EVM User's Guide: MCF8329HSRRYEVM

MCF8329HSRRY Evaluation Module

Description

The MCF8329HSRRYEVM enables users to evaluate the performance of a 32-pin WQFN packaged MCF8329HS-Q1 motor driver. The evaluation module (EVM) includes an onboard FTDI chip to convert USB communication, from the micro-USB connector, into UART. An onboard MSP430FR2355 microcontroller (MCU) translates the UART communication into either control signals or I2C formatted data, which is sent to the MCF8329HS-Q1. There are many user-selectable jumpers, resistors, connectors, and test points to assist with evaluating the many features of the MCF8329HS-Q1 IC and the configurable device-specific settings.

Get Started

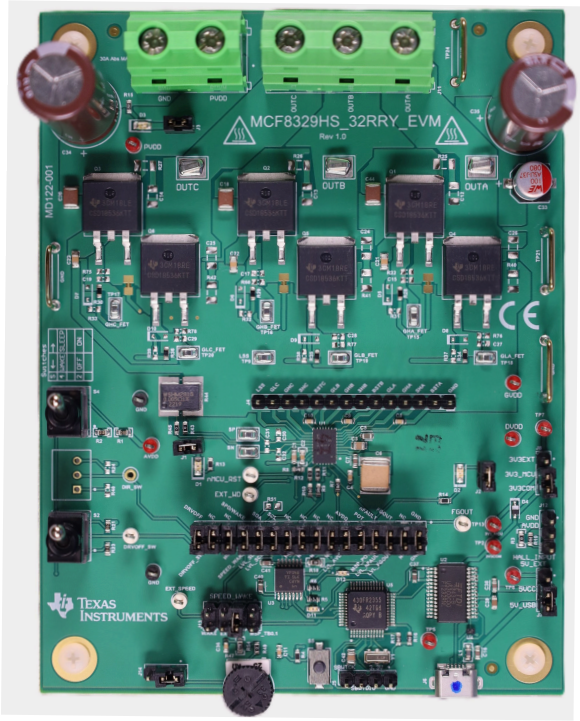
1. Download the latest design files from the MCF8329HSRRYEVM tool page on ti.com.
2. Download the latest version of the Motor Studio GUI and firmware from the MOTORSTUDIO tool page on ti.com.

Features

- GUI software to simplify the MCx tuning process and performance evaluation
- 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 MCF8329HS-Q1 IC with an external MCU or to use the EVM MCU to control an external MCF8329HS-Q1 IC

Applications

- Coolant, water, fuel, and oil pumps
- Automotive body electronics
- Automotive thermal management



MCF8329HSRRYEVM (Top View)

1 Evaluation Module Overview

1.1 Introduction

The user's guide details how to set up, configure, and operate the Motor Studio GUI and MCF8329HSRRYEVM. Throughout this document, the terms evaluation board, evaluation module, and EVM are synonymous with the MCF8329HSRRYEVM. This document also provides information on the operating procedure, input and output connections, an electrical schematic, printed circuit board (PCB) layout drawings, and a bill of materials (BOM) for the EVM.

WARNING

Hot Surface

Contact with marked surfaces can cause burns. Do not touch.

1.2 Kit Contents

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

Table 1-1. Kit Contents

Item	Quantity
MCF8329HSRRYEVM	1
USB-A to USB-B micro-cable	1

1.3 Specification

The MCF8329HSRRYEVM is rated for operation of 60V absolute maximum and currents up to 30A peak. To prevent personal injury, electrical shock hazard, damage to the EVM, or a combination, confirm that the EVM voltage and current specifications are not exceeded.

1.4 Device Information

The MCF8329HS-Q1 is a 4.5V to 60V, three-phase brushless-DC gate driver IC with code-free sensorless field oriented control (FOC) for motor drive applications. The MCF8329HS-Q1 integrates a charge pump and uses bootstrap architecture to drive three high-side and three low-side N-channel MOSFETs with up to 1A peak source and 2A peak sink current. The MCF8329HS-Q1 also integrates a trickle charge pump to support 100% PWM duty cycle.

The internal sensorless FOC algorithm register configuration can be stored in non-volatile EEPROM enabling the device to operate stand-alone once the algorithm has been configured. Motor current is sensed using an integrated current sense amplifier supporting a single external shunt resistor. The device can receive a speed command through a PWM input, analog voltage, variable frequency square wave, or I2C command. There are a large number of protection features integrated into the MCF8329HS-Q1, intended to protect the device, motor, and system against fault events.

Part Number	Firmware Version
MCF8329HSIQRRYRQ1	A

2 Hardware

2.1 Quick Start Guide

The MCF8329HSRRYEVM requires a power supply source, which has a recommended operating range from a 4.5V to 60V. To setup and power the EVM, follow the following sequence:

1. Connect motor phases to A, B, and C on connector J11.
2. Do not turn on the power supply yet. Connect the motor supply to PVDD and GND on connector J10.
3. Select J7 to 5V_USB and J8 to 3V3COM to power MSP430 from USB power supply.
4. Connect the micro-USB cable into the computer.
5. Turn the potentiometer fully counter clockwise to set the motor to zero speed upon power up.
6. Flip the switch S2 to the top to configure DRVOFF = ON, and switch S4 to the bottom to configure WAKE.
7. Set the Jumper J13 to the POT position to apply the analog voltage from potentiometer R47 to the SPEED/ WAKE pin.
8. Turn on the motor power supply.
9. Use the potentiometer R47 to control the speed of the motor and the switches to disable the motor driver. Optionally, use the GUI to monitor the real-time speed of the motor, put the MCF8329HS into a low-power sleep mode, and read the status of the LEDs.

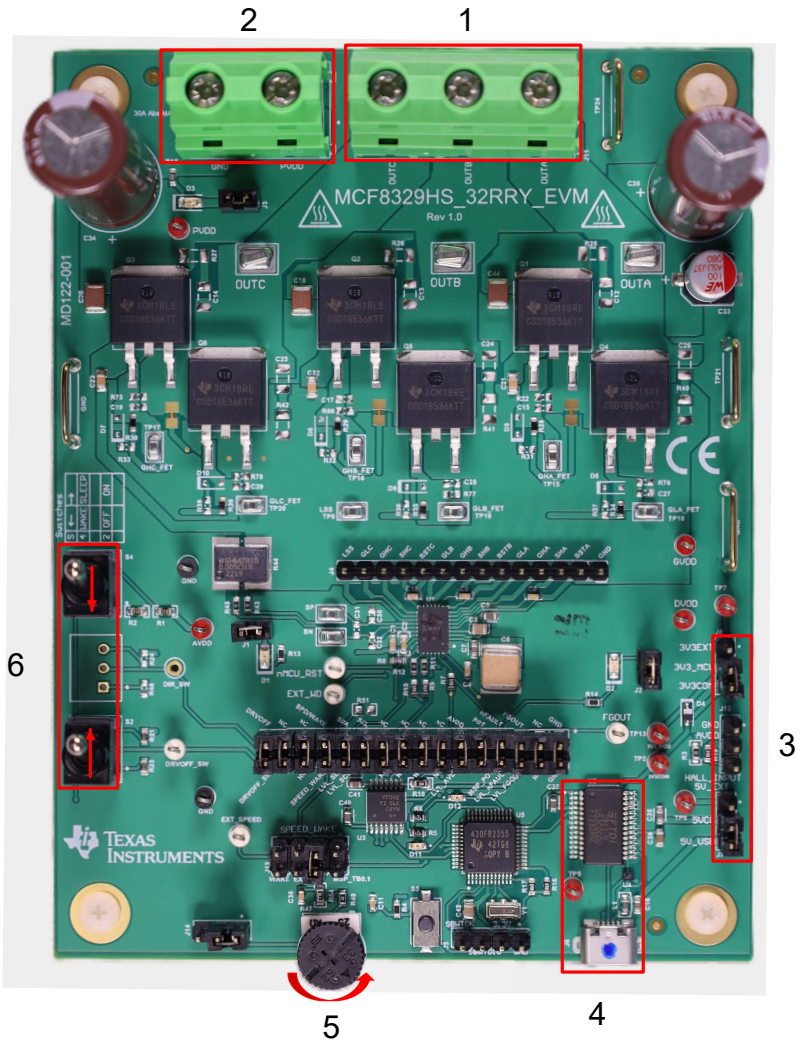


Figure 2-1. Reference for Quick Start Guide

2.2 Hardware Setup

The hardware required to run the motor is the MCF8329HSRRYEVM, a micro-USB cable, and a power supply with a DC output from 4.5V to 60V. Follow these steps to start up the MCF8329HSRRYEVM:

1. Connect the DC power supply to header J10. Connect to PVDD and GND.
2. Set user configurable jumper settings. For more information, see Section 2.7.
3. Turn on the power supply to power up the MCF8329HSRRYEVM.
4. Connect a Micro-USB cable to the MCF8329HSRRYEVM and computer.

If using the MCF8329HSRRYEVM with an external microcontroller, then remove all shunt jumpers from jumper bridge J9. Connect the external MCUs pins to the respective jumpers on the right side of the jumper bridge J9.

2.3 Hardware Connections Overview

Figure 2-2 shows the major blocks of MCF8329HSRRYEVM. The MCF8329HSRRYEVM is designed for an input supply from 4.5V to 60V at 30A maximum. The MCF8329HSRRYEVM includes a power stage with six external N-channel power MOSFETs and supporting passive components including a 5mΩ current sense shunt resistor. For interfacing with the GUI, the MCF8329HSRRYEVM has an onboard FTDI chip and MSP430FR2355.

