



# 1 Evaluation Module Overview

## 1.1 Introduction

This document is the user's guide for the evaluation board (EVM) meant for testing the TRF2001 FEM in both transmit and receive mode configuration. Two DC power supply rails are required, VOLT\_PA\_supply (VCC\_PA) for power amplifier and other VOLT\_3P3V\_supply (VCC) for LNA and control signals. To configure the device for the desired operating mode, use jumper settings on header J1 (see [Section 1.3](#)). TRF2001EVM operating mode settings are shown in [Table 1-1](#).

**Table 1-1. TRF2001EVM Operating Mode Settings**

Mode	Control signals	I/O Configurations	Comment
TX path enabled	CTL0 (CEN) = 1 CTL1 (CIB) = 1 CTL2 (CTR) = 1	Signal generator at TR connector and spectrum analyzer at ANT connector	Device configured for RF transmit mode
RX path enabled	CTL0 (CEN) = 1 CTL1 (CIB) = 1 CTL2 (CTR) = 0	Signal generator at ANT connector and spectrum analyzer at TR connector	Device configured for RF receive mode
Power down	CTL0 (CEN) = 0 CTL1 (CIB) = 0 CTL2 (CTR) = 0	No operation	Device in powered down state

This document also includes schematic diagram ([Section 3.1](#)), printed-circuit board (PCB) layouts ([Section 3.2](#)), a bill of materials (BOM, [Section 3.3](#)), and hardware usage information ([Section 2](#)). This user's guide describes the basic steps and functions that are required for the proper operation and quick setup of the TRF2001EVM.



## 1.2 Kit Contents

[Table 1-2](#) lists the contents of the EVM kit. Contact Texas Instruments [Customer support center](#) if any components are missing.

**Table 1-2. Kit Contents**

Item	Quantity
TRF2001EVM	1
Jumpers SPC02SVGN-RC or similar	4

## 1.3 Specifications

This section covers the specifications and information about the RF connectors and header J1. Every pin of the header J1 has a detailed silkscreen for each pin. The summary is shown in [Table 1-3](#).

**Table 1-3. Specifications**

Connector	Parameter	Input Value
TR (TX path enabled)	RF Input	Max 16dBm
ANT (TX path enabled)	RF Output	
TR (RX path enabled)	RF Output	
ANT (RX path enabled)	RF Input	Max 10dBm
J1.1	VCC_3P3V	Pull up for CTL0 (CEN) control pin
J1.2	GND	
J1.3	CTL0	CEN control pin
J1.4	CTL0_DCARD	Unused
J1.5	GND	Pull down for CTL0 (CEN) control pin
J1.6	VCC_3P3V	Pull up for CTL1 (CIB) control pin
J1.7	CTL1_DCARD	Unused
J1.8	CTL1	CIB control pin
J1.9	VCC_3P3V	Pull up for CTL2 (CTR) control pin
J1.10	GND	Pull down for CIB control pin
J1.11	CTL2	CTR control pin
J1.12	CTL2_DCARD	Unused
J1.13	GND	Pull down for CTR control pin
J1.14	GND	
J1.15	GND	
J1.16	GND	
J1.17	VOLT_PA_supply	VCC_PA power supply
J1.18	GND	
J1.19	VOLT_PA_supply	VCC_PA power supply
J1.20	GND	
J1.21	VOLT_3P3V_supply	VCC power supply
J1.22	GND	
J1.23	VOLT_3P3V_supply	VCC power supply
J1.24	GND	
J3.1	VDET	Monitor transmit RF power as voltage
J3.2	GND	

## 1.4 Device Information

See the [TRF2001](#) datasheet for detailed device information.

## 2 Hardware

### 2.1 General Usage Information

This section provides general usage information for the TRF2001EVM. See [Figure 2-1](#) for single tone setup for TX path enabled mode and [Figure 2-2](#) for single tone setup for RX path enabled mode as reference setups for the following instructions (some components, such as supply bypass capacitors, are omitted for clarity):

1. Recommended power up sequence:
  - a. Set VOLT\_PA\_supply to 3.3V and current limit to 900mA.
    - Connect the power supply at J1.17 (VOLT\_PA\_supply) and J1.18 (GND).
    - Connect power supply sense lines at J1.19 (VOLT\_PA\_supply) and J1.20 (GND).
  - b. Set VOLT\_3P3V\_supply to 3.3V and current limit to 100mA.
    - Connect the power supply at J1.21 (VOLT\_3P3V\_supply) and J1.22 (GND).
    - Connect power supply sense lines at J1.23 (VOLT\_3P3V\_supply) and J1.24 (GND).
  - c. Set operating mode (TX path enabled, RX path enabled, or power down) using the jumpers at J1. See [Table 2-1](#) for configuring the operating modes.

