EVM User's Guide: MCF8315PWPEVM

MCF8315PWPEVM Evaluation Module

Description

The MCF8315PWPEVM is an evaluation module for the MCF8315 BLDC driver in the 24-pin HTSSOP (PWP) package. The MCF8315 is a 4.5V to 35V, 4A peak, sensorless FOC, integrated FET, and three-phase BLDC motor driver IC.

This EVM allows quick evaluation and configuration of the MCF8315 device to optimize for your BLDC motor application.

Get Started

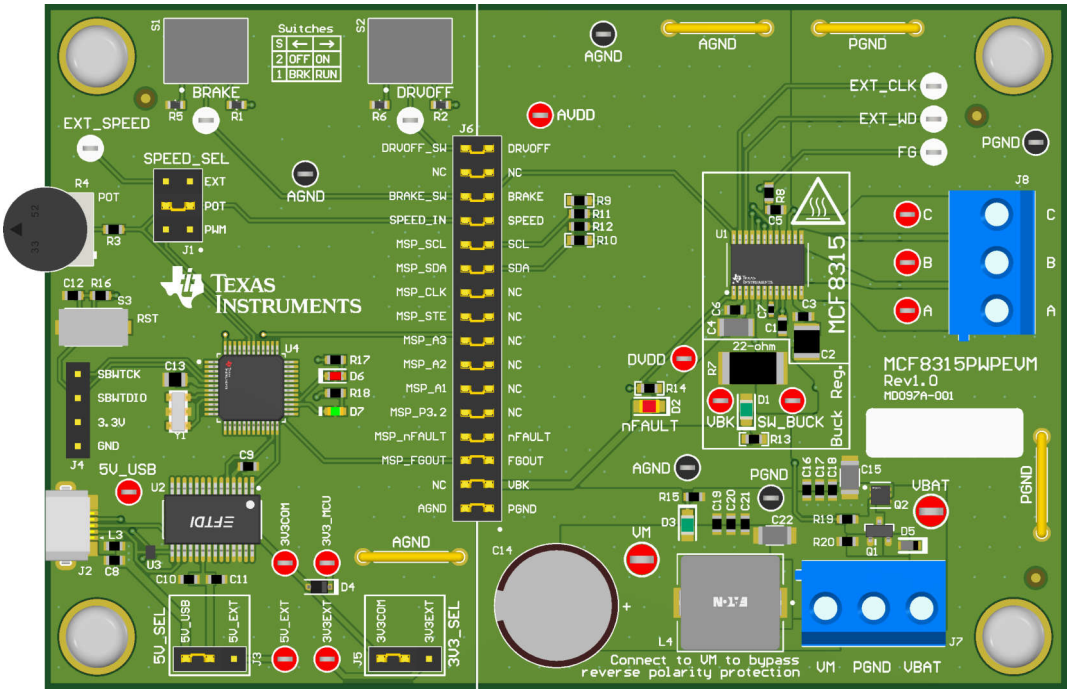
1. Download the latest design files from the MCF8315PWPEVM tool page on ti.com.
2. Download the latest version of the Motor Studio GUI and firmware from the Motor Studio tool page on ti.com.

Features

- 4.5V to 35V operation with 4A peak current
- Onboard USB-to-I2C communication interface
- Sensorless Field Oriented Control (FOC)
- Low MOSFETs RDS(ON)(H+L) at TJ=25°C: 265mΩ(typ.)
- GUI software to simplify the MCx tuning process and performance evaluation

Applications

- Brushless-DC (BLDC) Motor Modules
- Residential and Living Fans
- Air Purifiers and Humidifier Fans
- Washer and Dishwashers Pumps
- CPAP Machines



MCF8315PWPEVM Printed Circuit Board (PCB - Top View)

1 Evaluation Module Overview

1.1 Introduction

This document is provided with the MCF8315PWPEVM evaluation module (EVM) as a supplement to the MCF8315 data sheet (MCF8315A Three-Phase Sensorless-FOC BLDC Motor Driver). This user's guide details the hardware setup instructions, GUI installation, and usage instructions. The MCF8315PWPEVM allows users to evaluate the performance of an MCF8315 motor driver in the 24-pin HTSSOP (PWP) package. This EVM can be configured using the accompanying Motor Studio GUI, which makes it easy to tune and optimize the device register settings for a specific motor.

The MCF8315PWPEVM includes an onboard FTDI chip to convert USB communication from the micro-USB connector into UART and an onboard MSP430FR2355 MCU to interface with the MCF8315. There are user-selectable jumpers, resistors, connectors, and test points available to configure and evaluate many features of the device.

WARNING

Voltages exceeding the standard EVM ratings as specified on the data sheet can cause personal injury, electrical shock hazard, damage to the EVM, or a combination.

Additionally, do not leave power connections to the EVM connected while not in operation.

CAUTION

	**Hot surface**	Caution Hot Surface! Contact may cause burns. Do not touch. Please take the proper precautions when operating.

1.2 Kit Contents

Item	Description	Quantity
MCF8315PWPEVM	PCB	1
Box	Cardboard box	1
USB Cabel	USB A Male-to-USB B Micro Male Cable	1
Foam	Antistatic foam	2
Literature	EVM disclaimers	1

1.3 Specification

The MCF8315PWPEVM can support voltages up to 40V and currents up to 4A. To prevent damage to both the IC and the EVM, please confirm that these voltage and current specifications are not exceeded.

1.4 Device Information

The MCF8315 is a 4.5V to 35V, 4A peak three-phase gate driver IC with integrated code-free sensorless field-oriented control (FOC) for motor drive applications. The internal sensorless FOC algorithm is highly configurable through register settings in a non-volatile EEPROM ranging from motor start-up behavior to closed loop operation, which allows for the device to operate stand-alone once the device has been configured.

The device provides three accurately trimmed and temperature-compensated half-bridge MOSFETS, gate drivers, a charge pump, a current sense amplifier, a linear regulator for the external load, and an adjustable buck regulator. The device can receive a speed command through a PWM input, analog voltage, variable frequency square wave, or I2C command. Internal protection functions are provided for undervoltage lockout, FET overcurrent, and overtemperature. The nFAULT pin indicates fault events detected by the protection features.

2 Hardware

2.1 Quick Start Guide

The MCF8315PWPEVM requires a power supply source, which has a recommended operating range from 4.5V to 35V. To set up and power the EVM, follow the sequence below:

1. Connect motor phases to A, B, and C on connector J8.
2. Do not turn on the power supply yet. Connect the motor supply to VBAT/VM and PGND on connector J7.
   a. To enable reverse polarity protection and Pi filter, connect to VBAT. Note that when connecting to VBAT, VM will be VM – 0.7V less, due to a diode drop in the reverse-polarity protection circuit.
   b. To disable reverse-polarity protection and the Pi filter, connect to the VM.
3. Select J3 to 5V_USB and J5 to 3V3COM to power MSP430 from the USB power supply.
4. Connect the micro-USB cable to the computer.
5. Turn the potentiometer fully clockwise to set the motor to zero speed upon power-up.
6. Flip the switch S1 to the right to configure BRAKE = RUN and switch S2 to the right to configure DRVOFF = Driver output ON
7. Turn on the motor power supply.
8. Use the Motor Studio GUI (as shown in Section 3) to configure and tune the device registers and spin up the motor.

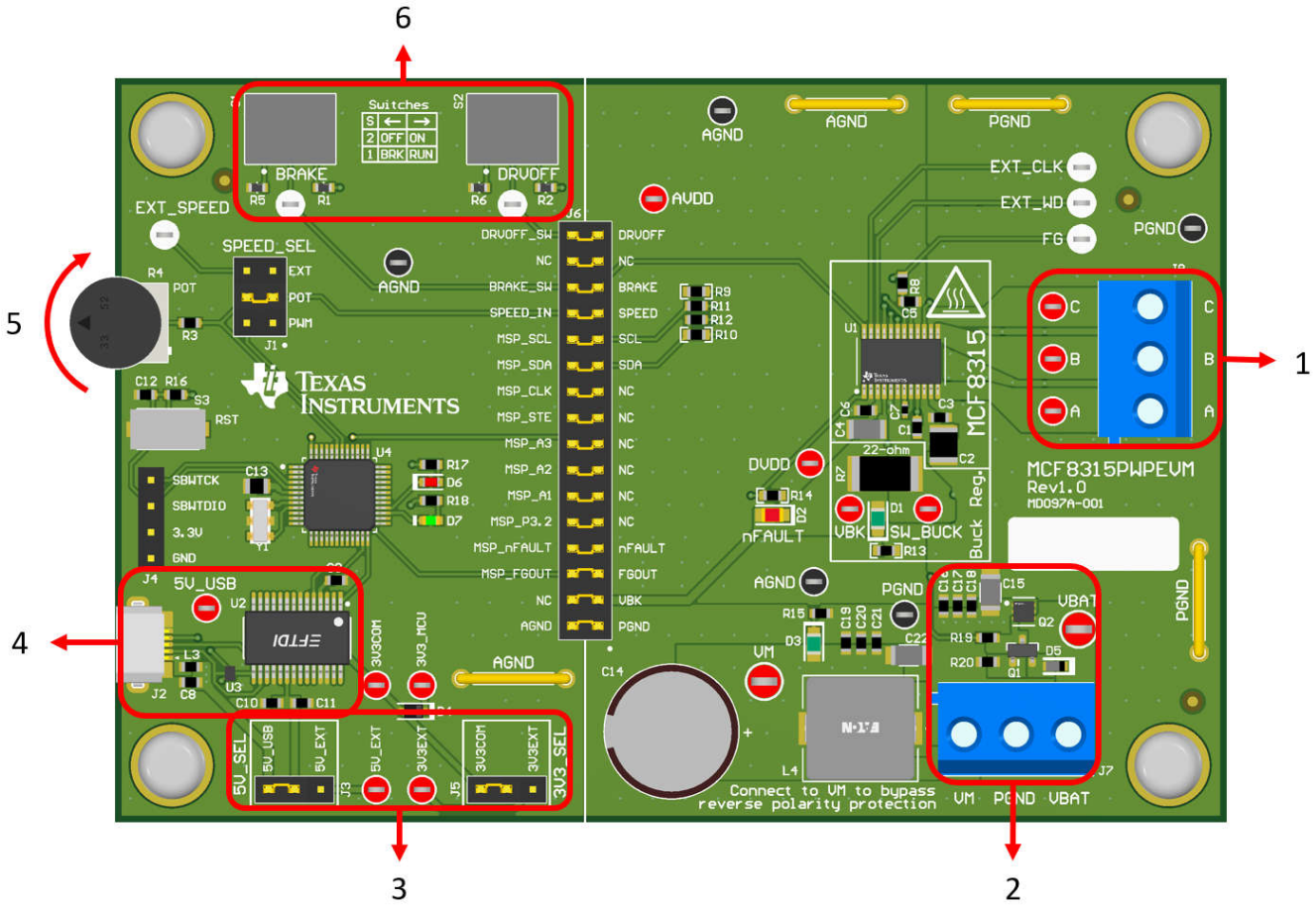


Figure 2-1. Reference for Quick Start Guide

2.2 Hardware Setup

The hardware required to run the motor is the MCF8315PWPEVM, a micro-USB cable, and a power supply with a DC output from 4.5V to 35V. Follow these steps to start up the MCF8315PWPEVM:

1. Connect the DC power supply to header J7. Connect to VBAT and PGND to utilize the reverse polarity protection and the pi filter to the EVM. Otherwise, connect to VM and PGND to bypass the reverse polarity protection and pi filter.
2. Apply user-configurable jumper settings. See Section 2.7 section for more information.
3. If needed, flash program into the MCU as described in Section 3.2.2. Disconnect the 4-pin JTAG connections.
4. Turn on the DC power supply and power up the PCB.
5. Connect a Micro-USB cable to the MCF8315PWPEVM and computer.
6. Launch Motor Studio GUI

If using the MCF8315PWPEVM with an external microcontroller, then remove all shunt jumpers from jumper bridge J6. Connect with external jumpers to the left side of the jumper bridge from the external MCU.

2.3 Hardware Connections Overview – MCF8315PWPEVM

Figure 2-2 shows the major blocks of MCF8315PWPEVM evaluation module. The MCF8315PWPEVM is designed for an input supply from 4.5V to 35V. The MCF8315 includes three integrated half-bridges and implements a sensorless FOC algorithm to spin a motor with up to 4A peak current. It also integrates an adjustable buck regulator.

