

User's Guide

INA226EVM Rev A Model

User's Guide and Software Tutorial



Patrick Simmons, Dennis Goeke, and Scott Hill

High-Performance Linear Product

ABSTRACT

This user's guide describes the characteristics, operation, and use of the INA226EVM revision A 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 INA226EVM. This 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.

Table of Contents

1 Trademarks.....	2
2 Overview.....	2
2.1 INA226EVM Kit Contents.....	3
2.2 Related Documentation from Texas Instruments.....	4
3 INA226EVM Hardware Setup.....	4
3.1 Theory of Operation for INA226 Hardware.....	5
3.2 Signal Definitions of H1 (10-Pin Connector Socket).....	5
4 INA226EVM Hardware.....	6
4.1 Electrostatic Discharge Warning.....	6
4.2 Connecting the Hardware.....	7
4.3 Connecting Power.....	7
4.4 Connecting the USB Cable to the SM-USB-DIG Platform.....	8
4.5 INA226EVM Default Jumper Settings.....	9
4.6 INA226EVM Features.....	10
5 INA226EVM Software Setup.....	12
5.1 Hardware Requirements.....	12
5.2 Software Installation.....	12
6 INA226EVM Software Overview.....	14
6.1 Starting the INA226EVM Software.....	14
6.2 Configuring the INA226EVM Software.....	15
6.3 Using the INA226EVM Software.....	18
7 INA226EVM Documentation.....	22
7.1 Schematic.....	23
7.2 PCB Layout.....	24
7.3 Bill of Materials.....	25
8 Revision History.....	26

List of Figures

Figure 2-1. Hardware Included With INA226EVM Kit.....	3
Figure 3-1. INA226EVM Hardware Setup.....	4
Figure 3-2. INA226EVM Board Block Diagram.....	5
Figure 3-3. SM-USB-DIG Platform Block Diagram.....	6
Figure 4-1. Typical Hardware Test Connections for INA226EVM.....	7
Figure 4-2. Connecting the USB Cable to the SM-USB-DIG Platform.....	8
Figure 4-3. Confirmation of SM-USB-DIG Platform Driver Installation.....	8
Figure 4-4. INA226EVM Default Jumper Settings.....	9
Figure 4-5. Typical Filter Setup.....	11

Figure 4-6. INA226 Shunt Configurations.....	12
Figure 5-1. INA226EVM Software Installation.....	13
Figure 5-2. INA226EVM License Agreements.....	13
Figure 5-3. INA226EVM Software Installation Progress.....	13
Figure 6-1. INA226EVM Software Interface.....	14
Figure 6-2. INA226EVM Software: Communication Error With the SM-USB-DIG Platform.....	15
Figure 6-3. Setting the I ² C Address.....	16
Figure 6-4. Configuring Operating Mode.....	16
Figure 6-5. Configuring Conversion Times.....	17
Figure 6-6. Setting the Configuration Register (Calibration Register).....	18
Figure 6-7. Setting the Configuration Register (Current LSB).....	18
Figure 6-8. Configuring the Alert Pin.....	18
Figure 6-9. INA226 Results Bar.....	19
Figure 6-10. Theory of Operation Flowchart on the Calculation Tab.....	19
Figure 6-11. Registers Tab.....	20
Figure 6-12. Graphing the INA226 Data.....	21
Figure 6-13. Auto-Write, Power Button, and Voltage Control.....	22
Figure 7-1. INA226EVM Schematic.....	23
Figure 7-2. INA226EVM PCB Top Layer (Component Side).....	24

List of Tables

Table 2-1. INA226EVM Kit Contents.....	3
Table 2-2. Related Documentation.....	4
Table 3-1. Signal Definition of J1 on INA226EVM Board.....	5
Table 4-1. INA226EVM Test Board Jumper Functions.....	10
Table 6-1. INA226 I ² C Address Configuration.....	15
Table 7-1. Bill of Materials: INA226EVM.....	25

1 Trademarks

Microsoft® and Windows® are registered trademarks of Microsoft Corporation.

WinZIP® is a registered trademark of WinZip International LLC.

All trademarks are the property of their respective owners.

2 Overview

The [INA226](#) is a high- or low-side current sensor and power monitor with an I²C interface. The INA226 monitors both current and supply voltage, with programmable conversion times and averaging modes. The INA226EVM is a platform for evaluating the performance of the INA226 under various signal, shunt, and supply conditions.

This document gives a general overview of the INA226EVM, and provides a general description of the features and functions to consider while using this evaluation module.

2.1 INA226EVM Kit Contents

Table 2-1 summarizes the contents of the INA226EVM kit. Figure 2-1 shows all of the included hardware. Contact the [Texas Instruments customer support center](#) if any component is missing. TI highly recommends that you also check the [INA226 product folder](#) on the TI web site at www.ti.com to verify that you have the latest versions of the related software.

Table 2-1. INA226EVM Kit Contents

ITEM	QUANTITY
INA226EVM PCB Test Board	1
SM-USB-DIG Platform PCB	1
USB Extender Cable	1
SM-Dig Connector Ribbon Cable	1
User's Guide CD-ROM	1

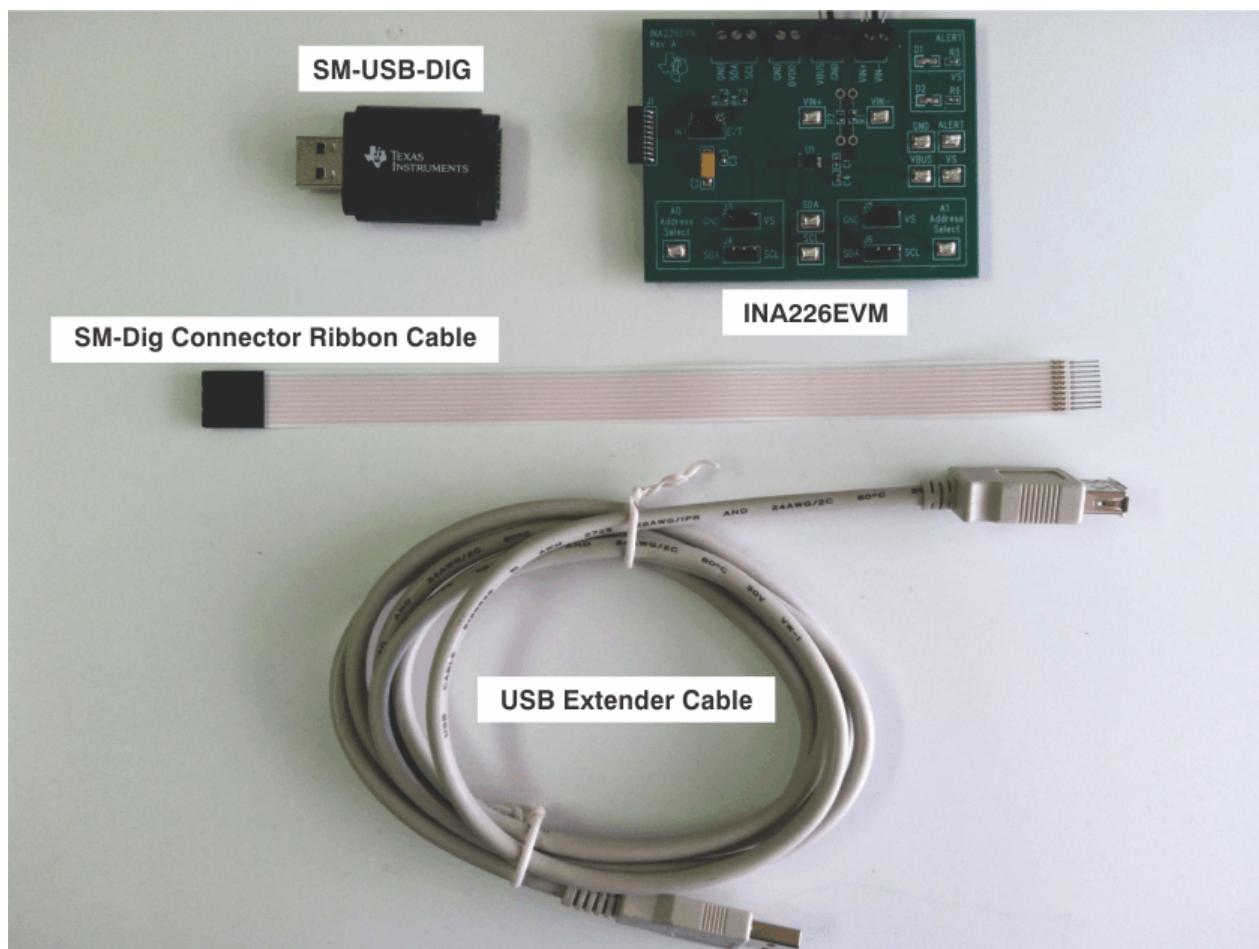


Figure 2-1. Hardware Included With INA226EVM Kit

2.2 Related Documentation from Texas Instruments

The following documents provide information regarding Texas Instruments' integrated circuits used in the assembly of the INA226EVM. This user's guide is available from the TI web site under literature number **SBOU113**. 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 may be available from the [TI web site](#), or call the Texas Instruments' Literature Response Center at (800) 477-8924 or the Product Information Center at (972) 644-5580. When ordering, identify the document by both title and literature number.

Table 2-2. Related Documentation

DOCUMENT	LITERATURE NUMBER
INA226 Product Data Sheet	SBOS547
SM-USB-DIG Platform User Guide	SBOU098

3 INA226EVM Hardware Setup

Figure 3-1 shows the overall system setup for the INA226EVM. 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 INA226 test board. Connectors on the INA226EVM test board allow the user to connect to the system under test conditions and monitor the power, current, and voltage.