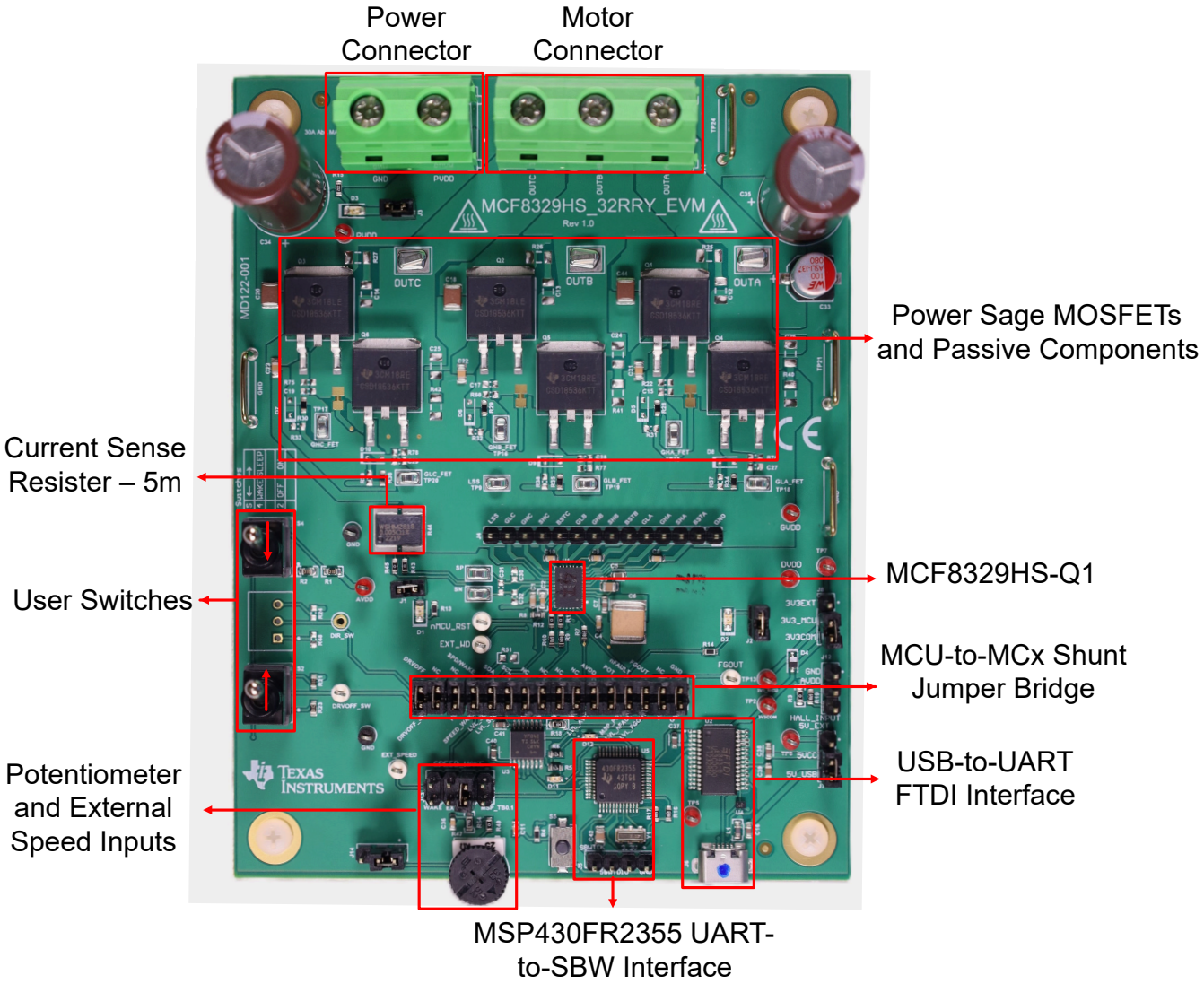


Figure 2-2. MCF8329HSRRYEVM Major Hardware Blocks

2.4 Connection Details

The specific connections that must be made to the MCF8329HSRRYEVM to spin a 3-phase sensorless brushless-DC motor are shown in Figure 2-3.

Connect a 4.5V to 60V power supply to the PVDD and GND terminals on connector J10.

Connect the three phases of the BLDC motor to the A, B, and C terminals of the screw terminal connector J11 or to the OUTA, OUTB, and OUTC test points.

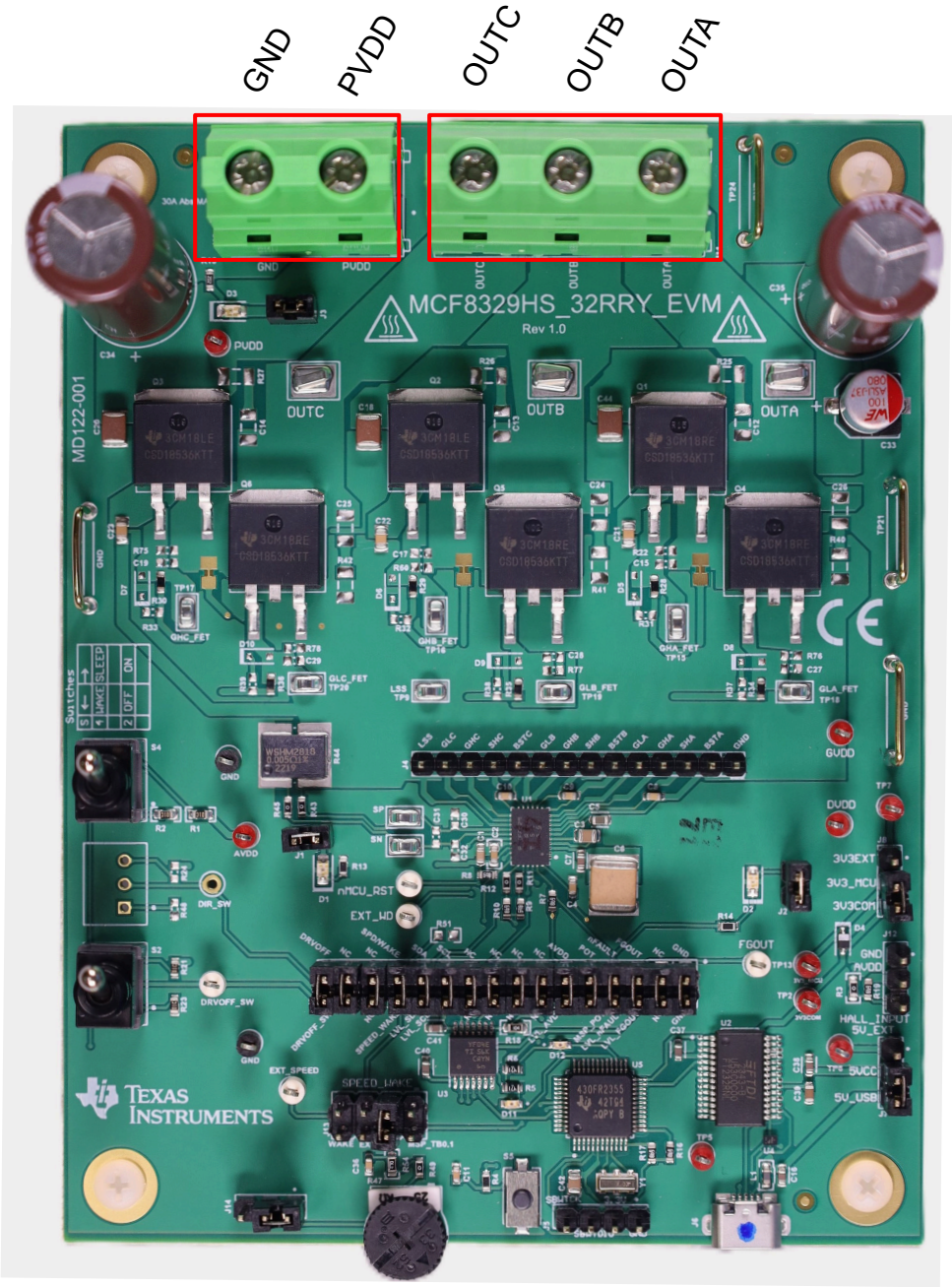


Figure 2-3. Connections from Motor to MCF8329HSRRYEVM

Where the micro-USB cable is plugged into the MCF8329HSRRYEVM to provide communication between evaluation module and GUI is shown in Figure 2-4. The USB data and 5V power from the USB is converted, by the FTDI chip, into UART data and 3.3V power which is used 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. To supply more

current to these power rails, set the 5V_SEL jumper J7 to 5V_EXT and set the 3V3_SEL jumper J8 to 3V3EXT and connect the external supply to the 5V_EXT and 3V3EXT test points.

