EVM User's Guide: MCT8314ZEVM

MCT8314Z Evaluation Module

Description

The MCT8314ZEVM allows users to evaluate the performance of the MCT8314Z motor driver. The EVM includes an onboard FTDI chip to convert USB communication from the micro-USB connector into UART. An onboard MSP430FR2355 MCU translates the UART communication and onboard potentiometers into control signals and a variable duty cycle for the PWM input of the MCT8314Z. The MCU can also provide SPI communication for the SPI variant of the MCT8314Z device. There are many user-selectable jumpers, resistors, connectors, and test points to assist with evaluating the many features of the MCT8314Z device and the configurable device-specific settings.

Get Started

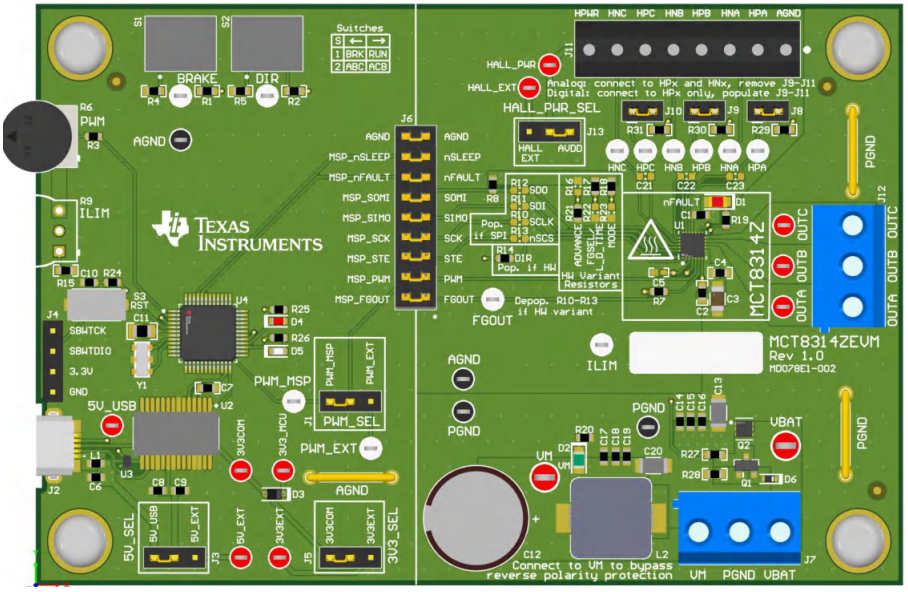
1. Order the MCT8314ZEVM on ti.com.
2. Visit dev.ti.com/gallery to download the GUI software or access the web hosted GUI software.
3. Download the latest firmware for the MCT8314ZEVM on ti.com.

Features

- GUI software with full configuration & control capability.
- MCU-to-MCx shunt jumper header with removable shunts to disconnect main signals going to the motor driver IC from the MCU. The shunts can be removed if the user desires to control the MCT8314Z IC with an external MCU or to use the EVM MCU to control an external MCT8314Z IC.

Applications

- Vacuum robots
- Motorized blinds
- IP cameras



MCT8314ZEVM Printed Circuit Board (PCB - Top View)

1 Evaluation Module Overview

1.1 Introduction

This document is provided with the MCT8314Z evaluation module (EVM) as a supplement to the MCT8314Z data sheet. This user's guide details the hardware setup instructions, GUI installation, and usage instructions.

CAUTION

Hot surface temperature

The EVM can have high surface temperatures marked by the FIRE triangular symbol on the EVM. Avoid touching the marked hot surface are when driving high currents to prevent potential burn damage.

Note

The MCT8314ZEVM comes automatically populated with and configured for the MCT8314ZH. For compatibility with the MCT8314ZS see Section 2.7.2.

1.2 Kit Contents

Table 1-1 lists the contents of the EVM kit. Contact the Texas Instruments Product Information Center nearest to you if any components are missing. TI highly recommends that users check the TI website at https://www.ti.com to verify that the latest version of the related software is being used.

Table 1-1. Kit Contents

Item	Quantity
MCT8314ZEVM	1
USB A Male-to-USB B micro male cable	1

1.3 Specification

The MCT8314ZEVM is rated for operation of 40 V absolute maximum and up to 1.5 A peak. To prevent damage to the MCT8314Z IC and EVM, confirm that the voltage and current specifications are not exceeded.

1.4 Device Information

The MCT8314Z is a 4.5 V to 35 V, 1.5 A peak three-phase gate driver IC with sensored trapezoidal control for motor drive applications. The MCT8314Z provides three integrated half-bridges and a sensored trapezoidal control in a fixed-function state machine capable of directly driving a 3-phase brushless-DC motor without a microcontroller.

The MCT8314Z integrates a current sensing feature eliminating the need for external sense resistors, an LDO for powering external circuits, three analog hall comparators, and many protection features.

Table 1-2. MCT8314Z Variants

Device Name	Variant
MCT8314ZH	Hardware
MCT8314ZS	SPI

2 Hardware

2.1 Quick Start Guide

The MCT8314ZEVM requires a power supply source, which has a recommended operating range from 4.5 V to 35 V. To setup and power the EVM, follow the sequence below:

1. Connect motor phases to A, B, and C on connector J12.
2. Connect Hall sensors to J11 and select Hall power supply to come from AVDD or an external Hall supply using J13.
   a. If using digital Hall inputs, then populate J8–J10 with shunt jumpers to enable pullups. Connect the single-ended inputs to only the HPx pins on connector J11. This is the default configuration of the MCT8314ZEVM.
   b. If using analog Hall inputs, then remove J8-J10 and connect differential Hall inputs to HPx and HNx on connector J11.
3. Populate the R15 Resistor to set the desired setting for the CBC Current limit as described in User Selectable Settings.
4. If using the MCT8314ZH, then make sure resistors are populated in HW variant resistors for desired device settings as described in Section 2.7.1.
5. Do not turn on the power supply yet. Connect the motor supply to VBAT or VM and PGND on connector J7.
   a. To enable the reverse polarity protection and Pi filter, connect to VBAT. Note, that when connecting to VBAT, VM is VM – 0.7 V less due to a diode drop in the reverse-polarity protection circuit.
   b. To disable the reverse-polarity protection and the Pi filter, connect to VM.
6. Select J3 to 5V_USB and J5 to 3V3COM to power MSP430 from USB power supply.
7. Connect the micro-USB cable into the computer.
8. Turn the R6 potentiometer fully clockwise to set the motor to zero speed upon power up.
9. Flip the switch S1 to the right to configure BRAKE = RUN and switch S2 to the left to configure DIR = ABC.
10. Turn on the motor power supply.
11. Use the R6 potentiometer to control the speed of the motor, the R9 potentiometer to control the cycle-by-cycle current limit, and the switches to disable the motor driver, change the motor's direction, or brake the motor. Optionally, use the MCF8314Z GUI, refer to Section 3.1, to monitor the real-time speed of the motor, put the MCT8314Z into a low-power sleep mode, and read status of the EVMs LEDs.

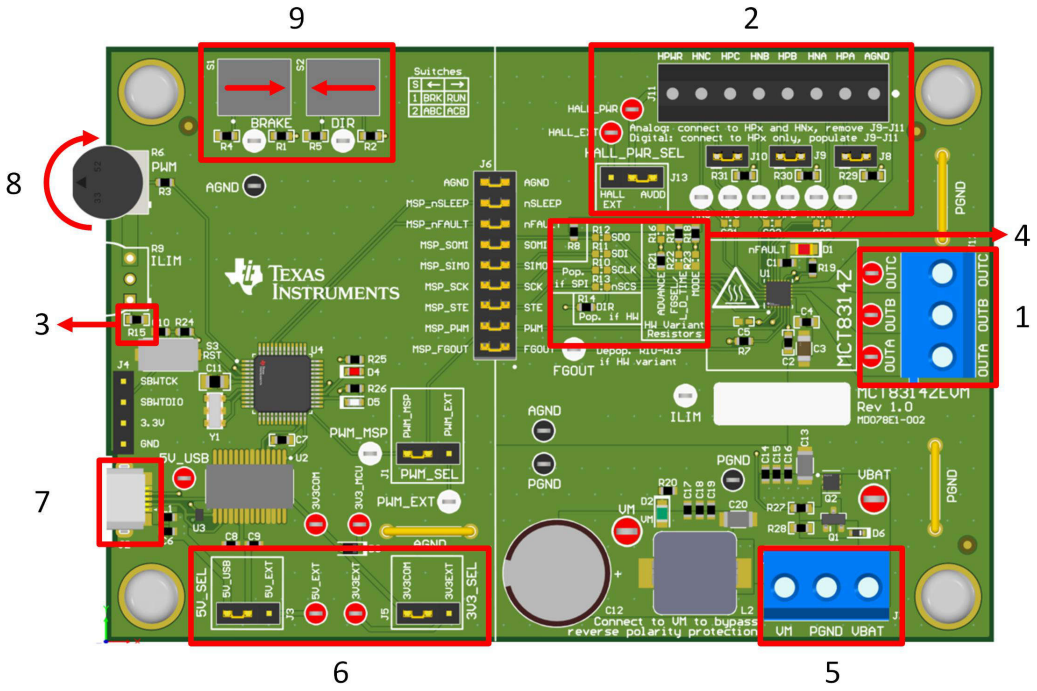


Figure 2-1. Reference for Quick Start Guide

2.2 Hardware Setup

The hardware required to run a motor is the MCT8314ZEVM, a micro-USB cable, and a power supply with a DC output from 4.5 V to 35 V. Follow these steps to start up the MCT8314ZEVM:

1. Connect the DC power supply to header J7. Connect to VBAT and PGND to apply 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. If using the MCT8314ZH, populate the desired resistor settings in the “HW Variant Resistors” silk screen box, see Table 2-3. If using the MCT8314ZS populate the resistors R10-R13 in the "Pop. if SPI" silk screen box.
3. Apply user-configurable jumper settings. See the Section 2.7 section for more information.
4. Flash the program into the MCU as described in Section 3.1. Launch the GUI in GUI Composer and disconnect the 4-pin JTAG connections.
5. Connect a micro-USB cable to the MCT8314ZEVM and computer.
6. Turn on the power supply and power up the PCB.

If using the MCT8314ZEVM with an external microcontroller, 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

Figure 2-2 shows the major blocks of the MCT8314ZEVM. The MCT8314ZEVM is designed for an input supply from 4.5 V to 35 V and offers reverse-polarity protection and a Pi filter. The MCT8314ZEVM can support all variants of the MCT8314Z device with locations for Hardware resistors and SPI resistors. Through the use of configurable shunts the MCT8314ZEVM can support many types of Hall sensor configurations. For interfacing with the MCT8314Z GUI the MCT8314ZEVM has a FTDI chip to support USB-to-UART and a MSP430.

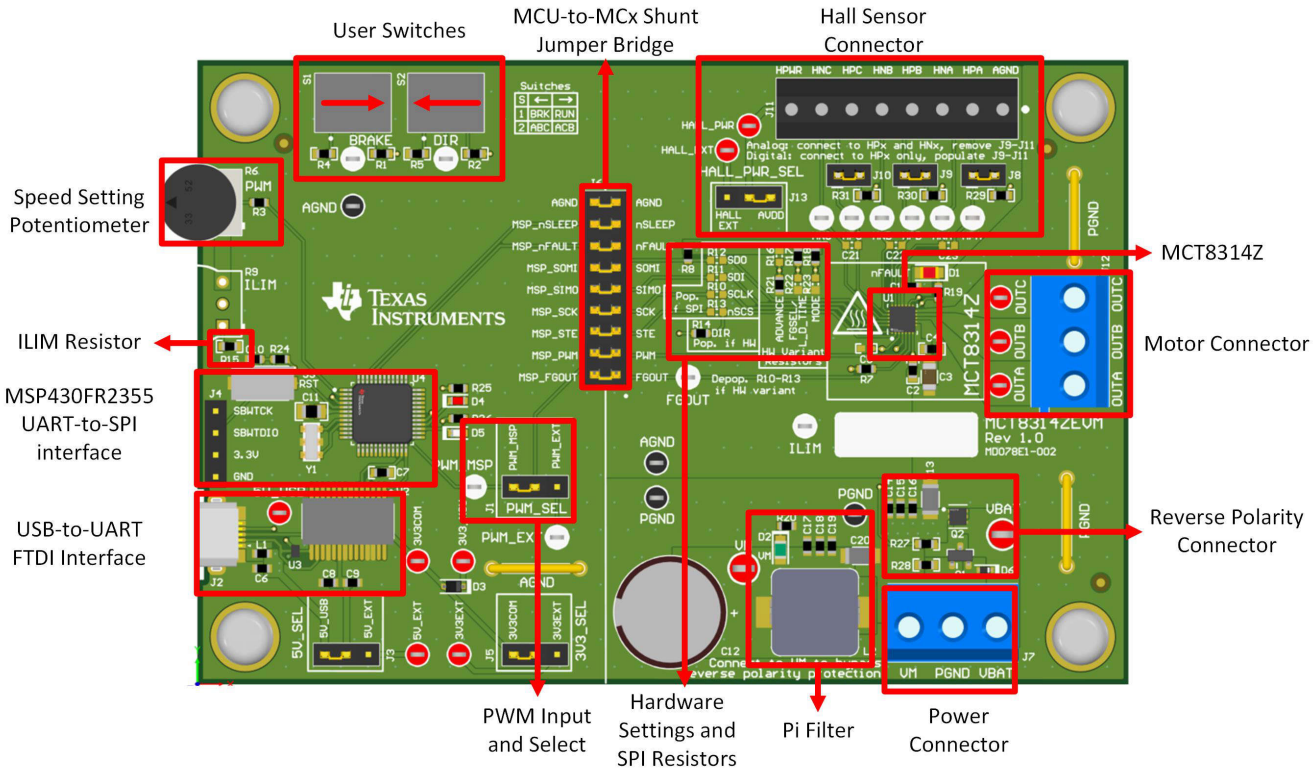


Figure 2-2. MCT8314ZEVM Major Hardware Blocks

2.4 Connection Details

Figure 2-3 shows the connections made to the MCT8315ZEVM to spin a 3-phase sensored brushless-DC motor.

