THS3491RGT Evaluation Module

This document provides information about the evaluation module of the amplifier under test. Additionally, this document provides a good example of printed-circuit board (PCB) design for high-speed applications. Remember the following points:

- TI recommends initially reviewing the data sheet of the device under test.
- Review the schematic and layout of the THS3491RGT EVM to determine the design techniques used in the evaluation board.
- The high-speed amplifier PCB design should be approached with care and special attention must be provided to the board parasitic which impacts the overall system performance.

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Trademarks

1 Introduction

The Texas Instruments THS3491RGT evaluation module (EVM) helps designers evaluate the performance of the THS3491 high-speed, high-voltage, and low-distortion current feedback amplifier in a 16-pin RGT package. This document details the THS3491RGT EVM and should be a good starting point for high-speed PCB design involving the THS3491RGT device. The document includes a brief description of the module and a list of EVM features, followed by EVM specifications and default EVM configuration, details on connecting and using the EVM, and a discussion of high-speed amplifier PCB design considerations.

1.1 Description

The THS3491RGT evaluation module (EVM) is used to evaluate the THS3491 device, which is a high-speed, high-voltage and low-distortion current-feedback amplifier in a 16-pin RGT package. The EVM is designed to quickly and easily demonstrate the functionality and performance of THS3491 in a gain of 5 V / V, driving an equivalent R_{LOAD} = 100 Ω. The EVM is ready to connect to power supplies, signal source, and test instruments through the use of onboard connectors. The board is set up for single-ended input and output operation for interfacing with 50-Ω test equipment. By default, the THS3491EVM comes with a heat-sink attached on the bottom of the board directly underneath the device that helps in the overall device thermal dissipation for high-output voltage swings.

1.2 Evaluation Module Features

The THS3491 high-speed operational amplifier EVM features include:

- Configured for split-supply operation and easily modified for single supply
- Designed for single-ended 50-Ω input and output connection
- Configured for non-inverting gain of 5 V / V configuration and easily modified for inverting gain configuration
- Simple interface to the inputs and outputs through the SMA connectors
- Heat-sink on the bottom of the board to help with the overall device thermal dissipation for high-output voltage swings

1.3 THS3491 Operating Conditions

Supply voltage range, $\pm V_{CC}$ = ±7 to ±16 Vdc (see the device data sheet for min and max values).

Supply current, I_Q = 17.4 mA (see the device data sheet for min and max values).

For complete THS3491 amplifier IC specifications, parameter measurement information, and additional application information, see the THS3491 data sheet (SBOS875).

2 EVM Default Configuration

As delivered, the EVM has a fully functional example circuit; just provide power supplies, a signal source, and a measuring instrument as shown in Figure 1. Some components, such as supply bypass capacitors and test points, are omitted on the application schematics of Figure 1 for clarity.

See Figure 3 for the default schematic diagram of the THS3491RGT EVM.