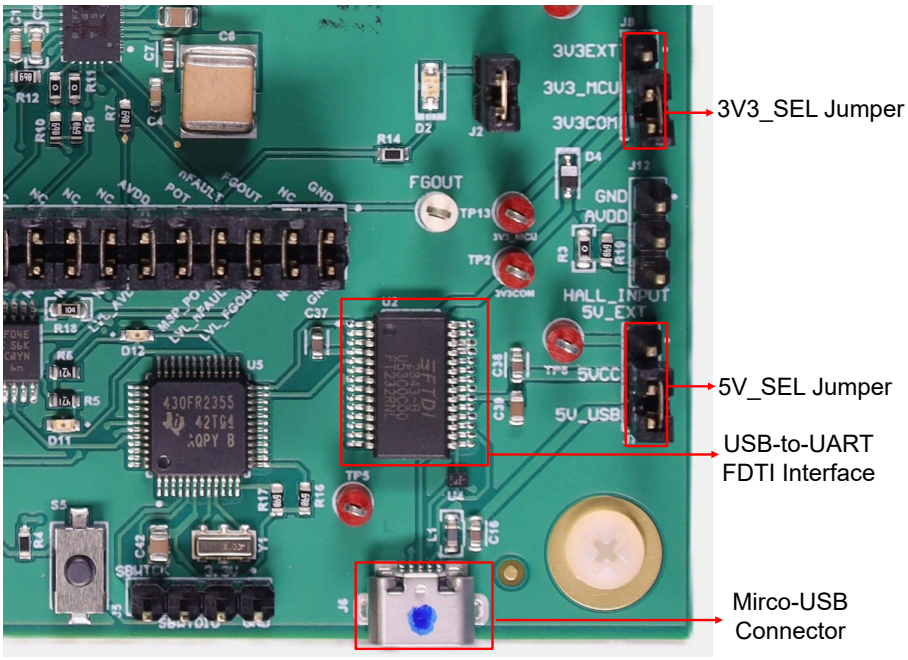


Figure 2-4. Micro-USB Connector and USB-to-UART Interface

2.5 MSP430FR2355 Microcontroller

The MCF8329HSRRYEVM includes a MSP430FR2355 low-power MCU, shown in Figure 2-5, to communicate through I2C with the MCF8329HS-Q1 IC.

To program the MSP430FR2355, an external MSP430 FET programmer must be connected to the Spy-Bi-Wire (SBW) interface connector J5. Many MSP430 LaunchPad™ development kits provide an onboard eZ-FET Debug Probe that can be jumper-wired to the MCF8329HSRRYEVM to flash the firmware into the onboard MSP430FR2355 microcontroller.

Press the Reset (RST) button at any time to restart the MCU program. Two active-low LEDs, D11 and D1, can be used for debug purposes as well.

The 32-pin shunt jumper bridge J9 ties all signals between the microcontroller and MCF8329HS-Q1 IC. These jumpers can be inserted or removed as needed to isolate the microcontroller from the gate driver. This action allows for microcontroller signal debugging or using the MCF8329HSRRYEVM as a standalone gate driver with an external microcontroller.

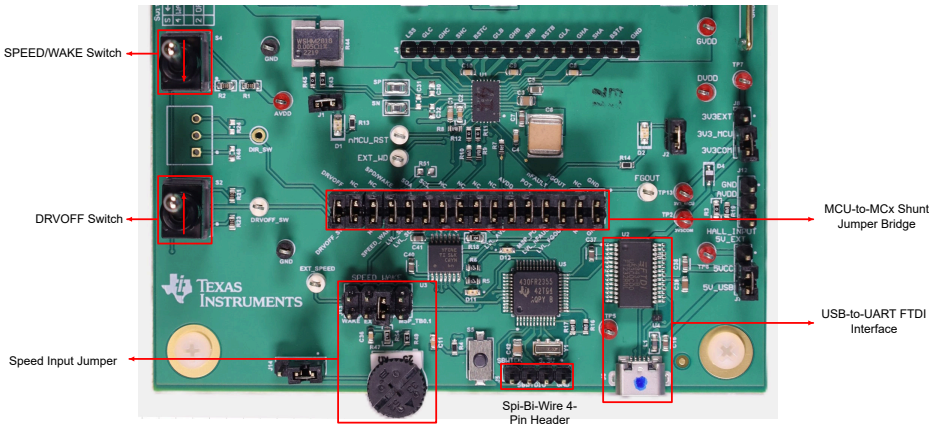


Figure 2-5. MSP430FR2355 MCU on MCF3829RRYEVM

2.6 LED Lights

The MCF8329HSRRYEVM has five status LEDs that provide the status of power supplies and functions of the evaluation module. By default, the PVDD LED and AVDD LED lights up when the board is powered and the program has been flashed onto the microcontroller. Table 2-1 shows LED descriptions including those that are on during power up in bold with Figure 2-6 showing the locations of the LEDs.

Table 2-1. Description of MCF8329HSRRYEVM LEDs

Designator	Name	Color	Description
D1	3.3V	Green	Lights up when AVDD is turned ON
D2	nFAULT	Red	Lights up when fault condition has occurred on MCF8329HS-Q1
D3	PVDD	Green	Lights up when voltage is applied on PVDD
D12	MSP_LED1	Red	Used for UART or debugging
D11	MSP_LED2	Red	Used for UART or debugging

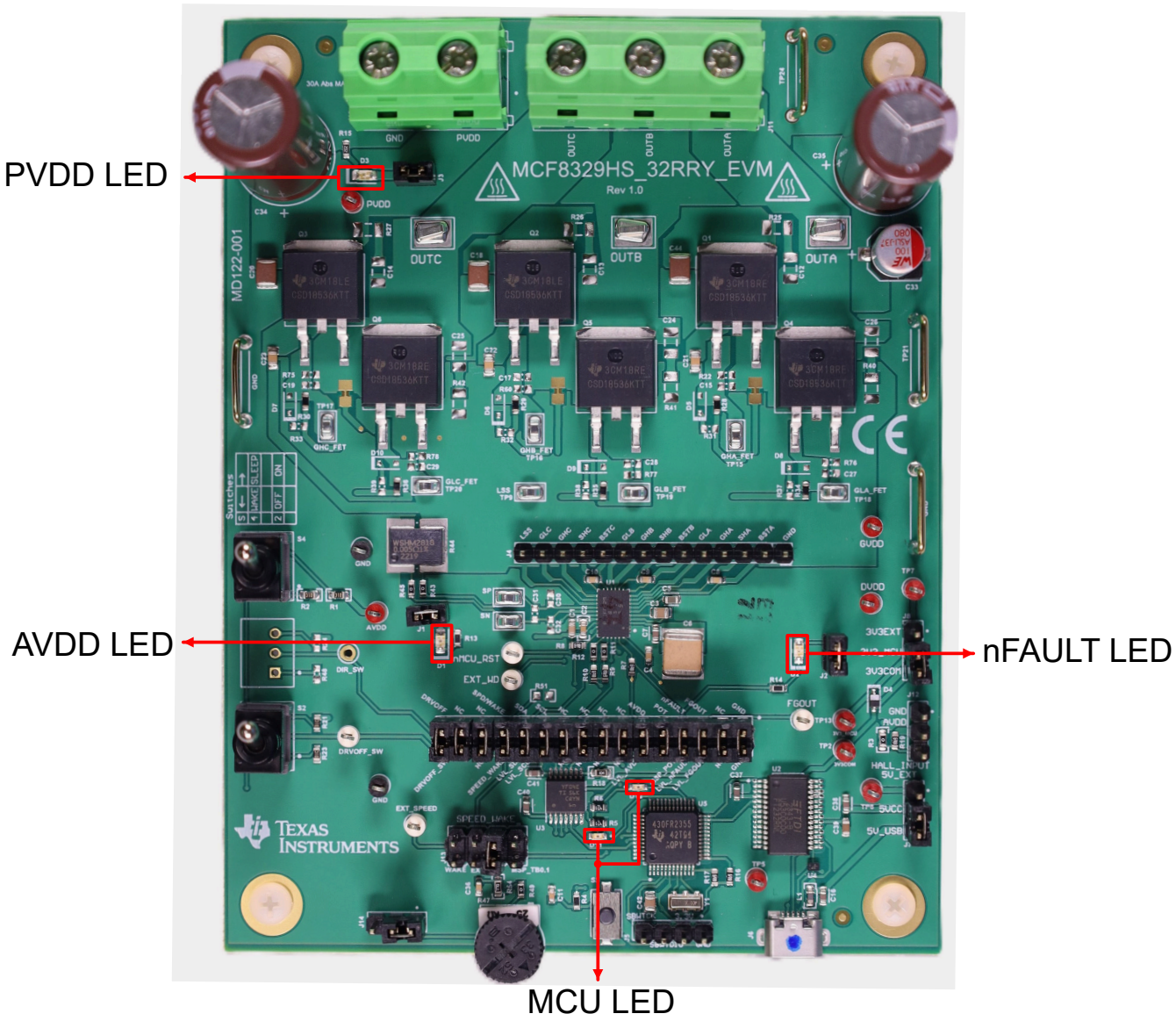


Figure 2-6. MCF8329HSRRYEVM LED Locations

2.7 User Configurable Settings

The MCF8329HSRRYEVM includes a variety of user-selectable jumpers, switches, and resistors on the entirety of the evaluation board to configure settings. Table 2-2 lists a summary all of these configurable settings.

