

EVM User's Guide: TRF1108EVM

TRF1108 Evaluation Module



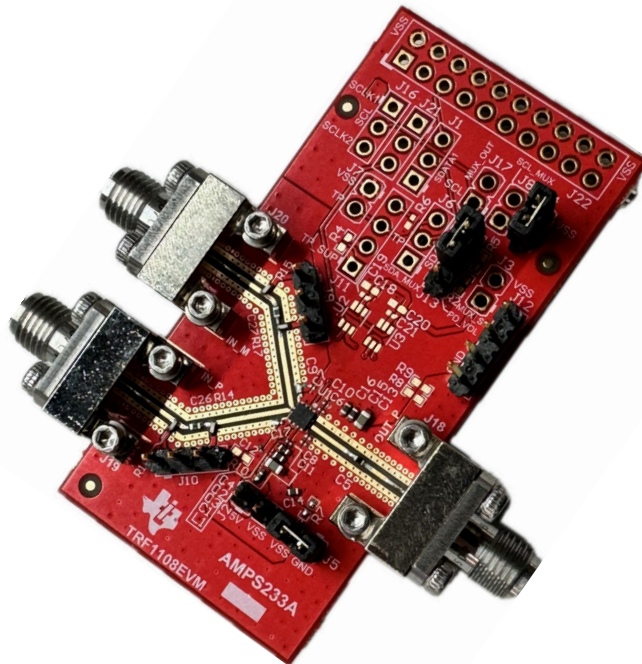
Description

The TRF1108 evaluation module (EVM) is used to evaluate the TRF1108 device, which is a differential input to single-ended (D2S) output RF amplifier. The device is designed for applications that require a D2S conversion when driven by a digital-to-analog converter (DAC)

The board is set up for 100 Ω differential input matching. The amplifier has a low output impedance. The board has ac-coupling capacitors at input and output. The EVM is ready to connect to a +5-V power supply, signal source, and test instruments for the measurements.

Features

- Operates on a single +5V supply
- AC-coupled by default, can be DC-coupled with bill of material changes
- Designed for a 100 Ω differential input matching
- Simple interface to the inputs and output through onboard SMA connectors
- Power down option available onboard using a jumper connector

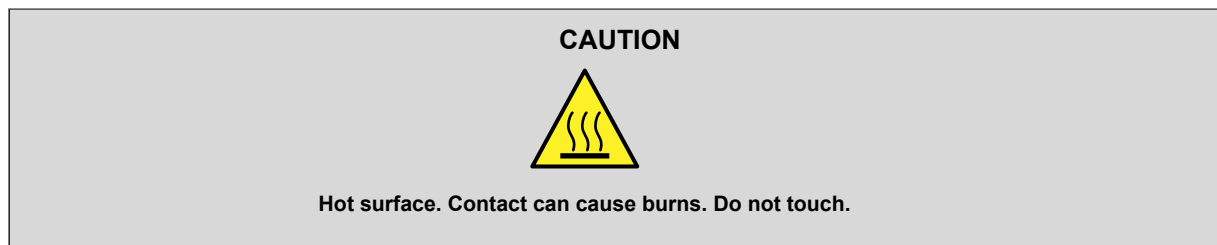


TRF1108EVM (Top View)

1 Evaluation Module Overview

1.1 Introduction

The basic steps and functions that are required to verify the proper operation and quick setup of the TRF1108EVM. This document also includes a schematic diagram, a bill of materials (BOM), printed-circuit board (PCB) layouts, and test block diagrams is outlined in this document. Throughout this document, the abbreviations *EVM*, *TRF1108EVM* and the term *evaluation module* are synonymous with the TRF1108-EVM, unless otherwise noted.



1.2 Kit Contents

Item	Quantity
TRF1108EVM	1

1.3 Specification

Connector	Parameter	Value
J2	J2.1 VDD J2.2 VSS	VDD = 5V VSS = GND
J5	J5.1 VSS J5.2 GND	Short
J13	PD2 Select	Short 1,2 (V_PD) to disable Ch2 Short 2,3 (GND) to enable Ch2
J18	RF Output	
J19	RF Input INP	Max 20dBm
J20	RF Input INP	Max 20dBm

1.4 Device Information

The TRF1108 is a very high performance, differential-to-single-ended (D2S) RF amplifier that has an operational bandwidth from true-dc to 12GHz. The device is excellent choice for applications that require a D2S conversion when driven by a digital-to-analog converter (DAC) such as the high-performance [DAC39RF10](#) or [AFE7950](#). The on-chip matching components simplify printed circuit board (PCB) implementation and provide the highest performance over the usable bandwidth. The device is fabricated using Texas Instruments' advanced complementary BiCMOS process and is available in a space-saving, WQFN-FCRLF 2mm x 2mm package.

