

**ABSTRACT**

This document is provided with the MCT8316ZT customer evaluation module (EVM) as a supplement to the MCT8316Zx data sheet ([MCT8316Z Three-Phase Sensored-Trapezoidal BLDC Motor Driver Data Sheet](#)). This User's Guide details the hardware implementation of the EVM and how to setup and power the board.

Note

The MCT8316ZTEVM comes automatically populated with and configured for the MCT8316Z0T. It is also compatible for the MCT8316Z0R variant (see [MCT8316Z0R Compatibility](#)), but the user will need to replace the MCT8316Z0T with the MCT8316Z0R for compatibility.

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Trademarks

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1 Cautions and Warnings

Observe the following cautions and warnings as printed on the EVM board.

CAUTION:



Read the User's Guide before use.

HOT SURFACE:



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

2 Introduction

The MCT8316Z is a 4.5-V to 35-V, 8-A peak integrated three-phase gate driver IC with sensed trapezoidal control for motor drive applications. It provides three integrated half-bridges and a sensed trapezoidal algorithm capable of directly driving a 3-phase brushless-DC motor. The hardware interface variant (MCT8316ZT) integrates an adjustable buck regulator, protection features, and flexible parameter settings such as slew rate control and buck output voltage. See [Table 3-1](#).

Table 2-1. MCT8316Z variants

Device Name	Variant
MCT8316Z0T	Buck regulator and Hardware
MCT8316Z0R	Buck regulator and SPI

The MCT8316ZTEVM 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 potentiometer into control signals and a variable duty cycle for the PWM input of the MCT8316Z. It can also provide SPI communication for the SPI variant of the MCT8316Z device. There are many user-selectable jumpers, resistors, connectors, and test points to evaluate the features of the device and configure device-specific settings.

This document serves as a startup guide to supplement the MCT8316ZTEVM. It is intended for engineers to design, implement, and validate reference hardware for the MCT8316ZT (H/W variant) along with the device data sheet.

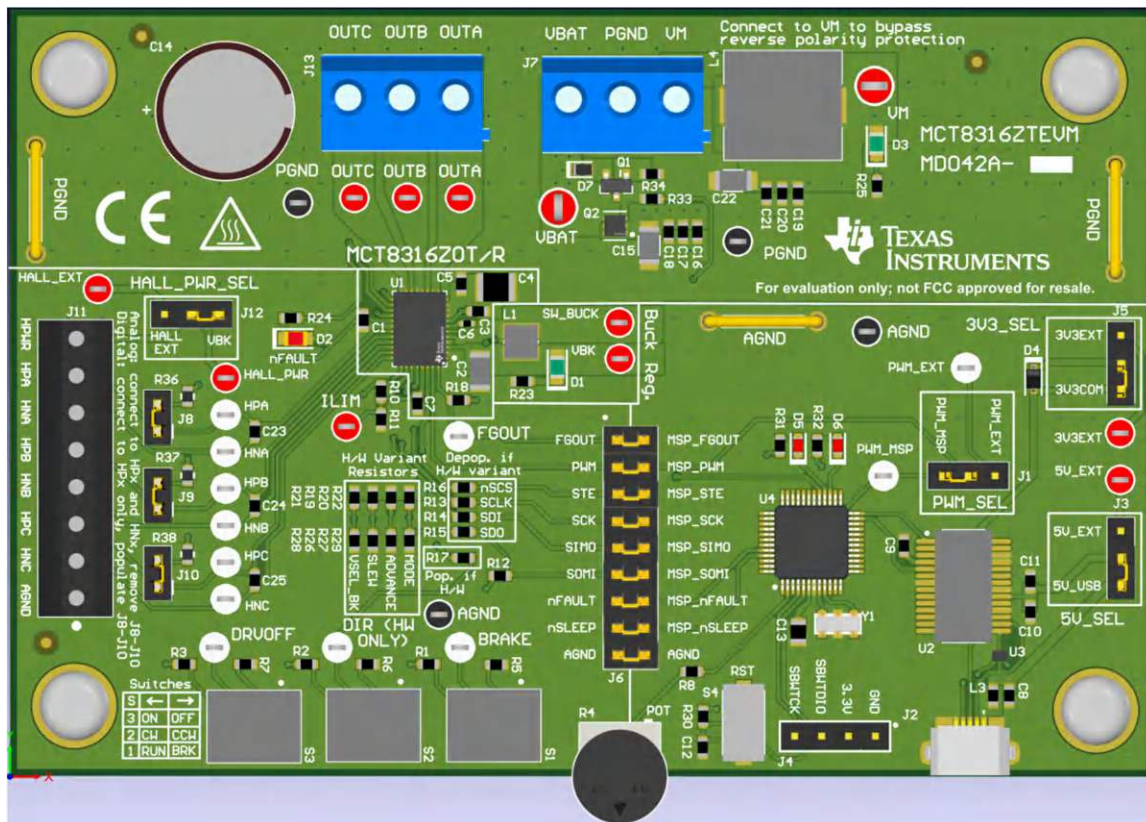


Figure 2-1. MCT8316ZTEVM Printed Circuit Board (PCB - Top View)

3 Quick Start Guide

The MCT8316ZTEVM requires a power supply source, which has a recommended operating range from a 4.5 V to 35 V. To setup and power the EVM, use the following the sequence:

1. Connect motor phases to A, B, and C on connector J13.
2. Connect Hall sensors to J11 and select Hall power supply as 3.3 V from buck or an external Hall supply on J12. Ensure the MODE resistors are set correctly to use the appropriate Hall sensor configuration as described in [Section 4.6](#).
 - a. If using digital Hall inputs, 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 of the MCT8316ZTEVM.
 - b. If using analog Hall inputs, remove J8–J10 and connect differential Hall inputs to HPx and HNx on connector J11.
3. Ensure resistors are populated in H/W variant resistors for desired hardware settings.
4. Do not turn on the power supply yet. Connect the motor supply to VBAT or 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 $VM - 0.7\text{ V}$ less, due to a diode drop in the reverse-polarity protection circuit.
 - b. To disable reverse-polarity protection and the Pi filter, connect to VM.
5. Select J3 to 5V_USB and J5 to 3V3COM to power MSP430 from USB power supply.
6. Connect the micro-USB cable into the computer.
7. Turn the potentiometer fully clockwise to set the motor to zero speed upon powerup.
8. Turn on the motor power supply.
9. Use the potentiometer to control the speed of the motor and the switches to disable the motor driver, change the direction, or apply a brake to the motor. Optionally, use the GUI (as shown in [Section 6](#)) to monitor real-time speed of the motor, put the MCT8316ZT into a low-power sleep mode, and read status of the LEDs.

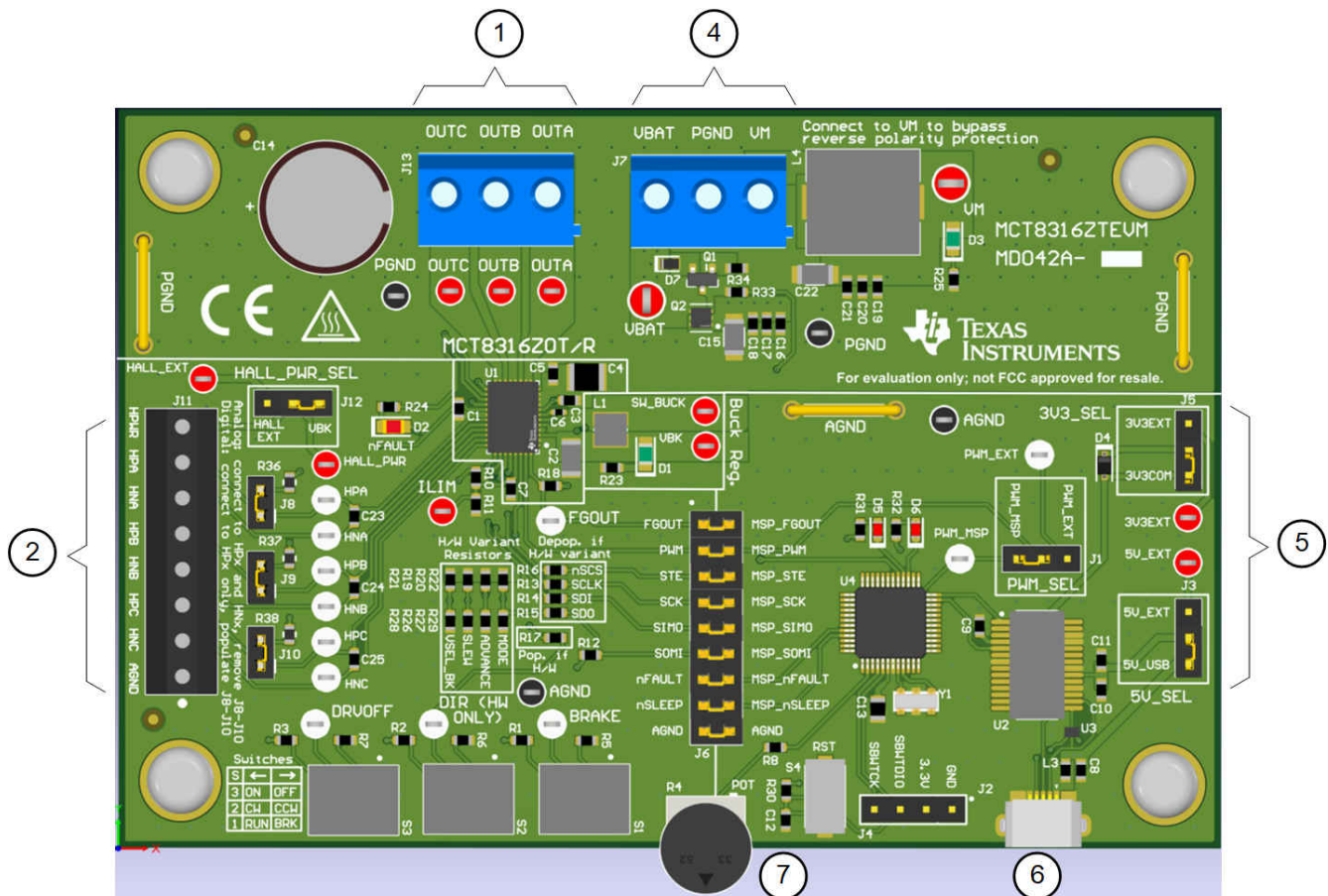


Figure 3-1. Reference for Quick Start Guide

4 Hardware and Software Overview

4.1 Hardware Connections Overview – MCT8316ZTEVM

Figure 4-1 shows the major blocks of the MCT8316ZTEVM evaluation module. The MCT8316ZTEVM is designed for an input supply VBAT from 4.5 V to 36 V. The MCT8316Z includes three integrated half-bridges and implements a sensed trapezoidal algorithm to spin a motor with up to 8-A peak current. It also integrates an adjustable buck regulator and can support many types of Hall sensor configurations or be used to power external circuits.

