Motor Control 10-24V Driver Board (Dual/Single) User's Guide

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Object of Declaration: Motor Control 10-24V Driver Board (Dual/Single)

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The development/evaluation tool is designed to be used for research and development in a laboratory environment. This development/evaluation tool is not intended to be a finished appliance, nor is it intended for incorporation into finished appliances that are made commercially available as single functional units to end users. This development/evaluation tool complies with EU EMC Directive 2004/108/EC and as supported by the European Commission's Guide for the EMC Directive 2004/108/EC (8th February 2010).

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Signed for and on behalf of Microchip Technology Inc. at Chandler, Arizona, USA

Derek Carlson
VP Development Tools

16-July-2013
Date

NOTES:

MOTOR CONTROL 10-24V DRIVER BOARD (DUAL/SINGLE) USER'S GUIDE

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Preface

NOTICE TO CUSTOMERS

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

Documents are identified with a "DS" number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is "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 Motor Control 10-24V Driver Board (Dual/Single). Items discussed in this chapter include:

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

DOCUMENT LAYOUT

This document describes how to use the Motor Control 10-24V Driver Board (Dual/Single). This user's guide is composed of the following chapters:

- **Chapter 1. "Introduction"** provides a brief overview of the Motor Control 10-24V Driver Board (Dual/Single) and its features.
- **Chapter 2. "Board Interface Description"** summarizes the Motor Control 10-24V Driver Board (Dual/Single) input and output interfaces.
- **Chapter 3. "Hardware Description"** provides the hardware descriptions of the Motor Control 10-24V Driver Board (Dual/Single).
- **Appendix A. "Board Schematics and Layout"** provides a block diagram, board layouts and detailed schematics of the Motor Control 10-24V Driver Board (Dual/Single).
- **Appendix B. "Electrical Specifications"** provides the electrical specifications of the Motor Control 10-24V Driver Board (Dual/Single).
- **Appendix C. "Component Selection"** details the component selection of the motor current amplifier, brake current amplifier and the hardware brake enable circuit.

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

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

	Represents code supplied by user	`void main (void)`
		`{ ...`
		`}`

Notes	A Note presents information that we want to re-emphasize, either to help you avoid a common pitfall or to make you aware of operating differences between some device family members. A Note can be in a box, or when used in a table or figure, it is located at the bottom of the table or figure.	**Note:** This is a standard note box. **CAUTION** **This is a Caution note.** **Note 1:** This is a note used in a table.

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RECOMMENDED READING

This user's guide describes how to use the Motor Control 10-24V Driver Board (Dual/Single). The following Microchip documents are available and recommended as supplemental reference resources.

MPLAB® X IDE User's Guide (DS50002027)

This user's guide is a comprehensive guide that describes installation and features of Microchip's MPLAB X Integrated Development Environment (IDE), as well as the editor and simulator functions in the MPLAB X IDE environment. Please visit www.microchip.com/mplabx for more information.

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.

MPLAB® XC16 Assembler, Linker and Utilities User's Guide (DS52106)

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

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 for more information.

dsPIC® DSC Signal Board User's Guide (DS50002263)

This user's guide describes how to use Microchip's dsPIC DSC Signal Board.

dsPIC33EV256GM106 5V Motor Control Plug-In Module (PIM) Information Sheet (DS50002225)

This information sheet provides information specific to the dsPIC33EV256GM106 5V Motor Control Plug-In Module (PIM).

dsPIC33EP512GM710 Plug-In Module (PIM) Information Sheet for Single-Dual Motor Control (DS50002216)

This information sheet provides information specific to the dsPIC33EP512GM710 Plug-In Module (PIM) for Single-Dual Motor Control.

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

AN1160, Sensorless BLDC Control with Back-EMF Filtering Using a Majority Function (DS01160)

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)

AN1017, Sinusoidal Control of PMSM Motors with dsPIC30F DSC (DS01017)

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- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listings of seminars and events; and listings of Microchip sales offices, distributors and factory representatives

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The Development Systems product group categories are:

- **Compilers** – The latest information on Microchip C compilers and other language tools
- **Emulators** – The latest information on the Microchip in-circuit emulator, MPLAB REAL ICE™
- **In-Circuit Debuggers** – The latest information on the Microchip in-circuit debugger, MPLAB ICD 3
- **MPLAB X IDE** – The latest information on Microchip MPLAB X IDE, the Windows® Integrated Development Environment for development systems tools
- **Programmers** – The latest information on Microchip programmers including the PICkit™ 3 development programmer

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- Field Application Engineer (FAE)
- Technical Support

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

DOCUMENT REVISION HISTORY

Revision A (April 2014)

This is the initial release of this document.

Chapter 1. Introduction

1.1 OVERVIEW

The Motor Control 10-24V Driver Board (Dual/Single) is a low-voltage, dual motor control power stage, targeted to drive two Brushless DC (BLDC) motors or Permanent Magnet Synchronous Motors (PMSMs) concurrently.

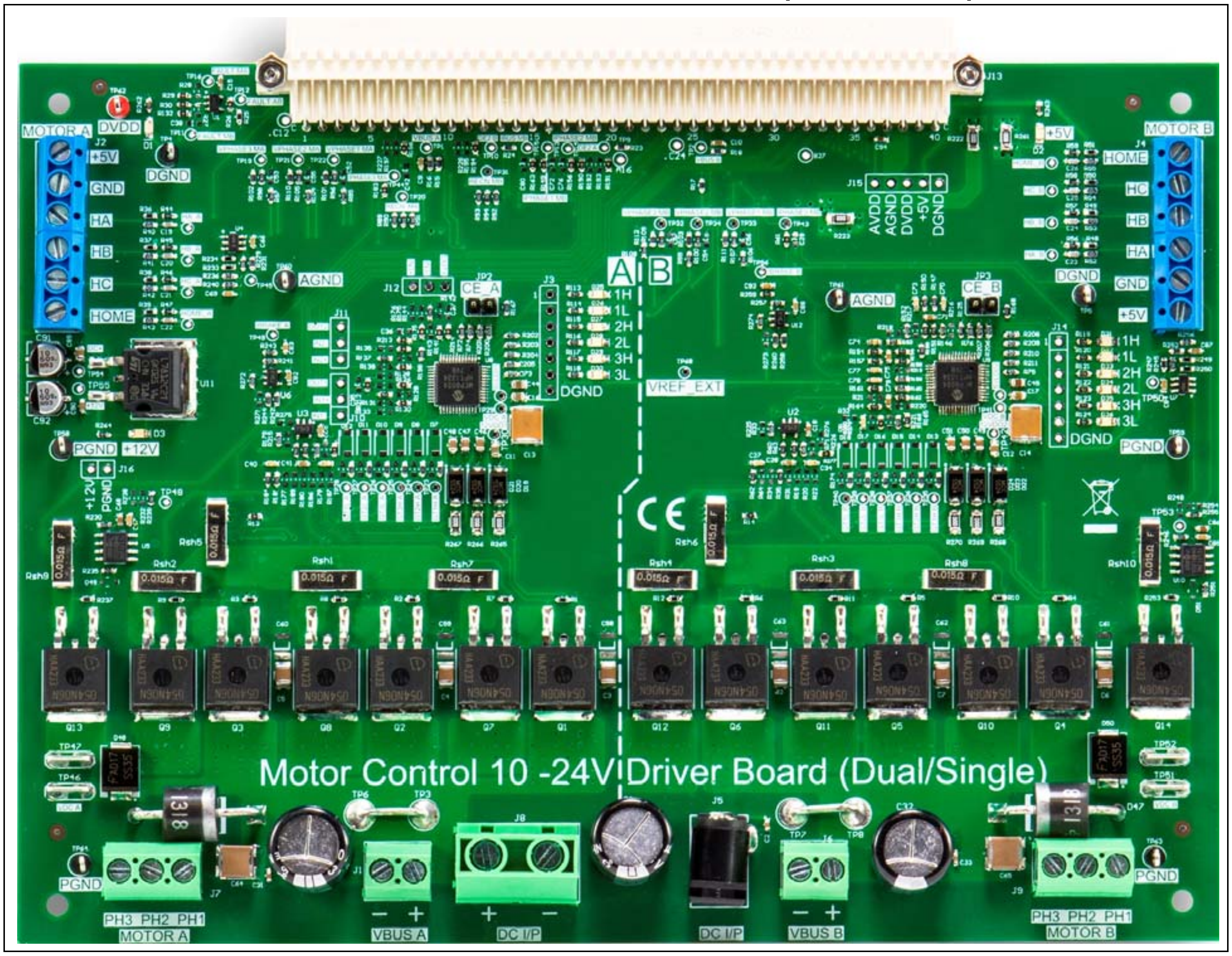
The Motor Control 10-24V Driver Board (Dual/Single), along with the compatible dsPIC® DSC Signal Board, provides a software development platform to build and evaluate embedded motor control application software using Microchip's high-performance motor control Digital Signal Controllers (DSCs) and Microcontrollers (MCUs).

1.2 MOTOR CONTROL 10-24V DRIVER BOARD (DUAL/SINGLE) FEATURES

The Motor Control 10-24V Driver Board (Dual/Single) is shown in Figure 1-1. The board includes these key features:

- Two PMSM/BLDC motor control power stages with electrical specifications:
  - Input DC voltage: 10-24V DC ±10% (9V-26.4V DC)
  - Output phase RMS current: 10A nominal @ +25ºC per phase
- MCP8024 gate drivers with undervoltage, overvoltage, overcurrent, shoot-through and short-circuit protection
- Hall sensors/Quadrature Encoder Interface (QEI) in each motor control stage to enable sensor-based motor control algorithms
- Phase voltage and reconstructed neutral feedback signals in each motor control stage to enable sensorless BLDC operation
- DC bus current sense resistor for overcurrent protection, torque control of the BLDC motor and single-shunt Field Oriented Control (FOC) of PMSMs
- Phase current sensing resistors for Field Oriented Control
- DC bus voltage sensing
- Dynamic braking chopper circuit with hardware and software brake control for both the inverter stages
- Overcurrent protection
- LED indication for PWM signals and Power-on Status

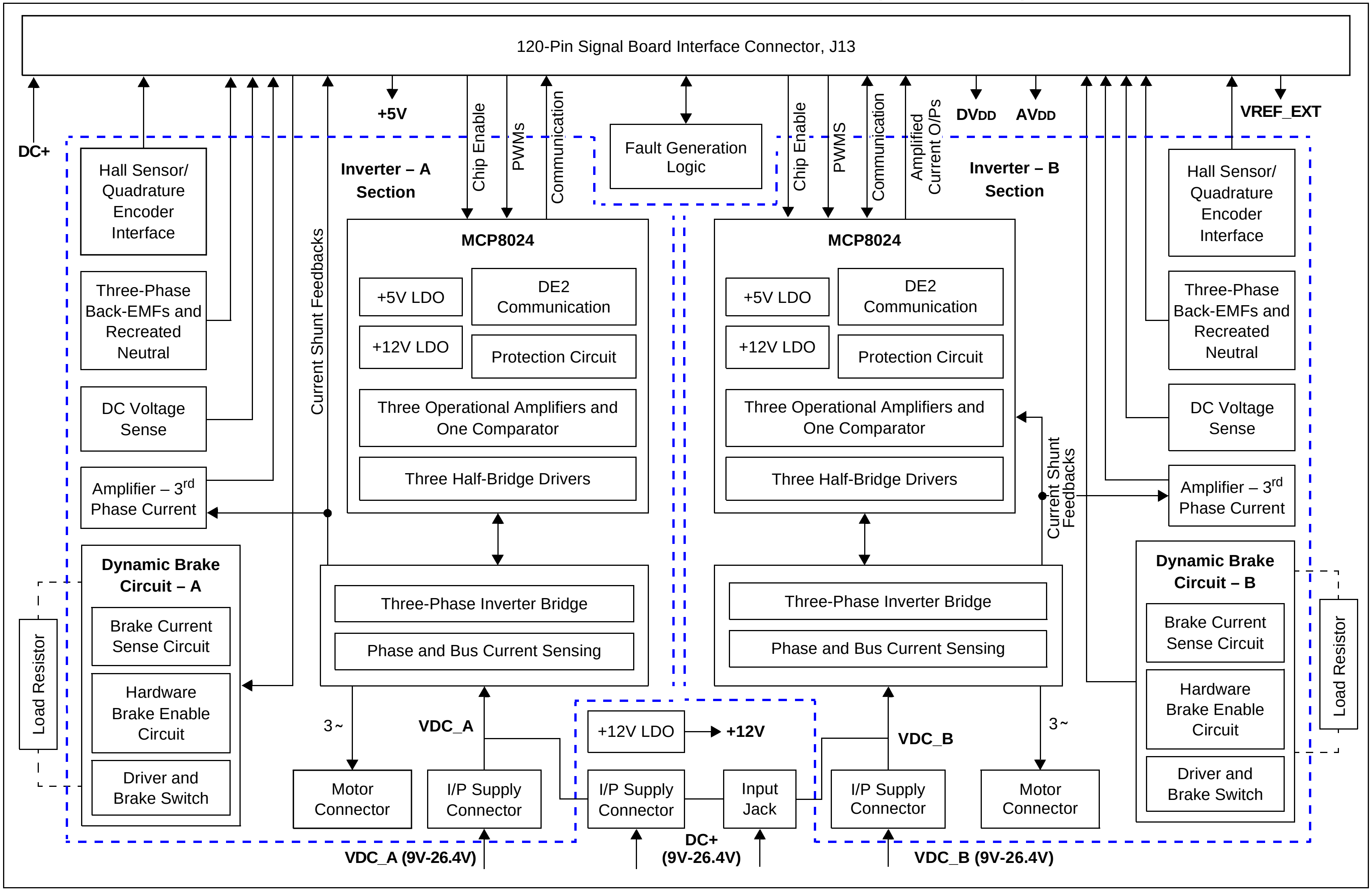
FIGURE 1-1: MOTOR CONTROL 10-24V DRIVER BOARD (DUAL/SINGLE)



The block diagram of the Motor Control 10-24V Driver Board (Dual/Single) is shown in Figure 1-2. For more information on electrical specifications, see **Appendix B. "Electrical Specifications"**.

1.3 BLOCK DIAGRAM

FIGURE 1-2: BLOCK DIAGRAM OF THE MOTOR CONTROL 10-24V DRIVER BOARD (DUAL/SINGLE)



NOTES:

Chapter 2. Board Interface Description

2.1 INTRODUCTION

This chapter provides a more detailed description of the input and output interfaces of the Motor Control 10-24V Driver Board (Dual/Single).

2.2 HIGHLIGHTS

This chapter covers the following topics:

- Board Connectors
- User Interface Hardware

The input power supply for powering the gate drivers, inverters and other control circuits on the board, must be in the range of 10-24V DC ±10%.

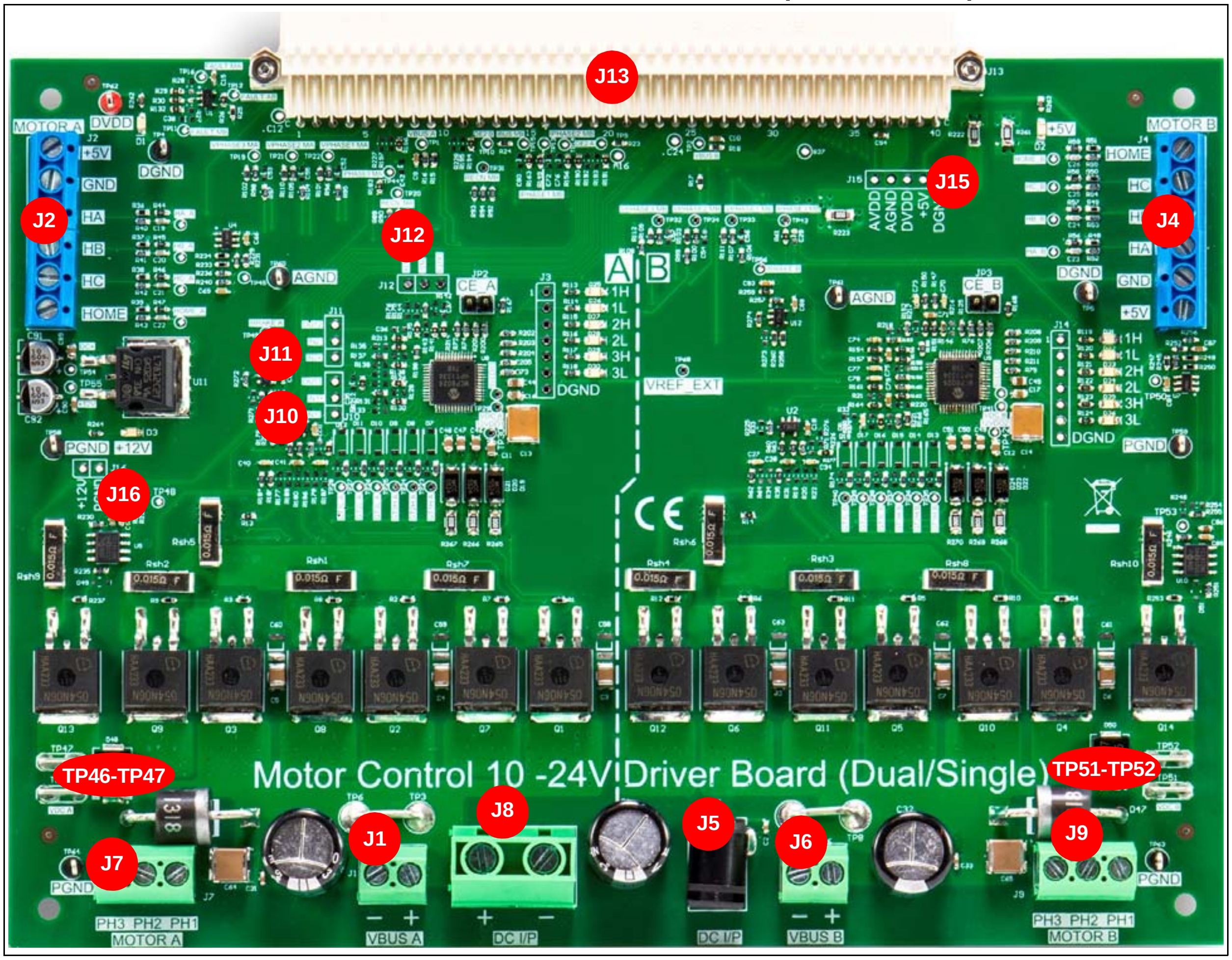
2.3 BOARD CONNECTORS

The Motor Control 10-24V Driver Board (Dual/Single) has various connectors, jumpers and LED indications. The on-board connectors are provided in Table 2-1 and are shown in Figure 2.3.

TABLE 2-1: MOTOR CONTROL 10-24V DRIVER BOARD (DUAL/SINGLE) CONNECTORS

Designator	Description
J1	Input DC Power Supply Connector for Inverter A
J2	Hall Sensor/Quadrature Encoder Interface Connector for Motor A
J4	Hall Sensor/Quadrature Encoder Interface Connector for Motor B
J5,J8	Input DC Power Supply Connector
J6	Input DC Power Supply Connector for Inverter B
J7	Inverter A Three-Phase Output Connector
J9	Inverter B Three-Phase Output Connector
J10, J11, J12	MCP8024 (U8) Operational Amplifier Interface Connector
J13	dsPIC® DSC Signal Board Interface Connector
J15	Auxiliary Power Supply Output Connectors for +5V, DV_{DD}, AV_{DD}, AGND, DGND
J16	+12V LDO (U11) Output Connector
TP46-TP47	Terminals to Connect Brake Resistor on Inverter A Side
TP51-TP52	Terminals to Connect Brake Resistor on Inverter B Side

FIGURE 2-1: MOTOR CONTROL 10-24V DRIVER BOARD (DUAL/SINGLE) CONNECTORS



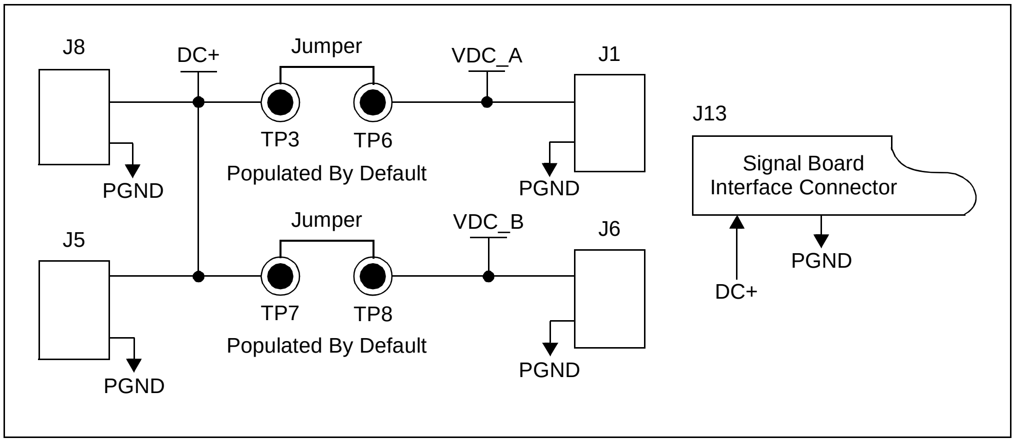
The following are the on-board connectors:

- Power Supply Connectors (J5, J8, J1 and J6)
- Inverter Output Connectors (J7, J9)
- Signal Board Interface Connector (J13)
- Hall Sensor/Quadrature Encoder Interface Connectors (J2, J4)
- Terminals for Brake Resistors (TP46-TP47, TP51-TP52)
- Auxiliary Power Supply Output Connectors (J15, J16)
- MCP8024 (U8) Operational Amplifier Interface Connectors (J10, J11, J12)

2.3.1 Power Supply Connectors (J5, J8, J1 and J6)

The Motor Control 10-24V Driver Board (Dual/Single) is designed to operate in the DC voltage range of 9-26.4V. The possible input DC power supply connections are shown in Figure 2-2.