The TRF1108 operates on a single 5V supply with an internally set common-mode voltage for ac-coupled applications. Dual supplies with an externally set input common-mode voltage enables dc-coupled applications. A power-down feature is also available for power savings.

2 Hardware

2.1 General Usage Information

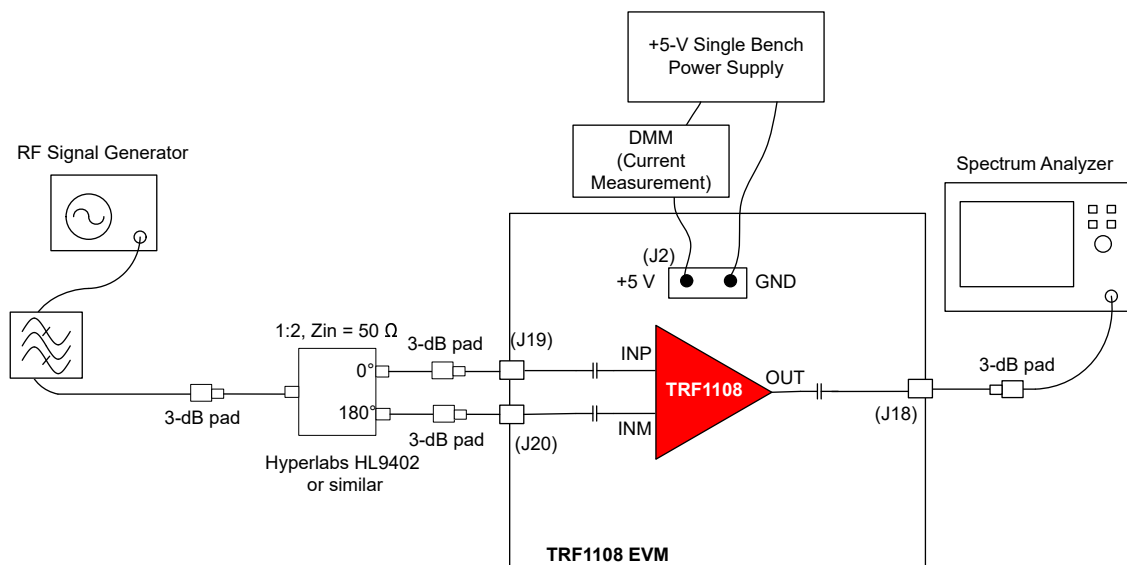


Figure 2-1. Single Tone Setup for Gain and Output P1dB

This section provides general usage information for the TRF1108 EVM. See for a general single tone setup diagram as a reference point for the following instructions (some components, such as supply bypass capacitors, are omitted for clarity):

1. Recommended power up sequence:
 - a. Before connecting the power-supply cables to the EVM, set the DC output power supply to +5V.
 - b. Set the current limit of the DC output power supply at 300 mA.
 - c. Making sure the supply is turned off, connect the power supply cables to the J2 connector of the EVM.
 - d. Now turn on the DC power supply of $V_{CC} = +5V$. The supply current (I_Q) drawn from the power supply is approximately 175mA.
 - e. If the supply current is low, then verify that the device is not disabled by the PD pin.
2. Power-down option:
 - a. Connect +1.8 V (logic-1) on PD pin to power-down the chip. Ground the PD pin to enable the chip using J13.
3. Single tone measurement setup recommendation:
 - a. The EVM inputs are fully differential (or 180° out-of-phase) at J19 and J20 SMA connectors. The single-ended signal out of the RF signal generator must be converted to a differential signal using an external passive balun and connected to inputs SMA connectors J19, J20 as shown in [Figure 2-1](#). When measuring single tone distortion, use an RF band pass filter as shown in [Figure 2-1](#).
 - b. The RF signal generator used must support up to 12GHz signal frequency for testing out the TRF1108 EVM.
 - c. The TRF1108 device input is 100Ω differential in the pass-band. To minimize signal reflections due to impedance mismatch, TI recommends using an attenuator pad of approximately 3dB to 6dB at the three terminals of the passive balun.
 - d. The EVM output is single-ended at J18 SMA connector. The TRF1108 device has low output impedance at dc and low frequencies.
 - e. The single-ended signal out of the EVM is connected to spectrum analyzer as shown in . Usage of an attenuator pad of approximately 3dB to 6dB is recommended at the output to minimize reflections.
 - f. Lastly, TI recommends to properly characterize and account for the insertion loss of RF coaxial (coax) cables, attenuator pads, and passive baluns to measure accurate gain and power levels for the device.

