Programmer/Debugger Interface"**

Note 1: U9 is populated with the dsPIC33CDVL64MC106 in the dsPIC33CDVL64MC106 Motor Control Development Board.

2: U9 is populated with the dsPIC33CDV64MC106 in the dsPIC33CDV64MC106 Motor Control Development Board.

NOTES:

Chapter 2. Board Interface Description

2.1 INTRODUCTION

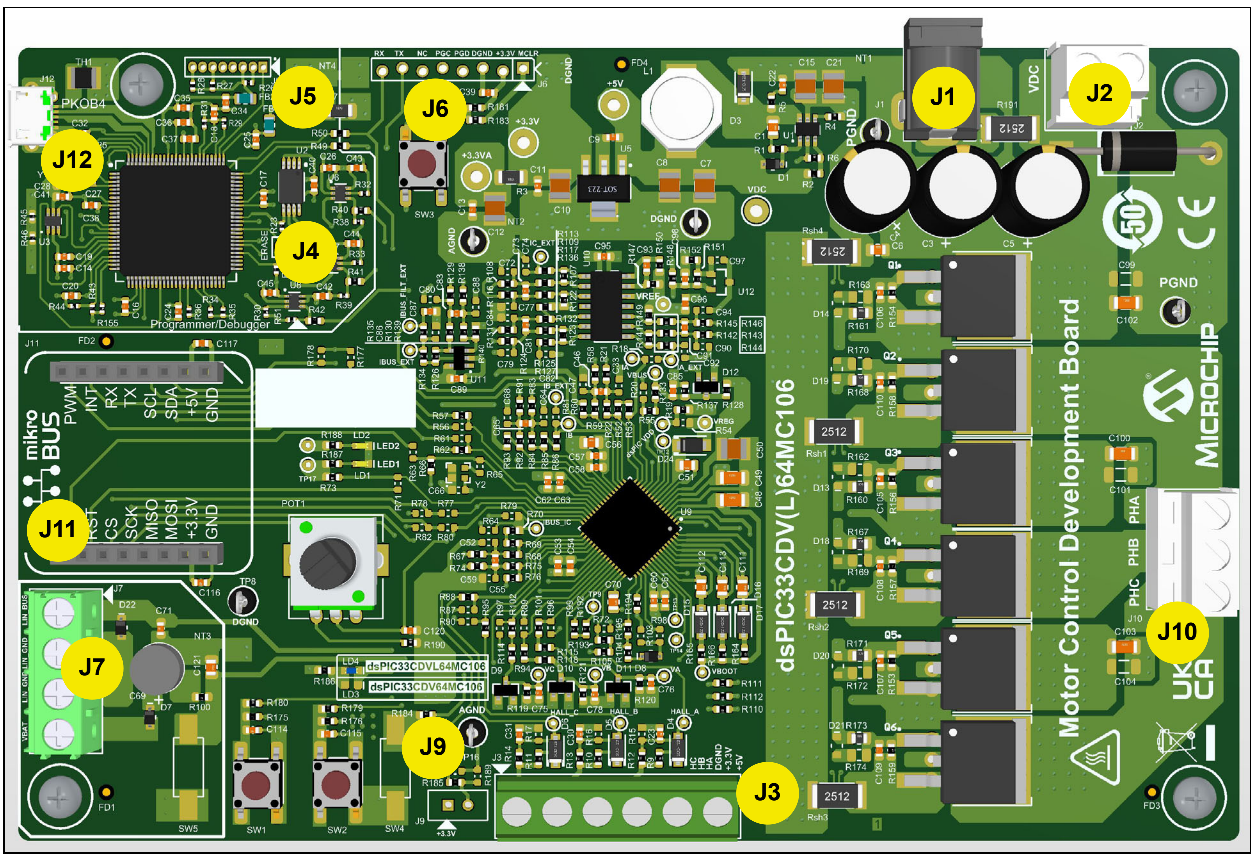
This chapter provides a more detailed description of the input and output interfaces of the Development Board. The following topics are covered:

- Board Connectors
- User Interface Hardware
- Pin Functions of the dsPIC33CDVL64MC106 Family of Devices

2.2 BOARD CONNECTORS

This section summarizes the connectors on the Development Board. The connectors on the Development Board are shown in Figure 2-1 and summarized in Table 2-1.

FIGURE 2-1: CONNECTORS – dsPIC33CDVL64MC106 MOTOR CONTROL DEVELOPMENT BOARD



Note:	J7 is unpopulated in the dsPIC33CDV64MC106 Motor Control Development Board.

TABLE 2-1: CONNECTORS – dsPIC33CDVL64MC106 AND dsPIC33CDV64MC106 MOTOR CONTROL DEVELOPMENT BOARDS

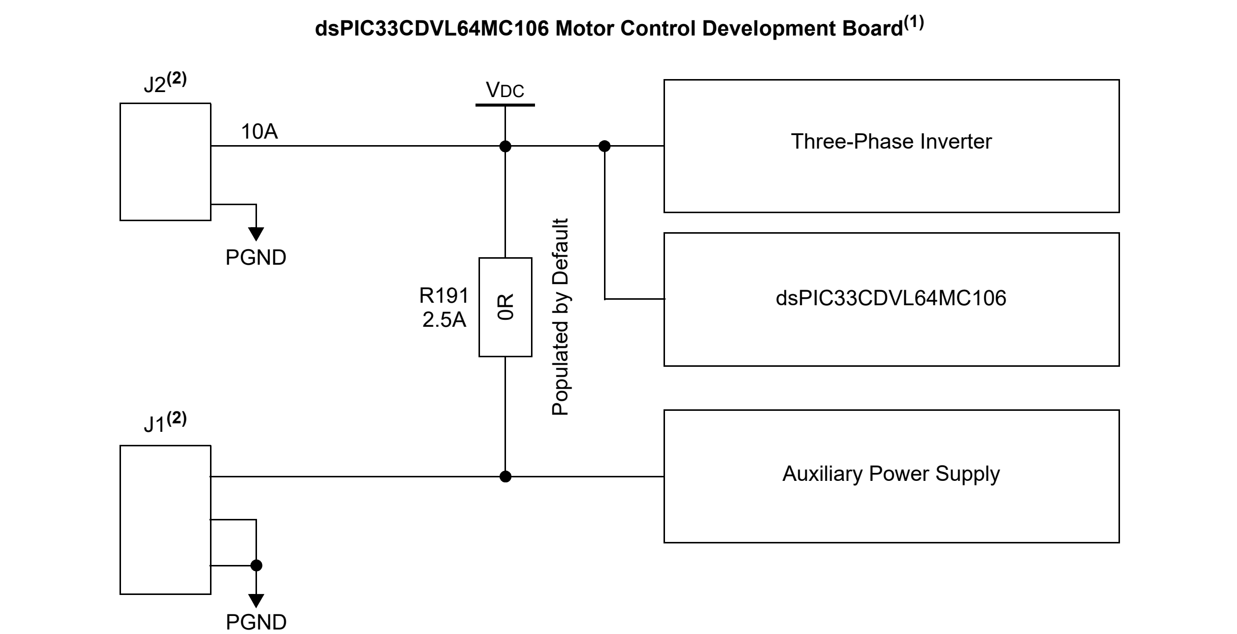
Connector Designator	No. of Pins	Status	Description
J1	3	Populated	Input DC Power Supply Jack
J2	2	Populated	Input DC Power Supply – Two-Pin Terminal Connector
J3	6	Populated	Hall Sensor/Quadrature Encoder Interface Connector
J4	2	Not Populated	Erase Jumper – Used to Switch PICkit™ On-Board (PKOB) Programmer/Debugger to Boot Recovery mode through MPLAB® X IDE
J5	8	Not Populated	SWD Header – For Programming/Debugging ATSAME70N21B in the PKOB Section
J6	8	Not Populated	ICSP™ Header – Interfacing Programmer/Debugger to the dsPIC® DSC
J7	4	Populated	LIN Interface Connector
J9	2	Not Populated	External Temperature Sensor (thermistor) Interface Connector
J10	3	Populated	Three-Phase Inverter Output for Connecting Motor
J11	16	Populated	mikroBUS™ Socket for Interfacing Click board™
J12	5	Populated	PICkit™ On-Board (PKOB) Programmer/Debugger Interface Connector (standard female USB Micro-B connector)

Note: J7 is unpopulated in the dsPIC33CDV64MC106 Motor Control Development Board.

2.2.1 Power Supply Connectors (J1, J2)

The board is designed to operate in the DC voltage range of 12-24V. As shown in Figure 2-2, the Development Board can be powered through either coaxial plug J1 or through terminal connector J2.

FIGURE 2-2: INPUT DC POWER SUPPLY CONNECTORS



Note 1: The Development Board is designed to operate in the DC voltage range of 12V to 24V.

2: When J1 and J2 are shorted through R191, always power the Development Board using only one connector; either J1 or J2.

The inverter can be separately powered through the connector J2 after removing jumper R191. Then, the rest of the circuitry can be powered through the coaxial plug J1. The connection between J1 and J2 can be bridged back by populating jumper R191 for powering the Development Board through either J1 or J2. Connector J1 can carry current up to 2.5A and connector J2 can handle up to 10A. Table 2-2 and Table 2-3 summarize pin assignments of connectors J1 and J2, respectively.

TABLE 2-2: PIN DESCRIPTIONS – CONNECTOR J1

Pin No.	Signal Name	Pin Description
1	VDC	DC Input Supply Positive
2	PGND	DC Input Supply Negative or PGND
3	PGND	DC Input Supply Negative or PGND

TABLE 2-3: PIN DESCRIPTIONS – CONNECTOR J2

Pin No.	Signal Name	Pin Description
1	PGND	DC Input Supply Negative or PGND
2	VDC	DC Input Supply Positive

2.2.2 Hall Sensor/Quadrature Encoder Interface Header (J3)

Hall sensors or Quadrature Encoder is used to detect the rotor position and speed of the motor. Connector J3 can be used to interface the Hall sensor outputs or Quadrature Encoder outputs with the Development Board, enabling sensor-based BLDC or PMSM motor control applications. Table 2-4 shows the pin descriptions of connector J3. The connector provides two supply outputs, +5V and +3.3V, which can be used for powering the Hall sensors or Quadrature Encoder depending on its specification. Refer to **Section 3.2.6 "Hall Sensor/Quadrature Encoder Interface"** for a detailed explanation.

TABLE 2-4: PIN DESCRIPTIONS – CONNECTOR J3

Pin No.	Signal Name	Pin Description
1	HC/INDX	Hall Sensor C Feedback from the Motor or Quadrature Encoder Index Feedback of the Motor
2	HB/QEB	Hall Sensor B Feedback from the Motor or Quadrature Encoder Phase B Feedback of the Motor
3	HA/QEA	Hall Sensor A Feedback from the Motor or Quadrature Encoder Phase A Feedback of the Motor
4	DGND	Digital Ground
5	+3.3V	+3.3V Supply to Hall Sensors or Quadrature Encoder
6	+5V	+5V Supply to Hall Sensors or Quadrature Encoder

2.2.3 Emergency Recovery Jumper – PICkit™ 4 On-Board (J4)

The PICkit™ 4 On-Board (PKOB4) debugger may need to be forced into Recovery Boot mode (reprogrammed) in rare situations. The 2-pin header J4 is an emergency recovery jumper of the PKOB4 on the Development Board. These jumper pins can be shorted together during a Hardware Tool Emergency Boot Firmware Recovery process. Refer to the *"MPLAB® X IDE User's Guide"* for more information on Hardware Tool Emergency Boot Firmware Recovery.

2.2.4 ICSP™ Header for Programmer/Debugger Interface (J6)

The 8-pin header J6 can be used for connecting the programmer/debugger, for example, PICkit™ 4, for programming and debugging the dsPIC33CDVL64MC106 family of devices. This is not populated by default. When needed, populate the connector with
Part Number 68016-108HLF or similar. The pin details are provided in Table 2-5.

TABLE 2-5: PIN DESCRIPTIONS – HEADER J6

Pin No.	Signal Name	Pin Description
1	$\overline{MCLR}$	Device Master Clear ($\overline{MCLR}$)
2	+3.3V	Supply Voltage
3	GND	Ground
4	PGD	Device Programming Data Line (PGD)
5	PGC	Device Programming Clock Line (PGC)
6	No Connection	—
7	TX	Device Virtual COM Port Transmit Line
8	RX	Device Virtual COM Port Receive Line

2.2.5 LIN Interface Connector (J7)[1]

LIN (Local Interconnect Network) is a low-speed serial network protocol designed to support automotive networks in combination with the Controller Area Network (CAN). The dsPIC33CDVL64MC106 integrates a LIN Transceiver, ATA663211 (physical layer), which is an essential part of the LIN interface circuit. The Development Board includes a LIN interface circuit and it can be connected to the LIN network via connector J7. Table 2-6 summarizes the pin descriptions of connector J7.

TABLE 2-6: PIN DESCRIPTIONS – CONNECTOR J7

Pin No.	Signal Name	Pin Description
1	LIN_BUS	LIN Bus Line Input/Output
2	LIN_GND	LIN Ground
3	LIN_GND	LIN Ground
4	VBAT	LIN Supply (5V to 28V)

Note 1: The LIN interface connector (J7) is unpopulated in the dsPIC33CDV64MC106 Motor Control Development Board.

2.2.6 External Temperature Sensor Interface Connector (J9)

The 2-pin connector (2.5 mm pitch) J9 can be used for interfacing a thermistor to the Development Board. This is not populated by default. When needed, populate the connector with Part Number B2B-EH-A(LF)(SN) or similar.

2.2.7 Inverter Output Connector (J10)

The Development Board can drive a three-phase PMSM/BLDC motor. Motor control inverter outputs are available through connector J10. Pin assignments of connector J10 are shown in Table 2-7.

TABLE 2-7: PIN DESCRIPTIONS – CONNECTOR (J10)

Pin No.	Signal Name	Pin Description
1	PHASE C	Phase 3 Output of Inverter
2	PHASE B	Phase 2 Output of Inverter

Pin No.	Signal Name	Pin Description
3	PHASE A	Phase 1 Output of Inverter

2.2.8 mikroBUS™ Socket for Interfacing Click boards™ (J11)

One mikroBUS socket is provided on the Development Board, which can be used to expand the functionality by attaching an add-on board, called a 'Click board'. The Development Board implements the mikroBUS socket as specified in the *"mikroBUS™ Standard Specifications v2.0"* (refer to www.mikroe.com/mikrobus). The pinout consists of three groups of communication pins (SPI, UART and I^2C), six additional pins (PWM, interrupt, analog input, Reset and chip select) and two power groups (+3.3V-GND and 5V-GND).

For pin mapping between the dsPIC DSC and the mikroBUS socket, refer to the schematics in **Appendix A. "Schematics and Layout"** or Table 2-8. As specified in Table 2-8, connection between the mikroBUS socket and the dsPIC33CDVL64MC106 device can be established by populating and/or unpopulating the corresponding resistors.

TABLE 2-8: PIN MAPPING – dsPIC33CDVL64MC106 TO mikroBUS™ SOCKET

mikroBUS™		dsPIC33CDVL64MC106		To Interface dsPIC33CDVL64MC106 with mikroBUS™		
Pin No.	**Pin Name**	**Pin No.**	**Pin Function**	**Populate**	**Remove if Populated**	**Remarks**
1	AN	28	OSCI/CLKI/AN5/RP32/RB0	R63	R65, R66	Disconnects input signals TEMP_EXT and CLKI to the dsPIC® DSC
2	RST	29	OSCO/CLKO/AN6/RP33/RB1	R71	R73	Disconnects dsPIC DSC output controlling LD1 (LED1)
3	CS	44	PGC1/AN11/RP41/SDA1/RB9	R96	R101	Disconnects input signal V_A to the dsPIC DSC
4	SCK	42	TDO/AN2/RP39/RB7	R97	R102	Disconnects input signal V_C to the dsPIC DSC
5	MISO	14	AN12/RP48/RC0	R20	R55	Disconnects input signal V_BUS to the dsPIC DSC
6	MOSI	24	IBIAS1/RP54/RC6	R56	R57	Disconnects dsPIC DSC output controlling LD2 (LED2)
7	+3.3V	—				mikroBUS Supply
8	GND	—				
9	GND	—				
10	+5V	—				
11	SDA	35	RP56/ASDA1/SCK2/RC8	R87	R88	Disconnects input signal HALL_C to the dsPIC DSC
12	SCL	36	RP57/ASCL1/SDI2/RC9	R90	R95	Disconnects input signal HALL_B to the dsPIC DSC
13	TX	31	ISRC2/RP55/RC7	R80	R82, R49	Disconnects output signal DEBUG_TX
		51[1]	RP59/RC11	R82	R80	—
14	RX	30	ISRC3/RP74/RD10	R77	R78, R50	Disconnects input signal DEBUG_RX
		49[1]	RP58/RC10	R78	R77	—
15	INT	43	PGD1/AN10/RP40/SCL1/RB8	R89	R94	Disconnects input signal V_B to the dsPIC DSC

Note 1: Only applicable to the dsPIC33CDV64MC106 Motor Control Development Board.

mikroBUS™		dsPIC33CDVL64MC106		To Interface dsPIC33CDVL64MC106 with mikroBUS™		
Pin No.	Pin Name	Pin No.	Pin Function	Populate	Remove if Populated	Remarks
16	PWM	27	AN15/IBIAS2/RP51/RC3	R61	R62, R72	Disconnects input signal POT
		47(1)	RP53/RC5	R72	R61	—

Note 1: Only applicable to the dsPIC33CDV64MC106 Motor Control Development Board.

2.2.9 PKOB Interface USB Connector (J12)

This is a standard female USB Micro-B connector provided for interfacing with the PICkit™ On-Board (PKOB) programming/debugging tool. Pin assignments for connector J12 are shown in Table 2-9.

TABLE 2-9: PIN DESCRIPTIONS – CONNECTOR J12

Pin No.	Signal Name	Pin Description
0	No Connection	Body is connected to GND
1	VBUS	USB 5V
2	USB_N	USB Data-
3	USB_P	USB Data+
4	No Connection	—
5	GND	PKOB Ground (GND)

2.3 USER INTERFACE HARDWARE

This section summarizes 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 2-10.

FIGURE 2-3: LEDs – dsPIC33CDVL64MC106 MOTOR CONTROL DEVELOPMENT BOARD

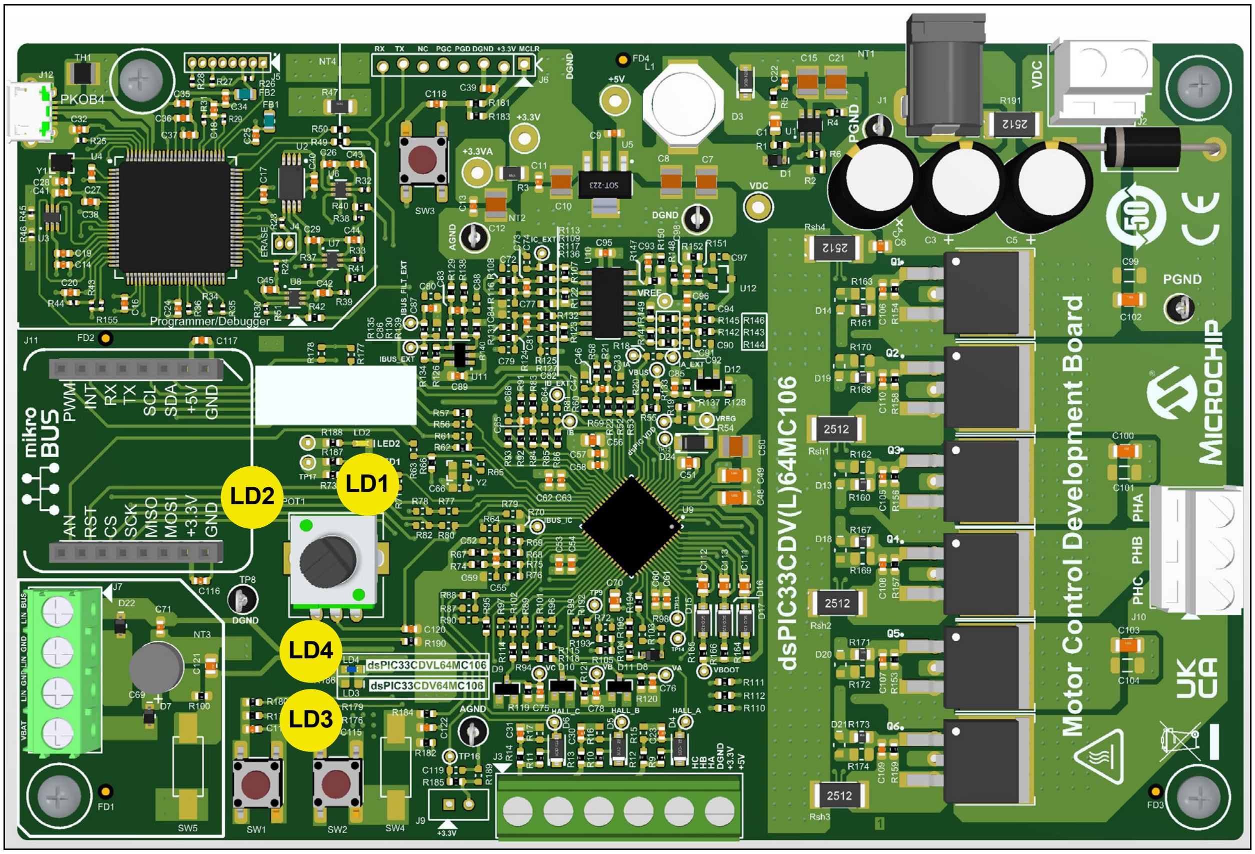


TABLE 2-10: LEDS

LED Designator	LED Color	LED Indication
LD1	Yellow	Provided for debugging purposes (LED1).
LD2	Yellow	Provided for debugging purposes (LED2).
LD3	Green	Board is populated with the dsPIC33CDV64MC106.
LD4	Blue	Board is populated the with the dsPIC33CDVL64MC106.

2.3.2 Push Buttons

The push buttons provided on the Development Board are shown in Figure 2-4 and summarized in Table 2-11.

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

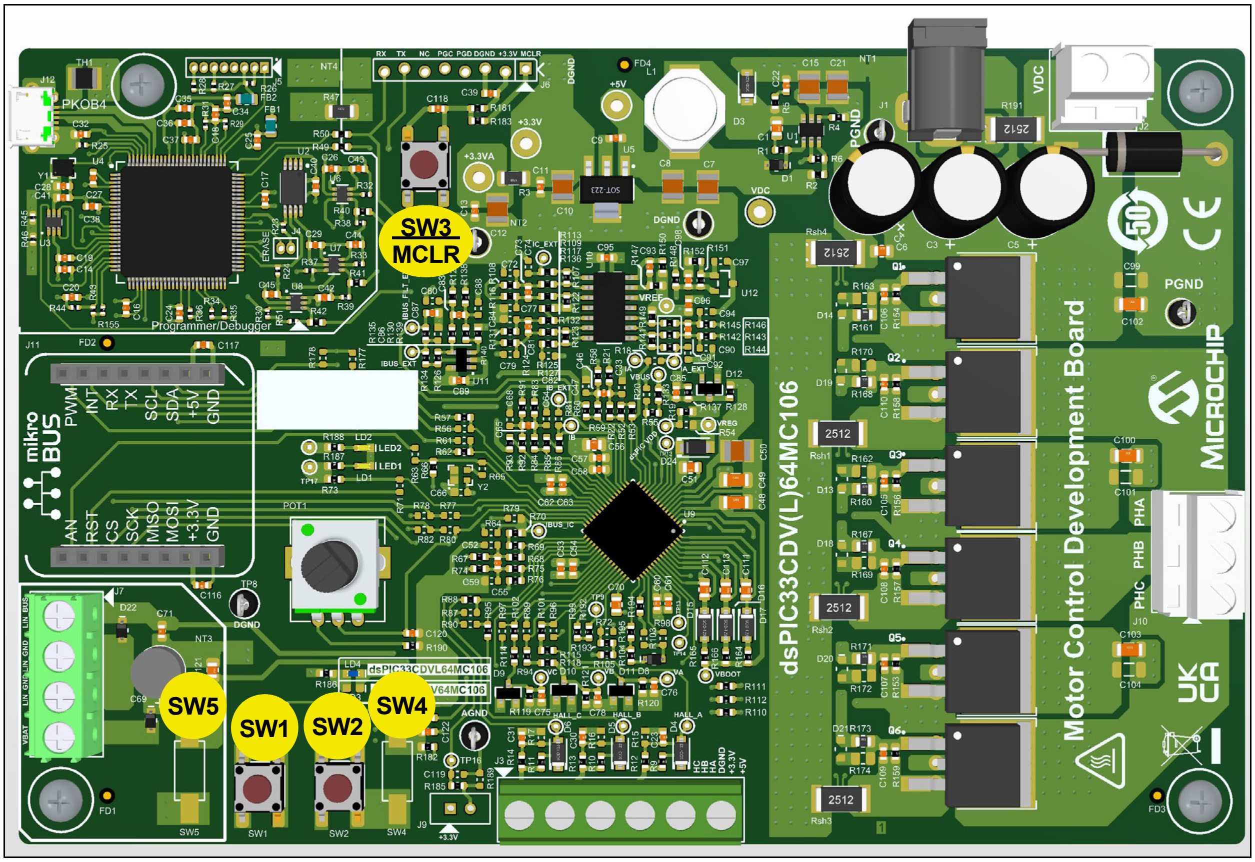
The push buttons, SW3, SW4 and SW5, have specific functions. Refer to Table 2-11 for their functional description.