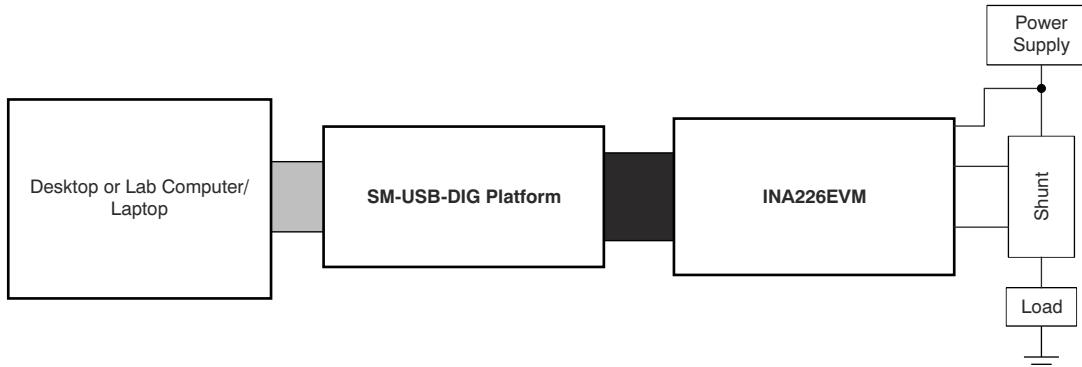


Figure 3-1. INA226EVM Hardware Setup

3.1 Theory of Operation for INA226 Hardware

Figure 3-2 shows a block diagram of the INA226 test board hardware setup. The PCB provides connections to the I²C interface and general-purpose inputs/outputs (GPIOs) on the SM-USB-DIG Platform board. It also provides connection points for external connections of the shunt voltage, bus voltage, and ground.

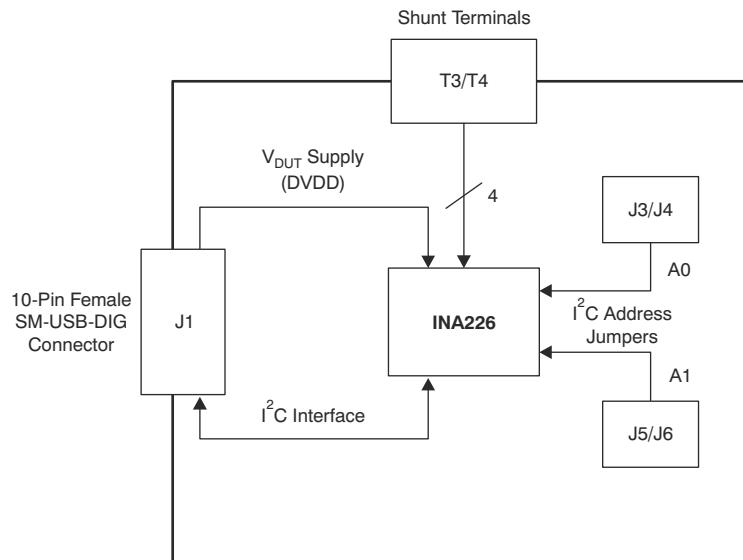


Figure 3-2. INA226EVM Board Block Diagram

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

Table 3-1 lists the pinout for the 10-pin connector socket used to communicate between the INA226EVM and the SM-USB-DIG. It should be noted that the INA226EVM only uses the necessary I²C communication lines (pins 1 and 3) and the V_{DUT} and GND pins (pin 6 and pin 8) to issue commands to the INA226 chip.

Table 3-1. Signal Definition of J1 on INA226EVM Board

PIN ON J1	SIGNAL	DESCRIPTION
1	I ² C_SCL	I ² C Clock Signal (SCL)
2	CTRL/MEAS4	GPIO: Control Output or Measure Input
3	I ² C_SDA1	I ² C Data Signal (SDA)
4	CTRL/MEAS5	GPIO: Control Output or Measure Input
5	SPI_DOUT1	SPI Data Output (MOSI)
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 (CS)
10	SPI_DIN1	SPI Data Input (MISO)

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

3.2.1 Theory of Operation for SM-USB-DIG Platform

Figure 3-3 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 3-3 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, I²C, 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.

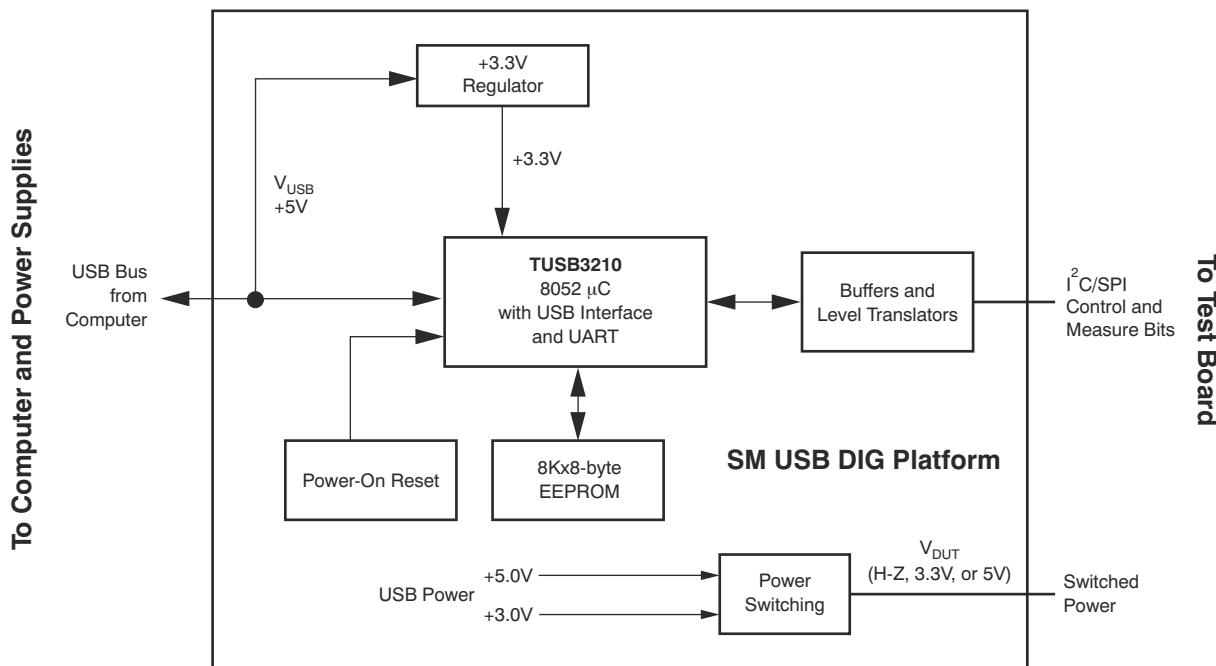


Figure 3-3. SM-USB-DIG Platform Block Diagram

4 INA226EVM Hardware

Setting up the INA226EVM hardware involves connecting the two PCBs of the EVM together, applying power, connecting the USB cable, and setting the jumpers. This section presents the details of this procedure.

4.1 Electrostatic Discharge Warning

CAUTION

Many of the components on the INA226EVM 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.

4.2 Connecting the Hardware

To set up the INA226EVM and connect the two PCBs of the EVM together (that is, the INA226 Test Board and SM-USB-DIG Platform board), gently slide the plug and socket ends of the 10-pin connectors together. Make sure that the two connectors are completely pushed together; loose connections may cause intermittent operation.

4.3 Connecting Power

After the EVM and SM-USB-DIG are conjoined, as [Figure 4-1](#) illustrates, connect the desired V_{BUS} and shunt configuration intended to be measured. Typically, setup involves a high- or low-side load and a shunt resistor across V_{IN+} and V_{IN-} . The setup in [Figure 4-1](#) represents a test scenario with a low-side shunt attached. This source for V_{BUS} is not included with the kit, and its voltage may differ depending on your testing needs. The external power source is connected to the terminal strip T3.

Note

It is always necessary to connect the power to the SM-USB-DIG Platform board before connecting the USB cable.

