INA220 Evaluation Module

This user's guide describes the characteristics, operation, and use of the INA220 evaluation module (EVM). It covers all pertinent areas involved to properly use this EVM board. This document includes the physical printed circuit board layout, schematic diagrams, and circuit descriptions.

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1 Overview

This document provides the information needed to set up and operate the INA220EVM evaluation module, a test platform for the INA220, a high or low side, bi-directional current/power monitor with an I²C™ interface. For a more detailed description of the INA220, please refer to the product data sheet (SBOS459) available from the Texas Instruments web site at http://www.ti.com. Additional support documents are listed in the section of this guide entitled *Related Documentation from Texas Instruments* .

The INA220EVM is an evaluation module that is used to fully evaluate the INA220 current/power monitor device. The INA220EVM consists of two printed circuit boards (PCBs). One board (the USB DIG Platform) generates the digital signals required to communicate with the INA220, which is part of the second board (INA220_Test_Board), as well as support and configuration circuitry.

Throughout this document, the abbreviation *EVM* and the term *evaluation module* are synonymous with the INA220EVM.

NOTE: Much of the information contained in this user's guide is also presented in a quick-start video (SBOU296), available for download from the INA220 product folder. It is highly recommended that you watch this video.

1.1 INA220EVM Hardware

Figure 1 shows the hardware included with the INA220EVM kit. Contact the factory if any component is missing. It is highly recommended that you check the TI web site at http://www.ti.com to verify that you have the latest versions of the related software.

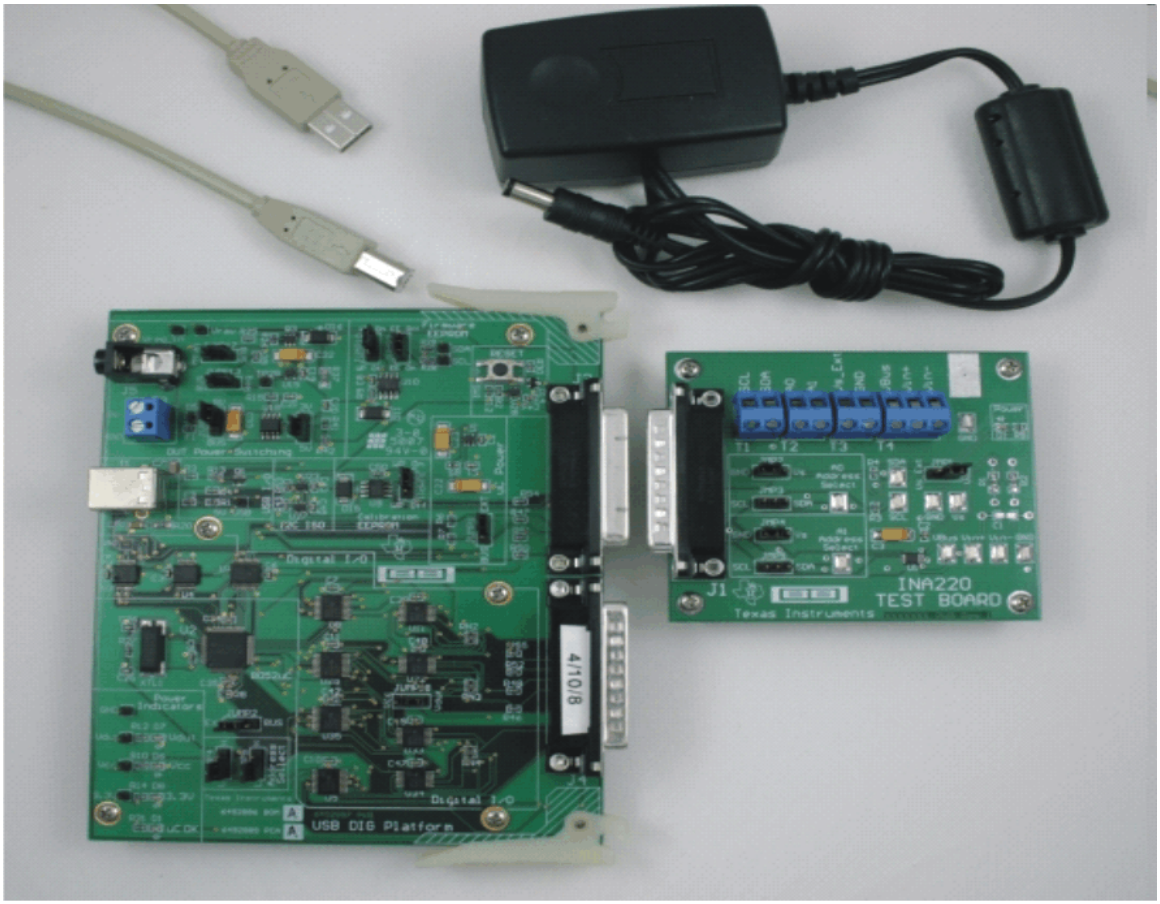

Figure 1. Hardware Included with the INA220EVM

The complete kit includes the following items:

- INA220 test PCB
- USB DIG platform PCB
- USB cable
- +6V power supply
- CD-ROM containing this user's guide, product software, and a demonstration video

1.2 Related Documentation from Texas Instruments

The following document provides information regarding Texas Instruments integrated circuits used in the assembly of the INA220EVM. This user's guide is available from the TI web site under literature number SBOU079. 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 at http://www.ti.com/, or call the Texas Instruments Literature Response Center at (800) 477-8924 or the Product Information Center at (972) 644-5580. When ordering, identify the document by both title and literature number.

Document	Literature Number
INA220 Product Data Sheet	SBOS459
USB DIG Platform Users Guide	SBOU058

1.3 Information About Cautions and Warnings

This document contains caution statements.

CAUTION

This is an example of a caution statement. A caution statement describes a situation that could potentially damage your software or equipment.

The information in a caution or a warning is provided for your protection. Please read each caution carefully.

2 System Setup

Figure 2 shows the system setup for the INA220EVM. The PC runs software that communicates with the USB DIG Platform. The USB DIG Platform generates the analog and digital signals used to communicate with the INA220_Test_Board. Connectors on the INA220_Test_Board allow the user to connect to the system under test whose power, current, and voltage will be monitored.

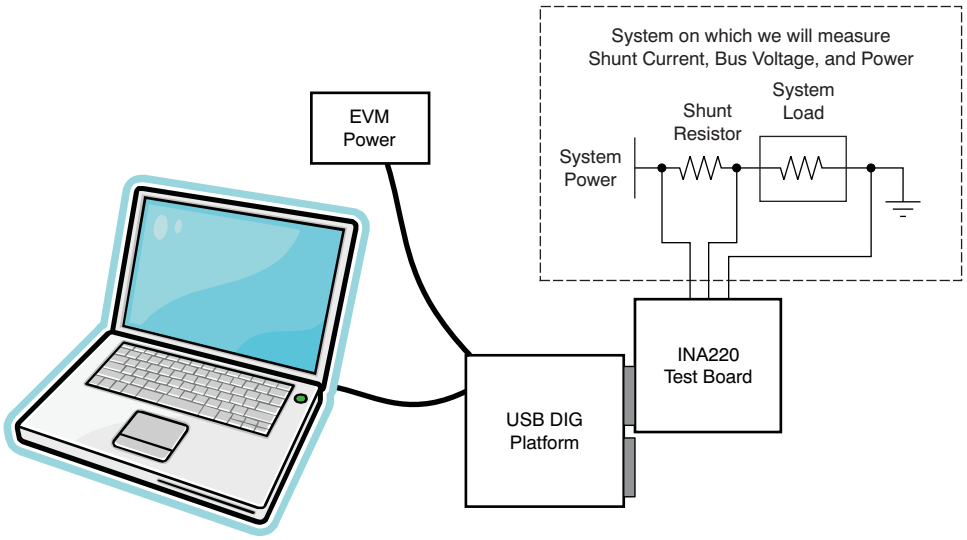

Figure 2. INA220EVM Hardware Setup

2.1 Theory of Operation for INA220_Test_Board Hardware

Figure 3 presents a block diagram of the INA220_Test_Board. The functionality of this PCB is relatively simple. It provides connections to the I^2C interface and general-purpose input/outputs (GPIO) on the USB DIG Platform board. It also provides connection points for external connections of the shunt voltage, bus voltage, and GND.

