User's Guide

SBOU212–September 2018

INA1651EVM SoundPlus™ High Common-Mode Rejection Line Receiver Evaluation Module

This user's guide contains information for the INA1651 as well as support documentation for the INA1651 evaluation module (EVM). Included are the performance specifications, set-up procedure, modifications, measured data, printed circuit board (PCB) layout, schematic, and bill of materials of the INA1651EVM.

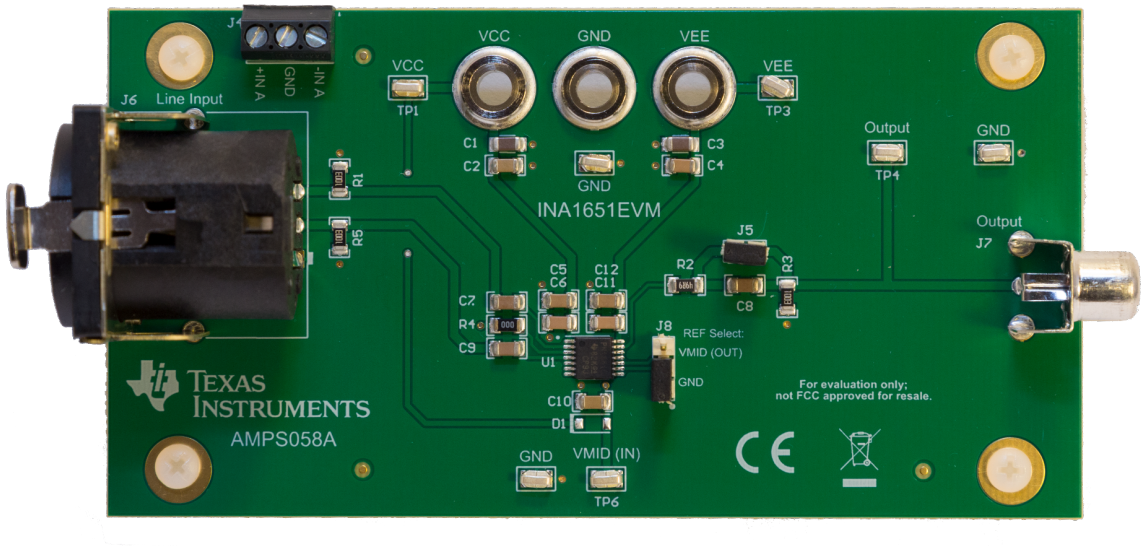

Figure 1. INA1651 SoundPlus™ Evaluation Module (EVM)

Contents

List of Figures

List of Tables

Trademarks

SoundPlus is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

1 Introduction

The INA1651 is a high common-mode rejection audio line receiver from the SoundPlus line of audio amplifier products from Texas Instruments. For a full list of electrical characteristics of the INA1651, please refer to the INA1651 product data sheet (*INA165x SoundPlus™ High Common-Mode Rejection Line Receivers*).

2 EVM Measured Performance Summary

A summary of the INA1651EVM performance specifications is provided in Table 1. Specifications are given for a supply voltage of V_S = ±15 V at an ambient temperature of 25°C, unless otherwise noted.

Table 1. INA1651EVM Measured Performance Summary

Specification	Test Conditions	Measured Performance
Common-Mode Rejection Ratio (CMRR)	V_{IN} = 1 V_{RMS} at 1 kHz	–90 dB
THD+N at 1 kHz	V_{IN} = 22 dBu	–121 dB
Second Harmonic	V_{OUT} = 10 V_{RMS}, F = 1 kHz	–142.86 dBc
Start-Up Time		1.5 s

3 Modifications

This EVM is designed to provide access to the features of and measure the performance of the INA1651. Modifications of the INA1651EVM can be made and include; adjusting the ac-coupled corner frequency, filtering the VMID (IN) pin, adjusting the start-up time, and increasing the common-mode input impedance. A simplified schematic of the INA1651EVM is displayed in Figure 2. For a full schematic of the INA1651EVM, see Figure 13.