Table 2-2. Description of User-Selectable Settings on MCF8329HSRRYEVM

Designator	Setting Name	Description	Layer	Position	Function
J8	3V3_SEL	Select 3.3V source for MCU power	Top	J8 = 3V3EXT	External
				J8 = 3V3COM	From FTDI (30mA)
J7	5V_SEL	Select 5V source for FTDI power	Top	J7 = 5V_EXT	External
				J7 = 5V_USB	From USB power (500mA)
J13	SPEED_SEL	Selects SPEED input source	Top	J13 = I2C	From S4 switch
				J13 = EXT	External EXT_SPEED test point
				J13 = POT	From Potentiometer R47
				J13 = INT_PWM	From internal PWM. PWM Duty cycle can be varied by rotating the POT R47
J9	MSP to MCx Shunt jumper bridge	Connects signals from MCU and user switches to MCF8329HS-Q1 when jumpers are inserted	Top	DRVOFF_SW	DRVOFF
				NC	NC
				NC	NC
				SPEED_WAKE	SPEED/WAKE
				MSP_SCL	SCL
				MSP_SDA	SDA
				NC	NC
				NC	NC
				NC	NC
				NC	NC
				LVL_AVDD	AVDD
				MSP_POT	POT
				LVL_nFAULT	nFAULT
				LVL_FGOUT	FGOUT
				NC	NC
				GND	GND
J12	HALL sensor input	External Hall sensor connection	Top	J12 = HALL_INPUT	Hall sensor input
				J12 = AVDD	AVDD
				J12 = GND	GND
J14	POT supply	POT supply selection jumper	Top	J14 = 3V3_MCU	3V3_MCU is connected to POT
				J14 = AVDD	AVDD is connected to POT
J1	AVDD LED	Connects AVDD LED to 3.3V pullup	Top	Connected	D1 lights up when AVDD is turned ON
J2	nFAULT LED	Connects nFAULT LED to 3.3V pullup	Top	Connected	D2 Lights up when nFAULT is pulled low
J3	PVDD LED	Connects PVDD LED to 3.3V pullup	Top	Connected	D3 lights up when voltage is applied to PVDD
S2	DRVOFF	Disables gate drivers	Top	Bottom	MCF8329HS-Q1 Disabled
				Top	MCF8329HS-Q1 Enabled
S4	SPEED/WAKE	Pulls SPEED/WAKE pin High or Low. Used to keep MCF8329HS-Q1 awake and not idle when in I2C speed mode.	Top	Bottom	Pulls Speed/WAKE pin LOW
				Top	Pulls SPEED/WAKE pin High

3 Software

3.1 Firmware and GUI Application

The MCF8329HSRRYEVM includes a FTDI chip and MSP4302355 microcontroller which serve as a communication bridge between the host PC and the MCF8329HS-Q1 device for configuring various device settings and reading fault diagnostic information. Using this communication interface, the MC8329RRYEVM can connect to the Motor Studio GUI to configure the MCF8329HS-Q1. The Motor Studio GUI simplifies the tuning process of the MCF8329HS-Q1 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.

By default, the onboard MSP430FR2355 already contains the 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 3.4.

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

3.2 Downloading and Running Motor Studio

1. Connect the MCF8329HSRRYEVM as described in Section 2.2.
2. Download the latest version of the Motor Studio GUI.
3. Run the Motor Studio GUI application after the Motor Studio GUI is installed.
4. Click the *Setup Now* button and follow the instructions to set up the EVM.
5. Click on *Quick Spin* to begin configuring the device after setting up the MCF8329HSRRYEVM.

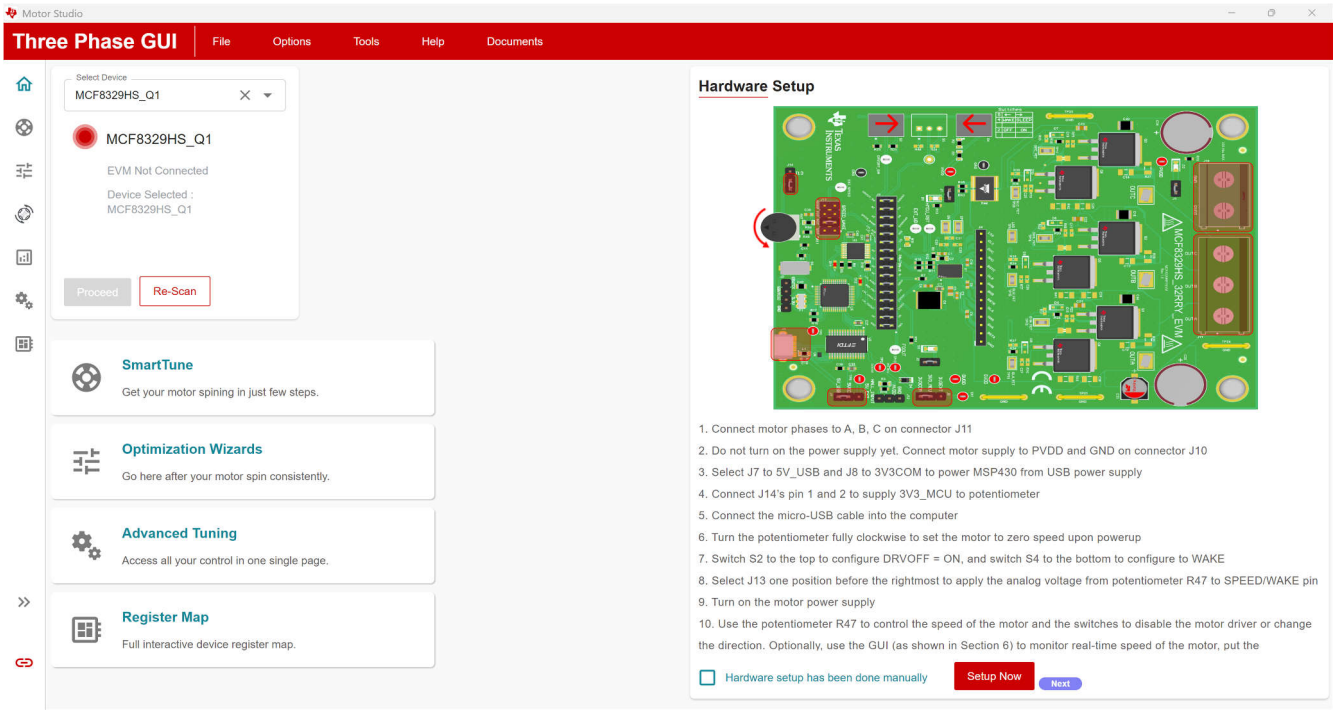


Figure 3-1. Motor Studio GUI MCF8329HS-Q1 Home Page

3.3 Downloading Code Composer Studio™ IDE and Importing GUI Firmware

1. Download and extract the Motor Studio firmware to a location on your computer.
2. Download the latest version of Code Composer Studio IDE to set up a folder in the directory C:\ti.
   a. Accept all agreements, default install instructions, and select *Next* to proceed through the menus.
   b. In the *Selected Components* window, make sure to check *MSP430 Low-Power MCUs* to install the required packages for the MSP430 Launchpad development 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 into your workspace as shown in Figure 3-2.

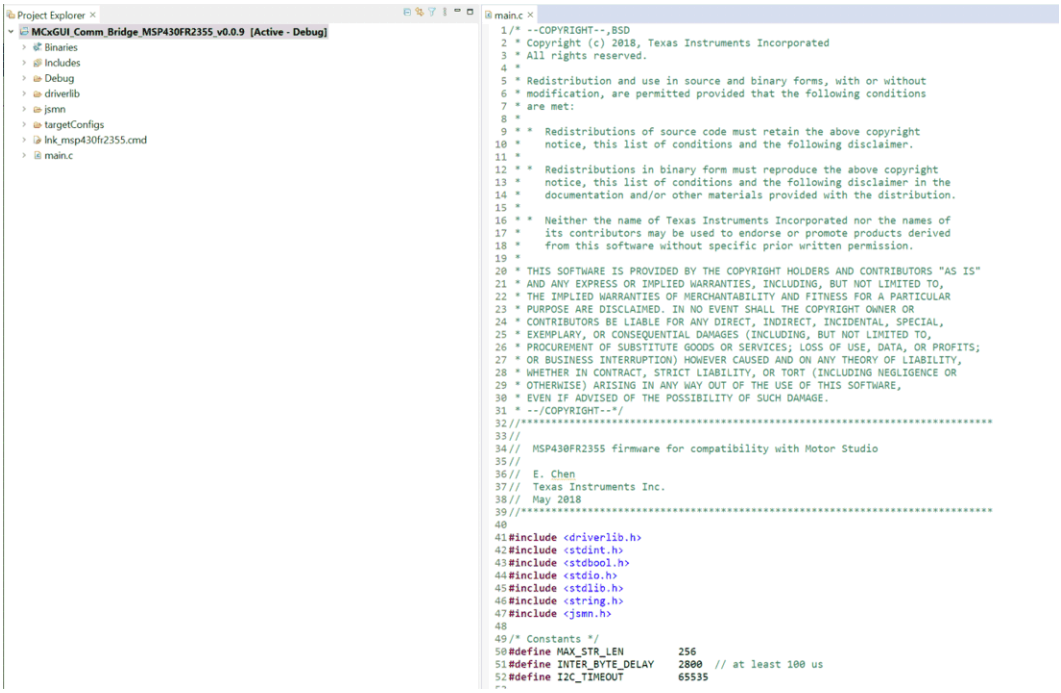


Figure 3-2. MSP430FR2355 Interface Firmware Code in Code Composer Studio™ IDE

3.4 Using eZ-FET to Program the Onboard MSP430FR2355

The eZ-FET Debug Probe on the MSP430FR2355 LaunchPad development kit uses a Spy-Bi-Wire JTAG interface to program the MSP430FR2355 MCU on the MCF8329HSRRYEVM. Consult the MSP430 Launchpad Development Kits for MSP430 Launchpad development kit to include an onboard eZ-FET Debug Probe.

