Description

The EZShunt™ Digital Power Monitor evaluation modules demonstrate the performance and features of the INA780, INA781, INA740, INA741, INA745, and INA746. Paired with the Sensor Control Board (SCB), the graphical user interface (GUI composer) provides the device power and digital setup and evaluation with real-time data capture. The EVM has I2C inputs.

Features

- GUI support to read and write device registers as well as view and save results data
- EVM detached from SCB for custom use cases
- Multiple EVM support with single SCB/GUI
- Conveniently powered from a common micro-USB connector through the SCB
Evaluation Module Overview

1.1 Introduction

This user’s guide describes the characteristics, operation, and use of the EZShunt™ digital power monitor EVMs (evaluation modules), specifically EVMs for the INA740, INA741, INA745, INA746, INA780, and INA781. Throughout this document, the terms evaluation board, evaluation module and EVM are synonymous with the INA740AEVM, INA740BEVM, INA741EVM, INA745AEVM, INA745BEVM, INA746EVM, INA780AEVM, INA780BEVM, and INA781EVM. This document includes a schematic, reference printed-circuit board (PCB) layouts, and a complete bill of materials (BOM).

The EZShunt digital power monitors integrate 20-bit (INA741, INA746, and INA781) and 16-bit (INA740, INA745, and INA780) delta-sigma ADCs that measure an internal current sensing element capable of varying continuous current at common-mode voltages, as high as +85 V, that are independent of the supply. These devices can automatically calculate and report current, bus voltage, die temperature, power, energy, and charge accumulation. These devices also have built-in diagnostic capabilities to indicate system health accessible through a digital output pin, ALERT. These devices operate from a single supply of 2.7 V to 5.5 V, drawing less than 1 mA of current during operation over temperature, and < 5-µA current during shutdown. Users can interface the output with a multitude of microcontrollers (MCUs) in a standard I2C interface.

1.2 Kit Contents

Table 1-1 lists the contents of the EVM kit. Contact Texas Instruments Customer Support if any component is missing.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QUANTITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>INA740AEVM, INA740BEVM, INA741EVM, INA745AEVM, INA745BEVM, INA741EVM, INA780AEVM, INA780BEVM, OR INA781EVM test board</td>
<td>1</td>
</tr>
</tbody>
</table>

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

1.3 Specification

The EZShunt digital power monitors included in the EVMs pertaining to this document can report current, bus voltage, power, temperature, energy, and charge, while also providing robust diagnostic capabilities and a corresponding ALERT pin.

Figure 1-1. Functional Block Diagram for 16-bit digit Device Variant
1.4 Device Information

The devices are under evaluation (U1) digital power monitors with integrated EZShunt technology, an internal current sense element. The devices are thermally packaged resistors with a digital power monitor where the Kelvin sense connection is determined so the designer does not have to worry about the Kelvin force and sense connections of a shunt resistor.

Table 1-2. Device Summary

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>NOMINAL RESISTANCE</th>
<th>MAX INPUT COMMON MODE VOLTAGE</th>
<th>DIGITAL PROTOCOL</th>
<th>ADC RESOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>INA740A</td>
<td>1 mΩ</td>
<td>85 V</td>
<td>I²C</td>
<td>16-bit</td>
</tr>
<tr>
<td>INA740B</td>
<td></td>
<td></td>
<td>I²C</td>
<td>16-bit</td>
</tr>
<tr>
<td>INA741</td>
<td></td>
<td></td>
<td>I²C</td>
<td>20-bit</td>
</tr>
<tr>
<td>INA745A</td>
<td>900 µΩ</td>
<td>40 V</td>
<td>I²C</td>
<td>16-bit</td>
</tr>
<tr>
<td>INA745B</td>
<td></td>
<td></td>
<td>I²C</td>
<td>16-bit</td>
</tr>
<tr>
<td>INA746</td>
<td></td>
<td></td>
<td>I²C</td>
<td>20-bit</td>
</tr>
<tr>
<td>INA780A</td>
<td>560 mΩ</td>
<td>85 V</td>
<td>I²C</td>
<td>16-bit</td>
</tr>
<tr>
<td>INA780B</td>
<td></td>
<td></td>
<td>I²C</td>
<td>16-bit</td>
</tr>
<tr>
<td>INA781</td>
<td></td>
<td></td>
<td>I²C</td>
<td>20-bit</td>
</tr>
</tbody>
</table>
2 Hardware

This EVM is an easy-to-use platform for evaluating the main features and performance of the INA740, INA741, INA745, INA780, or INA781. The INA780-INA781EVM supports measurable, continuous current levels up to 50-A over temperature, while the INA740-INA741EVM and INA745-INA746EVM support 25-A over temperature. The measurable full-scale current range of these devices is a function of layout, ambient temperature, and current duration. Please refer to the data sheet for more information. EVM software includes a graphical user interface (GUI) used to read and write device registers as well as view and save results data.

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

2.1 Quick Start Setup

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

1. Purchase an SCB if there is not one.
   a. Follow the download prompts. An account on my.TI™ on-line information services is required.
   b. Take note that this driver is labeled as a PAMB driver and is also used for the SCB.
3. Attach the EVM to the SCB Controller as shown in Figure 2-1.
   a. Refer to Figure 2-2 when connecting multiple EVMs of the same type together.
4. Connect the EVM to the PC using the provided USB cable.
   a. Insert the micro USB cable into the SCB Controller onboard USB receptacle J2.
   b. Plug the other end of the USB cable into a PC.
5. Access the GUI from this link in either Chrome, Firefox, or Safari: [https://dev.ti.com/gallery/info/CurrentSensing/EZShunt-EVM-GUI/](https://dev.ti.com/gallery/info/CurrentSensing/EZShunt-EVM-GUI/).
6. Connect the GND reference of the external system to the GND node of the EVM (any test point or clip labeled “GND”).
7. Verify the load current source is disabled, then connect the EVM MP1 (IS+) and MP2 (IS-) nodes in-series to the load line with properly current rated cables as explained in [Current Sensing Operation](#).
2.2 EVM Operation

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

Figure 2-1. EVM (Bottom) Connected to SCB Controller (Top)

If using multiple EVMs, then connect them as shown in Figure 2-2. Make sure to use a different chip select/address for each device. The GUI only supports one EVM or device type at a time; up to four EVMs total.