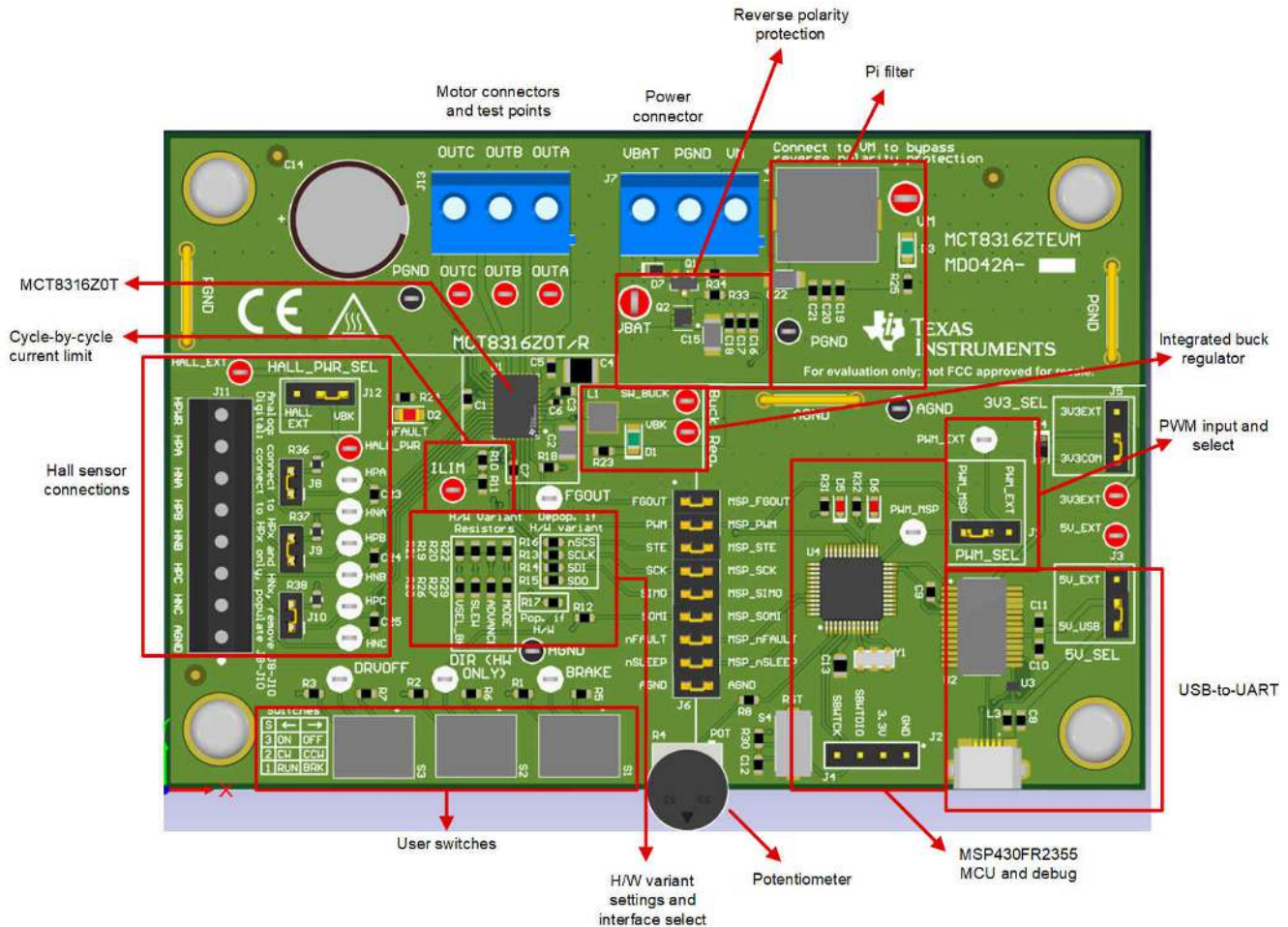


Figure 4-1. MCT8316ZTEVM Major Hardware Blocks

4.2 Connection Details

Figure 4-2 shows the connections made to the MCT8316ZTEVM to spin a 3-phase sensed brushless-DC motor.

A 4.5-V to 36-V power supply or battery is connected to the supply voltage (VBAT) or motor voltage (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 J13 provided on the MCT8316ZTEVM.

Use connector J11 on the MCT8316ZTEVM to connect single-ended digital or analog differential Hall inputs. Use HALL_PWR 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 R8–R10.

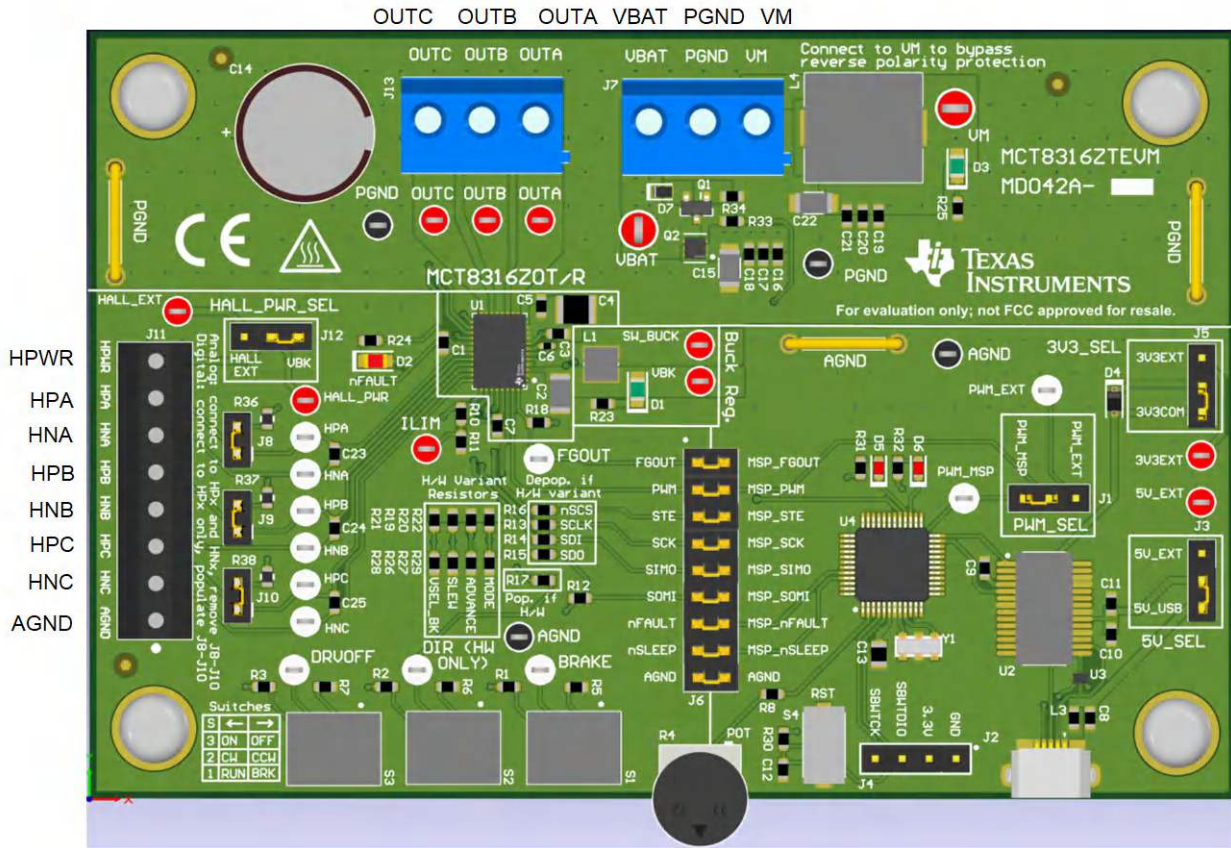


Figure 4-2. Connections from Motor to MCT8316ZTEVM

Figure 4-3 shows where the micro-USB cable is plugged into the MCT8316ZTEVM to provide communication between evaluation module and GUI. The USB data and 5-V power from the USB is converted into UART data and 3.3-V power to power the MSP430FR2355 microcontroller. The 5 V from the USB power is limited to 500 mA by the PC and the 3.3 V from the FTDI chip is limit to 30 mA. 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.

