User's Guide

INA233EVM Rev A User's Guide And Software Tutorial

ABSTRACT

This EVM user's guide describes the characteristics, operation, and use of the INA233EVM evaluation board. It discusses how to set up and configure the software and hardware, and reviews various aspects of the program operation. Throughout this document, the terms *evaluation board*, *evaluation module*, and *EVM* are synonymous with the INA233EVM. This EVM user's guide also includes information regarding operating procedures and input/output connections, an electrical schematic, printed circuit board (PCB) layout drawings, and a parts list for the EVM.

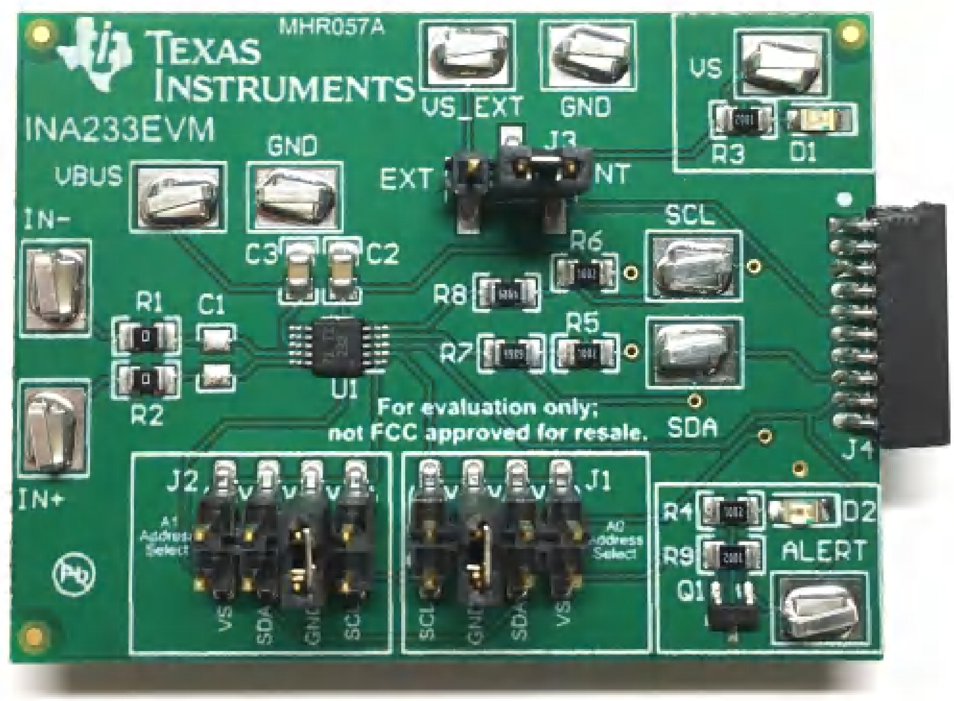

Figure 1-1. INA233EVM Evaluation Module

Table of Contents

List of Figures

List of Tables

Trademarks

Windows® is a registered trademark of Microsoft.

All trademarks are the property of their respective owners.

1 Overview

The INA233 is a current shunt and power monitor with an I2C/SMBus/PMBus-compatible interface. The device monitors and reports values for current, power, and voltage. The integrated power accumulator can be used for energy or average power calculations. Programmable calibration value, conversion times, and averaging, combined with an internal multiplier, enable direct readouts of current in amperes and power in watts. The INA233EVM is a platform for evaluating the performance of the INA233 under various signal, shunt, and supply conditions.

This document gives a general overview of the INA233EVM, and provides a general description of the features and functions to be considered while using this evaluation module.

1.1 INA233EVM Kit Contents

Table 1-1 summarizes the contents of the INA233EVM kit. Figure 1-1 shows all of the included hardware. Contact the Texas Instruments Product Information Center if any component is missing. TI also highly recommends checking the INA233 product folder on the TI web site at www.ti.com to update to the latest versions of the related software.

Table 1-1. INA233EVM Kit Contents

Item	Quantity
INA233EVM PCB Test Board	1
SM-USB-DIG Platform PCB	1
USB Extender Cable	1

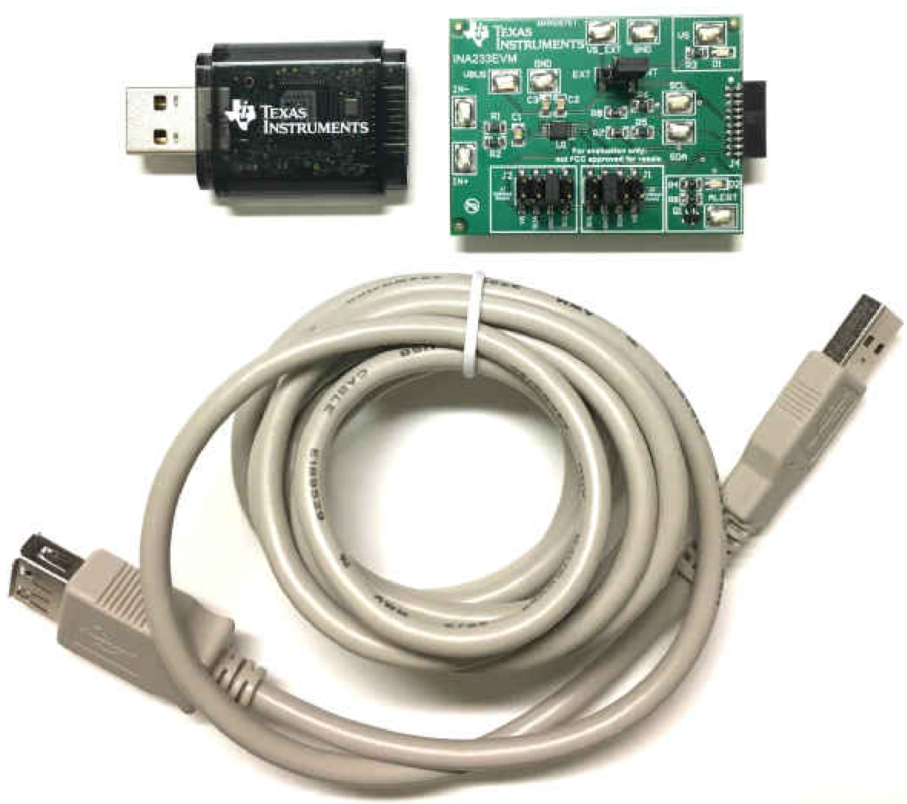

Figure 1-1. Hardware Included With INA233EVM Kit

1.2 Related Documentation from Texas Instruments

The following documents provide information regarding Texas Instruments integrated circuits used in the assembly of the INA233EVM. This EVM user's guide is available from the TI web site under literature number SBOU187. 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 can be available from the TI web site. When ordering, identify the document by both title and literature number.

Table 1-2. Related Documentation

DOCUMENT	LITERATURE NUMBER
INA233 Product Data Sheet	SBOS790
SM-USB-DIG Platform User Guide	SBOU098

2 INA233EVM Hardware

Figure 2-1 shows the overall system setup for the INA233EVM. The PC runs software that communicates with the SM-USB-DIG Platform. The SM-USB-DIG Platform generates the analog and digital signals used to communicate with the INA233 test board. Connectors on the INA233EVM test board allow the user to connect to the system under test conditions and monitor the power, current, and voltage.

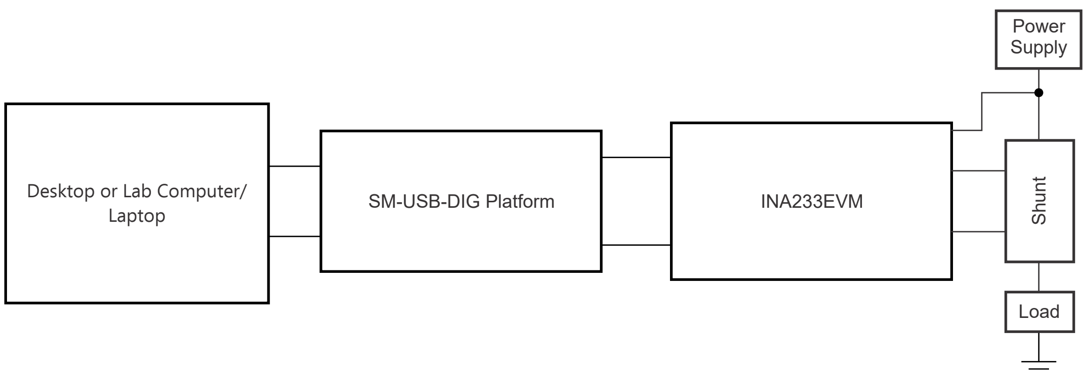

Figure 2-1. INA233EVM Hardware Setup

2.1 Theory of Operation for INA233 Hardware

Figure 2-2 depicts a block diagram of the INA233EVM PCB highlighting the power supplies, analog inputs, and digital I/O signals.

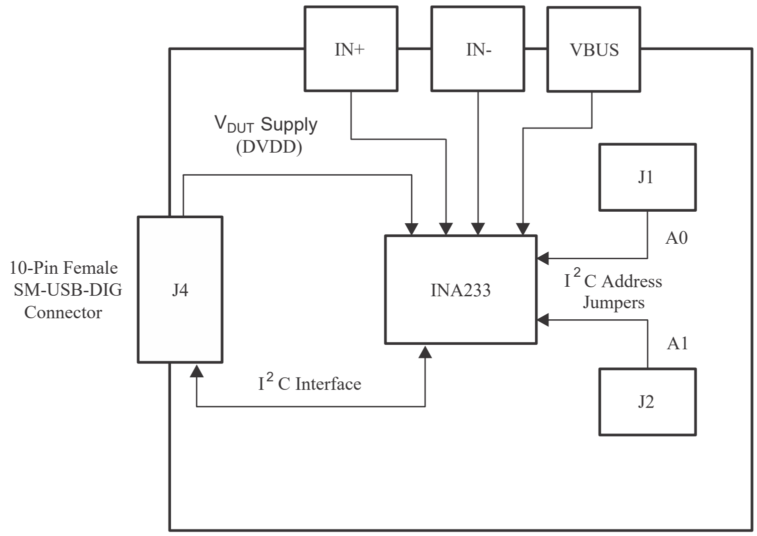

Figure 2-2. INA233EVM Board Block Diagram

2.2 Signal Definitions of H1 (10-Pin Connector Socket)

Table 2-1 lists the pinout for the 10-pin connector socket used to communicate between the INA233EVM and the SM-USB-DIG. It should be noted that the INA233EVM only uses the necessary I^2C communication lines (pins 1 and 3) and the VS and GND pins (pin 6 and pin 8) to issue commands to the INA233 chip.