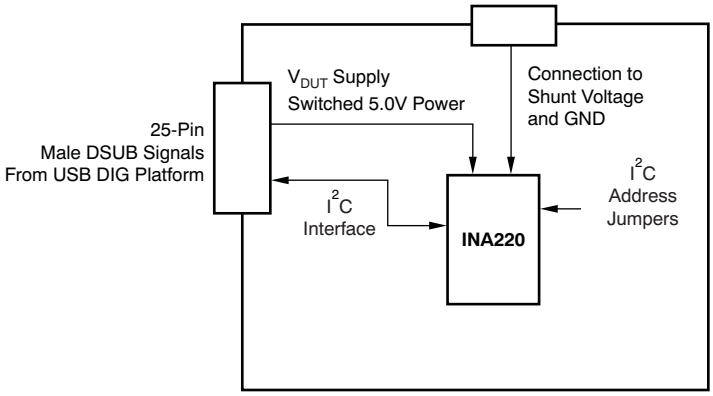

Figure 3. INA220_Test_Board Block Diagram

Figure 4 illustrates the system setup for the INA220_Test_Board schematic. D1 is an LED that indicates whether the INA220 Test Board is receiving power. Jumpers allow the selection of the power source as well as configuration of A0 and A1. Connector T4 allows the connection of the shunt and bus voltages.

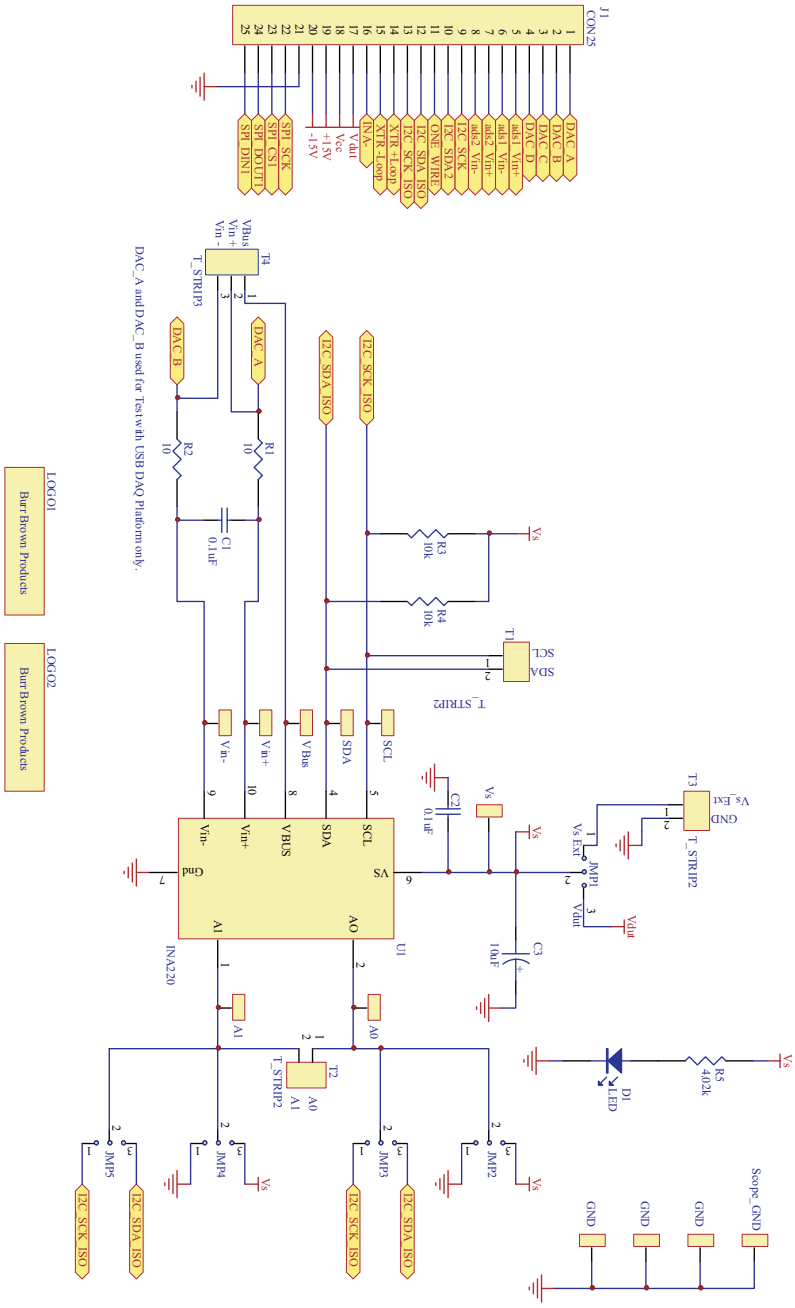

Figure 4. INA220_Test_Board Schematic

2.2 Signal Definitions of J1 (25-Pin Male DSUB)

Table 1 lists the different signals connected to J1 on the INA220_Test_Board. This table also identifies signals connected to pins on J1 that are not used on the INA220_Test_Board.

Table 1. Signal Definition of J1 (25-Pin Male DSUB) on INA220_Test_Board

J1 Pin	Signal	INA220 Pin
1	NC	No connection
2	NC	No connection
3	NC	No connection
4	NC	No connection
5	NC	No connection
6	NC	No connection
7	NC	No connection
8	NC	No connection
9	I2C_SCK	No connection
10	I2C_SDA2	No connection
11	NC	No connection
12	I2C_SCK_ISO	I^2C clock signal (SCL) channel 1; can be disconnected using a switch
13	I2C_SDA_ISO	I^2C data signal (SDA) channel 1; can be disconnected using a switch
14	NC	No connection
15	NC	No connection
16	NC	No connection
17	V_{DUT}	Switched 3V or 5V power. Note that when power is switched off, the digital I/O is also switched off.
18	V_{CC}	No connection
19	NC	No connection
20	NC	No connection
21	GND	Common or ground connection for power
22	SPI_SCK	No connection
23	SPI_CS1	No connection
24	SPI_DOUT	No connection
25	SPI_DIN1	No connection

2.3 Theory of Operation For USB_DIG_Platform

Figure 5 shows the block diagram for the 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 (available for download at www.ti.com). The block diagram shown in Figure 5 gives a brief overview of the platform. The primary control device on the USB DIG Platform is the TUSB3210.

