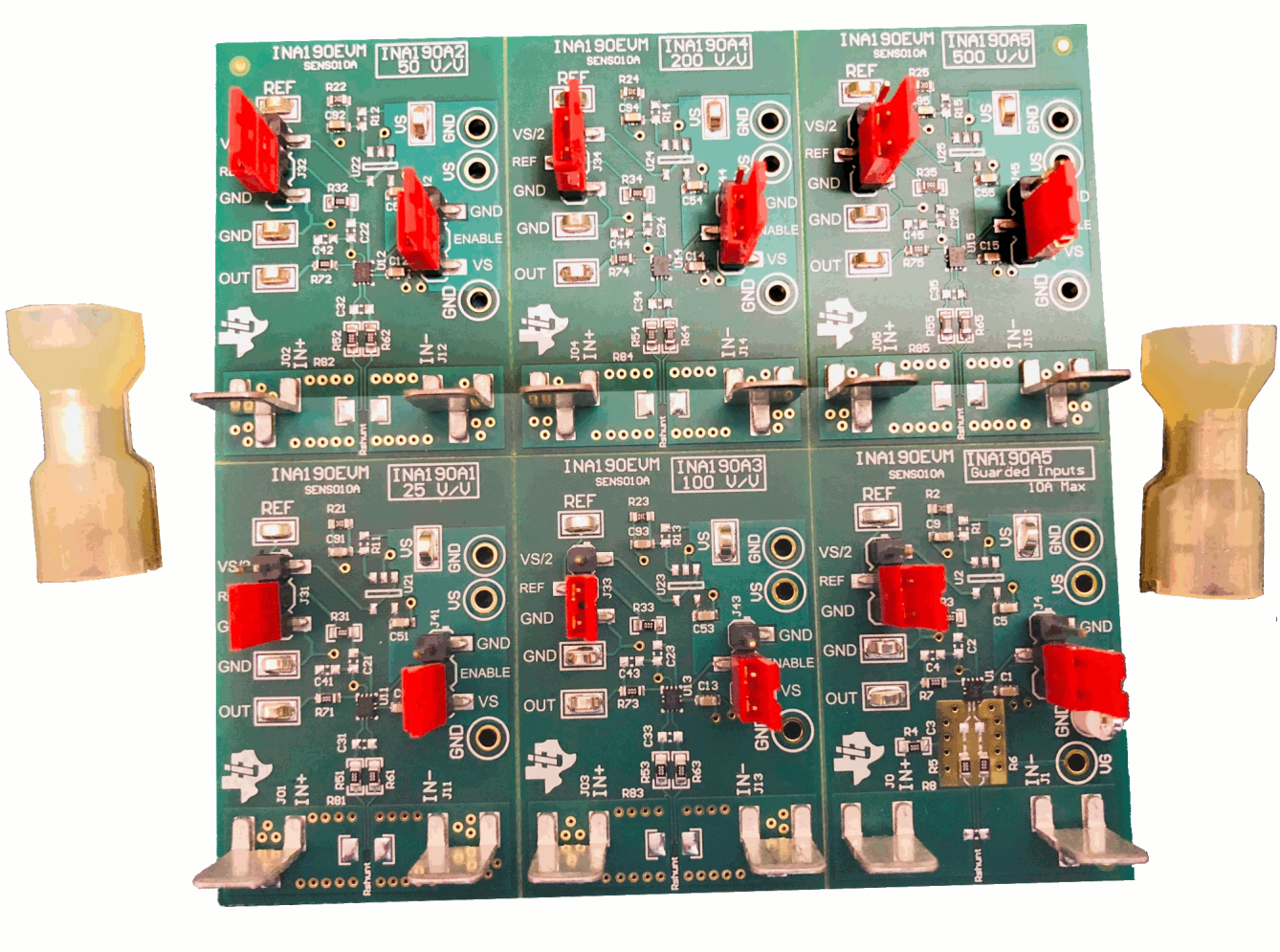
INA190EVM User's Guide



This user's guide describes the characteristics, operation, and use of the INA190 evaluation module (EVM). This EVM is designed to evaluate the performance of the INA190 voltage-output, current shunt monitor in a variety of configurations. This document also includes a schematic, reference printed-circuit board (PCB) layouts, and a complete bill of materials (BOM).

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1 Overview

The INA190 devices are voltage output, high- and low-side measurement, bi-directional, zero-drift current shunt monitors. This family of devices has gains that range from 25 V/V to 500 V/V. The voltage developed across the device inputs is amplified by the corresponding gain of the specific device and is presented at the output pin. These devices can accurately sense voltage drops across shunts at common-mode voltages from –0.1 V to 40 V, independent of supply voltages. These devices operate with supply voltages between 2.7 V and 5.5 V and draw a maximum of 65 µA at room temperature. The low offset of the zero-drift architecture enables the sensing of very small differential input voltage which helps widen the usable input dynamic range. Additionally, the INA190 has a very low input bias current and thus, can easily measure microamps of current.

The INA190 devices are currently available in a QFN package. Table 1 summarizes the available device gain options.

Table 1. INA190 Device Summary

Product	Gain
INA190A1	25
INA190A2	50
INA190A3	100
INA190A4	200
INA190A5	500

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1.1 INA190 Kit Contents

Table 2 summarizes the contents of the INA190EVM kit. Contact the Texas Instruments Product Information Center nearest you if any component is missing. TI also recommends checking the INA190 device product folder at www.ti.com for any further information regarding this product.

Table 2. INA190EVM Kit Contents

Item	Item Part Number	Quantity
INA190EVM test board	SENS010	1
Quick Connect Receptacle 10-12AWG, 0.250"	4-520448-2	2
Shunt Connector 2POS	2-881545-2	12

1.2 Related Documentation From Texas Instruments

This document provides information regarding Texas Instruments' integrated circuits used in the assembly of the INA190EVM.

