MCP8022
BLDC Motor Driver Development Board User's Guide

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ISBN: 978-1-6683-3835-3

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MCP8022 BLDC MOTOR DRIVER DEVELOPMENT 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 "DSXXXXXA", where "XXXXX" 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 MCP8022. Items discussed in this chapter include:

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

DOCUMENT LAYOUT

This document describes how to use the MCP8022 as a development tool. The manual layout is as follows:

- **Chapter 1. "Product Overview"** – Important information about the MCP8022.
- **Chapter 2. "Installation and Operation"** – Includes instructions on how to get started with this reference design and a description of the reference design.
- **Chapter 3. "Application Hints"** – This chapter gives important hints about the operation of the MCP8022.
- **Chapter 4. "Software"** – This chapter explains the software architecture.
- **Appendix A. "Schematic and Layouts"** – Shows the schematic and layout diagrams for the MCP8022.
- **Appendix B. "Bill of Materials (BOM)"** – Lists the parts used to build the MCP8022.

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 reference design describes how to use the MCP8022. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

- **MCP8021/2 Data Sheet –** ***"3-Phase Brushless DC (BLDC) Motor Gate Driver with Power Module, Sleep Mode, Opamps"*** **(DS20006265)**
- **dsPIC33CK256MP508 Family Data Sheet –** ***"28/36/48/64/80-Pin Digital Signal Controllers with High-Resolution PWM and CAN Flexible Data (CAN FD)"*** **(DS70005349)**
- **AN1078 –** ***"Sensorless Field Oriented Control of a PMSM"*** **(DS00001078)**
- **AN992 –** ***"Sensorless BLDC Motor Control Using dsPIC30F2010"*** **(DS00000992)**
- **AN1292 –** ***"Sensorless Field Oriented Control (FOC) for a Permanent Magnet Synchronous Motor (PMSM) Using a PLL Estimator and Field Weakening (FW)"*** **(DS00001292)**
- **AN901 –** ***"Using the dsPIC30F for Sensorless BLDC Control"*** **(DS00000901)**

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

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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:

https://www.microchip.com/support.

DOCUMENT REVISION HISTORY

Revision B (January 2024)

- Updated the **A.2 “Board – Schematic”**.
- Updated **Appendix B. “Bill of Materials (BOM)”**.
- Minor text changes throughout.

Revision A (September 2022)

- Initial release of this document.

Chapter 1. Product Overview

1.1 INTRODUCTION

This chapter provides an overview of the MCP8022 Reference Design and covers the following topics:

- MCP8022 Device Overview
- MCP8022 BLDC Motor Driver Development Board Key Features
- What Does the MCP8022 BLDC Motor Driver Development Kit Include?

1.2 MCP8022 DEVICE OVERVIEW

The MCP8022 BLDC Motor Driver Development Board is used to demonstrate the drive capabilities/facilities offered by the MCP8022 in BLDC/PMSM motor applications.

The board is designed for using the MCP8022 for 3-Phase Brushless DC (BLDC) motor gate driver in conjunction with the Microchip dsPIC33CK128MP503.

The board is equipped with three shunts, two branch shunts and one sum shunt. This makes it well suited for sinusoidal dual or single-shunt FOC motor control algorithm in sensorless mode.

As provided, the MCP8022 BLDC Motor Driver Development Board is ready to drive a BLDC motor using 2-shunt algorithm. The board is equipped with a **RUN/STOP** button and a potentiometer for speed adjustment.

In conjunction with a 'HURST-300' motor, the algorithm is optimized to drive few amperes at the automotive supply voltage level of 13.5V.

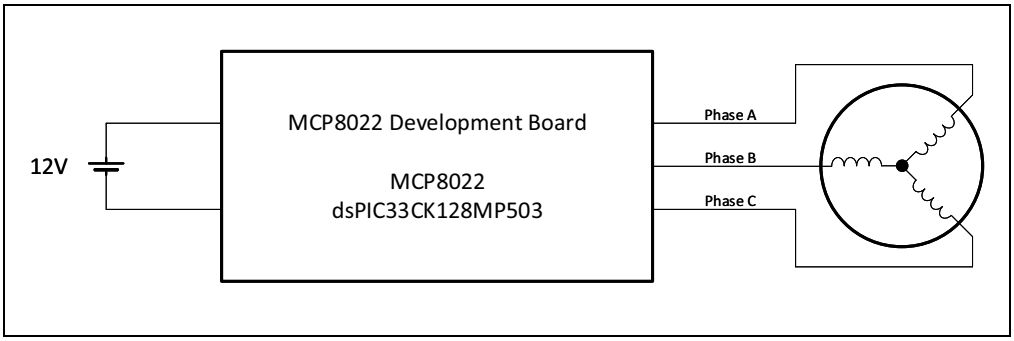


FIGURE 1-1: *MCP8022 BLDC Motor Driver Development Board Block Diagram.*

1.3 MCP8022 BLDC MOTOR DRIVER DEVELOPMENT BOARD KEY FEATURES

The MCP8022 BLDC Motor Driver Development Board is a stand-alone motor controller for brushless DC motors (BLDC). The board can drive a three-phase brushless DC motor rated at up to 25 A and 24V. The input voltage range for the board is +6V to +24V. The on-board MCP8022 generates 3.3V and 12V using internal voltage regulators. The 12V regulator provides the power for the MOSFET gate drivers. The 3.3V generates the power for the attached dsPIC33CP128MP503 host microcontroller.

An input terminal block is provided to apply the input voltage to the board.

An output header connector provides the connection to the external motor.

A programming header connector is available for updating the firmware into the dsPIC33CP128MP503 using a PICkit™ 4 programmer/debugger.

For purpose of rotor position feedback, an input terminal block is placed on the board. It allows connection of 5V Hall sensors. Alternatively, a Quadrature Encoder Interface (QEI) can be connected to those pins.

For UART external communication, the user can attach a header connector to use a PICkit Serial Communication interface.

An UART communication header COM_EXT is prepared for integration into the automotive environment.

For other user purposes, a 3-pin connector can be planted on the board for MCP8022 internal communication level adaptor usage.

1.4 WHAT DOES THE MCP8022 BLDC MOTOR DRIVER DEVELOPMENT KIT INCLUDE?

This MCP8022 BLDC Motor Driver Development Board kit includes:

- The MCP8022 BLDC Motor Driver Development Board (DT100123)
- Key Information Sheet

Chapter 2. Installation and Operation

2.1 GETTING STARTED

The MCP8022 BLDC Motor Driver Development Board demonstrates the features of Microchip's 3-Phase Brushless DC (BLDC) Motor Driver with Power Module, the MCP8022, used in a BLDC motor driver application. When used in conjunction with a microcontroller, the MCP8022 provides the necessary drive signals for a 3-Phase BLDC motor.

A dsPIC33CK128MP503 processor is used to supply the PWM inputs to the MCP8022 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.

For a demonstration of the MCP8022's capabilities, a firmware based on a 2-shunt FOC algorithm providing a sine wave commutation control is available on the Microchip website.

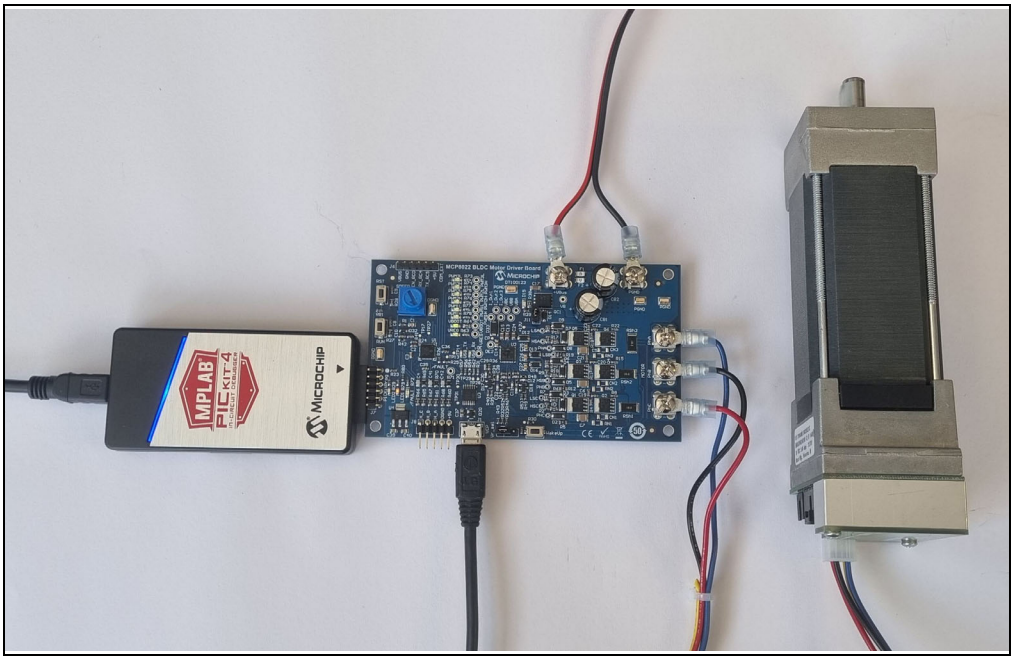


FIGURE 2-1: *Getting Started Setup.*

2.2 FEATURES

The MCP8022 BLDC Motor Driver Development 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 20A RMS BLDC Motor
- 3.3V LDO for Microcontroller Supply
- ON/OFF Push Button (RUN)
- Reset Push Button (RST)
- Wake-Up Push Button (WakeUp)
- PWM Signal LED Indicators
- Fault Signal LED Indicator
- UART Tx and Rx LED Indicator
- 2 Multi-Purpose LED Indicator
- PICkit 4 Debugger Interface
- Speed Control Potentiometer
- Terminal Block for 5V Hall-Effect Sensors or Alternatively QEI Interface
- 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 evaluation board webpage)

2.3 BOARD DESCRIPTION

The MCP8022 BLDC Motor Driver Development Board is fully assembled and tested for driving a BLDC motor. The board can be configured to drive a BLDC motor in both sensored or sensorless modes, as well as for a sinusoidal FOC or trapezoidal motor control algorithm. This board requires the use of an external voltage source that is capable of supplying from 6V to 24V at the rated motor current.

