EVM User's Guide: DRV8213EVM, DRV8214EVM, DRV8215EVM, DRV8234EVM, DRV8235EVM

DRV821x and DRV823x Evaluation Module

Description

The DRV821x or DRV823x evaluation module (EVM) allows for easy evaluation of the DRV8213, DRV8214, DRV8215, DRV8234, and DRV8235 devices. The EVM has been programmed and configured to work out of the box and begin spinning motors right away. The EVMs showcase an integrated motor driver with N-channel H-bridge, charge pump, current sense output, current regulation, and protection circuitry. The DRV8214 and DRV8234 integrate a ripple counting technology that allows for sensorless motor position monitoring, stall detection, and speed/voltage regulation. The DRV8215 and DRV8235 integrate stall detection and speed/voltage regulation. DRV8213 integrates stall detection. The charge pump integrates all capacitors and allows for 100% duty cycle operation. The EVM is accompanied by a GUI application for easy control of the motor driver.

Get Started

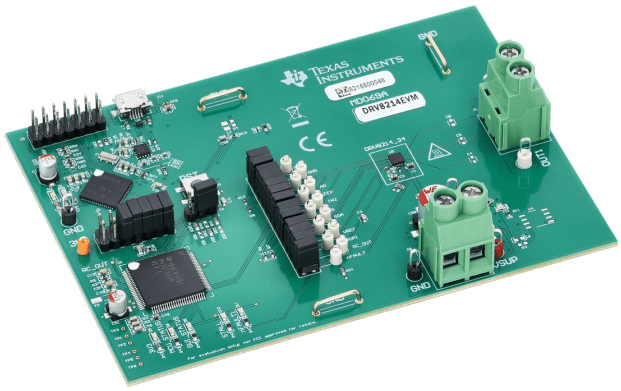
1. Order the EVM
   a. https://www.ti.com/tool/DRV8213EVM
   b. https://www.ti.com/tool/DRV8214EVM
   c. https://www.ti.com/tool/DRV8215EVM
   d. https://www.ti.com/tool/DRV8234EVM
   e. https://www.ti.com/tool/DRV8235EVM
2. Use the web-based GUI here: https://dev.ti.com/gallery/view/MotorDriversBSM/DRV821x_DRV823x-EVM-GUI/.
3. Connect USB and external power supply.
4. Launch DRV821x_DRV823x-EVM-GUI and select the EVM variant on the home page.

Features

- Onboard 3.3V LDO for digital voltage supply
- eZ-FET lite USB-based on-board emulator for ease of programming and debugging MSP430 microcontroller
- Main signal header with removable shunts to disconnect main signals going to the motor driver IC from the MCU
- GUI software to control EVM and DRV IC

Applications

- Brushed DC motor, solenoid, & relay driving
- Vacuum robot
- Water and gas meters
- Electronic smart lock
- Electronic and robotic toys
- Infusion pumps and other portable medical equipments
- Electric toothbrush
- Portable printers
- Point-of-sale (POS) devices
- Other battery powered DC motor applications



DRV8214EVM

1 Evaluation Module Overview

1.1 Introduction

The DRV8213, DRV8214, DRV8215, DRV8234, and DRV8235 family of devices consists of low or medium voltage single integrated H-bridge driver with following features:

- DRV8213: 11V / 4A brushed DC motor driver with integrated current sense, current regulation and stall detection.
- The DRV8213 is a low voltage motor driver with integrated H-bridge FETs capable of driving up to 4A peak (for 4.2µs duration). The main feature of this driver is the stall detection feature. When stall detection is active, the driver reports a STALL flag when a motor stall is detected. Please read the device data sheet to learn about how stall detection works in this device.
- DRV8214: 11V / 4A brushed DC motor driver with sensorless position control, stall detection, speed regulation, and voltage regulation.
- The DRV8214 is a high-performance integrated H- bridge motor driver with current sense output, current regulation, stall detection, motor speed regulation, sensorless position control based on ripple counting, and protection circuitry. The tripler charge pump allows the device to operate down to 1.65V to accommodate 1.8V supply rails and low- battery conditions. The charge pump integrates all capacitors and allows for 100% duty cycle operation. The DRV8214 is capable of driving up to 4A peak or 2A RMS continuously.
- DRV8215: 11V / 4A brushed DC motor driver with stall detection, speed regulation, and voltage regulation.
- The DRV8215 has all the features of DRV8214, except for the sensorless position control based on ripple counting. The DRV8215 still has stall detection, speed regulation, voltage regulation, and soft start/stop.
- DRV8234: 38V / 2A Brushed DC motor driver with sensorless position control, stall detection, speed regulation, and voltage regulation
- The DRV8234 is a high-performance integrated H- bridge motor driver with current sense output, current regulation, stall detection, motor speed regulation, sensorless position control based on ripple counting, and protection circuitry. The device operates from a 4.5V to 38V supply voltage. The charge pump integrates all capacitors and allows for 100% duty cycle operation. The DRV8234 is capable of driving up to 4A peak or 2A RMS continuously.
- DRV8235: 38V / 2A Brushed DC Motor Driver with Stall Detection, Speed Regulation, and Voltage Regulation
- The DRV8235 has all the features of DRV8234, except for the sensorless position control based on ripple counting. The DRV8235 still has stall detection, speed regulation, voltage regulation, and soft start/stop.

This document is provided with the DRV8213, DRV8214, DRV8215, DRV8234, and DRV8235 evaluation modules (EVM) as a supplement to the DRV8213, DRV8214, DRV8215, DRV8234, and DRV8235 data sheets. This user's guide covers EVM hardware setup instructions, GUI installation, and usage instructions.

1.2 Kit Contents

Table 1-1 lists the contents of the EVM kit. Contact the nearest Texas Instruments Product Information Center if any component is missing.

Table 1-1. Kit Contents

ITEM	QUANTITY
One of DRV8213EVM, DRV8214EVM, DRV8215EVM, DRV8234EVM, or DRV8235EVM	1
3ft White USB-A to Micro-USB Cable	1

1.3 Specification

The DRV821x and DRV823x EVM connect to a local computer USB port through a USB-A to Micro-USB cable. An onboard eZ-FET lite USB emulator allows for programming and debugging the main MSP430 microcontroller without the need for an external debugger. A 3.3V LDO generates a 3.3V rail from the USB 5V supply. This 3.3V is used to power the EZFET MCU, main MSP430, and motor driver VCC pin. P1 signal header uses removable shunts to pass the signals from the MCU to the motor driver. Remove any of these shunts to easily jump in the control signals to the driver. Provide an external motor power supply to the J8 screw terminal within the operating range of the device. DRV8213, DRV8214, and DRV8215 support 1.65V to 11V supply voltage range, while DRV8234 and DRV8235 support 4.5V to 38V.

1.4 Device Information

The DRV8213, DRV8214, DRV8215, DRV8234, and DRV8235 family of devices have a voltage and current range from 1.65V - 38V and up to 4A peak or 2A continuous.

The documents in Table 1-2 provide information regarding Texas Instruments integrated circuits used in the assembly of the EVM. This user's guide is available from the TI web site under literature number SLVUCO1. Any letter appended to the literature number corresponds to the document revision that is current at the time of the writing of this document. Newer revisions are available from the TI web site at www.ti.com, or call the Texas Instruments Literature Response Center at (800) 477-8924 or the Product Information Center at (972) 644-5580. When ordering, identify the document by both title and literature number

Table 1-2. Related Device Documentation

Description	Data Sheet
ezFET-Lite MCU	MSP430F5528
Main MSP430 MCU	MSP430F5338
3.3V LDO	TPS735
Motor Driver	DRV8213, DRV8214, DRV8215, DRV8234, or DRV8235
ESD protection diode	TPD2E001

2 Hardware

2.1 Headers and Test Points Information

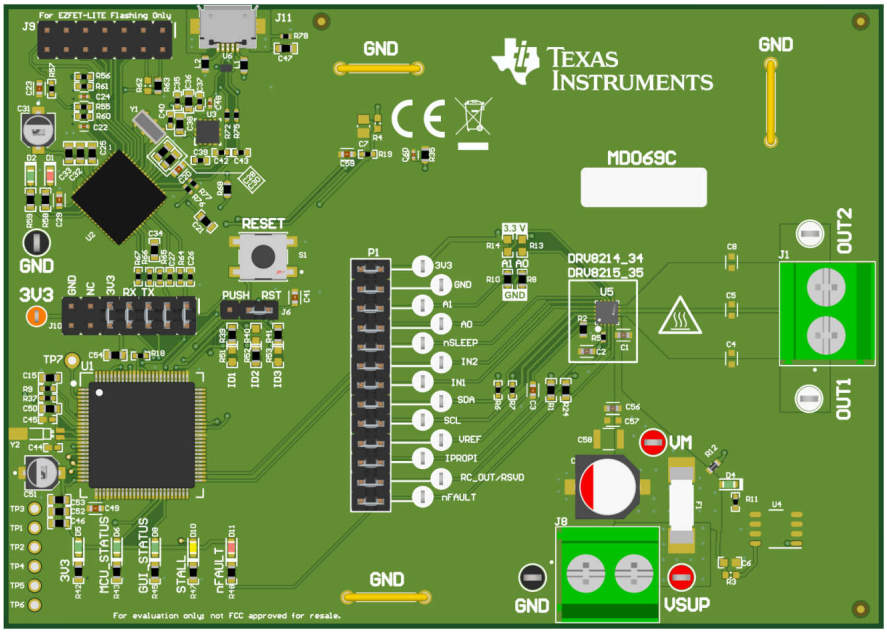


Figure 2-1. DRV8214EVM (MD069-001) Top View

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 area when driving high currents to prevent potential burn damage.

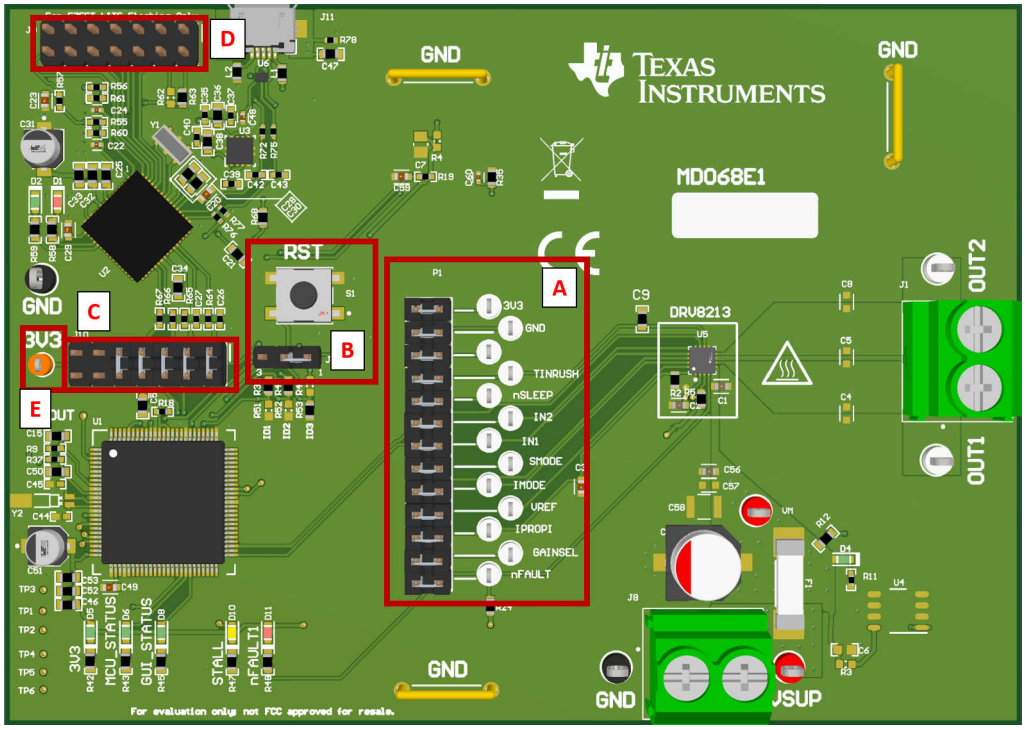


Figure 2-2. DRV8213EVM Header and Test Point Information

Table 2-1. Header and Test Point Description - DRV8213EVM

Component label	Description
A	Main signal header: • **3V3**: 3.3V from LDO. • **GND**: GND test point. • **TINRUSH**: Sets timing for stall detection to ignore motor inrush current. • **IN1**: control input IN1. • **IN2**: control input IN2. • **SMODE**: stall detection response configuration (see *Table 8-6. SMODE configuration* of data sheet (SLVSGV9)). • **IMODE**: current regulation mode configuration (see *Table 8-4. IMODE configuration* of data sheet (SLVSGV9)). • **VREF**: current regulation reference voltage (tied to DAC of MSP430). • **IPROPI**: IPROPI pin voltage for monitoring voltage proportional output current. • **GAINSEL**: Configures IPROPI gain factor depending on the output current range (see *Table 8-3. GAINSEL Setting* of data sheet (SLVSGV9)). • **nFAULT:** fault indicator output (LOW = fault detected; HIGH= no fault detected).
B	Reset/PUSH button can have to functions based on the location of the SHUNT in J6 (below RST button): • **RST** (SHUNT in position 1): Pressing the button resets the MCU. • **PUSH** (SHUNT in position 3): Pressing the button does a user defined action. Currently not implemented in firmware.
C	JTAG connector between MSP430F5338 and MSP430F5528.
D	Connector for programming MSP430F5528 used in the eZ-FET lite debugger circuit. Only used one time by PCB manufacturer to programmed eZ-FET lite debugger MCU.
E	3V3 LDO connector.