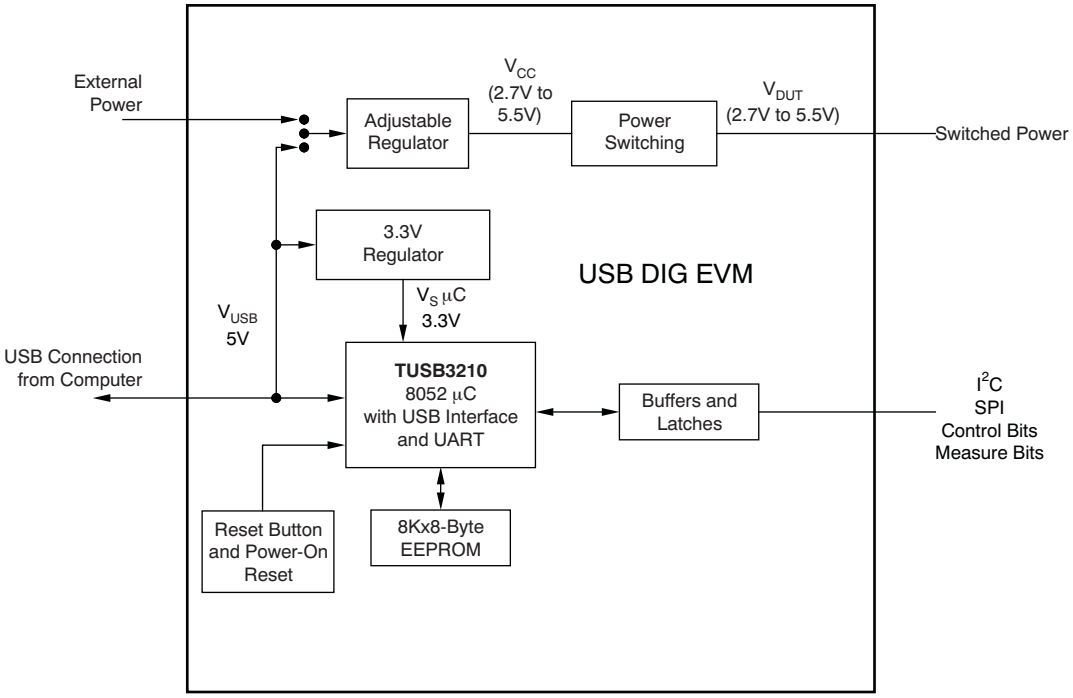

Figure 5. USB_DIG_Platform Theory of Operation

3 INA220EVM Hardware Setup

The INA220EVM hardware setup 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.

3.1 Electrostatic Discharge Warning

Many of the components on the INA220EVM 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.

CAUTION

Failure to observe ESD handling procedures may result in damage to EVM components.

3.2 Typical Hardware Connections

The INA220EVM hardware setup involves connecting the two PCBs of the EVM together, applying power, and connecting an external shunt and load. The external connections may be the real-world system that the INA220 will be incorporated into. Figure 6 shows the typical hardware connections.

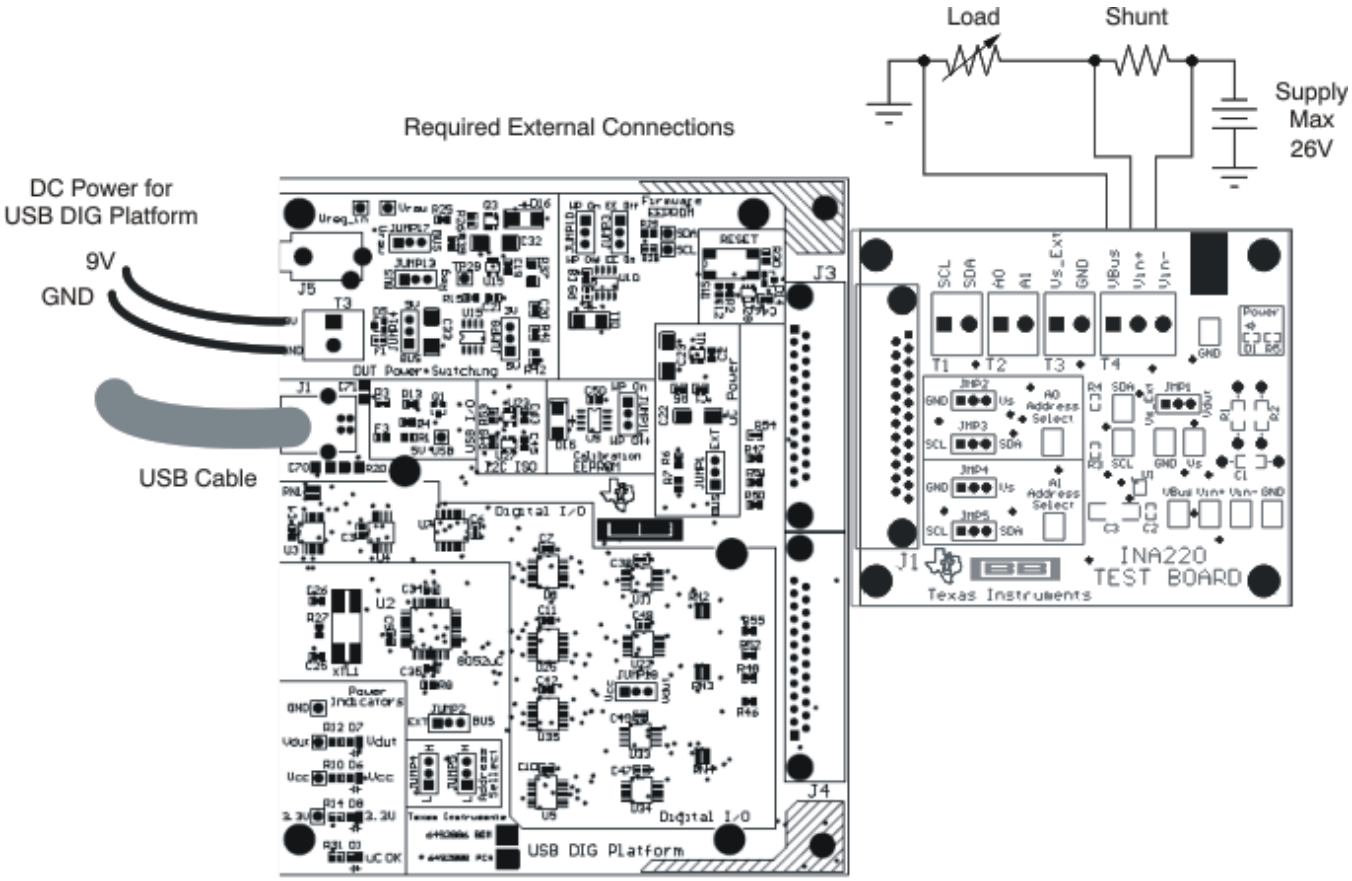

Figure 6. Typical Hardware Connections

3.3 Connecting the Hardware

To connect the two PCBs of the INA220EVM together, gently push on both sides of the D-SUB connectors (as shown in Figure 7). Make sure that the two connectors are completely pushed together; loose connections may cause intermittent operation.

3.4 Connecting Power

After the two parts of the INA220 EVM are connected, as Figure 7 illustrates, connect the power to the EVM. Always connect power before connecting the USB cable. If you connect the USB cable before connecting the power, the computer will attempt to communicate with an unpowered device that will not be able to respond.