Table 3. Related Documentation

Document	Literature Number
INA190 product data sheet	SBOS863

2 INA190EVM Hardware

The INA190EVM is intended to provide basic functional evaluation of the INA190 device family. The fixture layout is not intended to be a model for the target circuit, nor is it laid out for electromagnetic compatibility (EMC) testing. The INA190EVM consists of one PCB with an option to cut out six individual PCBs, one for each of the five gain variants (INA190A1, INA190A2, INA190A3, INA190A4, and INA190A5). Each of the PCB cutouts consists of one INA190AXIRSW device (where x is 1, 2, 3, 4, and 5) and test points for external hardware connections, as well as pads to solder down optional circuitry. A sixth board includes a guarding scheme to guard the input traces thus, preventing leakage current. This board has the INA190A5 as the installed test device.

2.1 Features

The INA190EVM PCB provides the following features:

- Evaluation of all gain options through provided device boards
- Ease of access to device pins with test points
- Pads for optional filtering at the input pins, output pin, and reference pin
- Pads for optional reference buffer driving circuit with SOT-23-5 op amp
- Multiple input signal options including a method to solder the shunt resistor and safely measure current up to 15 A
- Low-current measurement panel with a voltage guarding plane to minimize leakage currents

Refer to *INA190 Low Supply, Voltage Output, Low- or High-Side Measurement, Bidirectional, Zero-Drift Series, Current-Shunt Monitors* for comprehensive information about the INA190 family of devices.

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3 Quick Start Setup and Use

Follow these procedures to set up and use one of the panels of the INA190EVM. For the following instructions, x = 1, 2, 3, 4, 5, or [blank].

Step 1. Choose the desired gain option panel.

Step 2. Ensure the J3x and J4x headers for the enable (EN) and reference (VREF) pins are set to the appropriate voltages. For the device to amplify the input signal, it must be enabled by connecting the VS and ENABLE pins of J4x. For the device to have a ground reference, the REF and GND pins for J3x must be connected. If a custom reference voltage is desired, remove the jumper from J3x and drive the REF pin with an external voltage source.

Step 3. Connect an external DC supply voltage between 1.7 V and 5.5 V to a VS test point (TP1x or TP3x), and connect the ground reference of that supply to a GND test point (TP2x,TP4x, TP8x) on same panel.

Step 4. Provide an input voltage signal (referenced to GND) to the IN+ and IN– pins by connecting signal leads to J0x and J1x quick-fit tabs. This is explained in Section 3.1.

3.1 Measurements

The INA190EVM allows the user to either simulate the voltage developed across a sense resistor based on a given set of system conditions, or to connect it remotely to an existing shunt already included in an example application. Additionally, a surface-mount technology (SMT) shunt resistor can be soldered across the IN+ and IN– pads these inputs can be connected in-series with their system and load.

To configure a measurement evaluation without a shunt resistor, follow these procedures:

1. Connect a differential voltage to the IN+ (J0x) and IN– (J1x) tabs. With the reference voltage set at ground, ensure that the IN+ pin is the more positive of the two inputs.
2. Additionally, if the differential voltage supply is a floating supply, connect a –0.1-V to 40-V common-mode voltage to the inputs by connecting the positive lead of the external voltage source to the IN– (J1x) tab and source ground to a GND testpoint. This effectively raises the absolute voltage of the input pins, while still retaining a positive input differential signal.
3. Measure the output voltage at the OUT test point (TP5x).

To configure a measurement evaluation with a shunt resistor, follow these procedures:

1. Solder down a resistor at the R8x pad that connects the IN+ (J0x) and IN– (J1x) inputs.
2. Connect the IN+ (J0x) and IN– (J1x) tabs in series with the load and bus voltage sources while powered off.

WARNING

If measuring current, please first ensure the equipment (shunt resistor, wires, connectors, and so forth) being used can support the amperage and power dissipation. Secondly, ensure the current flowing through J0x and J1x does not exceed 15 A. If using the "Guarded Inputs" panel, ensure current flowing between J0 and J1 does not exceed 10 A. Failure to do any of this could result in hot surfaces (> 55°C), damage to the EVM, or personal injury.

3. Power on the system and measure the output voltage at the OUT test point (TP5x).

NOTE: The output voltage (if measured with respect to reference voltage) is equal to the gain of the device multiplied by the differential voltage measured directly at the device input pins.

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4 INA190EVM Circuit and Components

This section summarizes the INA190EVM components. For the following instructions, x = 1 to 5 or a [blank].

4.1 R5x, R6x, R7x, R3x,C2x, C3x, C4x, C9x

R5x, R6x, R7x, and R3x are factory-installed 0-Ω resistors. C2x, C3x, C4x, and C9x are not populated except for C9x. Collectively, these pads allow for user-defined filters for the input, reference signal, and output. If a filter is desired, remove these resistors and replace them with > 0-Ω SMT resistors and populate the capacitor pads with capacitors. Additional information regarding the use of input filtering is provided in *INA190 Low Supply, Voltage Output, Low- or High-Side Measurement, Bidirectional, Zero-Drift Series, Current-Shunt Monitors*.

4.2 C1x, C5x

C1x and C5x are 0.1-µF power supply bypass capacitors.

4.3 R1x, R2x

R1x and R2x are resistors used to divide down VS supply voltage and drive a custom, on-board reference voltage into U2x if R2x and U2x are populated.

4.4 R4

R4 is a connection resistor for the "Guarded Inputs" panel. Populate this with a 0-Ω resistor to connect the guarding plane to automatically be driven to the same voltage as the input common-mode voltage. This may only be necessary if measuring very small currents at high common-mode voltages.

4.5 R8x

R8x is unpopulated, but allows a surface-mount shunt resistor to be soldered down in between the IN+ and IN– inputs. If used, ensure R8x has proper power dissipation for the user-set current load. This resistor chosen must at a minimum have a 0603 Imperial footprint.

