

THS6212 Evaluation Module

This manual provides information about the evaluation module of the amplifier under test. Additionally, this document provides a good example of PCB design for high-speed applications. The user should keep in mind the following points:

- It is recommended that the user initially review the data sheet of the device under test.
- It is helpful to review the schematic and layout of the THS6212 EVM to determine the design techniques used in the evaluation board.
- The design of the high-speed amplifier PCB is a sensitive process. The user must approach high-speed PCB design with care and awareness.

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1 Introduction

The Texas Instruments THS6212 evaluation module (EVM) helps designers evaluate the performance of the THS6212 single-port current feedback architecture, differential line driver amplifier system in a 24-pin QFN package. This EVM is a good example of high-speed PCB design.

This document details the THS6212 EVM. It includes a list of EVM features, a brief description of the module illustrated with a series of schematic diagrams, EVM specifications, details on connecting and using the EVM, and a discussion of high-speed amplifier design considerations.

1.1 Description

The THS6212 evaluation module (EVM) is used to evaluate the THS6212, which is a single-port current-feedback architecture, differential line driver amplifier system in a 24-pin QFN package. The EVM is designed to quickly and easily demonstrate the functionality and performance of THS6212 in a gain of 10 V/V, driving an $R_{LOAD} = 100 \Omega$. The EVM is ready to connect to power supplies, signal source, and test instruments through the use of onboard connectors. The board is setup for single-ended input and output operation for interfacing with 50- Ω test equipment. By default, the THS6212EVM comes with the bias setting in Full Bias mode and can be configured in Mid Bias and Low Bias modes using jumper connectors.

1.2 Evaluation Module Features

The THS6212 high-speed operational amplifier EVM features include:

- Configured for split-supply operation and easily modified for single supply
- Designed for single-ended input and output connection facilitated by the onboard balun
- Simple interface to the inputs and outputs through the SMA connectors
- Bias mode settings changed using jumper connectors
- Active termination capability (R12 and R13)
- Non-inverting gain configuration for DSL

1.3 THS6212 Operating Conditions

Supply voltage range, $\pm V_{CC} = \pm 5$ to ± 13 Vdc (see the device data sheet).

Supply current, I_Q (see the device data sheet).

For complete THS6212 amplifier IC specifications, parameter measurement information, and additional application information, see the THS6212 data sheet ([SBOS758](#)).

1.4 EVM Default Configuration

As delivered, the EVM has a fully functional example circuit; just add power supplies, a signal source, and a monitoring instrument. See [Figure 8](#) for the default schematic diagram of the THS6212 EVM.

The default configuration assumes a differential gain of 10, as determined by R7, R8, and R9 in combination with series-matching resistors R10 and R11, and assuming a 50- Ω load on the output at J2.

Some components, such as supply bypass capacitors, JP1 and JP2, are omitted on the application schematics of [Section 3](#) for clarity.