Figure 2-2. Multiple EVMs Connected to SCB Controller

2.2.1 Current Sensing Operation

These EZShunt digital power monitor EVMs come equipped with internal shunt resistors and are out-of-the-box ready to measure up to 25 A (INA74x devices) or 50 A continuous current (INA78x devices) up to the rated input common-mode voltage. The EVMs have exposed pads (MP1 and MP2) for IS+ and IS- pins to run current through. MP1 and MP2 are designed for terminal connector lugs compatible with a 1/4 inch stud, such as the LAMA6-14-QY.

Note that the VBUS pin is electrically tied to the IS+ net.
2.2.1.1 Detailed Setup

To configure a measurement evaluation, follow these steps:

1. Gather a voltage source and/or load/current source capable of the desired voltage and current.
2. With instruments powered off, connect the load current carrying lines to the MP1 (IS+) and MP2 (IS-) terminals.
   a. **WARNING**
      
      When measuring current, first make sure that the equipment (EVM, wires, connectors, and so on) can support the amperage and power dissipation. Secondly, make sure that the current flowing through IS+ and IS- terminals does not exceed 25 A for INA74x nor 50 A for INA78x devices. Failure to do so can result in damage to the EVM, or personal injury.
      
      Do not touch high voltage terminals.
      
      The EVM and wires connected to IS+ and IS- nets can get hot.
3. Connect the system ground to the GND terminal (J1 pin 1) or any other GND labeled testpoint on the EVM.
4. Power on the system, and observe the device states and outputs through the GUI.

2.3 Circuitry

This section summarizes the EVM subsystems and their components.

2.3.1 Current Sensing IC

U1 is the main INA current-sensing device. The specific U1 variant is notated on the PCB via the population of a resistor in silkscreen table.

For the SENS108 PCB (INA740-INA741EVM), the 001, 002, and 003 variants have U1 populated with INA740A, INA740B, and INA741 respectively.

For the SENS109 (INA745-INA746EVM), the 001, 002, and 003 variants have U1 populated with INA745A, INA745B, and INA746 respectively.

For the SENS119 PCB (INA780-INA781EVM), the 001, 002, and 003 variants have U1 populated with INA780A, INA780B, and INA781 respectively.

C1 and C2 are bypass capacitors that are placed near the sensor to help mitigate power supply noise and provide current quickly to the device when needed. LED D1 with current limiting resistor R7 are used to indicate when the EVM is powered on.

The device pins can be monitored directly through the labeled test points and vias.

2.3.2 Input Signal Path

This section describes the circuitry of the input signal path.

The EZShunt digital power monitors provide an integrated shunt (IS+ to IS-), Kelvin sense connections (SH+ to SH-), and ADC differential input pins (IN+ and IN-). Thus, these devices have the ability to implement differential input filtering if desired in between the SH+/SHI pins and the IN+/IN- pins; however, to maximize thermal capability the input filters cannot be added to the EVM as of now because Kelvin sense pins are electrically tied to internal ADC input pins. If current filtering is necessary, then a user can configure longer conversion times and/or higher number of averages for the current register.

The VBUS pin is also electrically tied to the IS+ net to also optimize thermal performance.

All that is necessary to provide an input signal to U1 is to simply insert the IS+ (MP1) and IS- (MP2) nets in-series of the EVM with any current carrying wire provided the current and voltage are within EVM limits.

2.3.3 Digital Circuitry

This section describes the digital circuitry around the device.
2.3.3.1 I2C

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

SW0 (sets A0 pin) and SW1 (sets A1 pin) set the I2C address of the device. This can be useful when using the EVM with a custom controller (other than the SCB Controller), or when connecting multiple EVMs together. Currently the SCB Controller and GUI are set up to use four EVMs at a time.

R8 is used as a pullup resistor for the ALERT pin, which is routed to both J2 and J3. LED D2 and current limiting resistor R7 are used to indicate when the ALERT has triggered.

General Texas Instruments High Voltage Evaluation (TI HV EVM) User Safety Guidelines

![WARNING]

Always follow TI's set-up and application instructions, including use of all interface components within their recommended electrical rated voltage and power limits. Always use electrical safety precautions to help ensure your personal safety and those working around you. Contact TI's Product Information Center [http://ti.com/customer support](http://ti.com/customer support) for further information.

Save all warnings and instructions for future reference.

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### WARNING

Failure to follow warnings and instructions can result in personal injury, property damage or death due to electrical shock and burn hazards.

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The term TI HV EVM refers to an electronic device typically provided as an open framed, unenclosed printed circuit board assembly. It is intended strictly for use in development laboratory environments, solely for qualified professional users having training, expertise and knowledge of electrical safety risks in development and application of high voltage electrical circuits. Any other use and/or application are strictly prohibited by Texas Instruments. If you are not suitably qualified, you should immediately stop from further use of the HV EVM.

1. Work Area Safety:
   a. Keep work area clean and orderly.
   b. Qualified observers must be present anytime circuits are energized.
   c. Effective barriers and signage must be present in the area where the TI HV EVM and the interface electronics are energized, indicating operation of accessible high voltages can be present, for the purpose of protecting inadvertent access.
   d. All interface circuits, power supplies, evaluation modules, instruments, meters, scopes, and other related apparatus used in a development environment exceeding 50Vrms/75VDC must be electrically located within a protected Emergency Power Off EPO protected power strip.
   e. Use stable and non-conductive work surface.
   f. Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.