4. Matching considerations:

- a. TRF1108 is a wide-band amplifier and expects 100Ω input matching over the operating bandwidth up to about 12GHz. A signal generator or Noise Source that drives this EVM has 50Ω impedance over a wide band width. But, if this EVM is driven by a narrow-band driver or a source that has non 50Ω matching, then there can be instability issues with the amplifier. To avoid such issues, additional matching can be required at the input. See the [TRF1108 DC to 12GHz Bandwidth, Differential-to-Single-Ended RF Amplifier](#) data sheet for more information.
- b. As mentioned earlier, the TRF1108 device has low output impedance. When the EVM outputs are connected spectrum analyzer, TI recommends to use attenuator pads to minimize reflections.

3 Implementation Results

3.1 Test Setup Diagrams

This section includes general recommendations for S-parameter, noise figure, and two-tone OIP3 setup while measuring the TRF1108 EVM.

3.1.1 S-Parameter Test Setup

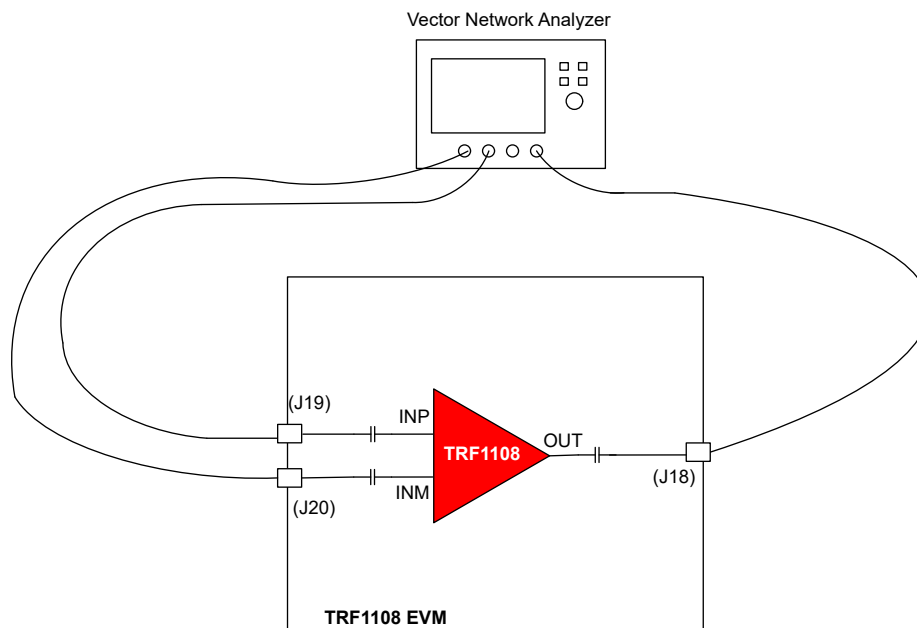


Figure 3-1. S-Parameter Test Setup

Use the following guidelines for S-parameter measurement:

1. As [Figure 3-1](#) shows, the S-parameter measurement is typically done using a Vector Network Analyzer (VNA). For measuring the TRF1108 EVM, a 3-port VNA is recommended which can generate differential and receive single-ended signals at the input and output ports of EVM respectively.
2. Before connecting the RF coax cables to the EVM, you must calibrate the VNA along with the cables using a calibration kit.
3. Make sure the frequency sweep and output power level from the VNA is set within the linear operating range of the TRF1108 devices. The resolution bandwidth (RBW) and dynamic range of the VNA can be adjusted to give optimum sweep time for the measurement.
4. Account for board trace losses at the input and output side of the device during gain measurements. [Figure 3-2](#) gives typical input and output trace losses measured on the EVM.

