MCP8026
TQFP BLDC Motor Driver Evaluation Board User's Guide

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Object of Declaration: MCP8026 TQFP BLDC Motor Driver Evaluation Board

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This declaration of conformity is issued by the manufacturer.
The development/evaluation tool is designed to be used for research and development in a laboratory environment. This development/evaluation tool is not a Finished Appliance, nor is it intended for incorporation into Finished Appliances that are made commercially available as single functional units to end users under 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).
This development/evaluation tool complies with EU RoHS2 Directive 2011/65/EU.
This development/evaluation tool, when incorporating wireless and radio-telecom functionality, is in compliance with the essential requirement and other relevant provisions of the R&TTE Directive 1999/5/EC and the FCC rules as stated in the declaration of conformity provided in the module datasheet and the module product page available at www.microchip.com.
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Rodger Richey
Director of Development Tools

4/4/17

Date

NOTES:

MCP8026 TQFP BLDC MOTOR DRIVER EVALUATION BOARD 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 MCP8026 TQFP BLDC Motor Driver Evaluation Board. Items discussed in this chapter include:

- Document Layout
- Conventions Used in this Guide
- Recommended Reading
- The Microchip Web Site
- Customer Support
- Document Revision History

DOCUMENT LAYOUT

This document describes how to use the MCP8026 TQFP BLDC Motor Driver Evaluation Board as a development tool to emulate and debug firmware on a target board. The manual layout is as follows:

- **Chapter 1. "Product Overview"** – Important information about the MCP8026 TQFP BLDC Motor Driver Evaluation Board.
- **Chapter 2. "Installation and Operation"** – Includes instructions on how to get started with this user's guide and a description of the user's guide.
- **Appendix A. "Schematic and Layouts"** – Shows the schematic and layout diagrams for the MCP8026 TQFP BLDC Motor Driver Evaluation Board.
- **Appendix B. "Bill of Materials"** – Lists the parts used to build the MCP8026 TQFP BLDC Motor Driver Evaluation Board.
- **Appendix C. "Software"** – Provides information about the application firmware and where the source code can be found.

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

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

RECOMMENDED READING

This user's guide describes how to use the MCP8026 TQFP BLDC Motor Driver Evaluation Board. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

- **MCP8025/6 – *"3-Phase Brushless DC (BLDC) Motor Gate Driver with Power Module, Sleep Mode, and LIN Transceiver"* (DS20005339) —** This data sheet provides detailed information regarding the MCP8025/6 product family.
- **dsPIC33EPXXXGP50X, dsPIC33EPXXXMC20X/50X and PIC24EPXXXGP/MC20X – *"16-Bit Microcontrollers and Digital Signal Controllers with High-Speed PWM, Op Amps and Advanced Analog"* (DS70000657) —** This data sheet provides detailed information regarding the dsPIC33EP256MC504 product family.
- ***"dsPIC33E/PIC24E Family Reference Manual"* (DS70573)**
- ***"dsPIC33EPXXXGP50X, dsPIC33EPXXXMC20X/50X, and PIC24EPXXXGP/MC20X Family Silicon Errata and Data Sheet Clarification"* (DS80000533G) —** This data sheet contains anomalies and clarifications for the dsPIC33EPXXXMC504 processor.
- **AN1078 – *"Sensorless Field Oriented Control of a PMSM"* (DS01078)**
- **AN1160 – *"Sensorless BLDC Control with Back-EMF Filtering Using a Majority Function"* (DS01160)**
- **AN992 – *"Sensorless BLDC Motor Control Using dsPIC30F2010"* (DS00992)**
- **AN1292 – *"Sensorless Field Oriented Control (FOC) for a Permanent Magnet Synchronous Motor (PMSM) Using a PLL Estimator and Field Weakening (FW)"* (DS01292)**
- **AN901 – *"Using the dsPIC30F for Sensorless BLDC Control"* (DS00901)**

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- **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

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- **Compilers** – The latest information on Microchip C compilers, assemblers, linkers and other language tools. These include all MPLAB® C compilers; all MPLAB assemblers (including MPASM assembler); all MPLAB linkers (including MPLINK object linker); and all MPLAB librarians (including MPLIB object librarian).
- **Emulators** – The latest information on Microchip in-circuit emulators.This includes the MPLAB REAL ICE™ and MPLAB ICE 2000 in-circuit emulators.
- **In-Circuit Debuggers** – The latest information on the Microchip in-circuit debuggers. This includes MPLAB ICD 3 in-circuit debuggers and PICkit 3 Debug Express.
- **MPLAB IDE** – The latest information on Microchip MPLAB IDE, the Windows Integrated Development Environment for development systems tools. This list is focused on the MPLAB IDE, MPLAB IDE Project Manager, MPLAB Editor and MPLAB SIM simulator, as well as general editing and debugging features.
- **Programmers** – The latest information on Microchip programmers. These include production programmers such as MPLAB REAL ICE in-circuit emulator, MPLAB ICD 3 in-circuit debugger and MPLAB PM3 device programmers. Also included are nonproduction development programmers such as PICSTART Plus and PICkit 2 and 3 programmers.

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 web site at:
http://www.microchip.com/support

DOCUMENT REVISION HISTORY

Revision A (July 2017)

- Initial Release of this Document.

Chapter 1. Product Overview

The MCP8026 TQFP BLDC Motor Driver Evaluation Board is used to demonstrate the drive capabilities of the MCP8026. The board uses the MCP8026 3-Phase Brushless DC (BLDC) motor gate driver and dsPIC33EP256MC504 processor to implement a 6-step trapezoidal BLDC motor controller.

The MCP8026 TQFP BLDC Motor Driver Evaluation Board is used to evaluate Microchip's MCP8026 in a BLDC motor application. As provided, the MCP8026 TQFP BLDC Motor Driver Evaluation Board is ready to operate a BLDC motor using one on-board push button to start and stop the motor plus one on-board potentiometer to set motor speed. The evaluation board can drive a BLDC motor with a supply voltage of up to 24V and a motor current up to 15 amps. The MCP8026 TQFP BLDC Motor Driver Evaluation Board provides a 6-step trapezoidal control algorithm along with a 750 mW buck converter, 5V and 12V LDO, high-to-low level voltage translators, current sense operational amplifiers, and Hall-effect inputs. The evaluation board provides a status indication for the power supplies and the six on-board Pulse-Width Modulation (PWM) inputs.

This chapter covers the following topics:

- What Is the MCP8026 TQFP BLDC Motor Driver Evaluation Board?
- What Does the MCP8026 TQFP BLDC Motor Driver Evaluation Board Kit Include?

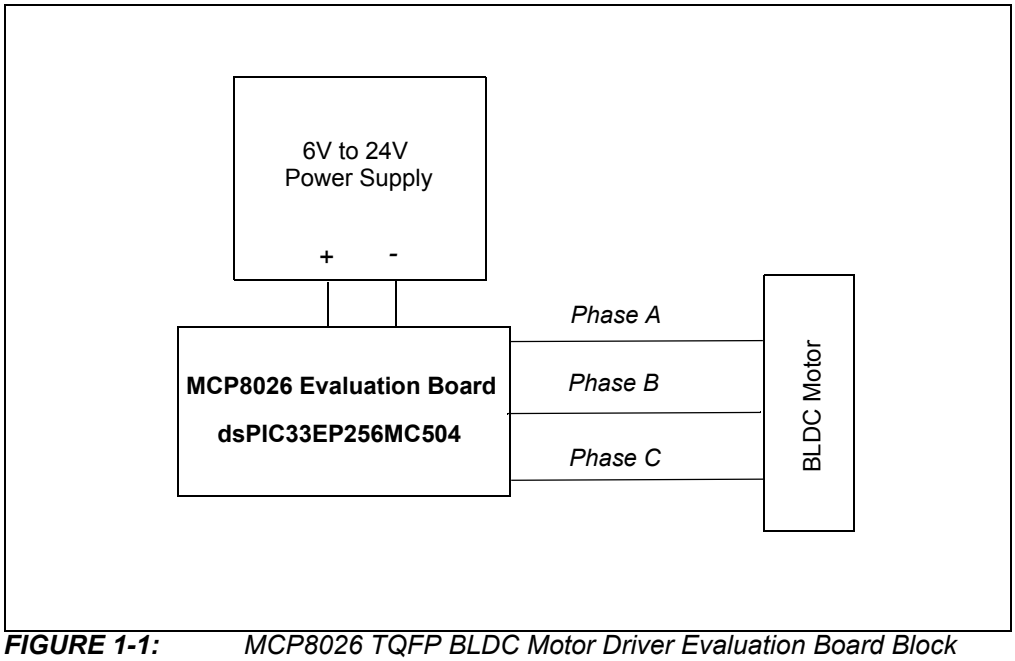


FIGURE 1-1: *MCP8026 TQFP BLDC Motor Driver Evaluation Board Block Diagram.*

1.1 WHAT IS THE MCP8026 TQFP BLDC MOTOR DRIVER EVALUATION BOARD?

The MCP8026 TQFP BLDC Motor Driver Evaluation Board is a complete stand-alone motor controller for brushless DC motors (BLDC). The board is capable of driving a three-phase brushless DC motor rated at up to 15 amps and 24V. The input voltage range for the board is 6V to 24V. The on board MCP8026 generates 5V and 12V using internal voltage regulators. The MCP8026 also contains an internal buck regulator which generates the power for the attached dsPIC33EP256MC504 host microcontroller.

An input terminal block is provided to apply the input voltage to the board. An output header and plated Printed Circuit Board (PCB) through-hole pads are also provided as a means to connect the external motor. Two programming headers are available for updating the firmware contained in the dsPIC33EP256MC504 using either a PICkit 3 programmer/debugger or an MPLAB® ICD3 in-circuit debugger.

An input terminal block is also supplied on the board, to allow users to connect 5V/12V Hall sensors signals.

1.2 WHAT DOES THE MCP8026 TQFP BLDC MOTOR DRIVER EVALUATION BOARD KIT INCLUDE?

This MCP8026 TQFP BLDC Motor Driver Evaluation Board kit includes:

- The MCP8026 TQFP BLDC Motor Driver Evaluation Board, ADM00599
- Information Sheet

Chapter 2. Installation and Operation

2.1 INTRODUCTION

The MCP8026 TQFP BLDC Motor Driver Evaluation Board demonstrates Microchip's 3-Phase Brushless DC (BLDC) Motor Gate Driver with Power Module, MCP8026, used in a BLDC motor drive application. When used in conjunction with a microcontroller, the MCP8026 will provide the necessary drive signals to drive for a 3-Phase BLDC motor. The MCP8026 contains the high-side and low-side drivers for external N-channel MOSFETs. A dsPIC33EP256MC504 processor is used to supply the PWM inputs to the MCP8026 as well as handle the high-speed Analog-To-Digital Conversion (ADC) required for 50 kHz PWM operation.

The MCP8026 UART interface is used to configure the MCP8026 device and to send fault information to the dsPIC® Digital Signal Controller (DSC). The evaluation board firmware, available on the Microchip web site, uses a 6-step trapezoidal drive control algorithm to demonstrate the MCP8026 capabilities.