Table 2-1. Signal Definition of J4 on INA233EVM Board

Pin on J4	Signal	Description
1	I2C_SCL	I^2C Clock Signal (SCL)
2	CTRL/MEAS4	GPIO: Control Output or Measure Input
3	I2C_SDA1	I^2C Data Signal (SDA)
4	CTRL/MEAS5	GPIO: Control Output or Measure Input
5	SPI_DOUT1	SPI Data Output (PICO)
6	V_{DUT}	Switchable DUT Power Supply: +3.3 V, +5 V, Hi-Z (Disconnected)(1)
7	SPI_CLK	SPI Clock Signal (SCLK)
8	GND	Power Return (GND)
9	SPI_CS1	SPI Chip Select Signal ($\overline{CS}$)
10	SPI_DIN1	SPI Data Input (POCI)

(1) When V_{DUT} is Hi-Z, all digital I/O are Hi-Z as well.

2.2.1 SM-USB-DIG Platform Description

Figure 2-3 shows the block diagram for the SM-USB-DIG Platform. This platform is a general-purpose data acquisition system that is used on several different Texas Instruments evaluation modules. The details of its operation are included in a separate document, SBOU098 (available for download at www.ti.com). The block diagram shown in Figure 2-3 gives a brief overview of the platform. The primary control device on the SM-USB-DIG Platform is the TUSB3210. The TUSB3210 is an 8052 microcontroller that has an onboard USB interface. The microcontroller receives information from the host computer that it interprets into power, I^2C, SPI, and other digital I/O patterns. During the digital I/O transaction, the microcontroller reads the response of any device connected to the I/O interface. The response from the device is sent back to the PC where it is interpreted by the host computer.

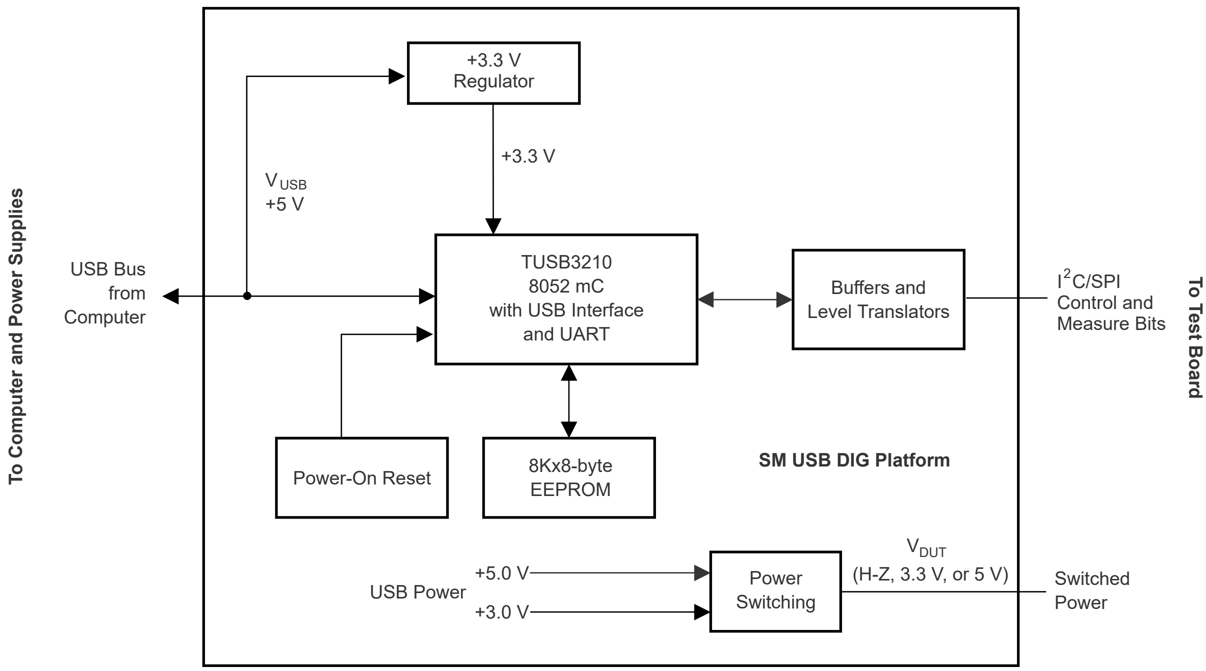

Figure 2-3. SM-USB-DIG Platform Block Diagram

3 INA233EVM Hardware Setup

Setting up the INA233EVM involves the following sequence of operations:

- Perform a one-time GUI software installation
- Configure the EVM jumpers
- Connect the hardware
- Power-up the EVM and input source

3.1 Electrostatic Discharge Warning

CAUTION

Many of the components on the INA233EVM are susceptible to damage by electrostatic discharge (ESD). Customers are advised to observe proper ESD handling precautions when unpacking and handling the EVM, including the use of a grounded wrist strap at an approved ESD workstation.

3.2 One-Time INA233EVM GUI Software Setup

This section discusses how to install the INA233EVM software.

3.2.1 Hardware Requirements

The INA233EVM software must be installed on a computer running Windows® XP operating system or later. Windows 7 is the recommended operating system.

3.2.2 Software Installation

Make sure the hardware is not connected to the computer. Download the INA233EVM GUI from the INA233 Tools & Software folder. Extract the contents of the downloaded .zip file and run Setup_INA233EVM.exe. Follow the on-screen instructions provided in Figure 3-1 to complete the software installation.

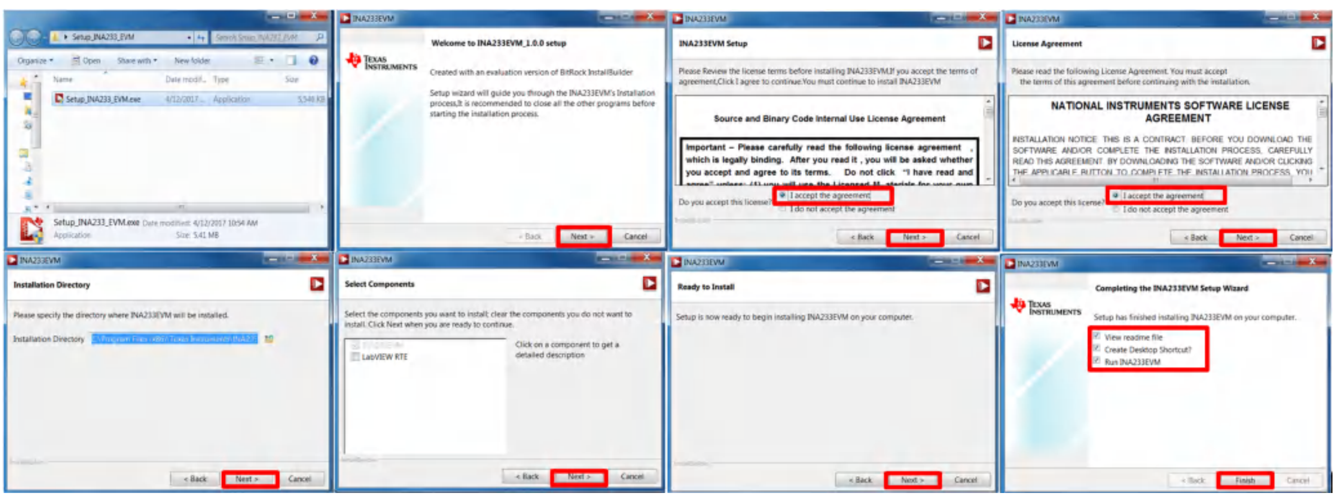

Figure 3-1. INA233EVM Software Installation

3.3 Configuration of INA233EVM Jumper Settings

Figure 3-2 shows the default jumper configuration for the INA233EVM. In general, the jumper settings of the SM-USB-DIG Platform do not need to be changed. Change the jumpers on the INA233EVM board to match your specific configuration. For example, set a specific I2C address by configuring J1 and J2.

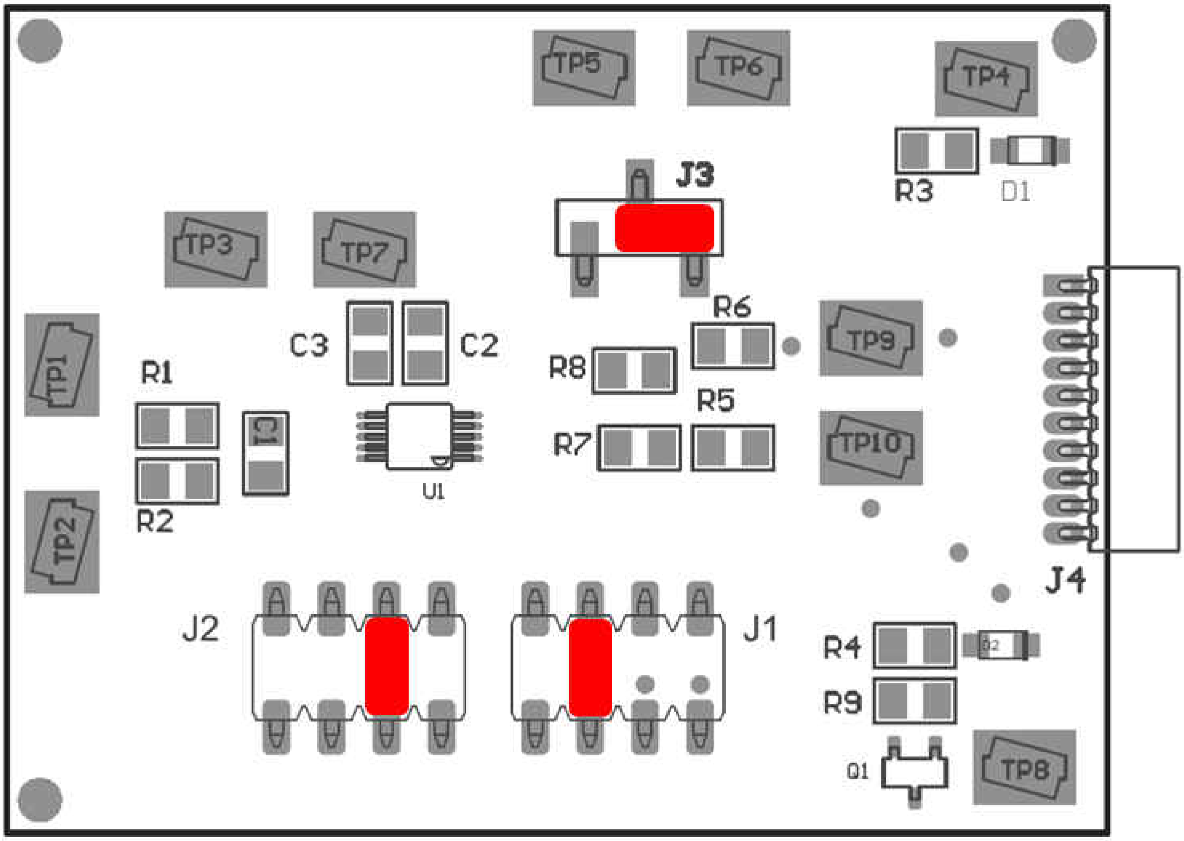

Figure 3-2. INA233EVM Default Jumper Settings

Typically, jumper 3 (J3) on the INA233EVM is always set to the INT position. When set to the INT position, the SM-USB-DIG Platform provides the supply for the INA233. When this jumper is set to the EXT position, an external supply voltage can be connected to test point VS_EXT to provide the supply for the INA233.