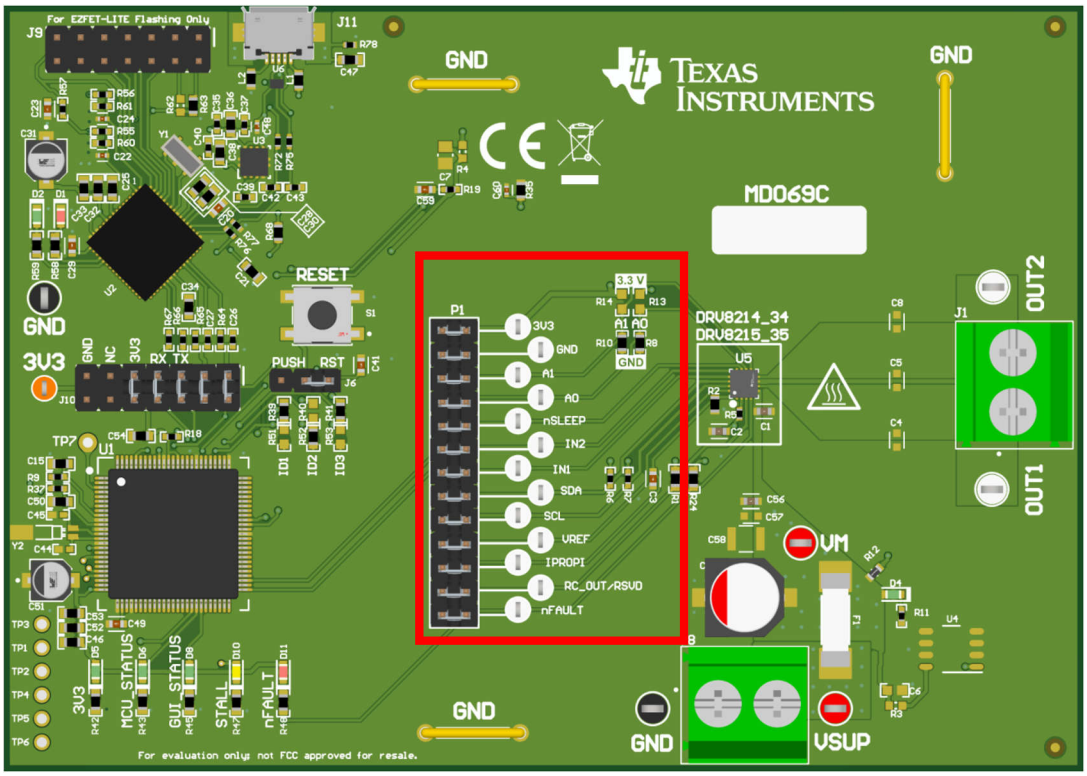


Figure 2-3. DRV8214, DRV8215, DRV8234, and DRV8235 EVM Header and Test Point Information

Table 2-2. DRV8214, DRV8215, DRV8234, and DRV8235 EVMs

Description
Main signal header: • **3V3**: 3.3V from LDO. • **GND**: GND test point. • **A0**: Configures I2C device address along with A1 via R10 and R14 resistors (see *Table 8-28. Device Addresses* of data sheet). • **A1:** Configures I2C device address along with A0 via R8 and R13 resistors (see *Table 8-28. Device Addresses* of data sheet). • **nSLEEP**: device nSLEEP pin (LOW = ASLEEP & HIGH = AWAKE). • **IN2**: control input IN2. • **IN1**: control input IN1. • **SDA**: Data line of I2C bus. • **SCL**: Clock line of I2C bus. • **VREF**: current regulation reference voltage (tied to DAC of MSP430). • **IPROPI**: IPROPI pin voltage for monitoring voltage proportional output current. • **RC_OUT** (not applicable to DRV8215EVM or DRV8235EVM): Ripple count pulse output from the driver. Corresponds to the ripples of the motor during commutation. • **nFAULT:** fault indicator output (LOW = fault detected; HIGH= no fault detected).

2.2 Connector Information

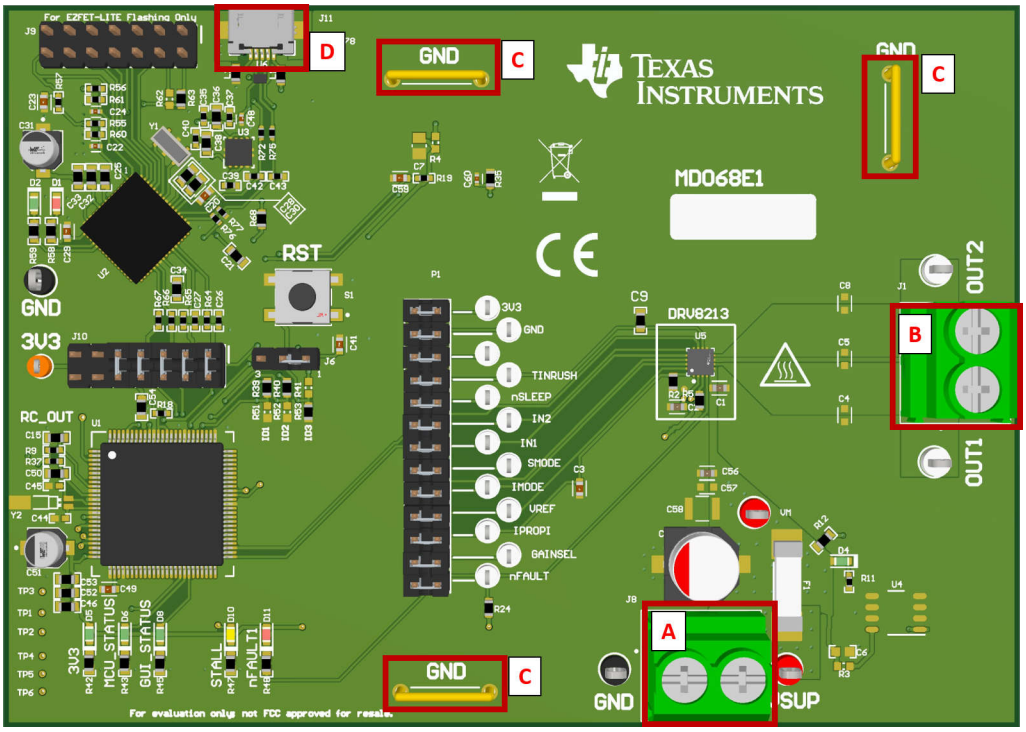


Figure 2-4. Connectors

Table 2-3. Connectors Description

Component label	Description
A	Input power supply connector. Power cables can be directly connected to the screw terminals or clipped to the test points on either side of the connector.
B	Driver output connector. OUT1 and OUT2 signals from DRV output. Connect the motor terminals across OUT1 and OUT2.
C	GND strip for grounding voltage probes and digital multimeter leads
D	USB connector

2.3 Indicator LEDs

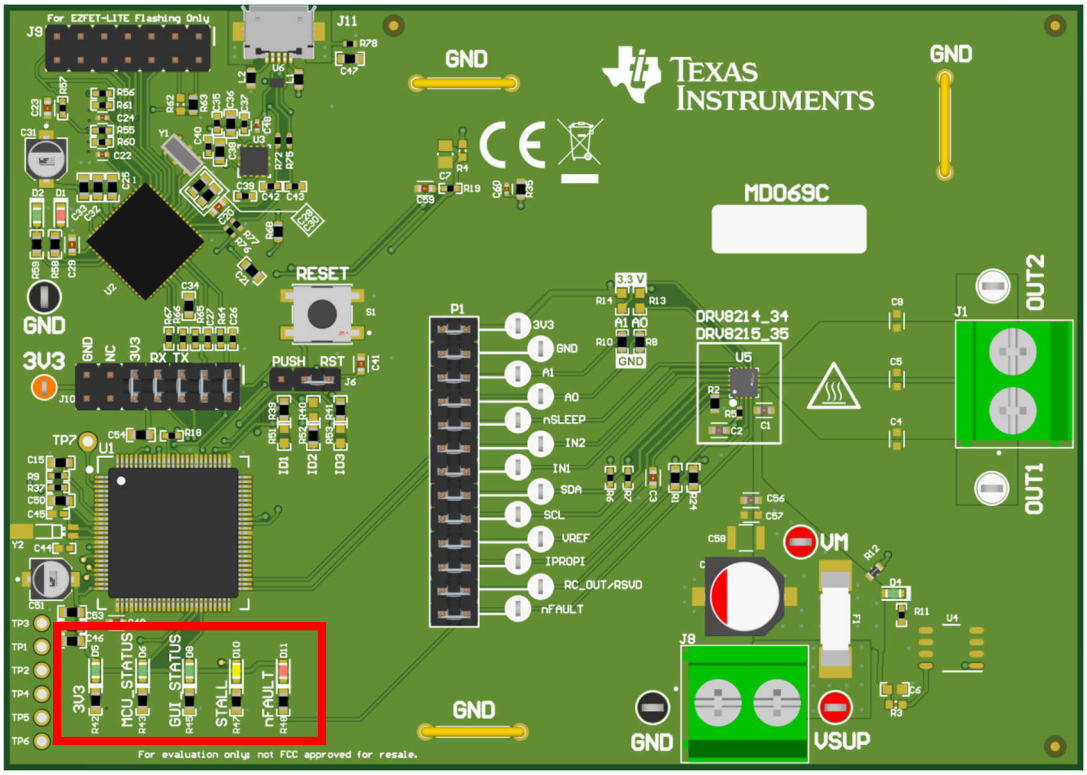


Figure 2-5. LED indicators

LED	Function
D4	**VM**: ON when VSUP or VM is connected and turned on.
D5	**3V3**: **OFF** when 3.3V is not active. **ON** when 3.3V is active
D6	**MCU_STATUS**: LED toggles at a rate of around 1s when MCU is active. Unplug and reconnect the EVM to the computer if this stops flashing.
D8	**GUI_STATUS**: LED toggles when EVM is communicating with GUI software. LED OFF means there is no communication with GUI.
D10	**STALL**: **OFF** when no motor stall is detected by DRV. **ON** when motor stall is detected.
D11	**nFAULT**: **OFF** when no fault present. **ON** when DRV flags a fault.

2.4 Hardware Setup

The EVM hardware is designed and kitted to simplify setup and begin spinning motors. The EVM comes with the jumpers placed at the appropriate location in the headers. The location of the jumpers, also called shunts, are shown in Figure 2-1.

Note

Before using the EVM, check that the shunt location matches the location shown in Figure 2-1.

Before connecting the EVM to the GUI software, follow these steps:

1. Connect EVM to PC via USB connector. D2 (EZFET), D5 (3.3V), must be solid ON. D5 (MCU STATUS) needs to be toggling ON/OFF at a 1s intervals
2. Connect power supply (less than 11V for DRV8213/DRV8214/DRV8215, less than 38V for DRV8234/DRV8235) to power connector. Make sure terminals are connected correctly to avoid damage due to reverse battery connection.

   This EVM does not have reverse polarity protection circuitry.
3. Turn ON power supply. D4 (VM) turns ON. See Figure 2-6 for setup image.
4. Connect motor to output connector.
5. Set up is now complete. See Figure 2-6 for setup image.

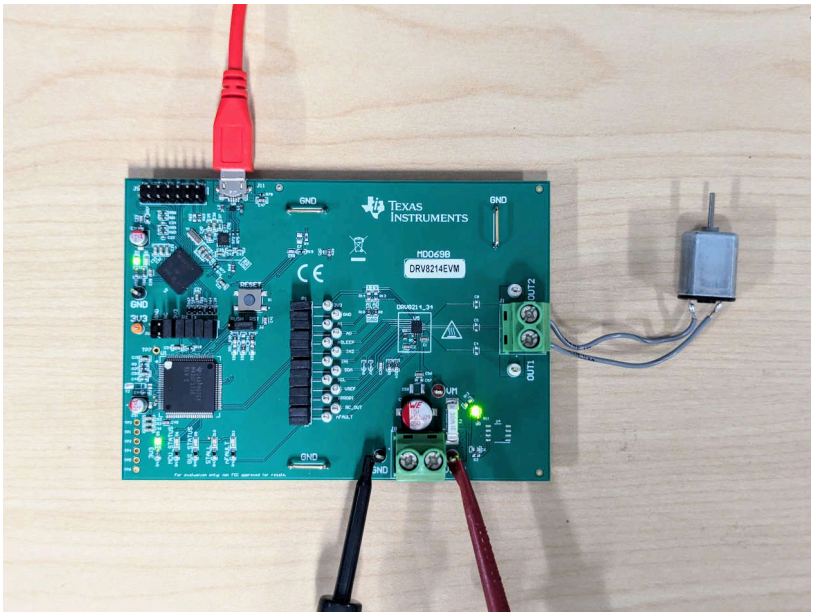


Figure 2-6. Hardware Setup

3 Software

3.1 Software Setup

1. Install the TI MSP430 USB driver from MSP430 FET Drivers.
   a. Click on the first driver download link, *ti_msp430driver_setup_1.0.1.1-windows.zip | Windows Installer*.
   b. Please log in with myTI credentials when prompted and provide the requested information. The approval to access the download is automatic and immediate as long as the U.S. Government export approval requirements are complied with.
   c. Click on the download button to download the installer to your PC.
   d. Double-click on the downloaded zip file and run the installer by double-clicking on the *.exe* file. Complete the installation to install the required USB drivers to use the EVM on the PC.
      i. Follow proper safety precautions working with sensitive electronics as well as high voltage and high current hardware.
      ii. Power sequencing: The USB cable must be plugged in first between the EVM and the computer. Then turn on the power supply to the EVM. Powering the EVM external bench supply before connecting the USB cable can cause the USB device to not start up properly and result with driver error.
      iii. Set up the bench supply to <=11V for DRV8213/DRV8214/DRV8215 EVM or <38V for DRV8234/DRV8235 EVM with current limit set to appropriate requirements of the motor.