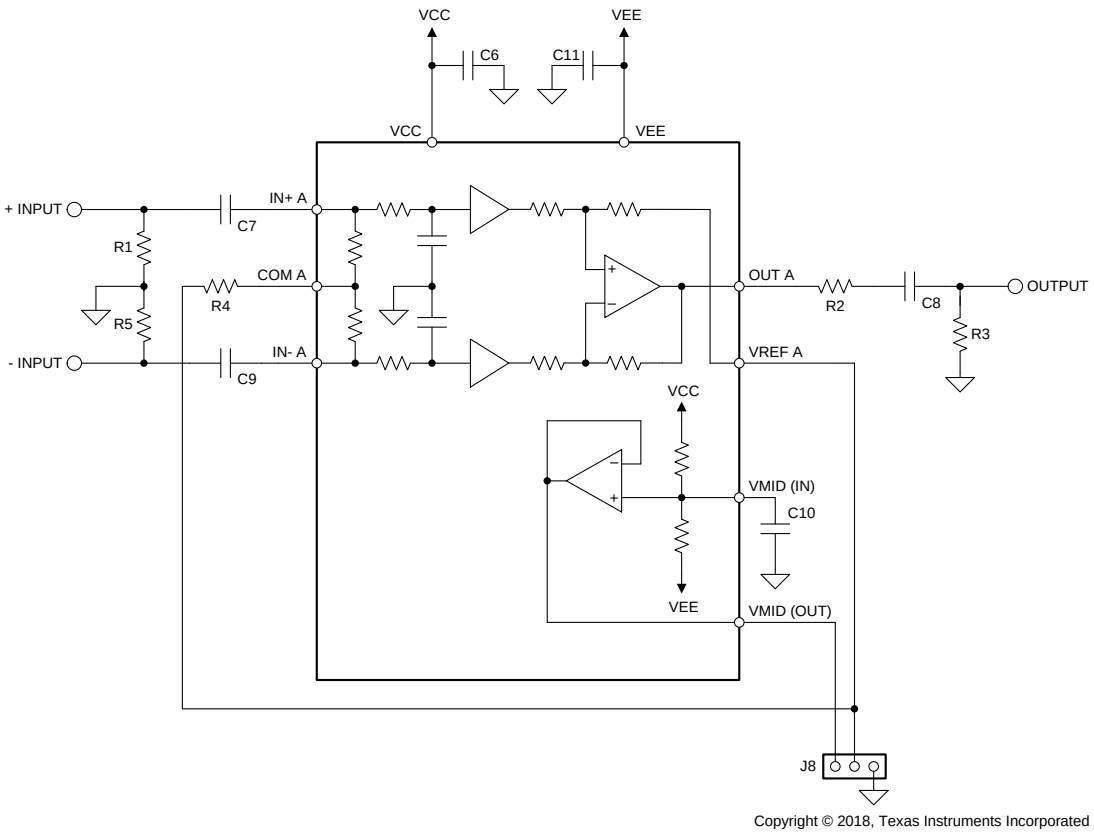

Figure 2. Simplified INA1651EVM Schematic

3.1 AC-Coupled Corner Frequency

Capacitors C7 and C9 provide the option to ac couple the input of the INA1651 and capacitor C8 provides the option to ac couple the output of the INA1651. Equation 1 calculates the high pass corner frequency of input A and input B due to capacitors, C7 and C9 on the input.

$$f_{c\_in} = \frac{1}{\pi \times C_7 \times R_{in}} \quad (1)$$

where

- $C_7 = C_9$
- R_{IN} is the differential input impedance of the INA1651

Equation 2 calculates the high-pass corner frequency due to capacitor C8 and resistors R2 and R3 on the output.

$$f_{c\_out} = \frac{1}{2\pi \times (R_2 + R_3) \times C_8} \quad (2)$$

Resistors R2 and R3 form a voltage divider on the output of the INA1651 and will attenuate the output signal. Equation 3 calculates the attenuation on the INA1651 output.

$$\text{Attenuation} = \frac{R_3}{R_2 + R_3} \quad (3)$$

3.2 Filtering the VMID (IN) Pin

Capacitor C10 provides an option to filter the input to the internal reference buffer, VMID (IN). Equation 4 calculates the cut-off frequency due to C10.

$$f_{c\_VMID} = \frac{1}{2\pi \times 250k\Omega \times C_{10}} \quad (4)$$

3.3 Start-Up Time

Capacitor C10 increases the settling time of the VMID (OUT) pin due to the resistance of the internal voltage divider for VMID (IN) and C10 creating an RC time constant. Equation 5 calculates one RC time constant.

$$\tau_{RC} = 250k\Omega \times C_{10} \quad (5)$$

Figure 3 displays the rate at which an RC circuit charges to its final value. Notice at one time constant, the voltage across the capacitor is at 63.2% of its final value.

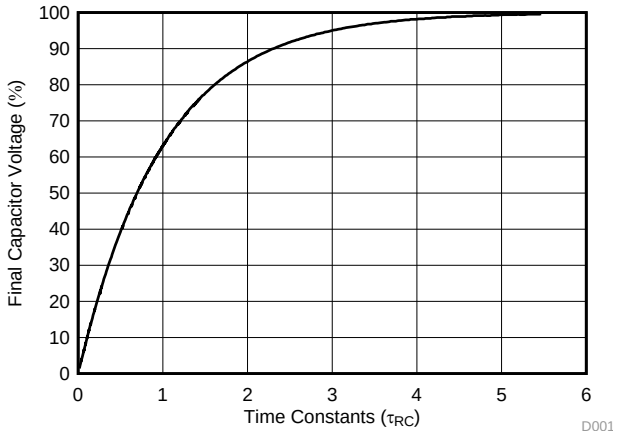

Figure 3. RC Charging Rate

Table 2 shows the final capacitor voltage at multiple time constants.

Table 2. Final Capacitor Voltage

Time Constant (τ_{RC})	Final Capacitor Voltage (%)
1	63.2%
2	86.4%
3	95.0%
4	98.1%
5	99.3%
6	99.7%

To decrease the settling time of the VMID (OUT) voltage the Zener diode, D1, can be populated. The Zener voltage of the diode should be chosen to be greater than 100 mV more than one half of the supply voltage. Equation 6 calculates the recommended Zener voltage of the diode (Vz). Note that due to the leakage current of the Zener diode interacting with the internal voltage divider resistance an error may be seen on the VMID (OUT) pin.

$$V_Z \geq \frac{1}{2} V_{CC} + 100\ mV \quad (6)$$

3.4 Increasing the Common-Mode Input Impedance

The high CMRR of many line receivers can be degraded by source impedance mismatches in the system. Resistor R4 provides an option to increase the common-mode input impedance of the INA1651 to reduce the effects of source impedance mismatch. For an explanation on the effects of increasing the common-mode input impedance, refer to section 8.1.2 of the INA1651 product data sheet (SBOS818).

4 Test Setup and Results

This section describes how to properly connect, set up, and use the INA1651EVM. This section also includes measured data of the INA1651EVM to display typical performance of the INA1651EVM. Measurements include:

- Common-mode rejection ratio (CMRR)
- THD+N vs. Amplitude
- THD+N vs. Frequency
- Fast-Fourier Transform (FFT)

The *THD+N vs. Amplitude*, *THD+N vs. Frequency*, and *FFT* measurements were taken using an *Audio Precision APx555*. All measurements used ±15-V supplies at an ambient temperature of 25 °C.

4.1 Power Supply Connections

The power supply connections for the INA1651EVM are provided through the use of the banana jacks or test points located at the top of the EVM. The positive power supply connections are labeled as VCC, the negative power supply connections are labeled as VEE, and the ground connections are labeled as GND. For the minimum and maximum supply voltages of the INA1651EVM, refer to the INA1651 product data sheet (SBOS818).