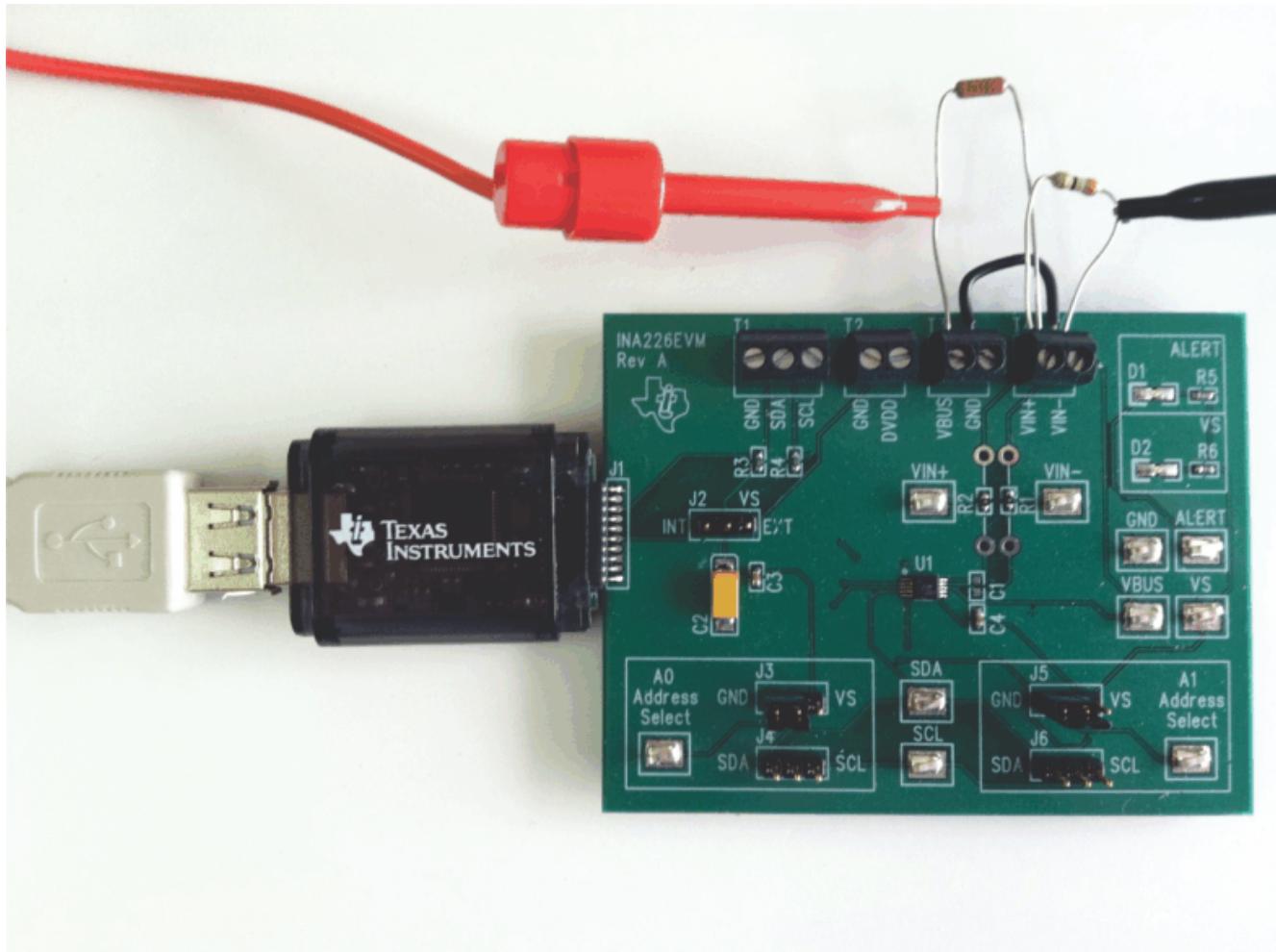


Figure 4-1. Typical Hardware Test Connections for INA226EVM

4.4 Connecting the USB Cable to the SM-USB-DIG Platform

When the power is connected, as shown in [Figure 4-2](#), the computer typically responds with a *Found New Hardware, USB Device* pop-up dialog. The pop-up window typically changes to *Found New Hardware, USB Human Interface Device*. This pop-up indicates that the device is ready to be used. The SM-USB-DIG Platform uses the human interface device drivers that are part of the Microsoft® Windows® operating system.

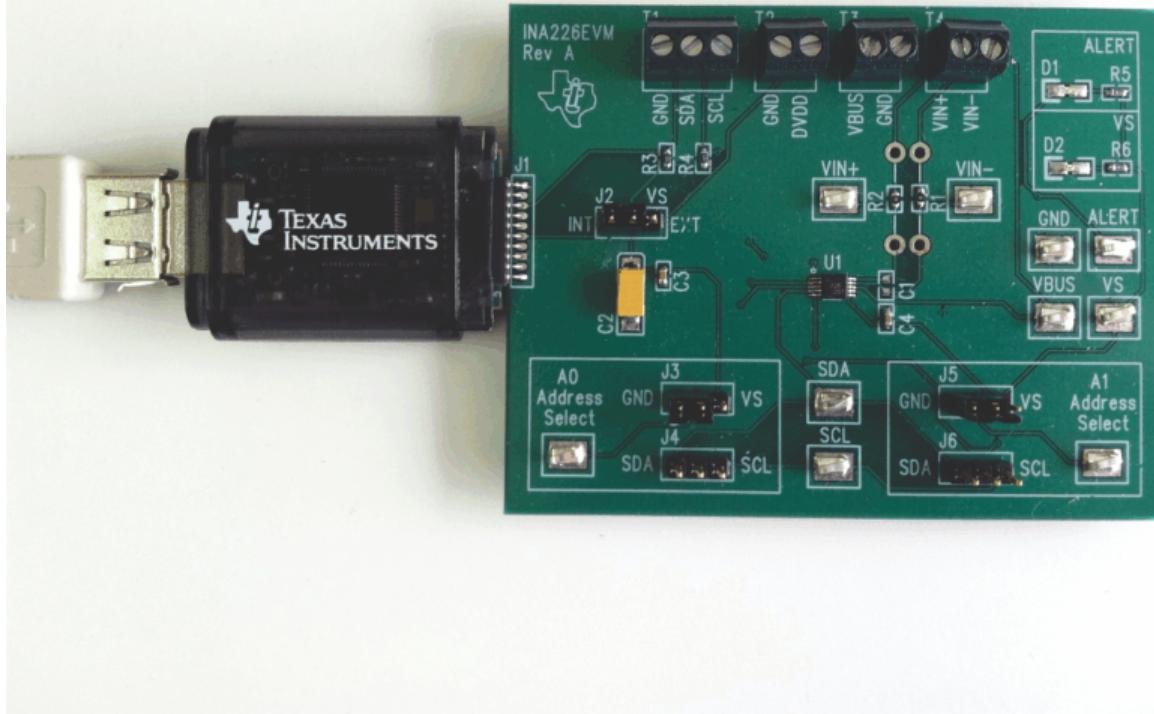


Figure 4-2. Connecting the USB Cable to the SM-USB-DIG Platform

In some cases, the Windows *Add Hardware Wizard* may pop up. If this prompt appears, click *Yes* to allow the system device manager to install the human interface drivers. [Figure 4-3](#) shows the confirmation message when the drivers are installed.



Figure 4-3. Confirmation of SM-USB-DIG Platform Driver Installation

4.5 INA226EVM Default Jumper Settings

Figure 4-4 shows the default jumper configuration for the INA226EVM. In general, the jumper settings of the SM-USB-DIG Platform do not need to be changed. You may want to change some of the jumpers on the INA226EVM board to match your specific configuration. For example, you may wish to set a specific I²C address by configuring J3-J6.

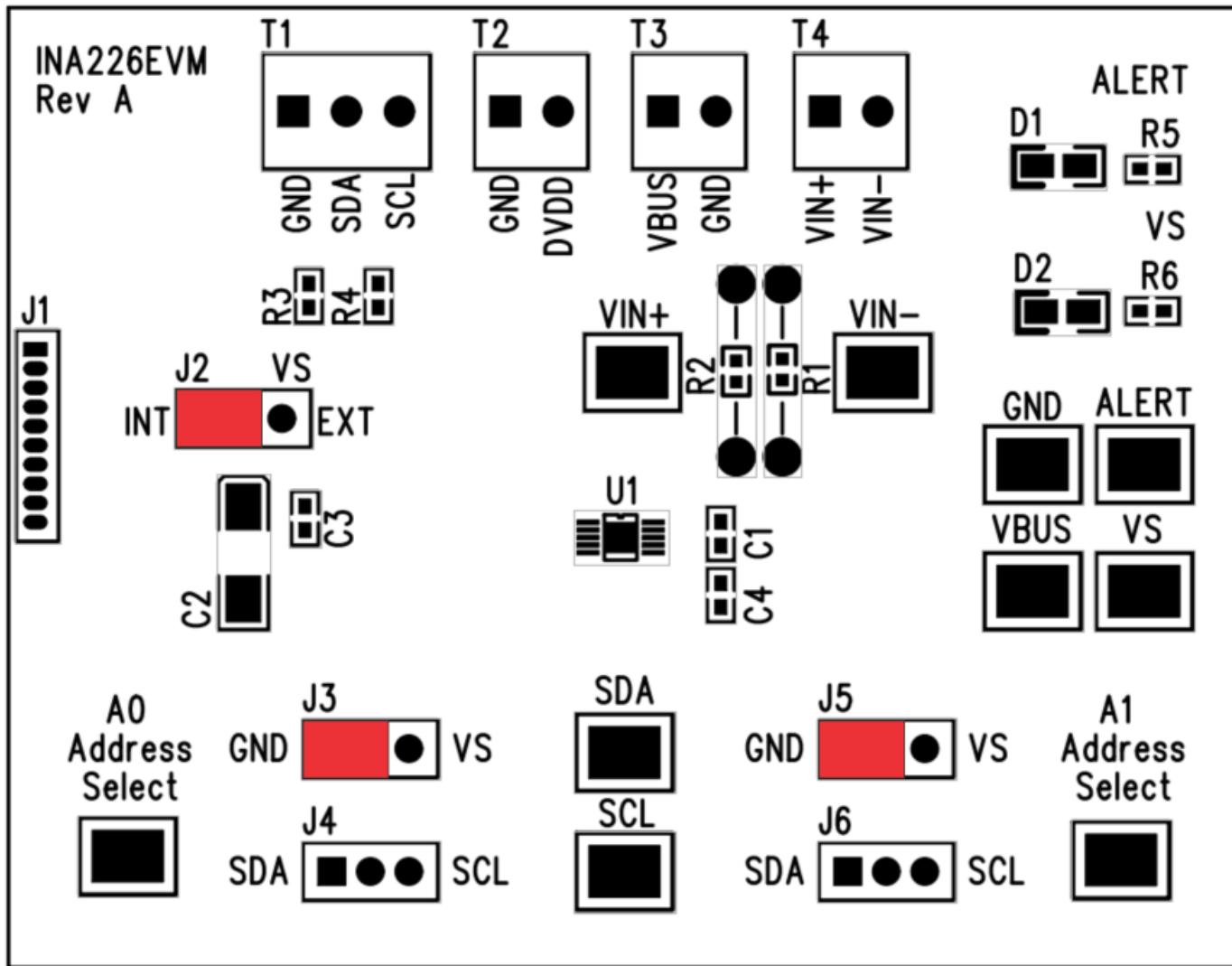


Figure 4-4. INA226EVM Default Jumper Settings

Typically, jumper 2 on the INA226EVM is always set to the INT position. When set to the INT position, the SM-USB-DIG Platform provides the supply for the INA226. When this jumper is set to the EXT position, an external supply voltage can be connected to terminal strip T2 to provide the supply for the INA226.

Jumpers 3 through 6 control the I²C address pins for the INA226. 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 INA226 addressing, refer to the [INA226 product data sheet](#).

Table 4-1 summarizes the function of the INA226 Test Board jumpers. For most applications, all jumpers should be left in the respective default configurations.