Jumper 1 (J1) and jumper 2 (J2) control the I2C address pins for the INA233. These jumpers can set the address for A0 and A1 to either supply, ground, SCL, or SDA. Make sure to only connect one jumper at a time for each address control. Failure to properly connect jumpers can cause shorts or interruptions in the communication lines. For more information on the INA233 addressing, refer to the INA233 product data sheet.

Table 3-1 summarizes the function of the INA233 Test Board jumpers. For most applications, all jumpers must be left in the respective default configurations.

Table 3-1. INA233EVM Test Board Jumper Functions

Jumper	Default	Purpose
J3	INT	This jumper selects whether the V_S pin on the INA233 is connected to the V_{DUT} signal generated from the SM-USB-DIG Platform or whether the digital supply pin is connected to test point VS_EXT, allowing for an external supply to power the device. The default INT position connects the V_S pin to the V_{DUT} control signal.
J1	GND	This jumper selects the I2C A0 address selection for A0.
J2	GND	This jumper selects the I2C A1 address selection for A1.

3.4 Connecting the Hardware

To set up the INA233EVM and connect the two PCBs of the EVM together (that is, the INA233 test board and SM-USB-DIG Platform board), gently slide the male and female ends of the 10-pin connectors together. Make sure that the two connectors are completely pushed together; loose connections can cause intermittent operation. Figure 3-3 show the proper orientation.

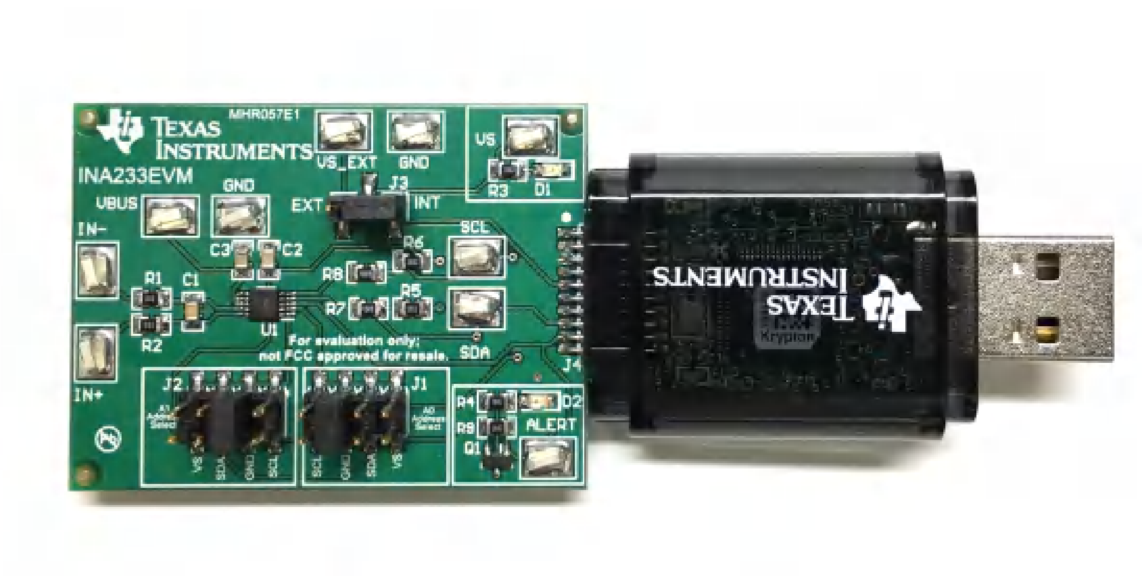

Figure 3-3. Connecting the INA233 Test Board and SM-USB-DIG Platform Board to the Computer

Lastly, connect the SM-USB-DIG to the computer, using the included USB extender cable. At this point the SM-USB-DIG powers on, but the EVM does not as shown in Figure 3-4. The power supply to the EVM must be enabled from the GUI.

Figure 3-4. Connecting the INA233 Test Board and SM-USB-DIG Platform Board

3.4.1 System Power Up

Launch the INA233EVM GUI software. By default the Power button on the GUI is enabled so the VS LED on the EVM (D1) immediately lights up, indicating that the EVM PCB is receiving power, as shown Figure 3-5.

Figure 3-5. INA233 Power Up Using SM_USB DIG and INA233EVM GUI Software

The INA233EVM software allows users to customize the board level voltage, regulated by the SM-USB DIG. By selecting either 3.3 V or 5 V, the user can designate which voltage the device operates at. The supply voltage (VDUT) is set to 3.3 V by default, but if necessary, the 5-V option can be selected, as shown in Figure 3-6.

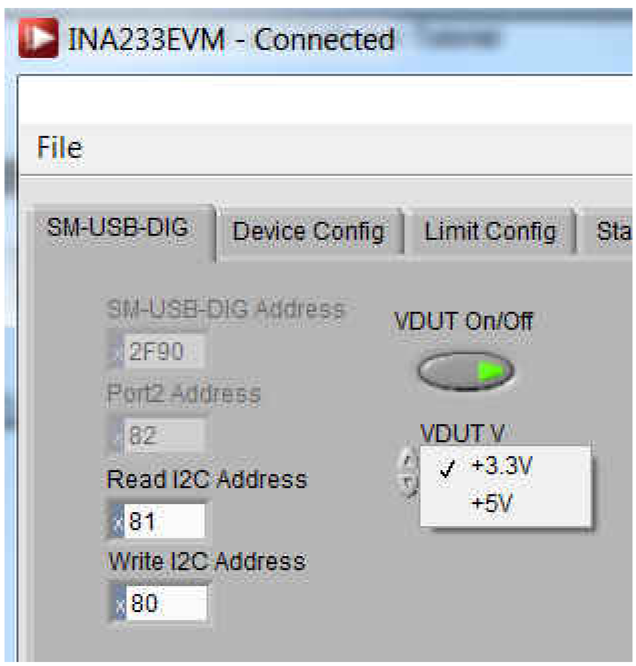

Figure 3-6. VDUT Voltage Selection in INA233EVM GUI

3.5 INA233EVM Features

This section describes some of the hardware features present on the INA233EVM test board.

3.5.1 J3: I2C VS Control Setting

Jumper J3 selects what the INA233 supply pin is connected to. If J3 is set to the INT position, the VS pin is connected to the switchable V_{DUT} signal generated from the SM-USB-DIG Platform. This voltage can be set to either 3.3 V or 5 V, depending on how it is configured in the software. While J2 is set in the INT position, the VS Power button in the INA233EVM software is able to control whether the V_{DUT} supply voltage is turned on or off.

When J2 is set in the EXT position, an external supply connected to test point VS_EXT can be used to provide the supply voltage for the INA233.

3.5.2 J1: I2C Address Hardware Setting (A0)

Jumper J1 is used to set the hardware setting for the A0 I2C address pin on the INA233. Using J1, the A0 address can be set to VS, GND, SCL or SDA. See Section 4.2.1 on how to configure the INA233EVM software to match the J1 hardware setting.

3.5.3 J2: I2C Address Hardware Setting (A1)

Jumper J2 is used to set the hardware setting for the A1 I2C address pin on the INA233. Using J2, the A1 address can be set to VS, GND, SCL or SDA. See Section 4.2.1 on how to configure the INA233EVM software to match the J2 hardware setting.

3.5.4 External I2C Lines and Test Points SCL and SDA

The I2C communication lines on the INA233EVM are tied to two sources: the internal I2C communication lines from the SM-USB-DIG and test points SCL and SDA. If the user wants to add external signals separate from the SM-USB-DIG, simply disconnect the SM-USB-DIG from the INA233EVM board and hook up the necessary SDA, SCL, and GND lines. Also, remember to apply an external supply to the lines that is compatible with the I2C communication device being used.

Note

Failure to disconnect the SM-USB-DIG while using external I2C communication can cause damage to the SM-USB-DIG or any external communication devices that are connected.

3.5.5 IN+/IN– Input Filter (R1, R2, and C1)

The INA233EVM has an optional input filter to remove high-frequency noise from the inputs IN+ and IN–. This filter is typically unpopulated. The default values for R1 and R2 are 0-Ω resistors.

3.5.6 Shunt Monitor Configuration

The INA233 is generally used in either a high-side or low-side shunt configuration, as shown in Figure 3-7. Depending on the user's needs, either of these configurations can be used without making any changes to the INA233EVM board or software. The INA233EVM have VBUS, GND, IN+ and IN- test points. Use these test points to apply external voltage sources depending the configuration selected.

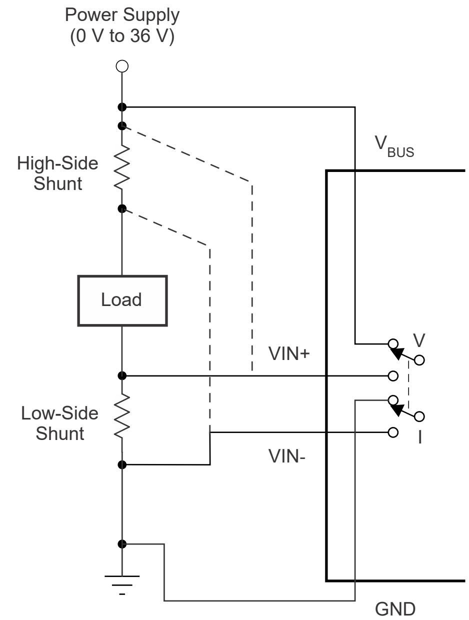

Figure 3-7. INA233 Shunt Configurations

4 INA233EVM Software Overview

This section discusses how to use the INA233EVM software. Software operation involves a two-step process: configuration of the INA233 settings, and operation of the tool.

4.1 Starting the INA233EVM Software

The INA233 software can be operated through the Windows *Start* menu. From Start, select *All Programs*; then select the *INA233EVM* program.