TABLE 2-11: PUSH BUTTONS

Sl No.	Push Button Designator	Function of the Push Button
1	SW1	Push button provided for general purpose (BUTTON1).
2	SW2	Push button provided for general purpose (BUTTON2).
3	SW3	This push button is tied to the $\overline{\text{MCLR}}$ pin of the dsPIC® DSC. Pressing this button will reset the dsPIC DSC.
4	SW4(1)	This push button is tied to the WAKE pin of the MOSFET Gate Driver. 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 µs. Refer to the device data sheet for more details.
5	SW5(1)	This push button is tied to the LIN_WKIN pin of dsPIC33CDVL64MC106. This button can be used for waking up its LIN Transceiver from Sleep mode. Refer to the device data sheet for more details.

Note 1: SW4 and SW5 are unpopulated on the Motor Control Development Board.

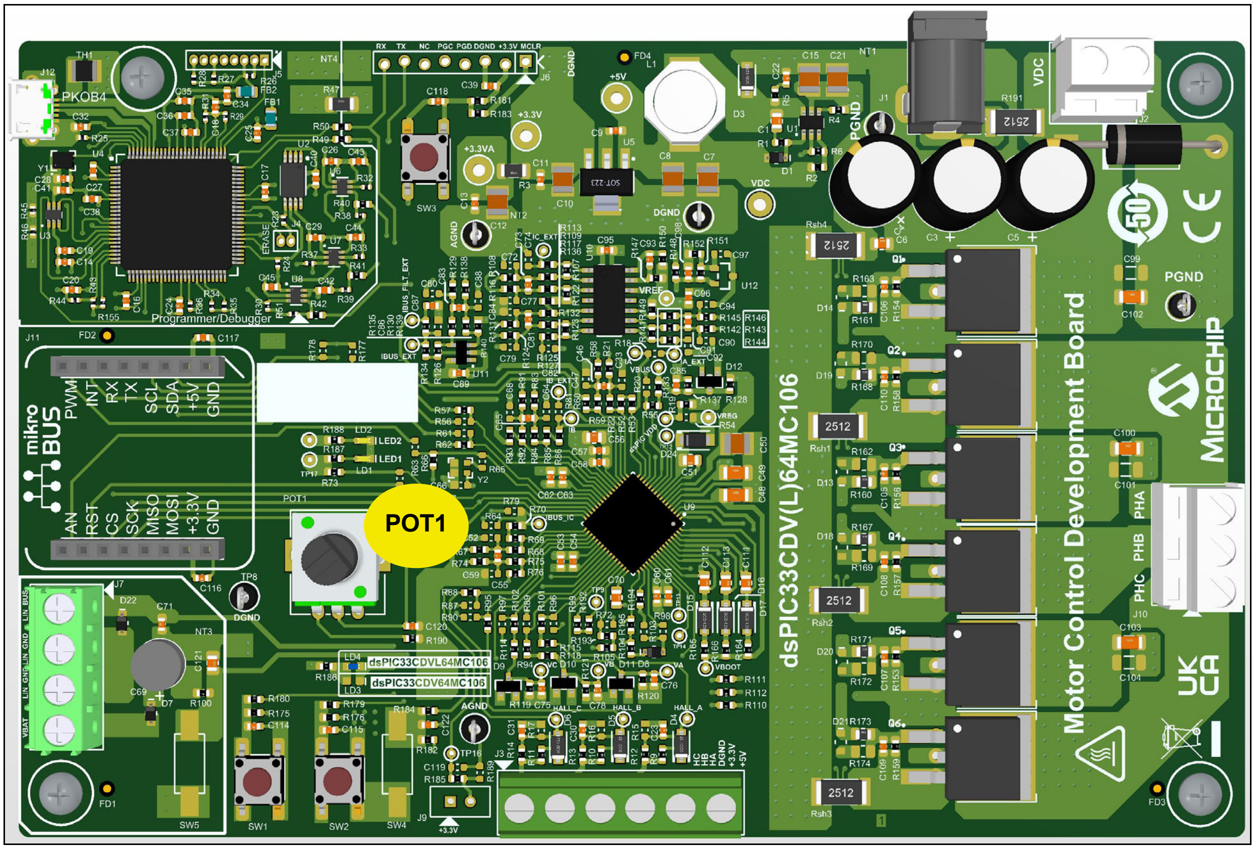
FIGURE 2-4: PUSH BUTTONS – dsPIC33CDVL64MC106 MOTOR CONTROL DEVELOPMENT BOARD



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/current/duty reference.

FIGURE 2-5: POTENTIOMETER – dsPIC33CDVL64MC106 MOTOR CONTROL DEVELOPMENT BOARD



2.3.4 Test Points

There are several test points on the Development Board to monitor various signals, such as phase voltages, motor currents, auxiliary supply outputs, etc. These test points are marked in Figure 2-6 and summarized in Table 2-12.

FIGURE 2-6: TEST POINT – dsPIC33CDVL64MC106 MOTOR CONTROL DEVELOPMENT BOARD

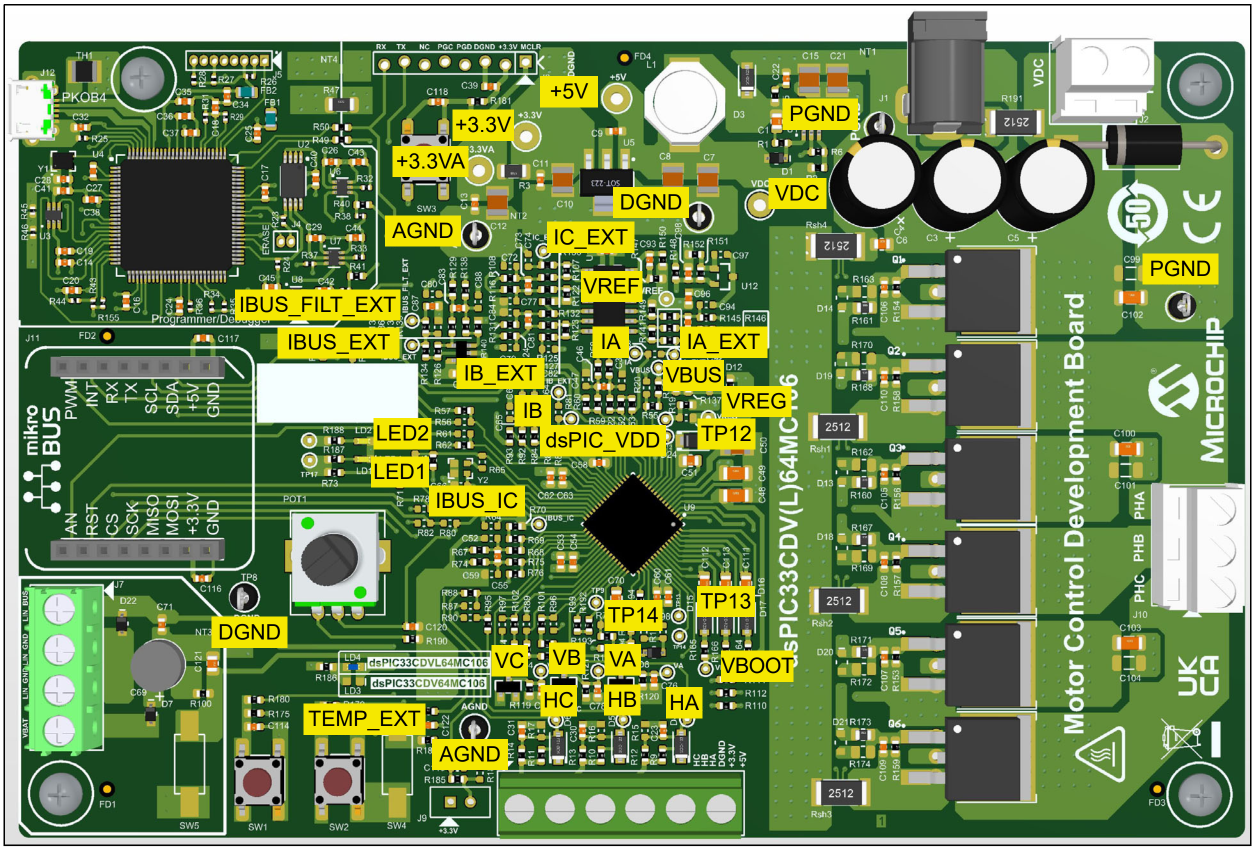


TABLE 2-12: TEST POINTS

Test Point No.	Signal	Description
Power Supply and Outputs		
TP1	VDC	Input DC Power Supply
VBOOT	VBOOT	VBOOT Output of dsPIC33CDVL64MC106 – Bootstrap Supply Output (+12V)
TP5	PGND	Power Ground
TP6	PGND	Power Ground
VREG	VREG	VREG Output of dsPIC33CDVL64MC106 – +3.3V Output
dsPIC_VDD	dsPIC_VDD	3.3V Supply Connected to V_{DD}/AV_{DD} Pins of dsPIC33CDVL64MC106
TP2	+5V	+5V Power Supply Output – Output of On-Board MCP16301 Step-Down Regulator
TP3	+3.3V	+3.3V Digital Power Supply – Output of On-Board +3.3V LDO (MCP1826)
TP7	DGND	Digital Ground
TP8	DGND	Digital Ground
TP4	+3.3VA	+3.3V Analog Power Supply
TP10	AGND	Analog Ground
TP11	AGND	Analog Ground
Analog Signals		
TP15	VREF	+1.65V Voltage Reference to Bias Op Amp Outputs
IA	IA	Phase A Leg Current Feedback of Inverter – Internal Amplifier (dsPIC33CK64MC105 Op Amp 1) Output
IA_EXT	IA_EXT	External Amplifier (MCP6024 U10C) Output – Phase A Leg Current Feedback of Inverter
IB	IB	Phase B Leg Current Feedback of Inverter – Internal Amplifier (dsPIC33CK64MC105 Op Amp 3) Output
IB_EXT	IB_EXT	External Amplifier (MCP6024 U10B) Output – Phase B Leg Current Feedback of Inverter
IC_EXT	IC_EXT	External Amplifier (MCP6024 U10A) Output – Phase C Leg Current Feedback of Inverter
IBUS_IC	IBUS_IC	Bus Current Feedback of Inverter – Internal Amplifier (dsPIC33CK64MC105 Op Amp 2) Output or Phase C Leg Current Feedback of Inverter
IBUS_EXT	IBUS_EXT	Bus Current Feedback of Inverter which is Amplified by MCP651S (U11)
IBUS_FILT_EXT	IBUS_FILT_EXT	Filtered Bus Current Feedback of Inverter which is Amplified by MCP651S (U11); this output is connected to the negative input of one of the internal comparators of the dsPIC® DSC for overcurrent protection
VA	VA	Phase A Voltage Feedback
VB	VB	Phase B Voltage Feedback
VC	VC	Phase C Voltage Feedback
VBUS	VBUS	DC Bus Voltage Feedback
TP16	TEMP_EXT	Output of External Temperature Sensor Interfaced through Connector J9
Hall Sensor Feedbacks		
HA	HALL_A	Hall Sensor A or Quadrature Encoder A Feedback Connected to dsPIC® DSC Input
HB	HALL_B	Hall Sensor B or Quadrature Encoder B Feedback Connected to dsPIC DSC Input
HC	HALL_C	Hall Sensor C or Quadrature Encoder Index Feedback Connected to dsPIC DSC Input
LEDs		
TP17	LED1	LED1 Output from dsPIC DSC
TP18	LED2	LED2 Output from dsPIC DSC
Test Points		
TP12	TP12	Connected to 10th Pin of dsPIC33CDVL64MC106
TP13	TP13	Connected to 53rd Pin of dsPIC33CDVL64MC106
TP14	TP14	Connected to 54th Pin of dsPIC33CDVL64MC106

2.4 PIN FUNCTIONS OF THE dsPIC33CDVL64MC106 FAMILY OF DEVICES

The on-board dsPIC33CDVL64MC106 device (see U9 in Figure A-2) enables the control of various features of the Development Board through its modules, peripherals and CPU capability. Pin functions of the dsPIC33CDVL64MC106 are grouped according to their functionality and presented in Table 2-13.

TABLE 2-13: dsPIC33CDVL64MC106 PIN FUNCTIONS

Signal	Pin Number	Pin Function	Peripheral or Module	Remarks
dsPIC® DSC (U9A) Configuration – Supply, Reset, Clock and Programming				
+3.3V	25, 39, 52	VDD	Supply	+3.3V Digital Supply to dsPIC DSC
DGND	12, 26, 38	VSS		Digital Ground
+3.3VA	20	AVDD		+3.3V Analog Supply to dsPIC DSC
AGND	21	AVSS		Analog Ground
CLKI	28	OSCI/CLKI/AN5/RP32/RB0	Oscillator with PLL	Connects to Pin 3 of the MEMS oscillator (Y2) through jumper resistor R65
$\overline{\text{MCLR}}$	11	$\overline{\text{MCLR}}$	Reset	Connects to a push button (SW3), ICSP header (J6) and PKOB circuit
PGD	40	PGD3/RP37/RB5	In-Circuit Serial Programming™ (ICSP™) or In-Circuit Debugger	Connects to ICSP header (J6) and PKOB circuit
PGC	41	PGC3/RP38/RB6		
dsPIC DSC (U9A) Internal Amplifier Connections for Current Amplification				
SHUNT_IA_P	17	OA1IN+/AN9/RA2	Operational Amplifier 1 (Op Amp #1) and Shared ADC Core	Differential current feedback from shunt resistor, Rsh1, connects to noninverting and inverting inputs of Op Amp #1 through input resistors
SHUNT_IA_N	16	OA1IN-/RA1		
IA	15	OA1OUT/AN0/CMP1A/IBIAS0/RA0		Op Amp #1 output, which is amplified Phase A current; for the output to be available, configure and enable Op Amp #1, populate the resistor R53 (0R) in the amplifier feedback and remove R18 if populated
SHUNT_IB_P	23	OA3IN+/AN14/ISRC1/RP50/RC2	Operational Amplifier 3 (Op Amp #3) and Shared ADC Core	Differential current feedback from shunt resistor, Rsh2, connects to noninverting and inverting inputs of Op Amp #3 through input resistors
SHUNT_IB_N	22	OA3IN-/AN13/CMP1B/ISRC0/RP49/RC1		
IB	19	OA3OUT/AN4/IBIAS3/RA4		Op Amp #3 output, which is amplified Phase B current; for the output to be available, configure and enable Op Amp #3, populate the resistor R86 (0R) in the amplifier feedback and remove R81 if populated
SHUNT_IBUS_P	34	PGC2/OA2IN+/RP36/RB4	Operational Amplifier 2 (Op Amp #2) and Shared ADC Core	Differential current feedback from shunt resistor, Rsh4, connects to noninverting and inverting inputs of Op Amp #2 through input resistors
SHUNT_IBUS_N	33	PGD2/OA2IN-/AN8/RP35/RB3		
IBUS_IC	32	OA2OUT/AN1/AN7/CMP1D/RP34/INT0/RB2		Op Amp #2 output, which is amplified bus current; for the output to be available, configure and enable Op Amp #2, populate the resistor R70 (0R) in the amplifier feedback, and remove R64 and R79 if populated

Note 1: Only applicable to the dsPIC33CDV64MC106 Motor Control Development Board.
2: Only applies to the device with the LIN Transceiver module (dsPIC33CDVL64MC106).

TABLE 2-13: dsPIC33CDVL64MC106 PIN FUNCTIONS (CONTINUED)

Signal	Pin Number	Pin Function	Peripheral or Module	Remarks
Amplified Currents from External Amplifiers, U10 and U11				
IA_EXT	15	OA1OUT/AN0/CMP1A/IBIAS0/RA0	Shared ADC Core	Phase Current A amplified by the amplifier U10-C; when using this output, populate the resistor R18 (0R), remove the resistor R53 if populated and disable dsPIC DSC Operational Amplifier #1
IB_EXT	19	OA3OUT/AN4/IBIAS3/RA4	Shared ADC Core	Phase Current B amplified by the amplifier U10-B; when using this output, populate the resistor R81 (0R), remove the resistor R86 if populated and disable dsPIC DSC Operational Amplifier #3
IC_EXT	32	OA2OUT/AN1/AN7/CMP1D/RP34/INT0/RB2	Shared ADC Core	Phase Current C amplified by the amplifier U10-A; when using this output, populate the resistor R79 (0R), remove the resistors R64 and R70 if populated
IBUS_EXT	32	OA2OUT/AN1/AN7/CMP1D/RP34/INT0/RB2	Shared ADC Core	Bus current amplified by the amplifier U11; when using this output, populate the resistor R64 (0R), remove the resistors R79 and R70 if populated, and disable dsPIC DSC Operational Amplifier #2
Overcurrent Detection and Fault Output				
IBUS_FILT_EXT	18	DACOUT/AN3/CMP1C/RA3	High-Speed Analog Comparator #1 (CMP #1) and DAC #1	Amplified bus current is further filtered prior to connecting to the positive input of the CMP #1 used for overcurrent detection; overcurrent threshold can be set through DAC; comparator output is internally available as Fault input of the PWM Generators so that it can be used for shutting down PWMs without CPU intervention
Voltage Feedback				
V_BUS	14	AN12/RP48/RC0	Shared ADC Core	DC bus voltage feedback
V_A	44	PGC1/AN11/RP41/SDA1/RB9	Shared ADC Core	Phase A voltage feedback
V_B	43	PGD1/AN10/RP40/SCL1/RB8	Shared ADC Core	Phase B voltage feedback
V_C	42	TDO/AN2/RP39/RB7	Shared ADC Core	Phase C voltage feedback
Temperature Interface and Potentiometer (POT1)				
TEMP_EXT	28	OSCI/CLKI/AN5/RP32/RB0	Shared ADC Core	Feedback from external temperature sensor interfaced via connector J9
POT	27	AN15/IBIAS2/RP51/RC3	Shared ADC Core	Potentiometer (POT1) can be used for setting the speed/current/duty reference in motor control application
Hall Sensor/Quadrature Encoder Feedback (interfaced via connector J3)				
HALL_A	45	RP52/RC4	I/O Ports, Change Notification (CN), Remappable Feature of I/O and Quadrature Encoder Interface	Change Notification interrupt can be enabled to identify the transitions of any of the Hall sensor inputs; Quadrature Encoder Interface module can be configured to read position or speed information based on the encoder signals as required by the motor control application
HALL_B	36	RP57/ASCL1/SDI2/RC9		
HALL_C	35	RP56/ASDA1/SCK2/RC8		
Debug Interface (J6, PKOB)				
DEBUG_RX	30	ISRC3/RP74/RD10	Remappable Function of I/O and UART	These signals are connected to ICSP header J6; connect and disconnect appropriate jumper resistors to establish serial communication via any of these channels
DEBUG_TX	31	ISRC2/RP55/RC7		

Note 1: Only applicable to the dsPIC33CDV64MC106 Motor Control Development Board.
2: Only applies to the device with the LIN Transceiver module (dsPIC33CDVL64MC106).

TABLE 2-13: dsPIC33CDVL64MC106 PIN FUNCTIONS (CONTINUED)

Signal	Pin Number	Pin Function	Peripheral or Module	Remarks
User Interface (LEDs, Push Buttons)				
LED1	29	OSCO/CLKO/AN6/RP33/RB1	I/O Ports	Connected to general purpose LED LD1
LED2	24	IBIAS1/RP54/RC6		Connected to general purpose LED LD2
BUTTON1	37	RP72/PCI19/SDO2/RD8		Connected to push button SW1
BUTTON2	13	ANN0/RP77/RD13		Connected to push button SW2
mikroBUS™ Socket Signals (J11)				
CLICK_AN	28	OSCI/CLKI/AN5/RP32/RB0	Analog Channel or GPIO	mikroBUS™ Socket is provided to extend the feature by interfacing appropriated Click board™; Pin feature requirement changes based on the Click board™ inserted in the socket, the signals are allocated as per the general requirements.
CLICK_RST	29	OSCO/CLKO/AN6/RP33/RB1	GPIO	
CLICK_CS	44	PGC1/AN11/RP41/SDA1/RB9	Remappable Pin or PWM or GPIO	
CLICK_SCK	42	TDO/AN2/RP39/RB7	Can be configured as SPI Input/Output or Clock through Remappable Feature	
CLICK_MISO	14	AN12/RP48/RC0		
CLICK_MOSI	24	IBIAS1/RP54/RC6		
CLICK_SDA	35	RP56/ASDA1/SCK2/RC8	Alternate I^2C Data and Clock Pins of I^2C #3	
CLICK_SCL	36	RP57/ASCL1/SDI2/RC9		
CLICK_TX	31	ISRC2/RP55/RC7	Can be configured as UART RX and TX through Remappable Feature	
	51(1)	RP59/RC11		
CLICK_RX	30	ISRC3/RP74/RD10		
	49(1)	RP58/RC10		
CLICK_INT	43	PGD1/AN10/RP40/SCL1/RB8	Can be configured as Interrupt Pin through Remappable Feature	
CLICK_PWM	27	AN15/IBIAS2/RP51/RC3	Can be configured as SCCP Input or Output or use PWM Generator Output	
	47(1)	RP53/RC5		

Note 1: Only applicable to the dsPIC33CDV64MC106 Motor Control Development Board.

2: Only applies to the device with the LIN Transceiver module (dsPIC33CDVL64MC106).

TABLE 2-13: dsPIC33CDVL64MC106 PIN FUNCTIONS (CONTINUED)

Signal	Pin Number	Pin Function	Peripheral or Module	Remarks
Integrated Gate Driver (U9B) of dsPIC33CDVL64MC106				
HVDD	7	HVDD	Integrated Gate Driver (U9B) of dsPIC33CDVL64MC106; this is Part B of the dsPIC33CDVL64MC106	Refer to the data sheet for more details
HVSS	5	HVSS		
CAP1	9	CAP1		
CAP2	8	CAP2		
DRV_VBOOT	4	VBOOT		
DRV_VREG	6	VREG		
DRV_WAKE	55	WAKE		
	58	VBA		
	61	VBB		
	64	VBC		
PHASE_A	56	PHA		
PHASE_B	59	PHB		
PHASE_C	62	PHC		
	57	HSA		
	60	HSB		
	63	HSC		
	1	LSA		
	2	LSB		
	3	LSC		
Integrated LIN Transceiver (U9C) of dsPIC33CDVL64MC106(2)				
LIN_VDD	50	LIN_VDD	Integrated LIN Transceiver (U9C) of dsPIC33CDVL64MC106; this is Part C of the dsPIC33CDVL64MC106	Refer to the data sheet for more details
LIN_VSS	48	LIN_VSS		
LIN_BUS	49	LIN_BUS		
LIN_INH	51	LIN_INH		
LIN_RXD	46	LIN_RXD		
LIN_WKIN	47	LIN_WKIN		

Note 1: Only applicable to the dsPIC33CDV64MC106 Motor Control Development Board.
2: Only applies to the device with the LIN Transceiver module (dsPIC33CDVL64MC106).

Chapter 3. Hardware Description

3.1 INTRODUCTION

This chapter provides a detailed description of the hardware features of the Development Board. The Development Board is intended to demonstrate the capability of the dsPIC33CDVL64MC106 device family for motor control applications.

The Development Board incorporates a Hall sensor/Quadrature Encoder Interface (QEI), sensing circuits to measure DC voltage, phase voltages, bus current and phase currents, etc. In addition, a LIN bus interface, mikroBUS™ socket and an on-board programmer/debugger (PKOB) circuit are provided.

The motor control inverter can be operated by using an input voltage in the range of 12V 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

This chapter covers the following hardware sections of the Development Board:

- dsPIC33CDVL64MC106 and Auxiliary Circuits
- Power Supply
- Three-Phase Inverter Bridge
- Current Sensing Circuits
- Voltage Sensing Circuit
- Hall Sensor/Quadrature Encoder Interface
- External Temperature Sensor Interface
- User Interface
- LIN Bus Interface
- mikroBUS™ Socket
- Programmer/Debugger Interface

Figure 3-1 and Table 3-1 describe the hardware sections of the Development Board.