FIGURE 2-2: INPUT DC POWER SUPPLY CONNECTORS



If the wire jumpers between TP3-TP6 and TP7-TP8 are populated, Inverter A and Inverter B can be powered by a common voltage source, DC+, connected to either the coaxial plug, J5, or to the connector, J8. The voltage source, DC+, supplies power to the dsPIC DSC Signal Board through the signal board interface connector, J13. Connector, J5, can carry current up to 2.5A and connector, J8, can carry current up to 30A.

Note: On the Motor Control 10-24V Driver Board (Dual/Single),TP3-TP6 and TP7-TP8 wire jumpers are populated by default.

Both the Inverter A and Inverter B sections on the Motor Control 10-24V Driver Board (Dual/Single) can be powered independently by different voltage sources, such as VDC_A and VDC_B. Inverter A can be powered up by different voltage sources connected to connector, J1, if a wire jumper between TP3-TP6 is disconnected. Similarly, Inverter B can be powered up by different voltage sources connected to connector, J6, if a wire jumper between TP7-TP8 is disconnected. Connectors, J1 and J6, can carry the maximum current of 15A each. If both the jumpers, TP3-TP6 and TP7-TP8, are opened, then the dsPIC DSC Signal Board is powered from the connector, J5 or J8. Input power supply configuration is shown in Table 2-2.

TABLE 2-2: INPUT POWER SUPPLY CONFIGURATION

Wire Jumper Configuration		Power Supply Connectors		
TP3-TP6	**TP7-TP8**	**Inverter A Section**	**Inverter B Section**	**Signal Board**
Connected	Connected	J5/J8 (DC+)	J5/J8 (DC+)	J5/J8
Disconnected	Connected	J1 (VDC_A)	J5/J8	
Connected	Disconnected	J5/J8	J6 (VDC_B)	
Disconnected	Disconnected	J1 (VDC_A)	J6 (VDC_B)	

2.3.2 Inverter Output Connectors (J7, J9)

The Motor Control 10-24V Driver Board (Dual/Single) can drive two three-phase PMSM/BLDC motors. These motors are driven through Inverter A and Inverter B outputs from connectors, J7 and J9. The pin assignments for connectors, J7 and J9, are provided in Table 2-3 and Table 2-4.

TABLE 2-3: INVERTER A OUTPUT CONNECTOR (J7)

Pin #	Signal Name	Pin Description
1	PHASE3_MA	Phase 3 Output of Inverter A
2	PHASE2_MA	Phase 2 Output of Inverter A
3	PHASE1_MA	Phase 1 Output of Inverter A

TABLE 2-4: INVERTER B OUTPUT CONNECTOR (J9)

Pin #	Signal Name	Pin Description
1	PHASE3_MB	Phase 3 Output of Inverter B
2	PHASE2_MB	Phase 2 Output of Inverter B
3	PHASE1_MB	Phase 1 Output of Inverter B

2.3.3 Signal Board Interface Connector (J13)

The signal board interface connector, J13, is used to interface the Motor Control 10-24V Driver Board (Dual/Single) to the dsPIC DSC Signal Board. The signal board interface connector, J13, has three rows and each row has 40 pins. The signals on the connector, J13, can be grouped into the following function sets:

- Control Signals to the Motor Control 10-24V Driver Board (Dual/Single) for each Inverter:
  - Three pairs of PWMH/L signals
  - Braking chopper circuit control signal
- Feedback Signals from the Motor Control 10-24V Driver Board (Dual/Single) for each Inverter:
  - Current shunt feedbacks
  - DC bus voltage and current feedback
  - Three-phase back-EMF signals and recreated neutral signals
  - Hall Sensor/Quadrature Encoder Interface (QEI) sensor feedbacks
  - Fault signals
- Power Supply Signals to Signal Board:
  - Input DC power signal, DC+, and power ground
- Power Supply Signals from Signal Board:
  - Auxiliary power supply signals, DV_{DD}, +5V, DGND, AV_{DD} and AGND
  - DC bias voltage (VREF_EXT) signal to offset op amp outputs by a fixed DC voltage and this potential is referenced to AGND
- Signal Interface between Gate Driver and Microcontroller for each Inverter:
  - Chip enable signal from microcontroller
  - UART RX and TX to establish DE2 communication between controller and the MCP8024 gate driver

Connector, J13, pin function and pin mapping to the mate connector on the signal board are provided in Table 2-5 and Table 2-6. In Table 2-5, J13 pins are tabulated in order of their number, whereas in Table 2-6, signals on connector, J13, are grouped according to their functionality.

TABLE 2-5: SIGNAL BOARD INTERFACE CONNECTOR (J13)

On-Board J13 Connector Pin #	Mating Connector Pin #[(1)]	Signal Name	Pin Function	Signal Type
A1	A40	DV_{DD}	+3.3V or +5V Digital Power Supply from dsPIC® DSC Signal Board[(2)]	Power Supply
B1	B40	DV_{DD}	+3.3V or +5VDigital Power Supply from dsPIC DSC Signal Board[(2)]	Power Supply
C1	C40	DV_{DD}	+3.3V or +5V Digital Power Supply from dsPIC DSC Signal Board[(2)]	Power Supply
A2	A39	DGND	Digital Ground	Ground
B2	B39	DGND	Digital Ground	Ground
C2	C39	DGND	Digital Ground	Ground
A3	A38	VPHASE1_MB	Phase 1 BEMF Voltage Feedback of Motor B	Analog Output
B3	B38	—	—	—
C3	C38	DGND	Digital Ground	Ground
A4	A37	—	—	—
B4	B37	FAULT_AB	Inverter A and Inverter B Combined Fault Output generated by Fault Generation Logic Circuit	Digital Output
C4	C37	VPHASE2_MB	Phase 2 BEMF Voltage Feedback of Motor B	Analog Output
A5	A36	VPHASE1_MA	Phase 1 BEMF Voltage Feedback of Motor A	Analog Output
B5	B36	VPHASE2_MA	Phase 2 BEMF Voltage Feedback of Motor A	Analog Output
C5	C36	VPHASE3_MA	Phase 3 BEMF Voltage Feedback of Motor A	Analog Output
A6	A35	VPHASE3_MB	Phase 3 BEMF Voltage Feedback of Motor B	Analog Output
B6	B35	RECN_MA, IPHASE3_MA, IBRAKE_A	Recreated Neutral Feedback for Motor A or Inverter A Phase 3 Current Feedback, or Braking Chopper Circuit – A Current Sense Output	Analog Output
C6	C35	—	—	—
A7	A34	VREF_EXT	+1.65V/+2.5V Voltage Reference to Shift Op Amp Outputs[(4)]	Analog Output
B7	B34	—	—	—
C7	C34	—	—	—
A8	A33	—	—	—
B8	B33	—	—	—
C8	C33	—	—	—
A9	A32	—	—	—
B9	B32	VBUS_A	DC Bus Feedback of Inverter A	Analog Output
C9	C32	—	—	—
A10	A31	—	—	—
B10	B31	—	—	—
C10	C31	—	—	—

Note 1: The mating connector pin refers to the mating connector on the dedicated signal board interfaced to the Motor Control 10-24V Driver Board (Dual/Single).

2: On the dsPIC® DSC Signal Board, the DV_{DD} voltage level is configured as either +3.3V or +5V by the PIM plugged into the board.

3: On the dsPIC DSC Signal Board, the AV_{DD} voltage level is configured as either +3.3V or +5V by the PIM plugged into the board.

4: On the dsPIC DSC Signal Board, the VREF_EXT voltage level is configured as either +1.65 or +2.5V by the PIM plugged into the board.

TABLE 2-5: SIGNAL BOARD INTERFACE CONNECTOR (J13) (CONTINUED)

On-Board J13 Connector Pin #	Mating Connector Pin #(1)	Signal Name	Pin Function	Signal Type
A11	A30	DGND	Digital Ground	Ground
B11	B30	DGND	Digital Ground	Ground
C11	C30	DGND	Digital Ground	Ground
A12	A29	RECN_MB, IPHASE3_MB, IBRAKE_B	Recreated Neutral Feedback for Motor B or Inverter B Phase 3 Current Feedback, or Braking Chopper Circuit – B Current Sense Output	Analog Output
B12	B29	DE2_RX_B	UART RX from Microcontroller to establish DE2 Communication with MCP8024 (U9)	Digital Output
C12	C29	—	—	—
A13	A28	—	—	—
B13	B28	HALLC_MA	Hall Sensor C/INDEX Feedback from Motor A	Digital Output
C13	C28	HALLB_MA	Hall Sensor B/QEB Feedback from Motor A	Digital Output
A14	A27	—	—	—
B14	B27	—	—	—
C14	C27	—	—	—
A15	A26	IBUS_MB	Bus Current Feedback of Inverter B	Analog Output
B15	B26	DE2_TX_B	UART TX from Microcontroller to establish DE2 Communication with MCP8024 (U9)	Digital Input
C15	C26	BRAKE_EN_B	Software Brake Enable Signal for Braking Chopper Circuit – B	Digital Input
A16	A25	—	—	—
B16	B25	IPHASE2_MB	Inverter B Phase 2 Current Feedback	Analog Output
C16	C25	IPHASE1_MB	Inverter B Phase 1 Current Feedback	Analog Output
A17	A24	BRAKE_EN_A	Software Brake Enable Signal for Braking Chopper Circuit – A	Digital Input
B17	B24	—	—	—
C17	C24	—	—	—
A18	A23	—	—	—
B18	B23	—	—	—
C18	C23	HOME_MA	Quadrature Encoder Interface HOME Signal from Motor A	Digital Output
A19	A22	—	—	—
B19	B22	SHUNT_LOW_SUM_A	Inverter A Bus Current Shunt (Rsh5) Negative Terminal	Analog Output
C19	C22	SHUNT_HIGH_SUM_A	Inverter A Bus Current Shunt (Rsh5) Positive Terminal	Analog Output

Note 1: The mating connector pin refers to the mating connector on the dedicated signal board interfaced to the Motor Control 10-24V Driver Board (Dual/Single).

2: On the dsPIC® DSC Signal Board, the DVDD voltage level is configured as either +3.3V or +5V by the PIM plugged into the board.

3: On the dsPIC DSC Signal Board, the AVDD voltage level is configured as either +3.3V or +5V by the PIM plugged into the board.

4: On the dsPIC DSC Signal Board, the VREF_EXT voltage level is configured as either +1.65 or +2.5V by the PIM plugged into the board.

TABLE 2-5: SIGNAL BOARD INTERFACE CONNECTOR (J13) (CONTINUED)

On-Board J13 Connector Pin #	Mating Connector Pin #(1)	Signal Name	Pin Function	Signal Type
A20	A21	FAULT_MA	Inverter A Bus Current Fault Output from Signal Board	Digital Output
B20	B21	DE2_RX_A	UART RX from Microcontroller to establish DE2 Communication with MCP8024	Digital Output
C20	C19	—	—	—
A21	A20	DGND	Digital Ground	Ground
B21	B20	DGND	Digital Ground	Ground
C21	C20	DGND	Digital Ground	Ground
A22	A19	—	—	—
B22	B19	SHUNT_HIGH_SUM_A	Inverter A Phase 2 Current Shunt (Rsh1) Negative Terminal	Analog Output
C22	C21	—	—	—
A23	A18	—	—	—
B23	B18	SHUNT_HIGH_1_A	Inverter A Phase 1 Current Shunt (Rsh7) Positive Terminal	Analog Output
C23	C18	SHUNT_HIGH_2_A	Inverter A Phase 2 Current Shunt (Rsh1) Positive Terminal	Analog Output
A24	A17	—	—	—
B24	B17	DE2_TX_A	UART TX from Microcontroller to establish DE2 Communication with MCP8024	Digital Input
C24	C17	—	—	—
A25	A16	HALLA_MA	Hall Sensor A/QEA Feedback from Motor A	Digital Output
B25	B16	VBUS_B	DC Bus Feedback of Inverter B	Analog Output
C25	C16	—	—	—
A26	A15	—	—	—
B26	B15	CE_A	Chip Enable Signal to MCP8024 (U8)	Digital Input
C26	C15	SHUNT_HIGH_SUM_A	Inverter A Phase 1 Current Shunt (Rsh7) Negative Terminal	Analog Output
A27	A14	—	—	—
B27	B14	—	—	—
C27	C14	—	—	—
A28	A13	CE_B	Chip Enable Signal to MCP8024 (U9)	Digital Input
B28	B13	HOME_MB	Quadrature Encoder Interface HOME Signal of Motor B	Digital Output
C28	C13	—	—	—

Note 1: The mating connector pin refers to the mating connector on the dedicated signal board interfaced to the Motor Control 10-24V Driver Board (Dual/Single).

2: On the dsPIC® DSC Signal Board, the DV_{DD} voltage level is configured as either +3.3V or +5V by the PIM plugged into the board.

3: On the dsPIC DSC Signal Board, the AV_{DD} voltage level is configured as either +3.3V or +5V by the PIM plugged into the board.

4: On the dsPIC DSC Signal Board, the VREF_EXT voltage level is configured as either +1.65 or +2.5V by the PIM plugged into the board.

TABLE 2-5: SIGNAL BOARD INTERFACE CONNECTOR (J13) (CONTINUED)

On-Board J13 Connector Pin #	Mating Connector Pin #(1)	Signal Name	Pin Function	Signal Type
A29	A12	PWM1L_A	PWM for Inverter A Phase 1 Bottom MOSFET Control	Digital Input
B29	B12	HALLC_MB	Hall Sensor C/INDEX Feedback of Motor B	Digital Output
C29	C12	—	—	—
A30	A11	HALLA_MB	Hall Sensor A/QEA Feedback of Motor B	Digital Output
B30	B11	HALLB_MB	Hall Sensor B/QEB Feedback of Motor B	Digital Output
C30	C11	PWM1H_A	PWM for Inverter A Phase 1 Top MOSFET Control	Digital Input
A31	A10	DGND	Digital Ground	Ground
B31	B10	DGND	Digital Ground	Ground
C31	C10	DGND	Digital Ground	Ground
A32	A9	PWM2H_A	PWM for Inverter A Phase 2 Top MOSFET Control	Digital Input
B32	B9	PWM2L_A	PWM for Inverter A Phase 2 Bottom MOSFET Control	Digital Input
C32	C9	—	—	—
A33	A8	PWM3H_A	PWM for Inverter A Phase 3 Top MOSFET Control	Digital Input
B33	B8	—	—	—
C33	C8	PWM3L_A	PWM for Inverter A Phase 3 Bottom MOSFET Control	Digital Input
A34	A7	PWM2L_B	PWM for Inverter B Phase 2 Bottom MOSFET Control	Digital Input
B34	B7	PWM1L_B	PWM for Inverter B Phase 1 Bottom MOSFET Control	Digital Input
C34	C7	PWM1H_B	PWM for Inverter B Phase 1 Top MOSFET Control	Digital Input
A35	A6	PWM3H_B	PWM for Inverter B Phase 3 Top MOSFET Control	Digital Input
B35	B6	PWM3L_B	PWM for Inverter B Phase 3 Bottom MOSFET Control	Digital Input
C35	C6	PWM2H_B	PWM for Inverter B Phase 2 Top MOSFET Control	Digital Input
A36	A5	—	—	—
B36	B5	—	—	—
C36	C5	FAULT_MB	Inverter B Bus Current Fault Output to Microcontroller on Signal Board	Digital Input

Note 1: The mating connector pin refers to the mating connector on the dedicated signal board interfaced to the Motor Control 10-24V Driver Board (Dual/Single).

2: On the dsPIC® DSC Signal Board, the DVDD voltage level is configured as either +3.3V or +5V by the PIM plugged into the board.

3: On the dsPIC DSC Signal Board, the AVDD voltage level is configured as either +3.3V or +5V by the PIM plugged into the board.

4: On the dsPIC DSC Signal Board, the VREF_EXT voltage level is configured as either +1.65 or +2.5V by the PIM plugged into the board.

TABLE 2-5: SIGNAL BOARD INTERFACE CONNECTOR (J13) (CONTINUED)

On-Board J13 Connector Pin #	Mating Connector Pin #(1)	Signal Name	Pin Function	Signal Type
A37	A4	AVDD	+3.3V or +5V Analog Power Supply from Signal Board(3)	Power Supply
B37	B4	AVDD	+3.3V or +5V Analog Power Supply from Signal Board(3)	Power Supply
C37	C4	AGND	Analog Ground	Ground
A38	A3	+5V	+5V Digital Power Supply from Signal Board	Power Supply
B38	B3	+5V	+5V Digital Power Supply from Signal Board	Power Supply
C38	C3	AGND	Analog Ground	Ground
A39	A2	PGND	Power Ground	Ground
B39	B2	PGND	Power Ground	Ground
C39	C2	PGND	Power Ground	Ground
A40	A1	DC+	DC Supply (10-24V) from Power Board to Signal Board	Power Supply
B40	B1	DC+	DC Supply (10-24V) from Power Board to Signal board	Power Supply
C40	C1	DC+	DC Supply (10-24V) from Power Board to Signal Board	Power Supply

Note 1: The mating connector pin refers to the mating connector on the dedicated signal board interfaced to the Motor Control 10-24V Driver Board (Dual/Single).

2: On the dsPIC® DSC Signal Board, the DVDD voltage level is configured as either +3.3V or +5V by the PIM plugged into the board.

3: On the dsPIC DSC Signal Board, the AVDD voltage level is configured as either +3.3V or +5V by the PIM plugged into the board.

4: On the dsPIC DSC Signal Board, the VREF_EXT voltage level is configured as either +1.65 or +2.5V by the PIM plugged into the board.

TABLE 2-6: SIGNAL BOARD INTERFACE CONNECTOR (J13), GROUPED BY FUNCTIONALITY

On-Board J13 Connector Pin #	Mating Connector Pin #(1)	Signal Name	Pin Function	Signal Type
A. Power Supply Signals				
A1	A40	DVDD	+3.3V or +5V Digital Power Supply from Signal Board(2)	Power Supply
B1	B40	DVDD	+3.3V or 5V Digital Power Supply from Signal Board(2)	Power Supply
C1	C40	DVDD	+3.3V or 5V Digital Power Supply from Signal Board	Power Supply
A2	A39	DGND	Digital Ground	Ground
B2	B39	DGND	Digital Ground	Ground
C2	C39	DGND	Digital Ground	Ground
C3	C38	DGND	Digital Ground	Ground
A11	A30	DGND	Digital Ground	Ground
B11	B30	DGND	Digital Ground	Ground
C11	C30	DGND	Digital Ground	Ground
A21	A20	DGND	Digital Ground	Ground
B21	B20	DGND	Digital Ground	Ground
C21	C20	DGND	Digital Ground	Ground
A31	A10	DGND	Digital Ground	Ground
B31	B10	DGND	Digital Ground	Ground
C31	C10	DGND	Digital Ground	Ground
A37	A4	AVDD	+3.3V or +5V Analog Power Supply from Signal Board(3)	Power Supply
B37	B4	AVDD	+3.3V or +5V Analog Power Supply from Signal Board(3)	Power Supply
C37	C4	AGND	Analog Ground	Ground
A38	A3	+5V	+5V Digital Power Supply from Signal Board	Power Supply
B38	B3	+5V	+5V Digital Power Supply from Signal Board	Power Supply
C38	C3	AGND	Analog Ground	Ground
A39	A2	PGND	Power Ground	Ground
B39	B2	PGND	Power Ground	Ground
C39	C2	PGND	Power Ground	Ground
A40	A1	DC+	DC Supply (10-24V) from Power Board to Signal Board	Power Supply
B40	B1	DC+	DC Supply (10-24V) from Power Board to Signal Board	Power Supply
C40	C1	DC+	DC Supply (10-24V) from Power Board to Signal Board	Power Supply

Note 1: The mating connector pin refers to the mating connector on the dedicated signal board interfaced to the Motor Control 10-24V Driver Board (Dual/Single).