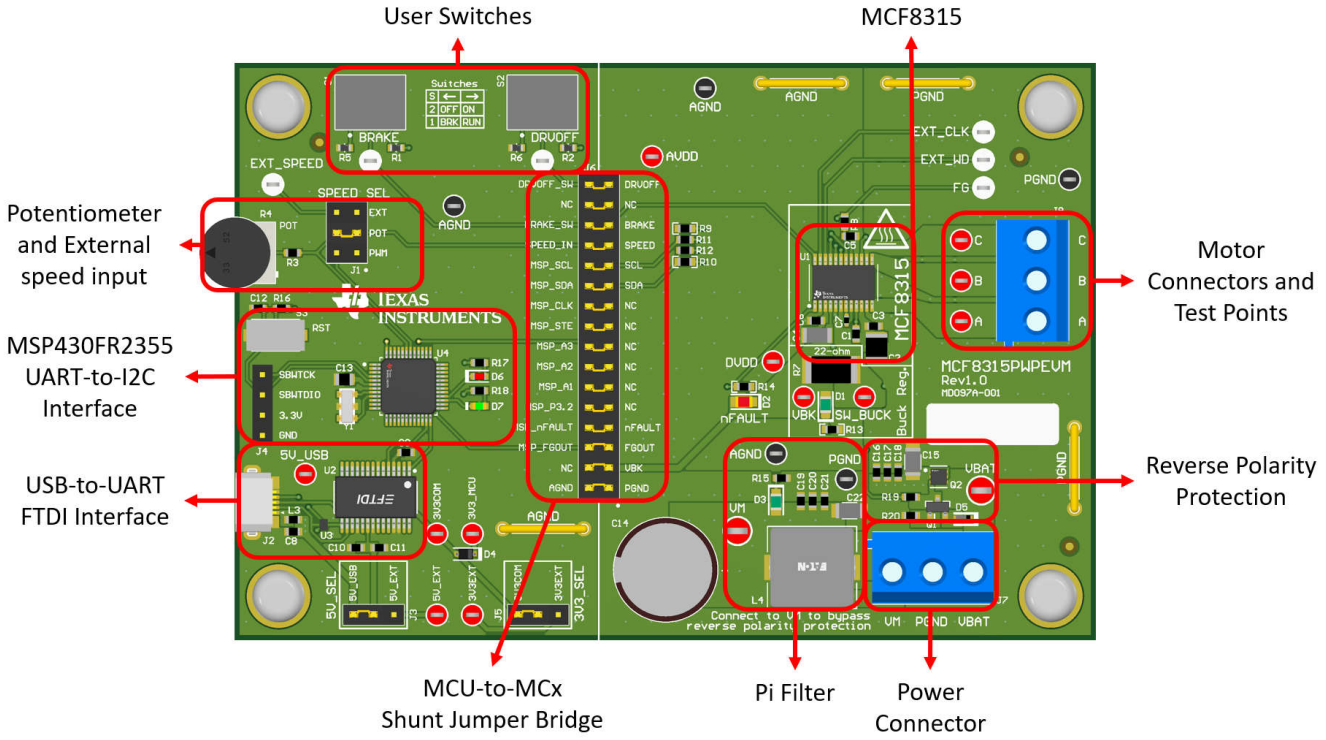


Figure 2-2. MCF8315PWPEVM Major Hardware Blocks

2.4 Connection Details

Figure 2-3 shows the connections made to the MCF8315PWPEVM to spin a 3-phase sensorless Brushless-DC motor.

A 4.5V to 35V power supply or battery is connected to the VBAT or VM and PGND terminals on connector J7. There is a reverse polarity protection and Pi filter implemented on the VBAT and PGND terminals. To bypass the reverse polarity protection and Pi filter, connect the power supply to the VM terminal or VM test point on the board and PGND.

The three phases of the BLDC motor connect directly to the A, B, and C terminals of the screw terminal connector J8 provided on the MCF8315PWPEVM.

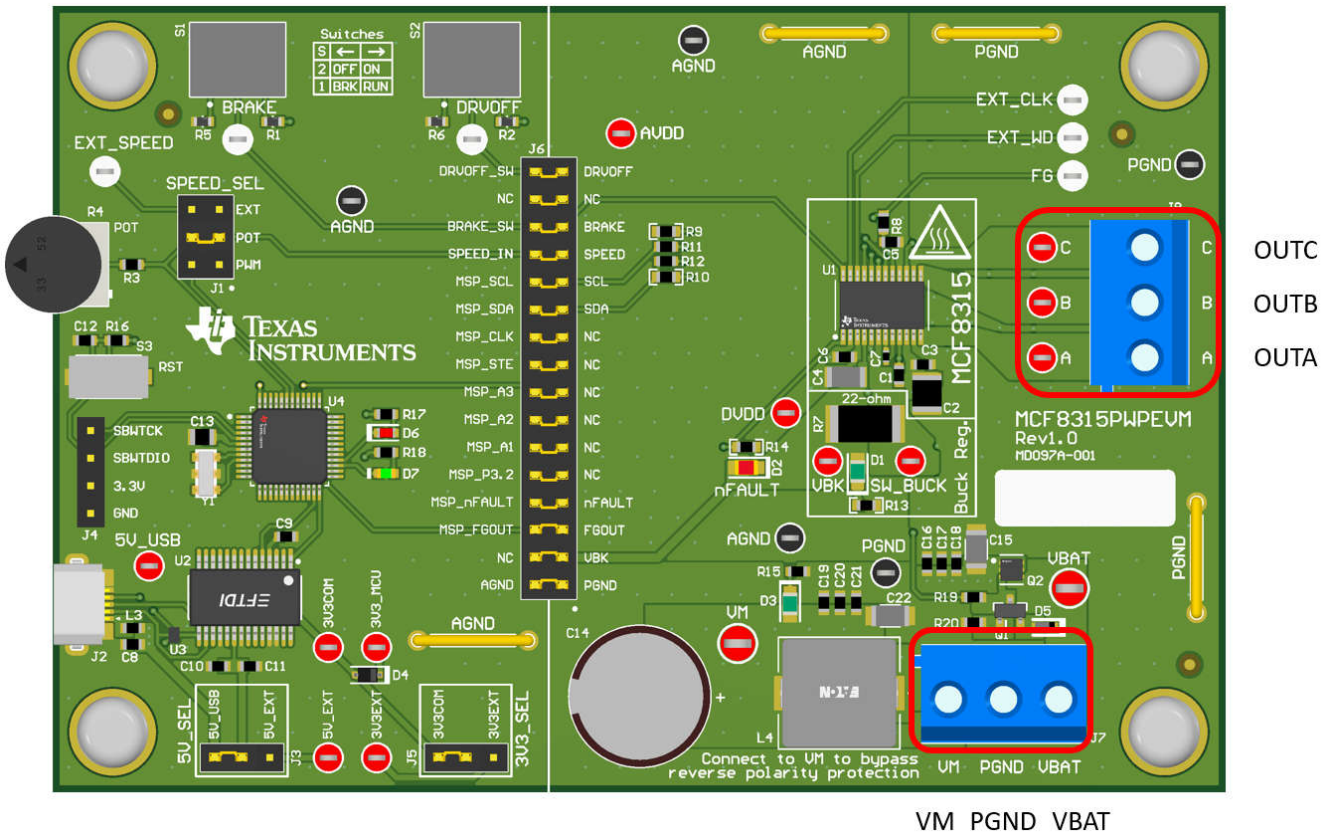


Figure 2-3. Connections from Motor to MCF8315PWPEVM

Figure 2-4 shows where the micro-USB cable is plugged into the MCF8315PWPEVM to provide communication between the evaluation module and GUI. The USB data and 5V power from the USB are converted into UART data and 3.3V power to power the MSP430FR2355 microcontroller. The 5V from the USB power is limited to 500mA and the 3.3V from the FTDI chip is limited to 30mA. If the user wishes to supply more current to these rails, they may use the 5V_SEL jumper J3 and 3V3_SEL jumper J5 to connect external power rails.

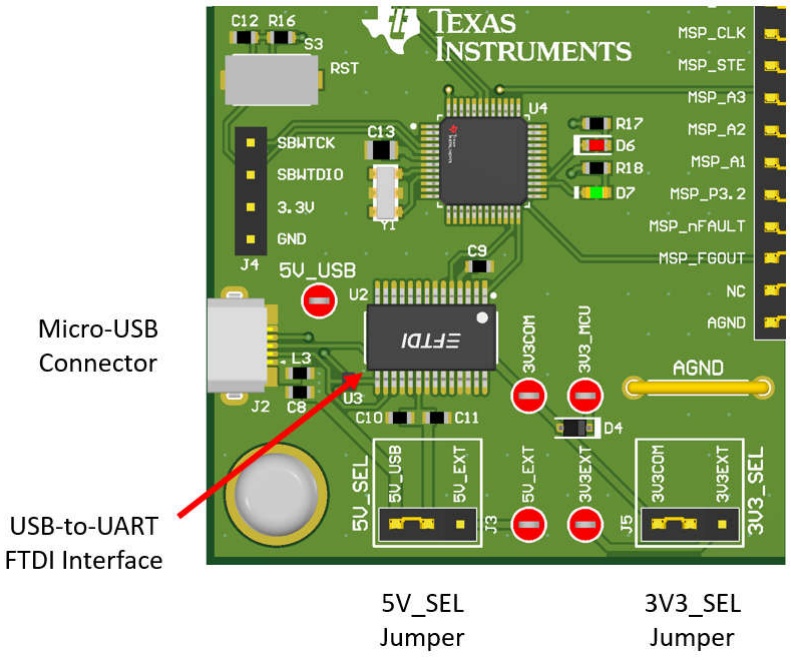


Figure 2-4. Micro-USB Connector and UART for MCF8315PWPEVM

2.5 MSP430FR2355 Microcontroller & User Interface

The MCF8315PWPEVM includes the MSP430FR2355 low-power MCU (as shown in Figure 2-5) to communicates via I2C with the MCF8315.

In order to program the MSP430FR2355, an external MSP430 FET programmer must be connected to the Spy-Bi-Wire (SBW) interface connector J4. Many MSP430 LaunchPad™ provide an onboard eZ-FET Debug Probe that can be jumper-wired to the MCF8315PWPEVM to flash the firmware into the MSP430FR2355 microcontroller.

The user can use the Reset (RST) button at any time to reset and restart the MCU program. Two active-low LEDs, D6 and D7, can be used for debug purposes as well.

Finally, a shunt jumper bridge on the 32-pin connector J6 ties all signals between the microcontroller and MCF8315. These jumpers can be inserted or removed as needed in order to isolate the microcontroller from the gate driver. This allows for microcontroller signal debugging or using the MCF8315PWPEVM as a standalone gate driver with an external microcontroller.

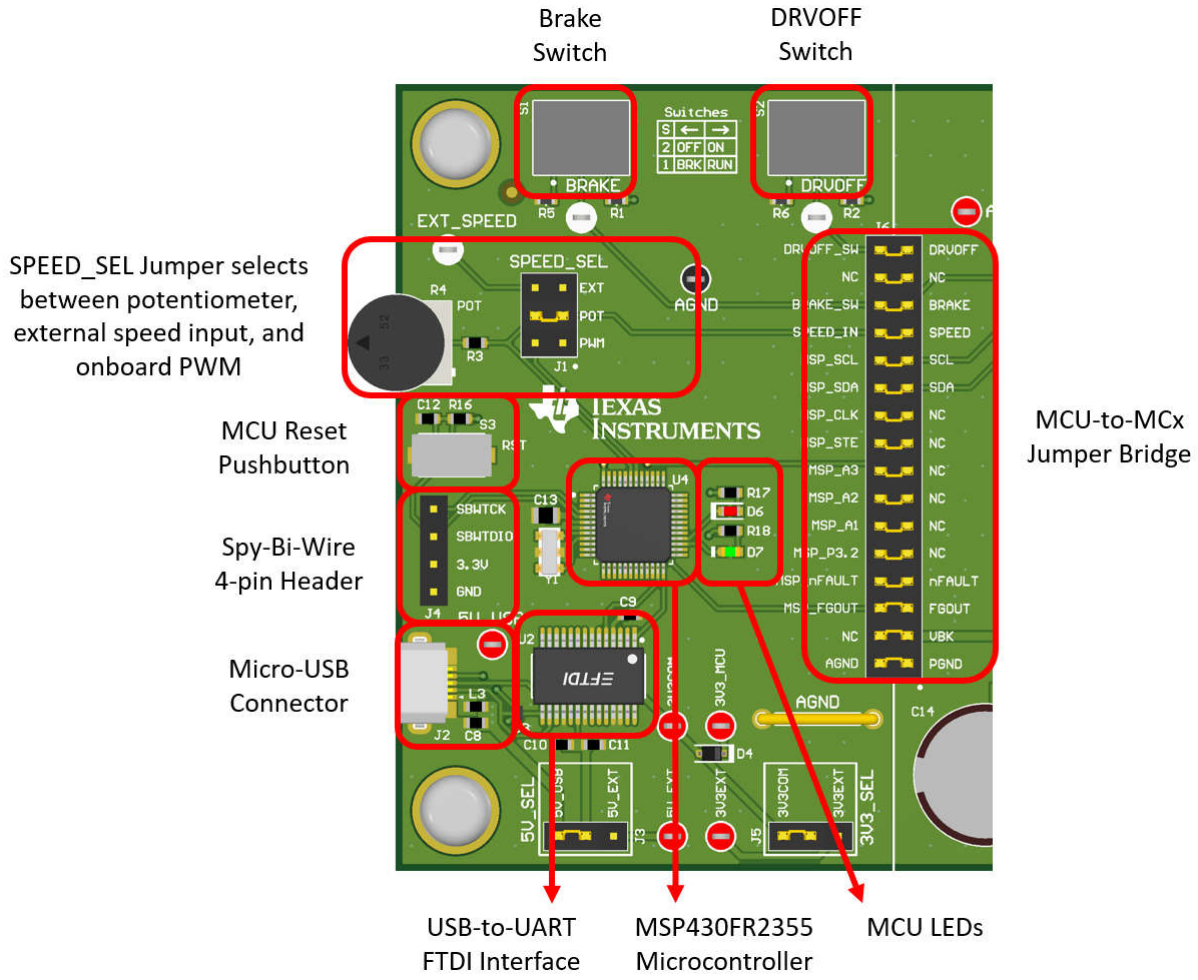


Figure 2-5. MSP430FR2355 MCU and User Interface on MCF8315PWPEVM

2.6 LED Lights

The MCF8315PWPEVM has 5 status LEDs that provide the status of power supplies and functionalities of the evaluation module. By default, the VM LED and Internal Buck regulator LED will light up when the board is powered and the D7 LED will light up when the firmware on the MSP430FR2355 microcontroller runs. Table 2-1 shows LED descriptions including those that are on during power up in bold and Figure 2-6 shows the locations of the LEDs.