FIGURE 3-1: HARDWARE SECTIONS

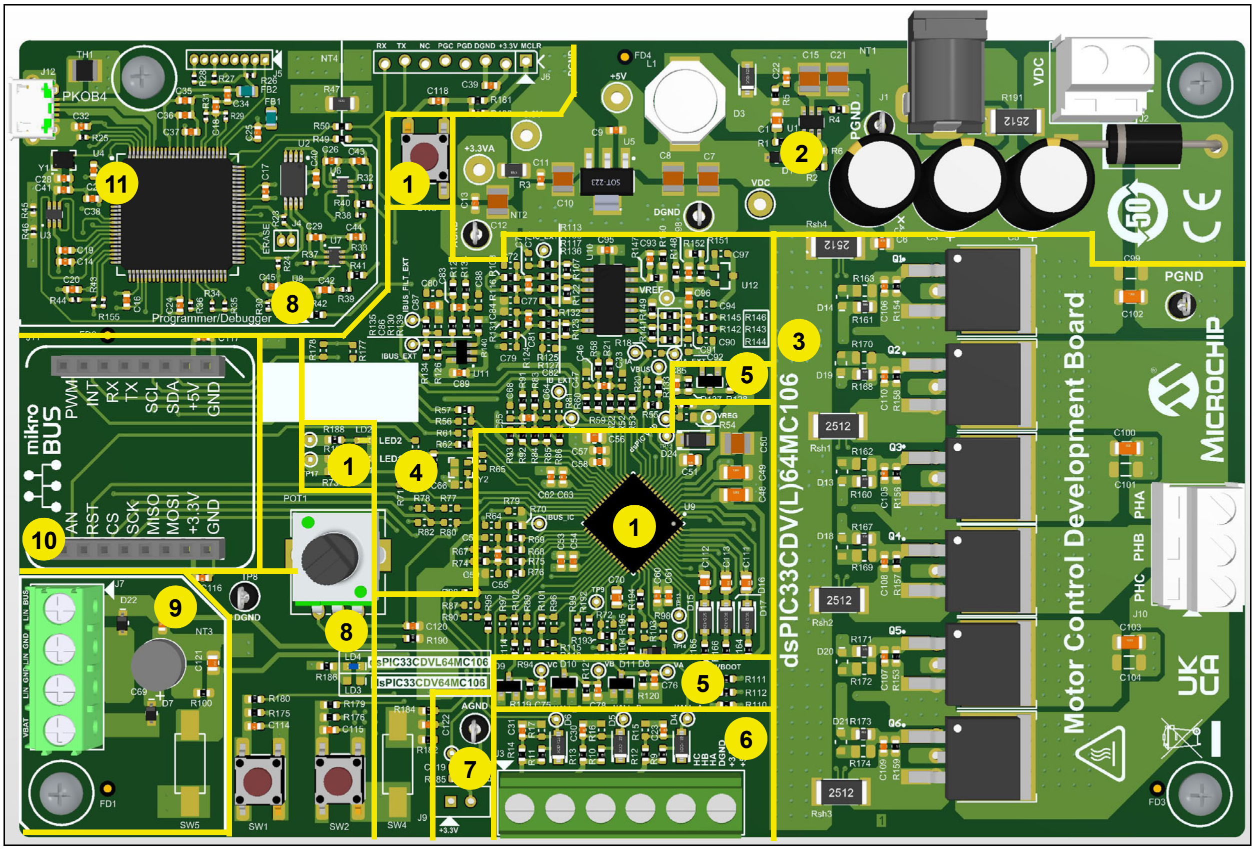


TABLE 3-1: HARDWARE SECTIONS

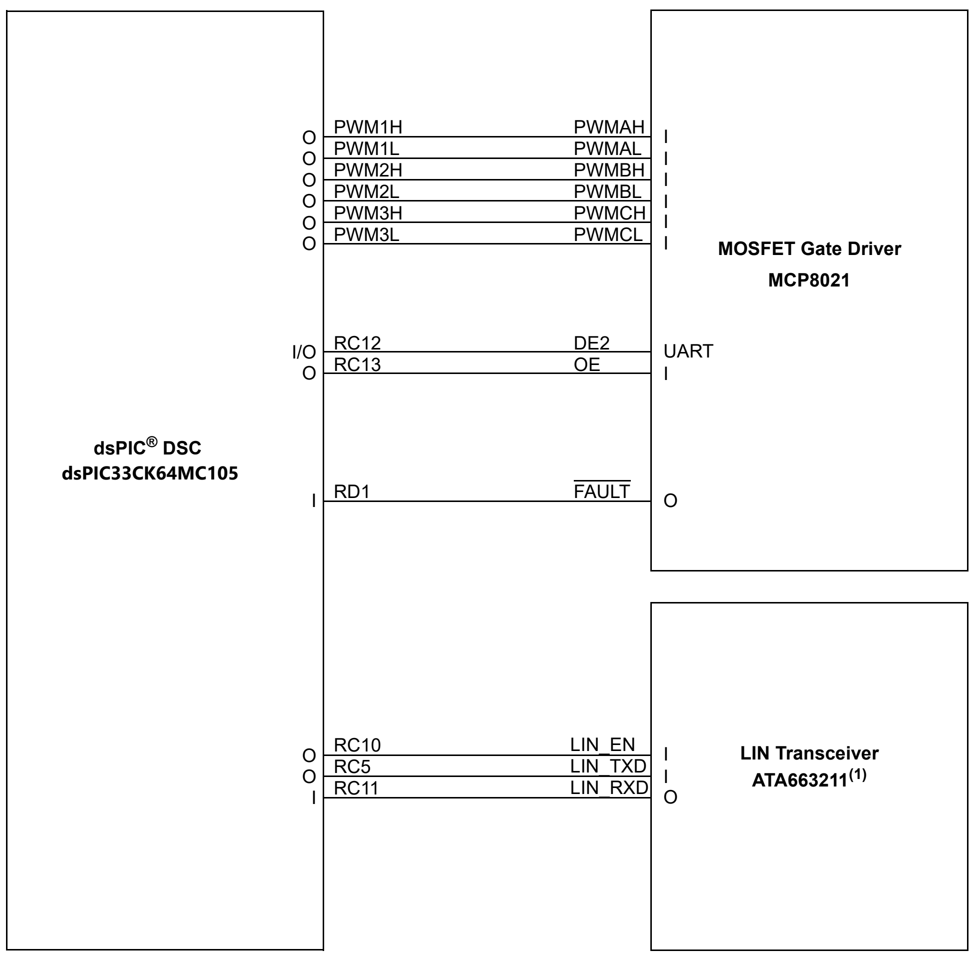
Section	Hardware Section
1	dsPIC33CDVL64MC106 and Auxiliary Circuits
2	Power Supply Section
3	Three-Phase Motor Control Inverter
4	Current Sensing Circuits
5	Voltage Sensing Circuits
6	Speed or Position Feedback Interfaces
7	External Temperature Sensor Interface
8	User Interface
9	LIN Bus Interface
10	mikroBUS™ Socket
11	PICkit™ On-Board (PKOB)

3.2.1 dsPIC33CDVL64MC106 and Auxiliary Circuits

The dsPIC33CDVL64MC106 and dsPIC33CDV64MC106 Motor Control Development Boards feature the dsPIC33CDVL64MC106 device from Microchip's dsPIC® DSC portfolio. The device contains a dsPIC33CK64MC105, a MOSFET Gate Driver and a LIN Transceiver. They are interconnected as shown in Figure 3-2 and Table 3-3. The co-existence of the dsPIC DSC, the MOSFET Gate Driver and the LIN Transceiver offers a single chip solution for the development of a cost-effective low-voltage PMSM/BLDC motor drive that can be networked via LIN.

The dsPIC33CDV64MC106 Motor Control Development Board features the dsPIC33CDV64MC106 device from Microchip's dsPIC DSC portfolio. The device contains a dsPIC33CK64MC105 and a MOSFET Gate Driver. The co-existence of the dsPIC DSC and the MOSFET Gate Driver offers a single-chip solution for the development of a cost-effective, low-voltage PMSM/BLDC motor drive.

FIGURE 3-2: dsPIC33CDVL64MC106 DEVICE INTERNAL CONNECTIONS



Note 1: Only applies to the device with the LIN Transceiver module (dsPIC33CDVL64MC106).

3.2.1.1 dsPIC DSC – dsPIC33CK64MC105

The main component of the dsPIC33CDVL64MC106 is a 100 MIPS high-performance dsPIC33CK64MC105 device with peripherals, such as high-speed ADCs, op amps, analog comparator, and Pulse-Width Modulators (PWMs) with built-in Fault protection, triggering and synchronization features.

The high-speed PWM module in the dsPIC DSC can generate multiple ADC triggers for measuring motor currents, phase voltage, inverter input voltage, total/bus inverter current, etc., at specific instances, with respect to PWM, used for controlling the inverter. These feedbacks are required for implementing motor control algorithms, such as sensor or sensorless Field Oriented Control (FOC), torque control, trapezoidal control, initial position detection, wind milling, flux weakening and single-shunt current reconstruction. The PWM Control Input (PCI) of the PWM module can be used for shutting down PWM outputs immediately when a Fault is detected and synchronizing multiple PWM Generators (PGs) used for controlling the three-phase inverter bridge.

The comparator module, along with the Digital-to-Analog Converter (DAC), can be used for detecting overcurrent Faults to protect the inverter or motor in case of malfunction. The dsPIC DSC has three operational amplifiers; these can be configured by connecting external input and feedback resistors for amplifying currents sensed by the shunt resistors.

The Change Notification (CN) feature of the I/O ports, along with the timer, can be used for detection of a Hall sensor state change to obtain position and speed of the motor in a sensor-based BLDC motor control application. Similarly, the Quadrature Encoder Interface (QEI) module in the dsPIC DSC can be configured to obtain the position/speed information from the Quadrature Encoder feedbacks of the motor, which is required for sensor-based Field-Oriented Control or sinusoidal control of PMSMs.

The dsPIC DSC also integrates several communication peripherals, such as SPI, I^2C and UART, for communicating with the host PC, central controller or main controller. Additionally, it features a Watchdog Timer, Deadman Timer, ECC engine and BIST module required for safety-critical applications.

In the Development Board, a provision is given to mount the external crystal oscillator to use its output as a dsPIC DSC clock input. The push button SW3 is tied to the $\overline{MCLR}$ pin of the device and is provided to reset the dsPIC DSC, if required. One of the program/debug pins, PGC3/PGD3, of the device is connected to the programmer/debug interfaces provided on the Development Board, along with $\overline{MCLR}$ to allow program/debug of the dsPIC DSC. Decoupling capacitors are provided on all the power supply pins of the dsPIC DSC, including the V_{DD}/GND and AV_{DD}/AGND pairs.

3.2.1.2 MOSFET GATE DRIVER – MCP8021

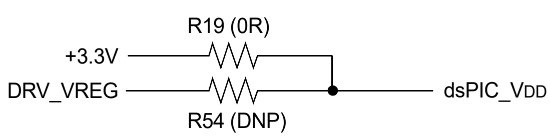
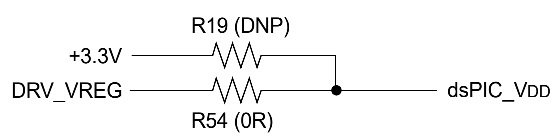
The second component of the dsPIC33CDVL64MC106 is a MOSFET Gate Driver capable of driving three-phase inverter bridges. The MOSFET Gate Driver module provides several protection features, such as undervoltage, overvoltage, shoot-through and short-circuit protection of the inverter bridge. The DE2 communication 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 precharged 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 precharged 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 precharge 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 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 3-4 for resistor jumper settings to select the required power supply input of the dsPIC DSC, which is internal to the dsPIC33CDVL64MC106 device.

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), DE2 Communication (DE2) and Fault Output (FAULT) from the MOSFET Gate Driver module 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 *"dsPIC33CDVL64MC106 Family Data Sheet"* (DS70005441).

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

Resistor Configuration to Power the dsPIC® DSC by the On-Board LDO Output of the Auxiliary Power Supply, +3.3V[1]	Resistor Configuration to Power the dsPIC DSC by the Internal LDO Output of the MOSFET Gate Driver, VREG[2]
	

Note 1: When internal LDOs are operating, the power dissipation of the dsPIC33CDVL64MC106 will increase in proportion to the current drawn from the LDOs. Ensure that the heating is at an acceptable limit.

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.

3.2.1.3 LIN TRANSCEIVER – ATA663211

The third component of the dsPIC33CDVL64MC106 is a LIN Transceiver. The fully integrated LIN Transceiver is designed in compliance with the LIN Specification 2.0, 2.1, 2.2, 2.2A and SAEJ2602-2. It interfaces the LIN protocol handler and the physical layer. Improved slope control at the LIN bus ensures data communication of up to 20 Kbaud. For more information about the LIN Transceiver, refer to the *"dsPIC33CDVL64MC106 Family Data Sheet"* (DS70005441).

The LIN Transceiver pins, LIN_EN, LIN_TXD and LIN_RXD, are internally connected to the dsPIC DSC remappable inputs, allowing its UART to be configured and used for establishing the LIN interface.

TABLE 3-3: INTERNAL INTERCONNECTIONS OF THE dsPIC33CDVL64MC106

dsPIC® DSC		MOSFET Gate Driver	
Pin Function	**Description**	**Pin Function**	**Description**
RP46/PWM1H/RB14(1)	Digital Output. Configure PG1 and enable the PWM High Output.	PWMAH	Digital Input, Phase A High-Side Control, Internal 47 kΩ Pull-Down
RP47/PWM1L/RB15	Digital Output. Configure PG1 and enable the PWM Low Output.	PWMAL	Digital Input, Phase A Low-Side Control, Internal 47 kΩ Pull-Down
TDI/RP44/PWM2H/RB12(1)	Digital Output. Configure PG2 and enable the PWM High Output.	PWMBH	Digital Input, Phase B High-Side Control, Internal 47 kΩ Pull-Down
RP45/PWM2L/RB13	Digital Output. Configure PG2 and enable the PWM Low Output.	PWMBL	Digital Input, Phase B Low-Side Control, Internal 47 kΩ Pull-Down
TMS/RP42/PWM3H/RB10(1)	Digital Output. Configure PG3 and enable the PWM High Output.	PWMCH	Digital Input, Phase C High-Side Control, Internal 47 kΩ Pull-Down
TCK/RP43/PWM3L/RB11	Digital Output. Configure PG3 and enable the PWM Low Output.	PWMCL	Digital Input, Phase C Low-Side Control, Internal 47 kΩ Pull-Down
RP65/PWM4H/RD1	Configure as Digital Input, use Internal Pull-up.	$\overline{\text{FAULT}}$	Digital Output, Active-Low Fault, Open-Drain
RP60/RC12	Configure as Half-Duplex UART, use PPS and Internal Pull-up.	DE2	Digital Communications Port, Open-Drain
RP61/RC13	Configure as Digital Output.	OE	Digital Input, Output Enable, Fault Clearing, Internal 47kΩ Pull-Down
dsPIC DSC		**LIN Transceiver(2)**	
Pin Function	**Description**	**Pin Function**	**Description**
RP58/RC10	Configure as Digital Output.	LIN_EN	Digital Input, Enable Signal
RP53/RC5	Configure as UART TX, use PPS.	LIN_TXD	Transmit Data Input from Microcontroller.
RP59/RC11	Configure as UART RX, use PPS.	LIN_RXD(1)	Receive Data Output to Microcontroller, use 4.7 kΩ External Pull-up and 20 pF Load Capacitor.

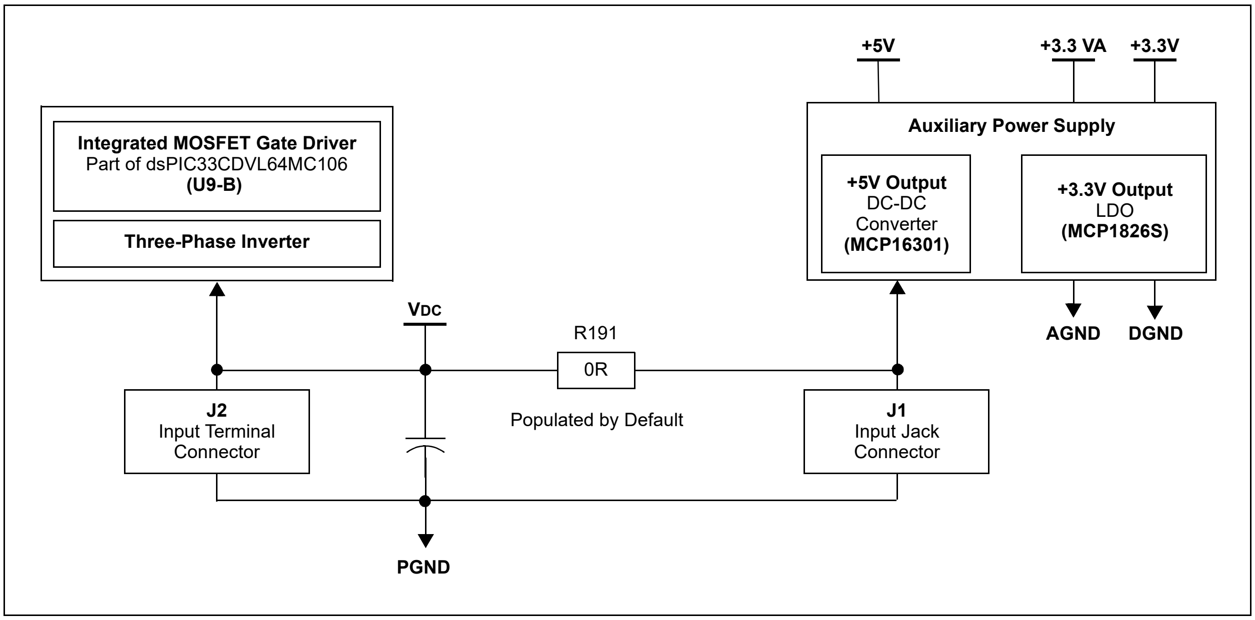
Note 1: Interconnect is also bonded to an external device pin.
2: Only applies to the device with the LIN Transceiver module (dsPIC33CDVL64MC106).

3.2.2 Power Supply

The Development Board can be powered through coaxial plug J1 or terminal connector J2. Connector J1 can carry current up to 2.5A, and connector J2 can handle up to 10A. The board is designed to operate in the DC voltage range of 12-24V. DC link capacitors are placed in parallel with the input to minimize the effects of voltage variation, depending on the load, and to reduce ripple voltage on the DC bus because of ripple currents generated by the motor control inverter during switching. The power supply block diagram is shown in Figure 3-3. The input DC supply connects to the MOSFET Gate Driver, motor control inverter and auxiliary power supply. The auxiliary power supply section consists of a DC-DC Converter and an LDO voltage regulator. The MCP16301 buck converter generates a +5V output, which is provided to power the speed/position sensors interfaced via connector J3 and the Click boards™ interfaced via the mikroBUS™ socket, J11. The fixed 3.3V LDO MCP1826S generates +3.3V, which powers all logical circuits, including the dsPIC33CK64MC105 (U9A), operational amplifiers, mikroBUS socket, user interface elements, temperature sensor, speed/position sensors and programmer/debugger interfaces.

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 dsPIC33CDVL64MC106. The internal +3.3V LDO, with an output current capability of 70 mA, can be used to power the dsPIC33CK64MC105 (U9A).

FIGURE 3-3: POWER SUPPLY BLOCK DIAGRAM



The +3.3V digital and analog supply, and ground connections are logically separated using jumper resistors. In the Development Board, the digital supply, digital ground, analog supply and analog ground are labeled as +3.3V, DGND, +3.3 VA and AGND, respectively. When required, the power to the inverter can be separated by disconnecting resistor R191. Then, the dsPIC33CDVL64MC106 and three-phase inverter can be powered through J2, and the rest of the circuitry through the coaxial plug J1. The connections between J1 and J2 can be restored by populating R191 with a 0R resistor. For additional details, refer to **Section C.3 "Auxiliary Power Supply"**, **Section 2.2.1 "Power Supply Connectors (J1, J2)"** and Figure A-1.

3.2.3 Three-Phase Inverter Bridge

The three-phase motor power stage is implemented using six N-channel MOSFETs (Q1-Q6) configured as three half bridges. A resistor is connected across the gate and source of each MOSFET 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. A transient voltage suppressor (D2) is provided between the inverter supply and ground for protecting the inverter and driver against voltage transients.

The three-phase Gate Driver, internal to the dsPIC33CDVL64MC106, is used for driving the low-side and high-side MOSFETs of the motor control inverter. The bootstrap circuit, consisting of a resistor, diode and capacitor, which is required to drive the high-side MOSFETs, is connected externally to the dsPIC33CDVL64MC106. However, the bootstrap circuit is powered by the +12V LDO (VBOOT – 30 mA), which is internal to the dsPIC33CDVL64MC106. The output of the three-phase inverter bridge is available on connector J10.

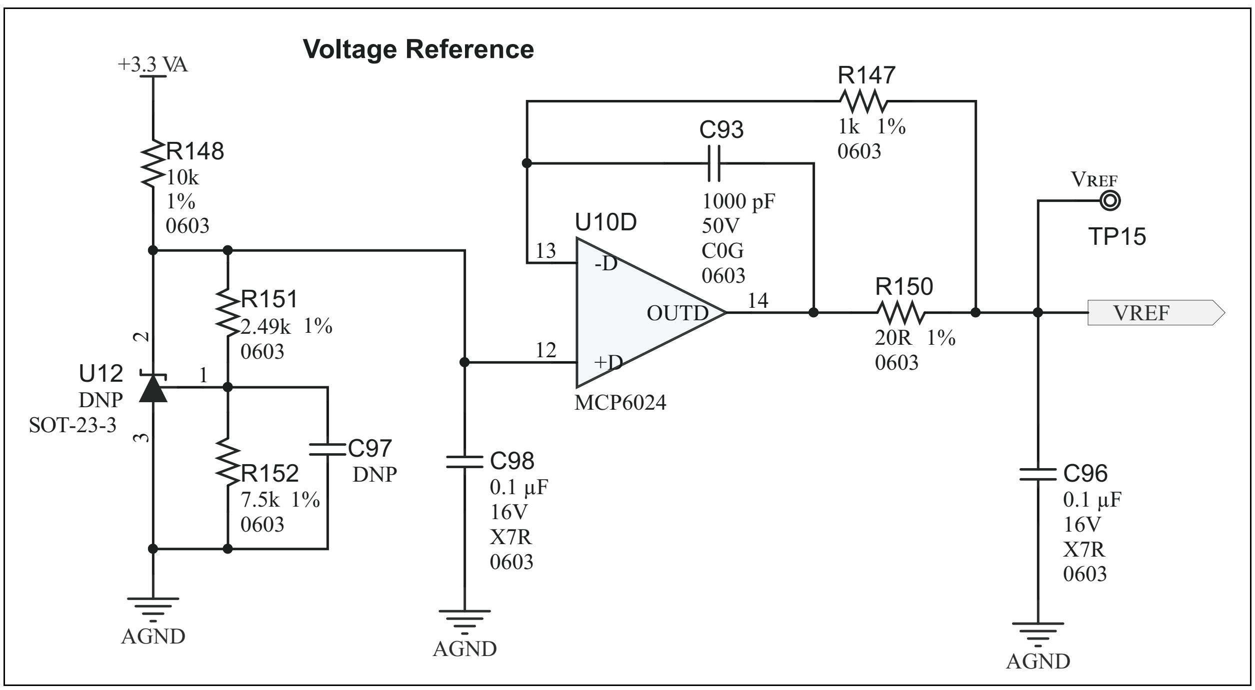
3.2.4 Current Sensing Circuits

3.2.4.1 VOLTAGE REFERENCE CIRCUIT

The Reference Voltage (VREF) is generated, which is half the analog supply voltage (+3.3 VA), that is approximately +1.65V. The reference circuit (see Figure 3-4) is built around one of the MCP6024 op amps (labeled as 'D'). The resistors, R148, R151 and R152, form the voltage divider circuit, and it sets half of the analog voltage (+3.3 VA) at the positive input of the amplifier. The op amp, U10D (MCP6024-D), is used as a buffer. The resistors, R147, R150 and C93, form a compensation circuit to drive capacitive loads, where C93 acts as a high-frequency feedback path, and R147 is used as a feedback path for low-frequency signals.

This reference output is connected to the positive input of the current amplifiers for adding DC bias to its outputs, thus allowing measurement of positive and negative current swings using single-supply amplifiers.

FIGURE 3-4: VOLTAGE REFERENCE CIRCUIT



3.2.4.2 CURRENT AMPLIFIERS

Field-Oriented Control (FOC) of the PMSM/BLDC motor requires the motor phase current information for implementation. In the Development Board, shunt resistors, Rsh1, Rsh2 and Rsh3, are provided in each inverter leg to measure the amount of current flowing through the motor phases. An additional shunt resistor, Rsh4, is provided for sensing the total bus current as this information is necessary for overcurrent protection and current control of BLDC motors. The DC bus current information can also be used for reconstruction of motor phase currents by appropriately sampling currents during the PWM switching period, which is called a single-shunt reconstruction algorithm.

Noninverting differential amplifier configuration is used for amplifying the voltage drop across the shunt resistors, proportional to the currents flowing through three-phase inverter Phases A, B and C, and bus current, respectively. The output voltage of the amplifiers is shifted by the Voltage Reference (VREF), +1.65V, to allow positive and negative current swings. The Common-mode and Differential-mode filters are added between the input pins of all the amplifiers for noise filtering. It is also possible to add filters at the output of the external amplifiers, U10-A, U10-B, U10-C and U11.

The block diagram in Figure 3-5 illustrates the interconnections between the external amplifiers and the dsPIC DSC analog peripherals, including internal amplifiers, comparator, ADC, etc. The Development Board enables phase and bus current amplification through external amplifiers, U10 and U11, and dsPIC DSC internal amplifiers, Op Amp 1 (OA1), Op Amp 2 (OA2) and Op Amp 3 (OA3). The op amps, OA1, OA3 and OA2, that are internal to dsPIC33CDVL64MC106, are used for Phase A, Phase B and bus current amplification. Three out of four amplifiers (U10-A, U10-B and U10-C) in the quad amplifier, MCP6024, are configured to amplify current flowing through inverter Phases A, B and C. Amplified Phase C current (IC_EXT) is connected to an analog input of the dsPIC DSC. The selection between internal and external amplifier outputs is done via resistor jumpers (see Table 3-4).