Figure 4-1 illustrates how the software appears if the INA233EVM is functioning properly. The Status Bar reads "VDUT On" and the Hardware Connected bar is on.

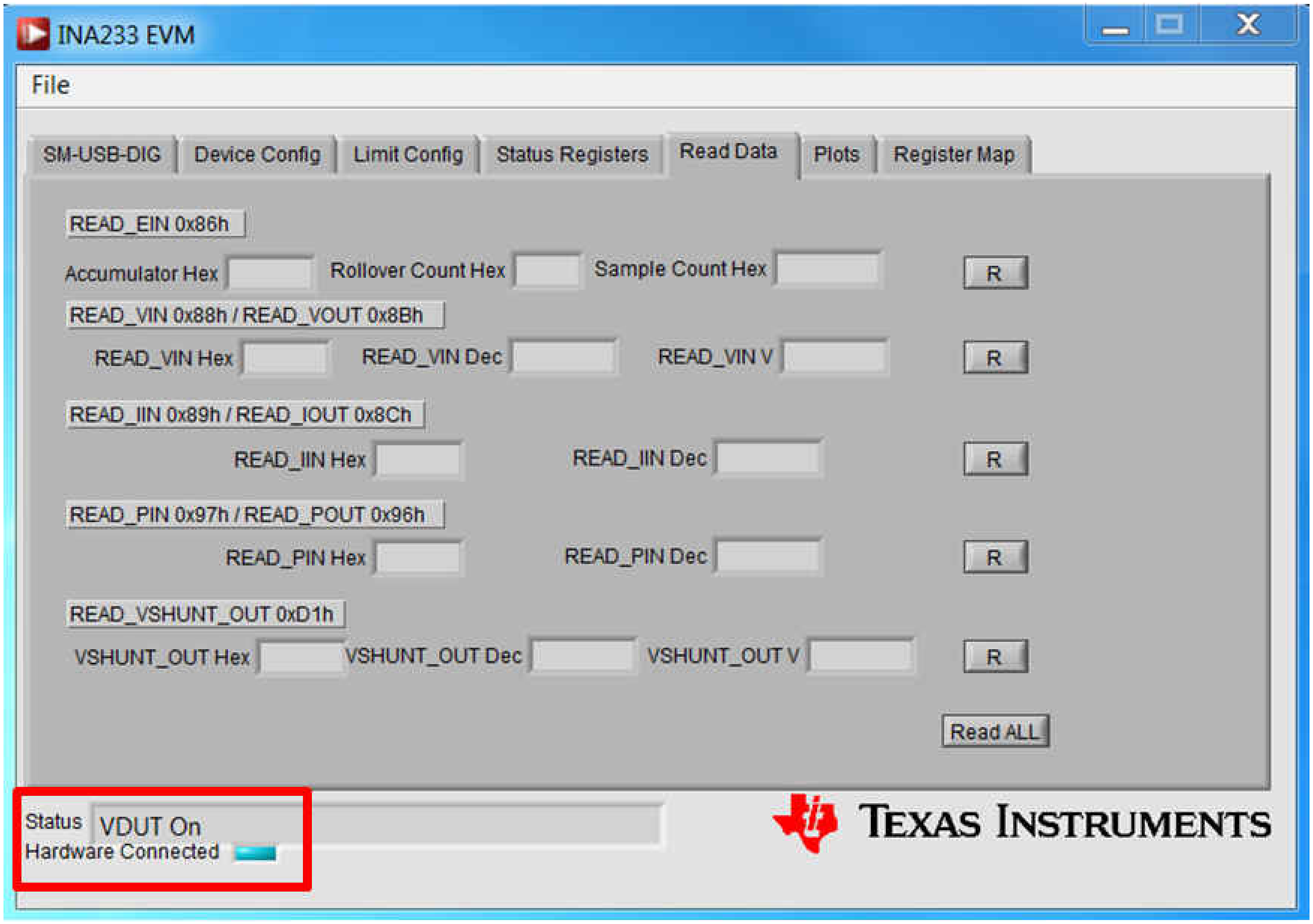

Figure 4-1. INA233EVM Software Interface

Figure 4-2 shows how the Software Interface looks if the computer cannot communicate with the EVM. The status bar reads "Check SM-USB-DIG-Connection" and the Hardware Connected light is off. If you receive this error, first check to see that the USB cable is properly connected on both ends. This error can also occur if you connect the USB cable before the SM-USB-DIG Platform power source. Another possible source for this error is a problem with your PC USB Human Interface Device driver. Make sure that the device is recognized when the USB cable is plugged in; recognition is indicated by a Windows-generated confirmation sound. After verifying all connections are correct, press Re-Initialize. The software interface then appears as shown in Figure 4-1.

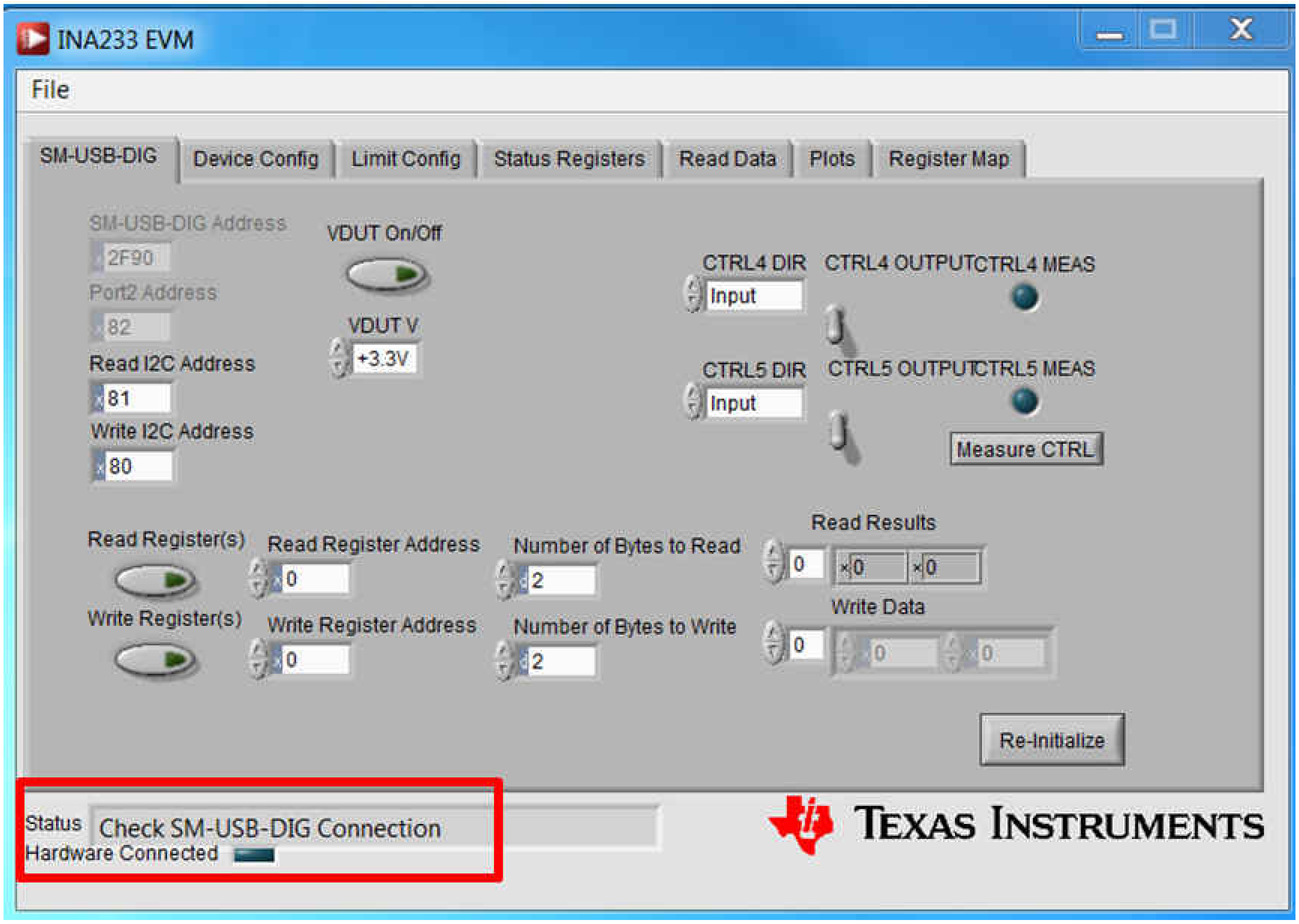

Figure 4-2. INA233EVM Software: Communication Error With the SM-USB-DIG Platform

4.2 Configuring the INA233EVM Software

The INA233EVM software first requires a series of setup processes to configure the device and make sure that the software works properly.

1. Set I^{2}C Address on the SM-USB-DIG Tab
2. Set Configuration Register on the Device Config Tab
   - Set Averaging Mode
   - Set Conversion Times
   - Set Operating Modes
3. Set Calibration Register on the Device Config Tab
4. Set the MFR_DEVICE_CONFIG Register on the Device Config Tab
5. Set the Warning Limits Registers on the Limit Config Tab

4.2.1 I²C Address Selection

The INA233 device has a flexible I²C address configuration that allows for multiple devices to be on the same I²C lines. By moving the A0 and A1 addresses on jumpers J1 and J2 to either GND, VS, SDA, or SCL, the INA233 can be changed to a total of 16 I²C addresses as shown in Table 4-1.

Table 4-1. INA233 I²C Address Configuration

A1	A0	Slave Address	Corresponding I2C Address in the GUI
GND	GND	1000000	Read: x81 Write: x80
GND	VS	1000001	Read: x83 Write: x82
GND	SDA	1000010	Read: x85 Write: x84
GND	SCL	1000011	Read: x87 Write: x86
VS	GND	1000100	Read: x89 Write: x88
VS	VS	1000101	Read: x8B Write: x8A
VS	SDA	1000110	Read: x8D Write: x8C
VS	SCL	1000111	Read: x8F Write: x8E
SDA	GND	1001000	Read: x91 Write: x90
SDA	VS	1001001	Read: x93 Write: x92
SDA	SDA	1001010	Read: x95 Write: x94
SDA	SCL	1001011	Read: x97 Write: x96
SCL	GND	1001100	Read: x99 Write: x98
SCL	VS	1001101	Read: x9B Write: x9A
SCL	SDA	1001110	Read: x9D Write: x9C
SCL	SCL	1001111	Read: x9F Write: x9E

Figure 4-3 illustrates how to configure the I²C addresses. To configure the I2C address in the GUI navigate to the SM-USB-DIG tab. Click on the Read I2C Address and Write I2C Address to input the I2C address configured on the INA233EVM hardware. Refer to Table 4-1 to make sure you assign the correct values.