2. Electrical Safety:
   a. As a precautionary measure, a good engineering practice is to assume that the entire EVM can have fully accessible and active high voltages.
   b. De-energize the TI HV EVM and all the inputs, outputs and electrical loads before performing any electrical or other diagnostic measurements. Re-validate that TI HV EVM power has been safely de-energized.
   c. With the EVM confirmed de-energized, proceed with required electrical circuit configurations, wiring, measurement equipment hook-ups and other application needs, while still assuming the EVM circuit and measuring instruments are electrically live.
   d. Once EVM readiness is complete, energize the EVM as intended.
3. Personal Safety
   a. Wear personal protective equipment (for example, latex gloves or safety glasses with side shields) or protect EVM in an adequate lucent plastic box with interlocks from accidental touch.

Limitation for safe use:

EVMs are not to be used as all or part of a production unit.
3 Software

3.1 Setup

3.1.1 Driver Installation
Download and install this driver: https://www.ti.com/lit/zip/sbac253. This is a one-time step per computer, and requires an account on my.TI™ on-line information services. Note that this driver is labeled as a PAMB driver and is also used for the SCB. Unzip the folder and run the .exe file with administrator privileges.

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

3.1.2.1 Firmware Debug
If the firmware must be manually reinstalled for any reason, then follow the steps below to reinstall the firmware. Make sure the EVM is connected to the SCB.

1. Check to see if the GUI can program the firmware manually.
   a. Launch the GUI.
   b. Plug in the SCB controller to the PC.
   c. Check to see if the MCU entered Device Firmware Update (DFU) mode. If so, then the GUI notifies the user and attempts to update the firmware to the latest version.
   d. If the GUI does not update automatically, go to File →>Program Device....

2. If step 1 is unsuccessful (or if the Program Device button is grayed out), manually configure the MCU on the SCB Controller to be in DFU Mode through software or hardware:
   a. Through software:
      • Send the command 'bsl' on the SCB's USB Serial (COM) port.
   b. Though hardware:
      • For safety, **turn off and disconnect all load sources and external voltages**.
      • While shorting the two test points labeled DFU (shown in Figure 3-1) with a pair of tweezers (or wire), press and release the RESET button.

   ![](image)

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

   With the MCU in DFU mode, upload the firmware through the method outlined in Step 1.
3.1.3 GUI Setup and Connection

Access the GUI from this link in either Chrome, Firefox, or Safari: https://dev.ti.com/gallery/info/CurrentSensing/EZShunt-EVM-GUI/.

3.1.3.1 Initial Setup

To set up the GUI for the first time:

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

![GUI Composer Application](image)

Figure 3-2. GUI Composer Application

a. The GUI link bring up all versions of the GUI. TI recommends to launch the newest version available.

b. For first-time GUI Composer setup, follow the prompts to download the TI Cloud Agent and browser extension shown in Figure 3-3. Close the README.md dialog box to see these prompts.

![TI Cloud Agent](image)

Figure 3-3. TI Cloud Agent

TI Cloud Agent Installation

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

- **Step 1**: INSTALL browser extension

- **Step 2**: DOWNLOAD and install the TI Cloud Agent Application

- Help. I already did this
4. Optionally, click the icon in the GUI Composer application (see Figure 3-2) and follow the prompts to download the GUI for offline use.

3.1.3.2 GUI to EVM Connection

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

1. Setup and launch the GUI as described in Initial Setup.
   a. Check to make sure that the EVM connected to the GUI.
2. Close the README.md file page to initiate the connection. If successful, then the text Hardware Connected is visible near the bottom left corner of the GUI.

![Figure 3-4. Hardware Connected](image)

1. A green indicator with the device bit type (either 16 bit or 20 bit) appears and the text DEVICE CONNECTED is visible near the top left of the GUI.

![Figure 3-5. Device Type Connected](image)

2. From the Select Device drop-down menu, select the specific EVM to be used.
3. A green indicator with the device type and the text DEVICE CONNECTED is also be visible near the top left of the GUI.

![Figure 3-6. Device Connected](image)

4. The user needs to update the SW0 (pin A0) and SW1 (pin A1) field values to the values selected on the EVMs SW0 and SW1 address select switches.
5. If the text Hardware Connected and DEVICE CONNECTED does not show in the GUI, then long-press the RESET button on the EVM to try again.
   a. If that option does not work, then check different hardware COM ports under Options > Serial Port.

![Figure 3-7. Change Serial Port](image)

6. If the hardware still does not connect, then make sure the correct GUI/EVM combination is being used.
a. If the user is using the correct GUI/EVM combination, then reprogram the firmware of the SCB as described in Firmware Debug.

b. Many connectivity issues can be addressed by doing one of the following:
   i. Long-press the RESET button on the EVM with the EVM and SCB connected to each other.
      • Refreshing the GUI can also sometimes help.
   ii. Connect the EVM to a different USB port.
      • Avoid using long cables and USB hubs.
      • If using a desktop PC, then try a USB port on the back.

3.2 GUI Operation

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

3.2.1 Homepage Tab

The GUI starts out on the homepage tab. Click the (Home) icon on the menu to the left to return to the homepage tab at any time.

From the homepage, the user can easily confirm successful GUI to EVM connection (see GUI to EVM Connection), as well as access helpful resources through the buttons on the bottom (see Figure 3-8).