**Table 2-1. Jumper Configuration for Setting the Operating Mode**

Operating Mode	Header J1 Jumper Configuration	Comment
TX path enabled	Use a jumper to connect: <ul style="list-style-type: none"> <li>• J1.3 (CTL0/CEN) to J1.1 (VCC_3P3V)</li> <li>• J1.8 (CTL1/CIB) to J1.6 (VCC_3P3V)</li> <li>• J1.11 (CTL2/CTR) to J1.9 (VCC_3P3V)</li> </ul>	With no RF input at TR, approximately 60mA current is expected at VOLT_PA_supply (VCC_PA), and approximately 7mA at VOLT_3P3V_supply (VCC).
RX path enabled	Use a jumper to connect: <ul style="list-style-type: none"> <li>• J1.3 (CTL0/CEN) to J1.1 (VCC_3P3V)</li> <li>• J1.8 (CTL1/CIB) to J1.6 (VCC_3P3V)</li> <li>• J1.11 (CTL2/CTR) to J1.13 (GND)</li> </ul>	With no RF input at ANT, 0.3mA current is expected at VOLT_PA_supply (VCC_PA), and approximately 10mA at VOLT_3P3V_supply (VCC).
Power down	Use a jumper to connect: <ul style="list-style-type: none"> <li>• J1.3 (CTL0/CEN) to J1.5 (GND)</li> <li>• J1.8 (CTL1/CIB) to J1.10 (GND)</li> <li>• J1.11 (CTL2/CTR) to J1.13 (GND)</li> </ul>	Device in powered down state

2. Power-down sequence:
  - a. Turn OFF RF signals to the TRF2001EVM (TR and ANT connectors).
  - b. Set VOLT\_3P3V\_supply to 0V and then set VOLT\_PA\_supply to 0V.

## 2.2 Single Tone Measurement Setup

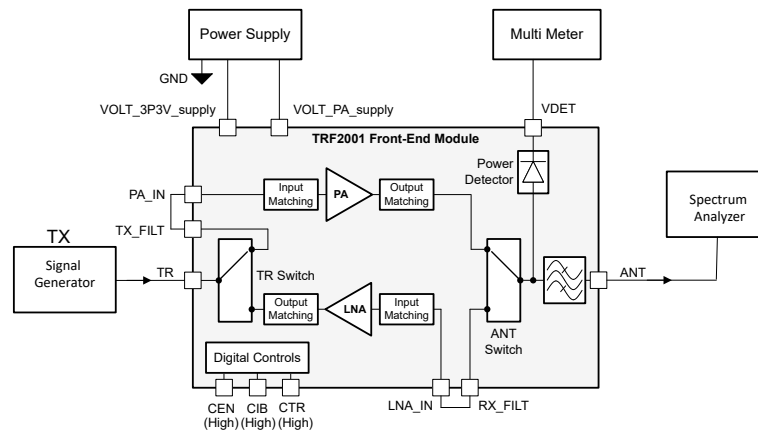
This section provides single tone measurement setup information.

### 1. TX path enabled mode:

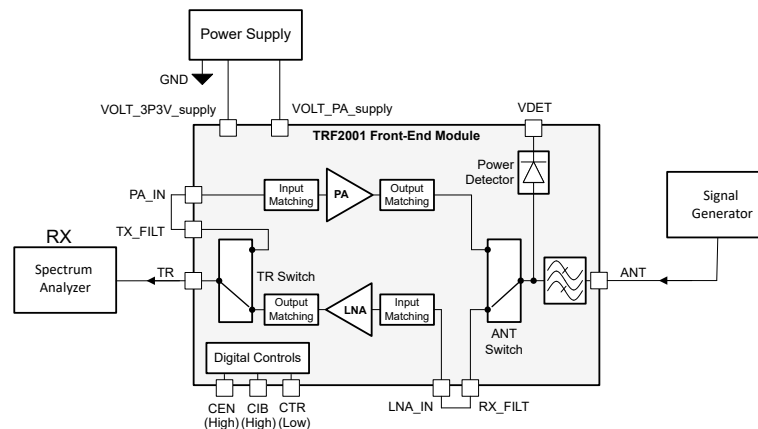
In TX path enabled mode, RF gain can be measured by connecting a signal generator at TR connector and a power meter at the ANT connector. For an input power of  $-30\text{dBm}$ , the expected gain is in an approximate range of  $22.5\text{dB}$  to  $24.5\text{dB}$ . A power sweep from a signal generator can be recorded from  $-30\text{dBm}$  to  $12\text{dBm}$  and output power can be measured with a power meter. The expected output power is in an approximate range of  $27\text{dBm}$  to  $28\text{dBm}$  for a  $12\text{dBm}$  input power. Use of a  $20\text{dB}$  attenuator pad at the ANT output is recommended for transmit measurements to protect the power meter or spectrum analyzer. See also [Figure 2-1](#).