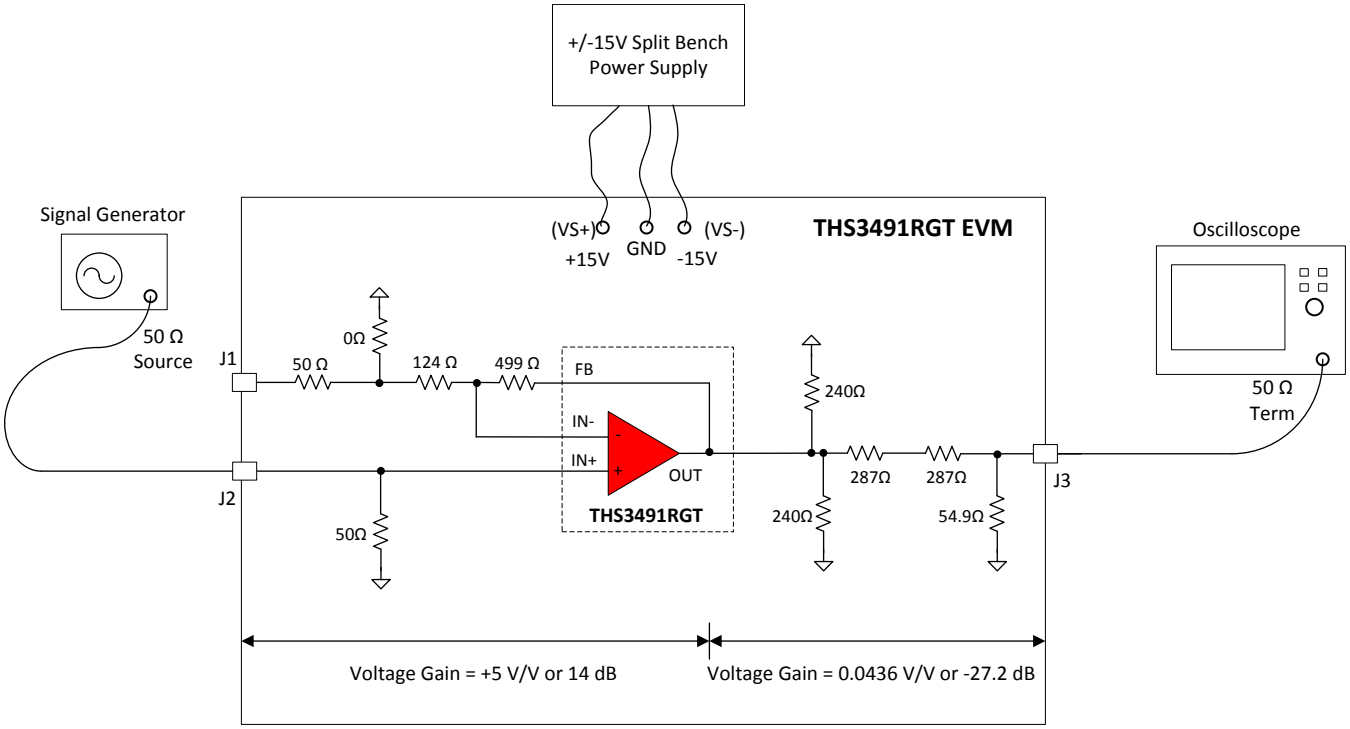

Figure 1. THS3491RGT EVM Default Configuration Setup Block Diagram

2.1 Standard Non-Inverting Gain Configuration

The THS3491RGT EVM default configuration is a single-ended input, single-ended output non-inverting gain of 5 from SMA input (J2) to the THS3491 device output pins as shown in Figure 1. The default configuration for non-inverting gain of 5 is determined by R3, and R4 in Figure 3. This gain is calculated according to Equation 1 that is given below for non-inverting op-amp.

$$\text{Non-Inverting Gain} = \frac{V_O}{V_I} = 1 + \frac{RF}{RG} \quad (1)$$

where

- RF = 499 Ω
- RG = 124 Ω

2.2 Output Voltage Loss Calculation to the Measuring Instrument

The THS3491RGT device output is driving an equivalent R_{LOAD} = 100 Ω determined by the output series and parallel matching resistor network as shown in Figure 2. The output resistor network affects the voltage that is measured at the SMA connector (J3). The designer should take into account the voltage division from the device output to the SMA connector (J3) which is approximately 0.0436 or -27.2 dB given by Equation 2. As a result, an overall voltage gain of –13.2 dB is achieved from SMA connector J2 to J3 for single-ended 50-Ω input and output.

Remember, the output resistor network is only present to protect the measuring instrument from being over-driven by the device output for high-output signal swings. Desoldering the output matching resistor and replacing it with a single 50-Ω series output resistor that gives only 6-dB output voltage loss at the measuring instrument is easily done.

