MCP8027
QFN40 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 website (www.microchip.com) to obtain the latest documentation available.

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

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

INTRODUCTION

This chapter contains general information that will be useful to know before using the MCP8027 QFN40 BLDC Motor Driver Evaluation Board. Items discussed in this chapter include:

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

DOCUMENT LAYOUT

This document describes how to use the MCP8027 QFN40 BLDC Motor Driver Evaluation Board. The manual layout is as follows:

- **Chapter 1. "Product Overview"** – Important information about the MCP8027 QFN40 BLDC Motor Driver Evaluation Board.
- **Chapter 2. "Installation and Operation"** – Includes instructions on installing and using the MCP8027 QFN40 BLDC Motor Driver Evaluation Board.
- **Appendix A. "Schematics and Layouts"** – Shows the schematic and layout diagrams for the MCP8027 QFN40 BLDC Motor Driver Evaluation Board.
- **Appendix B. "Bill of Materials (BOM)"** – Lists the parts used to build the MCP8027 QFN40 BLDC Motor Driver Evaluation Board.
- **Appendix C. "Software"** – Provides information about the demo application 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 MCP8027 QFN40 BLDC Motor Driver Evaluation Board. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

- ***MCP8027 - "3-Phase Brushless DC (BLDC) Motor Gate Driver with Power Module and Sleep Mode" (DS20006897)***
- ***dsPIC33CK256MP508 Family Data Sheet (DS70005349)***
- ***AN1078 - "Sensorless Field Oriented Control of PMSM Motors" (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 Flux 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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The Development Systems product group categories are:

- **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 3/4 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, 3 and 4 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 website at:
http://www.microchip.com/support.

DOCUMENT REVISION HISTORY

Revision A (June 2024)

- Initial release of this document.

Chapter 1. Product Overview

1.1 INTRODUCTION

This chapter covers the following topics:

- MCP8027 QFN40 BLDC Motor Driver Evaluation Board Overview
- What is the MCP8027 QFN40 BLDC Motor Driver Evaluation Board?
- What does the MCP8027 QFN40 BLDC Motor Driver Evaluation Board Kit Include?

1.2 MCP8027 QFN40 BLDC MOTOR DRIVER EVALUATION BOARD OVERVIEW

The MCP8027 QFN40 BLDC Motor Driver Evaluation Board is used to demonstrate the drive capabilities/facilities offered by the MCP8027 in BLDC/PMSM motor applications.

The board is designed to be very versatile, two-layered, low-cost, high-current, and easily configurable to meet as many customer's preferences as possible by using the MCP8027 for 3-Phase Brushless DC (BLDC) motor gate driver and the dsPIC33CK128MP503 microcontroller provided by Microchip. In order to implement different types of algorithms, like sinusoidal single shunt FOC or trapezoidal motor control algorithm in sensored or sensorless mode, the board can be easily configured by using the jumpers that are available on the board.

As provided, the MCP8027 QFN40 BLDC Motor Driver Evaluation Board is ready to drive a AC300022 - 24V 3-Phase Brushless DC Motor. The board is equipped with a Start/Stop button and a potentiometer that can be used to adjust the speed of the motor. The evaluation board can drive a BLDC motor with a supply voltage of up to 28V and a motor current up to 20A (rms). The MCP8027 QFN40 BLDC Motor Driver Evaluation Board provides a configurable 3.3V, 750 mW buck converter, 5V and 12V LDO, high-to-low level voltage translators, current sense operational amplifiers, and Hall effect sensors inputs.

Several key test points are available on the board in order to facilitate the user's measurements, tuning, and motor control optimization.

The evaluation board provides a LED for the fault status indication and six on-board LEDs for signaling the Pulse-Width Modulation (PWM) presence.

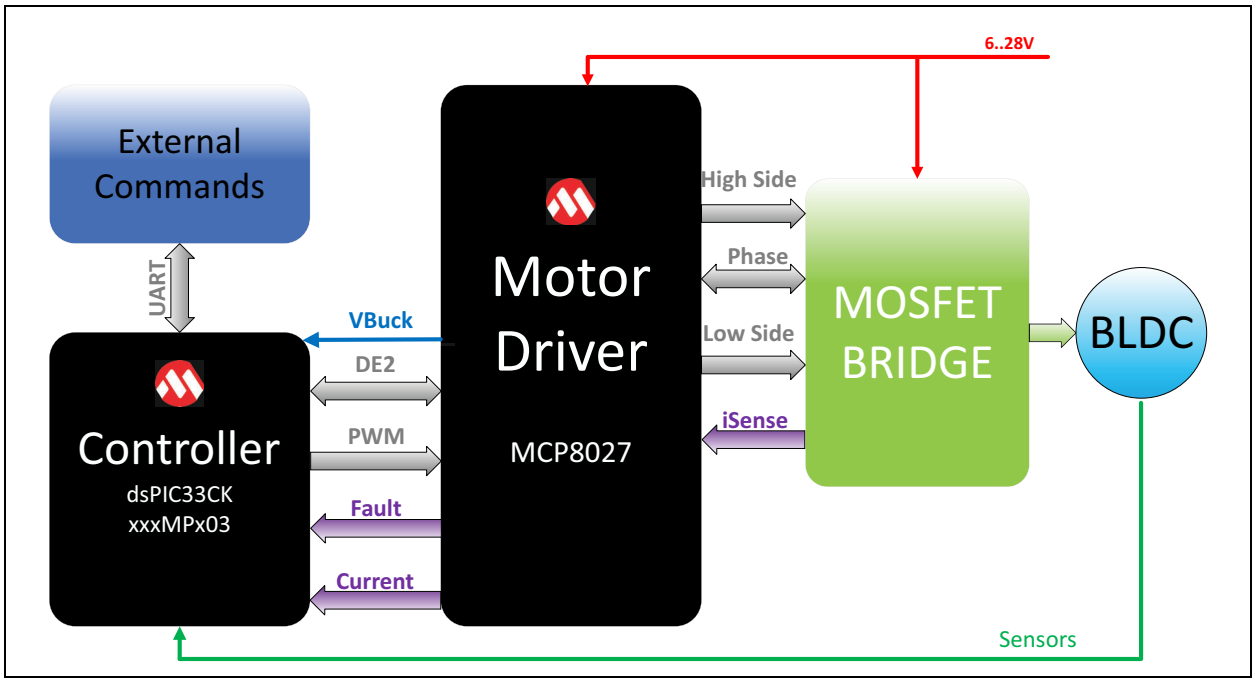


FIGURE 1-1: *MCP8027 QFN40 BLDC Motor Driver Evaluation Board Block Diagram.*

1.3 WHAT IS THE MCP8027 QFN40 BLDC MOTOR DRIVER EVALUATION BOARD?

The input operating voltage range for the board is +6V to +28V. The on-board MCP8027 generates 5V and 12V using internal voltage regulators. The MCP8027 also contains an internal buck regulator configured to provide 3.3V required for dsPIC33CK128MP503 host microcontroller.

An input terminal block is provided to apply the input voltage to the board. An output header connector and plated Printed Circuit Board (PCB) through-hole pads are also provided in order to connect the external motor. A programming header connector is available for updating the firmware contained in the dsPIC33CK128MP503 using a PICkit™ 3(4) programmer/debugger.

An input terminal block is also supplied on the board, to allow users to connect 5V/3V3 Hall sensors.

For UART external communication, the user has the possibility to attach a Serial Communication Interface device through header J3.

For other purposes, a 2-pin connector can be planted on the board for communication with the microcontroller using MCP8027's internal level translator.

Finally, the PCB layout design can serve as a reference for the users who want a robust and low-cost, two-layered, low-voltage, high-current board.

1.4 WHAT DOES THE MCP8027 QFN40 BLDC MOTOR DRIVER EVALUATION BOARD KIT INCLUDE?

The MCP8027 QFN40 BLDC Motor Driver Evaluation Board kit includes:

- The MCP8027 QFN40 BLDC Motor Driver Evaluation Board (EV83F07A)
- Key Information Sheet

Chapter 2. Installation and Operation

2.1 INTRODUCTION

The MCP8027 QFN40 BLDC Motor Driver Evaluation Board demonstrates the features of Microchip's 3-Phase Brushless DC (BLDC) Motor Driver with Power Module, MCP8027, used in a BLDC motor driver application. When used in conjunction with a microcontroller, the MCP8027 will provide the necessary drive signals to drive a 3-Phase BLDC motor.

The MCP8027 contains all necessary functional blocks for developing high performance BLDC/PMSM motor drivers: high and low-side MOSFETs drivers, bias generators, OPAMPs, protection circuity and communication interface for the configuration of the internal circuitry. The motor phase current can be measured using the two-shunt technique described in AN1078. The MCP8027 provides three current sense amplifiers, which can be used for implementation of advanced control algorithms, such as Field-Oriented Control (FOC). The board is equipped with a dsPIC33CK128MP503 high-performance Digital Signal Controller (DSC) and is able to handle simple motor control algorithms like the 6-step one and high-performance algorithm like the Field Oriented Control (FOC).

A dsPIC33CK128MP503 processor is used to supply the PWM inputs to the MCP8027 as well as handle the high-speed Analog-to-Digital Conversion (ADC) required for up to 50 kHz PWM operation. This dedicated microcontroller sustains a large range of motor control applications due to its specific synchronization between different peripherals. In order to demonstrate the MCP8027 capabilities, the evaluation board firmware that uses a trapezoidal drive control algorithm is available on the Microchip website.

2.2 FEATURES

The MCP8027 QFN40 BLDC Motor Driver Evaluation Board has the following features:

- Input operating voltage range: +6.0V to +28V
- Maximum of 500 mA of gate drive current for external N-Channel MOSFETs
- Drives up to a 20A RMS BLDC motor
- 750 mW buck regulator with resistor-programmable output voltage
- ON/OFF momentary contact switch (RUN)
- Reset momentary contact switch (RST)
- Spare user-programmable momentary contact switch (PB1)
- PWM signal LED indicators.
- Fault signal LED indicator.
- PICkit™ 3(4) debugger interface
- Speed control potentiometer
- Terminal block for 3.3V and 5V Hall effect sensors
- UVLO, OVLO and DUVLO protections
- 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 webpage)

2.3 GETTING STARTED

The MCP8027 QFN40 BLDC Motor Driver Evaluation Board is fully assembled and tested for driving a BLDC motor. The board can be easily configured to drive a BLDC motor in sensored or sensorless mode, as well as for sinusoidal triple shunt FOC or trapezoidal motor control algorithm. This board requires the use of an external voltage source capable of supplying 6V to 28V at the rated motor current. The board is presented in Figure 2-1. A BLDC motor is also required to evaluate the motor driver.

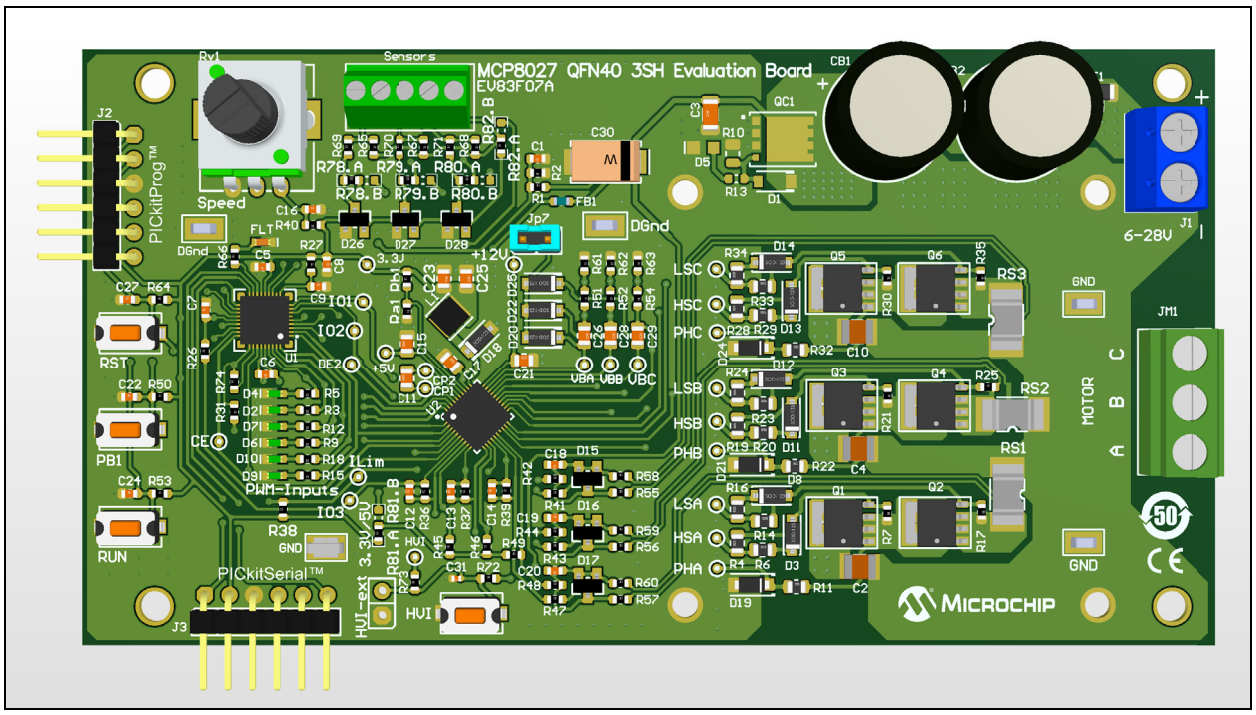


FIGURE 2-1: *MCP8027 QFN40 BLDC Motor Driver Evaluation Board PCB.*

2.3.1 Connections

2.3.1.1 JUMPER SETTINGS

The MCP8027 QFN40 BLDC Motor Driver Evaluation Board has several user-configurable jumpers. The jumpers are described in Table 2-1 below. The configuration jumpers positioning is illustrated in Figure 2-2:

TABLE 2-1: MCP8027 QFN40 BLDC MOTOR DRIVER EVALUATION BOARD JUMPERS

Jumper	Positions	Function Description
R78, R79, R80	Hall/Ph	Hall or BEMF are selected for monitoring
R82	3V3/5	3.3/5V Hall power voltage selection
Jp 7	12V	12V for bootstrap
R81	3V3/5	3.3/5V bias voltage for Op-amps

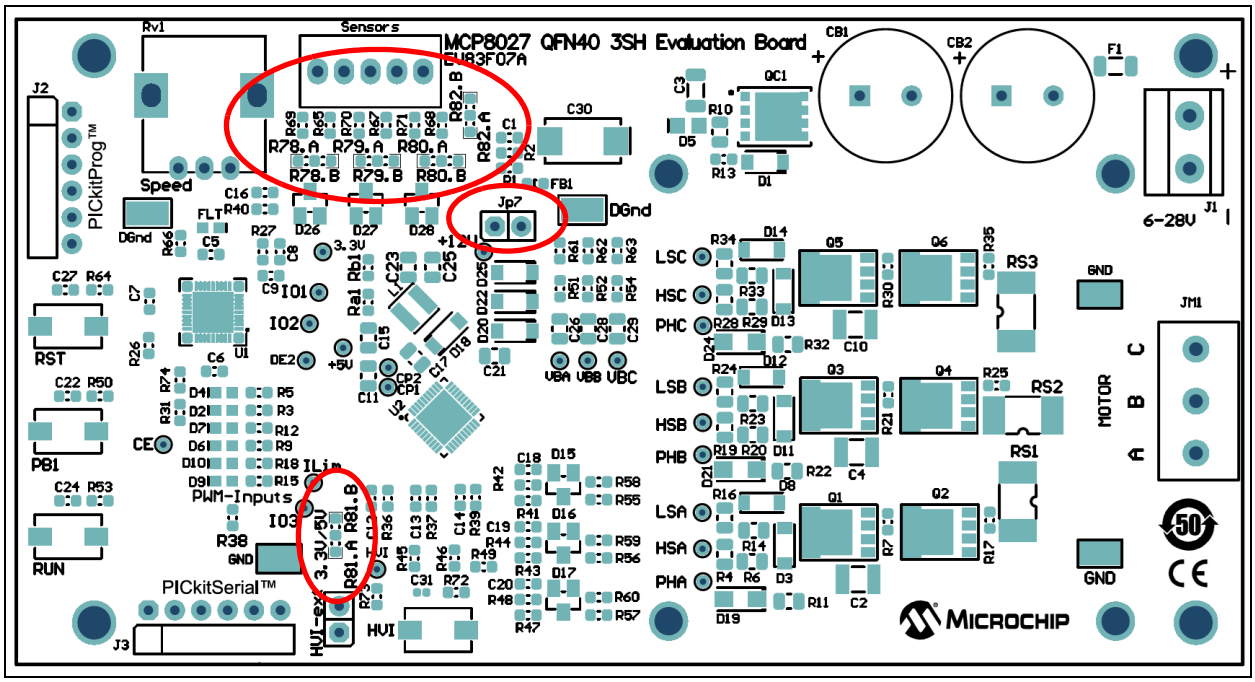


FIGURE 2-2: *Board's Jumpers Positioning.*

The board can be easily configured for different types of motor and control algorithms:

- BLDC Trapezoidal sensorless based on BEMF null cross detection.
- BLDC Trapezoidal based on sensor position detection.
- PMSM, FOC, single shunt sensorless (with/without wind milling).
- PMSM, FOC, single shunt based on sensor position detection.

Table 2-2 describes the jumper's settings for mode for these motor control types.

TABLE 2-2: MOTOR CONTROL MODE SETUP

Jumper	Positions	Description
Trapezoidal/FOC Sinusoidal Sensorless Mode		
R78, R79, R80	BEMF	Connect PhX → ADC via R78.B, R79.B, R80.B 0R resistors
Trapezoidal/FOC Sinusoidal Sensored Mode		
R78, R79, R80	HALL	Hall Outputs → uCtrl. via R78.A, R79.A, R80.A 0R resistors

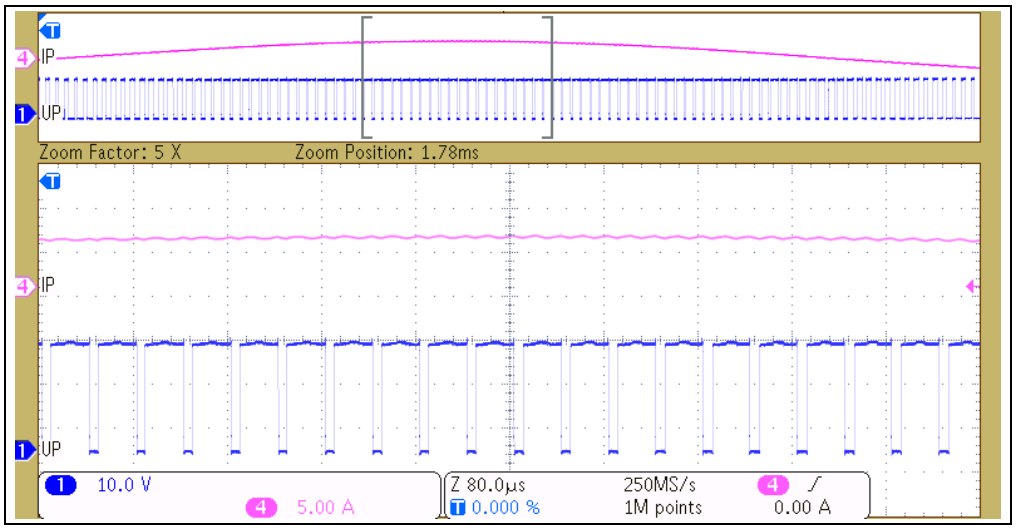


FIGURE 2-3: *Sinusoidal Motor Control Mode.*

For the same motor, Figure 2-3 shows the currents for sensorless sinusoidal mode, taken on this board.

2.3.1.2 AVAILABLE INTERFACING CONNECTORS

For external communication board interfacing, six connectors are available.

- J2 is mainly dedicated for microcontroller programming/debugging. After this step is finalized, it can be used for other purposes e.g. for rotary encoder interfacing due to microcontroller pin remapping feature.
- J3 is a simple header connector that can be used for serial communication using a PICkit serial communication tool or an USB to serial bridge (e.g. ADM00559 provided by Microchip).
- HVI-ext (not populated) can be used for external Wakeup command when SLEEP mode was induced or as adapter for high level command transmitter.
- J4 is a connector used to connect the Hall effect sensors to the dsPIC33CK128MP503 microcontroller available on the board.
  - Before connecting the Hall effect sensors, the user must make sure that the Hall effect sensors are powered with the right voltage by putting the R82 0R resistor in location R82.A for 3.3V or in location R82.B for 5V.
  - The user must also check if the R78, R79 and R80 0R resistors are in the correct location to select the Hall effect sensors (R78.A, R79.A and R80.A).
  - The included firmware is for sensorless only.
- JM1 is the motor driver output. This is the connection to the BLDC motor.
- J1 is the power supply connection. This board needs to be connected to a power supply with an output range of 6 to 28V, according to the voltage ratings of the motor used by the user.

2.3.1.3 POWERING THE MCP8027 QFN40 BLDC MOTOR DRIVER EVALUATION BOARD

- Apply the input voltage to the input power terminal block J1. The input voltage source should be limited to +28V. For proper operation the input voltage should be in concordance with the motor rated voltage. Connect the positive side of the input power source (+) to pin 2 of J1. Connect the negative or return side (-) of the input source to pin 1 of J1. Refer to Figure 2-2.

2.3.1.4 CONNECTING A MOTOR TO THE MCP8027 QFN40 BLDC MOTOR DRIVER EVALUATION BOARD

- Connect each phase winding of a 3-phase BLDC motor to the appropriate terminal on the board (A, B and C).

2.3.2 Operating a Motor

Step 1. Turn the SPEED adjust potentiometer (RV1) fully counterclockwise to obtain the slowest speed setting. Now turn the speed adjust approximately ¼ turn clockwise to allow for 25% motor speed.

Step 2. Turn on the power supply. At this moment, the yellow Fault LED is blinking at around 10 Hz.

Step 3. Press and release the RUN switch (ST1) to start the motor. At this moment, the PWM's LEDs indicate the motor powering.

Step 4. Turn the Speed potentiometer clockwise to increase motor speed and counterclockwise to decrease motor speed. The Speed Adjust changes the PWM duty cycle of the PWM signals being sent to the MCP8027.

Step 5. Press and release the RUN switch again to stop the motor.

2.3.3 Indicator LEDs

The MCP8027 QFN40 BLDC Motor Driver Evaluation Board has seven LEDs to indicate system status. Table 2-3 lists the LED indicators and their description.

TABLE 2-3: LED INDICATORS

PCB Location	Name	Description
Flt	Fault	Indicates Fault status
D2, D6, D9	PWMxL	PWM Phase x low-side input to MCP8027
D4, D7, D10	PWMxH	PWM Phase x high-side input to MCP8027

2.3.4 Test Points

There are several test points on the board that allow probing of voltages, currents and signals. An abridged listing is shown in Table 2-4.

TABLE 2-4: TEST POINTS DESCRIPTION

Test Point Name	Description
GND	Power supply ground (–)
3.3V	3.3V buck voltage
+5V	5V internal LDO output
+12V	12V internal LDO output
DGnd	Digital Reference ground
CE	CE driver chip enable signal
DE2	DE2 communications signal
CP1/2	Charge pump flying capacitor input
VBA/B/C	Bootstrap capacitor power input
LSA/B/C	A/B/C Phase Low driver outputs
HSA/B/C	A/B/C Phase High driver outputs

TABLE 2-4: TEST POINTS DESCRIPTION (CONTINUED)

Test Point Name	Description
PHA/B/C	A/B/C motor/driver phase signals
IO1/2/3	Sense Current Amplifier output for each phase
ILim	ILIMIT_OUT signal from MCP8027

2.3.5 Reprogramming the On-board dsPIC33CK128MP503

The on-board dsPIC33CK128MP503 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® or REAL ICE™ in-circuit emulator, or a PICkit 4 programmer.

1. Connect the power source to the board as explained in **Section 2.3.1.3**.
2. Connect a PICkit 3 or a PICkit 4 to the J2 header.
3. Startup up the MPLABX Integrated Development Environment (IDE) and load the MCP8027 QFN40 BLDC Motor Driver Evaluation Board firmware project.
   In MCP802X.H, replace the definition for driver type: #define DRIVER MCP8027.

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

- Add Library `libdsp-elf.a` located in the XC16 `???\src\Libdsp\lib` directory.
- Add XC16-as ASM. Include Directory in XC16 `???\src\Libdsp\asm`.
- Set hardware tool to "PICkit 3," "PICkit 4," or "REAL ICE".

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

2.3.6 Configuring the MCP8027

The MCP8027 has configuration registers that may be used to modify the operating parameters of the device. The parameters are modified by sending commands to the MCP8027 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 MCP8027 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 4-5 of the MCP8027 Data Sheet, DS20006897, which is available at the corporate website (**www.microchip.com**).

2.3.7 MCP8027 Configuration Message Responses

A solicited response byte from the MCP8027 devices will always echo the command byte with bit 7 set to `'0'` (Response) and with bit 6 set to `'1'` for 'Acknowledged' (ACK) or `'0'` for 'Not Acknowledged' (NACK).

The second byte, if required, will be the data for the host command.

Table 4-6 in the MCP8027 Data Sheet, DS20006897, which is available at the corporate website at **www.microchip.com**, describes the messages sent to the host in response to a host command message.

If a multibyte command is sent to the MCP8027 device and no second byte is received by the MCP8027 device, then a 'Not Acknowledged' (NACK) message will be sent back to the host after a 5 ms time-out period.

The MCP8027 device may send unsolicited command messages to the host controller. No message is required as a response from the host controller.

2.3.7.1 MCP8027 REGISTER DEFINITIONS

The MCP8027 registers contain the bits operated on by the messaging system. The registers are only accessible via the various messages. The structure of the registers is listed below. (For more information see the MCP8027 datasheet.)

CFG 2-0: CONFIGURATION REGISTER 0

U-0	R/W-1	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	PU30K	SLEEP	NEUSIM	EXTULVO	EXTSC	EXTOC1	EXTOC0
bit 7							bit 0

CFG 2-1: CONFIGURATION REGISTER 1

R/W-0	R/W-0	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

CFG 2-2: 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
bit 7							bit 0

STAT 2-0: STATUS REGISTER 0

R-0	R-0	R-0	R-0	R-0	R-0	R-0	R-0
BUVLOF	BUVLOW	BIOCPW	OVLOF	DOVLOF	UVLOF	OTPF	OTPW
bit 7							bit 0

STAT 2-1: STATUS REGISTER 1

U-0	U-0	R-0	R-1	R-0	R-0	U-0	U-0
—	—	UVLOF5V	BORW	XOCPF	XUVLOF	—	—
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

The communication interface uses a standard UART baud rate of 9600 bits per second. The transmit/receive packet must be done in Half-duplex mode. The host must listen to the DE2 line in order to check for contentions. In case of contention, the host must release the line and wait for at least three packets time length before initiating a new transfer.