![Figure 3-8. Home Tab Links](image)

3.2.2 Registers Tab

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

![Figure 3-9. GUI Registers Tab](image)

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

• Use the Selected EVM drop-down menu at the top to choose which device to work with on the register map.
– Note, changing this here also changes the same setting for the Configuration tab.
– Functionally, this button sets the default read/write address in the MCU and then reads all register values back to update the register map. Note that if data is collected at a high frequency, then this can cause a minor delay in the data collection. For the best performance, set the device settings before starting to collect data.

- By default, all changes are automatically written to the device. If desired, then change the Immediate Write setting to Deferred Write to only allow writing when ready.
– Modify writable register values from any of these methods:
  • Through the widget settings in the Field View section on the right.
  • Changing the Value directly with either hex or decimal values.
  • Double-clicking on any individual bit.
- Turning on Auto Read only updates registers in the register map, and not the plots in Section 3.2.3.
– Leaving Auto Read on while collecting data for plots can interfere with data collection timing.

- For questions about a register or register bit field, click the icon.
– For more questions about registers, check the corresponding data sheet.
- For convenience, register settings can be saved and loaded back later to any device with the same register map. To do this, go to File > Register Data, as shown in Figure 3-10.

![Figure 3-10. Save and Load Register Settings](image)

– TI recommends to click the Read All Registers button after loading data to update the register map with the actual device values, in case the loaded registers were not compatible with the connected device.

### 3.2.3 Results Data Tab

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

![Figure 3-11. Results Page and Settings](image)

Below is a description of how to use the buttons and settings at the top of the results data page and next to each plot:

- Results to collect/show
Use this section to select which register values to collect data for. If a results register is unselected before the COLLECT DATA button is pressed, then the plot below is hidden and the EVM does not try to read this register during the collect cycle (even if the conversion is enabled).

If the user disables one of these settings while the EVM is collecting data, then the plot does not show, but data is still collected and the plot updates in the background. Reselect to show data.

• Number of EVMs
  – Set the Number of EVMs drop-down menu to the number of EVMs currently in use.
    • See Figure 2-2 for how to attach multiple EVMs together.
    • Changing this here also changes the same setting in the Configuration tab.
  – The GUI only supports one EVM/device type at a time, up to 4 EVMs total.

• Switch settings
  – Use the onboard switches to select a different address/chip select for each EVM.
  – Set the switch settings in the GUI to match the setting for each connected EVM.
    – EVM 1 automatically populates with the lowest addressed device unless a setting has already been selected.
    – Changing this here also changes the same setting in the Configuration tab.
  – If more than one device is being used, then a * symbol appears next to the selected EVM that is being used on the register map and configuration tabs.
    – Changing the switch settings of any EVM sets that EVM as the selected EVM.

• Collect/Plots settings
  – Collect Data
    • Press the COLLECT DATA button to start data collection.
    • In this mode, the MCU reads and sends the selected result values for each device over a USB BULK channel. All results from one device are read before moving on to the next device.
      – All result values from all EVMs together are considered one "sample set".
    • Although the user can read and write to other registers through the register map page while collecting data, this can add a delay to the data being collected.
    • Press the STOP COLLECT button to stop collecting data.
  – #Samples Only
    • If this checkbox is selected, then the GUI automatically stops collecting data after the number of samples specified in the #Samples box have been collected.
    • If not selected, the GUI continues collecting data and only store the most recent #Samples.
  – Delay between samples
    • Sets the delay between the start of each sample set.
    • Desired delay time is not be obtainable if delay time is set faster than the read loop, which depends on the number of results being collected, the number of EVMs, and the CPU.
    • Although the user can read and write to other registers through the register map page while collecting data, this can add a delay to the data being collected.
  – Auto Delay
    • Sets delay based on conversion times, averaging, and number of channels being converted.
    • If multiple EVMs are being used, then the time put in the delay box are from the EVM with the shortest calculated delay value.
  – Save All Plots
    • Press the SAVE ALL PLOTS button to save the data for each currently selected result from the Results to collect/show section in a spreadsheet.
    • Press the SAVE PLOT button next to each plot to save just the data from that plot in a spreadsheet.
  – Clear All Plots
    • Press the CLEAR ALL PLOTS button to clear the data from all plots together.
    • Press the CLEAR PLOT button next to each plot to clear the data from just that plot.
  – #Samples
    • Change the number in this box to change the number of samples shown in each plot.
      – Changing this number clears out the plot buffers, so the plots are cleared on the next read.
  – Y-Axis Options
    • Manual Scale
- Checking this box sets all EVM results in this plot to the same scale value specified by the Max and Min fields.
- When this is not selected, each EVM has their own Y-axis scale based on the min and max value for the result values of the EVM.
- For the DIETEMP Result, the units can also be toggled between °C and °F.
  - This processes the existing data in the plots, and converts new data coming in. If receiving new data while changing units, then a datapoint can be missed or duplicated.
  
  - **Max**
    - The maximum Y-axis value to use for all EVMs in this plot.
    - If this field is empty when Manual Scale is selected, then the field auto-populate with the maximum value currently in the plot.
  
  - **Min**
    - The minimum Y-axis value to use for all EVMs in this plot.
    - If this field is empty when Manual Scale is selected, then the field auto-populates with the minimum value currently in the plot.