Table 4-1. INA226EVM Test Board Jumper Functions

JUMPER	DEFAULT	PURPOSE
J2	INT	This jumper selects whether the V_S pin on the INA226 is connected to the V_{DUT} signal generated from the SM-USB-DIG Platform or whether the digital supply pin is connected to terminal T2, allowing for an external supply to power the device. The default INT position connects the V_S pin to the V_{DUT} control signal.
J3/J4	GND	This jumper selects the I ² C A0 address selection for A0.
J5/J6	GND	This jumper selects the I ² C A1 address selection for A1.

4.6 INA226EVM Features

This section describes some of the hardware features present on the INA226EVM test board.

4.6.1 J2: I²C V_S Control Setting

Jumper J2 selects what connects to the INA226 supply pin. If J2 is set to the INT position, the V_S 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 J4 is set in the INT position, the V_S Power button in the INA226EVM 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 terminal T2 can be used to provide the supply voltage for the INA226.

4.6.2 J3/J4: I²C Address Hardware Setting (A0)

Jumpers J3 and J4 are used to set the hardware setting for the A0 I²C address pin on the INA226. Using J3, the A0 address can be set to either a logic '1' or a logic '0'. Using J4, the A0 address can be set to either the SCL or SDA communication line. Make sure to only have either J3 or J4 connected individually; failure to keep these lines separate can lead to board shorts and problems with the I²C communication lines. See [Section 6.2.1](#) on how to configure the INA226EVM software to match the J3/J4 hardware setting.

4.6.3 J5/J6: I²C Address Hardware Setting (A1)

Jumpers J5 and J6 are used to set the hardware setting for the A1 I²C address pin on the INA226. Using J3, the A1 address can be set to either a logic '1' or a logic '0'. Using J4, the A1 address can be set to either the SCL or SDA communication line. Make sure to only have either J5 or J6 connected individually; failure to keep these lines separate can lead to board shorts and problems with the I²C communication lines. See [Section 6.2.1](#) on how to configure the INA226EVM software to match the J5/J6 hardware setting.

4.6.4 External I²C Lines and Terminal Block T1

The I²C communication lines on the INA226EVM are tied to two sources: the internal I²C communication lines from the SM-USB-DIG and the terminal block T1. If the user wants to add external signals separate from the SM-USB-DIG, simply disconnect the SM-USB-DIG from the INA226EVM 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.

4.6.5 VIN+/VIN– Input Filter (R1, R2, and C1)

The INA226EVM has an optional input filter to remove high-frequency noise from the inputs VIN+ and VIN–. This filter is typically unpopulated. The default values for R1 and R2 are 0-Ω resistors. [Figure 4-5](#) shows the typical setup, which is recommended for basic INA226 evaluation.

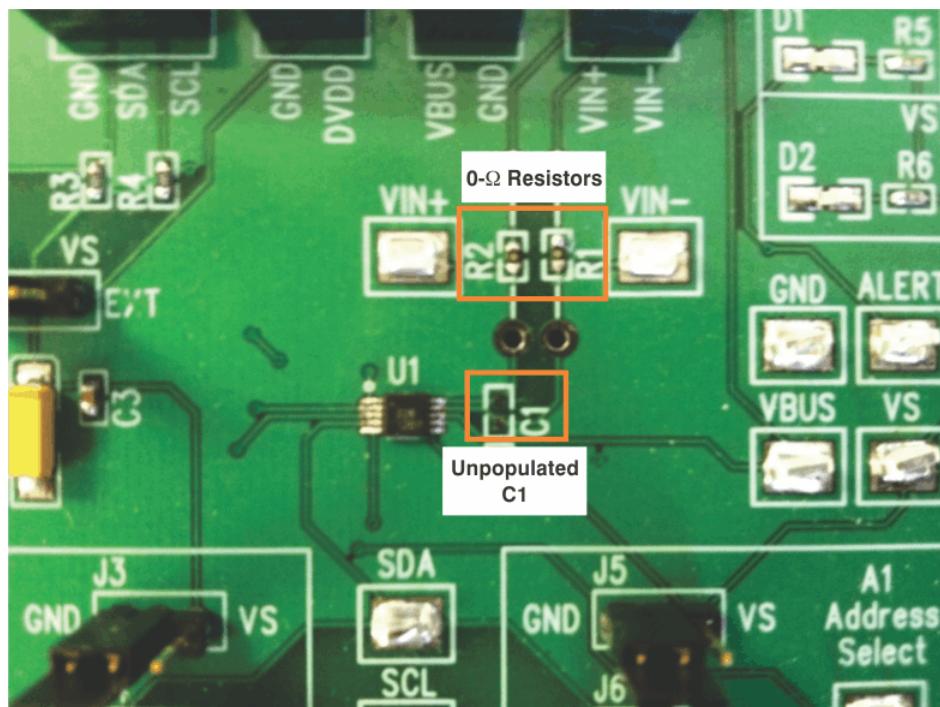


Figure 4-5. Typical Filter Setup

4.6.6 Shunt Monitor Configuration and Terminal Blocks T3 and T4

The INA226 is generally used in either a high-side or low-side shunt configuration, as shown in [Figure 4-6](#). Terminal block T3 represents V_{BUS} and ground, while terminal block T4 represents V_{IN+} and V_{IN-}. Depending on the user's needs, either of these configurations may be used without making any changes to the INA226EVM board or software.

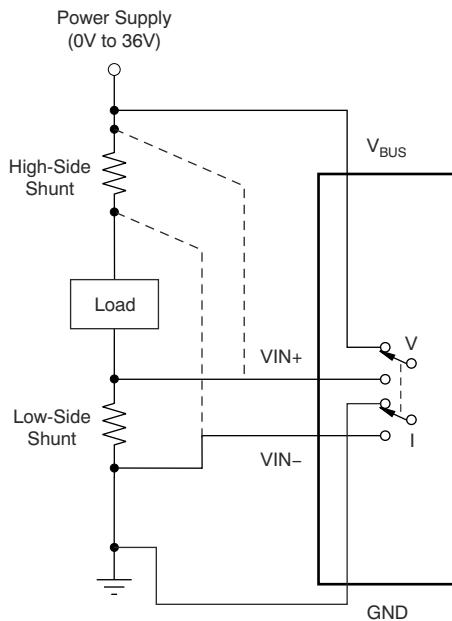


Figure 4-6. INA226 Shunt Configurations

5 INA226EVM Software Setup

This section discusses how to install the INA226EVM software.

5.1 Hardware Requirements

The INA226EVM software has been tested on Microsoft® Windows® XP operating systems (OS) with United States and European regional settings. The software should also function on other Windows OS platforms.

5.2 Software Installation

The INA226EVM software is included on the CD that is shipped with the EVM kit. It is also available through the [INA226EVM product folder](#) on the TI website. To install the software to a computer, insert the disc into an available CD-ROM drive. Navigate to the drive contents and open the INA226EVM software folder. Locate the compressed file (*INA226EVM.zip*) and open it using WinZIP® or a similar file compression program; extract the INA226EVM files into a specific INA226EVM folder (for example, C:\INA226EVM) on your hard drive.

After the files are extracted, navigate to the INA226EVM folder you created on the hard drive. Locate the *setup.exe* file and execute it to start the installation. [Figure 5-1](#) shows the installation process.

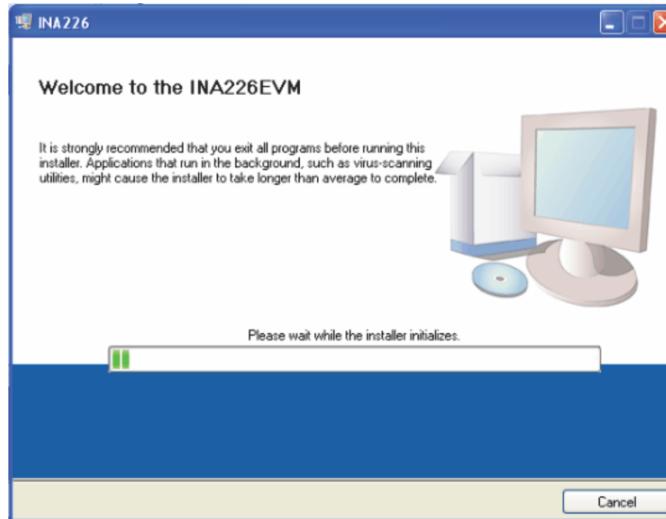


Figure 5-1. INA226EVM Software Installation

After the installation process initializes, the user can select the directory in which to install the program; the default location is *C:\Program Files\INA226* and *C:\Program Files\National Instruments*. Following this option, [Figure 5-2](#) shows the two license agreements that must be accepted to continue the install. After accepting the Texas Instruments and National Instruments license agreements, [Figure 5-3](#) shows the progress bar that opens and shows the installation of the software. After the installation process is complete, click *Finish* to close the window.

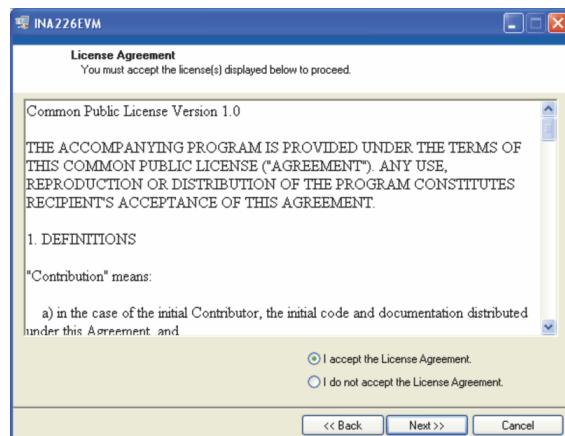


Figure 5-2. INA226EVM License Agreements

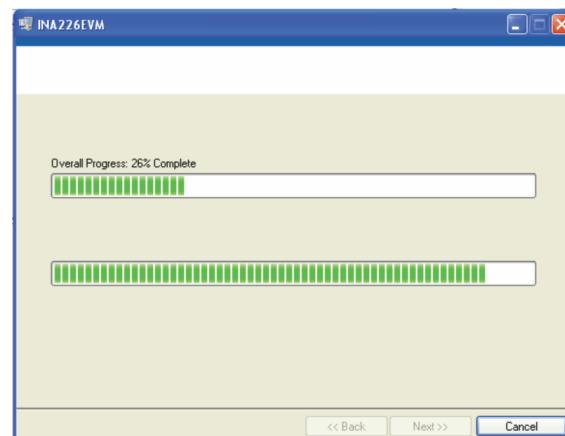


Figure 5-3. INA226EVM Software Installation Progress

6 INA226EVM Software Overview

This section discusses how to use the INA226EVM software. Software operation involves a two-step process: configuration of the INA226 settings, and operation of the tool.