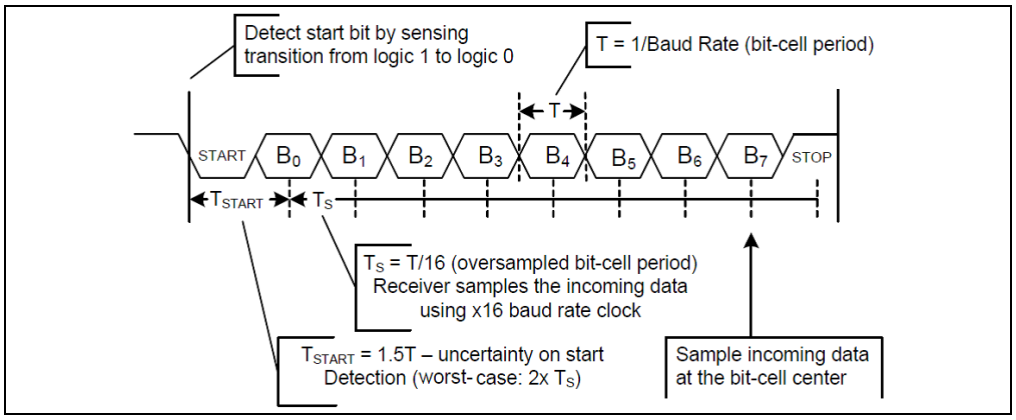


FIGURE 2-4: *DE2 Packet Format and Timing.*

2.4 SCHEMATIC PARTICULAR FEATURES

2.4.1 Current Sense Amplifier (CSA)

In order to avoid limitation for CSA output and assure the ADC range conversion, the initial offset of CSA is settled to around 1.65V. The total gain of the CSA is Gt = 16. As a recommendation, for high motor currents it is better to decrease the equivalent shunt resistor value to reduce the losses and to avoid analog limitation or any overflows in numerical computation.

For sense current detection the internal available operational amplifiers are configured as presented in Figure 2-5 for a high-speed robustness Current Sense Amplifier (CSA). CSA output is used, at the same time, by the internal over current comparator and by microcontroller's ADC for digital conversion.

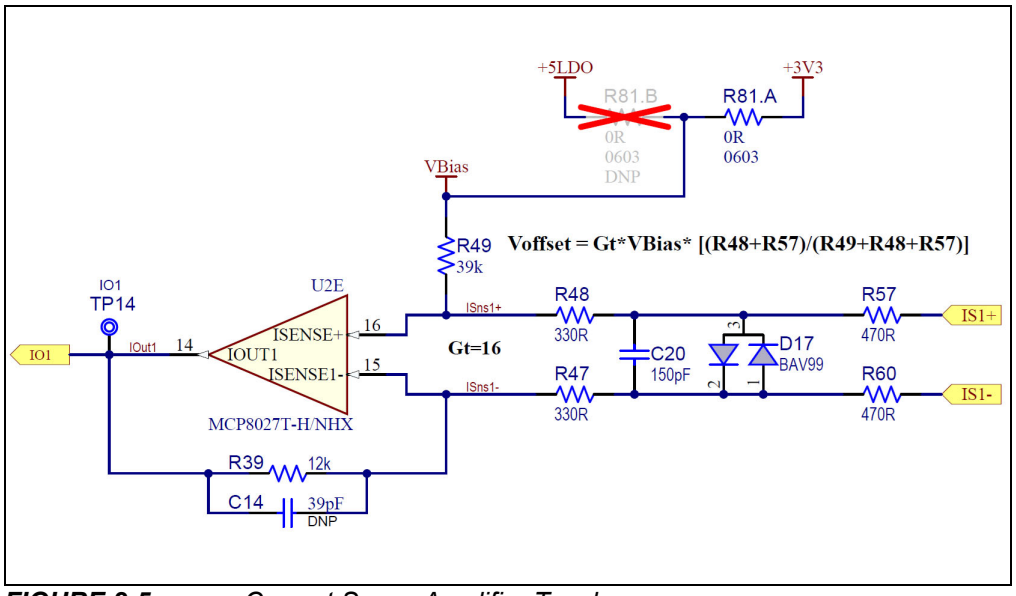


FIGURE 2-5: *Current Sense Amplifier Topology.*

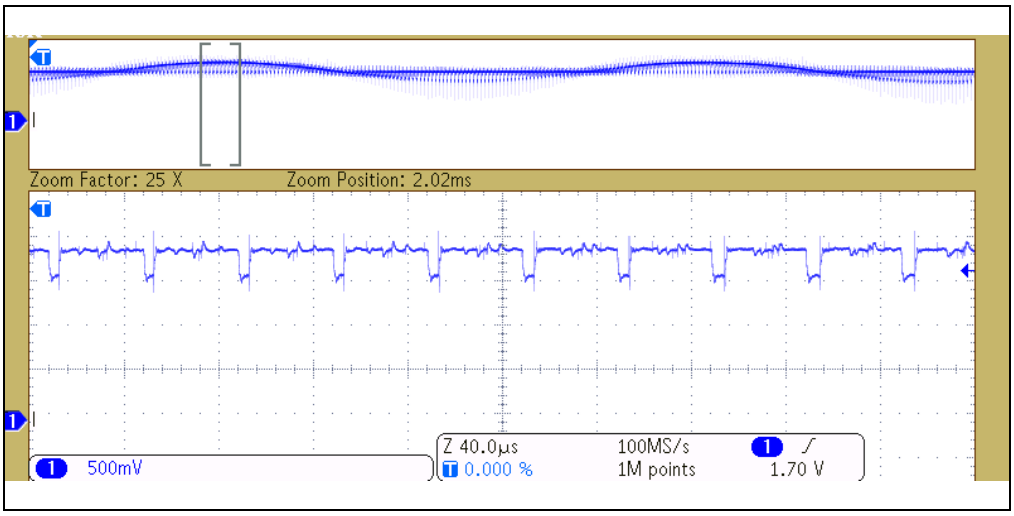


FIGURE 2-6: *Output Waveform of One CSA in Three Shunt, FOC Motor Control Mode.*

2.4.2 Asymmetric Turn On/Off External MOSFET Bridge

In PMSM, FOC, three shunt, sensorless, motor control it is recommended to use an asymmetric Turn On/Off external MOSFET's bridge. Beside the others adverse effects reduction, this technique gives a more accurate waveform for CSA output, a better phase currents measuring and as a result a more robustness in motor control process. Figure 2-7 illustrates the CSA output improvement.

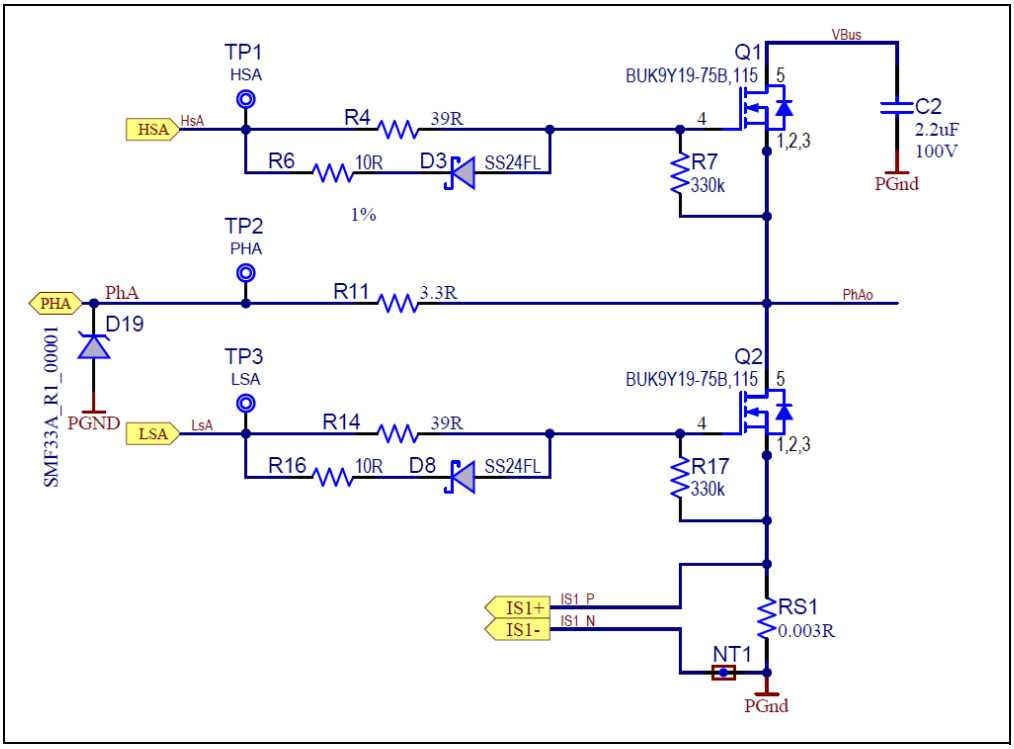


FIGURE 2-7: *Asymmetric Turn On/Off for One MOSFET Pair.*

2.5 APPLICATION HINTS

There are multiple combinations of motor types and MOSFETs used in external bridge and an excessive dV/dt can be achieved. Thus sometimes it is possible that dV/dt is just right to trigger the parasitic PNP between the two internal driver NMOS transistors. This transistor now discharges the external NMOS gate a little bit, thus reducing the dV/dt and switches off again, then the internal PMOS charges the gate again and thus discharges the bootstrap capacitor, so dV/dt increases, PNP is triggered again and so on. This repeats until the charging of the external gate no longer has enough dV/dt. (Figure 2-8).

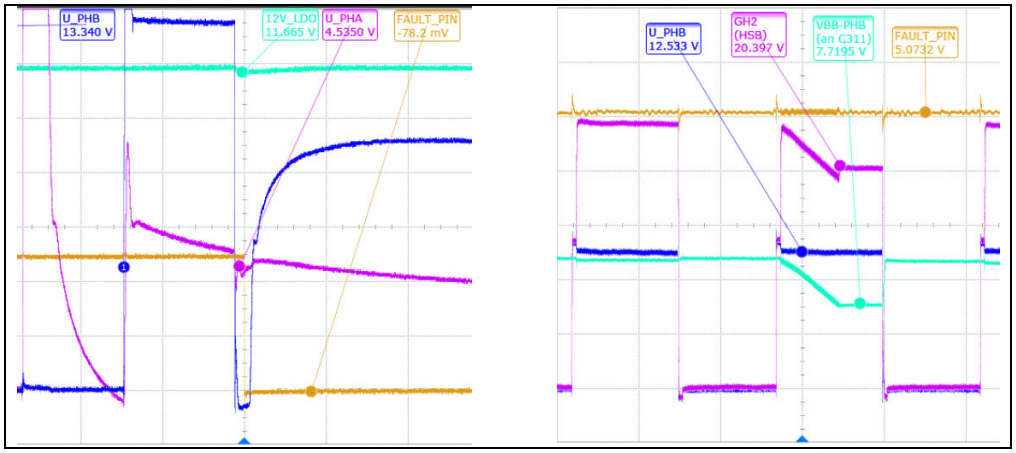


FIGURE 2-8: *Parasitic Triggering of the Bootstrap Capacitor Discharging.*

Application improvement:

1. For bootstrap circuits, use Schottky diodes (for example SS24) with low direct voltage. Schottky diodes with low junction direct voltage provide as much voltage as possible across the bootstrap capacitors to prevent premature UVLO fault triggering. In the motor control process, especially at high duty cycle, the phase node could not reach the ground and as a result the bootstrap capacitors will not fully charge. Additionally, the user must properly choose the value of the bootstrap capacitors according to the used MOSFET. Due to the HS commutation, the voltage will start to decrease and might reach the OVLO threshold.
2. Add BOOTSTRAP VOLTAGE SUPPRESSION diodes for a better protection. In this case, the parasitic junction capacitance along with small value resistor 2-4Ω placed on each input phase will increase the noise sensitivity.

In general, for trapezoidal control mode, without swapping PWM commutation or for Discontinuous SPVM these capacitors should be larger than 0.22 µF to avoid excessive discharging and the DUVLO fault trigger.

- Before the motor energizing, the bootstrap capacitors must be charged by low side activation for a time depending on value of the bootstrap capacitors.
- During this stage, the driver can give a D/UVLO fault condition, especially when large bootstrap capacitors are used (e.g. for trapezoidal motor applications). In this case a CLEAR FAULT sequence must be performed.
- It is better to activate the OCP, UVLO protections after the bootstrap charging sequence.
- The Duty Cycle value should be limited at:
  PWM period - Dead Time rising - Dead Time falling.
  A software duty cycle limitation for PWMs, correlated with dead time, is recommended to allow the phase node to reach the 0V potential and the bootstrap capacitors recharging, to avoid false D/UVLO fault. In addition, if the blanking time is not enough large, false faults can be triggered.