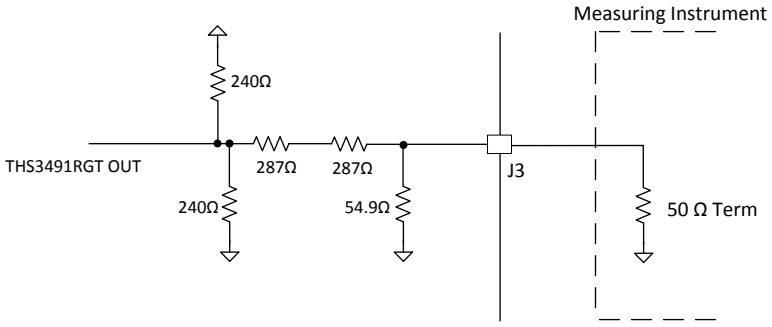

Figure 2. Output Interface to the Measuring Instrument

$$\text{Out Voltage at J3 (V)} = \frac{(50\Omega \,||\, 54.9\Omega)}{(50\Omega \,||\, 54.9\Omega) + (2 \text{ x } 287\Omega)} \text{x THS3491 OUT(V)}$$

$$\text{Out Voltage at J3 (V)} = 0.0436 \frac{\text{V}}{\text{V}} \text{ x THS3491 OUT(V)} \quad (2)$$

3 Using the THS3491 EVM

This section describes how to connect the THS3491 EVM to test equipment. TI recommends connecting the EVM as described in this section to avoid damage to the EVM or the THS3491 installed on the board.

CAUTION

Caution hot surface. The PCB surface can get very hot while passing high-output voltage swings. Contact may cause burns. Do not touch

3.1 Required Equipment

The following equipment is required:

- Dual dc output power supply (±15 V, 200-mA output minimum).
- Two dc current meters with resolution to 1 mA and capable of a maximum current which the dc power supply can supply. If available, set the current limit on the dc power supply to 200 mA.

NOTE: Some power supplies incorporate current meters which may be applicable to this test.

- 50-Ω source impedance signal generator (10 MHz, up to 4 V_{PP} sine wave).
- Oscilloscope (100-MHz bandwidth minimum, 50-Ω terminated BNC input).

3.2 Power Supply Setup (Reference Figure 1)

Use the following procedure for power supply setup:

- Before connecting the power supply cables to the EVM, set the dual dc output power supply to ±15 V.
- Make sure the dc power supply is turned off before proceeding to the next step.
- Connect the +15-V power supply to the +Vs of the power supply port on the EVM.
- Connect the –15-V power supply to the -Vs of the power supply port on the EVM.
- Connect the grounds of the +15-V and –15-V power supply to the GND port on the EVM.
- Make sure the dc current meters on the dual dc output power supply are set to at least 1-mA resolution and are set to 200-mA minimum output current capability.
- Turn-on the dual dc power supply to ±15 V

3.3 Input and Output Test Setup (Reference Figure 1)

Use the following procedure for input and output test setup:

- Set the signal generator to a 10 MHz, ±1.14 V (2.28 V_{PP} or 11.1 dBm) sine wave with no dc offset. The signal generator output should be set in 50-Ω termination mode.
- Turn off the signal generator before proceeding to the next step.
- Connect the signal generator output to SMA connector J2 on the EVM.
- Oscilloscope channel 1 should be connected to SMA connector J3 on the EVM. Set the oscilloscope to 500 mV / division and a time-base of 1 μs / division.

NOTE: The oscilloscope must be set in a 50-Ω termination for proper operation.

- Turn on the signal generator. The measured output on the scope channel 1 at SMA connector J3 should approximately be ±250 mV (500 mV_{PP}).

4 High-Speed Amplifier PCB Layout Tips

The THS3491 EVM layout, designed for use with high-speed signals, can be used as an example when designing PCBs incorporating the THS3491. Careful attention has been given to component selection, grounding, power supply bypassing, and signal path layout. Disregarding these basic design considerations could result in less than optimum performance of the THS3491 high-speed operational amplifier. Surface-mount components were selected because of the extremely low lead inductance associated with this technology. This helps minimize both stray inductance and capacitance. Also, because surface-mount components are physically small, the layout can be very compact.