4.6 U1x - INA190

U1x is the location for the INA190x test device. Six device boards are supplied with the INA190EVM board. Each board is populated with one of the available device gains. This option allows users to test the devices and determine the gain setting that is best suited for a given application.

The following list of factors are involved in selecting the appropriate device:

- The INA190 devices are identical with the exception of different gain settings.
- The differential input voltage is either applied across the inputs or developed based on the load current that flows through the shunt resistor.
- The limiting factor that requires attention to be given to device selection is the output voltage not exceeding the supply voltage or going below GND.
- The selected device must allow the output voltage to remain within the acceptable range after the developed input voltage is amplified by the respective device gain. The output voltage must remain with the swing limitations specified for the device for response in the linear range.
- An output below the minimum allowable output requires the selection of a device with a higher gain. Likewise, an output above the maximum allowable output requires the selection of a device with a lower gain.

4.7 U2x

U2x is not populated, but allows a SOT-23-5 operational amplifier to be soldered to the EVM. In conjunction with populating R1x and R2x with the desired ratio of resistances, U2x provides a low-impedance voltage source for the REF pin of the INA190. Two options to populate this pad are TLV6001IDBVR and TLV379IDBV.

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4.8 J0x, J1x

J0x and J1x are 0.240 inch non-insulated, quick-fit terminals that are designed to insert into similarly-sized female receptacles. The kit provides two receptacles. Using insulated receptacles with J0x and J1x terminals allows the user to ensure a strong and safe connection between the current source and EVM when dealing with high currents.

WARNING

If using the EVM to measure currents, ensure a proper power resistor is soldered at the R8x pad and the receptacles (connecting to J0x and J1x) and their crimped wires can support the amperage of the current being measured and the necessary power dissipation. Do not exceed 15 A of current flowing between J0x and J1x. If using the "Guarded Inputs" panel, ensure current flowing from J0 to J1 does not exceed 10 A. Failure to do any of this could result in hot surfaces (> 55°C), damage to the EVM, or personal injury.

Standard metal clips can electrically interface with these tabs for lower currents.

The IN+ (J0x) and IN– (J1x) inputs accept a differential voltage that is amplified by the selected device gain and is presented at the OUT test point (TP5x). These inputs could also be used to connect the differential voltage developed across an external shunt in an existing circuit. The acceptable differential input voltage range and polarity are determined by the supply voltage, reference voltage, and gain of the selected device.

5 Reference Voltage Setup

The INA190 devices allow for the use of an external reference through the REF pin. The INA190EVM provides a test point to drive the REF pin externally or pads to solder a buffer amplifier to drive a custom voltage generated from the resistor divider off the VS power plane. The reference determines what offset the output will have and allows these devices to be used in both unidirectional and bi-directional current sensing applications.

5.1 Unidirectional Mode

Unidirectional refers to a load current that flows in only one direction. For unidirectional applications, the reference voltage can be set to ground or to 5 V. If the reference is set to ground, the output is set at near ground with no input voltage, and responds to input voltages that are positive with respect to IN– / Load. If the reference is set to 5 V, the output is set near 5 V with no input voltage, and responds to input voltages that are negative with respect to IN– / Load.

5.2 Bi-Directional Mode

Bi-directional refers to a load current that flows in both directions. For bi-directional applications, the reference voltage should be set anywhere within the GND to VS range. The voltage applied to the reference pin establishes the output voltage of the device with no input voltage. The output voltage is limited by the supply voltage minus the specified output swing to VS in the data sheet.

5.3 REF Pin Configuration

The REF test point (TP6x) allows configuration of the INA190EVM for either unidirectional or bi-directional operation. The INA190EVM has an onboard circuit that allows the supply of a custom reference voltage that is powered through the supply voltage.

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5.3.1 U2x Buffer Not Populated

Jump pins 2 (REF) and 3 (GND) of the J3x header to make REF = GND. The jumper can be removed from the EVM and the REF test points (TP6x or pin 2 of J3x) can be driven with the external voltage source. Note this external source needs a common ground with the INA190 power source.

5.3.2 U2x Buffer Populated

Be sure to populate R2x. If R2x equals R1x, then the U2x buffer output will equal VS/2. Jump pins 2 (REF) and 1 (VS/2) of the J3x header to drive the REF pin with the output of U2x.

6 Guarding Voltage - Using the "Guarded Inputs" Panel

One panel on the INA190EVM is labeled as "Guarded Inputs" because it includes extra circuitry to help guard the input traces going into the IN+ and IN– pins of the INA190. When measuring a small current, it is desirable to minimize the input bias currents of the device, which is in the nanoamps. The input bias current could increase due to leakage currents sinking into a nearby ground plane and this is simply due to finite resistance of PCB material and a voltage potential. This voltage potential only grows as common-mode voltage increases. Guard the input traces with an isolated guarding plane and fence that is at the same potential and any leakage currents from the input traces will be significantly reduced. This technique is really more practical when dealing with currents in the picoamps level, but it is included to help evaluate any extreme cases: low-current or high common-mode voltage or both.

The guarding plane can be driven by an external voltage source using the VG tespoint (TP7) or by populating R4 with a 0-Ω resistor, which will automatically tie common-mode voltage at the inputs to the guarding plane. If using the VG tespoint, ensure the external source has a common ground with the INA190.

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7 INA190EVM Schematic and PCB Layout

NOTE: Board layouts are not to scale. These figures are intended to show how the board is laid out; they are not intended to be used for manufacturing INA190EVM PCBs.

7.1 Schematic

Figure 1 through Figure 3 show the schematics for the INA190EVM PCB.