2.2 FEATURES

The MCP8026 TQFP BLDC Motor Driver Evaluation Board has the following features:

- Input Operating Voltage Range: +6.0V to +24V
- Maximum of 500 mA of gate drive current for external N-Channel MOSFETs
- Drives up to a 15A BLDC motor
- 750 mW Buck Regulator with resistor-programmable output voltage
- ON/OFF momentary contact switch
- Reset momentary contact switch
- Spare user-programmable momentary contact switch
- PWM signal LED indicators
- PICkit 3 and MPLAB ICD 3 debugger interfaces
- Speed control potentiometer
- Terminal block for 5V and 12V Hall-effect sensors
- Programmable external MOSFET overcurrent protection
- Programmable PWM dead-time protection
- Programmable PWM blanking time for current switching spikes
- Complete "C" source code (provided on the board web page)

2.3 GETTING STARTED

The MCP8026 TQFP BLDC Motor Driver Evaluation Board is fully assembled and tested for driving a BLDC motor. This board requires the use of an external voltage source capable of supplying 6V to 24V at the rated motor current. A BLDC motor is also required to evaluate the motor driver.

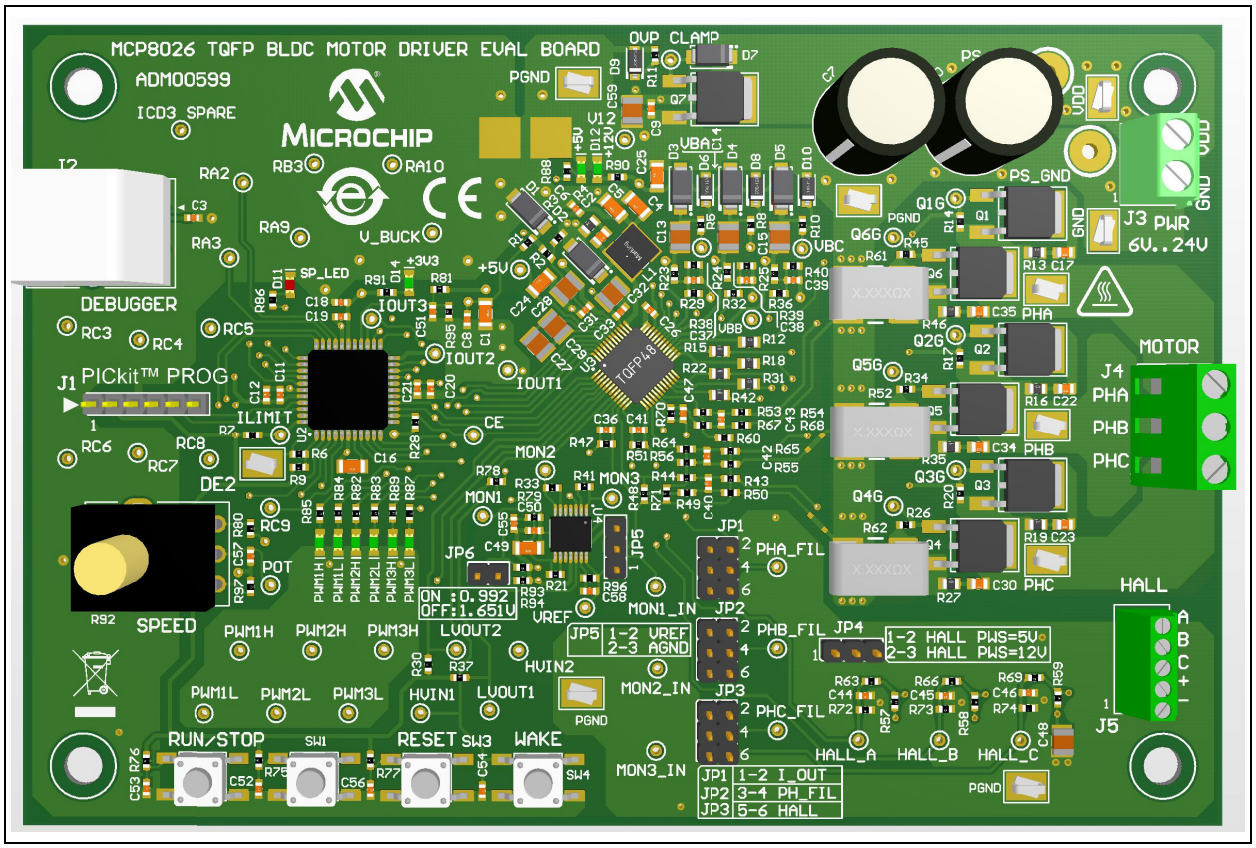


FIGURE 2-1: *MCP8026 TQFP BLDC Motor Driver Evaluation Board PCB.*

2.3.1 Connections

2.3.1.1 JUMPER SETTINGS

The MCP8026 TQFP BLDC Motor Driver Evaluation Board has several user-configurable jumpers. The jumpers are described in Table 2-1 below.

TABLE 2-1: MCP8026 TQFP BLDC MOTOR DRIVER EVALUATION BOARD JUMPERS

Jumper	Default	Position	Description
JP1 (MONITOR1) JP2 (MONITOR2) JP3 (MONITOR3)	3-4	1-2	Connect phase current to MONITORn
		3-4	Connect filtered phase to MONITORn
		5-6	Connect Hall Sensor to MONITORn
JP4	1-2	1-2	Supplies 5V to the Hall Sensors
		2-3	Supplies 12V to the Hall Sensors
JP15	1-2	1-2	Current Sense offset = JP6 selection
		2-3	Current Sense offset = 0.0V
JP6	OFF	ON	Current Sense reference = 1.651V
		OFF	Current Sense reference = 0.992V

2.3.1.1.1 The jumpers and their use are described in Table 2-2.

TABLE 2-2: JUMPER DESCRIPTION

Jumper	Name	Position	Description
JP1	Monitor 1 Input Selection (A/D Channel AN0)	1-2	Connects Phase A Current to Monitor 1 net
		3-4	Connects Filtered Phase A Voltage to MONITOR1 net
		5-6	Connects Hall Sensor A to Monitor 1 net
JP2	Monitor 2 Input Selection (A/D Channel AN1)	1-2	Connects Phase B Current to Monitor 2 net
		3-4	Connects Filtered Phase B Voltage to MONITOR2 net
		5-6	Connects Hall Sensor B to Monitor 2 net
JP3	Monitor 3 Input Selection (A/D Channel AN2)	1-2	Connects Phase C Current to Monitor 3 net
		3-4	Connects Filtered Phase C Voltage to MONITOR3 net
		5-6	Connects Hall Sensor C to Monitor 3 net
JP4	—	1-2	Supplies 5V to the Hall Sensors
		2-3	Supplies 12V to the Hall Sensors
JP5	—	1-2	Current Sense Offset Voltage = JP6 selection
		3-4	Current Sense Offset Voltage = 0.0V
JP6	—	1-2	Current Sense Reference Voltage = 1.651V
		3-4	Current Sense Reference Voltage = 0.992V

The jumper settings for use with the sensorless trapezoidal drive firmware are as described in Table 2-3.

TABLE 2-3: JUMPERS USED BY SENSORLESS TRAPEZOIDAL FIRMWARE

Jumper	Position	Description
JP1 (MONITOR1) JP2 (MONITOR2) JP3 (MONITOR3)	3-4	Connect filtered phase voltage to MONITORn

2.3.1.2 POWERING THE MCP8026 TQFP BLDC MOTOR DRIVER EVALUATION BOARD (REFERENCE Figure 2-2)

1. Apply the input voltage to the input power terminal block, J3. The input voltage source should be limited to +24V. For nominal operation the input voltage should be between +6.0V and +24V.
2. Connect the positive side of the input power source (+) to pin 2 of J3. Connect the negative or return side (-) of the input source to pin 1 of J3. Refer to Figure 2-2.

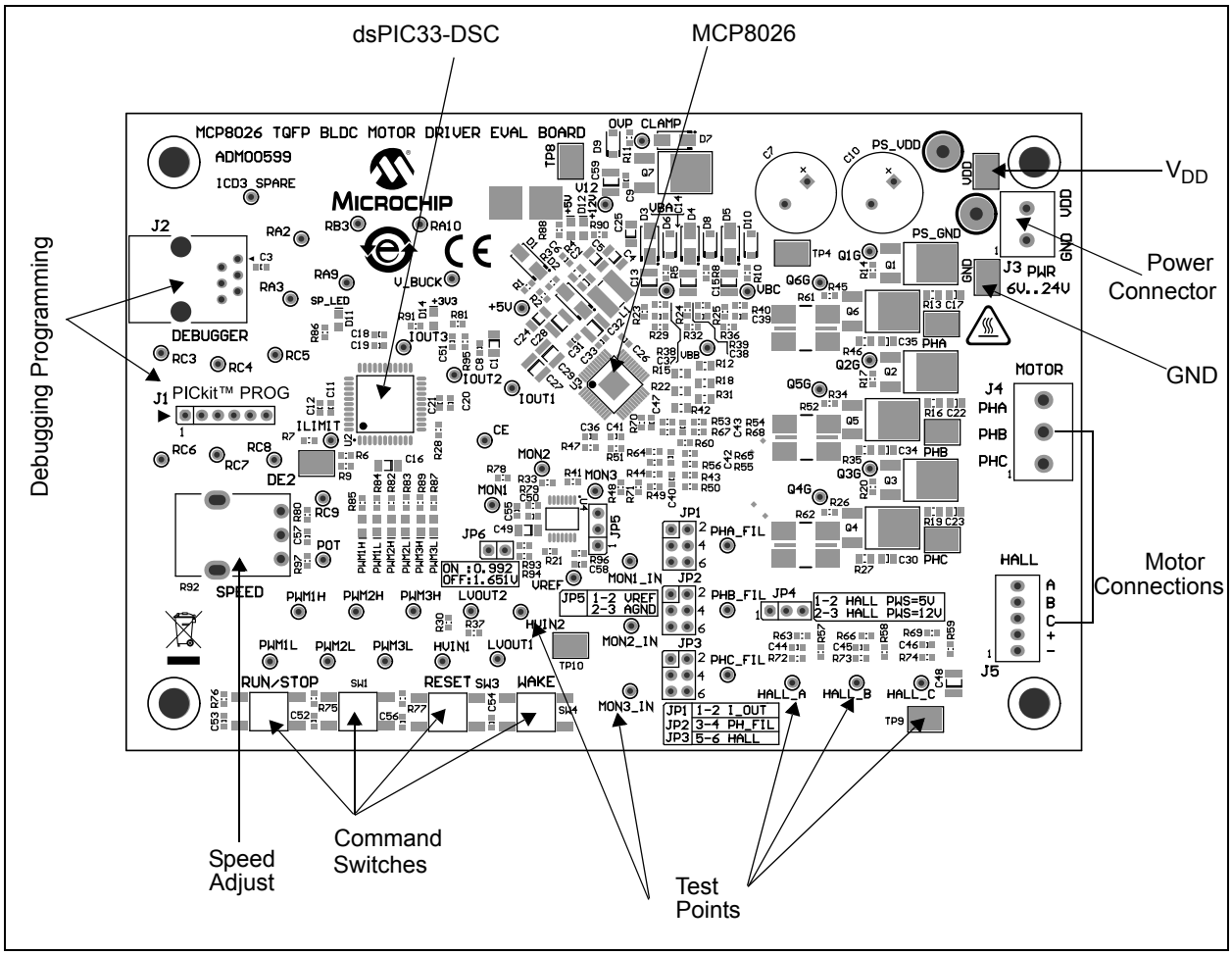


FIGURE 2-2: *Connection and Operation Diagram.*

2.3.1.3 CONNECTING A MOTOR TO THE MCP8026 TQFP BLDC MOTOR DRIVER EVALUATION BOARD

Connect each phase winding of a three-phase BLDC motor to the appropriate terminal of the motor terminal block, J4, terminals A,B,C.