The op amp, MCP651S (U11), is added for DC bus current amplification. This amplifier is configured to sense bus current. The U11 amplifier output is further filtered (IBUS_FILT_EXT) and is connected to the positive input of the internal Comparator 1 (CMP1C). The Comparator 1 negative input can be configured to connect to the internal DAC output for setting the overcurrent threshold. The Comparator 1 (CMP1) output generates an active-high output when overcurrent is detected. This comparator output is available to the PWM Generators of the high-speed PWM module as a Fault input. If the Fault is enabled in the PWM Generators, and CMP1 is selected as an active-high Fault source during an overcurrent Fault condition, the motor control PWMs will be disabled, thus protecting the hardware.

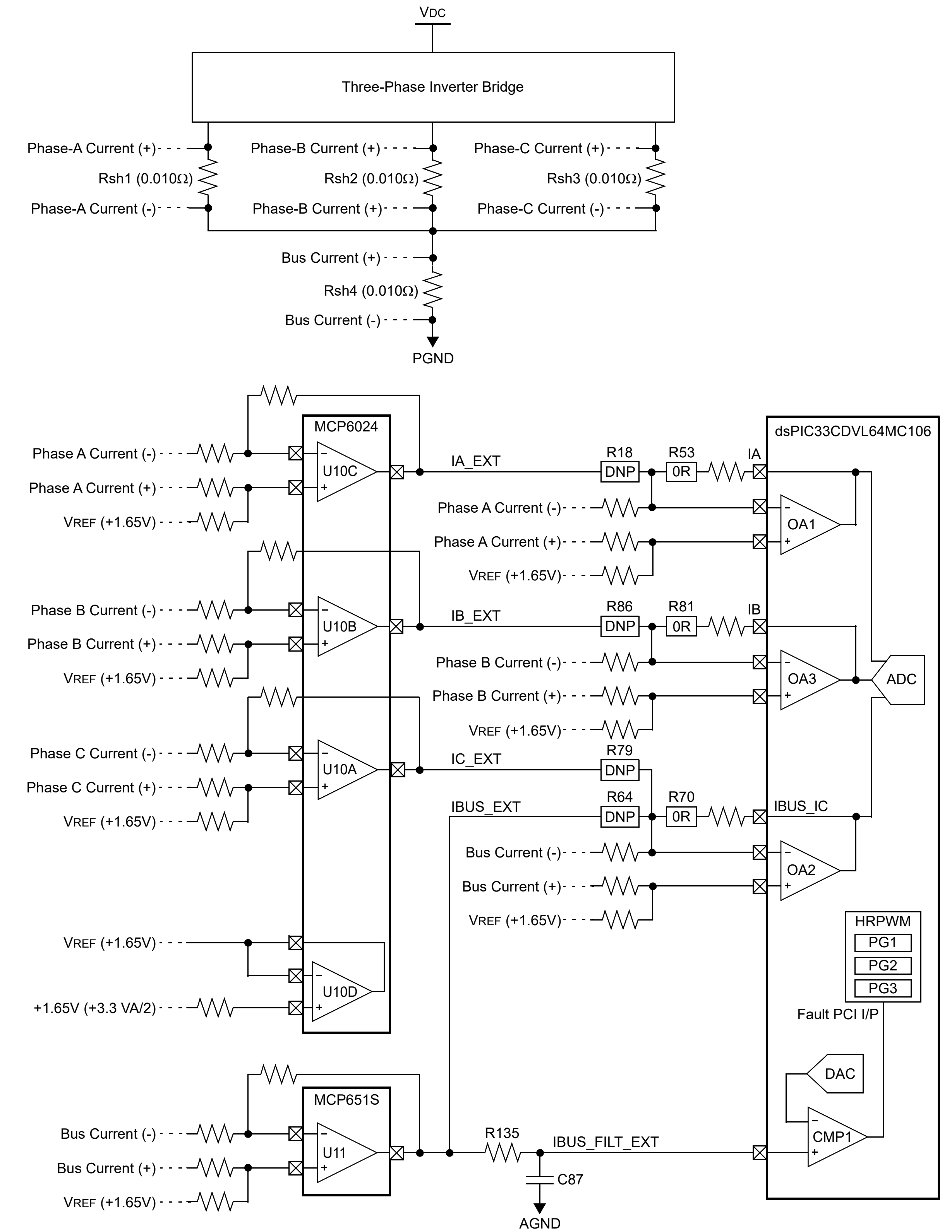
TABLE 3-4: SELECTION BETWEEN EXTERNAL AND INTERNAL AMPLIFIER OUTPUTS

Current Signal	Internal Amplifier Output		External Amplifier Output		Remarks
	Jumper Resistor Settings				
	Populate	Remove	Populate	Remove	
Amplified Phase A Currents **IA or IA_EXT**	R53	R18	R18	R53	In internal amplifier configuration, configure and enable Op Amp 1 (OA1). In external amplifier configuration, ensure internal amplifier Op Amp 1 (OA1) is disabled.
Amplified Phase B Currents **IB or IB_EXT**	R86	R81	R81	R86	In internal amplifier configuration, configure and enable Op Amp 3 (OA3). In external amplifier configuration, ensure internal amplifier Op Amp 3 (OA3) is disabled.
Amplified Phase C Currents **IC_EXT**	Not Implemented		R79	R64 and R70	In external amplifier configuration, ensure internal amplifier Op Amp 2 (OA2) is disabled.
Amplified Bus Currents **IBUS or IBUS_EXT**	R70	R64 and R79	R64	R70 and R79	In internal amplifier configuration, configure and enable Op Amp 2 (OA2). In external amplifier configuration, ensure internal amplifier Op Amp 2 (OA2) is disabled.

The gain of the amplifier used for phase and bus current sensing is set to sense 22A peak current by default. The gain of the amplifier can be changed, as required by the application, by modifying the amplifier input and feedback resistors.

For more information, refer to **Section C.2 "Current Amplifier Circuits"**.

FIGURE 3-5: CURRENT SENSE CONFIGURATION[(1)]

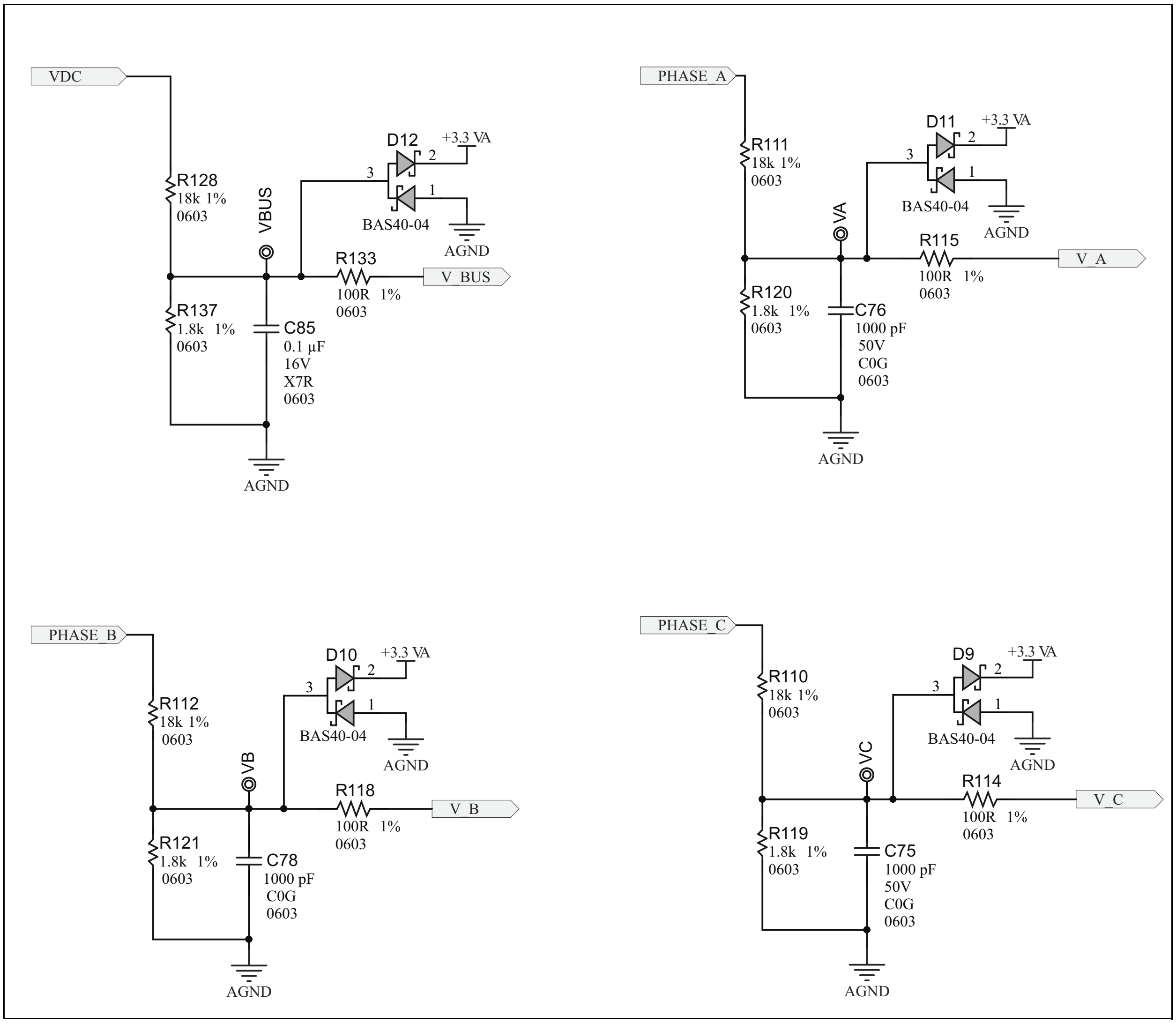


Note 1: This is a representational diagram only; for detailed schematics, refer to **Appendix A. "Schematics and Layout"**.

3.2.5 Voltage Sensing Circuit

A voltage sensing network is provided to scale down the phase and DC supply voltages for measurement. The voltage divider network, formed by resistors, R128 and R137, divides the DC input voltage (VDC) at a voltage scaling ratio of 1:11 (see Figure 3-6). The scaled DC input voltage (V_BUS) is connected to the analog input pin of the dsPIC DSC for measurement.

FIGURE 3-6: VOLTAGE SENSING CIRCUIT



The Development Board can also be used to run BLDC motors with a trapezoidal commutation scheme by monitoring back-EMF signals. The voltage divider network divides phase voltages (PHASE_A, PHASE_B and PHASE_C) at a voltage scaling ratio of 1:11 (see Figure 3-6). The scaled back-EMF signals (V_A, V_B and V_C) are connected to analog input pins of the dsPIC DSC. The filter capacitors are provided to filter the noise.

The clamping diodes are provided to ensure the voltage divider output does not exceed the input voltage limits of the dsPIC DSC during voltage transients, kickbacks or component failures.

3.2.6 Hall Sensor/Quadrature Encoder Interface

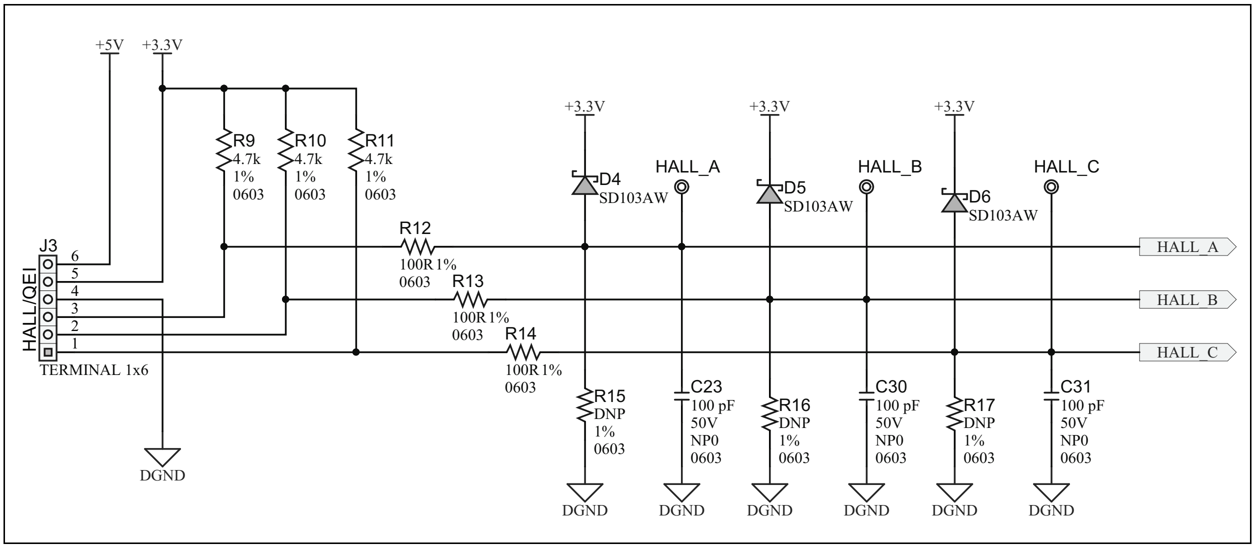
The Development Board can also be used to run PMSM/BLDC motor control applications using the Hall sensor/Quadrature Encoder to determine rotor position and speed. The connector J3 is provided to interface the Hall sensor or Quadrature Encoder to the Development Board. The interface circuit supports either open-collector or push-pull output sensors.

The Hall sensors or Quadrature Encoder can be powered by the +5V supply or +3.3V supply available through the interface connector terminals. A capacitor is added to each signal output to reduce the noise.

The voltage divider (R12 and R15, R13 and R16, R14 and R17) can be configured to scale down the sensor signal, from a +5V level to a +3.3V level when push-pull output sensors are powered by a +5V supply. When open collector output sensors are used, populate R9, R10 and R11. For circuit details, refer to Figure A-5 in **Appendix A. "Schematics and Layout"**.

The connector J3 pinouts are summarized in **Section 2.2.2 "Hall Sensor/Quadrature Encoder Interface Header (J3)"**.

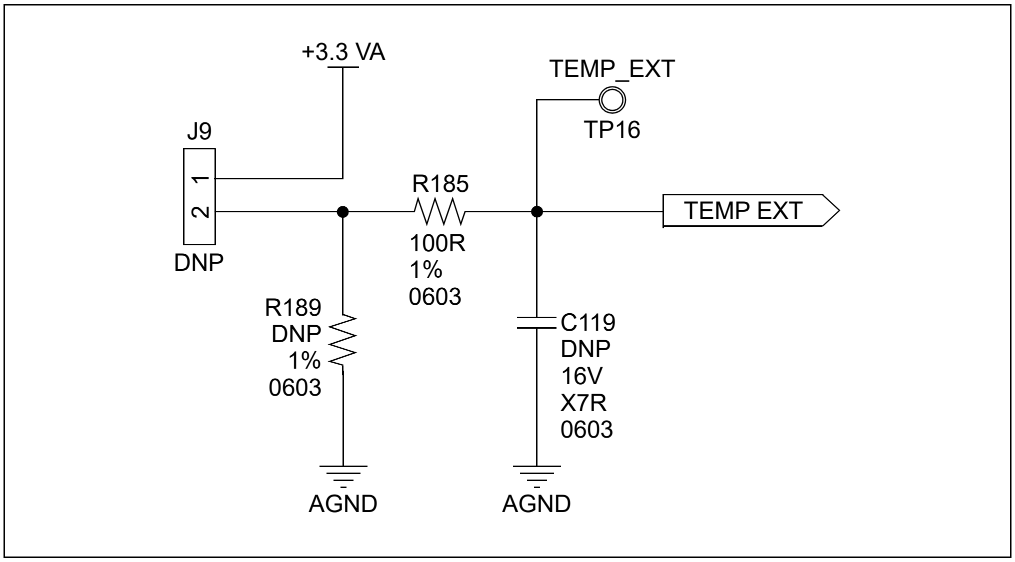
FIGURE 3-7: HALL SENSOR/QUADRATURE ENCODER INTERFACE



3.2.7 External Temperature Sensor Interface

The Development Board provides an optional external temperature sensor interface circuit. This circuit can be used to interface a thermistor for measuring motor winding temperature, etc. As shown in Figure 3-8, the temperature sensor and resistor R189 form a +3.3V analog supply voltage divider, setting the voltage proportional to the temperature at the analog input of the dsPIC DSC. To reduce the noise, temperature feedback can be further filtered by the RC filter, R185 and C119. This circuit is not populated by default. When used, populate the connector J9 with Part Number B2B-EH-A(LF)(SN) or similar, and components, R189 and C119, appropriately.

FIGURE 3-8: EXTERNAL TEMPERATURE INTERFACE CIRCUIT



3.2.8 User Interface

The user interface has two push buttons, along with a potentiometer and LEDs. The potentiometer (POT1) can be used for setting the speed reference. LEDs (LD1, LD2) are for status indication, and the general purpose push buttons (SW1, SW2) can be used to start and stop the motor.

For details, refer to **Section 2.3 "User Interface Hardware"**.

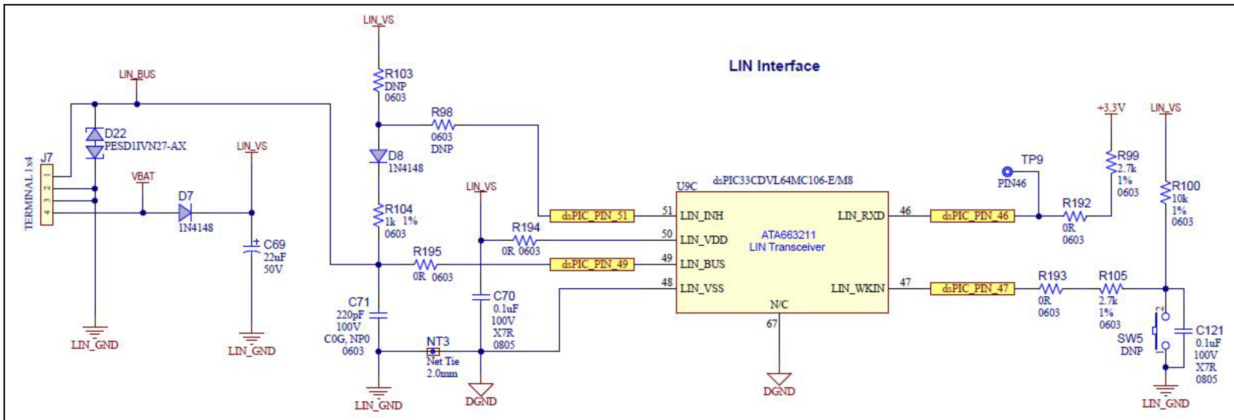
3.2.9 LIN Bus Interface

The dsPIC33CDVL64MC106 integrates a LIN Transceiver (ATA663211), thus reducing overall cost if it is employed in an application board networked through the LIN bus. The ATA663211 device is a fully integrated LIN Transceiver designed in compliance with the LIN Specification 2.0, 2.1, 2.2, 2.2A and SAEJ2602-2. It interfaces the LIN protocol handler and the physical layer. The device is designed to handle the low-speed data, for example, in vehicles. For more information, refer to the data sheet of the ATA663211 or dsPIC33CDVL64MC106 by visiting the microchip website (www.microchip.com). Improved slope control at the LIN bus ensures data communication up to 20 Kbaud.

The Development Board is shipped with all components necessary to immediately start the development of a LIN client node. An external DC power supply (5V to 28V), required for the LIN interface, can be connected between the terminals, VBAT (Pin 4 of Connector J7) and GND (Pin 3 of Connector J7).The LIN connection is established by attaching wires between LIN_BUS (Pin 1 of Connector J7) and GND (Pin 2 of Connector J7).

The node can be configured as 'Main' by populating either jumper resistor, R103 (0R), which connects LIN_VS or by populating jumper resistor, R98, which connects LIN_INH to the LIN main pull-up resistor, R106(1k), through diode D8. The LIN_WKIN pin of the transceiver is a high-voltage input used to wake up the device from Sleep mode. This is connected to an external switch to generate a local wake-up signal. The LIN_RXD signal can be probed at test point TP9.

FIGURE 3-9: LIN INTERFACE[1]



Note 1: The LIN Bus Interface circuit is not populated in the dsPIC33CDV64MC106 Motor Control Development Board.

3.2.10 mikroBUS™ Socket

The Development Board has an optional mikroBUS socket. The socket is provided to attach mikroBUS add-on boards, called Click boards, to expand the capability of the Development Board by adding sensors, displays, storage and communication interfaces. One hundred plus unique Click boards are available based on Microchip products (visit https://www.mikroe.com/brands/microchip), in categories such as wireless connectivity (Wi-Fi, Bluetooth®, LoRa®), sensors (inductive position sensors, remote temperature, thermocouple, ECG, IrDA®), interfaces (CAN, LIN, Ethernet®, DALI™, EtherCAT®), mixed signal (ADC, DAC), storage (EEPROM, Flash, SRAM) and security, for example.

The mikroBUS socket comprises a pair of 1x8 female headers with an exclusive pin configuration. The pinout consists of three communication interfaces, SPI, UART and I^2C, six additional pins for PWM, interrupt, analog input, Reset and chip select, and two power groups, +3.3V and +5V. For available Click boards, visit www.mikroe.com.

It is recommended that users verify that the connection requirement of the specific Click board is satisfied prior to interfacing. For pin mapping information between the dsPIC DSC and the mikroBUS socket, refer to the schematics in **Section A.1 "Board Schematics and Layout"** or **Section 2.4 "Pin Functions of the dsPIC33CDVL64MC106 Family of Devices"**. These interfaces are not isolated from the input supply connected to the Development Board.

Note:	Refer to Table 2-8 for pin mapping between the dsPIC33CDVL64MC106 and mikroBUS socket. Add or remove specified resistors to establish connection between specific pins of the dsPIC33CDVL64MC106 and the mikroBUS socket.

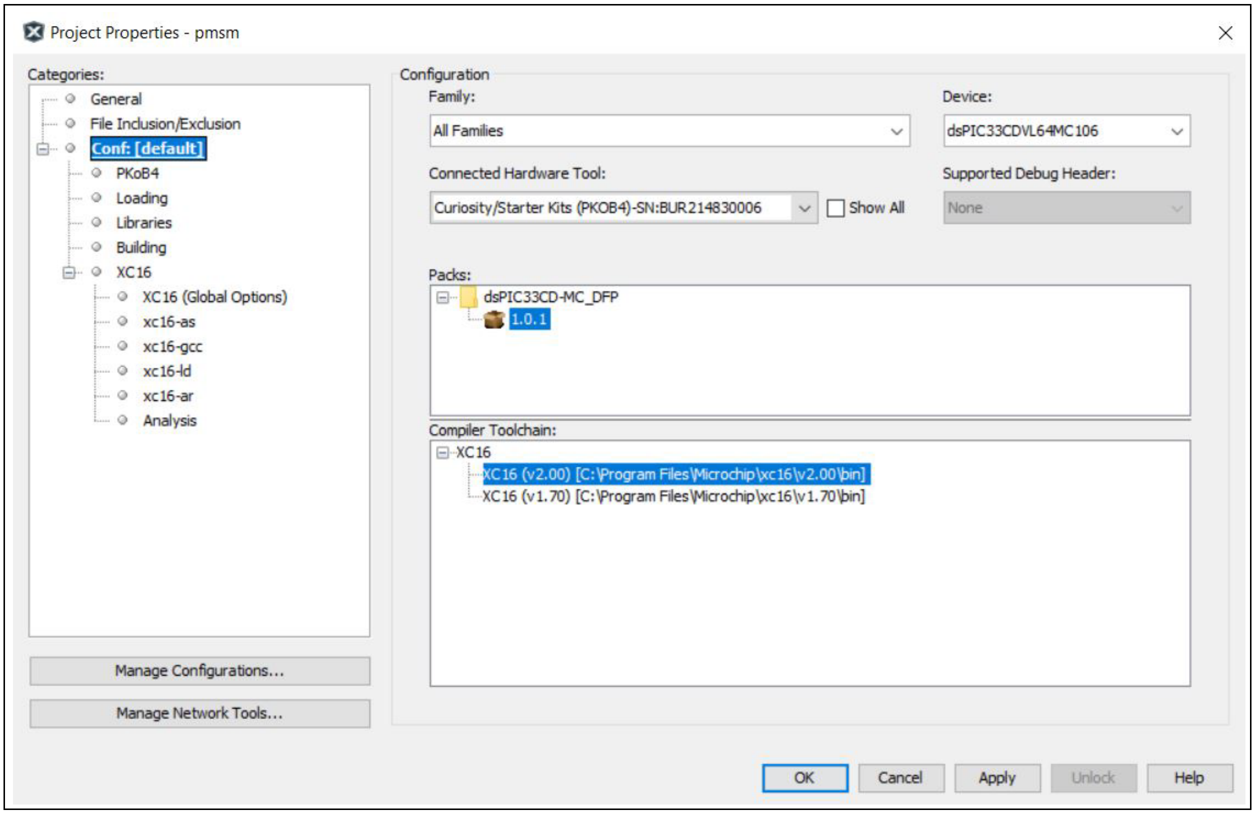
3.2.11 Programmer/Debugger Interface

3.2.11.1 PROGRAM/DEBUG INTERFACE

The board has a PICkit™ On-Board (PKOB) programming/debugging tool, which can be used to program and debug the target device: dsPIC33CDVL64MC106 (U9). The PKOB should automatically enumerate and be recognized by the MPLAB X IDE, v5.50 or later, when the dsPIC33CDVL64MC106 Motor Control Development Board is connected to the host PC via the USB Micro-B connector, J12. No custom USB driver installation is necessary as the PKOB relies on standard OS provided Human Interface Device (HID) drivers, and therefore, the driver installation should be fully automatic. When plugged in, the PKOB programmer/debugger tool can be selected from the MPLAB X IDE project properties page by selecting the device under:

Hardware Tools>Microchip Kits>Starter Kits (PKOB)>Curiosity/Starter Kits (PKOB4)> MPLAB PKoB 4, as shown in Figure 3-10.