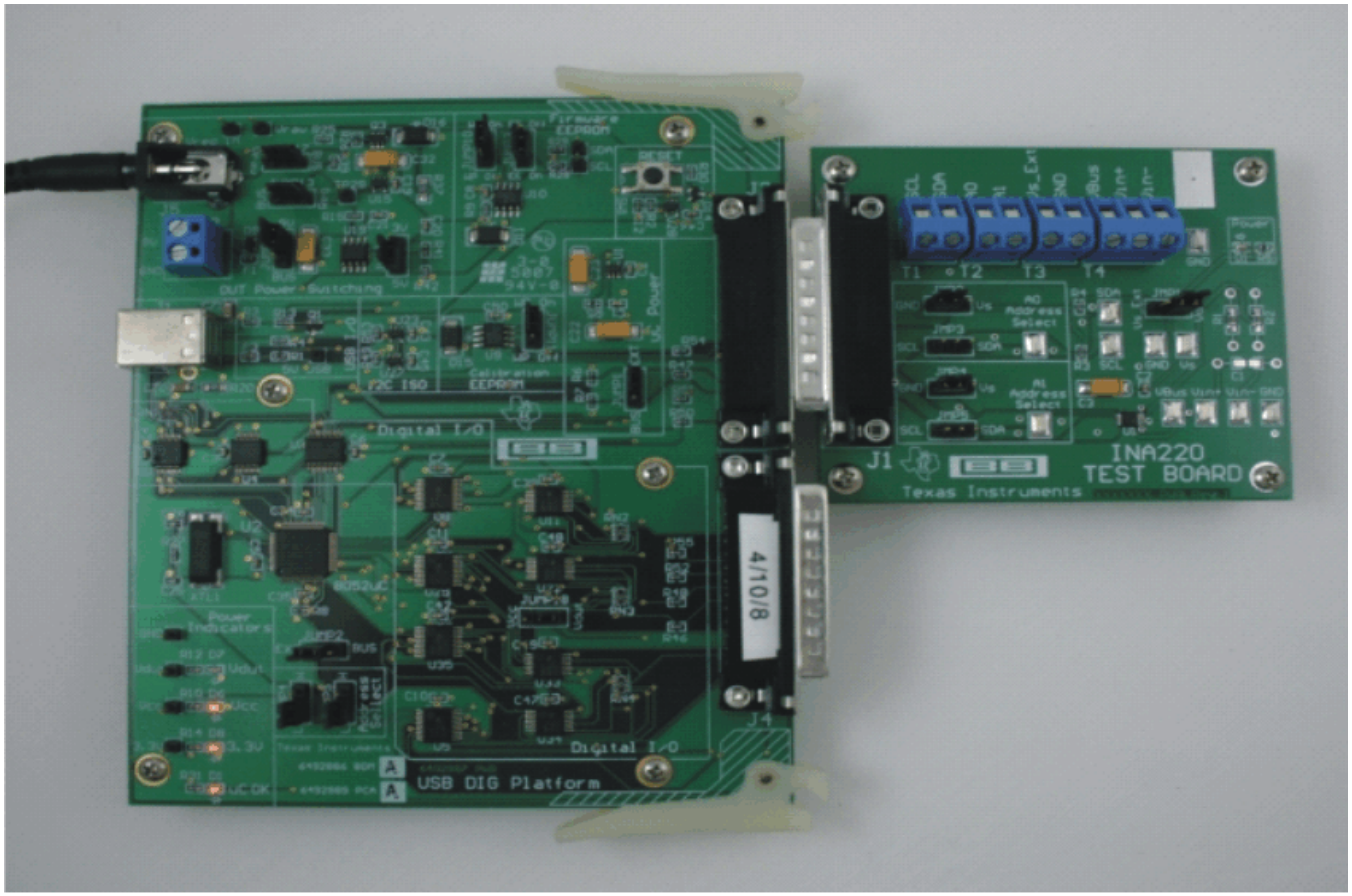

Figure 7. Connecting Power to the EVM

3.5 Connecting the USB Cable to the INA220EVM

Figure 8 shows the typical response to connecting the USB DIG platform to a PC USB port for the first time. Note that the EVM must be powered on before connecting the USB cable. Typically, the computer will respond with a *Found New Hardware, USB Device* pop-up. The pop-up typically changes to *Found New Hardware, USB Human Interface Device*. This pop-up indicates that the device is ready to be used. The USB DIG platform uses the *Human Interface Device Drivers* that are part of the Microsoft® Windows® operating system.

In some cases, the Windows *Add Hardware Wizard* will pop up. If this prompt occurs, allow the system device manager to install the *Human Interface Drivers* by clicking **Yes** when requested to install drivers.

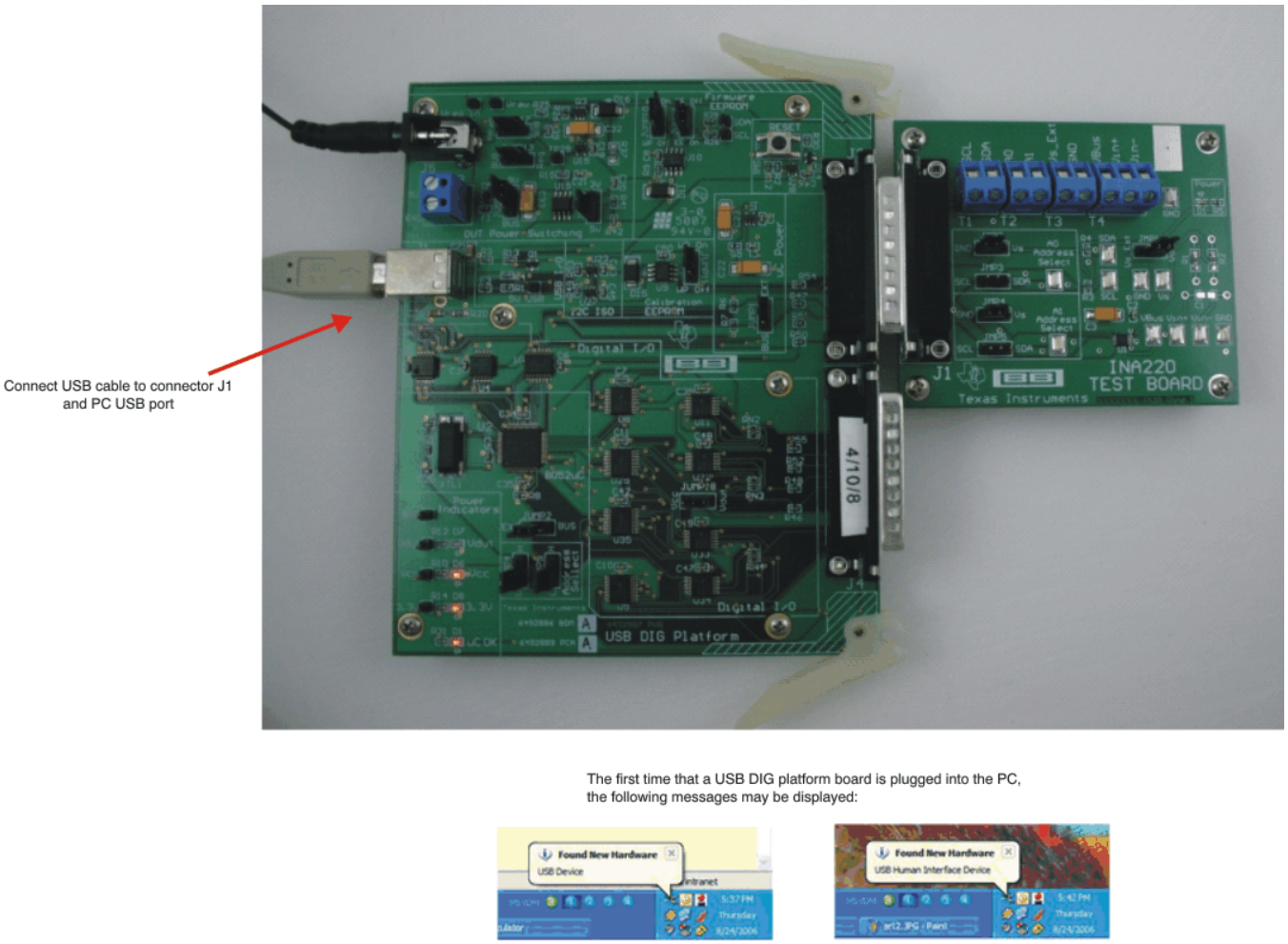

Figure 8. Connecting the USB Cable

3.6 INA220 Jumper Settings

Figure 9 shows the default jumpers configuration for the INA220EVM. In general, the jumper settings of the USB DIG Platform will not need to be changed. You may want to change some of the jumpers on the INA220_Test_Board to match your specific configuration. For instance, you may wish to set a specific I^2C address.