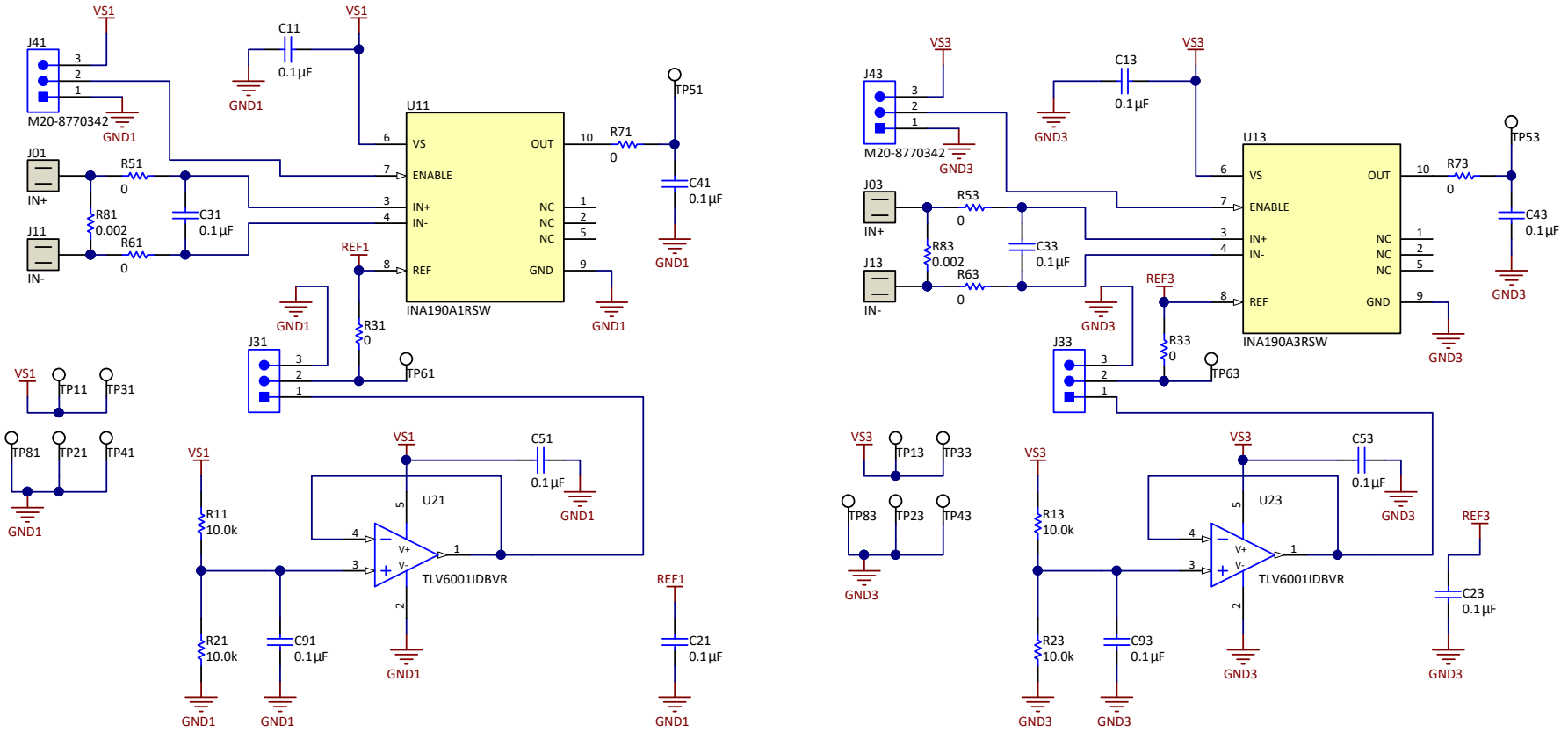


Figure 1. INA190EVM Schematic - Gain A1 and A3 Panels

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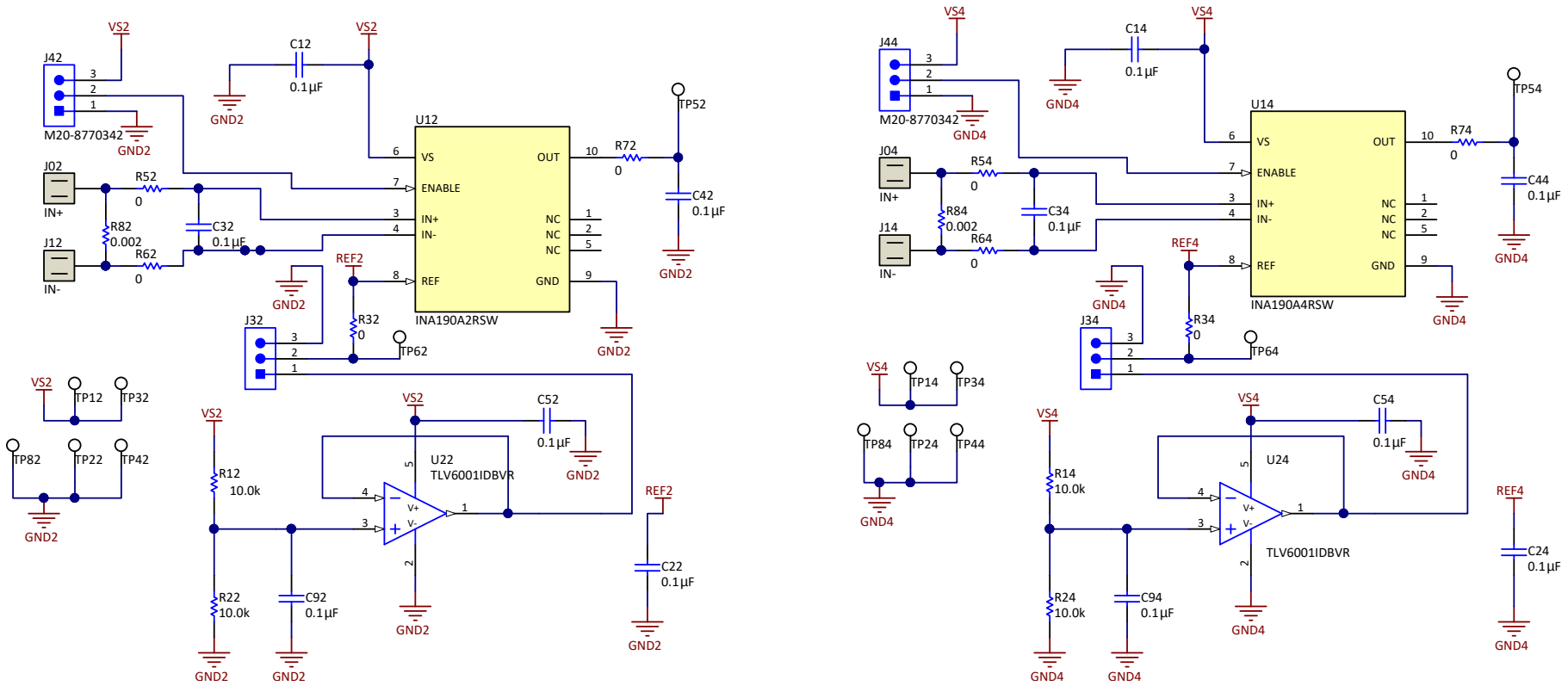