### 2. RX path enabled mode:

In RX path enabled mode, RF gain can be measured by connecting a signal generator at the ANT connector and a power meter at the TR connector. For an input power of  $-30\text{dBm}$ , the expected gain is in an approximate range of  $15\text{dB}$  to  $17\text{dB}$ . A power sweep from a signal generator can be recorded from  $-30\text{dBm}$  to  $-10\text{dBm}$  and output power can be measured with a power meter. The expected output power is in an approximate range of  $1\text{dBm}$  to  $3\text{dBm}$  for a  $-10\text{dBm}$  input power. See also [Figure 2-2](#).



**Figure 2-1. Single Tone TX Path Enabled Setup for Gain and Output P1dB**



**Figure 2-2. Single Tone RX Path Enabled Setup for Gain and Output P1dB**

### Note

TI recommends that you properly characterize and account for the insertion loss of RF coaxial (coax) cables, attenuator pads, and connectors to measure accurate gain and power levels for the device.

### 3 Hardware Design Files

#### 3.1 Schematic

Figure 3-1 shows the TRF2001EVM schematic.

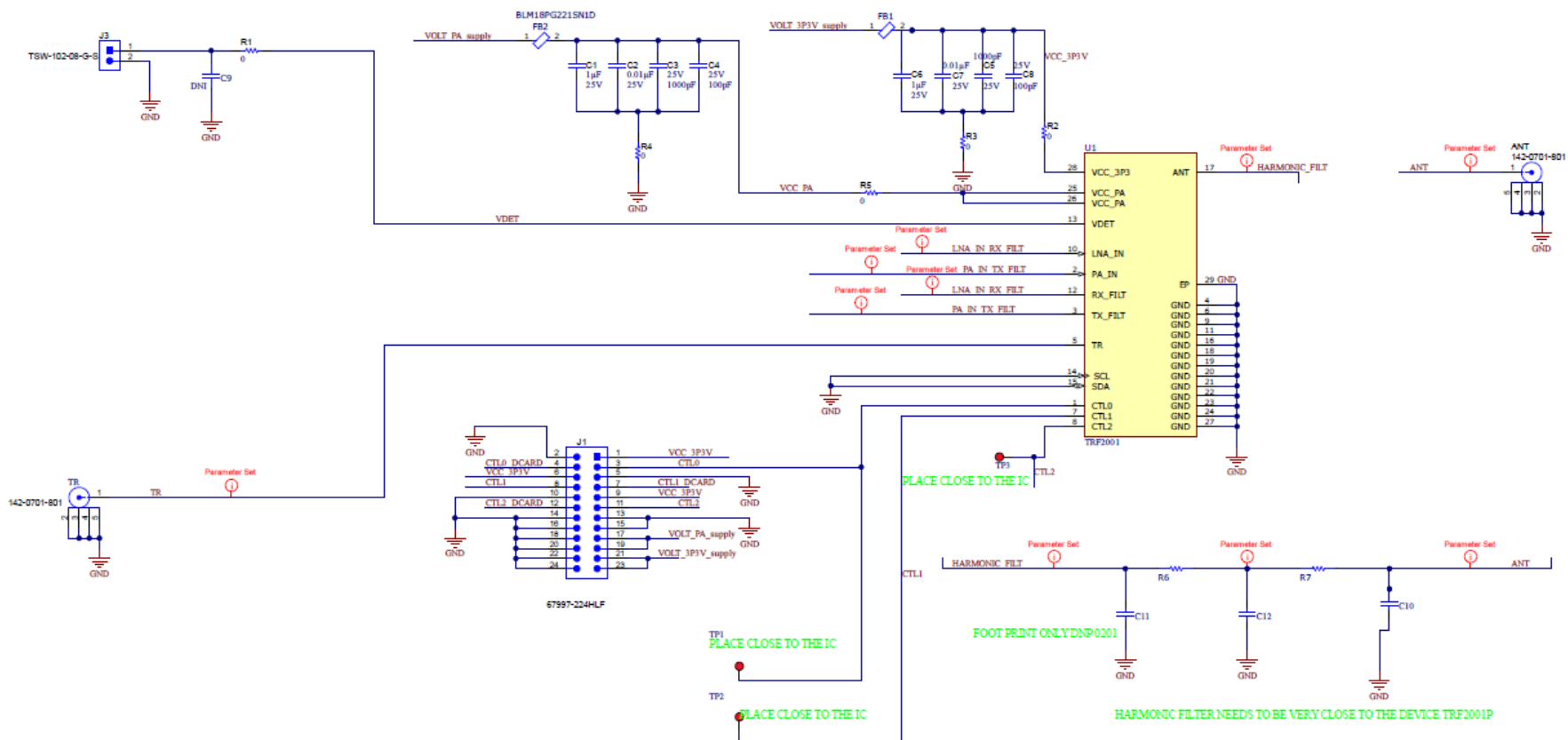


Figure 3-1. TRF2001EVM Schematic

### 3.2 PCB Layout

Figure 3-2 through Figure 3-5 illustrate the PCB layers for this EVM.