4.2 Input Connections

Input signals for the input are applied to the INA1651EVM through the use of the female XLR connector J1 or terminal block J3. The female XLR connector follows the standard female XLR pin out with pin 1 connected to ground, pin 2 connected to the positive input, and pin 3 connected to the negative input. The terminal block connections are labeled as +IN for the positive input, -IN for the negative input, and GND for the ground connection.

4.3 Output Connections

The right and left channel output connections are provided through BNC connectors, J7 and J8, RCA jacks, J9 and J10, and test points TP3 and TP5, respectively. The right channel outputs are labeled as RIGHT OUTPUT and the left channel outputs are labeled as LEFT OUTPUT. The RCA jacks provide a connection to a load while the BNC connectors and test points provide a way to measure the performance of the INA1651 while a load is connected.

4.4 REF A and COM A

Jumper J8 provides the option to connect pins VREF A and COM A to ground or VMID (OUT). In single supply operation, place a shunt in the upper position (pins 2 to 3) of J8, as indicated by the red box in Figure 4, to connect VREF A and COM A pins to VMID (OUT).

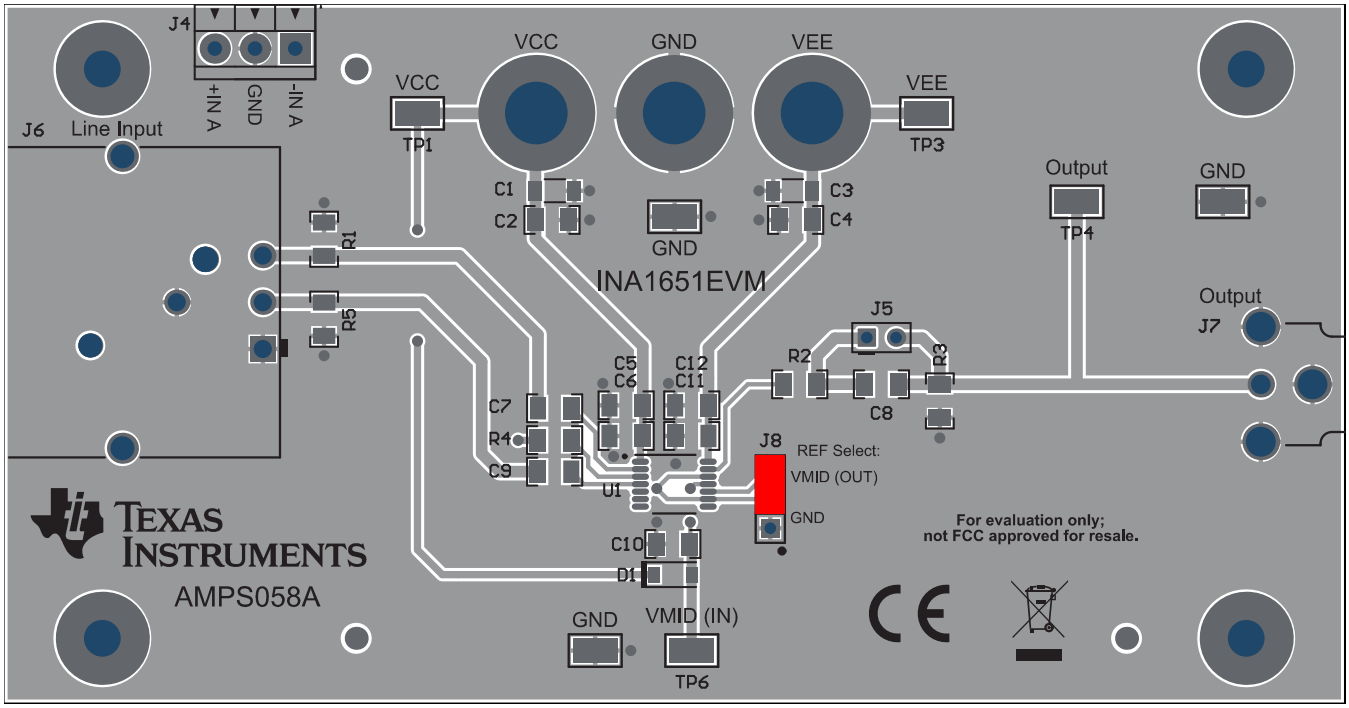

Figure 4. J8 Connection for Single-Supply Operation

For dual-supply operation, place a shunt in the lower position (pins 1 to 2) of J8, as indicated by the red box in Figure 5, to connect VREF A and COM A pins to ground (GND).