1. Remove the GND, 3V3, SBWTDIO, and SBWTCK jumpers from the MSP430 LaunchPad development kit.
2. Connect the top pins on the eZ-FET side of the LaunchPad development kit of the GND, 3V3, SBWTDIO, SBWTCK signals to the respective pins on J5 of the MCF8329HSRRYEVM as shown in Table 3-1 and Figure 3-3.
3. Connect a micro-USB cable to the MSP430 LaunchPad development kit 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 IDE, disconnect the Spy-Bi-Wire jumpers, and unplug the micro-USB cable from the MSP430 LaunchPad development kit.

Table 3-1. Spy-Bi-Wire Connections Needed to Program the MSP430FR2355

MSP430 LaunchPad™ Development Kit (eZ-FET Debug Probe Side) (J101)	MCF8329HSRRYEVM 4-pin Spy-Bi-Wire Header (J5)
GND	GND
3V3	3V3
SBWTDIO	SBWTDIO
SBWTCK	SBWTCK

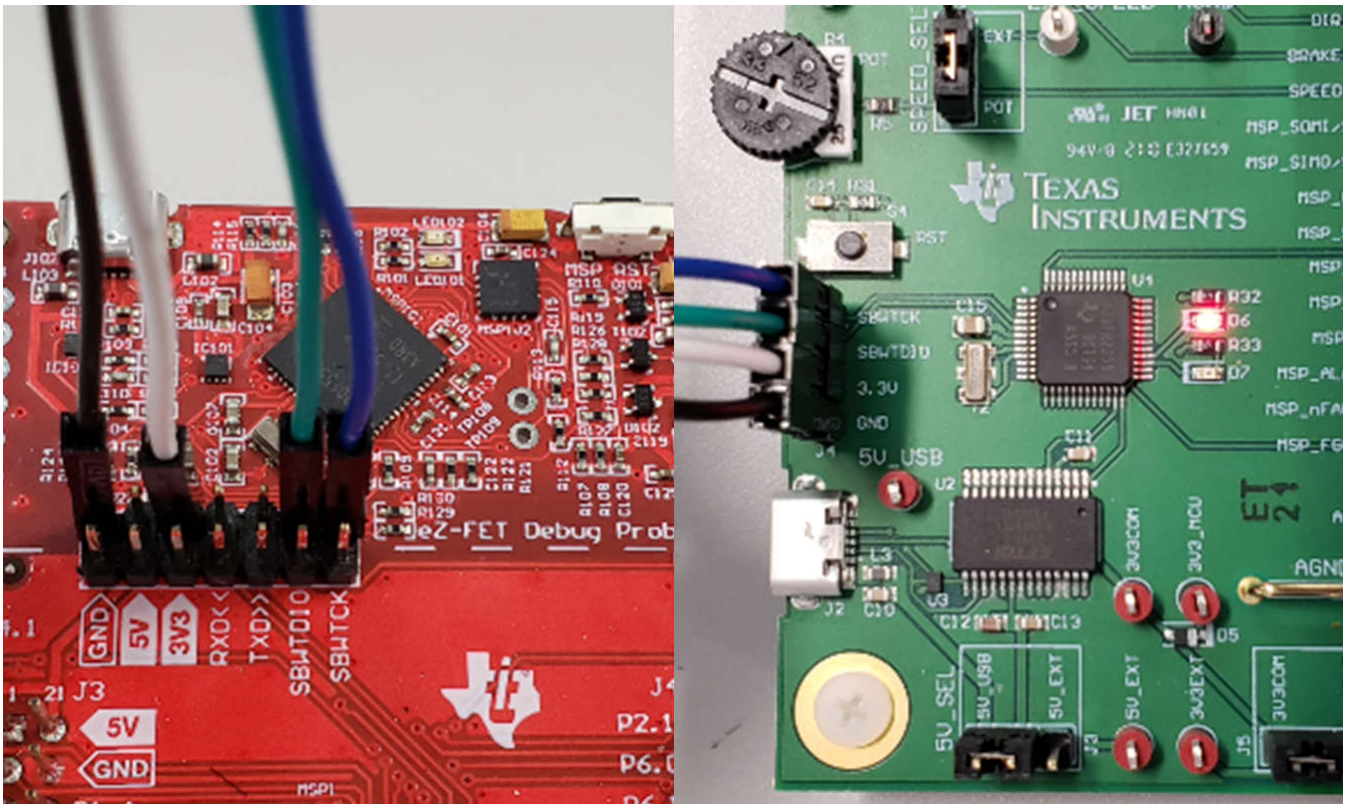


Figure 3-3. MSP430 LaunchPad™ Development Kit eZ-FET Debug Probe Connected to MSP430FR2355