2.3.2 Operating a Motor

1. Turn the SPEED adjust potentiometer (R92) fully counter-clockwise to obtain the slowest speed setting. Now turn the speed adjust approximately ¼ turn clockwise to allow for 25% motor speed.
2. Turn on the power supply.
3. Press and release the RUN/STOP switch (SW2) to start the motor.
4. Turn the Speed Adjust potentiometer clockwise to increase motor speed, counter-clockwise to decrease motor speed. The Speed Adjust changes the PWM duty cycle of the PWM signals being sent to the MCP8026.
5. Press and release the RUN/STOP switch again to stop the motor.

2.3.3 Indicator LEDs

The MCP8026 TQFP BLDC Motor Driver Evaluation Board has ten LEDs to indicate system status. Table 2-4 lists the LED indicators and their descriptions.

TABLE 2-4: LED INDICATORS

PCB Location	Name	Description
D11	SPARE	Spare LED on dsPIC DSC RA4 port
D12	+12V	+12V LDO voltage operating
D13	+5V	+5V LDO voltage operating
D14	+Buck	+3.3V Buck output voltage operating
D15	PWM3H	PWM Phase 3 high-side input to MCP8026
D16	PWM3L	PWM Phase 3 low-side input to MCP8026
D17	PWM2H	PWM Phase 2 high-side input to MCP8026
D18	PWM2L	PWM Phase 2 low-side input to MCP8026
D19	PWM1H	PWM Phase 1 high-side input to MCP8026
D20	PWM1L	PWM Phase 1 low-side input to MCP8026

2.3.4 Test Points

There are several test points on the board to allow probing of voltages, currents and signals. An abridged listing is shown in Table 2-5.

TABLE 2-5: TEST POINTS DESCRIPTION

Test Point	Name	Description
TP1	V_{DD}	Power supply (+)
TP2, 4, 8, 9, 10	PGND	Power supply ground (–)
TP3	DE2	MCP8026 DE2 communications signal
TP5	PHA	Motor Phase A connection
TP6	PHB	Motor Phase B connection
TP7	PHC	Motor Phase C connection
VBn	VBn	Driver Bootstrap Voltage For Phase n
POT	POT	Motor Speed Potentiometer Output
ILIMIT	ILIMIT	$\overline{\text{ILIMIT\_OUT}}$ signal from MCP8026
HVIN1	HVIN1	Level Shifter 1 input
HVIN2	HVIN2	Level Shifter 2 input

TABLE 2-5: TEST POINTS DESCRIPTION (CONTINUED)

Test Point	Name	Description
MON1	MON1	Monitor Signal 1: connects to A/D input AN0
MON2	MON2	Monitor Signal 2: connects to A/D input AN1
MON3	MON3	Monitor Signal 3: connects to A/D input AN2
LVOUT1	LVOUT1	Level Shifter 1 output
LVOUT2	LVOUT2	Level Shifter 2 output
OVP CLAMP	OVP CLAMP	Gate pin of supply overvoltage clamp
PHA_FIL	PHA_FIL	Filtered Phase A BEMF signal
PHB_FIL	PHB_FIL	Filtered Phase B BEMF signal
PHC_FIL	PHC_FIL	Filtered Phase C BEMF signal
PWM1H	PWM1H	PWM phase A high-side input to MCP8026
PWM1L	PWM1L	PWM phase A low-side input to MCP8026
PWM2H	PWM2H	PWM phase B high-side input to MCP8026
PWM2L	PWM2L	PWM phase B low-side input to MCP8026
PWM3H	PWM3H	PWM phase C high-side input to MCP8026
PWM3L	PWM3L	PWM phase C low-side input to MCP8026
Q1G	Q1G	Phase A high-side MOSFET gate
Q2G	Q2G	Phase B high-side MOSFET gate
Q3G	Q3G	Phase C high-side MOSFET gate
Q4G	Q4G	Phase C low-side MOSFET gate
Q5G	Q5G	Phase B low-side MOSFET gate
Q6G	Q6G	Phase A low-side MOSFET gate
RA2, 3, 9, 10	RA2, 3, 9, 10	dsPIC DSC spare I/O pins
RB3	RB3	dsPIC DSC spare I/O pin
RC3-9	RC3-9	dsPIC DSC spare I/O pins
V_BUCK	V_BUCK	Buck 3.3V output voltage

2.3.5 Reprogramming the On-Board dsPIC33EP256MC504

The on-board dsPIC33EP256MC504 may be reprogrammed with the user's desired firmware. The processor may be programmed by using an external power source and either a PICkit 3, MPLAB REAL ICE in-circuit emulator or MPLAB ICD3 programmer.

1. Connect the power source to the board as explained in **Section 2.3.1.2**.
2. Connect a PICkit 3 to the J1 header or connect an MPLAB ICD 3 or MPLAB REAL ICE in-circuit emulator to the J2 (RJ25) jack.
3. Start up the MPLABX Integrated Development Environment (IDE) and load the MCP8026 TQFP BLDC Motor Driver Evaluation Board firmware project. In MCP802X.H, replace the definition for driver type: #define DRIVER MCP8026.

Note: Note that the following project options may need to be changed for the computer being used to build the firmware:

- Add Library `libdsp-elf.a` located in XC16 `???\src\Libdsp\lib` directory.
- Add XC16-as ASM Include Directory in XC16 `???\src\Libdsp\asm`.
- Set Hardware tool to "ICD 3", "REAL ICE", or "PICkit3".

4. Build the project.
5. Program the device.
6. Press the RESET switch on the board to reset the processor and allow the processor to execute the new firmware program.

2.3.6 Configuring the MCP8026

The MCP8026 has configuration registers that may be used to modify operating parameters of the device. The parameters are modified by sending commands to the MCP8026 using the DE2 communication bus. The DE2 communication bus is a half-duplex, 9600 baud, 8-bit, 1-stop bit, 1-start bit, no parity, serial communication link. The user may add code to the evaluation board firmware to communicate with the registers. The evaluation board software contains a subroutine which initializes the MCP8026 registers.

There are three configuration registers that may be written to. The registers are written to by sending a `SET_CFG_X` command byte followed by the desired register value byte. The configuration messages and their respective requests are listed in Table 2-6.

TABLE 2-6: CONFIGURATION MESSAGE COMMANDS

Command	Byte	Bit	Value	Description
SET_CFG_0	1		10000001 (81H)	Set Configuration Register 0
	2	7	0	Reserved
		6	—	(Always '0' in SLEEP mode)
			0	Enable disconnect of 30 kΩ Level Translator pull up when CE = 0 (Default)
			1	Disable disconnect of 30 kΩ Level Translator pull up when CE = 0
		5	0	System enters Standby mode when CE = 0
			1	System enters Sleep mode when CE = 0 30 kΩ Level Translator pull up disconnect always enabled
		4	0	Unimplemented: Read as '0'
		3	0	Enable MOSFET Undervoltage Lockout (Default)
			1	Disable MOSFET Undervoltage Lockout
		2	0	Enable external MOSFET short circuit detection (Default)
			1	Disable external MOSFET short circuit detection
		1:0	00	Set external MOSFET overcurrent limit to 0.250V (Default)
			01	Set external MOSFET overcurrent limit to 0.500V
			10	Set external MOSFET overcurrent limit to 0.750V
			11	Set external MOSFET overcurrent limit to 1.000V
GET_CFG_0	1		10000010 (82H)	Get Configuration Register 0
SET_CFG_1	1		10000011 (83H)	Set Configuration Register 1 DAC motor current limit reference voltage
	2	7:0	00H – FFH	Select DAC Current Reference value (4.503V - 0.991V)/ 255 = 13.77 mV/bit 00H = 0.991 volts 40H = 1.872 volts (40H x 0.1377 mV/bit + 0.991V) (Default) FFH = 4.503 volts (FFH x 0.1377 mV/bit + 0.991V)
GET_CFG_1	1		10000100 (84H)	Get Configuration Register 1 Get DAC motor current limit reference voltage
SET_CFG_2	1		10000111 (87H)	Set Configuration Register 2
	2	7:5	00H	Reserved
		4:2	—	Driver Dead Time (For PWMH /PWML inputs)
			000	2000 ns (Default)
			001	1750 ns
			010	1500 ns
			011	1250 ns
			100	1000 ns
			101	750 ns
			110	500 ns
			111	250 ns
		1:0	—	Driver blanking time (ignore switching current spikes)
			00	4 µs (Default)
			01	2 µs
			10	1 µs
			11	500 ns
GET_CFG_2	1		10001000 (88H)	Get Configuration Register 2

2.3.7 MCP8026 Configuration Message Responses

Table 2-7 describes the messages sent to host in response to a host command message.