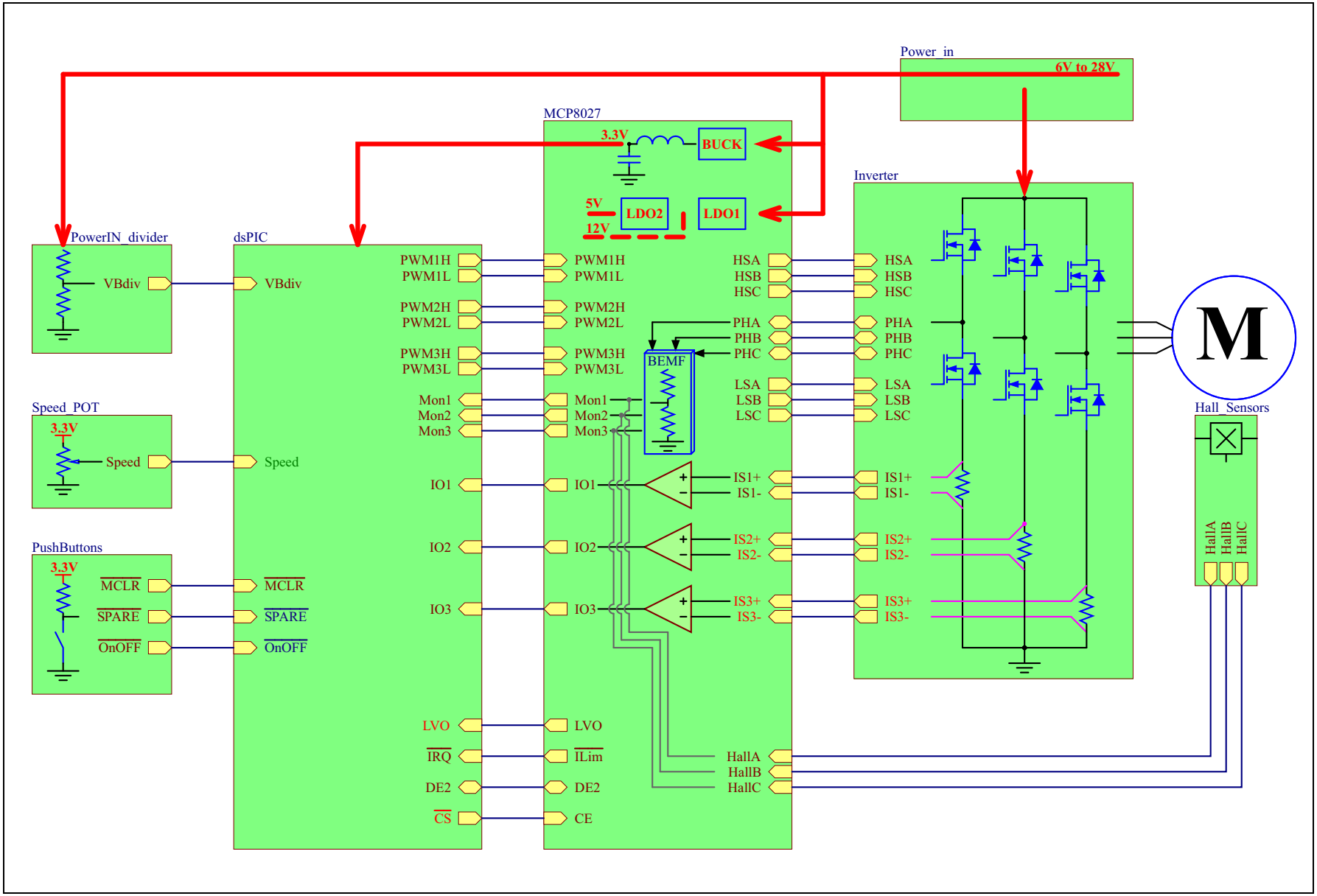
Appendix A. Schematics and Layouts

A.1 INTRODUCTION

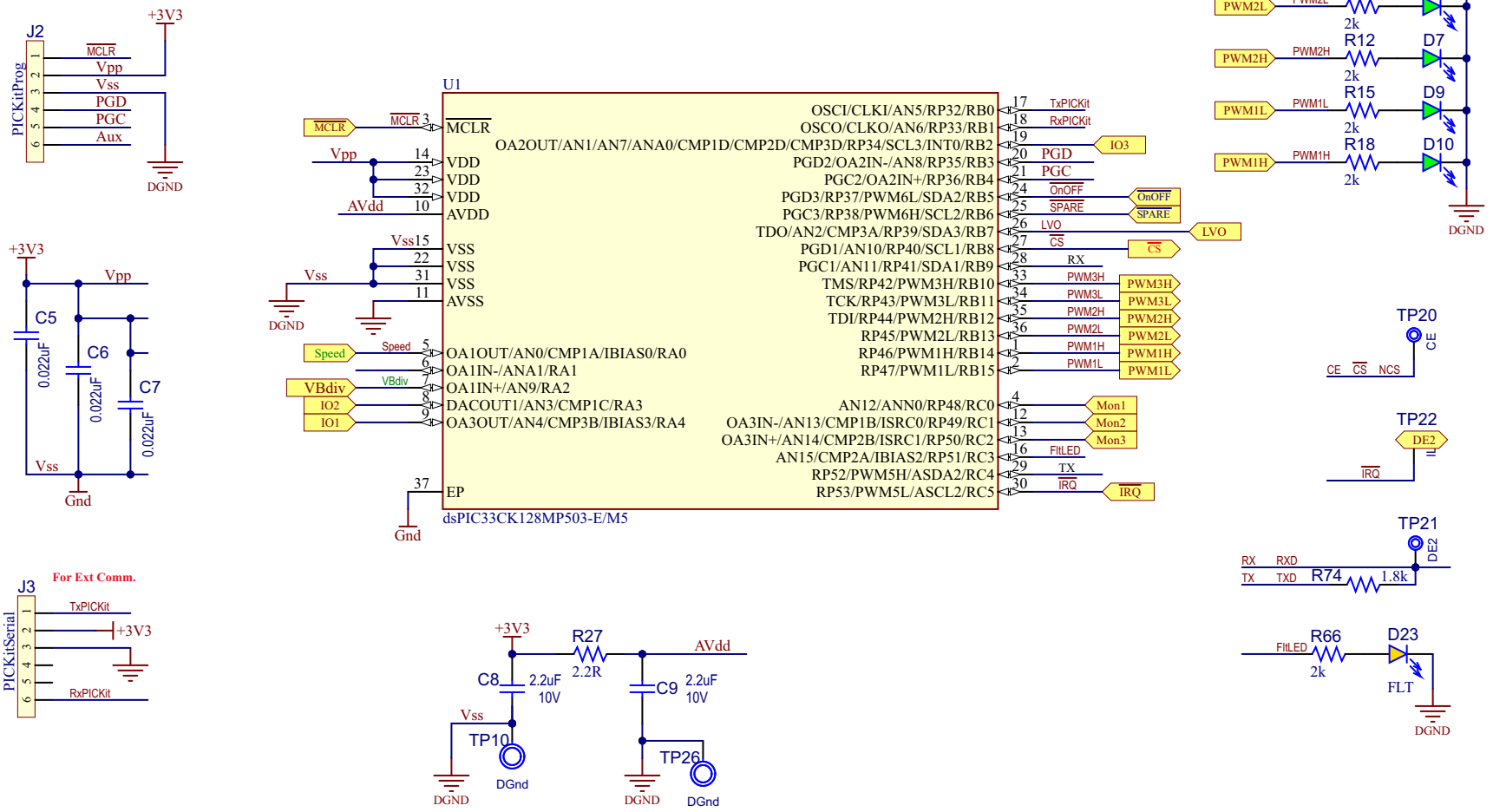
This appendix contains the schematics and layouts of the MCP8027 QFN40 BLDC Motor Driver Evaluation Board:

- EV83F07A – Top Schematic
- EV83F07A – dsPIC Connections
- EV83F07A – Hall Effect Sensors Connection
- EV83F07A – Inverter
- EV83F07A – MCP8027
- EV83F07A – Power Supply
- EV83F07A – Power Supply Divider
- EV83F07A – Push Buttons
- EV83F07A – Speed Potentiometer
- EV83F07A – Top Silk
- EV83F07A – Top Copper and Silk
- EV83F07A – Top Copper
- EV83F07A – Bottom Copper
- EV83F07A – Bottom Copper and Silk
- EV83F07A – Bottom Silk