3.3 Direct EVM USB Communication

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

3.3.1 Standard USB Read and Write Operations

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

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

- **Read register format:** rreg ADR
  - Where ADR is the address in hex, and rreg is always lower case.
  - Register addresses can be in upper or lower case, and do not need to be led by '0x'. 0 padding register addresses is also optional. For example, to read register address 0xB, some valid commands include:
    - rreg b
    - rreg 0B
    - rreg 0x0B
    - When '0x' is used, the 'x' must be lower case.
    - For this example, the EVM returns the results and state ("idle" or "collecting") in JSON format:
      ```json
      {"acknowledge":"rreg 0x0B"}
      {"register":{"address":11,"value":3}}
      {"evm_state":"idle"}
      ```

- **Write register format:** wreg ADR VAL.
  - Where ADR and VAL are in hex, and wreg is always lower case.
  - Register addresses and values can be in upper or lower case, and do not need to be led by '0x'. 0 padding register addresses and values is also optional. For example, to write register address 0x1 with the value 0xfb69, some valid commands include:
• wreg 1 fb69
• wreg 01 0xfb69
• wreg 0x01 0xFB69
  – When '0x' is used, the 'x' must be lower case.
  – For this example, the EVM returns the results and state ("idle" or "collecting") in JSON format:
    
    ```json
    {"acknowledge":"wreg 0x01 0xfb69"}
    {"console":"Writing 0xfb69 to ADC_CONFIG register"}
    {"evm_state":"idle"}
    ```

3.3.2 Collect Data Through the USB BULK Channel

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

- Start collecting data format: collect timerPeriod collectFlags channelAddressIDs numDevices.
  - Where collect is always lower case, and each parameter is the decimal representation of the value in the following format:
    - timerPeriod
      - The timer delay used in the MCU to allow data collection sample sets (in µs, unsigned 32-bit value).
    - collectFlags
      - A byte of data that has a 1 to collect and a 0 to not collect each register value type, according to the following definitions (note to only use energy and charge flags when the device supports that, otherwise set to 0):
        - VBUS = 0b0100000
        - DIETEMP = 0b0010000
        - CURRENT = 0b0001000
        - POWER = 0b0000100
        - ENERGY = 0b0000010
        - CHARGE = 0b0000001
    - channelAddressIDs
      - I2C
        - This is the 4 LSBs of each address chained together, starting with the LSBs.
          - For example, if EVM 1 is on channel 0x41 and EVM 2 is on 0x43, the value here is 0b00110001.
    - NumDevices
      - The number of EVMs chained together (1-4).
        - For example, to start data collection for VBUS, and DIETEMP every 3.156 ms, for two INA745s with EVM 1 address = 0x44 and EVM 2 address=0x46, the user needs to send: collect 3156 48 100 2.
        - For this example, the EVM returns the acknowledgment and state in JSON format:
          ```json
          {"acknowledge":"collect 3156 48 100 2"}
          {"evm_state":"collecting"}
          ```
      - The USB BULK channel receives data in the format: frameID deviceNumID address registerSize data.
        - Where each parameter is the decimal representation of the value in the following format:
          - frameID (1 byte)
            - Always reads 0. Used to verify data is aligned.
          - deviceNumID (1 byte)
            - An ID number corresponding to the EVM number.
              - From the above example, this is 1 if reading from EVM 1 which had an address set to 0x44, and 2 if reading from EVM 2 which had an address set to 0x46.
          - address (1 byte)
            - The register address that was read from the device.
          - registerSize (1 byte)
            - The number of bytes that the following data has.
– data (1 byte at a time)
  • The register data value, given in bytes with the most significant byte first.
• Stop collecting data format: stop
  – Where stop is always lower case.
  – The EVM returns the acknowledgment and state in JSON format:

    
    
    
    {"acknowledge":"stop"
    {"evm_state":"idle"}
4 Hardware Design Files

4.1 Schematics

This section shows the schematics separately for the SENS108, SENS109, and SENS119 boards. Note that each PCB has three BOM variants where U1 is the only difference so only one variant can be shown.

4.1.1 SENS108 (INA740AEVM, INA740BEVM, INA741EVM)

Figure 4-1 and Figure 4-2 show the schematic and the mechanical components of the EVM.

Figure 4-1. SENS108E1-002 Schematic (INA740BEVM)
Figure 4-2. SENS108E1 Hardware
4.1.2 SENS109 (INA745AEVM, INA745BEVM, INA746EVM)

Figure 4-3 and Figure 4-4 show the schematic and mechanical components of the EVM.

Figure 4-3. SENS109E1-003 Schematic (INA746EVM)

Figure 4-4. SENS109E1 Hardware
4.1.3 SENS119 (INA780AEVM, INA780BEVM, INA781EVM)

Figure 4-5 and Figure 4-6 show the schematic and mechanical components of the EVM.

Figure 4-5. SENS119E1-001 Schematic (INA780AEVM)
Figure 4-6. SENS119E1 Hardware
4.2 PCB Layout

All E1 boards are designed with following parameters:

- 8 mil minimum trace width
- 5 mil minimum clearance
- 5 mil minimum annular ring
- 8 mil spacing between IS+ and IS- pours
- 4 layers, each layers is 2 oz copper
- All vias in proximity to U1 are tented

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

4.2.1 SENS108 (INA740AEVM, INA740BEVM, INA741EVM)

Figure 4-7 through Figure 4-14 illustrate the PCB layers of the EVM.

Figure 4-7. SENS108 Top Overlay
Figure 4-8. SENS108 Top Layer
Figure 4-9. SENS108 Top Solder
Figure 4-10. SENS108 Signal Layer 1
4.2.2 SENS109 (INA745AEVM, INA745BEVM, INA746EVM)

Figure 4-15 through Figure 4-22 illustrate the PCB layers of the EVM.

Figure 4-15. SENS109 Top Overlay
Figure 4-16. SENS109 Top Layer
Figure 4-17. SENS109 Top Solder
Figure 4-18. SENS109 Signal Layer 1
4.2.3 SENS119 (INA780AEVM, INA780BEVM, INA781EVM)

Figure 4-23 through Figure 4-30 illustrate the PCB layers of the EVM.
Figure 4-27. SENS119 Signal Layer 2

Figure 4-28. SENS119 Bottom Layer

Figure 4-29. SENS119 Drill Drawing

Figure 4-30. SENS119 Drill Table
4.3 Bill of Materials

This section shows the bill of materials for the SENS108, SENS109, and SENS119.

