

1 Evaluation Module Overview

1.1 Introduction

The EVM is an easy-to-use platform for evaluating the main features and performance of the INA231. The EVM supports current measurements up to 10 amps through the PCB, and includes a graphical user interface (GUI) used to read and write device registers as well as view and save results data.

This user's guide describes the characteristics, operation, and use of the INA231 evaluation module (EVM). This EVM is designed to evaluate the performance of the INA231. Throughout this document, the terms evaluation board, evaluation module, and EVM are synonymous with the INA231EVM. This document includes a schematic, reference printed circuit board (PCB) layouts, and a complete bill of materials (BOM).

1.2 Kit Contents

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

Table 1-1. Kit Contents

ITEM	QUANTITY
INA231EVM test board	1

Note that this EVM requires the TI Sensor Control Board (SCB), which is sold separately.

1.3 Specification

The EVM is intended to provide basic functional evaluation of the device. The layout is not intended to be a model for the target circuit, nor laid out for electromagnetic compatibility (EMC) testing. The EVM consists of two printed-circuit boards (PCBs). The larger PCB is referred to as the EVM, and has the INA231 installed. The smaller PCB is referred to as the SCB Controller, and is used to interface the EVM with the GUI.

1.4 Device Information

The INA231 is a current-shunt and power monitor with a 1.8V compliant I2C interface that features 16 programmable addresses. The INA231 monitors both shunt voltage drops and bus supply voltage, providing increased protection by asserting the ALERT pin if the values are outside the programmed range. Programmable calibration value, conversion time, and averaging, combined with an internal multiplier, enable direct readouts of current in amperes and power in watts, thus reducing host processing.

The INA231 senses current on bus voltages that vary from 0V to 28V, with the device powered from a single 2.7V to 5.5V supply, drawing 330 μ A (typical) of supply current. The INA231 is specified over the operating temperature range of -40°C to $+125^{\circ}\text{C}$.

The INA231 is available in two versions: the INA231A starts up performing continuous conversions of the shunt and bus voltage, whereas the INA231B starts up in low-current, power-down mode.

Table 1-2. Device Summary

PRODUCT	DIGITAL PROTOCOL	ADC RESOLUTION	MAX GAIN ERROR	MAX OFFSET VOLTAGE
INA231	I2C	16-bit	0.5%	$\pm 50\ \mu\text{V}$

2 Hardware

2.1 Quick Start Setup

The following instructions describe how to set up and use the EVM.

- Purchase an SCB if you do not already have one.
 - To use a PAMB Controller instead, see [PAMB Compatibility](#).
- Download this driver and install **as an administrator**: <https://www.ti.com/lit/zip/sbac253>.
 - Follow the download prompts, a myTI account is required.
 - Note that this driver is labeled as a PAMB driver, but is also used for the SCB.

3. Attach the EVM to the SCB Controller as shown in [Figure 2-1](#).
 - a. Refer to [Figure 2-2](#) when connecting multiple EVMs of the same type together.
4. Connect the EVM to the PC using the provided USB cable.
 - a. Insert the micro USB cable into the SCB Controller onboard USB receptacle J2.
 - b. Plug the other end of the USB cable into a PC.
5. Access the GUI from this link in either Chrome, Firefox, or Safari: https://dev.ti.com/gallery/info/CurrentSensing/INA231EVM_GUI/.
6. Connect the GND reference of the external system to the GND node of the EVM (pin 1 of J1).
7. Provide a differential input voltage signal to the IN+ and IN- nodes by connecting the signal leads to J1 pin 5 or 6 and J1 pin 3 or 4 on the EVM as explained in [Current Sensing Operation](#).

2.2 EVM Operation

To use the EVM with the SCB Controller (sold separately), connect the EVM as shown in [Figure 2-1](#).

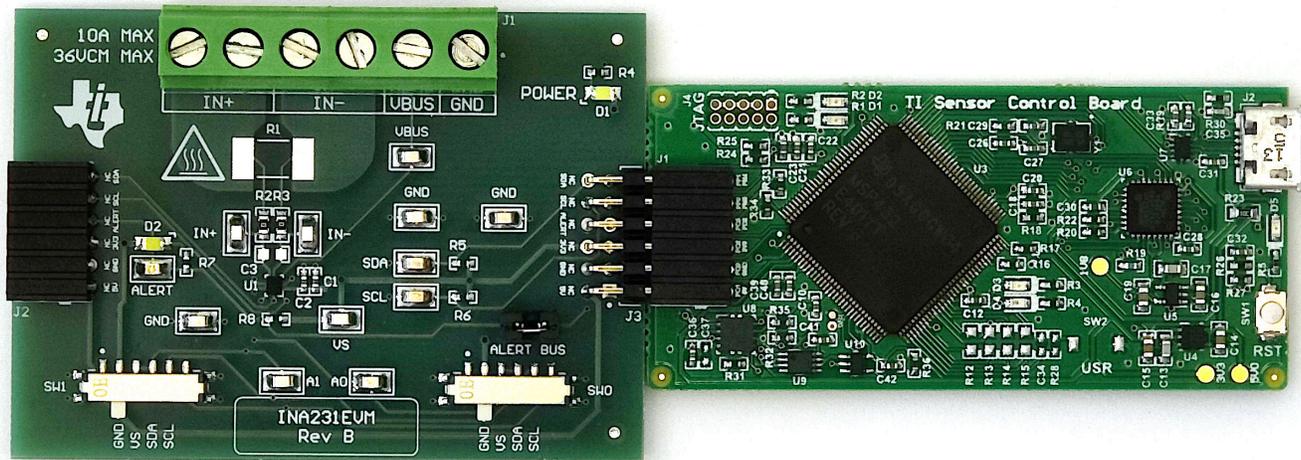


Figure 2-1. EVM (Left) Connected to SCB Controller (Right)

If using multiple EVMs, then connect them as shown in [Figure 2-2](#). Make sure to use a different I2C address for each device. The GUI only supports up to 4 EVMs total.

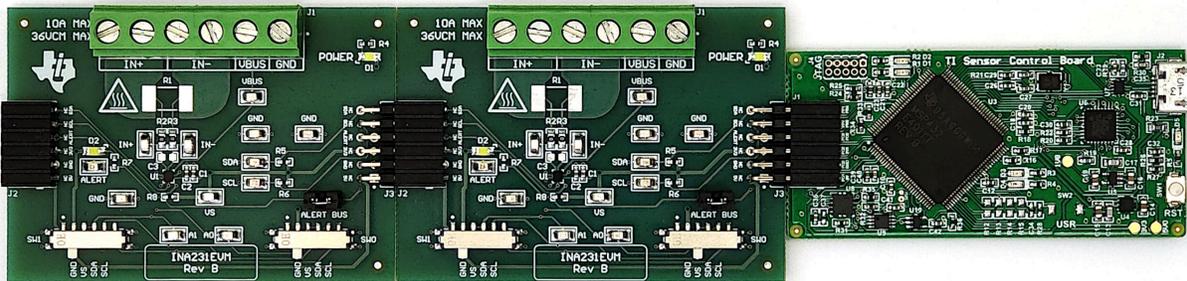


Figure 2-2. Multiple EVMs Connected to SCB Controller

2.2.1 Current Sensing Operation

The EVM can be used with either an onboard or external shunt resistor. To use the onboard shunt resistor, solder a 2512 surface-mount technology (SMT) shunt resistor across the pads of R1, and connect in series with the external system and load current through J1. An external shunt can be connected directly across the terminals of J1. There are two terminals each for IN+ (J1 pins 5 and 6) and IN- (J1 pins 3 and 4) for convenience.