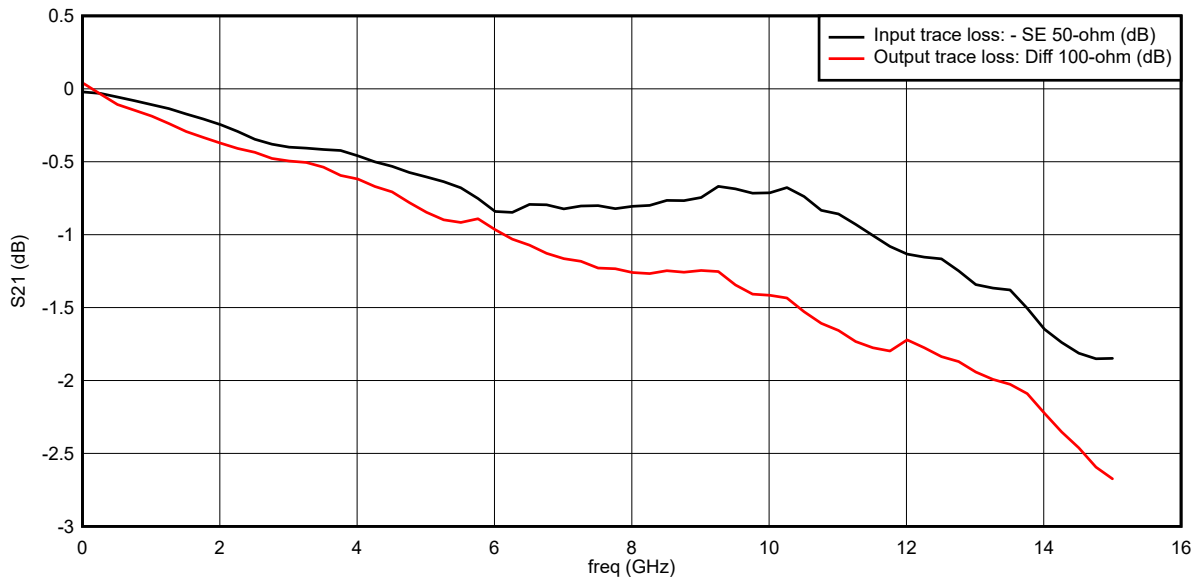


Figure 3-2. PCB Trace Loss vs Frequency

3.1.2 Noise Figure Test Setup

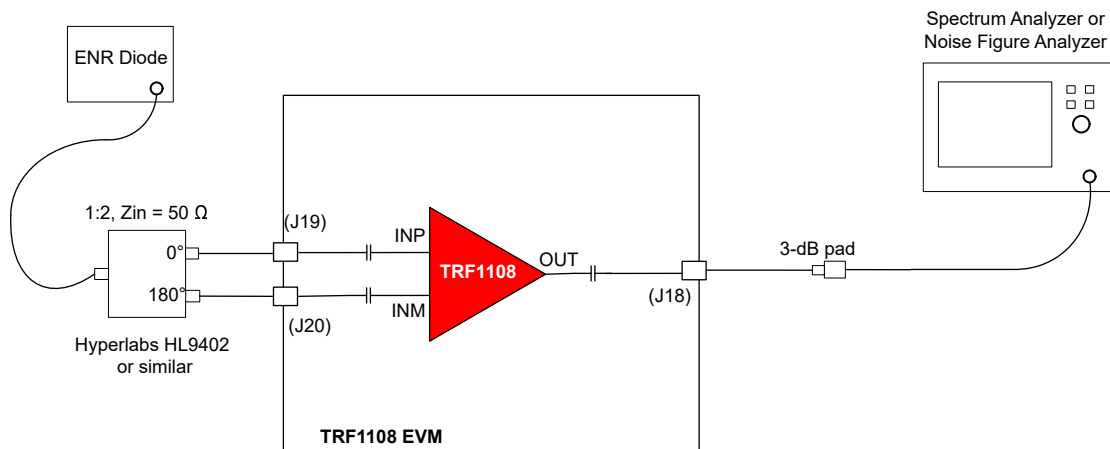


Figure 3-3. Noise Figure Test Setup

Use the following guidelines for Noise Figure (NF) measurement:

1. As [Figure 3-3](#) shows, the traditional Y-factor method can be used for the NF measurement using a Noise Diode and a spectrum analyzer (or a Noise Figure Analyzer).
2. While doing the measurement, take into account any RF cable losses to the EVM board. Any external input attenuator added for matching results in proportional NF degradation and must be calibrated out in the measurement.
3. Also, onboard losses of the input traces at the device input pin must be factored into the NF measurement.
4. If the loss after the device output is significant, then note to factor the output loss into the NF measurement. Use the Friis equation to calculate the Noise Figure of the device from the total measured NF.