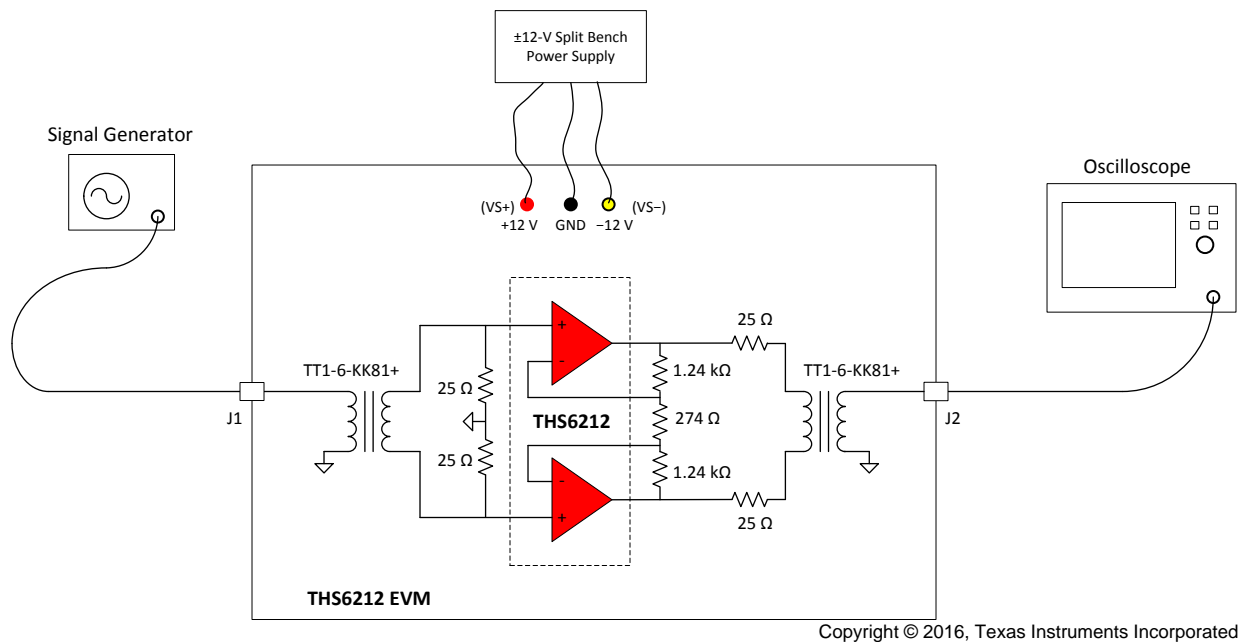


Figure 1. THS6212 EVM Default Configuration Setup Block Diagram

2 Using the THS6212 EVM

This section describes how to connect the THS6212 EVM to test equipment. It is recommended that the user connect the EVM as described in this section to avoid damage to the EVM or the THS6212 installed on the board.

2.1 Required Equipment

A list of the required equipment appears in the following:

- Dual dc output power supply (± 12 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 function generator (1 MHz, 1 V_{pp} sine wave).
- Oscilloscope (50-MHz bandwidth minimum, 50- Ω terminated BNC input).

2.2 Power Supply Setup (Reference [Figure 1](#))

Follow the below procedure for power supply setup:

- Before connecting the power supply cables to the EVM, set the dual dc output power supply to ± 12 V.
- Make sure the dc power supply is turned off before proceeding to the next step.
- Connect the +12 V power supply to the +Vs of the power supply port (P1) on the EVM.
- Connect the -12 V power supply to the -Vs of the power supply port (P1) on the EVM.
- Connect the ground(s) of the +12 V and -12 V power supply to the middle port of P1 (GND) 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 ± 12 V

The following table provides the typical supply current read on the current meter for the different plug-in jumper (JP1 and JP2) connections.

Table 1. Typical Power Supply Current Reading for Different Bias Modes

Bias Mode	JP1 position	JP2 position	$I_q(\text{typ})$
Full	Open	Open	21 mA
Mid	Closed	Open	16 mA
Low	Open	Closed	11 mA
Shut-down	Closed	Closed	< 1mA

2.3 *Input and Output Test Setup (Reference [Figure 1](#))*

Follow the below procedure for input and output test setup:

- Set the function generator to a 1 MHz, ± 0.24 V ($0.42 V_{pp}$) sine wave with no dc offset. The function generator output should be set in 50- Ω termination mode.
- Turn off the function generator before proceeding to the next step.
- Connect the function generator output to SMA connector J1 on the EVM.
- Scope channel 1 should be connected to SMA connector J2 on the EVM. Set the oscilloscope to 500 mV/division and a time-base of 1 μ s / division.

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

- Turn on the function generator. The measured output on the scope channel 1 at SMA connector J2 should approximately be ± 1 V ($2 V_{pp}$).

3 THS6212 EVM Applications

Couple of example applications are presented in this section. These applications demonstrate the most popular circuits to the user, but many other circuits can be constructed. The user is encouraged to experiment with different circuits, exploring new and creative design techniques.

3.1 Standard Gain Configuration

The THS6212 EVM default configuration is a fully differential input, fully differential output gain of 10 (at the THS6212 device output pins) as shown in Figure 2. This gain is calculated according an equation that is similar to the one that describes an instrumentation amplifier:

$$\text{Differential Gain} = \frac{V_O (\text{diff})}{V_I (\text{diff})} = 1 + \frac{2 \times R_F}{R_G}$$

where

- $R_F = 1.24 \text{ k}\Omega$
- $R_G = 274 \Omega$

(1)

The two series resistors $R_S = 25 \Omega$ affect the differential output voltage at J2. The designer needs to take the voltage divider law into account for their load impedance and R_S . In-addition to the two series resistors R_S , the insertion loss in the input and output baluns affects the measured gain and bandwidth of the EVM. As a result, it is required to remove the input and output balun insertion loss from the EVM measurement to determine the true THS6212 device performance.