4.3.1 SENS108 (INA740-INA741EVM), SENS109 (INA745-INA746EVM), SENS119 (INA780-INA781EVM)

Table 4-1 through Table 4-10 provide the parts list for all EVMs. Table 4-1 through Table 4-1 are variant specific, while Table 4-10 shows the parts common to all SENS108, SENS109, and SENS119 variants.

<table>
<thead>
<tr>
<th>Designator</th>
<th>QTY</th>
<th>Value</th>
<th>Description</th>
<th>Package Reference</th>
<th>Part Number</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1</td>
<td>1</td>
<td></td>
<td>85-V, Integrated Sense Element, 16-Bit, Precision Power/Energy/Charge Monitor With I 2C Interface</td>
<td>QFN14</td>
<td>INA740AIREMR</td>
<td>Texas Instruments</td>
</tr>
<tr>
<td>R740A</td>
<td>1</td>
<td>4.7k</td>
<td>RES, 4.7 k, 5%, 0.1 W, 0603</td>
<td>603</td>
<td>CRCW06034K70JNEA</td>
<td>Vishay-Dale</td>
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</table>

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<th>Value</th>
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<th>Package Reference</th>
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<th>Manufacturer</th>
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<td>INA740BIREMR</td>
<td>Texas Instruments</td>
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<td>Vishay-Dale</td>
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<th>Manufacturer</th>
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<td>Texas Instruments</td>
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<tr>
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<td>4.7k</td>
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<td>603</td>
<td>CRCW06034K70JNEA</td>
<td>Vishay-Dale</td>
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<th>Part Number</th>
<th>Manufacturer</th>
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<td>40-V, Integrated Sense Element, 16-Bit, Precision Power/Energy/Charge Monitor With I 2C Interface</td>
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<td>Texas Instruments</td>
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<tr>
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<td>RES, 4.7 k, 5%, 0.1 W, 0603</td>
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<td>Vishay-Dale</td>
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<th>Description</th>
<th>Package Reference</th>
<th>Part Number</th>
<th>Manufacturer</th>
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<td>INA746AIRELR</td>
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### Table 4-6. INA746EVM (SENS109-003) Exclusive Bill of Materials (continued)

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<td>Vishay-Dale</td>
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### Table 4-7. INA780AEVM (SENS119-001) Exclusive Bill of Materials

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<th>Part Number</th>
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<td>INA780AIDEKR</td>
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<td>Vishay-Dale</td>
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</tbody>
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### Table 4-8. INA780BEVM (SENS119-002) Exclusive Bill of Materials

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<th>Package Reference</th>
<th>Part Number</th>
<th>Manufacturer</th>
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<tbody>
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<td>U1</td>
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<td>85-V, Integrated Sense Element, 16-Bit, Precision Power/Energy/Charge Monitor With I2C Interface</td>
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<td>INA780BIDEKR</td>
<td>Texas Instruments</td>
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</tr>
<tr>
<td>R780B</td>
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<td>4.7k</td>
<td>RES, 4.7 k, 5%, 0.1 W, 0603</td>
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<td>CRCW06034K70JNEA</td>
<td>Vishay-Dale</td>
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### Table 4-9. INA781EVM (SENS119-003) Exclusive Bill of Materials

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<th>Package Reference</th>
<th>Part Number</th>
<th>Manufacturer</th>
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<tbody>
<tr>
<td>U1</td>
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<td>85-V, Integrated Sense Element, 20-Bit, Precision Power/Energy/Charge Monitor With I2C Interface</td>
<td>WSON15</td>
<td>INA781AIDEKR</td>
<td>Texas Instruments</td>
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<tr>
<td>R781</td>
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<td>RES, 4.7 k, 5%, 0.1 W, 0603</td>
<td>603</td>
<td>CRCW06034K70JNEA</td>
<td>Vishay-Dale</td>
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### Table 4-10. SENS108, SENS109, SENS119 Variants Bill of Materials