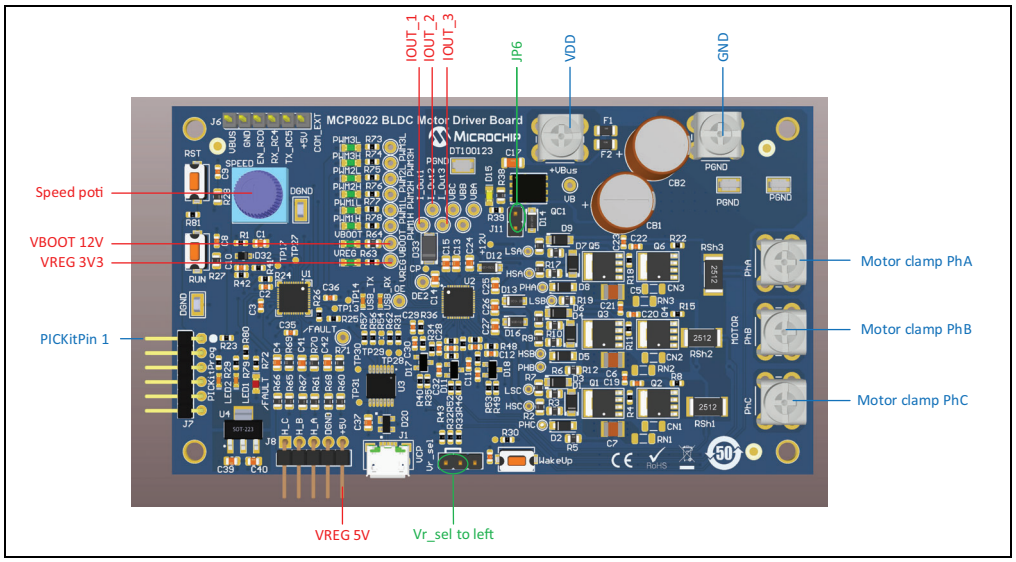


FIGURE 2-2: *MCP8022 BLDC Motor Driver Development Board.*

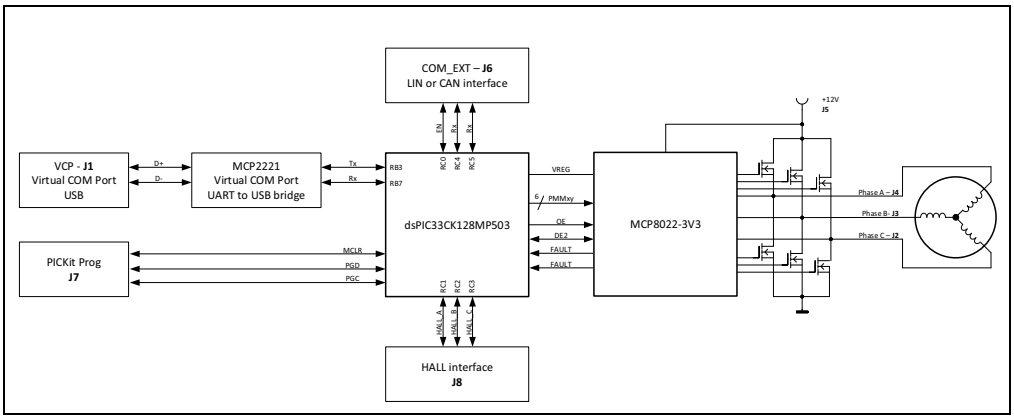


FIGURE 2-3: *MCP8022 BLDC Motor Driver Development Board Block Diagram.*

2.3.1 Getting Started

The board comes preprogrammed with a 2-shunt FOC algorithm. For a simple motor start, follow these steps:

- Connect an BLDC HURST motor to the motor clamps J2, J3, J4.
- Supply the board with V_{DD} = 13.5 V via the supply connectors J5+ and J5-.
- Ensure the SPEED potentiometer arrow points to the right bottom corner for medium speed.
- Press the **RUN** button to start the motor.

2.3.2 Connections

2.3.2.1 JUMPER SETTINGS

The jumpers are described in Table 2-1. The jumper's positioning can be seen in Figure 2-4, (circled in green).

TABLE 2-1: BLDC MOTOR DRIVER DEVELOPMENT BOARD JUMPERS

Jumper	Name	Position	Function Description
J10 - JP1	Vr_sel	1-2 **(default)**	Set MCP8022 op amp 3 reference voltage to 1.637V
—	—	2-3	Set MCP8022 op amp 3 reference voltage to 0V
J11 - JP2	VB_PROT	ON **(default)**	Battery supply clamp selection to 27V
—	—	OFF	No maximum battery supply voltage clamp

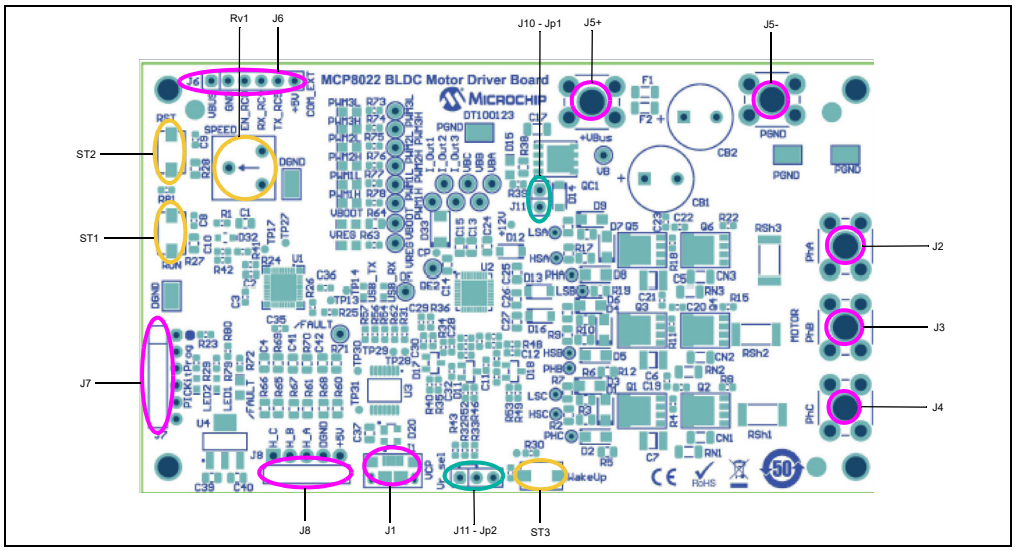


FIGURE 2-4: *BMCP8022 BLDC Motor Driver Board Jumper/Connector/User Interfaces.*

2.3.2.2 CONNECTORS

The connectors are described in Table 2-2. The jumpers positioning can be seen in Figure 2-4 (circled in pink).

TABLE 2-2: MCP8022 BLDC MOTOR DRIVER DEVELOPMENT BOARD CONNECTORS

Connectior	Style	Name	Function Description
J1	USB Micro-B	VCP	UART to USB Virtual COM Port
J2	Screw Connector	PhC	BLDC Motor Phase C Connection
J3	Screw Connector	PhB	BLDC Motor Phase B Connection
J4	Screw Connector	PhA	BLDC motor phase A Connection
J5+, J5-	Block Screw Connector	Power Supply	Board Power Supply Connector. Motor Operating Range 6V - 24V
J6	6-pin header	COM_EXT	External Communication Interface
J7	6-pin header	PICKitProg	PICKit Programmer Debugger interface
J7-1	—	MCLR	—
J7-2	—	+3V3	—
J7-3	—	Ground	—
J7-4	—	PGD	—
J7-5	—	PGC	—
J1-6	—	Aux	—
J8	5-pin header	HALL or QEI	HALLor QEI Interface

2.3.2.3 USER INTERFACES

The push buttons and the potentiometer are described in Table 2-4. The positioning can be seen in Figure 2-4, (circled in orange).

TABLE 2-3: MCP8022 BLDC MOTOR DRIVER DEVELOPMENT USER INTERFACES

Push Button	Name	Position	Function Description
ST1	Push Button	RUN	Toggle Push Button function for Start / Stop
ST2	Push Button	RST	Reset Button
ST3	Push Button	WAKE	Wake Up Button
Rv1	Potentiometer	SPEED	Motor speed 50% position is the setting for zero speed in the pre-programmed firmware

2.3.2.4 POWERING THE MCP8022 BLDC MOTOR DRIVER DEVELOPMENT BOARD (REFERENCE FIGURE 2-4)

Apply the power supply to the input power block connector, J5+, J5-. The operation range of the board is limited by the MCP8022 operation voltage, ranging from 6.25V to 29V.

The preprogrammed dual shunt software is optimized for a typical automotive supply voltage level of 13.5V.

2.3.2.5 CONNECTING A MOTOR TO THE MCP8022 BLDC MOTOR DRIVER DEVELOPMENT BOARD

Connect each phase winding of a three-phase BLDC motor to the appropriate terminal of the motor terminals PhA, PhB, PhC.

The preprogrammed dual shunt software is optimized for the HURST motor 'HURST-300', Microchip Direct part number AC300022.

2.3.3 Operating a Motor

The potentiometer Rs1 'SPEED' is intended to adjust the speed setting.

The preprogrammed firmware takes the 50% setting of the potentiometer as zero speed.

In the 50% position, the arrow indicates horizontal to right. Tuning the potentiometer left of the 50% value makes the motor turn into one direction whereas right into the other direction.

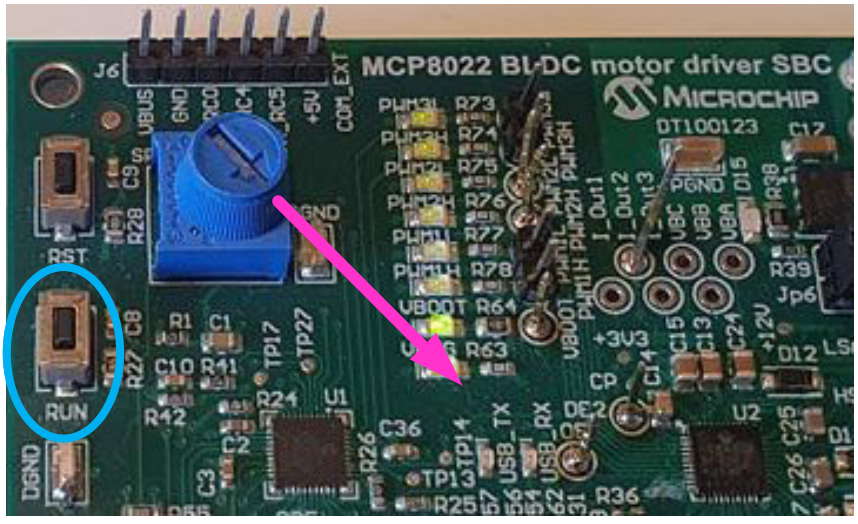


FIGURE 2-5: *Motor Inrush Speed Setting 25% and RUN Button.*

- For inrush, a speed potentiometer position of 25% is recommended.
- The power supply activation is indicated by the green LED 'VBOOT'.
- The toggle button ST1 'RUN' starts the motor. Pressing again stops the motor.
- Motor operation will be indicated by the PWM input LEDs PWMxL and PWMxH.
- Turning the Speed Potentiometer adjusts the motor speed. The Speed Adjust changes the target speed of the motor.

2.3.4 Indicator LEDs

Table 2-4 lists the MCP8022 BLDC Motor Driver Development Board LED indicators.

TABLE 2-4: LED INDICATORS

PCB Location	Name	Description
D10	LED1	Motor operation status
D31	LED2	Debug operation status
D19, D21	USB_RX, _TX	USB2UART Virtual Com Port Operation
D22	VREG	MCP8022 3.3V VREG output, indicates 'ACTIVE' mode
D23	VBOOT	MCP8022 12V VBOOT output
D24	/FAULT	MCP8022 failure indication
D25, D27, D29	PWMxL	PWM Phase x low-side input to MCP8022
D26, D28, D30	PWMxH	PWM Phase x high-side input to MCP8022

2.3.5 Test Points

Table 2-5 lists the test points for diagnosis and debug purposes.