FIGURE 3-10: PKOB 4 SELECTION IN MPLAB® X IDE



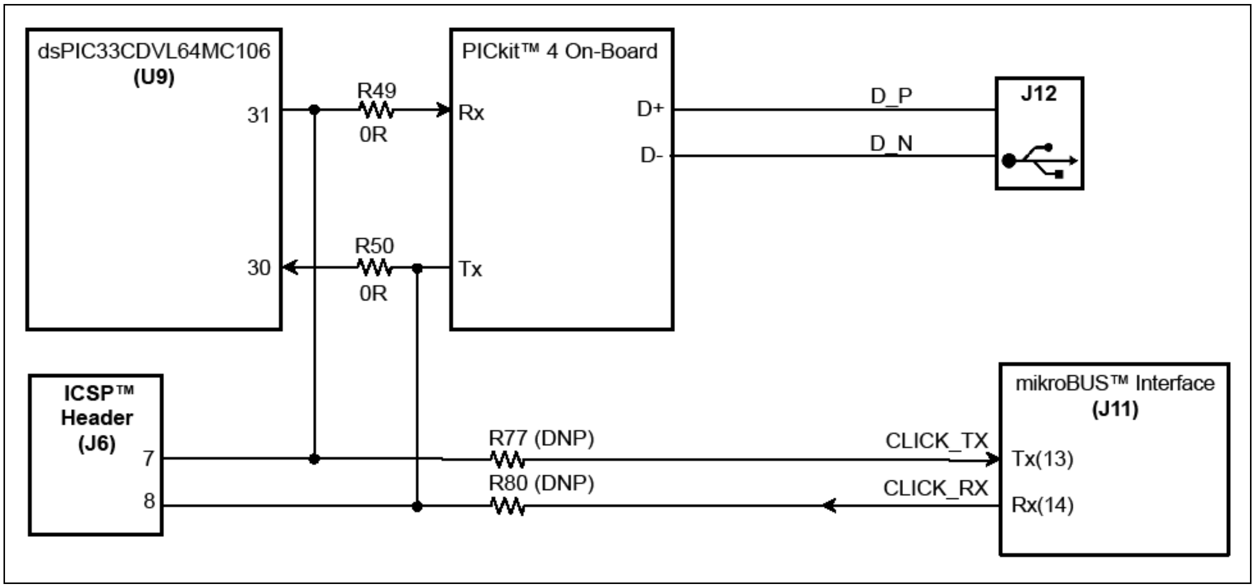
Additionally, an 8-pin ICSP™ programming header, J6, is provided for connecting the programmer/debugger (for example, MPLAB PICkit™ 4 In-Circuit Debugger, Part Number: PG164140). For connector pin details, refer to **Section 2.2.4 "ICSP™ Header for Programmer/Debugger Interface (J6)"**.

3.2.11.2 DEBUG SERIAL INTERFACE

The PICkit On-Board (PKOB) programming/debugging tool can also be used as a debug serial interface through the virtual COM port feature of the tool. The RX and TX signals of the dsPIC33CDVL64MC106 are connected to the PKOB circuit by populating jumper resistors, R49 and R50, with 0 Ohms. Under Windows® OS, after successful driver installation, the device will appear as the 'COMx' port object, which standard terminal programs can open to read and write data. This USB-UART connection setup can support a baud rate of up to 460800 bps.

The interconnections of the debug serial UART RX and TX signals from the dsPIC33CDVL64MC106 are shown in Figure 3-11.

FIGURE 3-11: DEBUG SERIAL INTERFACE – UART



The virtual COM port feature of the MPLAB PICkit 4 In-Circuit Debugger can be utilized for establishing a debug serial interface if the tool is interfaced via ICSP header, J6, and by populating jumper resistors, R78 and R82, and connecting header pins 8 and 7 to dsPIC DSC pins 30 and 31, respectively.

The MPLAB X IDE hosts a plug-in, which allows real-time diagnostics through the serial USB-UART interface with the external Host PC:

- X2C-Scope from the Linz Center of Mechatronics GmbH for use with the X2C-Scope plug-in for MPLAB X.

The PKOB or ICSP programming header is not isolated from the input supply connected to the Development Board.

Appendix A. Schematics and Layout

A.1 BOARD SCHEMATICS AND LAYOUT

A.1.1 Schematics of the dsPIC33CDVL64MC106 Motor Control Development Board

This section provides schematics of the dsPIC33CDVL64MC106 Motor Control Development Board. The Development Board uses a four-layer FR4, 1.6 mm, Plated Through-Hole (PTH) construction.

Table A-1 summarizes the schematics of the Development Board.

TABLE A-1: SCHEMATICS – dsPIC33CDVL64MC106 MOTOR CONTROL DEVELOPMENT BOARD

Figure Index	Schematics Sheet No.	Hardware Sections
Figure A-1	1 of 8	Input Power Supply Connections, +5V DC-DC Converter, +3.3V LDO
Figure A-2	2 of 8	dsPIC33CDVL64MC106-dsPIC® DSC (U9A) Interconnections, MCLR Reset, ICSP™ Header, dsPIC DSC Operational Amplifiers for amplifying a Bus Current and Phase Currents
Figure A-3	3 of 8	1.65V Voltage Reference Buffer, External Operational Amplifiers for amplifying Bus Current and Phase Currents, DC Bus Voltage Sensing Circuit, Phase Voltages Sensing Circuit
Figure A-4	4 of 8	Motor Control Inverter – Three-Phase MOSFET Bridge, dsPIC33CDVL64MC106-MOSFET Gate Driver (U9B)
Figure A-5	5 of 8	Click board™ Socket, LED Indications, Push Buttons, Potentiometer, Hall Sensor/Quadrature Encoder Interface, Temperature Sensor Interface
Figure A-6	6 of 8	PKOB – Microcontroller, USB Port, etc.
Figure A-7	7 of 8	PKOB – Buffers
Figure A-8	8 of 8	LIN Interface (U9C)

FIGURE A-1: dsPIC33CDVL64MC106 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATICS – SHEET 1 OF 8

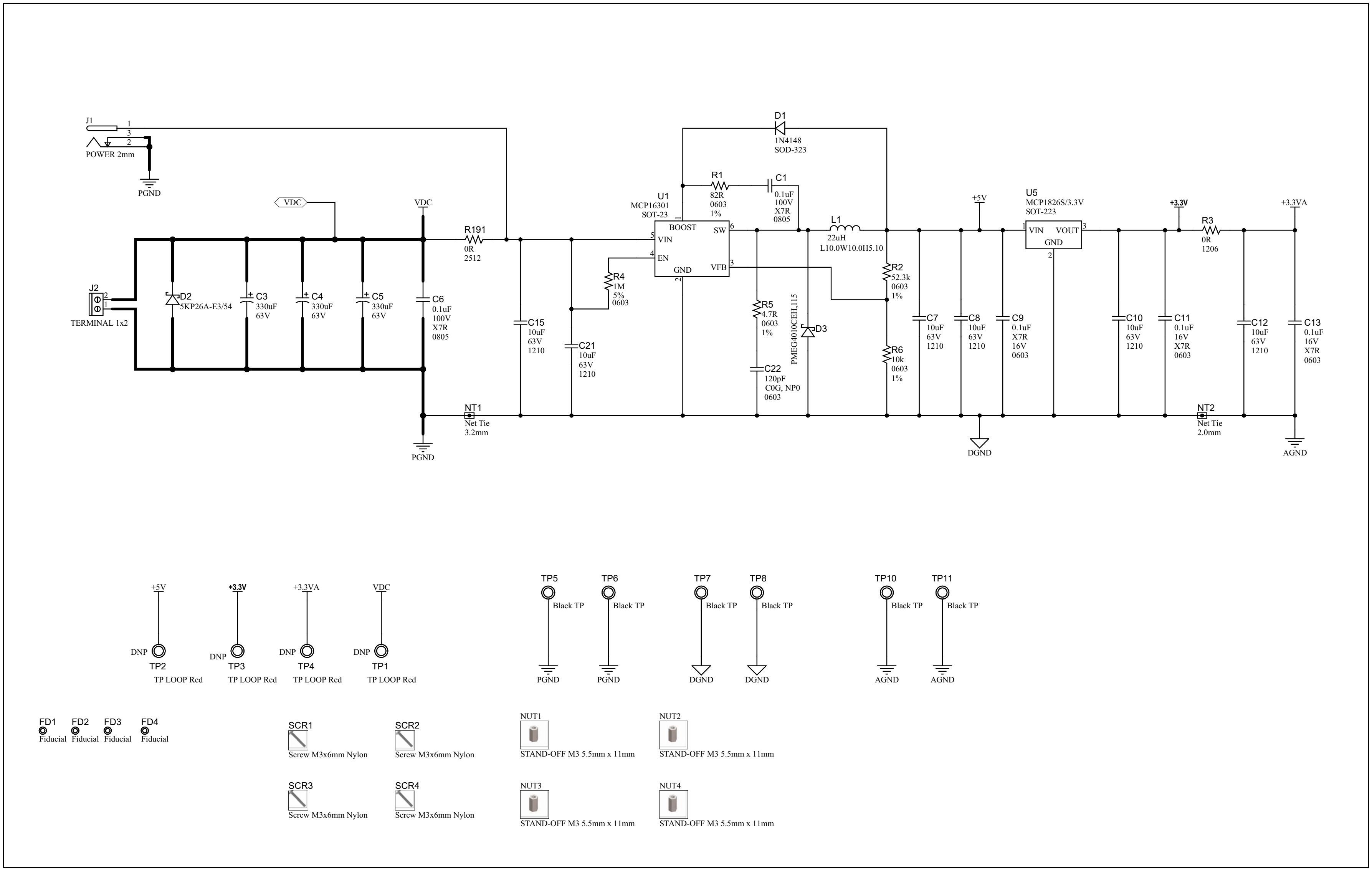


FIGURE A-2: dsPIC33CDVL64MC106 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATICS – SHEET 2 OF 8

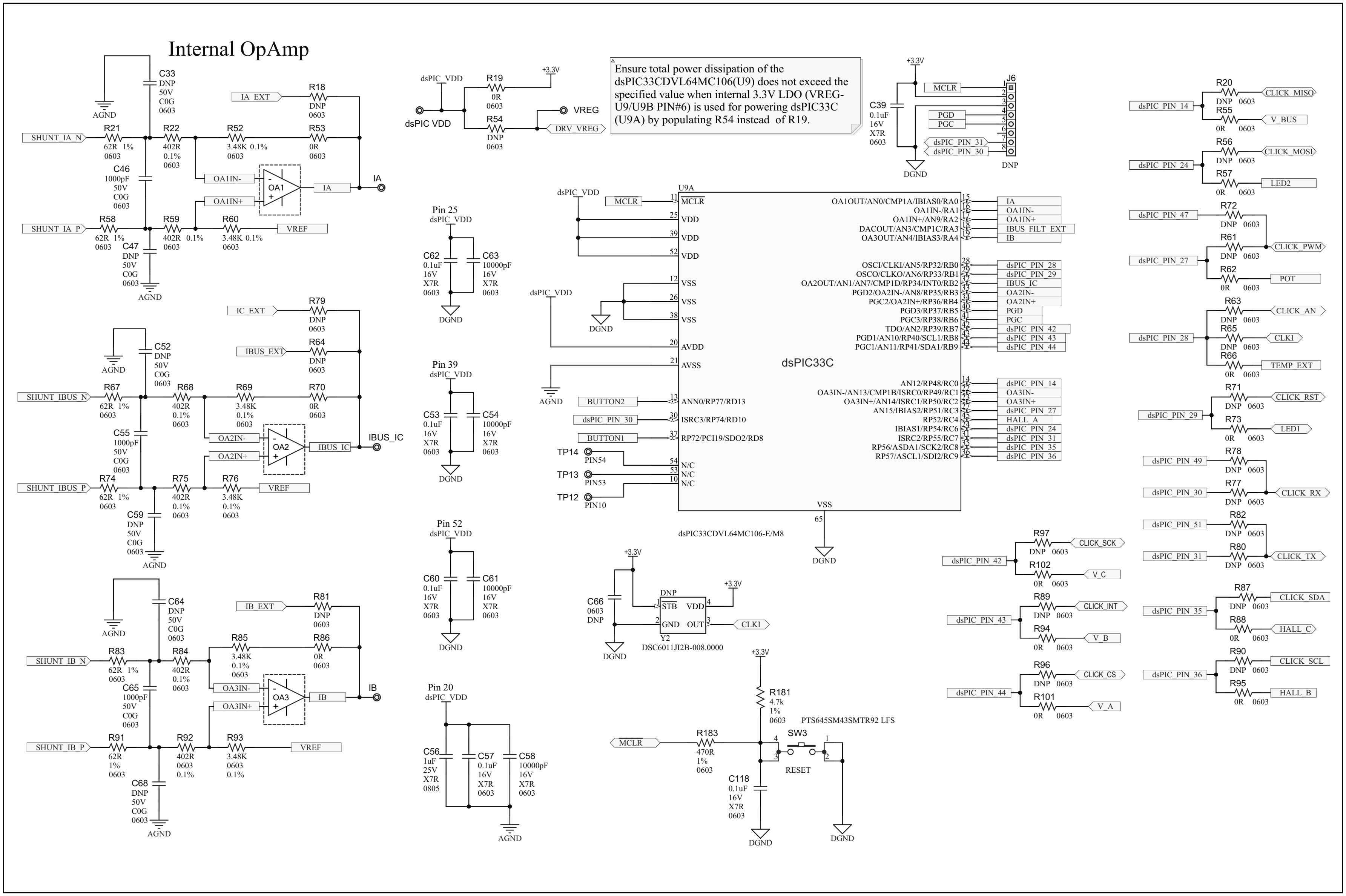


FIGURE A-3: dsPIC33CDVL64MC106 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATICS – SHEET 3 OF 8

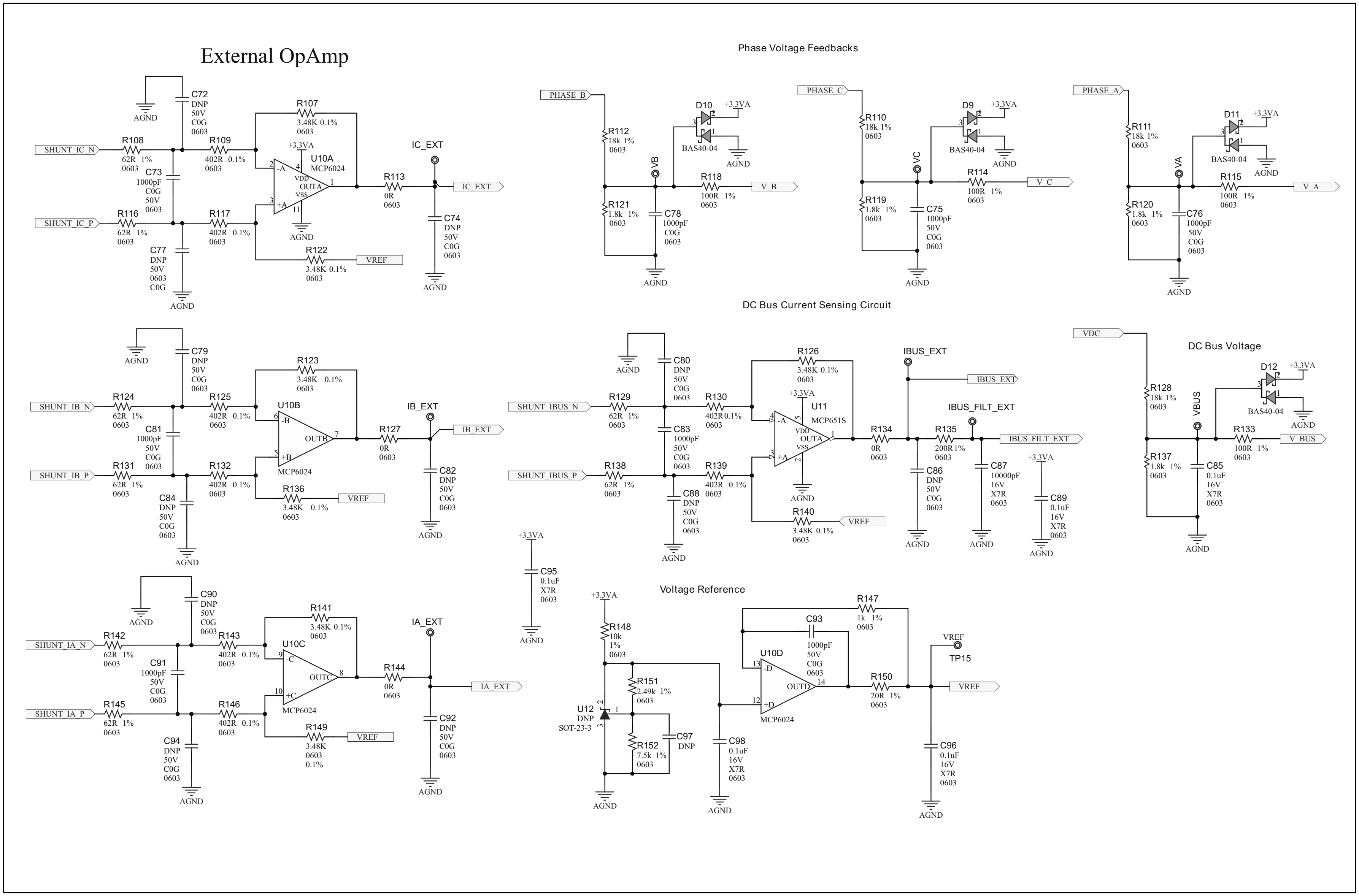


FIGURE A-4: dsPIC33CDVL64MC106 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATICS – SHEET 4 OF 8

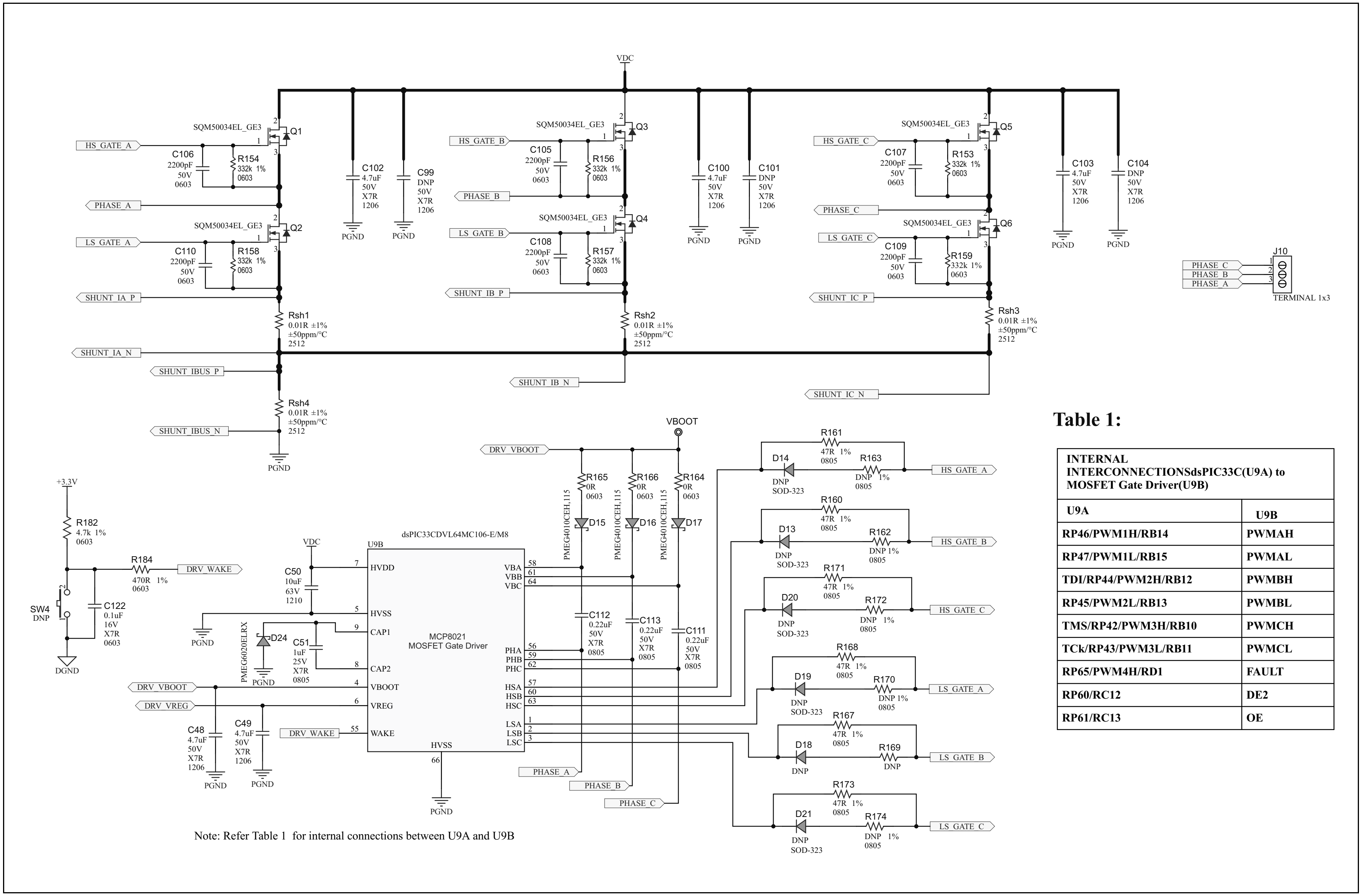


Table 1:

INTERNAL INTERCONNECTIONSdsPIC33C(U9A) to MOSFET Gate Driver(U9B)	
U9A	U9B
RP46/PWM1H/RB14	PWMAH
RP47/PWM1L/RB15	PWMAL
TDI/RP44/PWM2H/RB12	PWMBH
RP45/PWM2L/RB13	PWMBL
TMS/RP42/PWM3H/RB10	PWMCH
TCk/RP43/PWM3L/RB11	PWMCL
RP65/PWM4H/RD1	FAULT
RP60/RC12	DE2
RP61/RC13	OE

FIGURE A-5: dsPIC33CDVL64MC106 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATICS – SHEET 5 OF 8

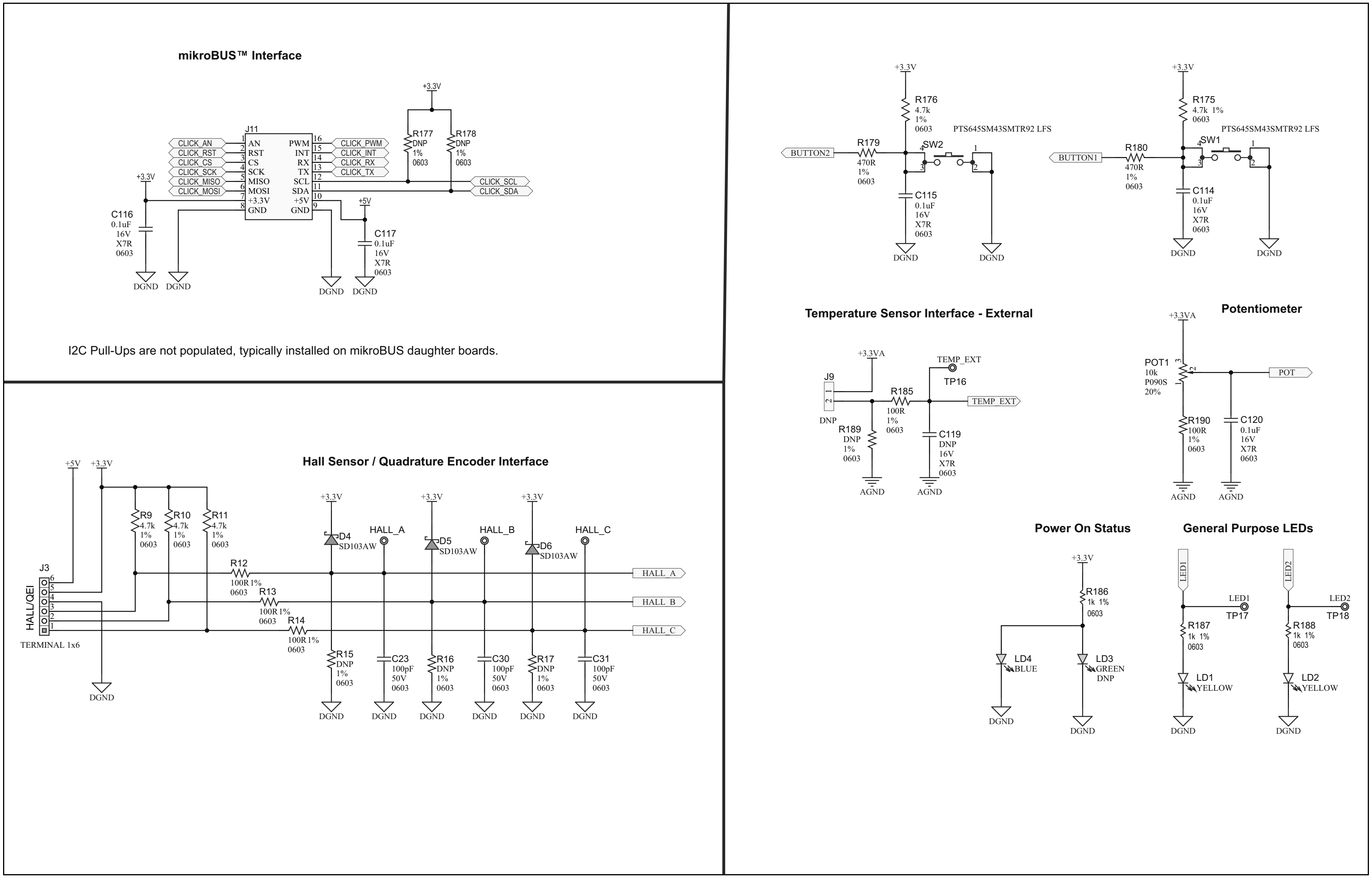


FIGURE A-6: dsPIC33CDVL64MC106 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATICS – SHEET 6 OF 8