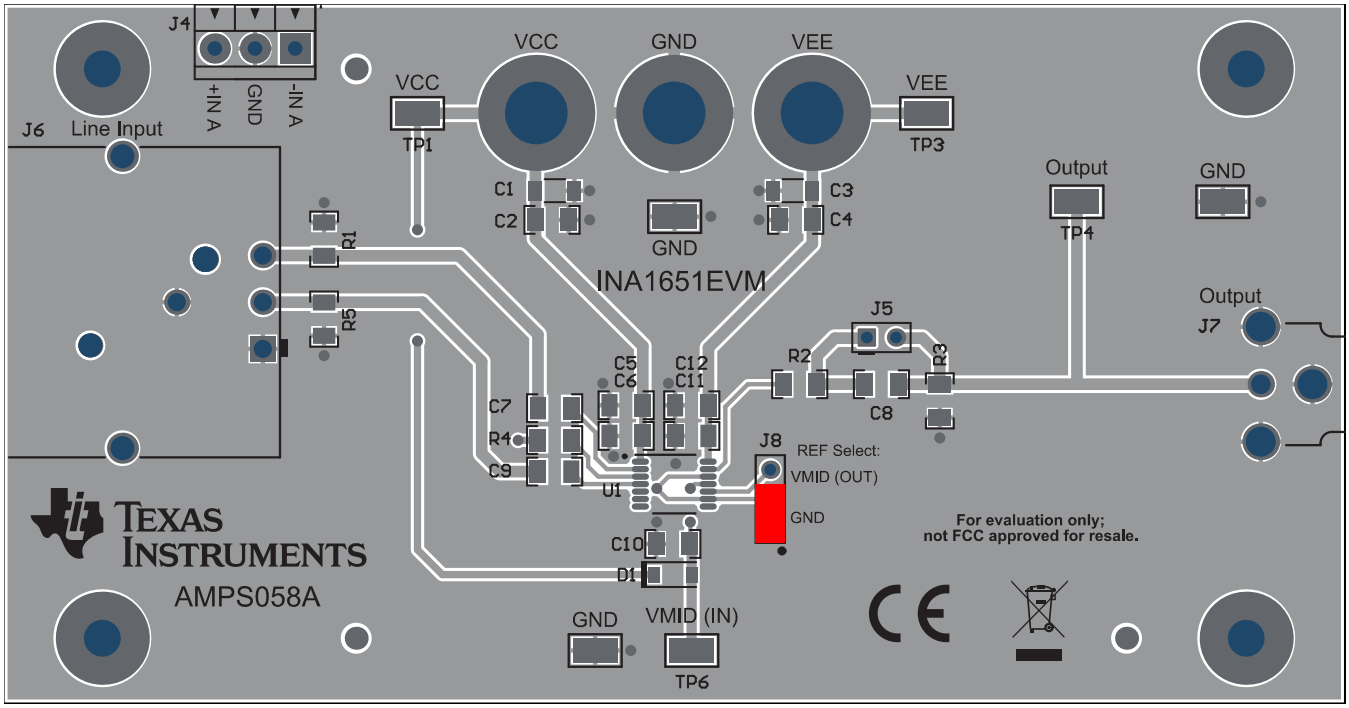

Figure 5. J8 Connection for Dual Supply Operation

4.5 Common-Mode Rejection Ratio

The common-mode rejection ratio measurement was performed by applying a 1-Vrms common-mode signal to the input and measuring the gain of the signal at the output. The frequency of the input signal was swept from 20 Hz to 90 kHz, and the measurement bandwidth of the *Audio Precision APx555* was set to 90 kHz. Figure 6 shows a measurement of the CMRR.

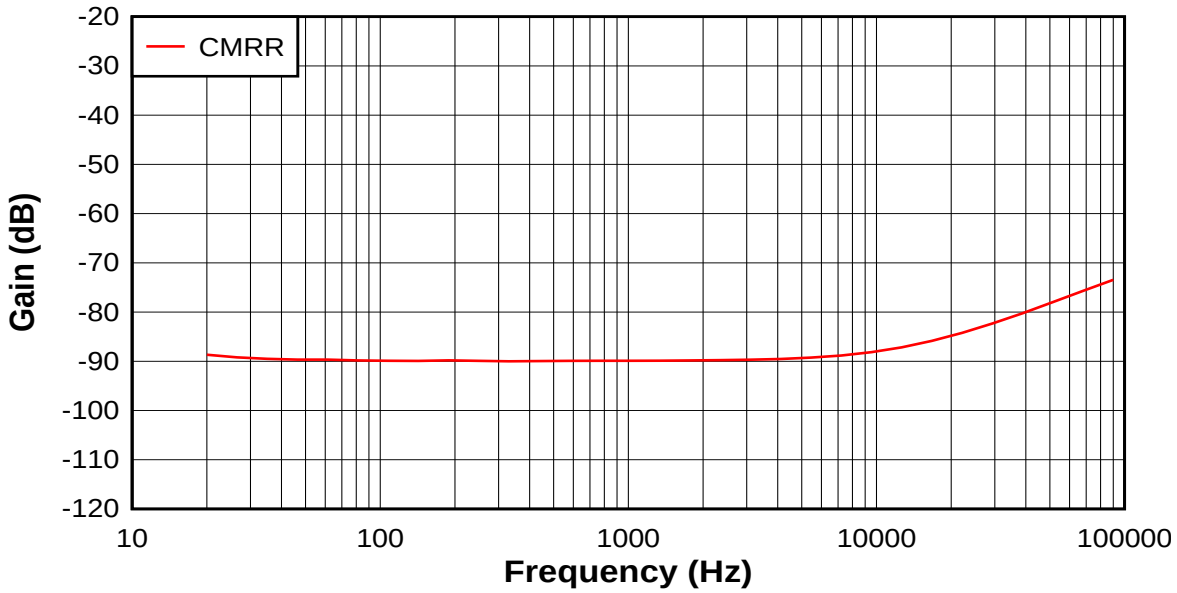

Figure 6. Common-Mode Rejection Ratio (CMRR) Measurement ±15-V Supplies, 1-V_{RMS} Input, 90-kHz MBW

4.6 THD+N vs. Amplitude

The *THD+N vs. Amplitude* measurement was performed by sweeping the output signal amplitude from 1 mV_{RMS} to 13 V_{RMS} at a frequency of 1 kHz. The measurement bandwidth of the *Audio Precision APx555* was set to 22 kHz. Figure 7 shows a measurement of the *THD+N vs. Amplitude*.