Figure 4-3. Setting the I²C Address

4.2.2 Set the Configuration Register (MFR_ADC_CONFIG)

The Configuration Register settings control the operating modes for the device. This register controls the conversion time settings for both the shunt and bus voltage measurements as well as the averaging mode used. The operating mode that controls what signals are selected to be measured is also programmed in the Configuration Register. The Device Configuration tab of the INA233EVM GUI allows the user to set the averaging mode (AVG[2:0]), Vbus conversion time (VBUSCT[2:0]), Vshunt conversion time(VSHCT[2:0]) and operating mode (MODE[2:0]).

4.2.2.1 Set Averaging Mode

The Device Configuration tab contains a drop down box for selecting the Averaging Mode, as shown in Figure 4-4. The averaging mode selected determines the number of samples that are collected and averaged before storing the value of the measurements in the register table.

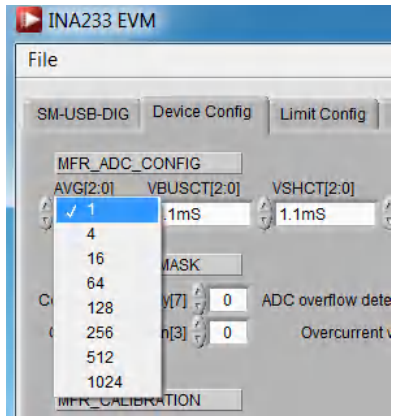

Figure 4-4. Configuring Averaging Mode

4.2.2.2 Set Conversion Times

Setting the conversion times allows the user to customize the amount of measurement time for conversions. Typically, for the INA233EVM software, the user is not able to notice a visual difference between the conversion times unless a high averaging mode and conversion time are chosen. The Shunt and Bus conversion times can be set as shown in Figure 4-5.

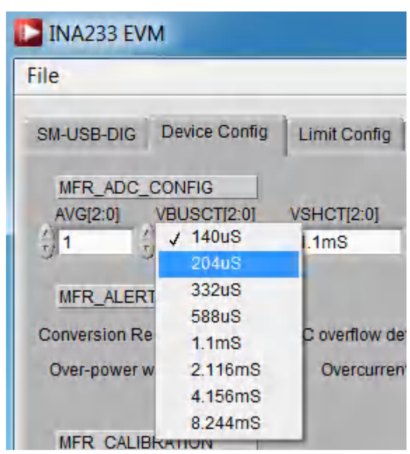

Figure 4-5. Configuring Conversion Times

4.2.2.3 Set Operating Mode

The Device Configuration tab contains a drop down box for selecting the Operating Mode, as shown in Figure 4-6.The Operating mode allows the user to restrict the amount of calculations done within the INA233 by changing the conversion to be triggered or continuous, or shutting down the part altogether. The Device Configuration tab of the INA233EVM GUI allows the user to set the averaging mode (AVG[2:0]), Vbus conversion time (VBUSCT[2:0]), Vshunt conversion time(VSHCT[2:0]) and operating mode (MODE[2:0]).

It is important to note that for complete functionality of the INA233, a configuration must be chosen with Shunt and Bus configuration. Failure to choose Shunt and Bus configuration disables a considerable portion of the unit functionality as discussed in the INA233 data sheet.

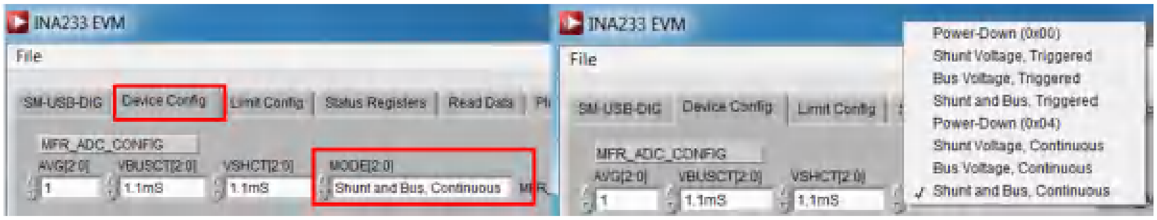

Figure 4-6. Configuring Operating Mode

4.2.3 Set Calibration Register (MFR_CALIBRATION)

The Calibration Register must then be set correctly for the software to operate properly. The user needs to manually calculate the desired value using Equation 1 and then input that value into the MFR_Calibration box, as shown in Figure 4-7. After this, the user must press W in order to write into the Calibration Register. If inputs were correct the MFR_CALIBRATION and MFR_CALIBRATION Hex boxes should display the same values after pressing R (Pressing R reads the Calibration Register).

$$\text{Calibration Register} = \frac{0.00512}{\text{Current\_LSB} \times R_{SHUNT}} \tag{1}$$

The current LSB is calculated by a recommended range in the INA233 data sheet as shown in Equation 2. It is important to note that the Current LSB and the Calibration Register values are calculated based on the other variable and the R_{SHUNT} value. See the section, *Programming the INA233* in the product data sheet for more information on setting the Calibration Register value.

$$\frac{\text{Maximum Expected Current}}{2^{15}} \leq \text{Current\_LSB} \leq \frac{\text{Maximum Expected Current}}{2^{12}} \tag{2}$$

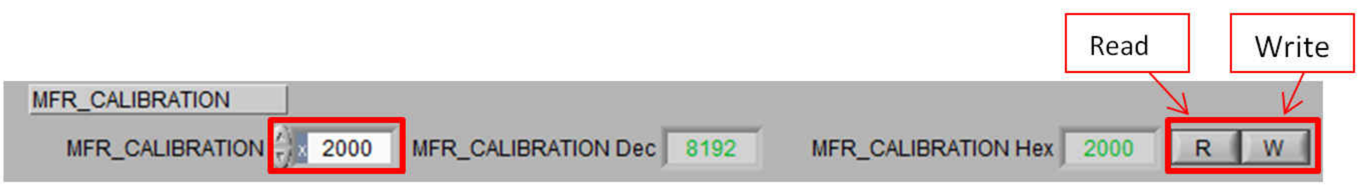

Figure 4-7. Setting the Calibration Register (MFR_CALIBRATION)

4.2.4 Set the MFR_DEVICE_CONFIG Register

This register configures various behaviors of the device in regards to data communications and alerts. The user is able to write and read these registers in the Device Configuration Tab as shown in Figure 4-8. Refer to MFR_DEVICE_CONFIG Register section on the data sheet for register details.

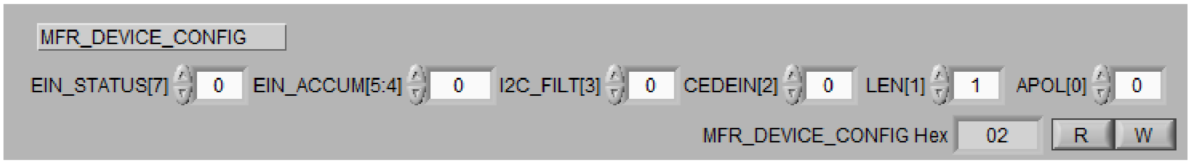

Figure 4-8. Set the MFR_DEVICE_CONFIG Register

4.2.5 Set the MFR_ALERT_MASK

The bits in this register correspond to the bits in the STATUS_MFR_SPECIFIC register. Setting a bit in this register will block the corresponding bit in the STATUS_MFR_SPECIFIC register from having an effect on the ALERT pin. The user is able to write and read these registers in the Device Configuration Tab as shown in Figure 4-9. Refer to MFR_ALERT_MASK Register table in the data sheet for register bits details.

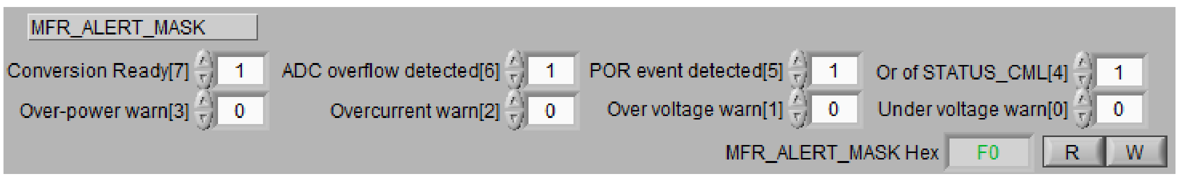

Figure 4-9. Set the MFR_ALERT_MASK Register

4.2.6 Set the Warning Limit Registers

The Limit configuration tab allows the user to set the values for the following warning limit registers:

- OUT_OC_WARN_LIMIT Register
- VIN_OV_WARN_LIMIT Register
- VIN_UV_WARN_LIMIT Register
- POUT_OP_WARN_LIMIT Register

The user is able to write and read these registers in the Device Configuration Tab as shown in Figure 4-10. Refer to data sheet *Standard PMBus Commands* section for register descriptions.

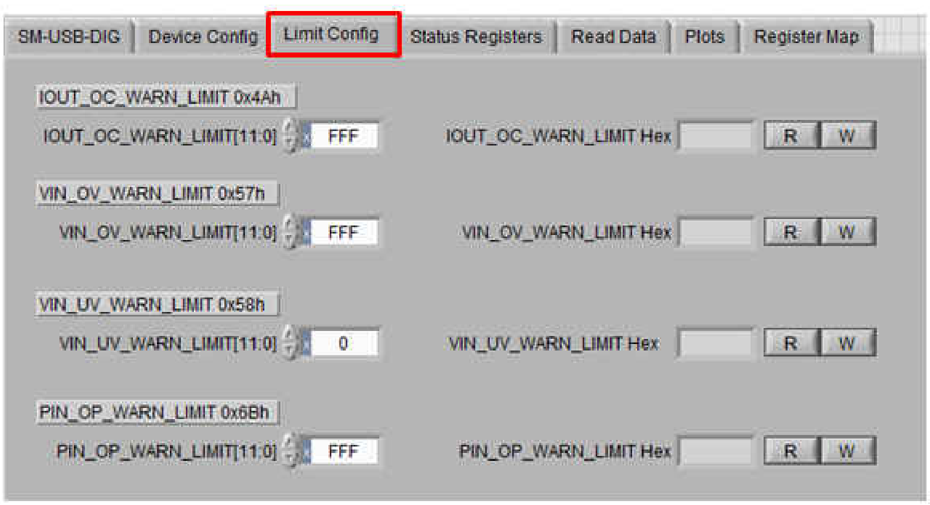

Figure 4-10. Set the Warning Limit Registers

4.3 Using the INA233EVM Software

After configuring the INA233EVM software, the rest of the tabs can be evaluated. This section describes the basic operation of the device, and offers guidelines for interpreting the graphic user interface (GUI).