3.2 Web GUI Access or Local GUI Installation

The EVM is controlled via a GUI application and can be used via a chrome-based browser or installed locally to a PC. Download the latest GUI installer here or use web-based GUI here.

To use the Web GUI (recommended), follow these steps:

1. Open the latest version of the GUI at this link: https://dev.ti.com/gallery/view/MotorDriversBSM/DRV821x_DRV823x-EVM-GUI/
   a. Alternatively, log into https://dev.ti.com/gallery/ and search for *DRV821x_DRV823x* sorting by *Recently updated*.
   b. Click on the title or blank space of the first search result to open the Web-Based GUI.

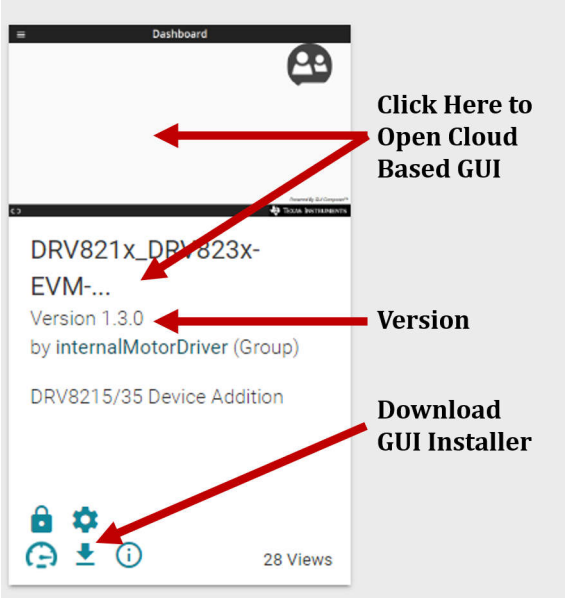


Figure 3-1. TI GUI Composer Gallery Results for Launching or Downloading Local Installer

To install the GUI locally follow these steps:

1. Log in to https://dev.ti.com/gallery/ using myTI log in credentials. Note that the GUI composer log in searches for a very specific username match including case input at the time of sign up.
2. Open the latest version of the GUI at this link: https://dev.ti.com/gallery/info/MotorDriversBSM/DRV821x_DRV823x-EVM-GUI/
   a. Alternatively, search for *DRV821x_DRV823x* sorting by *Recently updated*.
3. Hover the mouse over the *Download* icon and select the installer for the relevant operating system from the top list. Refer back to the previous section for a visual depiction of the gallery page.
4. Extract the ZIP folder with the installer and run the installer. The installer contents is self-explanatory and look slightly different for each OS.
5. Click *Next* and then agree to the terms and conditions on the following page.
6. Keep the application and runtime directory to the default locations. Click *Next* to install GUI.
7. Select *Download from Web* to download the GUI Composer Runtime if prompted, then click *Next*.
   a. If a network firewall prevents Runtime download from the web, then the Runtime installer can be downloaded here.
8. Check the box to create a desktop shortcut and click *Finish* to complete installation.
9. GUI is now installed.

3.3 Connecting EVM to GUI

Now that the EVM hardware setup and GUI installation is complete, the EVM can now be connected to the GUI. The following steps outline how to connect the EVM to GUI:

1. With the EVM connected to the PC, open the GUI. The home page is shown in Figure 3-2.

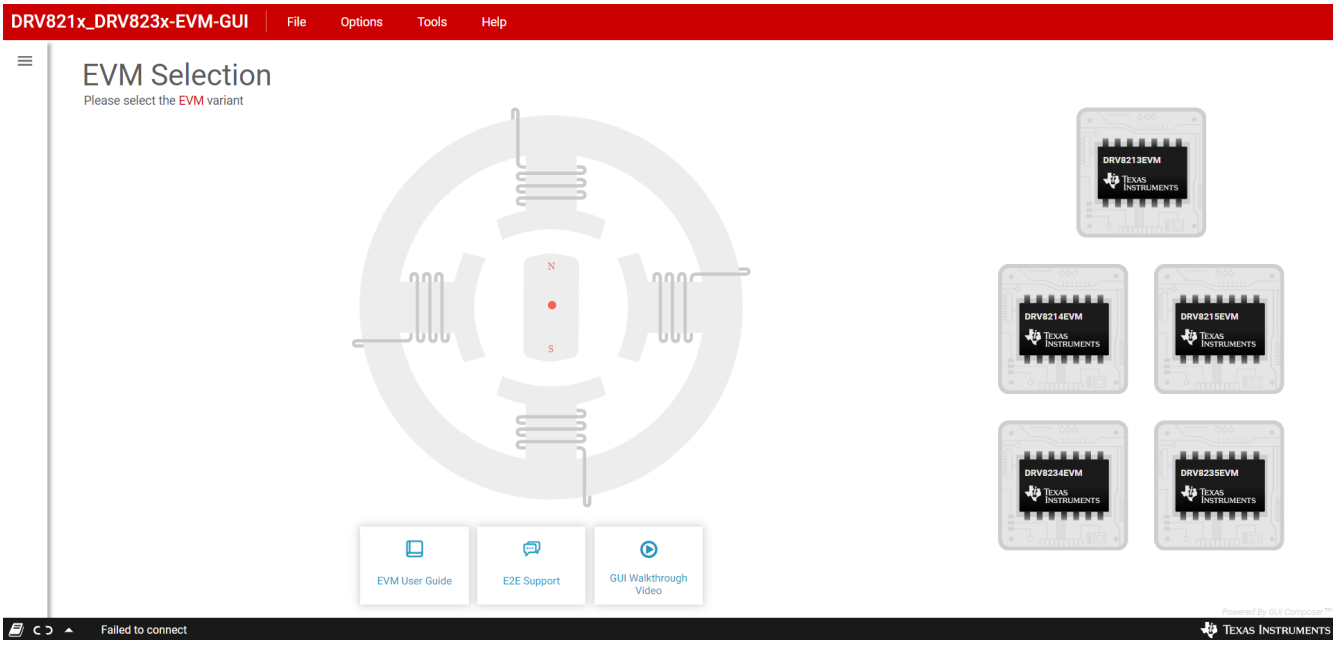


Figure 3-2. GUI Landing Page

2. Program EVM with latest software by clicking on *File -> Program Device*. (See Figure 3-3).

   This needs to be done the first time the user sets up the EVM, as a software update can have been released since the EVM was initially programmed.

   a.

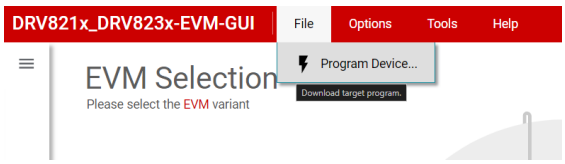


Figure 3-3. Program Device

3. Select the appropriate GUI variant from the five options for the EVM (Figure 3-3).

a.

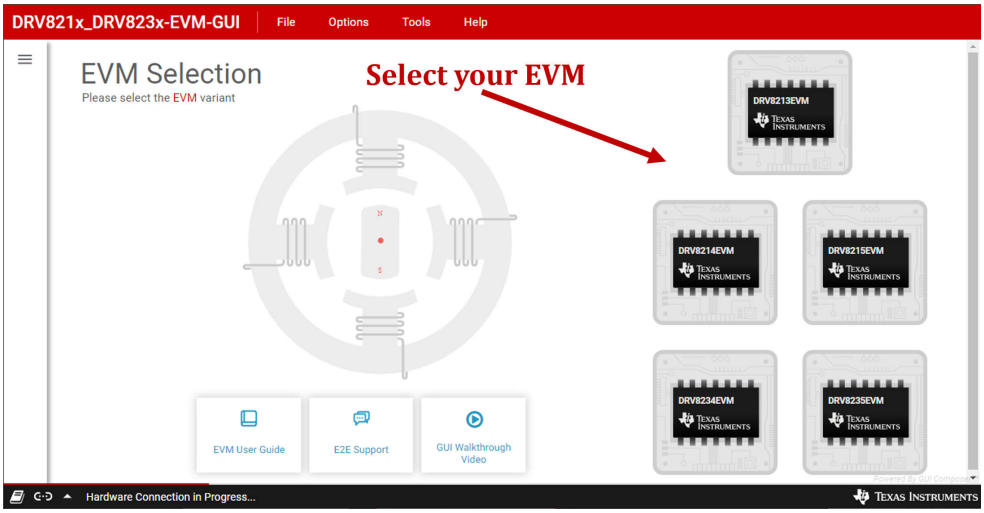


Figure 3-4. Select EVM Variant

4. The GUI attempts to connect with EVM. The GUI displays the following once successfully connected. If there is no successful connection, then double check hardware setup is correct following steps in Section 2.4.

a.

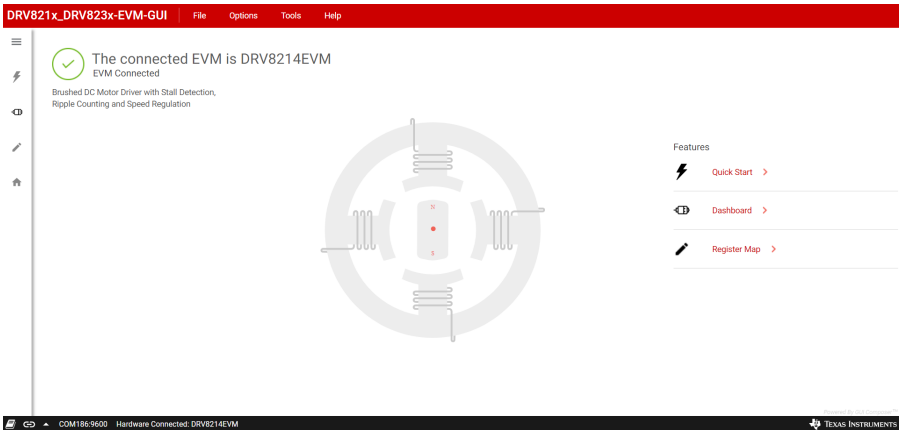


Figure 3-5. Successful GUI connection

5. Once successfully connected, click on *Quick Start* to open the *QuickStart* page, or *Dashboard* or *Driver Control* (DRV8213EVM) to open the main control page.
6. The GUI setup is now complete. The following section provides an overview of the GUI and how to use the GUI to control EVM.

3.4 GUI Overview

These following sections provides an overview for each of the GUI variants, such as DRV8213EVM versus DRV8234EVM. The GUI variant is selected in the GUI home page.

3.5 DRV8213EVM

Figure 3-6 provides the overview of all the widgets and features of the DRV8213EVM GUI.