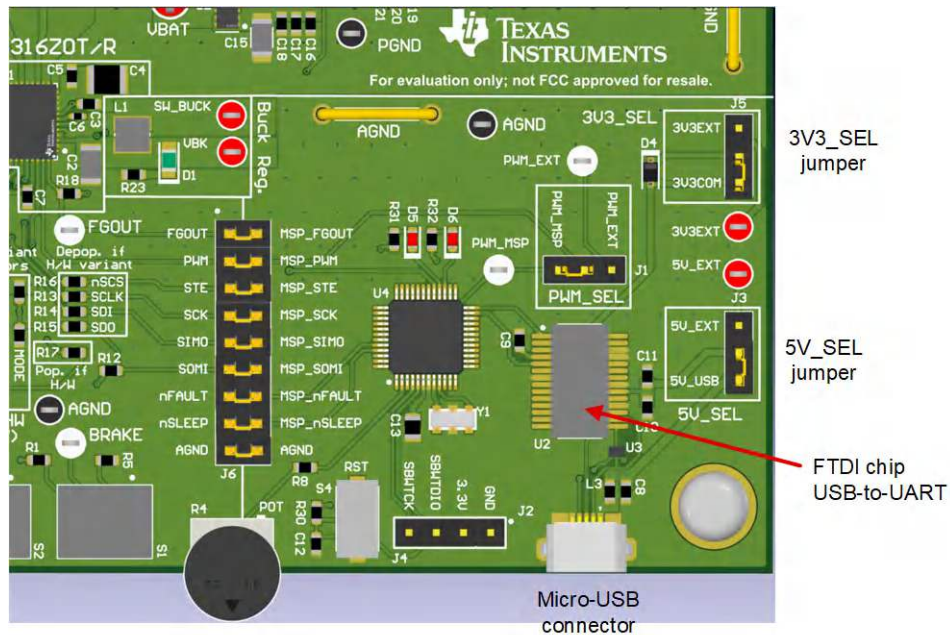


Figure 4-3. Micro-USB Connector and UART for MCT8316ZTEVM

4.3 MSP430FR2355 Microcontroller

The MCT8316ZTEVM includes the MSP430FR2355 low-power MCU (as shown in [Figure 4-4](#)) 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 R4. The motor speed will increase the more the potentiometer is turned counterclockwise, and will decrease when turned clockwise. To select whether the PWM signal from the MSP or an external PWM is sourced to the MCT8316Z, use the PWM_SEL jumper J1.

To program the MSP430FR2355, an external MSP430 LaunchPad™ must be connected to the four-pin connector J4. Many MSP430 LaunchPads provide an onboard eZ-FET Debug Probe to flash the program into the microcontroller and support debug using a 2-pin Spy-by-Wire (SBW).

The user can use the Reset (RST) button at any time to restart the MCU program. Two active-low LEDs, D5 and D6, can be used for debug purposes as well.

Finally, a shunt jumper bridge on 18-pin connector J6 ties all signals between the microcontroller and the MCT8316Z 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 MCT8316ZTEVM as a standalone gate driver with an external microcontroller.

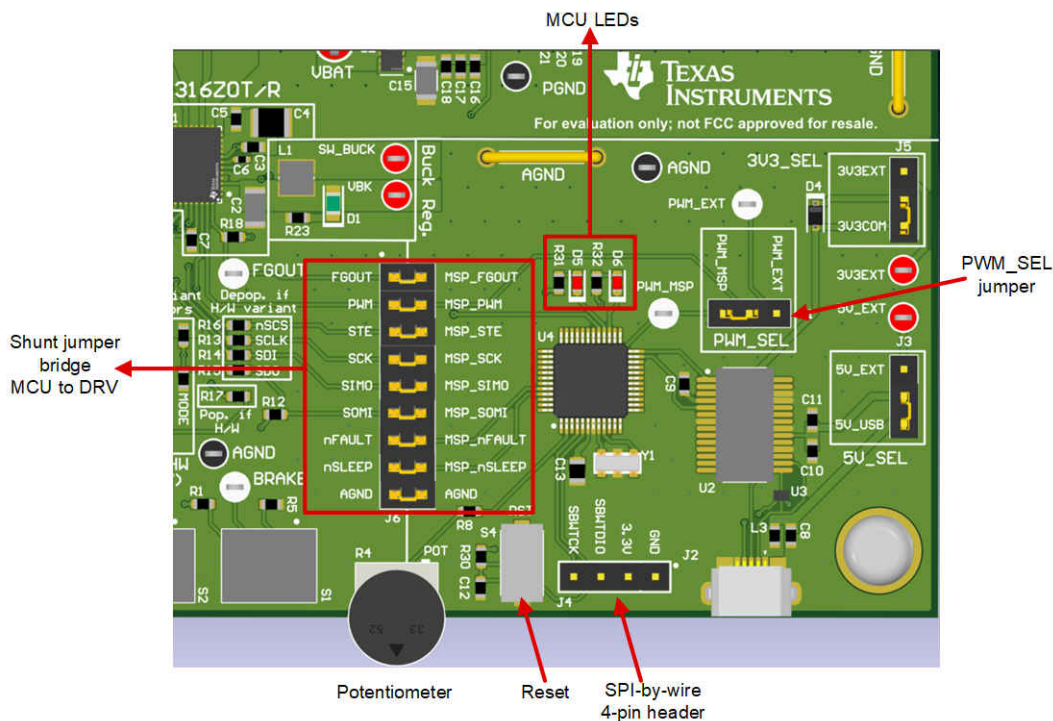


Figure 4-4. MSP430FR2355 MCU on MCT8316ZTEVM

4.4 LED Lights

The MCT8316ZTEVM has 5 status LEDs that provide the status of power supplies and functionalities of the evaluation module. By default, the VM LED and 3.3-V buck LEDs will light up when the board is powered and the program has been flashed onto the microcontroller. [Table 4-1](#) shows LED descriptions including those that are on during power up in bold and [Figure 4-5](#) shows the locations of the LEDs.

Table 4-1. Description of MCT8316ZTEVM LEDs (default in bold after powerup)

Designator	Name	Color	Description
D1	3.3 V	Green	Internal buck regulator is outputting 3.3 V
D2	nFAULT	Red	Lights up when fault condition has occurred on MCT8316Z
D3	VM	Green	Motor power is supplied to the board
D5	MSP_LED0	Red	Used for UART or debugging
D6	MSP_LED1	Red	Used for UART or debugging

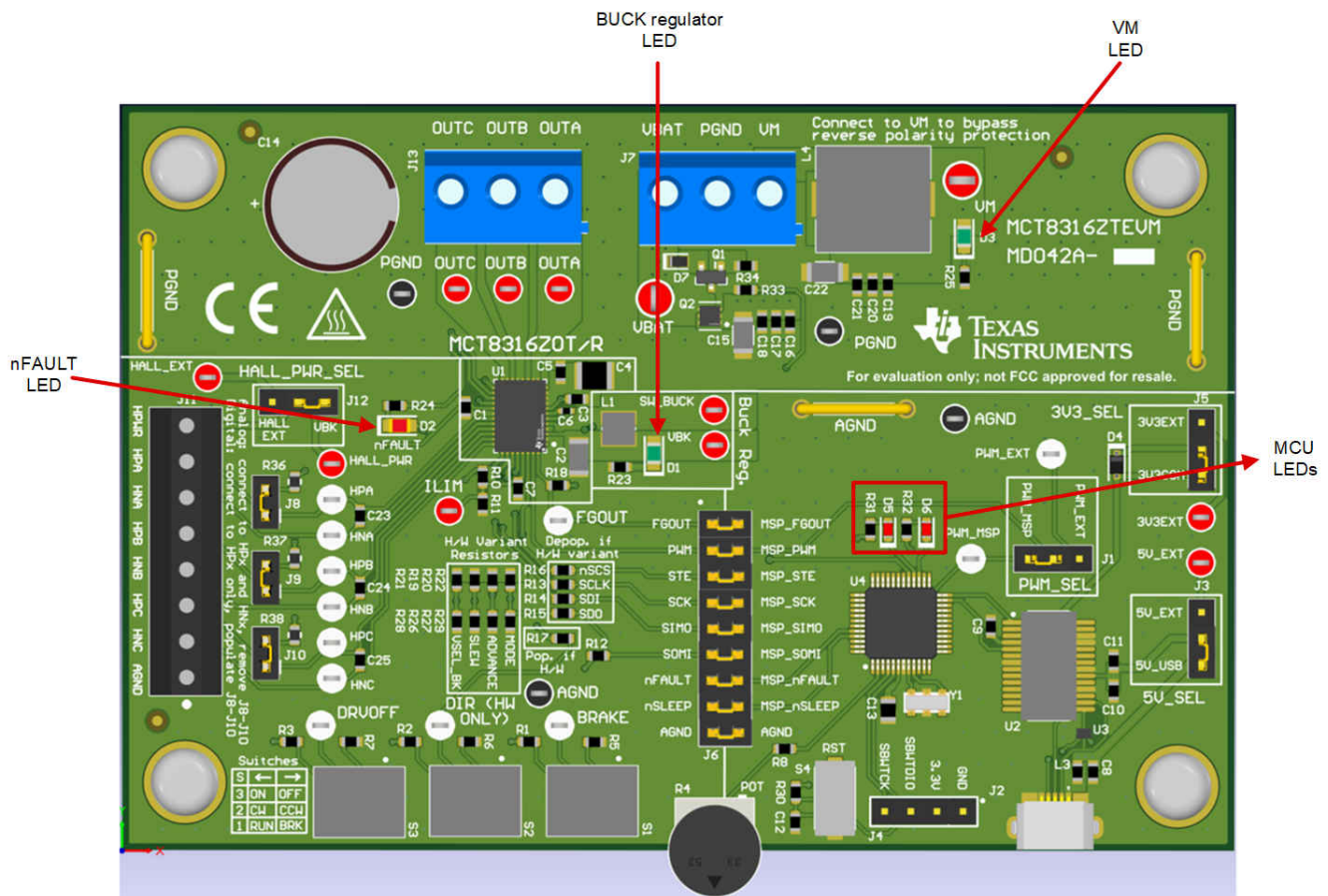


Figure 4-5. MCT8316ZTEVM LEDs

4.5 User-Configurable Settings

The MCT8316ZTEVM includes a variety of user-selectable jumpers, switches, and resistors on the entirety of the evaluation board to configure settings. Table 4-2 summarizes all of these configurable settings.