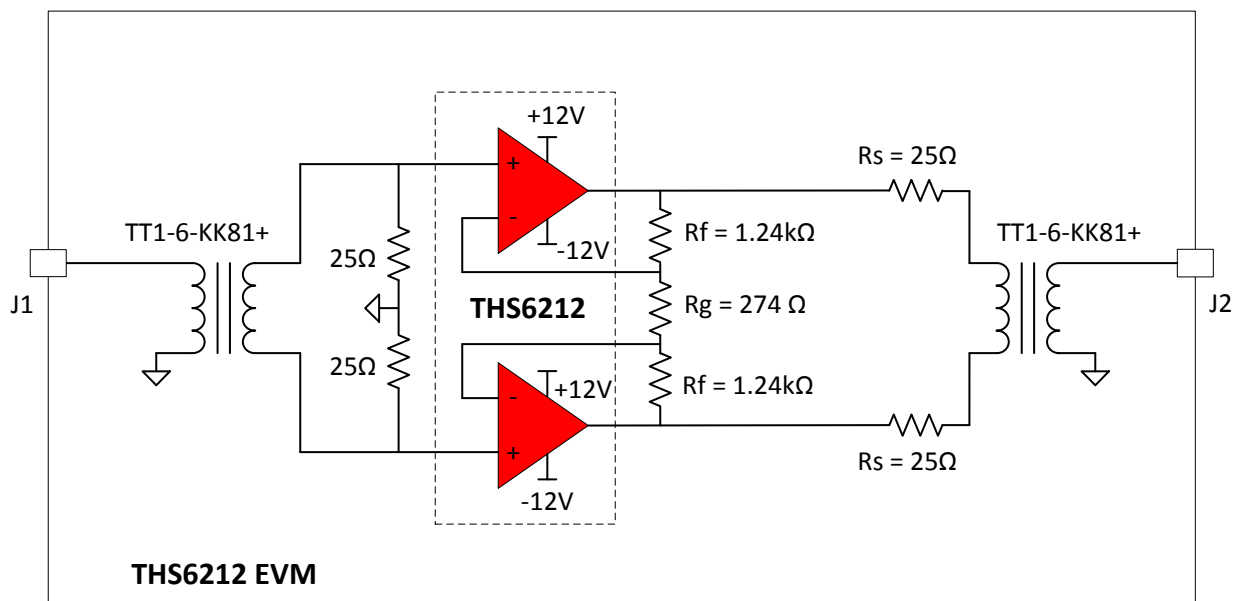


Figure 2. Default Configuration Operation

3.2 Active Termination

Active termination is a technique that allows the designer to use a small value resistor for the series resistance (R_S). The circuit then utilizes positive feedback to make the impedance of this resistor, when looking from the line-side, appear much larger. This accomplishes two things:

- A very small resistance when the line-driver amplifier transmits signals to the line. This lowers the output voltage swing range required from the driver stage.
- Proper matching impedance when looking from the line to the amplifier.

Figure 3 shows the basic circuit for differential positive feedback.

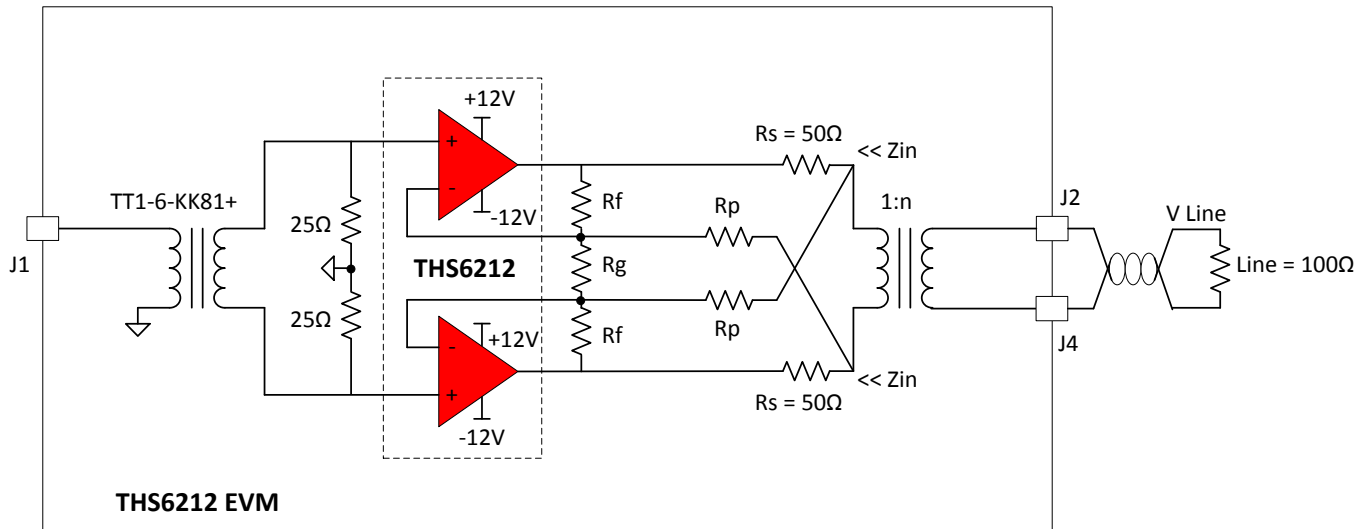


Figure 3. Differential Positive Feedback

Active feedback creates larger impedance (Z) than what is actually placed there by series resistors R_S :

$$Z(\Omega) = \frac{R_S}{1 - \frac{R_F}{R_P}} \quad (2)$$

The important thing to consider is that regardless of the forward gain from V_i to V_o , the active impedance (Z) value remains constant.