2.2.1.1 Detailed Setup

To configure a measurement evaluation, follow these steps:

1. Connect a shunt resistor by doing either of the following:
 - a. Solder a 2512 resistor across the pads of R1 that connects the IN+ and IN- inputs.
 - b. Connect an external shunt across the IN+ and IN- terminals of J1, preferably across pins 4 and 5, as shown in [Figure 2-3](#) and [Figure 2-4](#).
 - i. If an external shunt is being used, then make the connections such that the sensing location is across the shunt and there is no high current on the sensing path. See the [TI Precision Labs - Current Sense Amplifiers: Shunt Resistor Layout](#) video for more information.
2. Connect the IN+ and IN- terminals in series with the load while powered off.
 - a. When measuring more than 10 A, make sure the high current path does not go through the EVM (including the terminal block J1), as shown in [Figure 2-3](#).

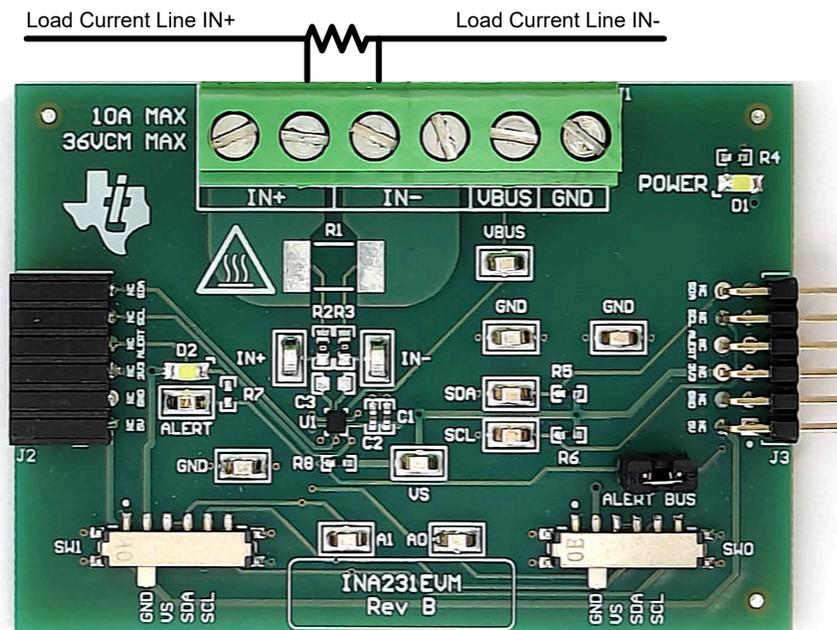


Figure 2-3. IN+ and IN- Wiring for More Than 10A

- b. When using 10A or less with either an onboard or external shunt, the current path can be passed through the EVM. [Figure 2-4](#) shows a convenient way to use the multiple IN+ and IN- terminals with an external shunt for this use case.

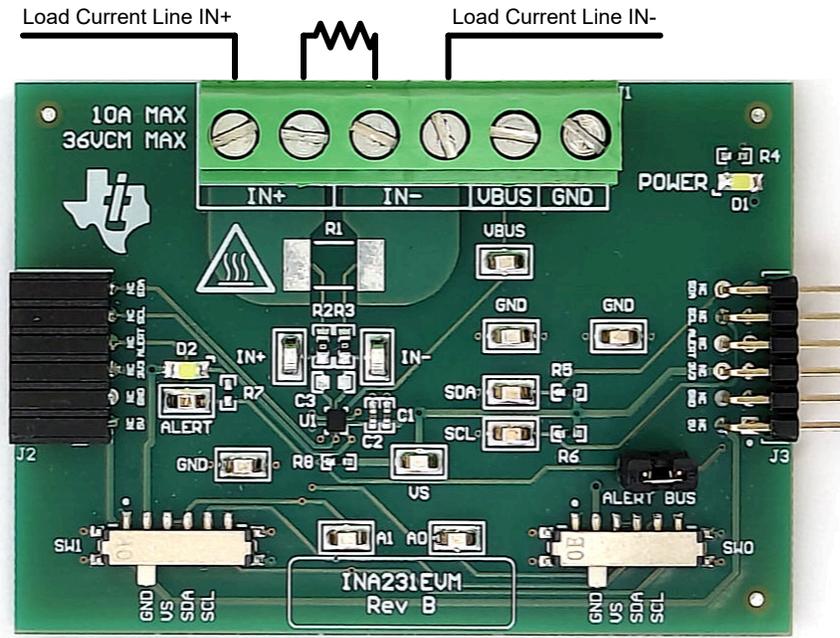


Figure 2-4. IN+ and IN- Wiring for 10A or Less

WARNING

When measuring current, first make sure that the equipment (shunt resistor, wires, connectors, and so on) can support the amperage and power dissipation. Secondly, make sure that the current flowing through J1 does not exceed 10A. Failure to do so can result in damage to the EVM, or personal injury.

The EVM can get hot.

3. Connect the VBUS terminal (J1 pin 2) to the desired bus voltage (likely either IN+ or IN-).
 - a. If VBUS and dependent features are not being used, then this channel can be used as an ADC input for another voltage.
4. Connect the system ground to the GND terminal (J1 pin 1).
5. Power on the system, and observe the device states and outputs through the GUI.

2.3 Circuitry

This section summarizes the EVM subsystems and the components.

2.3.1 Current Sensing IC

This section describes the INA231 and supporting components.

U1 is the INA231 current-sensing device. C1 and C2 are bypass capacitors that are placed near the sensor to help mitigate power supply noise and provide current quickly to the device when needed. LED D1 with current limiting resistor R4 are used to indicate when the EVM is powered on.

The device pins can be monitored directly through the test points TP1 – TP12. Note that there are two extra test points on GND for convenience.

2.3.2 Input Signal Path

This section describes the circuitry of the input signal path.

J1 is the main connection terminal. Pin 1 of J1 is used to tie the system ground to the EVM ground. Pin 2 of J1 is used for the VBUS measurement within the sensor. Pins 3 and 4 are tied to IN–, and Pins 5 and 6 are tied to IN+. There are two pins each for IN– and IN+ for convenience.

R1 can be used for an optional onboard shunt resistor with a 2512 footprint. Alternatively, a shunt can be placed across the IN+ and IN– terminals of J1. If desired, a differential voltage can be applied directly for measurement tests.

C3, R2, and R3 combine to make an optional input filter. R2 and R3 are populated with 0-Ω resistors by default. When using input filtering, take into account the input bias current of the device. C3 can also be used without R2 and R3 to reduce noise. See the data sheet for more info on input filtering.

2.3.3 Digital Circuitry

This section describes the digital circuitry around the device.

J2 and J3 are the main header pins that connect the digital and power pins to the SCB Controller or other EVMs. J3 connects to the EVM/SCB on the right, while J2 connects to more EVMs on the left. R5 and R6 are used as pullup resistors for the main digital IO pins.

SW0 and SW1 set the I2C address of the device. This can be useful when using the EVM with a custom controller (other than the SCB Controller), or when connecting multiple EVMs together. Currently the SCB Controller and GUI are set up to use four EVMs at a time.

R8 is used as a pullup resistor for the ALERT pin, which is routed to both J2 and J3. LED D2 and current limiting resistor R7 are used to indicate when the ALERT has triggered. Header J4 and jumper SH-J4 are used to disconnect the ALERT pin from the EVM ALERT bus by disconnecting from J3. This is primarily used when working with multiple EVMs, so that the individual ALERT LEDs can be seen on each EVM when the ALERT bus is not needed.

2.4 PAMB Compatibility

If desired, then this EVM and GUI can be used with the PAMB Controller (DC081A) by jumper wiring the pin headers of the PAMB to the EVM. [Figure 2-5](#) shows which pins on the PAMB correspond to the EVM header pins. Note not to add too much resistance in the jumper wire connection setup or the signal can degrade and cause communication errors.

