

EVM User's Guide: INA780, INA740, INA745, INA780A, INA780B, INA781, INA740A, INA740B, INA741, INA745A, INA745B, INA746, INA780-781EVM, INA740-INA741EVM, INA745-746EVM
EZShunt™ Digital Current and Power Monitors

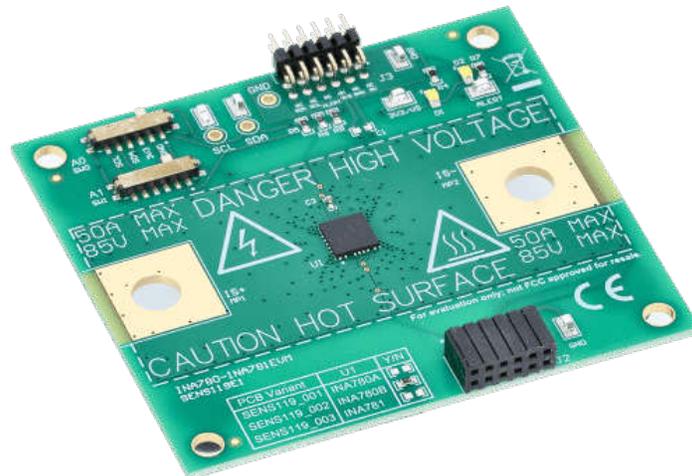


Description

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
- Includes high power lugs and hardware for quick high current evaluation (only available for Version A with fully released devices)



1 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- μ A current during shutdown. Users can interface the output with a multitude of microcontrollers (MCUs) in a standard I2C interface.

WARNING

NOTICE: The INA740BEVM (SENS108A-002) does not currently ship with INA740B populated. To evaluate INA740B, order functionally equivalent INA740AEVM (SENS108E1-001) or functionally similar INA741EVM (SENS108E1-003) or solder INA740B onto the INA740BEVM.

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 1-1. Kit Contents

ITEM	QUANTITY
INA740AEVM, INA740BEVM, INA741EVM, INA745AEVM, INA745BEVM, INA741EVM, INA780AEVM, INA780BEVM, OR INA781EVM test board	1

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

Currently, there are two versions to the EVMs: version E1 and version A. This is because not all device variants are being fully released at the same time. Version A is functionally and thermally equivalent to E1 except for the following:

- Device U1 is part of the full release inventory and performs according to the corresponding data sheet
- Header J4 and shunt H5 are included to optionally open the ALERT bus
- Lugs MP1 and MP2 are included with associated hardware MP3, MP4, MP5, and MP6

Until all devices have been fully released, this document covers both versions.

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.

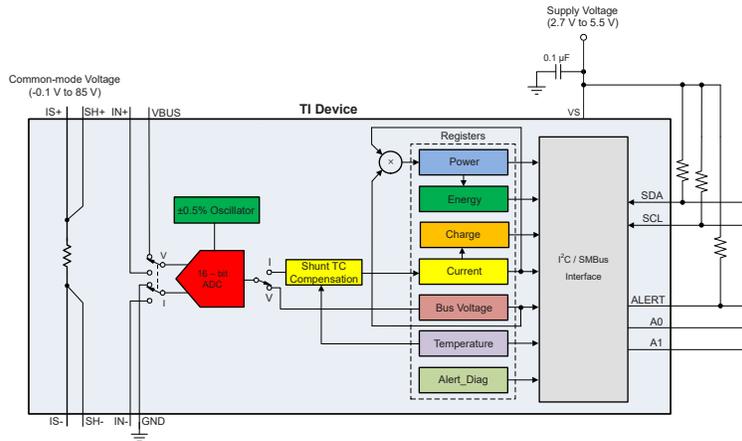


Figure 1-1. Functional Block Diagram for 16-bit digit Device Variant

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

PRODUCT	NOMINAL PACKAGE RESISTANCE	MAX INPUT COMMON MODE VOLTAGE	DIGITAL PROTOCOL	ADC RESOLUTION
INA740A	1 mΩ	85 V	I ² C	16-bit
INA740B			I ² C	16-bit
INA741			I ² C	20-bit
INA745A	900 μΩ	40 V	I ² C	16-bit
INA745B			I ² C	16-bit
INA746			I ² C	20-bit
INA780A	560 mΩ	85 V	I ² C	16-bit
INA780B			I ² C	16-bit
INA781			I ² C	20-bit

2 Hardware

This EVM is an easy-to-use platform for evaluating the main features and performance of the INA740, INA741, INA745, INA746, 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.
2. Download this driver and install as an administrator: <https://www.ti.com/lit/zip/sbac253>.
 - 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/>.
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](#).

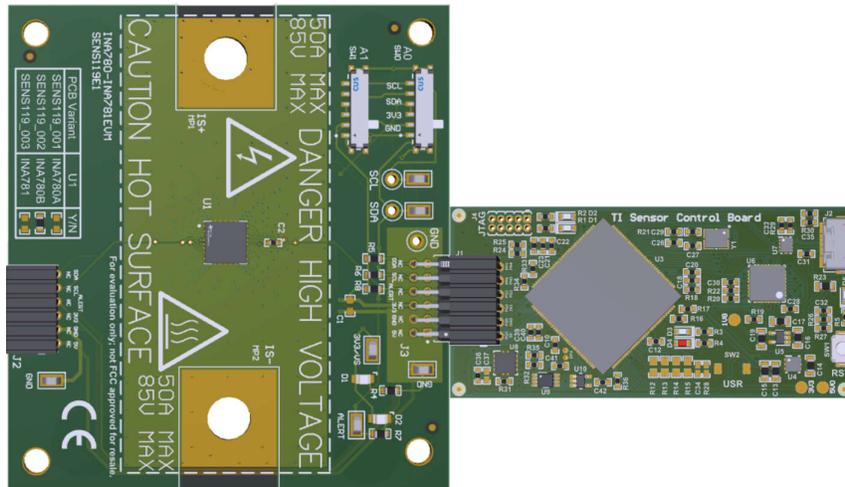


Figure 2-1. EVM (Bottom) Connected to SCB Controller (Top)

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.

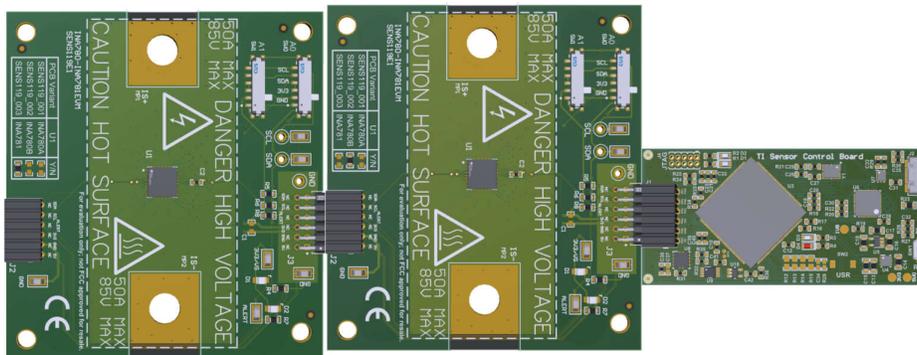


Figure 2-2. Multiple EVMs Connected to SCB Controller

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 over temperature. Failure to do so can result in damage to the EVM, or personal injury. See data sheet for more information on safe operating conditions.

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 test point 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



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> for further information.

Save all warnings and instructions for future reference.

WARNING

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

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.

WARNING

While the EVM is energized, never touch the EVM or the electrical circuits, as the circuits and EVM can be at high voltages capable of causing electrical shock hazard.

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. Through hardware:
 - For safety, **turn off and disconnect all load sources and external voltages.**
 - While shorting the two test points labeled *DFU* (shown in [Figure 3-1](#)) with a pair of tweezers (or wire), press and release the *RESET* button.

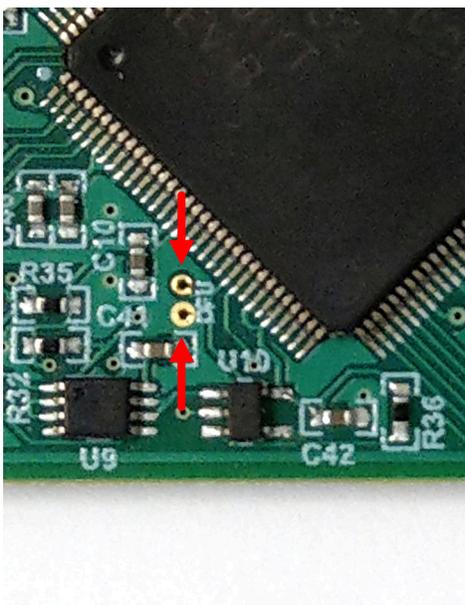


Figure 3-1. Test Points Used to Enter DFU Mode Manually

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.

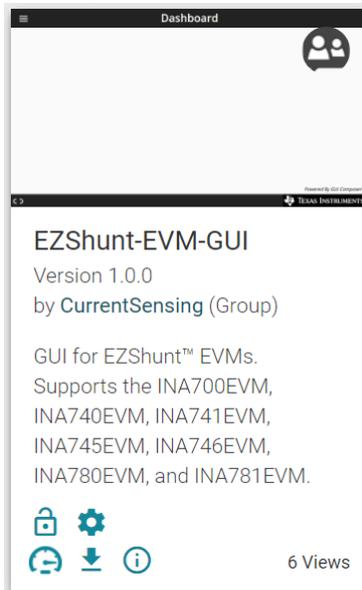


Figure 3-2. GUI Composer Application

- 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 Installation

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

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

FINISH

Figure 3-3. TI Cloud Agent

4. Optionally, 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

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

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.

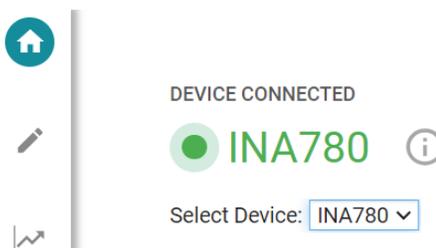


Figure 3-6. Device Connected

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

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.

- 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](#).

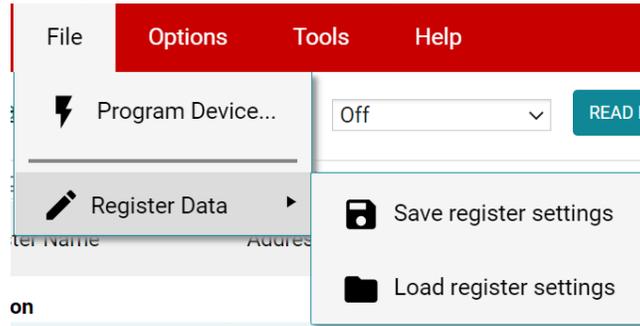


Figure 3-10. Save and Load Register Settings

- 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

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:

```

{"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:

```

{"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:

```

{"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 μ s, 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:


```

          {"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

Currently, there are two versions to the EVMs: version E1 and version A. Version A is functionally and thermally equivalent to E1 except for the following:

- Device U1 is part of the full release inventory and performs according to the corresponding data sheet
- Header J4 and shunt H5 are included to optionally open the ALERT bus
- Lugs MP1 and MP2 are included with associated hardware MP3, MP4, MP5, and MP6

Until all devices have been fully released, this document covers both versions.