Figure 2. INA190EVM Schematic - Gain A2 and A4 Panels

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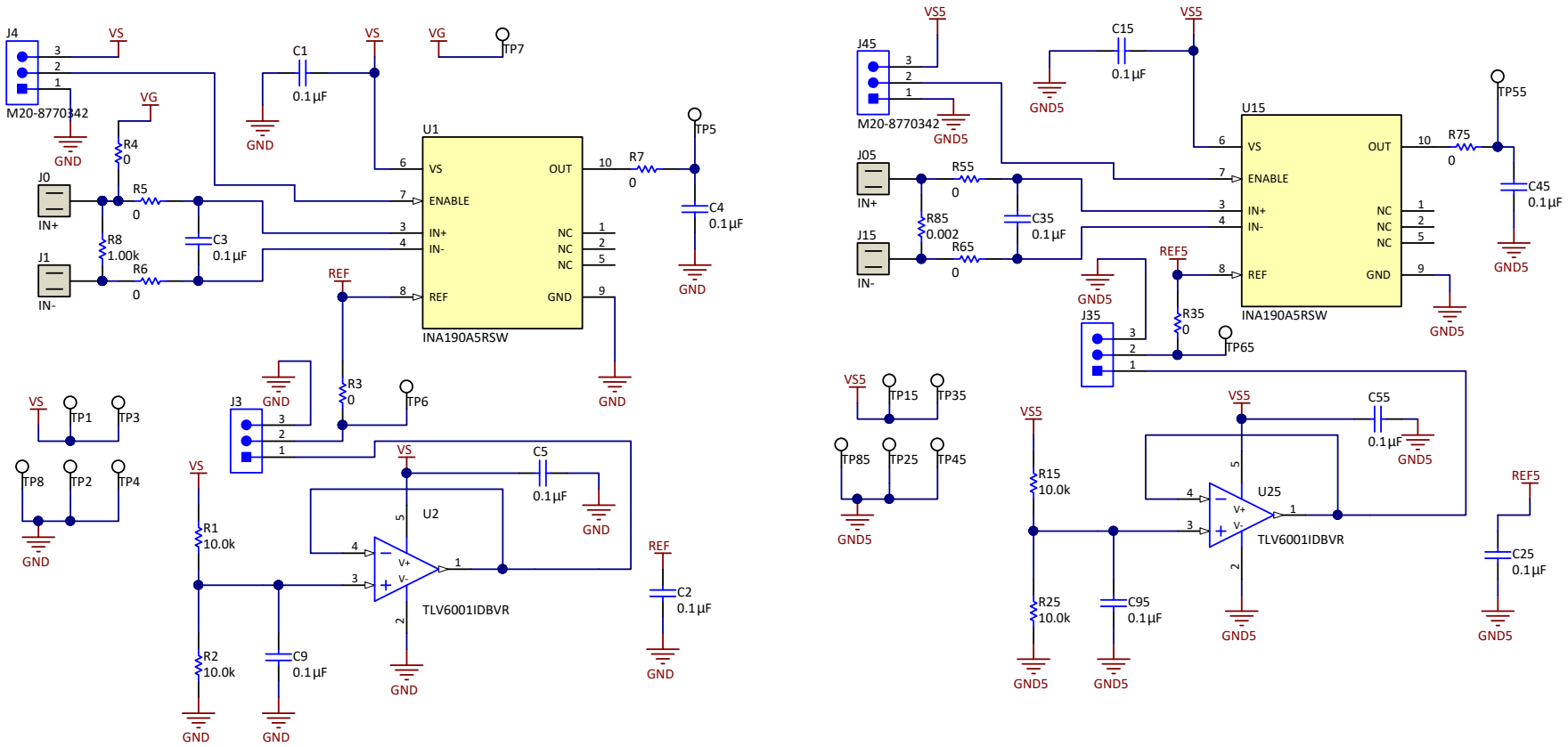


Figure 3. INA190EVM Schematic - Gain A5 and Guarding Panels

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7.2 PCB Layout

Figure 4 through Figure 10 illustrate the PCB layout for the INA190EVM.