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<tr>
<th>Designator</th>
<th>QTY</th>
<th>Value</th>
<th>Description</th>
<th>Package Reference</th>
<th>Part Number</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2</td>
<td>1</td>
<td>0.1uF</td>
<td>CAP, CERM, 0.1 uF, 50 V, +/- 20%, X7R, 0402</td>
<td>0402</td>
<td>GRM155R71H104ME14D</td>
<td>Murata</td>
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<tr>
<td>D1, D2</td>
<td>2</td>
<td>White</td>
<td>LED, White, SMD</td>
<td>0805</td>
<td>VAOL-S8WR4</td>
<td>Visual Communications Company, LLC</td>
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<tr>
<td>H1, H2, H3, H4</td>
<td>4</td>
<td>Bumpon, Hemisphere, 0.375 X 0.235, Black</td>
<td>Black Bumpon</td>
<td>SJ61A2</td>
<td>3M</td>
<td></td>
</tr>
<tr>
<td>J2</td>
<td>1</td>
<td>Receptacle, 2 mm, 6x2, Gold, R/A, TH</td>
<td>Receptacle, 2 mm, 6x2, R/A, TH</td>
<td>NPPN062FJFN-RC</td>
<td>Sullins Connector Solutions</td>
<td></td>
</tr>
<tr>
<td>J3</td>
<td>1</td>
<td>&quot;Connector Header Through Hole, Right Angle 12 position 0.079&quot; (.2.00mm)</td>
<td>HDR12</td>
<td>NRP062PARN-RC</td>
<td>Sullins Connector Solutions</td>
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<tr>
<td>R4, R7</td>
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<td>10k</td>
<td>RES, 10 k, 5%, 0.1 W, 0603</td>
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<td>CRCW060310K0JNEA</td>
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<td>R5, R6, R8</td>
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<td>CRCW06034K70JNEA</td>
<td>Vishay-Dale</td>
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<tr>
<td>SW0, SW1</td>
<td>2</td>
<td>Slide Switch SP4T Surface Mount, Right Angle</td>
<td>SMT_SW_11MM3_4MM1</td>
<td>CUS-14TB</td>
<td>Nidec Copal Electronics</td>
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<td>TP3, TP4, TP5, TP7, TP8, TP11</td>
<td>6</td>
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<td>Testpoint_Keystone_Miniatu re</td>
<td>5015</td>
<td>Keystone</td>
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<tr>
<td>C1</td>
<td>0</td>
<td>1uF</td>
<td>CAP, CERM, 1 uF, 50 V, +/- 10%, X6S, 0603</td>
<td>0603</td>
<td>C1608X6S1H105K080AC</td>
<td>TDK</td>
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<tr>
<td>FID1, FID2, FID3</td>
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<td>Fiducial mark. There is nothing to buy or mount.</td>
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<td>N/A</td>
<td>N/A</td>
<td></td>
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<tr>
<td>Designator</td>
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<td>Value</td>
<td>Description</td>
<td>Package Reference</td>
<td>Part Number</td>
<td>Manufacturer</td>
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<tr>
<td>------------</td>
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<td>--------------------------------------------</td>
<td>-----------------------------------------------------</td>
<td>-------------------</td>
<td>---------------</td>
<td>----------------</td>
</tr>
<tr>
<td>J1, J6, J7</td>
<td>0</td>
<td>CONN PIN RCPT .018-.021 SOLDERPIN_RCPT</td>
<td>PIN_RCPT</td>
<td>3-331272-8</td>
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<td>MP1, MP2</td>
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<td>Terminal Connector Rectangular Lug, Grounding 6-14 AWG 1/4 Stud</td>
<td>TERMINAL_CONN</td>
<td>LAMAS-14-QY</td>
<td>Panduit</td>
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4.3.1 SENS108 (INA740-INA741EVM), SENS109 (INA745-INA746EVM), SENS119 (INA780-INA781EVM)

Table 4-1 through Table 4-10 provide the parts list for all EVMs. Table 4-1 through Table 4-5 are variant specific, while Table 4-10 shows the parts common to all SENS108, SENS109, and SENS119 variants.

### Table 4-1. INA740AEVM (SENS108-001) Exclusive Bill of Materials

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<tbody>
<tr>
<td>U1</td>
<td>1</td>
<td>85-V, Integrated Sense Element, 16-Bit, Precision Power/Energy/Charge Monitor With I 2C Interface</td>
<td>QFN14</td>
<td>INA740AIREMR</td>
<td>Texas Instruments</td>
<td></td>
</tr>
<tr>
<td>R740A</td>
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<td>RES, 4.7 k, 5%, 0.1 W, 0603</td>
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### Table 4-2. INA740BEVM (SENS108-002) Exclusive Bill of Materials

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<th>Part Number</th>
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<td>U1</td>
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<td>85-V, Integrated Sense Element, 16-Bit, Precision Power/Energy/Charge Monitor With I 2C Interface</td>
<td>QFN14</td>
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<td>Texas Instruments</td>
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<tr>
<td>R740B</td>
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<td>RES, 4.7 k, 5%, 0.1 W, 0603</td>
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<td>CRCW06034K70JNEA</td>
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### Table 4-3. INA741EVM (SENS108-003) Exclusive Bill of Materials

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<th>Part Number</th>
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<tbody>
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<td>INA741AIREMR</td>
<td>Texas Instruments</td>
<td></td>
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### Table 4-4. INA745AEVM (SENS109-001) Exclusive Bill of Materials

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<th>Package Reference</th>
<th>Part Number</th>
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<tbody>
<tr>
<td>U1</td>
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<td>40-V, Integrated Sense Element, 16-Bit, Precision Power/Energy/Charge Monitor With I 2C Interface</td>
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<td>INA745AIRELR</td>
<td>Texas Instruments</td>
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<tr>
<td>R745A</td>
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### Table 4-5. INA745BEVM (SENS109-002) Exclusive Bill of Materials

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<td>U1</td>
<td>1</td>
<td>40-V, Integrated Sense Element, 16-Bit, Precision Power/Energy/Charge Monitor With I 2C Interface</td>
<td>QFN14</td>
<td>INA745BIRELR</td>
<td>Texas Instruments</td>
<td></td>
</tr>
<tr>
<td>R745B</td>
<td>1</td>
<td>4.7k</td>
<td>RES, 4.7 k, 5%, 0.1 W, 0603</td>
<td>603</td>
<td>CRCW06034K70JNEA</td>
<td>Vishay-Dale</td>
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### Table 4-6. INA746EVM (SENS109-003) Exclusive Bill of Materials

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<th>QTY</th>
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<th>Description</th>
<th>Package Reference</th>
<th>Part Number</th>
<th>Manufacturer</th>
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<td>40-V, Integrated Sense Element, 20-Bit, Precision Power/Energy/Charge Monitor With I 2C Interface</td>
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<td>INA746AIRELR</td>
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<td>RES, 4.7 k, 5%, 0.1 W, 0603</td>
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<td>CRCW06034K70JNEA</td>
<td>Vishay-Dale</td>
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### Table 4-7. INA780AEVM (SENS119-001) Exclusive Bill of Materials