Now that the return impedance is corrected, forward voltage gain from input to output is calculated. Equation 3 shows the simplified forward gain from V_i to V_o .

$$A_V = \frac{V_{O\pm}}{V_{in\pm}} = \frac{1 + \left(\frac{R_F}{R_G \parallel R_P}\right)}{1 - \left(\frac{R_F}{R_P}\right) \left(\frac{R_L}{R_L + R_S}\right)} \text{ iff } R_L \ll R_P \quad (3)$$

Where:

$$R_L = \frac{R_{LINE}}{2n^2} \quad (4)$$

The reader is cautioned that active termination is a very complex topic, with many considerations. Carefully read the Texas Instruments Application Report, Active Output Impedance for ADSL Line Drivers, SLOA100 to gain a more complete understanding of the topic and all of the subtle implications of active termination.

4 High-Speed Amplifier PCB Layout Tips

The THS6212 EVM layout, designed for use with high-speed signals, can be used as an example when designing PCBs incorporating the THS6212. 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 THS6212 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- μ F 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 printed-circuit board 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 <http://www-s.ti.com/sc/techlit/slma002> and <http://www-s.ti.com/sc/techlit/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 amplifier's load 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 amplifier's phase-margin 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 printed-circuit board layout.

5.1 Bill of Materials

Table 2 lists the EVM bill of materials.

Table 2. THS6212 EVM Bill of Materials

Item #	Designator	Qty	Value	Part Number	Manufacturer	Description	Package Reference
1	!PCB1	1		HSP017	Any	Printed Circuit Board	
2	C1, C2	2	2.2uF	GRM21BR61E225KA12L	Murata	CAP, CERM, 2.2 μ F, 25 V, +/- 10%, X5R, 0805	0805
3	C3	1	1000pF	CX0603MRX7R0BB102	Yageo America	CAP, CERM, 1000 pF, 100 V, +/- 20%, X7R, 0603	0603
4	C4	1	0.01uF	08055C103KAT2A	AVX	CAP, CERM, 0.01 μ F, 50 V, +/- 10%, X7R, 0805	0805
5	J1, J2	2		142-0701-851	Emerson Network Power	Connector, End launch SMA, 50 ohm, SMT	SMA End Launch
6	JP1, JP2	2		TSW-102-07-G-S	Samtec	Header, 100mil, 2x1, Gold, TH	2x1 Header
7	L1, L2	2	90 ohm	MI1206K900R-10	Laird-Signal Integrity Products	Ferrite Bead, 90 ohm @ 100 MHz, 1.5 A, 1206	1206
8	P1	1		ED120/3DS	On-Shore Technology	Terminal Block, 5.08 mm, 3x1, Brass, TH	3x1 5.08 mm Terminal Block
9	R1, R2	2	24.9	ERJ-2RKF24R9X	Panasonic	RES, 24.9, 1%, 0.1 W, AEC-Q200 Grade 0, 0402	0402
10	R3, R4, R5, R6	4	10k	RC1608J103CS	Samsung Electro-Mechanics	RES, 10 k, 5%, 0.1 W, 0603	0603
11	R7, R8	2	1.24k	CRCW04021K24FKED	Vishay-Dale	RES, 1.24 k, 1%, 0.063 W, 0402	0402
12	R9	1	274	CRCW0402274RFKED	Vishay-Dale	RES, 274, 1%, 0.063 W, 0402	0402
13	R10, R11	2	24.9	RC0603FR-0724R9L	Yageo America	RES, 24.9, 1%, 0.1 W, 0603	0603
14	R14, R18	2	0	RC0603JR-070RL	Yageo America	RES, 0, 5%, 0.1 W, 0603	0603
15	R15, R16, R17	3	0	RC0402JR-070RL	Yageo America	RES, 0, 5%, 0.063 W, 0402	0402
16	T1, T2	2		TT1-6-KK81+	Minicircuits	RF Transformer, 50ohm, 0.004 to 300 MHz, SMT	7.62x6.86mm
17	U1	1		THS6212IRHFR	Texas Instruments	VDSL2 Line Driver Amplifier, RHF0024A	RHF0024A
18	FID1, FID2, FID3	0		N/A	N/A	Fiducial mark. There is nothing to buy or mount.	Fiducial
19	H2, H5, H8, H11	0		1902C	Keystone	Standoff, Hex, 0.5"L #4-40 Nylon	Standoff
20	H3, H6, H9, H12	0		NY PMS 440 0025 PH	B&F Fastener Supply	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	Screw
21	J3, J4	0		142-0701-851	Emerson Network Power	Connector, End launch SMA, 50 ohm, SMT	SMA End Launch
22	R12, R13	0	49.9	CRCW040249R9FKED	Vishay-Dale	RES, 49.9, 1%, 0.063 W, 0402	0402
23	TP1	0		5000	Keystone	Test Point, Miniature, Red, TH	Red Miniature Testpoint