Table 2-1. Description of MCF8315PWPEVM LEDs (default in bold after powerup)

Designator	Name	Color	Description
D1	**Buck Regulator**	**Green**	**Internal buck regulator is voltage output**
D2	nFAULT	Red	Lights up when fault condition has occurred on MCF8315
D3	**VM**	**Green**	**Motor power is supplied to the board**
D6	MSP_LED1	Red	Blinks when UART/I2C transactions occur
D7	**MSP_LED2**	**Green**	**MSP430FR2355 Power indicator**

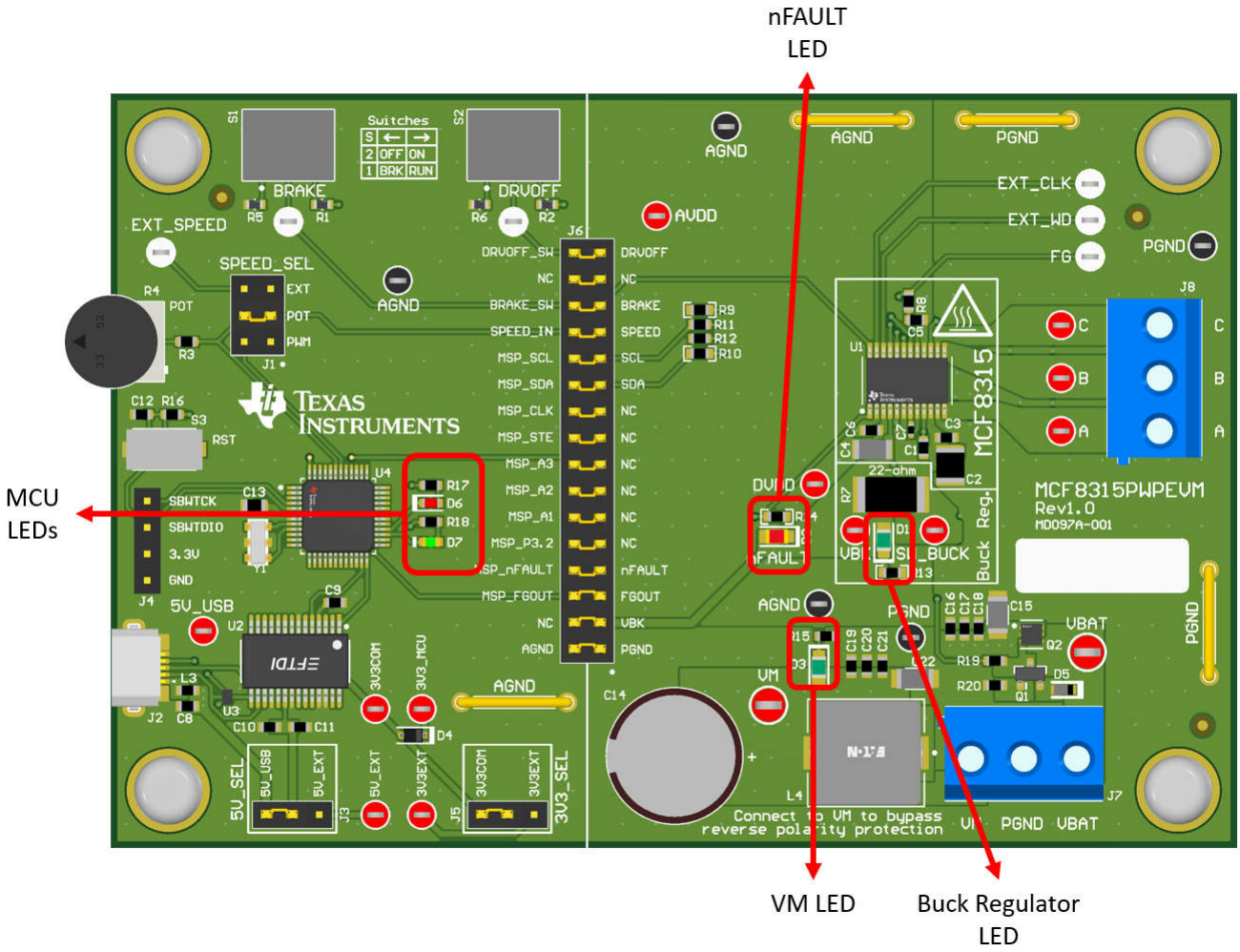


Figure 2-6. MCF8315PWPEVM LEDs

2.7 User-Configurable Settings

The MCF8315PWPEVM includes a variety of user-selectable jumpers, switches, and resistors on the entirety of the evaluation board to configure settings. Table 2-2 summarizes all of these configurable settings.

Table 2-2. Description of User-Selectable Settings on MCF8315PWPEVM (Default in Bold)

Designator	Jumper Setting Name	Description	Layer	Position	Function
L1/L2/R7	Buck Regulator mode	User populates L1, L2, or R7 to choose switching component for buck regulator	Top	L1 = 47uH Inductor	Inductor Mode
			Bottom	L2 = 22 µH	Inductor Mode
			Bottom	**R7 = 22 Ω**	**Resistor Mode**

Table 2-2. Description of User-Selectable Settings on MCF8315PWPEVM (Default in Bold) (continued)

Designator	Jumper Setting Name	Description	Layer	Position	Function
J5	3V3_SEL	Select 3.3 V for MCU power	Top	J5 = 3V3EXT	External
				J5 = 3V3COM	**From FTDI (30 mA)**
J3	5V_SEL	Select 5 V for FTDI power	Top	J3 = 5V_EXT	External
				J3 = 5V_USB	**From USB power (500 mA)**
J1	SPEED_SEL	Selects SPEED input source	Top	J1 = EXT	External EXT_SPEED test point
				J1 = POT	**From Potentiometer R4**
				J1 = PWM	On-board PWM from MSP430
J6	MSP to MCx Shunt jumper bridge	Connects signals from MCU and user switches to MCx8315 when jumpers are inserted	Top	**DRVOFF_SW**	**DRVOFF**
				NC	**NC**
				BRAKE_SW	**BRAKE**
				SPEED_IN	**SPEED**
				MSP_SCL	**SCL**
				MSP_SDA	**SDA**
				MSP_CLK	**NC**
				MSP_STE	**NC**
				MSP_A3	**NC**
				MSP_A2	**NC**
				MSP_A1	**NC**
				MSP_P3.2	**NC**
				MSP_nFAULT	**nFAULT**
				MSP_FG	**FGOUT**
				NC	**VBK**
				AGND	**AGND**
S1	BRAKE	Turns on all low-side MOSFETs	Top	Left	Brake enabled
				Right	**Brake disabled**
S2	DRVOFF	Disables gate drivers	Top	Left	MCF8315 FETs disabled
				Right	**MCF8315 FETs enabled**

3 Software

3.1 Motor Studio GUI Application

The Motor Studio GUI simplifies the tuning process of the MCF8315 by offering guided tuning instructions, a virtual oscilloscope for real-time variable monitoring, and more. The latest version of the Motor Studio GUI can be downloaded on ti.com.

3.1.1 Downloading and Running Motor Studio GUI

The Motor Studio GUI can be used to interface with and configure the MCF8315.

1. Connect the MCF8315PWPEVM as described in Section 2.2.
2. Download the latest version of the Motor Studio GUI.
3. Once the Motor Studio GUI is installed, run the Motor Studio GUI application.
4. Click the red *Setup Now* button under *Hardware Setup* on the bottom right side of the window.
5. After setting up the hardware settings of the MCF8315PWPEVM, click on the *Quick Spin* option to begin configuring the device.

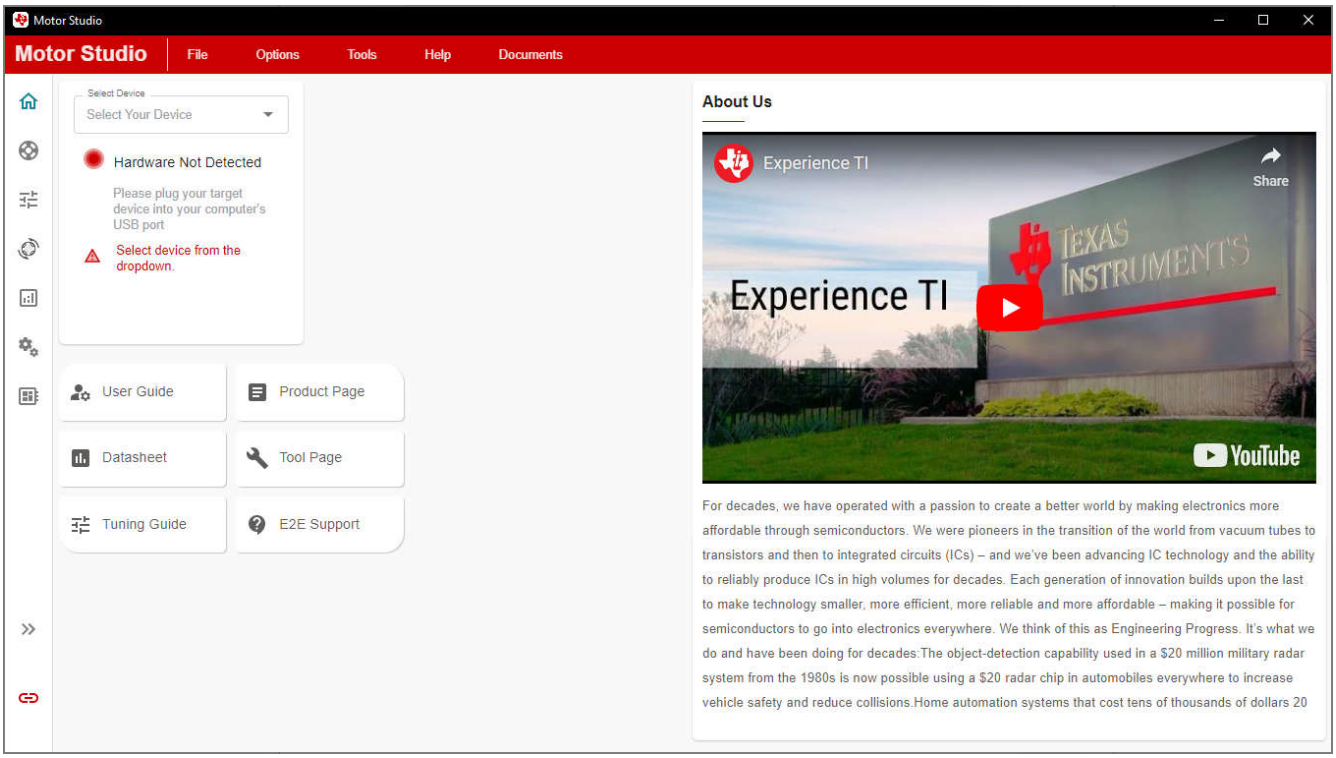


Figure 3-1. Motor Studio GUI Home Page

Once the GUI is loaded, follow the Quick Spin page of the GUI to spin up the motor.

3.2 MSP430FR2355 Interface Firmware

The MCF8315PWPEVM includes a USB-to-UART-to-I2C interface, using an MSP430FR2355 microcontroller, that serves as a communication bridge between a host PC and the MCF8315 device for configuring various device settings and reading fault diagnostic information.