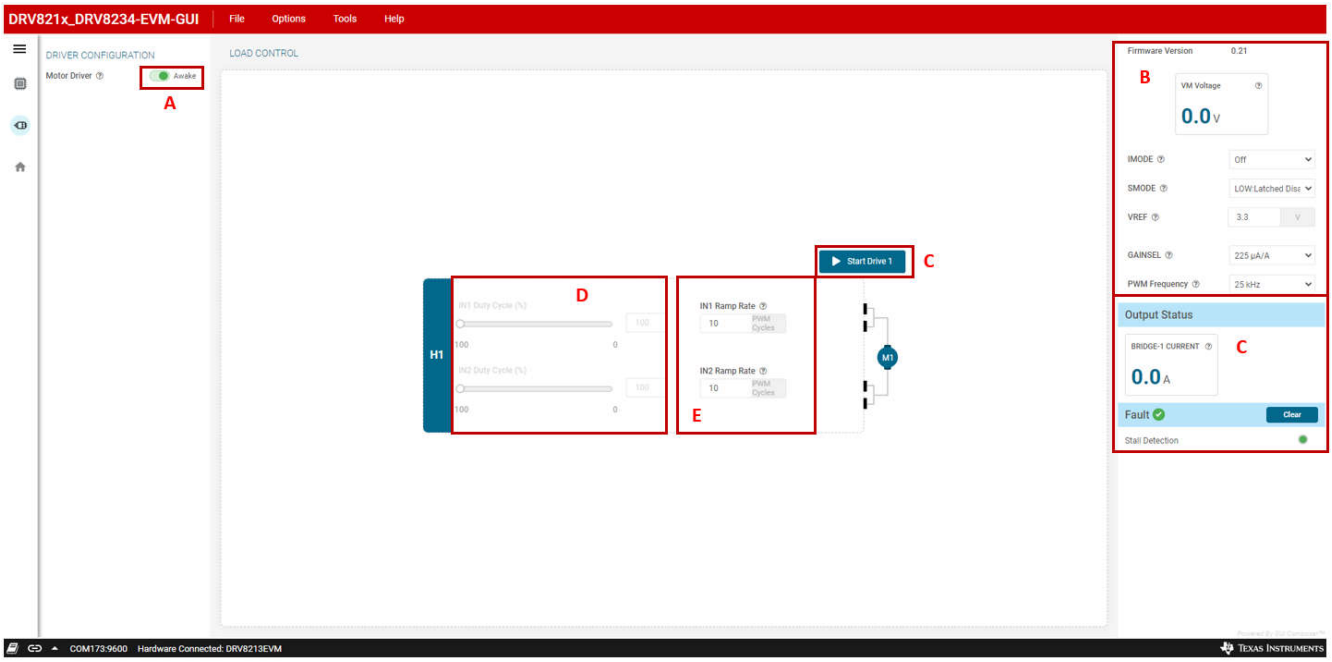


Figure 3-6. DRV8213 GUI Driver Control Page

Table 3-1. DRV8213EVM GUI Overview

Component	Description
A	Device enable. Set slider to *GREEN* position to enable the driver.
B	1. Firmware Version: EVM firmware version. 2. VM voltage: supply voltage value. 3. IMODE: current regulation mode (**OFF**: regulation disabled; **ON**: regulation always enabled; **INRUSH**: enabled only during inrush). 4. SMODE: stall mode (**LOW**: latched nFAULT with outputs disabled; **HIGH**: nFAULT indication only with outputs remaining enabled; **Hi-Z**: NFAULT indication only with internal VREF=500mV). 5. VREF: VREF value (range of 0V-3.3V). 6. GAINSEL: current sense amplifier gain selection. 7. PWM frequency: Switching PWM frequency selector. Default value is 25kHz and up to 100kHz.
Col	1. Bridge Current: Output current (currently not functional. GUI to be updated) 2. nFAULT: Fault status. Mirrors nFAULT LED (D11). 3. CLEAR: click to clear fault or stall warning. 4. STALL DETECTION: turns yellow when stall is detected. Cleared by pressing CLEAR button.
D	IN1 and IN2 duty cycle control widget. Duty cycle ranges from 0-100 at the user selected PWM frequency. The duty cycle is adjustable by using the slider or writing to the input box.
E	IN1 and IN2 ramp rate. The PWM slowly ramps up or down the duty cycle to avoid sudden speed changes. The ramp rate is adjustable from 0-25 with 0=no ramp and 25=slowest ramp rate.

3.6 DRV8214EVM, DRV8215EVM, DRV8234EVM, and DRV8235EVM

The DRV8214 and DRV8234 GUI variants are identical to each other, except for some slight register map differences. The DRV8215 and DRV8235 GUI variants are also the same, but with some features disabled if the feature is not available on that device. For example, the DRV8215 device has all of the same features and controls as DRV8214 except for the RC_OUT pin and moving a set number of ripples functionality, so the controls related to those functions are disabled.

The DRV82x4/DRV82x5 GUIs have three main pages: *Quick Start*, *Dashboard*, and *Register Map*. The Quck Start page gives a walkthrough of how to set up the key parameters for the motor model with the device. This is intended to be followed the first time the user sets up a new motor with this device to find what register values need to be loaded for that motor. The *Dashboard* page provides easy access to many controls of the device on a single page including standard motor tuning, advanced tuning parameters, position control, and speed/voltage regulation control and plotting. There is also a *Status & Faults and Driver Control* panel that can be expanded from any GUI screen.

Access the Status & Faults and Driver Control pane at any time by clicking the blue control on the right side of the screen. Figure 3-7 below shows the Driver Control Panel with the main sections enclosed in red boxes with a letter assigned.

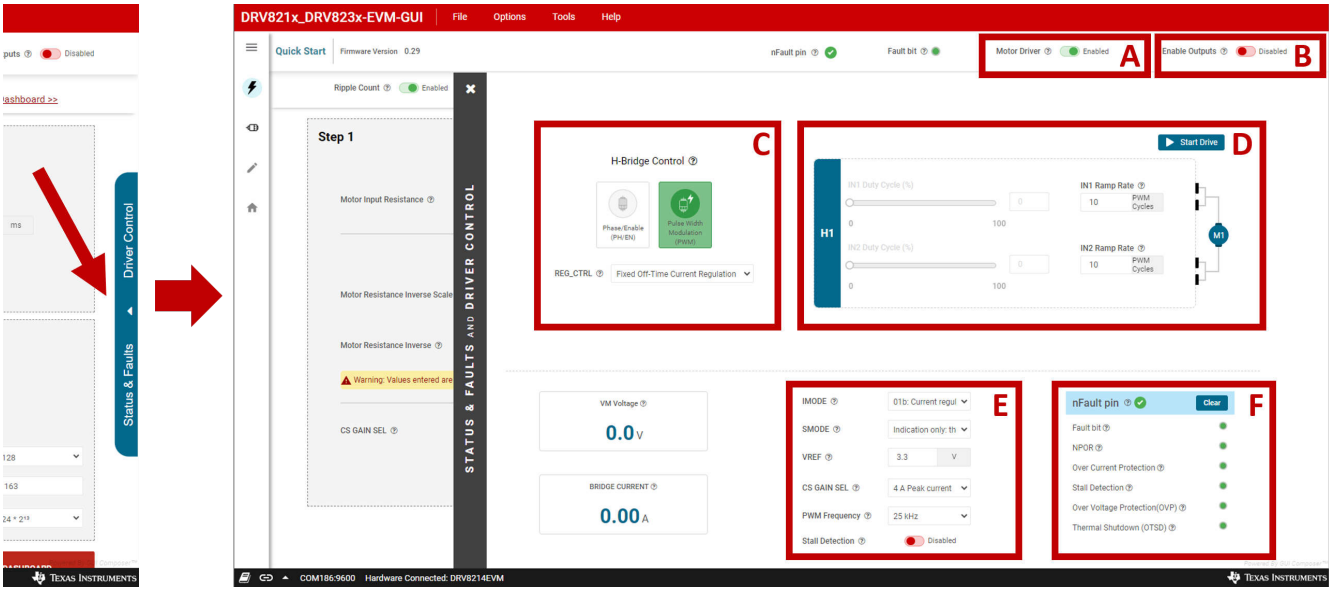


Figure 3-7. Driver Control Panel

A: Motor Driver Enabled/Disabled

Enable/Disable motor (sets the nSLEEP pin). Set this to Enabled to activate the rest of the GUI controls.

B: Enable Outputs

Enable/Disable the motor outputs (sets the EN_OUT bit).

C: H-Bridge Control

Select between Phase/Enable (PH/EN) control mode or Pulse Width Modulation (PWM) mode. The REG_CTRL dropdown can select the current regulation mode between Fixed Off-Time, Cycle-by-Cycle, Speed Regulation, and Voltage Regualtion. These items can only be selected when the EN_OUT bit is 0, so set the *Enable Outputs* toggle to *Disabled* to modify these. See the device data sheet for more information about these modes.

D: IN1 and IN2 Control

Click *Start Drive* to enable the IN1 and IN2 sliders. The IN1 and IN2 duty cycle ranges from 0-100 at the user selected PWM frequency. The duty cycle is adjustable by using the slider or writing to the input box. The PWM slowly ramps up or down the duty cycle at the IN1 or IN2 ramp rate to avoid sudden speed changes. The ramp rate is adjustable from 0-25 with 0=no ramp and 25=slowest ramp rate.

The DRV8214/DRV8215 and DRV8234/DRV8235 have the capability to control the IN1 and IN2 signals via I2C. To enable this control method, set the I2C_BC bit in register CONFIG4 to 1b to enable SPI control. Then simply set the IN1 and IN2 bits in CONFIG4 register to control the motor.

E: Various Mode Controls

This section displays the firmware version, VM voltage, contains input widgets for configuring IMODE, SMODE, VREF, CS GAIN SEL (current sense gain selection), stall detection, and PWM frequency for external IN1 and IN2 signals. To change the PWM frequency, the motor has to be stopped. This can be achieved by disabling the outputs or clicking on the *Stop Drive* button in section B.

F: Fault Status

This section displays indicators for various fault conditions. To clear any fault, click on the *Clear* button.asdfvidual registers. Immediate write option writes to the registers right after modification while deferred write requires manual input to write.

3.6.1 Quick Start

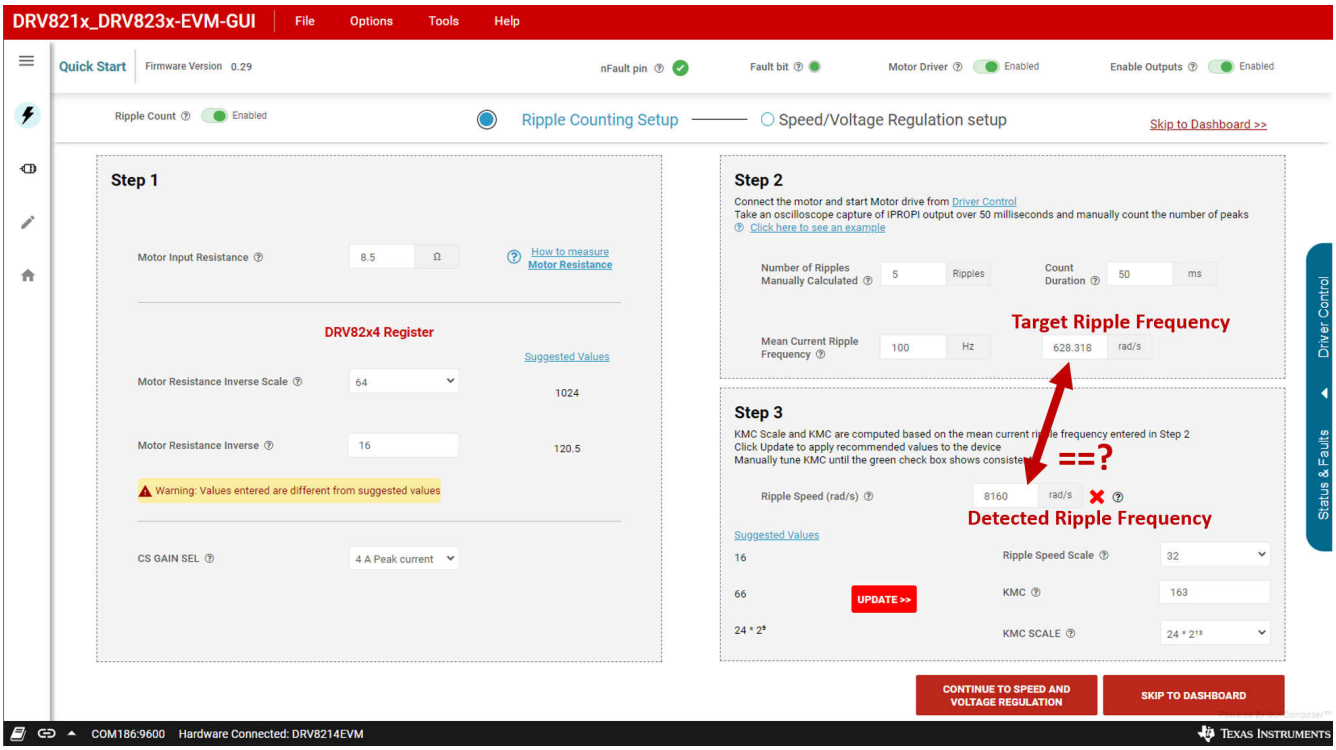


Figure 3-8. Quick Start Page - Ripple Counting Setup

The Quick Start page gives a three-step process to tune the device parameters with your motor. This is applicable for all four of these EVMs (not DRV8213), even DRV8215/DRV8235 which do not have RC_OUT. The steps to follow are the same between all four devices.

Step 1 - Motor Resistance and Current

1. Input the motor resistance into the first box. Click *How to measure motor resistance* for a few ways to determine the resistance of the motor if not given in the motor data sheet.

2. The *Suggested Values* for Motor Resistance Inverse Scale (INV_R_SCALE) and Motor Resistance Inverse automatically updates. Use the corresponding drop-down and input box to apply these suggested values to the device registers. Once the values are near the suggested values, the warning goes away.
3. Select an appropriate CS GAIN SEL for the motor (DRV8214/DRV8215 only). This scales the output of IPROPI, and help achieve maximum accuracy. DRV8234/DRV8235 have a single set value for CS GAIN SEL, so this drop-down is disabled in those GUI variants.

Step 2 - Ripple Frequency

1. Use the Driver Control Panel to start spinning the motor at 100% duty cycle with no load. The motor must be spinning for the reminder of the tuning steps.
2. Attach an oscilloscope or logic analyzer to the IPROPI test point on the EVM, or clamp a current probe around a motor lead.
3. Capture at least 50 milliseconds of current waveform. Count the number of peaks as shown in Figure 3-9. Input the number of peaks into the *Number of Ripples Manually Calculated* box, and enter the capture time (ex. 50ms) into the Count Duration box. TI recommends counting at least 20 ripples for a given motor.