6.1 Starting the INA226EVM Software

The INA226 software can be operated through the Windows *Start* menu. From Start, select *All Programs*; then select the *INA226EVM* program.

Figure 6-1 shows how the software should appear if the INA226EVM is functioning properly.

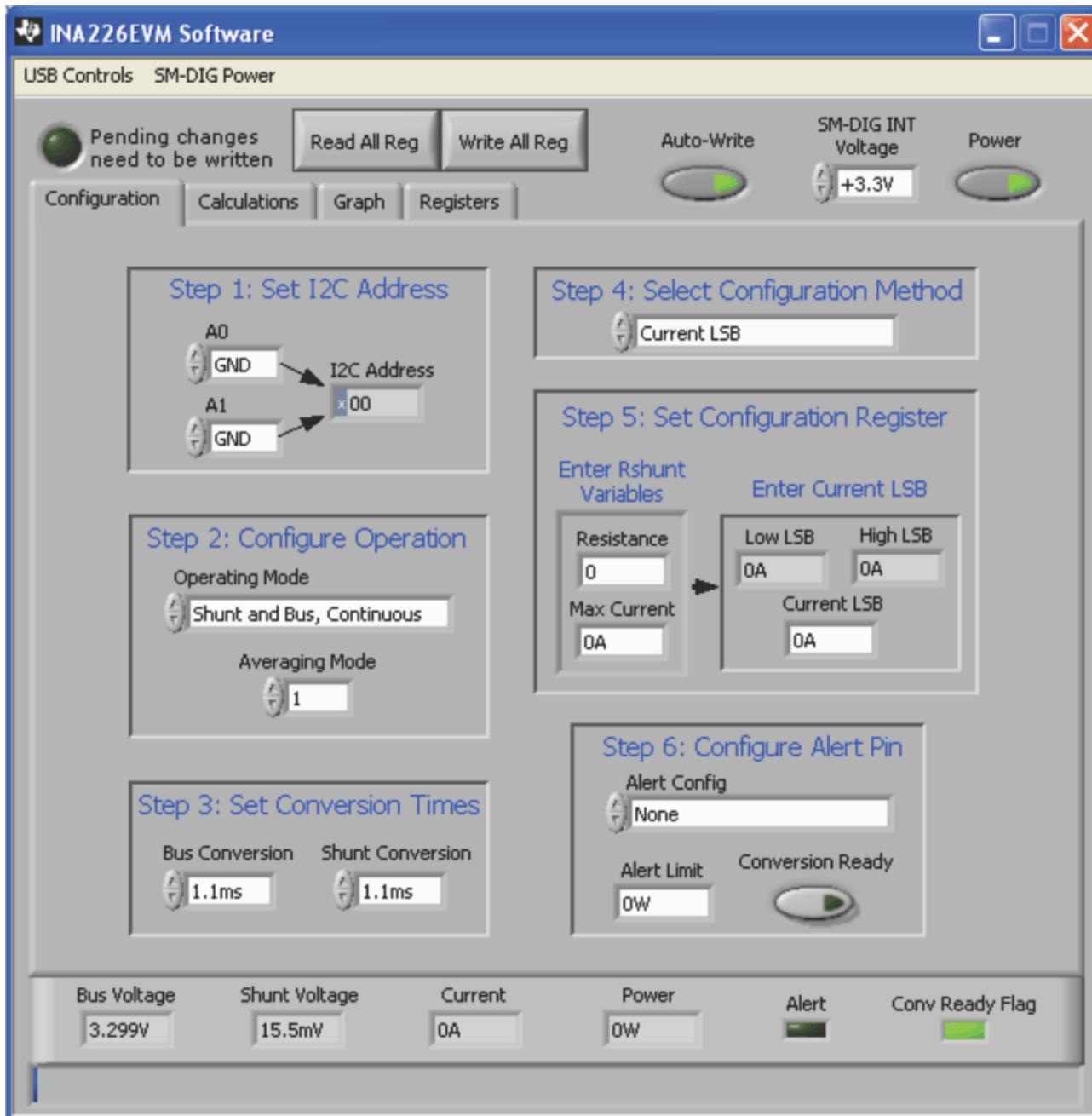


Figure 6-1. INA226EVM Software Interface

Figure 6-2 shows an error that pops up if the computer cannot communicate with the EVM. 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.

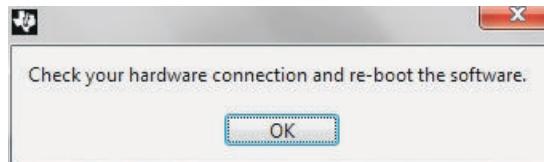


Figure 6-2. INA226EVM Software: Communication Error With the SM-USB-DIG Platform

6.2 Configuring the INA226EVM Software

The INA226EVM software first requires a series of setup processes to configure the device and ensure that it works properly. On the Configuration tab (see Figure 6-1), there are six steps noted:

1. Set I²C Address
2. Configure Operation
3. Set Conversion Times
4. Select Configuration Method
5. Set Configuration Register
6. Configure Alert Pin

This section explains how to configure the software and reviews some of the different setups that can be done.

6.2.1 I²C Address Selection

The INA226 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 J3-J6 to either GND, V_S, SDA or SCL, the INA226 can be changed to a total of 16 I²C addresses as shown in Table 6-1.

Table 6-1. INA226 I²C Address Configuration

A1	A0	TARGET ADDRESS
GND	GND	1000000
GND	V _{S+}	1000001
GND	SDA	1000010
GND	SCL	1000011
V _{S+}	GND	1000100
V _{S+}	V _{S+}	1000101
V _{S+}	SDA	1000110
V _{S+}	SCL	1000111
SDA	GND	1001000
SDA	V _{S+}	1001001
SDA	SDA	1001010
SDA	SCL	1001011
SCL	GND	1001100
SCL	V _{S+}	1001101
SCL	SDA	1001110
SCL	SCL	1001111

Figure 6-3 shows how to configure the I²C addresses. Click either the A0 or A1 box and select how the hardware is configured on the EVM. Failure to select the correct address prevents the INA226 device from communicating with the software.

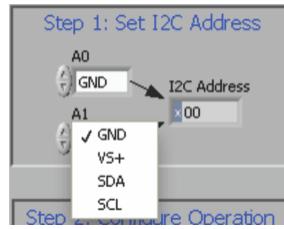


Figure 6-3. Setting the I²C Address

6.2.2 Configure Operating Mode

The second step of the INA226EVM configuration process allows the user to set the operating mode and the averaging mode.

The operating mode allows the user to restrict the amount of calculations done within the INA226 by changing the conversion to be triggered or continuous, or shutting down the part altogether. When the device is operating in triggered mode, it only performs conversions when the operating mode is set and the *Write All Reg* button at the top of the screen is selected. After the mode changes and *Write All Reg* has been selected, the *Read All Reg* button must also be selected in order for the changes on the device to be reflected in the software.

When the INA226 is operating in continuous mode, conversions are performed directly after the previous conversion is completed. When the INA226EVM software is in continuous mode, the software can be updated at any time by pressing the *Read All Reg* button.

Power-down mode stops all conversions from taking place until the operating mode changes again. The device remains attached to power but draws minimal current and does not perform any conversions.

Figure 6-4 shows how to limit all three operating modes to measure only certain components of the device. It is important to note that for complete functionality of the INA226, 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 [INA226 data sheet](#).

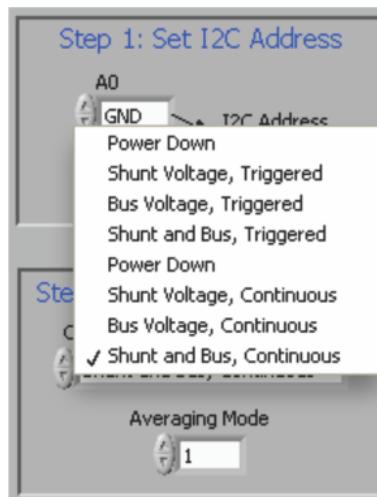


Figure 6-4. Configuring Operating Mode

The *Configure Operation* step also contains a drop-down box to help the user select the averaging mode. The INA226 can be setup to take the average of several measurements before storing the value of the measurements in the register table.

6.2.3 Set Conversion Times

Setting the conversion times allows the user to customize the amount of measurement time for conversions. Typically, for the INA226EVM 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. [Figure 6-5](#) shows how to set the Shunt and Bus conversion times.