TABLE 2-5: TEST POINTS DESCRIPTION

Test Point Name	Description
VB	Power Supply (+)
PGND (3)	Power Supply Ground (-)
VREG	MCP8022 3.3V LDO Output Voltage
VBOOT	MCP8022 12V LDO Output Voltage
/FAULT	MCP8022 /FAULT Output
OE	MCP8022 Enable Signal
DE2	MCP8022 DE2 Communication Signal
PWM1-3L	MCP8022 PWMs Low Driver Inputs
PWM1-3H	MCP8022 PWMs High Driver Inputs
LSA/B/C	MCP8022 Phase A/B/C Low-Side Driver Outputs
HSA/B/C	MCP8022 Phase A/B/C High-Side Driver Outputs
I_Out1/2/3	MCP8022 Shunt Current Sense Amplifier Outputs
VBA/B/C	MCP8022 Bootstrap Input Voltage Pins

2.4 SCHEMATIC DESCRIPTION

2.4.1 Current Sense Amplifier (CSA)

The CSAs 1 and 2 are amplifying the string current of phase C and phase B while the CSA 3 amplifies the sum current of all three strings.

All the 3-Current Shunt Amplifiers CSA are set to an offset of 1.637V. The reference supply of half of the microcontroller supply voltage level allows measuring positive, as well as negative, voltages in the same range.

The third CSA's offset can alternatively be switched down to 0V, for only positive current measurement.

The amplification gain of all the three CSA's is adjusted to 15.

The op amps are switched as inverters. The positive clamps of the shunts are connected to the inverted inputs and the shunt's negative clamps are connected each to the noninverted inputs.

In combination with the 10 mΩ shunt, a current of 10A should be possible to measure per string. For higher current, lower shunt resistors RSh1, RSh2, RSh3 need to be installed.

2.4.2 HALL Sensor or QEI interface

The purpose of the connector J8 is to connect rotor position feedback sensors. The microcontroller input signals are suitable to take position signals back from either three HALL sensors or a Quadrature Encoder Interface (QEI). The pinning is shown in Table 2-6.

TABLE 2-6: J8 HALL SENSOR OR QEI INTERFACE CONNECTOR

Pin	Style	Name	Function Description
J8-1	5-pin header	+5V	Sensor supply for HALL or QEI Sensor
J8-2	—	Ground	—
J8-3	—	HALL_A	HALL or QEI input channel A
J8-4	—	HALL_B	HALL or QEI input channel B
J8-5	—	HALL_C	HALL or QEI input channel C

2.4.3 External Communication Interface

The intention of connector J8 is to provide an interface to a higher-ranking system. This can eventually be the automotive environment in a car. The selected pins of the microcontroller dsPIC33CK128MP503 are suitable to support LIN and CAN-FD protocol, see Table 2-7. Any of Microchip's LIN or CAN transceiver interface boards can be attached by interface cables. For LIN applications, the power supply VBus voltage is available on J6-1 while for CAN applications, a +5V supply signal is provided (J6-6). The Rx/Tx UART signals provide an enable signal.

TABLE 2-7: J6 EXTERNAL COMMUNICATION INTERFACE

Connector	Style	Name	Function Description
J6	6-pin header	COM_EXT	Multi-Purpose Communication Interface
J6-1	—	VBus	Board Power supply voltage, e.g. 12V LIN supply
J6-2	—	Ground	Ground
J6-3	—	EN_RC0	Multipurpose I/O, e.g. CAN/LIN enable
J6-4	—	RX_RC4	Multipurpose I/O, e.g. CAN/LIN UART RX
J6-5	—	TX_RC5	Multipurpose I/O, e.g. CAN/LIN UART TX
J6-6	—	+5V	5V output, e.g. for CAN voltage reference

2.4.4 PICKit 4 Interface

J7 is the Microcontroller Programmer Debugger interface, intended to program the firmware.

TABLE 2-8: PICkit INTERFACE PINS

Connector	Style	Name
J7-1	6-pin header	MCLR
J7-2	—	+3V3
J7-3	—	Ground
J7-4	—	PGD
J7-5	—	PGC
J7-6	—	Aux

2.4.5 VCP Virtual COM Port

The USB connector J1 purpose is to communicate to the microcontroller UART via the USB to UART bridge device MCP2221A. For further information about the MCP2221A, see data sheet at:

https://www.microchip.com/downloads/en/DeviceDoc/20005565E.pdf

Third-party source code generation framework tools like Scilab-X2C can communicate via the Virtual COM Port VCP connector J1 with the Microcontroller. The tool X2C communicator establishes the communication after assigning the correct communication port.

The Scilab and X2C communication is described in **Chapter 4. "Software"**.

Chapter 3. Application Hints

3.1 GATE DRIVER SUPPLY

The gate drivers are supplied out of the 12V VBOOT regulator, see Figure 3-1 for VBOOT and bootstrap circuitry.

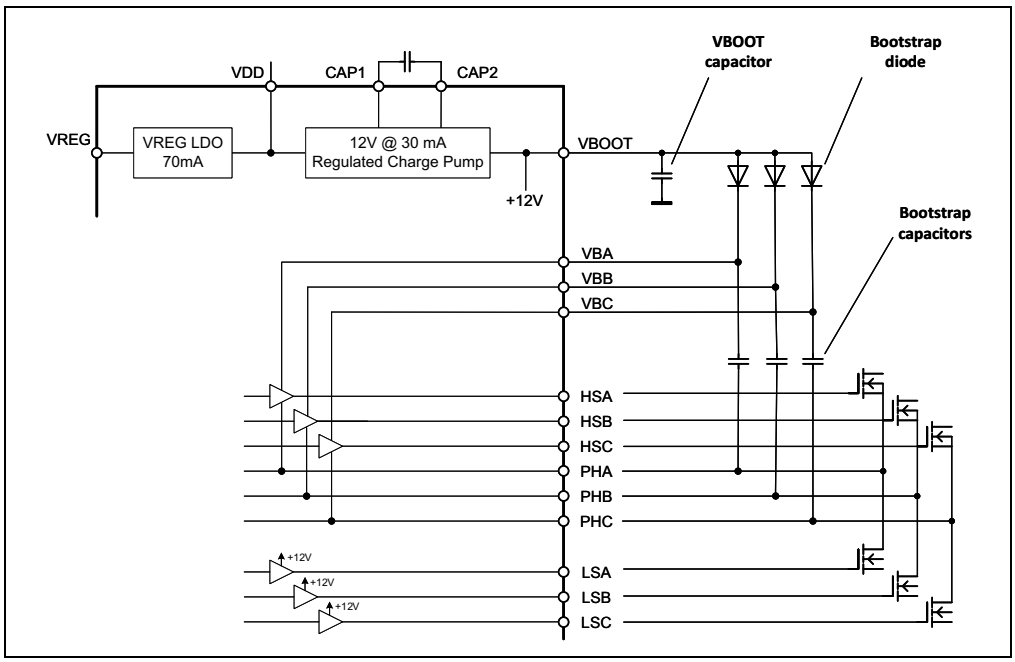


FIGURE 3-1: *VBOOT and Bootstrap Circuitry.*

3.2 VBOOT CAPACITOR PRECHARGE

VBOOT is supplied as soon as the output enable pin OE is set to active.

For V_{DD} supply voltages below the Charge Pump operation threshold voltage level of 13V, VBOOT is supplied from the charge pump. For V_{DD} supply voltages higher than Charge Pump operation threshold voltage level, the VBOOT is directly supplied out of the V_{DD} via an LDO.

Before using the VBOOT function, the user must ensure VBOOT is fully charged.

VBOOT is enabled after Power On Reset, with the rising edge of Output Enable pin OE. The charging time depends on the size of VBOOT. This is typically 1 ms for a VBOOT capacitor size of 10 µF. This time is valid for both charge pump and 12-V-LDO charging.

3.3 BOOTSTRAP CAPACITOR PRECHARGE

The low-side gate drivers are directly supplied out of the VBOOT capacitor while the high-side gate drivers need a bootstrap capacitor for high-voltage gate supply.

Before high-side gate driver activation, be certain the bootstrap capacitors are fully charged.

The bootstrap capacitors are charged by activation of the corresponding low-side gate drivers. The low-side drivers switch the anode of the low capacitors across the corresponding motor clamp to power ground. This allows the bootstrap capacitors to charge out of the VBOOT capacitors across the bootstrap diode.

The VBOOT capacitor should be fully loaded for charging the bootstrap capacitors. The VBOOT capacitor powers the low-side gate driver as well as directly powering the bootstrap capacitor's charging process.

The charge inrush current of the bootstrap capacitors may trigger the overcurrent protection of the MCP8022. The low ohmic capacitors act almost like a short circuit and will draw a high peak current. Depending on the capacitor size, the peak can last a few hundred microseconds. Bootstrap charge precautions need to be taken, which can be sequential charging of the three bootstrap capacitors. This is not as efficient as if the three clamps were connected to each other across the motor coils. A more practical solution may be a PWM-controlled bootstrap capacitor precharge.

It must be considered that overcurrent protection is triggered and will lock further operation of the MCP8022 by a FAULT signal.

Chapter 4. Software

4.1 SOFTWARE ARCHITECTURE

The open-source demonstration software package is created using multiple software tools and techniques. The demo is available as the MPLAB X IDE project. The software architecture builds-up from some layers. The low-level peripherals are configured by the MPLAB Code configurator. In addition, some higher-level MCC libraries are used, like X2C® and MCP8022 controller libs. The motor control algorithm is implemented by a model-based approach with Scilab and X2C® tools. The X2C® ecosystem also enables the user to do run-time monitoring, control algorithm parameter tuning and debugging via the UART port.

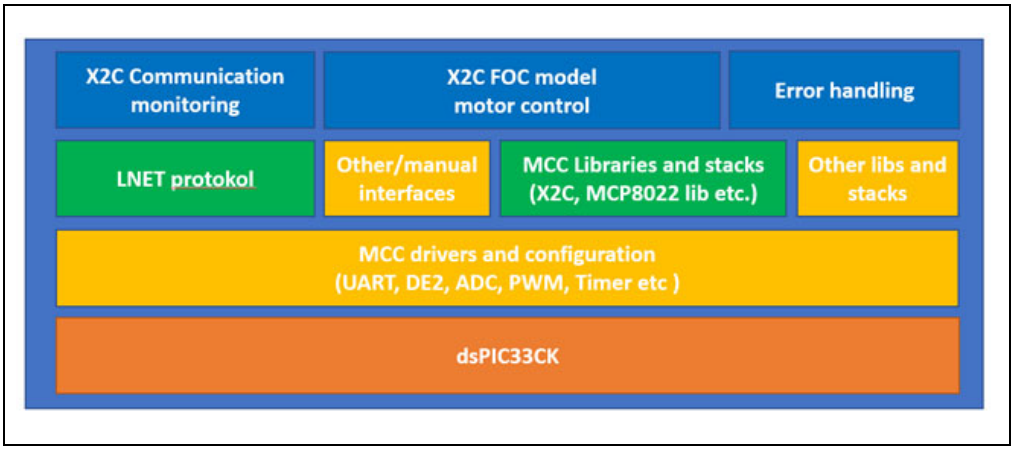


FIGURE 4-1: *SW Architecture.*

The demo code implements a sensorless, field-oriented motor control to demonstrate the MCP802x family capabilities. Therefore, this documentation focuses on the development board, not on the motor control algorithm. For further details about the motor control technique used, please refer to the application note AN1292 (see https://ww1.microchip.com/downloads/en/AppNotes/01292A.pdf).