4 Hardware Design Files

4.1 Schematics

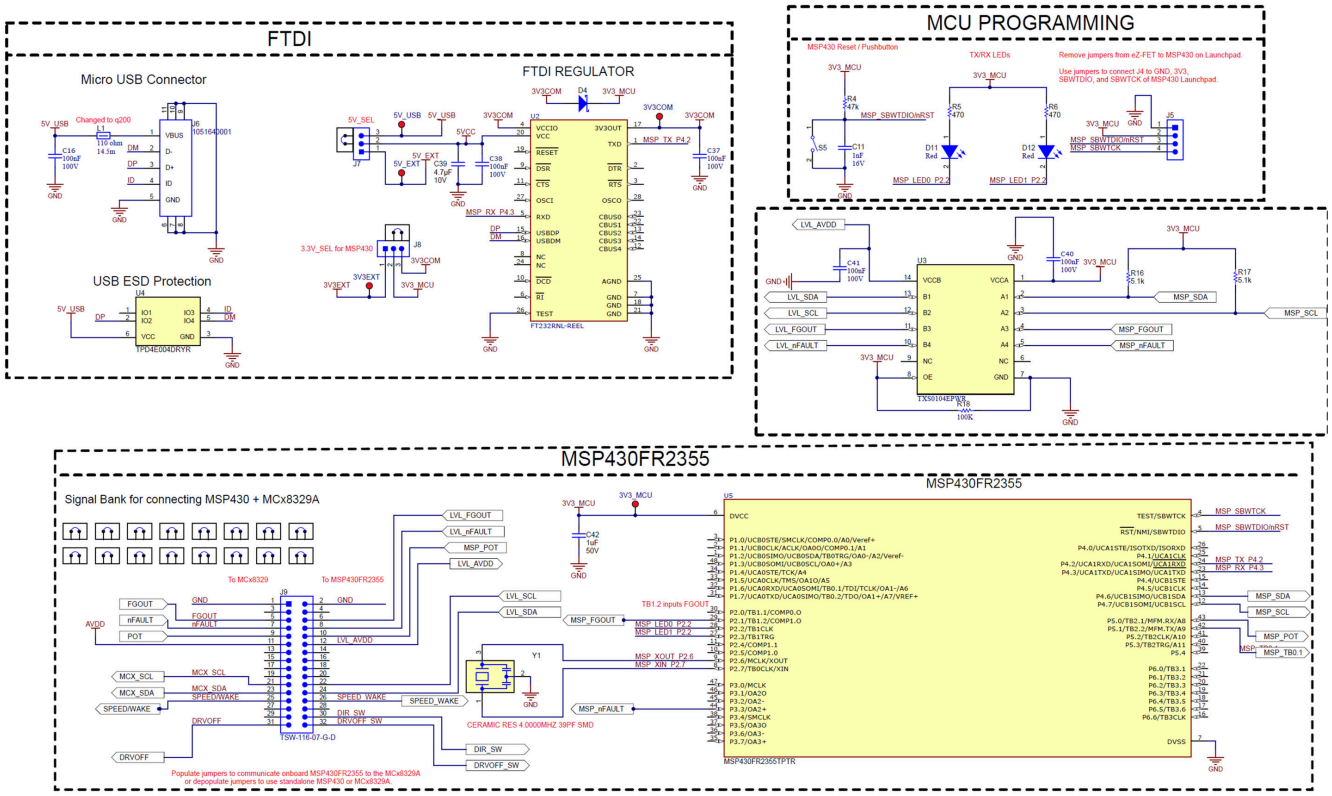


Figure 4-1. Interfaces

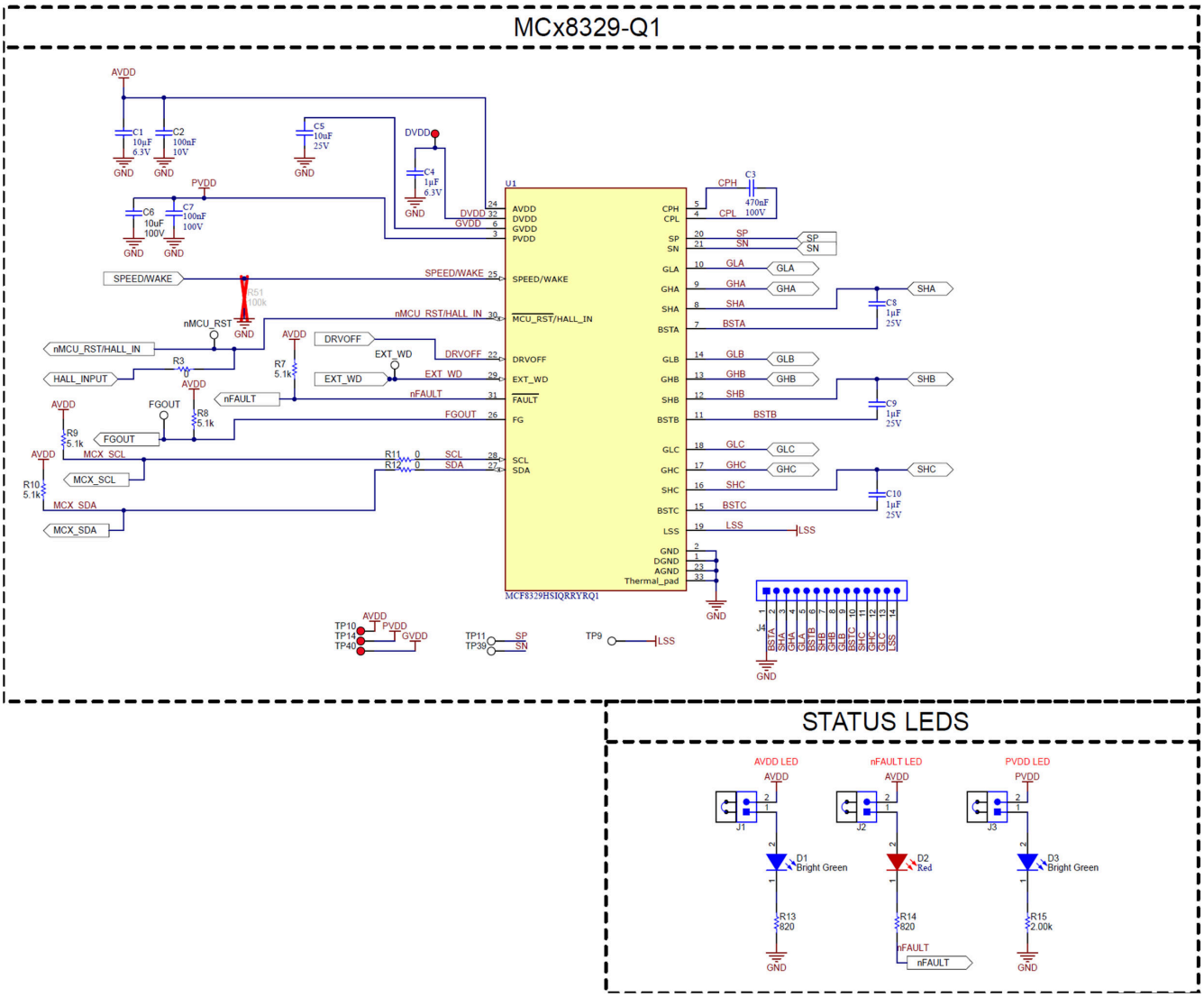


Figure 4-2. Driver

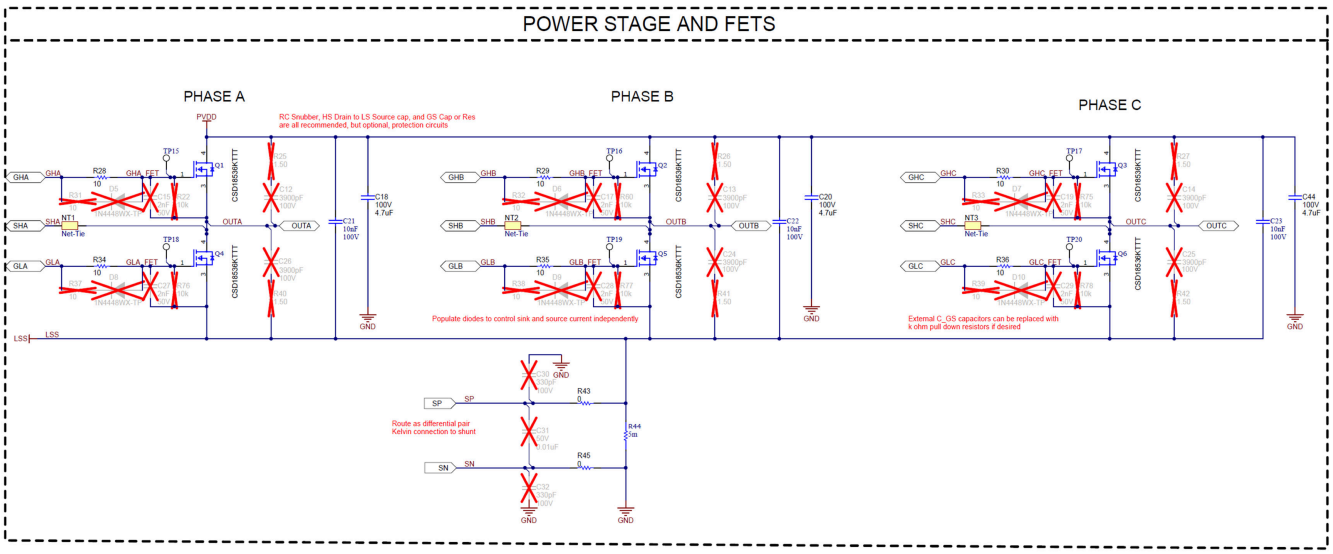


Figure 4-3. MOSFETs and Power Stage

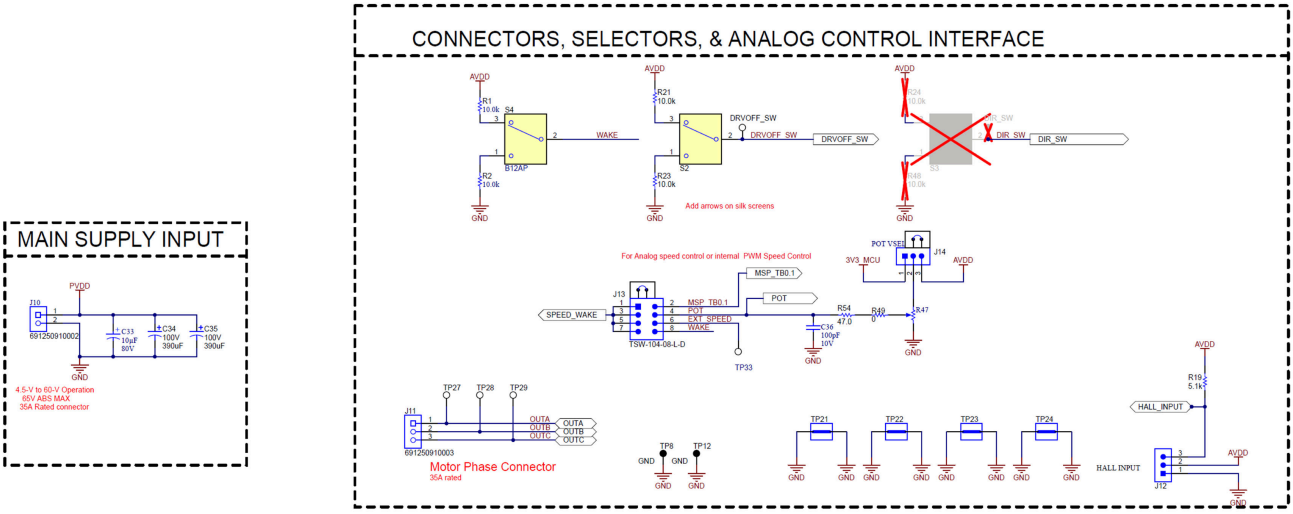


Figure 4-4. Power and Connectors

4.2 PCB Layouts

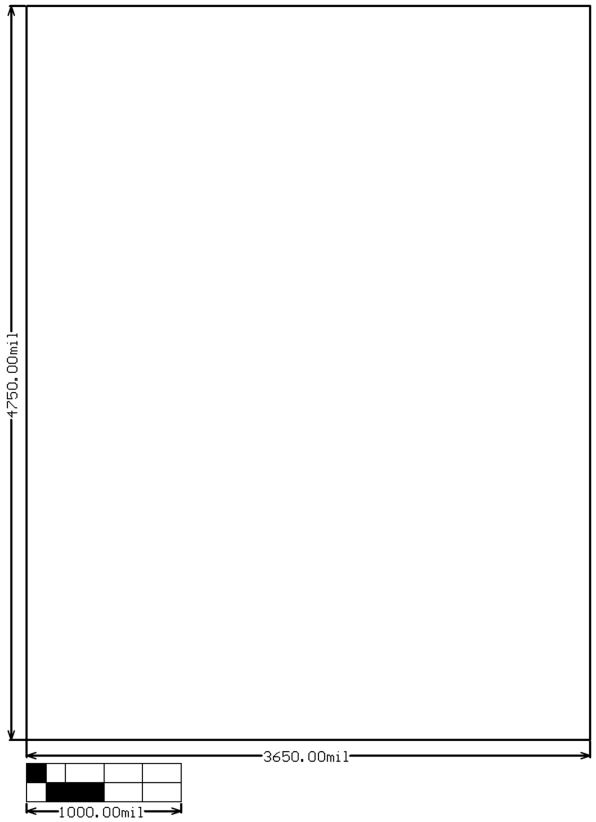


Figure 4-5. EVM Board Dimensions

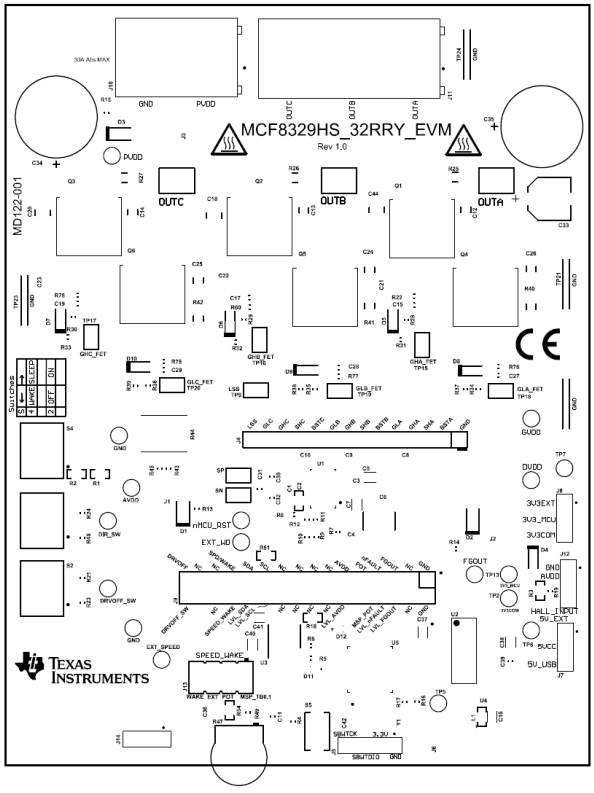


Figure 4-6. EVM Top Overlay

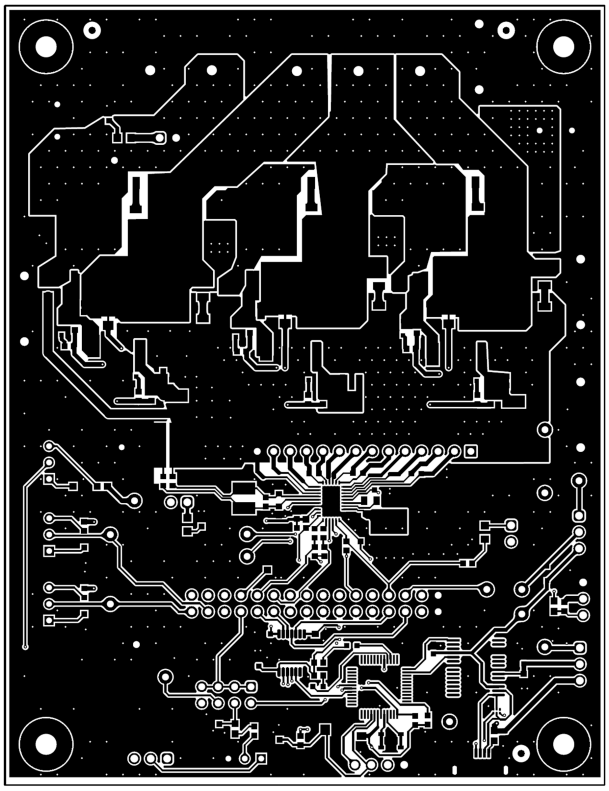


Figure 4-7. EVM Top Layer

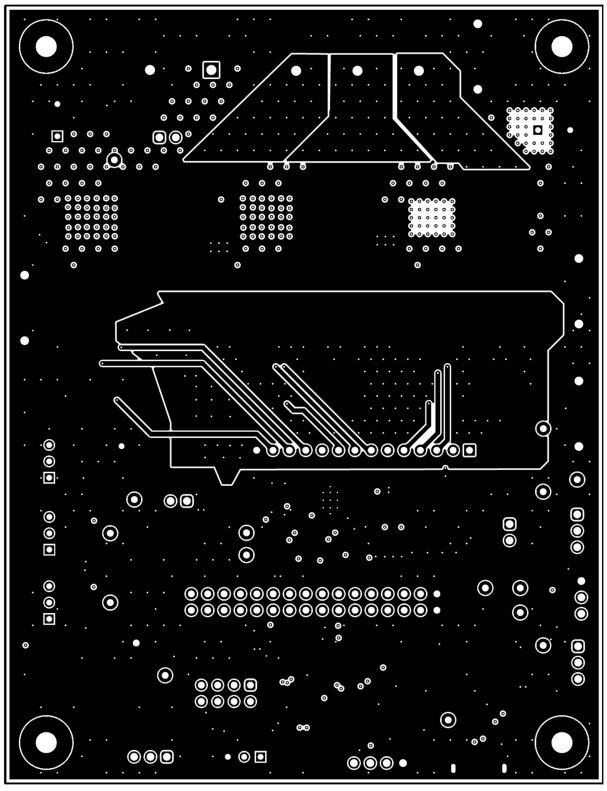


Figure 4-8. EVM Signal Layer 1

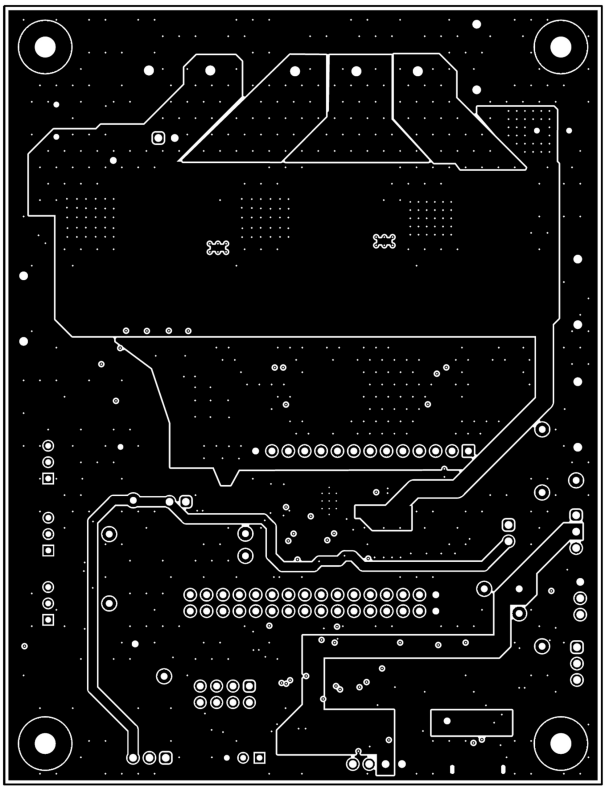


Figure 4-9. EVM Signal Layer 2

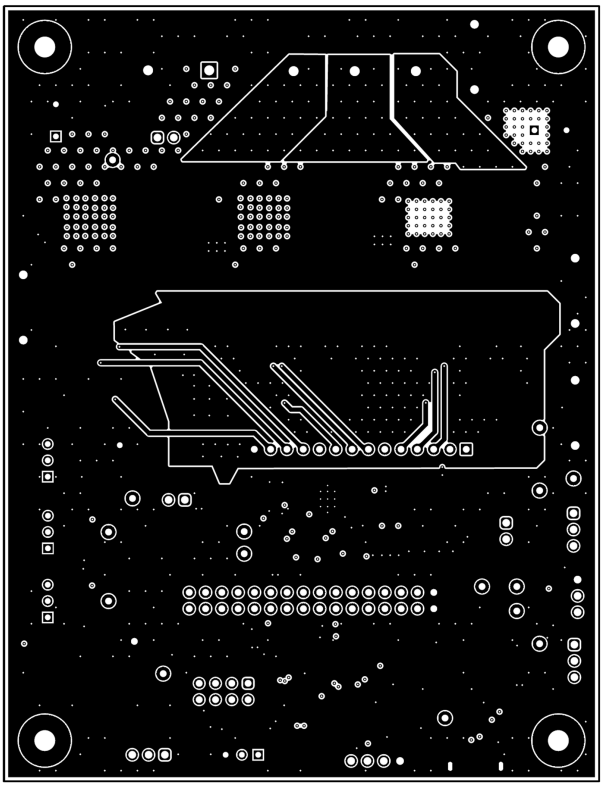


Figure 4-10. EVM Bottom Layer

4.3 Bill of Materials (BOM)

Table 4-1. Bill of Materials

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
C1	1	10uF	WCAP-CSGP Multilayer Ceramic Chip Capacitor, General Purpose, size 0603, X5R, 10µF, 6.3VDC	603	885012106006	Wurth Elektronik
C2	1	0.1uF	CAP, CERM, 0.1uF, 10V,+/- 10%, X7R, 0603	603	885012206020	Wurth Elektronik
C3	1	470nF	WCAP-CSGP Multilayer Ceramic Chip Capacitor, General Purpose, size 0805, X7R Class II, 470nF, 100VDC	805	885012207130	Wurth Elektronik
C4	1	1uF	WCAP-CSGP Multilayer Ceramic Chip Capacitor, General Purpose, size 0603, X5R, 1µF, 6.3VDC	603	885012106003	Wurth Elektronik
C5	1	10µF	10µF ±20% 25V Ceramic Capacitor X5R 0603 (1608 Metric)	603	885012106031	Wurth
C6	1	10uF	CAP, CERM, 10uF, 100V, +/- 20%, X7R, 2220	2220	22201C106MAT2A	AVX
C7, C16, C37, C38, C40, C41	6	100nF	0.1µF ±10% 100V Ceramic Capacitor X7R 0603 (1608 Metric)	603	885012206120	Wurth Electronics
C8, C9, C10	3	1uF	WCAP-CSGP Multilayer Ceramic Chip Capacitor, General Purpose, size 0603, X5R, 1µF, 25VDC	603	885012106022	Wurth Elektronik
C11	1	1000pF	CAP, CERM, 1000pF, 16V, +/- 10%, X7R, 0603	603	885012206034	Wurth Elektronik
C18, C20, C44	3	4.7uF	CAP, CERM, 4.7uF, 100V, +/- 10%, X7S, 1210	1210	GRM32DC72A475KE01L	MuRata
C21, C22, C23	3	0.01uF	WCAP-CSGP Multilayer Ceramic Chip Capacitor, General Purpose, size 0805, X7R, 10nF, 100VDC	805	885012207122	Wurth Elektronik
C33	1	10uF	WCAP-ASLI Aluminum Electrolytic Capacitor, V-Chip, D6.3x H7.7mm, 10uF, 80V	D6.3x H7.7mm	865081745005	Wurth Elektronik
C34, C35	2	390uF	CAP, AL, 390uF, 100V, +/- 20%, 0.026ohm, TH	D12.5xL35mm	EKYB101ELL391MK35S	Chemi-Con
C36	1	100pF	WCAP-CSGP Multilayer Ceramic Chip Capacitor, General Purpose, size 0603, X7R, 100pF, 10VDC	603	885012206003	Wurth Elektronik
C39	1	4.7uF	CAP, CERM, 4.7uF, 10V, +/- 20%, X7R, 0603	603	GRM188Z71A475ME15D	MuRata