2: On the dsPIC® DSC Signal Board, the DVDD voltage level can be configured as either +3.3V or +5V by the PIM plugged into the board.

3: On the dsPIC DSC Signal Board, the AVDD voltage level can be configured as either +3.3V or +5V by the PIM plugged into the board.

4: On the dsPIC DSC Signal Board, the VREF_EXT voltage level is configured as either +1.65 or +2.5V by the PIM plugged into the board.

TABLE 2-6: SIGNAL BOARD INTERFACE CONNECTOR (J13), GROUPED BY FUNCTIONALITY (CONTINUED)

On-Board J13 Connector Pin #	Mating Connector Pin #(1)	Signal Name	Pin Function	Signal Type
B. Signals to and from Inverter A Section				
B.1 PWM Signals				
C30	C11	PWM1H_A	PWM for Inverter A Phase 1 Top MOSFET Control	Digital Input
A29	A12	PWM1L_A	PWM for Inverter A Phase 1 Bottom MOSFET Control	Digital Input
A32	A9	PWM2H_A	PWM for Inverter A Phase 2 Top MOSFET Control	Digital Input
B32	B9	PWM2L_A	PWM for Inverter A Phase 2 Bottom MOSFET Control	Digital Input
A33	A8	PWM3H_A	PWM for Inverter A Phase 3 Top MOSFET Control	Digital Input
C33	C8	PWM3L_A	PWM for Inverter A Phase 3 Bottom MOSFET Control	Digital Input
A17	A24	BRAKE_EN_A	Software Brake Enable Signal for Braking Chopper Circuit – A	Digital Input
B.2 Interface Signals between Microcontroller and Gate Driver, MCP8024 (U8)				
B26	B15	CE_A	Chip Enable Signal to MCP8024 (U8)	Digital Input
B24	B17	DE2_TX_A	UART TX from Microcontroller to establish DE2 Communication with MCP8024	Digital Input
B20	B21	DE2_RX_A	UART RX from Microcontroller to establish DE2 Communication with MCP8024	Digital Output
B.3 Hall Sensor/Quadrature Encoder Interface Feedback Signals from Motor A				
A25	A16	HALLA_MA	Hall Sensor A/QEA Feedback from Motor A	Digital Output
C13	C28	HALLB_MA	Hall Sensor B/QEB Feedback from Motor A	Digital Output
B13	B28	HALLC_MA	Hall Sensor C/INDEX Feedback from Motor A	Digital Output
C18	C23	HOME_MA	Quadrature Encoder Interface HOME Signal from Motor A	Digital Output

Note 1: The mating connector pin refers to the mating connector on the dedicated signal board interfaced to the Motor Control 10-24V Driver Board (Dual/Single).

2: On the dsPIC® DSC Signal Board, the DVDD voltage level can be configured as either +3.3V or +5V by the PIM plugged into the board.

3: On the dsPIC DSC Signal Board, the AVDD voltage level can be configured as either +3.3V or +5V by the PIM plugged into the board.

4: On the dsPIC DSC Signal Board, the VREF_EXT voltage level is configured as either +1.65 or +2.5V by the PIM plugged into the board.

TABLE 2-6: SIGNAL BOARD INTERFACE CONNECTOR (J13), GROUPED BY FUNCTIONALITY (CONTINUED)

On-Board J13 Connector Pin #	Mating Connector Pin #(1)	Signal Name	Pin Function	Signal Type
B.4 Voltage and Current Feedback Signals				
A5	A36	VPHASE1_MA	Phase 1 Voltage Feedback of Motor A	Analog Output
B5	B36	VPHASE2_MA	Phase 2 Voltage Feedback of Motor A	Analog output
C5	C36	VPHASE3_MA	Phase 3 Voltage Feedback of Motor A	Analog Output
B6	B35	RECN_MA, IPHASE3_MA, IBRAKE_A	Recreated Neutral Feedback for Motor A or Inverter A Phase 3 Current Feedback, or Braking Chopper Circuit – A Current Sense Output	Analog Output
B23	B18	SHUNT_HIGH_1_A	Inverter A Phase 1 Current Shunt (Rsh7) Positive Terminal	Analog Output
C26	C15	SHUNT_HIGH_SUM_A	Inverter A Phase 1 Current Shunt (Rsh7) Negative Terminal	Analog Output
C23	C18	SHUNT_HIGH_2_A	Inverter A Phase 2 Current Shunt (Rsh1) Positive Terminal	Analog Output
B22	B19	SHUNT_HIGH_SUM_A	Inverter A Phase 2 Current Shunt (Rsh1) Negative Terminal	Analog Output
C19	C22	SHUNT_HIGH_SUM_A	Inverter A bus Current Shunt (Rsh5) Positive Terminal	Analog Output
B19	B22	SHUNT_LOW_SUM_A	Inverter A bus Current Shunt (Rsh5) Negative Terminal	Analog Output
B9	B32	VBUS_A	DC Bus Feedback of Inverter A	Analog Output
C. Signals to and from Inverter B Section				
C.1 PWM Signals				
C34	C7	PWM1H_B	PWM for Inverter B Phase 1 Top MOSFET Control	Digital Input
B34	B7	PWM1L_B	PWM for Inverter B Phase 1 Bottom MOSFET Control	Digital Input
C35	C6	PWM2H_B	PWM for Inverter B Phase 2 Top MOSFET Control	Digital Input
A34	A7	PWM2L_B	PWM for Inverter B Phase 2 Bottom MOSFET Control	Digital Input
A35	A6	PWM3H_B	PWM for Inverter B Phase 3 Top MOSFET Control	Digital Input
B35	B6	PWM3L_B	PWM for Inverter B Phase 3 Bottom MOSFET Control	Digital Input
C15	C26	BRAKE_EN_B	Software Brake Enable Signal for Braking Chopper Circuit – B	Digital Input

Note 1: The mating connector pin refers to the mating connector on the dedicated signal board interfaced to the Motor Control 10-24V Driver Board (Dual/Single).

2: On the dsPIC® DSC Signal Board, the DV_{DD} voltage level can be configured as either +3.3V or +5V by the PIM plugged into the board.

3: On the dsPIC DSC Signal Board, the AV_{DD} voltage level can be configured as either +3.3V or +5V by the PIM plugged into the board.

4: On the dsPIC DSC Signal Board, the VREF_EXT voltage level is configured as either +1.65 or +2.5V by the PIM plugged into the board.

TABLE 2-6: SIGNAL BOARD INTERFACE CONNECTOR (J13), GROUPED BY FUNCTIONALITY (CONTINUED)

On-Board J13 Connector Pin #	Mating Connector Pin #(1)	Signal Name	Pin Function	Signal Type
C.2 Interface Signals between Microcontroller and Gate Driver, MCP8024 (U9)				
A28	A13	CE_B	Chip Enable Signal to MCP8024 (U9)	Digital Input
B15	B26	DE2_TX_B	UART TX from Microcontroller to establish DE2 Communication with MCP8024 (U9)	Digital Input
B12	B29	DE2_RX_B	UART RX from Microcontroller to establish DE2 Communication with MCP8024 (U9)	Digital Output
C.3 Hall Sensor/Quadrature Encoder Interface Feedback Signals from Motor B				
A30	A11	HALLA_MB	Hall Sensor A/QEA Feedback of Motor B	Digital Output
B30	B11	HALLB_MB	Hall Sensor B/QEB Feedback of Motor B	Digital Output
B29	B12	HALLC_MB	Hall Sensor C/INDEX Feedback of Motor B	Digital Output
B28	B13	HOME_MB	Quadrature Encoder Interface HOME Signal of Motor B	Digital Output
C.4 Voltage and Current Feedback Signals				
A3	A38	VPHASE1_MB	Phase 1 BEMF Voltage Feedback of Motor B	Analog Output
C4	C37	VPHASE2_MB	Phase 2 BEMF Voltage Feedback of Motor B	Analog Output
A6	A35	VPHASE3_MB	Phase 3 BEMF Voltage Feedback of Motor B	Analog Output
A12	A29	RECN_MB, IPHASE3_MB, IBRAKE_B	Recreated Neutral Feedback for Motor B or Inverter B Phase 3 Current Feedback, or Braking Chopper Circuit – B Current Sense Output	Analog Output
C16	C25	IPHASE1_MB	Inverter B Phase 1 Current Feedback	Analog Output
B16	B25	IPHASE2_MB	Inverter B Phase 2 Current Feedback	Analog Output
A15	A26	IBUS_MB	Bus Current Feedback of Inverter B	Analog Output
B25	B16	VBUS_B	DC Bus Feedback of Inverter B	Analog Output
D. Others				
D.1 Fault Signals				
A20	A21	FAULT_MA	Inverter A Bus Current Fault Output from Signal Board	Digital Output
C36	C5	FAULT_MB	Inverter B Bus Current Fault Output to Microcontroller on Signal Board	Digital Input
B4	B37	FAULT_AB	Inverter A and Inverter B Combined Fault Output generated by Fault Generation Logic Circuit	Digital Input
D.2 Voltage Offset				
A7	A34	VREF_EXT	+1.65V/+2.5VVoltage Reference to Shift Op Amp Outputs(4)	Analog Input

Note 1: The mating connector pin refers to the mating connector on the dedicated signal board interfaced to the Motor Control 10-24V Driver Board (Dual/Single).

2: On the dsPIC® DSC Signal Board, the DVDD voltage level can be configured as either +3.3V or +5V by the PIM plugged into the board.

3: On the dsPIC DSC Signal Board, the AVDD voltage level can be configured as either +3.3V or +5V by the PIM plugged into the board.

4: On the dsPIC DSC Signal Board, the VREF_EXT voltage level is configured as either +1.65 or +2.5V by the PIM plugged into the board.

TABLE 2-6: SIGNAL BOARD INTERFACE CONNECTOR (J13), GROUPED BY FUNCTIONALITY (CONTINUED)

On-Board J13 Connector Pin #	Mating Connector Pin #(1)	Signal Name	Pin Function	Signal Type
E. Pins – Not Connected on Motor Control 10-24V Driver Board (Dual/Single)(2)				
B3	B38	—	—	—
A4	A37	—	—	—
C6	C35	—	—	—
B7	B34	—	—	—
C7	C34	—	—	—
A8	A33	—	—	—
B8	B33	—	—	—
C8	C33	—	—	—
A9	A32	—	—	—
C9	C32	—	—	—
A10	A31	—	—	—
B10	B31	—	—	—
C10	C31	—	—	—
C12	C29	—	—	—
A13	A28	—	—	—
A14	A27	—	—	—
B14	B27	—	—	—
C14	C27	—	—	—
A16	A25	—	—	—
B17	B24	—	—	—
C17	C24	—	—	—
A18	A23	—	—	—
B18	B23	—	—	—
A19	A22	—	—	—
C20	C19	—	—	—
A22	A19	—	—	—
C22	C21	—	—	—
A23	A18	—	—	—
A24	A17	—	—	—
C24	C17	—	—	—
C25	C16	—	—	—
A26	A15	—	—	—

Note 1: The mating connector pin refers to the mating connector on the dedicated signal board interfaced to the Motor Control 10-24V Driver Board (Dual/Single).

2: On the dsPIC® DSC Signal Board, the DV_{DD} voltage level can be configured as either +3.3V or +5V by the PIM plugged into the board.

3: On the dsPIC DSC Signal Board, the AV_{DD} voltage level can be configured as either +3.3V or +5V by the PIM plugged into the board.

4: On the dsPIC DSC Signal Board, the VREF_EXT voltage level is configured as either +1.65 or +2.5V by the PIM plugged into the board.

TABLE 2-6: SIGNAL BOARD INTERFACE CONNECTOR (J13), GROUPED BY FUNCTIONALITY (CONTINUED)

On-Board J13 Connector Pin #	Mating Connector Pin #(1)	Signal Name	Pin Function	Signal Type
A27	A14	—	—	—
B27	B14	—	—	—
C27	C14	—	—	—
C28	C13	—	—	—
C29	C12	—	—	—
C32	C9	—	—	—
B33	B8	—	—	—
A36	A5	—	—	—
B36	B5	—	—	—

Note 1: The mating connector pin refers to the mating connector on the dedicated signal board interfaced to the Motor Control 10-24V Driver Board (Dual/Single).

2: On the dsPIC® DSC Signal Board, the DVDD voltage level can be configured as either +3.3V or +5V by the PIM plugged into the board.

3: On the dsPIC DSC Signal Board, the AVDD voltage level can be configured as either +3.3V or +5V by the PIM plugged into the board.

4: On the dsPIC DSC Signal Board, the VREF_EXT voltage level is configured as either +1.65 or +2.5V by the PIM plugged into the board.

2.3.4 Hall Sensor/Quadrature Encoder Interface Connectors (J2, J4)

The Hall sensors or Quadrature Encoder Interfaces (QEIs) are used for determining the motor position. Connectors, J2 and J4, can be used to interface the Hall Sensor/ Quadrature Encoder Interface of motors driven by Inverter A and Inverter B, respectively. The pin descriptions of connectors, J2 and J4, are shown in Table 2-7 and Table 2-8.

TABLE 2-7: HALL SENSOR/QUADRATURE ENCODER INTERFACE CONNECTOR (J2)

Pin #	Signal Name	Pin Description
1	+5V	Hall Sensors/QEI Power Supply
2	DGND	Digital Ground
3	HALLA_MA	Hall Sensor A/QEI Phase A Feedback for Motor A
4	HALLB_MA	Hall Sensor B/QEI Phase B Feedback for Motor A
5	HALLC_MA	Hall Sensor C/QEI INDEX Feedback for Motor A
6	HOME_MA	QEI HOME Signal Feedback for Motor A

TABLE 2-8: HALL SENSOR/QUADRATURE ENCODER INTERFACE CONNECTOR (J4)

Pin #	Signal Name	Pin Description
1	+5V	Hall Sensors/QEI Power Supply
2	DGND	Digital Ground
3	HALLA_MB	Hall Sensor A/QEI Phase A Feedback for Motor B
4	HALLB_MB	Hall Sensor B/QEI Phase B Feedback for Motor B
5	HALLC_MB	Hall Sensor C/QEI INDEX Feedback for Motor B
6	HOME_MB	QEI HOME Signal Feedback for Motor B

2.3.5 Terminals for Brake Resistors (TP46-TP47, TP51-TP52)

Brake resistors can be added to Braking Chopper Circuit of Inverter A and Inverter B through terminals provided on the Motor Control 10-24V Driver Board (Dual/Single). Table 2-7 and Table 2-10 provides the terminal pin-outs.

TABLE 2-9: TERMINALS FOR BRAKE RESISTOR ON INVERTER A SIDE

Terminal #	Terminal Name	Terminal Description
1	TP46	Inverter A Brake Resistor Positive Terminal
2	TP47	Inverter A Brake Resistor Negative Terminal

TABLE 2-10: TERMINALS FOR BRAKE RESISTOR ON INVERTER B SIDE

Terminal #	Terminal Name	Terminal Description
1	TP51	Inverter B Brake Resistor Positive Terminal
2	TP52	Inverter B Brake Resistor Negative Terminal

2.3.6 Auxiliary Power Supply Output Connectors (J15, J16)

Various auxiliary power supply outputs can be tapped through connectors, J15 and J16. The auxiliary power supply outputs on connector, J15, are provided in Table 2-11 and Table 2-12 provides the power supply outputs on connector, J16.

TABLE 2-11: AUXILIARY POWER SUPPLY OUTPUT CONNECTOR (J15)

Pin #	Signal Name	Signal Description
1	DGND	Digital Ground
2	+5V	+5V Digital Power Output
3	DVDD	+3.3V/+5V Digital Power Output
4	AGND	Analog Ground
5	AVDD	+3.3V/+5V Analog Power Output

TABLE 2-12: +12V LDO (U11) OUTPUT CONNECTOR (J16)

Pin #	Signal Name	Signal Description
1	+12V	+12V Output of LDO U11 (L7812CD2T-TR)
2	PGND	Power Ground

2.3.7 MCP8024 (U8) Operational Amplifier Interface Connectors (J10, J11, J12)

The three-phase BLDC motor gate driver with the power module, MCP8024, has three internal operational amplifiers. These amplifiers can be configured as either inverting or non-inverting, and are labeled as U8-A, U8-B and U8-C. Each of these amplifier inputs and outputs are accessible through connectors, J10, J11 and J12 (see Figure A-1). The inputs and output of the gate driver amplifiers, U8-A, U8-B and U8-C, are provided in Table 2-13 through Table 2-15, respectively.

TABLE 2-13: AMPLIFIER U8-A INPUT AND OUTPUT CONNECTOR (J12)

Pin #	Signal Name	Signal Description
1	IN3+	Positive Input of U8-A Amplifier Circuit
2	IN3-	Negative Input of U8-A Amplifier Circuit
3	OUT3	U8-A Amplifier Output

TABLE 2-14: AMPLIFIER U8-B INPUT AND OUTPUT CONNECTOR (J11)

Pin #	Signal Name	Signal Description
1	IN2+	Positive Input of U8-B Amplifier Circuit
2	IN2-	Negative Input of U8-B Amplifier Circuit
3	OUT2	U8-B Amplifier Output

TABLE 2-15: AMPLIFIER U8-C INPUT AND OUTPUT CONNECTOR (J10)

Pin #	Signal Name	Signal Description
1	IN1-	Negative Input of U8-C Amplifier Circuit
2	IN1+	Positive Input of U8-C Amplifier Circuit
3	OUT1	U8-C Amplifier Output

By default, the U8-A, U8-B and U8-C amplifiers are configured as non-inverting buffers with their non-inverting input connected to VREF_EXT (half of the amplifier supply voltage) for low-power consumption. For circuit details, see Figure A-1.

2.4 USER INTERFACE HARDWARE

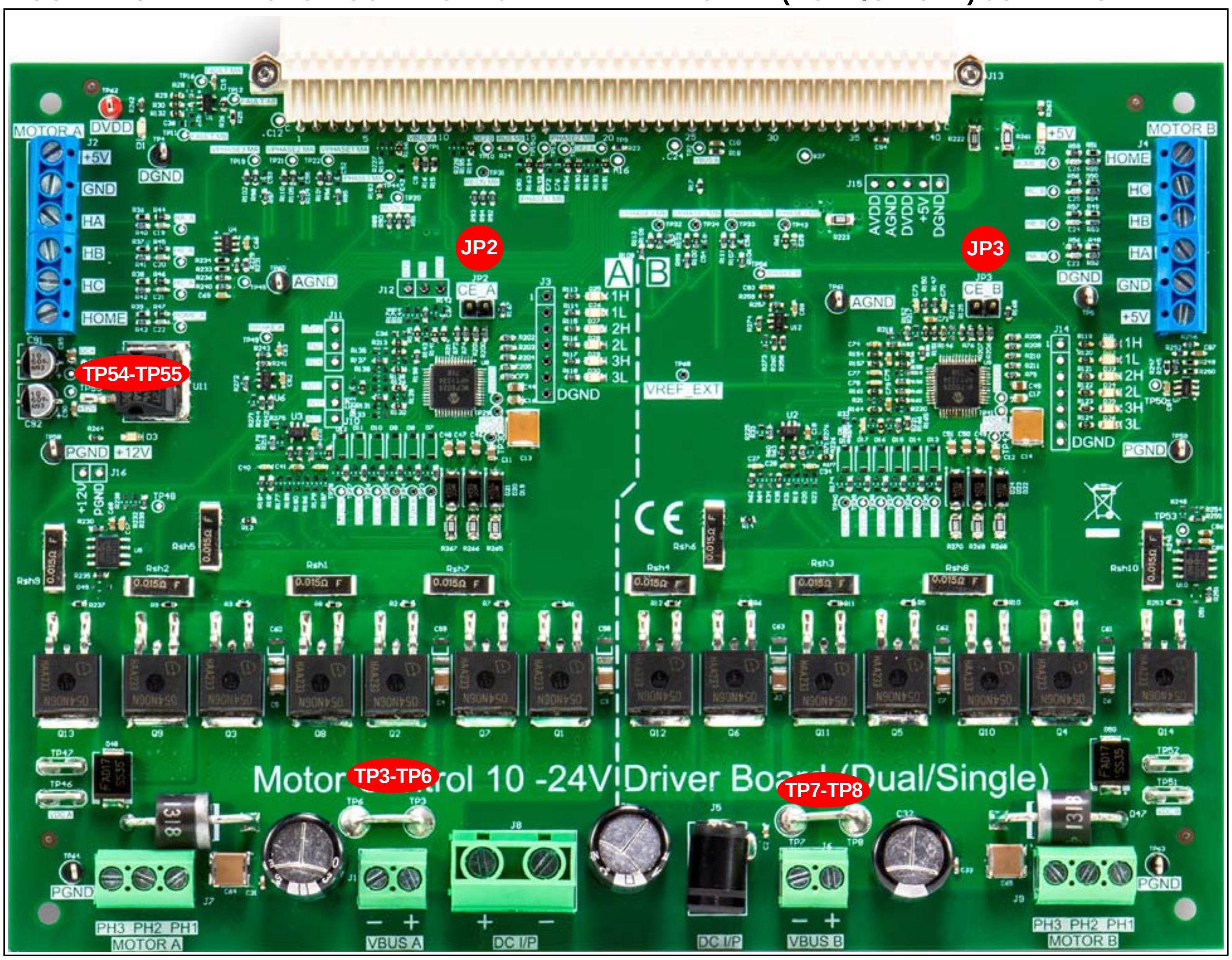
2.4.1 Board Jumpers

The Motor Control 10-24V Driver Board (Dual/Single) has three power jumpers and two signal jumpers. The on-board jumpers are provided in Table 2-16. Figure 2-3 shows the jumper positions.

