

## **LMH5401EVM-CVAL Evaluation Module (EVM)**

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The LMH5401EVM-CVAL is an evaluation module for the single LMH5401-SP amplifier in a 14-pin *Leadless Ceramic Chip Carrier* (LCCC) high-performance RF package. This evaluation module is designed to quickly and easily demonstrate the functionality and versatility of the amplifier. The EVM is ready to connect to power, signal source, and test instruments through the use of onboard connectors. The EVM comes configured for easy connection with common 50-Ω laboratory equipment on its inputs and outputs. The amplifier is configured for single-ended input with gain of 17 dB (7 V/V). The board has differential outputs, one for each of the amplifier outputs. The EVM can be easily configured for differential inputs, and single- or split-supply operation.

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### **Trademarks**

All trademarks are the property of their respective owners.

## 1 Features

This EVM has the following features:

- Configured for split-supply operation and easily modified for single supply
- Single ended or differential input signals
- Fully differential output
- Designed for easy connection to standard 50- $\Omega$  input/output impedance test equipment
- Inputs and outputs include SMA connectors

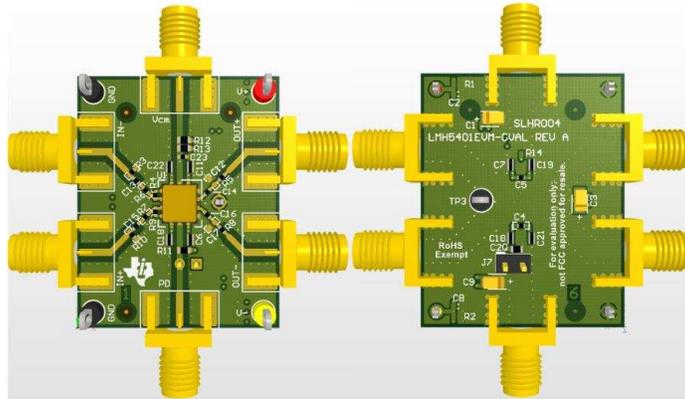


Figure 1. LMH5401EVM-CVAL Board

## 2 EVM Specifications

Table 1 displays the EVM specifications:

Table 1. EVM Specifications

Parameter	Value
$V_S$ Single-supply voltage range ( $V_- = \text{ground}$ )	3.15 V to 5.25 V
$V_{S\pm}$ Split-supply voltage range	$\pm 1.58$ V to $\pm 2.625$ V
GND Ground reference pins	( $V_+ - 2$ V) to $V_-$
PD Power down (PD) input voltage	GND to $V_{CC}$
$I_{S\pm}$ Supply current	58 mA
$I_{IN}$ Input voltage	$V_{S\pm}$ , Max
$I_{OUT}$ Output drive	$\pm 40$ mA

### 3 Power Connections

The LMH5401EVM-CVAL is equipped with test loops for easy power connection. The positive supply input is red and is labeled V+. The negative supply input is yellow and is labeled V-. Ground is black and is labeled GND.

#### 3.1 Split-Supply Operation

To operate as split supply, apply the positive supply voltage to V+, negative supply voltage to V-, and the ground reference from supply to GND. The supply voltages do not need to be symmetrical, provided that the total supply voltage is between 3.15 V and 5.25 V, any combination of positive and negative supply voltages is acceptable. This feature is often used when the output common-mode voltage must be set to a particular value. For best performance, the power supply voltages should be symmetrical around the desired output common-mode voltage.

#### 3.2 Single-Supply Operation

To operate as single supply, connect jumper V- to GND, and apply the positive supply voltage to V+. Inputs and outputs must be biased as in [LMH5401-SP Class-V, 8-GHz, Low-Noise, Low-Power, Fully-Differential Amplifier](#), specifications for proper operation.

### 4 Input and Output Connections

The LMH5401EVM-CVAL is equipped with SMA connectors for easy connection of signal generators and analysis equipment. As shipped, the EVM is configured for a gain of 17 dB, split supply, single-ended input and differential outputs each with 50- $\Omega$  termination. For best results, signals must be routed to and from the EVM with cables having 50- $\Omega$  characteristic impedance. The input connectors for single-ended input signals are IN+ and IN-, which are symmetrical. The output connectors are OUT+ and OUT-. In addition to the signal cables, a 50- $\Omega$  resistive termination is required for the unused input. See [LMH5401-SP Class-V, 8-GHz, Low-Noise, Low-Power, Fully-Differential Amplifier](#) for additional details on configuring the device.