TABLE 2-7: CONFIGURATION MESSAGE RESPONSES

MESSAGE	BYTE	BIT	VALUE	DESCRIPTION
SET_CFG_0	1	7:0	00000001 (01H)	Set Configuration Register 0 Not Acknowledged (Response)
			01000001 (41H)	Set Configuration Register 0 Acknowledged (Response)
	2	7	0	Reserved
		6	—	(Ignored in SLEEP mode)
			0	Enable disconnect of 30 kΩ Level Translator pull up when CE = 0 (Default)
			1	Disable disconnect of 30 kΩ Level Translator pull up when CE = 0
		5	0	System enters Standby mode when CE = 0
			1	System enters Sleep mode when CE = 0, 30 kΩ Level Translator Pull Up disconnect always enabled
		4	0	Unimplemented: Read as '0'
		3	0 1	Undervoltage Lockout enabled (Default) Undervoltage Lockout disabled
		2	0	External MOSFET overcurrent detection enabled (Default)
			1	External MOSFET overcurrent detection disabled
		1:0	00	0.250V external MOSFET overcurrent limit (Default)
			01	0.500V external MOSFET overcurrent limit
			10	0.750V external MOSFET overcurrent limit
			11	1.000V external MOSFET overcurrent limit
GET_CFG_0	1	7:0	00000010 (02H)	Get Configuration Register 0 Response Not Acknowledged (Response)
			01000010 (42H)	Get Configuration Register 0 Response Acknowledged (Response)
	2	7	0	Reserved
		6	—	(Ignored in SLEEP mode)
			0	Enable disconnect of 30 kΩ Level Translator pull up when CE = 0 (Default)
			1	Disable disconnect of 30 kΩ Level Translator pull up when CE = 0
		5	0	System enters Standby mode when CE = 0
			1	System enters Sleep mode when CE = 0, 30 kΩ Level Translator Pull Up disconnect always enabled
		4	0	Unimplemented: Read as '0'
		3	0	Undervoltage Lockout enabled
			1	Undervoltage Lockout disabled
		2	0	External MOSFET overcurrent detection enabled
			1	External MOSFET overcurrent detection disabled
		1:0	00	0.250V external MOSFET overcurrent limit
			01	0.500V external MOSFET overcurrent limit
			10	0.750V external MOSFET overcurrent limit
			11	1.000V external MOSFET overcurrent limit

TABLE 2-7: CONFIGURATION MESSAGE RESPONSES (CONTINUED)

MESSAGE	BYTE	BIT	VALUE	DESCRIPTION
SET_CFG_1	1		00000011 (03H)	Set DAC Motor Current Limit Reference Voltage Not Acknowledged (Response)
			01000011 (43H)	Set DAC Motor Current Limit Reference Voltage Acknowledged (Response)
	2	7:0	00H – FFH	Current DAC Current Reference value 13.77 mV/bit + 0.991V
GET_CFG_1	1		00000100 (04H)	Get DAC Motor Current Limit Reference Voltage Not Acknowledged (Response)
			01000100 (44H)	Get DAC Motor Current Limit Reference Voltage Acknowledged (Response)
	2	7:0	00H – FFH	Current DAC Current Reference value 13.77 mV/bit + 0.991V
SET_CFG_2	1		00000111 (07H)	Set Configuration Register 2 Not Acknowledged (Response)
			01000111 (47H)	Set Configuration Register 2 Acknowledged (Response)
	2	7:5	00H	Reserved
		4:2	—	Driver Dead Time (For PWMH /PWML inputs)
			000	2000 ns (Default)
			001	1750 ns
			010	1500 ns
			011	1250 ns
			100	1000 ns
			101	750 ns
			110	500 ns
			111	250 ns
		1:0	—	Driver Blanking Time (ignore switching current spikes)
			00	4 µs (Default)
			01	2 µs
			10	1 µs
			11	500 ns
GET_CFG_2	1		00001000 (08H)	Get Configuration Register 2 Response Not Acknowledged (Response)
			01001000 (48H)	Get Configuration Register 2 Response Acknowledged (Response)
	2	7:5	00H	Reserved
		4:2	—	Driver Dead Time (For PWMH /PWML inputs)
			000	2000 ns (Default)
			001	1750 ns
			010	1500 ns
			011	1250 ns
			100	1000 ns
			101	750 ns
			110	500 ns
			111	250 ns
		1:0	—	Driver Blanking Time (ignore switching current spikes)
			00	4 µs (Default)
			01	2 µs
			10	1 µs
			11	500 ns

2.3.8 MCP8026 Status Messages

The host may also solicit MCP8026 status information by issuing a STATUS_0 or STATUS_1 command. The MCP8026 may send an unsolicited STATUS_0 or STATUS_1 command to the host in the event of a fault or warning. The status messages are listed in Table 2-8.

TABLE 2-8: STATUS MESSAGES

Command	Byte	Bit	Value	Description
STATUS_0	1	7:0	00000101 (05H)	Status Register 0 Response Not Acknowledged (Response)
			01000101 (45H)	Status Register 0 Response Acknowledged (Response)
			10000101 (85H)	Status Register 0 Command To Host (Unsolicited)
	2	7:0	00000000	Normal operation
			00000001	Temperature warning (T_J > 72% T_{SD_MIN} = +115°C) (Default)
			00000010	Overtemperature (T_J > +160°C)
			00000100	Input undervoltage (V_{DD} < 5.5V)
			00001000	Unimplemented: Read as '0'
			00010000	Input overvoltage (V_{DD} > 32V)
			00100000	Buck regulator overcurrent
			01000000	Buck regulator output undervoltage warning
			10000000	Buck regulator output undervoltage (< 80%,brown-out error)
STATUS_1	1	7:0	00000110 (06H)	STATUS Register 1 Response Not Acknowledged (Response)
			01000110 (46H)	STATUS Register 1 Response Acknowledged (Response)
			10000110 (86H)	STATUS Register 1 Command To Host (Unsolicited)
	2	7:0	00000000	Normal operation
			00000001	Reserved
			00000010	Reserved
			00000100	External MOSFET Undervoltage Lockout (UVLO)
			00001000	External MOSFET Overcurrent Detection
			00010000	Brown-out Reset – Config Lost (start-up default = 1)
			00100000	5V LDO Undervoltage Lockout (UVLO)
			01000000	Reserved
			10000000	Reserved

2.3.9 MCP8026 Register Definitions

The MCP8026 registers contain the bits operated on by the messaging system. The registers are only accessible via the various messages. The registers are listed on the following pages.

REGISTER 2-1: CFG0: CONFIGURATION REGISTER 0

U-0	R/W-0	R/W-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0
—	PU30K	SLEEP	—	EXTUVLO	EXTSC	EXTOC1	EXTOC0
bit 7							bit 0

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

bit 7 **Unimplemented**: Read as '0'

bit 6 **PU30K**: 30 kΩ level translator pull up
1 = Disable disconnect of 30 kΩ pull up when CE = 0
0 = Enable disconnect of 30 kΩ pull up when CE = 0

bit 5 **SLEEP**: Sleep mode bit
Bit may only be changed while in Standby mode
1 = System enters Sleep Mode when CE = 0. Disconnect of 30 kΩ Level Translator pull up always enabled.
0 = System enters Standby Mode when CE = 0

bit 4 **Unimplemented**: Read as '0'

bit 3 **Unimplemented:** Read as '0'

bit 2 **EXTSC**: External MOSFET short circuit detection
1 = Disable
0 = Enable

bit 1-0 **EXTOC<1:0>**: External MOSFET overcurrent limit value
00 = Overcurrent limit set to 0.250V
01 = Overcurrent limit set to 0.500V
10 = Overcurrent limit set to 0.750V
11 = Overcurrent limit set to 1.000V

REGISTER 2-2: CFG1: CONFIGURATION REGISTER 1

R/W-0	R/W-1	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
DACREF7	DACREF6	DACREF5	DACREF4	DACREF3	DACREF2	DACREF1	DACREF0
bit 7							bit 0

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

bit 7-0 **DACREF<7:0>**: DAC current reference value
(4.503V - 0.991V)/255 = 13.77 mV/bit
00H = 0.991V
40H = 1.872V (40H × 0.1377 mV/bit + 0.991V)
FFH = 4.503V (FFH × 0.1377 mV/bit + 0.991V)

REGISTER 2-3: CFG2: CONFIGURATION REGISTER 2

U-0	U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
–	–	–	DRVDT2	DRVDT1	DRVDT0	DRVBL1	DRVBL0
bit7							bit 0

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

bit 7-5 **Unimplemented**: Read as '0'

bit 4-2 **DRVDT<2:0>**: Driver Dead Time selection bits
000 = 2000 ns
001 = 1750 ns
010 = 1500 ns
011 = 1250 ns
100 = 1000 ns
101 = 750 ns
110 = 500 ns
111 = 250 ns

bit 1-0 **DRVBL<1:0>**: Driver Blanking Time selection bits
00 = 4000 ns
01 = 2000 ns
10 = 1000 ns
11 = 500 ns

REGISTER 2-4: STAT0: STATUS REGISTER 0

R-0	R-0	R-0	R-0	U-0	R-0	R-0	R-0
BUVLOF	BUVLOW	BIOCPW	OVLOF	—	UVLOF	OTPF	OTPW
bit7							bit 0

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

bit 7 **BUVLOF**: Buck Undervoltage Lockout fault
1 = Buck output voltage is below 80% of expected value
0 = Buck output voltage is above 80% of expected value

bit 6 **BUVLOW**: Buck Undervoltage Lockout warning
1 = Buck output voltage is below 90% of expected value
0 = Buck output voltage is above 90% of expected value

bit 5 **BIOCPW**: Buck input overcurrent protection warning
1 = Buck input current is above 2A peak
0 = Buck input current is below 2A peak

bit 4 **OVLOF**: Input Overvoltage Lockout fault
1 = V_{DD} Input voltage > 32V
0 = V_{DD} Input voltage < 32V

bit 3 Unimplemented: Read as ' 0'

bit 2 **UVLOF**: Input Undervoltage fault
1 = V_{DD} Input voltage < 5.5V
0 = V_{DD} Input voltage > 5.5V

bit 1 **OTPF**: Overtemperature protection fault
1 = Device junction temperature is > 160°C
0 = Device junction temperature is < 160°C

bit 0 **OTPW**: Overtemperature protection warning
1 = Device junction temperature is > 115°C
0 = Device junction temperature is < 115°C

REGISTER 2-5: STAT1: STATUS REGISTER 1

U-0	U-0	R-0	R-1	R-0	R-0	U-0	U-0
–	–	UVLOF5V	BORW	XOCPF	XUVLOF	–	–
bit7							bit 0

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

bit 7-6 **Unimplemented**: Read as '0'

bit 5 **UVLOF5V**: 5V LDO Undervoltage Lockout
1 = 5V LDO output voltage < 4.0V
0 = 5V LDO output voltage > 4.0V

bit 4 **BORW**: Brown-out Reset Warning, Configuration Lost
1 = Device internal reset has occurred since last configuration message
0 = No internal device reset has occurred since last configuration message

bit 3 **XOCPF**: External MOSFET overcurrent protection fault(Note 1)
1 = External MOSFET V_{DS} > EXTOC value in CFG0 Register
0 = External MOSFET V_{DS} < EXTOC value in CFG0 Register

bit 2 **XUVLOF**: External MOSFET Gate Drive undervoltage fault(Note 2)
1 = HSx output voltage < 8V
0 = HSx output voltage > 8V

bit 1-0 **Unimplemented**: Read as '0'

Note 1: Only valid when CFG0<EXTSC> = 1.
2: Only valid when EXTUVLO = 1 in CGF0 register

NOTES:

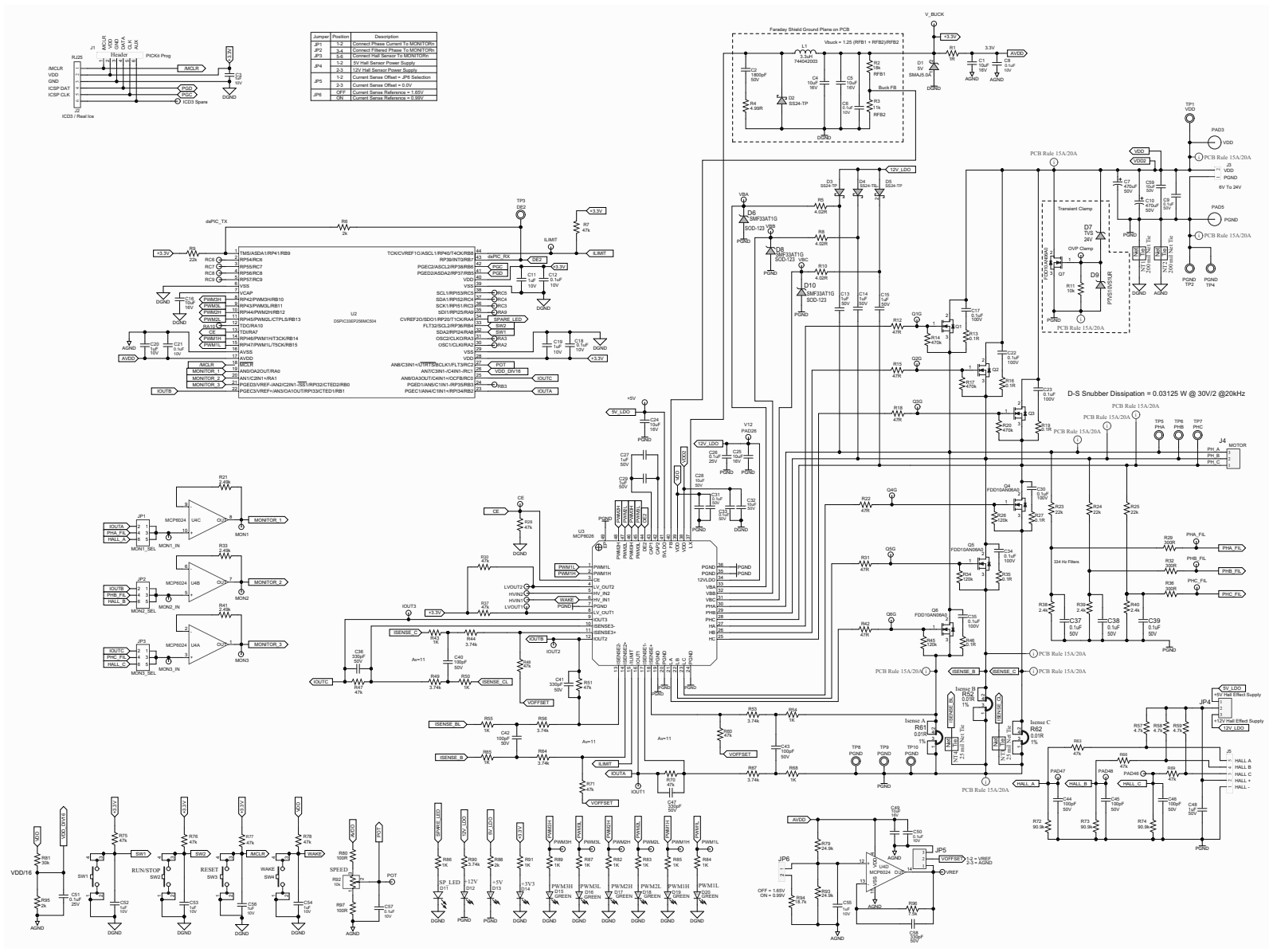
Appendix A. Schematic and Layouts

A.1 INTRODUCTION

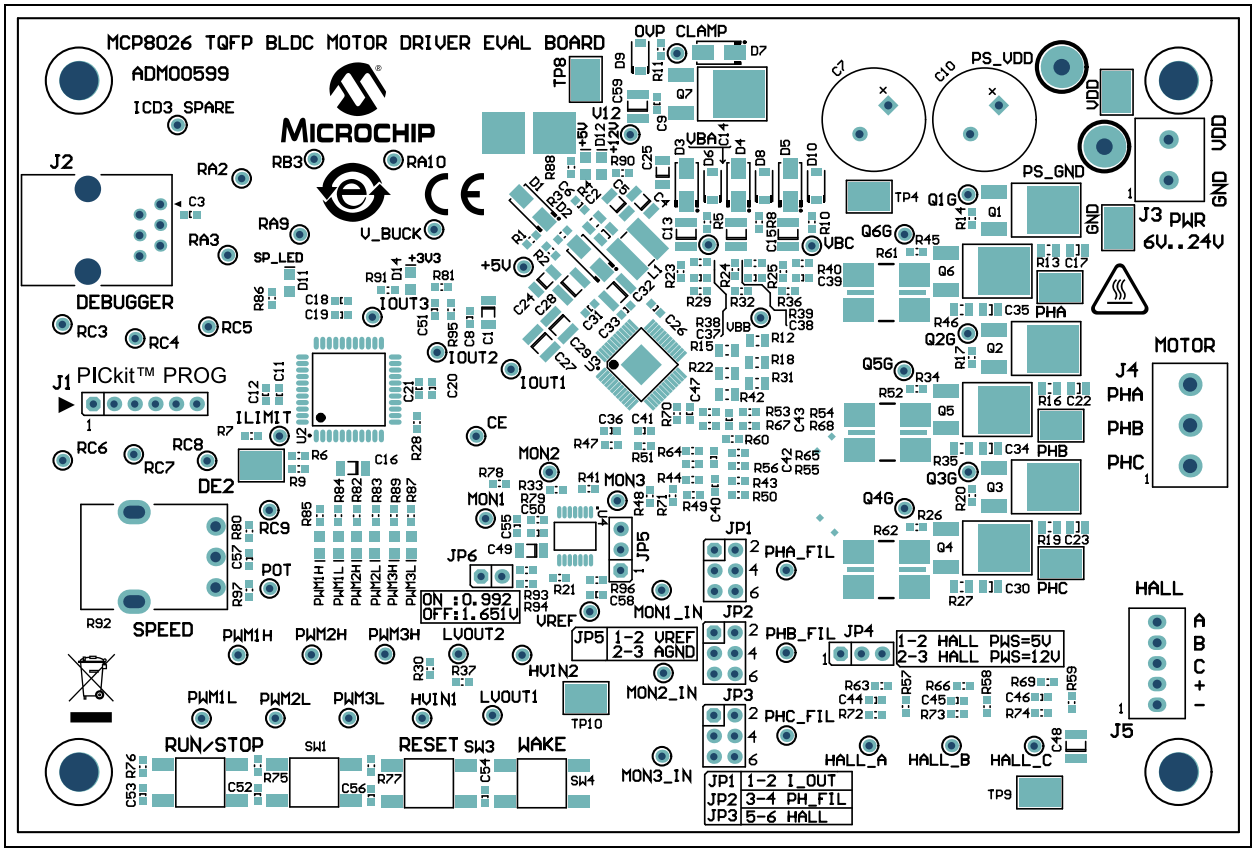
This appendix contains the following schematics and layouts for the MCP8026 TQFP BLDC Motor Driver Evaluation Board:

- Board – Schematic
- Board – Top Silk
- Board – Top Copper
- Board – Bottom Copper
- Board – MID1 Copper
- Board – MID2 Copper