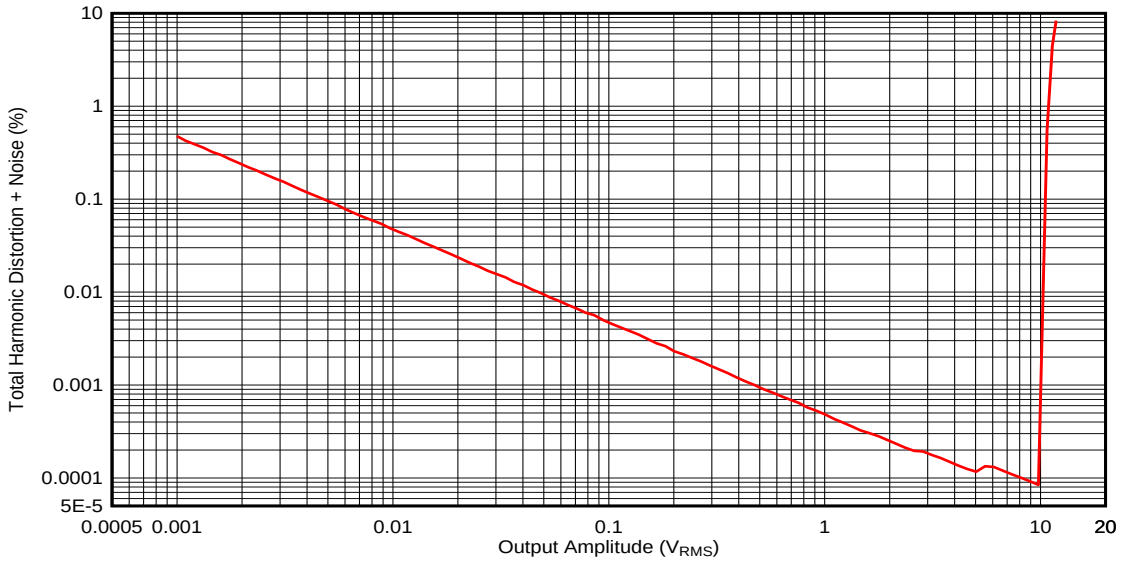

Figure 7. THD+N vs. Amplitude Measurement ±15-V Supplies, 1-kHz Output, 22-kHz MBW

4.7 THD+N vs. Frequency

The *THD+N vs. Frequency* measurements were performed by sweeping the input signal from 20 Hz to 20 kHz with the measurement bandwidth of the *Audio Precision APx555* set to 90 kHz. Figure 8 shows the *THD+N vs. Frequency* measurement with an amplitude of 1 V_{RMS} on the output of the INA1651. Note that capacitor C8 on the output of the INA1651 can increase distortion at low frequencies due to non-linear effects of the capacitor. Therefore, capacitor C8 is bypassed in these tests by a shunt installed across jumper J5.

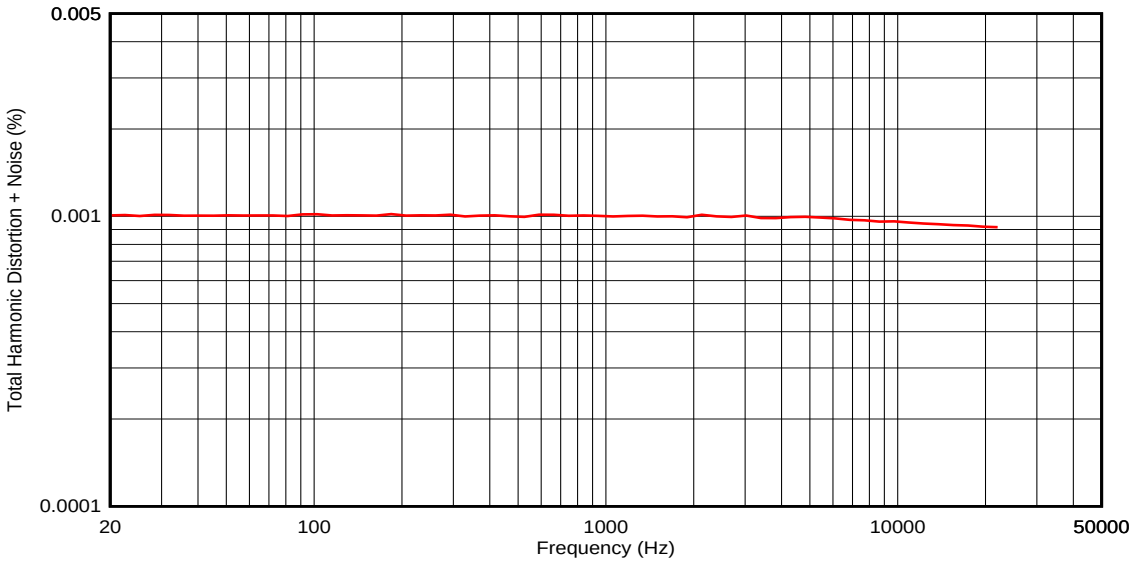

Figure 8. THD+N vs. Frequency Measurement with 1 V_{RMS} Output ±15-V Supplies, 1-V_{RMS} Output, 90-kHz MBW

Figure 9 shows the *THD+N vs. Frequency* measurement with an amplitude of 10 V_{RMS} on the output of the INA1651.