#### 4.1 CM (Output Common-Mode Voltage) Input

The LMH5401-SP device has an output common-mode control pin that sets the output common-mode voltage. The evaluation board is configured with a resistive divider to set the output common-mode voltage at the mid-supply voltage. If a different output common-mode voltage is specified, the SMA connector can be used to connect an external voltage source, provided the AC-coupling capacitors are removed.

#### 4.2 PD (Power Down) Input

The LMH5401-SP device has a power-down input pin that allows the amplifier to enter a low-power state when it does not need to be active. The LMH5401-SP PD pin is referenced to the GND pin. The threshold voltage is 1.1 V. Any voltage over 1.2 V above the ground reference pins will disable the amplifier. Any input below 0.9 V enables the amplifier. Because the PD pin is not referenced to either of the supply pins the same logic level can be used for the PD function regardless of the configuration of the supply voltages. The LMH5401EVM-CVAL has a jumper (JPD) that allows the amplifier to be manually disabled. In order to facilitate driving the PD pin with a high-speed signal source, the resistor-capacitor combination (R11, C20) provides high-frequency termination for signals from a 50- $\Omega$  pulse generator.

#### 4.3 Single-Ended Inputs

The LMH5401-SP device was designed for use with 50- $\Omega$  single-ended inputs. Even though the board was designed for single-ended inputs, the board is fully symmetrical, so either input can be used. Connect a 50- $\Omega$  signal source to either IN+ or IN- and connect a 50- $\Omega$  SMA termination to the other input. This way both inputs have the same termination condition and the circuit is balanced. In the case where no SMA 50- $\Omega$  termination is available, soldering a 50- $\Omega$  resistor from the unused input signal trace to the ground plane is acceptable. A small section of the ground plane has no solder mask that can be used for this purpose.

#### 4.4 Differential Inputs

Using the LMH5401-SP for differential inputs is possible, however, the on-board resistors must be changed first, as the default configuration of EVM is single-ended to differential. The LMH5401-SP device has an internal feedback resistance of  $25\ \Omega$  between the output and the FB connections. Therefore, once the total feedback resistance is determined for a desired gain, the actual external Rf feedback resistors to be installed should be reduced by the same  $25\ \Omega$ . To impedance match a  $100\text{-}\Omega$  differential source, the R<sub>i-</sub> and R<sub>2</sub> resistors both need to be  $50\ \Omega$ . The desired gain will then determine the required value for R<sub>f+</sub> and R<sub>f-</sub>. The gain will be  $A_v = (R_f + 25) / R_g$ . As with other RF devices, the final system gain depends on the source resistance and the load resistance.

#### 4.5 Differential Outputs

The LMH5401EVM-CVAL has two output SMA connectors that are designed to mate to  $50\text{-}\Omega$  test equipment. By connecting both outputs to  $50\text{-}\Omega$  test equipment, the output load is  $100\text{-}\Omega$  differential. The evaluation board has  $40\text{-}\Omega$  resistors on the board and there are  $10\text{-}\Omega$  output resistors on-chip inside the device. With the on-chip and onboard matching resistors, the total load seen by the amplifier is  $200\ \Omega$ . The matching resistors cause a 6-dB loss in voltage gain.

#### 4.6 Single-Ended Outputs

Using an external balun to combine the two differential outputs creates a single-ended signal that can be interfaced to most  $50\text{-}\Omega$  test equipment. This is the method used by TI engineers to create the data sheet plots. To match the performance of the LMH5401-SP device, a very broadband balun must be selected. TI recommends the Marki B0100 or the PicoPulse Labs 5310A baluns.

## 5 LMH5401EVM-CVAL Schematic, Layout, and Bill of Materials

This section contains the EVM schematic, PCB layouts, and the bill of materials (BOM).

### 5.1 Schematic

Figure 2 illustrates the LMH5401EVM-CVAL schematic.