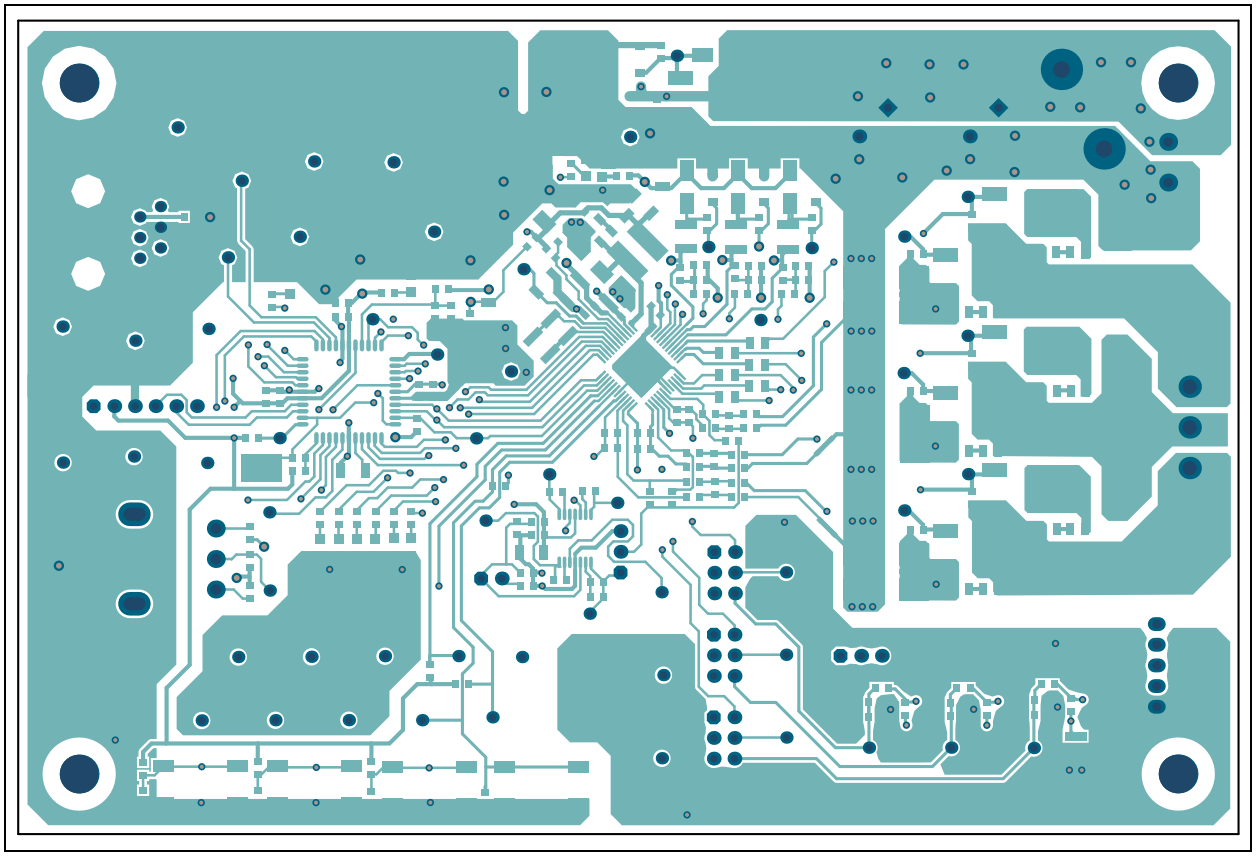
A.2 BOARD – SCHEMATIC



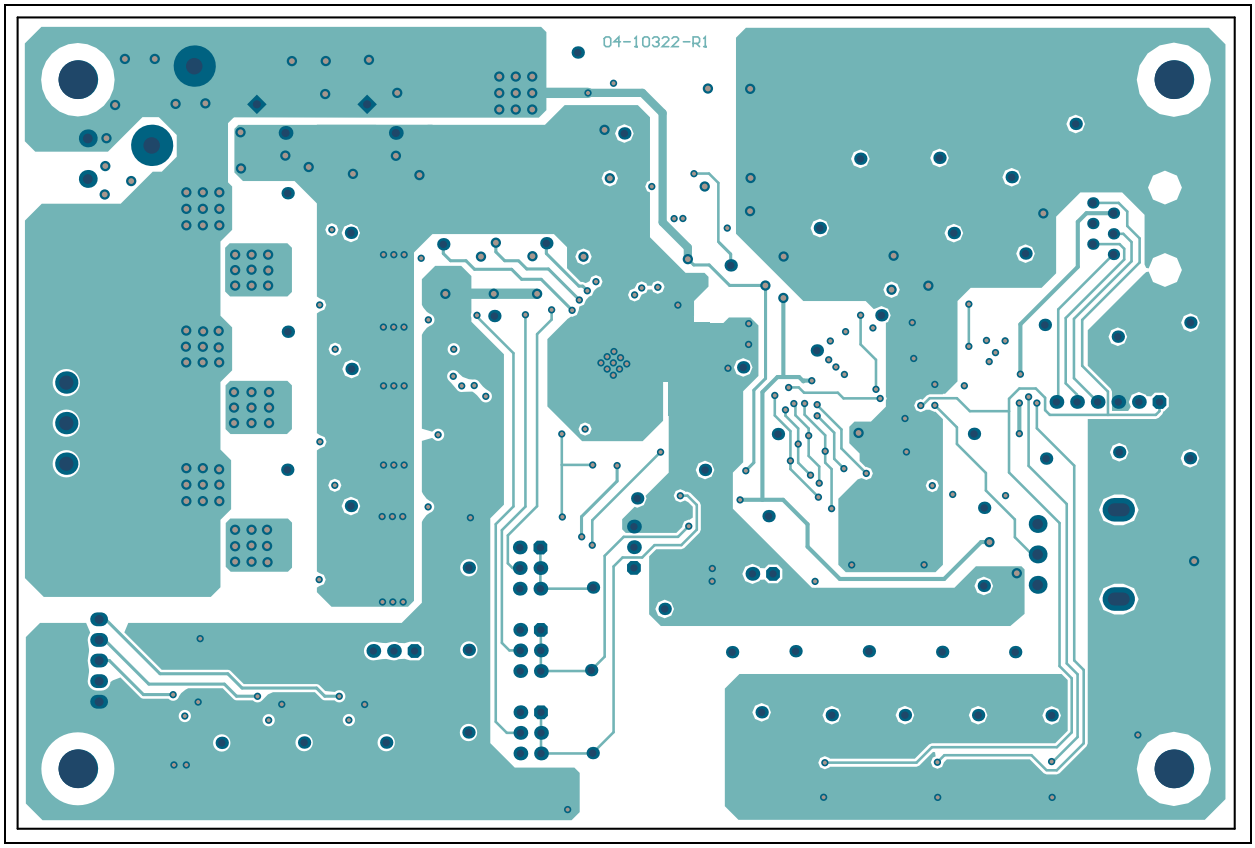
A.3 BOARD – TOP SILK



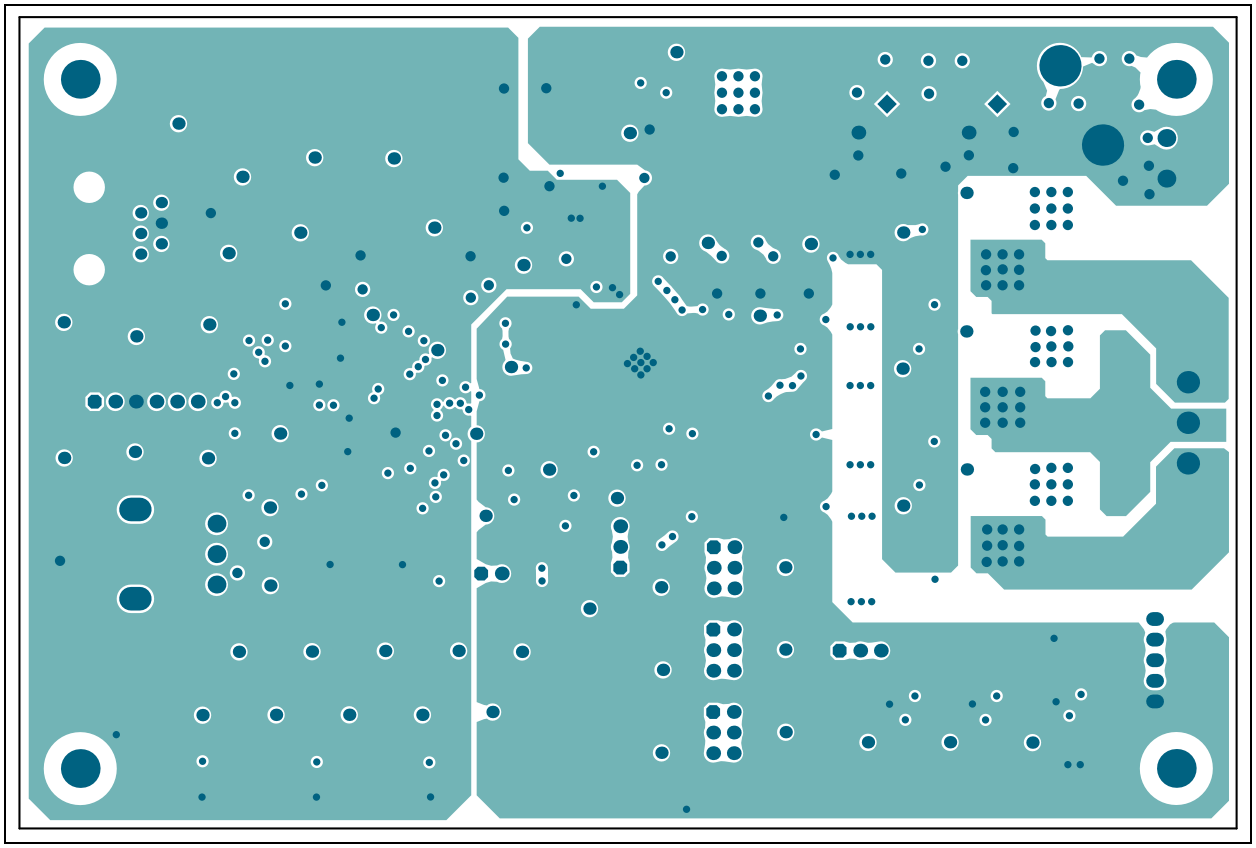
A.4 BOARD – TOP COPPER



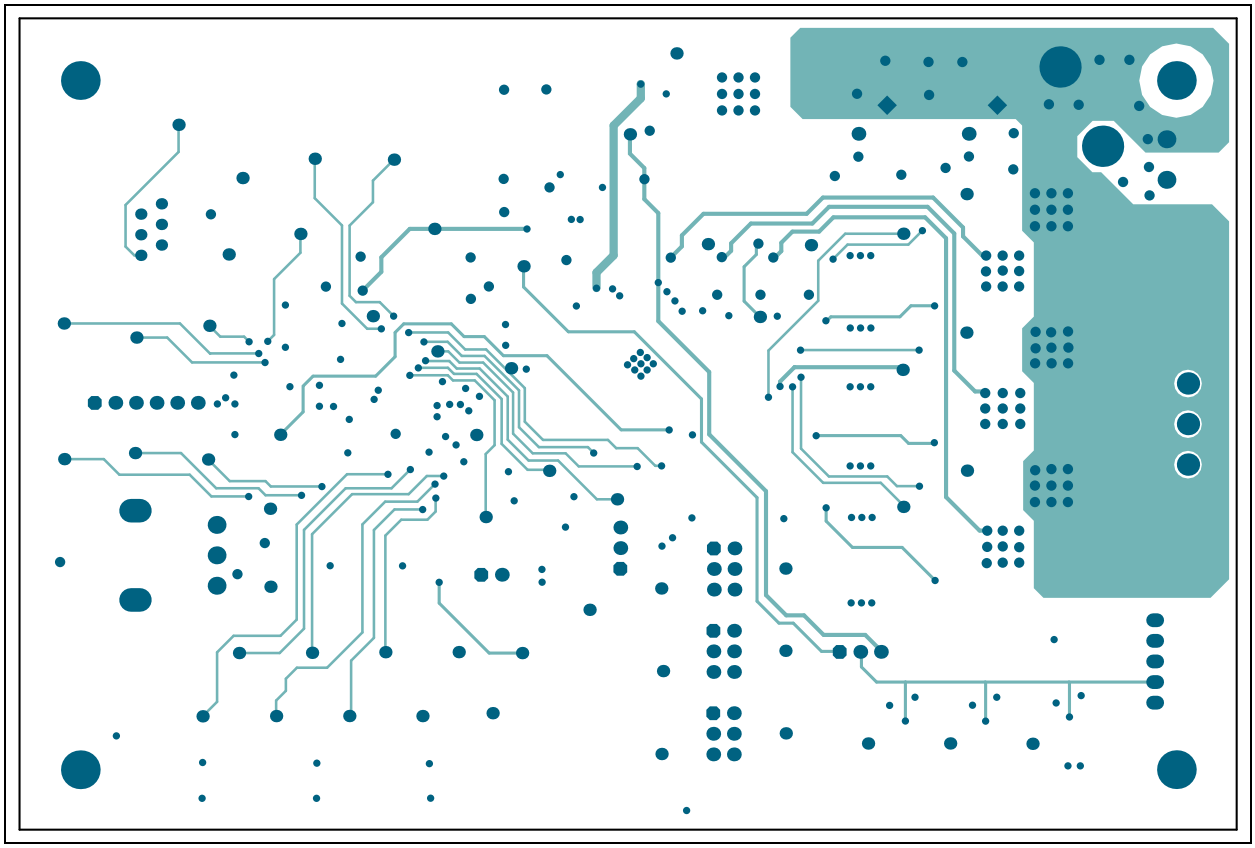
A.5 BOARD – BOTTOM COPPER



A.6 BOARD – MID1 COPPER



A.7 BOARD – MID2 COPPER



NOTES:

Appendix B. Bill of Materials

TABLE B-1: BILL OF MATERIALS (BOM)

Qty.	Reference	Description	Manufacturer	Part Number
7	C1, C4, C5, C16, C24, C25, C49	CAP CER 10uF 16V 10% X7R SMD 1206	TDK Corporation	C3216X7R1C106K
1	C2	CAP CER 1800pF 50V 10% X7R SMD 0805	AVX Corporation	08055C182KAT2A
9	C3, C11, C19, C20, C52, C53, C54, C55, C56	CAP CER 1uF 10V 10% X7R SMD 0603	Taiyo Yuden Co., Ltd.	LMK107B7105KA-T
7	C6, C8, C12, C18, C21, C50, C57	CAP CER 0.1uF 10V 10% X7R SMD 0603	KEMET	C0603C104K8RACTU
2	C7, C10	CAP ALU 470uF 50V 20% 0.027R RAD P5D12.5H20	United Chemi-Con	EKZE500ELL471MK20S
6	C9, C31, C33, C37, C38, C39	CAP CER 0.1uF 50V 10% X7R SMD 0603	Murata Electronics®	GRM188R71H104KA93D
6	C13, C14, C15, C27, C29, C48	CAP CER 1uF 50V 10% X7R SMD 1210	Taiyo Yuden Co., Ltd.	UMK325B7105KH-T
6	C17, C22, C23, C30, C34, C35	CAP CER 0.1uF 100V 10% X7R SMD 0805	TDK Corporation	C2012X7R2A104K
2	C26, C51	CAP CER 0.1uF 25V 10% X7R SMD 0603	Murata Electronics	GRM188R71E104KA01D
3	C28, C32, C59	CAP CER 10uF 50V 20% X7R SMD 1210	TDK Corporation	C3225X7R1H106M250AC
4	C36, C41, C47, C58	CAP CER 330pF 50V 5% NP0 SMD 0603	Cal-Chip Electronics Inc.	GMC10CG331J50NTLF
6	C40, C42, C43, C44, C45, C46	CAP CER 100pF 50V 10% X7R SMD 0603	Vishay Intertechnology	VJ0603Y101KXACW1BC
1	D1	DIO TVS SMAJ5.0A-E3/61 5V 400W DO-214AC_SMA	Vishay Intertechnology	SMAJ5.0A
4	D2, D3, D4, D5	DIO SCTKY SS24-TP 550mV 2A 40V SMD DO-214AC_SMA	Micro Commercial Components	SS24-TP
3	D6, D8, D10	TVS DIODE 33VWM 53.3VC SOD123FL	ON Semiconductor®	SMF33AT1G
1	D7	DIO TVS SMAJ24A 24V 400W DO-214AC_SMA	Littelfuse®	SMAJ24A