Tantalum power supply bypass capacitors at the power input pads help filter switching transients from the laboratory power supply. Power supply bypass capacitors are placed as close as possible to the IC power input pins to minimize the return path impedance. This improves high-frequency bypassing and reduces harmonic distortion. The GND side of these capacitors should be located close to each other, minimizing the differential current loops associated with differential output currents. If poor high-frequency performance is observed, replace the 0.1-μF capacitors with microwave capacitors with a self-resonance at the frequency that produces trouble. A proper ground plane on both sides of the PCB should be used with high-speed circuit design. This provides low-inductive ground connections for return current paths.

In the area of the amplifier input pins, the ground plane has been removed to minimize stray capacitance and to reduce ground plane noise coupling into these pins. This is especially important for the inverting input pin. A capacitance as low as 1 pF at the inverting input can significantly affect the response of the amplifier or even cause oscillation.

In general, it is best to keep signal lines as short and as straight as possible. Incorporation of microstrip or stripline techniques is also recommended when signal lines are greater than 1 inch in length. These traces must be designed with a characteristic impedance of either 50 Ω or 75 Ω, as required by the application. Such a signal line must also be properly terminated with an appropriate resistor.

The PCB that is used with PowerPAD™ packages must have features included in the design to remove the heat from the package efficiently. As a minimum, there must be an area of solder-tinned-copper underneath the PowerPAD package. This area is called the thermal land. The thermal land varies in size depending on the PowerPAD package being used, the PCB construction, and the amount of heat to be removed. In addition, this thermal land may or may not contain thermal vias, depending on PCB construction. The requirements for thermal lands and thermal vias are detailed in *PowerPAD™Thermally Enhanced Package* (SLMA002) and *PowerPAD™ Made Easy* (SLMA004).

Finally, all inputs and outputs must be properly terminated, either in the layout or in the load instrumentation. Unterminated lines, such as coaxial cable, can appear to be a reactive load to the amplifier. By terminating a transmission line with its characteristic impedance, the load of the amplifier then appears to be purely resistive, and reflections are absorbed at each end of the line. Another advantage of using an output termination resistor is that capacitive loads are isolated from the amplifier output. This isolation helps minimize the reduction in the phase-margin of the amplifier and improves the amplifier stability, resulting in reduced peaking and settling times.

On boards operated from dual power supplies, it is helpful to place a capacitor directly across the positive and negative power supplies. This helps the fully differential drive.

5 EVM Hardware Description

This section describes the EVM hardware. It includes the EVM parts list, and PCB layout.

5.1 Bill of Materials

Table 1 lists the EVM bill of materials.