4.2 MICROCHIP MPLAB CODE CONFIGURATOR MCC

The software package was generated by using Microchip's MPLAB Code Configurator (MCC). All the relevant configurations and middleware, including the ones for MCP8022, are part of MCC. For the MCP8022 DE2 register setup and all the UART communication created with the MCC, see Figure 4-1 for the used peripherals and MCP802x MCC Easy Setup Window.

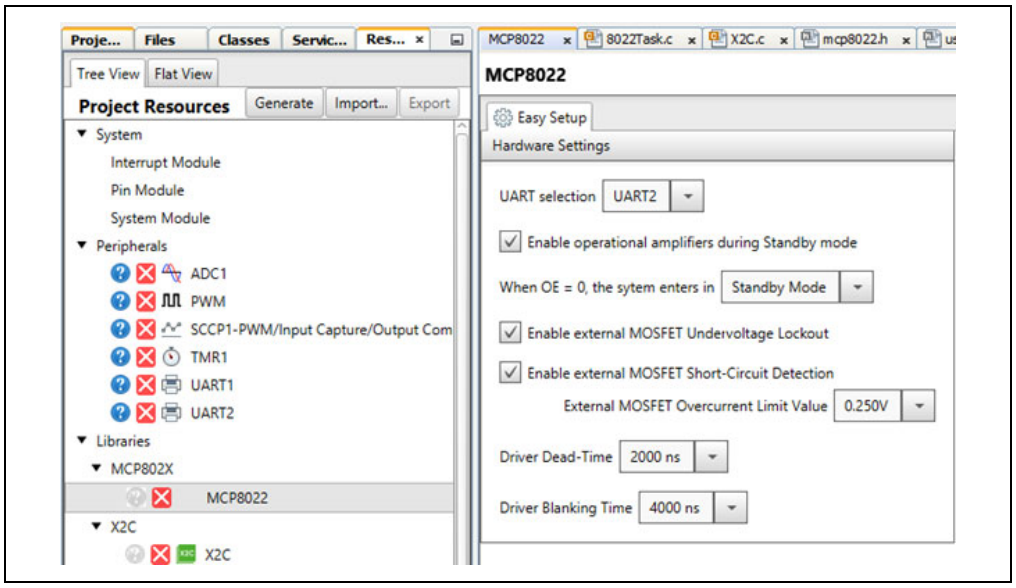
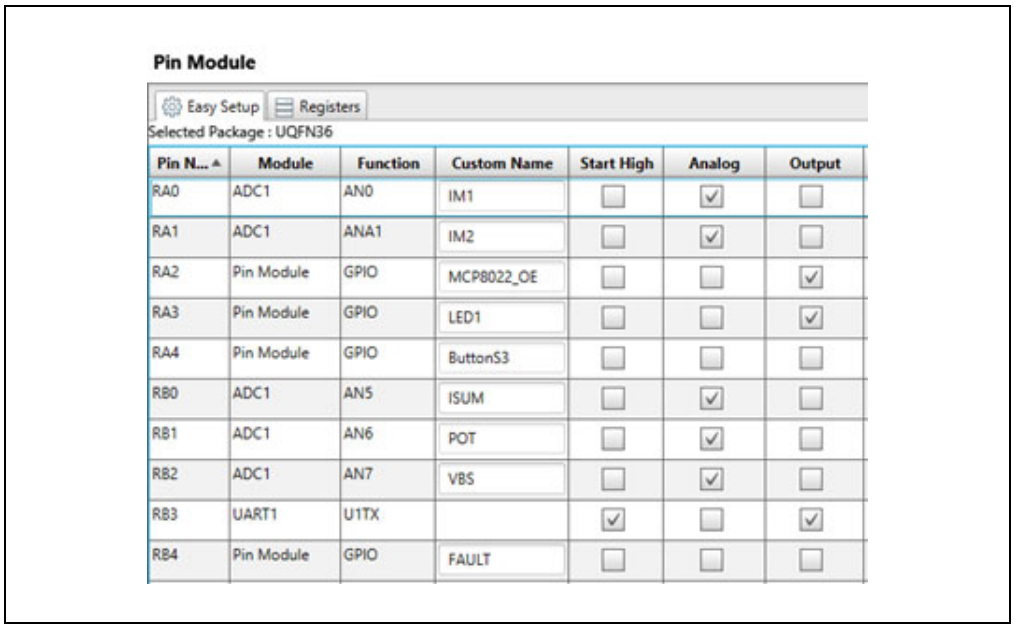


FIGURE 4-2: *MCP802x MCC Easy Setup Window.*

The I/O configuration is also done by MCC. Figure 4-2 shows a part of the configuration.

Hint: The MCP8022_OE is important to set, otherwise the MCP802X library cannot work properly.



Pin N...	Module	Function	Custom Name	Start High	Analog	Output
RA0	ADC1	AN0	IM1	☐	☑	☐
RA1	ADC1	ANA1	IM2	☐	☑	☐
RA2	Pin Module	GPIO	MCP8022_OE	☐	☐	☑
RA3	Pin Module	GPIO	LED1	☐	☐	☑
RA4	Pin Module	GPIO	ButtonS3	☐	☐	☐
RB0	ADC1	AN5	ISUM	☐	☑	☐
RB1	ADC1	AN6	POT	☐	☑	☐
RB2	ADC1	AN7	VBS	☐	☑	☐
RB3	UART1	U1TX		☑	☐	☑
RB4	Pin Module	GPIO	FAULT	☐	☐	☐

FIGURE 4-3: *Pin Module Settings.*

MCC generates a framework project with peripheral initialization functions. The following flowcharts show the peripherals are initialized and configured by the generated MCC functions at the beginning of the main routine. Then the MCP8022 is also initialized manually. Finally, the idle loop handles the diagnostics. The MCP802X high-level management functions are implemented using the middleware MCC library. These functions are organized in the MCP802X task function and executed in the Timer 1 interrupt. MCP802X can send unsolicited error messages in case of HW fault. These are handled at the UART RX (DE2) interrupt. To check the errors with the polling method, use the getStatus functions. It is also possible to use callback (push) method to increase response time. To do so, override the weak “Status_Notification” callback function to get notification at the application layer immediately after the error message arrives. Limit the callback function execution time, as it is running in the UART interrupt.

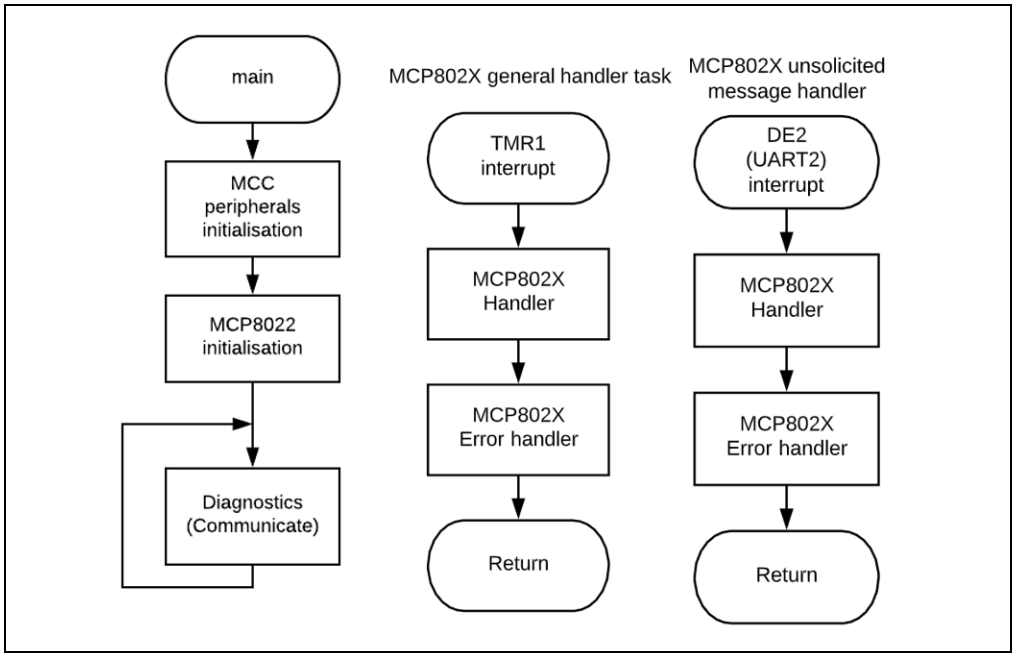


FIGURE 4-4: *MCP802X Software Function Flow Chart.*

The details of the MCC configuration are not part of the documentation as it can be opened in MPLAB X. The graphical peripheral configuration in MCC is self-explanatory, when added together with the schematics portion of this document. For further details on how to use the MCC, follow this link.

4.3 X2C - RAPID PROTOTYPING (MODEL-BASED SOFTWARE DESIGN)

The field-oriented motor control algorithm is implemented in a Scilab model. The compilable C code is generated from this model by the X2C® toolbox. This motor control model is part of the source code that can be opened with the free Scilab software. The model itself also contains a motor sub-block that is not part of the code generation but it enables PC simulation (shown in the green box in Figure 4-5).

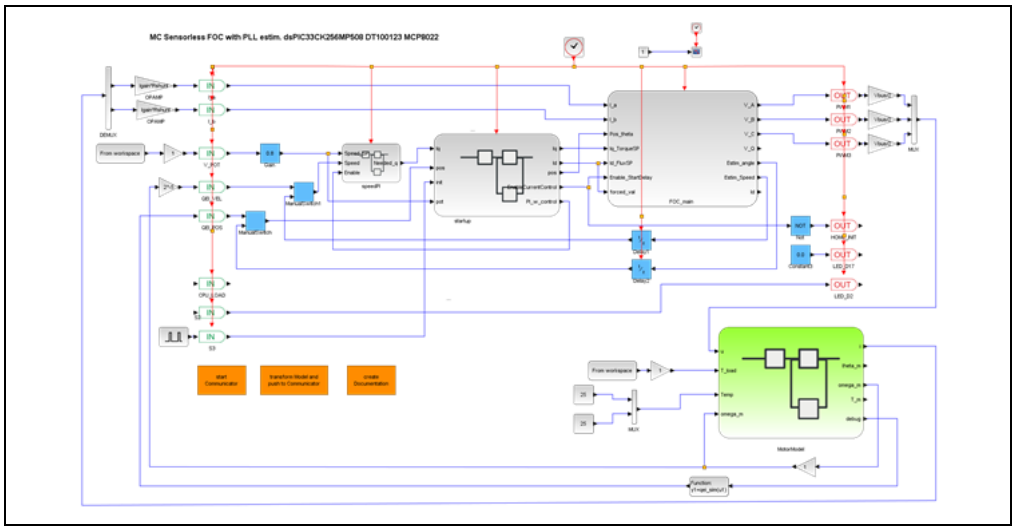


FIGURE 4-5: *MC Sensorless FOC with PLL Estimator dsPIC33CK256MP508 on DT100123.*

The high-level workflow with Scilab and X2C is demonstrated in Figure 4-6 and Figure 4-7. As described above, the MCC creates the peripheral configuration, the drivers and framework project that will execute the model code generated from Scilab.