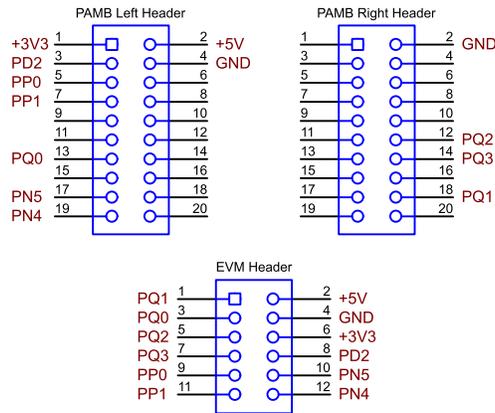


Figure 2-5. EVM to PAMB Connection

3 Software

3.1 Setup

3.1.1 Driver Installation

Download and install this driver: <https://www.ti.com/lit/zip/sbac253>. This is a one-time step per computer, and requires a myTI account. Note that this driver is labeled as a PAMB driver, but is also used for the SCB. Unzip the folder and **run the .exe file with administrator privileges**.

3.1.2 Firmware

Firmware updates are pushed through the GUI if the previous driver is installed. Downloaded offline GUIs only update the SCB Controller with the latest firmware available at the time of download. To check for the latest GUI or Firmware updates, launch the latest GUI version from the web browser.

3.1.2.1 Firmware Debug

If the firmware must be manually reinstalled for any reason, then follow these steps to reinstall the firmware. Make sure the EVM is connected to the SCB before being powered on.

1. First, see if the GUI can program the firmware.
 - a. Plug in the SCB controller to the PC.
 - i. Make sure the EVM is connected to the SCB first.
 - b. Launch the GUI and close the README.md window.
 - c. If the MCU is already in Device Firmware Update (DFU) mode, then a popup window appears saying "Connection Failure - No SCB controller detected".
 - i. Close this window.
 - d. If the GUI does not update automatically, then go to *File > Program Device...*
 - i. If the *Program Device...* button is still grayed out, then click the connect button in the lower left corner and then try again.
2. If step 1 is unsuccessful (or if the *Program Device...* button is still grayed out), then manually configure the MCU on the SCB Controller to be in DFU Mode. This can be done through either of the below methods with the SCB Controller powered on:
 - a. Through software:
 - Send the command 'bsl' on the SCB's USB Serial (COM) port.
 - b. Through hardware:
 - For safety, **turn off and disconnect all load sources and external voltages**.
 - While shorting the two test points labeled *DFU* (shown in [Figure 3-1](#)) with a pair of tweezers (or wire), press and release the RESET button.

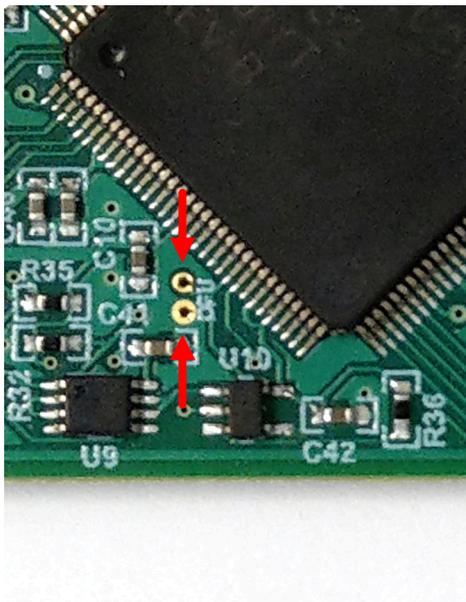


Figure 3-1. Test Points Used to Enter DFU Mode Manually

- If the PAMB board is being used instead, then these test points are located near PK1 and PK2.

With the MCU in DFU mode, the firmware can now be uploaded through the method outlined in [Step 1](#).

3.1.3 GUI Setup and Connection

You can access the GUI from this link in either Chrome, Firefox, or Safari: https://dev.ti.com/gallery/info/CurrentSensing/INA231EVM_GUI/.

3.1.3.1 Initial Setup

To set up the GUI the first time:

1. Make sure that the previously mentioned driver was installed successfully so that everything works properly and that the GUI can update the EVM firmware, if necessary.
2. Check to make sure the EVM and SCB Controller unit is plugged into the PC, then go to the previously-provided GUI link.
 - a. Verify that the EVM is connected to the SCB before plugging the SCB into a USB port.
3. Open the *GUI Composer* application to launch the GUI from the web browser (see [Figure 3-2](#)).

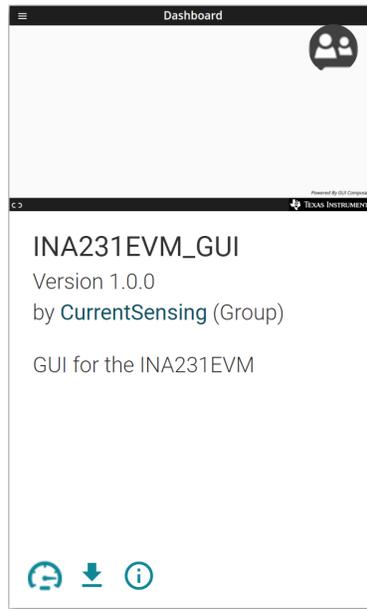


Figure 3-2. GUI Composer Application

- a. The GUI link brings up all versions of the GUI. TI recommends launching the newest version available.
- b. For first-time GUI Composer setup, follow the prompts to download the *TI Cloud Agent* and browser extension (see [Figure 3-3](#)). These prompts appear after you close the *README.md* dialog box.

TI Cloud Agent Installation

Hardware interaction requires additional one time set up. Please perform the actions listed below and try your operation again.(What's this?)

- Step 1: **INSTALL** browser extension
- Step 2: **DOWNLOAD** and install the TI Cloud Agent Application
- Help. I already did this

FINISH

Figure 3-3. TI Cloud Agent

4. Optionally, to download the GUI for offline use, click the  icon in the GUI Composer application and follow the prompts (see [Figure 3-2](#)).

3.1.3.2 GUI to EVM Connection

To connect the GUI to the EVM, follow these steps:

1. Setup and launch the GUI as described in [Initial Setup](#).
 - a. Make sure to connect the EVM to the SCB before powering on.
2. Close the *README.md* file page to initiate a connection between the EVM and the GUI. If successful, then the text *Hardware Connected* is visible near the bottom left corner of the GUI.

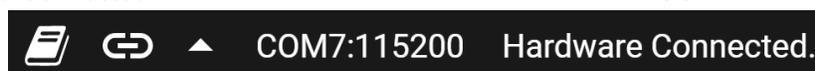


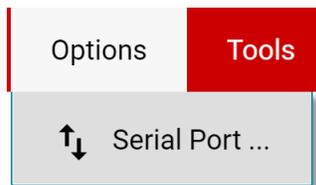
Figure 3-4. Hardware Connected

- a. A green indicator with the device type and the text *DEVICE CONNECTED* is also visible near the top left of the GUI.

DEVICE CONNECTED

**Figure 3-5. Device Connected**

- b. If *Hardware Connected* and *DEVICE CONNECTED* do not show in the GUI, then long-press the RESET button on the EVM to try again.
 - i. If that option does not work, then check different hardware COM ports under *Options > Serial Port*.