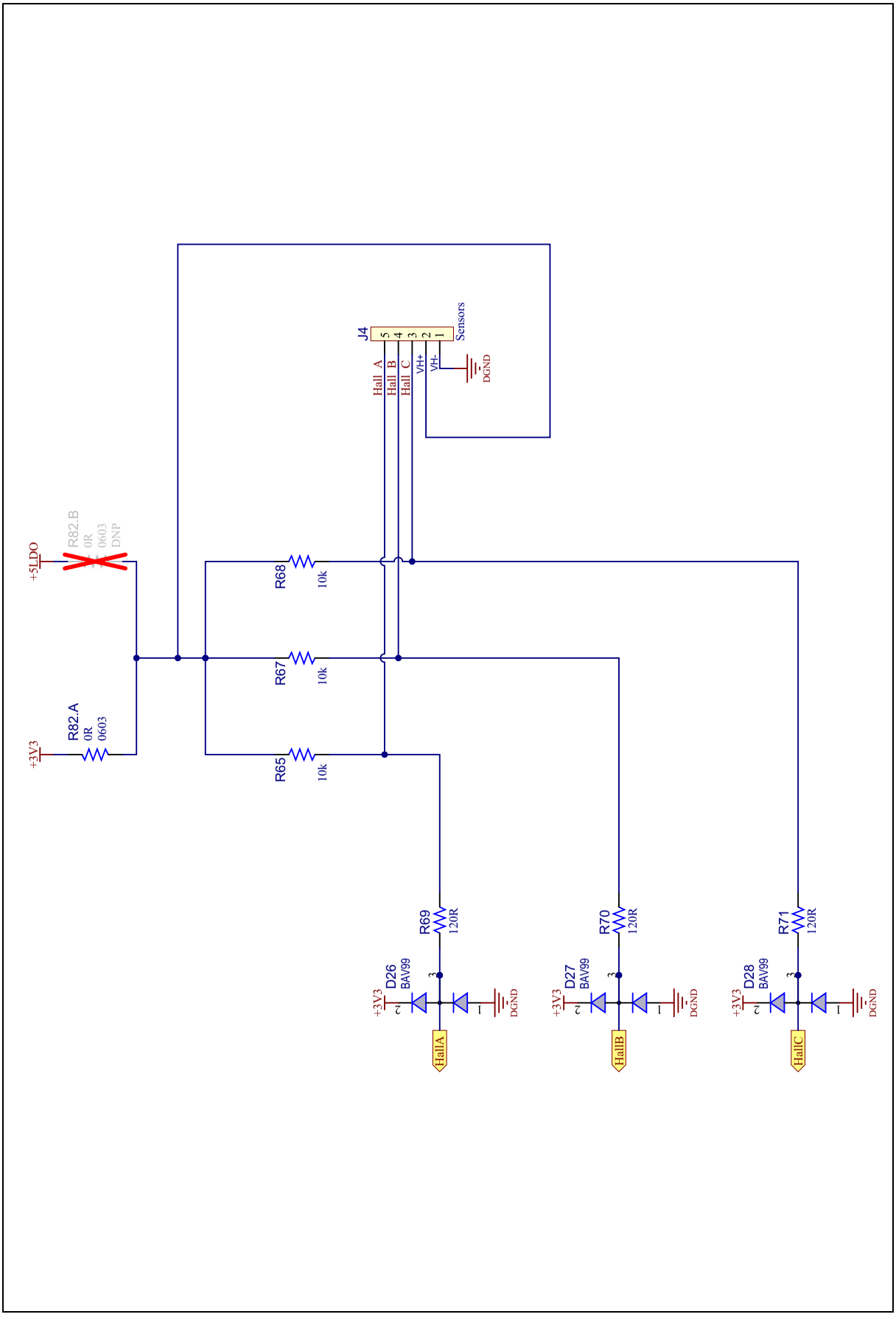
A.2 EV83F07A – TOP SCHEMATIC



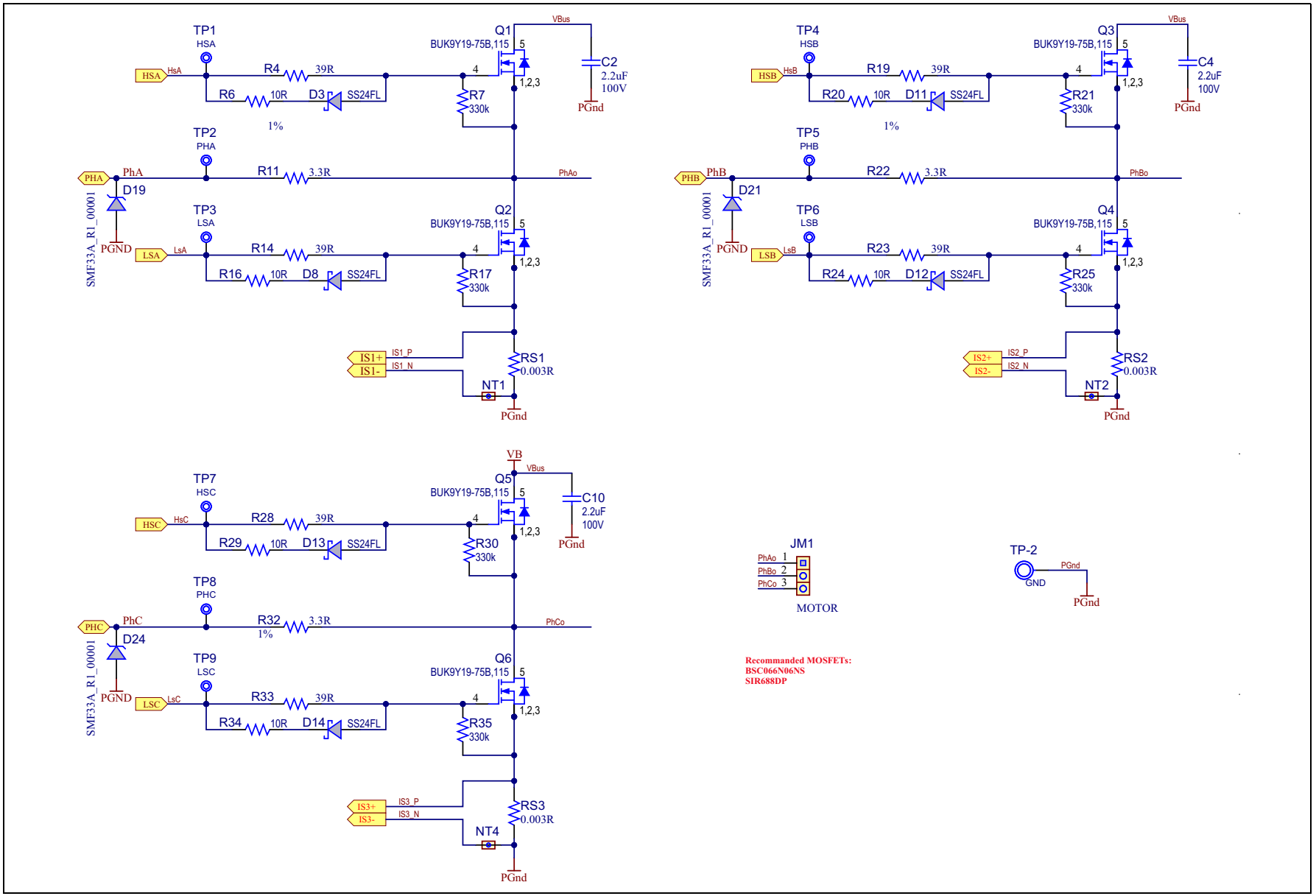
A.3 EV83F07A – DSPIC CONNECTIONS



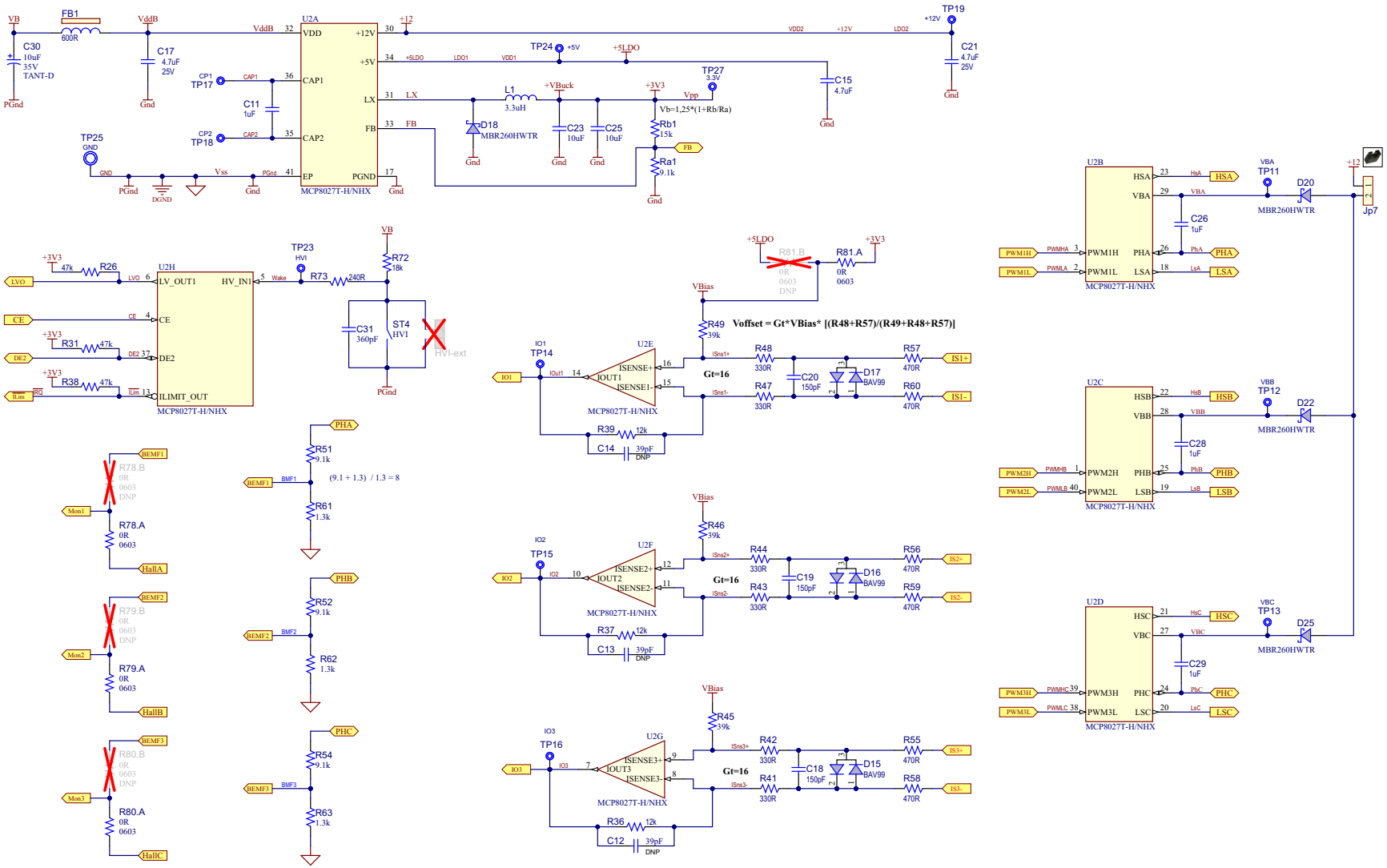
A.4 EV83F07A – HALL EFFECT SENSORS CONNECTION