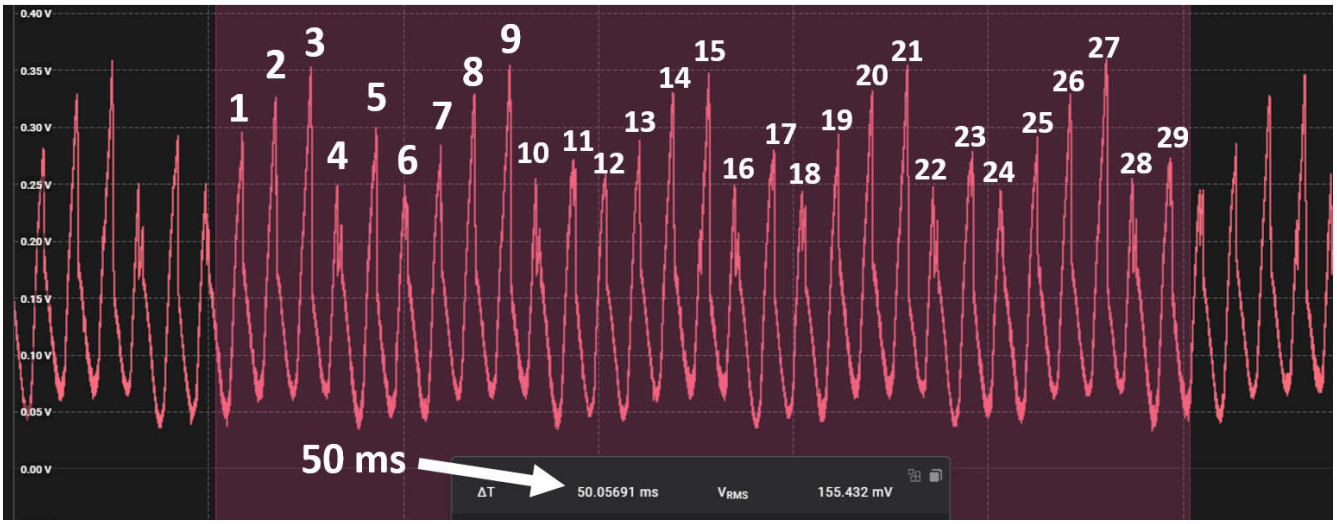


Figure 3-9. Electrical Ripple Speed Measurement

4. The *Mean Current Ripple Frequency* boxes automatically updates to convert this ripple count into Hz and rad/s. The value displayed in the rad/s box is the value to tune the device to measure and match in Step 3. Note that this is an electrical speed, not a mechanical speed. The mechanical motor RPM can be calculated with

$$\frac{Ripple\ Speed\ \times 60}{(\#\ of\ commutator\ segments\ \times 2\ \times \pi)} \quad (1)$$

.

Step 3 - Parameter Tuning

The Ripple Speed (rad/s) box in Step 3 displays the ripple speed value last detected by the motor driver. The goal of Step 3 is to adjust KMC, KMC_SCALE, and Ripple Speed Scale until the ripple speed detected by the device matches the target ripple frequency in Step 2. When the detected speed is within 2*Ripple_Speed_Scale of the target speed then a green check box appears.

The *Suggested Values* on the left automatically updates based on the device ripple speed box following the steps outlined in the data sheet to tune these parameters to match the target ripple frequency. Clicking the *UPDATE>>* button automatically applies all the suggested values to the device register. Alternatively, the user can use the drop-down options and input box to manually adjust these.

1. With the motor spinning, click the *UPDATE>>* button to apply the suggested values to the register.
2. Wait a few seconds for the detected Ripple Speed in step 3 to update, and if the Ripple Speed does not match, then press the *Update* button again.
3. Repeat step 2 until the green check box is continuously showing, indicating the detected ripple speed closely matches the target speed.

a. Overflow conditions can cause this algorithm to get stuck on the KMC_SCALE of 24 * 2^{13}. If this happens, then use the KMC SCALE drop-down to select 24 * 2^{12} or 24 * 2^{9}.
b. The Ripple Speed Scale is computed to give the maximum resolution of motor speed for the speed scale. However, if the target speed is very close to the maximum ripple speed of that scale (255 * Ripple Speed Scale. For example, 255 * 16 = 4080), then the user needs to increase ripple speed scale to the next value.
c. A higher value of KMC results in a lower detected ripple speed, and vice versa. So if the target speed is 3000 rad/s and the device is reading 4000 rad/s at a given KMC_SCALE, then try increasing KMC.

4. If the automatic update method is not working well for the motor, then manually adjust KMC and KMC_SCALE.
   a. Start with the lowest KMC_SCALE value and setting KMC to 255. If the detected ripple frequency is lower than the target ripple frequency, then move to the next KMC_SCALE and repeat the process until the detected frequency is higher than the target ripple frequency. At this point, choose the previous KMC_SCALE (for example, if ripple frequency becomes higher than target ripple frequency with KMC_SCALE=24*2^{12}, select KV_SCALE=24*2^{9}). Then, decrease KMC value from 255 until RC_OUT frequency matches with the current ripple frequency. The figure below shows RC_OUT and current ripple waveforms for correct tuned parameters. The RC_OUT and current ripple frequency is around the same value. There can be slight differences on variations in the frequencies of both signals, as long as the frequency is within an acceptable margin.

There is likely two combinations of KMC and KMC_SCALE that work for a given motor. In this case, pick the combination with the larger KMC value, this gives the tracking better resolution. For example, if the combinations [24*2^{8} with KMC=82] or [24*2^{9} with KMC=168] or both work, then select the second option since KMC is larger.

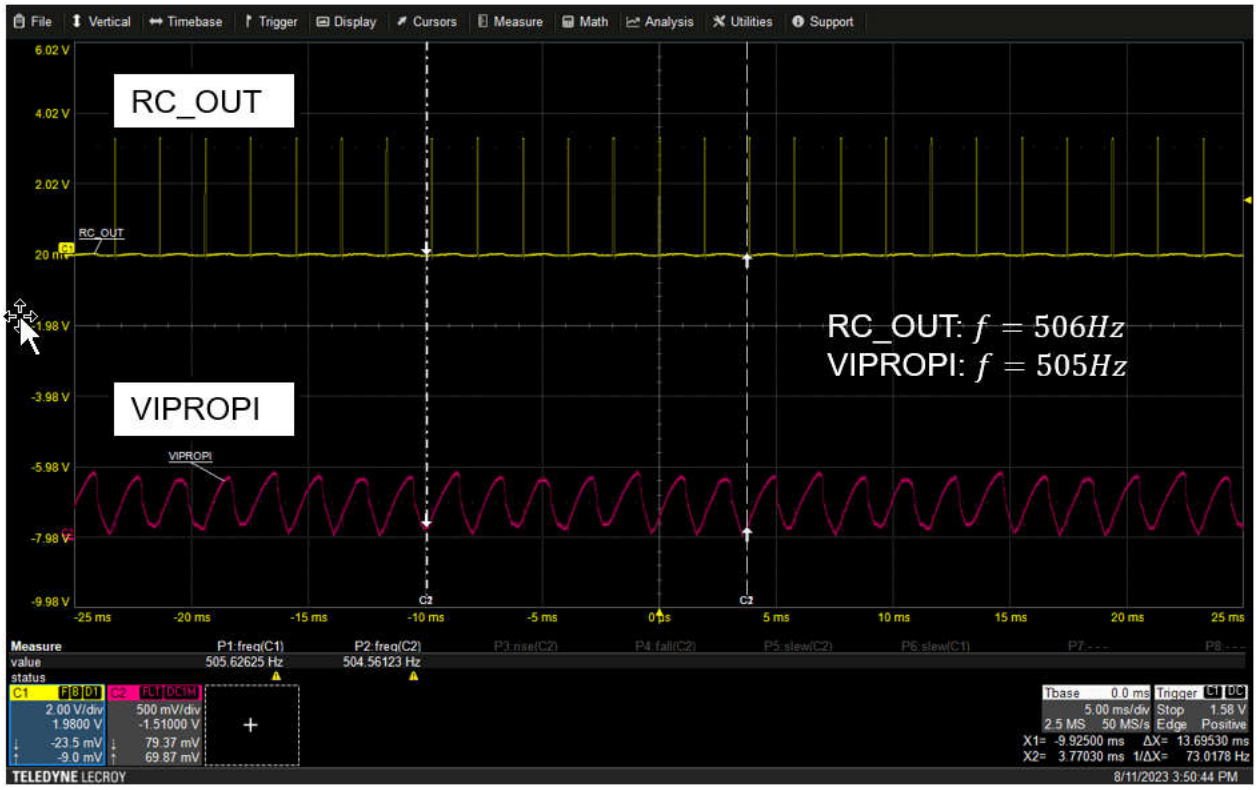


Figure 3-10. IPROPI and RC_OUT waveform after parameter tuning

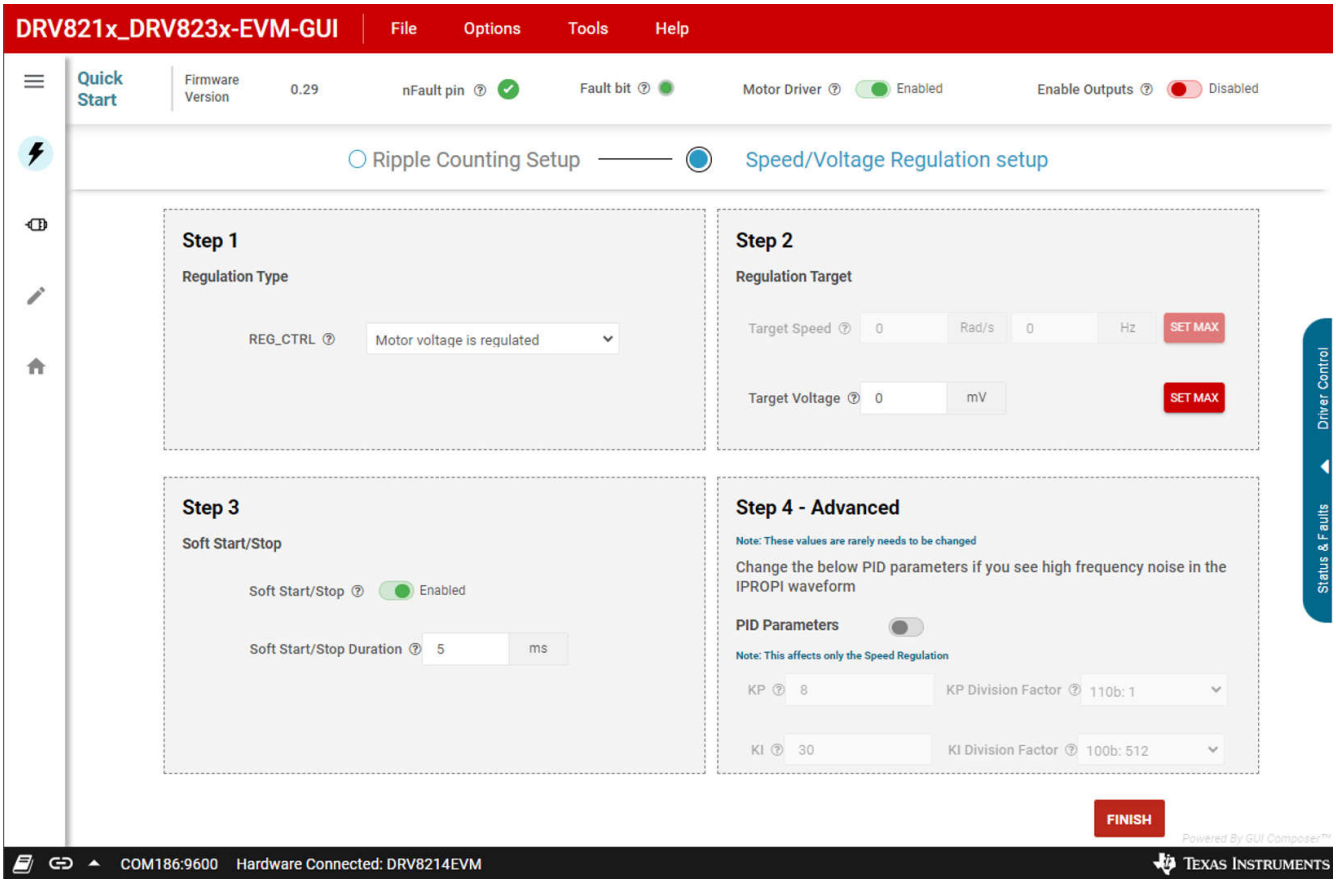


Figure 3-11. Quick Start Page - Speed/Voltage Regulation Setup

Step 1 - Regulation Type

The REG_CTRL drop-down changes the REG_CTRL register to the selected entry. Note that this can only be selected when outputs are disabled, so toggle the top right "Enable Outputs" toggle to off before changing these settings.

Step 2 - Regulation Target

Use the Target Speed and Target Voltage boxes to input the target parameter for the regulation mode if in speed/voltage regulation. The user can press the *Set Max* button to set them to the max value.

Step 3- Soft Start/Stop

Use the Soft Start/STop toggle to enable or disable this feature. Put the duration for soft start or soft stop in the input box with a unit of milliseconds. This updates the TINRUSH register.

Step 4 - Advanced - PI Parameters

This box can be used to adjust the KP, KP_DIV, KI, and KI_DIV parameters if needed. These rarely need to be adjusted, and the device tweaks these as the device functions as part of the control loop with the motor. TI does not recommended to change these under typical circumstances.