3.1.3 Two-Tone OIP3 Test Setup

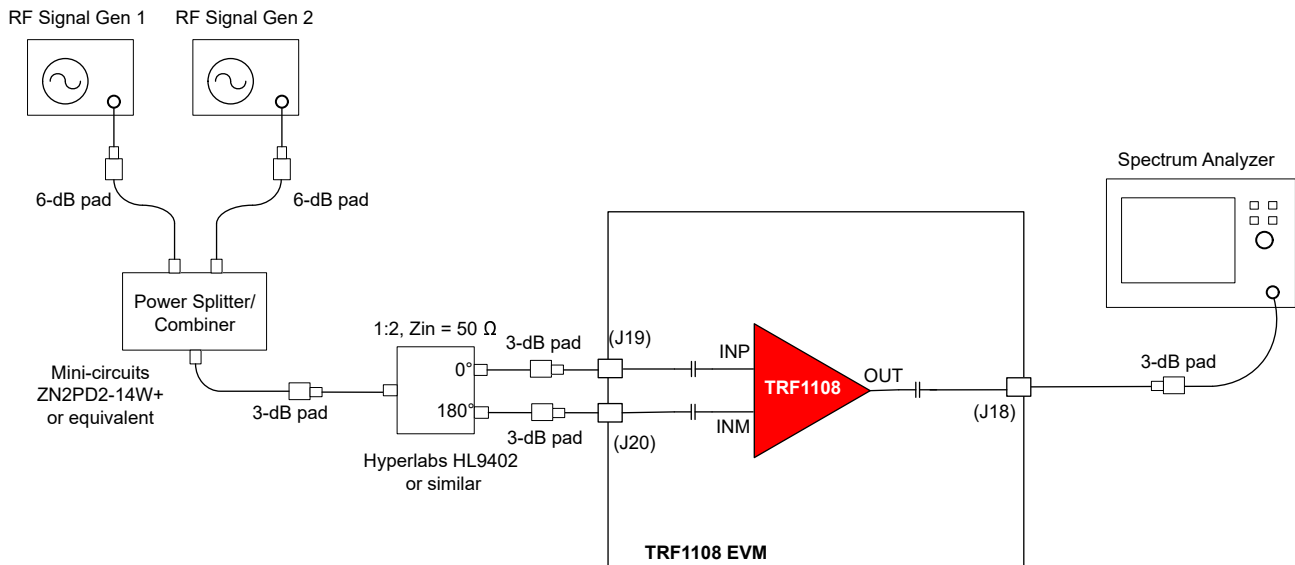


Figure 3-4. OIP3 Test Setup

Use the following guidelines for two-tone OIP3 measurement:

1. As [Figure 3-4](#) shows, combine two signal generator outputs using an in-phase power splitter and combiner. A 6dB attenuator is recommended at the signal generator outputs to prevent the generators from talking to each other and resulting in signal generator IMD3 spurs.
2. Set both the signal generator outputs to a power level and frequency spacing so that the signal generator yields the desired output power (P_{OUT}) at the device.
3. TI recommends that the output power level is within the linear operation range of the TRF1108 device. For example, if the total desired output power at the device is 8dBm, then set the signal generators such that each of the fundamental output power results in 2dBm per tone. As a general rule, TI recommends to keep the total output power level approximately 6 to 8dB lower than the 1dB compression point. See the device data sheet for the output power levels supported by the device.
4. For the OIP3 test, the two tones can be spaced by the specified frequency.
5. Set the spectrum analyzer attenuation setting appropriately so that the spectrum analyzer non-linearity does not affect the measurements.
6. Keep spectrum analyzer RBW and VBW settings identical for main tone and IM3 products.
7. For output IP3 calculation, take into account combined losses at the desired frequency band between the TRF1108 device output to the spectrum analyzer input. The combined power loss is due to PCB output trace, RF coax cable, 0/180-degree passive balun, and any attenuator pad used for external matching purposes. The calculated OIP3 is given in [Equation](#).

$$\text{Output IP3} = (P_{IN_SA} - \text{IMD3}) / 2 + P_{IN_SA} + P_{LOSS}$$

where,

- P_{IN_SA} = Input power per tone into the spectrum analyzer
 - P_{LOSS} = Power loss from the device output to the spectrum analyzer input
 - IMD3 = Higher power of the two intermodulation distortion products recorded at either $2f_1 - f_2$ or $2f_2 - f_1$
8. In [Equation](#), $P_{IN_SA} + P_{LOSS} = P_{OUT}$ is the amplifier output power per tone.

4 Hardware Design Files

4.1 Schematic

Figure 4-1 shows the TRF1108 EVM schematic.

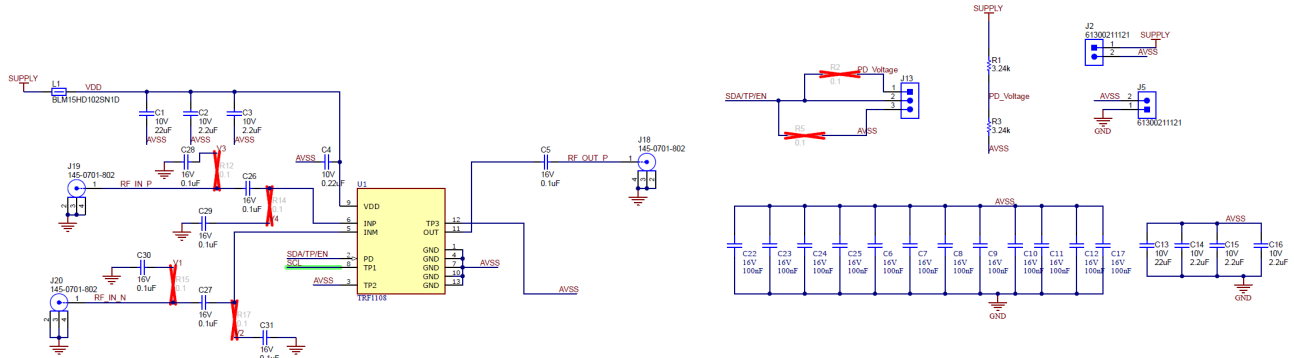


Figure 4-1. TRF1108 EVM Schematic

4.2 PCB Layers

Figure 4-2 through Figure 4-5 illustrate the PCB layers for this EVM.