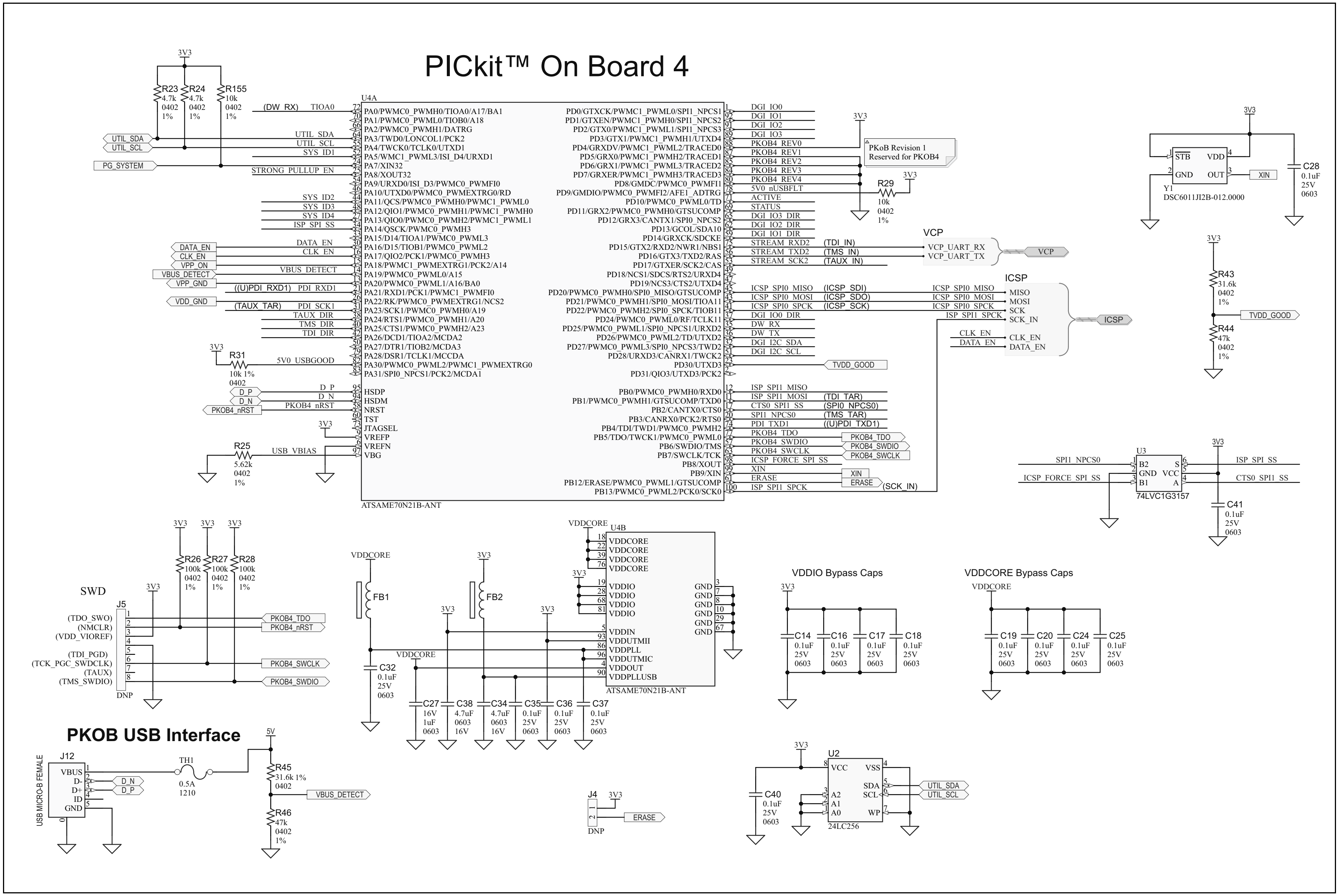


FIGURE A-7: dsPIC33CDVL64MC106 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATICS – SHEET 7 OF 8

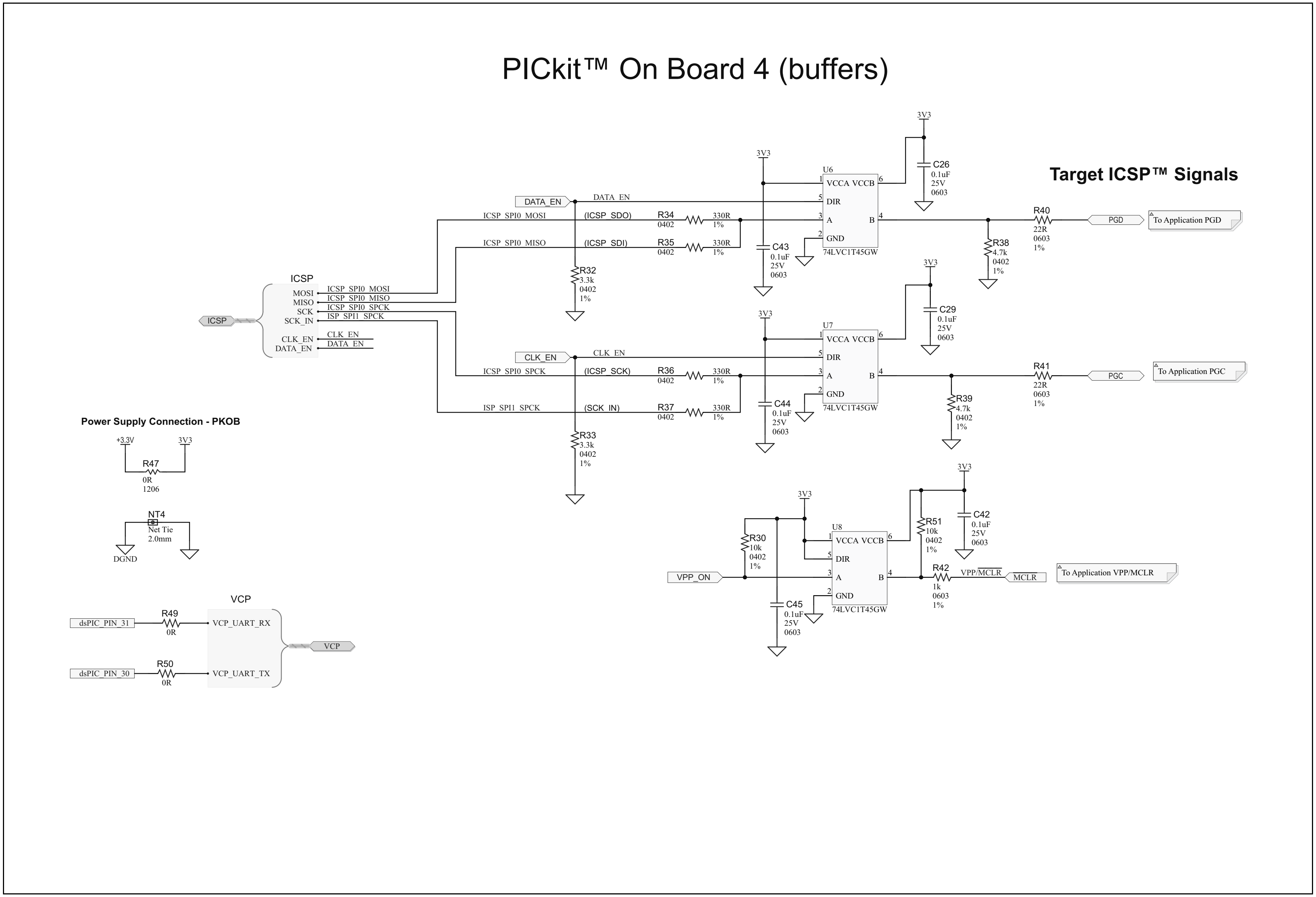
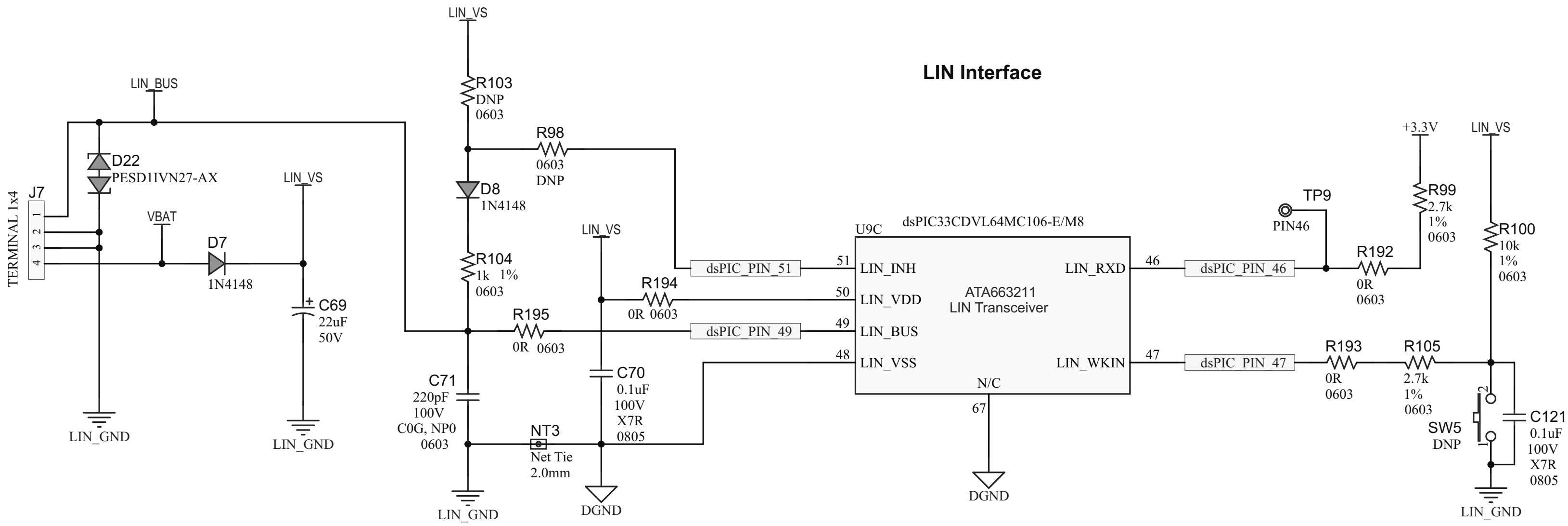


FIGURE A-8: dsPIC33CDVL64MC106 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATICS – SHEET 8 OF 8



Note: Refer Table 2 for internal connections between U9A and U9C

Table 2:

INTERNAL INTERCONNECTIONS dsPIC33C(U9A) to LIN Transciever(U9C)	
U9A	U9C
RP53/RC5	LIN_TXD
RP58/RC10	LIN_EN
RP59/RC11	LIN_RXD
Note : LIN_RXD is also connected to an external device pin.	

A.1.2 Schematics of the dsPIC33CDV64MC106 Motor Control Development Board

This section provides schematics of the dsPIC33CDV64MC106 Motor Control Development Board. The Development Board uses a four-layer FR4, 1.6 mm, Plated Through-Hole (PTH) construction.

Table A-2 summarizes the schematics of the Development Board.

TABLE A-2: SCHEMATICS – dsPIC33CDV64MC106 MOTOR CONTROL DEVELOPMENT BOARD

Figure Index	Schematics Sheet No.	Hardware Sections
Figure A-9	1 of 8	Input Power Supply Connections, +5V DC-DC Converter, +3.3V LDO
Figure A-10	2 of 8	dsPIC33CDV64MC106-dsPIC® DSC (U9A) Interconnections, MCLR Reset, ICSP™ Header, dsPIC DSC Operational Amplifiers for amplifying a Bus Current and Phase Currents
Figure A-11	3 of 8	1.65V Voltage Reference Buffer, External Operational Amplifiers for amplifying Bus Current and Phase Currents, DC Bus Voltage Sensing Circuit, Phase Voltages Sensing Circuit
Figure A-12	4 of 8	Motor Control Inverter – Three-Phase MOSFET Bridge, dsPIC33CDV64MC106-MOSFET Gate Driver (U9B)
Figure A-13	5 of 8	Click board™ Socket, LED Indications, Push Buttons, Potentiometer, Hall Sensor/Quadrature Encoder Interface, Temperature Sensor Interface
Figure A-14	6 of 8	PKOB – Microcontroller, USB Port, etc.
Figure A-15	7 of 8	PKOB – Buffers
Figure A-16	8 of 8	LIN Interface(1)

Note 1: The LIN bus interface circuit is not populated in the dsPIC33CDV64MC106 Motor Control Development Board.

FIGURE A-9: dsPIC33CDV64MC106 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATICS – SHEET 1 OF 8

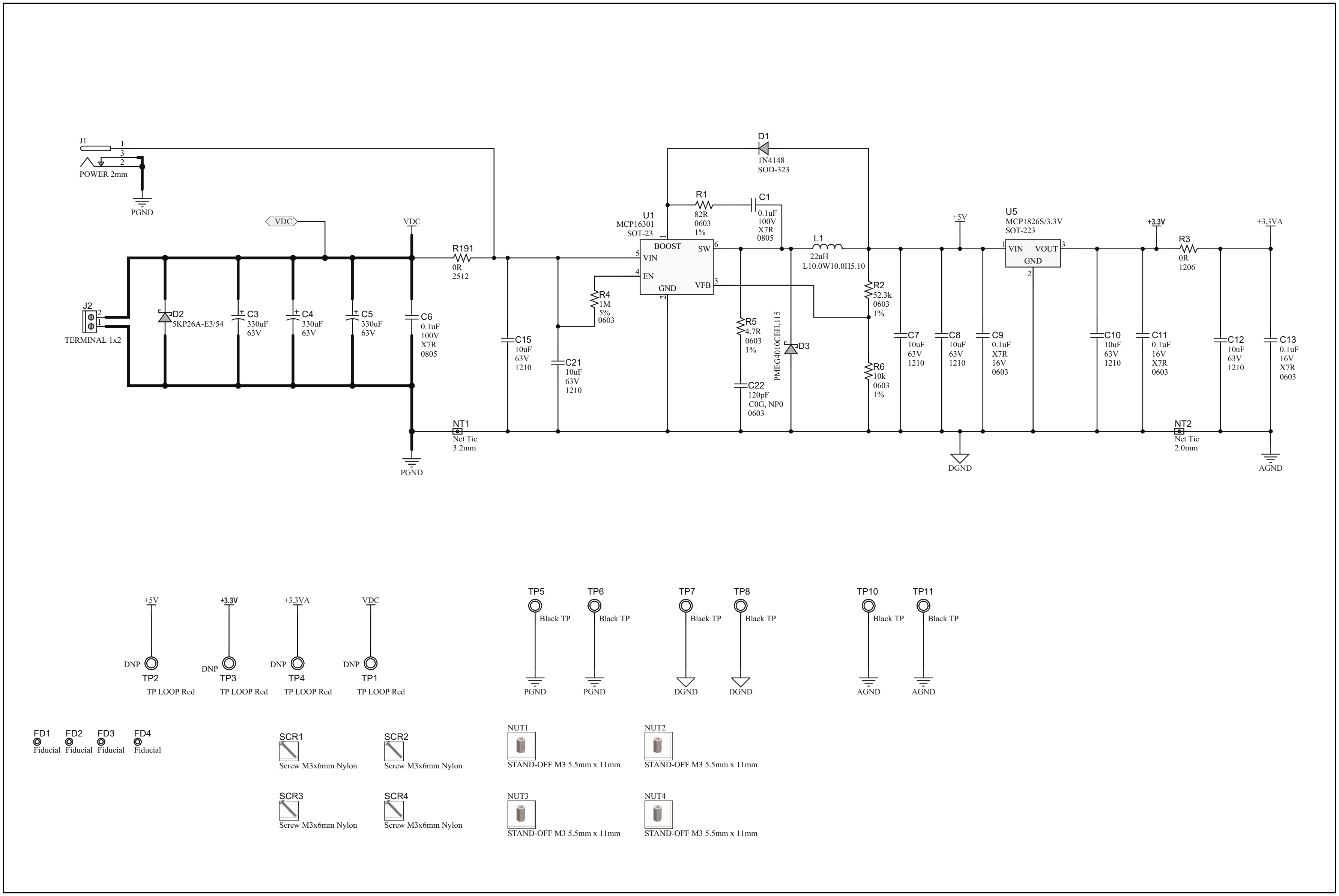


FIGURE A-10: dsPIC33CDV64MC106 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATICS – SHEET 2 OF 8

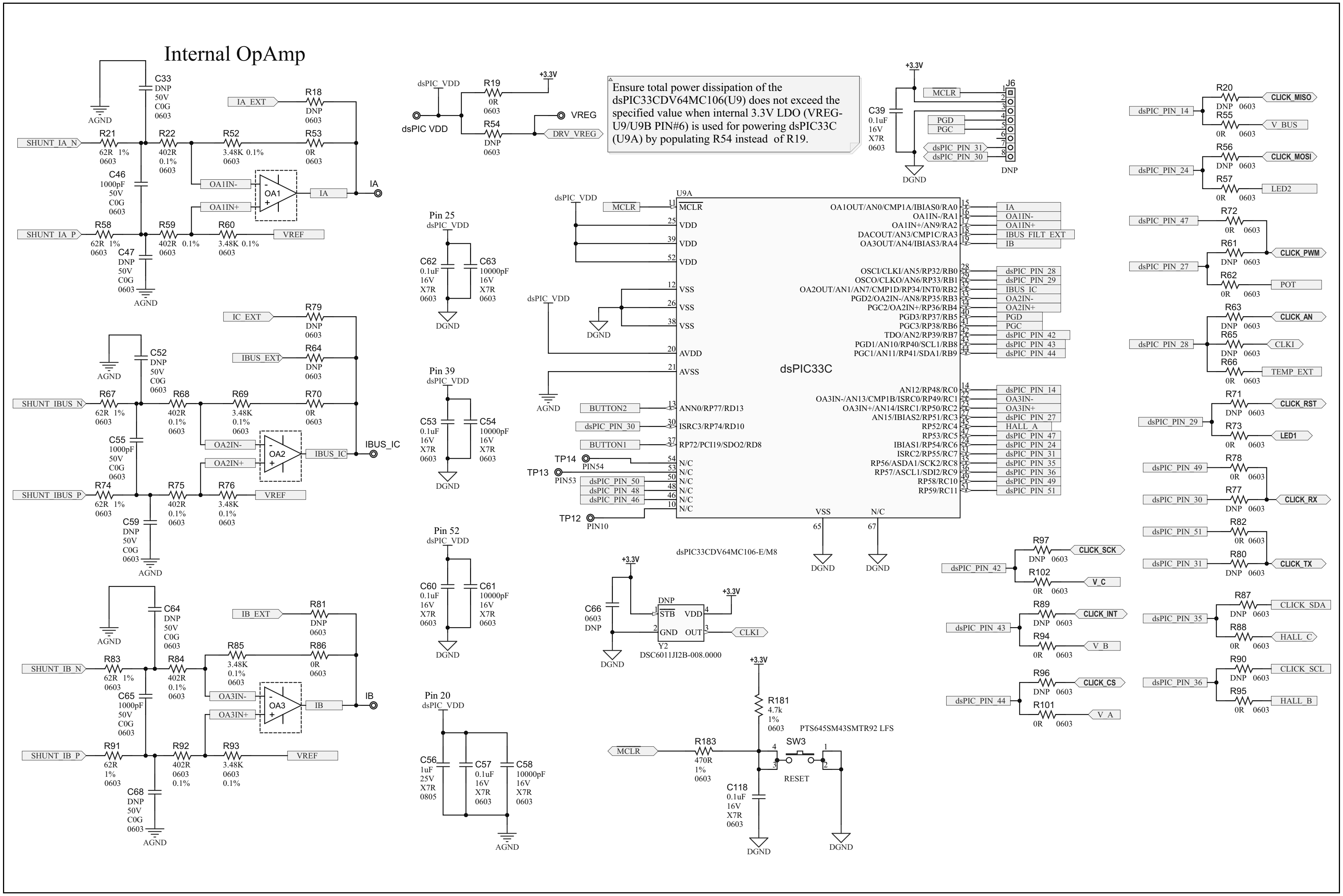


FIGURE A-11: dsPIC33CDV64MC106 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATICS – SHEET 3 OF 8

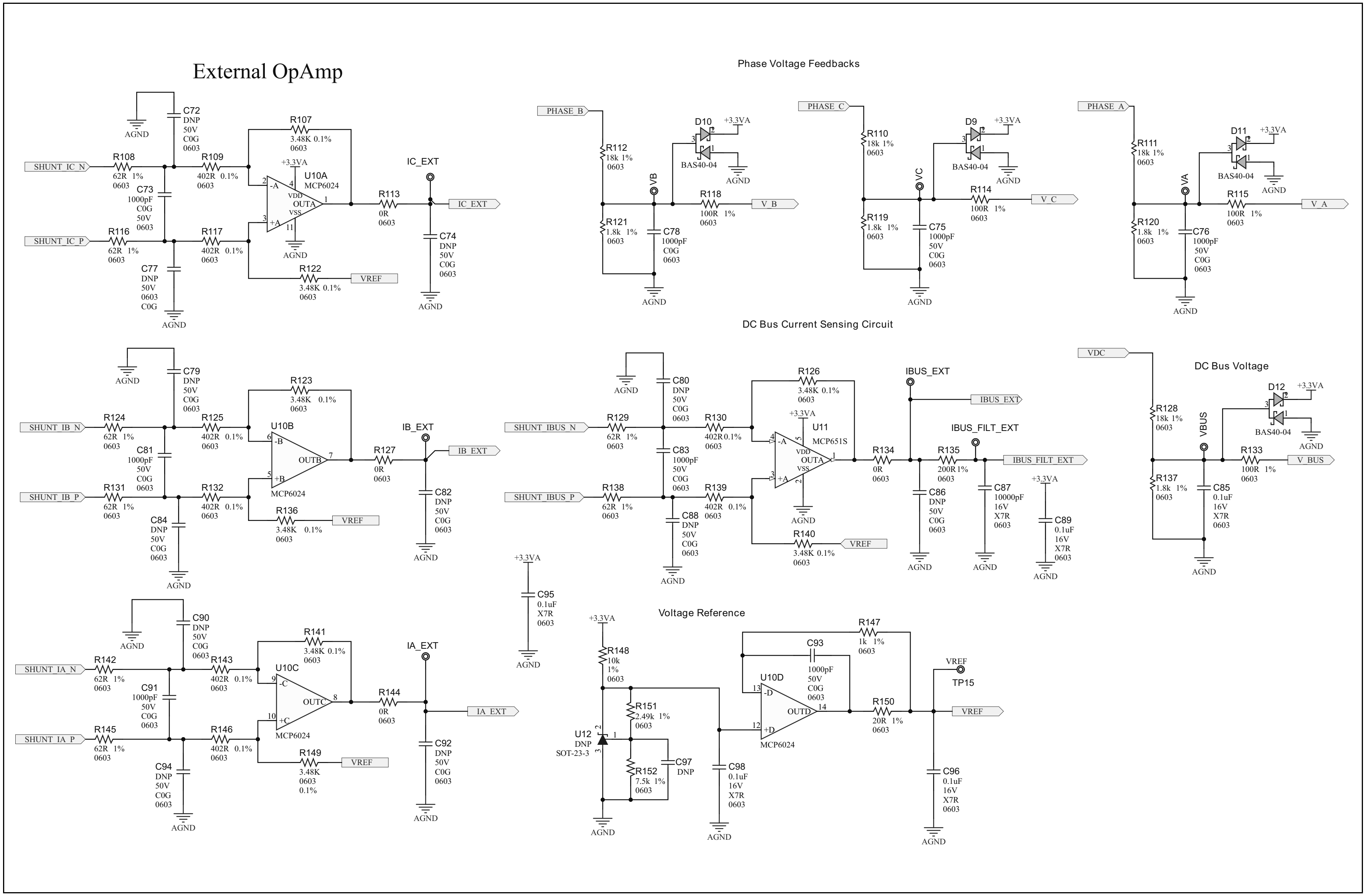


FIGURE A-12: dsPIC33CDV64MC106 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATICS – SHEET 4 OF 8