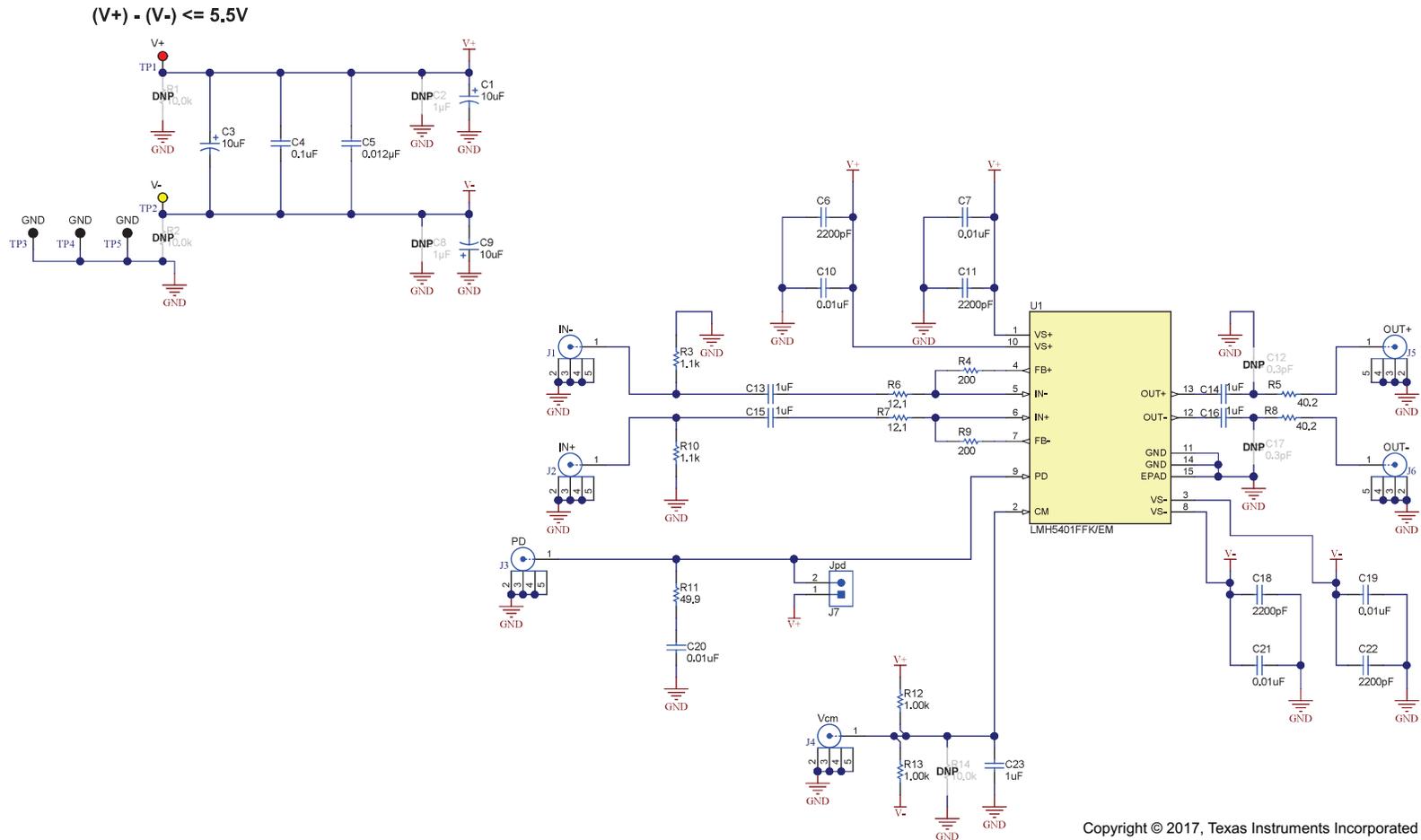


Figure 2. LMH5401EVM-CVAL Schematic

## 5.2 LMH5401EVM-CVAL Layers

Figure 3 through Figure 8 show the LMH5401EVM-CVAL layers.