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 (INA740AEMV, INA740BEVM, INA741EVM)

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

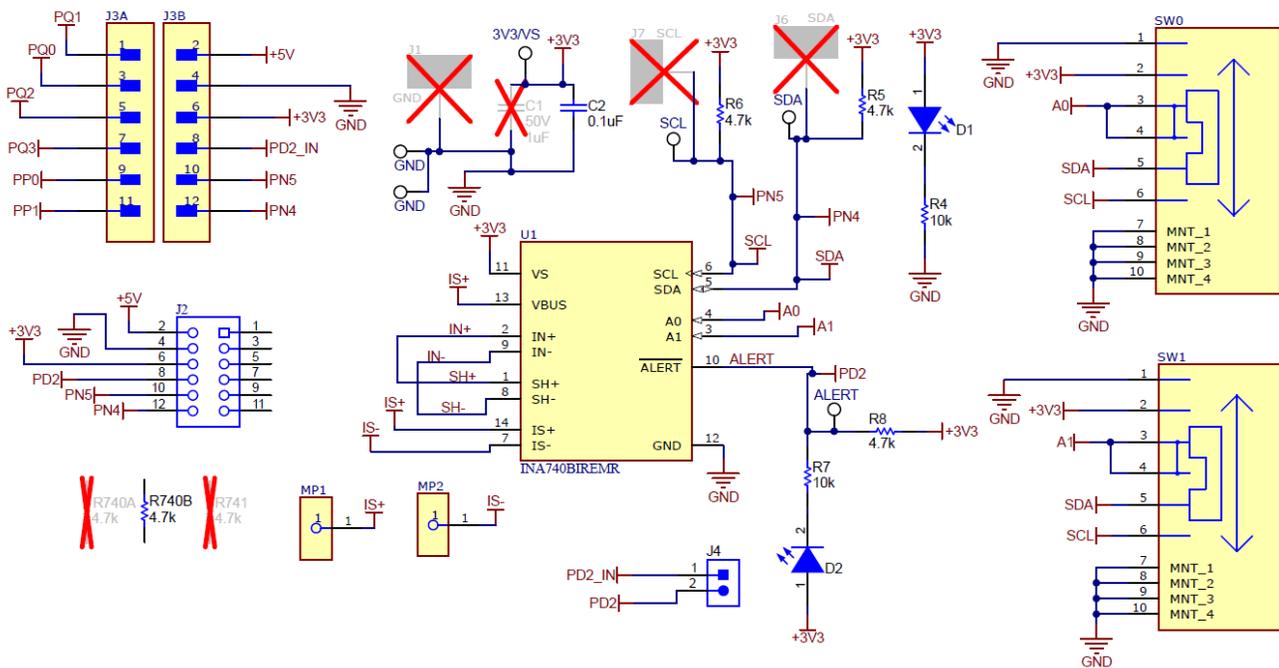


Figure 4-1. SENSE108A Schematic

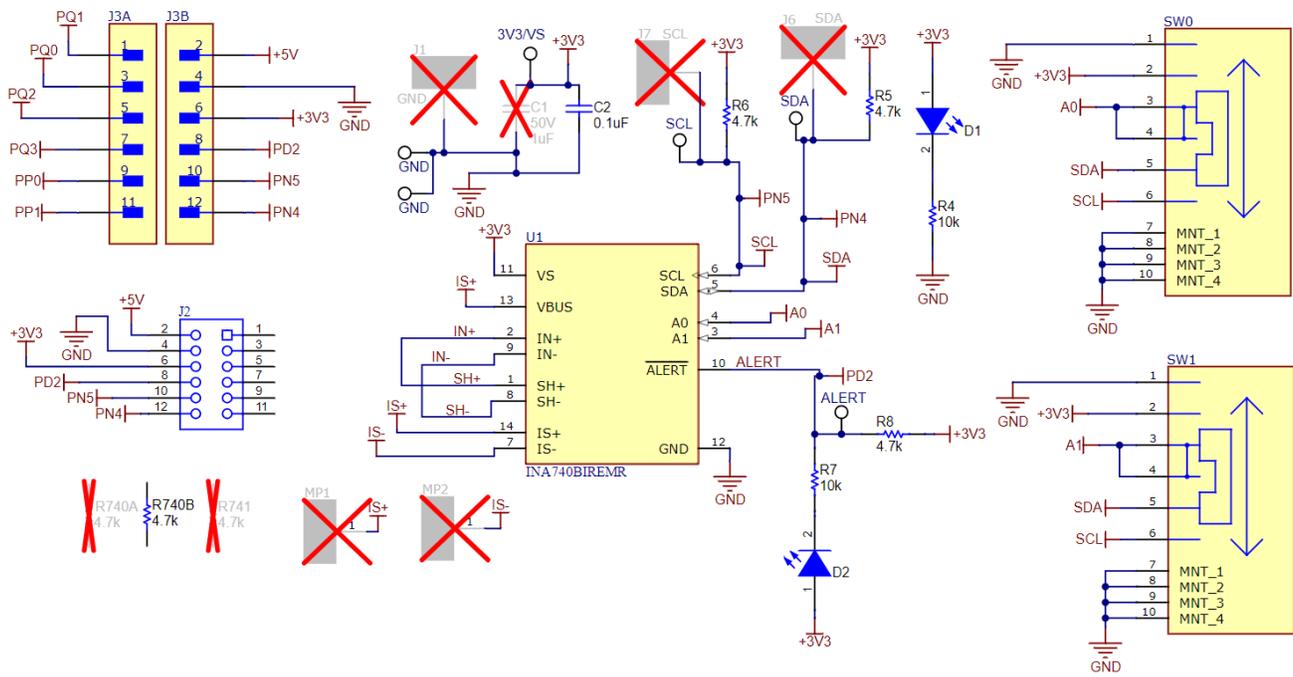
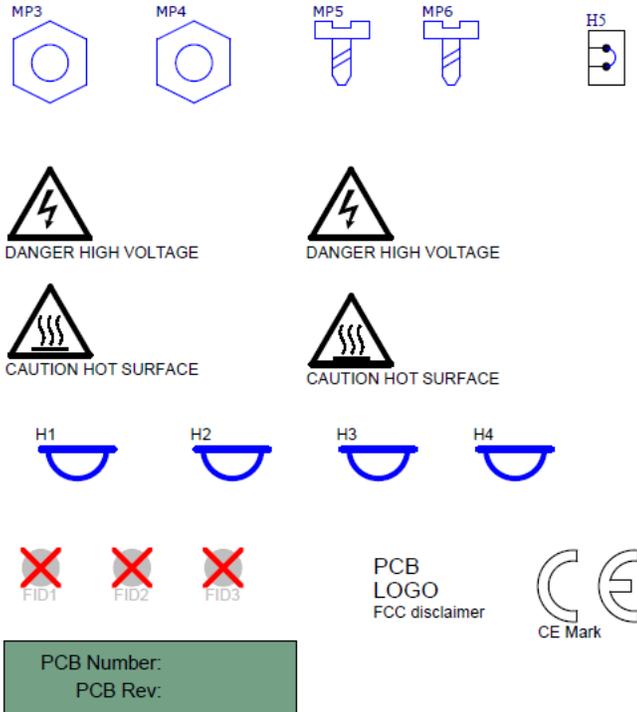


Figure 4-2. SENS108E1 Schematic



ZZ1
Label Assembly Note
This Assembly Note is for PCB labels only

ZZ2
Assembly Note
These assemblies are ESD sensitive, ESD precautions shall be observed.

ZZ3
Assembly Note
These assemblies must be clean and free from flux and all contaminants. Use of no clean flux is not acceptable.

ZZ4
Assembly Note
These assemblies must comply with workmanship standards IPC-A-610 Class 2, unless otherwise specified.

Figure 4-3. SENS108A Hardware

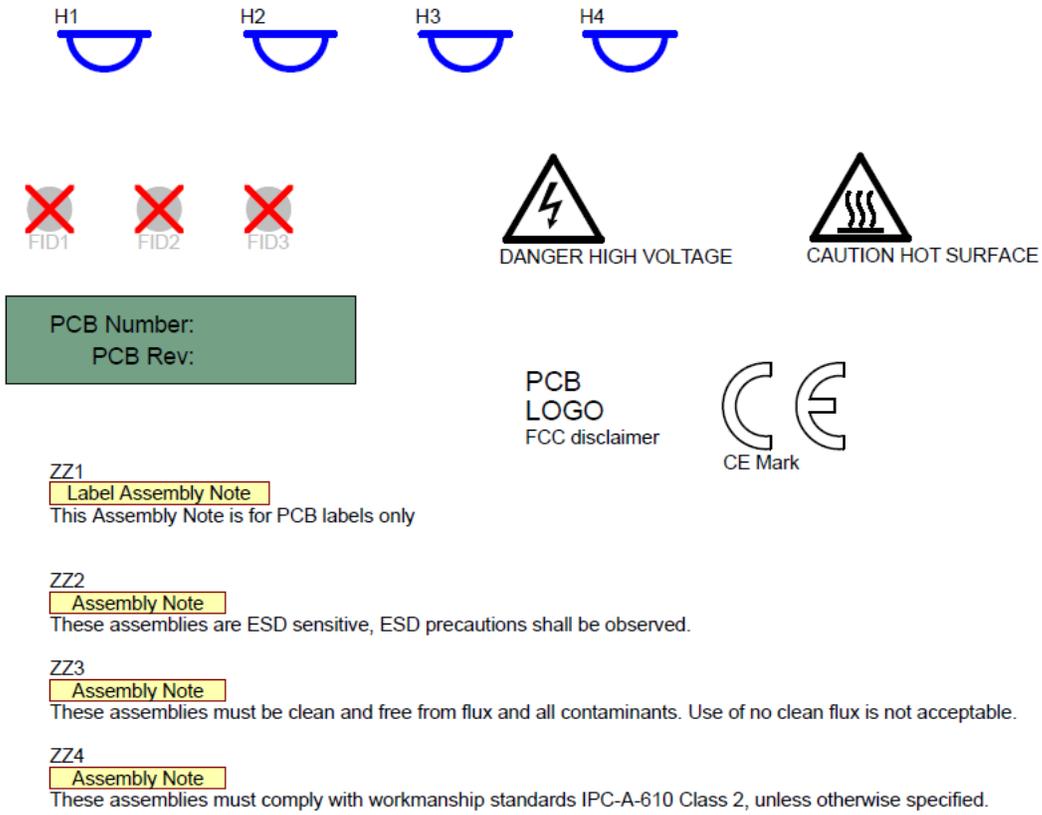


Figure 4-4. SENS108E1 Hardware

4.1.2 SENS109 (INA745AEVM, INA745BEVM, INA746EVM)

Figure 4-6 and Figure 4-8 show the schematic and mechanical components of the EVM.