**Figure 3-6. Change Serial Port**

- c. If the hardware still does not connect, then make sure the correct GUI and EVM combination is being used.
 - i. If you are using the correct GUI and EVM combination, then you may need to reprogram the firmware of the SCB, as described in [Firmware Debug](#).
 - ii. Many connectivity issues can be addressed by doing one of the following:
 1. Long-press the RESET button on the EVM with the EVM and SCB connected to each other.
 - Refreshing the GUI can also sometimes help this.
 2. Connect the EVM to a different USB port.
 - Avoid using long cables and USB hubs.
 - If using a desktop PC, try a USB port on the back.

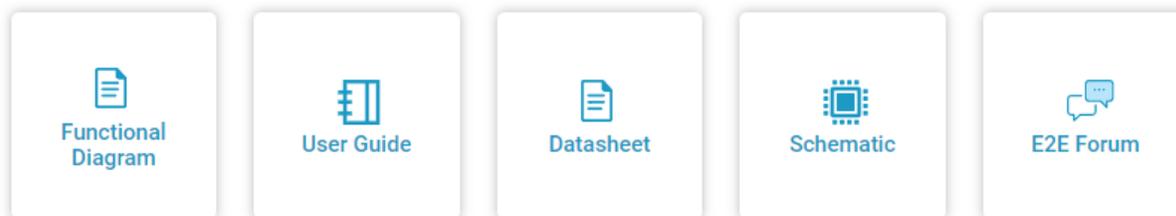
3.2 GUI Operation

Setup, launch, and connect the GUI to the EVM per [GUI Setup and Connection](#). Refer to the sections below for a description on how to use each page of the GUI.

3.2.1 Home Tab

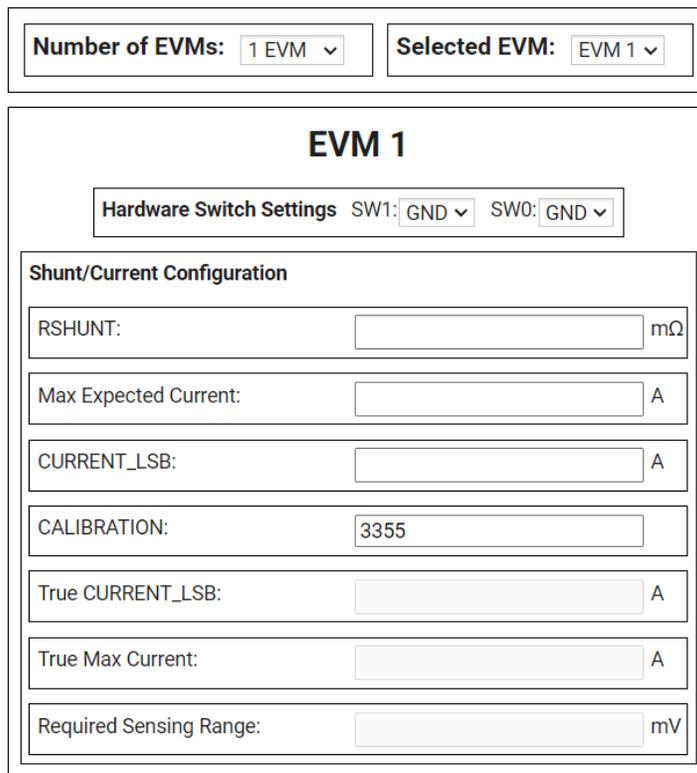
The GUI starts out on the Home tab. To get to this page from anywhere, click the  (Home) icon on the menu on the left.

From the homepage, you can easily confirm successful GUI to EVM connection (see [GUI to EVM Connection](#)), as well as access helpful resources through the buttons on the bottom (see [Figure 3-7](#)).

**Figure 3-7. Home Tab Links**

3.2.2 Configuration Tab

To do the initial setup for each connected EVM, click the  (Configuration) icon on the menu to the left. [Figure 3-8](#) shows an example of the configuration tool.



The screenshot shows a configuration tool interface. At the top, there are two dropdown menus: "Number of EVMs:" set to "1 EVM" and "Selected EVM:" set to "EVM 1". Below this is a section titled "EVM 1" containing "Hardware Switch Settings" with "SW1:" set to "GND" and "SW0:" set to "GND". The main section is "Shunt/Current Configuration" and includes the following fields:

- RSHUNT: [] mΩ
- Max Expected Current: [] A
- CURRENT_LSB: [] A
- CALIBRATION: [3355]
- True CURRENT_LSB: [] A
- True Max Current: [] A
- Required Sensing Range: [] mV

Figure 3-8. Configuration Tool

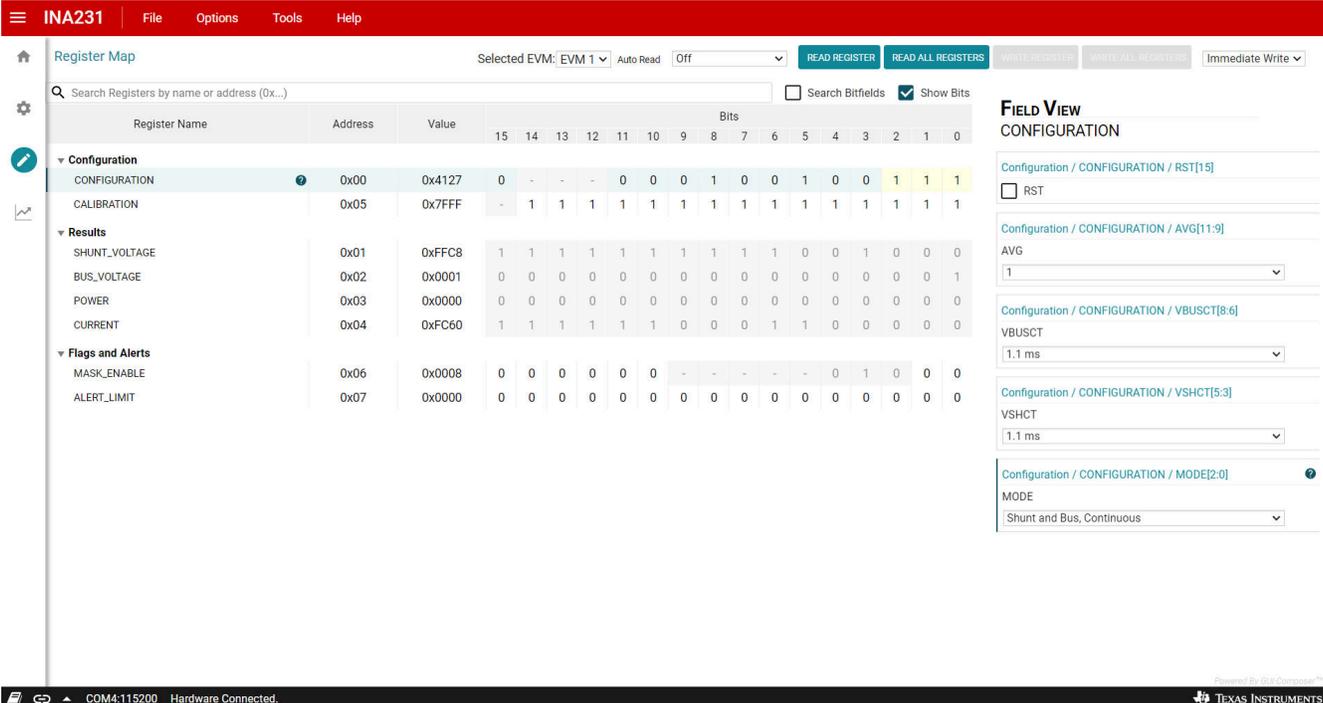
From this page you can set the number of EVMs you are using, and then for each EVM you can indicate the physical hardware switch settings and configure your shunt and CURRENT_LSB. Below is a description of each option and field on this page:

- Number of EVMs
 - This setting is used to tell the GUI how many EVMs are connected to the SCB.
 - Note, the SCB and GUI only support up to 4 INA231EVMs at a time.
 - Changing this here also changes the same setting in the Results Data tab.
- Selected EVM
 - This setting indicates which EVM you are currently changing settings for.
 - This also selects the EVM that is connected to the Registers tab.
- Hardware Switch Settings
 - Set these settings to match the physical switch settings on the EVM.
 - Note, this setting needs to be set before changing any other settings on this page. The GUI blocks the other settings until this is set.
 - Changing this here also changes the same setting in the Results Data tab.
- Shunt/Current Configuration
 - This section is used to input shunt information as well as to help calculate the CURRENT_LSB and set the CALIBRATION register. Here is a description of how to use each field:
 - RSHUNT
 - Input the value of the used shunt resistor in mΩ.
 - Max Expected Current
 - Input the value of the maximum expected current across the shunt resistor in Amps.