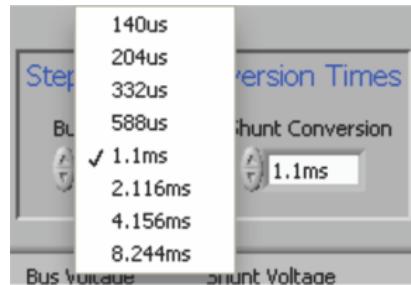


Figure 6-5. Configuring Conversion Times

6.2.4 Set Configuration Register

The Configuration register must then be set correctly for the software to operate properly. There are two methods used to set the Configuration register. First, the user can manually calculate the desired value and then input that value into the register table, as shown in [Equation 1](#). Alternatively, the user can allow the software to create a recommended window and choose an LSB for the current as shown in [Figure 6-7](#). Both methods accomplish the same goal by using [Equation 1](#), but the method is selected by changing the value in Step 4: *Select Configuration Method* (as [Figure 6-6](#) and [Figure 6-7](#) show).

$$\text{Calibration Register} = \frac{0.00512}{\text{Current_LSB} \cdot R_{SHUNT}} \quad (1)$$

Use [Equation 2](#) to calculate the current LSB by a recommended range in the INA226 data sheet. It is important to note that with either of the methods used, 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 INA226* in the [product data sheet](#) for more information on setting the Calibration register value.

$$\frac{\text{Maximum Expected Current}}{2^{15}} \leq \text{Current_LSB} \leq \frac{\text{Maximum Expected Current}}{2^{12}} \quad (2)$$

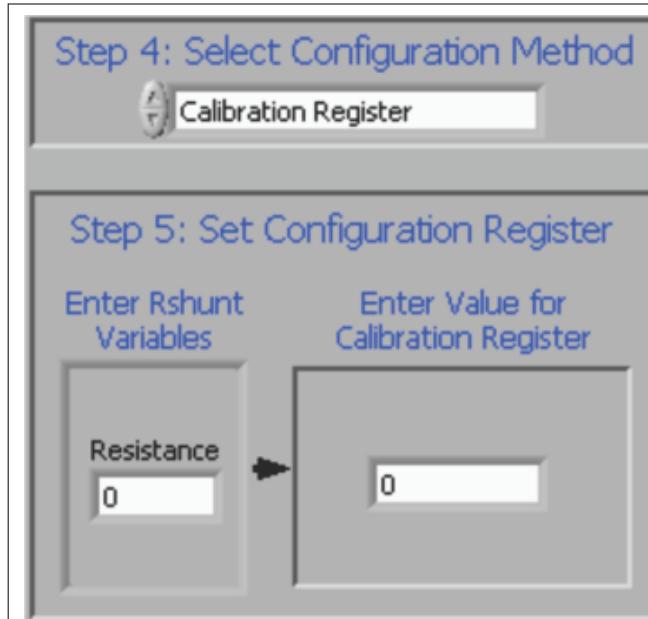


Figure 6-6. Setting the Configuration Register (Calibration Register)

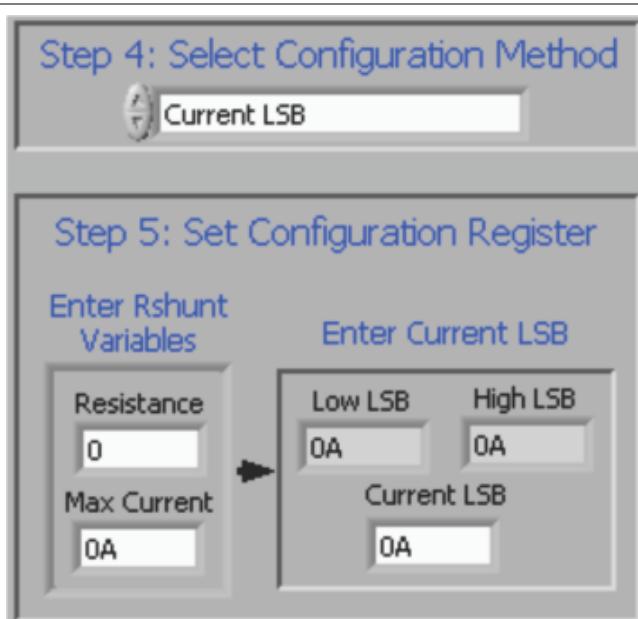


Figure 6-7. Setting the Configuration Register (Current LSB)

6.2.5 Configuring the Alert Pin

The Alert pin from the INA226 allows the user to set limits that monitor the registers and trigger a flag when they are exceeded. The register that is being monitored can be changed by selecting the desired alert configuration as shown in [Figure 6-8](#). The value that is being considered is compared to the *Alert Limit* box. This Alert Limit box modifies its functionality based on the selected configuration. It is important to note that by default, the INA226 Alert pin is set to active low.



Figure 6-8. Configuring the Alert Pin

In addition to the INA226EVM software alert configuration, the *Alert Configuration* box includes the *Conversion Ready* button that allows for a special functionality on the Alert pin. When the INA226 completes the conversions for its current operation, it triggers the Alert pin and notifies the user that another conversion can be performed. In most cases, the INA226 conversion ready flag is not visible because of the speed of the INA226 conversion process.

6.3 Using the INA226EVM Software

After configuring the INA226EVM 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).

6.3.1 INA226 Bus Voltage, Shunt Voltage, Current, and Power Reading Bar

[Figure 6-9](#) shows that the bottom bar of the INA226 software allows the user to constantly check the status of the INA226 unit itself. These values are updated each time the *Read All Reg* button is pressed at the top of the

software. In addition to the register values stored in the part, the software also includes flags for when the part is ready to trigger another conversion and when the Alert pin is triggered.

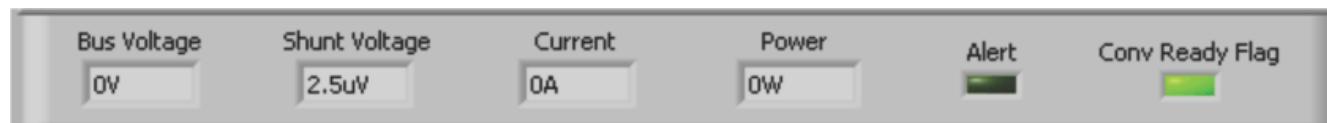


Figure 6-9. INA226 Results Bar

6.3.2 Calculation and Theory of Operation

The Calculation tab, as shown in Figure 6-10, allows the user to follow the software flow with basic calculations performed from within the device. It is important to note that the calculations are performed with the decimal values of the corresponding registers.

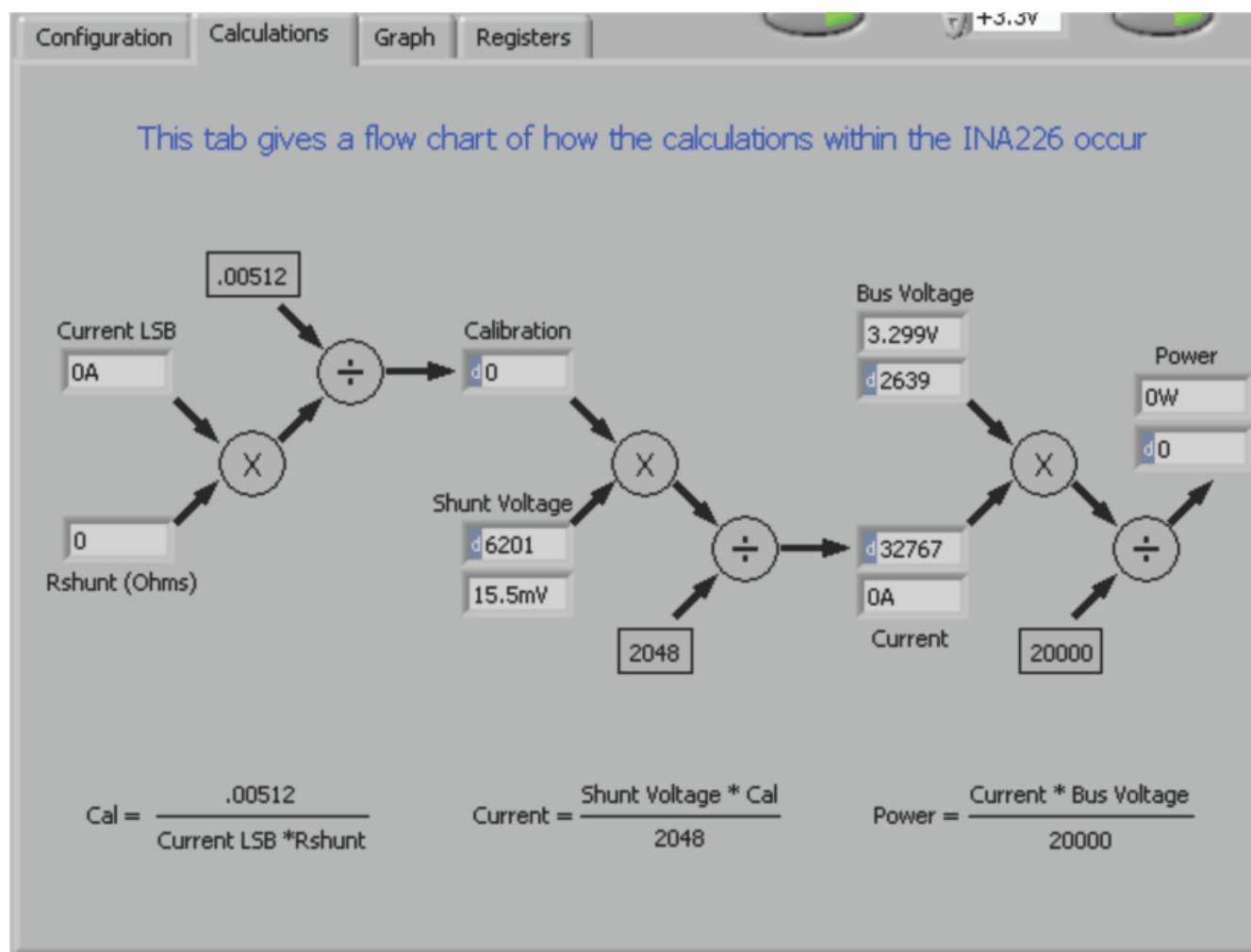


Figure 6-10. Theory of Operation Flowchart on the Calculation Tab

6.3.3 Register Tab

The Register tab contains information on the individual operation of the INA226 registers. Each register can be changed on a bit-by-bit basis to allow the user to have total control of the device beyond the general functionality of the GUI alone. Most of this functionality is displayed in the Configuration register tab, but if the user selects the appropriate register and clicks the *Help With Reg* button on the Register tab, as shown in [Figure 6-11](#), the user can diagnose the individual uses of each bit in each register.