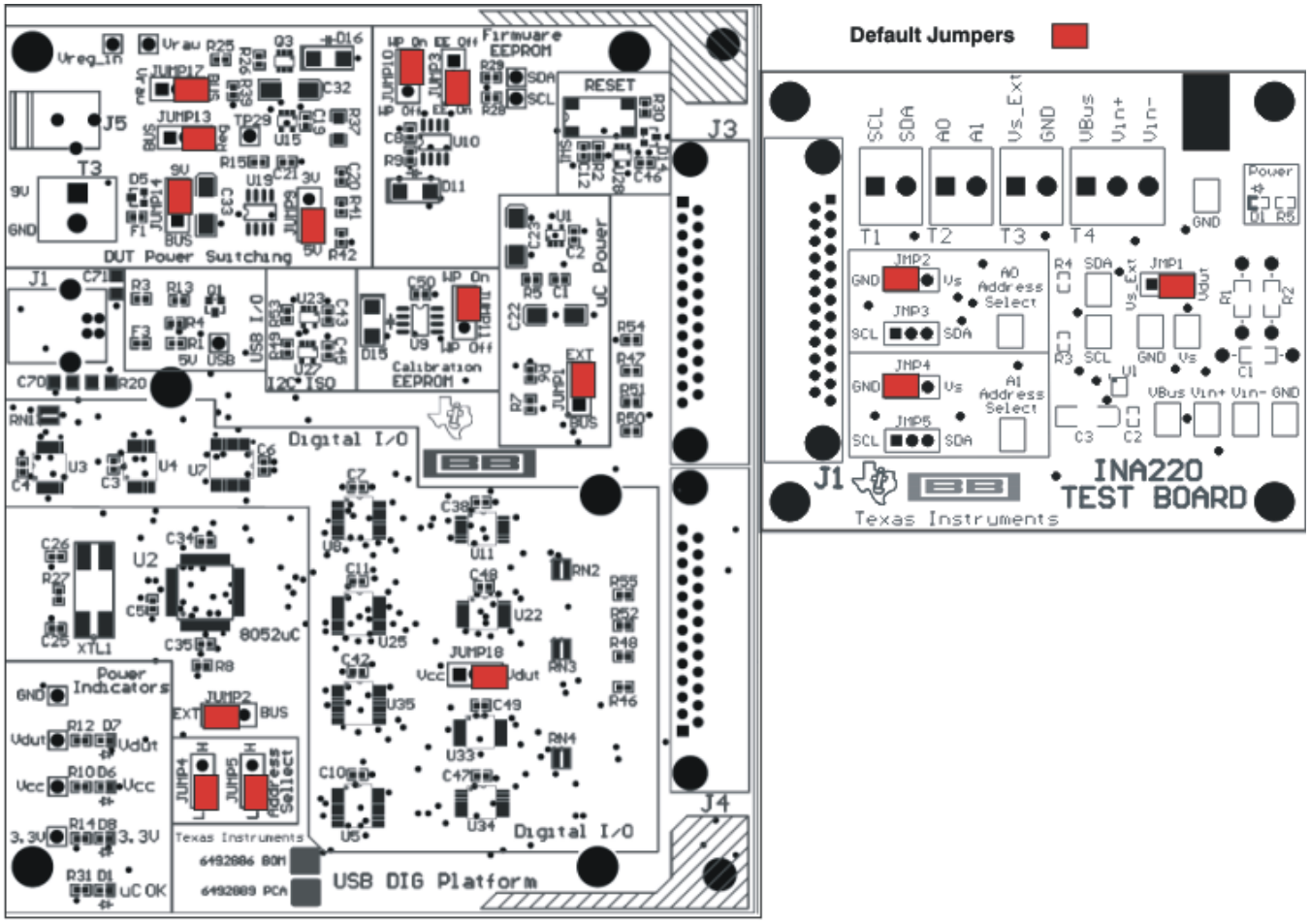

Figure 9. INA220EVM Default Jumper Settings

Table 2 explains the function of the jumpers on the INA220_Test_Board.

Table 2. INA220_Test_Board Jumper Functions

Jumper	Default	Purpose
JMP1	V_{DUT}	This jumper determines the source for the INA220 power supply. In the *Vdut* position, the USB DIG board supplies the power to the INA220. In the *Vs_Ext* position, an external supply connected to the INA220 T3 terminal supplies power.
JMP2, JMP3	JMP2 (GND)	A0 address input selection. This jumper determines which signal is connected to the A0 pin of the INA220.
JMP4, JMP5	JMP4 (GND)	A1 address input selection. This jumper determines which signal is connected to the A1 pin of the INA220.

Table 3 summarizes the function of the USB DIG platform jumpers. For most applications, the default jumper position should be used. Table 4 and Table 5 describe the options for the power-supply configuration. For example, the logic power supply can be changed from the default of 5V to 3V. A separate document (SBOU058) gives details regarding the operation and design of the USB DIG platform.

Table 3. USB DIG Platform Jumper Settings

Jumper	Default	Purpose
JUMP1	EXT	This jumper selects external power or bus power. External power is applied on J5 or T3 ($9V_{DC}$). Bus power is 5V from the USB. External power is typically used because the USB power is noisy.
JUMP2	EXT	Same as JUMP1.
JUMP3	EE ON	This jumper determines where the TUSB3210 will load the USB DIG Platform firmware upon power-up or reset. The *EE Off* position is used for development for development or firmware updates.
JUMP4, JUMP5	L, L	This jumper sets the address for the USB board. The only reason to change from the default setting is if multiple boards are being used.
JUMP9	5V	This selects the voltage of the device under test supply (V_{DUT} = 5V or 3V). This jumper is typically the only jumper that is changed for most applications.
JUMP10	WP ON	This write-protects the firmware EEPROM.
JUMP11	WP ON	This write-protects the calibration EEPROM.
JUMP13	Reg	Uses the regulator output to generate the V_{DUT} supply. The USB can be used as the V_{DUT} supply.
JUMP14	9V	Uses the external power (9V as apposed to the bus)
JUMP17	BUS	While in the BUS position, V_{DUT} operation is normal. While in the V_{RAW} position, the V_{DUT} supply is connected to an external source. This flexibility allows for any value of V_{DUT} between 3V and 5V. **CAUTION** When JUMP17 is in the V_{RAW} position, adjusting the V_{DUT} voltage beyond the 3V to 5V range will damage the EVM.
JUMP18	V_{DUT}	Connects the pull-up on the GPIO to the V_{DUT} supply or the V_{CC} supply.

Table 4. Power-Supply Jumper Configuration #1

Mode	Jumper	Comment
External Power—5V (default jumper settings)	JUMP17 = BUS (not used) JUMP13 = REG JUMP14 = 9V JUMP1 = EXT JUMP2 = EXT JUMP6 = 5V JUMP7 = REF	In this mode, all power is supplied to the EVM via J5 or T3. The external supply must be between 5.8V and 10.4V for proper operation. All digital I/Os are regulated to 5V using U19 (REG101).
External Power—3V (typical jumper settings)	JUMP17 = BUS (not used) JUMP13 = REG JUMP14 = 9V JUMP1 = EXT JUMP2 = EXT JUMP6 = 3V JUMP7 = REF	In this mode, all power is supplied to the EVM via J5 or T3. The external supply must be between 5.8V and 10.4V for proper operation. All digital I/Os are regulated to 3V using U19 (REG101).
External Power—Variable Supply	JUMP17 = Vraw JUMP13 = BUS JUMP14 = 9V (not used) JUMP1 = EXT JUMP2 = EXT JUMP6 = 5V (not used) JUMP7 = REG (ratiometric mode)	In this mode, all the digital I/Os are referenced to the supply that is attached to either J5 or T3. **CAUTION** It is absolutely critical that the supply voltage does not exceed 5.5V in this mode. The supply is directly applied to devices with 5.5V absolute maximum ratings. This mode of operation is useful when a device supply other then 3.0V or 5.0V is required.