Table 4-2. Description of User-Selectable Settings on MCT8316ZTEVM (Default in Bold)

Designator	Setting Name	Description	Layer	Position	Function
L1, L2, R1	3.3-V Buck Inductor	User populates L1, L2, or R1 to choose switching component for buck regulator	Top	L1 = 47 μH Inductor	Inductor Mode
			Bottom	L2 = 22 μ H	Inductor Mode
			Bottom	R1 = 22 Ω	Resistor Mode
J5	3V3_SEL	Select 3.3 V for MCU power	Top	J5 = 3V3EXT J5 = 3V3COM	External 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
J12	HALL_PWR_SEL	Selects Hall power source	Top	J12 = HALL_EXT	External Hall power
				J12 = 3.3 V	Hall power from VBK = 3.3 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

Table 4-2. Description of User-Selectable Settings on MCT8316ZTEVM (Default in Bold) (continued)

Designator	Setting Name	Description	Layer	Position	Function
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 MCT8316Z when jumpers are inserted	Top	FGOUT	MSP_FGOUT
				PWM	MSP_PWM
				STE	MSP_STE
				SCK	MSP_SCK
				SIMO	MSP_SIMO
				SOMI	MSP_SOMI
				nFAULT	MSP_nFAULT
				nSLEEP	MSP_nSLEEP
S1	BRAKE	Turns on all low-side MOSFETs	Top	Left	Brake enabled
				Right	Brake disabled
S2	DIR	Controls direction of motor	Top	Left	Clockwise
				Right	Counterclockwise
S3	DRVOFF	Disables gate drivers	Top	Left	MCT8316Z enabled
				Right	MCT8316Z disabled
R10 and R11	ILIM	Resistor divider that sets the cycle-by-cycle current limit (ILIM voltage of AVDD to AVDD - 0.4 sets limit proportionally from 0 to 8 A)	Top	16.2 kΩ (R10)	ILIM = 1.25 V = 8-A limit
				10 kΩ (R11)	

4.6 Hardware Variant Settings

The MCT8316ZT device uses the configurable resistors to control the MODE, SLEW, ADVANCE, and VSEL_BUCK settings.

When using the MCT8316ZT, the SPI enable resistors in the “Depop. if H/W Variant” silk screen box are to be depopulated (R13–R16) and the resistor dividers in the “H/W Variant Resistors” silk screen box are populated with the desired settings (R19–R22 and R26–R29). This setup is shown in [Figure 4-6](#).

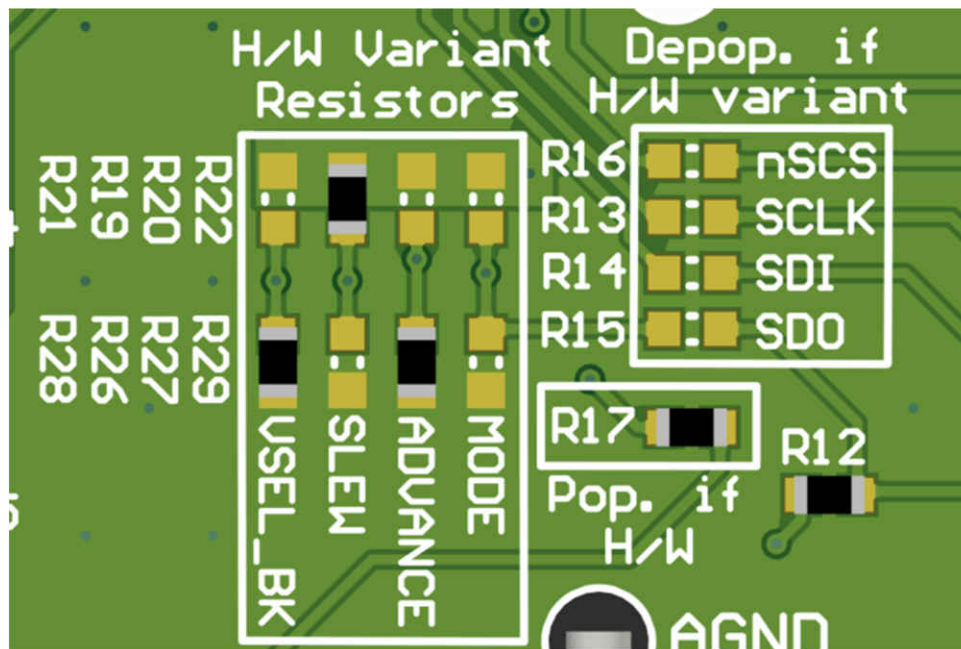


Figure 4-6. Resistor Divider Settings for MCT8316ZT (Hardware Variant)

[Table 4-3](#) shows the user-adjustable resistor divider settings when using the MCT8316ZT. R19–R22 resistors connect to AVDD and R26–R29 resistors connect to AGND. The defaults of the two tables are in bold.

Table 4-3. User-Adjustable Resistor Divider Settings for MCT8316ZT Variant (Defaults in Bold)

Setting	Name	Description	Resistors (AVDD and AGND)	Configuration	Setting
VSEL_BK	V _{BK}	Buck regulator average voltage (L _{BK} = 47 or 22 μH, C _{BK} = 22 μF)	R21 and R28	R28 = 0 Ω	3.3 V
				R21 = R28 = DNP	5.0 V
				R21 = 47 kΩ	4.0 V
				R21 = 0 Ω	5.7 V
MODE	PWM Control Mode	Selects the Hall configuration, modulation, Asynchronous Rectification (ASR), and Automatic Asynchronous Rectification (AAR) settings	R22 and R29	R29 = 0 Ω	Analog Hall Input, Asynchronous modulation, ASR and AAR Disabled
				R29 = 22 kΩ	Digital Hall Input, Asynchronous modulation, ASR and AAR Disabled
				R29 = 100 kΩ	Analog Hall Input, Synchronous modulation, ASR and AAR Disabled
				R22 = R29 = DNP	Digital Hall Input, Synchronous modulation, ASR and AAR Disabled
				R22 = 100 kΩ	Analog Hall Input, Synchronous modulation, ASR and AAR Enabled
				R22 = 22 kΩ	Digital Hall Input, Synchronous modulation, ASR and AAR Enabled
				R22 = 0 Ω	Digital Hall Input, Asynchronous modulation, ASR and AAR Enabled
SLEW	Slew Rate	Phase pin slew rate switching low to high (10-90%) and high to low (90-10%)	R19 and R26	R26 = 0 Ω	25 V/μs
				R19 = R26 = DNP	50 V/μs
				R19 = 47 kΩ	125 V/μs
				R19 = 0 Ω	200 V/μs
ADV	Advance	Advances the lead angle by a selectable value (in electrical degrees)	R20 and R27	R27 = 0 Ω	0°
				R27 = 22 kΩ	4°
				R27 = 100 kΩ	11°
				R20 = R27 = DNP	15°
				R20 = 100 kΩ	20°
				R20 = 22 kΩ	25°
				R20 = 0 Ω	30°

4.7 MCT8316Z0R Compatibility

The MCT8316ZTEVM is also compatible with the MCT8316Z0R (SPI variant) as the featured motor driver IC to spin a three-phase Brushless-DC motor. The MCT8316Z0R replaces the MODE, ADVANCE, SLEW, and VSEL_BK pins with four SPI pins (SDI, SDO, SCLK, nSCS) to configure control registers and read status registers. When using the MCT8316Z0R:

- SPI enable resistors in the “Depop. if H/W” silk screen box are to be **populated** (R13-R16)
- “Pop. If H/W” resistor (R17) is to be **depopulated**
- Resistor dividers in the “Hardware Variant Resistors” silk screen box are to be **depopulated** (R19-R22, R26-R29).

Table 4-4 and Figure 4-7 show the status of populated and DNP resistors for the two compatible MCT8316Zx variants.

Table 4-4. Status of resistors for MCT8316Z0T/R variants (defaults in bold)

Device	Variant	R13-R16 status	R17 status	H/W variant resistors status
MCT8316Z0T	Hardware	DNP	Populated	User Adjustable
MCT8316Z0R	SPI	Populated	DNP	DNP