TABLE 2-16: BOARD JUMPERS

Jumper Designator	Jumper Description
JP2	Connects the chip enable signal of gate driver, IC U8, to +5 VLDO1 (CE_A = High) enabling all device functions.
JP3	Connects the chip enable signal of gate driver, IC U9, to +5 VLDO2 (CE_B = High) enabling all device functions.
TP3-TP6	Connects the power supply, DC+ signal, to Inverter A circuits which are populated by default and can carry 15A current.
TP7-TP8	Connects the power supply, DC+ signal, to Inverter B circuits which are populated by default and can carry 15A current.
TP54-TP55	If populated, +12V LDO (U11) input and output are shorted bypassing the low LDO.

FIGURE 2-3: MOTOR CONTROL 10-24V DRIVER BOARD (DUAL/SINGLE) JUMPERS



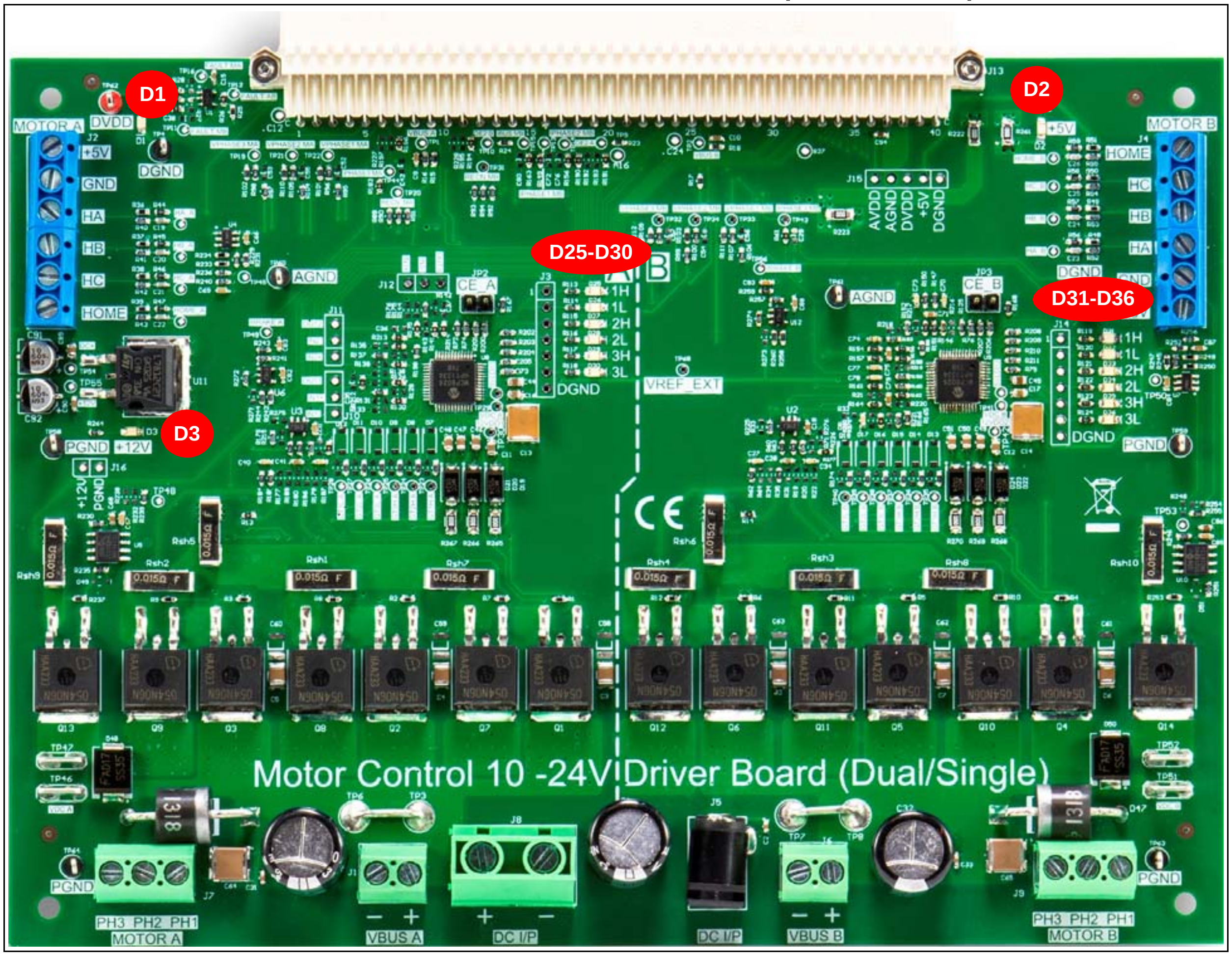
2.4.2 Board LED Indications

The on-board LEDs are provided in Table 2-17 and Figure 2-4 shows the LED positions.

TABLE 2-17: BOARD LEDs

LED Designator	LED Indication
D1	Power-on status indication for Auxiliary Supply Output DV_{DD} (+3.3V/+5V) from the Signal Board.
D2	Power-on status indication for Auxiliary Supply Output +5V from the Signal Board.
D3	Power-on status indication for the on-board +12V LDO (U11) output.
D25	Indicates PWM Pin status of Inverter A Phase 1 Top MOSFET control.
D26	Indicates PWM Pin status of Inverter A Phase 1 Bottom MOSFET control.
D27	Indicates PWM Pin status of Inverter A Phase 2 Top MOSFET control.
D28	Indicates PWM Pin status of Inverter A Phase 2 Bottom MOSFET control.
D29	Indicates PWM Pin status of Inverter A Phase 3 Top MOSFET control.
D30	Indicates PWM Pin status of Inverter A Phase 3 Bottom MOSFET control.
D31	Indicates PWM Pin status of Inverter B Phase 1 Top MOSFET control.
D32	Indicates PWM Pin status of Inverter B Phase 1 Bottom MOSFET control.
D33	Indicates PWM Pin status of Inverter B Phase 2 Top MOSFET control.
D34	Indicates PWM Pin status of Inverter B Phase 2 Bottom MOSFET control.
D35	Indicates PWM Pin status of Inverter B Phase 3 Top MOSFET control.
D36	Indicates PWM Pin status of Inverter B Phase 3 Bottom MOSFET control.

FIGURE 2-4: MOTOR CONTROL 10-24V DRIVER BOARD (DUAL/SINGLE) LEDs



2.4.3 Board Test Points

There are several test points on the Motor Control 10-24V Driver Board (Dual/Single) to allow probing of voltages, currents and signals. Table 2-18 provides all the test points on the board.

TABLE 2-18: BOARD TEST POINTS

Test Point Number	Test Point Name	Description
TP1	VBUS_A	DC Bus Feedback of Inverter A
TP2	VBUS_B	DC Bus Feedback of Inverter B
TP4	DGND	Digital Ground
TP5	DGND	Digital Ground
TP9	DE2_A	DE2 Communication Link of MCP8024 U8
TP10	DE2_B	DE2 Communication Link of MCP8024 U9
TP11	FAULT_MB	Inverter B Bus Current Fault Output to Microcontroller on Signal Board
TP12	FAULT_AB	Inverter A and Inverter B Combined Fault Output generated by Fault Generation Logic
TP13	IPHASE1_MB	Inverter B Phase 1 Current Feedback
TP14	IPHASE2_MB	Inverter B Phase 2 Current Feedback
TP15	IBUS_MB	Inverter B Bus Current Feedback
TP16	FAULT_MA	Inverter A Bus Current Fault Output from Signal Board
TP17	5VLDO1	Output of Internal +5V LDO Regulator of Gate Driver, MCP8024 U8
TP18	5VLDO2	Output of Internal +5V LDO Regulator of Gate Driver, MCP8024 U9
TP19	VPHASE3_MA	Phase 3 BEMF Voltage Feedback of Motor A
TP20	RECN_MA	Recreated Neutral Feedback for Motor A
TP21	VPHASE2_MA	Phase 2 BEMF Voltage Feedback of Motor A
TP22	VPHASE1_MA	Phase 1 BEMF Voltage Feedback of Motor A
TP23	GT1H_A	Gate Signal from Driver for Inverter A Phase 1 Top MOSFET Control
TP24	GT2H_A	Gate Signal from Driver for Inverter A Phase 2 Top MOSFET Control
TP25	GT3H_A	Gate Signal from Driver for Inverter A Phase 3 Top MOSFET Control
TP26	GT3L_A	Gate Signal from Driver for Inverter A Phase 3 Bottom MOSFET Control
TP27	GT2L_A	Gate Signal from Driver for Inverter A Phase 2 Bottom MOSFET Control
TP28	GT1L_A	Gate Signal from Driver for Inverter A Phase 1 Bottom MOSFET Control
TP29	VDC_A	DC Bus Voltage of Inverter A
TP30	12VLDO1	Output of Internal +12V LDO Regulator of Gate Driver, MCP8024 U8
TP31	RECN_MB	Recreated Neutral Feedback for Motor B
TP32	VPHASE3_MB	Phase 3 BEMF Voltage Feedback of Motor B

Note 1: On the dsPIC® DSC Signal Board, the DV_{DD} voltage level is configured as either +3.3V or +5V by the PIM plugged into the board

2: On the dsPIC DSC Signal Board, the VREF_EXT voltage level is configured as either +1.65V or +2.5V by the PIM plugged into the board

TABLE 2-18: BOARD TEST POINTS (CONTINUED)

Test Point Number	Test Point Name	Description
TP33	VPHASE1_MB	Phase 1 BEMF Voltage Feedback of Motor B
TP34	VPHASE2_MB	Phase 2 BEMF Voltage Feedback of Motor B
TP35	GT1H_B	Gate Signal from Driver for Inverter B Phase 1 Top MOSFET Control
TP36	GT2H_B	Gate Signal from Driver for Inverter B Phase 2 Top MOSFET Control
TP37	GT3H_B	Gate Signal from Driver for Inverter B Phase 3 Top MOSFET Control
TP38	GT3L_B	Gate Signal from Driver for Inverter B Phase 3 Bottom MOSFET Control
TP39	GT2L_B	Gate Signal from Driver for Inverter B Phase 2 Bottom MOSFET Control
TP40	GT1L_B	Gate Signal from Driver for Inverter B Phase 1 Bottom MOSFET Control
TP41	VDC_B	DC Bus Voltage of Inverter B
TP42	12VLDO2	Output of Internal +12V LDO Regulator of Gate Driver, MCP8024 U9
TP43	IPHASE3_MB	Inverter B Phase 3 Current Feedback
TP44	IPHASE3_MA	Inverter A Phase 3 Current Feedback
TP45	—	Reference Voltage Output of Comparator, U4
TP48	—	Brake Enable Input to Brake Switch Driver, U5
TP49	IBRAKE_A	Brake Circuit A Current Sensing Amplifier Output
TP50	—	Reference Voltage Output of Comparator, U7
TP53	—	Brake Enable Input to Brake Switch Driver, U10
TP54	DC+	DC Power Supply (10V-24V)
TP55	+12V	On-board +12V LDO (U11) Regulator Output
TP56	IBRAKE_B	Brake Circuit B Current Sensing Amplifier Output
TP58	PGND	Power Ground
TP59	PGND	Power Ground
TP60	AGND	Analog Ground
TP61	AGND	Analog Ground
TP62	DVDD	+3.3V or 5V Digital Power Supply from Signal Board[1]
TP63	PGND	Power Ground
TP64	PGND	Power Ground
TP68	VREF_EXT	+1.65V/+2.5V Voltage Reference to shift Op Amp Outputs[2]
J3-1	PWM1H_A	PWM Input to Driver for Inverter A Phase 1 Top MOSFET Control
J3-2	PWM1L_A	PWM Input to Driver for Inverter A Phase 1 Bottom MOSFET Control
J3-3	PWM2H_A	PWM Input to Driver for Inverter A Phase 2 Top MOSFET Control
J3-4	PWM2L_A	PWM Input to Driver for Inverter A Phase 2 Bottom MOSFET Control

Note 1: On the dsPIC® DSC Signal Board, the DVDD voltage level is configured as either +3.3V or +5V by the PIM plugged into the board

2: On the dsPIC DSC Signal Board, the VREF_EXT voltage level is configured as either +1.65V or +2.5V by the PIM plugged into the board

TABLE 2-18: BOARD TEST POINTS (CONTINUED)

Test Point Number	Test Point Name	Description
J3-5	PWM3H_A	PWM Input to Driver for Inverter A Phase 3 Top MOSFET Control
J3-6	PWM3L_A	PWM Input to Driver for Inverter A Phase 3 Bottom MOSFET Control
J3-7	DGND	Digital Ground
J14-1	PWM1H_B	PWM Input to Driver for Inverter B Phase 1 Top MOSFET Control
J14-2	PWM1L_B	PWM Input to Driver for Inverter B Phase 1 Bottom MOSFET Control
J14-3	PWM2H_B	PWM Input to Driver for Inverter B Phase 2 Top MOSFET Control
J14-4	PWM2L_B	PWM Input to Driver for Inverter B Phase 2 Bottom MOSFET Control
J14-5	PWM3H_B	PWM Input to Driver for Inverter B Phase 3 Top MOSFET Control
J14-6	PWM3L_B	PWM Input to Driver for Inverter B Phase 3 Bottom MOSFET Control
J14-7	DGND	Digital Ground
HA_A	HALLA_MA	Hall Sensor A/QEA Feedback of Motor A
HB_A	HALLB_MA	Hall Sensor B/QEB Feedback of Motor A
HC_A	HALLC_MA	Hall Sensor C/INDEX Feedback of Motor A
HOME_A	HOME_MA	QEI HOME Signal of Motor A
HA_B	HALLA_MB	Hall Sensor A/QEA Feedback of Motor B
HB_B	HALLB_MB	Hall Sensor B/QEB Feedback of Motor B
HC_B	HALLC_MB	Hall Sensor C/INDEX Feedback of Motor B
HOME_B	HOME_MB	QEI HOME Signal of Motor B

Note 1: On the dsPIC® DSC Signal Board, the DV_{DD} voltage level is configured as either +3.3V or +5V by the PIM plugged into the board

2: On the dsPIC DSC Signal Board, the VREF_EXT voltage level is configured as either +1.65V or +2.5V by the PIM plugged into the board

Chapter 3. Hardware Description

3.1 INTRODUCTION

This chapter provides a more detailed description of the hardware features of the Motor Control 10-24V Driver Board (Dual/Single).

The Motor Control 10-24V Driver Board (Dual/Single) is a power board with dual motor control and three-phase inverter stages that can be interfaced with the dsPIC® DSC Signal Board. The boards support PMSM/BLDC motor control application development using Microchip controllers. The Motor Control 10-24V Driver Board (Dual/Single) also features a three-phase Brushless DC (BLDC) motor gate driver with power module, MCP8024, from Microchip's product portfolio. Motor control algorithms, position feedback interface, and current and voltage sensing circuits are built-in to facilitate development of various PMSM/BLDC motors. Two dynamic brake circuit stages are also integrated on the board.

Both Inverter A and Inverter B can be operated from an input voltage in the range of 10-24V, and are capable of delivering a continuous output phase current of 10A (RMS) in the specified operating range. The dynamic brake circuit can also handle continuous current of 10A, without exceeding the specified operating conditions.

Note: Inverter A and Inverter B, and associated circuits are referred to using the symbols, A and B.

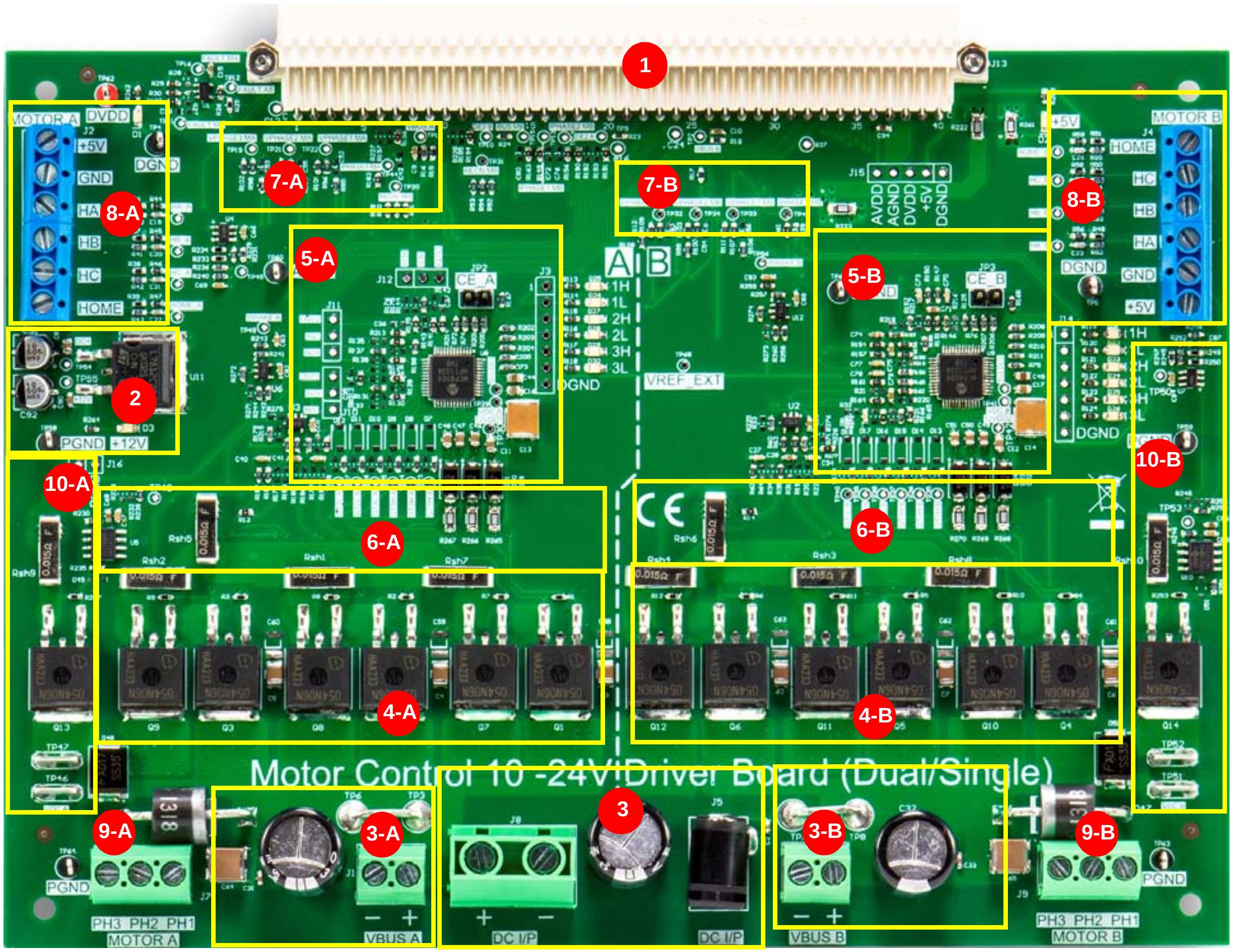
3.2 HIGHLIGHTS

This chapter covers the following hardware sections:

- Three-Phase Inverter Bridge and Gate Driver
- DC Bus Voltage Sensing
- Hall Sensor/Quadrature Encoder Interface
- Back-EMF and Recreated Neutral Signals
- Phase and Bus Current Sensing Circuits
- Fault Generation Logic Circuit
- Brake Circuit
- Power Supply

The hardware section of the Motor Control 10-24V Driver Board (Dual/Single) is shown in Figure 3-1.