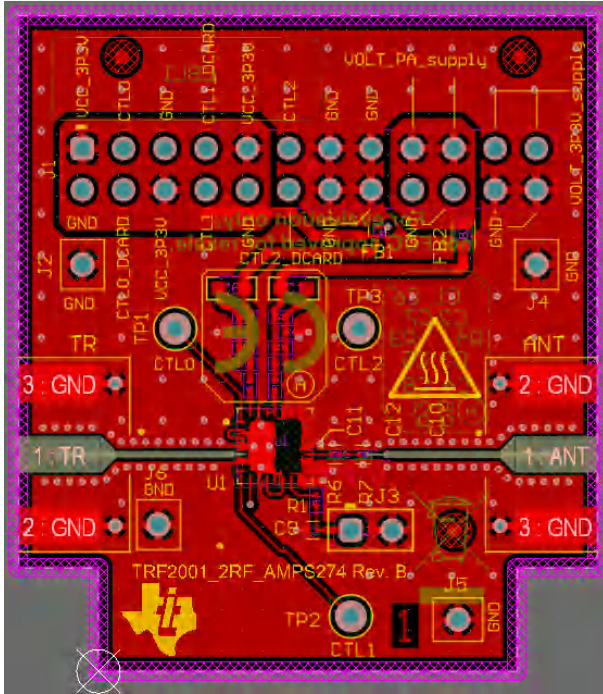


Figure 3-2. Top Layer

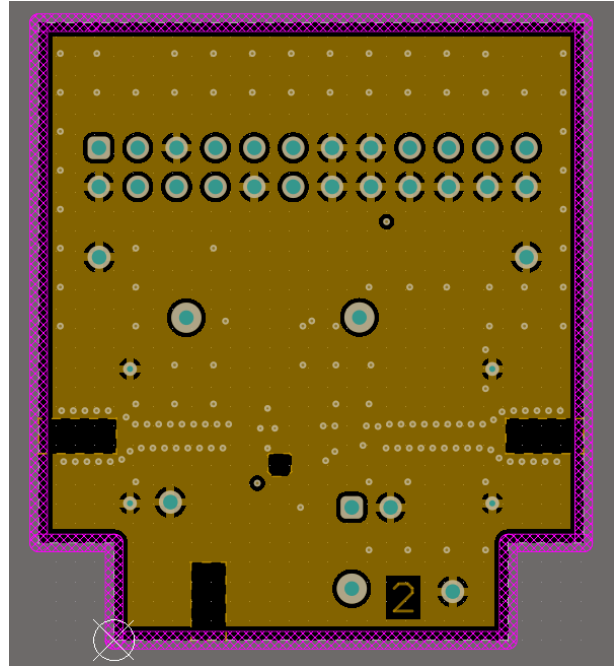


Figure 3-3. Layer 2

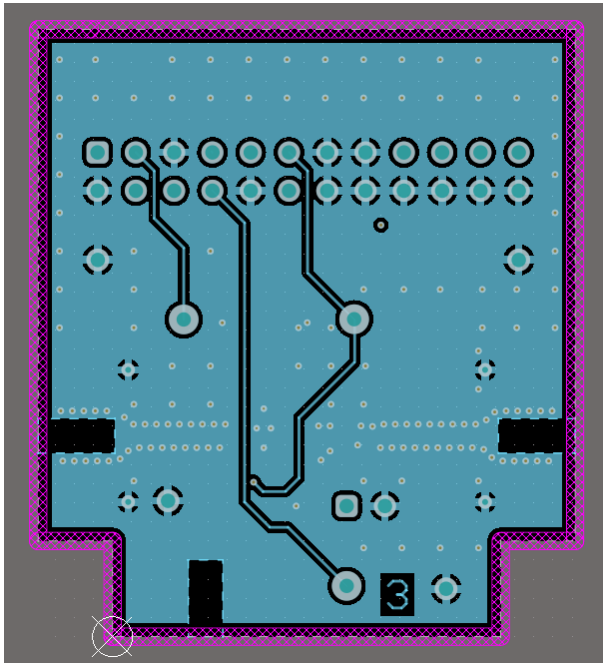


Figure 3-4. Layer 3

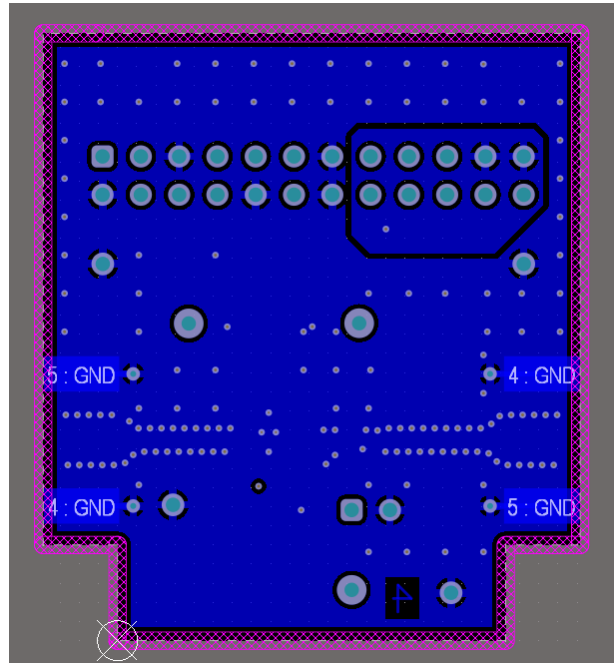


Figure 3-5. Bottom Layer

### 3.2.1 Stack-Up and Material

The TRF2001EVM is a 61.278-mil, 4-layer board with material type FR-4 370HR. The top layer routes the power, ground, and signals. Second layer is the reference RF ground layer. The RF signal trace characteristic impedance is targeted at 50Ω. Third layer is primarily ground layer with routing for the digital control signals. The bottom fourth layer is also primarily ground layer with a VOLT\_3P3V\_SUPPLY power island.