A 4.5-V to 35-V power supply or battery is connected to 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, resulting in a 0.7-V diode voltage supply drop to VM. To bypass the reverse-polarity protection and Pi filter, connect the power supply directly 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 J12 on the MCT8314ZEVM.

Use connector J11 on the MCT8314ZEVM to connect single-ended digital or analog differential Hall inputs. Use HPWR for Hall power and AGND for Hall ground. If connecting analog inputs from a Hall element, connect to the HPx and HNx pins for each respective phase and remove jumpers J8-10. Otherwise, if using single-ended input from a Hall sensor, connect to only the HPx pins for each phase and populate jumpers J8-J10.

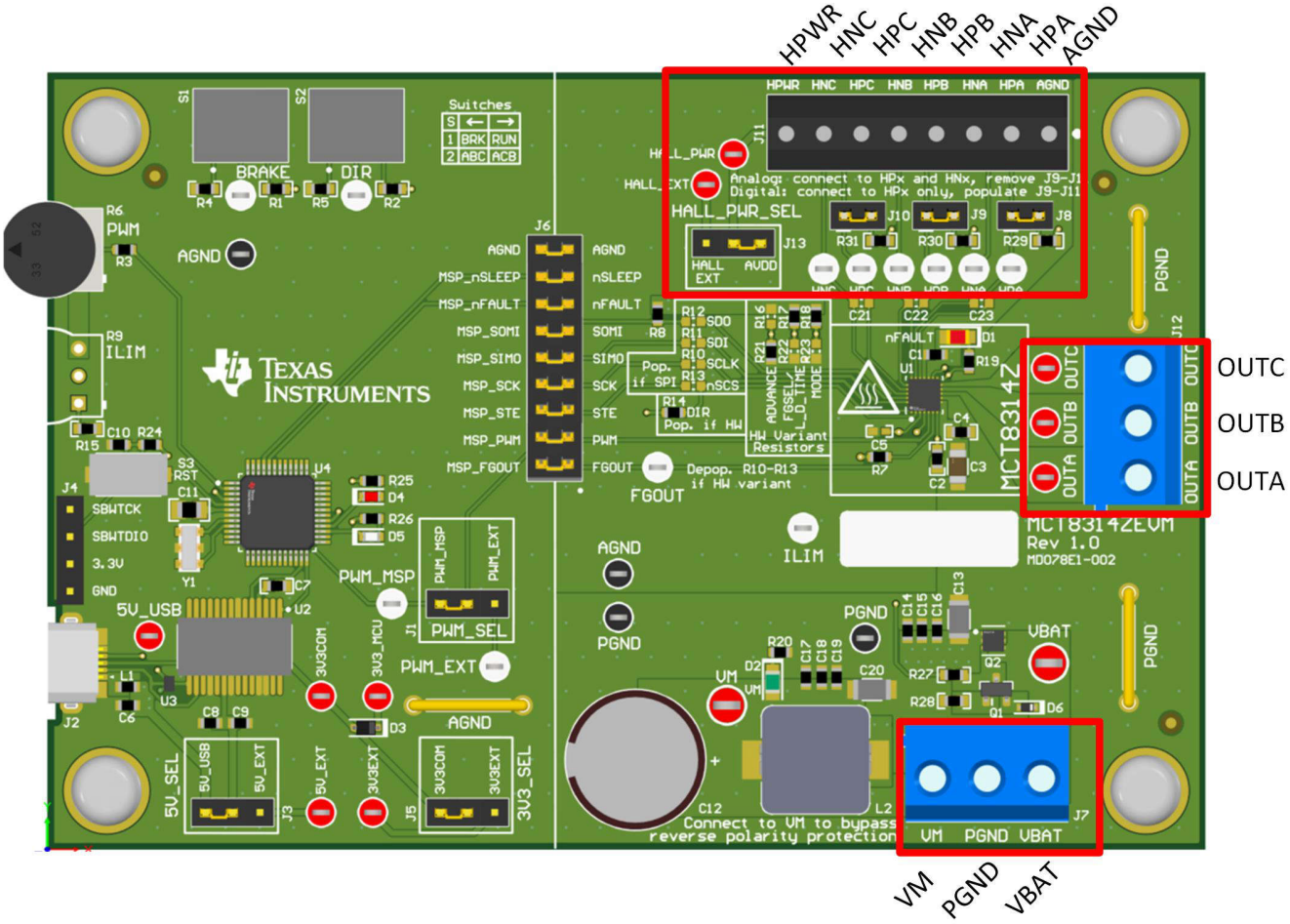


Figure 2-3. Connections from Motor to MCT8314ZEVM

Figure 2-4 shows where the micro-USB cable is plugged into the MCT8314ZEVM to provide communication between evaluation module and GUI. The USB data and 5-V power from the USB is converted, by the FTDI chip, into UART data and 3.3-V power, which is used to power the MSP430FR2355 microcontroller. The 5 V from the USB power is limited to 500 mA and the 3.3 V from the FTDI chip is limited to 30 mA. If the user wishes to supply more current to these rails, then the user can use the 5V_SEL jumper J3 and 3V3_SEL jumper J5 to connect external power rails.

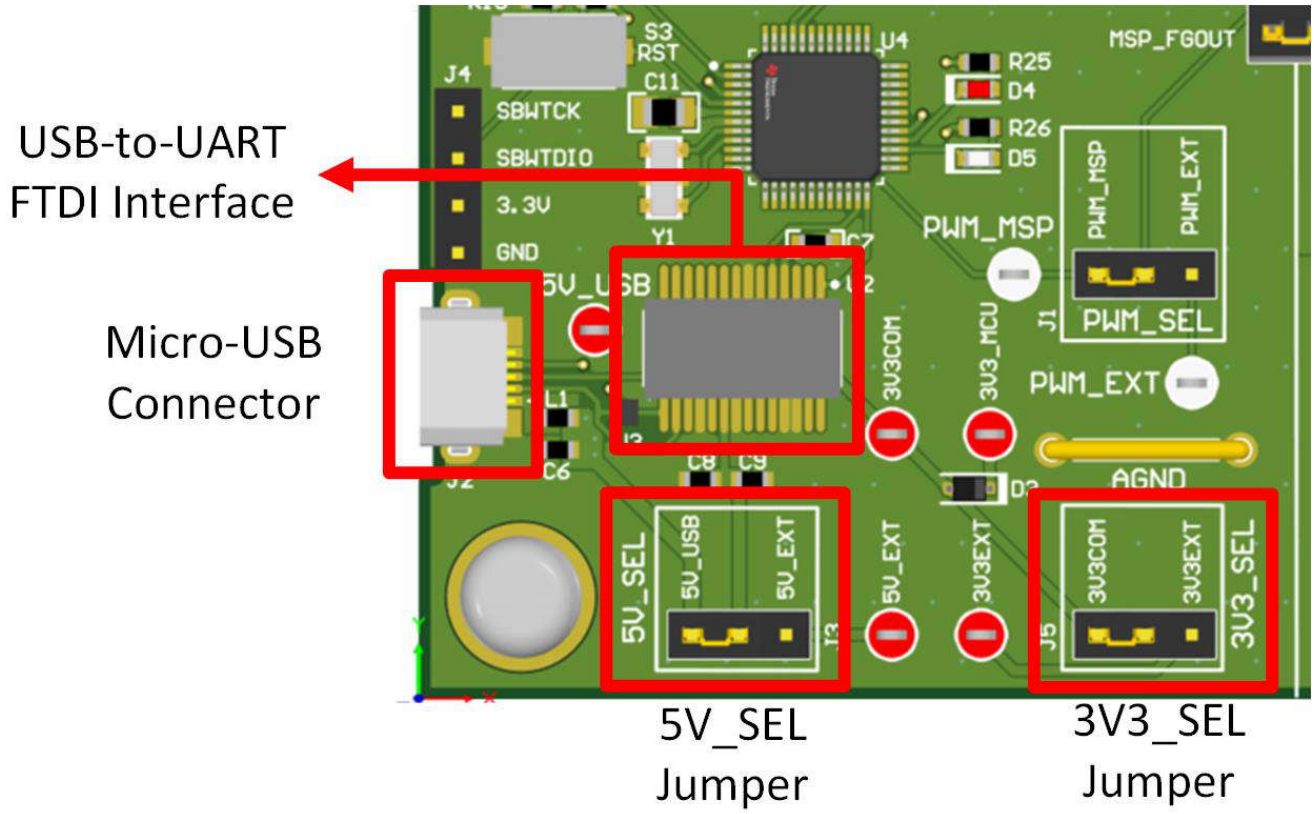


Figure 2-4. Micro-USB Connector and UART for MCT8314ZEVM

2.5 MSP430FR2355 Microcontroller

The MCT8314ZEVM includes a MSP430FR2355 low-power MCU, shown in Figure 2-5, to provide the pulse-width modulation (PWM) signal required to commutate the motor. The MCU outputs a 20-kHz PWM signal (PWM_MSP), and the duty cycle (ranging from 0–100%) is controlled by the potentiometer R6. The motor speed increases the more the potentiometer is turned counterclockwise, and decreases when turned clockwise. To select whether the PWM signal from the MSP or an external PWM is sourced to the MCT8314Z, use the PWM_SEL jumper J1.

To program the MSP430FR2355, an external MSP430 FET programmer must be connected to the Spy-Bi-Wire (SBW) interface connector J4. Many MSP430 LaunchPads™ provide an onboard eZ-FET Debug Probe that can be jumper-wired to the MCT8314ZEVM to flash the firmware into the MSP430FR2355 microcontroller.

The user can use the Reset (RST) button at any time to restart the MCU program. Two active-low LEDs, D4 and D5, can be used for debug purposes as well.

The 18-pin shunt jumper bridge J6 ties all signals between the microcontroller and the MCT8314Z device. These jumpers can be inserted or removed as needed to isolate the microcontroller from the gate driver. This allows for microcontroller signal debugging or using the MCT8314ZEVM as a standalone gate driver with an external microcontroller.

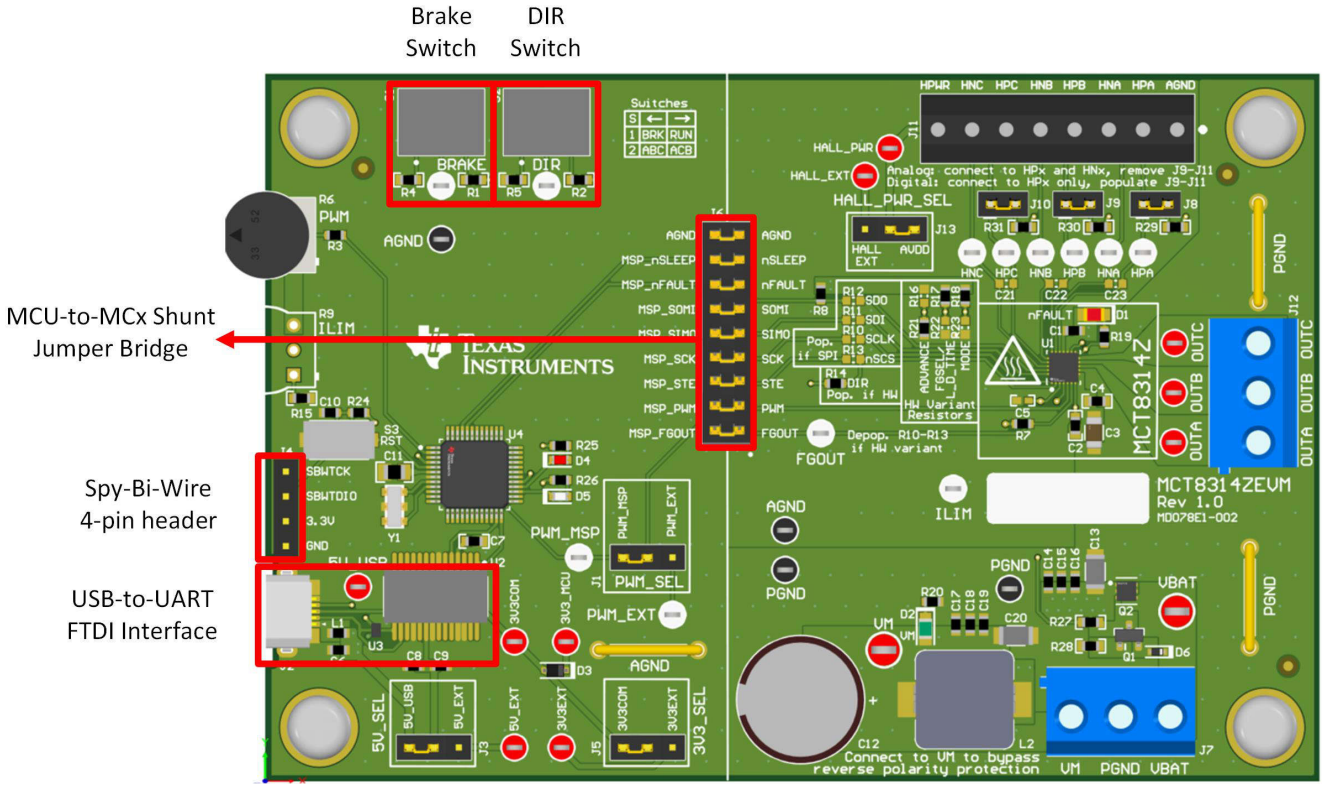


Figure 2-5. MSP430FR2355 MCU on MCT8314ZEVM

2.6 LED Lights

The MCT8314ZEVM has 4 status LEDs that provide the status of power supplies and functions of the evaluation module. By default, the VM LED lights up when the board is powered and the firmware has been flashed onto the microcontroller. 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 MCT8314ZEVM LEDs (Default in Bold After Power Up)