By default, the onboard MSP430 microcontroller already contains the MSP430FR2355 Motor Studio firmware needed to communicate with the Motor Studio GUI. If there is a firmware update or the GUI does not connect to the EVM, then the user must flash the firmware code into the MSP430 by following the steps outlined in Section 3.2.2.

Flashing the firmware code onto the MSP430 requires an integrated development environment (IDE) and an eZ-FET Debug Probe. The following example uses the Code Composer Studio™(CCS) IDE and the MSP-EXP430FR2355 LaunchPad™ Development Kit to provide the eZ-FET Debug Probe.

3.2.1 Downloading Code Composer Studio and Importing MSP430FR2355 Interface Firmware Code

1. Download and extract the MSP430FR2355 Motor Studio firmware to a location on your computer.
2. Download the latest version of Code Composer Studio. This will set up a ti folder in the directory C:\ti.
   a. Accept all agreements, default install locations, and hit “Next” to proceed through menus.
   b. In the *Selected Components* window, make sure to check *MSP430 Low-Power MCUs* to install the required packages for the MSP430 Launchpad Evaluation Kits.
3. After installing, run CCS and select a folder or the default to use as the workspace to store any new projects. The location and naming convention can be changed based on the user's preference. Click the OK button to accept.
4. In CCS, click on the Project tab and select *Import CCS Projects*. Click on *Browse*.
5. Select the folder created in step 1 by extracting the Motor Studio firmware.
6. Import the project “MCx8315EVM_MSP430FR2355_Firmware” into your workspace as shown in Figure 3-2.

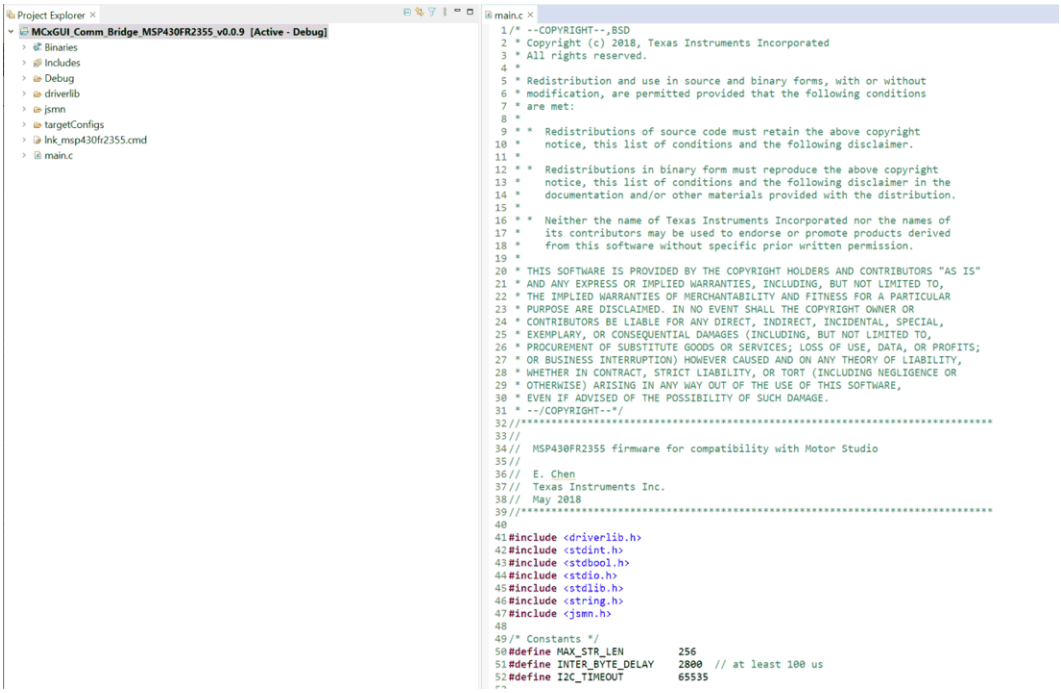


Figure 3-2. MSP430FR2355 Interface Firmware Code in Code Composer Studio

3.2.2 Using the eZ-FET to Program the MSP430FR2355

The MSP430FR2355 on the MCF8315EVM comes pre-programmed with the firmware necessary for communicating with the Motor Studio GUI and the MCF8315. To reprogram or flash custom code on the MSP430FR2355, you will need an external MSP430 LaunchPad™that includes the eZ-FET Debug Probe. In this example, we use the MSP-EXP430FR2355 LaunchPad Development Kit to provide the debug probe.

The eZ-FET Debug Probe on the MSP430FR2355 LaunchPad uses a SPI-by-Wire JTAG interface to program the MSP430FR2355 MCU on the MCF8315PWPEVM. Consult the MSP430 LaunchPad Development Kits for MSP430 LaunchPads that include an onboard eZ-FET Debug Probe.

1. Remove the GND, 3V3, SBWTDIO, and SBWTCK jumpers from the MSP430 LaunchPad.
2. Connect the top pins on the eZ-FET side of the LaunchPad of the GND, 3V3, SBWTCK, and SBWTDIO signals to their respective pins on J4 of the MCF8315PWPEVM as shown in Table 3-1 and Figure 3-3.
3. Connect a micro-USB cable to the MSP430 LaunchPad and the PC.
4. Click on the Build Project icon or CTRL+B to ensure the project builds successfully. Accept any updates if needed from the Console.
5. Click on Debug Project to set up a debug session and press the Play button to run the code.
6. Stop the debug session, close Code Composer Studio, disconnect the SPI-by-Wire jumpers and unplug the micro-USB cable from the MSP430 LaunchPad.

Table 3-1. SPY-BI-Wire Connections Needed to Program MSP430FR2355

MSP430 LaunchPad™ (eZ-FET Debug Probe Side) (J101)	MCF8315PWPEVM 4-pin SPI-by-Wire Header (J4)
GND	GND
3V3	3.3V
SBWTDIO	SBWTDIO
SBWTCK	SBWTCK