3.6.2 Dashboard

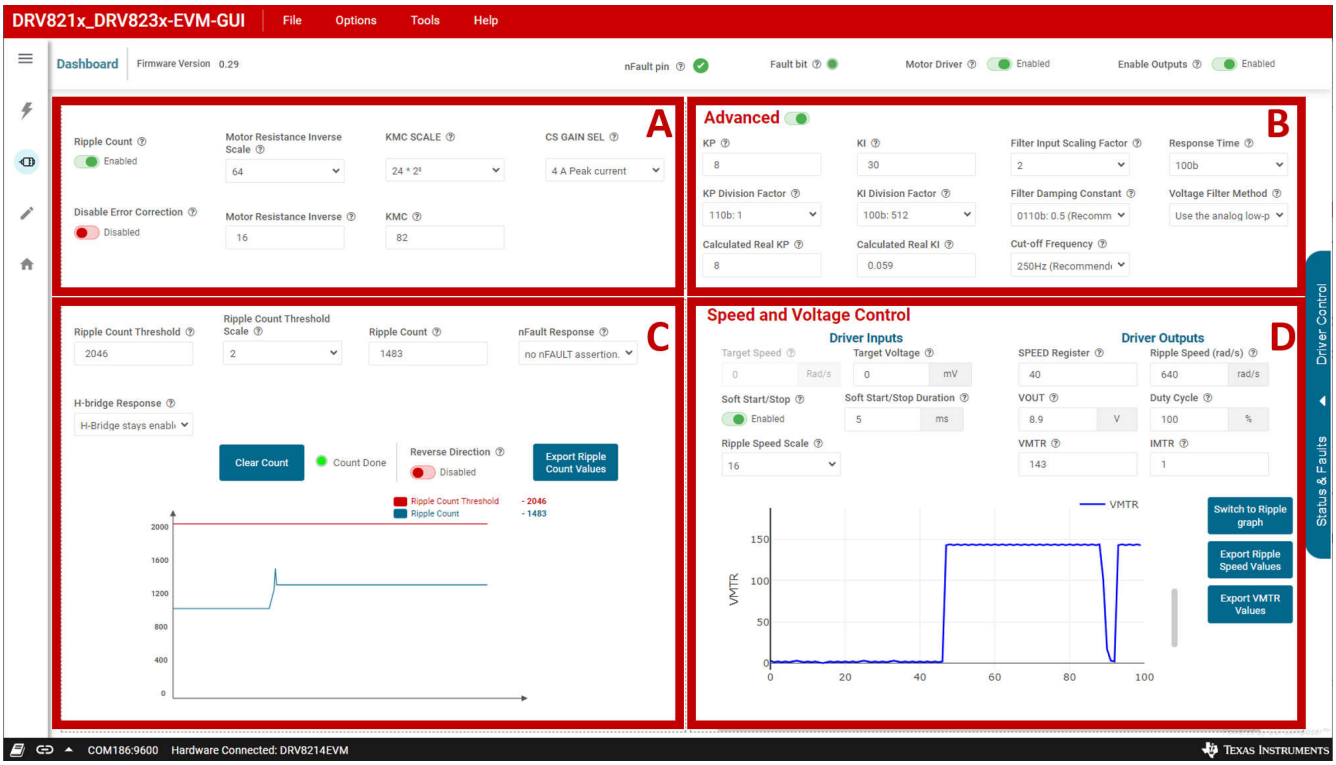


Figure 3-12. Dashboard

A: Ripple Speed Tuning

Ripple count button enables/disables the ripple counting algorithm (sets EN_RC bit in register RC CTRL0)

Error correction button enables/disables the error correction within the ripple count algorithm. Refer to the data sheet for detailed explanation on how error correction functions.

Hover over the (?) icon on any widget to see what bitfield value is being modified. For example, hovering over *Motor Resistance Inverse Scale* clarifies that the KMC_SCALE register field is being edited.

B: Advanced Parameter Tuning

This section contains various advanced parameters. Refer to the data sheet for more details on these parameters. These items often do not need to be edited for a given motor. Many of the drop-down options show a *recommended* value for one of the items on the list.

If the user wants to change an advanced parameter, then TI recommends starting with *Filter Input Scaling Factor*, then *Response Time*, and, finally, *Filter Damping Constant*. The data sheet or application note can provide further explanation for what these do and in what scenario the functions need to be changed.

C: Ripple Counting

The Ripple Count Threshold and Ripple Count Threshold Scale (RC_THR_SCALE) widgets are used to set the desired ripple count threshold. The Ripple Count Threshold box displays RC_THR * RC_THR_SCALE, so the box can only change in increments of the RC_THR_SCALE. For example, if the scale is 64, then pressing the *up* arrow on Ripple Count Threshold increments the value by 64, though the RC_THR register only increments by 1. This device does not internally support automatic stopping or signaling at odd-numbered counts, so if the user wants to stop at (for example, 53 ripples, then the user needs to use the MCU to implement.

The H-bridge Response and nFault Response widgets configure how the H-bridge and nFAULT signal respond due to the ripple count value exceeding the ripple count threshold.

The Count Done indicator turns yellow when the ripple counts is greater than the defined threshold. This widget mirrors the CNT_DONE bit in the FAULT_STATUS register. Clicking on the *Clear Count* button resets the ripple counts to zero.

When the Reverse Direction button is in the ON position, the motor reverses direction automatically when Ripple Count > Ripple Count Threshold. The ripple count values can be exported as CSV file using the *Export Ripple Count Values* button.

The Ripple Count graph shows both the cumulative ripple count (RC) value and the ripple count threshold. The threshold limit is fixed and changes position based on the configured RC threshold. The Ripple Count line outputs the ripple count values given by RC STATUS2 and RC STATUS3 registers.

Note

Due to communication delays between the EVM and the GUI, there is around a 1 second delay by default in between each sample measurement. This delay can be lowered to 500ms by setting the Auto Read delay in the register map to *Fast*. However, this fast option can lead to some instability issues in the GUI. The 1 second delay is the most stable option.

D: Speed and Voltage Regulation

The value displayed in the Ripple Speed graph and inside the Ripple Speed widget is calculated by W_{RIPPLE} = RC_STATUS1*W_SCALE. RC_STATUS1 (SPEED) register outputs the ripple speed in rad/s estimated by the observer in the ripple count algorithm. SPEED ranges from 0-255 and to obtain measurements beyond 255, W_SCALE is required. W_SCALE is selected with the Ripple Speed Scale widget, with options of 16, 32, 64, or 128 rad/s.

Sections of the graph can be magnified by clicking and dragging the mouse diagonally to create a box over the relevant section. The user can zoom in on a certain axis by clicking inside the graph window and dragging parallel to the relevant axis. Clicking and dragging the axes allows the user to scroll up and down the axis. Double-click a blank area on the chart to zoom out. The ripple speed data can be exported as a .csv file for post-processing of the data with the *Export Ripple Speed Values* button.

Note

The graph widget supports magnification of certain sections of the graph as well as zooming in on the X and Y axes. Click and drag a section on the chart to zoom. Click and drag on the X or Y axes to adjust. Double-click a blank area on the chart to zoom back out.

Note

The ripple speed displayed in the graph is NOT the same as the motor rotational speed. The ripple speed is proportional to the number of commutator segments per one motor revolution. To estimate the rotational speed of the motor in RPM, perform the following calculations:

- W_{MOTOR} (rad/s) = W_{RIPPLE} (rad/s) / Number of commutator segments
- W_{MOTOR} (RPM) = (W_{MOTOR} (rad/s) / (2*π))*60

The number of commutators of a motor can be found in the motor data sheet or by reaching out to the motor manufacturer for the information. Another method is by opening the motor and counting the segments. Many small DC motors have two brushes and three commutator segments.

3.6.3 Register Map

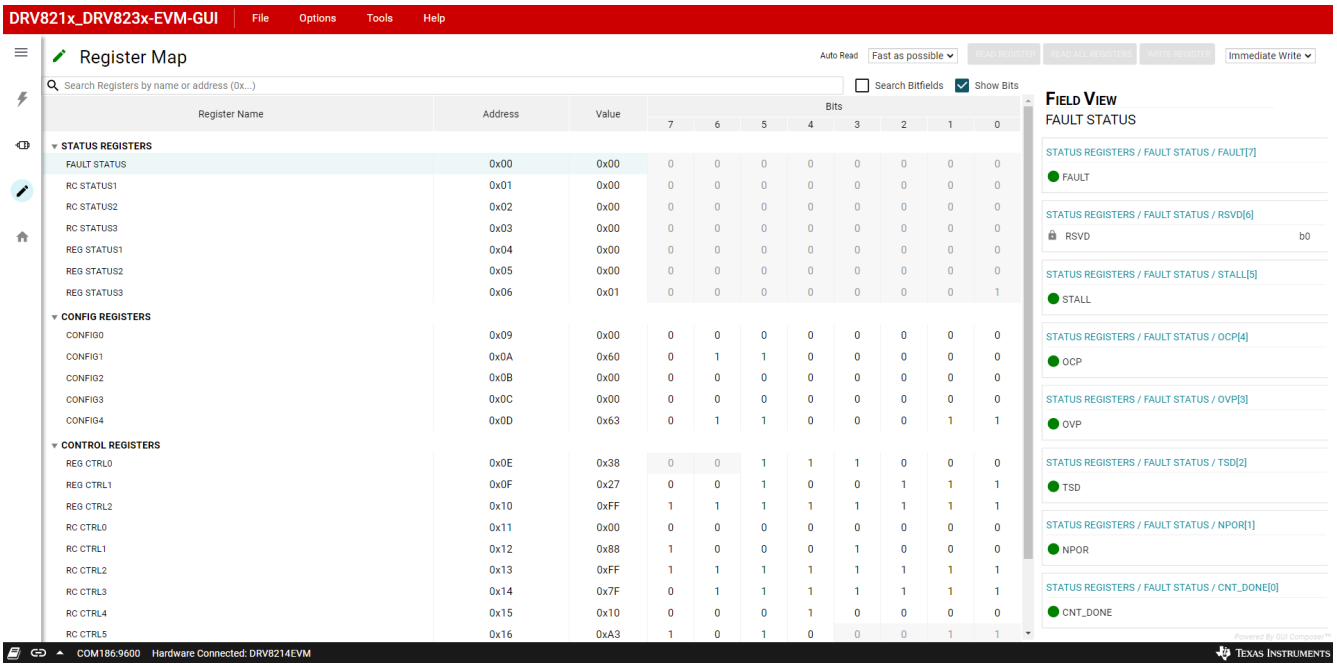


Figure 3-13. Register Map Page

The register map page is shown in Figure 3-13. The register names, address, and values are on the left hand side. The right hand side is the Field View, which provides more information regarding the bit fields of each register. The Auto Read widget sets how often the GUI reads back the register from the motor driver. The fastest option *Fast* is 500ms and the delay can be increase up to 1 minute. Setting Auto Read *Off* allows manual reading of either all registers at once or individually.

Saving and Loading Register Configurations

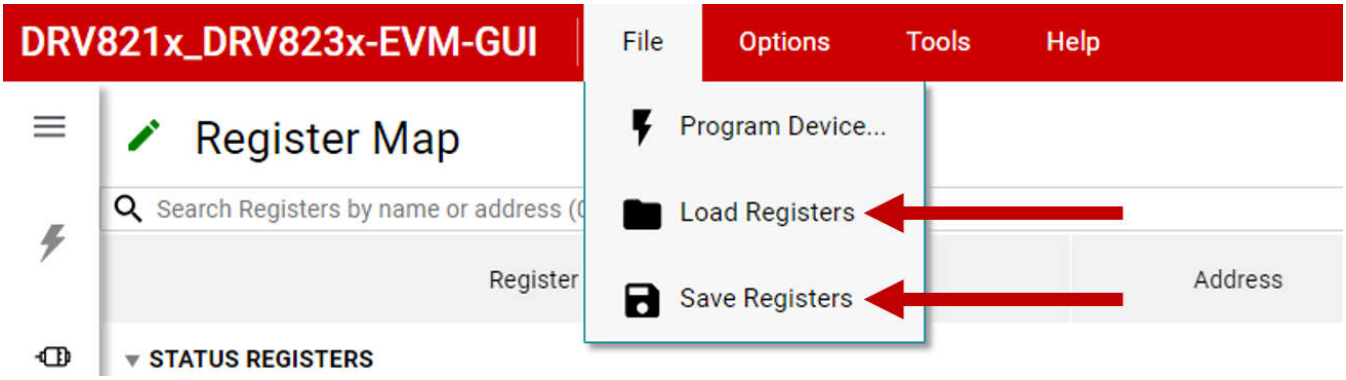


Figure 3-14. Load and Save Registers

The GUI has a built-in feature to save the current register configurations as a .json file which loads to the GUI. The following steps outline the procedure for saving and loading register configurations.

1. After writing the desired register values or using the GUI to configure the device, click on the *File* tab and click *Save Registers*. A save file pop-up window appears so the user can name and save the .json file. This is named with the EVM variant and GUI version in the file name, such as *RegsiterMap_DRV8214EVM_ver_2.0.0.json* if a DRV8214EVM was used with version 2.0.0 of the GUI.
2. To recall the register configurations, click on the *File* tab and then the click *Load Registers*. Select the saved .json file to load the register values.