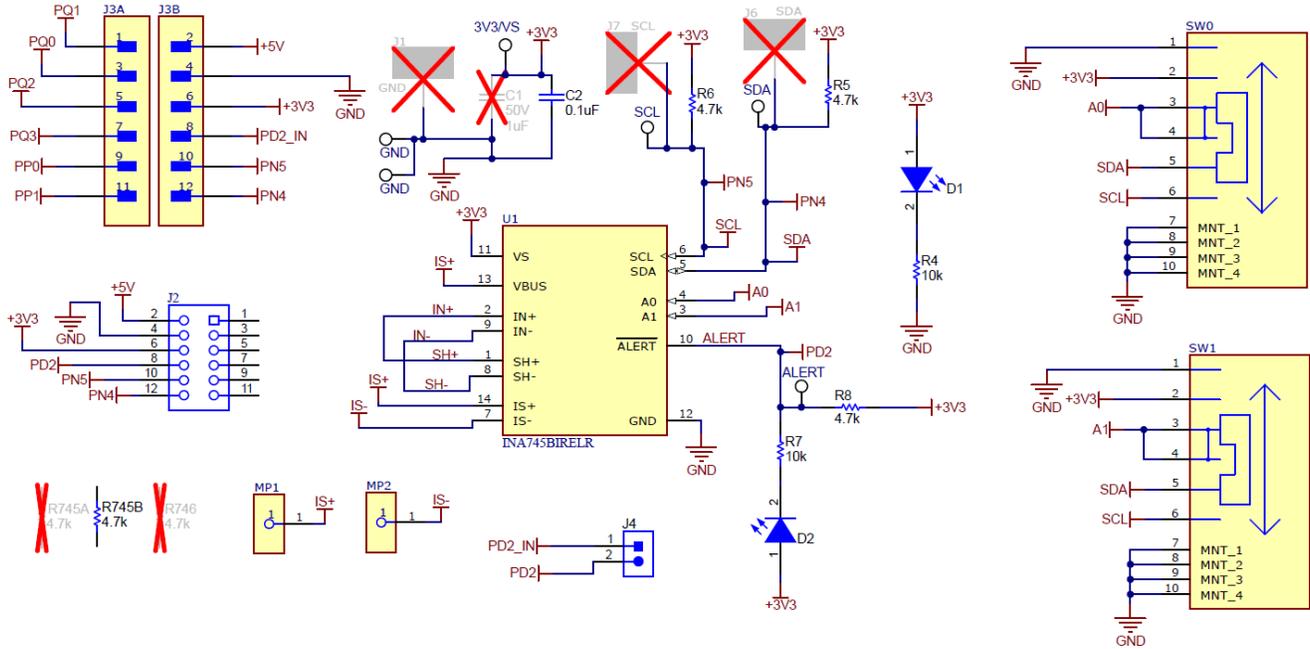


Figure 4-5. SENS109A Schematic

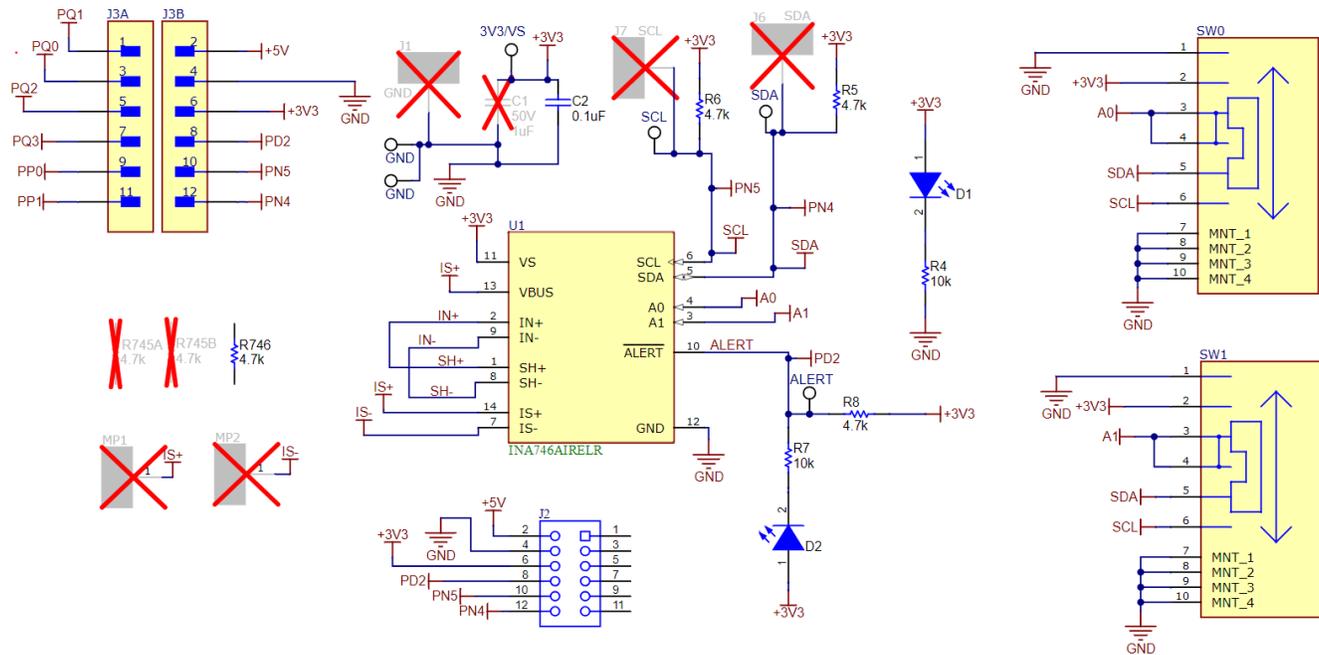
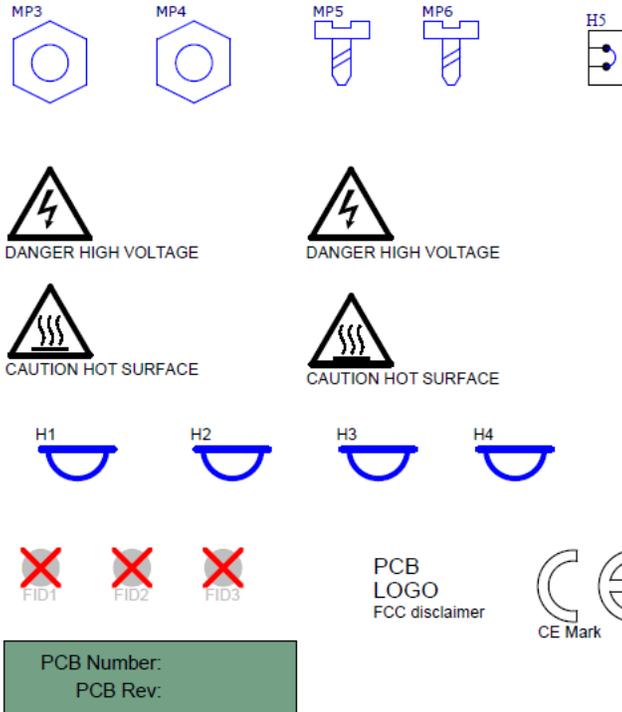


Figure 4-6. SENS109E1 Schematic



ZZ1

Label Assembly Note

This Assembly Note is for PCB labels only

ZZ2

Assembly Note

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

ZZ3

Assembly Note

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

ZZ4

Assembly Note

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

Figure 4-7. SENS109A Hardware

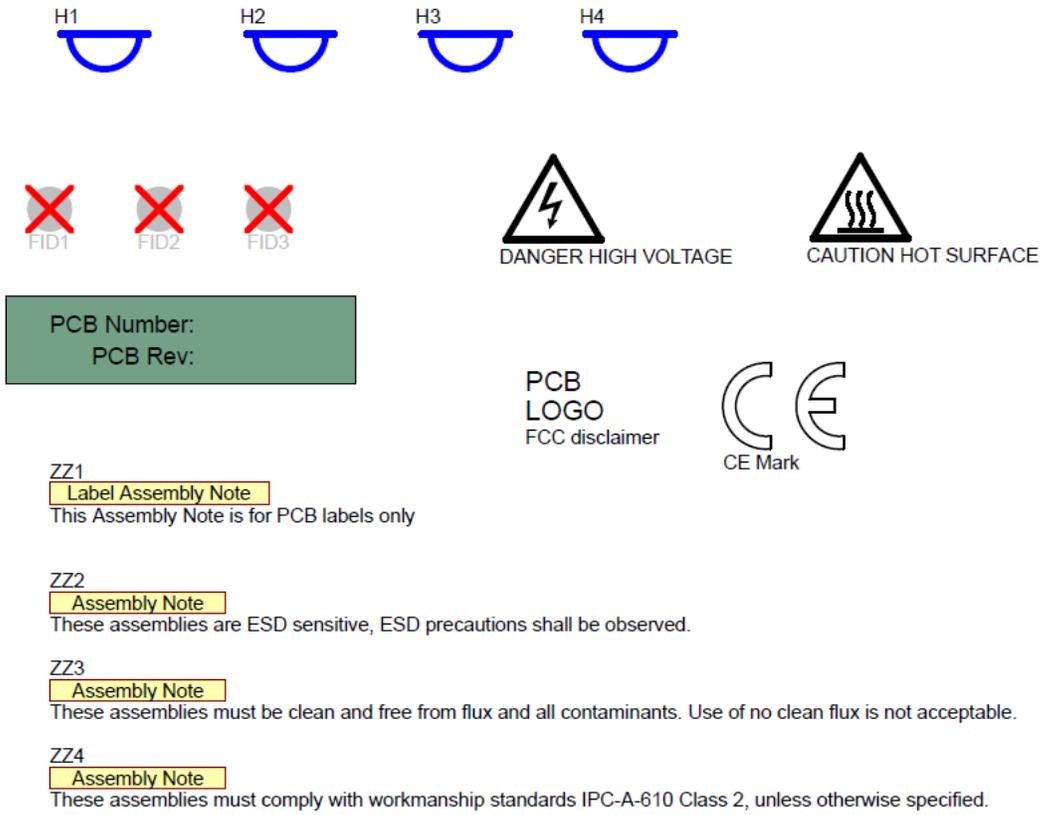


Figure 4-8. SENS109E1 Hardware

4.1.3 SENS119 (INA780AEMV, INA780BEVM, INA781EVM)

Figure 4-10 and Figure 4-12 show the schematic and mechanical components of the EVM.