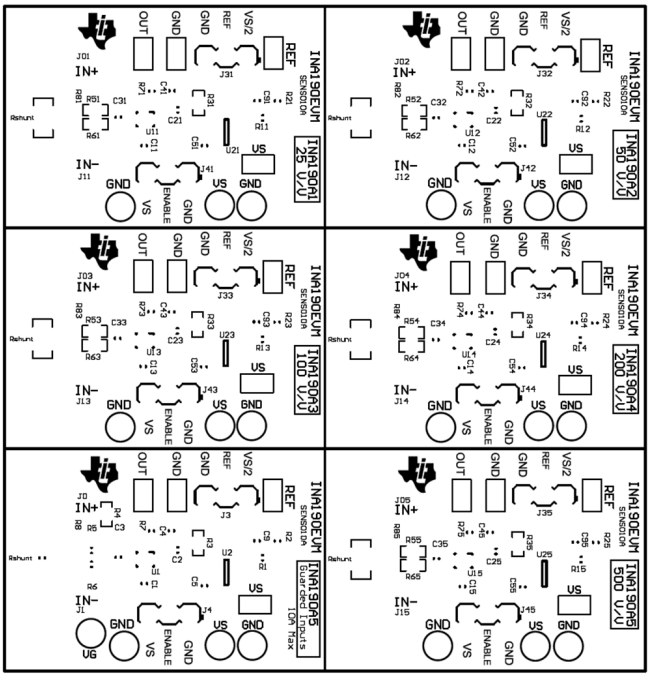


Figure 4. INA190EVM Top Overlay

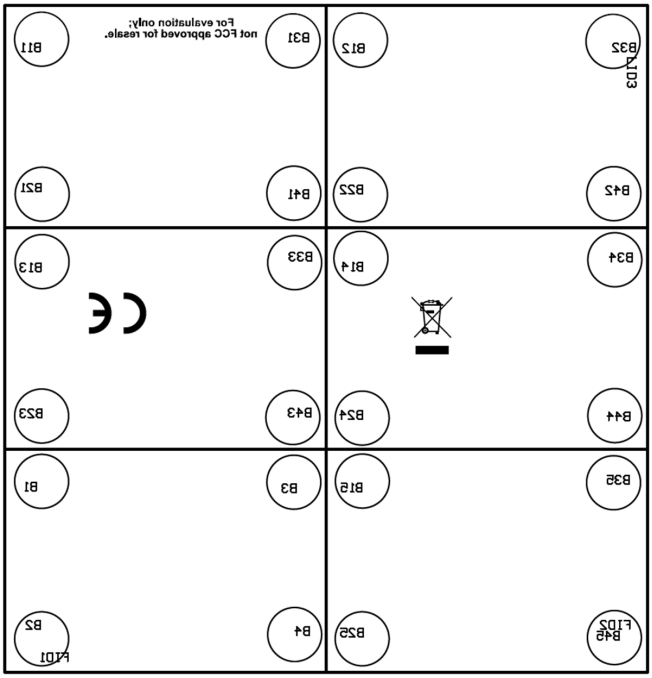


Figure 5. INA190EVM Bottom Overlay

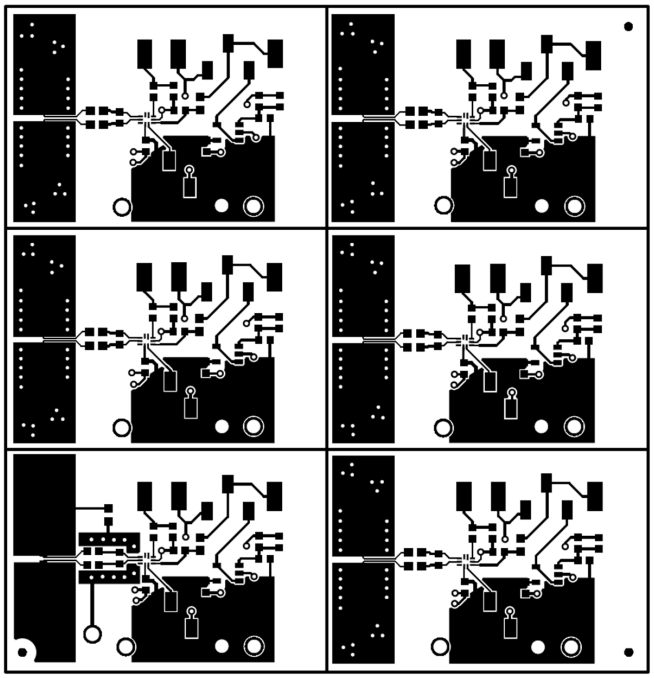


Figure 6. INA190EVM Top Layer

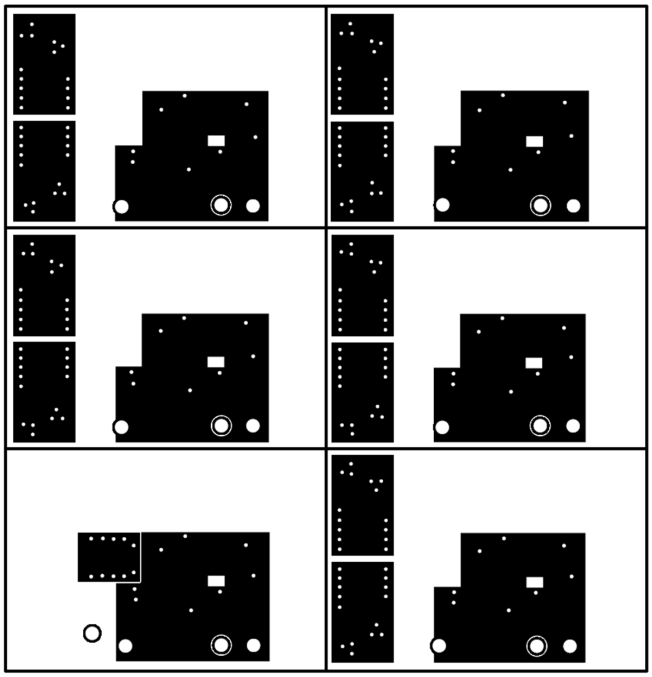


Figure 7. INA190EVM Bottom Layer

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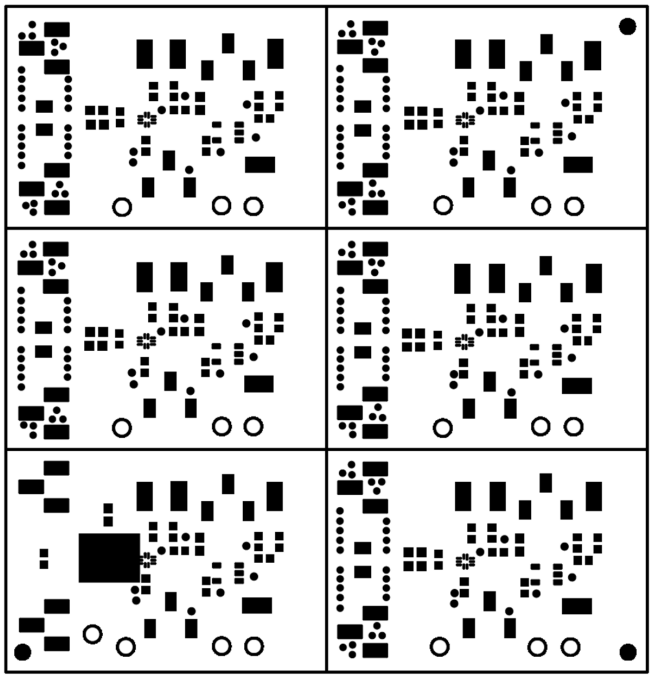


Figure 8. INA190EVM Top Solder