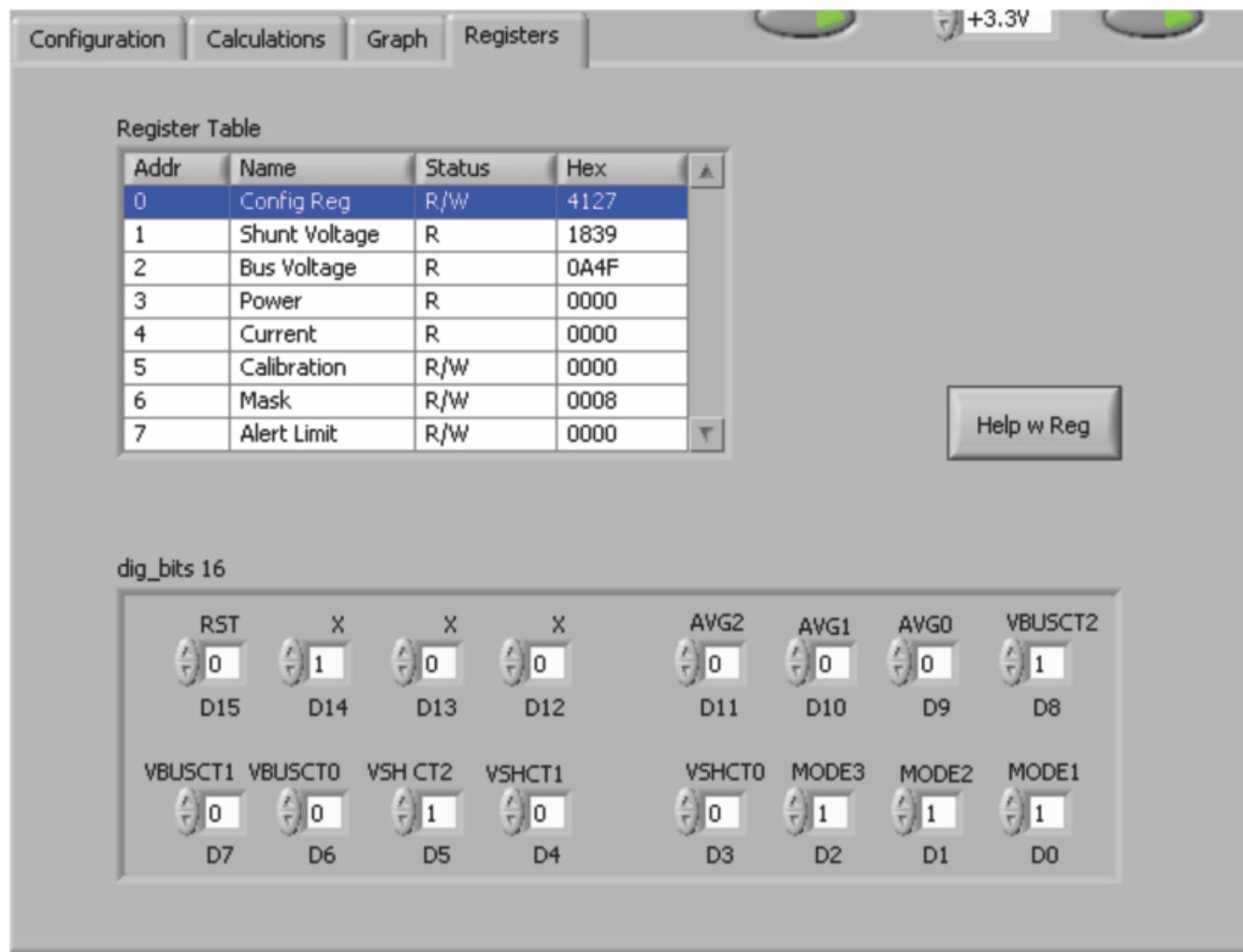


Figure 6-11. Registers Tab

6.3.4 Graph Tab

The Graph tab contains a plot window that shows the progression of data over time on the INA226. All four variables at the bottom of the EVM software (V_{BUS} , V_{SHUNT} , Current, and Power) can be plotted using the drop-down box directly above the graph. After the desired plot has been selected, toggle the *Continuously Poll Data* button above the plot to begin polling for data. If the user desires to save the data from the plot, simply select the *USB Controls* drop-down at the top of the page, then select the *Start Graph Log* option. When the *Start Graph Log* has been selected, the user is prompted to select a location for the data and to name the file.

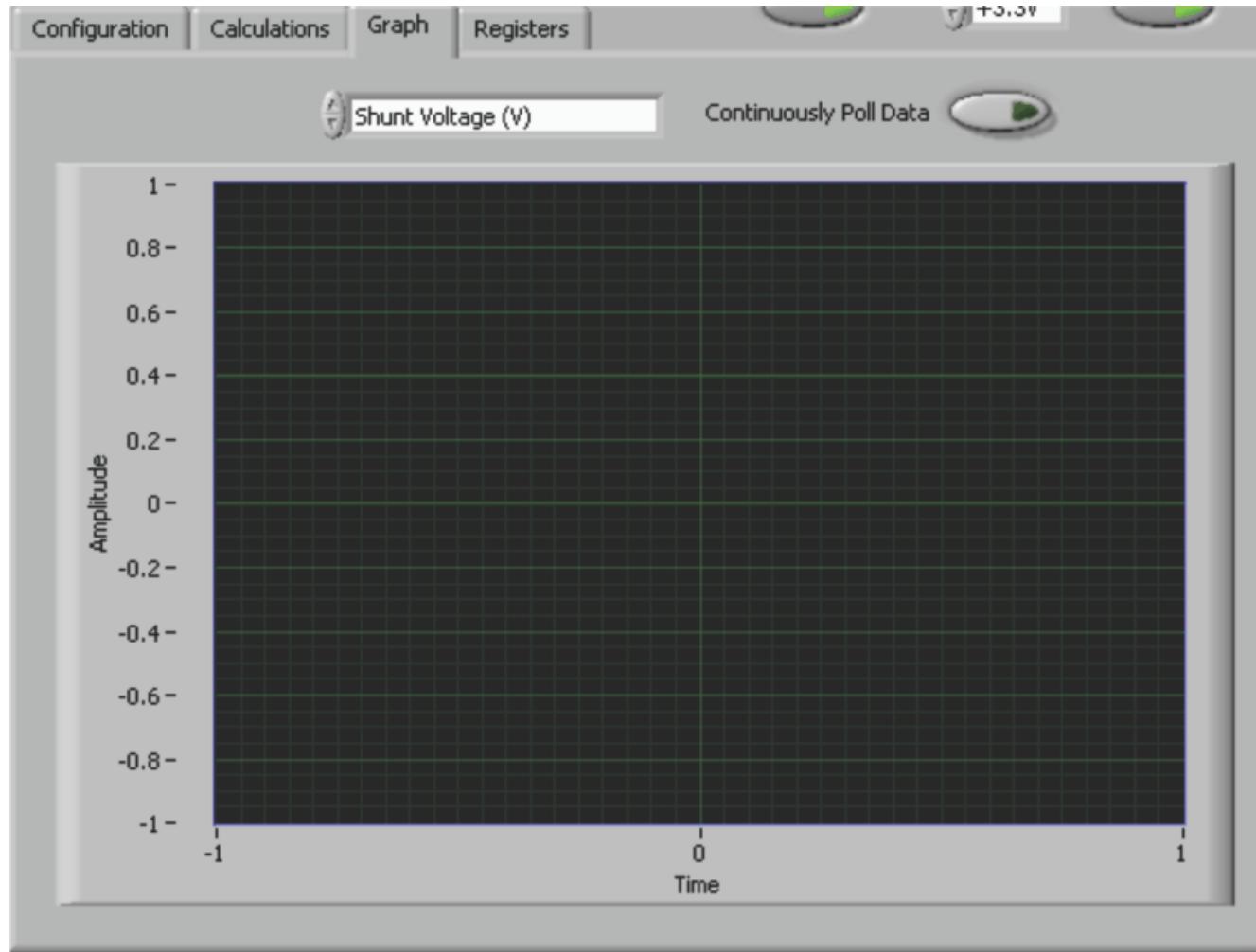


Figure 6-12. Graphing the INA226 Data

6.3.5 Auto-Write and the Supply Voltage

The INA226EVM 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 should operate at.

The software also includes an Auto-Write feature as shown in [Figure 6-13](#), which is enabled by default. This feature automatically updates the register table whenever a change is made. When this feature is enabled, the *Write All Registers* button serves little purpose and is only used as an alternative to when Auto-Write is disabled.

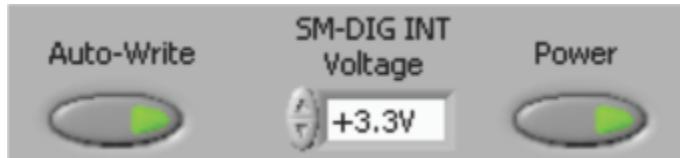


Figure 6-13. Auto-Write, Power Button, and Voltage Control

7 INA226EVM Documentation

This section contains the complete bill of materials, schematic diagram, and PCB layout for the INA226EVM.

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 INA226EVM PCBs.

7.1 Schematic

Figure 7-1 shows the schematic for the INA226EVM.