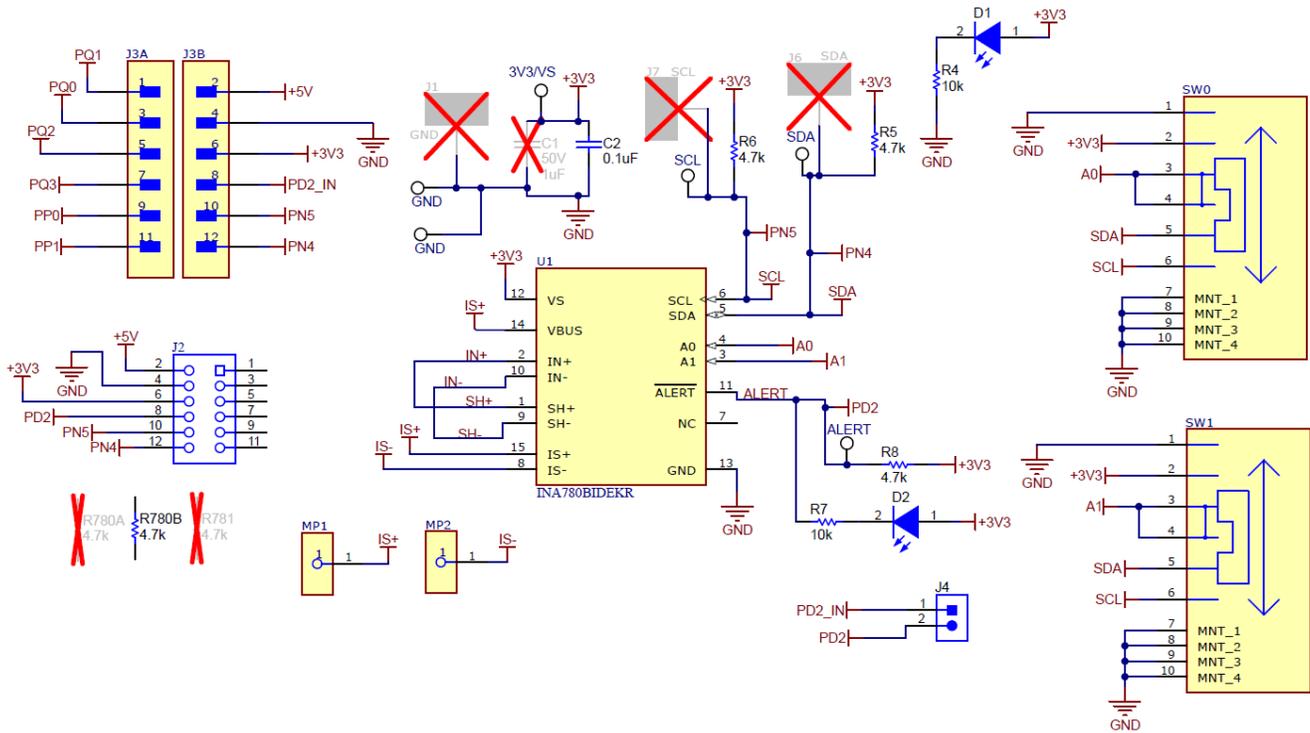


Figure 4-9. SENS119A Schematic

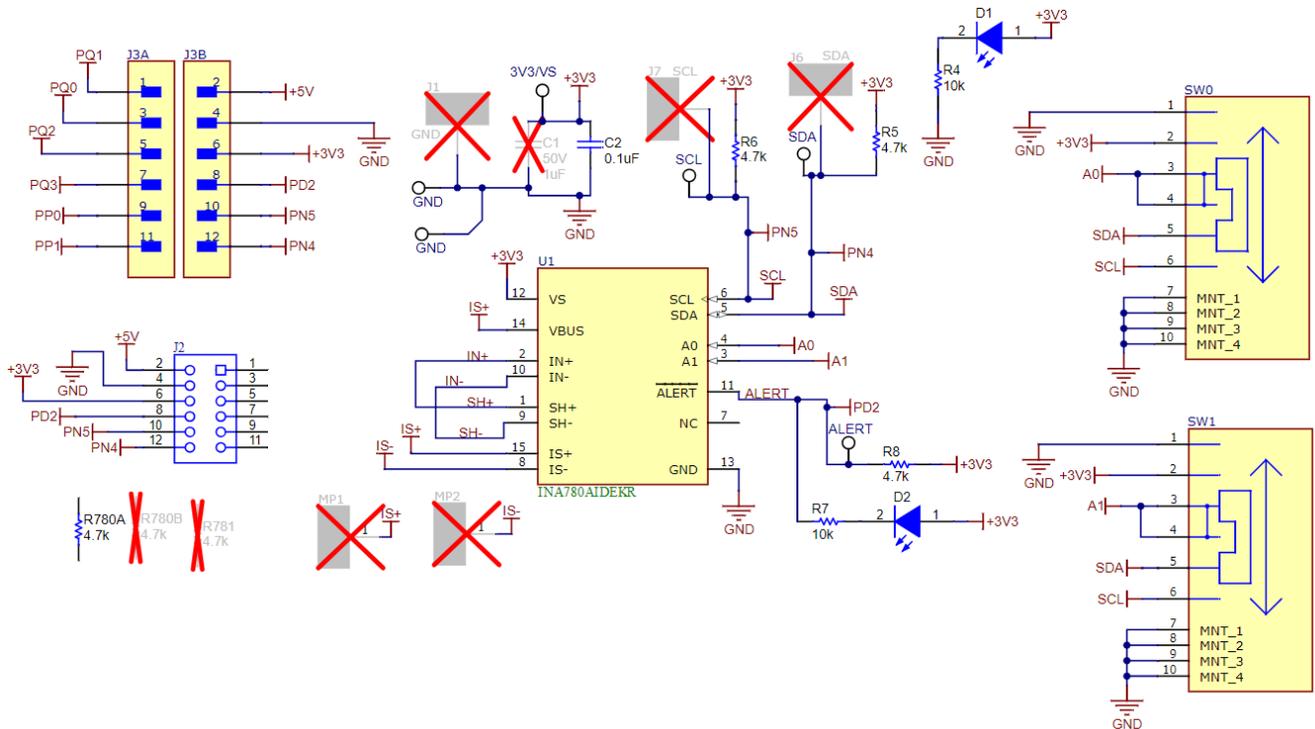
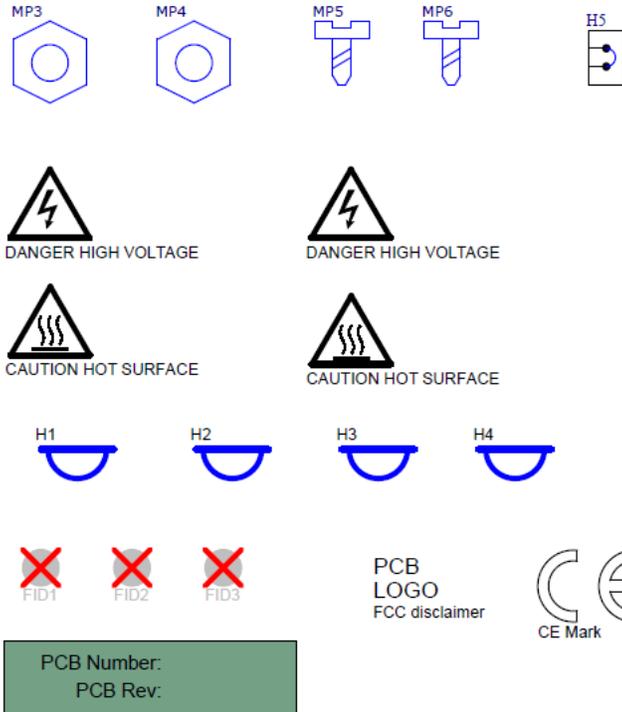


Figure 4-10. SENS119E1 Schematic



ZZ1
Label Assembly Note
 This Assembly Note is for PCB labels only

ZZ2
Assembly Note
 These assemblies are ESD sensitive, ESD precautions shall be observed.

ZZ3
Assembly Note
 These assemblies must be clean and free from flux and all contaminants. Use of no clean flux is not acceptable.

ZZ4
Assembly Note
 These assemblies must comply with workmanship standards IPC-A-610 Class 2, unless otherwise specified.

Figure 4-11. SENS119A Hardware

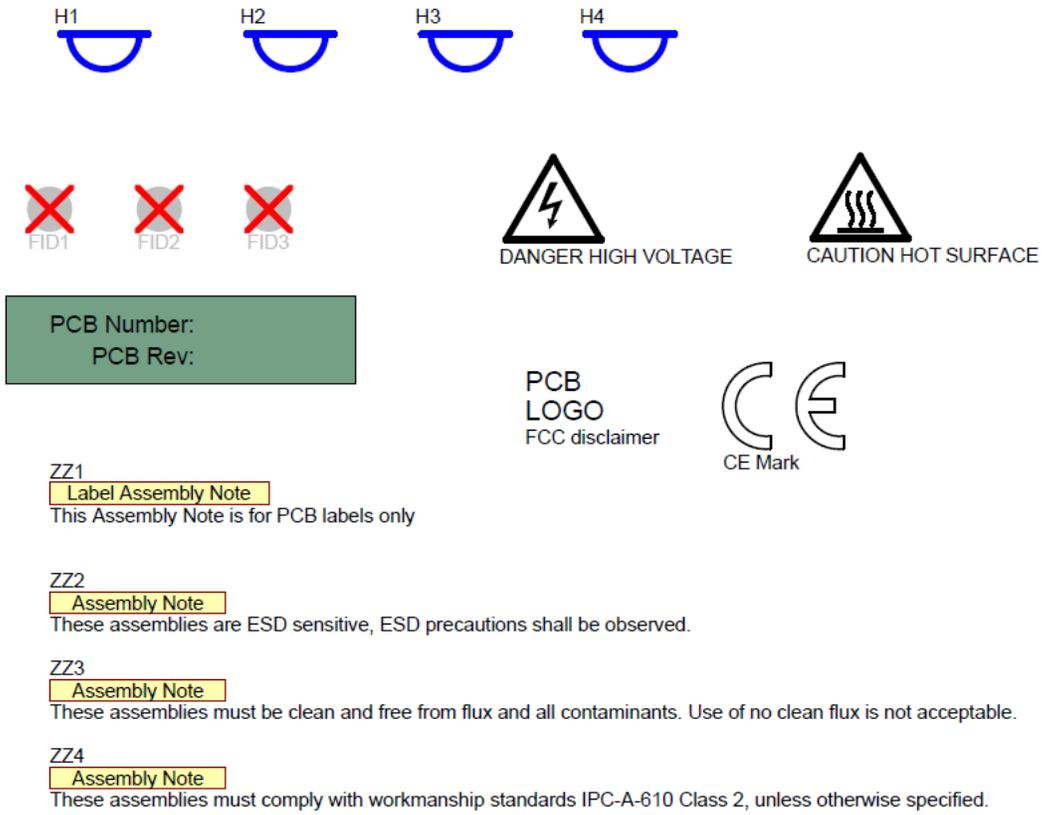


Figure 4-12. SENS119E1 Hardware

4.2 PCB Layout

All 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 signal layers, each layer is 2 oz copper
- Dielectric layers are 17 mil thick
- 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 4-14 through Figure 4-28 illustrate the PCB layers of the EVM.