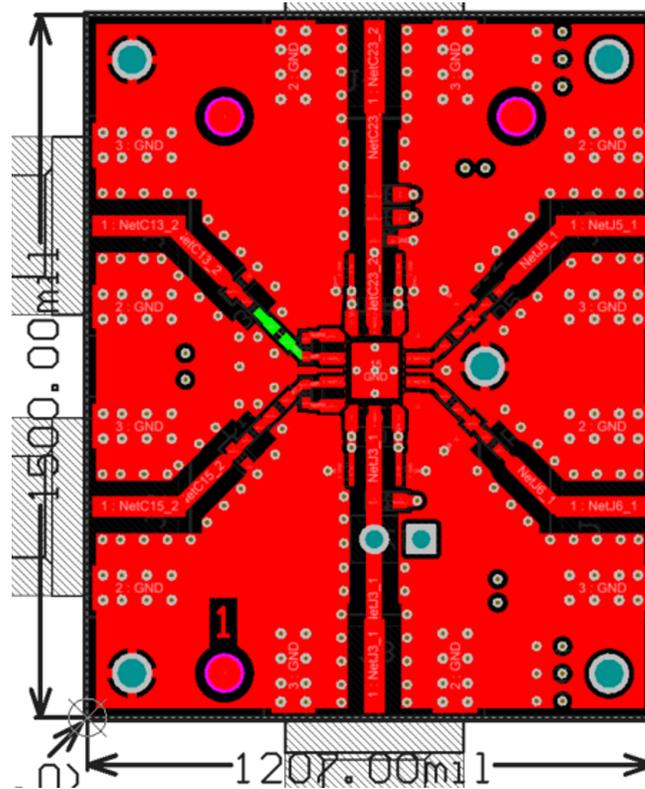


Figure 3. LMH5401EVM-CVAL Top Layer

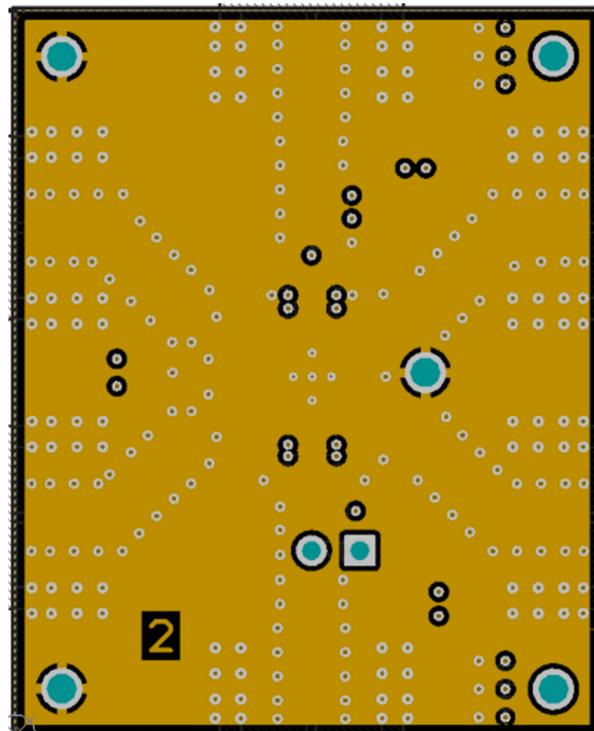


Figure 4. Layer 2

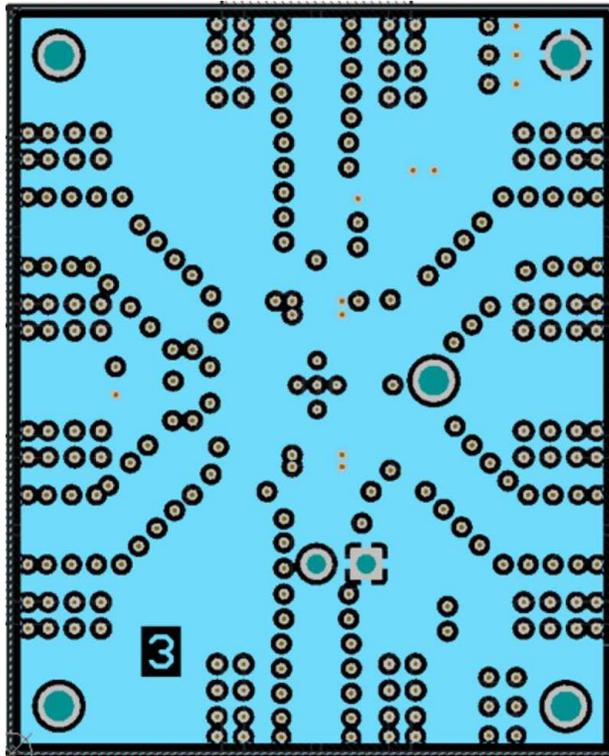


Figure 5. Layer 3