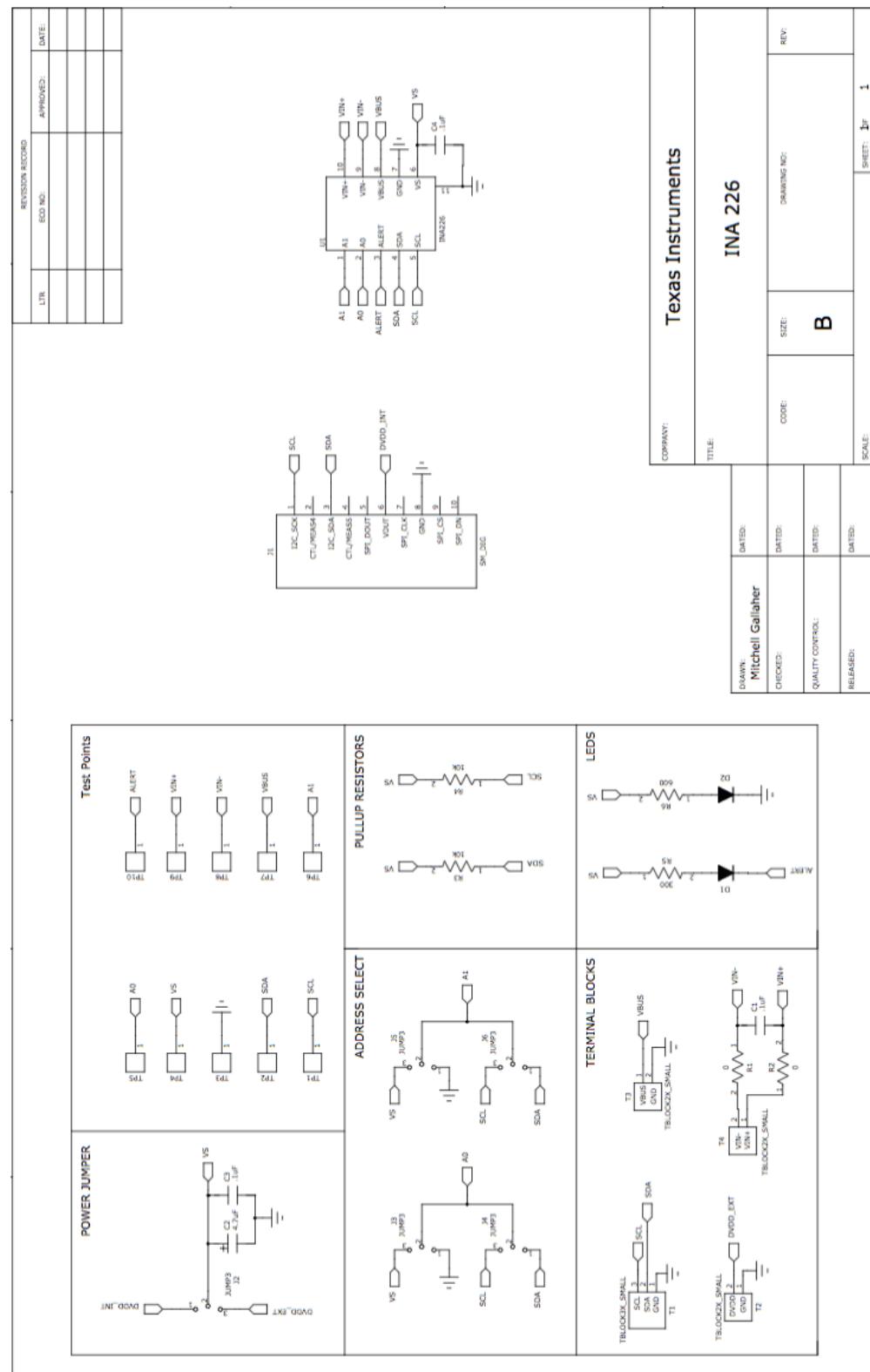


Figure 7-1. INA226EVM Schematic

7.2 PCB Layout

Figure 7-2 shows the component layout for the INA226EVM PCB.

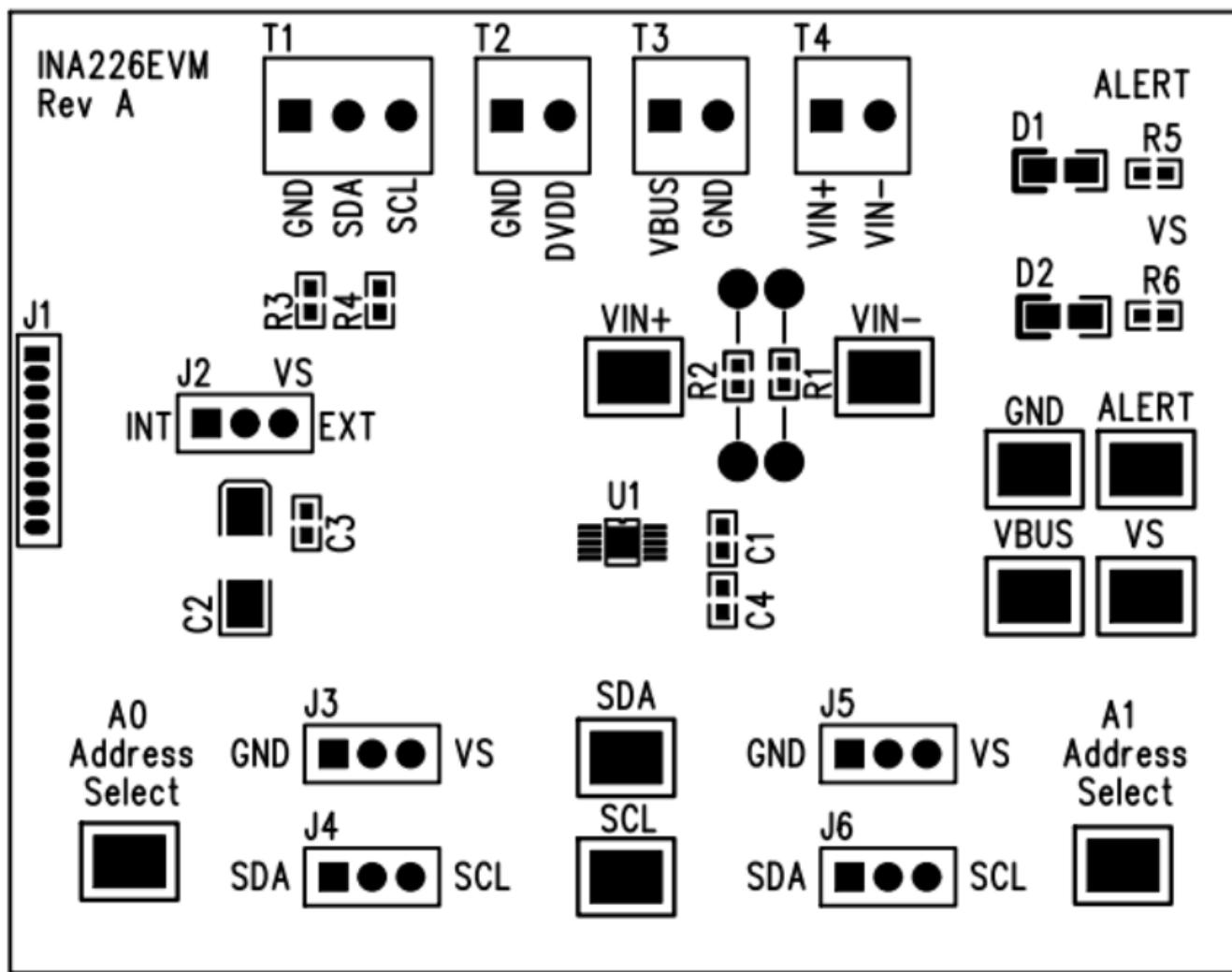


Figure 7-2. INA226EVM PCB Top Layer (Component Side)

7.3 Bill of Materials

Table 7-1 lists the bill of materials for the INA226EVM.

Table 7-1. Bill of Materials: INA226EVM

ITEM NO.	REF DES	DESCRIPTION	VENDOR/MFR	PART NUMBER
1	R5, R6	Resistor, 10 kΩ 1/10W 5% 0603 SMD	Stackpole Electronics	RMCF0603JT10K0
2	R3, R4	Resistor, 300 Ω 1/10W 5% 0603 SMD	Panasonic	ERJ-3GEYJ301V
3	R1, R2	Resistor, 0.0 Ω 1/10W 0603 SMD	Stackpole Electronics	RMCF0603ZT0R00
4	C2	Capacitor, Tantalum 4.7 μF 35V 10% SM	AVX Corp.	TAJC475K035RNJ
5	C3, C4	Capacitor, Ceramic .10 μF 25V X7R 10% 0603	TDK Corp.	C1608X7R1E104K
6	D1, D2	LED Green Wide Angle 0603 SMD	Panasonic	LNJ3W0C83RA
7	U1	INA226	Texas Instruments	
8	Jumpers All	Connector, Header 50-Position .100" SGL Gold	Samtec	TSW-150-07-G-S
9	Jumpers All	Shunt LP w/Handle 2-PoS 30AU	Tyco Electronics	881545-2
10	Test Points All	PC Test Point Compact SMT	Keystone Electronics	5016
11	T1	3-Block Terminal 3.5 mm	On Shore Technology Inc	ED555/3DS
12	T2, T3, T4	2-Block Terminal 3.5 mm	On Shore Technology Inc	ED555/2DS
13	Bumpons	Bumpon Hemisphere .50 x.14 Clear	3M	SJ-5312 (CLEAR)
14	J1	Connector, Socket RT Angle 1-Position .050	Mill-Max Manufacturing	851-93-10-20-001000

8 Revision History

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

Changes from Revision * (June 2011) to Revision A (January 2023)	Page
• Changed title to reflect the document is for the older INA226EVM hardware. See SBOU276 for documentation on the latest INA226EVM software and hardware.....	1
• Updated the numbering format for tables, figures, and cross-references throughout the document.....	1
• Changed all instances of legacy terminology to controller and target where I ² C is mentioned.....	1

STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an "EVM" or "EVMs") to the User ("User") in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.
 - 1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM ("Software") shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software
 - 1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.
- 2 *Limited Warranty and Related Remedies/Disclaimers:*
 - 2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.
 - 2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.
 - 2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

WARNING

Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.

User shall operate the Evaluation Kit within TI's recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI's recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI's instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE 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/lsts/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/lsts/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/LICENSENSORS 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, INDEMNITY 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
Copyright © 2023, Texas Instruments Incorporated

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](#) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

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

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2023, Texas Instruments Incorporated