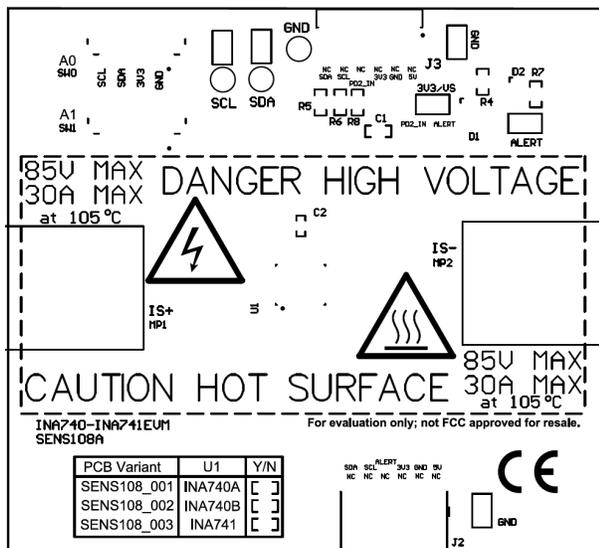


Figure 4-13. SENS108A Top Overlay

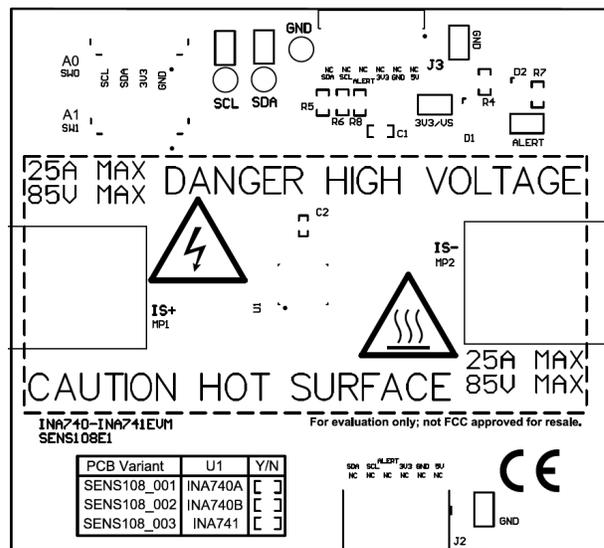


Figure 4-14. SENS108E1 Top Overlay

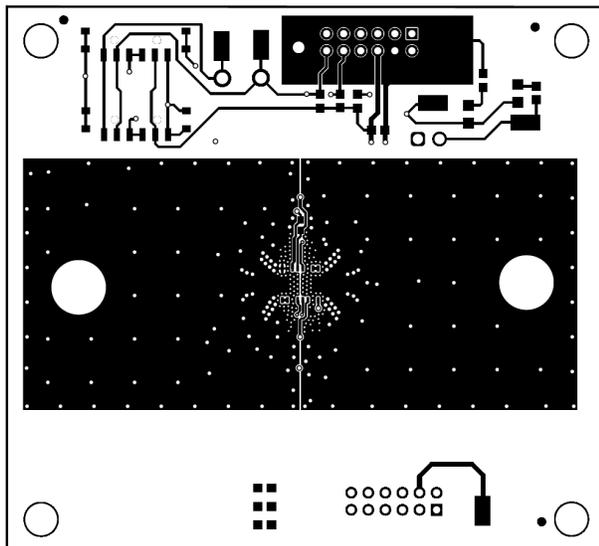


Figure 4-15. SENS108A Top Layer

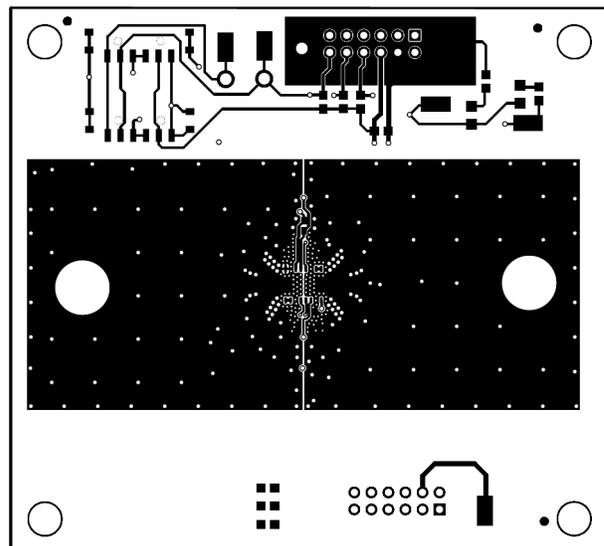


Figure 4-16. SENS108E1 Top Layer

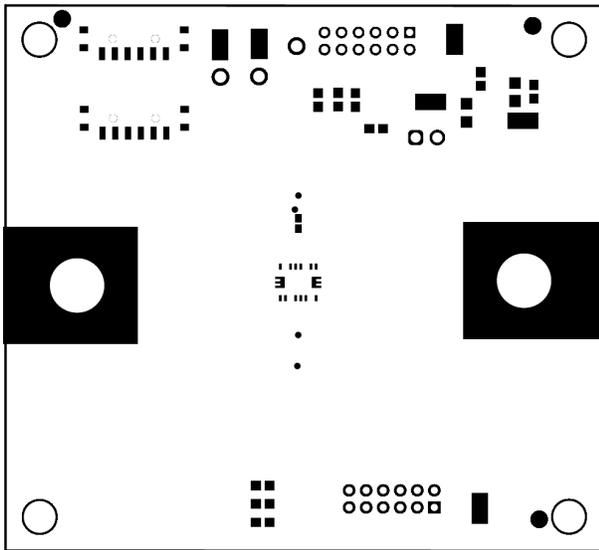


Figure 4-17. SENS108A Top Solder

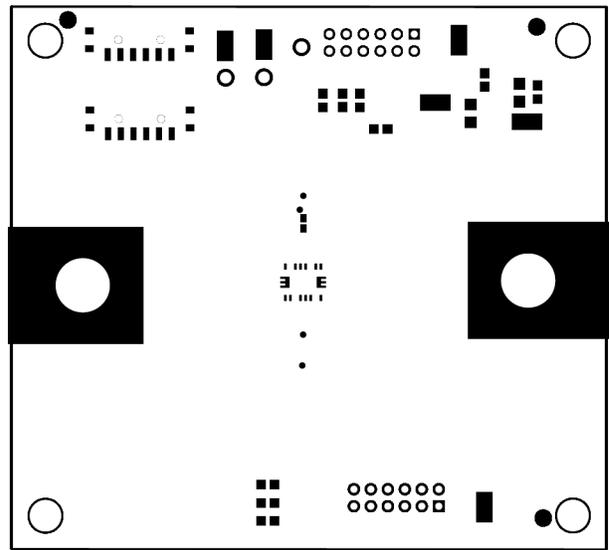


Figure 4-18. SENS108E1 Top Solder

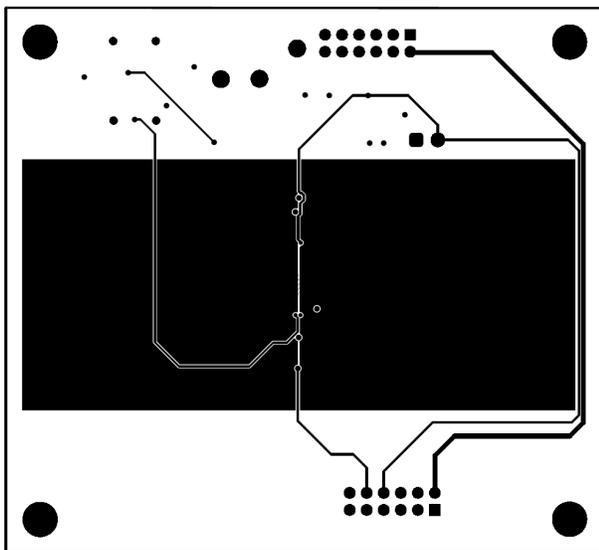


Figure 4-19. SENS108A Signal Layer 1

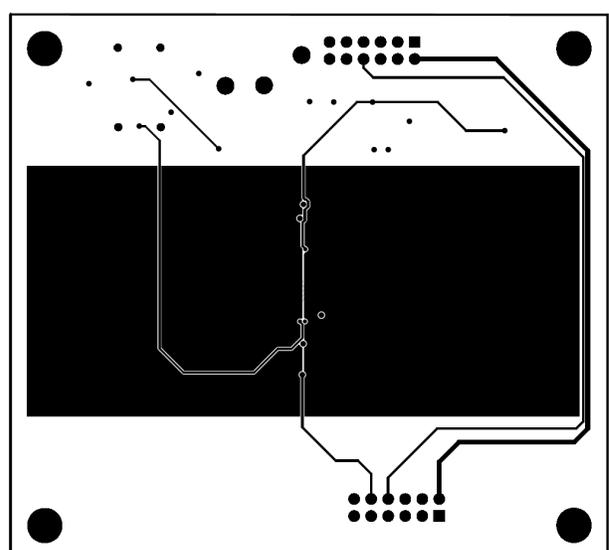


Figure 4-20. SENS108E1 Signal Layer 1

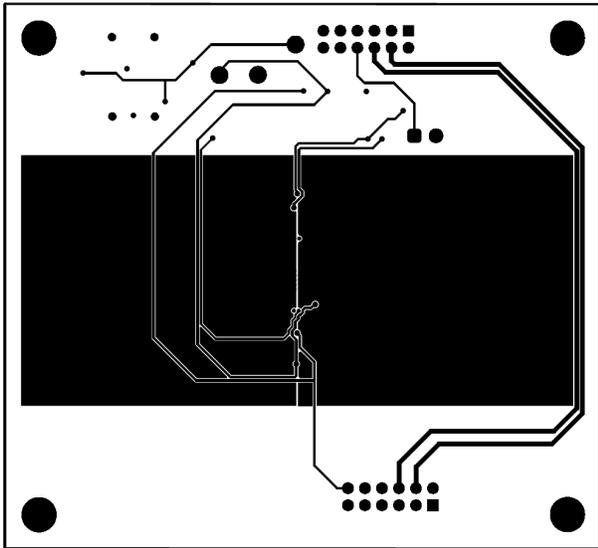


Figure 4-21. SENS108A Signal Layer 2

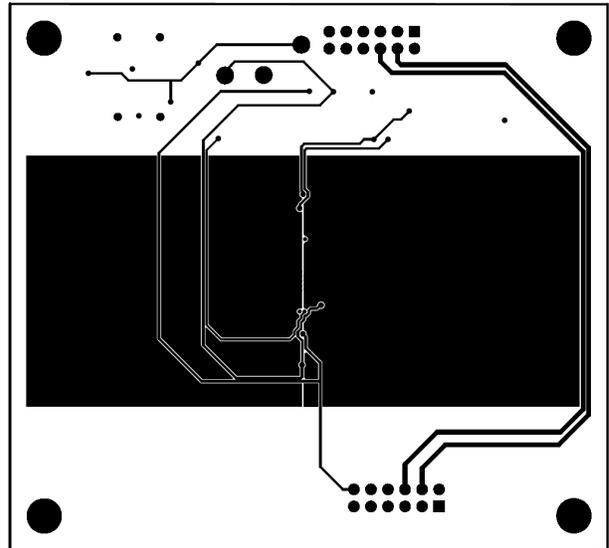


Figure 4-22. SENS108E1 Signal Layer 2

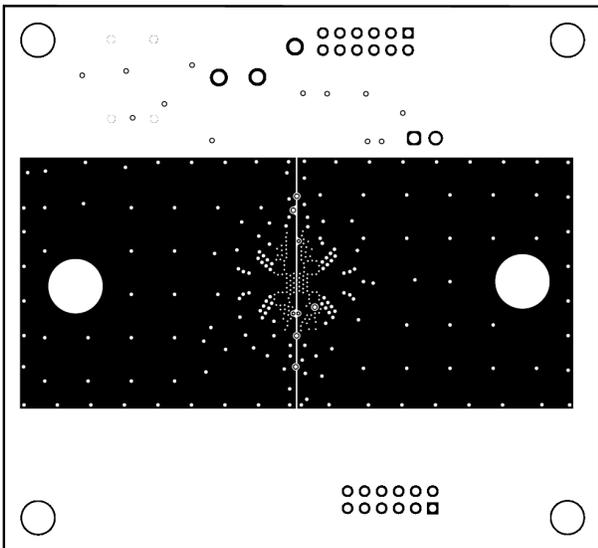


Figure 4-23. SENS108A Bottom Layer

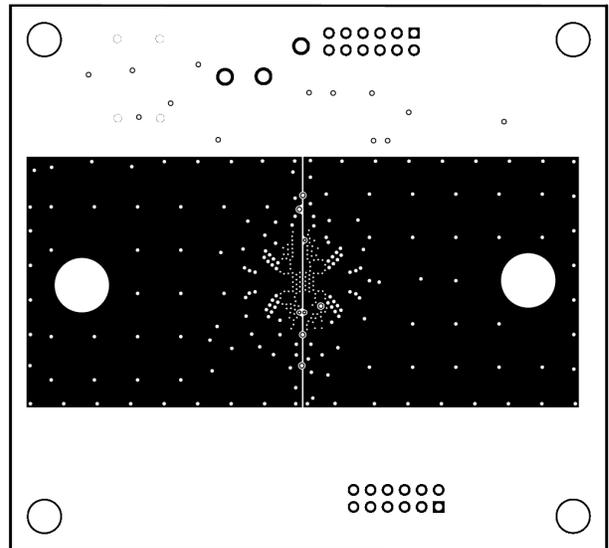


Figure 4-24. SENS108E1 Bottom Layer

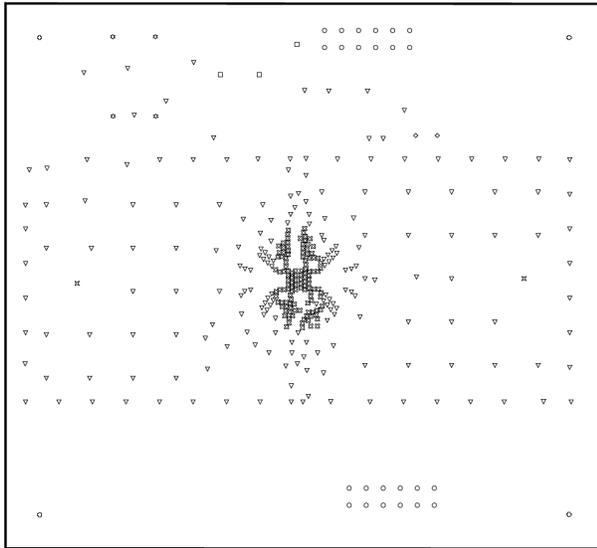


Figure 4-25. SENS108A Drill Drawing

Symbol	Count	Hole Size	Plated	Hole Type	Drill Layer Pair	Hole Tolerance
⊗	121	8.00mil (0.203mm)	PTH	Round	Top Layer - Bottom Layer	
▽	195	15.00mil (0.381mm)	PTH	Round	Top Layer - Bottom Layer	
○	24	31.50mil (0.800mm)	PTH	Round	Top Layer - Bottom Layer	
⊛	4	35.43mil (0.900mm)	NPTH	Round	Top Layer - Bottom Layer	
◇	2	45.28mil (1.150mm)	PTH	Round	Top Layer - Bottom Layer	
□	3	51.97mil (1.320mm)	PTH	Round	Top Layer - Bottom Layer	
⊕	4	145.00mil (3.683mm)	PTH	Round	Top Layer - Bottom Layer	
⊗	2	250.00mil (6.350mm)	PTH	Round	Top Layer - Bottom Layer	
■	2	267.00mil (6.782mm)	NPTH	Round	Top Layer - Bottom Layer	
	357 Total					

Figure 4-27. SENS108A Drill Table

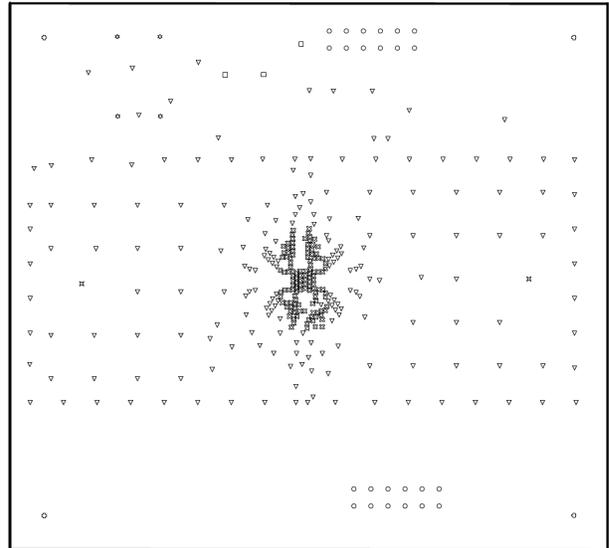


Figure 4-26. SENS108E1 Drill Drawing

Symbol	Count	Hole Size	Plated	Hole Type	Drill Layer Pair	Hole Tolerance
⊗	121	8.00mil (0.203mm)	PTH	Round	Top Layer - Bottom Layer	
▽	196	15.00mil (0.381mm)	PTH	Round	Top Layer - Bottom Layer	
○	24	31.50mil (0.800mm)	PTH	Round	Top Layer - Bottom Layer	
⊛	4	35.43mil (0.900mm)	NPTH	Round	Top Layer - Bottom Layer	
□	3	51.97mil (1.320mm)	PTH	Round	Top Layer - Bottom Layer	
⊕	4	145.00mil (3.683mm)	PTH	Round	Top Layer - Bottom Layer	
⊗	2	250.00mil (6.350mm)	PTH	Round	Top Layer - Bottom Layer	
	354 Total					

Figure 4-28. SENS108E1 Drill Table

4.2.2 SENS109 (INA745AEM, INA745BEVM, INA746EVM)

Figure 4-30 through Figure 4-44 illustrate the PCB layers of the EVM.