C42	1	1uF	CAP, CERM, 1uF, 50V, +/- 10%, X7R, 0805	805	885012207103	Wurth Elektronik
D1, D3	2	Bright Green	LED, Bright Green, SMD	LED_0805	150080VS75000	Wurth Elektronik
D2	1	Red	LED, Red, SMD	LED_0805	150080RS75000	Wurth Elektronik
D4	1	40V	Diode, Schottky, 40V, 0.75A, AEC-Q101, SOD-323	SOD-323	BAT165E6327HTSA1	Infineon Technologies
D11, D12	2	Red	Red 625nm LED Indication - Discrete 2V 0603 (1608 Metric)	603	150060RS75003	Wurth Electronics
H1, H2, H3, H4	4		Standoff, Hex, 1"L #4-40 Nylon	Standoff	1902E	Keystone
H5, H6, H7, H8	4		Machine Screw, Round, #4-40x 1/4, Nylon, Philips panhead	Screw	NY PMS 440 0025 PH	B&F Fastener Supply
J1, J2, J3	3		Header, 2.54mm, 2x1, Gold, TH	Header, 2.54mm, 2x1, TH	61300211121	Wurth Elektronik
J4	1		Header, 100mil, 14x1, Gold, TH	14x1 Header	TSW-114-07G-S	Samtec

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
J5	1		Header, 2.54mm, 4x1, Gold, TH	Header, 2.54mm, 4x1, TH	61300411121	Wurth Elektronik
J6	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
J7, J8, J12, J14	4		Header, 2.54mm, 3x1, Gold, TH	Header, 2.54mm, 3x1, TH	61300311121	Wurth Elektronik
J9	1		Header, 100mil, 16x2, Gold, TH	16x2 Header	TSW-116-07G-D	Samtec
J10	1		2 Position Wire to Board Terminal Block Horizontal with Board 0.375" (9.53mm) Through Hole	CONN_TERM_BLK2	691250910002	Wurth Electronics
J11	1		3 Position Wire to Board Terminal Block Horizontal with Board 0.375" (9.53mm) Through Hole	CONN_TERM_BLK3	691250910003	Wurth Electronics
J13	1		Header, 2.54mm, 4x2, Gold, TH	Header, 2.54mm, 4x2, TH	TSW-104-08L-D	Samtec
L1	1	110ohm	Ferrite Bead, 110ohm @ 100MHz, 4.1A, 0603	603	74279228111	Wurth Elektronik
LBL1	1			PCB Label 0.650x 0.200 inch	THT-14-423-10	Brady
Q1, Q2, Q3, Q4, Q5, Q6	6		MOSFET 60V, N channel NexFET power MOSFET, single D2PAK, 1.6 mOhm 3-DDPAK/TO-263 -55 to 175	DDPAK	CSD18536KTTT	Texas Instruments
R1, R2, R21, R23	4	10.0k	RES, 10.0k, 0.05%, 0.1W, AEC-Q200 Grade 0, 0603	603	ERA-3ARW103V	Panasonic
R3, R11, R12, R43, R45, R49	6	0	RES, 0, 5%, 0.1W, AEC-Q200 Grade 0, 0603	603	ERJ-3GEY0R00V	Panasonic
R4	1	47k	RES, 47k, 5%, 0.1W, 0603	603	RC0603JR-0747KL	Yageo
R5, R6	2	470	RES, 470, 5%, 0.1W, 0603	603	RC0603JR-07470RL	Yageo
R7, R8, R9, R10, R16, R17, R19	7	5.1k	RES, 5.1k, 5%, 0.1W, AEC-Q200 Grade 0, 0603	603	CRCW06035K10JNEA	Vishay-Dale
R13, R14	2	820	RES, 820, 5%, 0.1W, 0603	603	RC0603JR-07820RL	Yageo
R15	1	2.00k	RES, 2.00k, 0.1%, 0.1W, 0603	603	RG1608P-202B-T5	Susumu Co Ltd
R18	1	100k	RES, 100k, 0.1%, 0.1W, 0603	603	RT0603BRD07100KL	Yageo America
R28, R29, R30, R34, R35, R36	6	10	RES, 10, 5%, 0.1W, AEC-Q200 Grade 0, 0603	603	CRCW060310R0JNEA	Vishay-Dale