4.3.1 Read Data Tab

Navigate to the Read Data tab, refer to Figure 4-11. This Tab allows the user to read the following registers:

- READ_EIN (0x86h): Retrieves the energy reading measurement.
- READ_VIN (0x88h): Retrieves input BUS voltage measurement.
- READ_IIN (0x89h): Retrieves the input current measurement.
- READ_PIN (0x97h): Retrieves the input power measurement.
- READ_VSHUNT_OUT (0xD1h): Retrieves shunt voltage measurement.

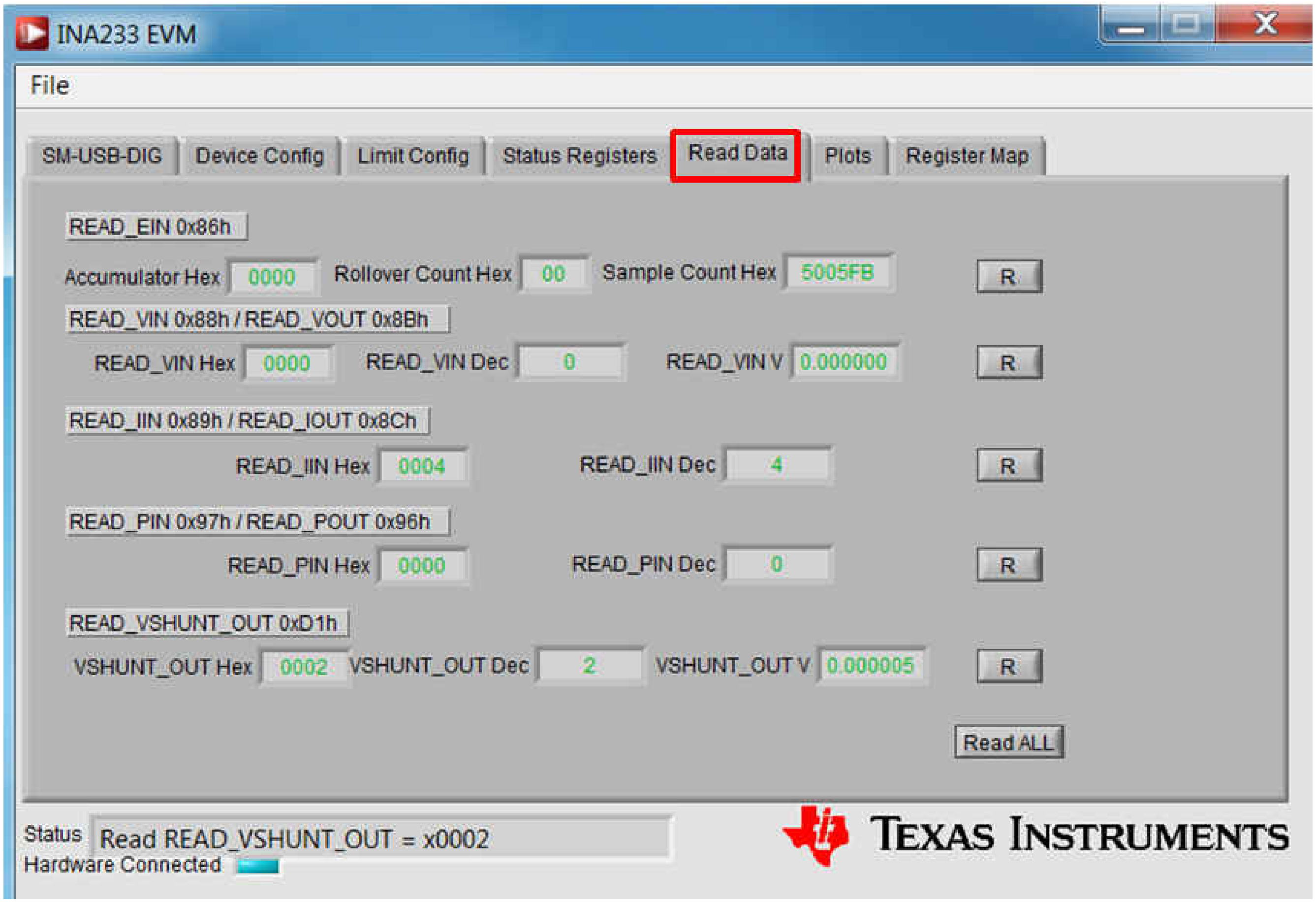

Figure 4-11. Read Data Tab

4.3.2 Status Register Tab

Navigate to the Status Registers Tab, refer to Figure 4-12. This Tab allows the user to read the following registers:

- STATUS BYTE(0x78h):Retrieves information about the part's operating status.
- STATUS_WORD (0x79h): Retrieves information about the part's operating status.
- STATUS_IOUT (0x7Bh): Retrieves information about output current status.
- STATUS_INPUT (0x7Ch): Retrieves information about input status.
- STATUS_CML (0x7Eh): Retrieves information about communications status.
- STATUS_MFR_SPECIFIC (0x80h): Retrieves information about manufacturer-specific device status.

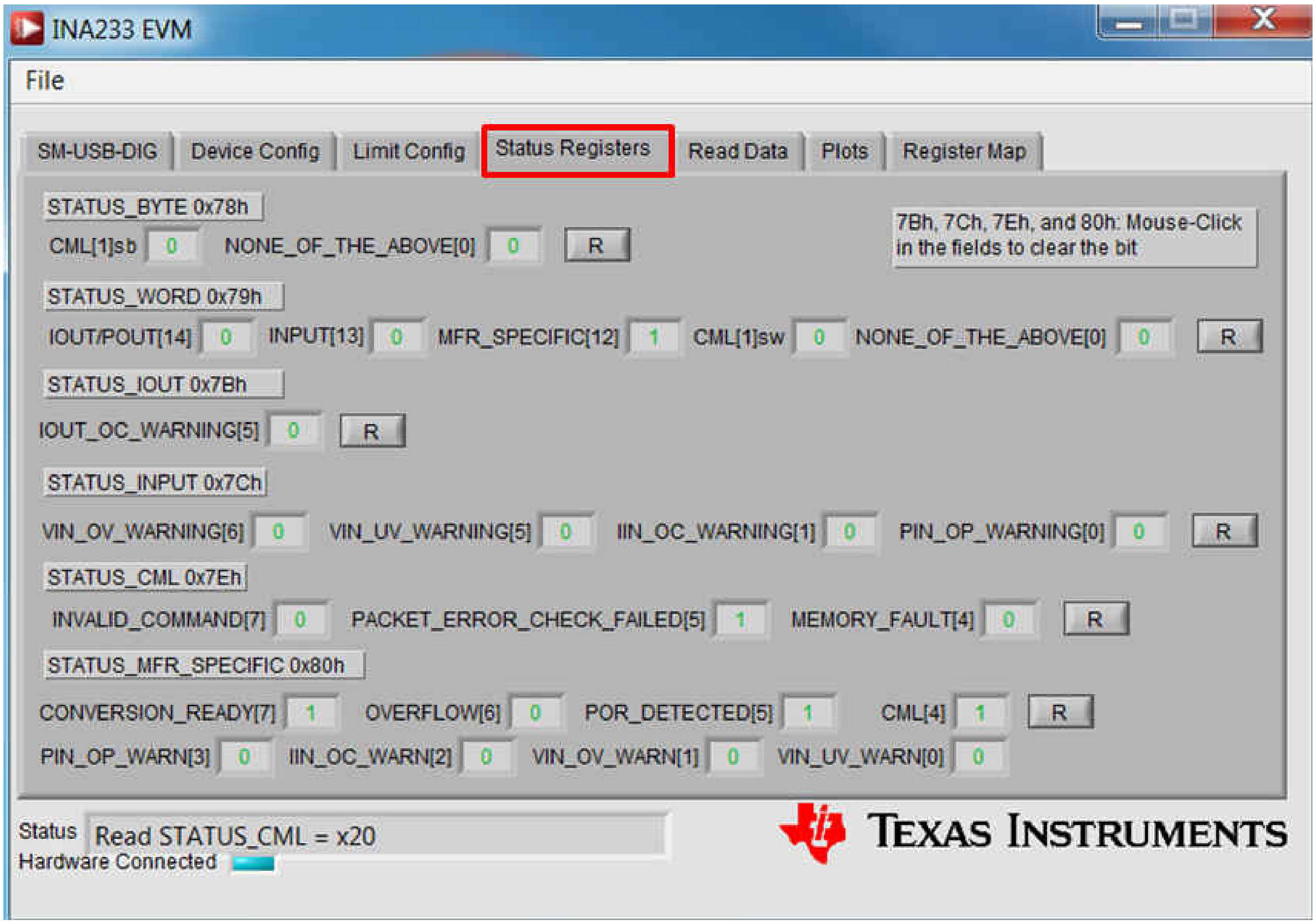

Figure 4-12. Status Register Tab

4.3.3 Register Map Tab

The Register tab contains information on the individual operation of the INA233 registers as shown in Figure 4-13.