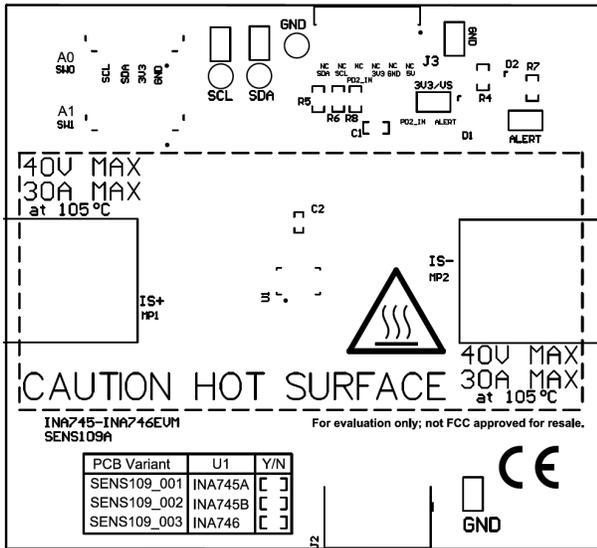


Figure 4-29. SENS109A Top Overlay

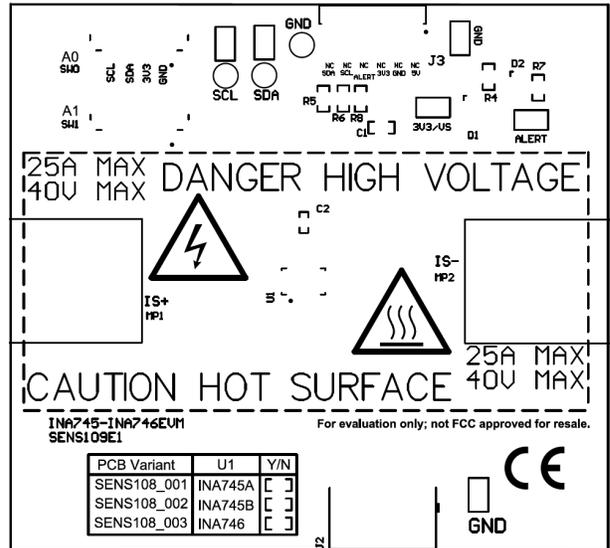


Figure 4-30. SENS109E1 Top Overlay

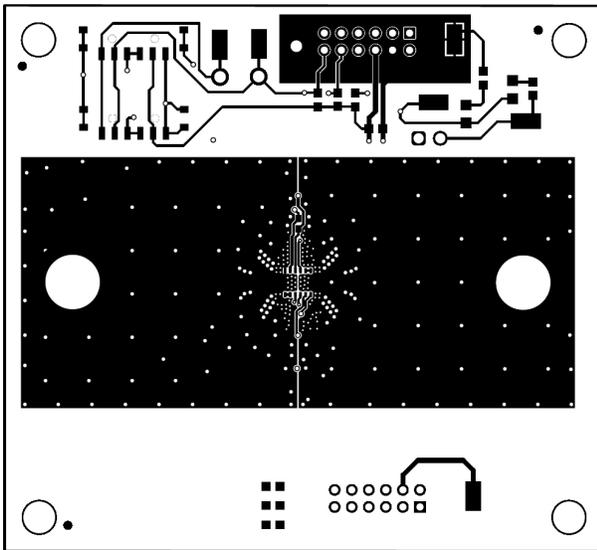


Figure 4-31. SENS109A Top Layer

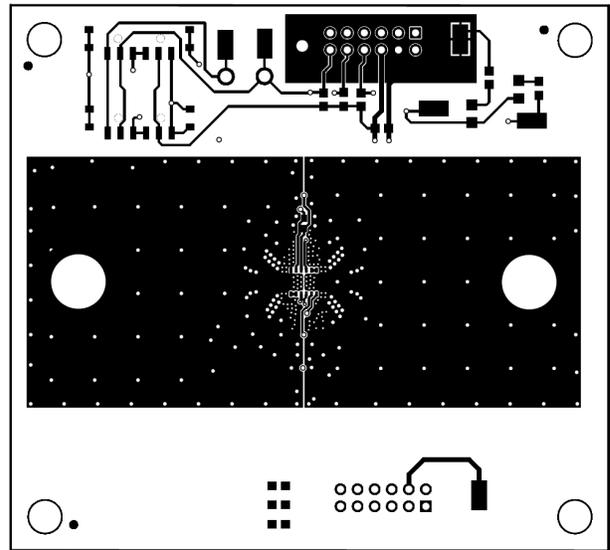


Figure 4-32. SENS109E1 Top Layer

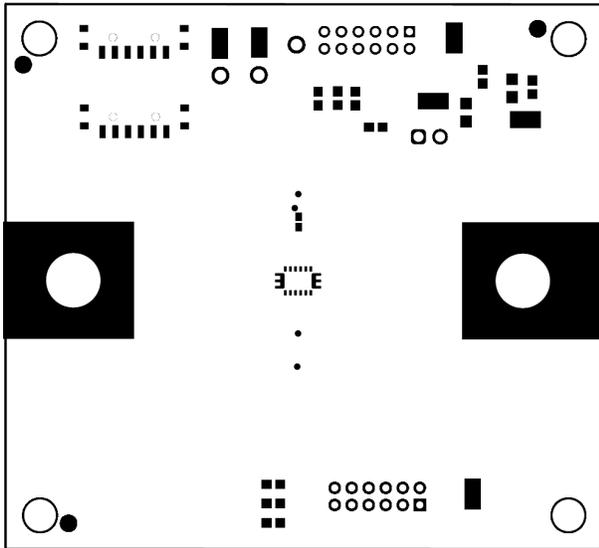


Figure 4-33. SENS109A Top Solder

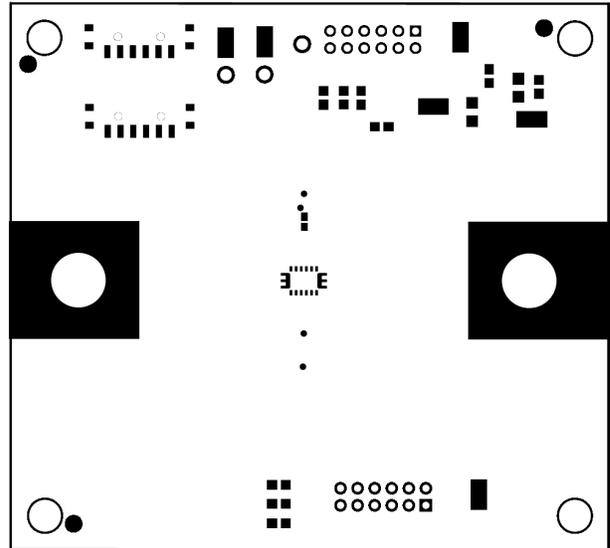


Figure 4-34. SENS109E1 Top Solder

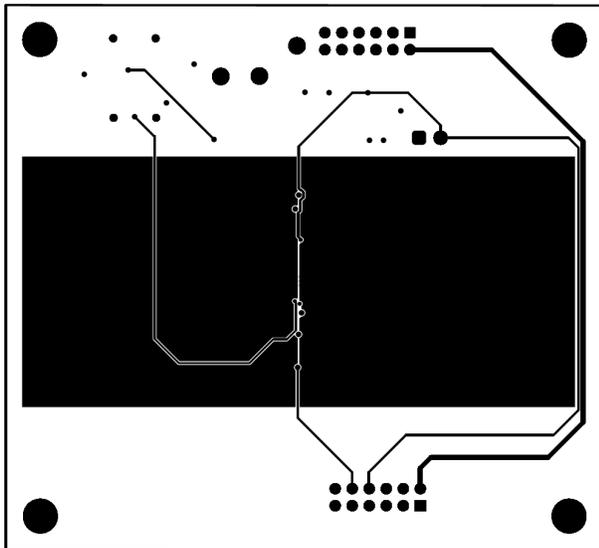


Figure 4-35. SENS109A Signal Layer 1

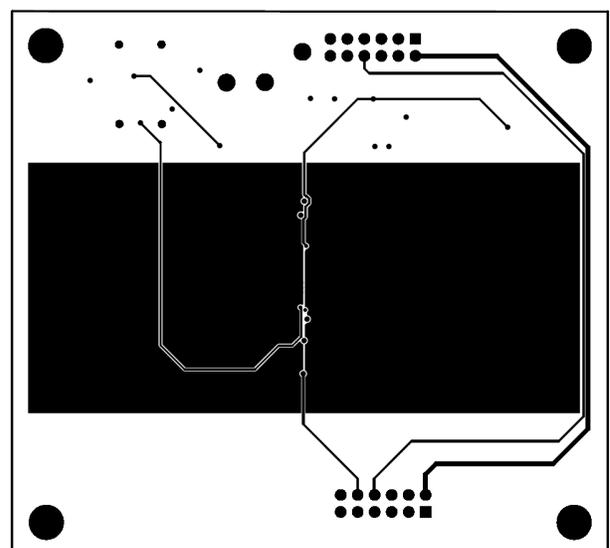


Figure 4-36. SENS109E1 Signal Layer 1

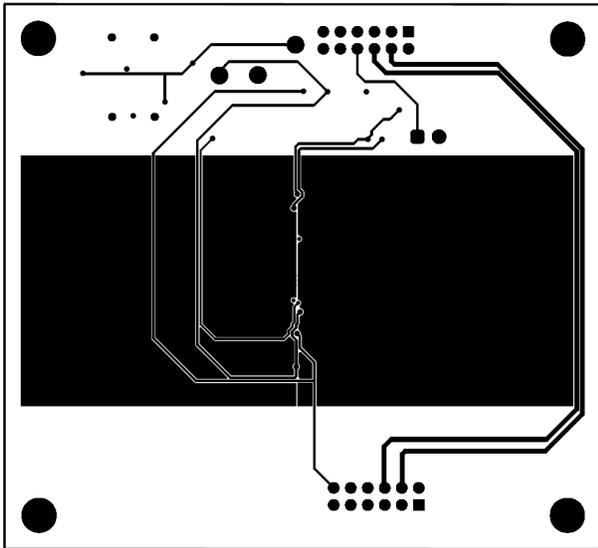


Figure 4-37. SENS109A Signal Layer 2

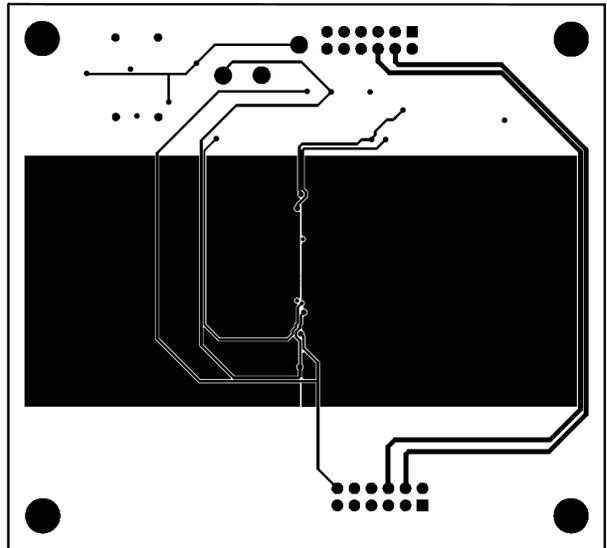


Figure 4-38. SENS109E1 Signal Layer 2

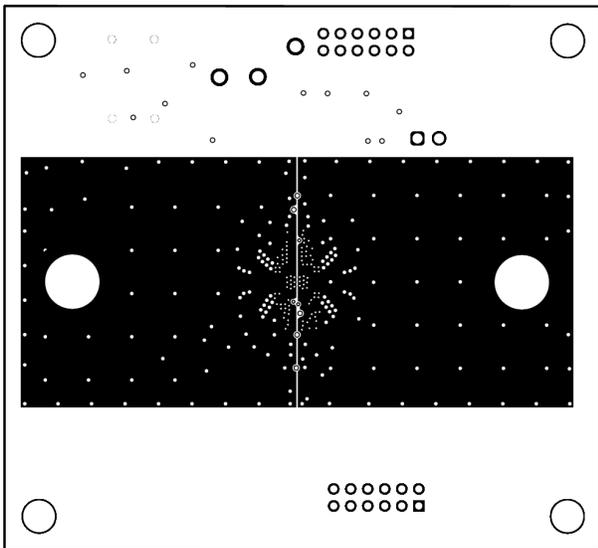


Figure 4-39. SENS109A Bottom Layer

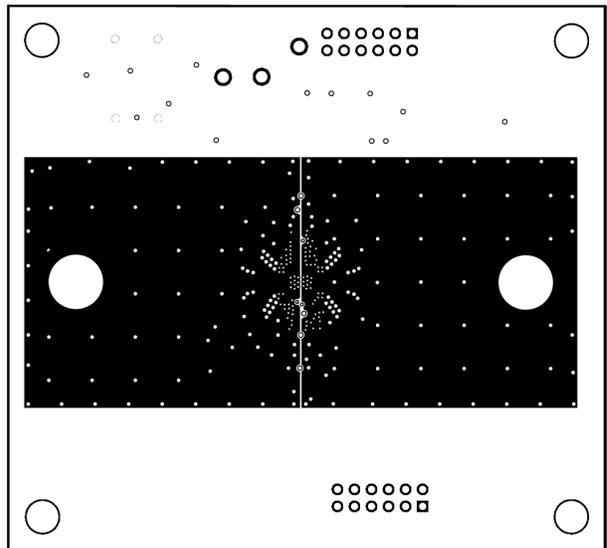


Figure 4-40. SENS109E1 Bottom Layer

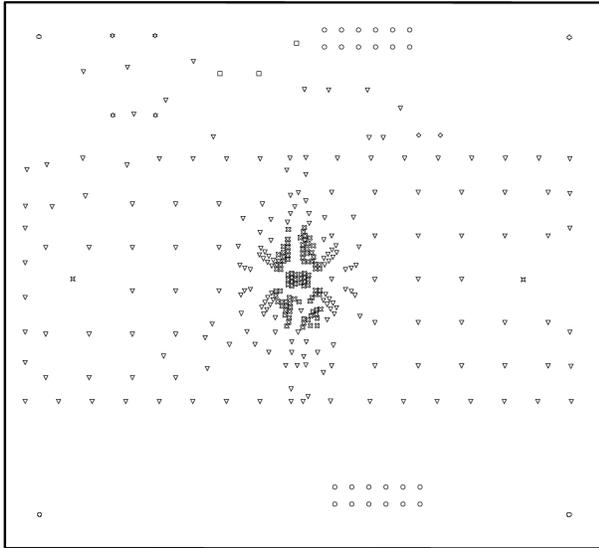


Figure 4-41. SENS109A Drill Drawing

Symbol	Count	Hole Size	Plated	Hole Type	Drill Layer Pair	Hole Tolerance
⊗	97	8.00mil (0.203mm)	PTH	Round	Top Layer - Bottom Layer	
▽	197	15.00mil (0.381mm)	PTH	Round	Top Layer - Bottom Layer	
○	24	31.50mil (0.800mm)	PTH	Round	Top Layer - Bottom Layer	
⊛	4	35.43mil (0.900mm)	NPTH	Round	Top Layer - Bottom Layer	
◇	2	45.28mil (1.150mm)	PTH	Round	Top Layer - Bottom Layer	
□	3	51.97mil (1.320mm)	PTH	Round	Top Layer - Bottom Layer	
⊗	4	145.00mil (3.683mm)	PTH	Round	Top Layer - Bottom Layer	
⊗	2	250.00mil (6.350mm)	PTH	Round	Top Layer - Bottom Layer	
■	2	267.00mil (6.782mm)	NPTH	Round	Top Layer - Bottom Layer	
	335 Total					

Figure 4-43. SENS109A Drill Table

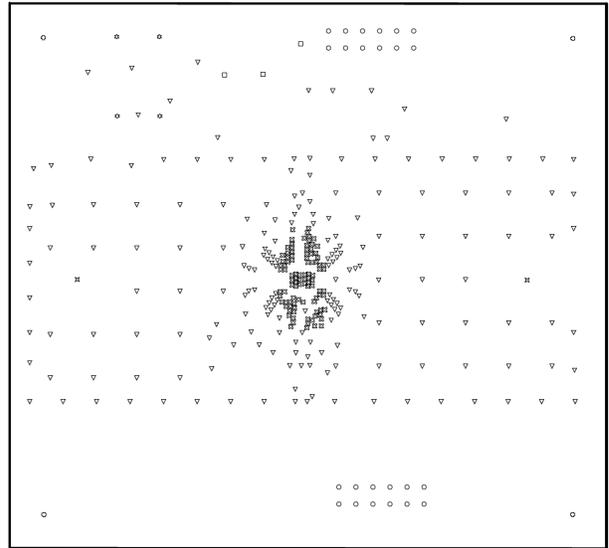


Figure 4-42. SENS109E1 Drill Drawing

Symbol	Count	Hole Size	Plated	Hole Type	Drill Layer Pair	Hole Tolerance
⊗	97	8.00mil (0.203mm)	PTH	Round	Top Layer - Bottom Layer	
▽	197	15.00mil (0.381mm)	PTH	Round	Top Layer - Bottom Layer	
○	24	31.50mil (0.800mm)	PTH	Round	Top Layer - Bottom Layer	
⊛	4	35.43mil (0.900mm)	NPTH	Round	Top Layer - Bottom Layer	
□	3	51.97mil (1.320mm)	PTH	Round	Top Layer - Bottom Layer	
⊗	4	145.00mil (3.683mm)	PTH	Round	Top Layer - Bottom Layer	
⊗	2	250.00mil (6.350mm)	PTH	Round	Top Layer - Bottom Layer	
	331 Total					