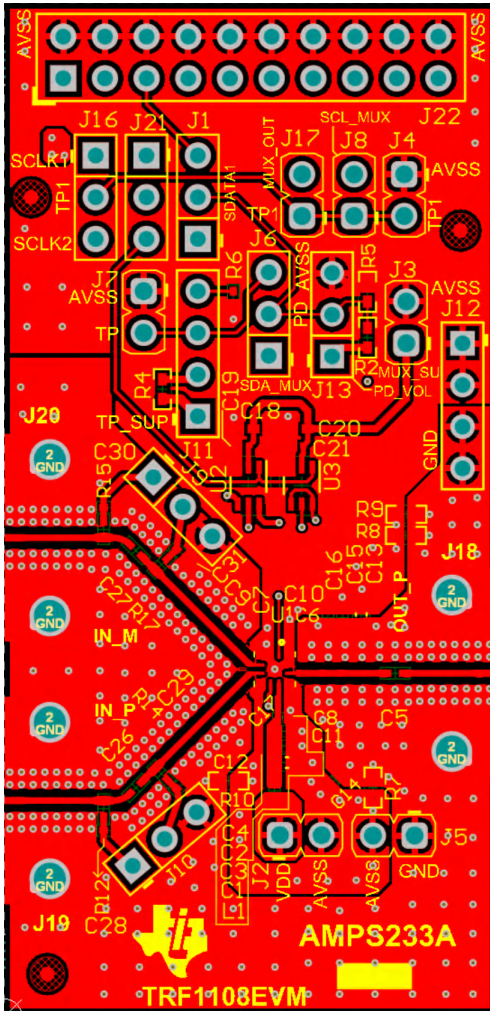


Figure 4-2. Top Layer

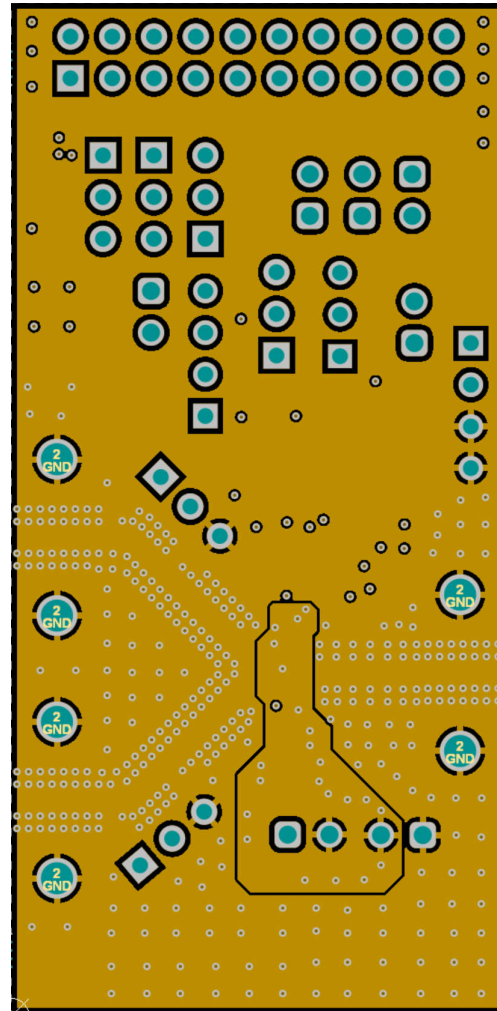


Figure 4-3. Layer 2

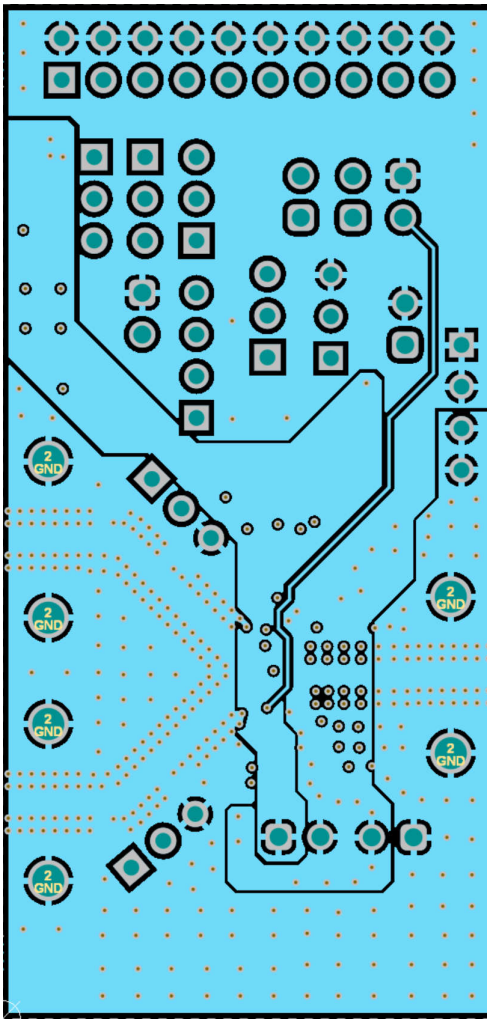


Figure 4-4. Layer 3

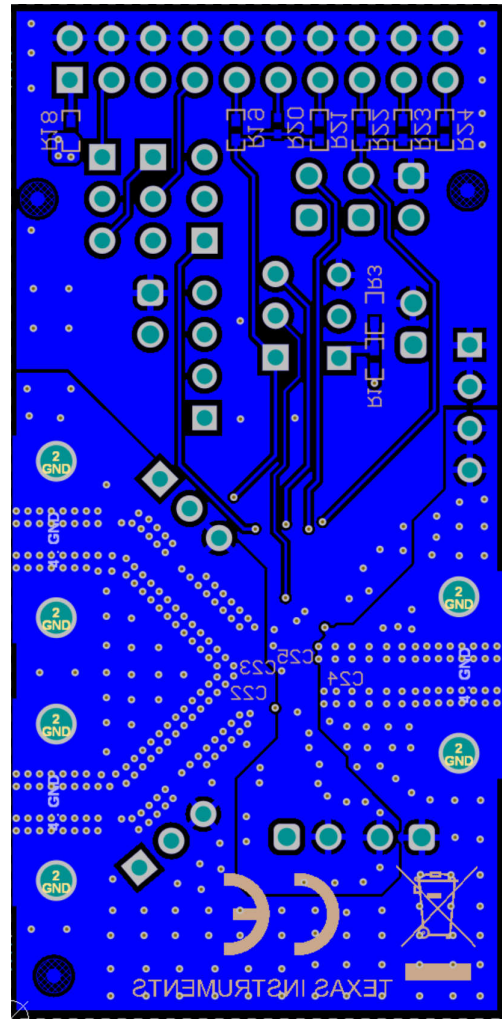


Figure 4-5. Bottom Layer

4.2.1 Stack-Up and Material

The TRF1108 EVM is a 67-mil, 4-layer board whose material type is Isola® 370HR. The top layer routes the power, ground, and signals between SMA connectors and the device. Second layer is the reference RF ground layer. The signal trace impedance is targeted at 50Ω. The bottom 3 layers are ground layers.

Layer	Stack up	Supplier	Supplier Description	Description	Base Thickness	Processed Thickness	εr
1		GOULD	COPPER FOIL	12+35 m	1.850	2.559	
		ISOLA	185HR	#2116	5.000	4.966	4.320
2		ISOLA	185HR	#2116	1.378	1.378	4.420
		ISOLA	185HR	1.00 1.0/1.0	39.370	39.370	4.420
3		ISOLA	185HR	#2116	5.000	4.966	4.320
		ISOLA	185HR	#2116	5.000	4.966	4.320
4		GOULD	COPPER FOIL	12+35 m	1.850	2.559	

Figure 4-6. TRF1108 EVM Stack-Up (Units in Mils)