- If the Max Expected Current field is left blank, then CALIBRATION can be adjusted manually, and the tool shows the True Max Current that can be measured with the EVM.
- CURRENT_LSB
 - This is the calculated CURRENT_LSB value in Amps. This field gets populated automatically from the Max Expected Current field.
 - This field can be changed manually if desired, and changes filter downward.
- CALIBRATION
 - Calculated value for CALIBRATION based off of RSHUNT and CURRENT_LSB. When this field changes, the value is automatically written to the CALIBRATION register.
 - This field can be changed manually if desired, and changes filter downward.
 - Changing this value from the register map page also changes here.
- True CURRENT_LSB
 - This is the actual CURRENT_LSB value in Amps back calculated from the CALIBRATION register with the given shunt resistor value.
 - This is the value used for calculations in the Results Data section.
- True Max Current
 - This is the maximum measurable current in Amps based off of the VSHUNT and CURRENT registers, using RSHUNT and the True CURRENT_LSB for calculations.
- Required Sensing Range
 - This shows the required sensing range to measure the Max Expected Current with the specified shunt resistor.
 - If a Max Expected Current is not specified, then the True Max Current field is used instead.

3.2.3 Registers Tab

To view and edit the device registers, click the  (Registers) icon on the menu to the left. The Registers tab looks like the one shown in [Figure 3-9](#).



The screenshot shows the 'Register Map' interface for the INA231. The top bar includes a menu icon, 'INA231', and menu items: File, Options, Tools, Help. Below the menu is a search bar for registers by name or address, and a bitfield view toggle. The main area contains a table of registers with columns for Register Name, Address, Value, and a bitfield view (Bits 15-0). The 'Configuration' section is expanded, showing registers like CONFIGURATION, CALIBRATION, SHUNT_VOLTAGE, BUS_VOLTAGE, POWER, and CURRENT. The 'Field View' panel on the right shows the bitfield for CONFIGURATION / RST[15], CONFIGURATION / AVG[11:9], CONFIGURATION / VBUSCT[8:6], CONFIGURATION / VSHCT[5:3], and CONFIGURATION / MODE[2:0].

Register Name	Address	Value	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CONFIGURATION	0x00	0x4127	0	-	-	-	0	0	0	1	0	0	1	0	0	1	1	1
CALIBRATION	0x05	0x7FFF	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SHUNT_VOLTAGE	0x01	0xFFC8	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	0
BUS_VOLTAGE	0x02	0x0001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
POWER	0x03	0x0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CURRENT	0x04	0xFC60	1	1	1	1	1	1	0	0	0	1	1	0	0	0	0	0
MASK_ENABLE	0x06	0x0008	0	0	0	0	0	0	-	-	-	-	-	0	1	0	0	0
ALERT_LIMIT	0x07	0x0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 3-9. GUI Registers Tab

From this page, you can read and write device registers on the EVM. Here are some important notes:

- Use the *Selected EVM* drop-down menu at the top to choose which device to work with on the Registers page.

- Note, changing this here also changes the same setting for the Configuration tab.
- Functionally, this setting sets the default read/write address in the MCU and then reads all register values back to update the Registers page. Note that if data is being collected at a high frequency, then this can cause a minor delay in the data collection. To prevent this, set device settings before you start collecting data.
- By default, all changes are automatically written to the device. If desired, then change the *Immediate Write* setting to *Deferred Write* to only allow writing when ready.
 - The user can modify writable register values from any of these methods:
 - Through the widget settings in the *Field View* section on the right.
 - Changing the *Value* directly with either hex or decimal values.
 - Double-clicking on any individual bit.
- Turning on *Auto Read* only updates registers in the Registers page, and not the plots in the *Results Data* section.
 - Leaving *Auto Read* on while collecting data for plots can interfere with data collection timing.
- For questions about a register or register bit field, select the  icon.
 - For even more questions about registers, check the data sheet.
- For convenience, register settings can be saved and loaded back later to any device with the same register map. To do this, go to *File > Register Data*, as shown in [Figure 3-10](#).

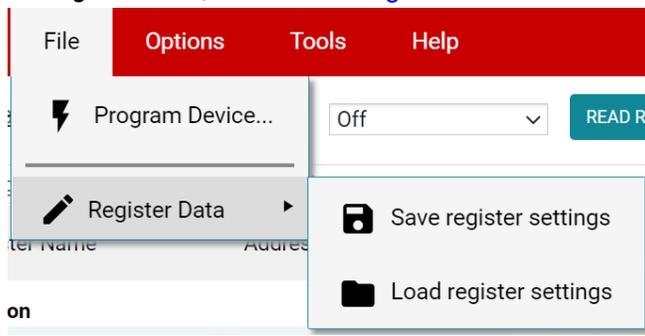


Figure 3-10. Save and Load Register Settings

- Press the *Read All Registers* button after loading data to update the Registers page with the actual device values in case the loaded registers were not compatible with the connected device.

3.2.4 Results Data Tab

To view and collect results data over time, click the  (Results Data) icon on the menu to the left. [Figure 3-11](#) shows part of the results data page for reference, which can look different depending on the number of connected EVMs.