R44	1	5m	5 mOhms ±1% 7W Chip Resistor Nonstandard Automotive AEC-Q200, Current Sense, Moisture Resistant, Pulse Withstanding Metal Element	2818	WSHM28185L000FEA	Vishay
R47	1	25 kohm	Trimmer Potentiometer, 25kohm, 0.5W, TH	9.53x8.89mm	3352T-1-253LF	Bourns
R54	1	47	RES, 47.0, 0.1%, 0.1W, 0603	603	RT0603BRD0747RL	Yageo America
S2, S4	2		SWITCH TOGGLE SPDT 0.4VA 28V	6.8x23.1x8.8mm	B12AP	NKK Switches

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
S5	1		Switch, Tactile, SPST, 12V, SMD	SMD, 6x3.9mm	434121025816	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, SH-J20, SH-J21, SH-J22, SH-J23	23	1x2	Shunt, 2.54mm, Gold, Black	Shunt, 2.54mm, Black	60900213421	Wurth Elektronik
TP1, TP2, TP5, TP6, TP7, TP10, TP13, TP14, TP40	9		Test Point, Miniature, Red, TH	Red Miniature Testpoint	5000	Keystone
TP3, TP4, TP31, TP33, TP50	5		Test Point, Miniature, White, TH	White Miniature Testpoint	5002	Keystone
TP8, TP12	2		Test Point, Miniature, Black, TH	Black Miniature Testpoint	5001	Keystone
TP9, TP11, TP15, TP16, TP17, TP18, TP19, TP20, TP39	9		Test Point, Miniature, SMT	Testpoint_Keystone_Miniature	5015	Keystone
TP21, TP22, TP23, TP24	4		1mm Uninsulated Shorting Plug, 10.16mm spacing, TH	Shorting Plug, 10.16mm spacing, TH	D3082-05	Harwin
TP27, TP28, TP29	3		Test Point, Compact, SMT	Testpoint_Keystone_Compact	5016	Keystone
U1	1		Automotive Sensorless Field Oriented Control (FOC) Three-phase BLDC Gate Driver	WQFN32	MCF8329HSIQRRYRQ1	Texas Instruments
U2	1		UART Interface IC USB Full Speed to Serial UART IC, Includes Oscillator and EEPROM, SSOP-28	SSOP28	FT232RNL-REEL	FTDI
U3	1		4-Bit Bidirectional Voltage-Level Shifter for Open-Drain and Push-Pull Applications, PW0014A (TSSOP-14)	PW0014A	TXS0104EPWR	Texas Instruments
U4	1		4-Channel ESD Protection Array for High-Speed Data Interfaces, DRY0006A (USON-6)	DRY0006A	TPD4E004DRYR	Texas Instruments
U5	1		CPU16 MSP430? FRAM Microcontroller IC 16-Bit 24MHz 32KB (32K x 8) FRAM 48-LQFP (7x7)	LQFP48	MSP430FR2355TPTR	Texas Instruments
Y1	1		Resonator, 4MHz, 39pF, AEC-Q200 Grade 1, SMD	4.5x1.2x2mm	CSTCR4M00G55B-R0	MuRata

5 Additional Information

5.1 Trademarks

LaunchPad™ and Code Composer Studio™ are trademarks of Texas Instruments.
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 DATASHEETS), 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 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, TI’s General Quality Guidelines, 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. Unless TI explicitly designates a product as custom or customer-specified, TI products are standard, catalog, general purpose devices.

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

Last updated 10/2025