Designator	Name	Color	Description
D1	nFAULT	Red	Lights up when fault condition has occurred on MCT8314Z.
D2	**VM**	**Green**	**Motor power is supplied to the board.**
D4	**MSP_LED0**	**Red**	**Used for UART or debugging.**
D5	MSP_LED1	Green	Used for UART or debugging.

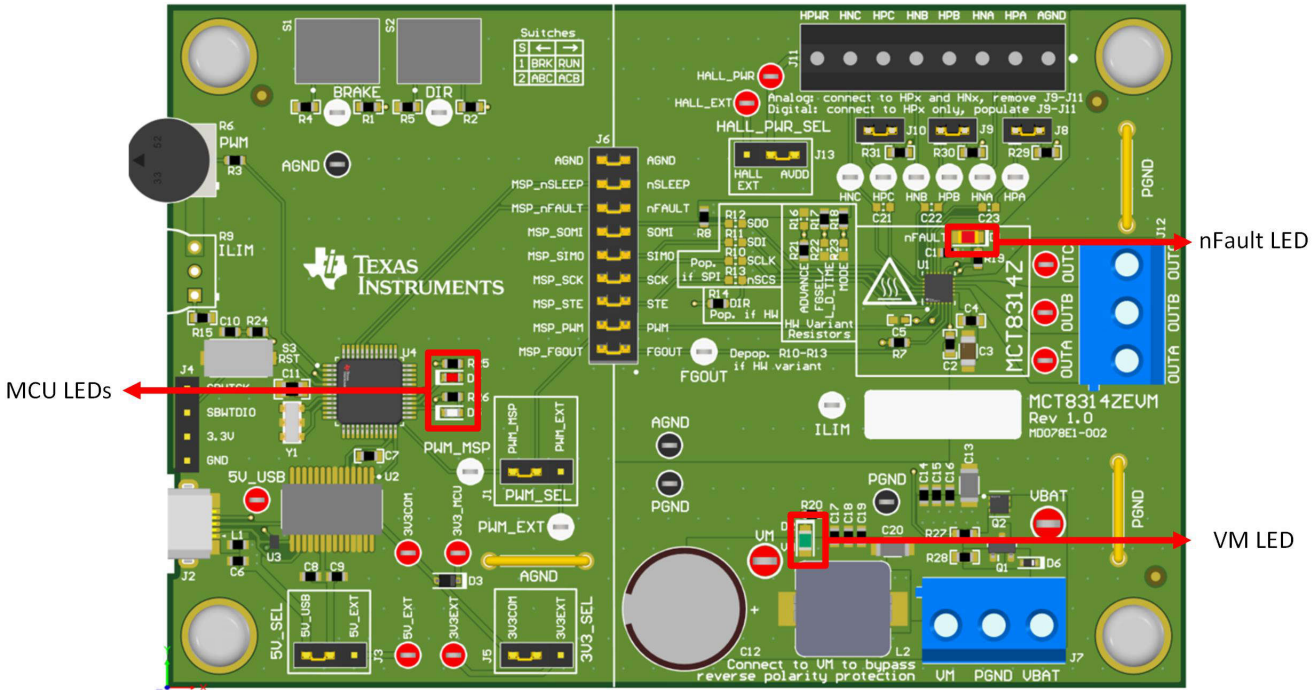


Figure 2-6. MCT8314ZEVM LEDs

2.7 User-Configurable Settings

The MCT8314ZEVM 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 MCT8314ZEVM (Default in Bold)

Designator	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	PWM_SEL	Selects PWM source	Top	J1 = PWM_EXT	External PWM
				J1 = PWM_MSP	**PWM from MSP430**
J13	HALL_PWR_SEL	Selects Hall power source	Top	J12 = HALL_EXT	External Hall power
				J12 = AVDD	**Hall power from AVDD = 5 V**
J8	HPA pullup	Enables pullup on Hall positive A (HPA)	Top	**J8 is inserted**	**Pullup, use for Digital Hall inputs**
				J8 is removed	Floating, use for Analog Hall inputs
J9	HPB pullup	Enables pullup on Hall positive B (HPA)	Top	**J9 is inserted**	**Pullup, use for Digital Hall inputs**
				J9 is removed	Floating, use for Analog Hall inputs
J10	HPC pullup	Enables pullup on Hall positive C (HPC)	Top	**J10 is inserted**	**Pullup, use for Digital Hall inputs**
				J10 is removed	Floating, use for Analog Hall inputs
J6	MSP to MCT Shunt jumper bridge	Connects signals from MCU to MCT8314Z when jumpers are inserted	Top	**FGOUT**	**MSP_FGOUT**
				PWM	**MSP_PWM**
				STE	**MSP_STE**
				SCK	**MSP_SCK**
				PICO	**MSP_PICO**
				POCI	**MSP_POCI**
				nFAULT	**MSP_nFAULT**
				nSLEEP	**MSP_nSLEEP**
				AGND	**AGND**
S1	BRAKE	Turns on all low-side MOSFETs	Top	Left	Brake enabled
				Right	**Brake disabled**
S2	DIR	Controls direction of motor	Top	**Left**	**ABC**
				Right	ACB
R15	ILIM	Pull down Resistor that sets the cycle-by-cycle current limit. The current limit can be calculated using the equation 9000 / R15 = cycle-by-cycle current limit.	Top	**6.2 kΩ**	**ILIM = 1.25 V = 1.45 A limit**

2.7.1 Hardware Variant Settings

The MCT8314ZH devices uses configurable resistor dividers to control the MODE, ADVANCE, FGOUT, and LOKC_DET_TIME settings. When using the MCT8314ZH:

- SPI enable resistors in the *Pop. if SPI* silk screen box needs to be depopulated (R10–R13).
- DIR resistor R14 in the *Pop. if HW* silk screen box needs be populated with a 0 Ω resistor.
- The resistor dividers in the *HW Variant Resistors* silk screen box needs be populated according to the desired settings (R16–R18 and R21–R23).

This setup is shown in Figure 2-7.

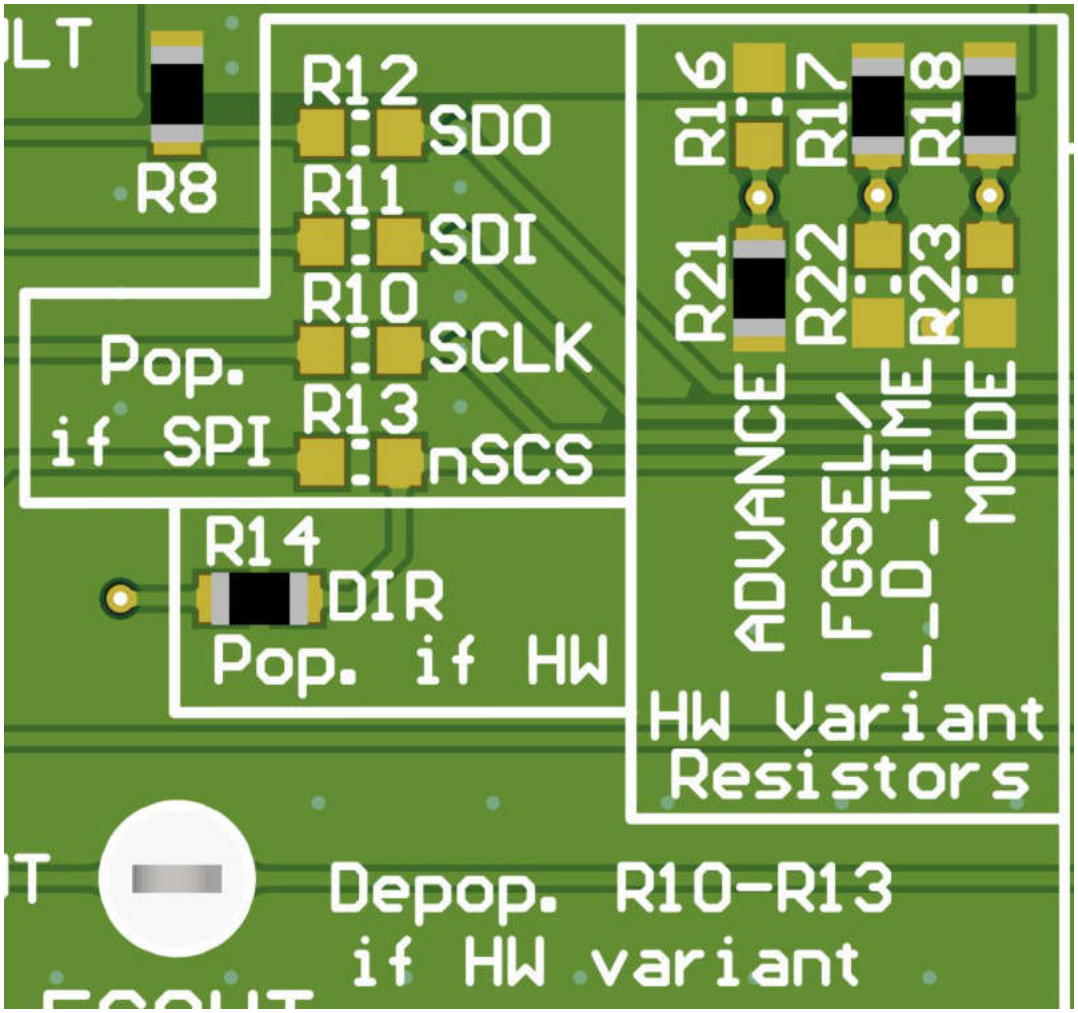


Figure 2-7. Resistor Divider Settings for MCT8314ZH (Hardware Variant)

Table 2-3 shows the user-adjustable resistor divider settings when using the MCT8314ZH. R16–R18 resistors connect to AVDD and R21–R23 resistors connect to AGND. The default resistor divider configurations are in bold.

Table 2-3. User-Adjustable Resistor Divider Settings for MCT8314ZH Variant (Defaults in Bold)

Setting	Name	Description	Resistors (AVDD and AGND)	Configuration	Setting
MODE	PWM Control Mode	Selects the Hall configuration, modulation, Asynchronous Rectification (ASR), and Automatic Asynchronous Rectification (AAR) settings	R18 and R23	R23 = 0 Ω	Analog Hall Input, Asynchronous modulation, ASR and AAR Disabled .
				R23 = 22 kΩ	Digital Hall Input, Asynchronous modulation, ASR and AAR Disabled.
				R23 = 100 kΩ	Analog Hall Input, Synchronous modulation, ASR and AAR Disabled.
				R18 = R23 = DNP	Digital Hall Input, Synchronous modulation, ASR and AAR Disabled.
				R18 = 100 kΩ	Analog Hall Input, Synchronous modulation, ASR and AAR Enabled.
				R18 = 22 kΩ	Digital Hall Input, Synchronous modulation, ASR and AAR Enabled.
				R18 = 0 Ω	**Digital Hall Input, Asynchronous modulation, ASR and AAR Enabled.**
FGOUT/ L_D_TIME	FGOUT and Motor lock configuration	Sets the FG output commutation frequency multiplier and time required to detect a motor lock fault condition	R17 and R22	R22 = 0 Ω	Motor Lock Detection time = 100 ms and FGOUT = 3x commutation frequency.
				R22 = 22 kΩ	Motor Lock Detection time = 500 ms and FGOUT = 3x commutation frequency.
				R22 = 100 kΩ	Motor Lock Detection time = 1000 ms and FGOUT = 3x commutation frequency.
				R17 = R22 = DNP	Motor Lock Detection time = 5000 ms and FGOUT = 3x commutation frequency.
				R17 = 100 kΩ	Motor Lock Detection time = 300 ms and FGOUT = 1x commutation frequency.
				R17 = 22 kΩ	Motor Lock Detection time = 500 ms and FGOUT = 1x commutation frequency.
				R17 = 0 Ω	**Motor Lock Detection time = 1000 ms and FGOUT = 1x commutation frequency.**
ADVANCE	Advance	Advances the lead angle by a selectable value (in electrical degrees)	R16 and R21	**R21 = 0 Ω**	**0°**
				R21 = 22 kΩ	4°
				R21 = 100 kΩ	11°
				R16 = R21 = DNP	15°
				R16 = 100 kΩ	20°
				R16 = 22 kΩ	25°
				R16 = 0 Ω	30°

2.7.2 SPI Variant Resistor Settings

The MCT8314ZS replaces the MODE, ADVANCE, and FGOUT/LOCK_DET_TIME pins with SPI pins (SDI, SDO, SCLK, nSCS) to configure control registers and read status registers. When using the MCT8315ZR:

- SPI enable resistors in the *Pop. if SPI* silk screen box needs be populated (R10-R13).
- The resistor in the *Pop. if HW* silkscreen box (R17) needs be depopulated.
- Resistor dividers in the *Hardware Variant Resistors* silk screen box needs be depopulated (R16-R18, R21-R23).