5.2 Circuit Board Layout

Figure 4 through Figure 7 illustrate the EVM PCB layout.

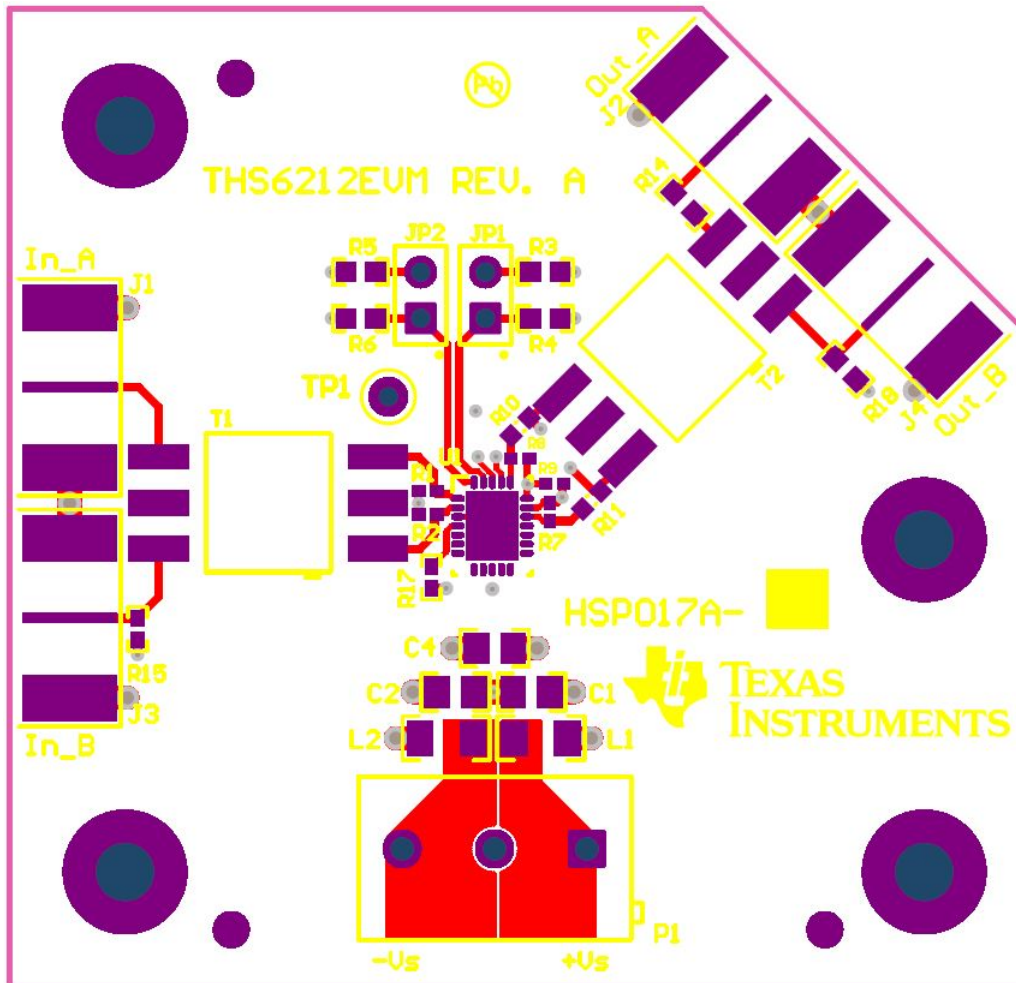


Figure 4. Top Components and Silk Screen

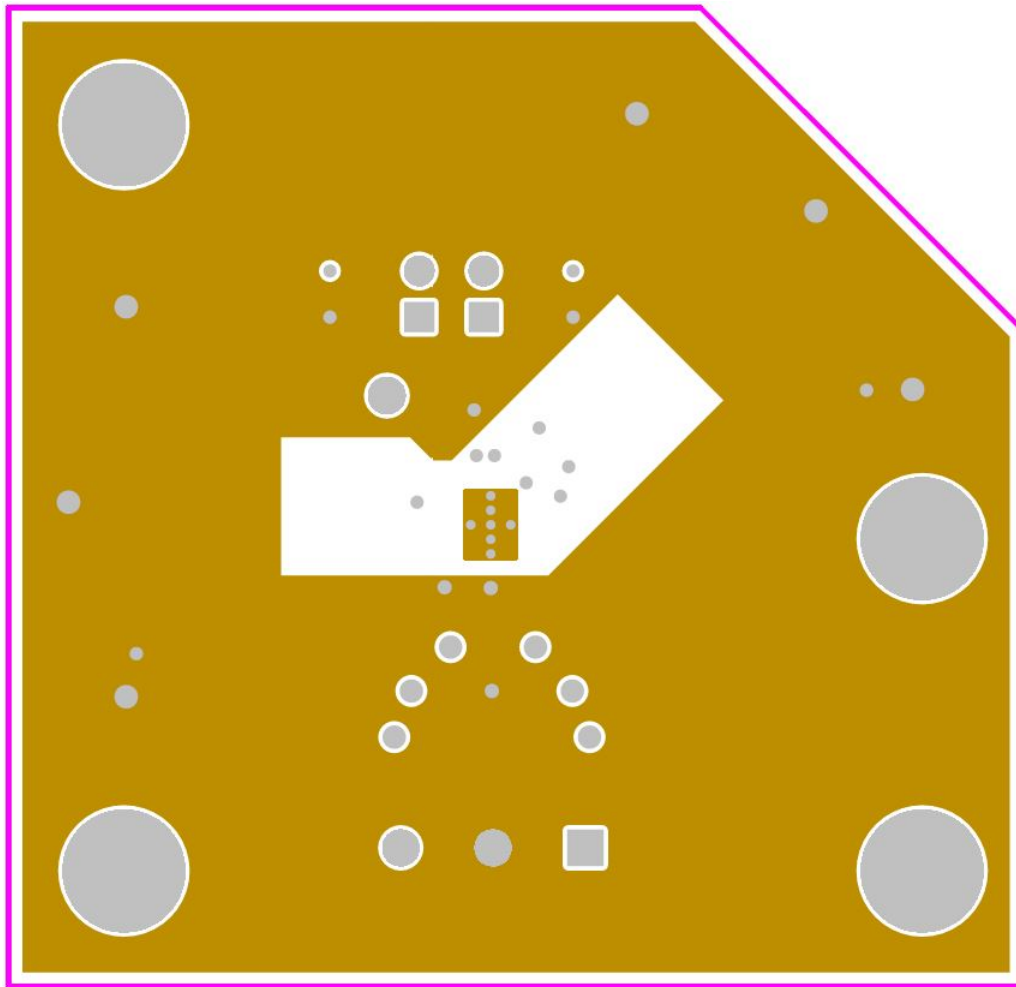


Figure 5. Ground Layer

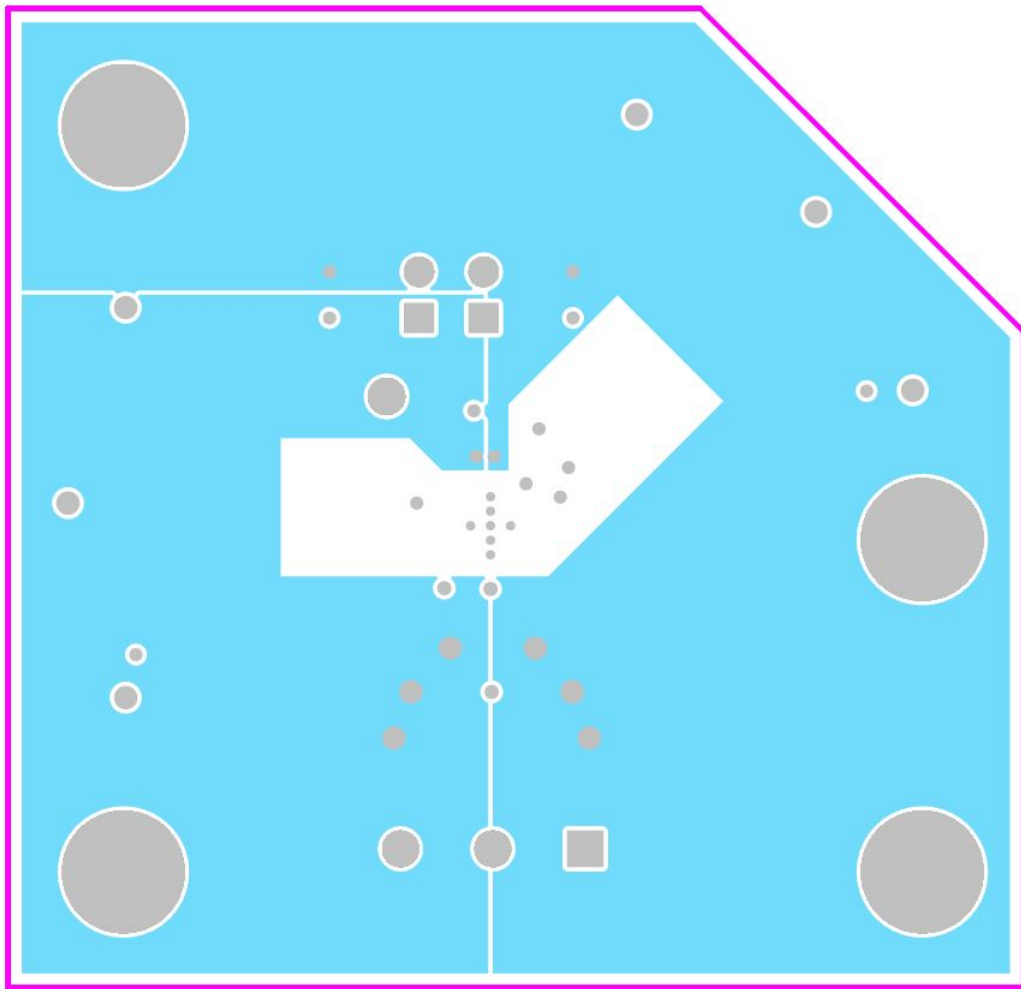


Figure 6. Power Layer

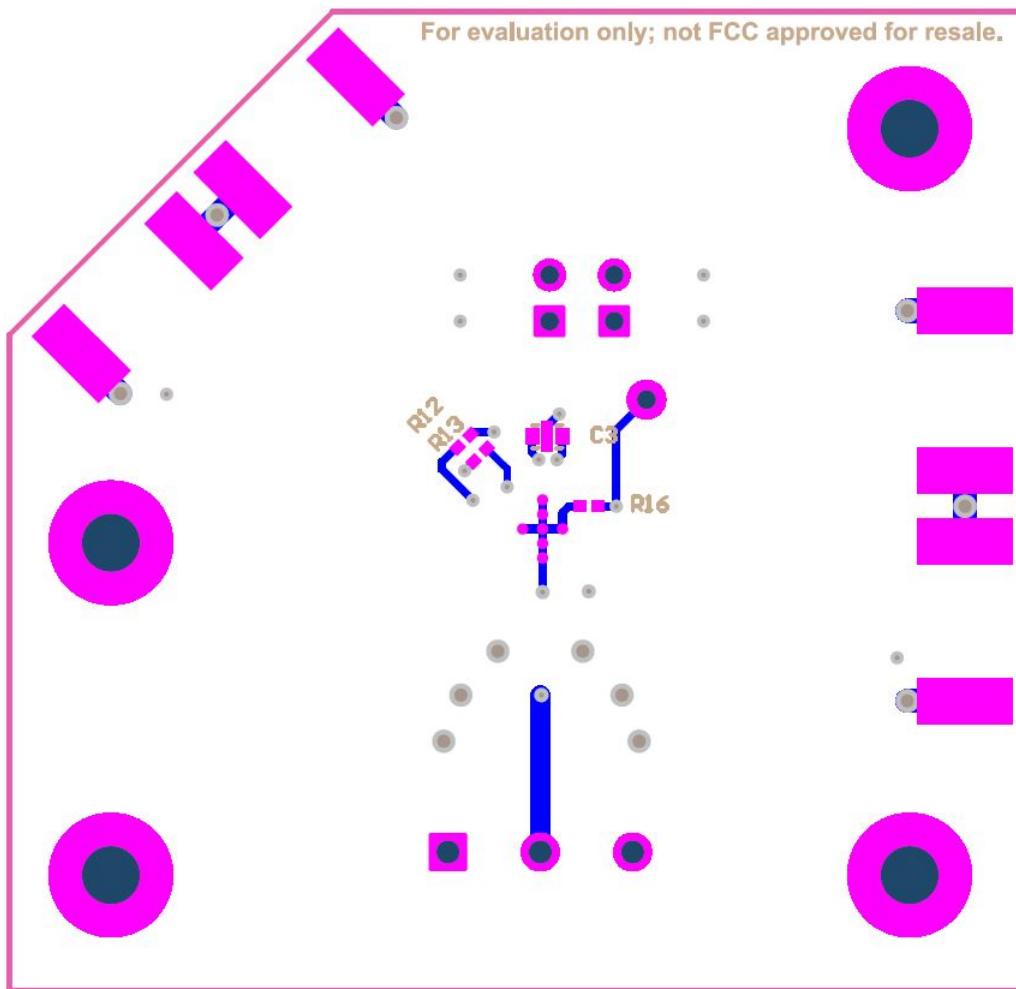