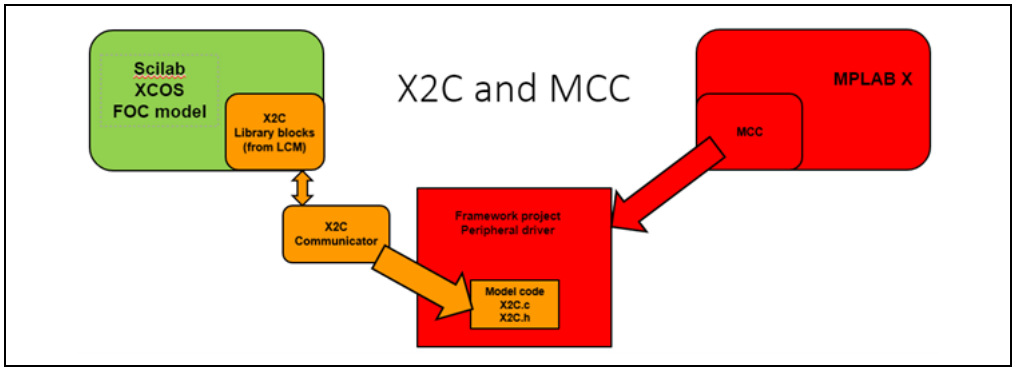


FIGURE 4-6: *MPLAB X, MCC and Scilab, X2C Integrating Together.*

The workflow looks like the following Figure 4-7:

1. Use Scilab to work on the model and simulate on PC
2. Use X2C Communicator to generate code from the model
3. Use MPLAB X to program the device and debug, if necessary
4. Use X2C Communicator's scope window to monitor real time analog signals.

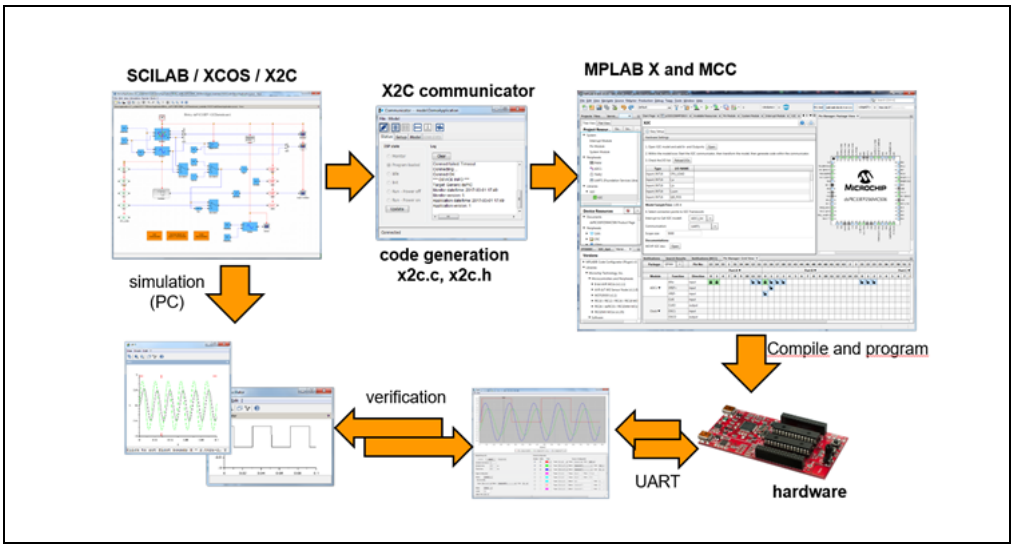


FIGURE 4-7: *Working with Scilab and MPLAB X.*

The FOC model calculation is executed in the ADC interrupt when the phase current measurements are ready. The ADC sampling is synchronized with the PWM frequency, which is 10 kHz. Therefore, the model execution period is 100 µs. At the beginning of the interrupt, the model “inport” variables are updated according to the phase currents measured by ADCs. Then the motor control model calculation function is executed. Finally, the results of the calculation, the outport variables of the model, are scaled and passed to the peripherals like PWM duty cycle.

Diagnostics:

The X2C framework provides additional features like run-time parameter change in control algorithm and virtual oscilloscope to monitor analog signal chains in the model. The main idle loop contains the necessary diagnostics functions to provide the communication interface via the J1 VCP Virtual COM Port.

To get more information about the model-based software development tools please follow the link:

https://mu.microchip.com/motor-control-rapid-prototyping

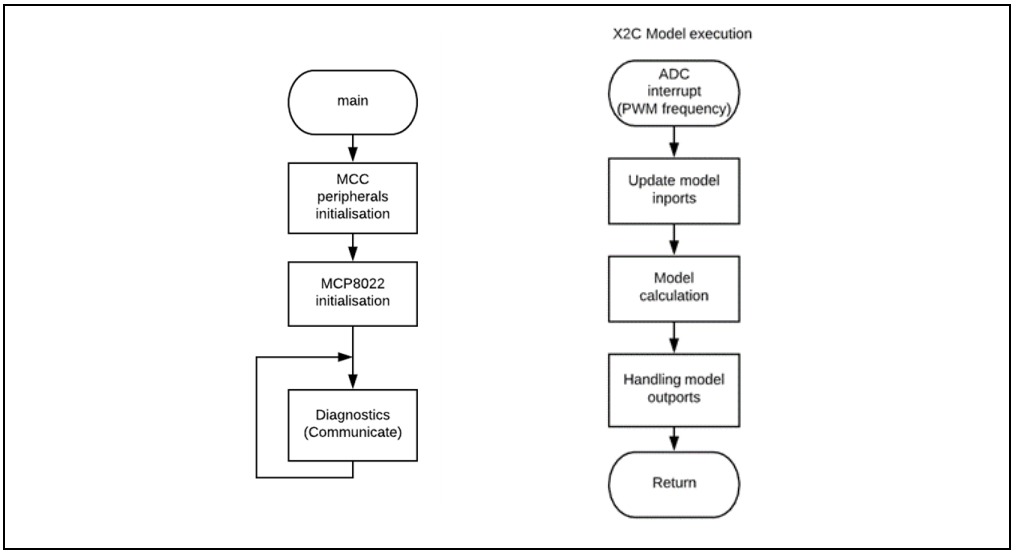


FIGURE 4-8: *X2C Model Flow Chart.*

NOTES:

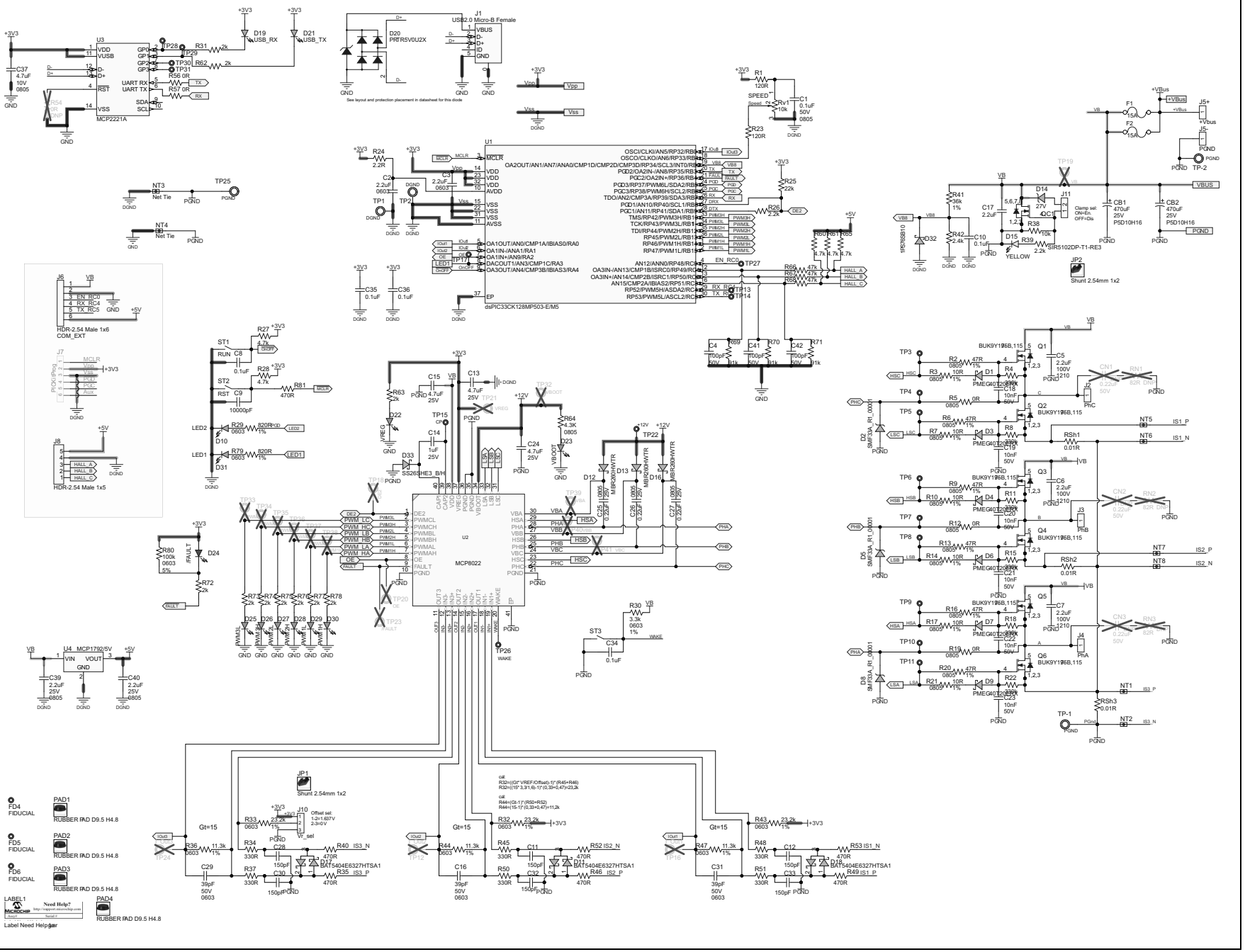
Appendix A. Schematic and Layouts

A.1 INTRODUCTION

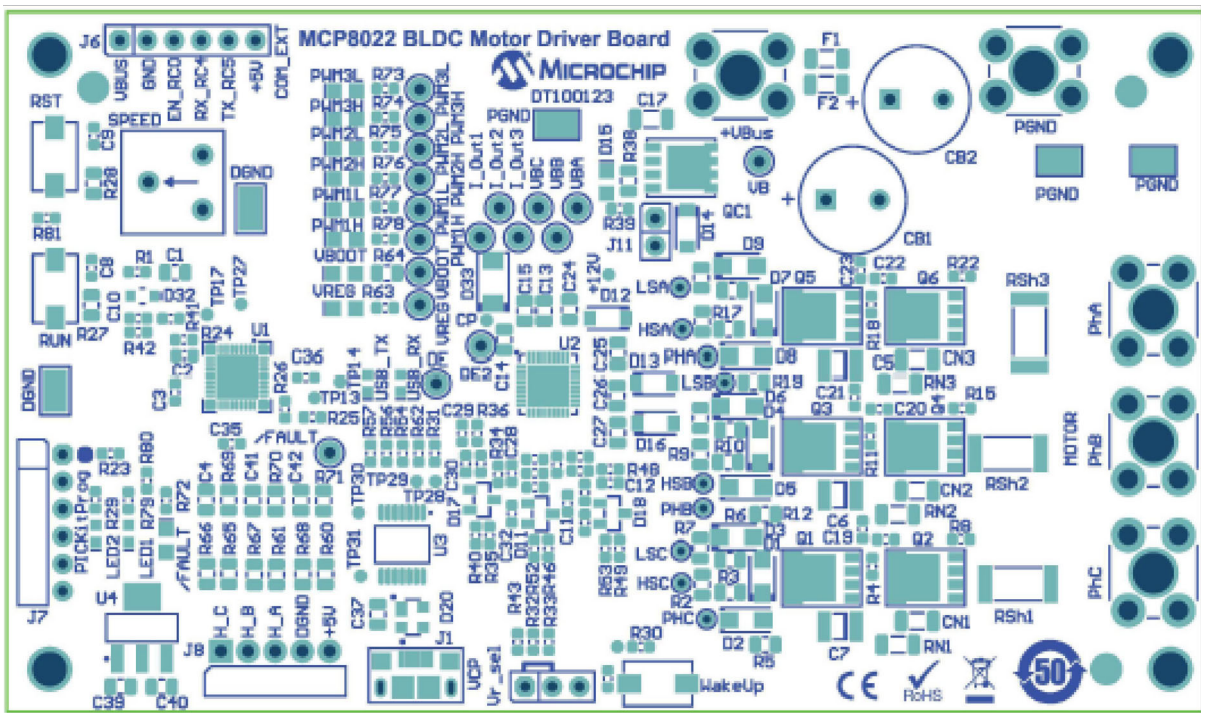
This appendix contains the following schematic and layouts for the MCP8022:

- Board – Schematic
- Board – Top Silk
- Board – Top Copper
- Board – Mid-Layer 1
- Board – Mid-Layer 2
- Board – Bottom Copper
- Board – 3D Top View
- Board – 3D Bottom View