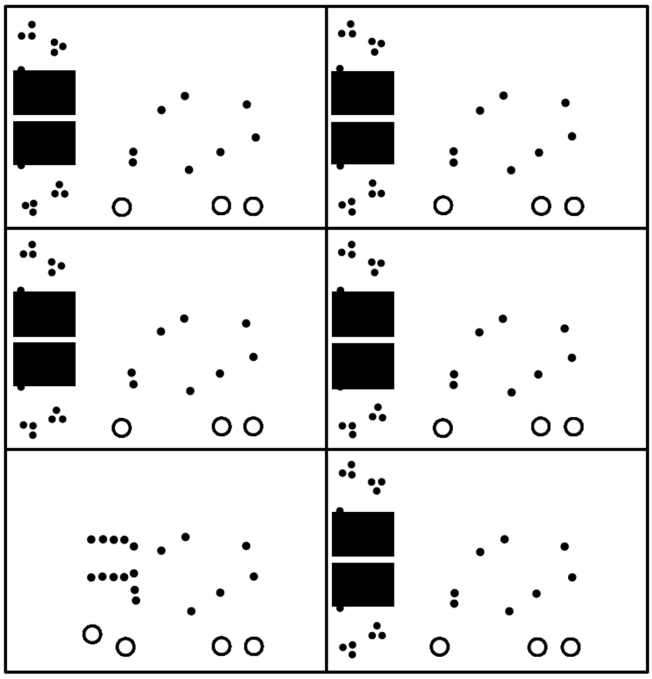
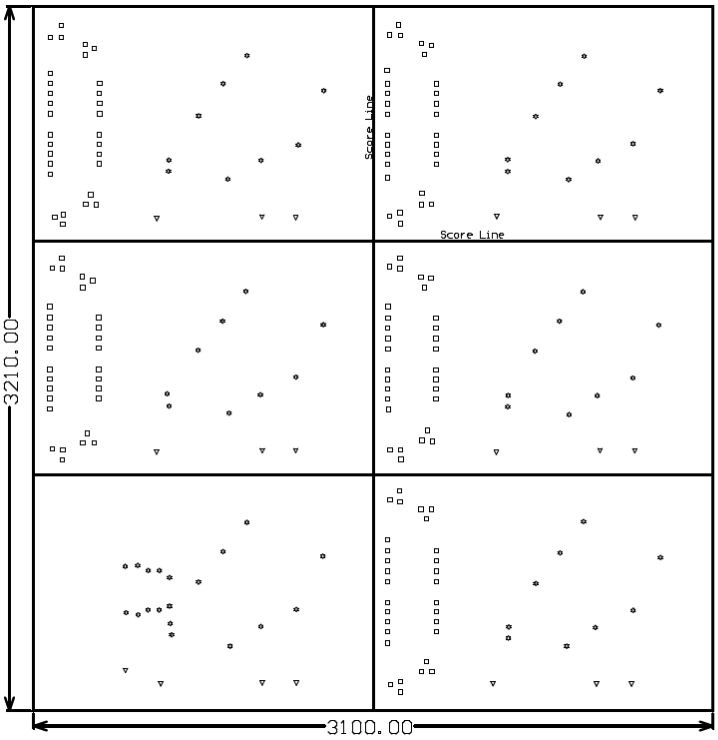


Figure 9. INA190EVM Bottom Solder



Symbol	Quantity	Finished Hole Size	Plated	Hole Type
□	150	15.00mil (0.381mm)	PTH	Round
⌑	64	16.00mil (0.406mm)	PTH	Round
▽	19	63.00mil (1.600mm)	PTH	Round
	233 Total			

Figure 10. INA190EVM Drill Drawing

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8 Bill of Materials

Table 4 provides the parts list for the INA190EVM.