3.7 Scripting Window

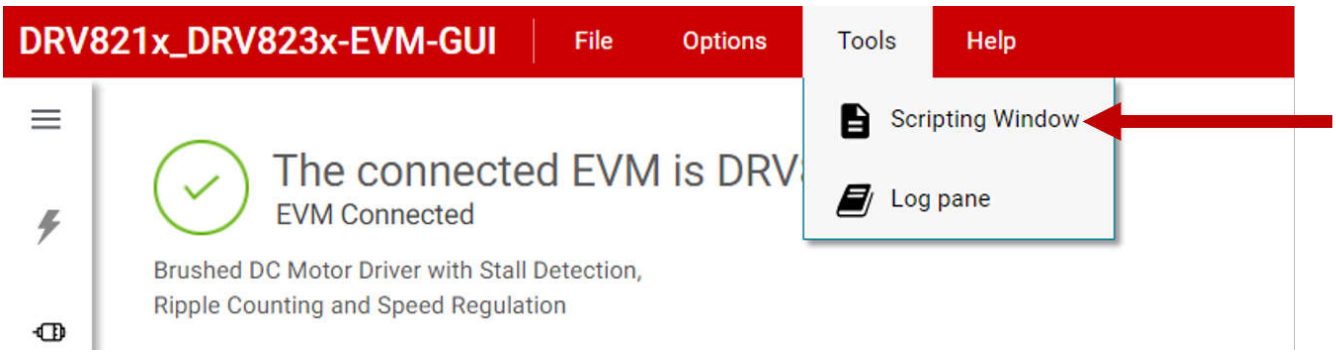


Figure 3-15. Scripting Window

The GUI supports scripting to programming control certain GUI widgets and register functions. This scripting window can be accessed by clicking *Tools, Scripting Window* (Figure 3-15). This opens an example script in a new window. The example script needs to describe how to use the scripting function to control the GUI and read/write to registers.

4 Hardware Design Files

The schematics, bill of materials (BOM), pcb layout, and 3D model STEP file for each EVM can be downloaded on the respective product folder page under the *Design Files* section.

- https://www.ti.com/tool/DRV8213EVM#design-files
- https://www.ti.com/tool/DRV8214EVM#design-files
- https://www.ti.com/tool/DRV8215EVM#design-files
- https://www.ti.com/tool/DRV8234EVM#design-files
- https://www.ti.com/tool/DRV8235EVM#design-files

4.1 Schematics

Figure 4-1shows the schematics for DRV8214EVM. Other variants have minor differences of which components are marked as Do Not Populate (DNP). See schematics of another variant by downloading the *Hardware Design Files* from any EVM tool folder under the *Design Files* section. DRV8213EVM Hardware Files.zip for DRV8213EVM and DRV821x, DRV823x Hardware Files.zip for DRV8214, DRV8215, DRV8234, or DRV8235EVMs.

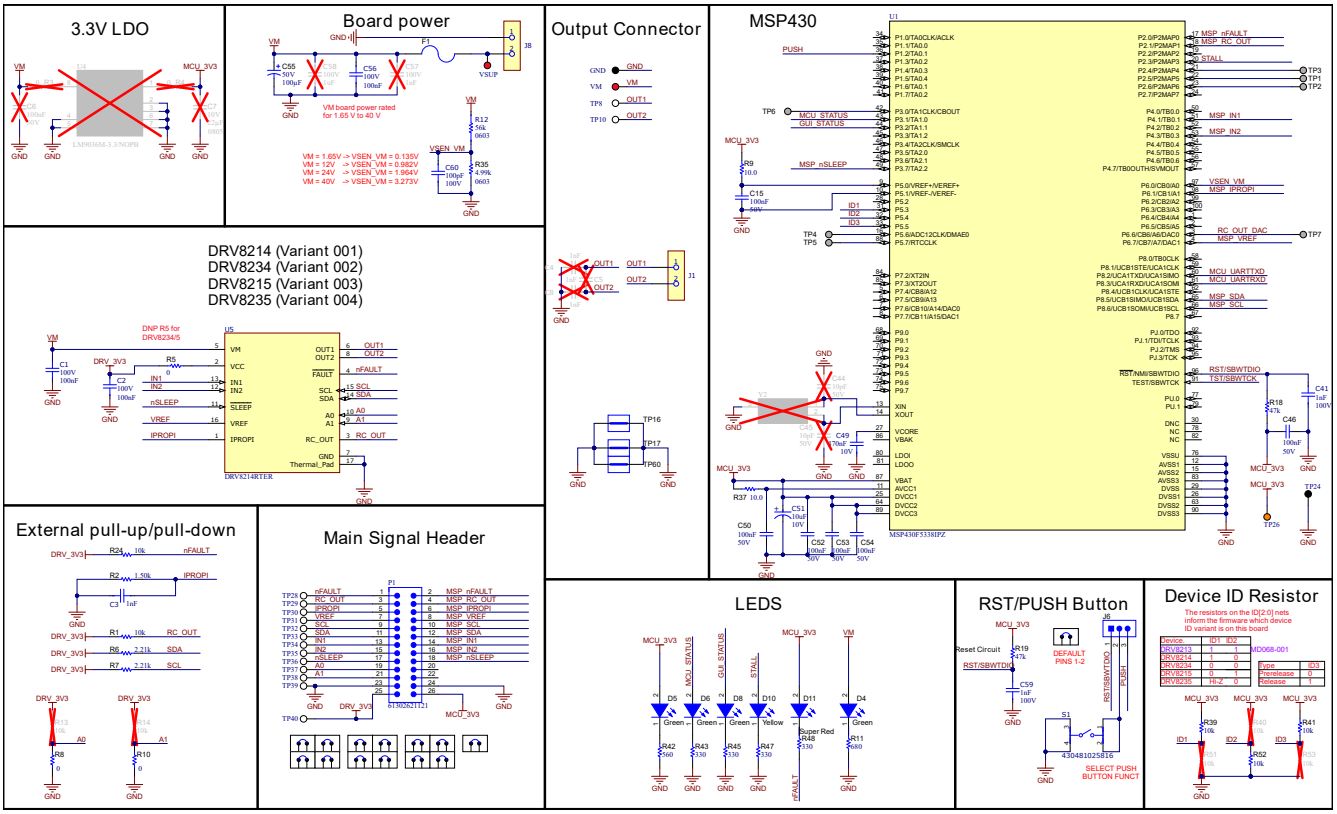


Figure 4-1. Motor Driver DRV82xx Device and MSP430

Figure 4-2 shows the schematics for the EZFET MSP430, 3.3V LDO, and USB interface sections of the EVM.

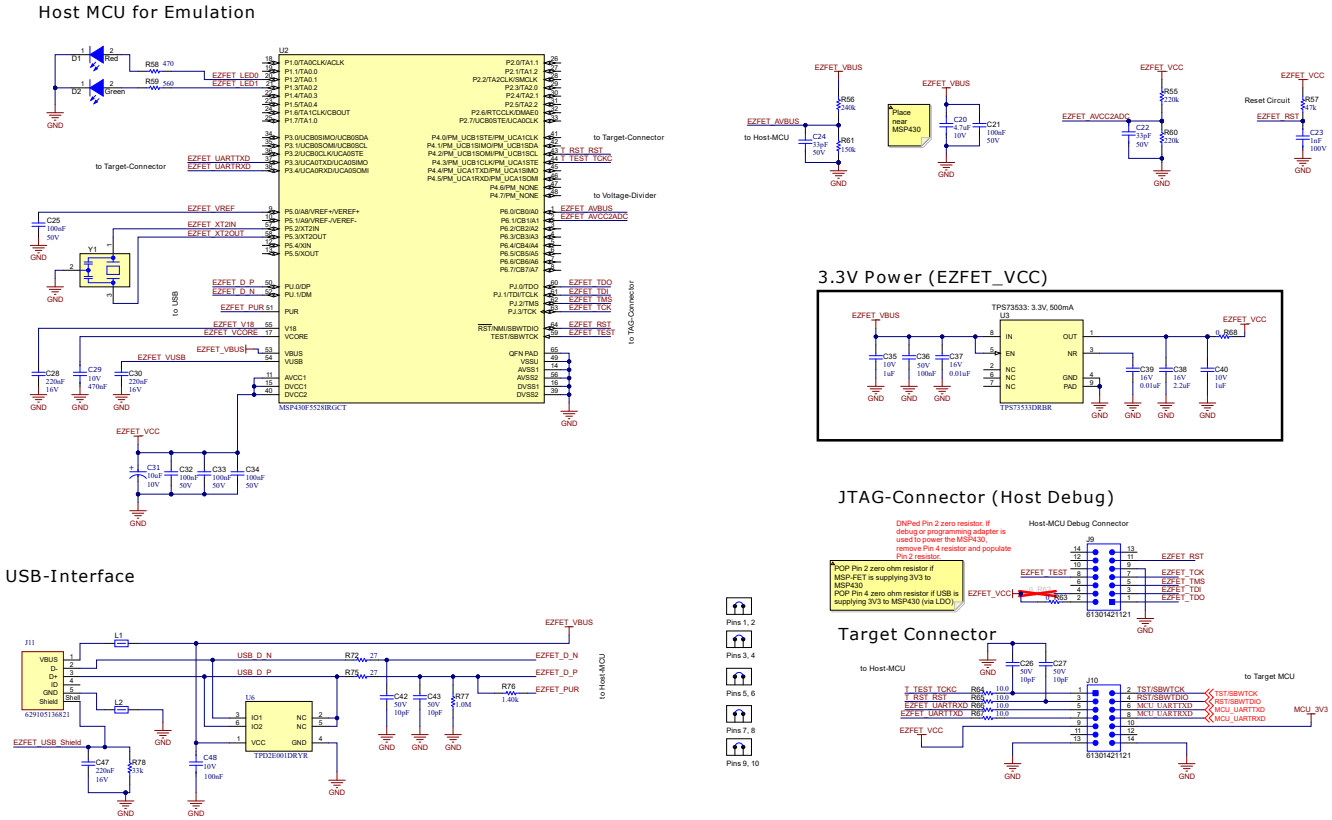


Figure 4-2. EZFET and USB

4.2 PCB Layout

Figure 4-3 through Figure 4-6 show the PCB layers of the EVM. The Altium source files can be downloaded in the aforementioned *Hardware Design Files* for a given EVM.