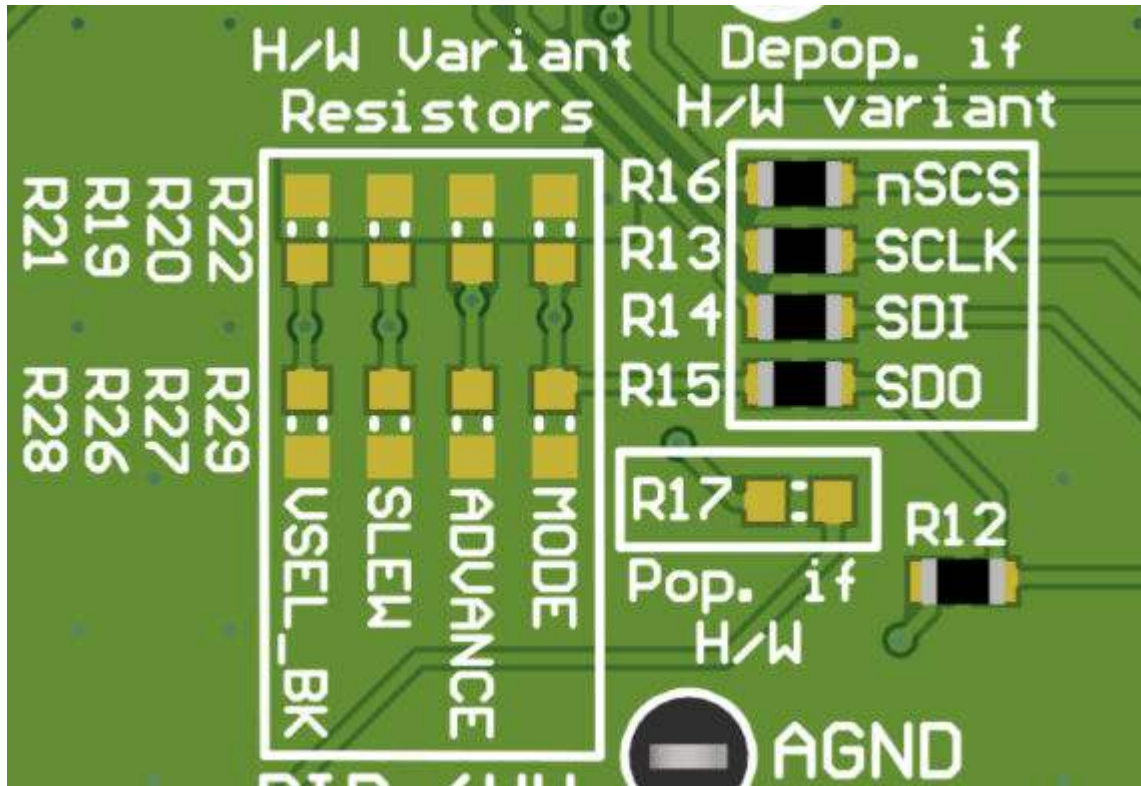


Figure 4-7. Resistors for MCT8316Z0R (SPI variant)

5 Hardware Setup

The hardware required to run the motor is the MCT8316ZTEVM, a micro-USB cable, and a power supply with a DC output from 8 V to 32 V. Follow these steps to start up the MCT8316ZTEVM:

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. Populate the desired resistor settings to the “H/W Variant Resistors” box, see [Table 4-3](#).
3. Apply user-configurable jumper settings. See the [User-Configurable Settings](#) section for more information.
4. Flash the program into the MCU as described in [Section 6](#). Launch the GUI in GUI Composer and disconnect the 4-pin JTAG connections.
5. Connect a micro-USB cable to the MCT8316ZTEVM and computer.
6. Turn on the power supply and power up the PCB.

If using the MCT8316ZTEVM 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.

6 Firmware and GUI Application

The MCT8316ZTEVM implements an internal sensed trapezoidal control algorithm that requires a PWM signal with variable duty cycle to control the speed of the motor. It also outputs an FGOUT signal to monitor the speed of the motor. Finally, the evaluation module includes a backchannel USB-UART interface that communicates to a host PC to monitor the motor real time and configure settings via SPI for the SPI variant of the device.

The MCT8316ZTEVM GUI is available on the [Gallery](#). This GUI monitors the duty cycle of the 20-kHz PWM waveform to control motor speed, the motor speed in revolutions per minute (RPM) based on the motor poles, and controls the nSLEEP signal.

By default, the MSP430 should already contain the user code to run the 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.

To flash user code, you need an external MSP430 LaunchPad that includes the eZ-FET Debug Probe and Code Composer Studio (CCS). This example uses the [MSP-EXP430FR2355 LaunchPad Development Kit](#) to provide the debug probe. Use the following steps to download the code for the MCT8316ZTEVM to use with the GUI.

6.1 Downloading Code Composer Studio and Importing GUI Code

1. Extract the “MCT8316ZTEVM_MSP430FR2355_Firmware_GUI.zip” to a location on the 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 select “Next” to proceed through menus.
 - b. In the “Select Components” window, ensure 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 “MCT8316ZTEVM_MSP430FR2355_Firmware_GUI” folder installed from step 1.
6. Import the project “MCT8316ZTEVM_MSP430FR2355_Firmware_GUI” into your workspace as shown in [Figure 6-1](#).

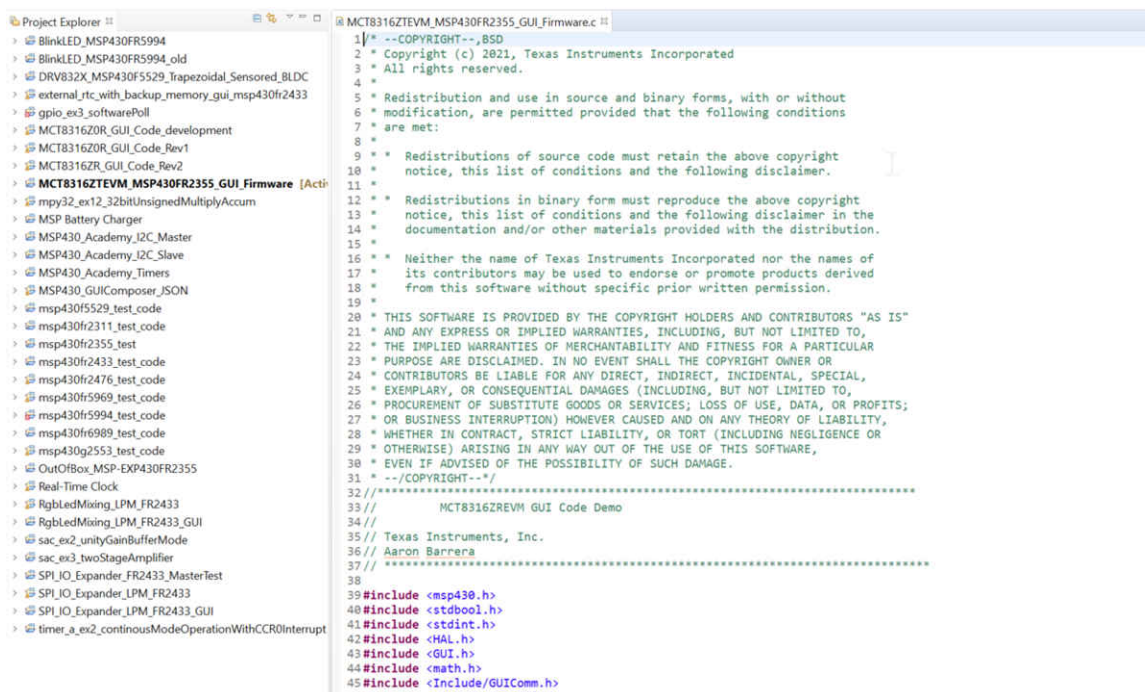


Figure 6-1. MCT8316ZTEVM GUI Code in Code Composer Studio

6.2 Using the eZ-FET to Program the MSP430FR2355

The eZ-FET Debug Probe on the MSP430FR2355 LaunchPad uses a SPI-by-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 MCT8316ZTEVM as shown in [Table 6-1](#) and [Figure 6-2](#).
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 6-1. SPI-by-Wire Connections Needed to Program MSP430FR2355

MSP430 LaunchPad™ (eZ-FET Debug Probe Side) (J101)	MCT8316ZTEVM 4-pin SPI-by-Wire Header (J4)
GND	GND
3V3	3.3V
SBWTDIO	SBWTDIO
SBWTCK	SBWTCK

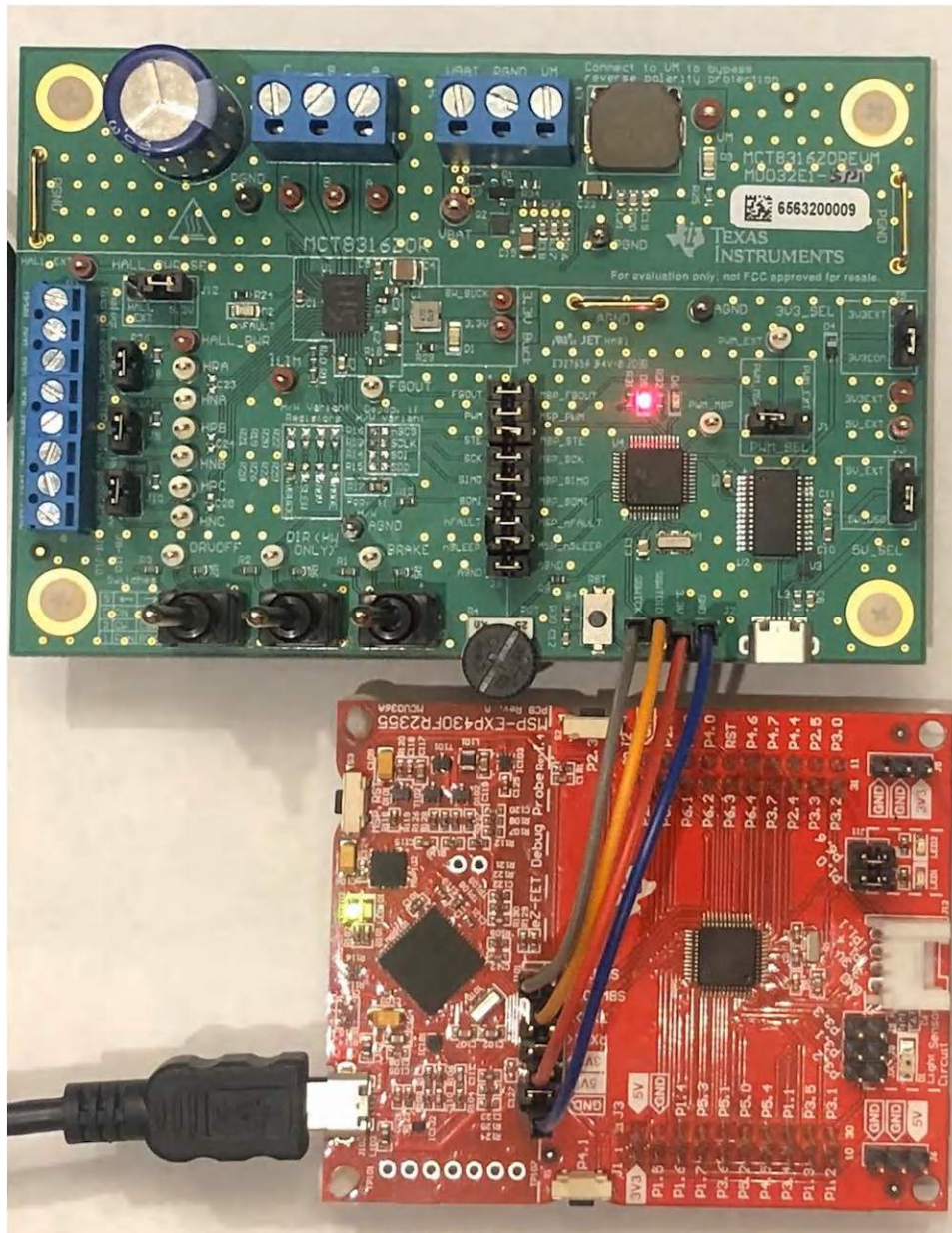



Figure 6-2. MSP430 LaunchPad™ eZ-FET Probe Connected to MCT8316ZTEVM

6.3 Importing GUI into GUI Composer

1. Connect the MCT8316ZTEVM as described in [Section 5](#).
2. Access the [MCT8316ZTEVM GUI](#) through the Gallery.
3. Once the project is loaded, click on the Play button () to launch the MCT8316ZTEVM GUI as shown in [Figure 6-3](#).