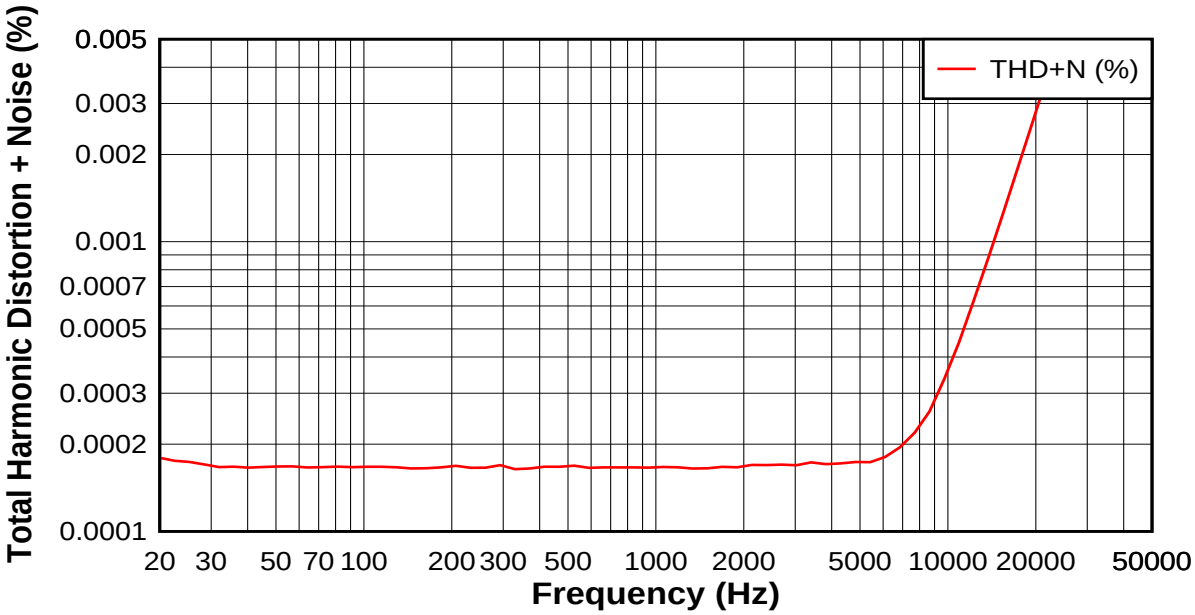

Figure 9. THD+N vs. Frequency Measurement With 10 V_{RMS} Output ±15-V Supplies, 10-V_{RMS} Output, 90-kHz MBW

4.8 Fast-Fourier Transform (FFT)

The *FFT* measurements were taken with a 1-kHz, 10-V_{RMS} signal on the output of the INA1651. A 10 V_{RMS} fundamental corresponds to 0 dBc in the *FFT* measurement. Figure 10 shows an *FFT* of the INA1651 output. The second harmonic was measured to be –142.86 dBc.

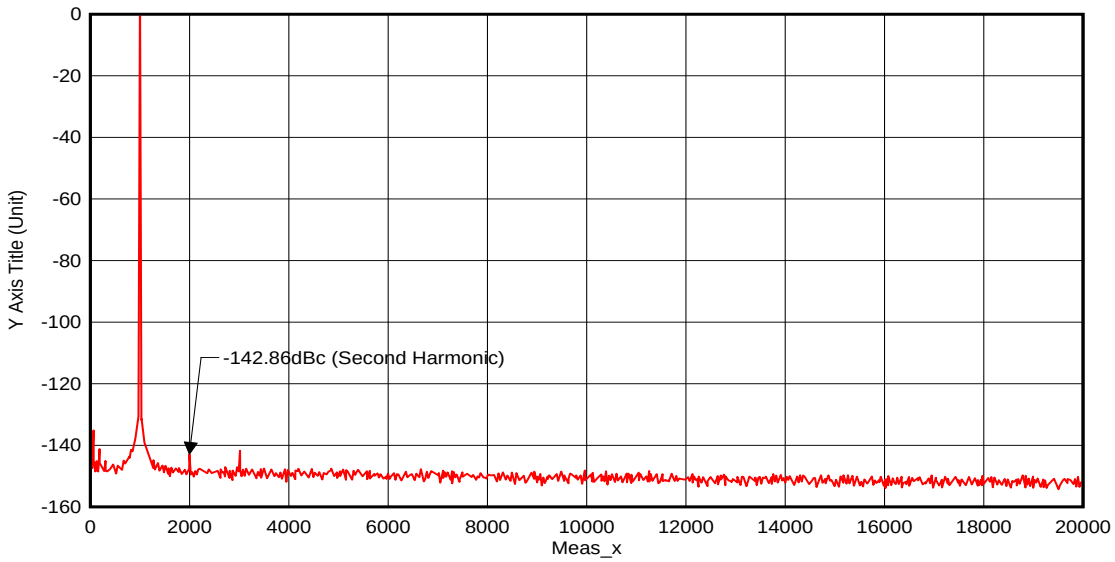

Figure 10. FFT Measurement 1 kHz, 10-V_{RMS} Output

5 Board Layout

This section provides a description of the INA1651EVM board layout and layer illustrations.

5.1 Layout

The board layout for the INA1651EVM is shown in Figure 11 and Figure 12. The top layer consists of all signal traces and is poured with a solid ground plane. The traces of the positive input (IN+ A) and negative input (IN- A) were kept as balanced as possible to reduce the possibility of a differential voltage from developing due to trace impedance mismatch. The decoupling capacitors, C5, C6, C11, and C12, were positioned as close as possible to the power supply pins of the device. Minimal traces were routed on the bottom layer so that a large solid ground plane could be poured. Vias were placed at the ground connection of every component to provide a low-impedance path on the bottom layer back to the supply ground. The trace from J8 to VREF A was kept as short as possible to maintain the exceptional common-mode rejection of the INA1651.