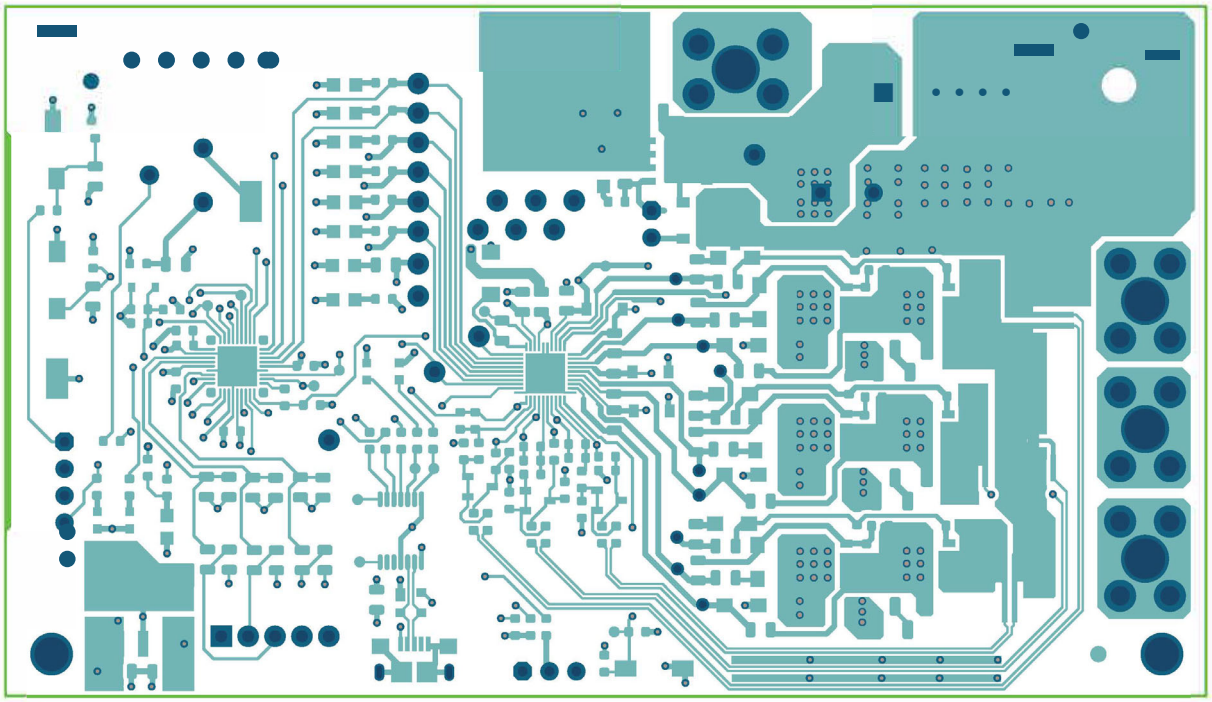
A.2 BOARD – SCHEMATIC



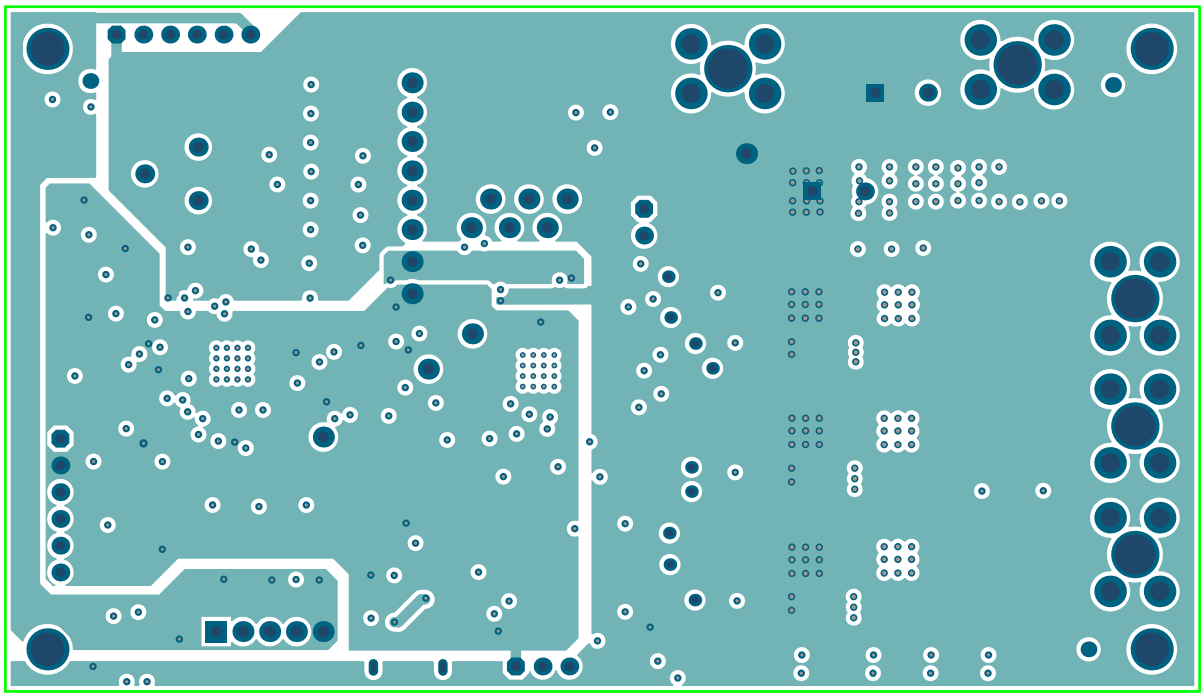
A.3 BOARD – TOP SILK



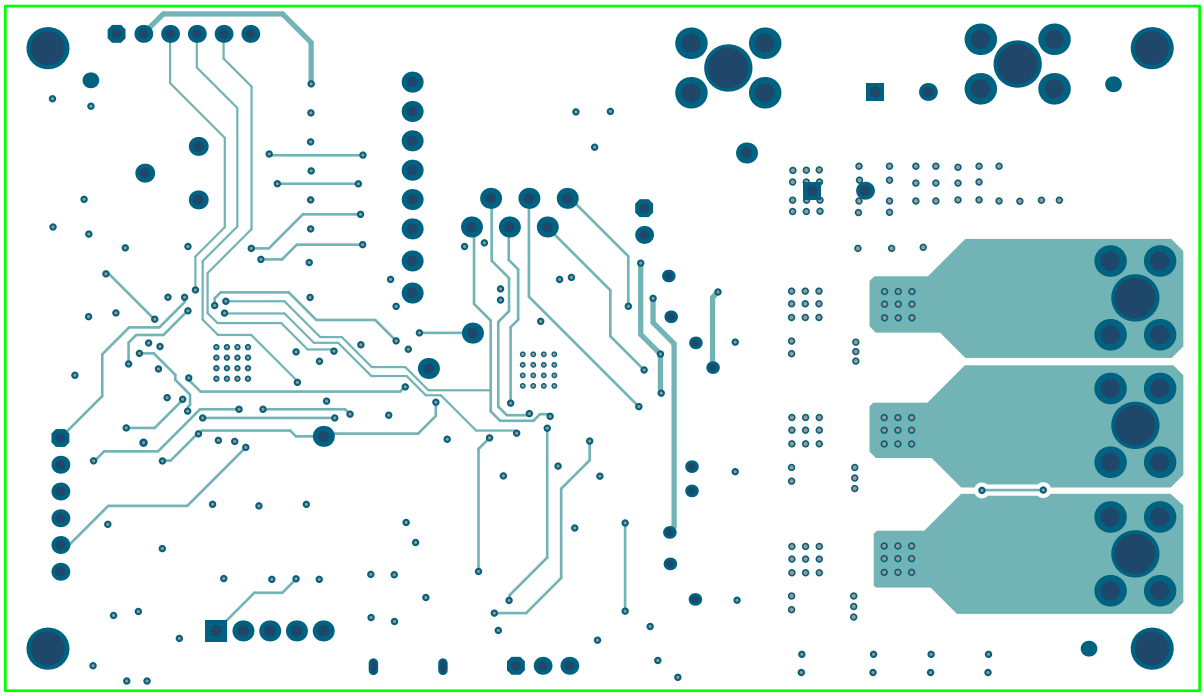
A.4 BOARD – TOP COPPER



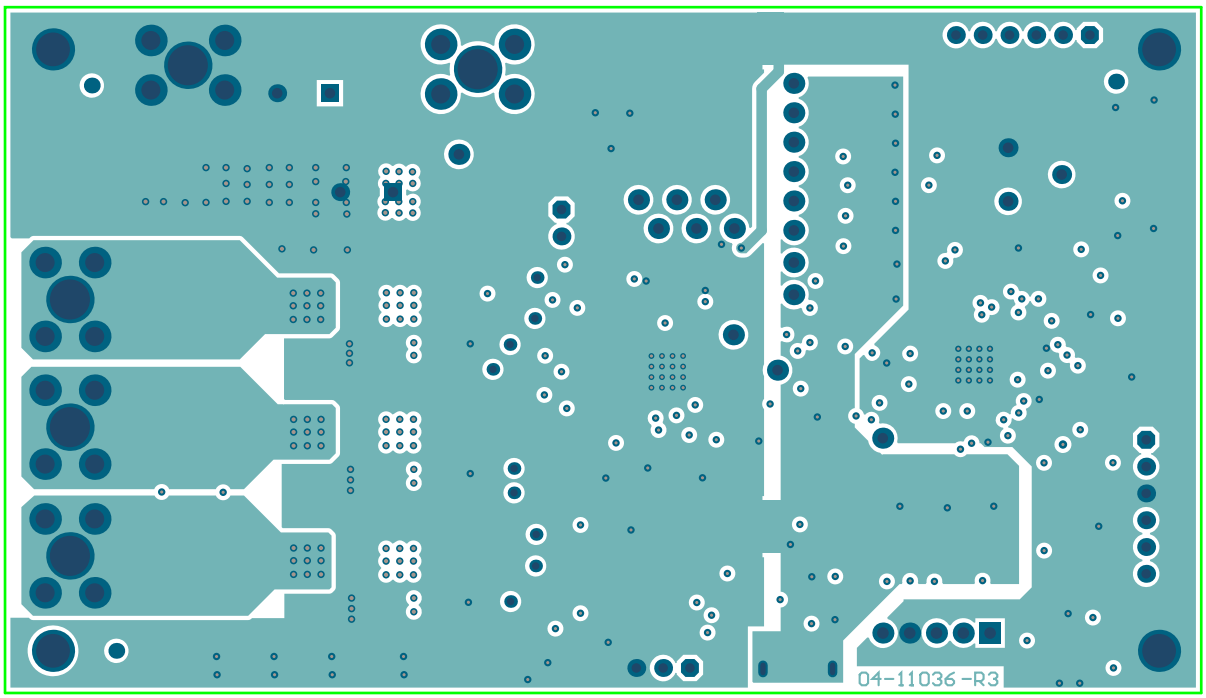
A.5 BOARD – MID-LAYER 1



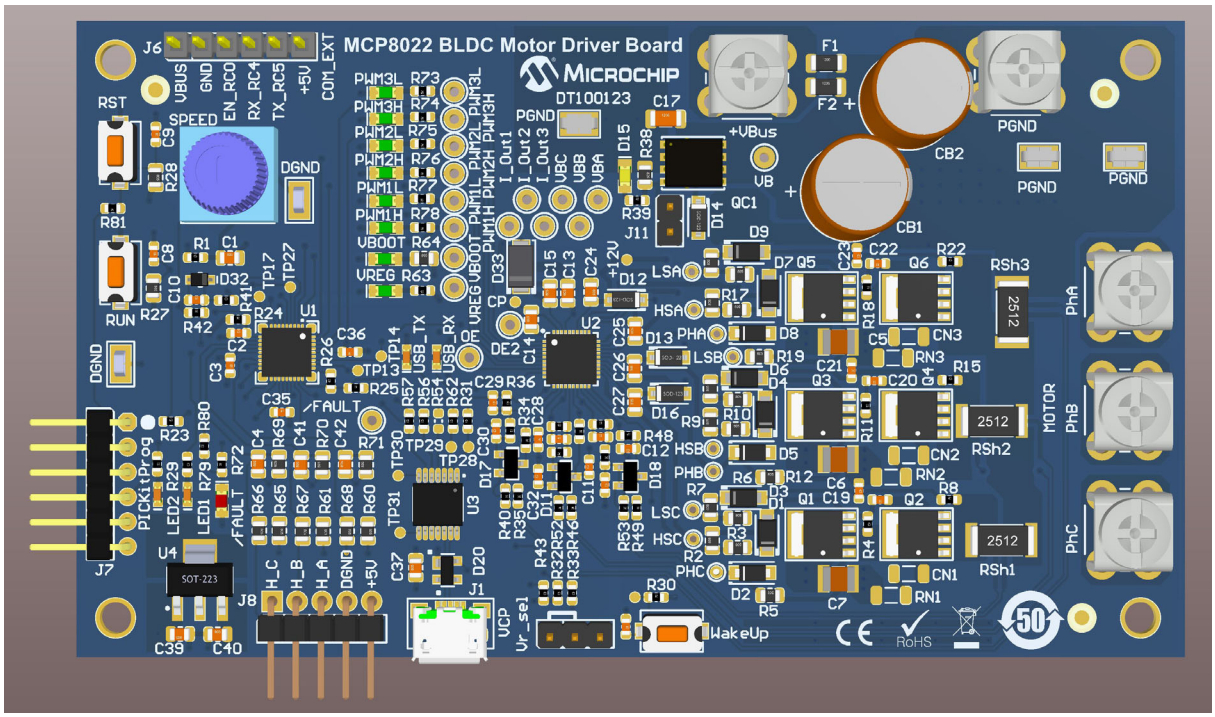
A.6 BOARD – MID-LAYER 2



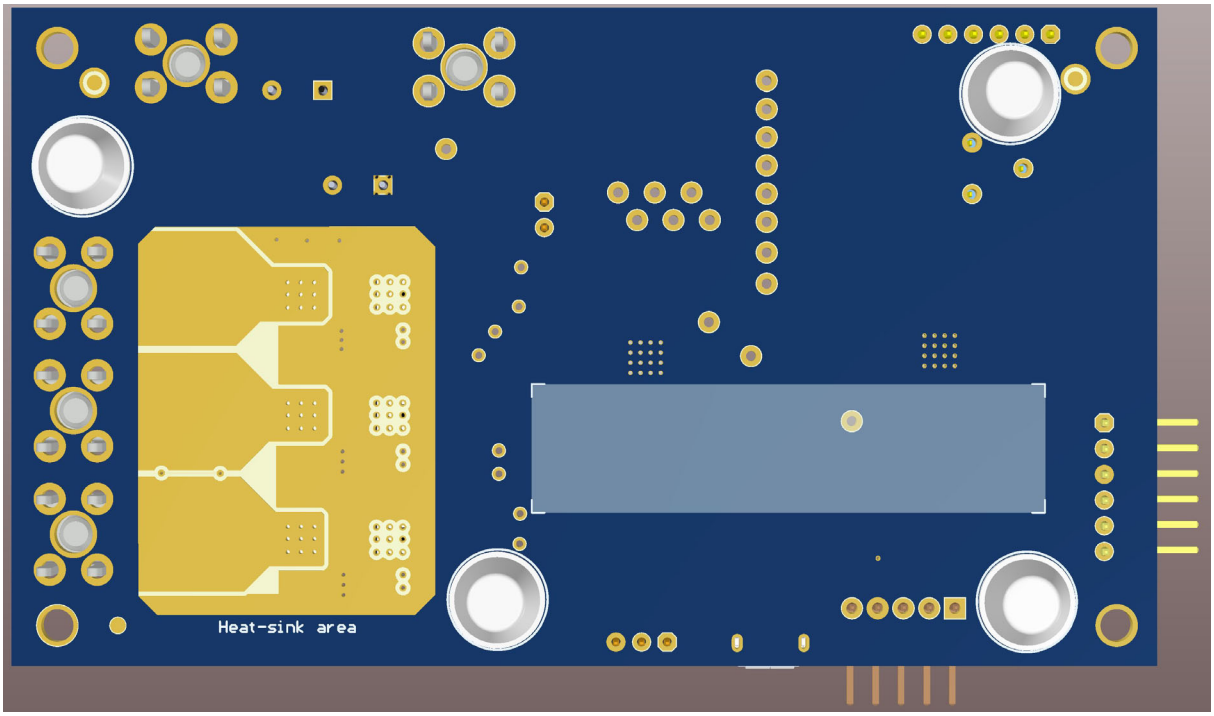
A.7 BOARD – BOTTOM COPPER



A.8 BOARD – 3D TOP VIEW



A.9 BOARD – 3D BOTTOM VIEW



Appendix B. Bill of Materials (BOM)

TABLE B-1: BILL OF MATERIALS (BOM)