FIGURE 3-1: MOTOR CONTROL10-24V DRIVER BOARD HARDWARE SECTIONS



Legend:

1	dsPIC® DSC Signal Board Interface Connector	2	+12V LDO Circuit
3	Input Power Supply	4	Three-Phase Inverter Bridge A and B
5	Gate Driver Circuit	6	Current Sensing Shunts
7	Back-EMF Sensing Circuit	8	Hall Sensor/QE Interface Circuit
9	Motor Connector	10	Dynamic Brake Circuit

Note: A and B indicates the inverter section to which each hardware block is associated.

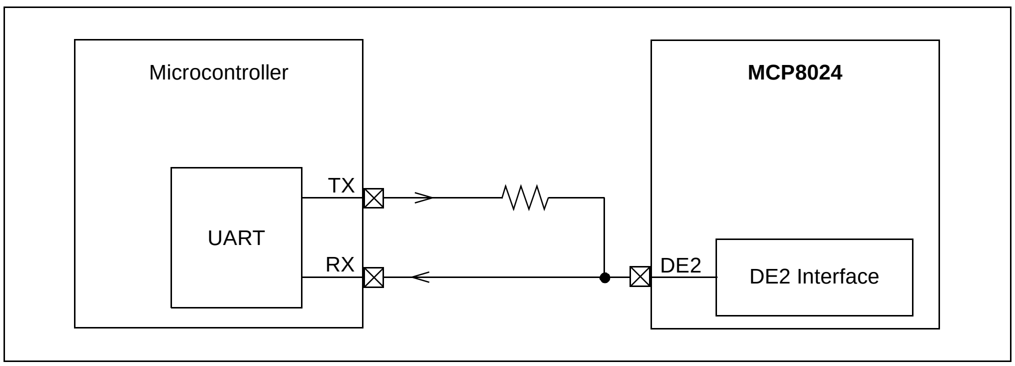
3.3 THREE-PHASE INVERTER BRIDGE AND GATE DRIVER

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 of each MOSFET, to ensure soft turn-off of the MOSFET, if the gate signal is disconnected. Low-ESR ceramic capacitors are provided across each half-bridge for filtering high-frequency currents due to switching. Transient voltage suppressors are connected between each inverter supply and ground for protecting inverter and driver against voltage transients.

Microchip's three-phase, BLDC motor gate driver along with the power module, MCP8024, are used for low and high side MOSFET gate drive. Gate driver inputs are 3.3V compatible. MCP8024 provides undervoltage, overvoltage, shoot-through and short-circuit protection of the inverter bridge. It also integrates three amplifiers and an overvoltage comparator. DE2 communication (half-duplex, 9600 baud, 8-bit, no parity, single line communication link) is provided for driver Fault status indication, driver configuration and setting parameters, such as dead time, blanking time, overcurrent threshold and so on.

The DE2 communication link that interfaces between the microcontroller and the MCP8024 can be established by the UART controller module, and by connecting the UART receive and transmit pins to a single line DE2 communication link of the gate driver, as shown in Figure 3-2.

FIGURE 3-2: DE2 COMMUNICATION LINK



The three-phase BLDC motor gate driver, with the power module MCP8024, also integrates +5V and +12V LDO voltage regulators, capable of delivering up to 20 mA of current. The +12V LDO output from MCP8024 supplies power to the bootstrap circuit on the same chip used for driving the high side MOSFETs. The +5V LDO output is used to supply power to the amplifier circuits on the board. Pull-down resistors are added to all driver inputs to turn off MOSFETs in the absence of PWM signals. For more information on MCP8024, refer to the *"3-Phase Brushless DC (BLDC) Motor Gate Driver with Power Module"* (DS20005228) data sheet.

3.4 DC BUS VOLTAGE SENSING

On the Motor Control 10-24V Driver Board (Dual/Single), the DC bus voltage sensing network is present in both the Inverter A and Inverter B sections. These inverters can be operated from different input voltage supplies.

3.5 HALL SENSOR/QUADRATURE ENCODER INTERFACE

The BLDC/PMSM 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 the noise. The Hall sensor outputs can be interfaced with a +3.3V or +5V microcontroller. By default, the voltage divider scales down the +5V output to +3.3V. If the sensor outputs are interfaced with a +5V microcontroller, and the V_{IH} of the controller input pins is less than 3.3V, the divider has to be modified to deliver a +5V output. Circuit configurations to set sensor output voltage are provided in Table 3-1 and Table 3-2.

TABLE 3-1: OUTPUT VOLTAGE LEVEL SETTING HALL SENSOR/ QUADRATURE ENCODER INTERFACE CIRCUIT A

Signal Description	Resistor Value to Set Signal Output Voltage Level	
	3.3V (default setting)	5V
HALLA_MA (Hall Sensor A/QEA Feedback from Motor A)	R40 47 kΩ	R40 0Ω
HALLB_MA (Hall Sensor B/QEB Feedback from Motor A)	R41 47 kΩ	R41 0Ω
HALLC_MA (Hall Sensor C/INDEX Feedback from Motor A)	R42 47 kΩ	R42 0Ω
HOME_MA (QEI HOME Signal from Motor A)	R43 47 kΩ	R43 0Ω

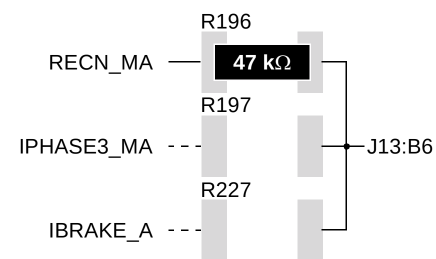
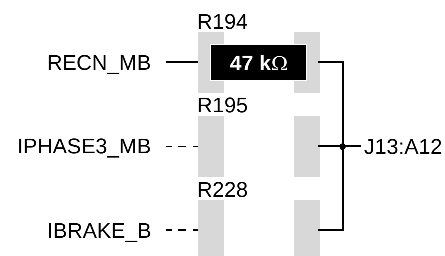
TABLE 3-2: OUTPUT VOLTAGE LEVEL SETTING HALL SENSOR/ QUADRATURE ENCODER INTERFACE CIRCUIT B

Signal Description	Resistor Value to Set Signal Output Voltage Level	
	3.3V (default setting)	5V
HALLA_MB (Hall Sensor A/QEA Feedback from Motor B)	R52 47 kΩ	R52 0Ω
HALLB_MB (Hall Sensor B/QEB Feedback from Motor B)	R53 47 kΩ	R53 0Ω
HALLC_MB (Hall Sensor C/INDEX Feedback from Motor B)	R54 47 kΩ	R54 0Ω
HOME_MB (QEI HOME Signal from Motor B)	R55 47 kΩ	R55 0Ω

3.6 BACK-EMF AND RECREATED NEUTRAL SIGNALS

The BLDC motors can be commutated by monitoring back-EMF signals. The motor back-EMF is scaled down by voltage dividers. The capacitors can be added at divider outputs to filter the noise. An additional resistor network is added to reconstruct motor neutral signals. The recreated neutral signals, RECN_MA and RECN_MB, are connected to the J13 connector pins through zero ohm resistors (board default setting). The back-EMF sensing circuits in both inverter sections are identical. Table 3-3 provides the resistor jumper setting for connecting the recreated neutral outputs to the J13 connector pins.

TABLE 3-3: RESISTOR JUMPER SETTING FOR RECREATED NEUTRAL OUTPUT SELECTION

Signal Description	Zero Ohm Resistor Jumper Setting
RECN_MA to J13:B6 To connect RECN_MA (recreated neutral output) to the B6 pin of the signal board interface connector, J13.	
RECN_MB to J13:A12 To connect RECN_MB (recreated neutral output) to the A12 pin of the signal board interface connector, J13.	

3.7 PHASE AND BUS CURRENT SENSING CIRCUITS

In the Motor Control 10-24V Driver Board (Dual/Single), shunt resistors are provided in each inverter leg to determine the amount of current flowing through the motor phases that are required to implement the field-oriented control of the PMSMs.

An additional shunt resistor is provided for sensing bus current. DC bus current information is necessary for overcurrent protection and to implement torque control of the BLDC motors. Motor phase currents can also be reconstructed from the DC bus current information by sampling currents appropriately in the PWM switching period.

A non-inverting differential amplifier is used for amplifying voltage drop across shunt resistors. The amplifier output voltage is shifted by VREF_EXT to allow positive and negative current swings. The voltage offset can be modified by a resistor divider provided in the non-inverting input of the bus current amplifiers. The Common mode and Differential mode filters are added to the op amp input pins for noise filtering. It is possible to add filters at the output of the amplifiers, if required. See **Section C.3 "Motor Current Amplifier Configuration"** for on-board amplifier gain setting and input filter details.

Note:	On the dsPIC DSC Signal Board, the VREF_EXT voltage level is configured as +1.65V or +2.5V by the PIM plugged into the board.

3.7.1 Inverter A Current Amplifiers

As shown in Figure 3-3, Phase 1, Phase 2 and the bus current shunt voltage drops are transferred to the dsPIC DSC Signal Board through connector, J13. On the dsPIC DSC Signal Board, amplifiers that are internal to the dsPIC DSC are used for amplification of Phase 1, Phase 2 and the bus current signals. The comparator that is internal to the dsPIC DSC is used for overcurrent detection. For more information, refer to the *"dsPIC® DSC Signal Board User's Guide"* (DS50002263). For dsPIC DSC internal amplifier gain setting information, refer to the *"dsPIC33EV256GM106 5V Motor Control Plug-In Module (PIM) Information Sheet"* (DS50002225) and the *"dsPIC33EP512GM710 Plug-In Module (PIM) Information Sheet for Single-Dual Motor Control"* (DS50002216). Please check the Microchip web site (www.microchip.com) for future Plug-In Module (PIM) Information Sheets.

The Phase 3 current can be amplified using the operational amplifier, MCP6021, provided in the Inverter A section. This amplifier can also be configured to sense any phase current or bus current by populating the appropriate input resistors. The output of this amplifier can be connected to the J13 pin through the zero ohm jumper resistors. The resistor jumper setting is provided in Table 3-4.

3.7.2 Inverter B Current Amplifiers

As shown in Figure 3-4, operational amplifiers, U9-A, U9-B and U9-C that are internal to MCP8024, are used for Phase 1, Phase 2 and bus current amplification. IOUT1 of the MCP8024 is also connected to an internal overcurrent comparator and generates a Fault output at the ILIMIT_OUT pin of the driver. The Motor Control 10-24V Driver Board (Dual/Single) exploits this driver feature to generate the Inverter B overcurrent Fault, known as FAULT_MB. The MCP8024 amplifier, U9-C (see Figure A-1), can be configured to sense third phase current instead of DC bus current by populating the input resistors appropriately.

The operational amplifier, MCP6021, is added for Phase 3 current amplification. This amplifier can be configured to sense any phase current or bus current by populating the appropriate input resistors. The output of this amplifier can be connected to the J13 pins through zero ohm jumper resistors. The resistor jumper setting is provided in Table 3-5.

TABLE 3-4: RESISTOR JUMPER FOR INVERTER A THIRD PHASE CURRENT OUTPUT SELECTION

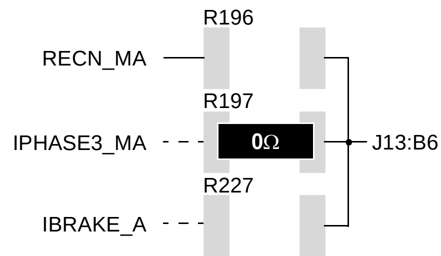
Signal Description	Zero Ohm Resistor Jumper Setting
IPHASE3_MA to J13:B6 To connect IPHASE3_MA (output of phase current sensing amplifier, U3) to the B6 pin of the signal board interface connector, J13.	

TABLE 3-5: RESISTOR JUMPER FOR INVERTER B THIRD PHASE CURRENT OUTPUT SELECTION

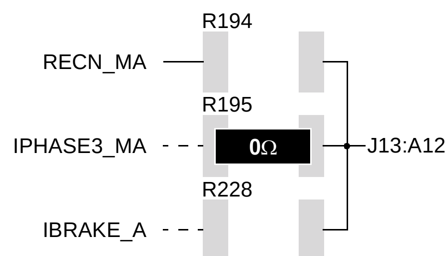
Signal Description	Zero Ohm Resistor Jumper Setting
IPHASE3_MB to J13:A12 To connect IPHASE3_MB (output of phase current sensing amplifier, U2) to the A12 pin of the signal board interface connector, J13.	

FIGURE 3-3: INVERTER A CURRENT SENSING CIRCUIT ARCHITECTURE

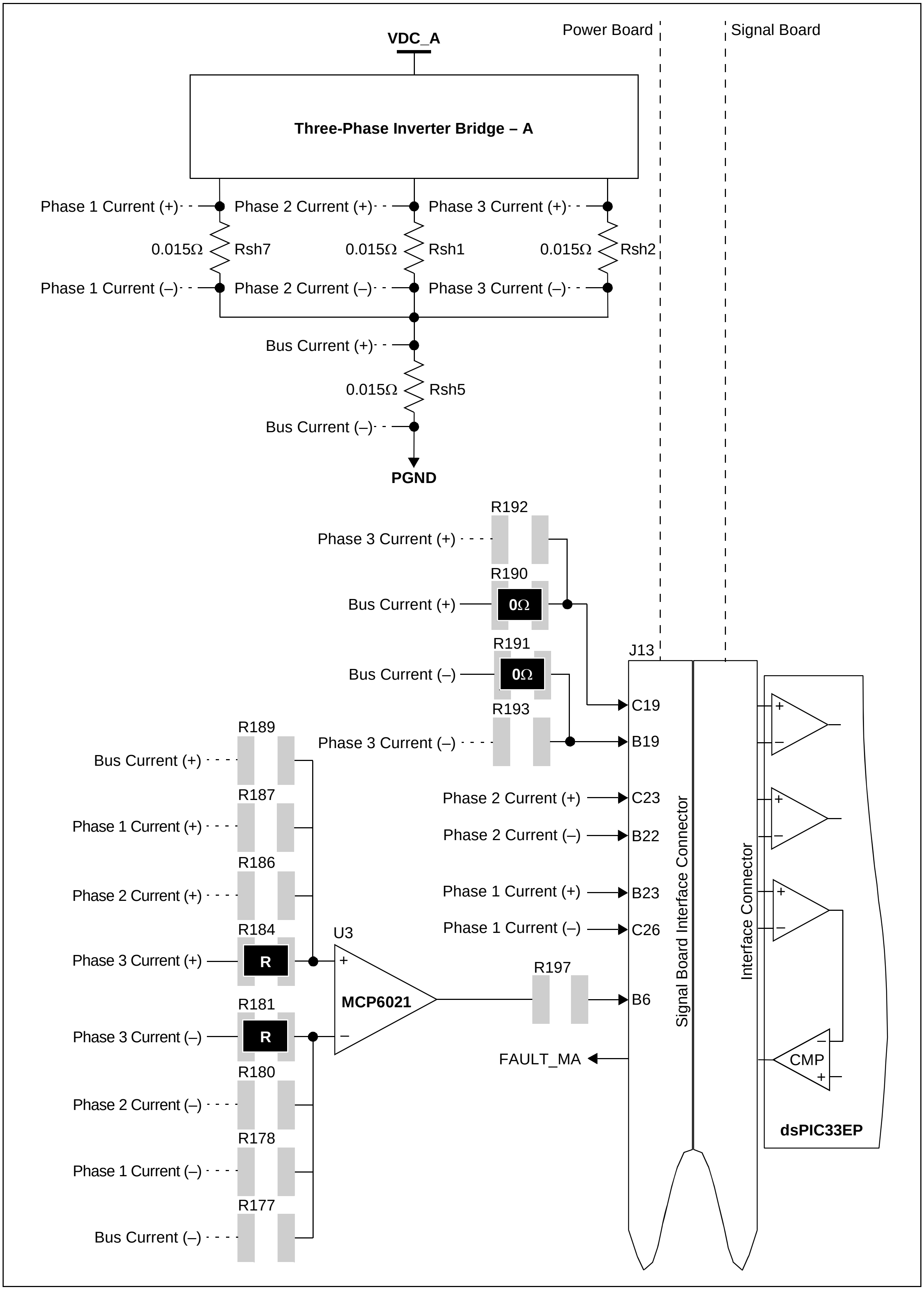
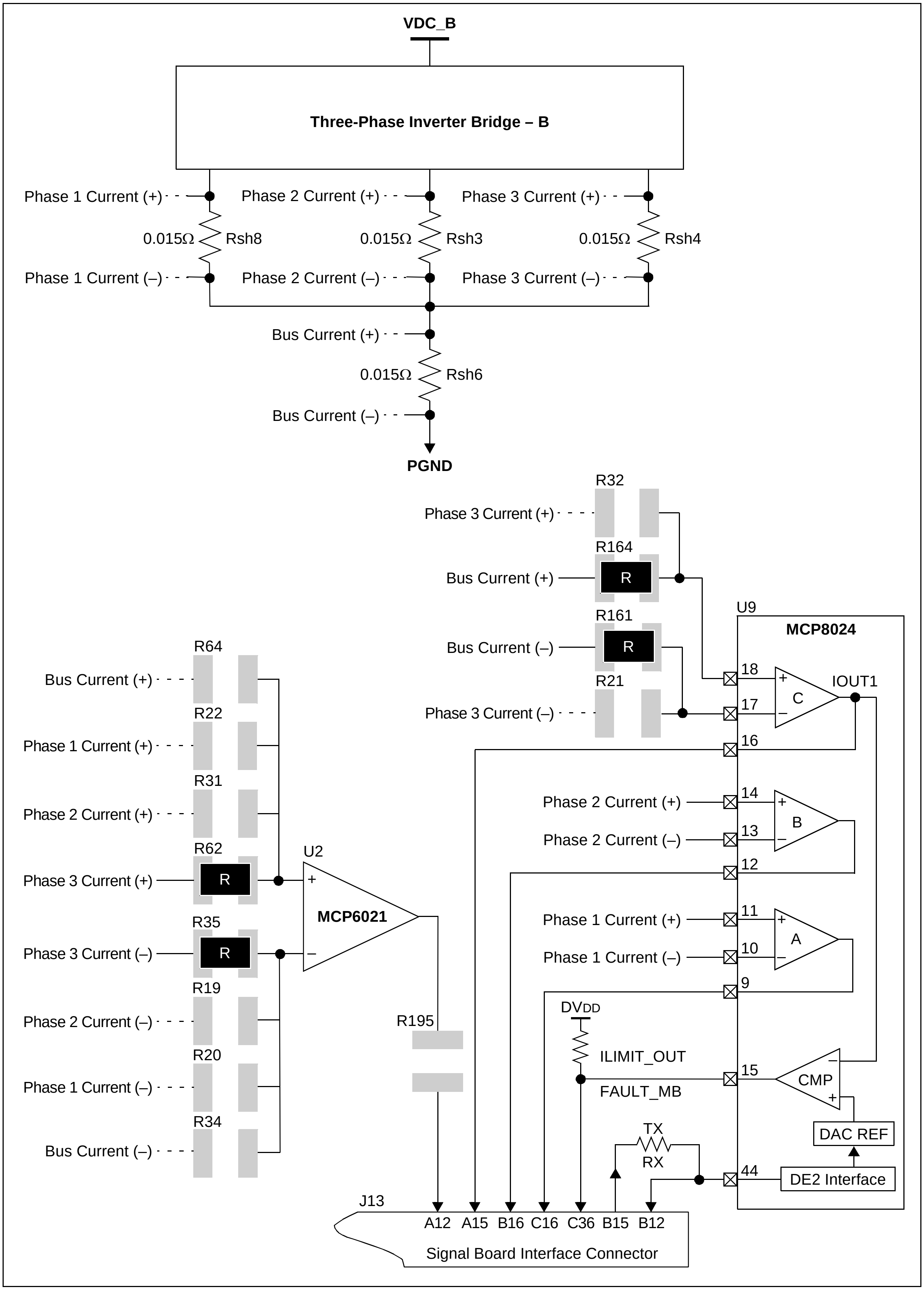


FIGURE 3-4: INVERTER B CURRENT SENSING CIRCUIT ARCHITECTURE



3.8 FAULT GENERATION LOGIC CIRCUIT

This section describes the Fault outputs on the Motor Control 10-24V Driver Board (Dual/Single). There are three Fault outputs: Inverter A Overcurrent Fault (FAULT_MA), Inverter B Overcurrent Fault (FAULT_MB) and combined Fault (Fault_AB). All Faults are active-low outputs.