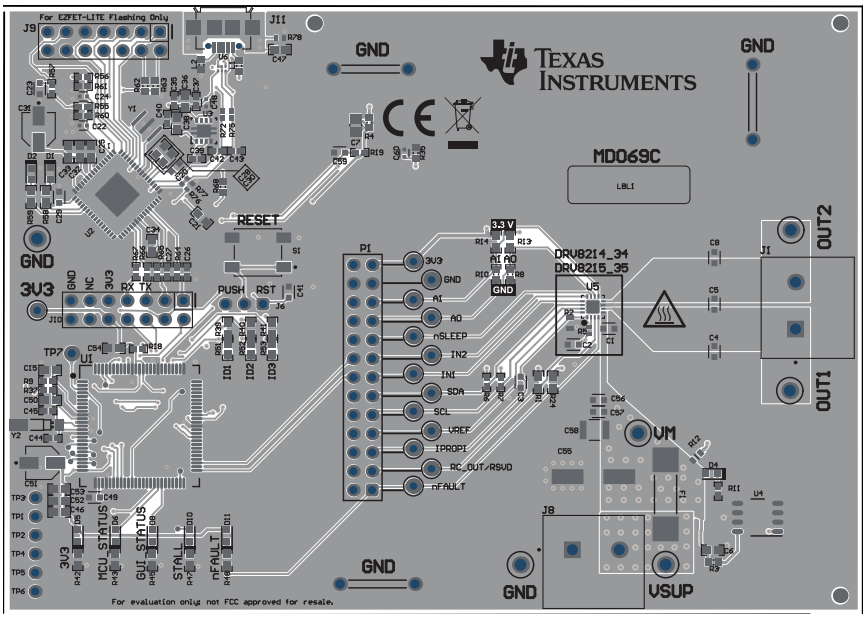


Figure 4-3. Top View

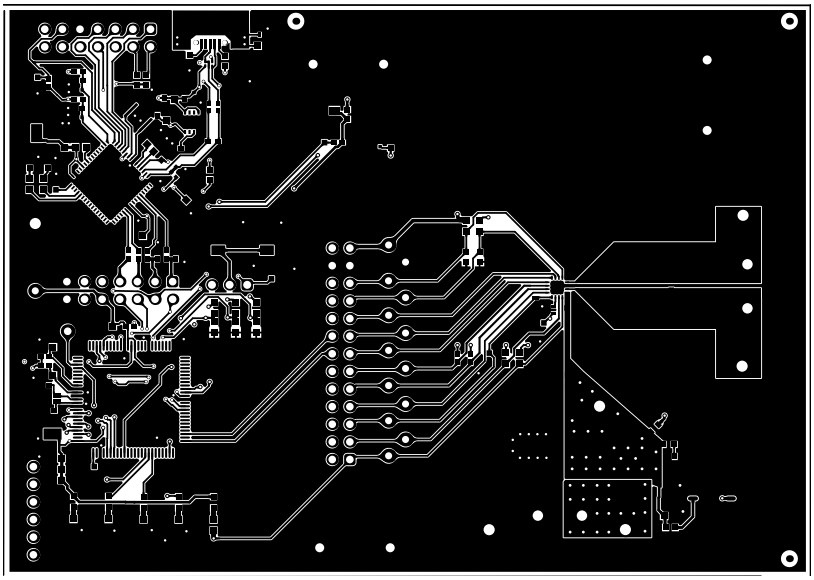


Figure 4-4. Top Layer

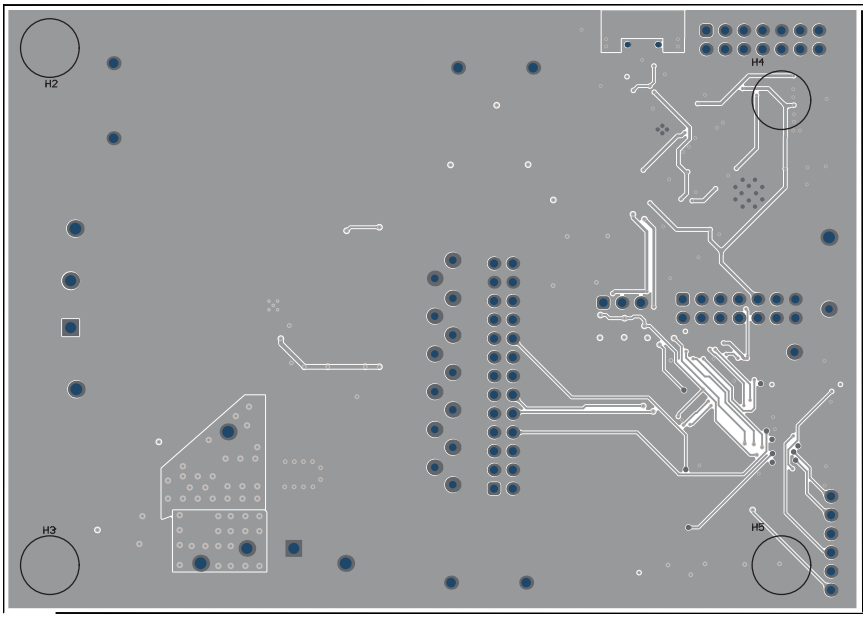


Figure 4-5. Bottom View

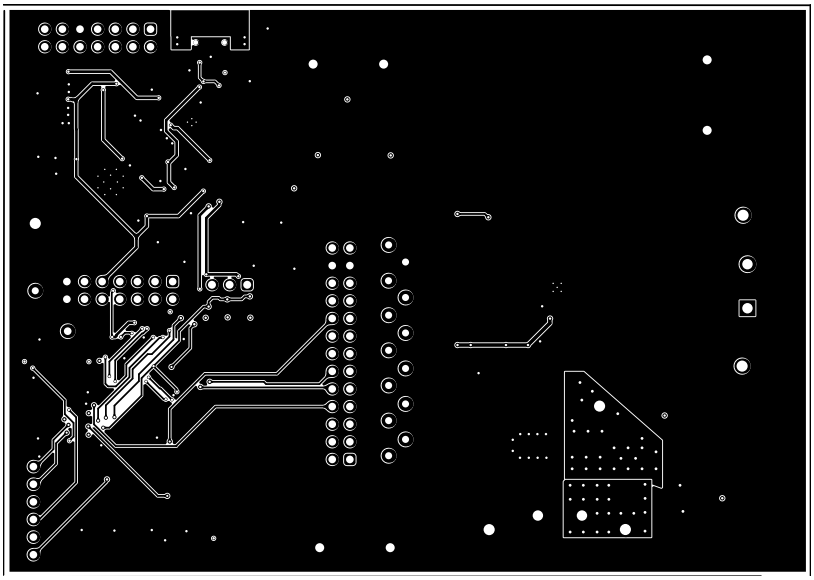


Figure 4-6. Bottom Layers

4.3 Bill of Materials (BOM)

Table 4-1 provides the parts list for DRV8214EVM. Other EVMs have similar BOMs that can be accessed in the aforementioned *Hardware Design Files*.

Table 4-1. Bill of Materials (DRV8214EVM)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		MD069	Any
C1, C2, C56	3	100nF	0.1µF ±10% 100V Ceramic Capacitor X7R 0603 (1608 Metric)	0603	885012206120	Wurth Electronics
C3, C23, C41, C59	4	1nF	1000pF ±5% 100V Ceramic Capacitor C0G, NP0 0603 (1608 Metric)	0603	885012006085	Wurth Electronics
C15, C21, C25, C32, C33, C34, C36, C46, C50, C52, C53, C54	12	0.1uF	CAP, CERM, 0.1uF, 50V, +/- 10%, X7R, 0603	0603	885012206095	Wurth Elektronik
C20	1	4.7µF	4.7µF ±20% 10V Ceramic Capacitor X5R 0603 (1608 Metric)	0603	885012106012	Wurth Electronics
C22, C24	2	33pF	33pF ±5% 50V Ceramic Capacitor C0G, NP0 0402 (1005 Metric)	0402	885012005058	Wurth Electronics
C26, C27, C42, C43	4	10pF	CAP, CERM, 10pF, 50V, +/- 5%, C0G/NP0, 0402	0402	885012005055	Wurth Elektronik
C28, C30, C47	3	0.22uF	CAP, CERM, 0.22uF, 16V, +/- 10%, X7R, 0603	0603	885012206048	Wurth Elektronik
C29, C49	2	470nF	0.47µF ±20% 10V Ceramic Capacitor X5R 0603 (1608 Metric)	0603	885012106008	Wurth Electronics
C31, C51	2	10µF	Alum. Polymer Cap 10µF 10V 5.5mmV-Chip WCAP-PSLP Series Lifetime 2000h +105°C	SMT_CAP_4MM3_4MM3	875105240001	Wurth Electronics
C35, C40	2	1uF	CAP, CERM, 1uF, 10V,+/- 20%, X5R, 0402	0402	885012105012	Wurth Elektronik
C37, C39	2	0.01uF	CAP, CERM, 0.01uF, 16V, +/- 10%, X7R, 0402	0402	885012205031	Wurth Elektronik
C38	1	2.2uF	CAP, CERM, 2.2uF, 16V, +/- 20%, X5R, 0603	0603	885012106018	Wurth Elektronik
C48	1	100nF	0.1µF ±10% 10V Ceramic Capacitor X7R 0402 (1005 Metric)	0402	885012205018	Wurth Electronics
C55	1	100uF	CAP, AL, 100µF, 50V, +/- 20%, SMD	D8xL10.5mm	865060653010	Wurth Elektronik
C60	1	100pF	100pF ±5% 100V Ceramic Capacitor C0G, NP0 0402 (1005 Metric)	0402	885012005080	Wurth Electronics
D1	1	Red	LED, Red, SMD	LED_0603	150060RS75000	Wurth Elektronik
D2, D4, D5, D6, D8	5	Green	LED, Green, SMD	LED_0603	150060VS75000	Wurth Elektronik

Table 4-1. Bill of Materials (DRV8214EVM) (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
D10	1	Yellow	LED, Yellow, SMD	LED_0603	150060YS75000	Wurth Elektronik
D11	1	Super Red	LED, Super Red, SMD	LED_0603	150060SS75000	Wurth Elektronik
F1	1		Fuse, 30A, 250 VAC, 100 VDC, SMD	10.1x3.12mm	0463030.ER	Littelfuse
FID1, FID2, FID3	3		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
GND, TP24	2		Test Point, Multipurpose, Black, TH	Black Multipurpose Testpoint	36-5011-ND	Keystone Electronics
H2, H3, H4, H5	4		Bumpon, Cylindrical, 0.312 X 0.200, Black	Black Bumpon	SJ61A1	3M
J1, J8	2		2 Position Wire to Board Terminal Block Horizontal with Board 0.250" (6.35mm) Through Hole	CONN_TERM_BLOCK2	691250610002	Wurth Electronics
J6	1		Header, 2.54mm, 3x1, Gold, TH	Header, 2.54mm, 3x1, TH	61300311121	Wurth Elektronik
J9, J10	2		Header, 2.54mm, 7x2, Gold, TH	Header, 2.54mm, 7x2, TH	61301421121	Wurth Elektronik
J11	1		USB - micro B USB 2.0 Receptacle Connector 5 Position Surface Mount, Right Angle	Micro USB Surface Mount, Right Angle	629105136821	Wurth Elektronik
L1, L2	2	140 ohm	Ferrite Bead, 140 ohm @ 100MHz, 0.55A, 0603	0603	742792621	Wurth Elektronik
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650 x 0.200 inch	THT-14-423-10	Brady
P1	1		Header, 2.54mm, 13x2, Gold, TH	Header, 2.54mm, 13x2, Gold, TH	61302621121	Wurth Elektronik
R1, R24, R39, R41, R52	5	10k	RES, 10 k, 5%, 0.1 W, 0603	0603	RC0603JR-0710KL	Yageo
R2	1	1.50k	RES, 1.50 k, 1%, 0.1 W, 0603	0603	ERJ-3EKF1501V	Panasonic
R5	1	0	RES, 0, 5%, 0.063 W, 0402	0402	RC0402JR-070RL	Yageo America
R6, R7	2	2.21k	RES, 2.21 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04022K21FKED	Vishay-Dale
R8, R10, R63, R68	4	0	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06030000Z0EA	Vishay-Dale
R9, R37, R64, R65, R66, R67	6	10	RES, 10.0, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040210R0FKED	Vishay-Dale
R11	1	680	RES, 680, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402680RJNED	Vishay-Dale

Table 4-1. Bill of Materials (DRV8214EVM) (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
R12	1	56k	56 kOhms ±1% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200 Thick Film	0603	ERJ-3EKF5602V	Panasonic
R18, R19, R57	3	47k	RES, 47 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040247K0JNED	Vishay-Dale
R35	1	4.99k	RES, 4.99 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06034K99FKEA	Vishay-Dale
R42, R59	2	560	RES, 560, 5%, 0.1 W, 0603	0603	RC0603JR-07560RL	Yageo
R43, R45, R47, R48	4	330	RES, 330, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603330RJNEA	Vishay-Dale
R55, R60	2	220k	RES, 220 k, 1%, 0.0625 W, 0402	0402	RC0402FR-07220KL	Yageo America
R56	1	240k	RES, 240 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402240KFKED	Vishay-Dale
R58	1	470	RES, 470, 5%, 0.1 W, 0603	0603	RC0603JR-07470RL	Yageo
R61	1	150k	RES, 150 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402150KFKED	Vishay-Dale
R72, R75	2	27	RES, 27, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040227R0JNED	Vishay-Dale
R76	1	1.40k	RES, 1.40 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04021K40FKED	Vishay-Dale
R77	1	1.0Meg	RES, 1.0M, 5%, 0.063W, AEC-Q200 Grade 0, 0402	0402	CRCW04021M00JNED	Vishay-Dale
R78	1	33k	RES, 33 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040233K0JNED	Vishay-Dale
S1	1		Tactile Switch SPST-NO Top Actuated Surface Mount	SMT_SW_6MM2_6MM2	430481025816	Wurth Electronics
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-J19, SH-J29, SH-J31, SH-J32, SH-J33, SH-J34, SH-J36	19		Shunt, 2.54mm, Gold, Black	Shunt, 2.54mm, Black	60900213421	Wurth Elektronik

Table 4-1. Bill of Materials (DRV8214EVM) (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
TP8, TP10	2		Test Point, Multipurpose, White, TH	White Multipurpose Testpoint	5012	Keystone Electronics
TP16, TP17, TP60	3		1mm Uninsulated Shorting Plug, 10.16mm spacing, TH	Shorting Plug, 10.16mm spacing, TH	D3082-05	Harwin
TP26	1		Test Point, Miniature, Orange, TH	Orange Miniature Testpoint	5003	Keystone Electronics
TP28, TP29, TP30, TP31, TP32, TP33, TP34, TP35, TP36, TP37, TP38, TP39, TP40	13		Test Point, Miniature, White, TH	White Miniature Testpoint	5002	Keystone Electronics
U1	1		20MHz Mixed Signal Microcontroller with 256 KB Flash, 18432 B SRAM and 74 GPIOs, -40 to 85 degC, 100-pin QFP (PZ), Green (RoHS & no Sb/Br)	PZT0100A	MSP430F5338IPZ	Texas Instruments
U2	1		16-Bit Ultra-Low-Power Microcontroller, 128KB Flash, 8KB RAM, USB, 12Bit ADC, 2 USCIs, 32Bit HW MPY, RGC0064B (VQFN-64)	RGC0064B	MSP430F5528IRGCT	Texas Instruments
U3	1		500mA, Adjustable, Low Quiescent Current, Low-Noise, High-PSRR, Single-Output LDO Regulator, DRB0008A (VSON-8)	DRB0008A	TPS73533DRBR	Texas Instruments
U5	1		2A Brushed DC Motor Driver with Stall Detection, Ripple Counting and Speed Regulation	WQFN16	DRV8214RTER	Texas Instruments
U6	1		Low-Capacitance 2-Channel +/-15kV ESD Protection Array for High-Speed Data Interfaces, DRY0006A (USON-6)	DRY0006A	TPD2E001DRYR	Texas Instruments
VM, VSUP	2		Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	36-5010-ND	Keystone Electronics
Y1	1		Oscillator, 4MHz, 700ppm, 39pF, SMD	4.5x2mm	CSTNR4M00GH5L000R0	MuRata

5 Additional Information

5.1 Trademarks

All trademarks are the property of their respective owners.

6 Revision History

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

Changes from Revision * (May 2023) to Revision A (April 2024)	Page
• Added support for DRV8213, DRV8214, and DRV8234	1
• Added support for DRV8215 and DRV8235. Updated for GUI version 2.0.0	1

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