This setup is shown in Figure 2-8.

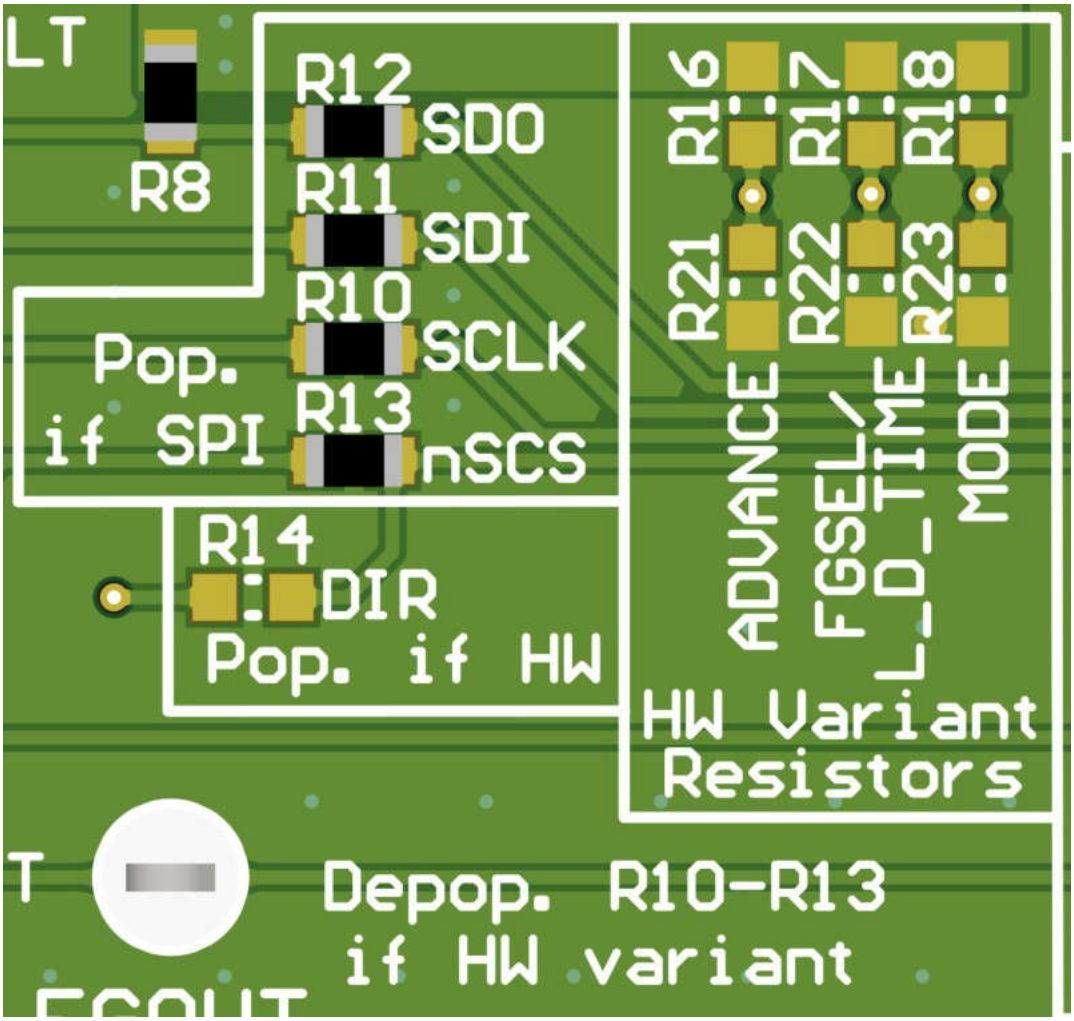


Figure 2-8. Resistors for MCT8314ZS (SPI variant)

Table 2-4 shows the recommended resistor values to when using a MCT8314ZS. The default resistor configurations are in bold.

Table 2-4. Recommended SPI Resistor Values for MCT8314ZS (Defaults in Bold)

Setting	Name	Description	Resistor	Configuration
SDO	Serial Data Out	Serial out of the MCT8314Z	R15	**R15 = 0 Ω**
SDI	Serial Data In	Serial input of the MCT8314Z	R14	**R14 = 0 Ω**
SCLK	Serial Clock	Clock generated by the MCU	R13	**R13 = 0 Ω**
nSCS	Chip Select	Pulled low by the MCU to enable communication	R16	**R16 = 0 Ω**

Table 2-5 show the status of populated and DNP resistors for the MCT834Z variants.

Table 2-5. Status of Resistors for MCT8314Z Variants

Device	R13-R16 status	R17 status	HW variant resistors status
MCT8314ZH	DNP	Populated	User adjustable
MCT8314ZS	Populated	DNP	DNP

3 Software

3.1 Firmware and GUI Application

The MCT8314ZEVM includes a USB-to-UART interface, using a MSP4302355 microcontroller, that serves as a communication bridge between a host PC and the MCT8314Z device for configuring various device settings and reading fault diagnostic information. The MCT8314Z GUI is available to monitor the motor the MCT8314Z device and in the case of the MCT8314ZS configure the device.

The MCT8314Z GUI is available on the dev.ti.com/gallery. The MCT8314Z GUI supports all variants of the MCT8314Z. The MCT8314Z GUI is able to measure the speed of the motor by monitoring the duty cycle of the 20-kHz PWM waveform and the frequency of the FGOUT output. Providing the number of poles the motor has to the GUI, the GUI calculates the speed of the motor in revolutions per minute (RPM). The GUI also allows for the ability to control the nSLEEP signal to put the MCT8314Z into a low power sleep mode. For the MCT8314ZS the GUI also includes a register map and the ability to read and write over SPI to configure the devices registers.

By default, the MSP430 already contains the firmware required for the EVM to be able to connect and communicate with the MCT8314Z GUI. If there is a FW update or the GUI does not connect to the EVM then the user must flash the code onto the MSP430.

Flashing the firmware onto the EVM requires an external MSP430 LaunchPad™ that includes the eZ-FET Debug Probe and Code Composer Studio™ (CCS). The example in Section 3.4 uses the MSP-EXP430FR2355 LaunchPad Development Kit to provide the eZ-FET Debug Probe.

3.2 MCT8314Z GUI

The following features are enabled in the MCT8314Z GUI:

PWM or Duty Cycle Settings

- Use the R6 potentiometer on the MCT8314ZEVM to control the duty cycle of the 20-kHz PWM waveform from the MSP430FR2355. The slider and gauge updates real-time with the duty cycle from 0–100%.

Motor Settings and Calculations

- Update the number of motor poles in the motor using the *Motor Poles* drop-down box.
- The FGOUT frequency is measured and updated real time in the FGOUT Freq (Hz) box.
- The value in the *FGOUT freq. (Hz)* and *Motor poles* boxes are used to calculate and update the value in the *Motor Speed (RPM)* box. The value for the RPM speed is calculated by the formula in Equation 1. Note that the FGOUT frequency is multiplied by 120 to achieve the frequency of one electrical cycle, in Hz.

$$1\ Motor\ Speed\ (RPM) = \frac{120 \times FGOUT}{\#\ Motor\ Poles} \quad (1)$$

Status LEDs and nSLEEP Control

- The status of the programmable MCU LEDs are shown by LED1 and LED2.
- To place the MCT8314Z into a low-power sleep mode, click the nSLEEP button into the right position. This causes the MSP430 to send an active-low signal to nSLEEP on the device.

3.3 Running the GUI

The MCT8314Z GUI can be run directly inside a web browser (supported in Google Chrome® and Firefox®). To run the GUI inside of a web browser, follow the steps below:

1. Connect the MCT8314ZEVM as described in Section 2.2.
2. Access the latest version of the MCT8314Z GUI through the gallery.
3. Once the GUI has launched a screen similar to the one shown in Figure 3-1 appears.

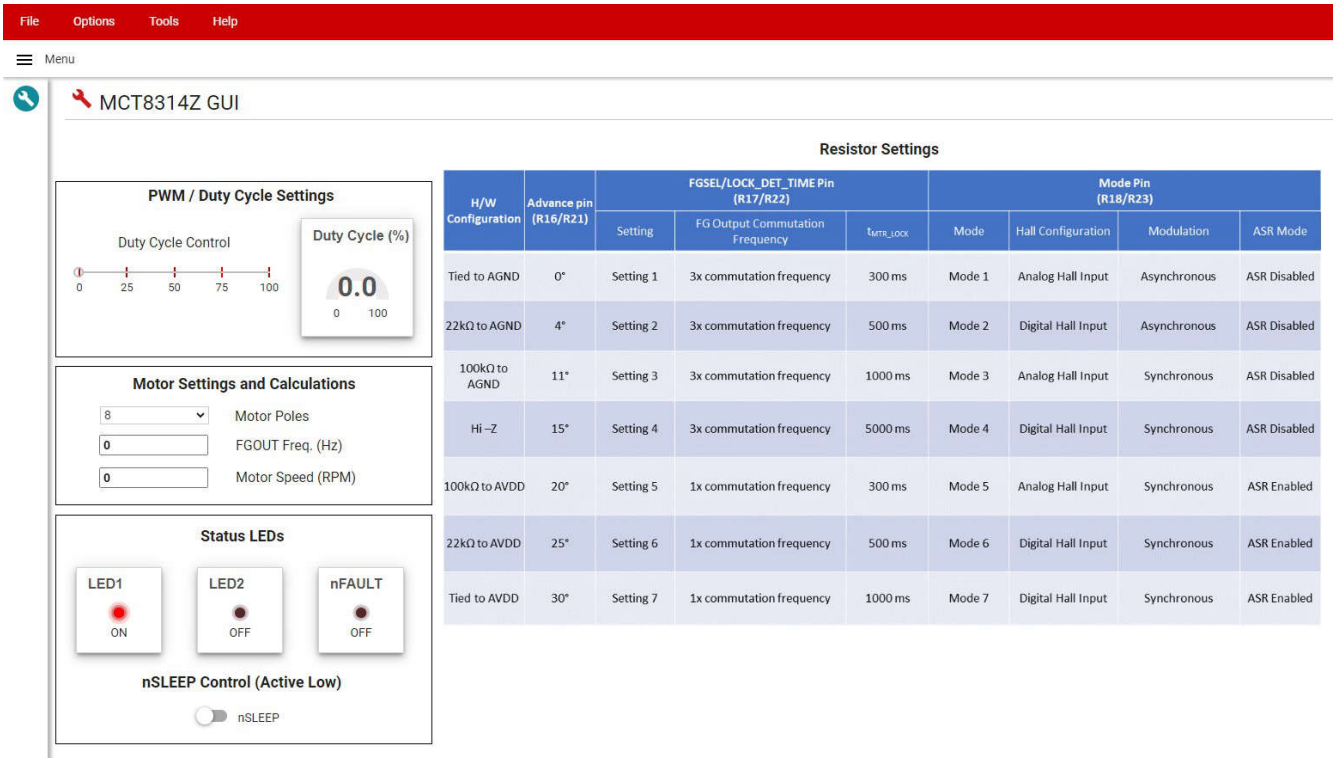


Figure 3-1. MCT8314Z GUI

Alternatively the MCT8314Z GUI can be downloaded and intalled for offline use using the download feature in the TI Cloud Gallery.

Figure 3-2. MCT8314Z GUI Download Feature

3.4 Downloading Code Composer Studio and Importing GUI Firmware

1. Download and extract the MCT8314ZEVM firmware to a location on the computer.
2. Download the latest version of Code Composer Studio. This sets up a folder at the directory C:\ti.
   a. Accept all agreements, default install locations, and select *Next* to proceed through menus.
   b. In the *Select 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 MCT8314Z firmware.
6. Import the project into the workspace as shown in Figure 3-3.