Table 4. Bill of Materials

Designator	QTY	Value	Description	Package Reference	Part Number	MFR
B1, B2, B3, B4, B11, B12, B13, B14, B15, B21, B22, B23, B24, B25, B31, B32, B33, B34, B35, B41, B42, B43, B44, B45	24		Bumpon, Hemisphere, 0.25 X 0.075, Clear	3M_SJ5382	SJ5382	3M
C1, C5, C9, C11, C12, C13, C14, C15, C51, C52, C53, C54, C55, C91, C92, C93, C94, C95	18	0.1 uF	CAP, CERM, 0.1 µF, 50 V, ±10%, X7R, 0603	0603L	06035C104KAT2A	AVX
H1, H2, H3, H4, H5, H6, H7, H8, H9, H10, H11, H12	12		CONN POST SHUNT NOVO 2POS	N/A	2-881545-2	TE Connectivity AMP Connectors
H13, H14	2		CONN QC RCPT 10-12AWG 0.250	N/A	4-520448-2	TE Connectivity AMP Connectors
J0, J01, J02, J03, J04, J05	6		Quick-Fit 0.240 Tab	Keystone_4928TR	4928	Keystone
J1, J11, J12, J13, J14, J15	6		Quick-Fit 0.240 Tab	Keystone_4928TR	4928	Keystone
J3, J4, J31, J32, J33, J34, J35, J41, J42, J43, J44, J45	12		Header, 2.54mm, 3x1, Gold, SMT	Harwin_M20-87703	M20-8770342	Harwin
R2, R21, R22, R23, R24, R25	6	10.0 kΩ	RES, 10.0 k, 1%, 0.1 W, 0603	0603L	RC0603FR-0710KL	Yageo America
R3, R4, R5, R6, R7, R31, R32, R33, R34, R35, R51, R52, R53, R54, R55, R61, R62, R63, R64, R65, R71, R72, R73, R74, R75	17	0 Ω	RES, 0, 5%, 0.1 W, 0603	0603	ERJ-3GEY0R00V	Panasonic
TP3, TP31, TP32, TP33, TP34, TP35, TP4, TP41, TP42, TP43, TP44, TP45, TP5, TP51, TP52, TP53, TP54, TP5, TP6, TP61, TP62, TP63, TP64, TP65	24		Test Point, Miniature, SMT	Testpoint_Keystone_Miniature	5015	Keystone
U1, U15	2	500 V/V	Low Supply, Voltage Output, Low- or High-Side Measurement, Bidirectional, Zero-Drift Series, Current-Shunt Monitor, RSW0010A (UQFN-10)	RSW0010A	INA190A5IRSW	Texas Instruments
U11	1	25 V/V	Low Supply, Voltage Output, Low- or High-Side Measurement, Bidirectional, Zero-Drift Series, Current-Shunt Monitor, RSW0010A (UQFN-10)	RSW0010A	INA190A1IRSW	Texas Instruments
U12	1	50 V/V	Low Supply, Voltage Output, Low- or High-Side Measurement, Bidirectional, Zero-Drift Series, Current-Shunt Monitor, RSW0010A (UQFN-10)	RSW0010A	INA190A2IRSW	Texas Instruments
U13	1	100 V/V	Low Supply, Voltage Output, Low- or High-Side Measurement, Bidirectional, Zero-Drift Series, Current-Shunt Monitor, RSW0010A (UQFN-10)	RSW0010A	INA190A3IRSW	Texas Instruments
U14	1	200 V/V	Low Supply, Voltage Output, Low- or High-Side Measurement, Bidirectional, Zero-Drift Series, Current-Shunt Monitor, RSW0010A (UQFN-10)	RSW0010A	INA190A4IRSW	Texas Instruments
C2, C3, C4, C21, C22, C23, C24, C25, C31, C32, C33, C34, C35, C41, C42, C43, C44, C45	0	0.1 uF	CAP, CERM, 0.1 µF, 50 V, ±10%, X7R, 0603	0603L	06035C104KAT2A	AVX

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Table 4. Bill of Materials (continued)

Designator	QTY	Value	Description	Package Reference	Part Number	MFR
R1, R11, R12, R13, R14, R15	0	10.0 kΩ	RES, 10.0 k, 1%, 0.1 W, 0603	0603L	RC0603FR-0710KL	Yageo America
R8	0	1.00 kΩ	RES, 1.00 k, 0.1%, 0.1 W, 0603	0603L	CRT0603-BY-1001EAS	Bourns Inc.
R81, R82, R83, R84, R85	0	0.002 Ω	RES, 0.002, 1%, 1 W, 1206	1206	CSNL1206FT2L00	Stackpole Electronics Inc
TP1, TP11, TP12, TP13, TP14, TP15, TP2, TP8, TP21, TP22, TP23, TP24, TP25, TP81, TP82, TP83, TP84, TP85, TP7	0		Test Point, Compact, White, TH	Keystone5007	5007	Keystone
U2, U21, U22, U23, U24, U25	0		1-MHz, Low-Power Operational Amplifier for Cost-Sensitive Systems, DBV0005A (SOT-23-5)	DBV0005A_N	TLV6001IDBVR	Texas Instruments

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Revision History

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

Changes from Original (April 2018) to A Revision **Page**

- Changed front page figure 1
- Changed *–0.3 V to 42 V* to *–0.1 V to 40 V* in *Overview* section 2
- Changed *a maximum of 60 µA* to *a maximum of 65 µA at room temperature* in *Overview* section 2
- Deleted WCSP option from document..... 2
- Changed *–0.3-V to 42-V common-mode voltage* to *–0.1-V to 40-V common-mode voltage* in *Measurements* section..... 4
- Deleted last sentence from R8x pad discussion in *Measurements* section 4
- Changed *C2x, C3x, C4x, and C9x are not populated* to *C2x, C3x, C4x, and C9x are not populated except for C9x* in *R5x, R6x, R7x, R3x,C2x, C3x, C4x, C9x* section 5
- Added *at high common-mode voltages* to description of small current measurement in *R4* section 5
- Changed *INA190EVM Schematic - Gain A1 and A3 Panels* figure through *INA190EVM Drill Drawing* figure 8
- Added all resistor designators to first Panasonic manufacturer row in *Bill of Materials* table, deleted last two Panasonic manufacturer rows..... 13

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STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

3 *Regulatory Notices:*

   3.1 *United States*

      3.1.1 *Notice applicable to EVMs not FCC-Approved:*

      FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

      3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

      CAUTION

      This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

      Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

      FCC Interference Statement for Class A EVM devices

      NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

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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1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

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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.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

   6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

   6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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