3.8.1 Inverter A Overcurrent Fault (FAULT_MA)

The Inverter A Overcurrent Fault output, FAULT_MA, is generated on the dsPIC DSC Signal Board and is transferred to the Motor Control 10-24V Driver Board (Dual/Single) through connector, J13. On the dsPIC DSC Signal Board, the comparator internal to the dsPIC DSC is used to generate the Overcurrent Fault FAULT_MA.

3.8.2 Inverter B Overcurrent Fault (FAULT_MB)

The Inverter B Overcurrent Fault, FAULT_MB, is generated by the comparator internal to the gate driver, MCP8024 (U9). The output of the operational amplifier (U9-C), configured to amplify bus current, is connected internally to the inverting input of the comparator. The non-inverting input of the comparator threshold may be set with a SET_ILIMIT command from the microcontroller to MCP8024 through the DE2 communications link. For more information on DE2 communication and message protocol, refer to the *"3-Phase Brushless DC (BLDC) Motor Gate Driver with Power Module"* (DS20005228A) data sheet.

3.8.3 Combined Fault (FAULT_AB)

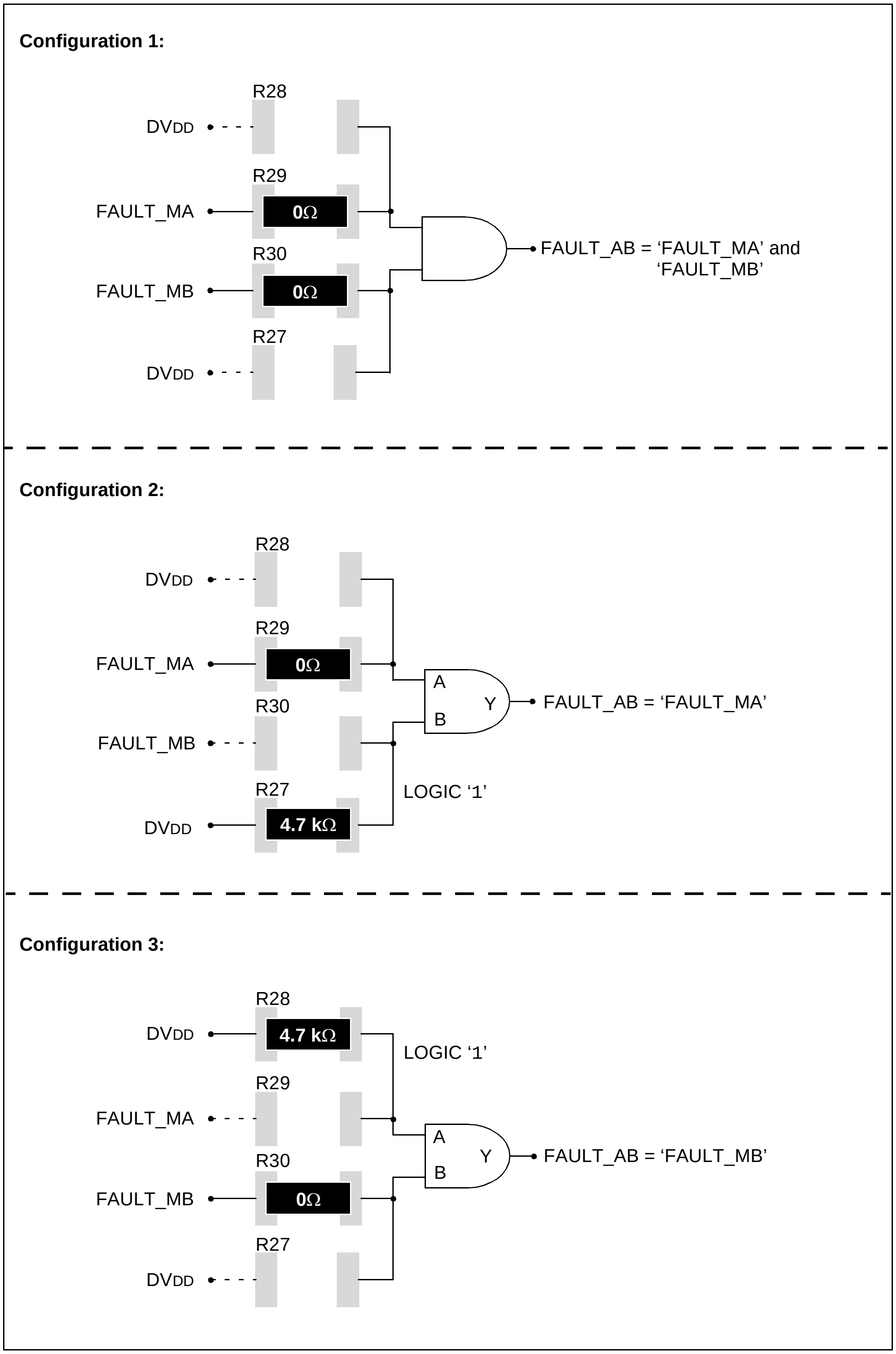
The Fault generation circuit performs logical and Overcurrent Faults, FAULT_MA and FAULT_MB, to generate a single Fault output called FAULT_AB. Table 3-6 provides the truth table of the Fault generation logic circuit.

TABLE 3-6: FAULT GENERATION LOGIC TRUTH TABLE

FAULT_MA	FAULT_MB	FAULT_AB
0	0	0
0	1	0
0	1	0
1	1	1

Fault inputs, FAULT_MA or FAULT_MB, can be transferred to the Fault logic circuit output, FAULT_AB, by setting the other input at logic '1'. Figure 3-5 shows three possible configurations of Fault generation logic.

FIGURE 3-5: FAULT GENERATION LOGIC CIRCUIT CONFIGURATIONS



3.9 BRAKE CIRCUIT

In motor control applications, during deceleration or periods of swift reversal, the motor can work as a generator, feeding energy back into the motor drive. When the motor drive does not provide four quadrant operation, and the braking power is not dissipated, the DC link voltage will increase and cause an overvoltage condition. During regeneration or braking, a dynamic brake (brake switch in-series with a brake resistor connected across the DC bus) can be employed to absorb this excess energy, thereby ensuring that the DC link voltage is maintained at a safe operating level.

In the Motor Control 10-24V Driver Board (Dual/Single), dynamic brake circuits are provided for both the inverters. As per the application requirement, the user can add a brake resistor to the respective brake circuits using the on-board terminals. The diode is provided across the brake resistor terminals to free wheel current due to the inductance of the brake resistor.

The brake switches can handle 10A (RMS) @ +25ºC in the operating voltage range. The value of the resistor should be chosen such that the current is less than 10A at peak DC bus voltage.

By default, the Braking Chopper Circuits are disabled by pull-down resistors connected as inputs of the MOSFET driver, TC1412N. The brake switch can be controlled either through a hardware overvoltage detection comparator with hysteresis or through software brake enable. Figure 3-6 shows the brake circuit block diagram. Resistors to select the brake enable signal are provided in Table 3-7.

FIGURE 3-6: BRAKE CIRCUIT BLOCK DIAGRAM

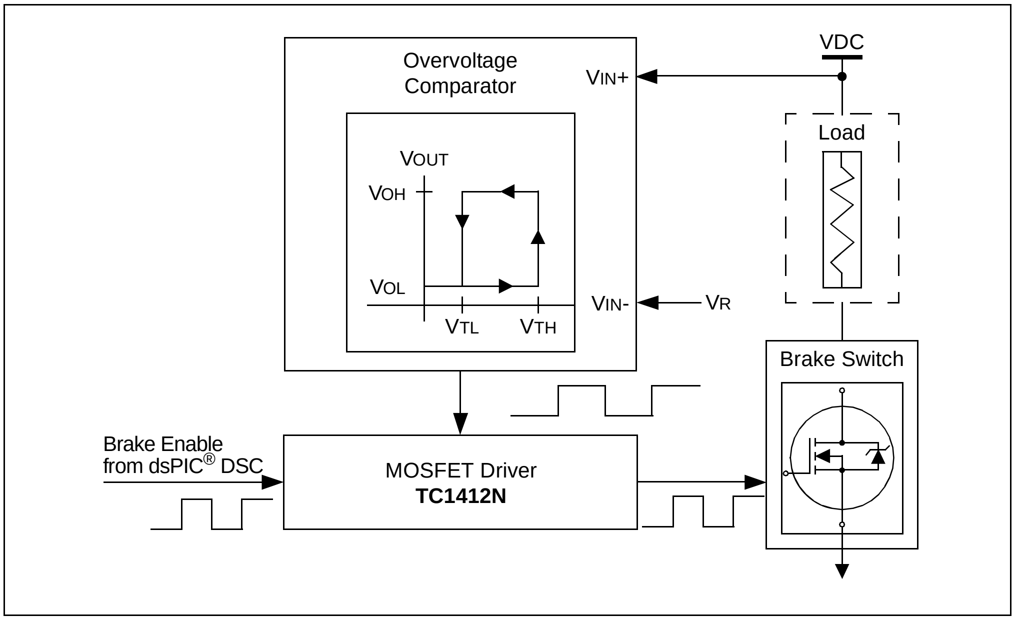


TABLE 3-7: BRAKE ENABLE SIGNAL CONFIGURATION RESISTORS

Brake Circuit	Brake Enable Signal		
	Hardware Brake Enable	**Firmware Brake Enable**	**Disable Brake Circuit (default setting)**
Brake Circuit – A	R232 0Ω R238 R239	R232 R238 0Ω R239	R232 R238 R239 10 kΩ
Brake Circuit – B	R248 0Ω R254 R255	R248 R254 0Ω R255	R248 R254 R255 10 kΩ

3.9.1 Firmware Brake Enable Signal (BRAKE_EN_A or BRAKE_EN_B):

The user firmware has to monitor the DC bus voltage and the brake enable signal to be made active if the voltage exceeds the predefined threshold level. The brake enable signal is turned off when the voltage reaches a safe inverter operating voltage. The firmware brake enable signal can be Pulse-Width Modulated at an appropriate frequency for brake switch control. The dsPIC DSC output compare module can be used for generating PWMs for controlling the brake switch.

3.9.2 Hardware Brake Enable Circuit

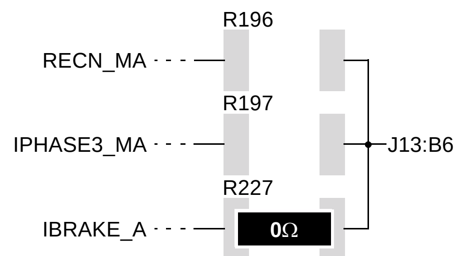
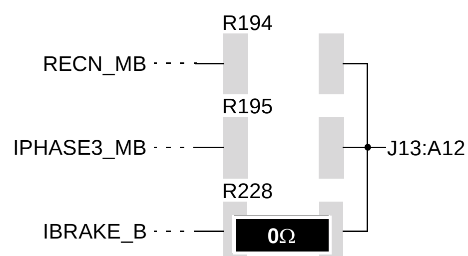
The non-inverting comparator circuit, MCP65R41, is provided on the board to generate a hardware brake enable signal and to control dynamic braking without firmware intervention. A voltage divider circuit is provided to monitor the bus voltage. The output of the DC bus voltage divider is fed to the non-inverting input of the comparator. The inverting input of the comparator is generated by dividing the Comparator Voltage Reference (VREF) output, 2.4V.

The hysteresis ensures that false triggering does not occur due to noise spikes and ripple voltage present on the DC bus voltage. The comparator hysteresis is configured externally by the resistors. There may be variation in the trip levels due to component tolerance and variation in comparator operating voltage. See **Section C.5 "Hardware Brake Enable Circuit Configuration"** for equations to calculate comparator hysteresis.

3.9.3 Brake Current Sensing Amplifier

An MCP6021 device-based, non-inverting differential amplifier is added to sense the current through the brake resistor. A shunt resistor is added in-series with the brake switch for sensing the current. The voltage across the shunt resistor is connected to the differential amplifier inputs. See **Section C.4 "Brake Current Amplifier Configuration"** for brake current amplifier gain setting. The brake current amplifier output can be connected to an analog pin of the controller through connector, J13, by configuring the resistor jumpers. The resistor jumper setting is shown in Table 3-8.

TABLE 3-8: RESISTOR JUMPER TO SELECT BRAKE CURRENT OUTPUT SIGNAL

Signal Description	Zero Ohm Resistor Jumper Setting
IBRAKE_A to J13:B6 To connect IBRAKE_A (output of brake current sensing amplifier, U6) to the B6 pin of the signal board interface connector, J13.	
IBRAKE_B to J13:A12 To connect IBRAKE_B (output of brake current sensing amplifier, U12) to the A12 pin of the signal board interface connector, J13.	

3.10 POWER SUPPLY

The Motor Control 10-24V Driver Board (Dual/Single) receives power through the connectors, J5 or J8. The same voltage is transferred to the signal board through connector, J13.

Each inverter bridge and its associated circuits can be powered independently, allowing each power stage to operate at a different voltage level. Inverter A can be powered up by a voltage source connected to connector, J1, if a wire jumper between TP3-TP7 is disconnected. Similarly, Inverter B can be powered up by a different voltage source connected to connector, J6, if a wire jumper between TP7-TP8 is disconnected. See **Section 2.3.1 “Power Supply Connectors (J5, J8, J1 and J6)”** for configuration details.

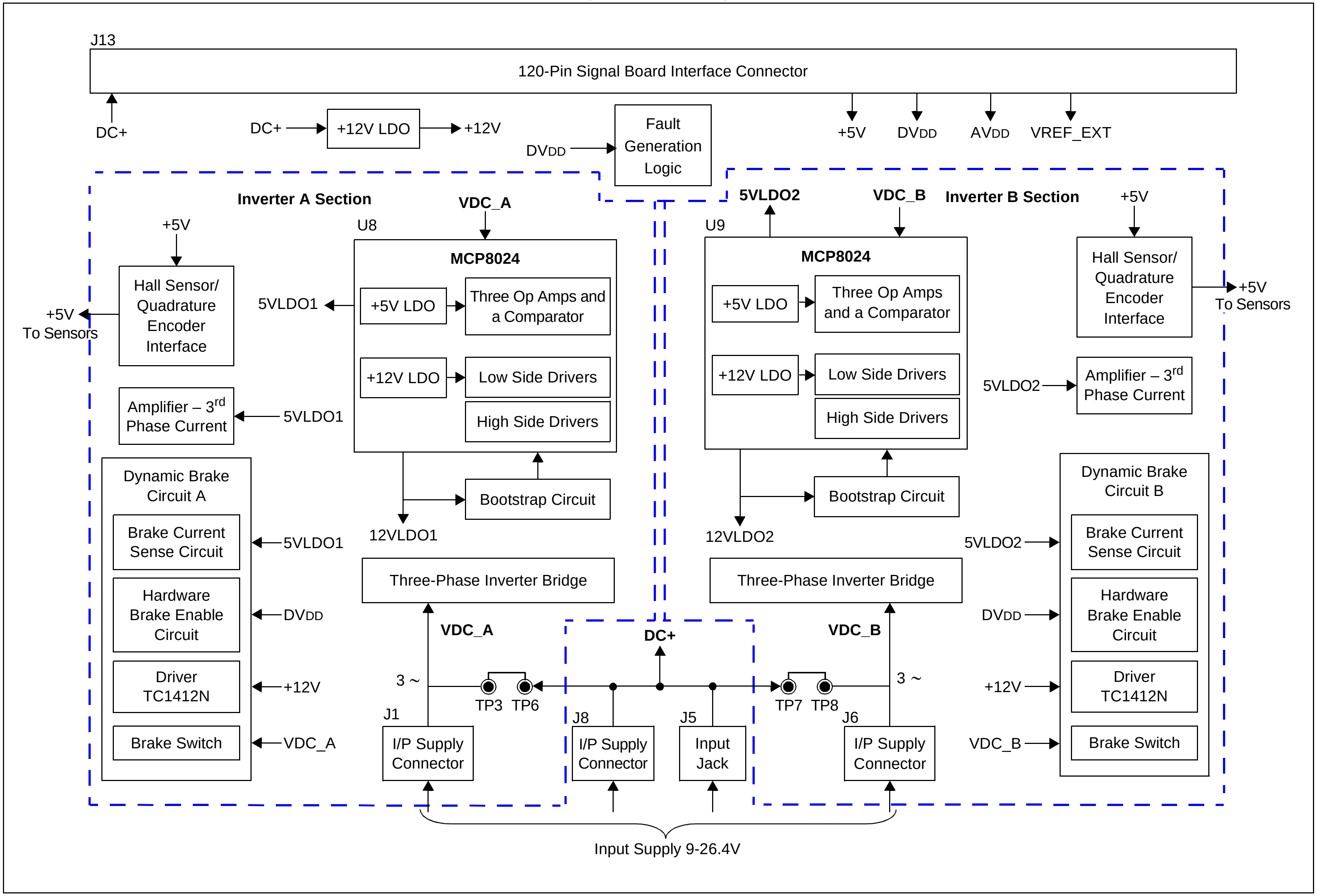
Each MCP8024 gate driver is operated from the voltage supply that is powering the respective inverter bridge. The supply for biasing the low side gate drive and the boot-strap circuit for the high side gate drive is regulated by the +12V LDO, internal to MCP8024. The output of the +5V LDO, internal to the gate drivers, U8 and U9, supplies power to the operational amplifier, MCP6021, in the respective inverter sections. The low dropout voltage regulators, +5V and +12V, internal to MCP8024, are capable of delivering current up to 20 mA. For more information on the specifications of the +5V or +12V LDO that are internal to MCP8024 and the bootstrap circuit requirements, refer to the *“3-Phase Brushless DC (BLDC) Motor Gate Driver with Power Module”* (DS20005228) data sheet.

The signal board provides a +5V DC output for powering Hall sensors or encoders. The DVDD (+3.3V/+5V) for powering the Fault generation logic for the overvoltage detection comparator circuit and the hardware brake enable is provided through connector, J13. The voltage reference (VREF_EXT) for the operational amplifier output offset is also provided by the signal board through connector, J13.

The on-board +12V LDO (U11) supplies power to the MOSFET driver, TC1412N (U5 and U10), circuitry. The same +12V LDO output is also available through connector, J16, for powering the external circuits.

Figure 3-7 shows the Motor Control 10-24V Driver Board (Dual/Single) power supply architecture.

FIGURE 3-7: MOTOR CONTROL 10-24V DRIVER BOARD (DUAL/SINGLE) POWER SUPPLY ARCHITECTURE



Appendix A. Board Schematics and Layout

A.1 INTRODUCTION

This chapter provides detailed technical information on the Motor Control 10-24V Driver Board (Dual/Single).