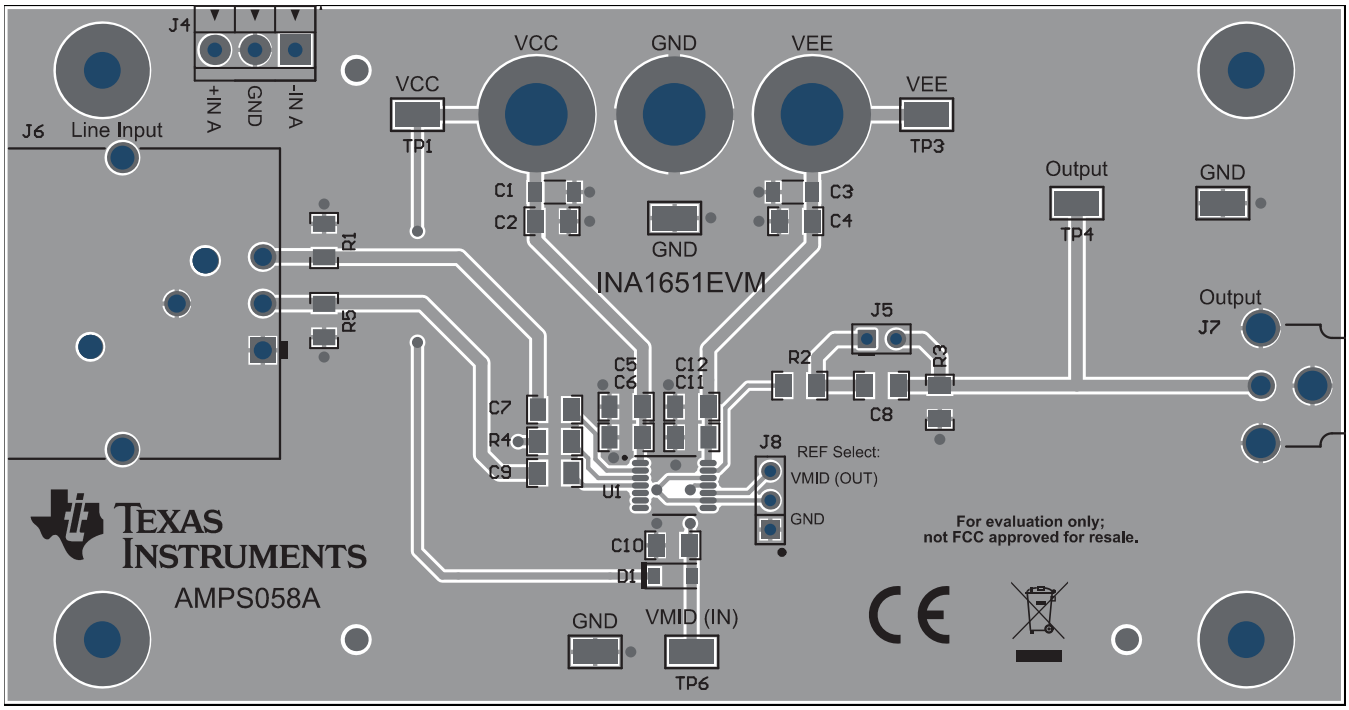

Figure 11. Top Layer PCB Layout

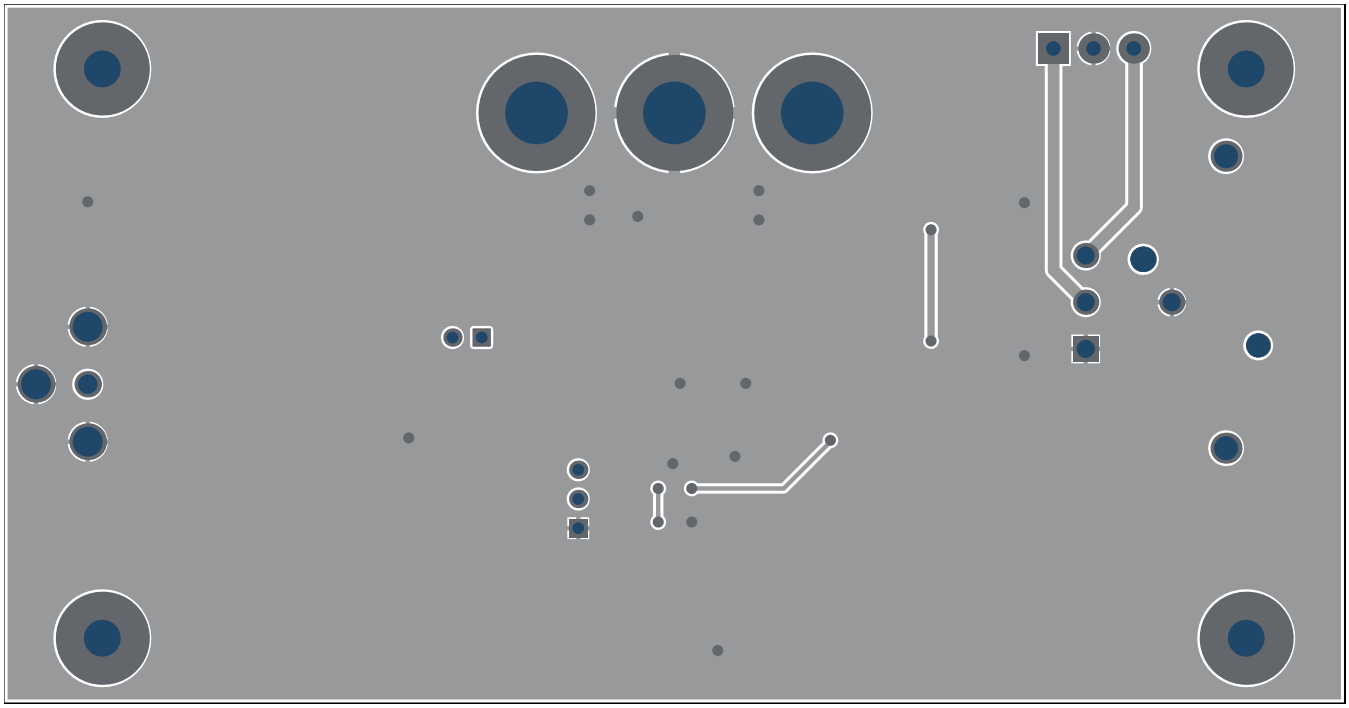

Figure 12. Bottom Layer PCB Layout

6 Schematic, Bill of Materials, and Reference

This section contains the schematic, bill of materials, and references for the INA1651EVM.

6.1 Schematic

Figure 13 illustrates the EVM schematic.