Qty.	Reference	Description	Manufacturer	Part Number
1	C1	Capacitor, Ceramic, 0.1 µF, 50V, 10%, X7R, SMD, 0805	Kyocera AVX	08055C104KAT2A
2	C2, C3	Capacitor, Ceramic, 2.2 µF, 6.3V, 10%, X7R, SMD, 0603, AEC-Q200	TDK Corporation	CGA3E1X7R0J225K080AC
3	C4, C41, C42	Capacitor, Ceramic, 100 pF, 50V, 5%, C0G, SMD, 0805	Wurth Elektronik	885012007057
3	C5, C6, C7	Capacitor, Ceramic, 2.2 µF, 100V, 10%, X7R, SMD, 1210	Samsung Group	CL32B225KCJSNNE
4	C8, C34, C35, C36	Capacitor, Ceramic, 0.1 µF, 25V, 20%, X7R, SMD, 0603	KEMET	C0603C104M3RACTU
7	C9, C18, C19, C20, C21, C22, C23	Capacitor, Ceramic, 10000 pF, 50V, 20%, X7R, SMD, 0603	Kyocera AVX	06035C103KAT2A
1	C10	Capacitor, Ceramic, 0.1 µF, 16V, 10% X7R SMD 0603	Samsung Group	CL10B104KO8NNNC
6	C11, C12, C28, C30, C32, C33	Capacitor, Ceramic, 150 pF, 50V, 5%, NP0, SMD, 0603	Yageo Corporation	CC0603JRNPO9BN151
3	C13, C15, C24	Capacitor, Ceramic, 4.7 µF, 25V, 10%, X7R, SMD, 0805, AEC-Q200	TDK Corporation	CGA4J1X7R1E475K125AC
1	C14	Capacitor, Ceramic, 1 µF, 25V, 10%, X7R, SMD, 0805	KEMET	C0805C105K3RACTU
3	C16, C29, C31	Capacitor, Ceramic, 39 pF, 50V, 5%, C0G, SMD, 0603	Murata Manufacturing Co., Ltd.	GRM1885C1H390JA01D
1	C17	Capacitor, Ceramic, 2.2 µF, 50V, 10%, X7R, SMD, 1206	TDK Corporation	CGA5L3X7R1H225K160AB
3	C25, C26, C27	Capacitor, Ceramic, 220 nF, 25V, 10%, X7R, SMD, 0805	Wurth Elektronik	885012207074
1	C37	Capacitor, Ceramic, 4.7 µF, 10V, 10%, X7R, SMD, 0805	Taiyo Yuden Co., Ltd.	LMK212B7475KG-T
2	C39, C40	Capacitor, Ceramic, 2.2 µF, 25V, 10%, X7R, SMD, 0805	Murata Manufacturing Co., Ltd.	GRM21BR71E225KE11L
2	CB1, CB2	Capacitor, Aluminum, 470 µF, 25V, 20%, RAD, P5D10H16	Nichicon Corporation	UHE1E471MPD6
6	D1, D3, D4, D6, D7, D9	Diode, Schottky, 515 mV, 2A, 40V, AEC-Q101, SOD-123F	Nexperia	PMEG40T20ERX
3	D2, D5, D8	Diode, TVS, 33V, 200W, SMD, SOD-123FL	PanJit Group	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
4	D10, D19, D21, D31	Diode, LED, Orange, 2V, 30 mA 90 mcd, Clear, SMD, 0603	Vishay Intertechnology, Inc.	LTST-C190KFKT
3	D11, D17, D18	Diode, Schottky, ARRAY, 800 mV, 200 mA, 30V, SMD, SOT-23-3	Infineon Technologies AG	BAT5404E6327HTSA1
3	D12, D13, D16	Diode, Schottky, 660 mV, 2A, 60V, SOD-123	SMC Diode Solutions LLC	MBR260HWTR
1	D14	Diode, Zener, 27V, 500 mW, SOD-123	Diodes Incorporated®	BZT52C27-7-F
1	D15	Diode, LED, Yellow, 2.1V, 30 mA, 10 mcd, Diffuse, SMD, 0805	Lumex® Inc.	SML-LXT0805YW-TR
1	D20	Diode, TVS, 5.5V, SMD, SOT-143	Nexperia	PRTR5V0U2X,215
8	D22, D23, D25, D26, D27, D28, D29, D30	Diode, LED, Green, 2.1V, 20 mA, 6 mcd, Diffuse, SMD, 0805	Vishay Intertechnology, Inc.	LTST-C170GKT
1	D24	Diode, LED, Red, 2.2V, 20 mA, 40 mcd, Clear, SMD, 0805	Dialight Corporation	5988110107F
1	D32	Diode, Schottky, 800 mV, 200 mA, 30V, SOD-323	NXP Semiconductors	1PS76SB10@115
1	D33	Diode, Schottky, 60V, 2A, DO214AC	Vishay Intertechnology, Inc.	SS26SHE3_B/H
2	F1, F2	Resistor, Fuse, 15A, 24V, Fast, SMD, 1206	Multicomp Pro	MP005485
1	J1	Connector, USB2.0, Micro-B, Female, SMD, Right Angle	Amphenol ICC (FCI)	10118193-0001LF
5	J2, J3, J4, J5-, J5+	Connector, Terminal, 15A, Female, 1x1, Through Hole, Vertical	Keystone® Electronics Corp.	8195
1	J6	Connector, HDR-2.54, Male, 1x6, Gold, 5.84 MH, Through Hole, Vertical	Amphenol ICC (FCI)	68001-106HLF
1	J7	Connector, HDR-2.54, Male, 1x6, Gold, 5.84 MH, Through Hole, Right Angle	Wurth Elektronik	61300611021
1	J8	Connector, HDR-2.54, Male, 1x5, Gold, 6.00 MH, Through Hole, Right Angle	Wurth Elektronik	61300511021
1	J10	Connector, HDR-2.54, Male, 1x3, Tin, 6.75 MH, Through Hole, Vertical	Molex, LLC	90120-0123
1	J11	Connector, HDR-2.54, Male 1x2, Tin, 7 MH, Through Hole, Vertical	Amphenol ICC (FCI)	861400021YO1LF
7	Q1, Q2, Q3, Q4, Q5, Q6, QC1	Transistor, MOSFET, N-Channel, 75V, 48.2A, 106W, SOT-669	Nexperia	BUK9Y19-75B,115
2	R1, R23	Resistor, Thick Film, 120R, 1%, 1/10W, SMD, 0603	Stackpole Electronics, Inc.	RMCF0603FT120R
6	R2, R6, R9, R13, R16, R20	Resistor, Thick Film, 47R, 1%, 1/8W, SMD, 0805	Yageo Corporation	RC0805FR-0747RL

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
6	R3, R7, R10, R14, R17, R21	Resistor, Thick Film, 10R, 1%, 1/8W, SMD, 0805, AEC-Q200	Stackpole Electronics, Inc.	RMCF0805FT10R0
6	R4, R8, R11, R15, R18, R22	Resistor, Thick Film, 330k, 5%, 1/10W, SMD, 0603	Panasonic® - ECG	ERJ-3GEYJ334V
3	R5, R12, R19	Resistor, Thick Film, 0R, 1/8W, SMD, 0805	Yageo Corporation	RC0805JR-070RL
1	R24	Resistor, Thick Film, 2.2R, 5%, 1/10W, SMD, 0603	Stackpole Electronics, Inc.	RMCF0603JT2R20
1	R25	Resistor, Thick Film, 22k, 5%, 1/10W, SMD, 0603, AEC-Q200	Stackpole Electronics, Inc.	RMCF0603JT22K0
2	R26, R39	Resistor, Thin Film, 2.2k, 1%, 1/10W, SMD, 0603, AEC-Q200	Stackpole Electronics, Inc.	RMCF0603FT2K20
5	R27, R28, R60, R61, R65	Resistor, Thick Film, 4.7k, 1%, 1/8W, SMD, 0805	Yageo Corporation	RC0805FR-074K7L
2	R29, R79	Resistor, Thick Film, 820R, 1%, 1/10W, SMD, 0603	Stackpole Electronics, Inc.	RMCF0603FT820R
1	R30	Resistor, Thick Film, 3.3k, 1%, 1/10W, SMD, 0603	Vishay Intertechnology, Inc.	CRCW06033K30FKEA
10	R31, R62, R63, R72, R73, R74, R75, R76, R77, R78	Resistor, Thick Film, 2k, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-072KL
3	R32, R33, R43	Resistor, Thick Film, 23.2k, 1%, 1/10W, SMD, 0603	Stackpole Electronics, Inc.	RMCF0603FT23K2
6	R34, R37, R45, R48, R50, R51	Resistor, Thick Film, 330R, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ3EKF3300V
7	R35, R40, R46, R49, R52, R53, R81	Resistor, Thick Film, 470R, 1%, 1/10W, SMD, 0603	Stackpole Electronics, Inc.	RMCF0603FT470R
3	R36, R44, R47	Resistor, Thick Film, 11.3K, 1%, 1/10W, SMD, 0603	Stackpole Electronics, Inc.	RMCF0603FT11K3
1	R38	Resistor, Thick Film, 10k, 5%, 1/2W, SMD, 0805	Panasonic - ECG	ERJ-P06J103V
1	R41	Resistor, Thick Film, 36k, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3EKF3602V
1	R42	Resistor, Thick Film, 2.4k, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-072K4L
2	R56, R57	Resistor, Thick Film, 0R, 1/10W, SMD, 0603	Yageo Corporation	RC0603JR-130RL
1	R64	Resistor, Thick Film, 4.3K, 1%, 1/8W, SMD, 0805	Stackpole Electronics, Inc.	RMCF0805FT4K30
3	R66, R67, R68	Resistor, Thick Film, 47k, 1%, 1/8W, SMD, 0805, AEC-Q200	Yageo Corporation	AC0805FR-0747KL

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	R69, R70, R71	Resistor, Thick Film, 91k, 1%, 1/8W, SMD, 0805	Vishay Intertechnology, Inc.	CRCW080591K0FKEA
1	R80	Resistor, Thick Film, 100k, 5%, 1/10W, SMD, 0603	KOA Speer Electronics, Inc.	RK73B1JTTD104J
3	RSh1, RSh2, RSh3	Resistor, Thick Film, 0.01R, 1%, 2W, SMD, 2512, AEC-Q200	ROHM Semiconductor	PMR100HZPFU10L0
1	Rv1	Resistor, Trimmer, Cermet, 10k, 10%, 500 mW, Through Hole, 3386F	Bourns®, Inc.	3386F-1-103TLF
3	ST1, ST2, ST3	Switch, Tactile, SPST, 24V, 50 mA, KSR231GLFS, SMD, 6 x 3.5 mm	TE Connectivity Alcoswitch	147873-2
2	TP1, TP2	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, 3.8 x 2.03, SMD	Keystone Electronics Corp.	5019
1	PCB1	Printed Circuit Board	—	11036-R3

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.	MCP8022T-3315H/NHXVAO
1	U3	Interface, USB, I2C, UART, TSSOP-14	Microchip Technology Inc.	MCP2221A-I/ST
1	U4	Analog, LDO, 5V, SOT-223-3	Microchip Technology Inc.	MCP1792-5002H/DB

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) – MECHANICAL PARTS

Qty.	Reference	Description	Manufacturer	Part Number
3	FD4, FD5, FD6	Fiducial, Round, PCB, 1 mm, SMD	—	—
2	JP1, JP2	Mechanical, Headers & Wires, Jumper, 2.54 mm, 1x2, Gold	Wurth Elektronik	60900213421
1	LABEL1	Label, Support, Datamatrix: Contact Information/Assy#/Serial#	—	—
4	PAD1, PAD2, PAD3, PAD4	Mechanical, Headers & Wires, Rubber Pad, Cylindrical, 0.374" x 0.189", Clear	Essentra PLC.	RBS-35

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-4: BILL OF MATERIALS (BOM) – DO NOT POPULATE

Qty.	Reference	Description	Manufacturer	Part Number
0	CN1, CN2, CN3	Capacitor, Ceramic, 0.22 µF, 50V, 10%, X7R, SMD, 1206	Kyocera AVX	12065C224K4T2A
0	R54	Resistor, Thick Film, 0R, 1/10W, SMD, 0603	Yageo Corporation	RC0603JR-070RL

TABLE B-4: BILL OF MATERIALS (BOM) – DO NOT POPULATE

Qty.	Reference	Description	Manufacturer	Part Number
0	RN1, RN2, RN3	Resistor, Thick Film, 82R, 1%, 1/4W, SMD, 1206	Yageo Corporation	RC1206FR-0782RL
0	TP12, TP16, TP18, TP19, TP20, TP21, TP23, TP24, TP32, TP33, TP34, TP35, TP36, TP37, TP38, TP39, TP40, TP41	Miscellaneous, Test Point, Multi-Purpose, Mini, Black	Keystone® Electronics Corp.	5001

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.

NOTES:

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