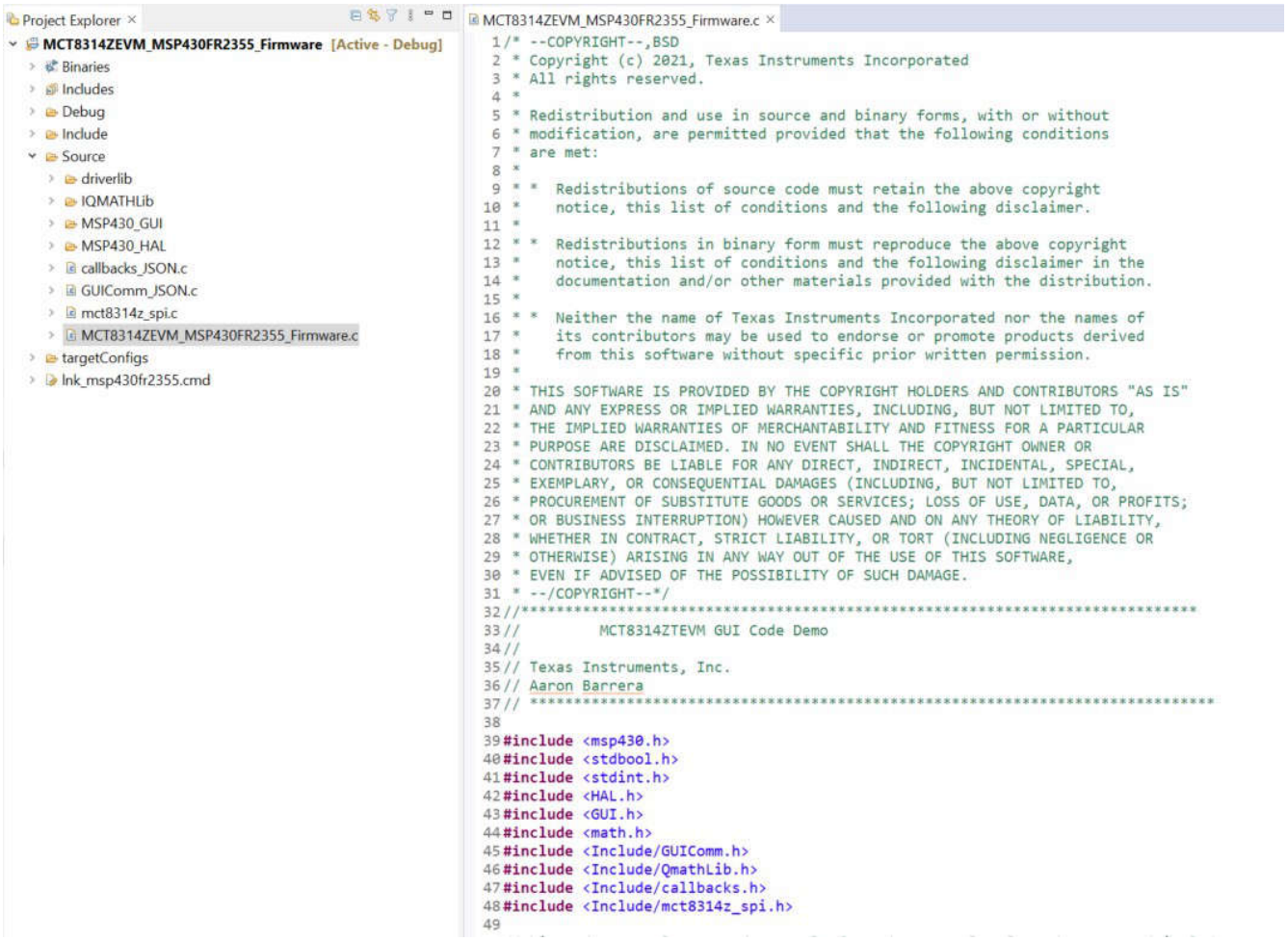


Figure 3-3. MSP430FR2355 Interface Firmware Code in Code Composer Studio

3.5 Using the eZ-FET to Program the MSP430FR2355

The eZ-FET Debug Probe on the MSP430FR2355 LaunchPad uses a Spy-Bi-Wire JTAG interface to program the MSP430FR2355 MCU on the MCT8316ZTEVM. 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 MCT8314ZEVM as shown in Table 3-1 and Figure 3-4.
3. Connect a micro-USB cable to the MSP430 LaunchPad and the PC.
4. Click on the Build Project icon or CTRL + B to make sure 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 Spy-Bi-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)	MCT8314ZEVM 4-pin Spy-Bi-Wire Header (J4)
GND	GND
3V3	3.3V
SBWTDIO	SBWTDIO
SBWTCK	SBWTCK

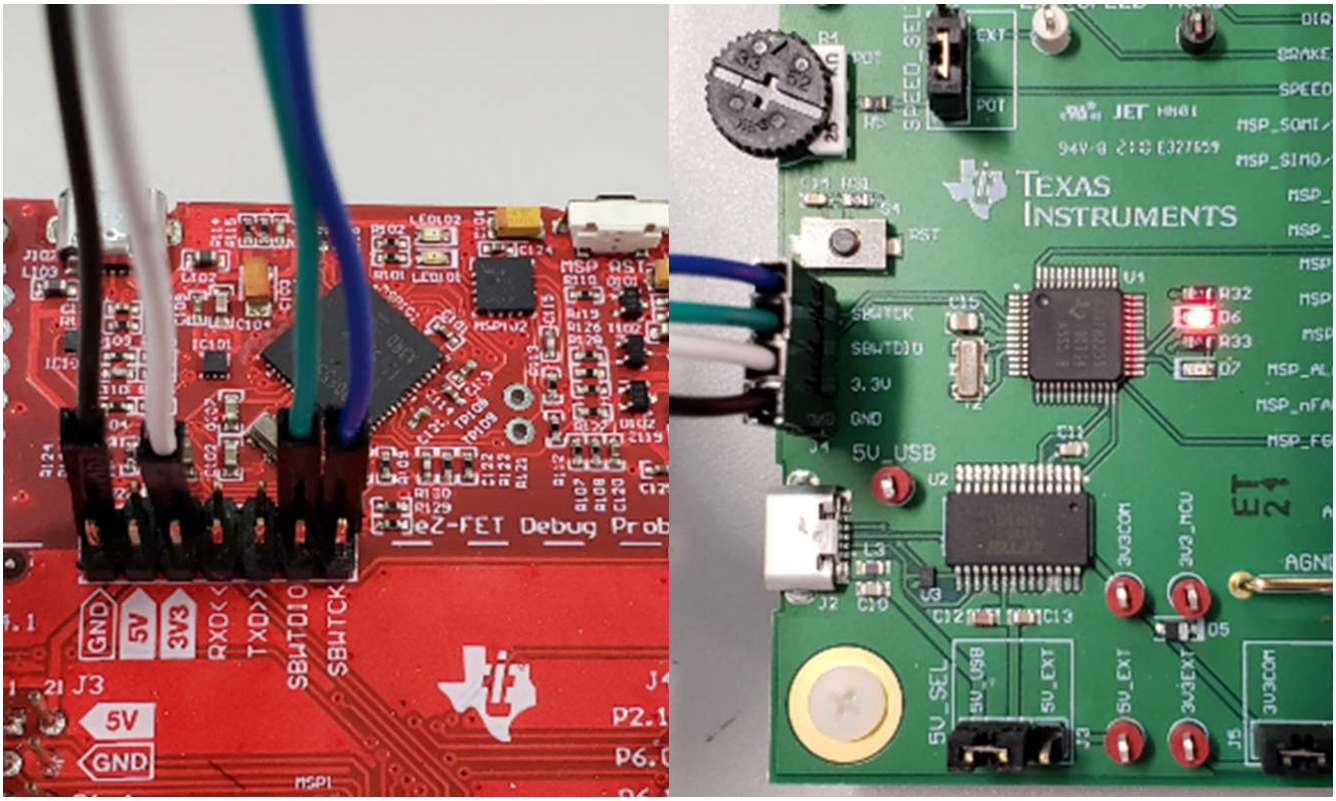


Figure 3-4. MSP430 LaunchPad eZ-FET Probe Connected to MCT8314ZEVM

4 Hardware Design Files

4.1 Schematics

Figure 4-1 through Figure 4-9 illustrate the EVM schematics.