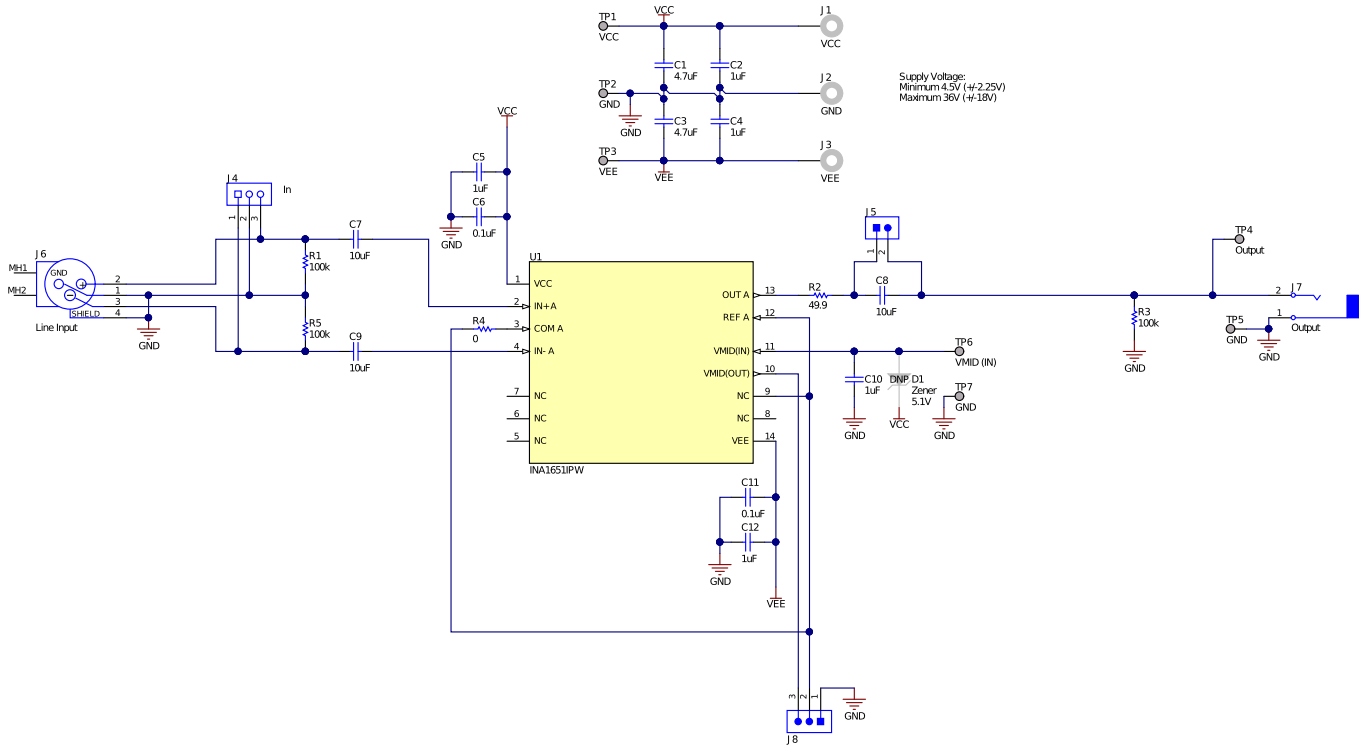

Figure 13. Schematic

6.2 Bill of Materials

Table 3 lists the INA1651EVM BOM.

Table 3. INA1651EVM Bill of Materials

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		AMPS058	Any
C1, C3	2	4.7uF	CAP, CERM, 4.7 uF, 50 V, +/- 20%, X7R, 1206_190	1206_190	C3216X7R1H475M160AC	TDK
C2, C4, C5, C10, C12	5	1uF	CAP, CERM, 1 uF, 50 V, +/- 10%, X7R, 1206	1206	GRM31MR71H105KA88L	MuRata
C6, C11	2	0.1uF	CAP, CERM, 0.1 uF, 50 V, +/- 5%, X7R, 1206	1206	C1206C104J5RACTU	Kemet
C7, C8, C9	3	10uF	CAP, CERM, 10 uF, 35 V, +/- 10%, X7R, 1206	1206	GMK316AB7106KL	Taiyo Yuden
H1, H2, H3, H4	4		Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	Screw	NY PMS 440 0025 PH	B&F Fastener Supply
H5, H6, H7, H8	4		Standoff, Hex, 0.5"L #4-40 Nylon	Standoff	1902C	Keystone
J1, J2, J3	3		Standard Banana Jack, Uninsulated, 5.5mm	Keystone_575-4	575-4	Keystone
J4	1		Terminal Block, 3.5mm Pitch, 3x1, TH	10.5x8.2x6.5mm	ED555/3DS	On-Shore Technology
J5	1		Header, 100mil, 2x1, Tin, TH	Header, 2 PIN, 100mil, Tin	PEC02SAAN	Sullins Connector Solutions
J6	1		Receptacle, 160mil, 3 Position, R/A, TH	Receptacle, 160mil, 3 Position, R/A, TH	PQG3FRA112	Switchcraft
J7	1		RCA Jack, 1Pos, Tin, Red, R/A, TH	RCA Jack, 1Pos, R/A, TH	RCJ-012	CUI Inc.
J8	1		Header, 100mil, 3x1, Tin, TH	Header, 3 PIN, 100mil, Tin	PEC03SAAN	Sullins Connector Solutions
R1, R3, R5	3	100k	RES, 100 k, 1%, 0.25 W, AEC-Q200 Grade 0, 1206	1206	CRCW1206100KFKEA	Vishay-Dale
R2	1	49.9	RES, 49.9, 1%, 0.25 W, AEC-Q200 Grade 0, 1206	1206	CRCW120649R9FKEA	Vishay-Dale
R4	1	0	RES, 0, 5%, 0.25 W, AEC-Q200 Grade 0, 1206	1206	CRCW12060000Z0EA	Vishay-Dale
SH-J1, SH-J2	2		Shunt, 100mil, Gold plated, Black	Shunt 2 pos. 100 mil	881545-2	TE Connectivity
TP1, TP2, TP3, TP4, TP5, TP6, TP7	7		Test Point, Miniature, SMT	Test Point, Miniature, SMT	5019	Keystone
U1	1		SoundPlus High Common-Mode Rejection Line Receiver, PW0014A (TSSOP-14)	PW0014A	INA1651IPW	Texas Instruments

6.3 Reference

INA1651 SoundPlus™ High Common-Mode Rejection Line Receiver

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.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

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

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

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・インスツルメンツ株式会社

東京都新宿区西新宿６丁目２４番１号

西新宿三井ビル

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

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

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.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

IMPORTANT NOTICE AND DISCLAIMER

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

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265