Table 1. THS3491RGT EVM Bill of Materials

Item #	Designator	Qty	Value	Part Number	Manufacturer	Description	Package Reference
1	!PCB1	1		HSP006	Any	Printed Circuit Board	
2	C1, C2	2	4.7uF	GRM319R61H475KA12D00	MuRata	CAP, CERM, 4.7 µF, 50 V, ±10%, X5R, 1206	1206
3	C3, C4	2	1uF	C2012X5R1H105K125AB	TDK	CAP, CERM, 1 µF, 50 V, ±10%, X5R, 0805	0805
4	C5, C6	2	0.1uF	C0603C104Z3VACTU	Kemet	CAP, CERM, 0.1 µF, 25 V, +80/-20%, Y5V, 0603	0603
5	C7	1	0.01uF	06031C103KAT2A	AVX	CAP, CERM, 0.01 µF, 100 V, ±10%, X7R, 0603	0603
6	C8	1	0.1uF	GRM155R61E104KA87D	MuRata	CAP, CERM, 0.1 µF, 25 V, ±10%, X5R, 0402	0402
7	H1, H2, H3, H4	4		PMSSS 440 0025 PH	B&F Fastener Supply	Machine Screw Pan Phillips 4-40	Machine Screw, 4-40, 1/4 inch
8	H5, H6, H7, H8	4		2204	Keystone	Hex Standoff 4-40 Aluminum 3/4"	Hex Standoff 4-40 Aluminum 3/4 inch
9	H9	1		7109DG	Aavid	Surface mount heat sink for D2PAK	Surface mount heat sink for D2PAK
10	J1, J2, J3	3		142-0701-851	Emerson Network Power	Connector, End launch SMA, 50 ohm, SMT	SMA End Launch
11	J4	1		SPC15363	Tenma	BANANA JACK, SOLDER LUG, RED, TH	Red Insulated Banana Jack
12	J5	1		6095	Keystone	Standard Banana Jack, Uninsulated	Keystone_6095
13	J6	1		SPC15354	Tenma	BANANA JACK, SOLDER LUG, BLACK, TH	Black Insulated Banana Jack
14	L1, L2	2	220 ohm	BLM21PG221SN1D	MuRata	Ferrite Bead, 220 ohm @ 100 MHz, 2 A, 0805	0805
15	LBL1	1		THT-14-423-10	Brady	Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650"H x 0.200"W
16	R1, R7	2	49.9	CRCW060349R9FKEA	Vishay-Dale	RES, 49.9, 1%, 0.1 W, 0603	0603
17	R2, R6, R8	3	0	CRCW06030000Z0EA	Vishay-Dale	RES, 0, 5%, 0.1 W, 0603	0603
18	R3	1	124	RC0603FR-07124RL	Yageo America	RES, 124, 1%, 0.1 W, 0603	0603
19	R4	1	499	RCS0603499RFKEA	Vishay-Dale	RES, 499, 1%, 0.25 W, 0603	0603
20	R9, R10	2	240	CRCW2512240RJNEG	Vishay-Dale	RES, 240, 5%, 1 W, AEC-Q200 Grade 0, 2512	2512
21	R11, R12	2	287	CRCW1206287RFKEA	Vishay-Dale	RES, 287, 1%, 0.25 W, 1206	1206
22	R13	1	54.9	CRCW060354R9FKEA	Vishay-Dale	RES, 54.9, 1%, 0.1 W, 0603	0603
23	TP1	1		TP105-01-09	Components Corporation	Test Point, Miniature, White, TH	Test-Point, Dia 100mil, TH
24	TP3	1		5000	Keystone	Test Point, Miniature, Red, TH	Red Miniature Testpoint

Table 1. THS3491RGT EVM Bill of Materials (continued)

Item #	Designator	Qty	Value	Part Number	Manufacturer	Description	Package Reference
25	U1	1		THS3491IRGT	Texas Instruments	High Voltage, Low Distortion, Current-Feedback Amplifier, RGT0016A	RGT0016A
26	C9	0	100pF	C0603C101J5GACTU	Kemet	CAP, CERM, 100 pF, 50 V, ±5%, C0G/NP0, 0603	0603
27	FID1, FID2, FID3, FID4, FID5, FID6	0		N/A	N/A	Fiducial mark. There is nothing to buy or mount.	Fiducial
28	R5	0	49.9	CRCW060349R9FKEA	Vishay-Dale	RES, 49.9, 1%, 0.1 W, 0603	0603

5.2 Schematic

Figure 3 illustrates the EVM schematic.