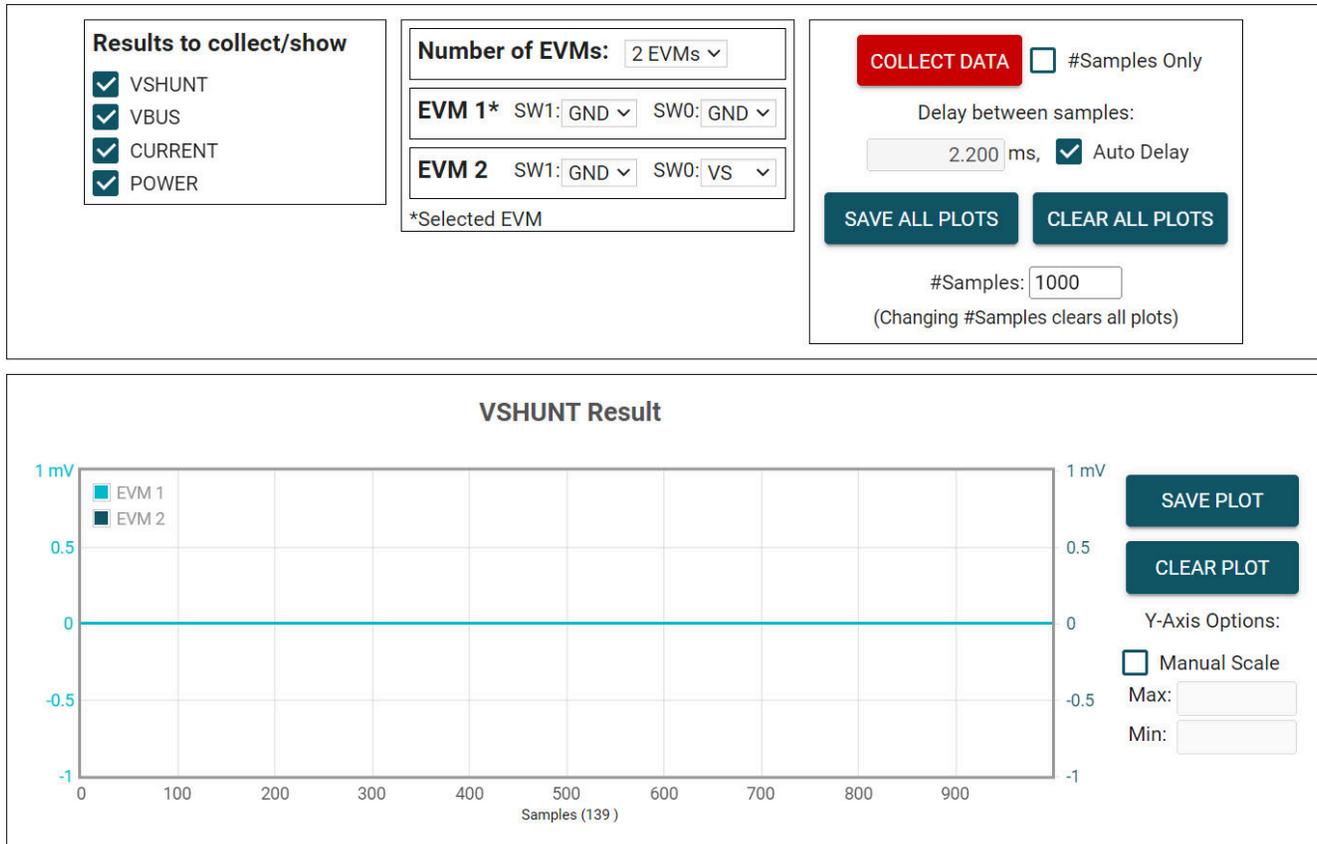


Figure 3-11. Results Page and Settings

Below is a description of how to use the buttons and settings at the top of the Results Data tab and next to each plot:

- Results to collect/show
 - Use this section to select which register values to collect data for. If a results register is unselected before the *COLLECT DATA* button is pressed, then the plot below is hidden and the EVM does not try to read this register during the collect cycle (even if the conversion is enabled).
 - If one of these settings is disabled while the EVM is collecting data, then the plot does not show, but data is still collected and the plot updates in the background. Reselect to show data.
- Number of EVMs
 - Set the *Number of EVMs* drop-down menu to the number of EVMs currently in use.
 - See [Figure 2-2](#) for how to attach multiple EVMs together.
 - Changing this here also changes the same setting in the Configuration tab.
 - The GUI only supports up to 4 INA231EVMs at a time.
 - Switch settings
 - Use the onboard switches to select a different address for each EVM.
 - Set the switch settings in the GUI to match the setting for each connected EVM.
 - *EVM 1* automatically populates with the lowest addressed device unless a setting has already been selected.
 - Changing this here also changes the same setting in the Configuration tab.

- If more than one device is being used, then an asterisk symbol (*) appears next to the selected EVM that is being used on the Registers and Configuration tabs.
 - Changing the switch settings of any EVM sets that EVM as the selected EVM.
- Collect/Plots settings
 - Collect Data
 - Press the *COLLECT DATA* button to start data collection.
 - In this mode, the MCU reads and sends the selected result values for each device over a USB BULK channel. All results from one device are read before moving on to the next device.
 - All result values from all EVMs together are considered one "sample set".
 - Although the user can read and write to other registers through the Registers tab while collecting data, this can add a delay to the data being collected.
 - Press the *STOP COLLECT* button to stop collecting data.
 - #Samples Only
 - If this checkbox is selected, then the GUI automatically stops collecting data after the number of samples specified in the #Samples box have been collected.
 - If not selected, then the GUI continues collecting data and only stores the most recent #Samples.
 - Delay between samples
 - Sets the delay between the start of each sample set.
 - Desired delay time is not obtainable if set faster than the read loop, which depends on the number of results being collected, the number of EVMs, and the CPU being used.
 - Although the user can read and write to other registers through the Registers tab while collecting data, this can add a delay to the data being collected.
 - Auto Delay
 - Sets delay based on conversion times, averaging, and number of channels being converted.
 - If multiple EVMs are being used, then the time put in the delay box is from the EVM with the shortest calculated delay value.
 - Save All Plots
 - Press the *SAVE ALL PLOTS* button to save the data for each currently selected result from the *Results to collect/show* section in a spreadsheet.
 - Press the *SAVE PLOT* button next to each plot to save just the data from that plot in a spreadsheet.
 - Clear All Plots
 - Press the *CLEAR ALL PLOTS* button to clear the data from all plots together.
 - Press the *CLEAR PLOT* button next to each plot to clear the data from just that plot.
 - #Samples
 - Change the number in this box to change the number of samples shown in each plot.
 - Changing this number clears out the plot buffers, so the plots are cleared on the next read.
 - Y-Axis Options
 - Manual Scale
 - Checking this box sets all EVM results in this plot to the same scale value specified by the Max and Min fields.
 - When this is not selected, each EVM has a separate Y-axis scale based on the minimum and maximum values currently in the plot for that EVM.
 - Max
 - The maximum Y-axis value to use for all EVMs in this plot.
 - If this field is empty when Manual Scale is selected, then the plot auto-populates with the maximum value currently in the plot.
 - Min
 - The minimum Y-axis value to use for all EVMs in this plot.
 - If this field is empty when *Manual Scale* is selected, then the plot auto-populates with the minimum value currently in the plot.

3.3 Direct EVM USB Communication

If desired, the EVM can be communicated with directly without the use of the GUI through the USB port. This is done by sending the desired command string over the serial COM port and receiving the results either through the COM port or the USB BULK channel, based on the mode. This is useful for interfacing the EVM with custom setups, scripts, or GUIs.

3.3.1 Standard USB Read and Write Operations

Use the serial COM port to read and write registers through USB commands using the following format:

- Set device address format: `setdevice DEVID`
 - Where `setdevice` is always lower case, and `DEVID` is defined as:
 - The 4 LSBs of the address in decimal format. Ex, for an address of `0x4A`, use `10`.
 - Note, when the SCB is reset while one or more EVMs are connected, the address defaults to the lowest address found.
 - The SCB checks for I2C or SPI at start up. If no device is attached, then the device defaults to SPI. Reset the SCB with an I2C EVM connected to use I2C.
 - For example, to set the INA231 with a register address of `0x4A`, send the command: `setdevice 10`
 - For this example, the EVM returns the acknowledgment and state ("idle" or "collecting") in JSON format:

```

{"acknowledge":"setdevice 10"}
{"evm_state":"idle"}

```
- Read register format: `rreg ADR`
 - Where `ADR` is the address in hex, and `rreg` is always lower case.
 - Register addresses can be in upper or lower case, and do not need to be led by '0x'. 0 padding register addresses is also optional. For example, to read register address `0x02`, some valid commands include:
 - `rreg 2`
 - `rreg 0002`
 - `rreg 0x02`
 - When '0x' is used, the 'x' must be lower case.
 - For this example, the EVM returns the results and state ("idle" or "collecting") in JSON format:

```

{"acknowledge":"rreg 0x02"}
{"register":{"address":2,"value":2637}}
{"evm_state":"idle"}