A.2 BOARD SCHEMATICS AND LAYOUT

The following are the Motor Control 10-24V Driver Board (Dual/Single) schematics:

- Figure A-1: Motor Control 10-24V Driver Board (Dual/Single) Schematics (Sheet 1 of 3)
- Figure A-2: Motor Control 10-24V Driver Board (Dual/Single) Schematics (Sheet 2 of 3)
- Figure A-3: Motor Control 10-24V Driver Board (Dual/Single) Schematics (Sheet 3 of 3)
- Figure A-4: Motor Control 10-24V Driver Board (Dual/Single) Layout

FIGURE A-1: MOTOR CONTROL 10-24V DRIVER BOARD (DUAL/SINGLE) SCHEMATIC REVISION 1.0 (SHEET 1 OF 3)

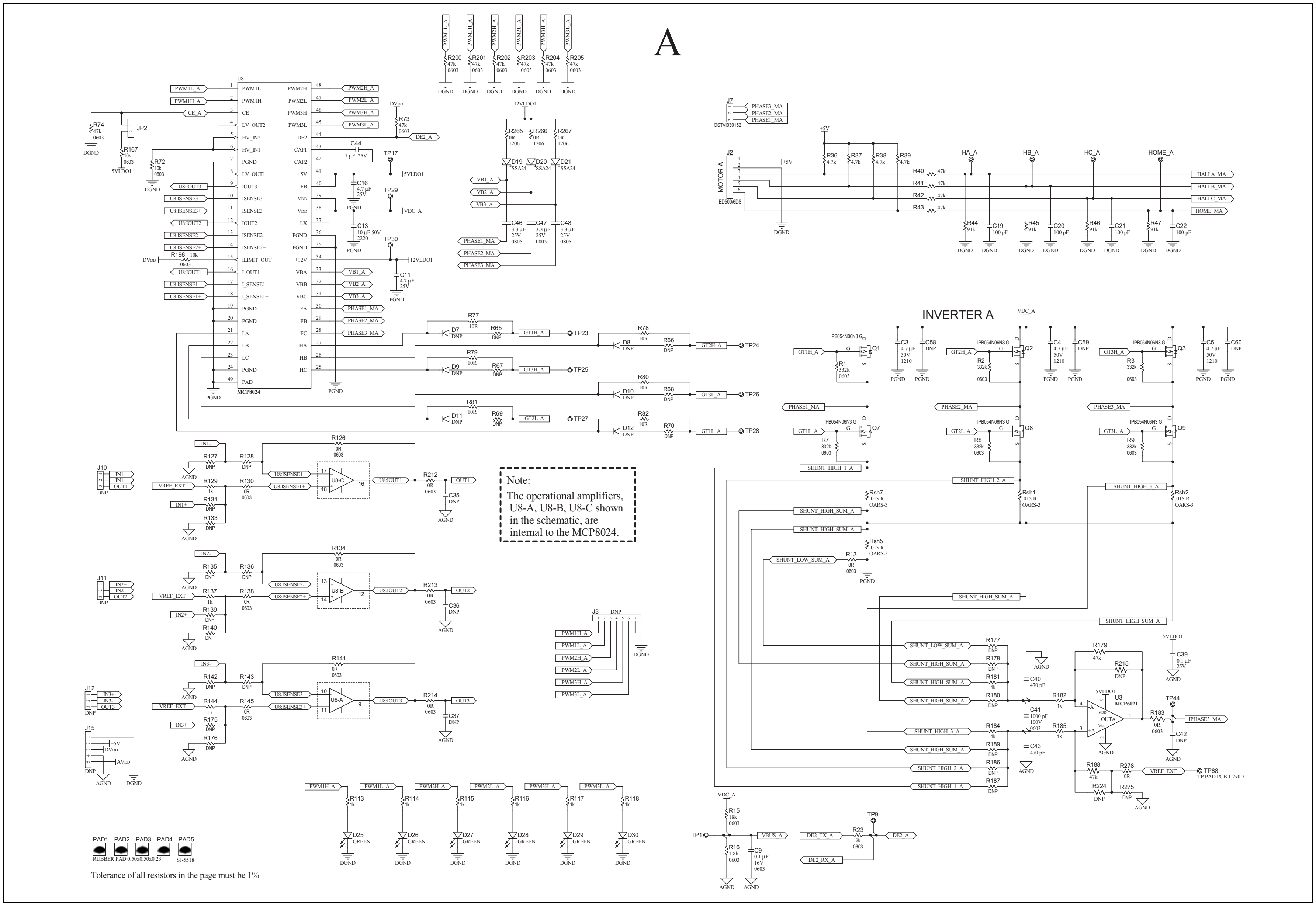


FIGURE A-2: MOTOR CONTROL 10-24V DRIVER BOARD (DUAL/SINGLE) SCHEMATIC REVISION 1.0 (SHEET 2 OF 3)

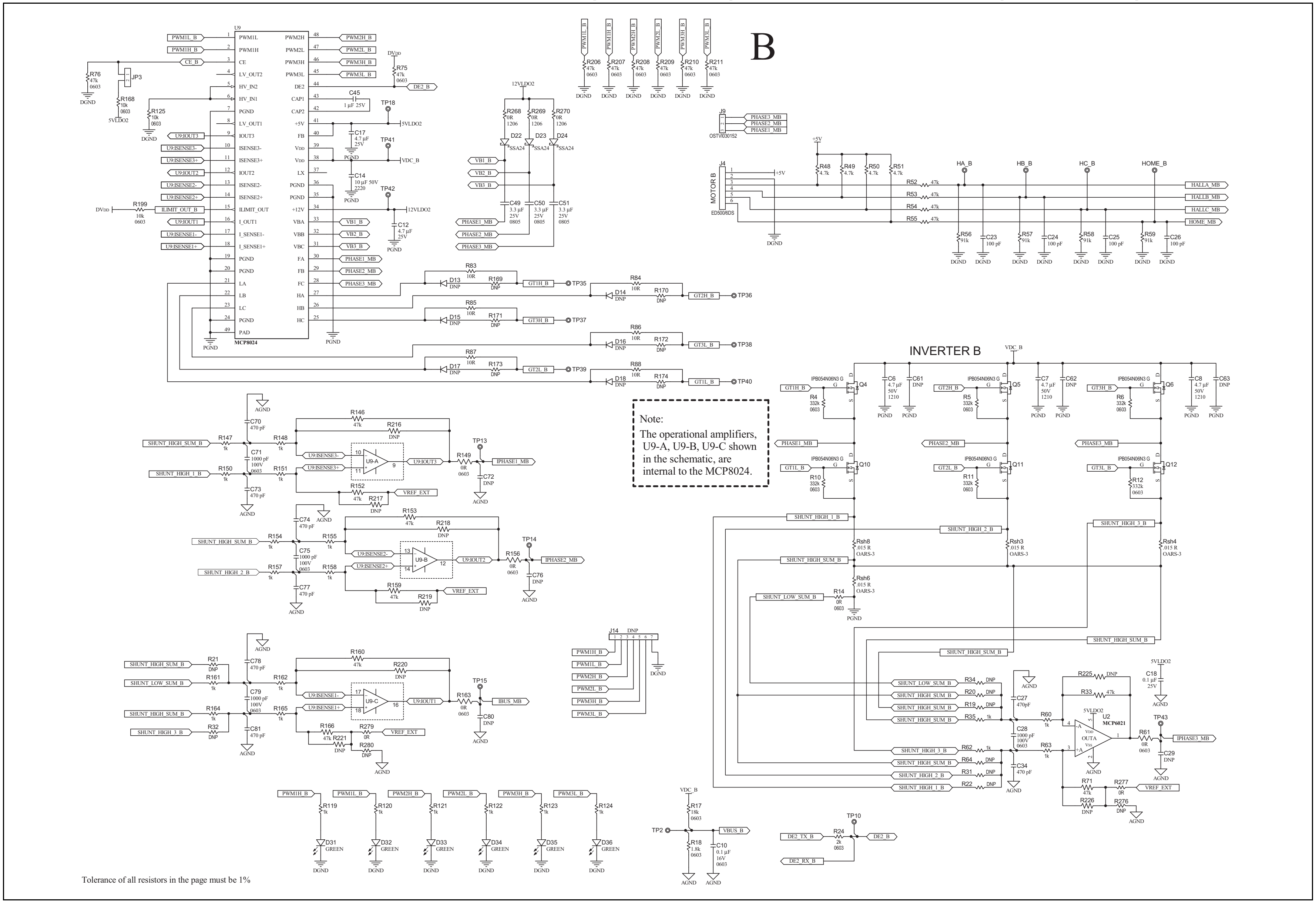


FIGURE A-3: MOTOR CONTROL 10-24V DRIVER BOARD (DUAL/SINGLE) SCHEMATIC REVISION 1.0 (SHEET 3 OF 3)

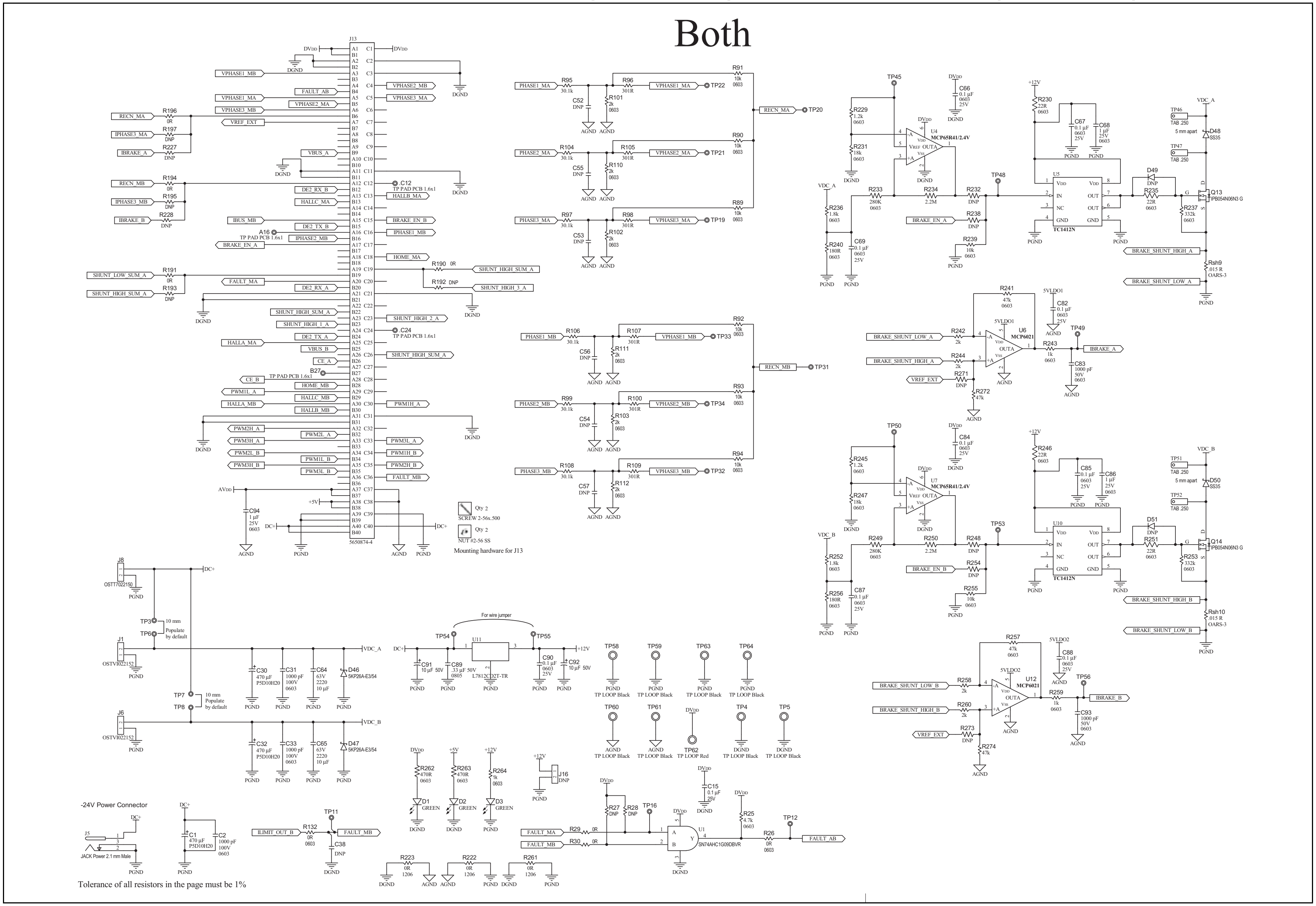
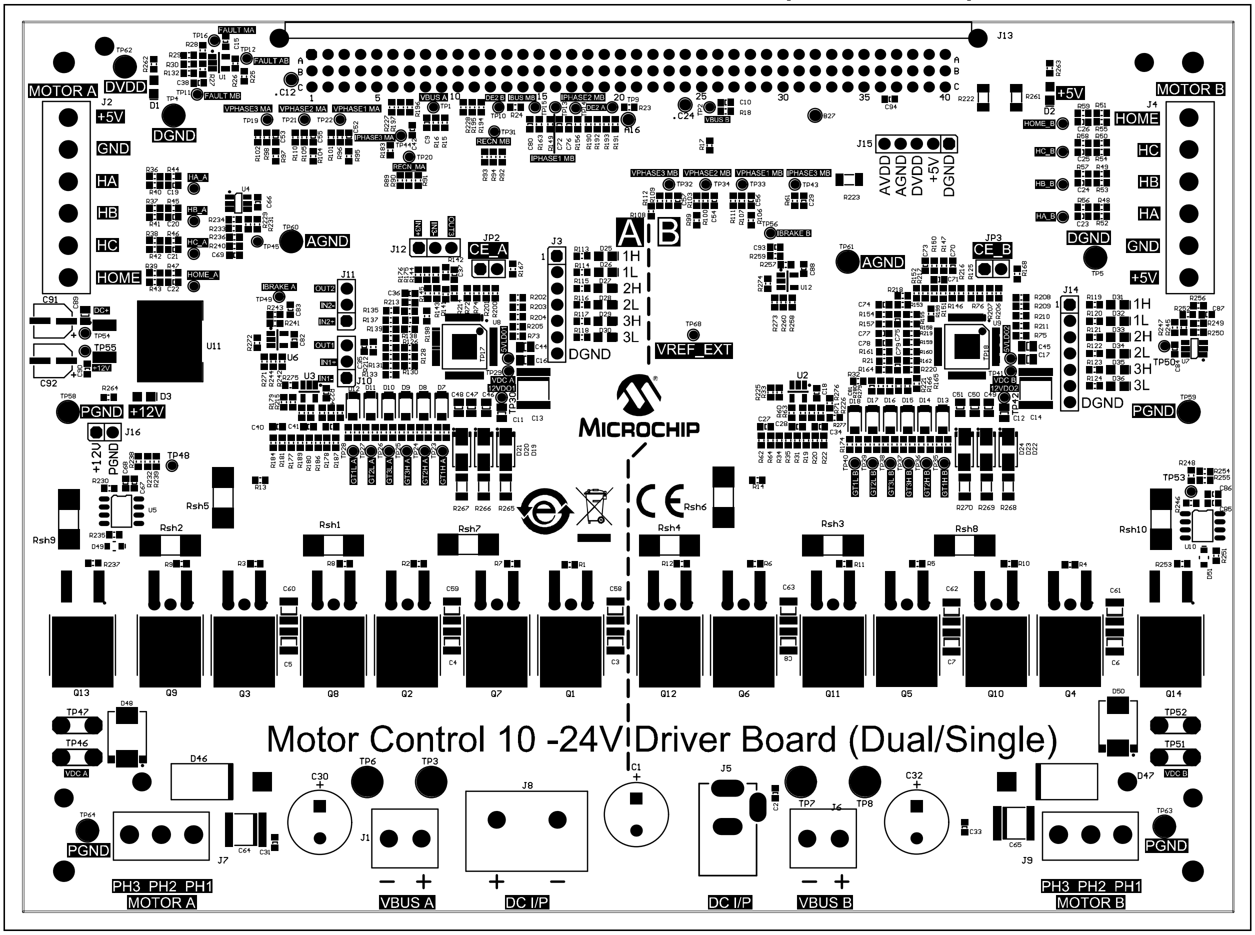


FIGURE A-4: MOTOR CONTROL 10-24V DRIVER BOARD (DUAL/SINGLE) LAYOUT



NOTES:

Appendix B. Electrical Specifications

B.1 INTRODUCTION

This chapter provides the electrical specifications for the Motor Control 10-24V Driver Board (Dual/Single) (see Table B-1).

TABLE B-1: ELECTRICAL SPECIFICATIONS

Parameter	Operating Range
Input DC Voltage	10-24V ±10% (9-26.4V)
Maximum Input Current through Connector J5	2.5A
Maximum Input Current through Connector J8	30A
Maximum Input Current through Connector J1 or J6	15A
Continuous Output Current per Phase @ +25ºC	10A (RMS)
Brake Switch Continuous Current @ +25ºC	10A (RMS)

At ambient temperature (+25ºC), the board remains within the thermal range when operating with continuous output currents of up to 10A (RMS) at the rated voltage.

NOTES:

Appendix C. Component Selection

C.1 INTRODUCTION

This chapter provides detailed information on the component selection of the motor current amplifier, brake current amplifier and the hardware brake enable circuit.

C.2 HIGHLIGHTS

This chapter covers the following topics:

- Motor Current Amplifier Configuration
- Brake Current Amplifier Configuration
- Hardware Brake Enable Circuit Configuration

C.3 MOTOR CURRENT AMPLIFIER CONFIGURATION

An amplifier circuit for sensing the motor currents on the Motor Control 10-24V Driver Board (Dual/Single), Inverter A and Inverter B sections, is shown in Figure C-1.

FIGURE C-1: MOTOR CURRENT SENSING AMPLIFIER

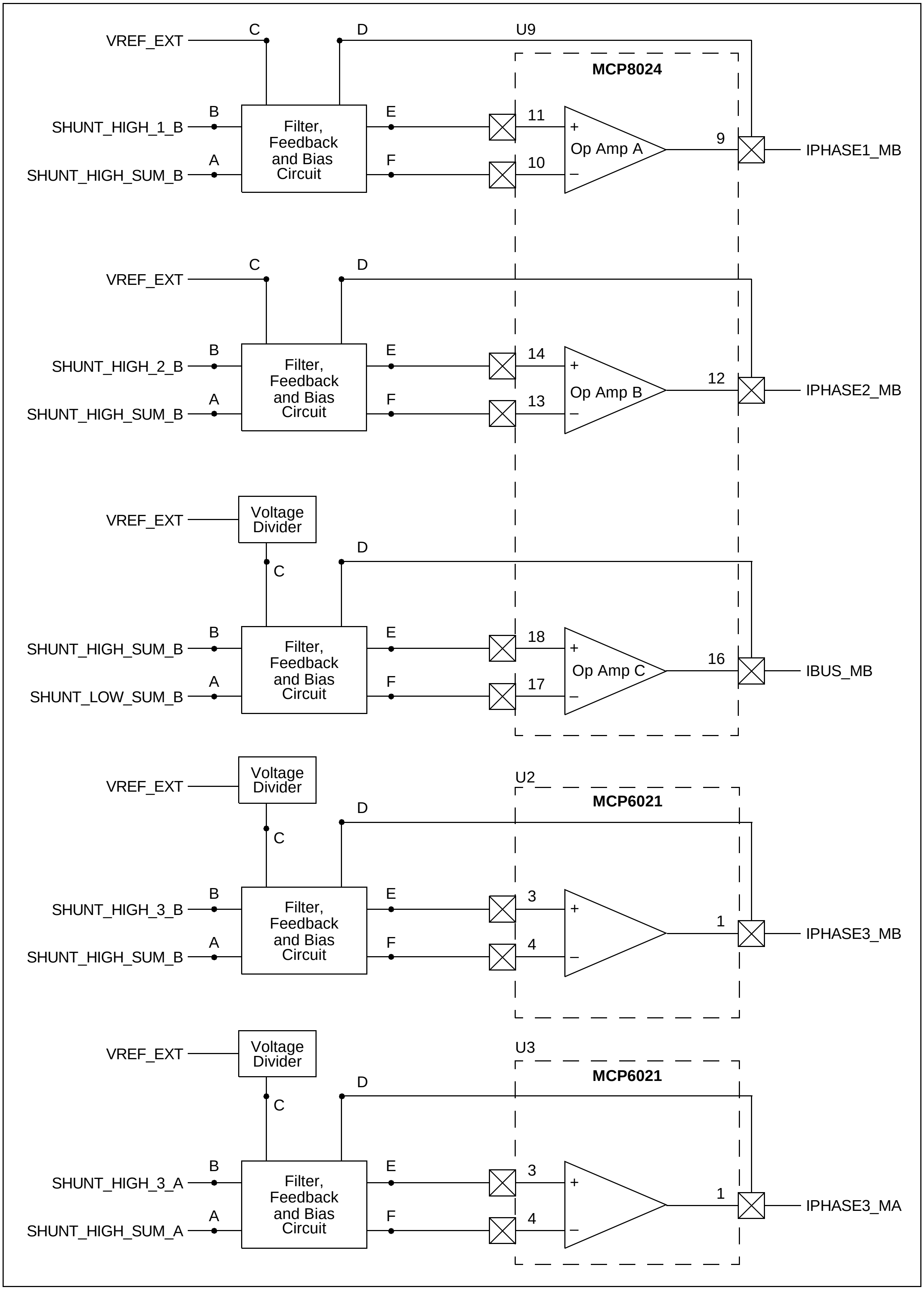
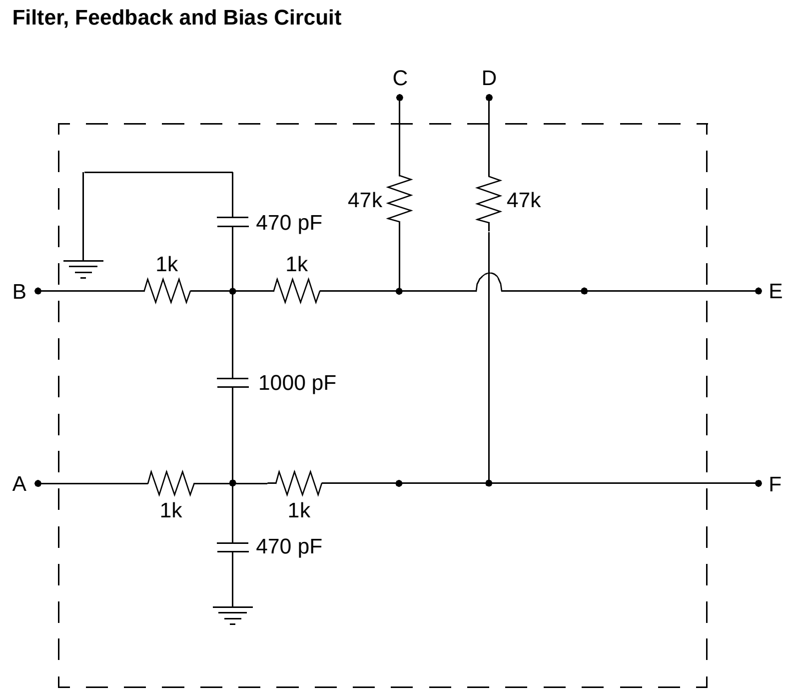


Figure C-2 shows the amplifier gain setting.