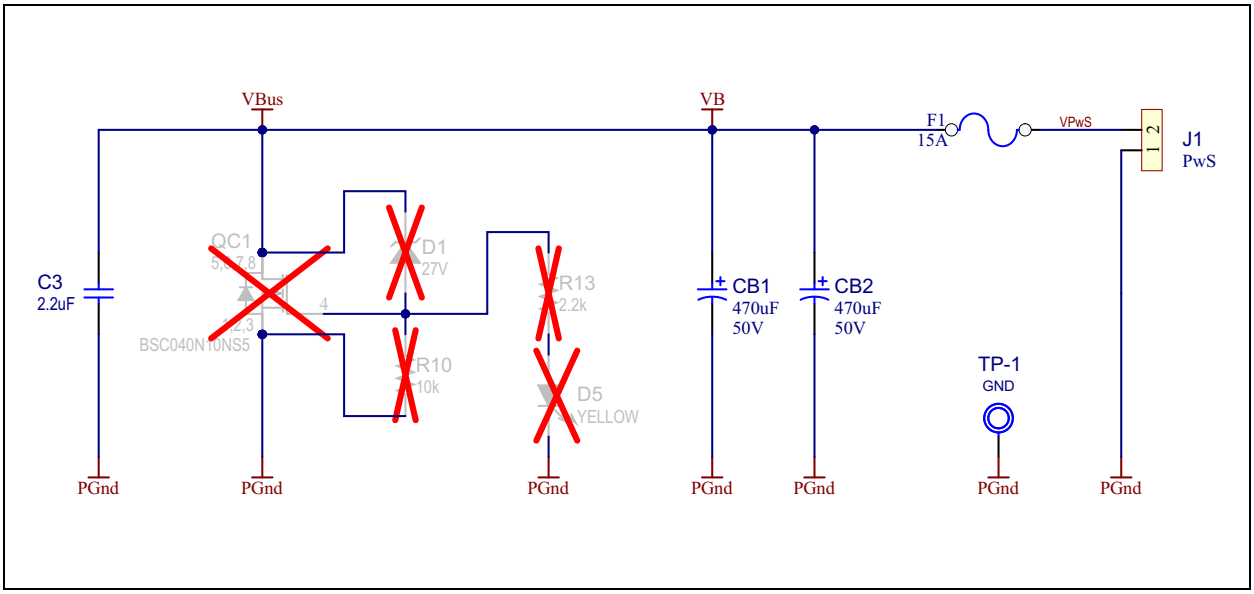
A.5 EV83F07A – INVERTER



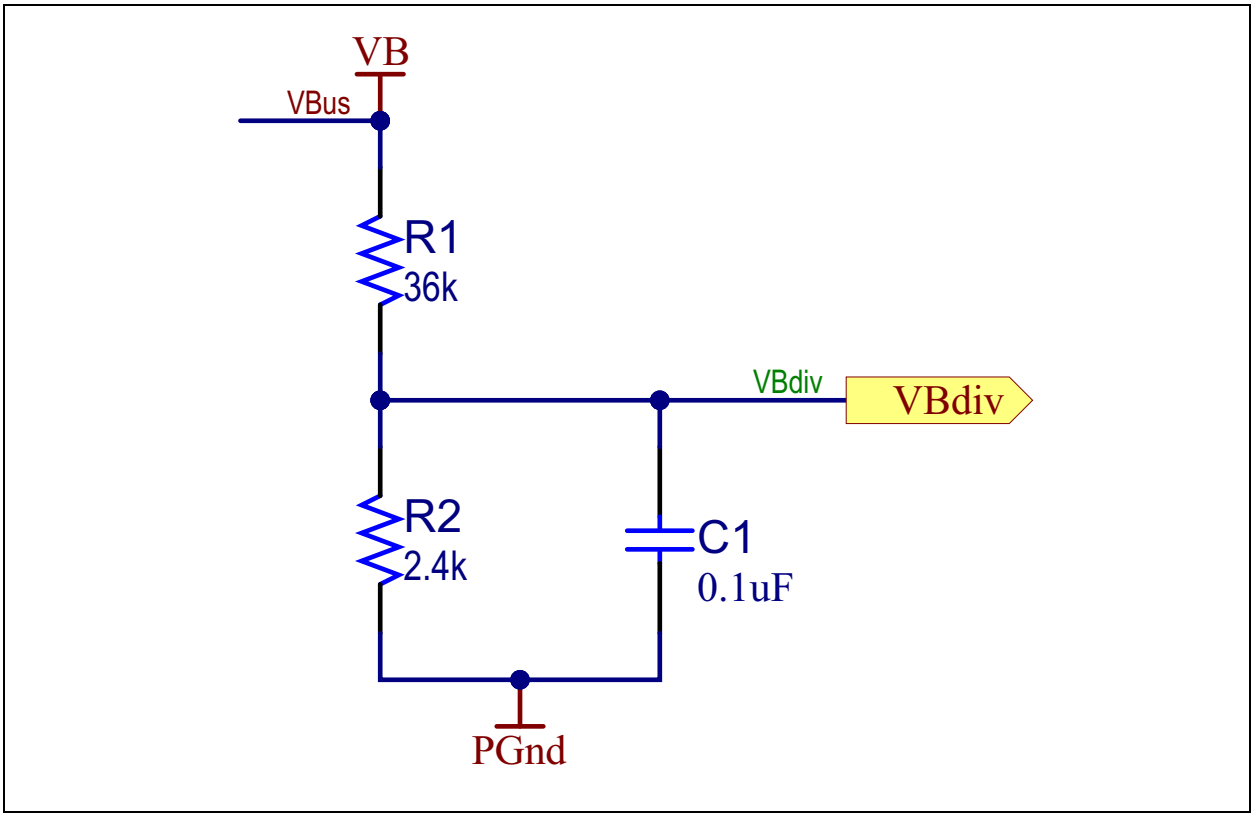
A.6 EV83F07A – MCP8027



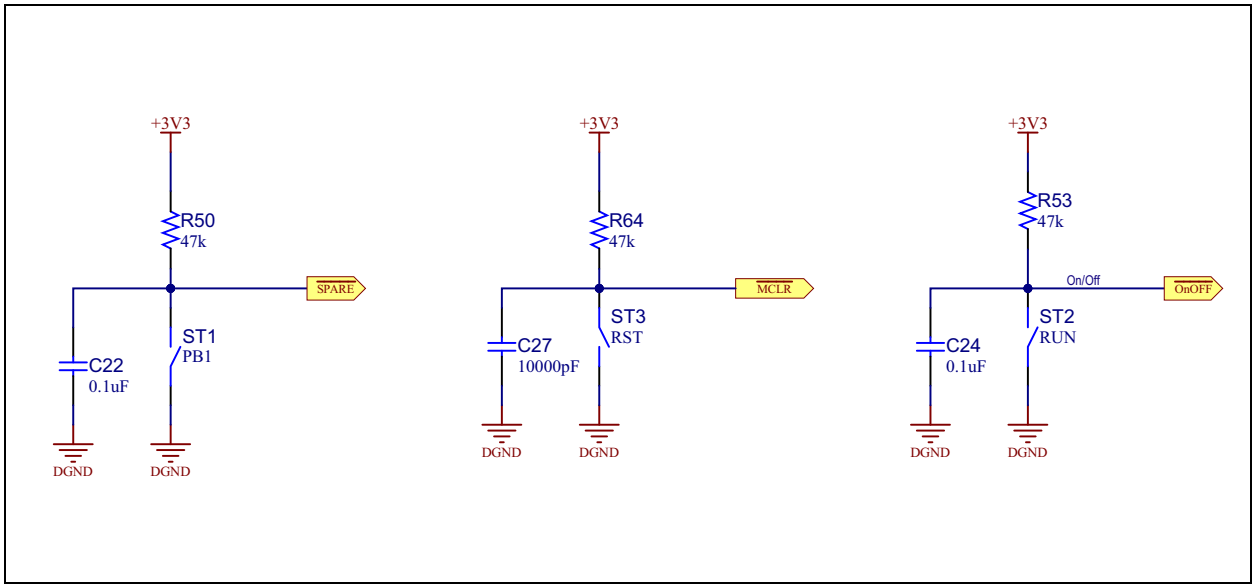
A.7 EV83F07A – POWER SUPPLY



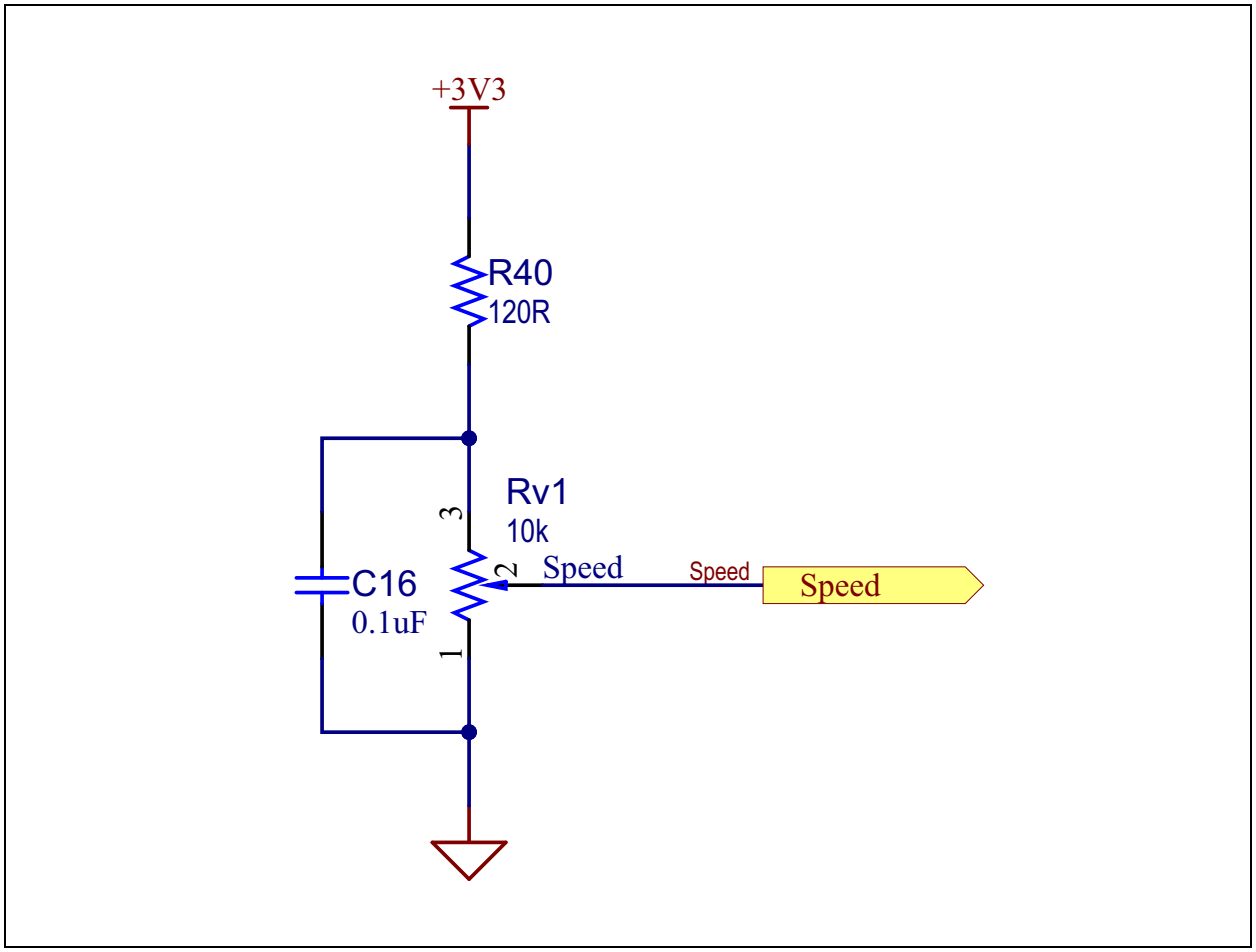
A.8 EV83F07A – POWER SUPPLY DIVIDER



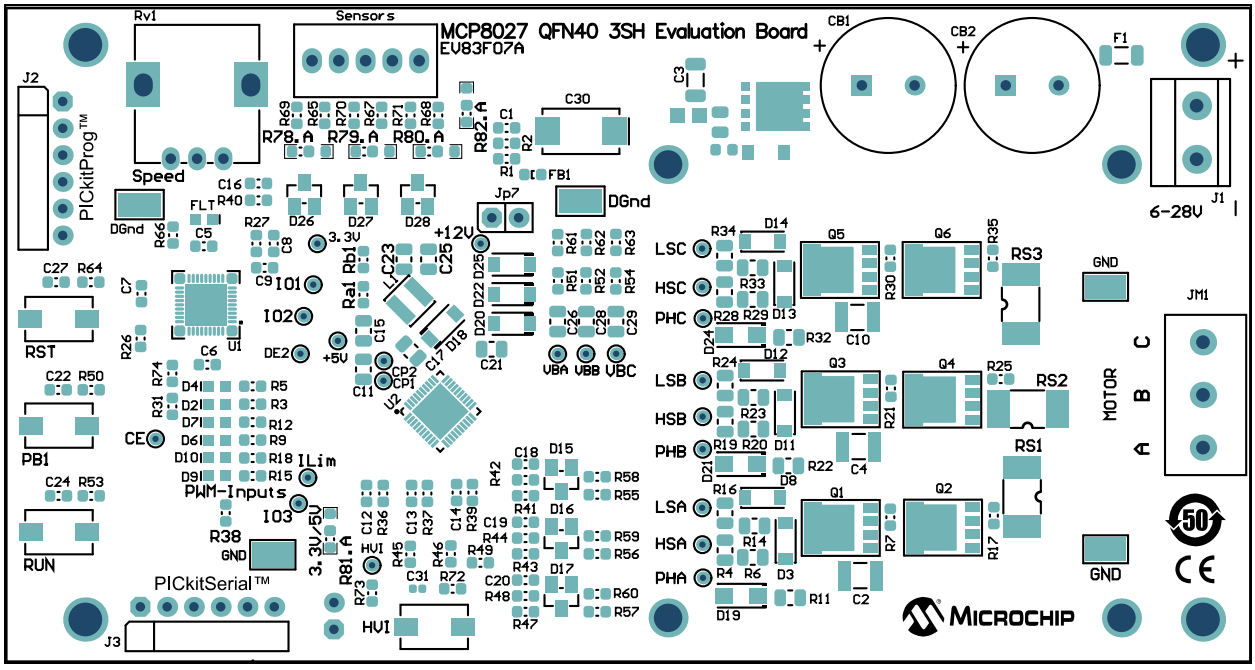
A.9 EV83F07A – PUSH BUTTONS



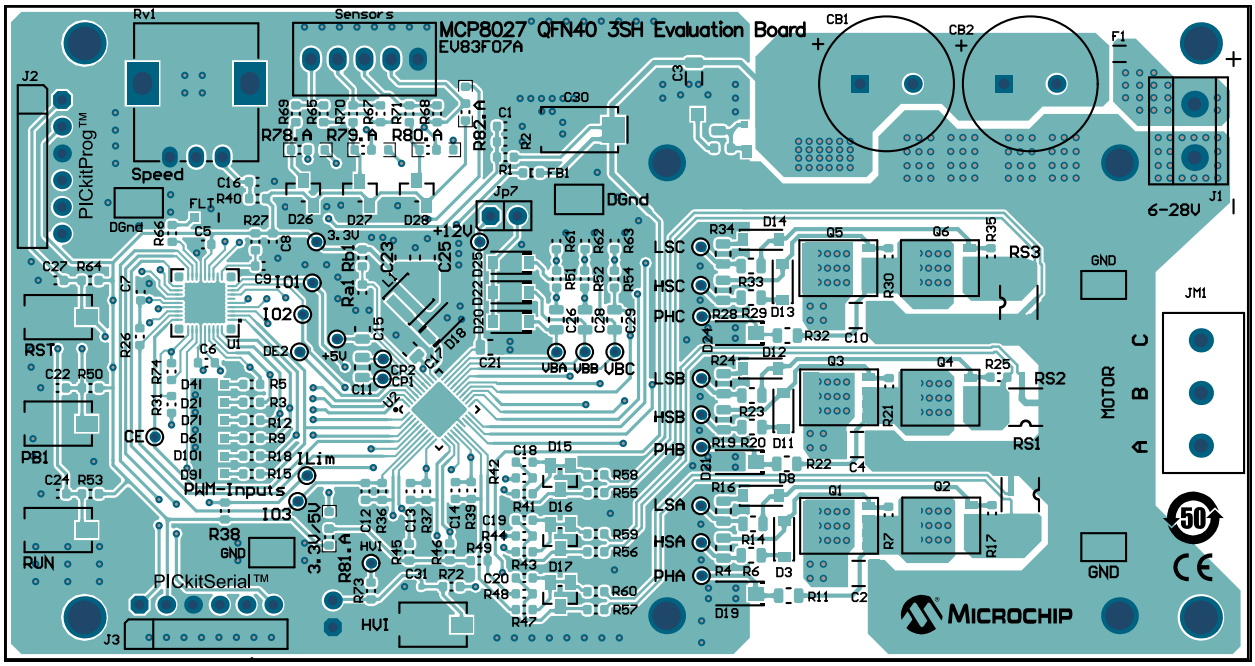
A.10 EV83F07A – SPEED POTENTIOMETER



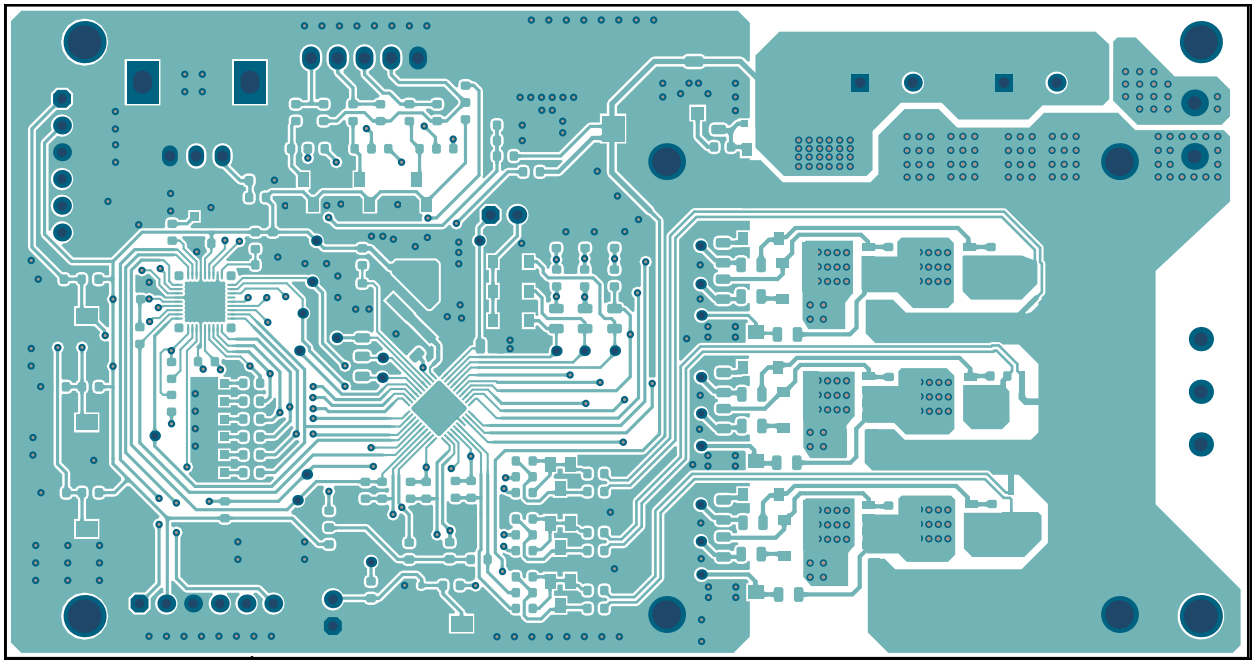
A.11 EV83F07A – TOP SILK



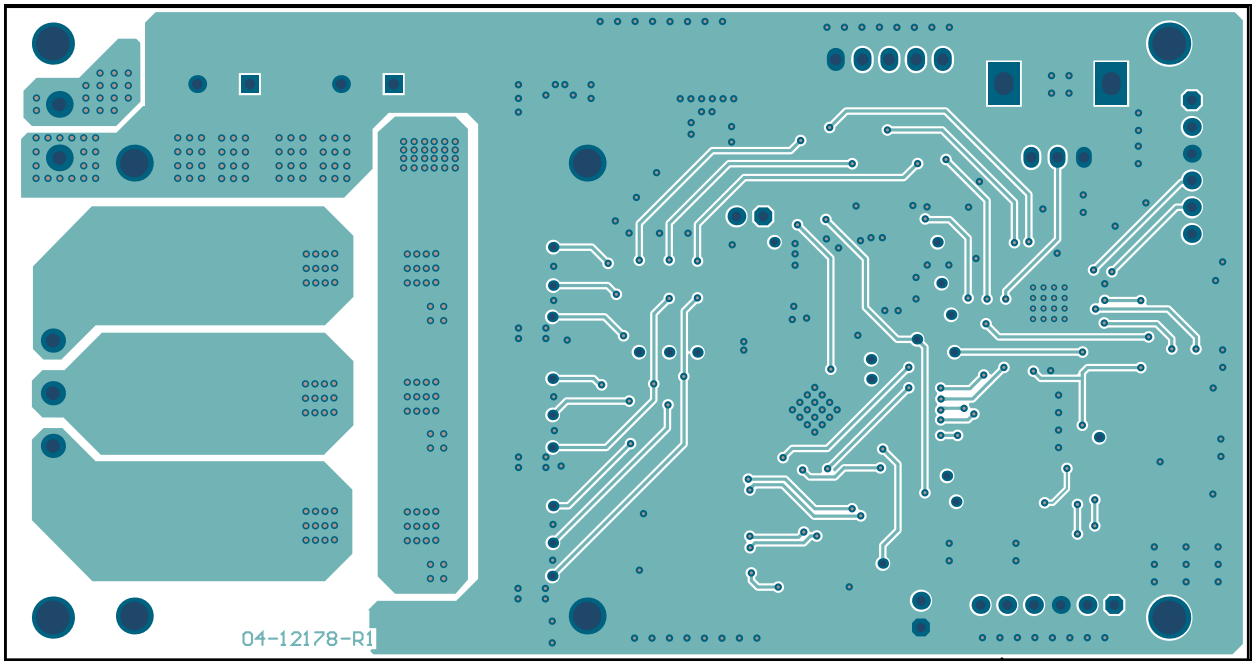
A.12 EV83F07A – TOP COPPER AND SILK



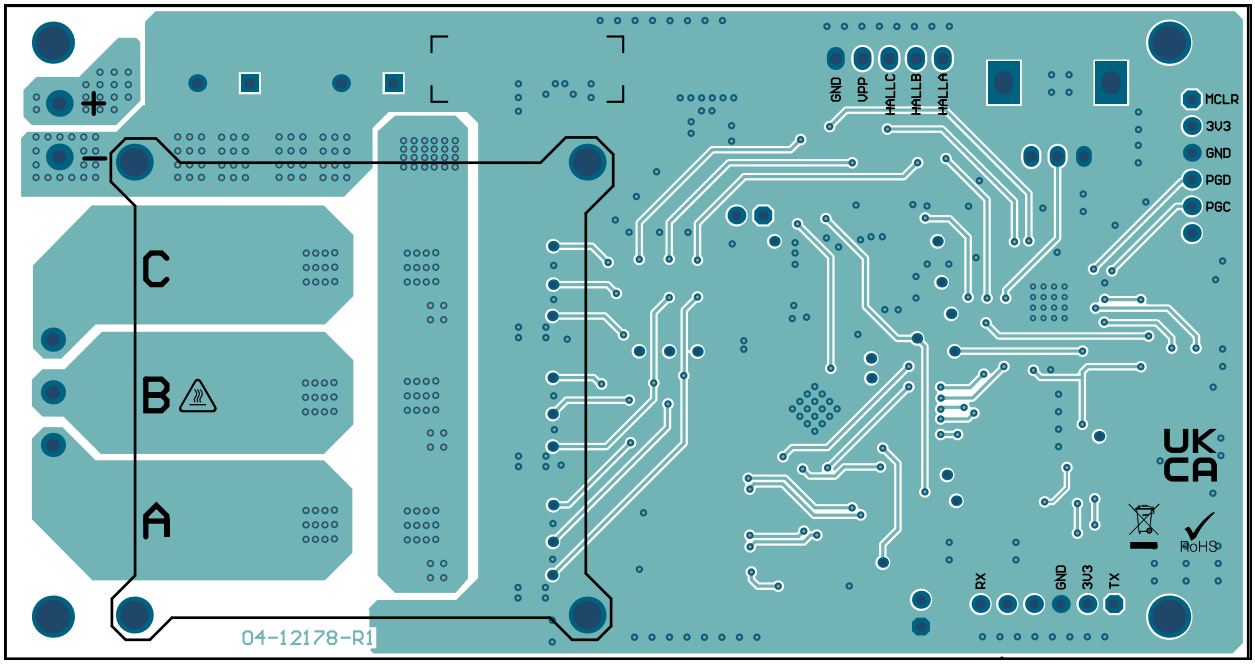
A.13 EV83F07A – TOP COPPER



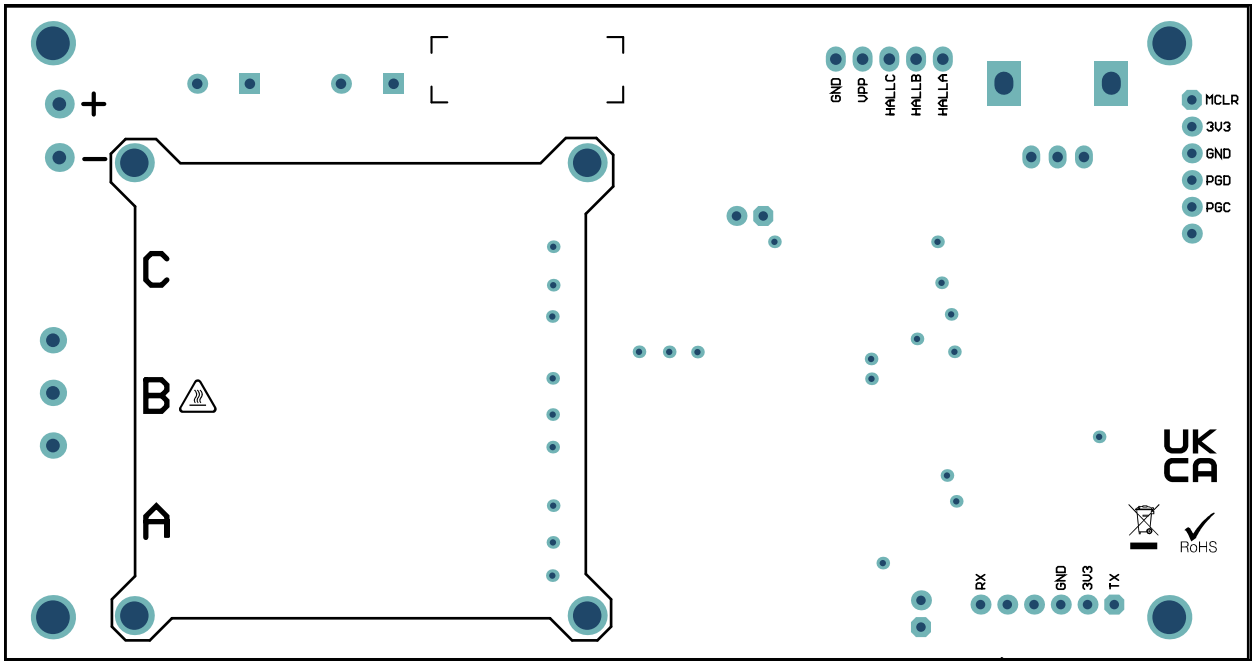
A.14 EV83F07A – BOTTOM COPPER



A.15 EV83F07A – BOTTOM COPPER AND SILK



A.16 EV83F07A – BOTTOM SILK



NOTES:

Appendix B. Bill of Materials (BOM)

TABLE B-1: BILL OF MATERIALS (BOM)

Qty.	Reference	Description	Manufacturer	Part Number
4	C1, C16, C22, C24	Capacitor, ceramic, 0.1 µF, 25V, 10%, X7R, SMD, 0603	Kyocera AVX®	06033C104KAT2A
3	C2, C4, C10	Capacitor, ceramic, 2.2 µF, 100V, 10%, X7R, SMD, 1210	KEMET	C1210C225K1RACTU
1	C3	Capacitor, ceramic, 2.2 µF, 50V, 10%, X7R, SMD, 1206	TDK Corporation	CGA5L3X7R1H225K160AB
3	C5, C6, C7	Capacitor, ceramic, 0.022 µF, 25V, 10%, X7R, SMD, 0603	Kyocera AVX	06033C223KAT2A
2	C8, C9	Capacitor, ceramic, 2.2 µF, 10V, 10%, X7R, SMD, 0603	Taiyo Yuden Co., Ltd.	LMK107B7225KA-T
4	C11, C26, C28, C29	Capacitor, ceramic, 1 µF, 35V, 10%, X7R, SMD, 0805	TDK Corporation	CGA4J3X7R1V105K125AB
3	C12, C13, C14	Capacitor, ceramic, 39 pF, 50V, 5%, C0G, SMD, 0603	Kyocera AVX	06035A390JAT2A
3	C15, C17, C21	Capacitor, ceramic, 4.7 µF, 25V, 10%, X5R, SMD, 0805	Murata Electronics®	GRM21BR61E475KA12L
3	C18, C19, C20	Capacitor, ceramic, 150 pF, 50V, 5%, NP0, SMD, 0603	Panasonic® - ECG	ECJ-1VC1H151J
2	C23, C25	Capacitor, ceramic, 10 µF, 10V, 10%, X5R, SMD, 0805	Taiyo Yuden Co., Ltd.	LMK212BJ106KG-T
1	C27	Capacitor, ceramic, 10000 pF, 50V, 20%, X7R, SMD, 0603	Kyocera AVX	06035C103KAT2A
1	C30	Capacitor, tantalum, 10 µF, 35V, 10%, 1Ω, SMD D	KEMET	T491D106K035AT
1	C31	Capacitor, ceramic, 360 pF, 50V, 5%, NP0, SMD, 0402	Walsin Technology Corporation	0402N361J500CT
2	CB1, CB2	Capacitor, aluminum, 470 µF, 50V, 20%, TH, P5D12.5H20	Panasonic - ECG	EEU-FM1H471
6	D2, D4, D6, D7, D9, D10	LED, yellow green, 0603, SMD	Vishay®/Dale	VLMG1300-GS08
6	D3, D8, D11, D12, D13, D14	Diode, Schottky, 40V, 2A, SOD-123F	Fairchild Semiconductor®/ON Semiconductor®	SS24FL