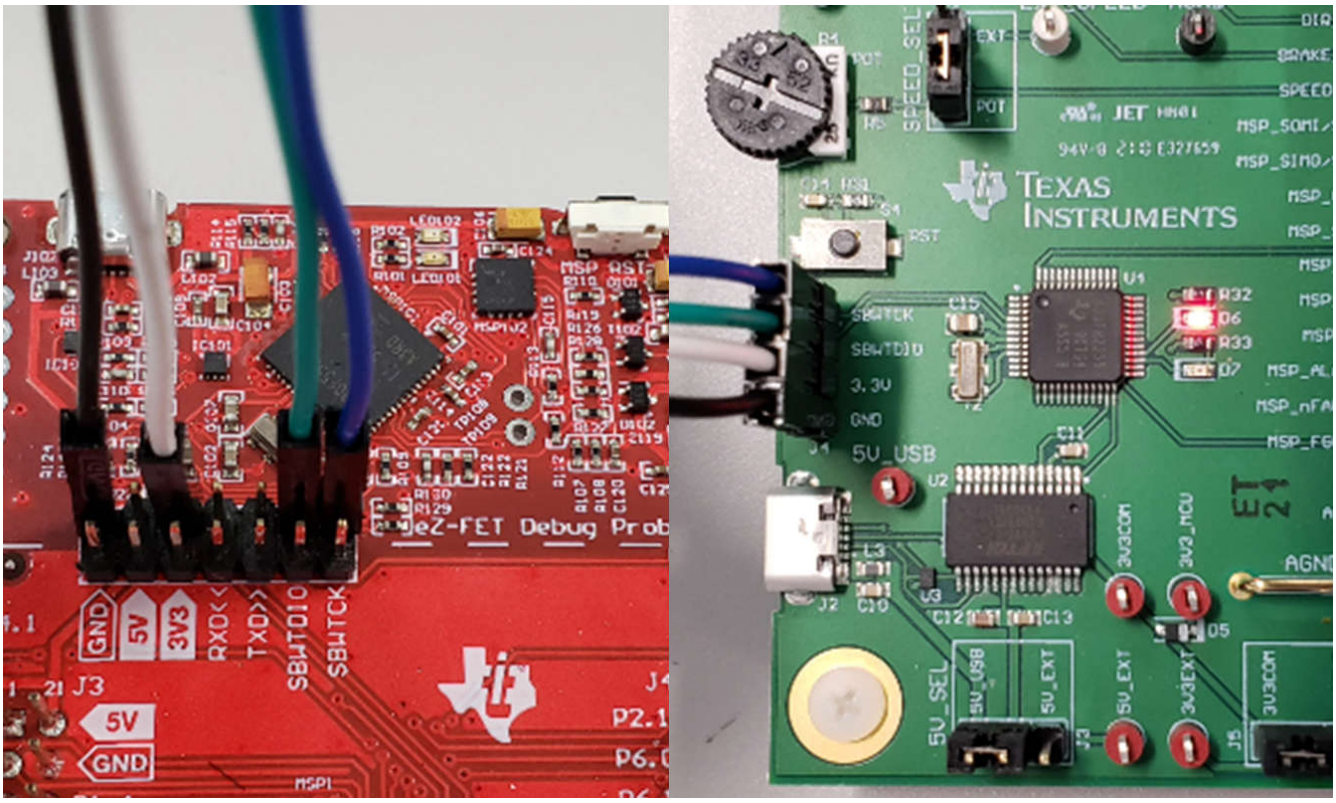


Figure 3-3. MSP430 LaunchPad™ eZ-FET Probe Connected to MCF8315PWPEVM

4 Hardware Design Files

4.1 Schematics

4.1.1 Main Supply and Pi Filter

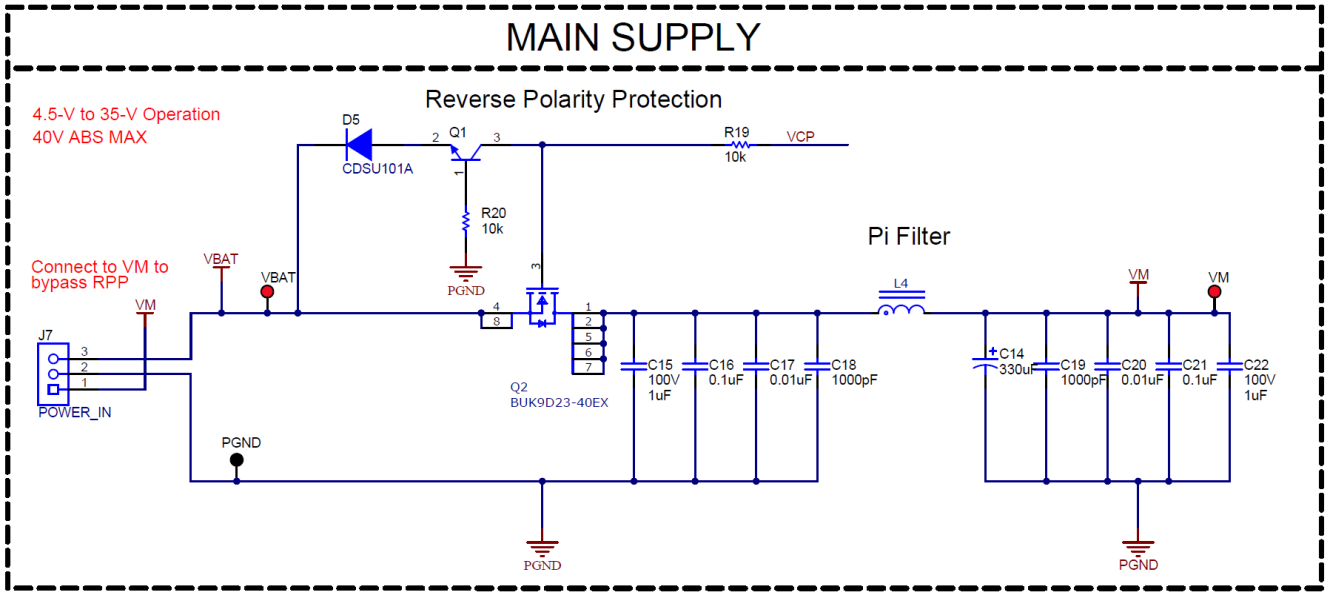


Figure 4-1. Main Supply and Pi Filter Schematic

4.1.2 Connectors and Interface

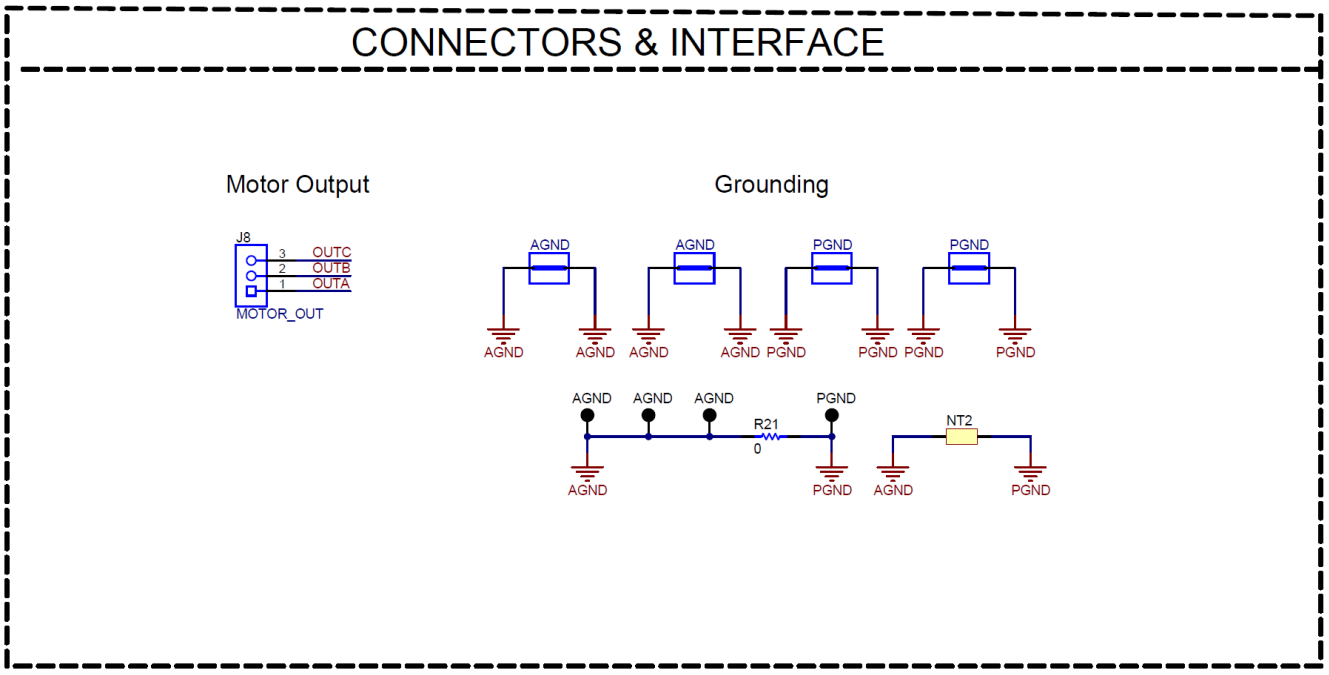


Figure 4-2. Connectors and Interface Schematic

4.1.3 USB to UART

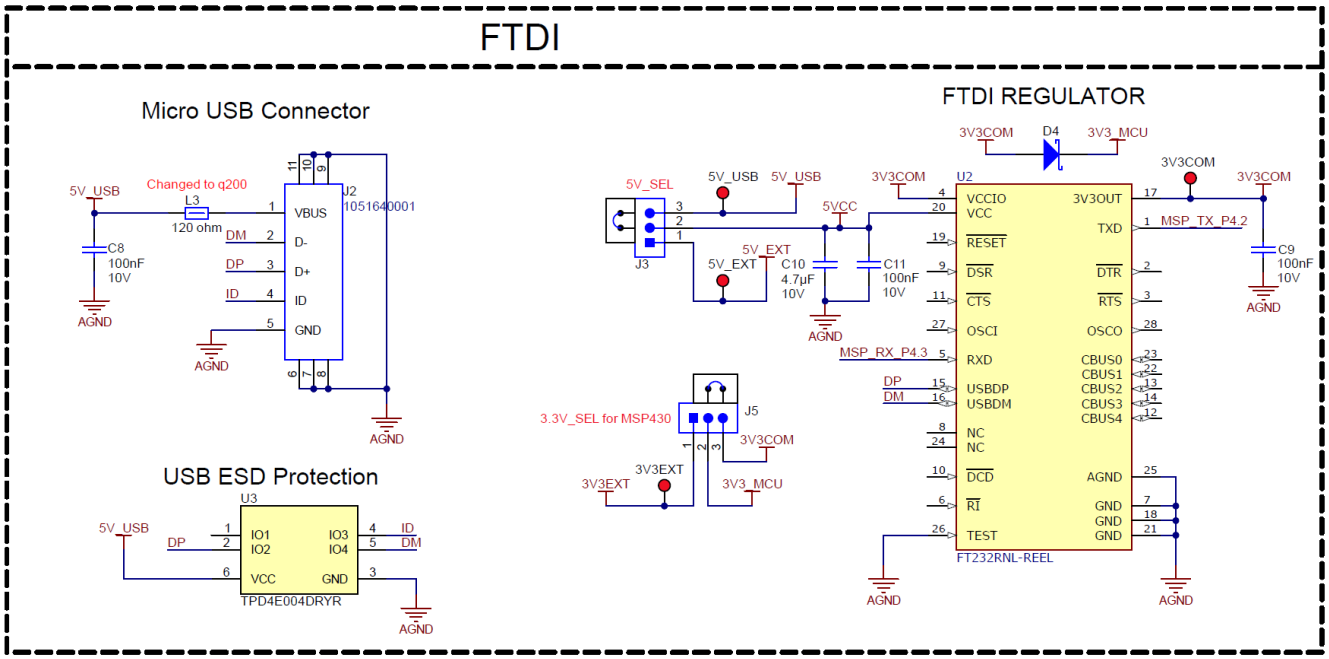


Figure 4-3. USB to UART Schematic

4.1.4 MCU Programming and Debug

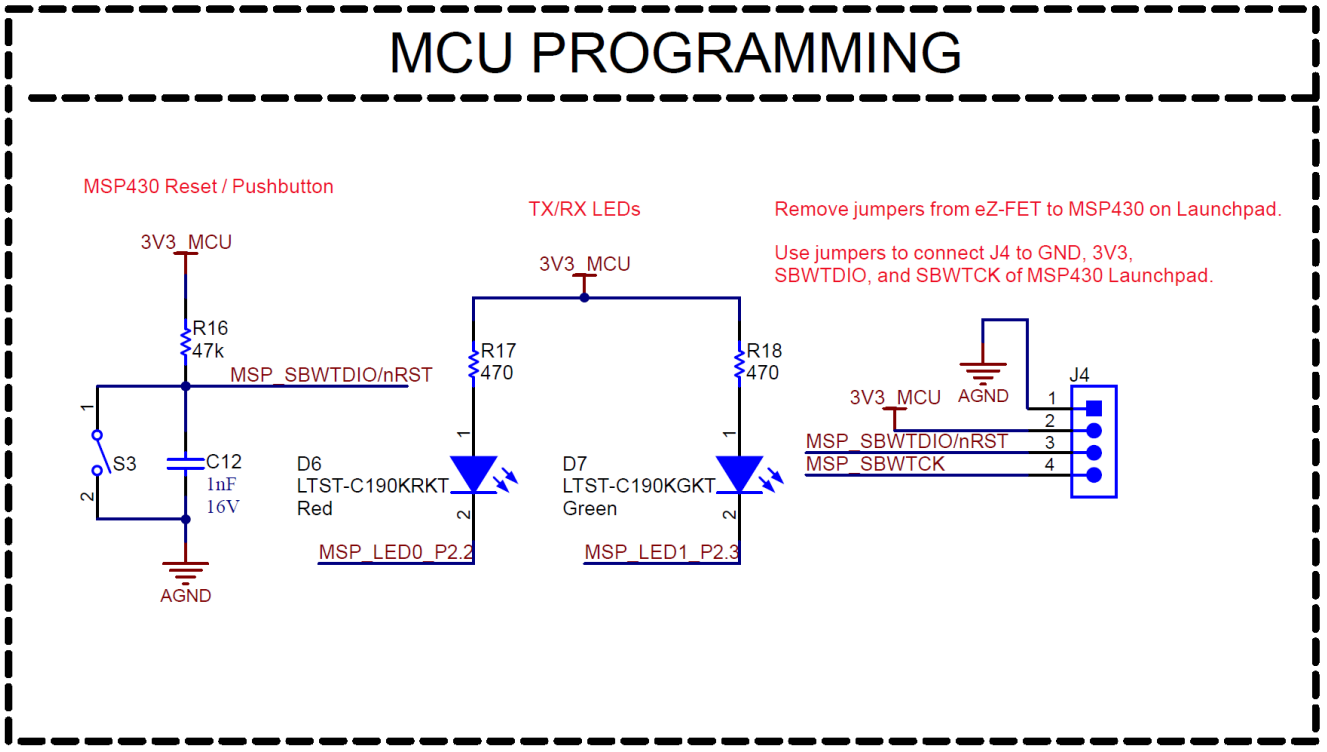


Figure 4-4. MCU Programming and Debug Schematic

4.1.5 MSP430FR2355 MCU

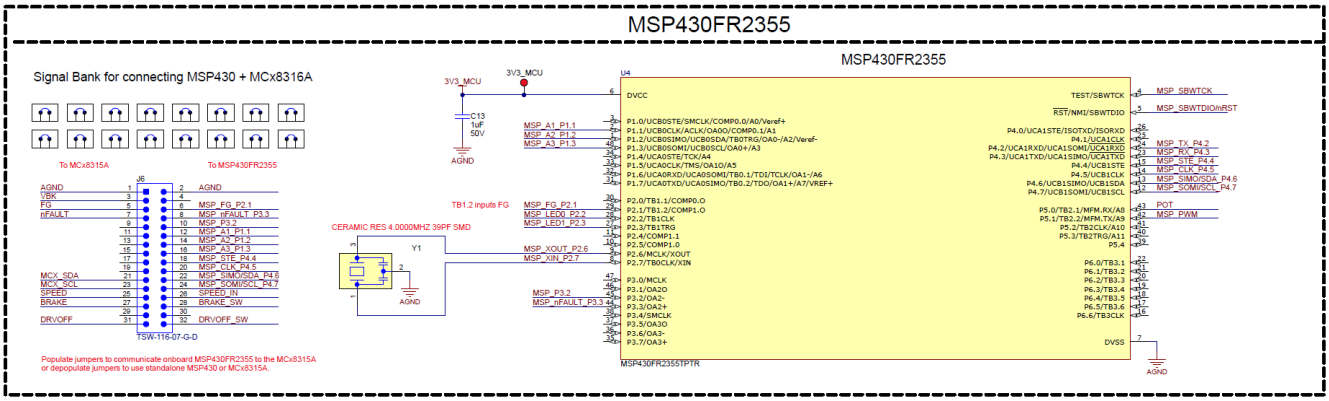


Figure 4-5. MSP430FR2355 MCU Schematic

4.1.6 MCF8315 3-Phase Sensorless FOC Integrated Driver

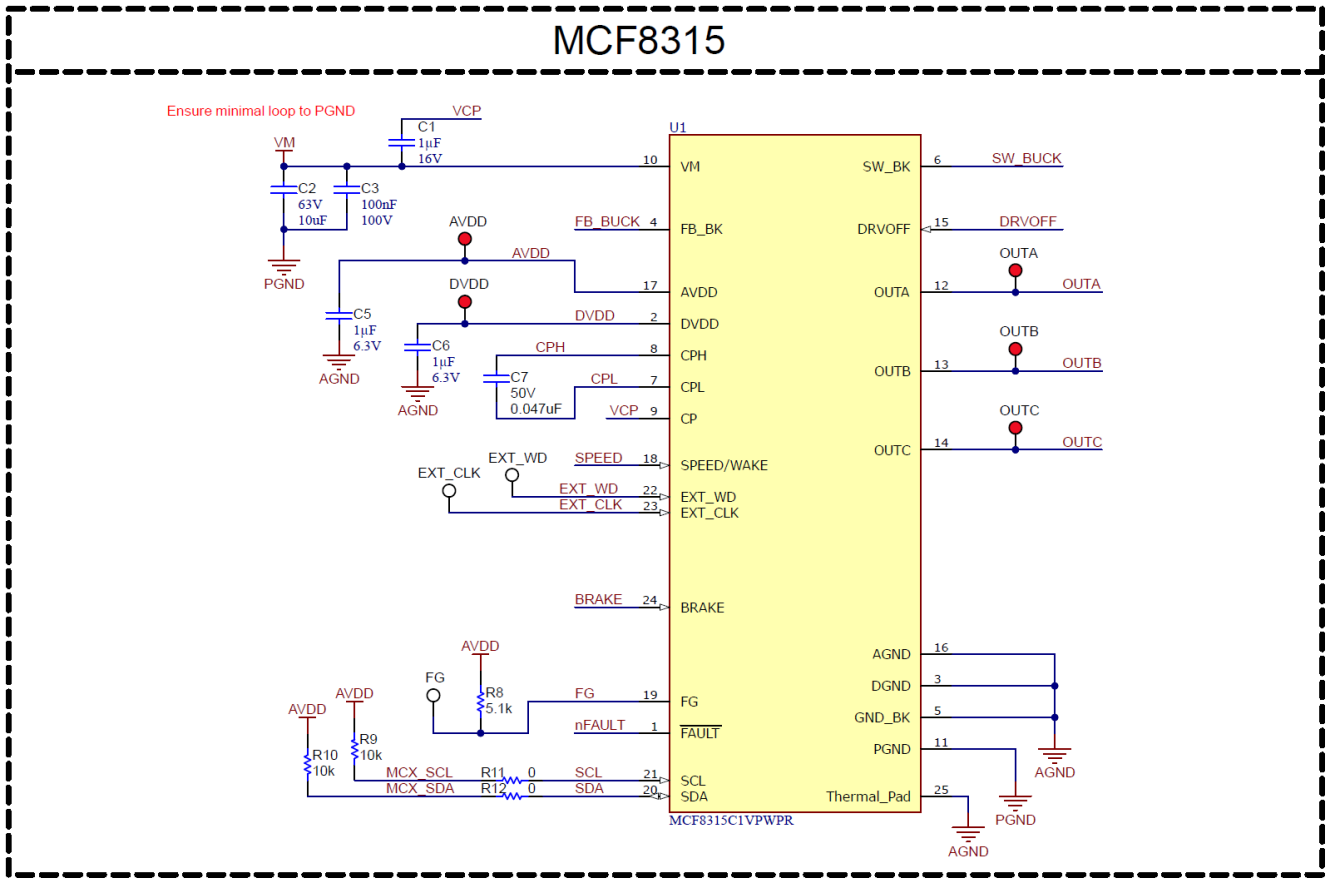


Figure 4-6. MCF8315 3-Phase Sensorless FOC Integrated Driver Schematic

4.1.7 Buck Regulator

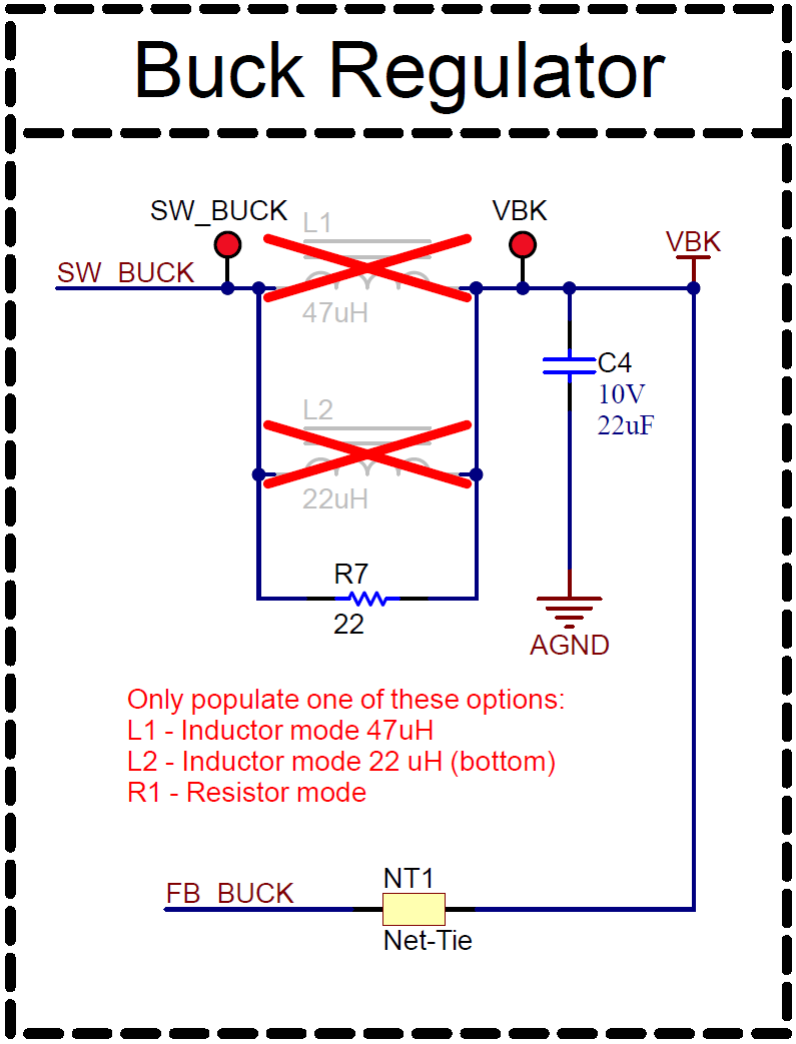


Figure 4-7. Buck Regulator Schematic

4.1.8 Status LEDs

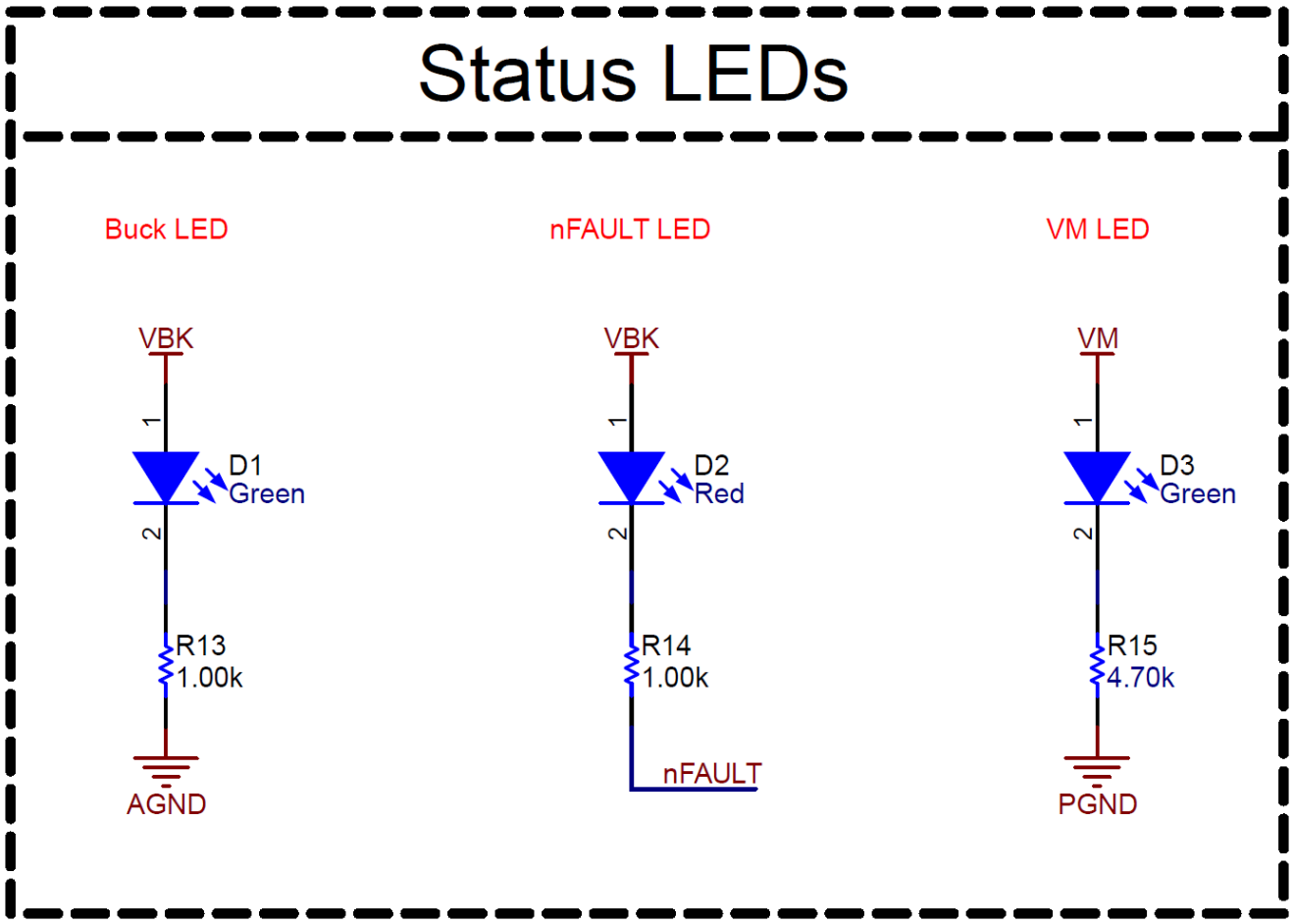


Figure 4-8. Status LEDs Schematic

4.1.9 Switches and Speed Input

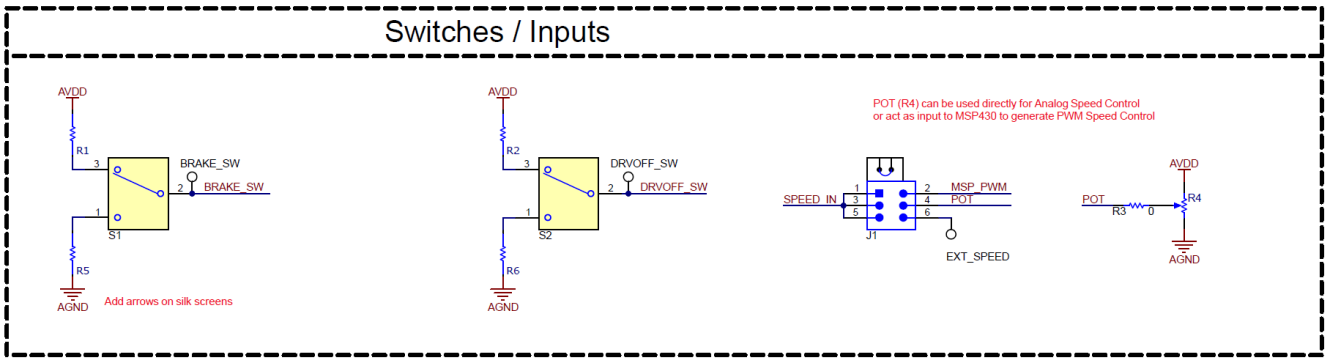


Figure 4-9. Switches and Speed Input

4.2 PCB Layouts

Figure 4-10. EVM Board Dimensions

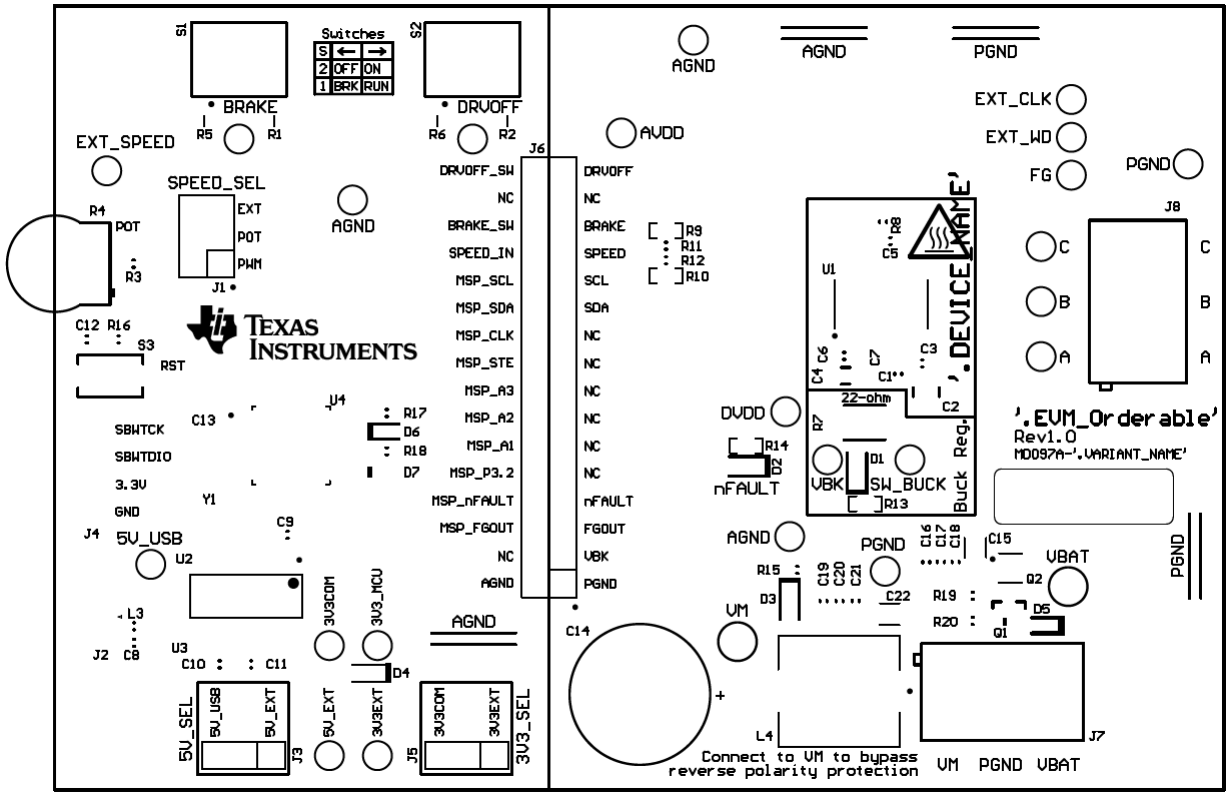


Figure 4-11. EVM Top Overlay

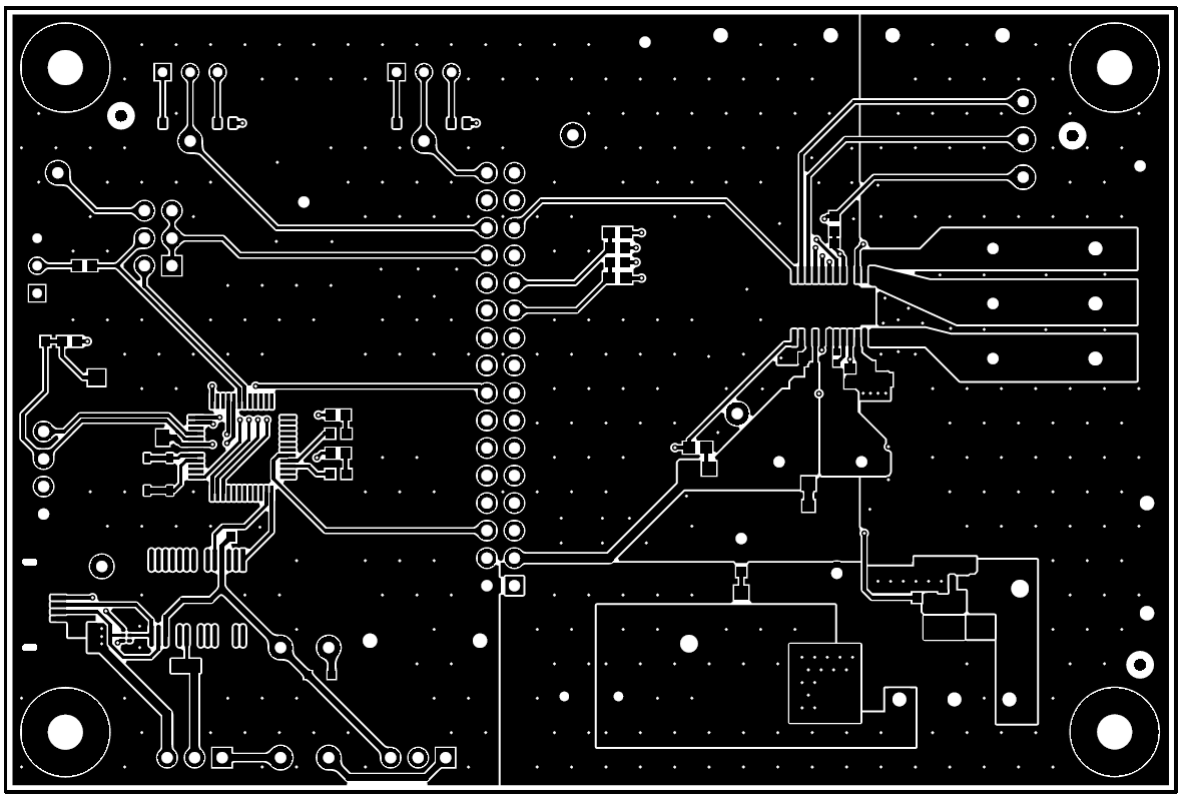


Figure 4-12. EVM Top Layer

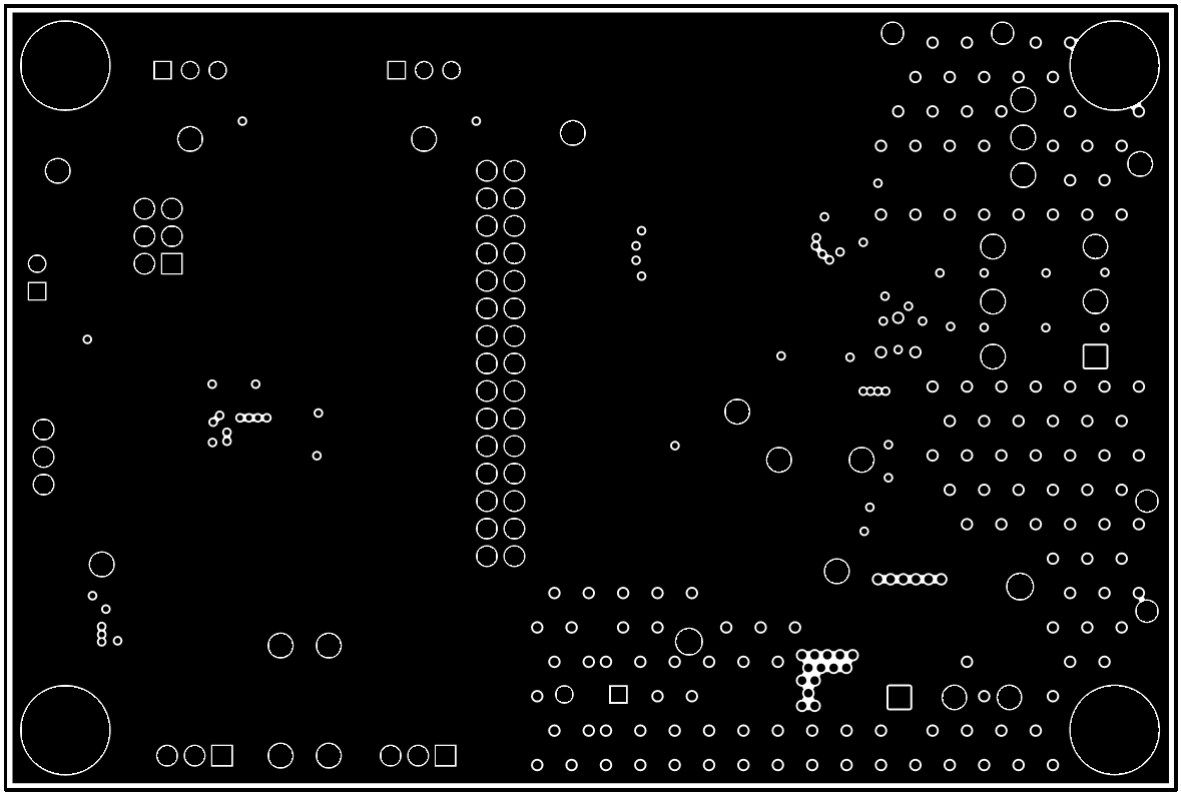


Figure 4-13. EVM Signal Layer 1

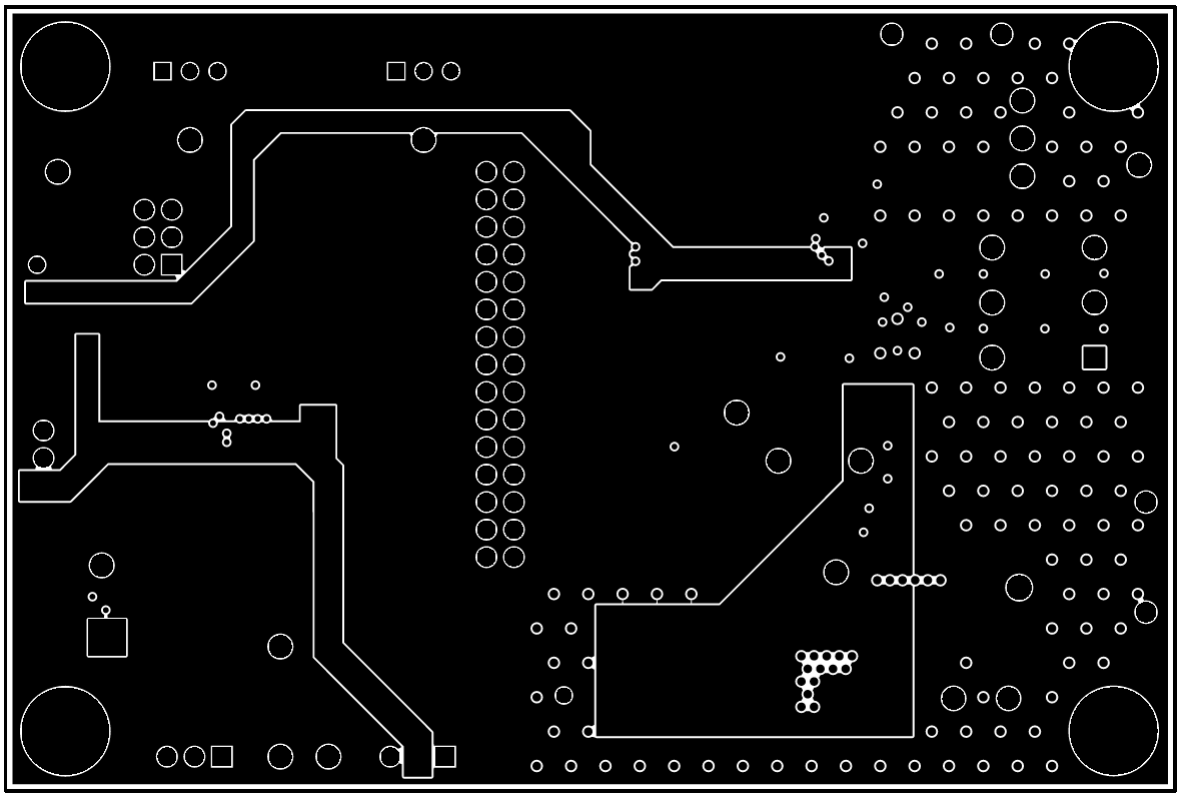


Figure 4-14. EVM Signal Layer 2

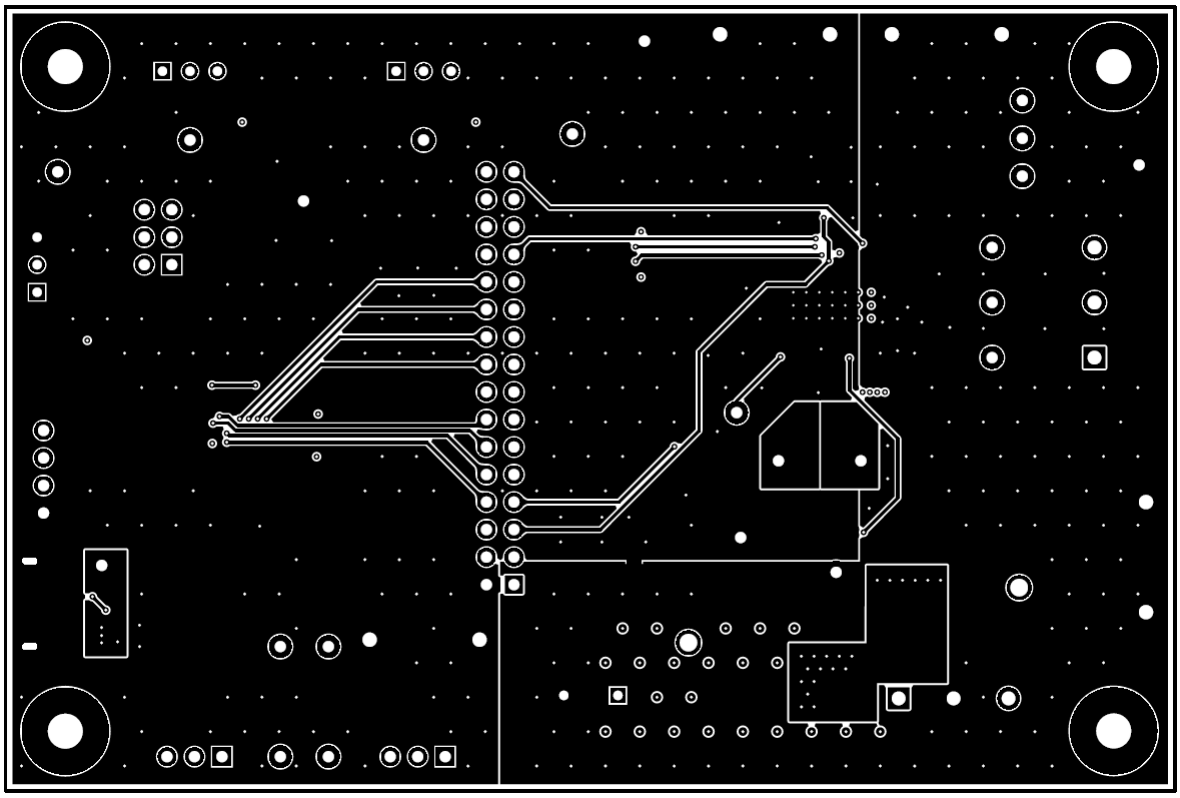


Figure 4-15. EVM Bottom Layer

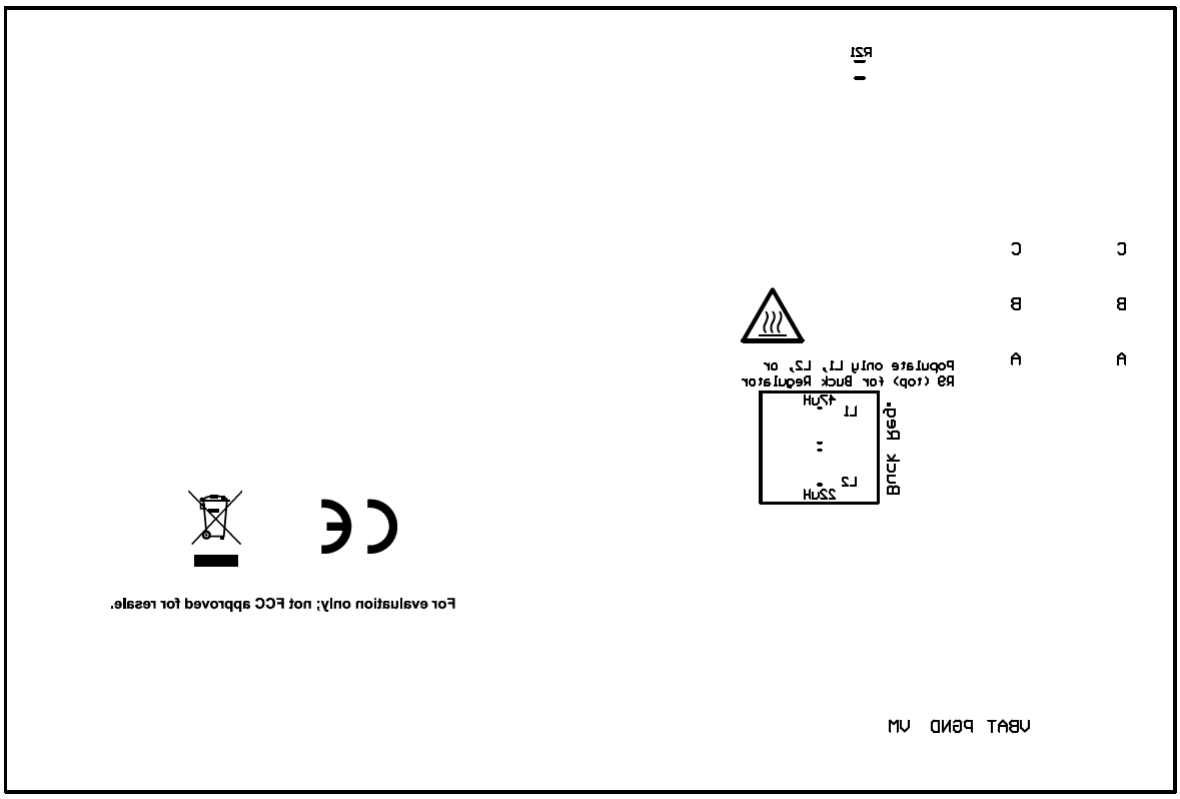


Figure 4-16. EVM Bottom Overlay

4.3 Bill of Materials (BOM)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer
!PCB1	1		Printed Circuit Board		MD097A	Any
C1	1	1uF	CAP, CERM, 1 µF, 16 V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	EMK107B7105KAHT	Taiyo Yuden
C2	1	10uF	CAP, CERM, 10 uF, 63 V, +/- 10%, X7R, 1210	1210	GRM32ER71J106KA12L	MuRata