Figure 4-44. SENS109E1 Drill Table

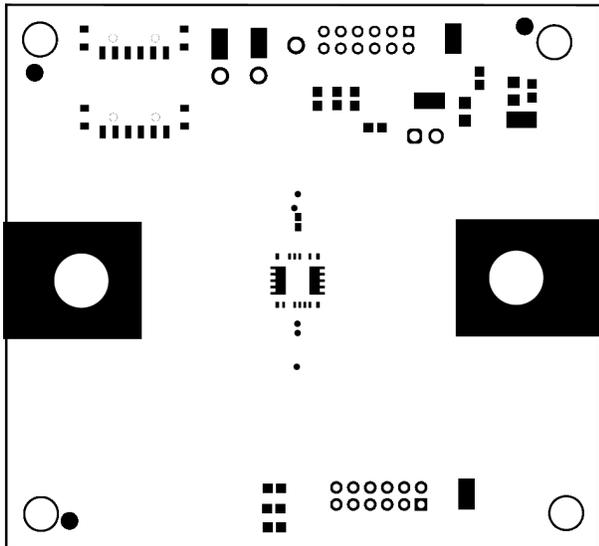


Figure 4-49. SENS119A Top Solder

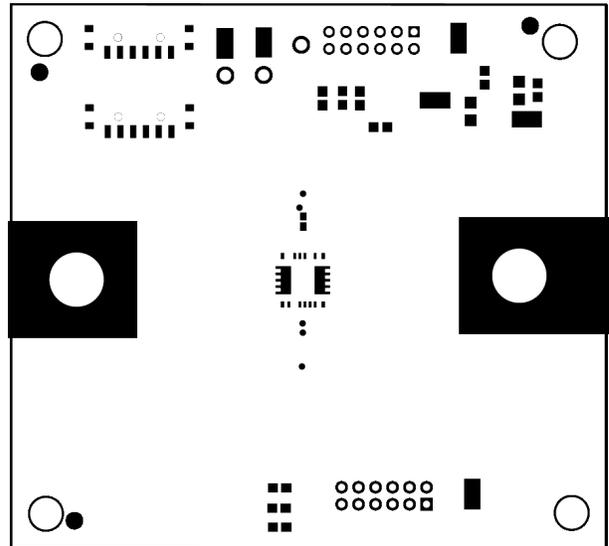


Figure 4-50. SENS119E1 Top Solder

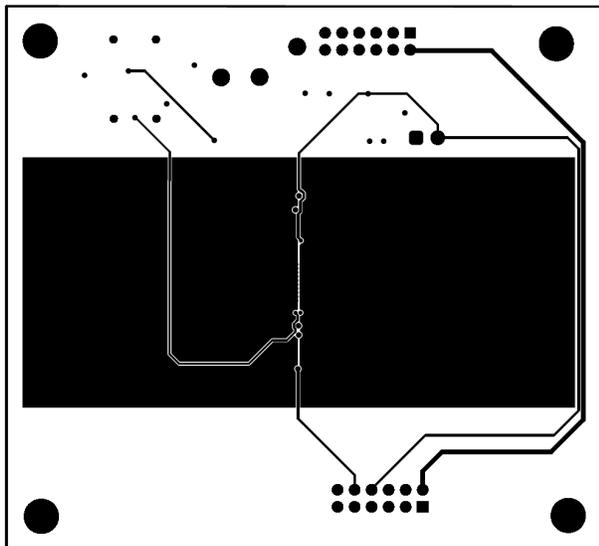


Figure 4-51. SENS119A Signal Layer 1

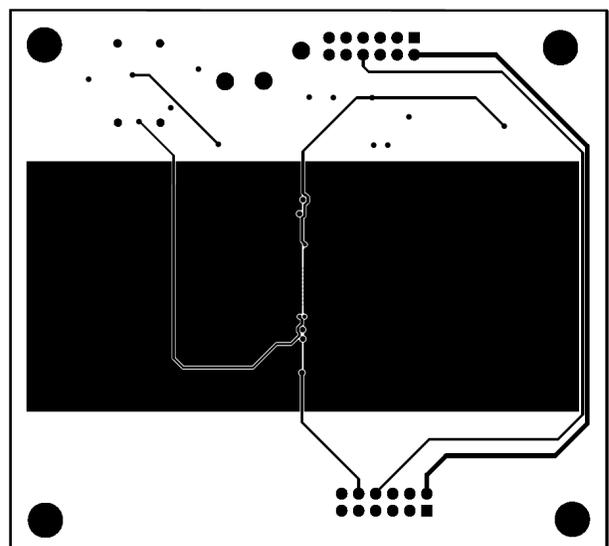


Figure 4-52. SENS119E1 Signal Layer 1

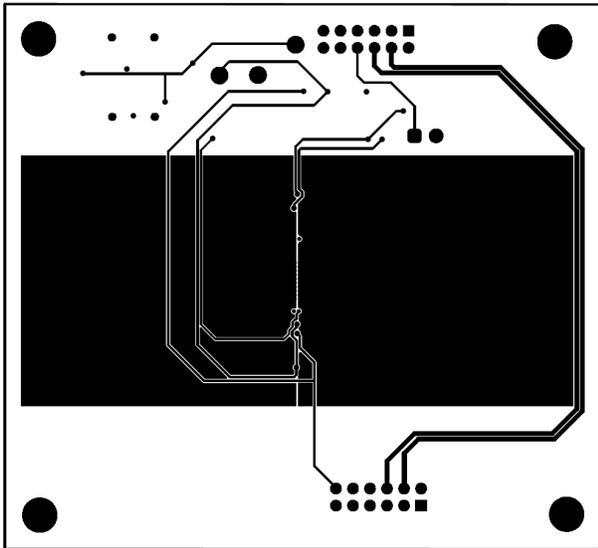


Figure 4-53. SENS119A Signal Layer 2

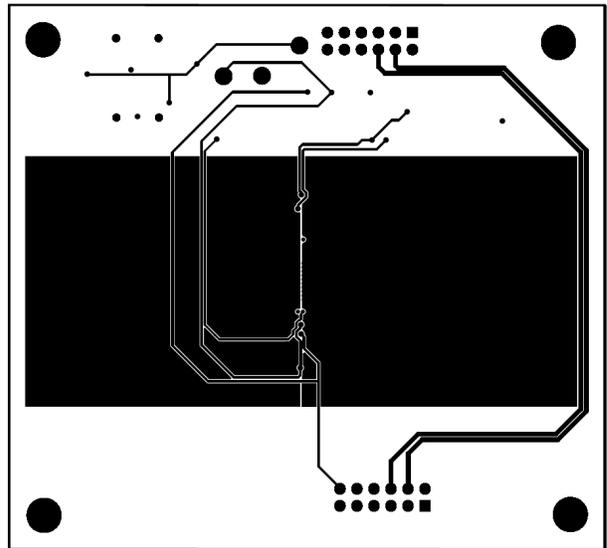


Figure 4-54. SENS119E1 Signal Layer 2

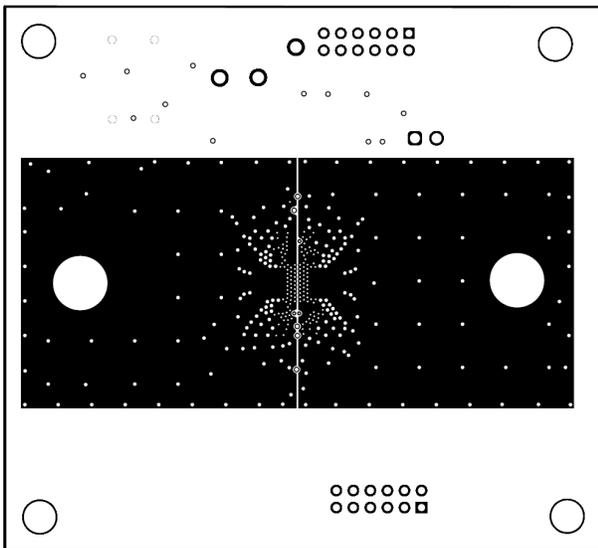


Figure 4-55. SENS119A Bottom Layer

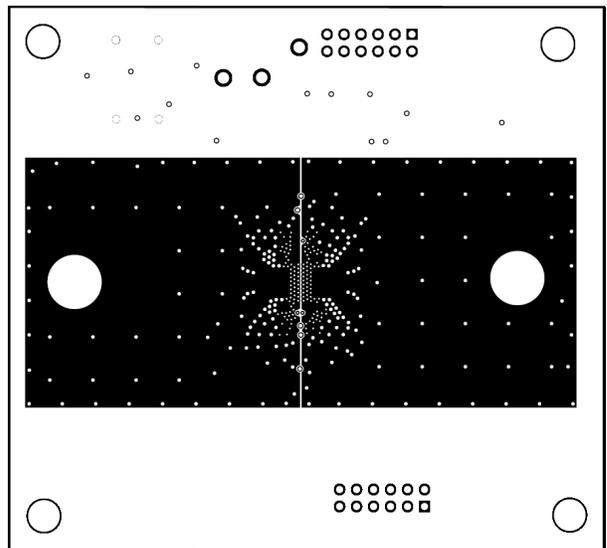


Figure 4-56. SENS119E1 Bottom Layer

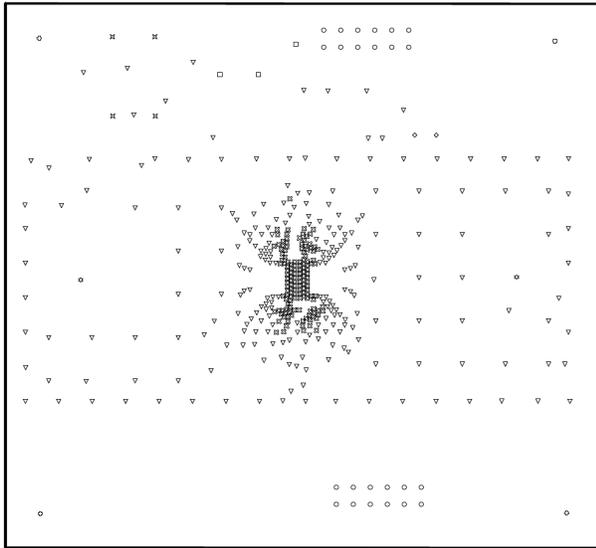


Figure 4-57. SENS119A Drill Drawing

Symbol	Count	Hole Size	Plated	Hole Type	Drill Layer Pair	Hole Tolerance
⊠	140	8.00mil (0.203mm)	PTH	Round	Top Layer - Bottom Layer	
▽	234	15.00mil (0.381mm)	PTH	Round	Top Layer - Bottom Layer	
○	24	31.50mil (0.800mm)	PTH	Round	Top Layer - Bottom Layer	
⊗	4	35.43mil (0.900mm)	NPTH	Round	Top Layer - Bottom Layer	
◇	2	45.28mil (1.150mm)	PTH	Round	Top Layer - Bottom Layer	
□	3	51.97mil (1.320mm)	PTH	Round	Top Layer - Bottom Layer	
⊛	4	145.00mil (3.683mm)	PTH	Round	Top Layer - Bottom Layer	
⊚	2	250.00mil (6.350mm)	PTH	Round	Top Layer - Bottom Layer	
■	2	267.00mil (6.782mm)	NPTH	Round	Top Layer - Bottom Layer	
	415 Total					

Figure 4-59. SENS119A Drill Table

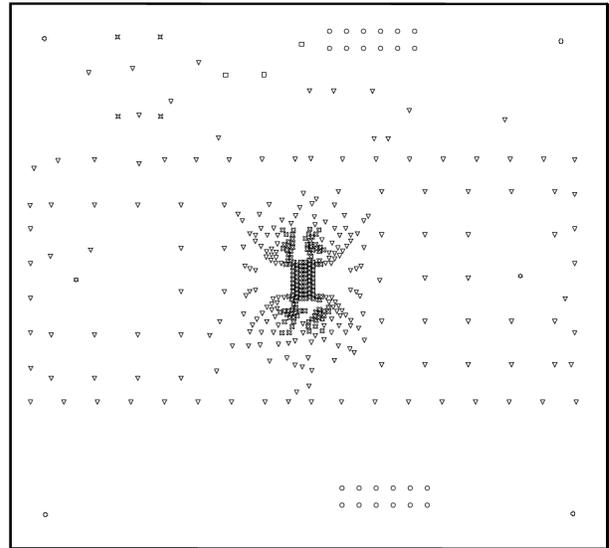


Figure 4-58. SENS119E1 Drill Drawing

Symbol	Count	Hole Size	Plated	Hole Type	Drill Layer Pair	Hole Tolerance
⊠	139	8.00mil (0.203mm)	PTH	Round	Top Layer - Bottom Layer	
▽	235	15.00mil (0.381mm)	PTH	Round	Top Layer - Bottom Layer	
○	24	31.50mil (0.800mm)	PTH	Round	Top Layer - Bottom Layer	
⊗	4	35.43mil (0.900mm)	NPTH	Round	Top Layer - Bottom Layer	
□	3	51.97mil (1.320mm)	PTH	Round	Top Layer - Bottom Layer	
⊛	4	145.00mil (3.683mm)	PTH	Round	Top Layer - Bottom Layer	
⊚	2	250.00mil (6.350mm)	PTH	Round	Top Layer - Bottom Layer	
	411 Total					

Figure 4-60. SENS119E1 Drill Table

4.3 Bill of Materials

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

Note that the E1 Version EVM does not include J4 and MP1 through MP6.

Note that the INA740BEVM Version A (SENS108A-002) does not have INA740B populated.

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

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

Table 4-2. INA740BEVM (SENS108-002) Exclusive Bill of Materials

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
U1	0		85-V, Integrated Sense Element, 16-Bit, Precision Power/Energy/Charge Monitor With I 2C Interface	QFN14	INA740BIREMR	Texas Instruments
R740B	1	4.7k	RES, 4.7 k, 5%, 0.1 W, 0603	603	CRCW06034K70JNEA	Vishay-Dale

Table 4-3. INA741EVM (SENS108-003) Exclusive Bill of Materials

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
U1	1		85-V, Integrated Sense Element, 20-Bit, Precision Power/Energy/Charge Monitor With I 2C Interface	QFN14	INA741AIREMR	Texas Instruments
R741	1	4.7k	RES, 4.7 k, 5%, 0.1 W, 0603	603	CRCW06034K70JNEA	Vishay-Dale

Table 4-4. INA745AEVM (SENS109-001) Exclusive Bill of Materials

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
U1	1		40-V, Integrated Sense Element, 16-Bit, Precision Power/Energy/Charge Monitor With I 2C Interface	QFN14	INA745AIRELR	Texas Instruments
R745A	1	4.7k	RES, 4.7 k, 5%, 0.1 W, 0603	603	CRCW06034K70JNEA	Vishay-Dale

Table 4-5. INA745BEVM (SENS109-002) Exclusive Bill of Materials

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
U1	1		40-V, Integrated Sense Element, 16-Bit, Precision Power/Energy/Charge Monitor With I 2C Interface	QFN14	INA745BIRELR	Texas Instruments
R745B	1	4.7k	RES, 4.7 k, 5%, 0.1 W, 0603	603	CRCW06034K70JNEA	Vishay-Dale

Table 4-6. INA746EVM (SENS109-003) Exclusive Bill of Materials

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
U1	1		40-V, Integrated Sense Element, 20-Bit, Precision Power/Energy/Charge Monitor With I 2C Interface	QFN14	INA746AIRELR	Texas Instruments
R746	1	4.7k	RES, 4.7 k, 5%, 0.1 W, 0603	603	CRCW06034K70JNEA	Vishay-Dale

Table 4-7. INA780AEVM (SENS119-001) Exclusive Bill of Materials

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
U1	1		85-V, Integrated Sense Element, 16-Bit, Precision Power/Energy/Charge Monitor With I 2C Interface	WSON15	INA780AIDEKR	Texas Instruments
R780A	1	4.7k	RES, 4.7 k, 5%, 0.1 W, 0603	603	CRCW06034K70JNEA	Vishay-Dale

Table 4-8. INA780BEVM (SENS119-002) Exclusive Bill of Materials

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
U1	1		85-V, Integrated Sense Element, 16-Bit, Precision Power/Energy/Charge Monitor With I 2C Interface	WSON15	INA780BIDEKR	Texas Instruments