6	D15, D16, D17, D26, D27, D28	Diode, rectifier, array, 1.25V, 200 mA, 70V, SOT-23-3	Micro Commercial Components (MCC)®	BAV99-TP
4	D18, D20, D22, D25	Diode, Schottky, 660 mV, 2A, 60V, SOD-123	SMC Diode Solutions	MBR260HWTR
3	D19, D21, D24	Diode, TVS, 33V, 200W, SMD, SOD-123FL	Panjit International Inc.	SMF33A_R1_00001

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	D23	Diode, LED, amber, 2.1V, 25 mA, 2mcd, clear, SMD, 0603	Lite-On®, Inc.	LTST-C190AKT
1	F1	Resistor, fuse, 15A, 24V, fast, SMD, 1206	Multicomp Pro	MP005485
1	FB1	Ferrite, 600R@100 MHz, 300 mA, SMD, 0603	Laird Technologies®	HZ0603C601R-00
1	J1	Connector, terminal, 5.08 mm, 1x2, female, 14-22AWG, 15A, TH, R/A	On-Shore Technology,Inc.	OSTTC022162
2	J2, J3	Connector, HDR-2.54, male, 1x6, gold, 5.84 MH, TH, R/A	FCI	68016-106HLF
1	J4	Connector, terminal, 2.54 mm, 1x5, female, 20-30AWG, 6A, TH, R/A	Phoenix Contact GmbH & Co.	1725685
1	JM1	Connector, terminal, 5 mm, 1x3, female, 12-30AWG, 16A, TH, R/A	Würth Elektronik	691137710003
1	Jp7	Connector, HDR-2.54, male, 1x2, tin, 6.75 MH, TH, vertical	Molex, LLC	0901200122
1	Js2	Mechanical, headers and wires, jumper, 2.54 mm, 1x2, gold	Würth Elektronik	60900213421
1	L1	Inductor, 3.3 µH, 1.5A, 20%, SMD, L3W3H1.5	Würth Elektronik	74404032033
1	LABEL1	Label, PCBA, 18x6 mm, Datamatrix Assy#/Rev/Serial/Date	ACT Logimark AS	505462
6	Q1, Q2, Q3, Q4, Q5, Q6	Transistor, MOSFET, N-Channel, 75V, 48.2A, 106W, SOT-669	Nexperia	BUK9Y19-75B,115
1	R1	Resistor, thick film, 36k, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3EKF3602V
1	R2	Resistor, thick film, 2.4k, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-072K4L
7	R3, R5, R9, R12, R15, R18, R66	Resistor, thick film, 2k, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3EKF2001V
6	R4, R14, R19, R23, R28, R33	Resistor, thick film, 39R, 1%, 1/8W, SMD, 0805, AEC-Q200	Stackpole Electronics, Inc.	RMCF0805FT39R0
6	R6, R16, R20, R24, R29, R34	Resistor, thick film, 10R, 1%, 1/8W, SMD, 0805	ROHM Semiconductor	MCR10EZHF10R0
6	R7, R17, R21, R25, R30, R35	Resistor, thick film, 330k, 5%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3GEYJ334V
3	R11, R22, R32	Resistor, thick film, 3.3R, 1%, 1/8W, SMD, 0805	Vishay/Dale	CRCW08053R30FKEA
1	R26	Resistor, thick film, 47k, 5%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3GEYJ473V
1	R27	Resistor, thick film, 2.2R, 5%, 1/10W, SMD, 0603	Stackpole Electronics, Inc.	RMCF0603JT2R20
5	R31, R38, R50, R53, R64	Resistor, thick film, 47k, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3EKF4702V