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<th>Part Number</th>
<th>Manufacturer</th>
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<tr>
<td>U1</td>
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<td>85-V, Integrated Sense Element, 16-Bit, Precision Power/Energy/Charge Monitor With I 2C Interface</td>
<td>WSON15</td>
<td>INA780AIDEKR</td>
<td>Texas Instruments</td>
</tr>
<tr>
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<td>4.7k</td>
<td>RES, 4.7 k, 5%, 0.1 W, 0603</td>
<td>603</td>
<td>CRCW06034K70JNEA</td>
<td>Vishay-Dale</td>
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### Table 4-8. INA780BEVM (SENS119-002) Exclusive Bill of Materials

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<th>Package Reference</th>
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<td>85-V, Integrated Sense Element, 16-Bit, Precision Power/Energy/Charge Monitor With I 2C Interface</td>
<td>WSON15</td>
<td>INA780BIDEKR</td>
<td>Texas Instruments</td>
</tr>
<tr>
<td>R780B</td>
<td>1</td>
<td>4.7k</td>
<td>RES, 4.7 k, 5%, 0.1 W, 0603</td>
<td>603</td>
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<td>Vishay-Dale</td>
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### Table 4-9. INA781EVM (SENS119-003) Exclusive Bill of Materials

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<td>85-V, Integrated Sense Element, 20-Bit, Precision Power/Energy/Charge Monitor With I 2C Interface</td>
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<td>INA781AIDEKR</td>
<td>Texas Instruments</td>
</tr>
<tr>
<td>R781</td>
<td>1</td>
<td>4.7k</td>
<td>RES, 4.7 k, 5%, 0.1 W, 0603</td>
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<td>CRCW06034K70JNEA</td>
<td>Vishay-Dale</td>
</tr>
</tbody>
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### Table 4-10. SENS108, SENS109, SENS119 Variants Bill of Materials

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<th>Package Reference</th>
<th>Part Number</th>
<th>Manufacturer</th>
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</thead>
<tbody>
<tr>
<td>C2</td>
<td>1</td>
<td>0.1uF</td>
<td>CAP, CERM, 0.1 uF, 50 V, +/- 20%, X7R, 0402</td>
<td>0402</td>
<td>GRM155R71H104ME14D</td>
<td>Murata</td>
</tr>
<tr>
<td>D1, D2</td>
<td>2</td>
<td>White</td>
<td>LED, White, SMD</td>
<td>0805</td>
<td>VAOL-S8WR4</td>
<td>Visual Communications Company, LLC</td>
</tr>
<tr>
<td>H1, H2, H3, H4</td>
<td>4</td>
<td></td>
<td>Bumpon, Hemisphere, 0.375 X 0.235, Black</td>
<td>Black Bumpon</td>
<td>SJ61A2</td>
<td>3M</td>
</tr>
<tr>
<td>J2</td>
<td>1</td>
<td></td>
<td>Receptacle, 2 mm, 6x2, Gold, R/A, TH</td>
<td>Receptacle, 2 mm, 6x2, R/A, TH</td>
<td>NPPN062FJFN-RC</td>
<td>Sullins Connector Solutions</td>
</tr>
<tr>
<td>J3</td>
<td>1</td>
<td></td>
<td>&quot;Connector Header Through Hole, Right Angle 12 position 0.079&quot; (2.00mm)</td>
<td>HDR12</td>
<td>NRPN062PARN-RC</td>
<td>Sullins Connector Solutions</td>
</tr>
<tr>
<td>R4, R7</td>
<td>2</td>
<td>10k</td>
<td>RES, 10 k, 5%, 0.1 W, 0603</td>
<td>0603</td>
<td>CRCW060310K0JNEA</td>
<td>Vishay-Dale</td>
</tr>
<tr>
<td>R5, R6, R8</td>
<td>3</td>
<td>4.7k</td>
<td>RES, 4.7 k, 5%, 0.1 W, 0603</td>
<td>0603</td>
<td>CRCW06034K70JNEA</td>
<td>Vishay-Dale</td>
</tr>
<tr>
<td>SW0, SW1</td>
<td>2</td>
<td></td>
<td>Slide Switch SP4T Surface Mount, Right Angle</td>
<td>SMT_SW_11MM3_4MM1</td>
<td>CUS-14TB</td>
<td>Nidec Copal Electronics</td>
</tr>
<tr>
<td>TP3, TP4, TP5, TP7, TP8, TP11</td>
<td>6</td>
<td></td>
<td>Test Point, Miniature, SMT</td>
<td>Testpoint_Keystone_Miniature</td>
<td>5015</td>
<td>Keystone</td>
</tr>
<tr>
<td>C1</td>
<td>1</td>
<td>1uF</td>
<td>CAP, CERM, 1 uF, 50 V, +/- 10%, X6S, 0603</td>
<td>0603</td>
<td>C1608X6S1H105K080AC</td>
<td>TDK</td>
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<tr>
<td>FID1, FID2, FID3</td>
<td>0</td>
<td></td>
<td>Fiducial mark. There is nothing to buy or mount.</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>J1, J6, J7</td>
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<td>CONN PIN RCPT .018-.021 SOLDERPIN_RCPT</td>
<td>PIN_RCPT</td>
<td>3-331272-8</td>
<td>TE Connectivity</td>
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<td>MP1, MP2</td>
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<td>Terminal Connector Rectangular Lug, Grounding 6-14 AWG 1/4 Stud</td>
<td>TERMINAL_CONN</td>
<td>LAMAS-14-QY</td>
<td>Panduit</td>
</tr>
</tbody>
</table>
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6 Related Documentation

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<table>
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<tr>
<th>DOCUMENT TITLE</th>
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<td>INA741 data sheet</td>
<td>SBOSAC2</td>
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<td>INA746 data sheet</td>
<td>SBOSAC4</td>
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<td>INA780 data sheet</td>
<td>SBOSAB6</td>
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<td>INA781 data sheet</td>
<td>SBOSAC0</td>
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