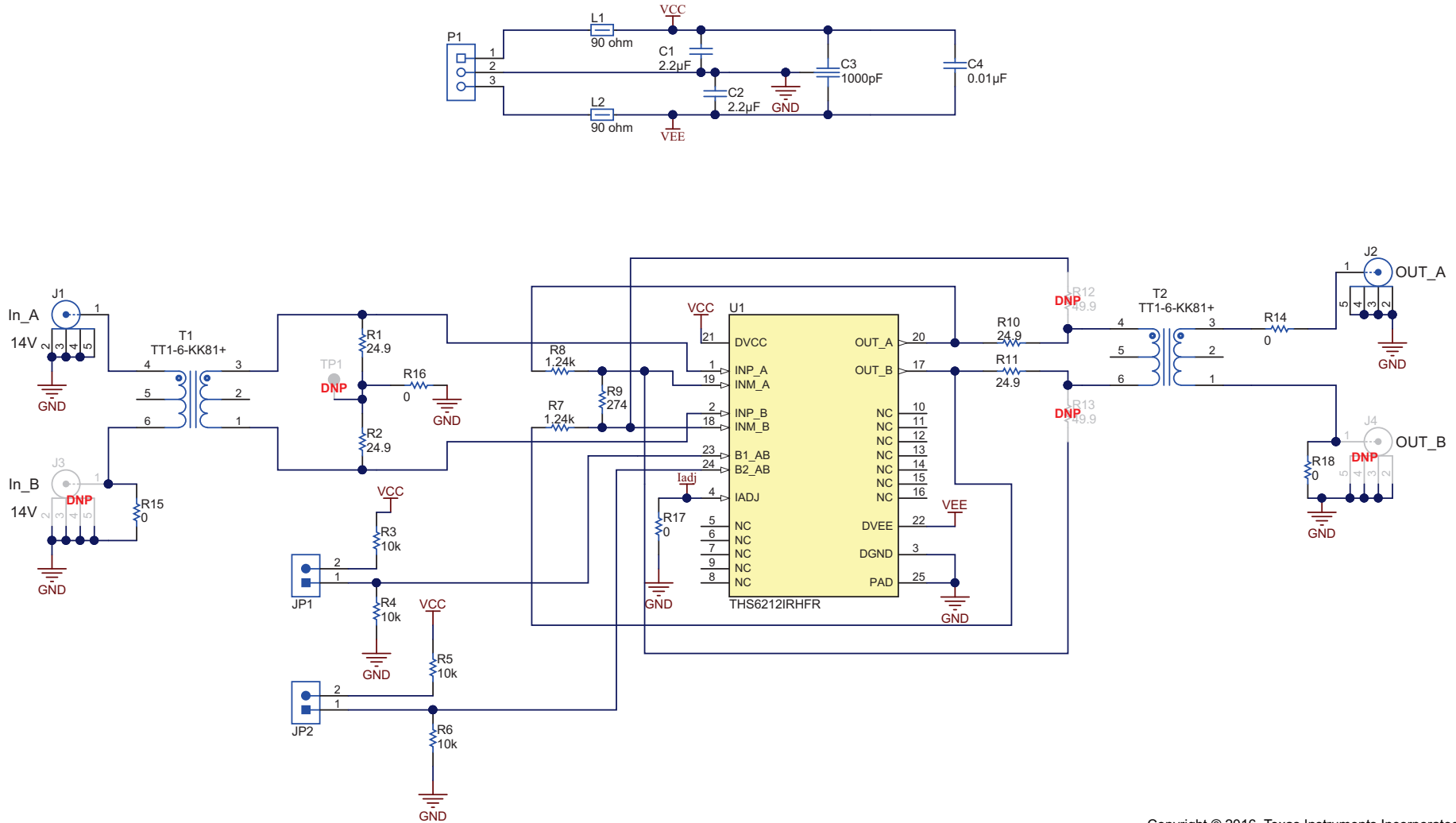


Figure 7. Bottom Components and Silk Screen

5.3 Schematic

Figure 8 illustrates the EVM schematic.



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Figure 8. Full Schematic of the THS6212 EVM

STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

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3. *Regulatory Notices:*
 - 3.1 *United States*
 - 3.1.1 *Notice applicable to EVMs not FCC-Approved:*

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

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

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

Concerning EVMs Including Detachable Antennas:

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

Concernant les EVMs avec antennes détachables

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

3.3 Japan

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

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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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.

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