Table 5. Power-Supply Jumper Configuration #2

Mode	Jumper	Comment
Bus Power—5V	JUMP17 = BUS JUMP13 = BUS JUMP14 = 9V (not used) JUMP1 = BUS JUMP2 = BUS JUMP6 = 5V (not used) JUMP7 = REG (ratiometric mode, 5V supply)	In this mode, the USB bus completely powers the EVM. The USB bus is regulated by the master (computer) to be 5V. This mode relies upon external regulation. This mode is recommended only when an external 9V supply is not available. If an external 9V supply is available, use either *External Power 5V* mode or *External Power 3V* mode.
Bus Power—3V	JUMP17 = BUS (not used) JUMP13 = REG JUMP14 = BUS JUMP1 = BUS JUMP2 = BUS JUMP6 = 3V JUMP7 = REG (ratiometric mode, 5V supply)	In this mode, the USB bus completely powers the EVM. The regulator (U19, REG101) is used to generate a 3V supply for all digital I/O.

3.7 Connecting External Power to the INA220EVM

The INA220 power supply (V_S) operates over the range of 3V to 5.5V (see the INA220 product data sheet). The default jumper position provides 5V to the INA220 from the USB-DIG-Platform. The power from the USB-DIG-Platform can be changed to 3V using JUMP9.

Another option is to connect power to the INA220 power supply (V_S) using an external power supply. In this case, connect power to the T3 terminal block and set JMP1 to the Vs_EXT positon. The INA220 power supply (V_S) operates over the range of 3V to 5.5V, so be careful to not exceed this range.

3.8 Connecting External Signals to the INA220EVM

The INA220 shunt and bus voltages are applied via terminal block T4. The T4 terminal block is a direct connection to V_{IN+} and V_{IN-} of the INA220. The bus voltage is monitored on V_{BUS} (26V max). The shunt voltage is the difference between V_{IN-} and V_{IN+} (320mV max). Refer to the INA220 data sheet for more details

4 INA220 Software Overview

This section discusses how to install and use the INA220 software.

4.1 INA220EVM Software Install

Follow these steps to install the INA220EVM software:

Step 1. Software can be downloaded from the INA220EVM web page, or from the disk included with the INA220EVM, which contains a folder called *Install_software*.

Step 2. Find the file called *setup.exe*. Double-click the file to start the installation process.

Step 3. Follow the on-screen prompts to install the software.

Step 4. To remove the application, use the Windows Control Panel utility, *Add/Remove Software*.

The INA220 Quick-Start Video (included with the kit, or available for download in the INA220 product folder) gives more detail regarding the initialization of the software.

4.2 Starting the INA220EVM Software

The INA220 software can be operated through the Windows *Start* menu. From Start, select *All Programs*; then select the *INA220EVM* program. Figure 10 shows how the software should appear if the EVM is functioning properly.

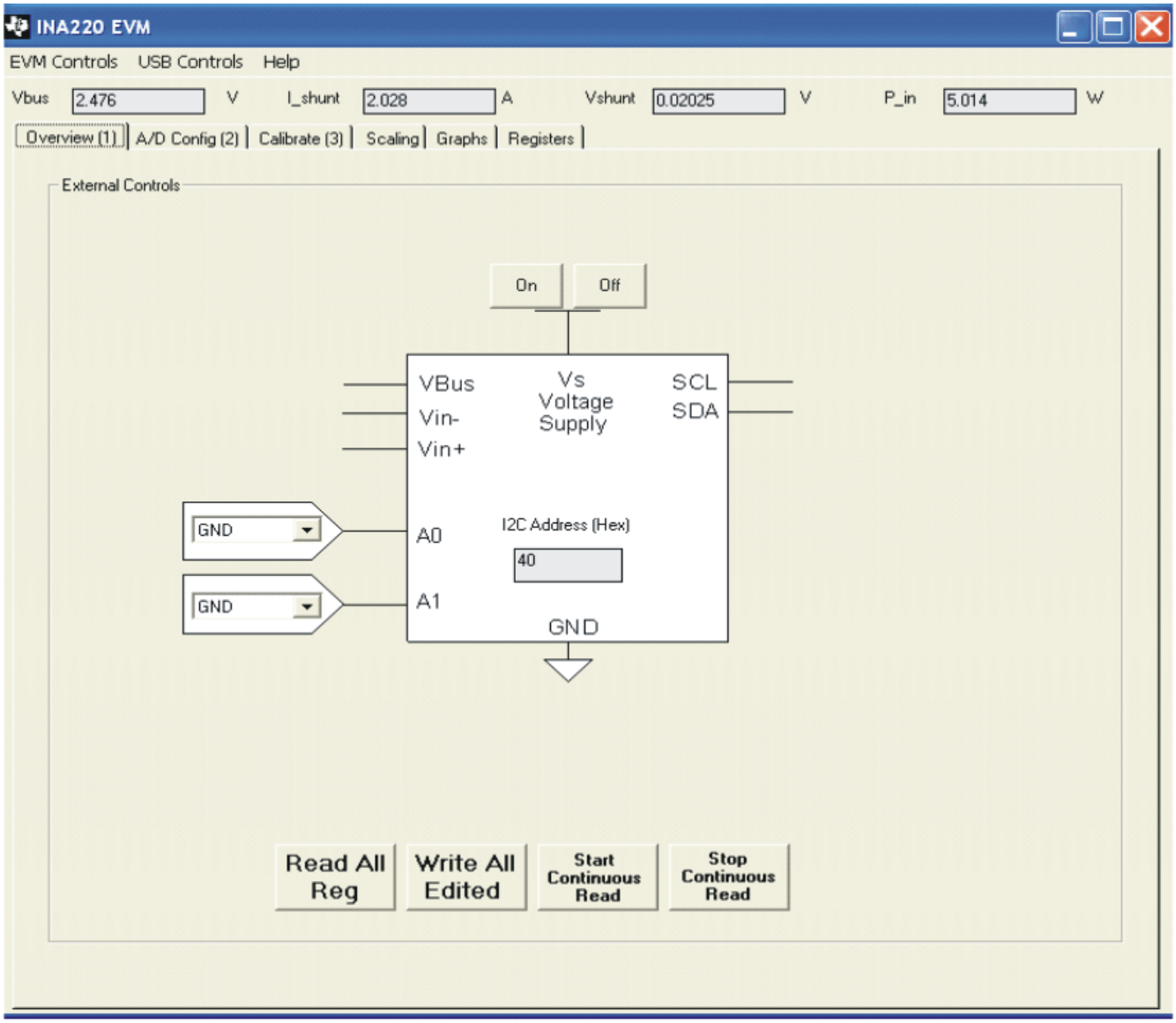

Figure 10. INA220EVM Software—Functioning Properly

Figure 11 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. This error can also occur if you connect the USB cable before the USB DIG Platform 9V power source. A second possible reason for this problem is that there may be a problem with your computer USB Human Interface Device Driver. Make sure that when you plug the in the USB cable, the computer recognizes the device. If the sound is on, you will hear the distinctive sound that you expect when a USB device is properly connected to the PC.