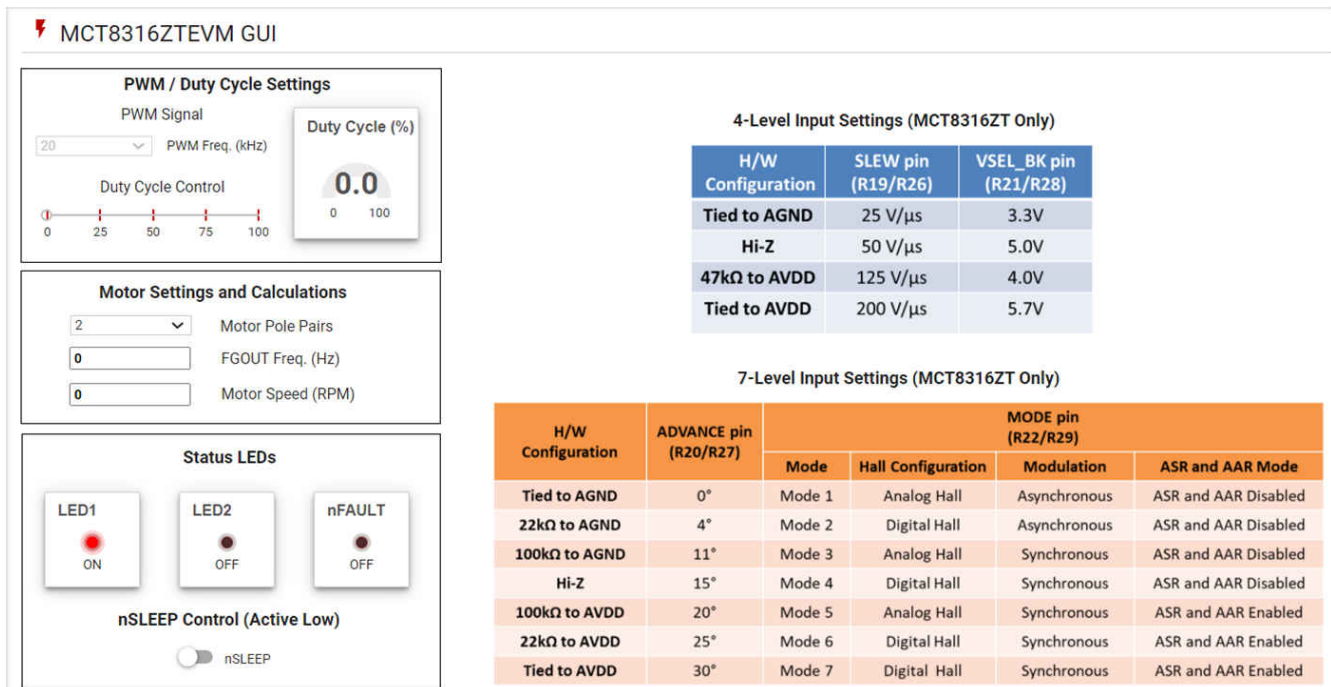


Figure 6-3. MCT8316ZTEVM GUI

6.4 MCT8316ZTEVM GUI

The following features are enabled in the MCT8316ZTEVM GUI:

PWM or Duty Cycle Settings

- Use the potentiometer on the MCT8316ZTEVM to control the duty cycle of the 20-kHz PWM waveform from the MSP430FR2355. The slider and gauge will update 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 Pole Pairs (#)” drop-down box.
- The FGOUT frequency is measured and updated real time in the FGOUT Freq (Hz) box.
- The FGOUT frequency and number of motor poles are used to calculate and update the Motor Speed (RPM) box. The speed is calculated by the *Motor Speed Calculation from FGOUT and Pole Pairs* formula below. Note that the FGOUT frequency is multiplied by 3 to achieve the frequency of one electrical cycle, in Hz.

$$\text{Motor Speed (RPM)} = \frac{60 \times \text{FGOUT} \times 3}{\# \text{ Motor Pole Pairs}} \quad (1)$$

Status LEDs and nSLEEP Control

- The statuses of the programmable MCU LEDs are shown by LED1 and LED2.
- To place the MCT8316Z into a low-power sleep mode, click the nSLEEP button into the right position. The MSP430 sends an active-low signal to nSLEEP on the device.

7 Schematics

Figure 7-1 through Figure 7-10 illustrate the EVM schematics.