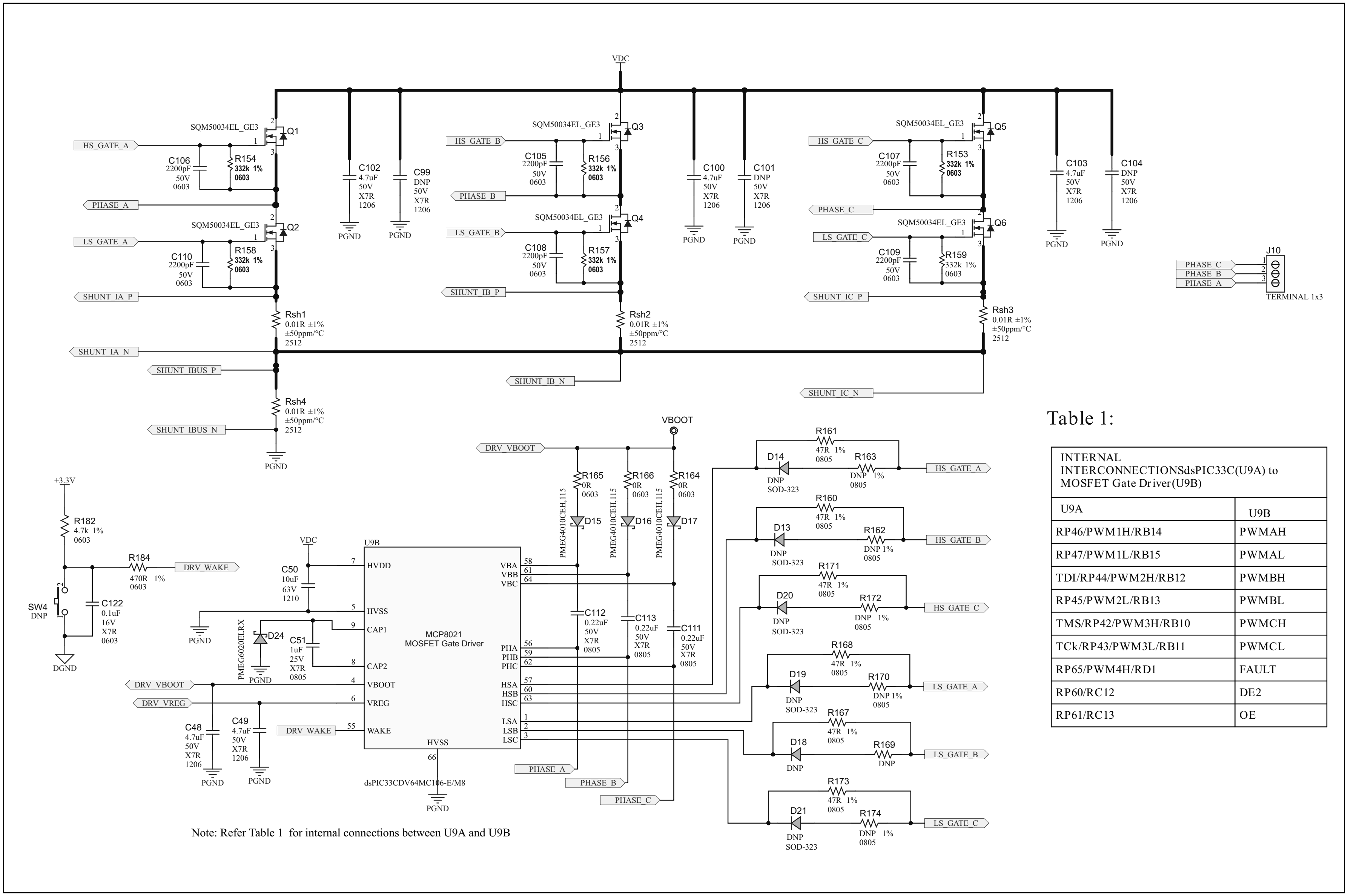


Table 1:

INTERNAL INTERCONNECTIONSdsPIC33C(U9A) to MOSFET Gate Driver(U9B)	
U9A	U9B
RP46/PWM1H/RB14	PWMAH
RP47/PWM1L/RB15	PWMAL
TDI/RP44/PWM2H/RB12	PWMBH
RP45/PWM2L/RB13	PWMBL
TMS/RP42/PWM3H/RB10	PWMCH
TCk/RP43/PWM3L/RB11	PWMCL
RP65/PWM4H/RD1	FAULT
RP60/RC12	DE2
RP61/RC13	OE

FIGURE A-13: dsPIC33CDV64MC106 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATICS – SHEET 5 OF 8

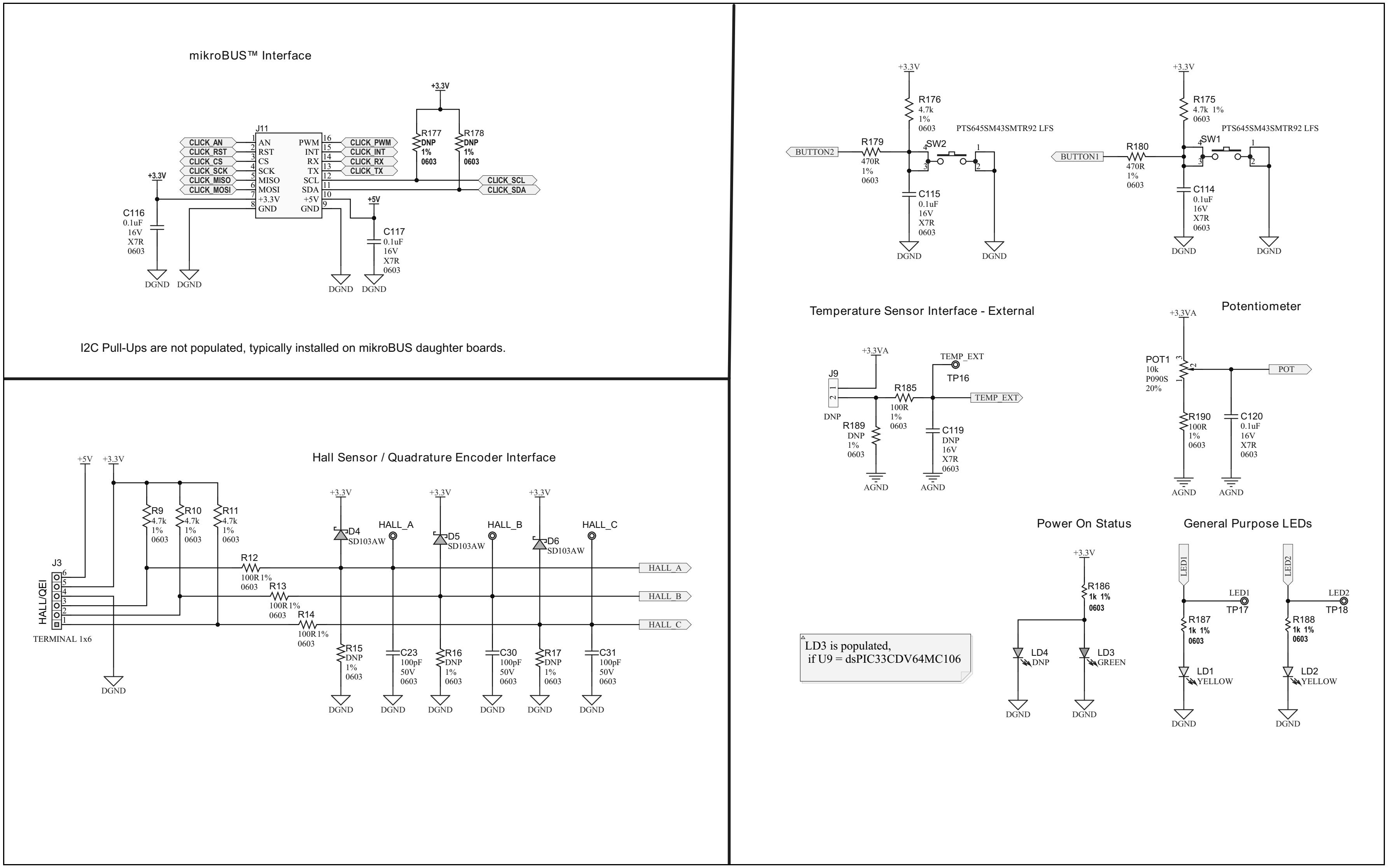


FIGURE A-14: dsPIC33CDV64MC106 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATICS – SHEET 6 OF 8

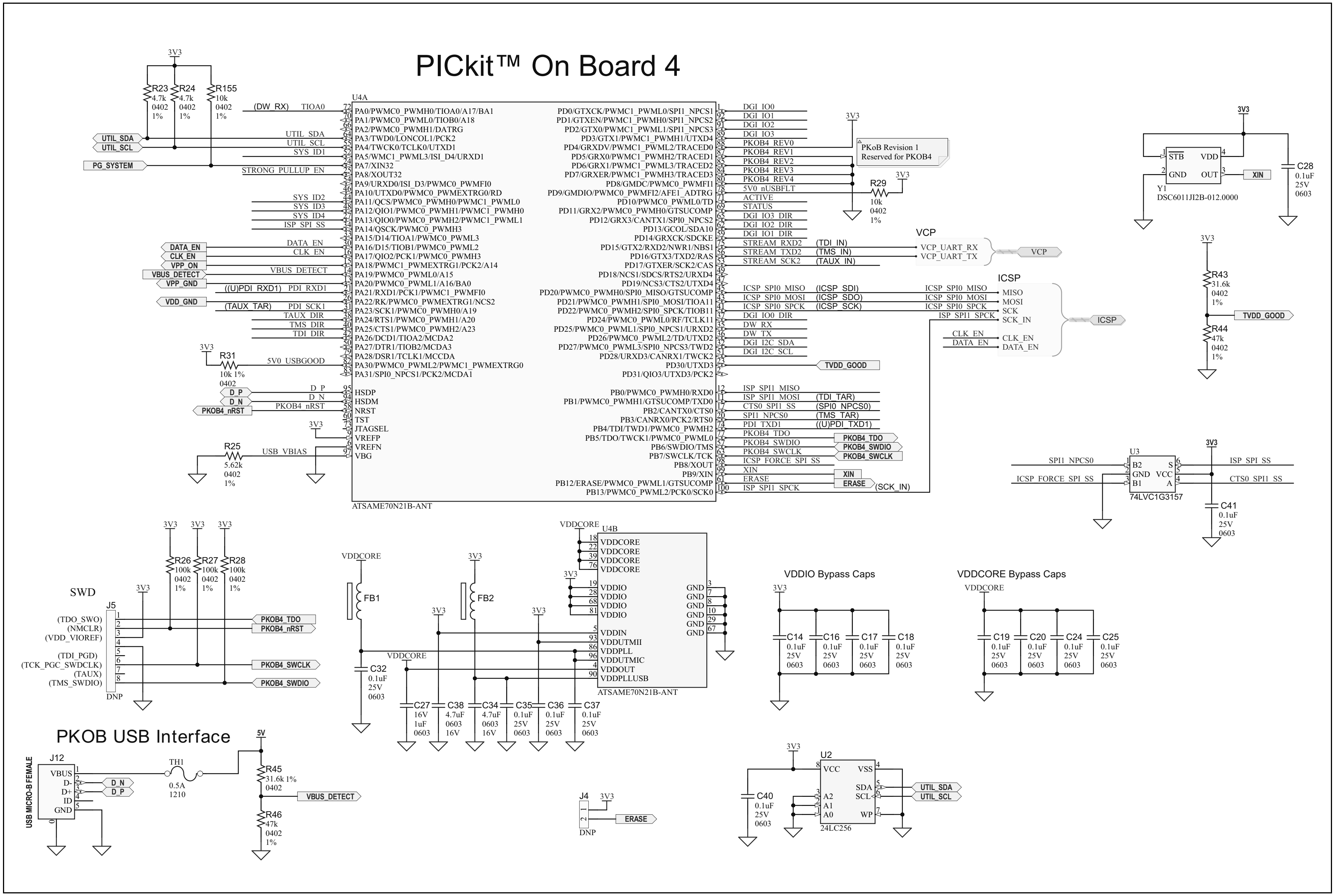


FIGURE A-15: dsPIC33CDV64MC106 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATICS – SHEET 7 OF 8

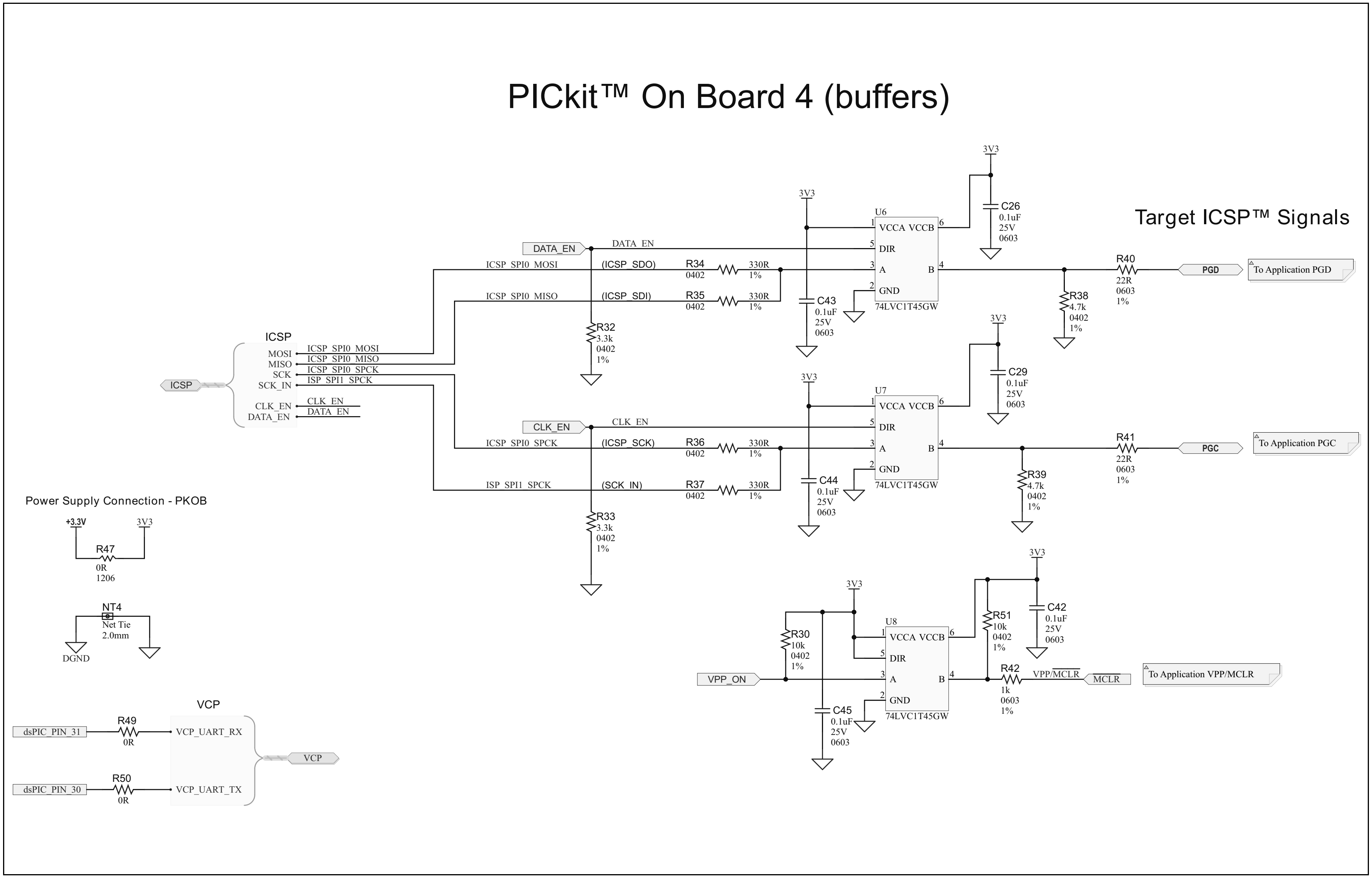
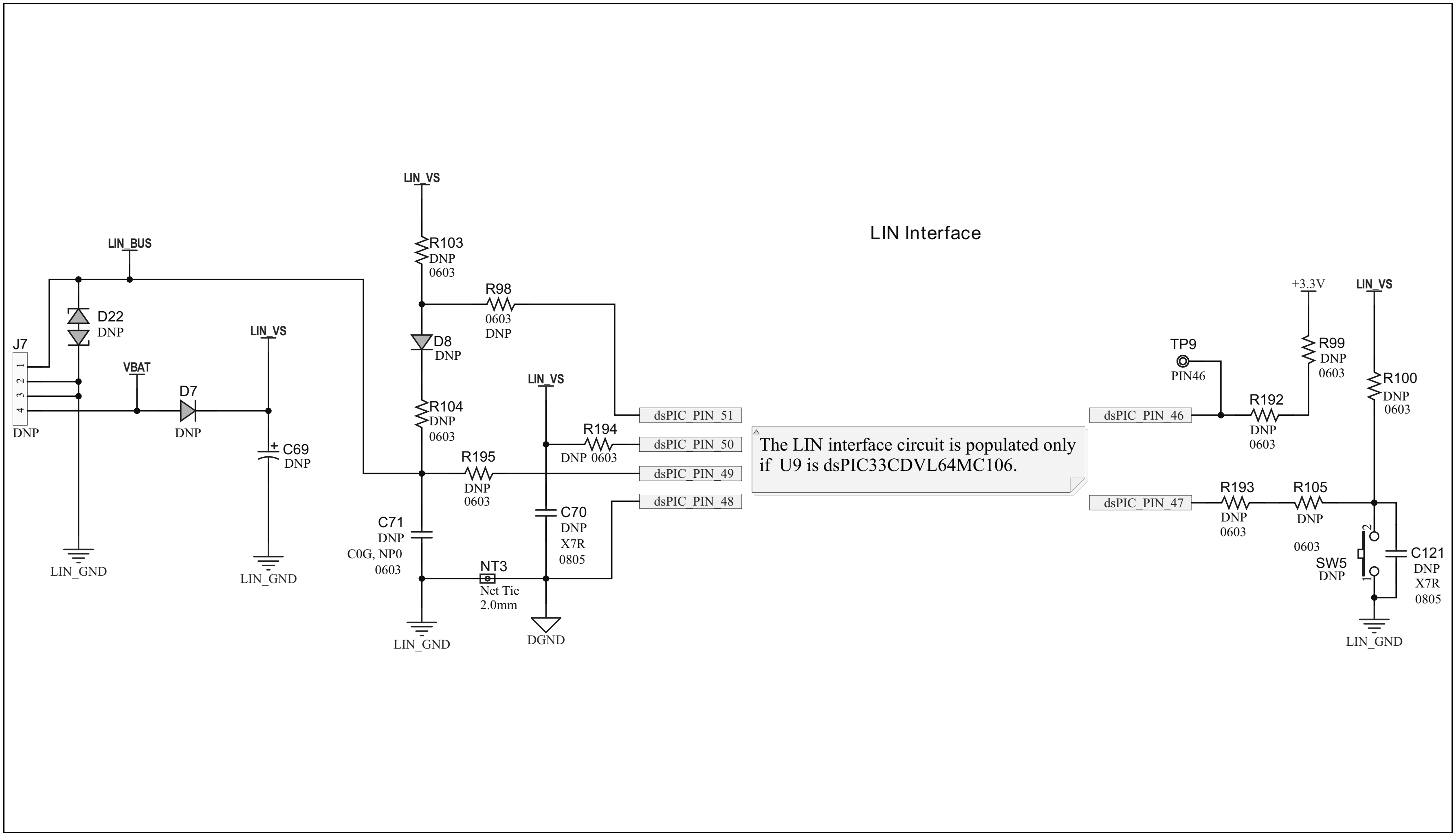


FIGURE A-16: dsPIC33CDV64MC106 MOTOR CONTROL DEVELOPMENT BOARD SCHEMATICS – SHEET 8 OF 8



A.1.3 Layout

The layout is the same for both the dsPIC33CDVL64MC106 Motor Control Development Board and the dsPIC33CDV64MC106 Motor Control Development Board.

Table A-3 summarizes the layout diagrams of the Development Board.

TABLE A-3: PCB LAYERS

Figure Index	Description
Figure A-17	Top Layer: Top Silk and Top Copper
Figure A-18	Mid Layer – 1: Copper
Figure A-19	Mid Layer – 2: Copper
Figure A-20	Bottom Layer: Bottom Silk and Bottom Copper