C3	1	0.1uF	CAP, CERM, 0.1 uF, 100 V, +/- 10%, X7R, 0603	0603	GRM188R72A104KA35D	MuRata
C4	1	22uF	CAP, CERM, 22 uF, 10 V, +/- 10%, X7R, 1206	1206	GRM31CR71A226KE15L	MuRata
C5, C6	2	1uF	CAP, CERM, 1 µF, 6.3 V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	C0603C105K9RACAUTO	Kemet
C7	1	0.047uF	CAP, CERM, 0.047 uF, 50 V, +/- 10%, X7R, 0402	0402	C1005X7R1H473K050BB	TDK
C8, C9, C11	3	0.1uF	CAP, CERM, 0.1 uF, 10 V, +/- 10%, X7R, 0603	0603	0603ZC104KAT2A	AVX
C10	1	4.7uF	CAP, CERM, 4.7 uF, 10 V, +/- 20%, X7R, 0603	0603	GRM188Z71A475ME15D	MuRata
C12	1	1000pF	CAP, CERM, 1000 pF, 16 V, +/- 10%, X7R, 0603	0603	8.85012E+11	Wurth Elektronik
C13	1	1uF	CAP, CERM, 1 uF, 50 V, +/- 10%, X7R, 0805	0805	8.85012E+11	Wurth Elektronik
C14	1	330uF	CAP, AL, 330 uF, 63 V, +/- 20%, AEC-Q200 Grade 2, TH	D12.5xL20mm	ELXZ630ELL331MK20S	Chemi-Con
C15, C22	2	1uF	CAP, CERM, 1 uF, 100 V, +/- 10%, X7R, 1206	1206	CL31B105KCHNNNE	Samsung
C16, C21	2	0.1uF	CAP, CERM, 0.1 uF, 100 V, +/- 10%, X7S, AEC-Q200 Grade 1, 0603	0603	CGA3E3X7S2A104K080AB	TDK

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer
C17, C20	2	0.01uF	CAP, CERM, 0.01 uF, 100 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	CGA3E2X7R2A103K080AA	TDK
C18, C19	2	1000pF	CAP, CERM, 1000 pF, 100 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	CGA3E2X7R2A102K080AA	TDK
D1, D3	2	Green	LED, Green, SMD	LED_0805	LTST-C170KGKT	Lite-On
D2	1	Red	LED, Red, SMD	Red 0805 LED	LTST-C170KRKT	Lite-On
D4	1	40V	Diode, Schottky, 40 V, 0.75 A, AEC-Q101, SOD-323	SOD-323	BAT165E6327HTSA1	Infineon Technologies
D5	1	90V	Diode, Switching, 90 V, 0.1 A, SOD-523F	SOD-523F	CDSU101A	Comchip Technology
D6	1	Red	LED, Red, SMD	Red LED, 1.6x0.8x0.8mm	LTST-C190KRKT	Lite-On
D7	1	Green	LED, Green, SMD	1.6x0.8x0.8mm	LTST-C190KGKT	Lite-On
FID1, FID2, FID3	3		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
H1, H2, H3, H4	4		Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	Screw	NY PMS 440 0025 PH	B&F Fastener Supply
H5, H6, H7, H8	4		Standoff, Hex, 0.5"L #4-40 Nylon	Standoff	1902C	Keystone