```
- Write register format: `wreg ADR VAL`
 - Where `ADR` and `VAL` are in hex, and `wreg` is always lower case.
 - Register addresses and values can be in upper or lower case, and do not need to be led by '0x'. 0 padding register addresses and values is also optional. For example, to write register address `0x0` with the value `0x436f`, some valid commands include:
 - `wreg 0 436f`
 - `wreg 00 0x436f`
 - `wreg 0x00 0x436F`
 - When '0x' is used, the 'x' must be lower case.
 - For this example, the EVM returns the results and state ("idle" or "collecting") in JSON format:

```

{"acknowledge":"wreg 0x00 0x436f"}
{"console":"Writing 0x436f to CONFIGURATION register"}
{"evm_state":"idle"}

```

3.3.2 Collect Data Through the USB BULK Channel

The *Collect Data* function reads the desired result registers and sends the data based on the specified settings. This function works best with continuous conversion mode and does not configure the EVM or associated register settings for you. Collect mode is started and stopped through the serial COM port, however the results are sent over the USB BULK channel. To use this mode, use the following format:

- Start collecting data format: collect timerPeriod collectFlags channelAddressIDs numDevices
 - Where collect is always lower case, and each parameter is the decimal representation of the value in the following format:
 - timerPeriod
 - The timer delay used in the MCU to allow data collection sample sets (in μ s, unsigned 32bit value).
 - collectFlags
 - a byte of data that has a 1 to collect and a 0 to not collect each register value type, according to the following definitions:
 - VSHUNT = 0b1000
 - VBUS = 0b0100
 - CURRENT = 0b0010
 - POWER = 0b0001
 - channelAddressIDs
 - This is the 4 LSBs of each I2C address chained together, starting with the LSBs.
 - For example, if EVM 1 is on address 0x41 and EVM 2 is on 0x43, the value here is 0b00110001
 - NumDevices
 - The number of EVMs chained together (1-4).
 - For example, to start data collection for VSHUNT and VBUS every 2.2 ms, for two INA231EVMs with EVM 1 address = 0x41 and EVM 2 address = 0x43, send: collect 2200 12 49 2
 - For this example, the EVM returns the acknowledgment and state in JSON format:

```

{"acknowledge": "collect 2200 12 49 2"}
{"evm_state": "collecting"}

```

- The USB BULK channel receives data in the format: frameID deviceNumID address registerSize data
 - Where each parameter is the decimal representation of the value in the following format:
 - frameID (1 byte)
 - Always reads 0. Used to verify data is aligned.
 - deviceNumID (1 byte)
 - An ID number corresponding to the EVM number.
 - From the above example, this is 1 if reading from EVM 1 which had address set to 0x41, and 2 if reading from EVM 2 which had a address set to 0x43.
 - address (1 byte)
 - The register address that was read from the device.
 - registerSize (1 byte)
 - The number of bytes that the following data has.
 - data (1 byte at a time)
 - The register data value, given in bytes with the most significant byte first.
- Stop collecting data format: stop
 - Where stop is always lower case.
 - The EVM returns the acknowledgment and state in JSON format:

```

{"acknowledge": "stop"}
{"evm_state": "idle"}

```

4 Hardware Design Files

4.1 Schematics

Figure 4-1 and Figure 4-2 show the schematic of the INA231EVM. Figure 4-1 shows the circuitry for the EVM. Figure 4-2 shows the mechanical components included with the EVM.

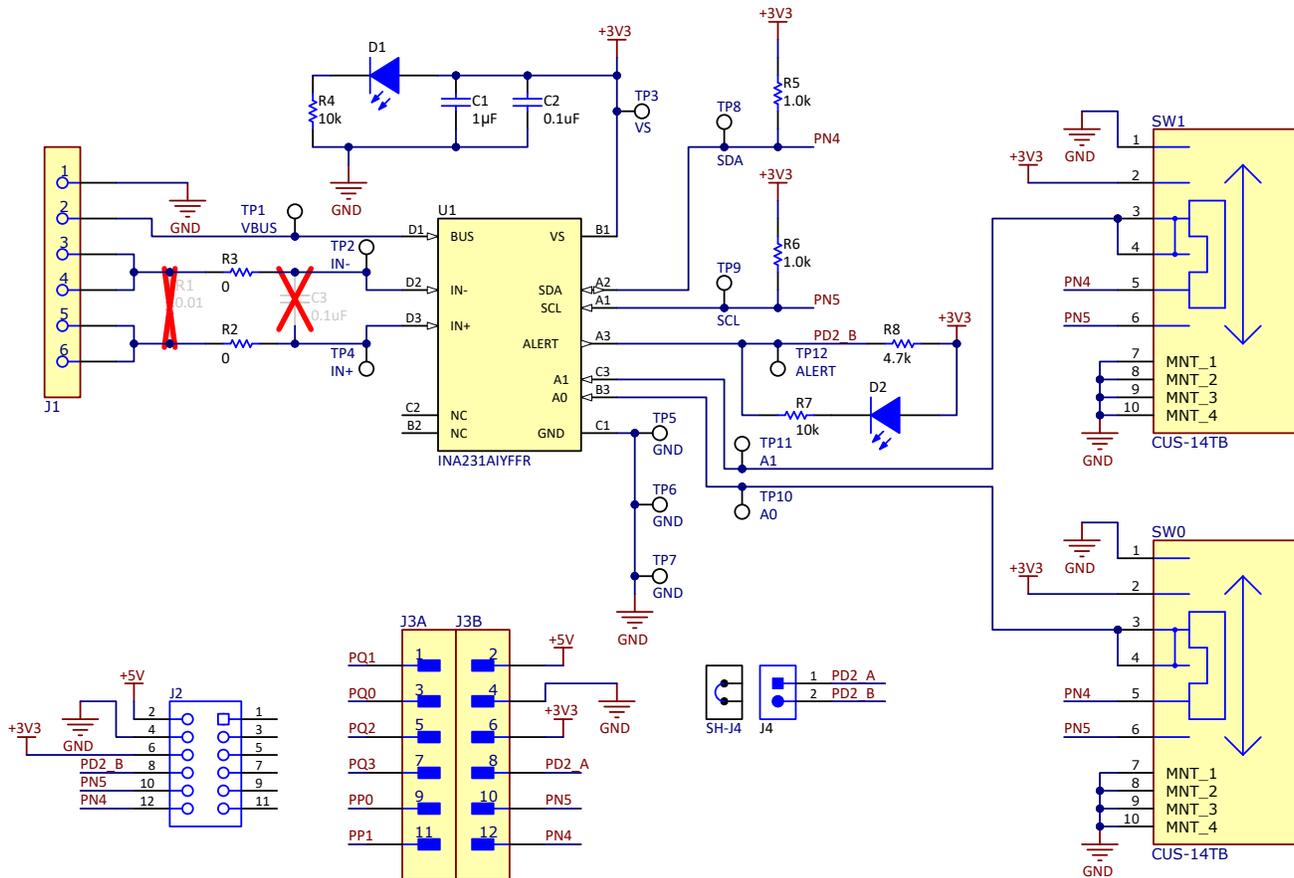


Figure 4-1. Schematic Circuitry



PCB Number: INA231EVM
PCB Rev: B

PCB
LOGO
Texas Instruments



PCB
LOGO
FCC disclaimer

PCB
LOGO
WEEE logo



ZZ2

Assembly Note

These assemblies are ESD sensitive, ESD precautions shall be observed.

ZZ3

Assembly Note

These assemblies must be clean and free from flux and all contaminants. Use of no clean flux is not acceptable.

ZZ4

Assembly Note

These assemblies must comply with workmanship standards IPC-A-610 Class 2, unless otherwise specified.

ZZ5

Assembly Note

Trim the leads under J1 (back of PCB) to give clearance from surface

Figure 4-2. Hardware Schematic

4.2 PCB Layout

Board layouts are not to scale. These figures are intended to show how the board is laid out. The figures are not intended to be used for manufacturing EVM PCBs.