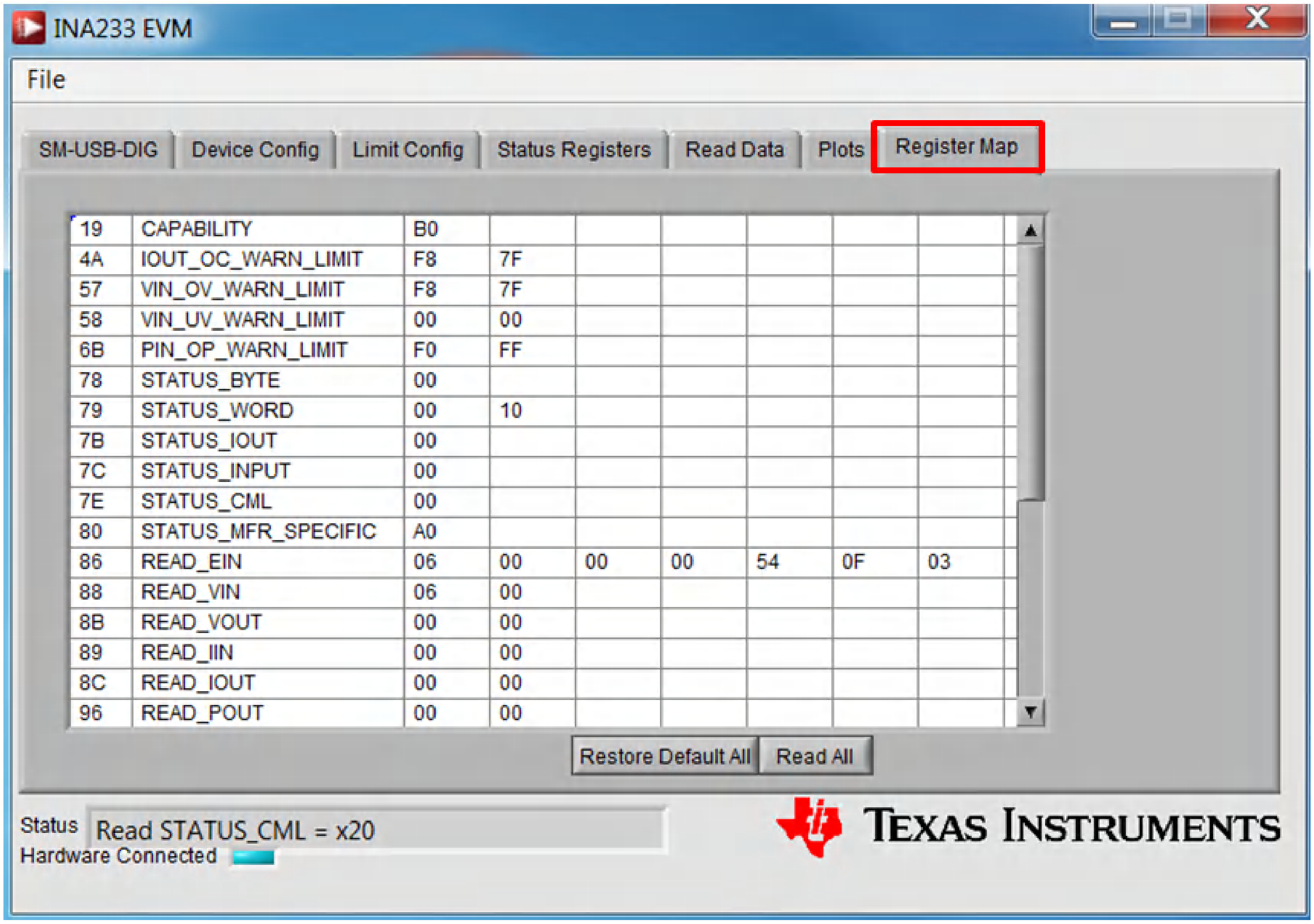

Figure 4-13. Registers Map Tab

4.3.4 Plots Tab

The Plots tab contains a plot window that shows the progression of data over time on the INA233. All four variables at the bottom of the EVM software (Vshunt (READ_VSHUNT_OUT), Vbus (READ_VIN), Current (READ_IIN) and Power (READ_PIN)) can be plotted using the drop-down box directly below the graph. After the desired plot has been selected, toggle the Capture Data in Loop button above the plot to begin polling for data.

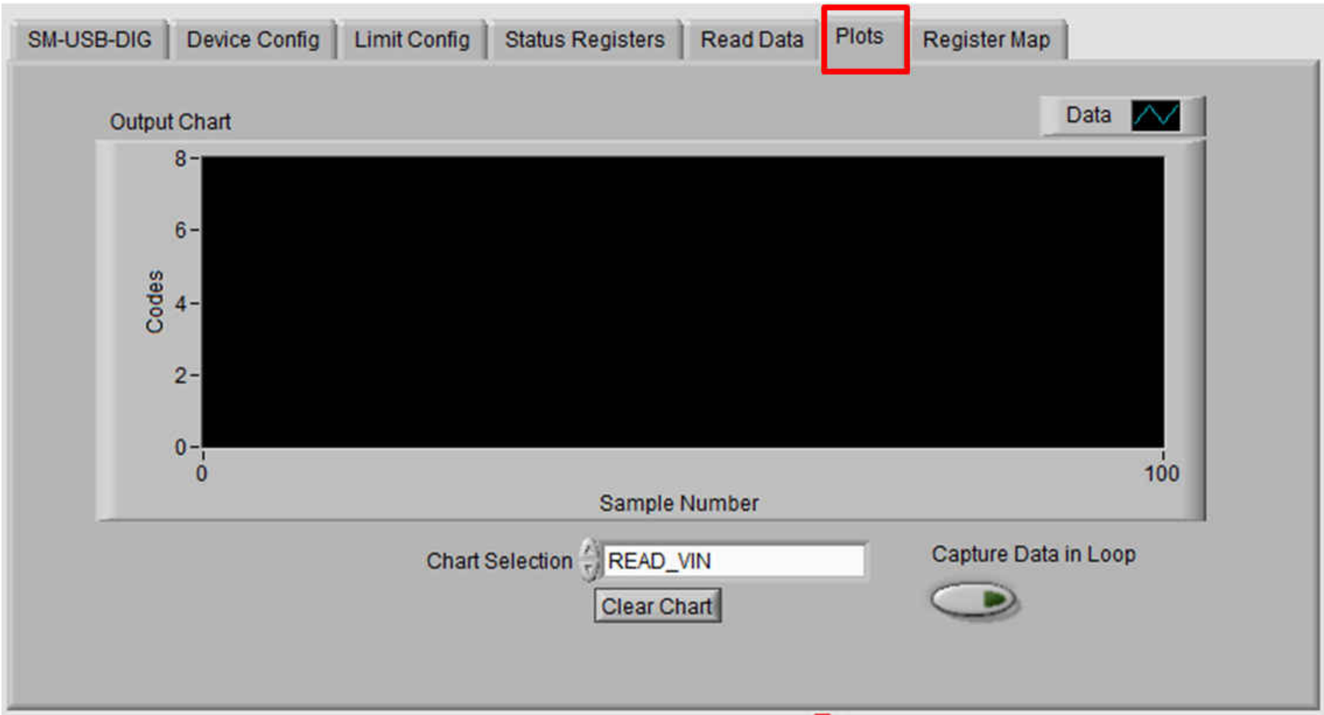

Figure 4-14. Graphing the INA233 Data

5 INA233EVM Documentation

This section contains the complete bill of materials, schematic diagram, and PCB layout for the INA233EVM.

Note

The board layout is not to scale. This image is intended to show how the board is laid out; it is not intended to be used for manufacturing INA233EVM PCBs.

5.1 Schematic

Figure 5-1 shows the schematic for the INA233EVM.

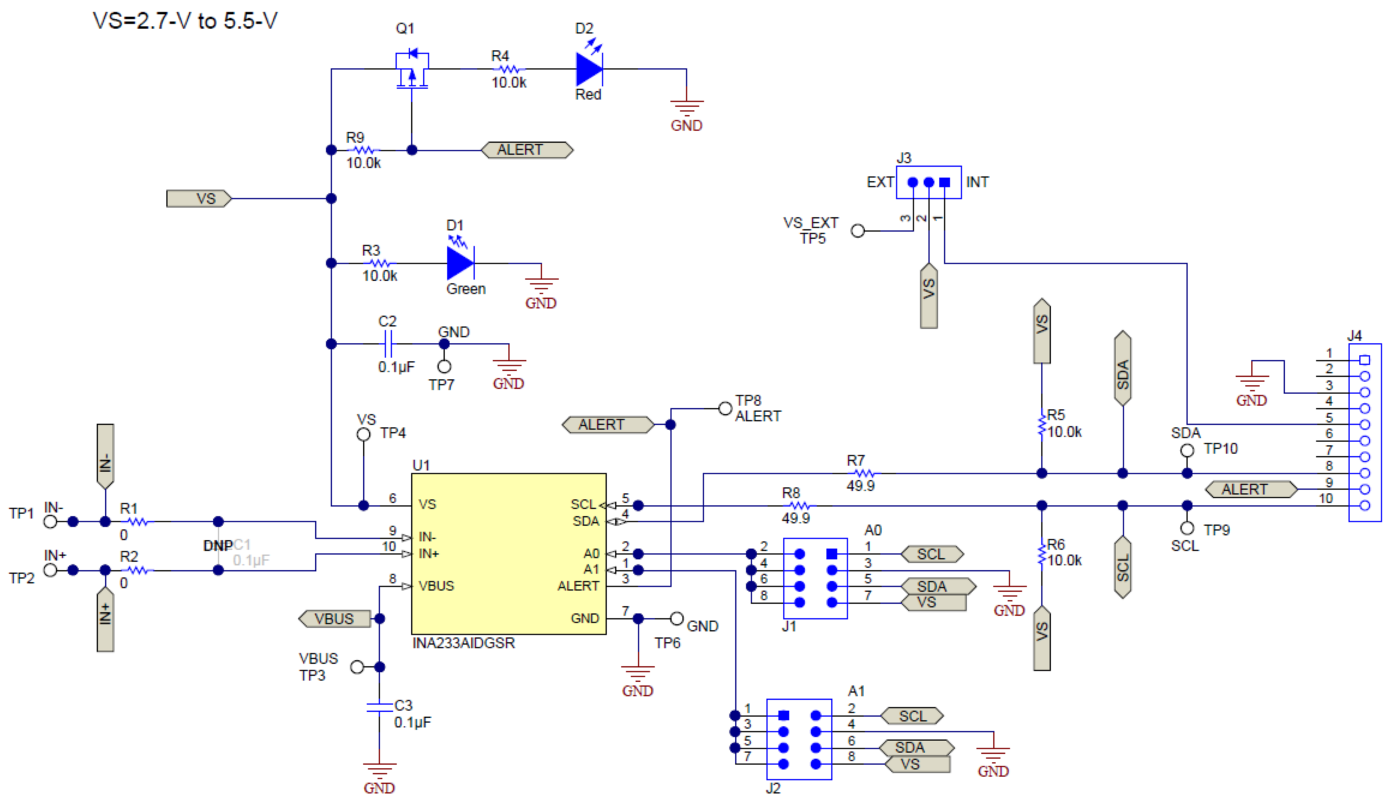

Figure 5-1. INA233EVM Schematic

5.2 PCB Layout

Figure 5-2 through Figure 5-5 illustrate the PCB layout for the INA233EVM.