R780B	1	4.7k	RES, 4.7 k, 5%, 0.1 W, 0603	603	CRCW06034K70JNEA	Vishay-Dale

Table 4-9. INA781EVM (SENS119-003) Exclusive Bill of Materials

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
U1	1		85-V, Integrated Sense Element, 20-Bit, Precision Power/Energy/Charge Monitor With I 2C Interface	WSON15	INA781AIDEKR	Texas Instruments
R781	1	4.7k	RES, 4.7 k, 5%, 0.1 W, 0603	603	CRCW06034K70JNEA	Vishay-Dale

Table 4-10. SENS108A, SENS109A, SENS119A Variants Bill of Materials

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
C2	1	0.1uF	CAP, CERM, 0.1 uF, 50 V, +/- 20%, X7R, 0402	0402	GRM155R71H104ME14D	MuRata
D1, D2	2	White	LED, White, SMD	0805	VAOL-S8WR4	Visual Communications Company, LLC
H1, H2, H3, H4	4		Bumpon, Hemisphere, 0.375 X 0.235, Black	Black Bumpon	SJ61A2	3M
J2	1		Receptacle, 2 mm, 6x2, Gold, R/A, TH	Receptacle, 2 mm, 6x2, R/A, TH	NPPN062FJFN-RC	Sullins Connector Solutions
J3	1		Connector Header Through Hole, Right Angle 12 position 0.079" (2.00mm)	HDR12	NRPN062PARN-RC	Sullins Connector Solutions
J4	1		Header, 2.54 mm, 2x1, Gold, TH	Header, 2.54mm, 2x1, TH	61300211121	Würth Elektronik
MP1, MP2	2		Terminal Connector Rectangular Lug, 1/4 Stud	TERMINAL_CONN	CB70-14-CY	Panduit
MP3, MP4	2		Medium-Strength Steel Hex Nut	NUT_1-4-20	95462A029	McMASTER-CARR
MP5, MP6	2		Pan Head Phillips Screw 1/4"-20, 3/8" Long		91735A535	McMASTER-CARR
R4, R7	2	10k	RES, 10 k, 5%, 0.1 W, 0603	0603	CRCW060310K0JNEA	Vishay-Dale
R5, R6, R8	3	4.7k	RES, 4.7 k, 5%, 0.1 W, 0603	0603	CRCW06034K70JNEA	Vishay-Dale

Table 4-10. SENS108A, SENS109A, SENS119A Variants Bill of Materials (continued)

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
SW0, SW1	2		Slide Switch SP4T Surface Mount, Right Angle	SMT_SW_11MM3_4MM1	CUS-14TB	Nidec Copal Electronics
TP3, TP4, TP5, TP7, TP8, TP11	6		Test Point, Miniature, SMT	Testpoint_Keystone_Miniatur e	5015	Keystone
C1	0	1uF	CAP, CERM, 1 uF, 50 V, +/- 10%, X6S, 0603	0603	C1608X6S1H105K080AC	TDK
FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
J1, J6, J7	0		CONN PIN RCPT .018-.021 SOLDERPIN_RCPT	PIN_RCPT	3-331272-8	TE Connectivity

5 Additional Information

5.1 Trademarks

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6 Related Documentation

This user's guide is available from the TI website under literature number [SBOU302](#). Any letter appended to the literature number corresponds to the document revision that is current at the time of the writing of this document. Newer revisions are available from www.ti.com or the Texas Instruments' Literature Response Center at (800) 477-8924 or the Product Information Center at (972) 644-5580. When ordering, identify the document by both title and literature number. [Table 6-1](#) lists documentation related to the EVM. Click the links in [Table 6-1](#) for further information. The device name links to the product web folder on www.ti.com. The literature number links to the document PDF.

Table 6-1. Related Documentation

DOCUMENT TITLE	DOCUMENT LITERATURE NUMBER
INA740 data sheet	SBOSAC1
INA741 data sheet	SBOSAC2
INA745 data sheet	SBOSAC3
INA746 data sheet	SBOSAC4
INA780 data sheet	SBOSAB6
INA781 data sheet	SBOSAC0

7 Revision History

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

Changes from Revision * (June 2023) to Revision A (December 2023)	Page
• Added bullet point to <i>Features</i>	1
• Updated board image.....	1
• Added information throughout document highlighting differences between the two EVM versions.....	2
• Updated schematics.....	17
• Updated PCB layout images.....	27
• Updated <i>Bill of Materials</i> tables	39

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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.
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 - 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.
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 - 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/lstds/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.

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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lstds/ti_ja/general/eStore/notice_02.page

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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.
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 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.
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 - 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.
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8. *Limitations on Damages and Liability:*

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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.

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