7.1 Main Supply and Pi Filter

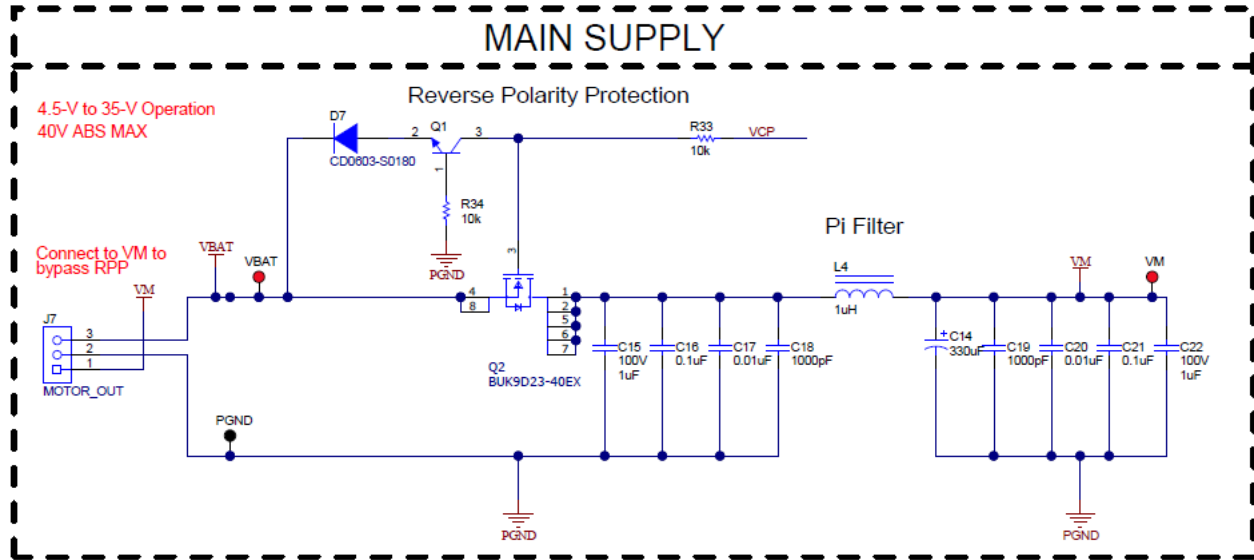


Figure 7-1. Main Supply and Pi Filter Schematic

7.2 Connectors and Interface

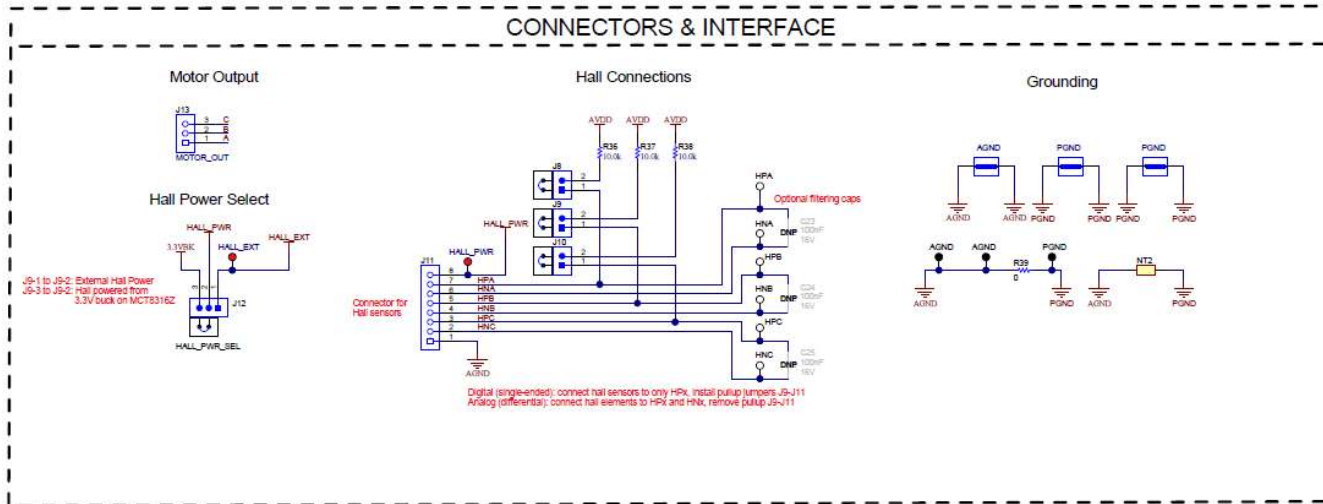


Figure 7-2. Connectors and Interface Schematic

7.3 USB to UART

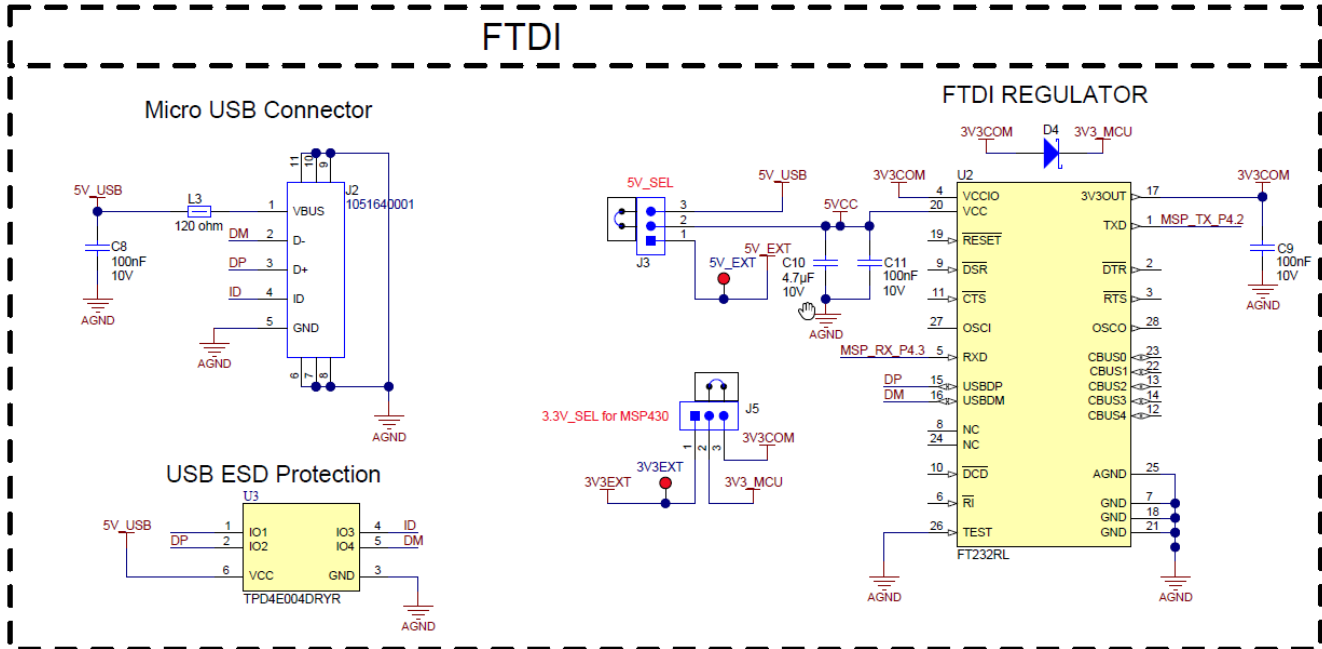


Figure 7-3. USB to UART Schematic

7.4 MCU Programming and Debug

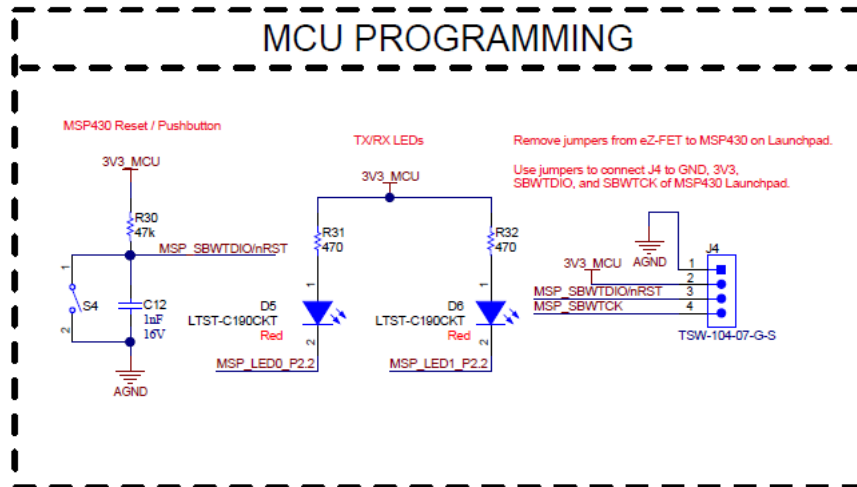


Figure 7-4. MCU Programming and Debug Schematic

7.5 MSP430FR2355 MCU

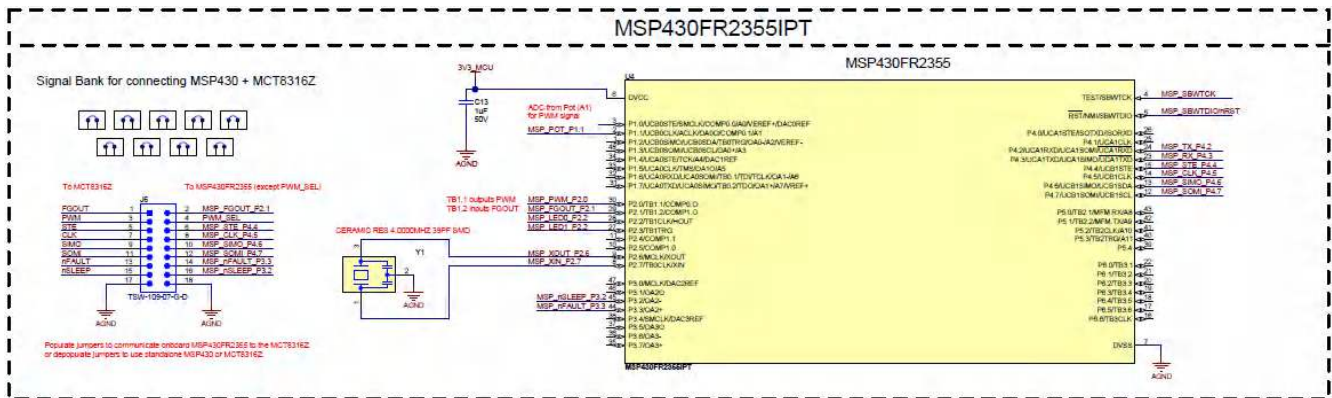


Figure 7-5. MSP430FR2355 MCU Schematic

7.6 MCT8316ZT 3-Phase Sensored Trapezoidal Integrated Driver

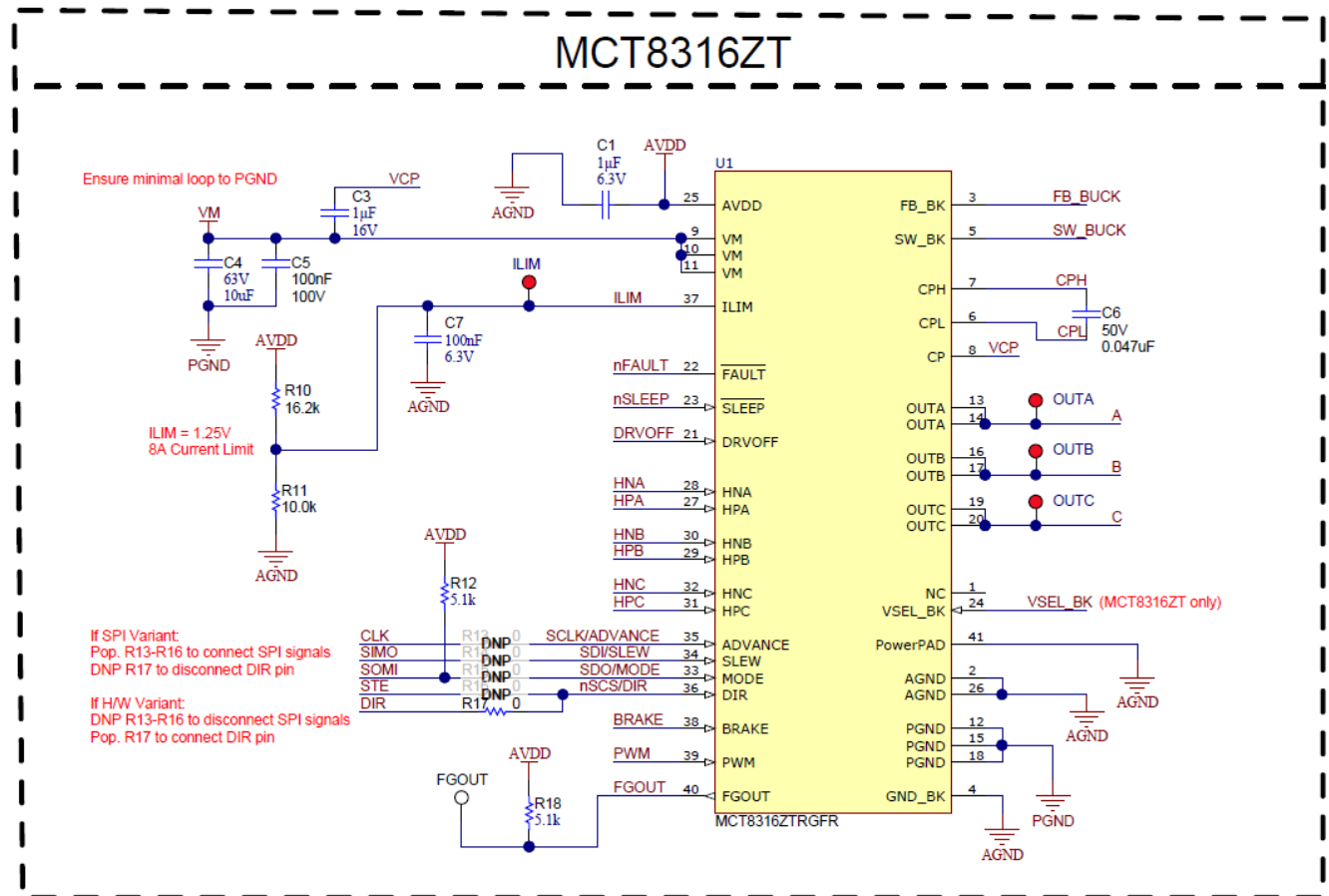


Figure 7-6. MCT8316ZT 3-Phase Sensored Trapezoidal Integrated Driver Schematic

7.7 3.3V Buck Regulator

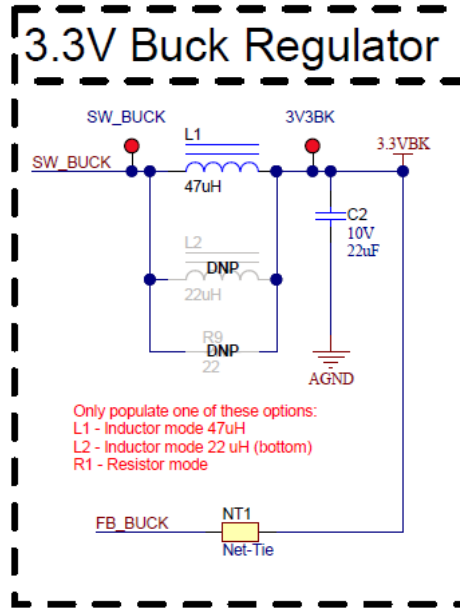