4.1.1 MCT8314Z 3-Phase Sensored Trapezoidal Motor Driver

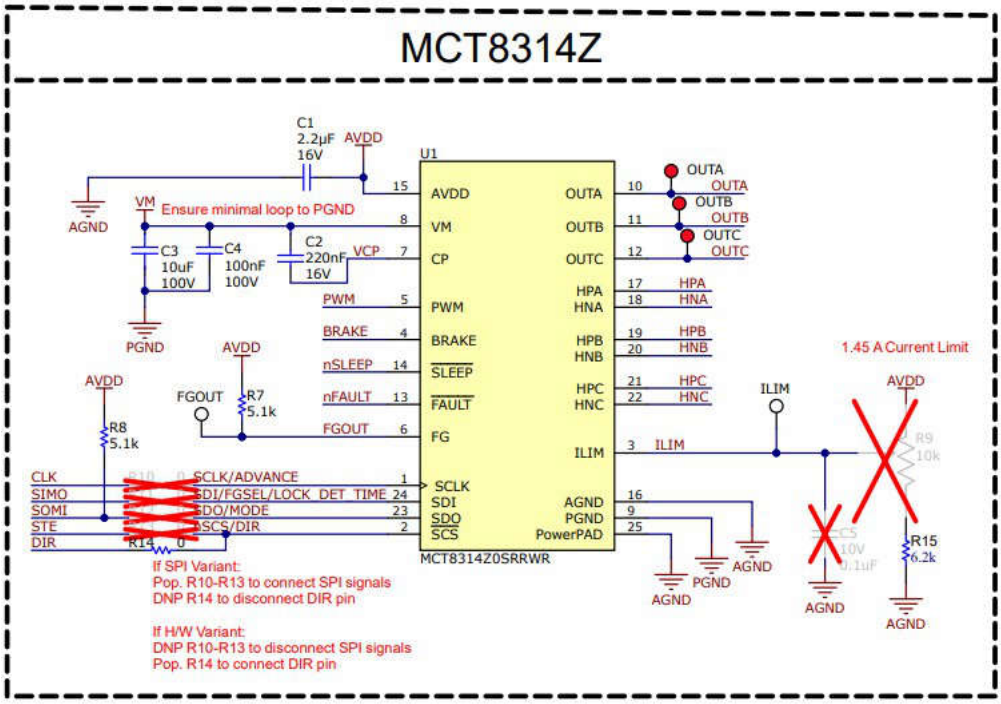


Figure 4-1. MCT8314Z 3-Phase Sensored Trapezoidal Motor Driver

4.1.2 Power Supplies

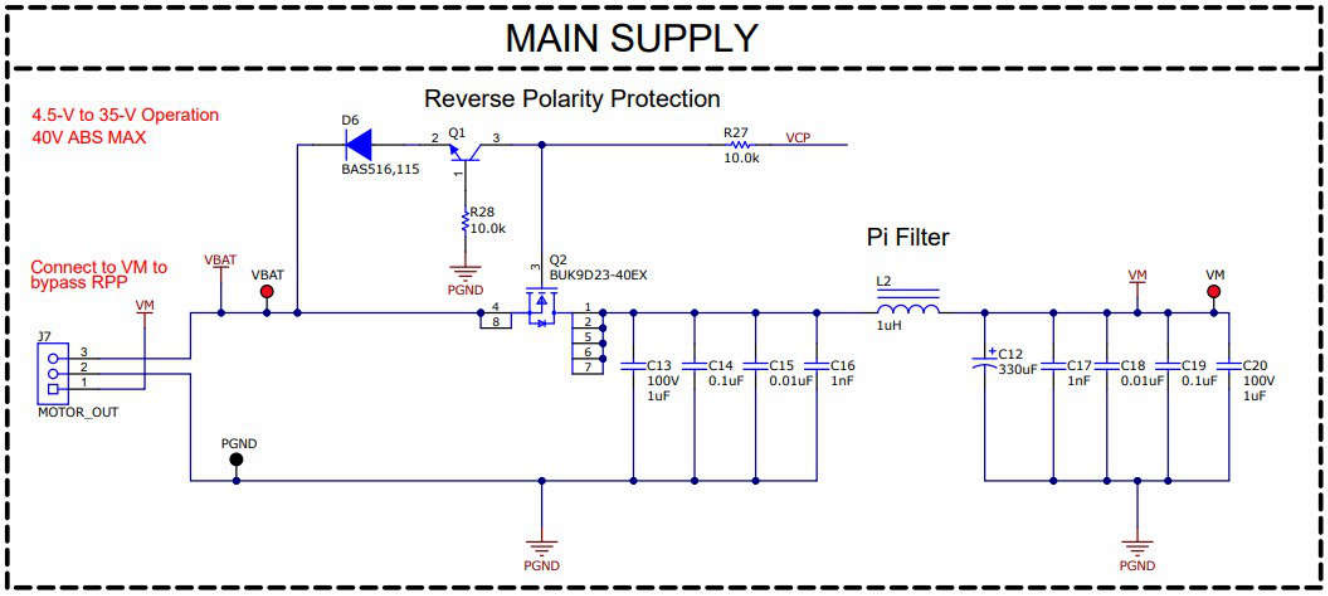


Figure 4-2. Main Supply

4.1.3 MCU Interface

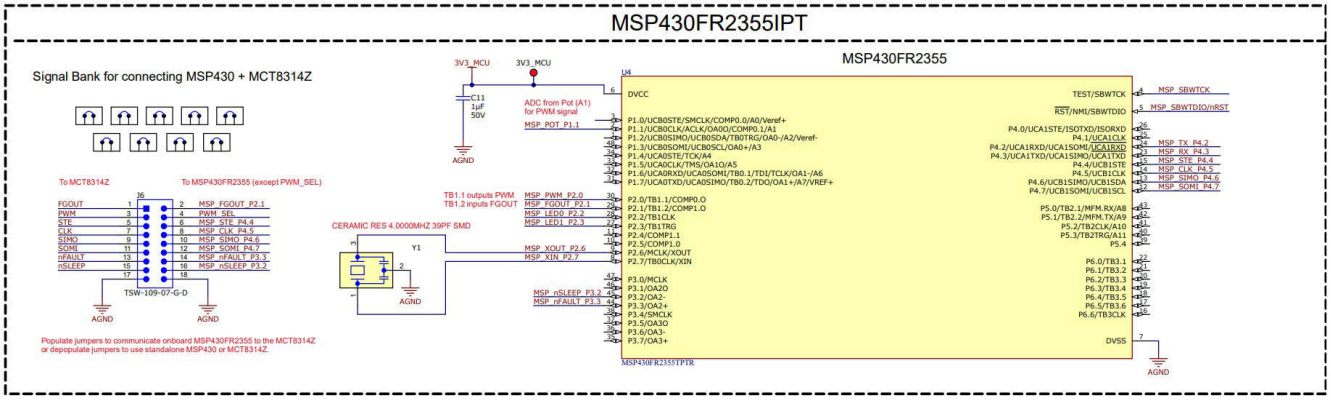


Figure 4-3. MSP430FR2355 MCU

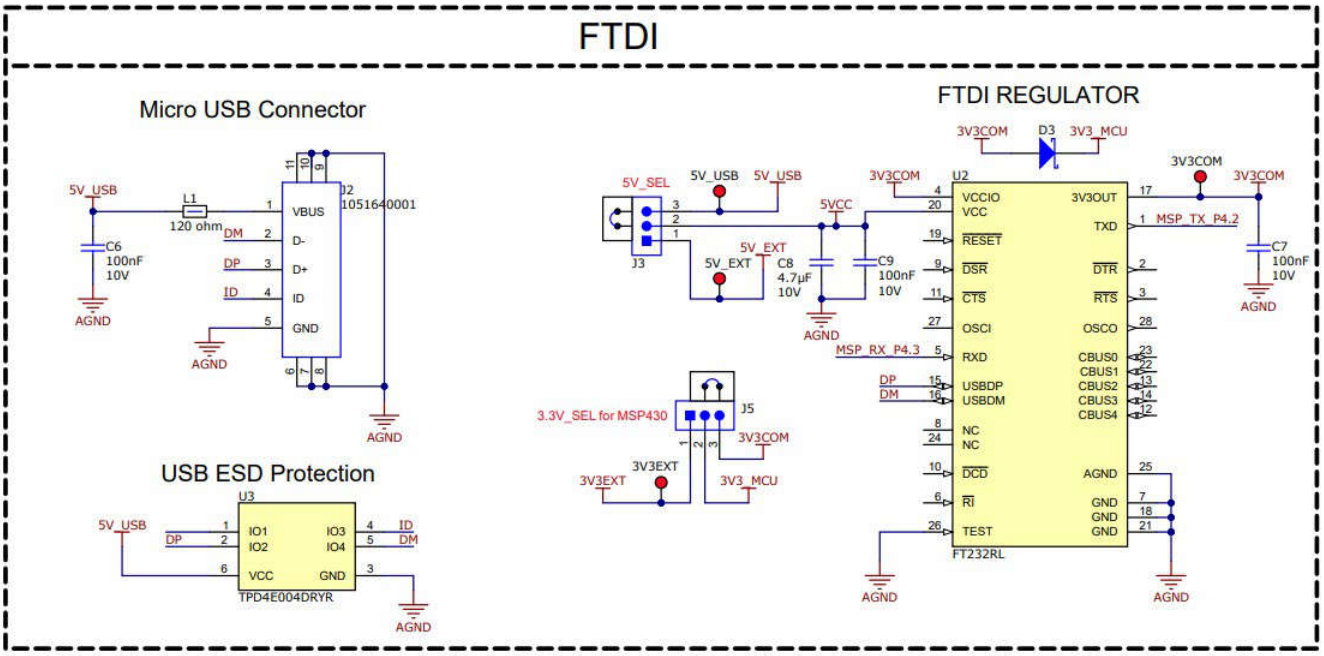


Figure 4-4. USB to UART Schematic

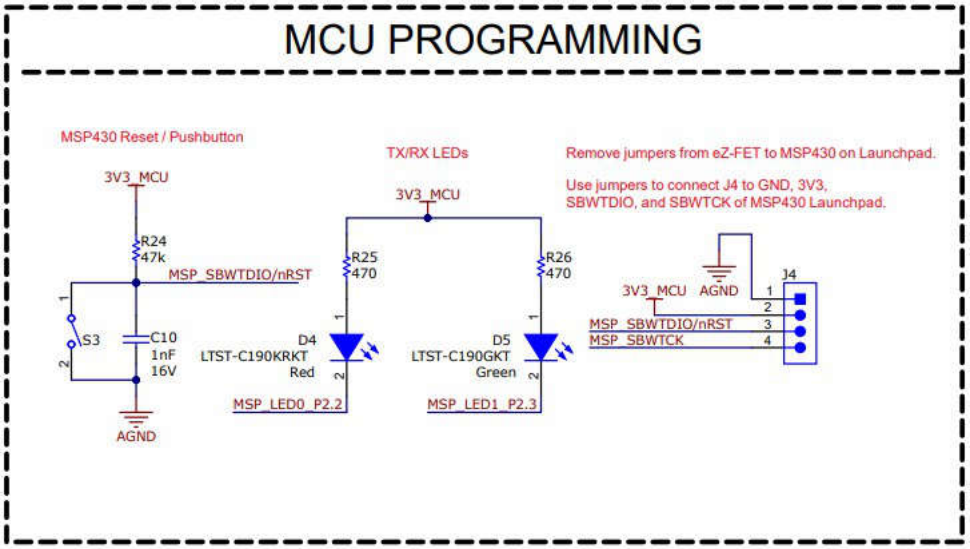


Figure 4-5. MCU Programming and Debug Schematic

4.1.4 User Interface

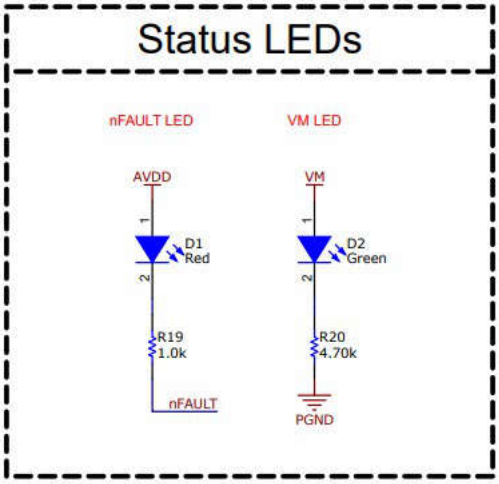


Figure 4-6. Status LEDs Schematic

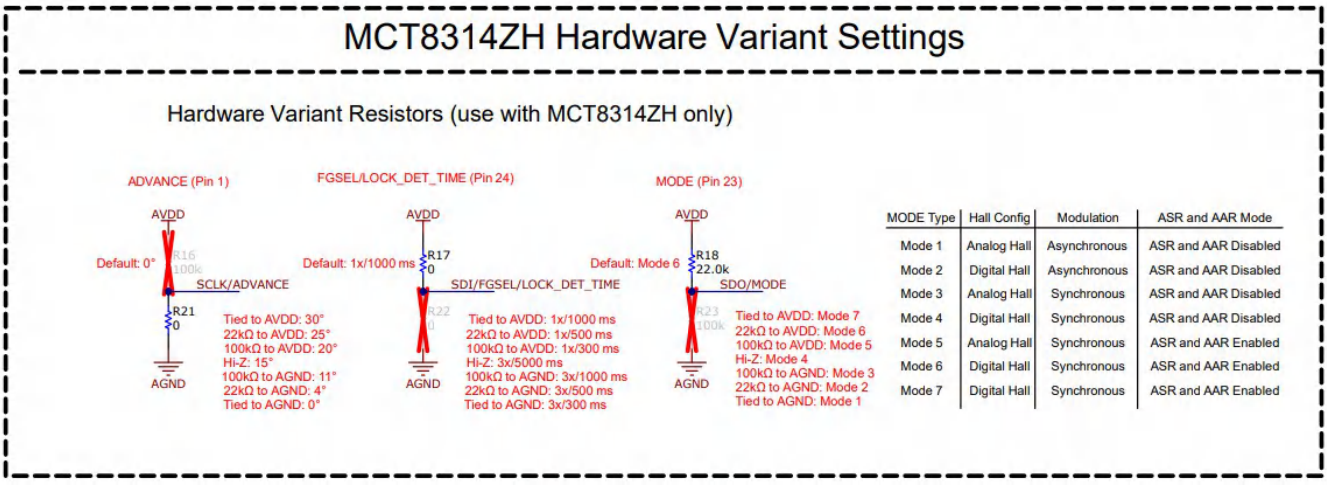


Figure 4-7. Hardware Variant Resistors Schematic

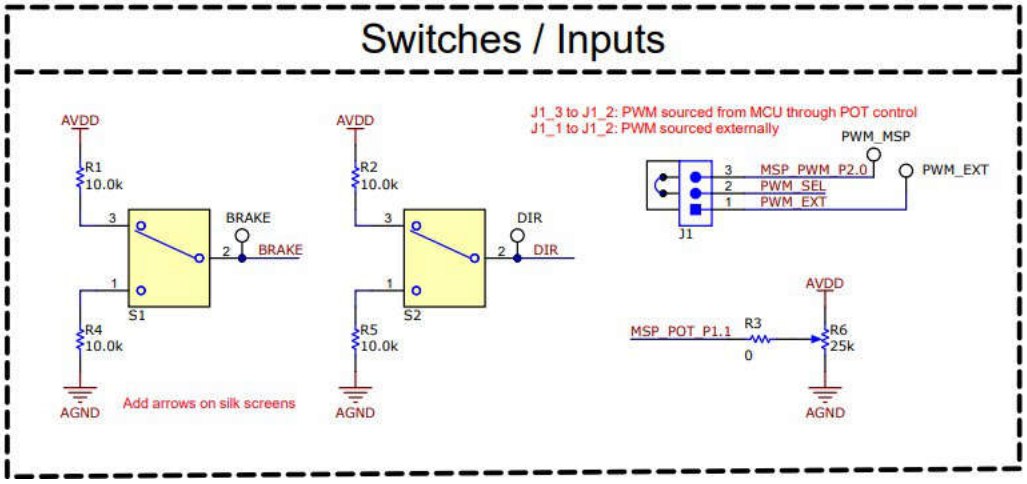


Figure 4-8. Switches and Speed Input Schematic

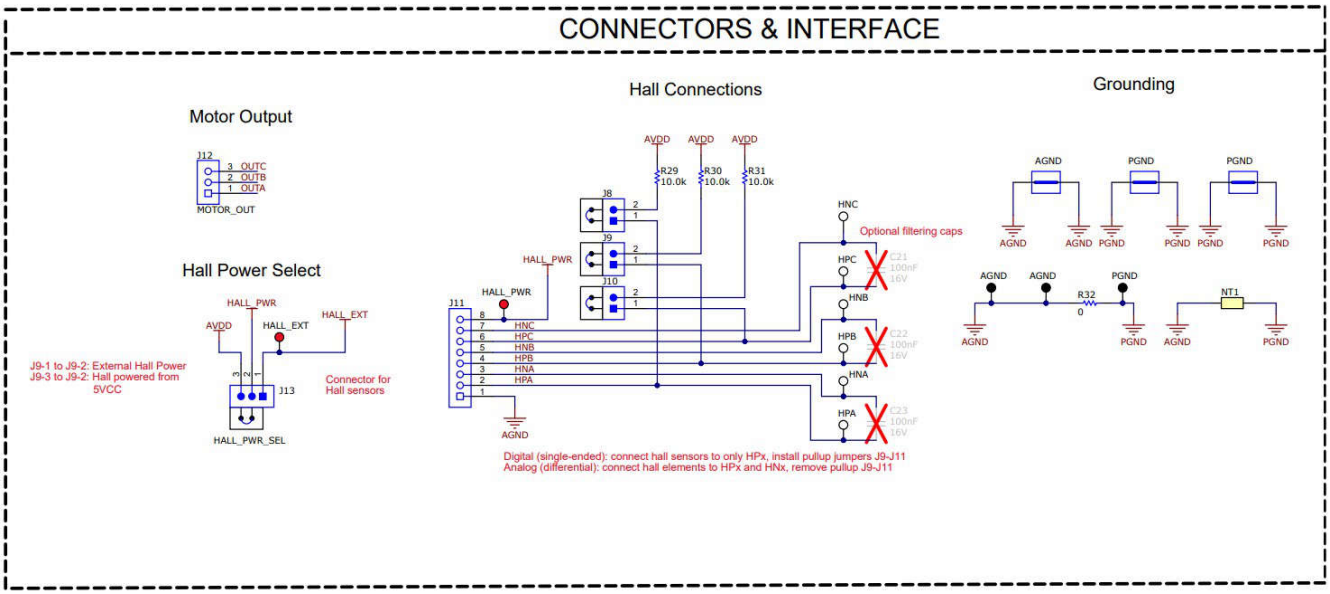


Figure 4-9. Connectors Schematic

4.2 PCB Layouts

Figure 4-10. EVM Board Dimensions

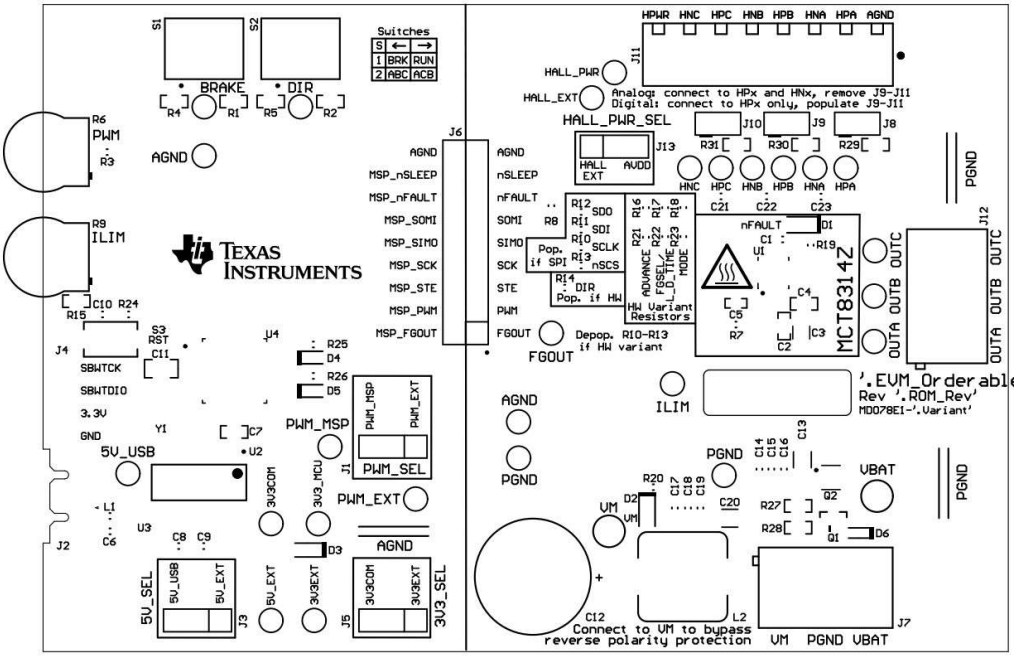


Figure 4-11. EVM Top Overlay

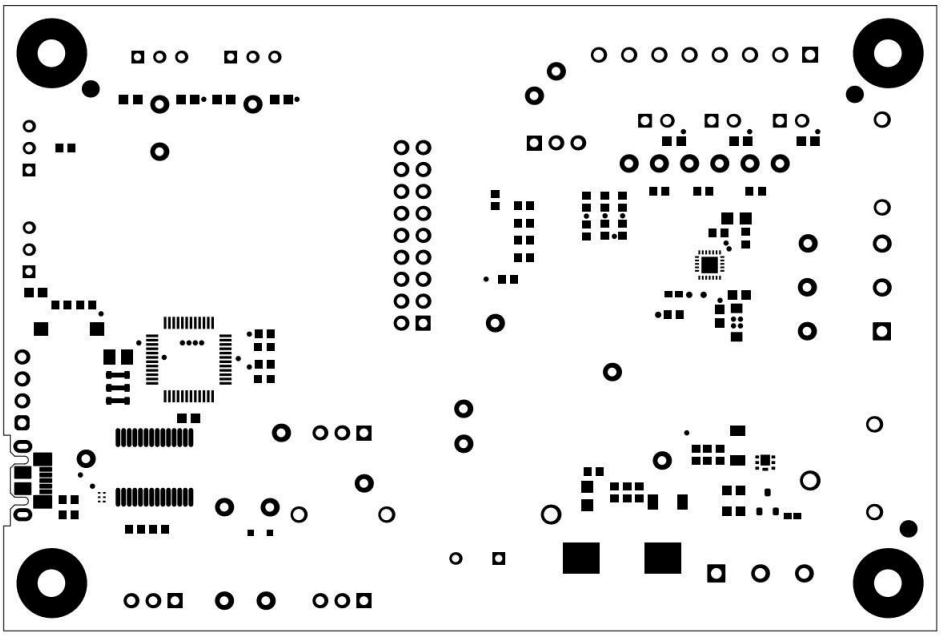


Figure 4-12. EVM Top Solder Mask

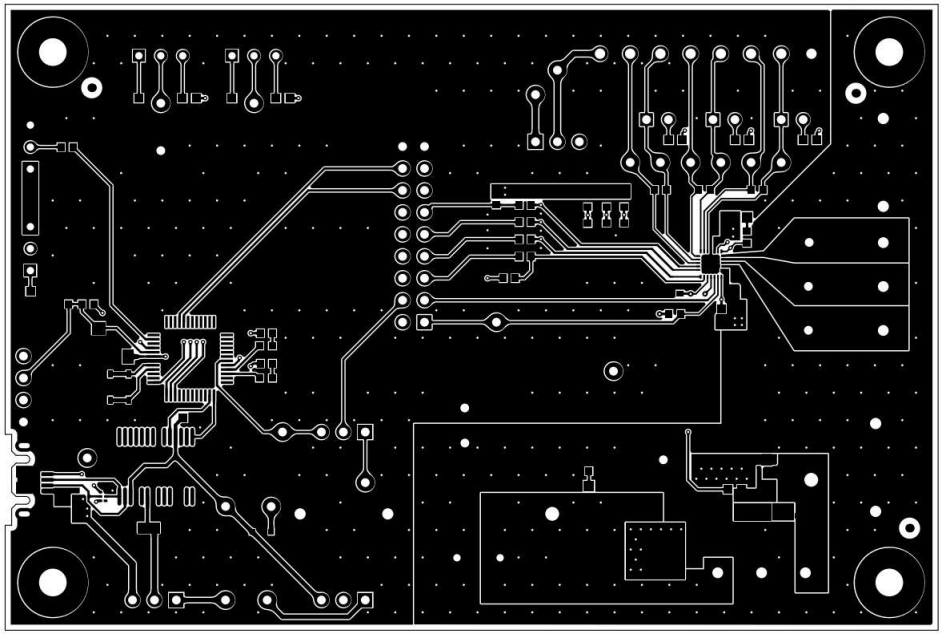


Figure 4-13. EVM Top Layer

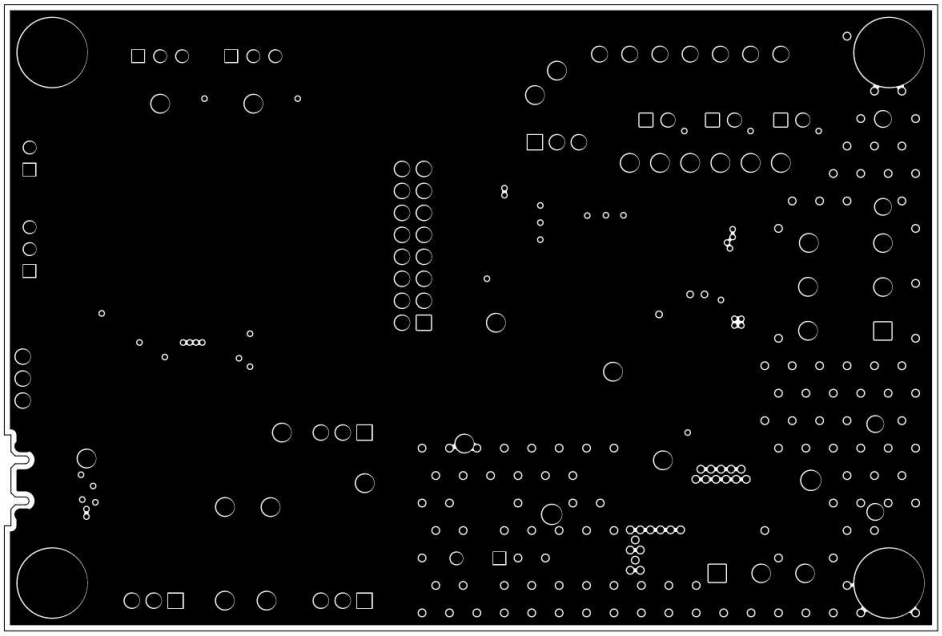


Figure 4-14. EVM Signal Layer 1

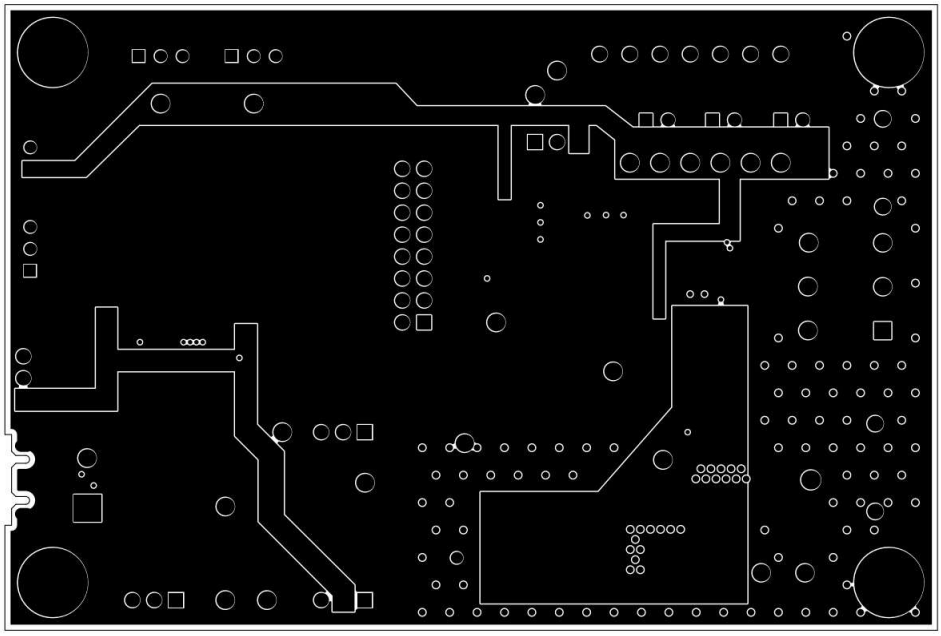


Figure 4-15. EVM Signal Layer 2

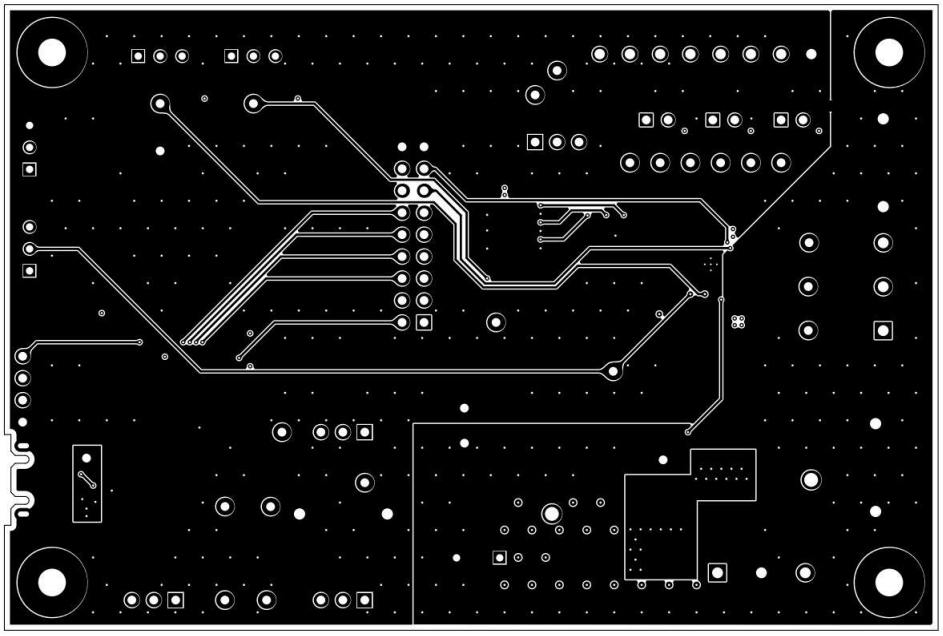


Figure 4-16. EVM Bottom Layer

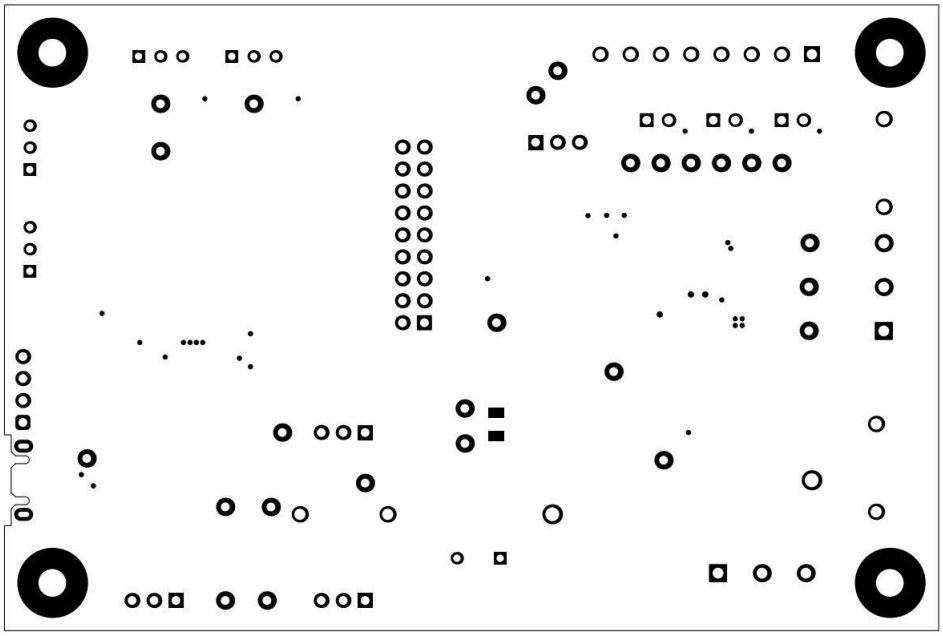


Figure 4-17. EVM Bottom Solder Mask

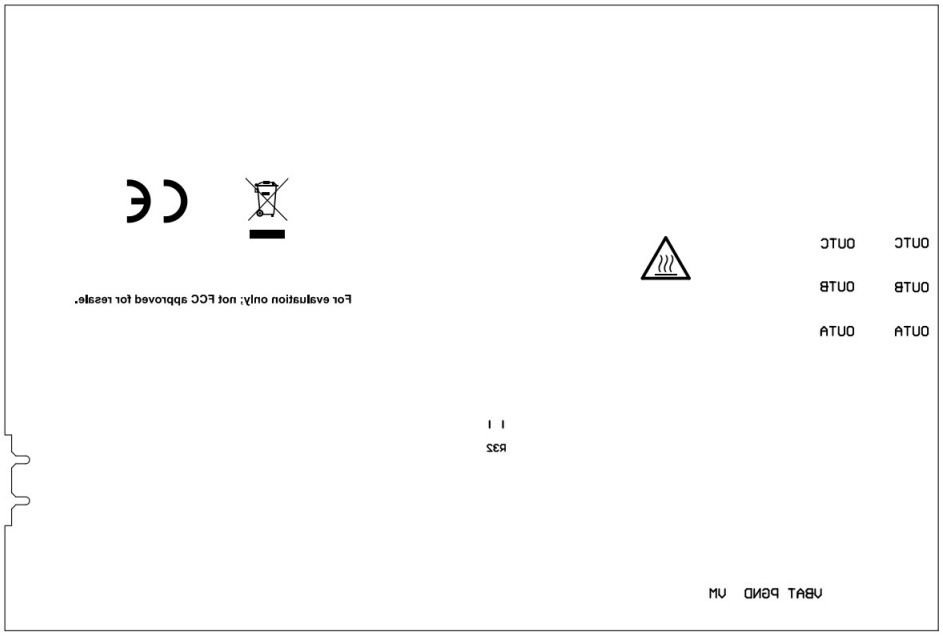


Figure 4-18. EVM Bottom Overlay

4.3 Bill of Materials (BOM)

Table 4-1. Bill of Materials

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
C1	1	2.2uF	CAP, CERM, 2.2 uF, 16 V, +/- 10%, X7R, 0603	603	GRM188Z71C225KE43	MuRata
C2	1	0.22uF	CAP, CERM, 0.22 uF, 16 V, +/- 10%, X7R, 0603	603	C0603C224K4RACTU	Kemet
C3	1	10 µF	10 µF ±10% 100 V Ceramic Capacitor X6S 1206 (3216 Metric)	1206	C3216X6S2A106K160AC	TDK
C4	1	0.1uF	CAP, CERM, 0.1 uF, 100 V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	603	GCJ188R72A104KA01D	MuRata
C6, C7, C9	3	0.1uF	CAP, CERM, 0.1 uF, 10 V, +/- 10%, X7R, 0603	603	C0603C104K8RACTU	Kemet
C8	1	4.7uF	CAP, CERM, 4.7 uF, 10 V, +/- 20%, X7R, 0603	603	GRM188Z71A475ME15D	MuRata
C10	1	1000 pF	CAP, CERM, 1000 pF, 16 V, +/- 10%, X7R, 0603	603	8.85012E+11	Wurth Elektronik
C11	1	1uF	CAP, CERM, 1 uF, 50 V, +/- 10%, X7R, 0805	805	C0805C105K5RACTU	Kemet
C12	1	330uF	CAP, AL, 330 uF, 63 V, +/- 20%, AEC-Q200 Grade 2, TH	D12.5xL20mm	ELXZ630ELL331MK20S	Chemi-Con
C13, C20	2	1uF	CAP, CERM, 1 uF, 100 V, +/- 10%, X7R, 1206	1206	GRM31CR72A105KA01L	MuRata
C14, C19	2	0.1uF	CAP, CERM, 0.1 uF, 100 V, +/- 10%, X7S, AEC-Q200 Grade 1, 0603	603	CGA3E3X7S2A104K080AB	TDK