Note 1: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

TABLE B-1: BILL OF MATERIALS (BOM) (CONTINUED)

Qty.	Reference	Description	Manufacturer	Part Number
1	D9	DIO TVS PTVS10VS1UR 10V 400W SMD SOD123	NXP Semiconductors	PTVS10VS1UR,115
1	D11	DIO LED RED 1.95V 20mA 220mcd Clear SMD 0805	Kingbright Electronic Co., Ltd.	APT2012SURCK
9	D12, D13, D14, D15, D16, D17, D18, D19, D20	DIO LED GREEN 2.1V 30mA Clear SMD 0805	Kingbright Electronic Co., Ltd.	APT2012CGCK
1	J1	CON HDR-2.54 Male 1x6 Tin 5.84MH TH VERT	Sullins Connector Solutions	PEC06SAAN
1	J2	CON MODULAR RJ25 TH R/A	TE Connectivity, Ltd.	5555165-1
1	J3	CON TERMINAL 5mm 18A Female 1x2 TH R/A	Phoenix Contact GmbH & Co.	1935161
1	J4	CON TERMINAL 5mm 1x3 Female 12-28AWG 16A TH R/A	On-Shore Technology, Inc.	OSTVI030152
1	J5	CON TERMINAL 2.54mm 1x5 Female 20-30AWG 6A TH R/A	Phoenix Contact GmbH & Co.	1725685
3	JP1, JP2, JP3	CON HDR-2.54 Male 2x3 Tin 5.84MH TH VERT	FCI	67996-406HLF
2	JP4, JP5	CON HDR-2.54 Male 1x3 Tin 5.84MH TH VERT	Samtec, Inc.	TSW-103-07-T-S
1	JP6	CON HDR-2.54 Male 1x2 Gold 5.84MH TH VERT	FCI	77311-118-02LF
6	JS1 – JS6	SHUNT JUMPER	Sullins Connector Solutions	SPC02SYAN
1	L1	INDUCTOR 3.3uH 1.95A 30% SMD L4.8W4.8H2	Wurth Elektronik	744042003
1	PCB	Printed Circuit Board - MCP8026 TQFP BLDC Motor Driver Evaluation Board	Microchip Technology Inc.	04-10322
7	Q1, Q2, Q3, Q4, Q5, Q6, Q7	TRANS FET N-CH FDD10AN06A0 60V 50A DPAK-3	Fairchild Semiconductor®	FDD10AN06A0
1	R1	RES TKF 1R 1% 1/10W SMD 0603	Panasonic® - ECG	ERJ-3RQF1R0V
1	R2	RES TKF 18k 1% 1/10W SMD 0603	ROHM Semiconductor	MCR03EZPFX1802
1	R3	RES TKF 11k 1% 1/10W SMD 0603	Panasonic - ECG	ERJ-3EKF1102V
1	R4	RES TKF 4.99R 1% 1/8W SMD 0805	Yageo Corporation	RC0805FR-074R99L
3	R5, R8, R10	RES TKF 4.02R 1% 1/10W SMD 0603	Yageo Corporation	RC0603FR-074R02L
3	R6, R88, R95	RES TKF 2k 1% 1/10W SMD 0603	Panasonic - ECG	ERJ-3EKF2001V

Note 1: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

TABLE B-1: BILL OF MATERIALS (BOM) (CONTINUED)

Qty.	Reference	Description	Manufacturer	Part Number
17	R7, R28, R30, R37, R47, R48, R51, R60, R63, R66, R69, R70, R71, R75, R76, R77, R78	RES TKF 47k 1% 1/10W SMD 0603	Stackpole Electronics Inc.	RMCF 1/16 47K 1% R
4	R9, R23, R24, R25	RES TKF 22k 1% 1/10W SMD 0603	Panasonic - ECG	ERJ-3EKF2202V
1	R11	RES TKF 10k 1% 1/10W SMD 0603	NIC Components Corp.	NRC06F1002TRF
6	R12, R15, R18, R22, R31, R42	RES TKF 47R 1% 1/8W SMD 0805	Yageo Corporation	RC0805FR-0747RL
6	R13, R16, R19, R27, R35, R46	RES TKF 0.1R 1% 1/8W SMD 0805	Panasonic - ECG	ERJ-L06KF10CV
3	R14, R17, R20	RES TKF 470k 1% 1/10W SMD 0603	Panasonic - ECG	ERJ-3EKF4703V
3	R21, R33, R41	RES TKF 2.49k 1% 1/10W SMD 0603	Panasonic - ECG	ERJ-3EKF2491V
3	R26, R34, R45	RES TKF 120k 1% 1/10W SMD 0603	Panasonic - ECG	ERJ-3EKF1203V
3	R29, R32, R36	RES TKF 300R 1% 1/10W SMD 0603	Yageo Corporation	RC0603FR-07300RL
3	R38, R39, R40	RES TKF 2.4K 1% 1/10W SMD 0603	Yageo Corporation	RC0603FR-072K4L
14	R43, R50, R54, R55, R65, R68, R82, R83, R84, R85, R86, R87, R89, R91	RES TKF 1k 1% 1/10W SMD 0603	Panasonic - ECG	ERJ-3EKF1001V
7	R44, R49, R53, R56, R64, R67, R90	RES TKF 3.74K 1% 1/10W SMD 0603	Yageo Corporation	RC0603FR-073K74L
3	R52, R61, R62	RES SHUNT 0.01R 1% 5W SMD L11.35W6.35H4.57	TT Electronics Plc.	OARSXPR010FLF
3	R57, R58, R59	RES TKF 4.7k 1% 1/10W SMD 0603	ROHM Semiconductor	MCR03EZPFX4701
3	R72, R73, R74	RES TKF 90.9k 1% 1/10W SMD 0603	Panasonic - ECG	ERJ-3EKF9092V
2	R79, R93	RES TKF 24.9K 1% 1/10W SMD 0603	Yageo Corporation	RC0603FR-0724K9L
2	R80, R97	RES TKF 100R 1% 1/10W SMD 0603	ROHM Semiconductor	MCR03EZPFX1000

Note 1: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

TABLE B-1: BILL OF MATERIALS (BOM) (CONTINUED)

Qty.	Reference	Description	Manufacturer	Part Number
1	R81	RES TKF 30k 1% 1/10W SMD 0603	Stackpole Electronics, Inc.	RMCF0603FT30K0
1	R92	RES VARIABLE CC 10K 20% 150mW TH 296U	CTS® Corporation	296UD103B1N
1	R94	RES TKF 10.7k 1% 1/10W SMD 0603	Panasonic - ECG	ERJ-3EKF1072V
1	R96	RES TKF 7.5k 1% 1/10W SMD 0603	Panasonic - ECG	ERJ-3EKF7501V
4	SW1, SW2, SW3, SW4	SWITCH TACT SPST 12V 50mA TL3301NF160QG/TR SMD	E-Switch®, Inc.	TL3301NF260QG/TR
10	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10	CON TP LOOP SILVER 3.4x5 SMD	Components Corp.	TP-107-2
1	U2	MCHP MCU 16-Bit 70MIPS 256kb 32kb DSPIC33EP256MC504-I/PT TQFP-44	Microchip Technology Inc.	**DSPIC33EP256MC504-I/PT**
1	U3	MCHP ANALOG MOTOR DRIVER MCP8026-115E/PT TQFP-48	Microchip Technology Inc.	**MCP8026-115E/PT**
1	U4	MCHP ANALOG OPAMP 4-Ch 10MHz MCP6024-E/ST TSSOP-14	Microchip Technology Inc.	**MCP6024-E/ST**

Note 1: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

Appendix C. Software

C.1 SOFTWARE LOCATION

The application software may be downloaded from the MCP8025/4 web page located on the Microchip web site, http://www.microchip.com.

C.2 SELECTED SOFTWARE CONSTANTS AND DEFINITIONS

1. **FOSC**
   Microprocessor Oscillator Frequency in Hz. based upon PLL scaling.
2. **FPWM = 15000, 20000, 40000, 50000**
   Selects dsPIC DSC PWM frequency in Hz.
3. **PWMRESBITS = 7 or 8 or 9**
   Sets the PWM resolution and corresponding PLL divisor. 20 kHz may use 7, 8, or 9 bits. 40 kHz may use 7 or 8 bits. 50 kHz may use 7 or 8 bits.
4. **FPLLO**
   PWM Phase Locked Loop Oscillator frequency.
5. **LOOPMODE = CLOSEDLOOPMODE**
   Sets motor controller to use closed-loop control. The PID control functions will be used to control motor speed.
6. **LOOPMODE = OPENLOOPMODE**
   Sets motor controller to use open-loop control. The speed adjust input relative position will be used to set the motor speed.
7. **PWM_COUNTS_PER_PERIOD = (FPLLO/FPWM –1)**
   Defines the number of timer counts per PWM period.
8. **RAMPUP_START_RATE_FULL_VOLTAGE**
   Defines the initial number of PWM periods to use to ramp the motor speed during startup. The firmware will force the number of PWM periods to occur between commutations. Both the RAMPUP_START_RATE_FULL_VOLTAGE and RAMPUP_END_RATE_OFFSET may need to be adjusted for different motors and voltages. The settings should be different by at least a value of 10. The motor will start with "RAMPUP_START_RATE_FULL_VOLTAGE" number of PWM periods occurring before the first commutation, then decrement the RAMPUP_START_RATE_FULL_VOLTAGE value and wait for the new number of PWM periods to occur before commutating again. This effectively reduces the time between forced commutations and allows for a controlled ramp up of motor speed during open loop starting.
9. **RAMPUP_END_RATE_OFFSET**
   Defines the final number of PWM periods to use to ramp the motor speed during startup.
10. **OPEN_LOOP_ACCEL_RATE**
    Defines the acceleration rate when changing speeds in open-loop mode.
11. **OPEN_LOOP_DECEL_RATE**
    Defines the deceleration rate when changing speeds in open-loop mode.
12. **MAX_DUTY_CYCLE**
    Defines the maximum desired PWM duty cycle.