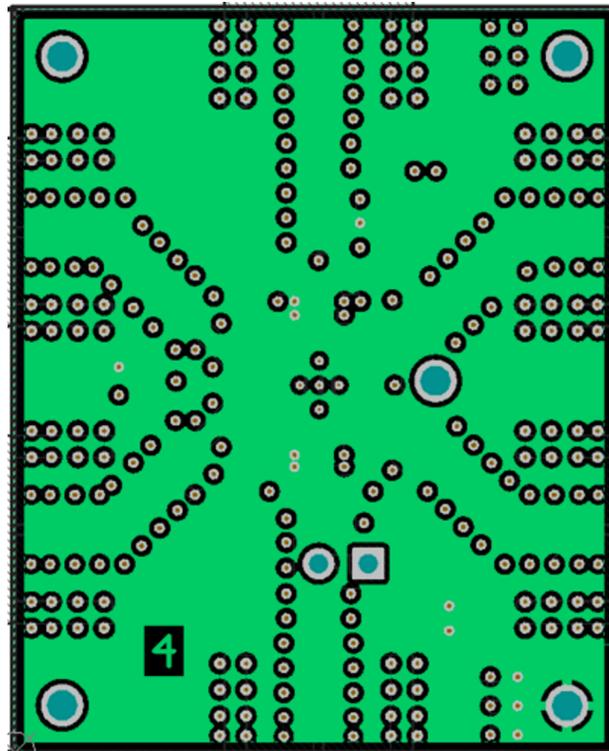


Figure 6. Layer 4

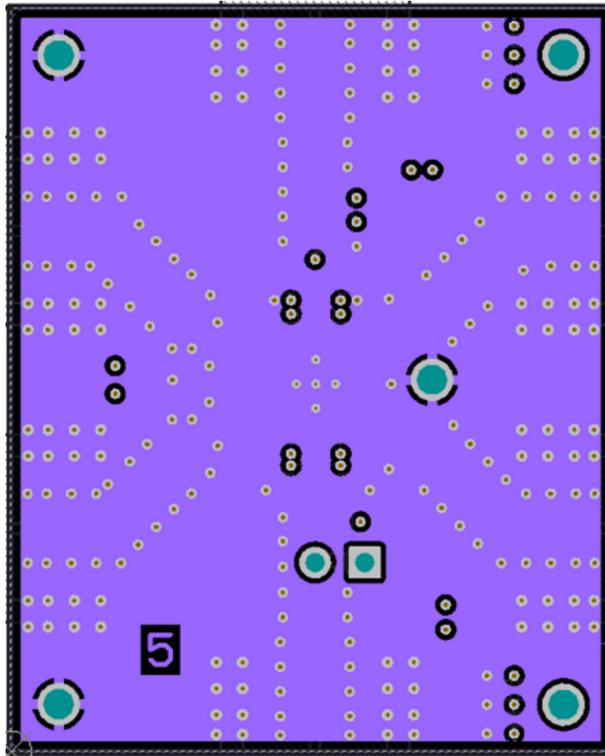


Figure 7. Layer 5

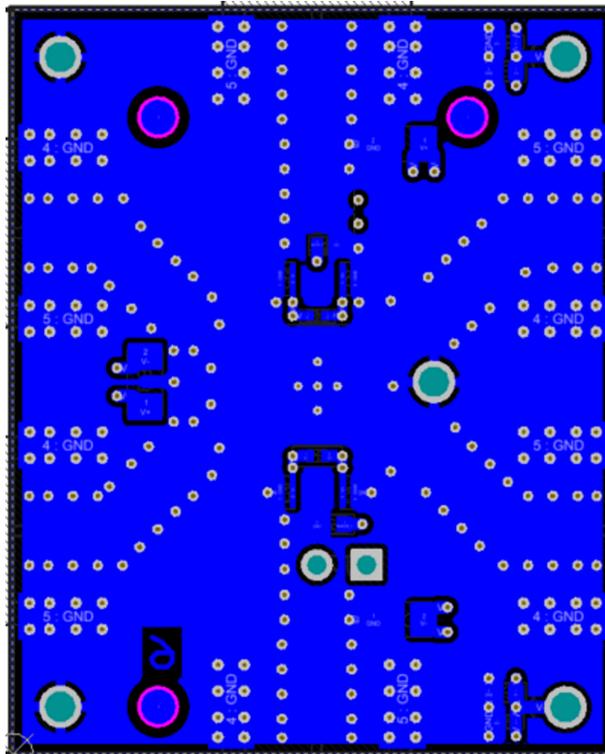


Figure 8. Bottom Layer

### 5.3 Bill of Materials

Table 2 lists the EVM BOM.