Figure 7-7. 3.3V Buck Regulator Schematic

7.8 Status LEDs

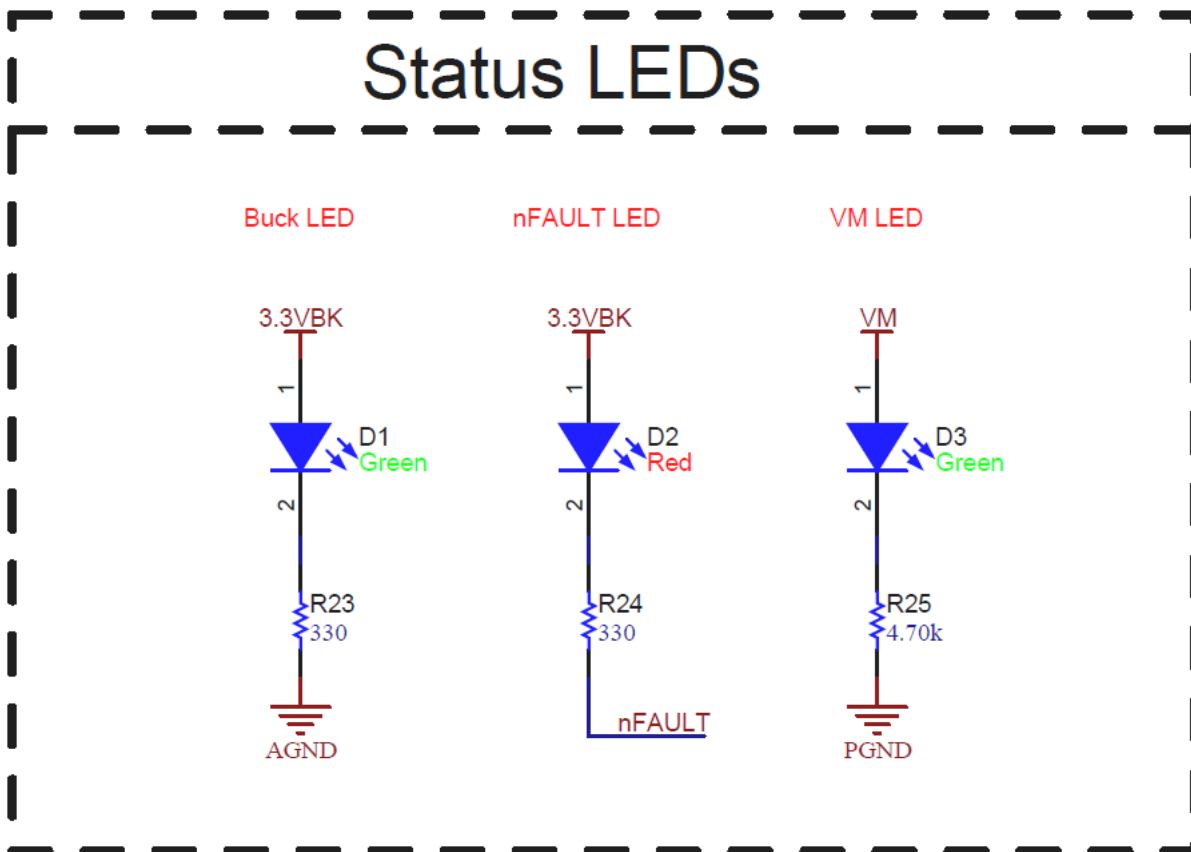


Figure 7-8. Status LED Schematics

7.9 Hardware Variant Settings

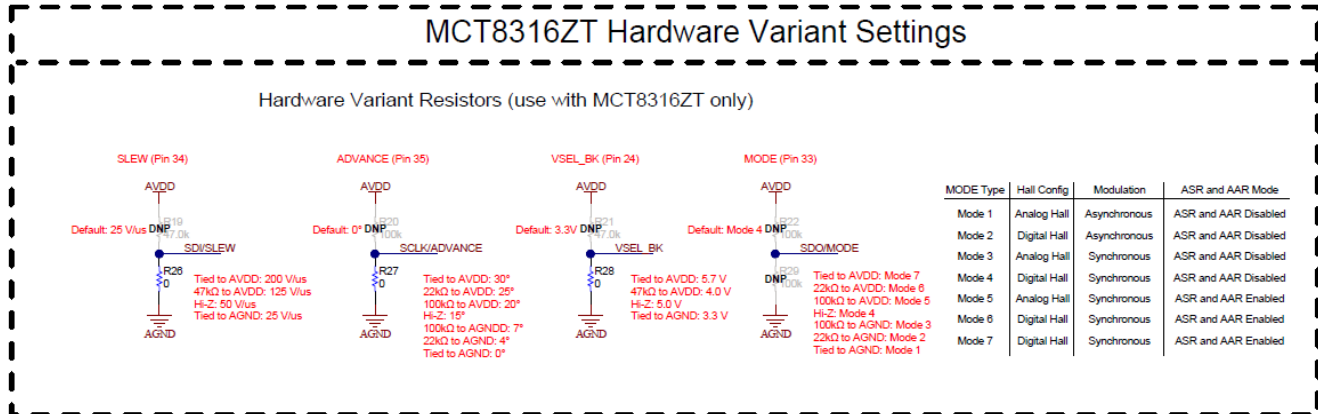


Figure 7-9. Hardware Variant Settings Schematic

7.10 Switches and PWM Input

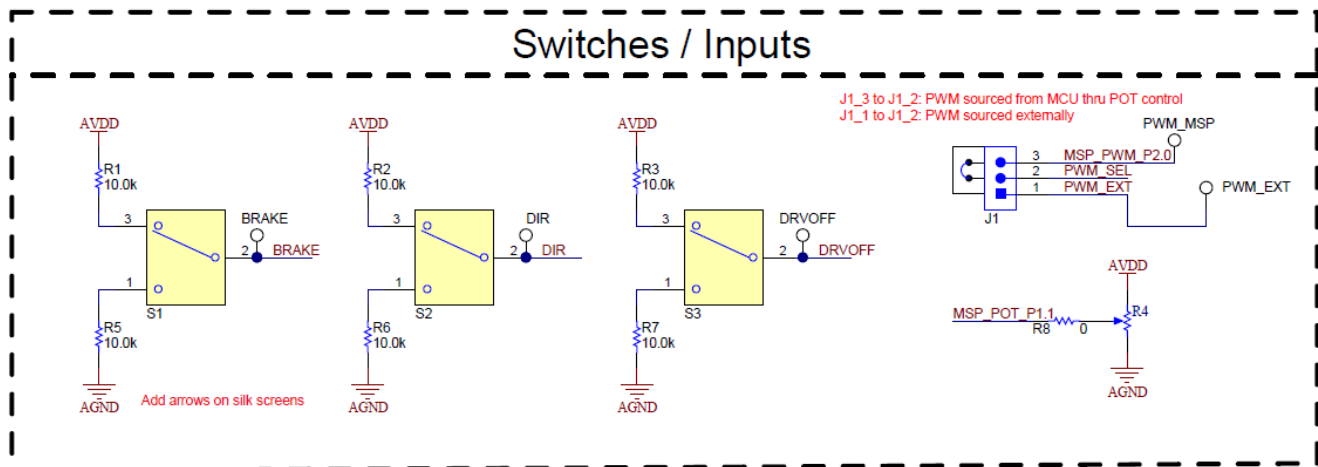


Figure 7-10. Switches and PWM Inputs Schematic

8 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision A (June 2021) to Revision B (August 2022)	Page
• Updated <i>Cautions and Warnings</i> section.....	3
• Added section <i>MCT8316Z0R Compatibility</i>	13
• Updated equation.	19

Changes from Revision * (March 2021) to Revision A (June 2021)	Page
• Added <i>Cautions and Warnings</i> section.....	3
• Updated equation.	19

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