4.3 TRF1108 EVM Bill of Material

Table 4-1. TRF1108 EVM Bill Of Materials

Designator	Quantity	Value	Description	Part Number	Manufacturer	Package Reference	Fitted
C1, C13	2	22uF	CAP, CERM, 22uF, 10V, +/- 20%, X5R, 0603	CL10A226MP8NUNE	Samsung Electro-Mechanics	0603	Fitted
C2, C3, C14, C15, C16	5	2.2uF	CAP, CERM, 2.2uF, 10V, +/- 10%, X7S, 0402	C1005X7S1A225K050BC	TDK	0402	Fitted
C4	1	0.22uF	CAP, CERM, 0.22uF, 10V, +/- 20%, X5R, 0201	LMK063BJ224MP-F	Taiyo Yuden	0201	Fitted
C5, C26, C27, C28, C29, C30, C31	7	0.1uF	CAP, CERM, 0.1uF, 16V, +/- 10%, X7R, 0402	ATC530L104KT16T	AT Ceramics	0402	Fitted
C6, C7, C8, C9, C10, C11, C12, C17, C22, C23, C24, C25	12	100nF	0.1µF ±20% 16V Ceramic Capacitor 0201 (0603 Metric)	560Z104MTT	KYOCERA AVX	0201	Fitted
J2, J4, J5	3		Header, 2.54mm, 2x1, Gold, TH	61300211121	Wurth Elektronik	Header, 2.54mm, 2x1, TH	Fitted
J9, J10	2		Header, 100mil, 3x1, Gold, TH	PBC03SAAN	Sullins Connector Solutions	PBC03SAAN	Fitted
J12	1		Header, 2.54mm, 4x1, Gold, TH	PBC04SAAN	Sullins Connector Solutions	Header, 2.54mm, 4x1, TH	Fitted
J13	1		Header, 100mil, 3x1, Tin, TH	PEC03SAAN	Sullins Connector Solutions	Header, 3 PIN, 100mil, Tin	Fitted
J18, J19, J20	3		50 Ohm JACK, SMT	145-0701-802	Cinch Connectivity	50 Ohm JACK, SMT	Fitted
L1	1	1000 ohm	Ferrite Bead, 1000 ohm at 100MHz, 0.25A, 0402	BLM15HD102SN1D	MuRata	0402	Fitted
R1, R3	2	3.24k	RES, 3.24 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW04023K24FKED	Vishay-Dale	0402	Fitted
SH-J1, SH-J2	2	1x2	Shunt, 100mil, Gold plated, Black	SNT-100-BK-G	Samtec	Shunt	Fitted
U1	1		10MHz to 12GHz 3dB BW, Differential to Single-Ended Amplifier	TRF1108RPVT	Texas Instruments	WQFN-FCRLF12	Fitted
C18, C20	0	10uF	CAP, CERM, 10µF, 10V, +/- 20%, X5R, 0402	CL05A106MP8NUB8	Samsung Electro-Mechanics	0402	Not Fitted
C19, C21	0	0.1uF	CAP, CERM, 0.1uF, 16V, +/- 10%, X5R, 0201	GRM033C71C104KE14D	MuRata	0201	Not Fitted
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A	Not Fitted

Table 4-1. TRF1108 EVM Bill Of Materials (continued)

Designator	Quantity	Value	Description	Part Number	Manufacturer	Package Reference	Fitted
J1, J6, J16, J21	0		Header, 100mil, 3x1, Gold, TH	PBC03SAAN	Sullins Connector Solutions	PBC03SAAN	Not Fitted
J3, J7, J8, J17	0		Header, 2.54mm, 2x1, Gold, TH	61300211121	Würth Elektronik	Header, 2.54mm, 2x1, TH	Not Fitted
J11	0		Header, 2.54mm, 4x1, Gold, TH	PBC04SAAN	Sullins Connector Solutions	Header, 2.54mm, 4x1, TH	Not Fitted
J22	0		Receptacle, 100mil, 10x2, Gold, TH	PPPC102LFBN-RC	Sullins Connector Solutions	10x2 Receptacle	Not Fitted
R2, R5, R7, R8, R9, R10, R12, R14, R15, R17, R18, R19	0	0.1	RES, 0.1, 1%, 0.25 W, 0402	ERJ2BWFR100X	Panasonic	0402	Not Fitted
R4, R6, R20	0	10.0k	RES, 10.0 k, 1%, 0.063 W, 0402	RC0402FR-0710KL	Yageo America	0402	Not Fitted
R21	0	20.0k	RES, 20.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040220K0FKED	Vishay-Dale	0402	Not Fitted
R22	0	2.20k	RES, 2.20 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	RMCF0402FT2K20	Stackpole Electronics Inc	0402	Not Fitted
R23	0	4.70k	RES, 4.70 k, 1%, 0.0625 W, 0402	RC0402FR-074K7L	Yageo America	0402	Not Fitted
R24	0	4.99k	RES, 4.99 k, 1%, 0.063 W, 0402	RC0402FR-074K99L	Yageo America	0402	Not Fitted

5 Additional Information

5.1 Trademarks

Isola® is a registered trademark of Isola USA Corporation.
All trademarks are the property of their respective owners.

6 Related Documentation

For related documentation, see the following:

- Texas Instruments, [TRF1108 DC to 12GHz Bandwidth, Differential-to-Single-Ended RF Amplifier](#) data sheet

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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 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。

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

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

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。日本テキサス・イ

ンスツルメンツ株式会社

東京都新宿区西新宿 6 丁目 2 4 番 1 号

西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/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.

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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.
 5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.
 6. *Disclaimers:*
 - 6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.
 - 6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.
 7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

8.1 *General Limitations.* IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMNITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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