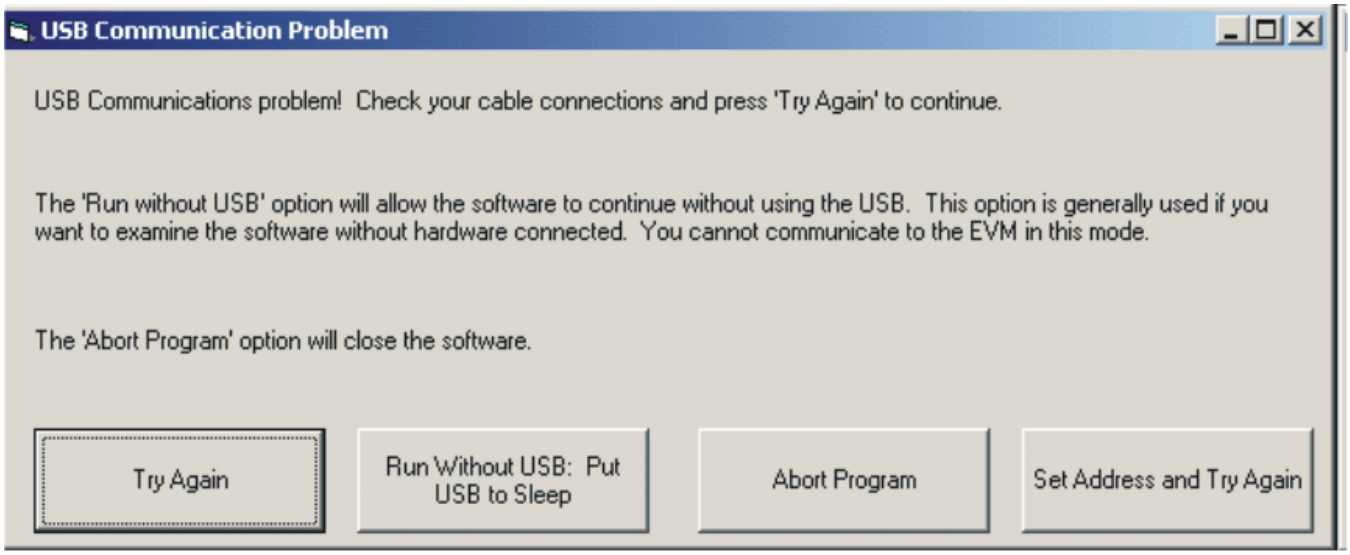

Figure 11. INA220EVM Software—No Communication with the USB DIG Platform

Figure 12 shows an error that occurs if the INA220_Test_Board is not communicating with the USB DIG Platform. If you see this error, check the connectors between the two boards; make sure the 25-pin connectors are completely pushed together. Another possible cause of this issue it that the INA220_Test_Board jumpers are set in the wrong position.

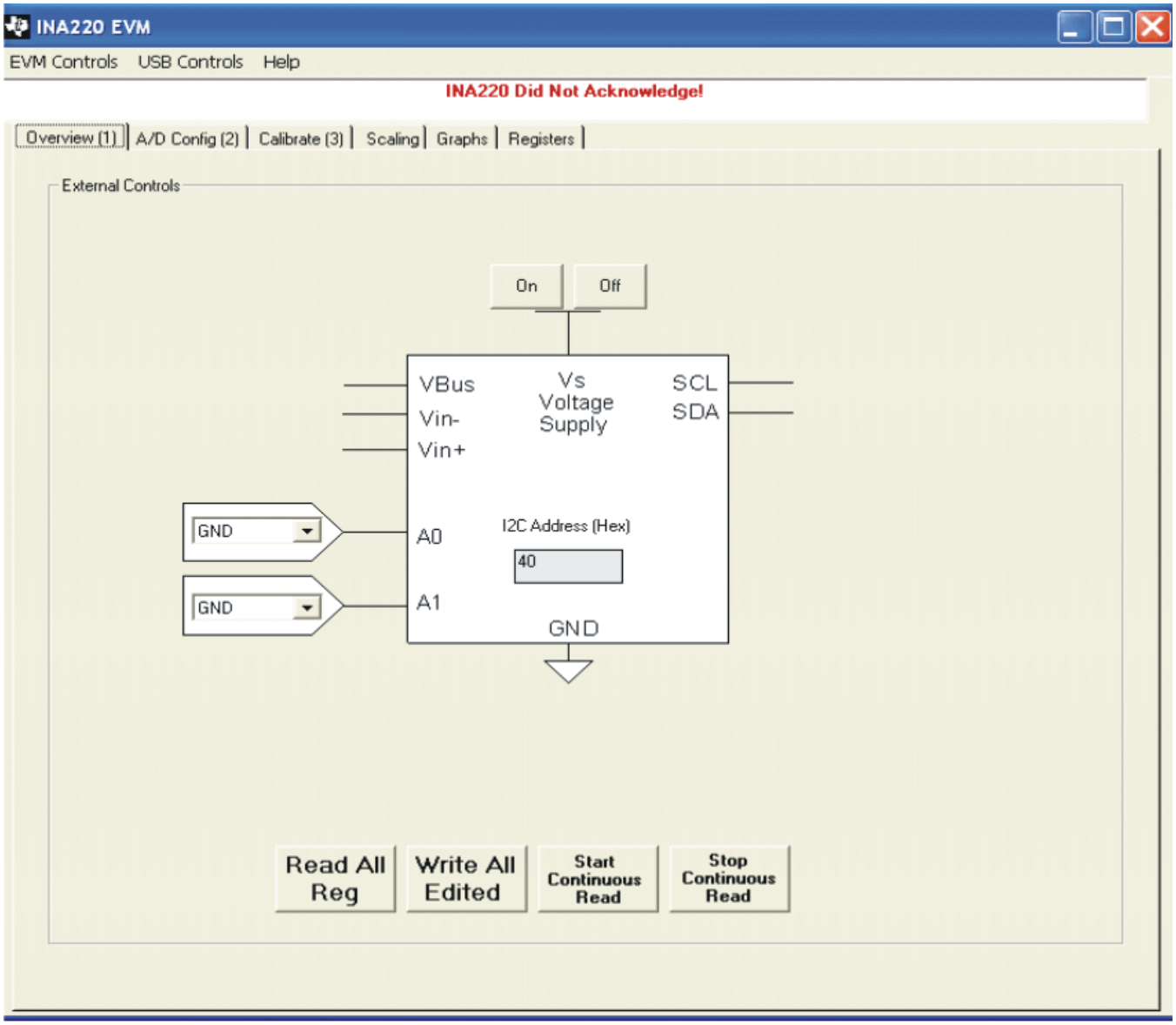

Figure 12. INA220EVM Software—No Communication with the USB DIG Platform and INA220

4.3 Using the INA220 Software

The INA220EVM software has six different tabs that allow you to access different features of the INA220. The first four tabs are designed so that you can completely configure the device by stepping through the tabs in order. Each of the tabs is intended to have an intuitive graphical interface that helps you gain a better understanding of the device.

4.3.1 Overview Tab

This tab has the following controls:

- Turn the power supply on and off
- Set the I^2C address

4.3.2 Config Tab

This tab has the following controls:

- Shunt voltage attenuator range (smallest range: 40mV; largest range: 320mV)
- Shunt voltage configuration: resolution and number of averages. Note that increasing the number of averages decreases the noise but slows down the conversion rate.
- Bus voltage attenuator range (16V and 32V): Note that the maximum bus voltage for the INA220 is 26V. Thus, the 32V range cannot be fully used.
- Bus voltage configuration: Resolution and number of averages. Note that increasing the number of averages decreases noise but slows down the conversion rate.
- A/D converter mode: This control determines how the converters work. The most commonly used modes are Shunt and Bus continuous conversion mode. This mode causes both converters to run continuously.

More details on these options are explained in the product data sheet.