J1	1		Header, 100mil, 3x2, Gold, TH	3x2 Header	TSW-103-07-G-D	Samtec
J2	1		Receptacle, USB 2.0, Micro B, 5 Position, R/A, SMT	Receptacle, USB 2.0, Micro B, 5 Pos, 0.65mm Pitch, R/A, SMT	1051640001	Molex
J3, J5	2		Header, 100mil, 3x1, Gold, TH	PBC03SAAN	PBC03SAAN	Sullins Connector Solutions
J4	1		Header, 100mil, 4x1, Gold, TH	4x1 Header	TSW-104-07-G-S	Samtec
J6	1		Header, 100mil, 16x2, Gold, TH	16x2 Header	TSW-116-07-G-D	Samtec
J7, J8	2		Terminal Block, 5.08 mm, 3x1, Brass, TH	3x1 5.08 mm Terminal Block	ED120/3DS	On-Shore Technology

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer
L3	1		Inductor, Ferrite Bead, Ferrite, 3 A, 120 ohm, AEC-Q200 Grade 1, SMD	0603	BLM18SG121TZ1D	MuRata
L4	1	1uH	1 µH Shielded - Inductor 19 A 3.1mOhm Max Nonstandard	SMD2	HCM1A1104V2-1R0-R	Eaton
LBL1	1			PCB Label 0.650 x 0.200 inch	THT-14-423-10	Brady
Q1	1	80 V	Transistor, NPN, 80 V, 1.5 A, AEC-Q101, SOT-23	SOT-23	FMMT620TA	Diodes Inc.
Q2	1		N-Channel 40V 8A (Ta) 15W (Tc) Surface Mount DFN2020MD-6	SOT1220	BUK9D23-40EX	Nexperia
R1, R2, R5, R6	4	10k	Res Thin Film 0603 10K Ohm 0.1% 1/10W ±10ppm/°C Molded SMD SMD Punched Carrier T/R	0603	ERA-3ARB103V	Panasonic
R3, R11, R12	3	0	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	ERJ-3GEY0R00V	Panasonic
R4	1	25 kohm	Trimmer Potentiometer, 25kohm, 0.5W, TH	9.53x8.89mm	3352T-1-253LF	Bourns
R7	1	22	RES, 22, 5%, 1.5 W, AEC-Q200 Grade 0, 2512	2512	CRCW251222R0JNEGHP	Vishay-Dale
R8	1	5.1k	RES, 5.1 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06035K10JNEA	Vishay-Dale
R9, R10, R19, R20	4	10k	RES, 10 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310K0JNEA	Vishay-Dale
R13, R14	2	1.00k	RES, 1.00 k, 1%, 0.1 W, 0603	0603	RC0603FR-071KL	Yageo
R15	1	4.70k	RES, 4.70 k, 0.1%, 0.1 W, 0603	0603	RT0603BRD074K7L	Yageo America
R16	1	47k	RES, 47 k, 5%, 0.1 W, 0603	0603	RC0603JR-0747KL	Yageo
R17, R18	2	470	RES, 470, 5%, 0.1 W, 0603	0603	RC0603JR-07470RL	Yageo

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer
R21	1	0	RES, 0, 5%, 0.25 W, AEC-Q200 Grade 0, 1206	1206	RCA12060000ZSEA	Vishay-Dale