FIGURE A-17: TOP LAYER: TOP SILK AND TOP COPPER

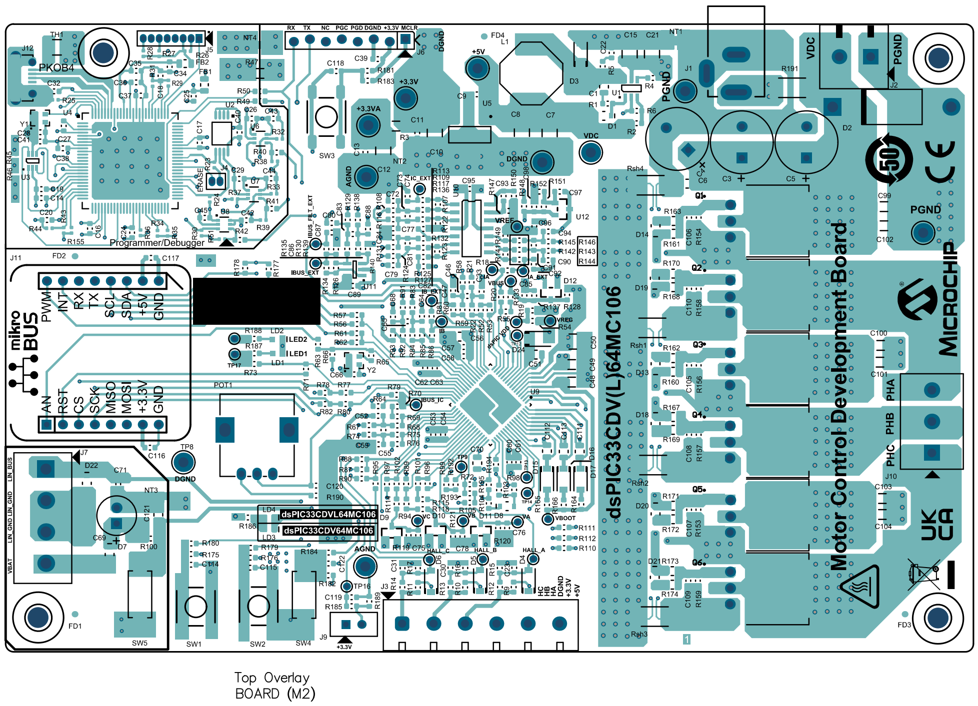


FIGURE A-18: MID LAYER – 1: COPPER

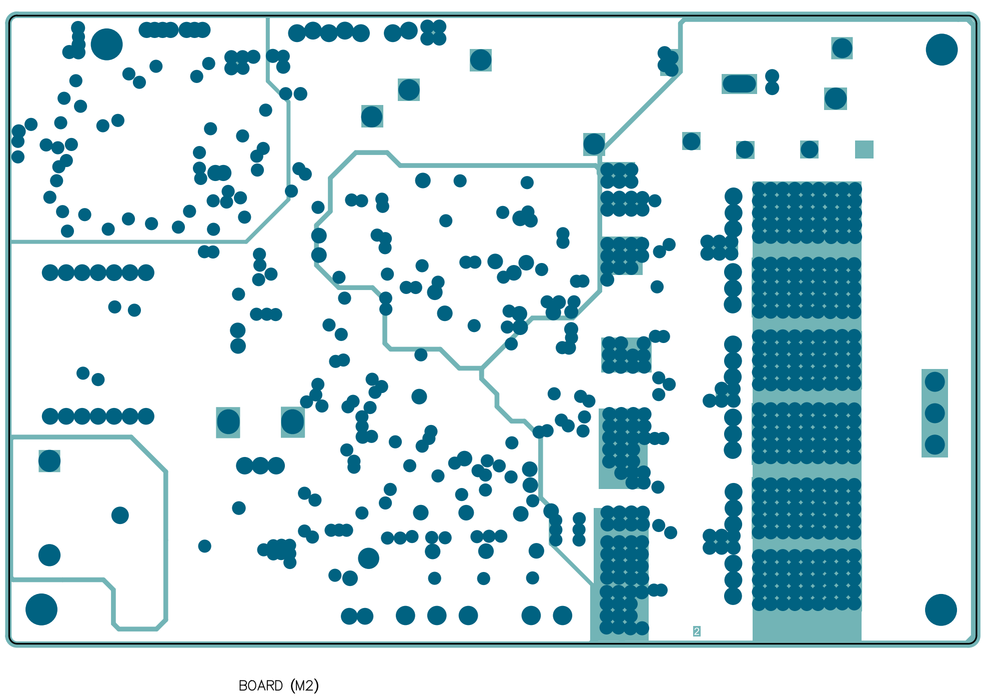


FIGURE A-19: MID LAYER – 2: COPPER

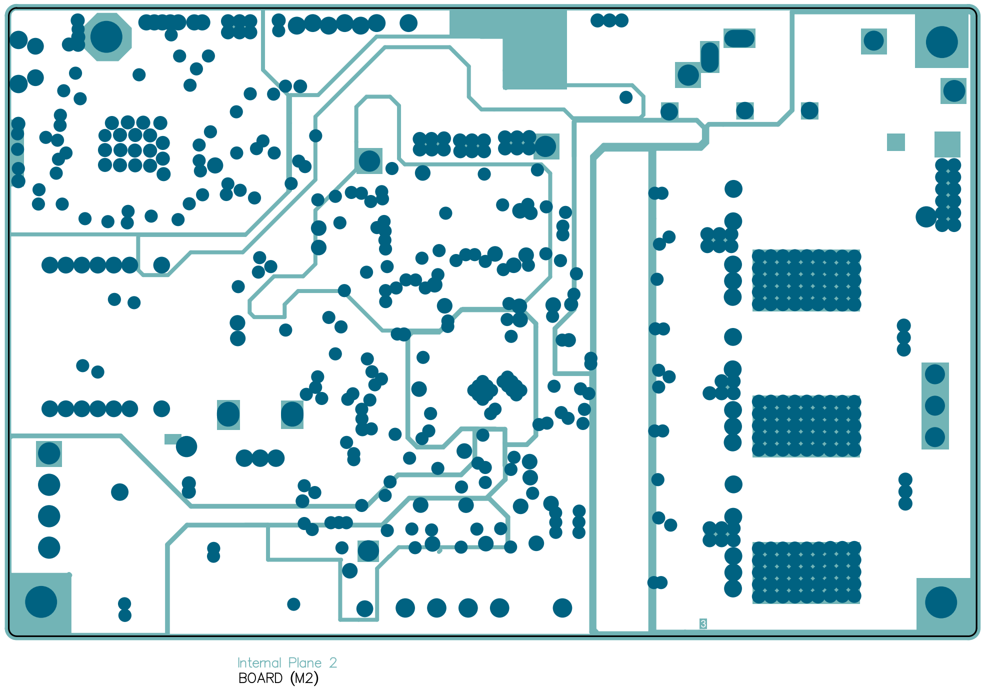
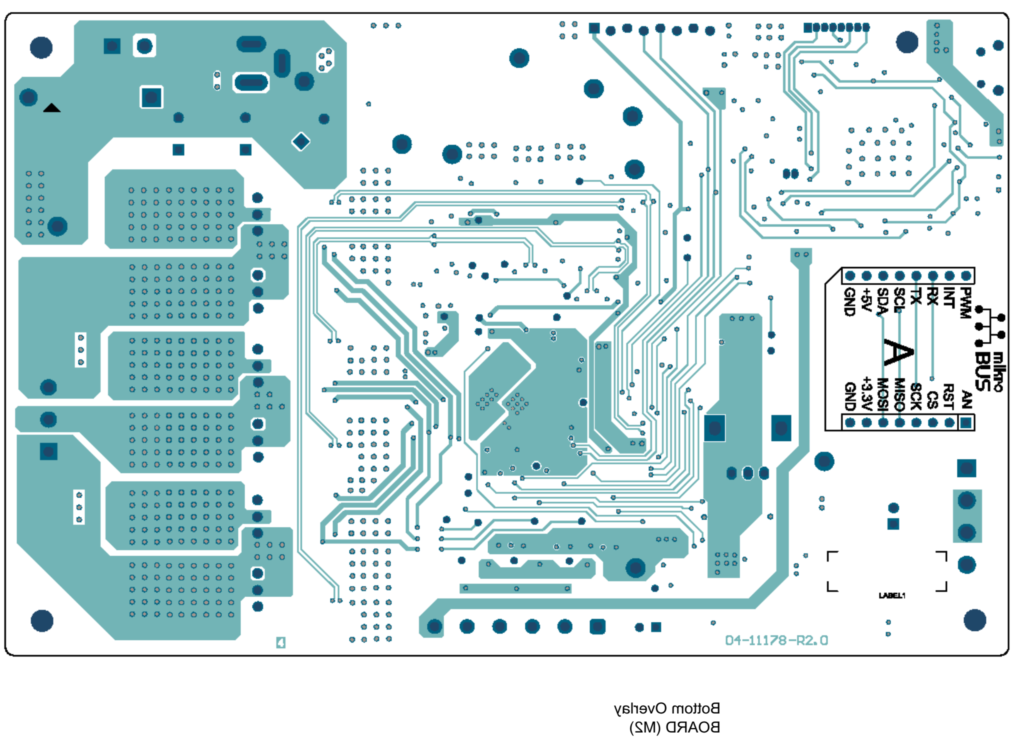


FIGURE A-20: BOTTOM LAYER: BOTTOM SILK AND BOTTOM COPPER



NOTES:

Appendix B. Electrical Specifications

B.1 ELECTRICAL SPECIFICATIONS

This section provides the electrical specifications for the dsPIC33CDVL64MC106 and dsPIC33CDV64MC106 Motor Control Development Boards (see Table B-1).

TABLE B-1: ELECTRICAL SPECIFICATIONS[1,2]

Parameter	Operating Range
Input DC Voltage	12-24V
Absolute Maximum Input DC Voltage	26V
Maximum Input Current through Connector J1	2.5A (RMS)
Maximum Input Current through Connector J2	10A (RMS)
Continuous Output Current per Phase @ +25°C	10A (RMS)

Note 1: 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.

2: Spinning the motor under certain conditions (field weakening or restarting the motor with inertia load while coasting down, direction reversal when motor is spinning at higher speed) may cause the DC bus voltage to rise beyond the applied input DC voltage (if the DC power supply is non-receptive). Under such conditions, ensure that the input DC voltage does not exceed the specified 'Absolute Maximum Input DC Voltage' (refer to Table B-1). Failure to ensure the DC voltage will cause permanent damage to the Development Board.

NOTES:

Appendix C. Design Details

C.1 INTRODUCTION

This chapter provides design details of the:

- Current Amplifier Circuits
- Auxiliary Power Supply

C.2 CURRENT AMPLIFIER CIRCUITS

Circuits used for amplifying motor phase currents and DC bus current using internal amplifiers of the dsPIC® DSC are shown in Figure C-1. Circuits used for amplifying motor phase currents and DC bus current using external amplifiers, U10A, U10B, U10C and U11, are shown in Figure C-2. The detailed schematics of the block diagram, "Filter, Feedback and Bias Circuit", used in Figure C-1 and Figure C-2 are shown in Figure C-3.

FIGURE C-1: dsPIC® DSC INTERNAL AMPLIFIERS

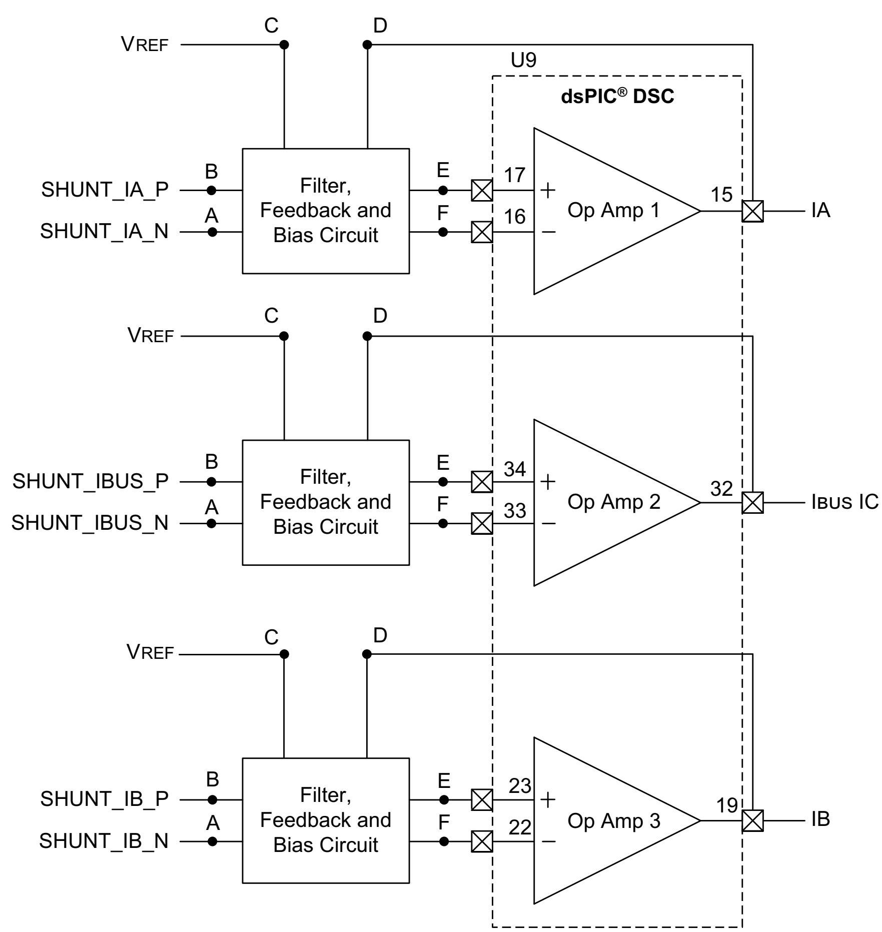


FIGURE C-2: EXTERNAL CURRENT AMPLIFIERS (U10, U11)

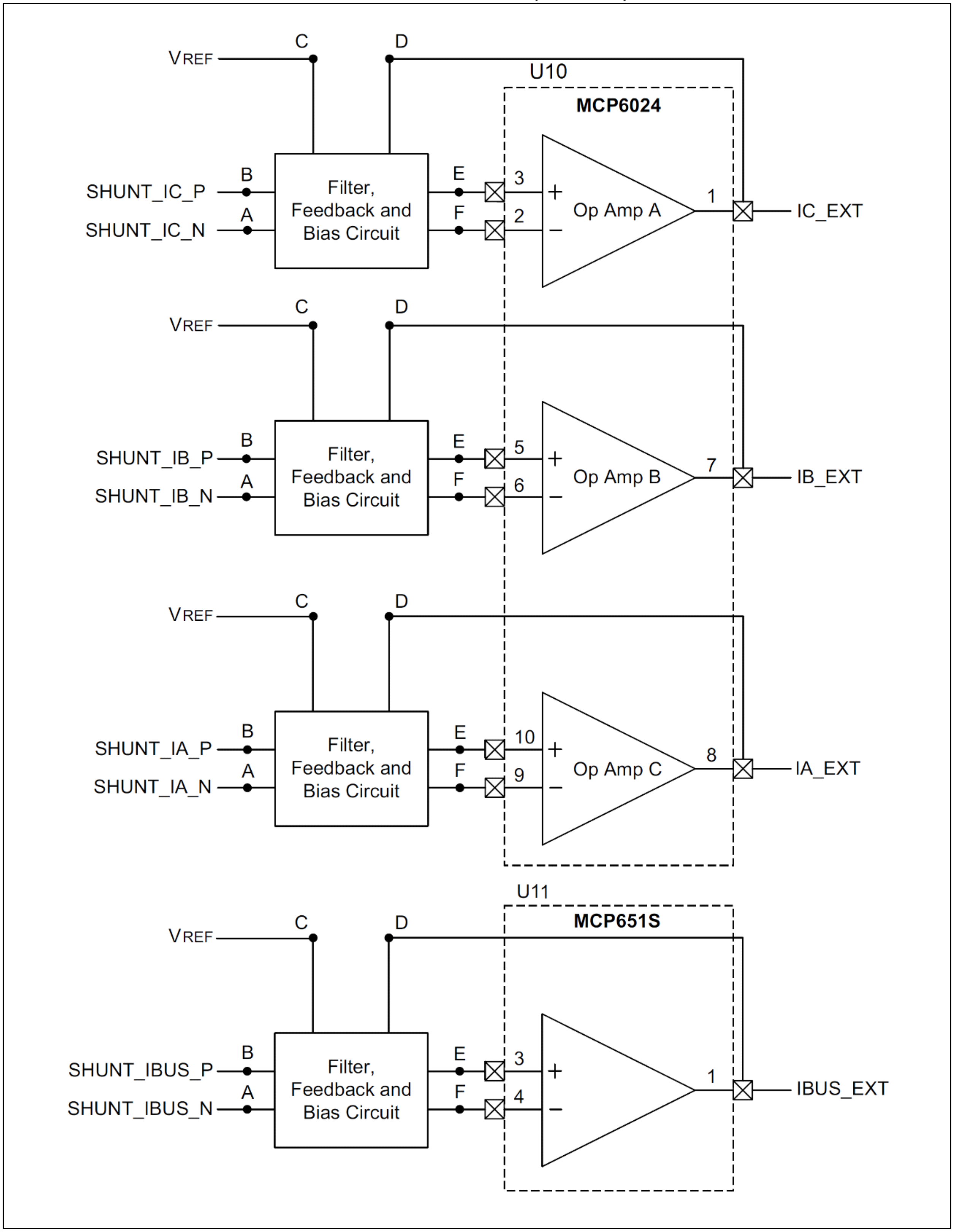
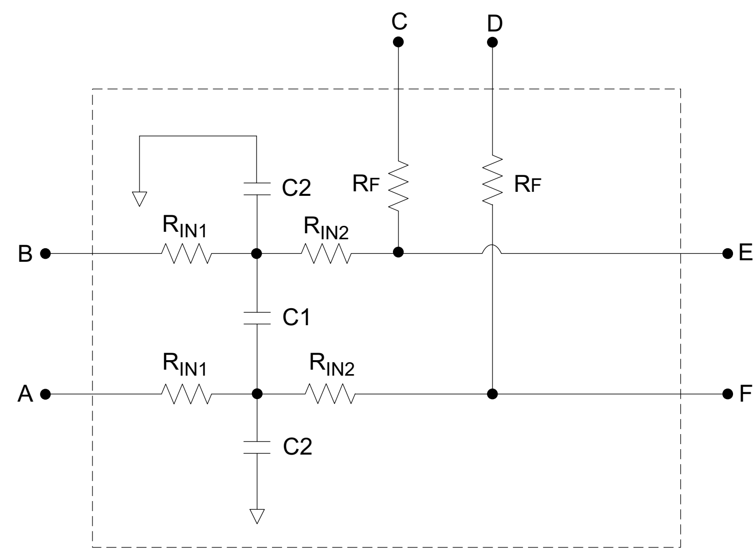


FIGURE C-3: FILTER, FEEDBACK AND BIAS CIRCUIT



Equation C-1 provides the amplifier gain calculations. Equation C-2 and Equation C-3 provide the equations to calculate cutoff frequencies of the Differential-mode and Common-mode filters.

EQUATION C-1: AMPLIFIER GAIN

$$Differential\ Amplifier\ Gain = \frac{Rf}{(R_{IN1} + R_{IN2})}$$

EQUATION C-2: CUTOFF FREQUENCY DIFFERENTIAL-MODE FILTER

$$Differential\text{-}mode\ f_{-3dB} \cong \frac{1}{2\pi(R_{IN1} + R_{IN2})\left(\frac{C2}{2} + C1\right)}$$

EQUATION C-3: CUTOFF FREQUENCY COMMON-MODE FILTER

$$Common\text{-}mode\ f_{-3dB} \cong \frac{1}{2\pi(R_{IN1})(C2)}$$

Table C-1 summarizes the amplifier gain and peak currents for various values of RF. The customer can select different values based on application requirements, ensuring peak current is within the board operating range.

TABLE C-1: AMPLIFIER GAIN AND PEAK CURRENTS

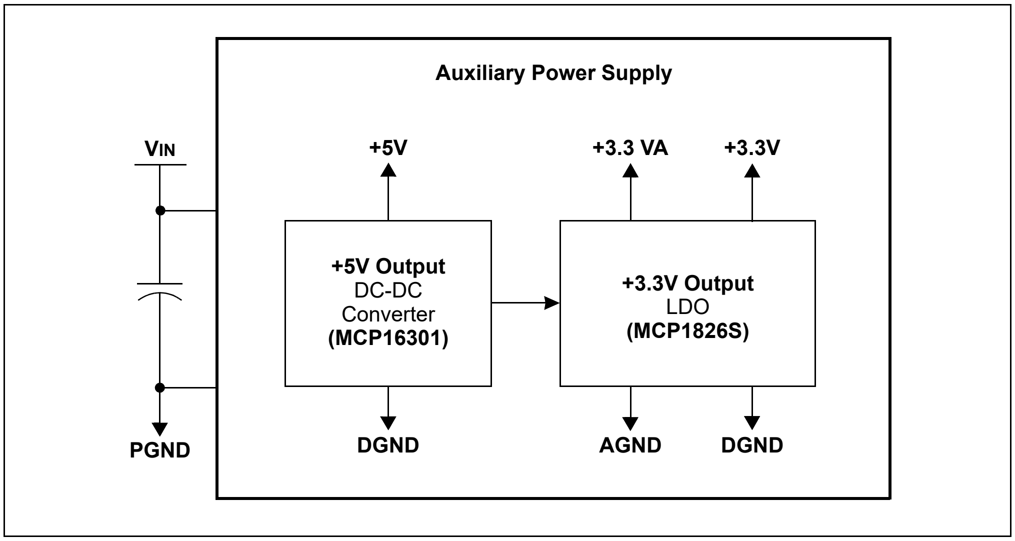
Summarizes Amplifier Gains and Peak Currents for Various Values of RF When R_{IN1} = 62R, R_{IN2} = 402R, R_{SHUNT} = 0.01R			
RF	**Amplifier Gain**	**Peak Current @ 1.65V**	**RF Resistor Part Number (use below part number or similar)**
6.98 kΩ	15	10.97A	ERA-3AEB6981V
3.48 kΩ	7.5	22A	ERA-3AEB3481V

C.3 AUXILIARY POWER SUPPLY

The auxiliary power supply circuit consists of the following stages (see Figure C-4):

- +5V Output Power Supply
- +3.3V Output Power Supply

FIGURE C-4: AUXILIARY POWER SUPPLY

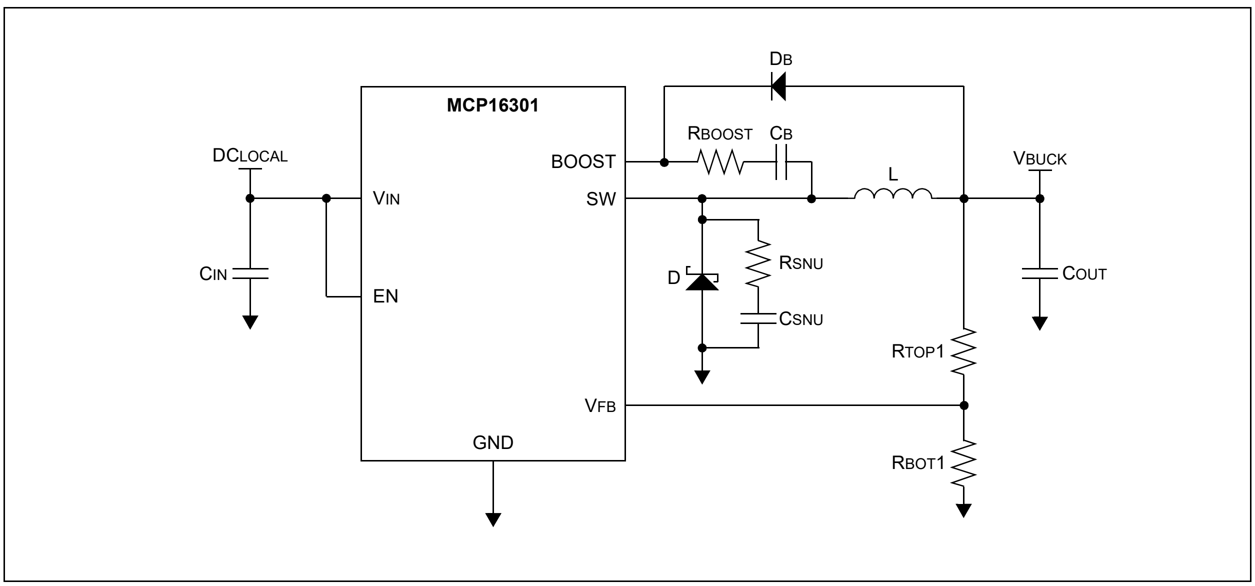


C.3.1 +5V Output Power Supply

The +5V output power supply is a buck converter (see Figure C-5) based on MCP16301 (U1). This power supply stage has the following specifications:

- Input Voltage (VIN) = 12-24V
- Output Voltage (labeled as '+5V') = +5V

FIGURE C-5: +5V POWER SUPPLY



The component values used in this circuit are listed in Table C-2 and were chosen using Equation C-4 with V_{BUCK} = +5V, V_{FB} = 0.8V and K = 0.22V/H.

EQUATION C-4:

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

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

TABLE C-2: +5V POWER SUPPLY COMPONENT VALUES

Label	Component Designator	Component Value
R_{BOT1}	R6	10k
R_{TOP1}	R2	52.5k
L	L1	22 µH
R_{BOOST}	R1	82R
C_B	C1	0.1 µF
C_{IN}	C15, C21	10 µF
C_{OUT}	C7	10 µF
R_{SNU}	R5	4.7R
C_{SNU}	C22	120 pF

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 MBRA140T3G Schottky diode is selected.

EQUATION C-5:

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

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, R_{BOOST}, refer to AN1466, *"Reduction of the High-Frequency Switching Noise in the MCP16301 High-Voltage Buck Converter"* (DS01466) application note.

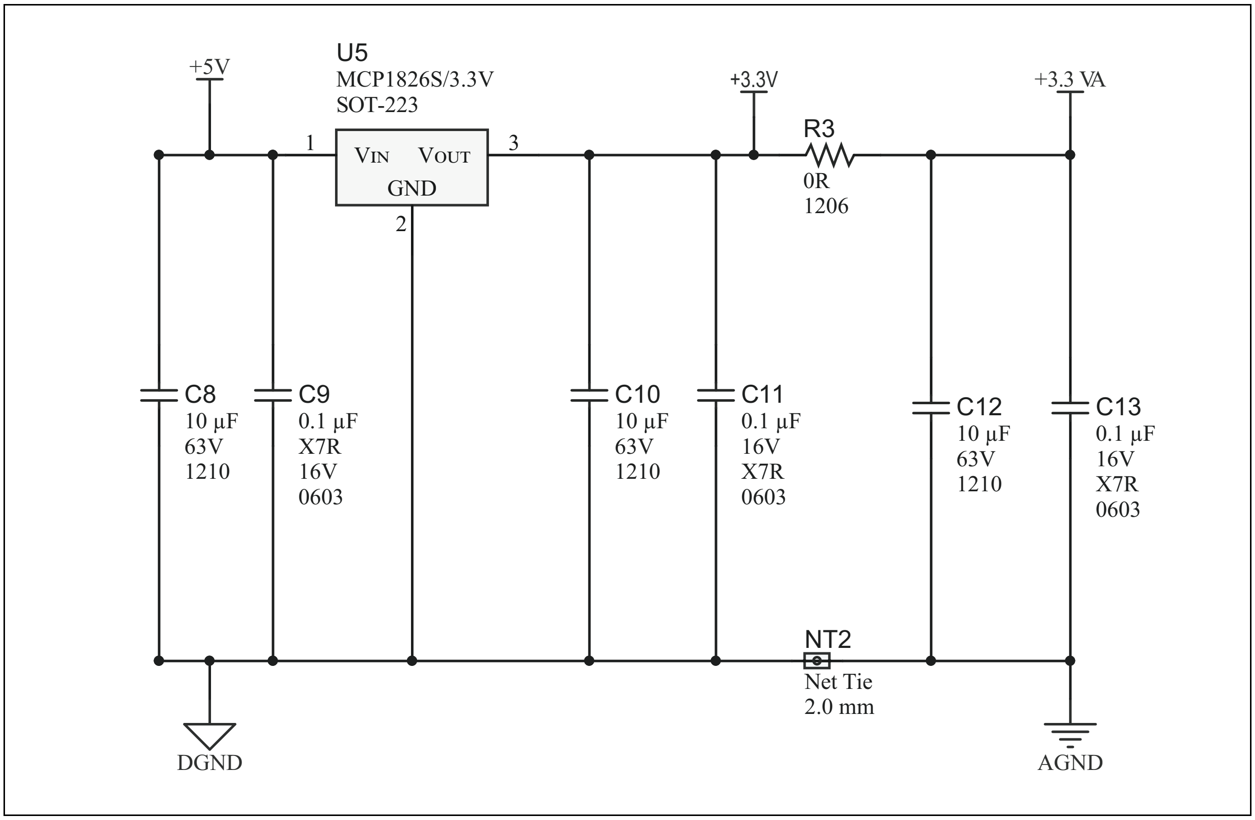
C.3.2 +3.3V Output Power Supply

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

- Input Voltage = +5.0V
- Output Voltage 1 (+3.3V and +3.3 VA) = +3.3V

The MCP1826S LDO is used for generating the +3.3V output. The input of the +3.3V LDO is the output of the +5V converter. In the Development Board, digital supply +3.3V and analog supply +3.3 VA (see Figure C-6) are separated by the jumper resistor R3. Similarly, Digital Ground (DGND) and Analog Ground (AGND) are separated by the Net tie, NT2. This is done to logically separate supply lines to analog and digital circuits during the board layout design.

FIGURE C-6: +3.3V POWER SUPPLY



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