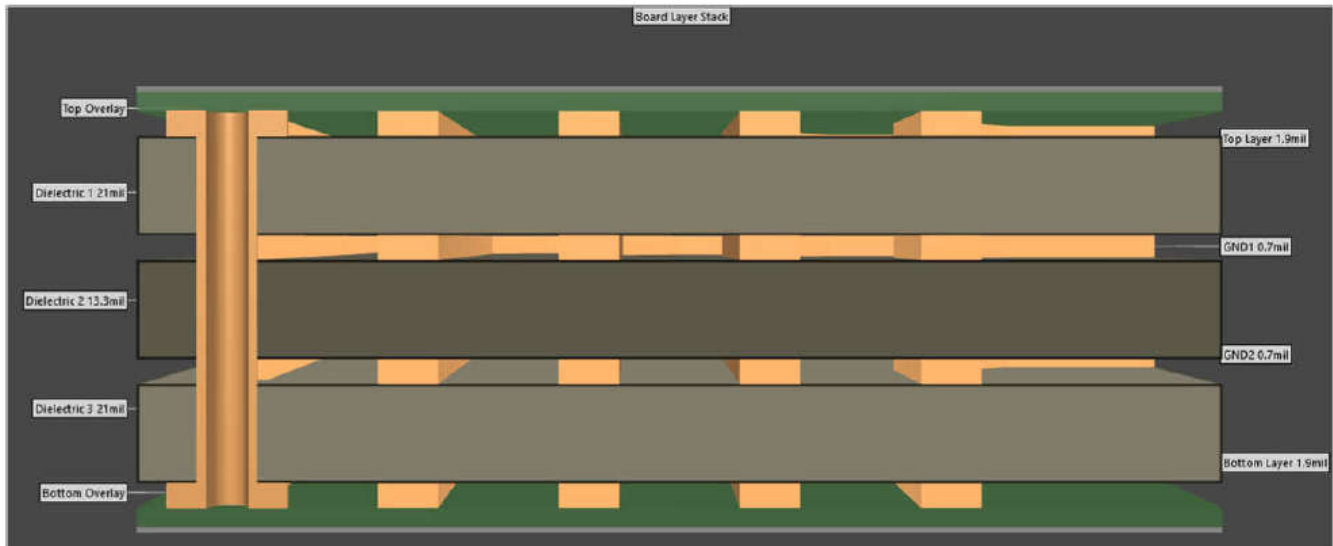


Figure 3-6. TRF2001EVM Stack-Up (Units in Mils)



### 3.3 Bill of Materials (BOM)

**Table 3-1. Bill of Materials**

Item	Designator	Qty	Value	Description	Part Number	Manufacturer	Package Reference
1	!PCB	1		Printed Circuit Board	AMPS274	Any	
2	ANT, TR	2		Connector, End launch SMA, 50 ohm, SMT	142-0701-801	Cinch Connectivity	End Launch SMA
3	C1, C6	2	1uF	CAP, CERM, 1 uF, 25 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	GCM188R71E105K A64D	MuRata	603
4	C2, C7	2	0.01uF	CAP, CERM, 0.01 uF, 25 V, +/- 10%, X7R, 0201	GRM033R71E103K E14D	MuRata	201
5	C3, C5	2	1000pF	CAP, CERM, 1000 pF, 25 V, +/- 10%, X7R, 0201	GRM033R71E102K A01D	MuRata	201
6	C4, C8	2	100pF	CAP, CERM, 100 pF, 25 V, +/- 10%, X7R, 0201	GRM033R71E101K A01D	MuRata	201
7	FB1	1		Ferrite Bead, 0201, 120Ω @ 100MHz, 25%, 0.23Ω, 450mA	BLM03AX121SN1D	Murata	201
8	FB2	1		Chip Ferrite Bead, 0603, 220Ω @ 100MHz, 0.1Ω, 25%, 1.4A	BLM18PG221SN1D	Murata	603
9	J1	1		Header, 2.54mm, 12x2, Gold, TH	67997-224HLF	FCI	Header, 2.54mm, 12x2, TH
10	J3	1		Header, 2.54mm, 2x1, Gold, TH	TSW-102-08-G-S	Samtec	Header, 2.54mm, 2x1, TH
11	LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	THT-14-423-10	Brady	PCB Label 0.650 x 0.200 inch
12	R1, R2, R3, R4, R5	5	0	RES, 0, 5%, 0.05 W, 0201	CRCW02010000Z0 ED	Vishay-Dale	201
13	R6, R7	2	0	0 Ohms Jumper 0.05W, 1/20W Chip Resistor 0201 (0603 Metric) Automotive AEC-Q200 Thick Film	NRC02ZOTRF	NIC Components	201
14	TP1, TP2, TP3	3		Test Point, Miniature, Red, TH	5000	Keystone Electronics	Red Miniature Testpoint
15	U1	1		TRF2001	TRF2001VBAR	Texas Instruments	WQFN-FCRLF28
16	C9	0	1nF	Chip Multilayer Ceramic Capacitors for General Purpose, 0201, 1000pF, C0G, 30ppm/°C, 5%, 25V	GRM0335C1E102J A01D	Murata	201
17	C10, C11, C12	0	3.3 pF	WCAP-CSRFB Multilayer Ceramic Chip Capacitor, High Frequency, size 0201, NP0 Class I, 3.3pF, 25VDC	885392004007	Würth Elektronik	
18	FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
19	J2, J4, J5, J6	0		CONN HEADER .100 SINGL STR 1POS	PBC01SAAN	Sullins Connector Solutions	HDR1

## 4 Additional Information

### 4.1 Trademarks

All trademarks are the property of their respective owners.

## 5 Related Documentation

For related documentation, see the following:

Texas Instruments, [TRF2001](#) datasheet for detailed device information.

## 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.

### **WARNING**

**Evaluation Kits 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 shall operate the Evaluation Kit within TI's recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI's recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI's instructions for electrical ratings of interface circuits such as input, output and electrical loads.**

**NOTE:**

**EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGRADATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.**

### 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。

<https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html>

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。

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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。

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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。 <https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html>

#### 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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