**Table 2. LMH5401EVM-CVAL Bill of Materials**

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
!PCB	1		Printed Circuit Board		SLHR004	Any
C1, C3, C9	3	10uF	CAP, TA, 10 uF, 10 V, ±10%, 0.9 ohm, SMD	3216-18	TPSA106K010R0900	AVX
C4	1	0.1uF	0.10µF ±10% 10V X5R Ceramic Capacitor -55°C ~ 85°C Surface Mount, MLCC 0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0.50mm)	0402	C1005X5R1A104K050BA	TDK Corporation
C5	1	0.012uF	10000pF ±10% 25V X7R Ceramic Capacitor -55°C ~ 125°C Surface Mount, MLCC 0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0.50mm)	0402	C1005X7R1E103K050BB	TDK Corporation
C6, C11, C18, C22	4	2200pF	CAP, CERM, 2200 pF, 50 V, ±20%, X7R, 0306	0306	LLL185R71H222MA01L	Murata
C7, C10, C19, C21	4	0.01uF	CAP, CERM, 0.01 uF, 25 V, ±20%, X7R, 0306	0306	LLL185R71E103MA01L	Murata
C13, C14, C15, C16, C23	5	1uF	CAP, CERM, 1 uF, 35 V, ±10%, X5R, 0402	0402	GRM155R6YA105KE11D	Murata
C20	1	0.01uF	CAP, CERM, 0.01 uF, 16 V, ±10%, X7R, 0603	0603	GRM188R71C103KA01D	Murata
J1, J2, J3, J4, J5, J6	6		Connector, End launch SMA, 50 ohm, SMT	SMA End Launch	142-0701-851	Cinch Connectivity
J7	1		Header, 100mil, 2x1, Gold, TH	2x1 Header	TSW-102-07-G-S	Samtec
R3, R10	2	1.1k	RES, 1.1 k, 5%, 0.063 W, 0402	0402	CRCW04021K10JNED	Vishay-Dale
R4, R9	2	200	RES, 200, 1%, 0.063 W, 0402	0402	CRCW0402200RFKED	Vishay-Dale
R5, R8	2	40.2	RES, 40.2, 1%, 0.063 W, 0402	0402	CRCW040240R2FKED	Vishay-Dale
R6, R7	2	12.1	RES, 12.1, 1%, 0.063 W, 0402	0402	CRCW040212R1FKED	Vishay-Dale
R11	1	49.9	RES, 49.9, 1%, 0.1 W, 0603	0603	CRCW060349R9FKEA	Vishay-Dale
R12, R13	2	1.00k	RES, 1.00 k, 1%, 0.1 W, 0603	0603	CRCW06031K00FKEA	Vishay-Dale
SH-Jpd_1-OPEN	1	1x2	Shunt, 100mil, Gold plated, Black		382811-6	AMP
TP1	1		Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	5010	Keystone
TP2	1		Test Point, Multipurpose, Yellow, TH	Yellow Multipurpose Testpoint	5014	Keystone
TP3, TP4, TP5	3		Test Point, Multipurpose, Black, TH	Black Multipurpose Testpoint	5011	Keystone
U1	1		LMH5401-SP, FFK0014A (LCCC-14)	FFK0014A	LMH5401FFK/EM	Texas Instruments
C2, C8	0	1uF	CAP, CERM, 1 µF, 35 V, ±10%, X5R, 0603	0603	GMK107BJ105KA-T	Taiyo Yuden
C12, C17	0	0.3pF	CAP, CERM, 0.3 pF, 50 V, ±30%, C0G/NP0, 0402	0402	500R07S0R3BV4T	Johanson Technology
R1, R2, R14	0	10.0k	RES, 10.0 k, 1%, 0.1 W, 0402	0402	ERJ-2RKF1002X	Panasonic

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## Revision History

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

Changes from Original (October 2017) to A Revision	Page
• Changed <a href="#">Section 4.4</a> .....	4

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## STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an "EVM" or "EVMs") to the User ("User") in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.
  - 1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductor 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/lstds/ti\\_ja/general/eStore/notice\\_01.page](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](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 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/lstds/ti\\_ja/general/eStore/notice\\_02.page](http://www.tij.co.jp/lstds/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/lstds/ti\\_ja/general/eStore/notice\\_02.page](http://www.tij.co.jp/lstds/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:*

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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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