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

$$Differential\ Amplifier\ Gain = \frac{47\ k\Omega}{2 \times 1\ k\Omega} = 23.5$$

EQUATION C-2: CUTOFF FREQUENCY DIFFERENTIAL-MODE FILTER

$$Differential\ mode\ f_{-3dB} \cong \frac{1}{2\pi(2 \times 1\ k\Omega)\left(\frac{470\ pF}{2} + 1000\ pF\right)} \cong 65\ kHz$$

EQUATION C-3: CUTOFF FREQUENCY COMMON-MODE FILTER

$$Common\ mode\ f_{-3dB} \cong \frac{1}{2\pi(1\ k\Omega)(470\ pF)} \cong 340\ kHz$$

C.4 BRAKE CURRENT AMPLIFIER CONFIGURATION

Figure C-3 shows an amplifier circuit for sensing current flow through brake switches in the Motor Control 10-24V Driver Board (Dual/Single). Figure C-4 shows the brake current amplifier configuration.

FIGURE C-3: BRAKE CURRENT SENSING AMPLIFIER

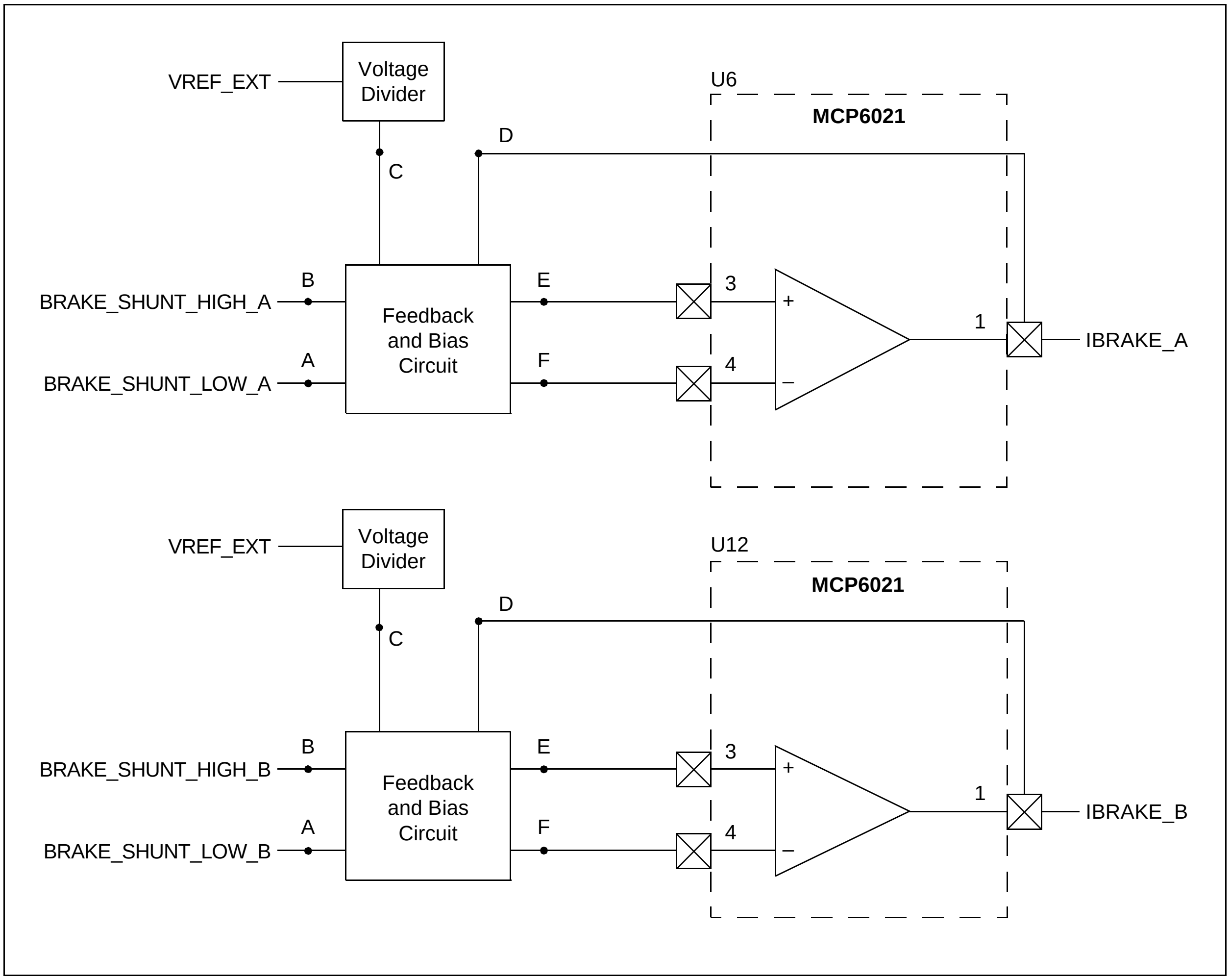
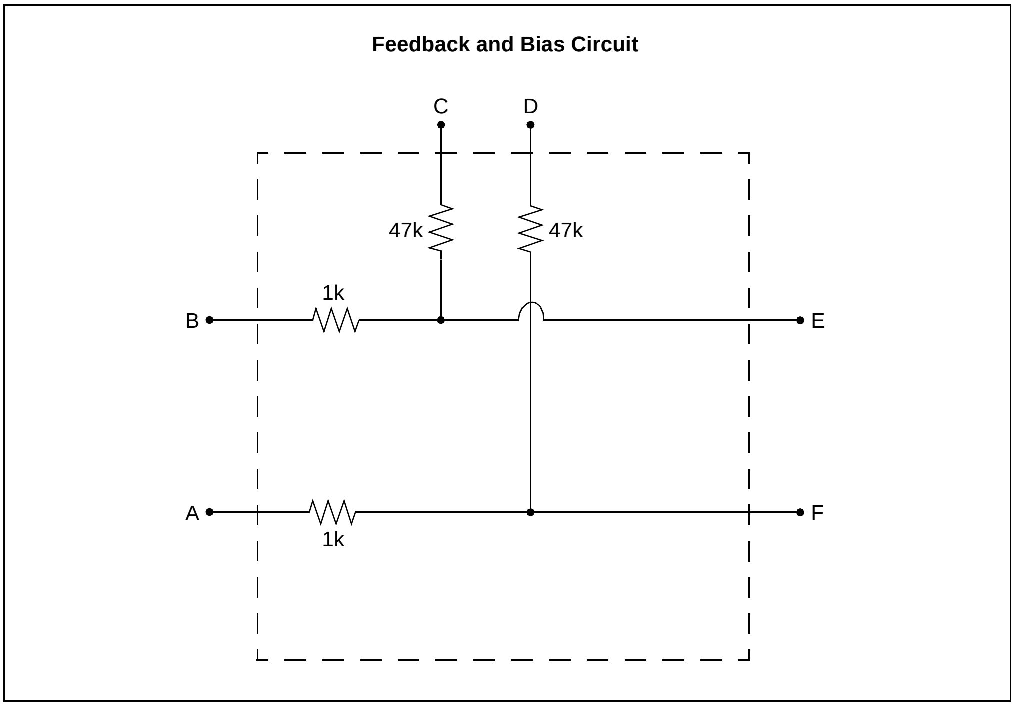


FIGURE C-4: BRAKE CURRENT AMPLIFIER CONFIGURATION



EQUATION C-4: AMPLIFIER GAIN

$$Differential\ Amplifier\ Gain = \frac{47\ k\Omega}{2\ k\Omega} = 23.5$$

C.5 HARDWARE BRAKE ENABLE CIRCUIT CONFIGURATION

Figure C-5 shows the hardware brake enable circuit comparator with hysteresis in the Motor Control 10-24V Driver Board (Dual/Single).

FIGURE C-5: HARDWARE BRAKE ENABLE CIRCUIT COMPARATOR WITH HYSTERESIS

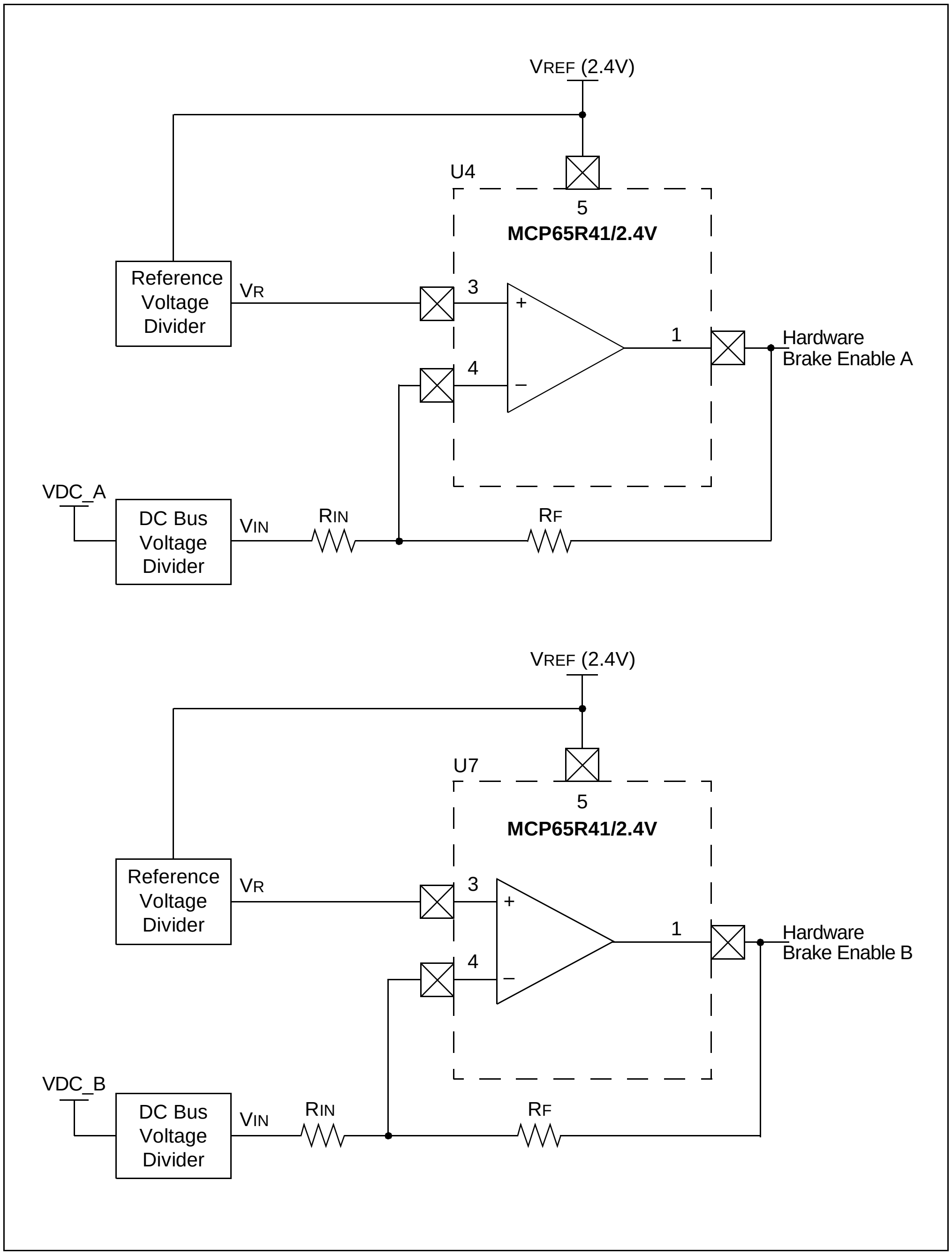
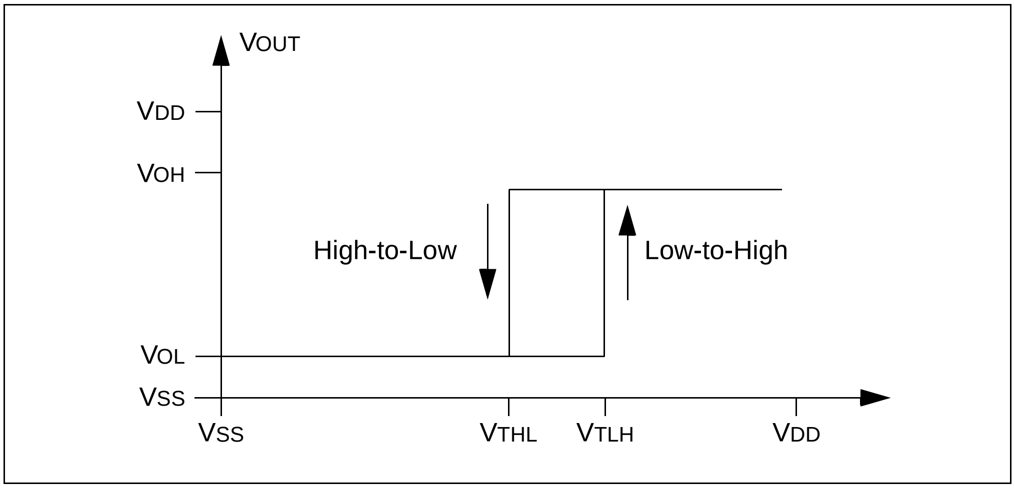


Figure C-6 shows the hysteresis diagram of the non-inverting comparator.

FIGURE C-6: HYSTERESIS DIAGRAM – NON-INVERTING COMPARATOR



Equation C-5 determines the input threshold voltages.

EQUATION C-5: INPUT THRESHOLD VOLTAGES

$$V_{TLH} = V_R\left(1 + \frac{R_{IN}}{R_F}\right) - V_{OL}\left(\frac{R_{IN}}{R_F}\right)$$

$$V_{THL} = V_R\left(1 + \frac{R_{IN}}{R_F}\right) - V_{OL}\left(\frac{R_{IN}}{R_F}\right)$$

Where:

V_{OL} is the saturation voltage in the low state at the comparator output.

V_{OH} is the saturation voltage in the high state at the comparator output.

V_{TLH} is the threshold voltage from low-to-high.

V_{THL} is the threshold voltage from high-to-low.

V_R is the comparator reference input voltage.

Equation C-6 determines R_F, R_{IN} and V_R from the threshold voltage.

EQUATION C-6: DETERMINING R_F, R_{IN} AND V_R FROM THRESHOLD VOLTAGE

$$V_{TRIP} = \frac{V_{TLH} + V_{THL}}{2}$$

$$\frac{R_F}{R_{IN}} = \frac{V_{OH} + V_{OL}}{V_{TLH} - V_{THL}}$$

$$V_R = \frac{R_{IN(V_{OH} + V_{OL})}}{2(R_{IN} + R_F)} + \frac{R_F}{(R_{IN} + R_F)} V_{TRIP}$$

Where:

V_{TRIP} is the average trip voltage at the middle of the comparator hysteresis.

C.5.1 Setting Trip Voltage

The example calculations to set the DC bus upper and lower trip points, DC Bus Voltage Low-to-High (V_{DCLH}) at 27.5V and DC Bus Voltage High-to-Low (V_{DCHL}) at 23.5V for the hardware brake enable circuit in the Motor Control 10-24V Driver Board (Dual/Single) are shown in Equation C-7. The comparator supply voltage is 3.3V, the DC bus voltage divider circuit ratio is 11, V_{OH} comparator is 3.1V and V_{OL} comparator is 0.2V.

The trip voltages scaled by the DC bus voltage divider circuit ratio (V_{TLH} and V_{THL}) can be calculated as shown in Equation C-8.

EQUATION C-7: THRESHOLD VOLTAGE CALCULATIONS

$$V_{TLH} = \frac{27.5}{11} = 2.5V$$

$$V_{THL} = \frac{23.5}{11} = 2.136V$$

From V_{TLH} and V_{THL}, the middle of the hysteresis or average Trip Voltage (V_{TRIP}) is calculated as shown in Equation C-8.

EQUATION C-8: CALCULATION FOR AVERAGE TRIP VOLTAGE

$$V_{TRIP} = \frac{(2.5V + 2.136V)}{2} = 2.318V$$

From V_{OH}, V_{OL}, V_{TLH} and V_{THL}, the hysteresis setting resistor ratio can be determined. By selecting one resistor value, the other resistor value can be calculated as in Equation C-9.

EQUATION C-9: HYSTERESIS SETTING RESISTOR RATIO VALUE

$$\frac{R_F}{R_{IN}} = \frac{(3.1V - 0.2V)}{(2.5V - 2.136V)} = 7.967$$

$$If\ R_{IN}\ is\ 280\ k\Omega$$

$$R_F = 7.967 \times 280\ k\Omega = 2230.76\ k\Omega \cong 2200\ k\Omega$$

After calculating the hysteresis setting resistor values, the Comparator Reference Voltage (V_R) input can be calculated as in Equation C-10.

EQUATION C-10: COMPARATOR REFERENCE (V_R) INPUT CALCULATION

$$V_R = \frac{280\ k\Omega(3.1V + 0.2V)}{2^*(280\ k\Omega + 2200\ k\Omega)} + \frac{2200\ k\Omega}{(280\ k\Omega + 2200\ k\Omega)} \times 2.318$$

$$= 0.186V + 2.056V = 2.24V$$

The Comparator Reference Voltage (V_R) input is generated by the voltage divider circuit supplied by the Comparator Reference Voltage (V_{REF}) output at 2.4V.

This voltage divider ratio can be calculated as, 2.4V/2.242V = 1.07.

Then, the voltage divider resistors can be determined:
If R2 = 18 kΩ, then R1 =18 kΩ × 1.07 = 1.2 kΩ.

C.6 HARDWARE BRAKE ENABLE CIRCUIT CONFIGURATION RESISTORS

Configuration resistors for setting the DC bus upper and lower trip points for comparator supply voltages of 3.3V and 5V are provided in Table C-1 and Table C-2.

TABLE C-1: CONFIGURATION RESISTORS IN HARDWARE BRAKE ENABLE CIRCUIT A

Resistor Designator	Resistor Value to Set V_{DCHL} @ 23.5V and V_{DCLH} @ 27.5V, If the Comparator Supply Voltage is	
	3.3V	5V
R233	280 kΩ	280 kΩ
R234	2200 kΩ	3600 kΩ
R231	18 kΩ	36 kΩ
R229	1.2 kΩ	1 kΩ

TABLE C-2: CONFIGURATION RESISTORS IN HARDWARE BRAKE ENABLE CIRCUIT B

Resistor Designator	Resistor Value to Set V_{DCHL} @ 23.5V and V_{DCLH} @ 27.5V, If the Comparator Supply Voltage is	
	3.3V	5V
R249	280 kΩ	280 kΩ
R250	2200 kΩ	3600 kΩ
R247	18 kΩ	36 kΩ
R245	1.2 kΩ	1 kΩ

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