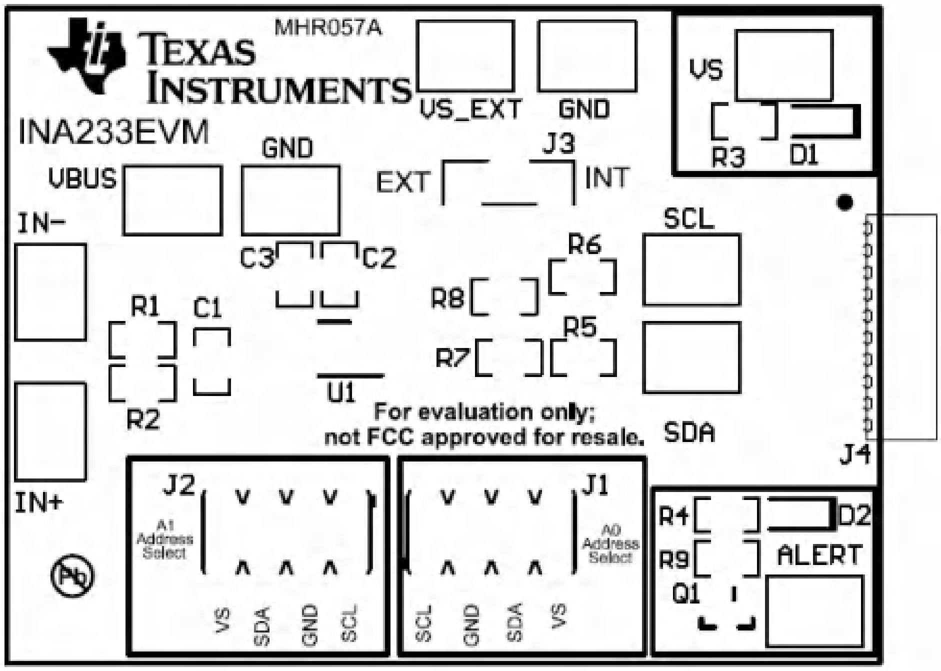

Figure 5-2. INA233EVM PCB Top Overlay

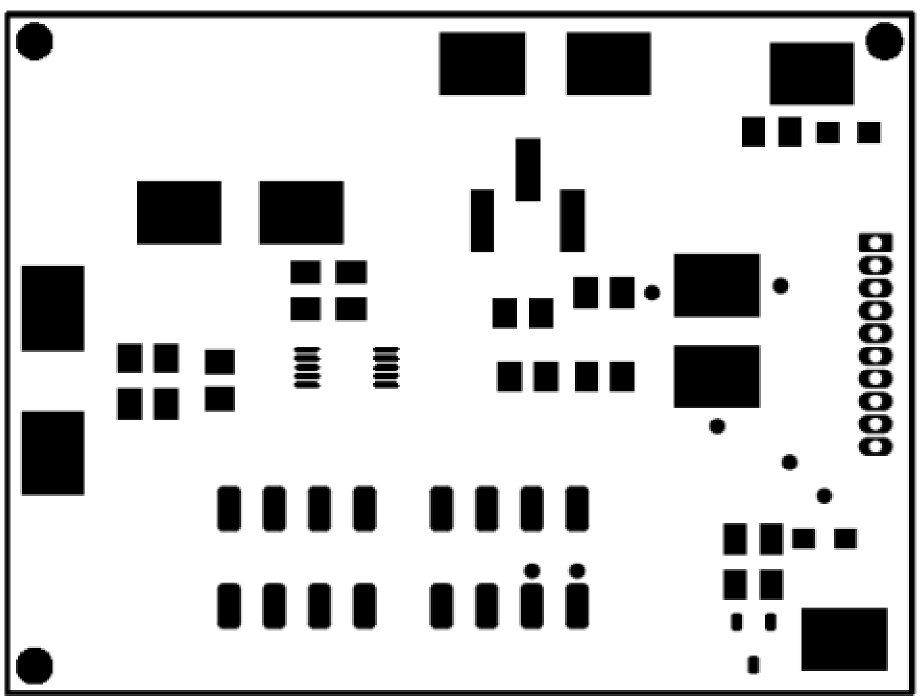

Figure 5-3. INA233EVM PCB Top Solder

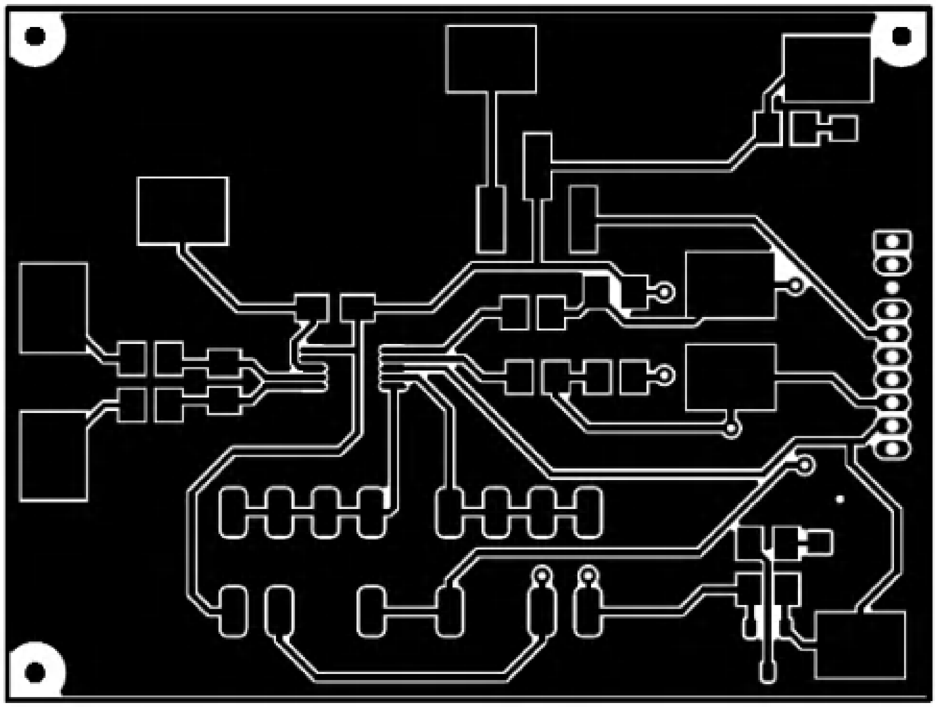

Figure 5-4. INA233EVM PCB Top Layer

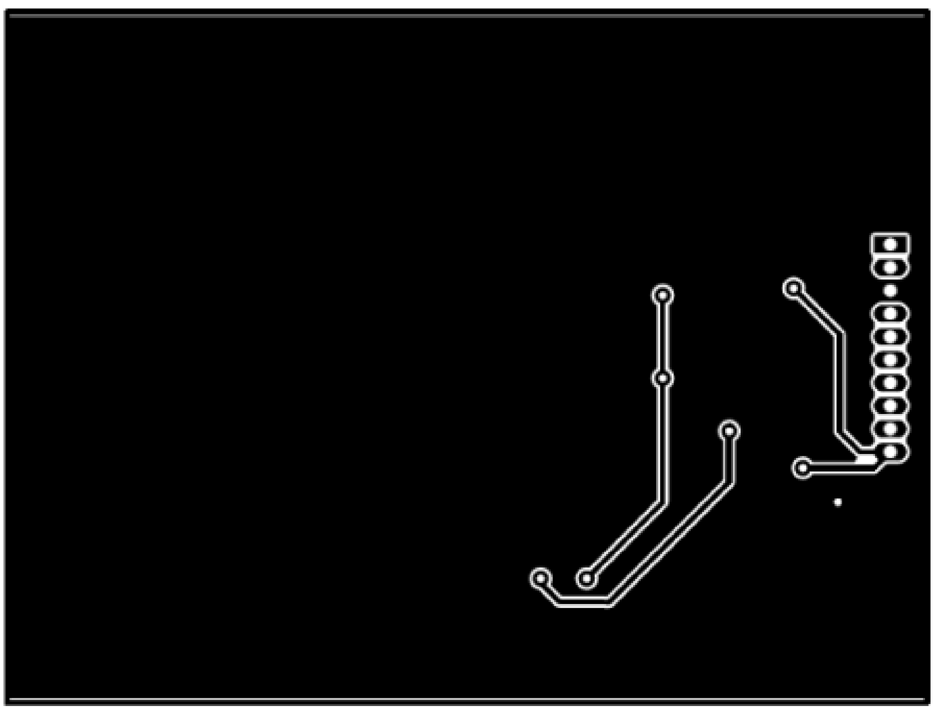

Figure 5-5. INA233EVM PCB Bottom Layer

5.3 Bill of Materials

Table 5-1 lists the bill of materials for the INA233EVM.

Table 5-1. Bill of Materials: INA233EVM

DESIGNATOR	QUANTITY	VALUE	DESCRIPTION	PACKAGE REFERENCE	PART NUMBER	MANUFACTURER
!PCB	1		Printed Circuit Board		MHR057	Any
C2, C3	2	0.1 µF	CAP, CERM, 0.1 µF, 50 V, ±5%, X7R, 0805	0805	08055C104JAT2A	AVX
D1	1	Green	LED, Green, SMD	LED_0805	APT2012LZGCK	Kingbright
D2	1	Red	LED, Red, SMD	SMD, 2-Leads, Body 2×1.25mm	APT2012LSECK/J3-PRV	Kingbright
H9, H10, H11, H12	4		Bumpon, Hemisphere, 0.44 × 0.20, Clear	Transparent Bumpon	SJ-5303 (CLEAR)	3M
J1, J2	2		Header, 2.54mm, 4×2, Gold, SMT	Header, 2.54mm, 4×2, SMT	95278-801A08LF	FCI
J3	1		Header, 100mil, 3×1, Gold, SMT	Samtec_TSM-103-01-X-SV	TSM-103-01-L-SV	Samtec
J4	1		Receptacle, 50mil, 10×1, Gold, R/A, TH	receptacle 10×1, 50mil	851-43-010-20-001000	Mill-Max
Q1	1	–50 V	MOSFET, P-CH, –50 V, –0.13 A, SOT-23	SOT-23	BSS84-7-F	Diodes Inc.
R1, R2	2	0	RES, 0, 5%, 0.125 W, 0805	0805	CRCW08050000Z0EA	Vishay-Dale
R3, R4, R5, R6, R9	5	10.0 k	RES, 10.0 k, 1%, 0.125 W, 0805	0805	CRCW080510K0FKEA	Vishay-Dale
R7, R8	2	49.9	RES, 49.9, 1%, 0.125 W, 0805	0805	CRCW080549R9FKEA	Vishay-Dale
SH-J1, SH-J2, SH-J3	3	1×2	Shunt, 100mil, Flash Gold, Black	Closed Top 100mil Shunt	SPC02SYAN	Sullins Connector Solutions
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10	10		Test Point, Compact, SMT	Testpoint_Keystone_Compact	5016	Keystone
U1	1		High-Side or Low-Side Measurement, Bidirectional Current and Power Monitor with PMBus Compatible Interface, DGS0010A (10-pin VSSOP)	DGS0010A	INA233AIDGSR	Texas Instruments

6 Revision History

Changes from Revision * (April 2017) to Revision A (April 2023)	Page
• Changed the numbering format for tables, figures, and cross-references throughout the document	1
• Changed document title to include software tutorial content	1
• Added registered trademark for Windows®	9

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２４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