13. **MIN_DUTY_CYCLE**
    Defines the minimum desired PWM duty cycle.
14. **STARTUP_DUTY_CYCLE**
    Defines the initial PWM duty cycle during motor startup. Set this parameter to the duty cycle required to start the motor for a given supply voltage.
15. **PHASE_ADVANCE_DEGREES**
    Defines the number of electrical degrees (in timer tics) that will be subtracted from the calculated commutation timer reload count. This allows for compensating for any latencies in the system.
16. **ZC_BLANKING_COUNT**
    Defines the number of PWM periods that the ADC readings are ignored. This allows filtering of signals after commutation when high voltage and current spikes may be present. Set this value to 2 when using the Hurst DMB0224C10002 motor that is available at Microchip Direct. Set the value to 1 for higher speed hobby motors like the Electrifly Rimfire 0.55 motor.
17. **int ReferenceSpeed**
    Contains the motor target speed based upon the SPEED potentiometer input.
18. **unsigned int DesiredPWMDutyCycle**
    Contains the desired PWM duty cycle based upon the SPEED potentiometer input.
19. **volatile int CurrentPWMDutyCycle**
    Contains the current PWM duty cycle.
20. **PWM_STATEn[] (n=PHASE=1,2,3)**
    Array containing the high-side and low-side gate driver output states for a given step of the six-step commutation algorithm.
21. **IOCONn_LOCKSTATE (n = 1,2,3)**
    High-side and low-side gate driver output states for locking the rotor to a known position prior to motor startup.
22. **BOOTSTRAP_CHARGE_STATE**
    High-side and low-side gate driver output states for charging the bootstrap capacitors prior to motor startup
23. **MOTOR_SHUTDOWN_STATE**
    High-side and low-side gate driver output states that may be used when shutting down the motor.
24. **ADC_MASK[]**
    A/D Back EMF mask used for majority detection.
25. **ADC_XOR[]**
    A/D Back EMF mask used for majority detection.
26. **ADC_BEMF_FILTER[]**
    A/D Back EMF filter table used to determine next commutation time.
27. **BEMFCommState[7]**
    Table of expected commutation comparator values for a given state. Value is ADC comparator to look for when in a given PWM_STATE[x].

C.3 DSPIC33EP256MC504 PIM PORT USAGE

C.3.1 Port A Mapping

```
#define AN0_MONITOR1  PORTAbits.RA0   /* AN0 - MONITOR1 */
#define AN1_MONITOR2  PORTAbits.RA1   /* AN1 - MONITOR2 */
#define UNUSED_RA2    PORTAbits.RA2   /* unused port bit */
#define UNUSED_RA3    PORTAbits.RA3   /* unused port bit */
#define FAULT_LED     PORTAbits.RA4   /* Fault LED */
#define TEST_LED      PORTAbits.RA4   /* Test LED */
#define NA_RA5        PORTAbits.RA5   /* N/A */
#define NA_RA6        PORTAbits.RA6   /* N/A */
#define DRIVER_CE     PORTAbits.RA7   /* driver CE pin */
#define SW1          !PORTAbits.RA8   /* SW1 Push Button */
#define UNUSED_RA9    PORTAbits.RA9   /* unused port bit */
#define UNUSED_RA10   PORTAbits.RA10  /* unused port bit */
```

C.3.2 Port B Mapping

```
#define AN2_MONITOR3  PORTBbits.RB0   /* AN2 - MONITOR3 */
#define AN3_IOUTB     PORTBbits.RB1   /* AN3 - IOUTB */
#define AN4_IOUTA     PORTBbits.RB2   /* AN4 - IOUTA */
#define AN5_MONITOR4  PORTBbits.RB3   /* AN5 - MONITOR4 */
#define SW2          !PORTBbits.RB4   /* SW2 Push Button */
#define PGD           PORTBbits.RB5   /* Programming Data */
#define PGC           PORTBbits.RB6   /* Programming Clock */
#define DE2_RX         PORTBbits.RB7  /* RX from DE2 Communications using RP39
                                         and UART */
#define nFAULT         PORTBbits.RB8   /* driver ILIMIT_OUT 1= ok, 0=Current
                                          Limit or fault, open-drain */
#define DE2_TX         PORTBbits.RB9   /* TX to DE2 Communications using RP41
                                          and UART */
#define PWM3H          PORTBbits.RB10  /* PWM3H */
#define PWM3L          PORTBbits.RB11  /* PWM3L */
#define PWM2H          PORTBbits.RB12  /* PWM2H */
#define PWM2L          PORTBbits.RB13  /* PWM2L */
#define PWM1H          PORTBbits.RB14  /* PWM1H */
#define PWM1L          PORTBbits.RB15  /* PWM1L */
```

C.3.3 Port C Mapping

```
#define AN6_IOUTC     PORTCbits.RC0   /* AN6 - IOUTC */
#define AN7_VDD_DIV16 PORTCbits.RC1   /* AN7 - VDD_DIV16 */
#define AN8_SPEED_POT PORTCbits.RC2   /* AN8 - Speed Pot */
#define UNUSED_RC3    PORTCbits.RC3   /* unused port bit */
#define UNUSED_RC4    PORTCbits.RC4   /* unused port bit */
#define UNUSED_RC5    PORTCbits.RC5   /* unused port bit */
#define UNUSED_RC6    PORTCbits.RC6   /* unused port bit */
#define UNUSED_RC7    PORTCbits.RC7   /* unused port bit */
#define UNUSED_RC8    PORTCbits.RC8   /* unused port bit */
#define UNUSED_RC9    PORTCbits.RC9   /* unused port bit */
```

C.3.4 A/D Mappings

AN0 (RA0) = MONITOR1

AN1 (RA1) = MONITOR2

AN2 (RB0) = MONITOR3

AN3 (RB1) = IOUTB

AN4 (RB2) = IOUTA

AN5 (RB3) = MONITOR4

AN6 (RC0) = IOUTC

AN7 (RC1) = VDD_DIV16

AN8 (RC2) = Speed Pot

C.3.5 UART Mappings

RP39 = RX from DE2 Communications

RP41 = TX to DE2 Communications

C.4 COMMUNICATIONS MESSAGE MAPPINGS

Message	Address
SET_CFG0_MSG	0x81
GET_CFG0_MSG	0x82
SET_CFG1_MSG	0x83
GET_CFG1_MSG	0x84
STAT0_MSG	0x85
STAT1_MSG	0x86
SET_CFG2_MSG	0x87
GET_CFG2_MSG	0x88

C.5 MPLAB X COMPILER STARTUP

1. Start up the MPLAB X compiler (not supplied, available on the Microchip web site).
2. From the toolbar, select *File>Open Project*.
3. Browse to the evaluation board source code path.
4. Select the existing project file named `ADM00599_6STEP`.
5. In the Projects window, right mouse-click on `ADM00599_6STEP` and select Properties. The page contains the project properties. Processor, Compiler, Hardware and Config settings may be changed here.

> **Note:** The user may need to modify the paths to the source files and linker files based upon their locations on the host computer. Be sure to verify the Libraries contain the correct path to `libdsp-elf.a`

6. Right mouse-click on `ADM00599_6STEP` again and select “Make and Program Device”. This will compile the firmware and download it to the programming hardware.
7. The compiler results will be displayed in the Output window frame. Verify success.

C.6 MPLAB X IDE AND PICKIT 3 EXERCISE

1. Start up the MPLAB X (not supplied, available on the Microchip web site).
2. From the toolbar, select *File>Open Project*.
3. Browse to the evaluation board source code path.
4. Select the existing workspace directory named `ADM00599_6STEP` or create a new one.
5. Connect the PICkit 3 programmer to header J1 on the evaluation board. Align Pin 1 of the header with the Pin 1 mark on the programmer.
6. Set the bench power supply voltage control to minimum voltage output.
7. Turn on the power supply and set the output voltage to 14V. Turn off the power supply.
8. Connect the bench power supply to the evaluation board. Connect +V(14V) to J3-2 and –V (Ground) to J3-1.
9. Turn on the power supply.
10. Right mouse-click on `ADM00599_6STEP` in the *Projects* window and select “Make and Program Device”. This will compile the firmware and program the dsPIC33EP256MC504 processor.
11. The compiler results will be displayed in the Output window frame. Verify success.
12. Connect a Brushless DC (BLDC) motor to connector J4 (MOTOR). Connect the motor phase wires to the PH_A (J4-3), PH_B (J4-2), and PH_C (J4-1) terminals.
13. Momentarily press the RESET switch on the evaluation board. This step is required to reset the dsPIC DSC device after programming.
14. Turn the SPEED adjustment fully counter-clockwise. This sets the motor to the slowest speed.
15. Momentarily press the SW2 (RUN/STOP) switch to start the motor.
16. Momentarily press the SW2 (RUN/STOP) switch again to stop the motor.
17. Momentarily press the SW2 (RUN/STOP) switch again to start the motor.
18. Turn the SPEED adjustment clockwise. The motor speed should increase.

19. You may probe the different test points on the board to see the various signals being generated. The Q1G through Q6G test points will show the external MOSFET gate drive signals. The D15 through D20 LEDs show the state of the PWM inputs to the MCP8026. The MON1 through MON3 test points show the output of the jumper-selected signals. PHA_FIL, PHB_FIL, and PHC_FIL are the filtered Back EMF voltages from the motor. They are used to determine the commutation time in the demonstration firmware. The SPARE_LED turns ON when a fault has occurred.
20. Stop the motor by pressing SW2 again.
21. Change the motor control from Closed Loop to Open Loop. This is done by editing the `MCP802X_EVALUATION.C` file.
22. Click on Source Files in the *Projects* window and then double-click on the `MCP802X_EVALUATION.C` entry.
23. Search for the preprocessor definition #define LOOPMODE.
24. Change the LOOPMODE definition from CLOSEDLOOPMODE to OPENLOOPMODE.
25. Right mouse-click `ADM00599_6STEP` in the Projects window and select "Make and Program Device". This will compile the firmware and program the dsPIC33EP256MC504 PIM module.
26. The compiler results will be displayed in the Output window frame. Verify success.
27. Momentarily press the RESET switch on the evaluation board. This step is required to reset the dsPIC DSC device after programming.
28. Turn the SPEED adjustment fully counter-clockwise. This sets the motor to the slowest speed.
29. Momentarily press the SW2 switch again to start the motor.
30. Turn the SPEED adjustment clockwise. The motor speed should increase.
31. In OPENLOOPMODE, the motor speed is forced based upon the position of the SPEED adjust potentiometer. If the SPEED adjust is set to 60%, the firmware will set the PWM duty cycle to 60%. While this allows for simple control of the motor, it is not efficient. If the motor is externally loaded, the motor may not be able to maintain the manually set commutation time which will result in a motor stall. The motor runs more efficiently when the motor is allowed to commutate based upon rotor location and not by an external reference. In CLOSEDLOOPMODE, the motor will commutate at the proper time based upon the Back EMF information. If the motor is externally loaded, the motor will automatically adjust for the load in order to maintain the correct commutation time.
32. Momentarily press the SW2 switch again to stop the motor.

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