C15, C18	2	0.01uF	CAP, CERM, 0.01 uF, 100 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	603	CGA3E2X7R2A103K080AA	TDK
C16, C17	2	1000 pF	CAP, CERM, 1000 pF, 100 V, +/- 5%, X7R, 0603	603	06031C102JAT2A	AVX
D1	1	Red	LED, Red, SMD	Red 0805 LED	LTST-C170KRKT	Lite-On
D2	1	Green	LED, Green, SMD	LED_0805	LTST-C170KGKT	Lite-On
D3	1	40 V	Diode, Schottky, 40 V, 0.75 A, AEC-Q101, SOD-323	SOD-323	BAT165E6327HTSA1	Infineon Technologies
D4	1	Red	LED, Red, SMD	Red LED, 1.6x0.8x0.8mm	LTST-C190KRKT	Lite-On
D5	1	Green	LED, Green, SMD	1.6x0.8x0.8mm	LTST-C190GKT	Lite-On
D6	1	100 V	Diode, Switching, 100 V, 0.25 A, SOD-523	SOD-523	BAS516,115	Nexperia
FID1, FID2, FID3	3		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
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, J3, J5, J13	4		Header, 100mil, 3x1, Gold, TH	PBC03SAAN	PBC03SAAN	Sullins Connector Solutions
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
J4	1		Header, 100mil, 4x1, Gold, TH	4x1 Header	TSW-104-07-G-S	Samtec
J6	1		Header, 100mil, 9x2, Gold, TH	9x2 Header	TSW-109-07-G-D	Samtec
J7, J12	2		Terminal Block, 5.08 mm, 3x1, Brass, TH	3x1 5.08 mm Terminal Block	ED120/3DS	On-Shore Technology
J8, J9, J10	3		Header, 100mil, 2x1, Tin, TH	Header, 2 PIN, 100mil, Tin	PEC02SAAN	Sullins Connector Solutions
J11	1		Terminal Block, 8x1, 3.5mm, TH	8x1 Terminal Block	OSTTE080161	On-Shore Technology
L1	1		Inductor, Ferrite Bead, Ferrite, 3 A, 120 ohm, AEC-Q200 Grade 1, SMD	603	BLM18SG121TZ1D	MuRata
L2	1	1uH	Inductor, Shielded, Powdered Iron, 1 uH, 18 A, 0.003 ohm, AEC-Q200 Grade 1, SMD	11x10mm	SRP1038A-1R0M	Bourns
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 40 V 8 A (Ta) 15W (Tc) Surface Mount DFN2020MD-6	SOT1220	BUK9D23-40EX	Nexperia
R1, R2, R4, R5, R27, R28, R29, R30, R31	9	10.0k	RES, 10.0 k, 1%, 0.1 W, 0603	603	RC0603FR-0710KL	Yageo
R3, R14, R17, R21	4	0	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	603	ERJ-3GEY0R00V	Panasonic
R6	1	25k	Trimmer Potentiometer, 25kohm, 0.5W, TH	9.53x8.89mm	3352T-1-253LF	Bourns
R7, R8	2	5.1k	RES, 5.1 k, 5%, 0.1 W, 0603	603	RC0603JR-075K1L	Yageo
R15	1	6.2k	RES, 6.2 k, 5%, 0.1 W, 0603	603	RC0603JR-076K2L	Yageo

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
R18	1	22.0k	RES, 22.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	603	ERJ-3EKF2202V	Panasonic
R19	1	1.0k	RES, 1.0 k, 5%, 0.1 W, 0603	603	RC0603JR-071KL	Yageo
R20	1	4.70k	RES, 4.70 k, 0.1%, 0.1 W, 0603	603	RT0603BRD074K7L	Yageo America
R24	1	47k	RES, 47 k, 5%, 0.1 W, 0603	603	RC0603JR-0747KL	Yageo
R25, R26	2	470	RES, 470, 5%, 0.1 W, 0603	603	RC0603JR-07470RL	Yageo