S1, S2	2		SWITCH TOGGLE SPDT 0.4VA 28V	6.8x23.1x8.8mm	B12AP	NKK Switches
S3	1		Switch, Tactile, SPST, 12 V, SMD	SMD, 6x3.9mm	4.34121E+11	Wurth Elektronik
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5, SH-J6, SH-J7, SH-J8, SH-J9, SH-J10, SH-J11, SH-J12, SH-J13, SH-J14, SH-J15, SH-J16, SH-J17, SH-J18, SH-J19	19	1x2	Shunt, 100mil, Gold plated, Black	Shunt	SNT-100-BK-G	Samtec
TP1, TP2, TP3, TP11, TP12, TP13	6		Test Point, Miniature, White, TH	White Miniature Testpoint	5002	Keystone Electronics
TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP14, TP15, TP16, TP17, TP18	12		Test Point, Miniature, Red, TH	Red Miniature Testpoint	5000	Keystone Electronics
TP19, TP20	2		Test Point, Compact, Red, TH	Red Compact Testpoint	5005	Keystone Electronics
TP21, TP26, TP27, TP28, TP29	5		Test Point, Miniature, Black, TH	Black Miniature Testpoint	5001	Keystone Electronics
TP22, TP23, TP24, TP25	4		1mm Uninsulated Shorting Plug, 10.16mm spacing, TH	Shorting Plug, 10.16mm spacing, TH	D3082-05	Harwin
U1	1		Sensorless Field Oriented Control (FOC) Integrated FET BLDC Driver, HTSSOP24	HTSSOP24	MCF8315C1VPWPR	Texas Instruments
U2	1		UART Interface IC USB Full Speed to Serial UART IC, Includes Oscillator and EEPROM, SSOP-28	SSOP28	FT232RNL-REEL	FTDI

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer
U3	1		4-Channel ESD Protection Array for High-Speed Data Interfaces, DRY0006A (USON-6)	DRY0006A	TPD4E004DRYR	Texas Instruments
U4	1		CPU16 MSP430™ FRAM Microcontroller IC 16-Bit 24MHz 32KB (32K x 8) FRAM 48-LQFP (7x7)	LQFP48	MSP430FR2355TPTR	Texas Instruments
Y1	1		Resonator, 4 MHz, 39 pF, AEC-Q200 Grade 1, SMD	4.5x1.2x2 mm	CSTCR4M00G55B-R0	MuRata
L1	0	47uH	Inductor, Shielded, Powdered Iron, 47 uH, 0.39 A, 2.3 ohm, AEC-Q200 Grade 1, SMD	SMD, 2-Leads, Body 3x3mm	78438335470	Wurth Elektronik
L2	0	22uH	Inductor, Shielded, Powdered Iron, 22 uH, 0.6 A, 1.04 ohm, AEC-Q200 Grade 1, SMD	SMD, 2-Leads, Body 3x3mm	78438335220	Wurth Elektronik

5 Additional Information

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