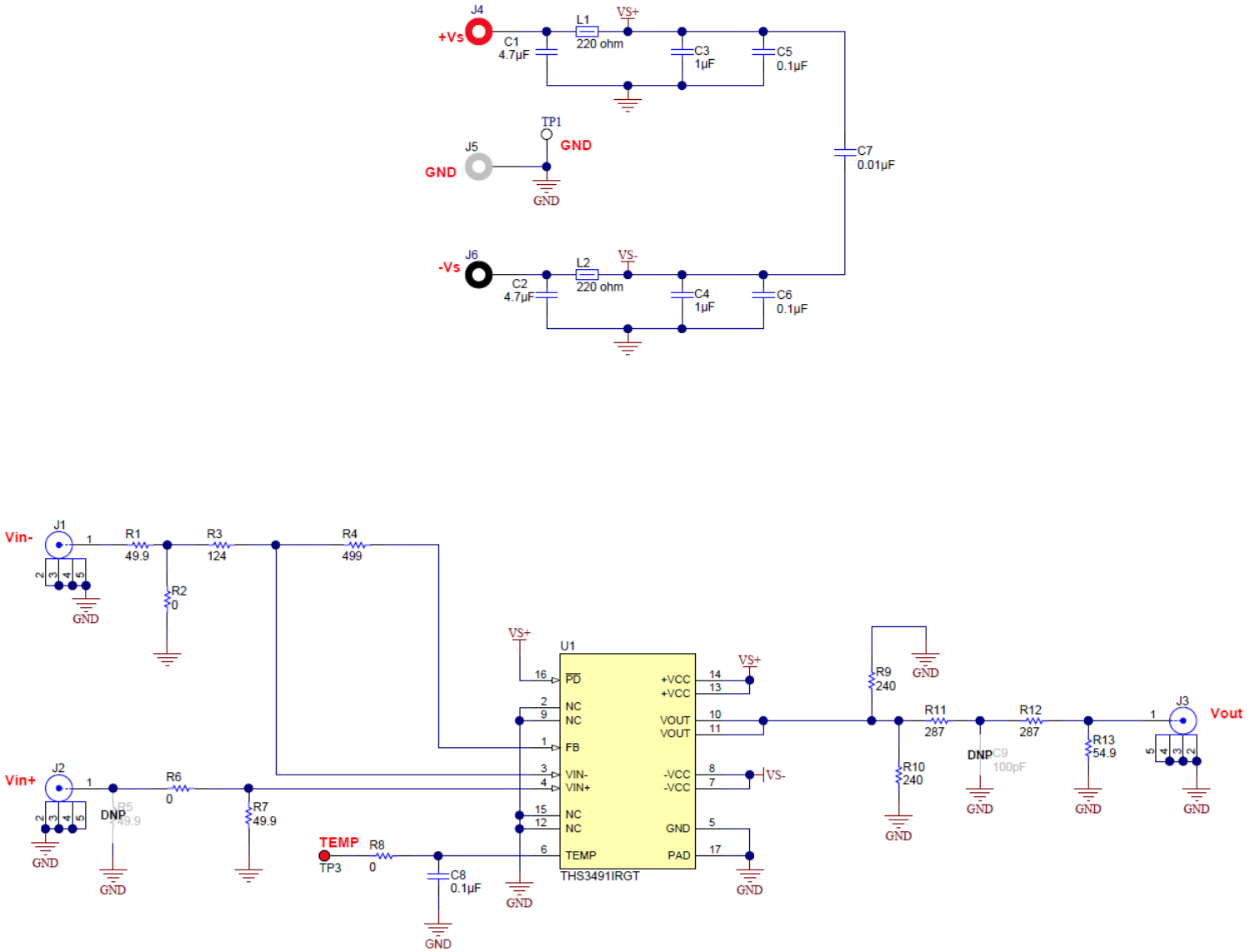

Figure 3. Full Schematic of the THS3491RGT EVM

5.3 Circuit Board Layout

Figure 4 through Figure 11 illustrate the EVM PCB layout.