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
3	R36, R37, R39	Resistor, thick film, 12k, 1%, 1/10W, SMD, 0603	Stackpole Electronics, Inc.	RMCF0603FT12K0
4	R40, R69, R70, R71	Resistor, thick film, 120R, 1%, 1/10W, SMD, 0603	Stackpole Electronics, Inc.	RMCF0603FT120R
6	R41, R42, R43, R44, R47, R48	Resistor, thick film, 330R, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3EKF3300V
3	R45, R46, R49	Resistor, thick film, 39k, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3EKF3902V
4	R51, R52, R54, Ra1	Resistor, thick film, 9.1k, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-079K1L
6	R55, R56, R57, R58, R59, R60	Resistor, thick film, 470R, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3EKF4700V
3	R61, R62, R63	Resistor, thick film, 1.3k, 5%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3GEYJ132V
3	R65, R67, R68	Resistor, thick film, 10k, 5%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3GEYJ103V
1	R72	Resistor, thick film, 18k, 5%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3GEYJ183V
1	R73	Resistor, thick film, 240R, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-07240RL
1	R74	Resistor, thick film, 1.8k, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3EKF1801V
4	R78.A, R79.A, R80.A, R81.A	Resistor, thick film, 0R, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-070RL
1	R82.A	Resistor, thick film, 0R, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3GSY0R00V
1	Rb1	Resistor, thick film, 15k, 1%, 1/10W, SMD, 0603, AEC-Q200	Vishay/Dale	CRCW060315K0FKEA
3	RS1, RS2, RS3	Resistor, shunt, ME, 0.003R, 1%, 4W, AEC-Q200, SMD, 2512	Vishay/Dale	WSLF25123L000FEA
1	Rv1	Resistor, variable, 10K, 20%, TH, P090S	BI Technologies/TT Electronics	P090S-14T20BR10K
4	ST1, ST2, ST3, ST4	Switch, tact., SPST, 24V, 50 mA, KSR231GLFS, SMD, 6 x 3.5 mm	TE Connectivity Alcoswitch	147873-2
2	TP10, TP26	Connector, test point, tab, Silver, Mini, 3.8 x 2.03, SMD	Keystone® Electronics Corp.	5019
3	TP25, TP-1, TP-2	Connector, test point, tab, silver, mini, 3.8x2.03, SMD	Keystone Electronics Corp.	5019
1	PCB1	Printed Circuit Board	—	04-12178-R1

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-2: BILL OF MATERIALS (BOM) – MICROCHIP PARTS

Qty.	Reference	Description	Manufacturer	Part Number
1	U1	MCU, 16-Bit, 100 MHz, 128k,16k, UQFN-36	Microchip Technology, Inc.	DSPIC33CK128MP503-E/M5
1	U2	Analog, Motor Driver, QFN-40	Microchip Technology, Inc.	MCP8027T-H/Q9X

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-3: BILL OF MATERIALS (BOM) – DO NOT POPULATE PARTS

Qty.	Reference	Description	Manufacturer	Part Number
0	D1	Diode, Zener, 27V, 500 mW, SOD-123	Diodes Incorporated®	BZT52C27-7-F
0	D5	Diode, LED, yellow, 2.1V, 30 mA, 10 mcd, diffuse, SMD, 0805	Lumex® Inc.	SML-LXT0805YW-TR
0	HVI-ext	Connector, HDR-2.54, male, 1x2, tin, 6.75 MH, TH, vertical	Molex, LLC	0901200122
0	QC1	Transistor, MOSFET, N-Channel, 100V, 100A, 139W, TDSON-8	Infineon Technologies AG	BSC040N10NS5ATMA1
0	R10	Resistor, thick film, 10k, 5%, 1/2W, SMD, 0805	Panasonic - ECG	ERJ-P06J103V
0	R13	Resistor, thick film, 2.2k, 5%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3GEYJ222V
0	R78.B, R79.B, R80.B, R81.B	Resistor, thick film, 0R, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-070RL
0	R82.B	Resistor, thick film, 0R, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3GSY0R00V

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 MCP8027 web page located on the Microchip website, http://www.microchip.com.

C.2 DSPIC33CK128MP503 PORT USAGE

C.2.1 Port's Mapping

```
/**********************   PWMs are outputs ***************************/
LATBbits.LATB10                 = 0;
TRISBbits.TRISB10               = 0;        //      PWM3H
LATBbits.LATB11                 = 0;
TRISBbits.TRISB11               = 0;        //      PWM3L
LATBbits.LATB12                 = 0;
TRISBbits.TRISB12               = 0;        //      PWM2H
LATBbits.LATB13                 = 0;
TRISBbits.TRISB13               = 0;        //      PWM2L
LATBbits.LATB14                 = 0;
TRISBbits.TRISB14               = 0;        //      PWM1H
LATBbits.LATB15                 = 0;
TRISBbits.TRISB15               = 0;        //      PWM1L


/**********************  MCP802X CEn ******************************/
LATBbits.LATB8                  = 0;
TRISBbits.TRISB8                = 0;        //      C_En


/************************ Push Buttons ports *********************/
LATBbits.LATB5                  = 1;        //      Input OnOff button (Dir)
TRISBbits.TRISB5                = 1;
LATBbits.LATB6                  = 1;        //      Input Spare button (Run)
TRISBbits.TRISB6                = 1;


/************************ LED ****************************/
LATCbits.LATC3                  = 0;
TRISCbits.TRISC3                = 0;        //      Fault_LED
```

```
/************************ DE2 - UART1 pins ***************************/
TRISBbits.TRISB9              = 1;      //      RX
TRISCbits.TRISC4              = 0;      //      TX


/************************ UART pins ***************************/
TRISBbits.TRISB1              = 0;      //      TX
TRISBbits.TRISB0              = 1;      //      RX
```

C.2.2 Macro Limits Definition and their Conversion

```
//**** Values Limits sittings ************************************************//
#define DeadTime              750       //      250;500; ...2000  [ns]
#define BlankTime             2000      //      500;1000;2000;4000[ns]
#define DAC_Vref              3195      //      991;1005;...4500  [mV} -DAC
                                              Overcurrent Limit
#define MOS_OCL               500       //      250;500;750;1000  [mV] -MOSFET
                                              Overcurrent Limit


/******************** MCP802X registers definition *********************/
//Send driver configuration    --command data
#define SET_CFG_0             0x81      //      CFG_0 Writing command
#define GET_CFG_0             0x82      //      CFG_0 reading command
#define SET_CFG_1             0x83      //      CFG_1 Writing command
#define GET_CFG_1             0x84      //      CFG_1 reading command
#define GET_STAT0             0x85      //      Get Status Register
#define GET_STAT1             0x86      //      Get Status Register
#define SET_CFG_2             0x87      //      CFG_2 Writing command
#define GET_CFG_2             0x88      //      CFG_2 reading command
```

C.2.3 Driver Initialization Sequence

```
/*****************************************************************************/
/***        MCP802x driver initializations as defined in "MCP802X.h"       ***/
/*****************************************************************************/
xCFG0.CFG0            = 0x00;               //    For sure reset CFG0 content
xCFG0.EXTOC           = Set_MOS_OCL();      //    Set MOSFET threshold limit
xCFG0.EXTSC           = Disabled;//Enabled; //    Ext. MOSFET Over Current
                                                  protection
xCFG0.D_UVLO          = Disabled;//Disabled;//    Driver UVLO protection
xCFG0.SLEEP           = Inactive;           //    Active driver enters in Sleep mode
xCFG0.INT_N           = Inactive;           //    Internal Neutral Simulator
xCFG0.PU30_OA         = Disabled;

xCFG1.CFG1            = 0;                  //    For sure reset CFG1 content
xCFG1.CFG1            = Set_DACref();       //    Set DAC I_Lim reference

xCFG2.CFG2            = 0;                  //    For sure reset CFG2 content
```

```
xCFG2.DRVDT           = Set_DeadTime();      //    Set desired dead time
xCFG2.DRVBL           = Set_BlankTime();     //    Set desired blanking time

MCP802x_Clr_Faults();
MCP802x_Drv_Init();
```

C.2.4 A/D Mappings

```
/** ADC Channel Definition */
typedef enum
{
ADC1_MON1             = 12,
ADC1_MON2             = 13,
ADC1_MON3             = 14,

ADC1_IO1              = 4,
ADC1_IO2              = 3,
ADC1_IO3              = 7,

ADC1_Speed            = 0,
ADC1_VBdiv            = 2,
} adc_channel_t;
```

C.2.5 UARTs and Interrupts Mappings

```
builtin_write_RPCON(0x0000);          //   Unlock Registers

_U1RXR                        = 41;  //   Assign U1Rx To Pin RP41 on RB9
_RP52R                        = 1;         Assign U1Tx To Pin RP52 on RC4

_U2RXR                        = 32;        Assign U2Rx To Pin RP32 on RB1
_RP33R                        = 3;   //   Assign U2Tx To Pin RP33 on RB0

_ INT1R                       = 53;  //   Assign External Interrupt 1 To    //IRQ
                                           Pin RP53 on RC5
_ INT2R                       = 37;        Assign External Interrupt 2 To    //OnOff
                                           Pin RP37 on RB5
_ INT3R                       = 38;  //   Assign External Interrupt 3 To    //Spare
                                           Pin RP38 on RB6

__builtin_write_RPCON(0x0800);        //   Lock Registers
```

C.3 COMMUNICATIONS MESSAGE MAPPINGS

```
/******************** MCP802X registers definition ********************/
//Send driver configuration    --command data
#define SET_CFG_0              0x81      //      CFG_0 Writing command
#define GET_CFG_0              0x82      //      CFG_0 reading command
#define SET_CFG_1              0x83      //      CFG_1 Writing command
#define GET_CFG_1              0x84      //      CFG_1 reading command
#define GET_STAT0              0x85      //      Get Status Register
#define GET_STAT1              0x86      //      Get Status Register
#define SET_CFG_2              0x87      //      CFG_2 Writing command
#define GET_CFG_2              0x88      //      CFG_2 reading command
```

C.4 MPLAB X COMPILER STARTUP

1. Start up the MPLAB X compiler (not supplied, available on the Microchip website).
2. From the toolbar, select File>Open Project.
3. Browse to the evaluation board source code path.
4. Select the existing project file named `MCP8027EvB_3Sh_ckX03.X`
5. In the Projects window, right mouse-click on `MCP8027EvB_3Sh_ckX03.X` 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 for PID controller implementation, 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 `MCP8027EvB_3Sh_ckX03.X` 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.5 MPLAB X IDE AND PICKIT 3 EXERCISE

1. Start up the MPLAB X (not supplied, available on the Microchip website).
2. From the toolbar, select File>Open Project.
3. Browse to the evaluation board source code path.
4. Select the existing workspace directory named `MCP8027EvB_3Sh_ckX03.X` or create a new one.
5. Connect the C 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 13-14V. Turn off the power supply.
8. Connect the bench power supply to the evaluation board. Connect +V(14V) to J1-2 and -V (Ground) to J1-1.
9. Turn on the power supply.
10. Right mouse-click on `MCP8027EvB_3Sh_ckX03.X` in the Projects window and select “Make and Program Device”. This will compile the firmware and program the dsPIC33CK128MP503 processor.
11. The compiler results will be displayed in the Output window frame. Verify success.
12. Connect a Brushless DC (BLDC) motor to connector JM1 (MOTOR). Connect the motor phase wires to the PH_A, PH_B, and PH_C 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 counterclockwise. This sets the motor to the slowest speed.
15. Momentarily press the ST1 (RUN) switch to start the motor.
16. Momentarily press the ST1 (RUN) switch again to stop the motor.
17. Momentarily press the ST1 (RUN) 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 LSA, LSB, LSC, HAS, HSB, HSC test points will show the external MOSFET gate drive signals. The D2, D4, D6, D7, D9, D10 LEDs show the state of the PWM inputs to the MCP8027.
20. Stop the motor by pressing RUN again.
21. Change the motor control from Open Loop to Closed Loop mode by uncommenting the directive where OPENLOOPmode is undefined. This is done by editing the `UserParams.H` file.
22. Click on Source Files in the Projects window and then double-click on the UserParams.h entry.
23. Search for the preprocessor definition #undef OPENLOOPmode.
24. Uncomment this line.
25. Right mouse-click `MCP8027EvB_3Sh_ckX03.X` in the Projects window and select “Make and Program Device”. This will compile the firmware and program the dsPIC33CK128MP503-E/M5 controller.
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 clockwise at around 50%-70%. This sets the

motor target speed.

29. Momentarily press the RUN switch again to start the motor.
30. The motor speed should increase with FLT LED on until the closed loop will be done. At this moment FLT LED turns off and the speed stabilizes. If the motor is loaded the speed is maintained.
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 to maintain the correct commutation time.
32. Momentarily press the RUN switch again to stop the motor.

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