Figure 4-3 through Figure 4-6 illustrate the PCB layers of the INA231EVM.

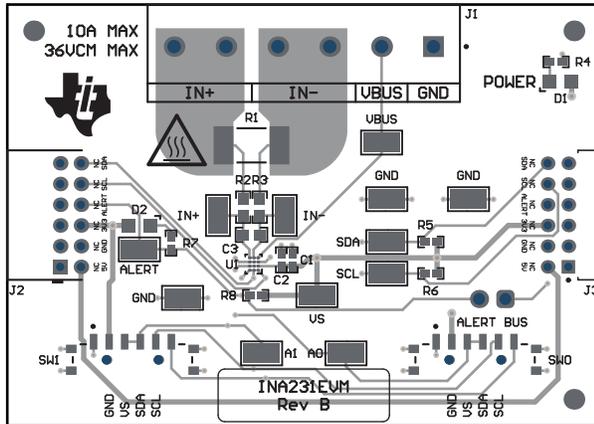


Figure 4-3. Top View

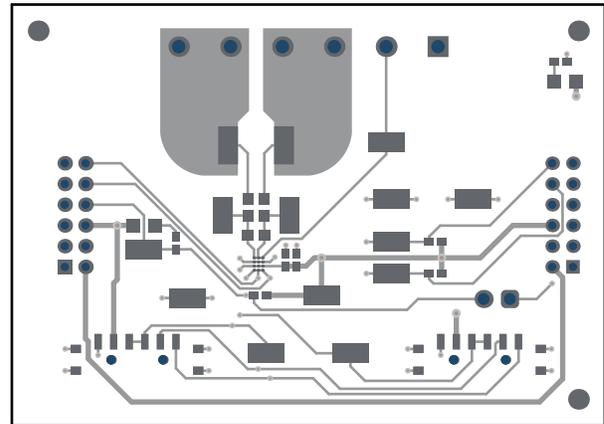


Figure 4-4. Top Layer

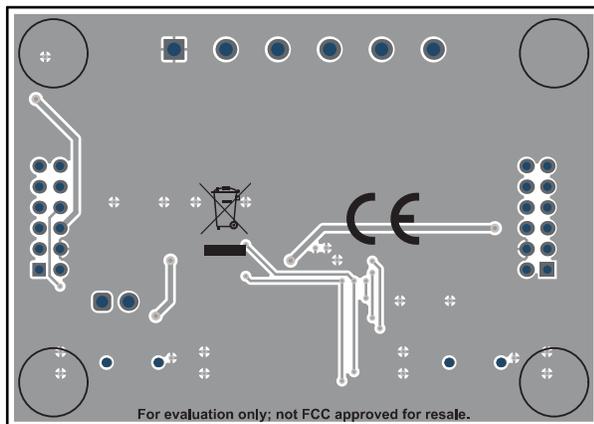


Figure 4-5. Bottom View

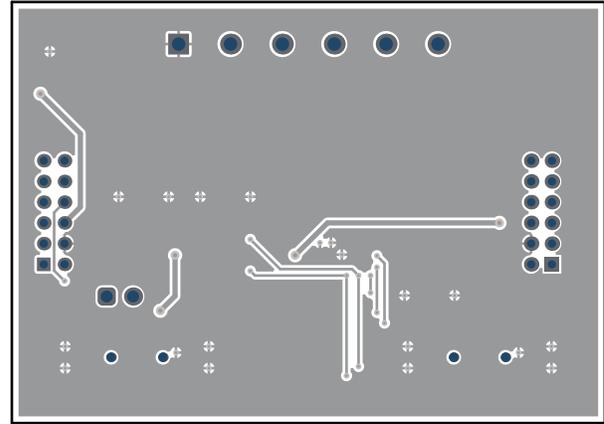


Figure 4-6. Bottom Layer

4.3 Bill of Materials

Table 4-1 provides the parts list for the INA231EVM.

Table 4-1. Bill of Materials

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		INA231EVM	Any
C1	1	1uF	CAP, CERM, 1 μ F, 16 V, +/- 20%, X5R, 0402	0402	GRM155R61C105MA12D	MuRata
C2	1	0.1uF	CAP, CERM, 0.1 uF, 50 V, +/- 20%, X7R, 0402	0402	GRM155R71H104ME14D	MuRata
D1, D2	2	White	LED, White, SMD	0805	VAOL-S8WR4	Visual Communications Company, LLC
H1, H2, H3, H4	4		Bumpon, Hemisphere, 0.25 X 0.075, Clear	75x250 mil	SJ5382	3M
J1	1		TERM BLK 6POS SIDE ENTRY 5MM PCB ASSEMBLY NOTE: Trim leads per ZZ5	HDR6	691137710006	Wurth Electronics
J2	1		Receptacle, 2mm, 6x2, Gold, R/A, TH	Receptacle, 2mm, 6x2, R/A, TH	NPPN062FJFN-RC	Sullins Connector Solutions
J3	1		Connector Header Through Hole, Right Angle 12 position 0.079" (2.00mm)	HDR12	NRPN062PARN-RC	Sullins Connector Solutions
J4	1		Header, 2.54 mm, 2x1, Gold, TH	Header, 2.54mm, 2x1, TH	61300211121	Wurth Elektronik
R2, R3	2	0	RES, 0, 5%, 0.125 W, 0603	0603	MCT06030Z0000ZP500	Vishay/Beyschlag
R4, R7	2	10k	RES, 10 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040210K0JNED	Vishay-Dale
R5, R6	2	1.0k	RES, 1.0 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04021K00JNED	Vishay-Dale
R8	1	4.7k	RES, 4.7 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04024K70JNED	Vishay-Dale
SH-J4	1		Shunt, 2.54mm, Gold, Black	Shunt, 2.54mm, Black	60900213421	Wurth Elektronik
SW0, SW1	2		Slide Switch SP4T Surface Mount, Right Angle	SMT_SW_11MM3_4M M1	CUS-14TB	Nidec Copal Electronics
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12	12		Test Point, Miniature, SMT	Testpoint_Keystone_Miniature	5015	Keystone
U1	1		28-V, Bi-Directional, Zero-Drift, Low-/High-Side, I2C Out Current/Power Monitor w/ Alert in WCSP, YFF0012AKAD (DSBGA-12)	YFF0012AKAD	INA231AIYFFR	Texas Instruments
C3	0	0.1uF	CAP, CERM, 0.1 uF, 100 V, +/- 10%, X7S, AEC-Q200 Grade 1, 0603	0603	CGA3E3X7S2A104K080AB	TDK
FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
LBL1	0		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

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
R1	0		10 mOhms \pm 0.5% 2W Chip Resistor 2512 (6432 Metric) Automotive AEC-Q200, Current Sense, Moisture Resistant Metal Film	2512	PCS2512DR0100ET	Ohmite

5 Additional Information

5.1 Trademarks

All trademarks are the property of their respective owners.

6 Related Documentation From Texas Instruments

This user's guide is available from the TI website under literature number [SBOU310](#). 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 www.ti.com or 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 6-1](#) lists documentation related to the EVM. Click the links in [Table 6-1](#) for further information. The device name links to the product web folder on www.ti.com. The literature number links to the document PDF.

Table 6-1. Related Documentation

DOCUMENT TITLE	DOCUMENT LITERATURE NUMBER
INA231 data sheet	SBOS547
INA231-Q1 data sheet	SBOS743
Getting Started with Digital Power Monitors	SBOA511

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 semiconductor 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 DEGRADATION 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/llds/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。

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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。

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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/llds/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.
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