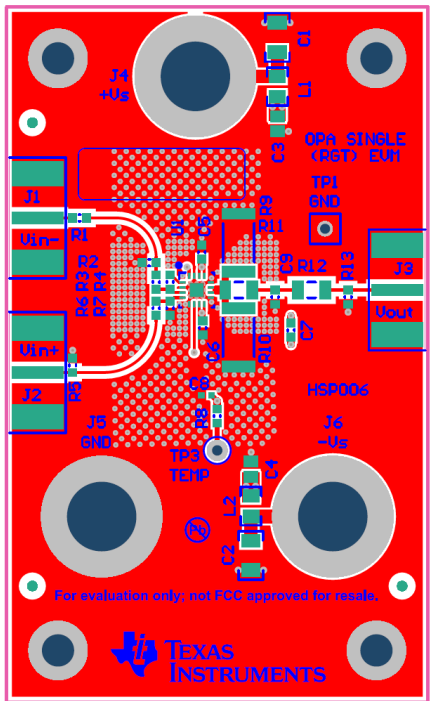

Figure 4. Top Components and Silk Screen Layer

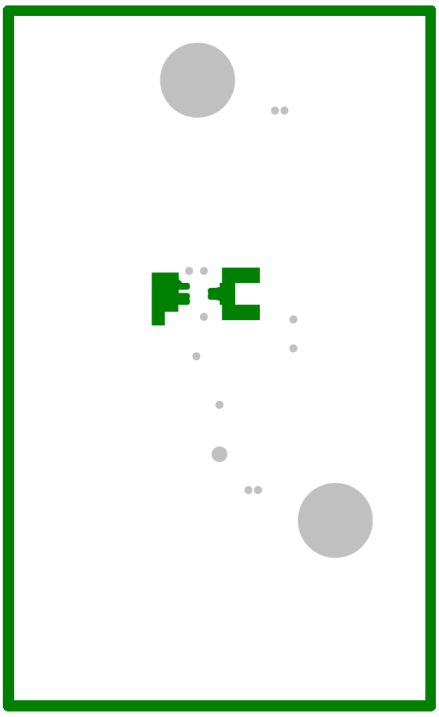

Figure 5. Layer 2 - GND

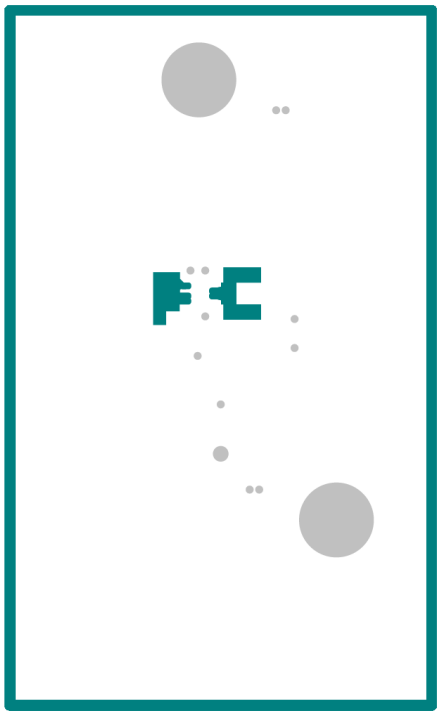

Figure 6. Layer 3 - GND

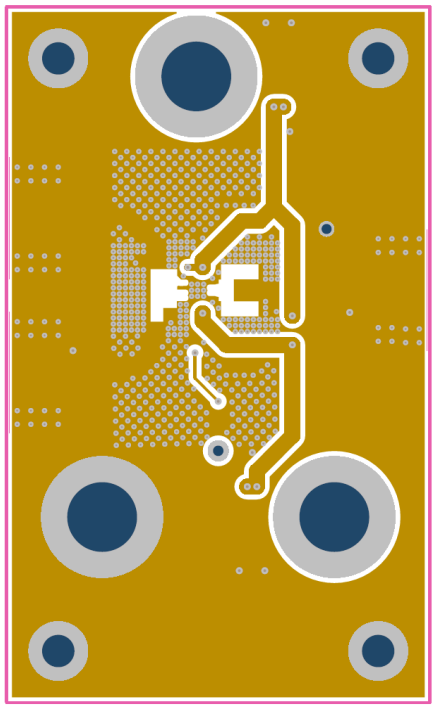

Figure 7. Layer 4 - GND/Signal

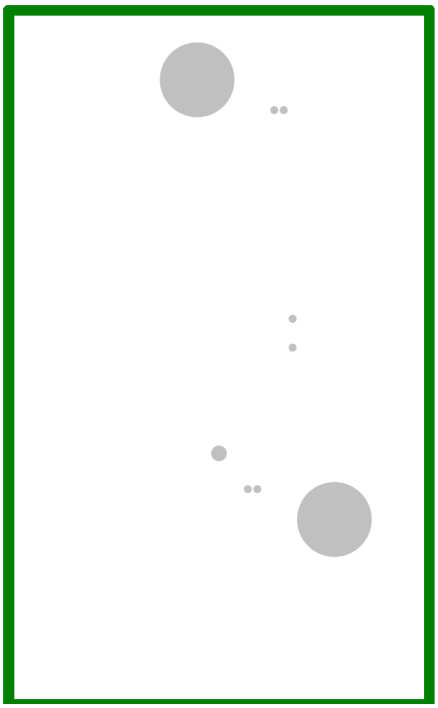

Figure 8. Layer 5 - GND

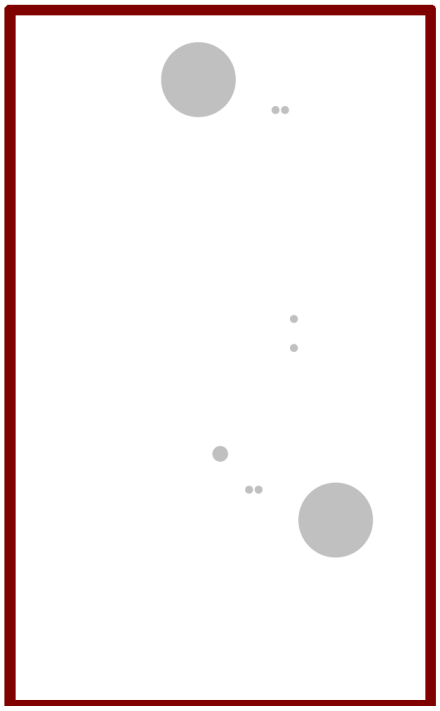

Figure 9. Layer 6 - GND

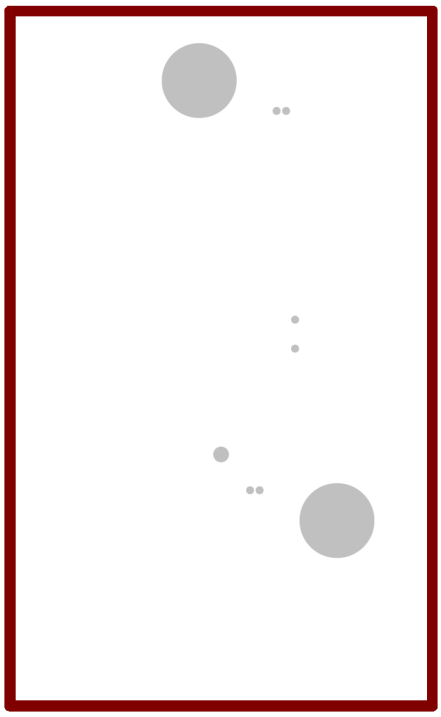

Figure 10. Layer 7 - GND

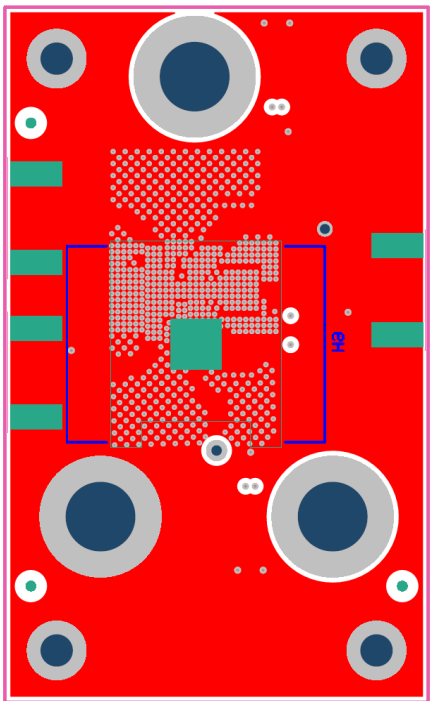

Figure 11. Bottom Components and Silk Screen Layer

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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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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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2. 実験局の免許を取得後ご使用いただく。
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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

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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.

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