R32	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 28 V	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	16	1x2	Shunt, 100mil, Gold plated, Black	Shunt	SNT-100-BK-G	Samtec
TP1, TP2, TP3, TP4, TP8, TP9, TP21, TP22, TP27, TP28, TP29, TP30	12		Test Point, Miniature, White, TH	White Miniature Testpoint	5002	Keystone Electronics
TP5, TP6, TP7, TP10, TP11, TP12, TP13, TP14, TP26, TP31	10		Test Point, Miniature, Red, TH	Red Miniature Testpoint	5000	Keystone Electronics
TP15, TP16	2		Test Point, Compact, Red, TH	Red Compact Testpoint	5005	Keystone Electronics
TP17, TP23, TP24, TP25	4		Test Point, Miniature, Black, TH	Black Miniature Testpoint	5001	Keystone Electronics
TP18, TP19, TP20	3		1 mm Uninsulated Shorting Plug, 10.16mm spacing, TH	Shorting Plug, 10.16mm spacing, TH	D3082-05	Harwin
U1	1		MCT8314Z0HRRWR	WQFN24	MCT8314Z0SRRWR	Texas Instruments
U2	1		USB to Serial UART, SSOP28	SSOP28	FT232RL	FTDI
U3	1		4-Channel ESD Protection Array for High-Speed Data Interfaces, DRY0006A (USON-6)	DRY0006A	TPD4E004DRYR	Texas Instruments

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
U4	1		CPU16 MSP430™ FRAM Microcontroller IC 16-Bit 24 MHz 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
C5	0	0.1uF	CAP, CERM, 0.1 uF, 10 V, +/- 10%, X5R, 0402	402	C1005X5R1A104K050BA	TDK
C21, C22, C23	0	0.1uF	CAP, CERM, 0.1 µF, 16 V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	603	0603YC104K4T4A	AVX
R9	0	10k	10 kOhms 0.5W, 1/2W Through Hole Thumbwheel Potentiometer Top Adjustment	PTM_PTH_8MM9_9MM53	3352T-1-103LF	Bourns
R10, R11, R12, R13, R22	0	0	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	603	ERJ-3GEY0R00V	Panasonic
R16, R23	0	100k	RES, 100 k, 0.1%, 0.1 W, AEC-Q200 Grade 0, 0603	603	ERA-3AEB104V	Panasonic

5 Additional Information

Trademarks

LaunchPads™, LaunchPad™, Code Composer Studio™, and MSP430™ are trademarks of Texas Instruments.
Google Chrome® is a registered trademark of Google LLC.
Firefox® is a registered trademark of Mozilla Foundation.
All trademarks are the property of their respective owners.

STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

WARNING

Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.

User shall operate the Evaluation Kit within TI’s recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI’s recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI’s instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 *Regulatory Notices:*

3.1 *United States*

3.1.1 *Notice applicable to EVMs not FCC-Approved:*

FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

CAUTION

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・インスツルメンツ株式会社

東京都新宿区西新宿 6 丁目 2 4 番 1 号

西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265