4.3.3 Calibrate Tab

The calibration tab allows users to enter some information regarding the INA220 configuration in a given application. This information is used to compute the Full-Scale Cal Register. The Full-Scale Cal Register converts the shunt voltage to a current value. The detailed mathematics behind this calibration feature is given in the INA220 data sheet. Also, this feature is explained in a step-by-step manner in the video.

4.3.4 Scaling Tab

This tab allows you to see how the mathematical operations work in the INA220. Specifically, this tab shows how the current and power values are computed using the full-scale calibration register.

4.3.5 Graph Tab

The graph tab will display bus voltage, shunt current, and power versus time when the software is in continuous convert mode.

4.3.6 Registers Tab

This tab allows you to read and edit all the registers in the INA220. All the previous tabs affect the register listing. For example, changing the A/D configuration on Tab 2 will affect Register 0 in the register list. It is also true that changing register 0 updates the A/D configuration on Tab 2. Thus, the graphical representation and register representation affect each other.

4.3.7 EVM Controls Pull-Down Menu

The INA220 Configuration (that is, the register settings) can be saved or loaded using the *EVM Controls* drop-down menu, as Figure 13 shows. The file that the configuration is saved into is a simple text file and can be viewed with any text editor.

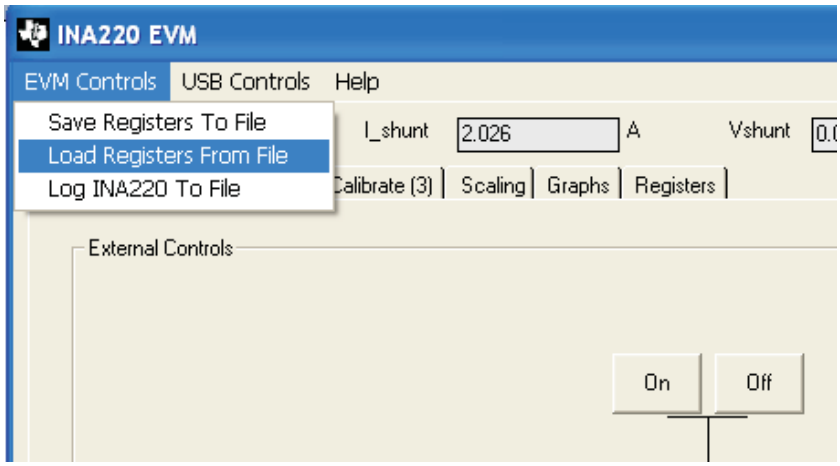

Figure 13. EVM Controls Drop-Down Menu

4.3.8 Software Revision

The *Help...About* feature can be used to check the current software revision, as Figure 14 illustrates. This document is based on revision 1.0.35.

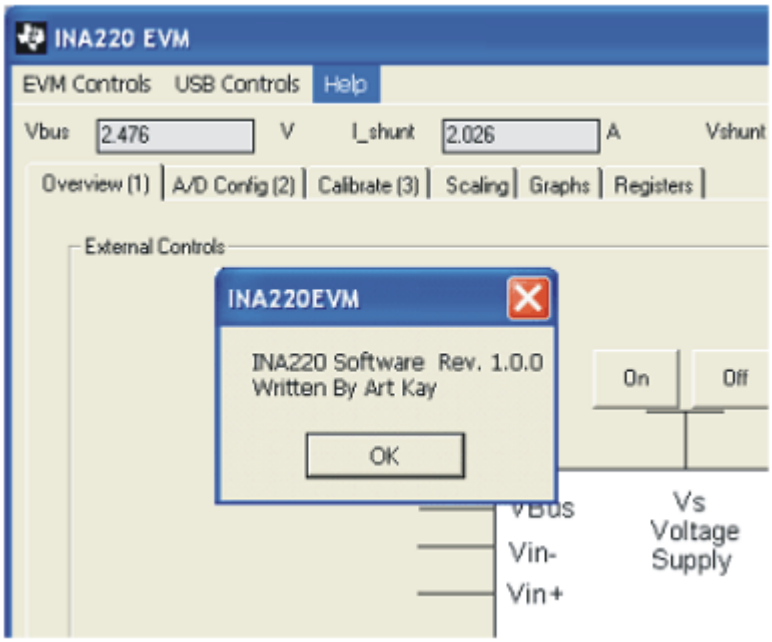

Figure 14. Current Software Revision

5 Bill of Materials

Table 6 shows the parts list for the INA220_Test_Board.

Table 6. INA220_Test_Board Parts List

No.	Quantity	Value	Ref Des	Description	Vendor	Part Number
1	1	4.02k	R5	Resistor, 4.02k, 603	ROHM	MCR03EZPFX4021
2	2	10k	R3, R4	Resistor, 10k, 603	Yageo Corporation	RC0603FR-0710KL
3	2	0Ω	R1, R2	RES 0.0 OHM 1/8W 5% 0805 SMD	Panasonic - ECG	ERJ-6GEY0R00V
4	1	10μF	C3	Capacitor, Tantalum, 10uF, 16V, 6032	Kemet	T491C106M016AT
5	1	0.1μF	C2	CAP .10UF 25V CERAMIC Y5V 0603	Kemet	C0603C104M3VACTU
6	0	Optional/Not Installed	C1	0603-1206 Capacitor	—	—
7	1	LED	D1	Diode, LED, Ultra Bright Diff, 603	Panasonic	LNJ208R8ARA
8	1	DSUB25M	J1	CONN D-SUB PLUG R/A 25POS 30GOLD (With Threaded Inserts and Board locks)	AMP/Tyco Electronics	5747842-4
9	3	N/A	N/A	SHUNT LP W/HANDLE 2 POS 30AU	AMP/Tyco Electronics	881545-2
10	5	JUMP3 cut to size	JMP1-JMP5	CONN HEADER 32POS .100" SGL GOLD (4 per Strip)	Samtec	TSW-132-07-G-S
11	4	Standoff	None	Standoffs, Hex , 4-40 Threaded, 0.500" length, 0.250" OD, Aluminum Iridite Finish	Keystone	2203
12	4	Screw	None	SCREW MACHINE PHIL 4-40X1/4 SS	Building Fasteners	PMSSS 440 0025 PH
13	11	Test point	N/A	5018 SMD Test Point	Keystone	5018
14	3	2-pin connector	T1, T2, T3	2-Position Terminal Strip, Cage Clamp, 45°, 15A, Dove-tailed	On-Shore Technology Inc	ED300/2
15	1	3-pin connector	T4	3-Position Terminal Strip, Cage Clamp, 45°, 15A, Dove-tailed	On-Shore Technology Inc	ED300/3

Revision History

Changes from Original (July, 2009) to A Revision	Page
• Revised Table 3	12
• Added Table 4 and Table 5	13
• Added Section 3.7	14
• Added Section 3.8	14

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

Evaluation Board/Kit Important Notice

Texas Instruments (TI) provides the enclosed product(s) under the following conditions:

This evaluation board/kit is intended for use for **ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY** and is not considered by TI to be a finished end-product fit for general consumer use. Persons handling the product(s) must have electronics training and observe good engineering practice standards. As such, the goods being provided are not intended to be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including product safety and environmental measures typically found in end products that incorporate such semiconductor components or circuit boards. This evaluation board/kit does not fall within the scope of the European Union directives regarding electromagnetic compatibility, restricted substances (RoHS), recycling (WEEE), FCC, CE or UL, and therefore may not meet the technical requirements of these directives or other related directives.

Should this evaluation board/kit not meet the specifications indicated in the User's Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

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EVM Warnings and Restrictions

It is important to operate this EVM within the input voltage range of 5.7V to 9V and the output voltage range of 0V to 5V.

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's 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, some circuit components may have case temperatures greater than +25°C. The EVM is designed to operate properly with certain components above +25°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

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