User's Guide

TRF0206-SP Evaluation Module

ABSTRACT

The basic steps and functions that are required to ensure the proper operation and quick setup of the TRF0206-SP-EVM is provided in this user's guide. This document also includes a schematic diagram, a bill of materials (BOM), printed-circuit board (PCB) layouts, and test block diagrams. The abbreviations *EVM, TRF0206-SP EVM*, and the term *evaluation module* throughout this document are synonymous with the TRF0206-SP-EVM, unless otherwise noted.

Table of Contents

List of Figures

List of Tables

Trademarks

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1 Description

The TRF0206-SP evaluation module (EVM) is used to evaluate the TRF0206-SP device, which is a single-ended input to differential output radiation hardened RF amplifier available in a 6.00 mm × 6.10 mm^2, 12-pin LCC-FC package. The device is designed to drive a high-speed differential input ADC without using a passive balun.

The board is set up for 50-Ω single-ended input matching. The amplifier has a low output impedance. The board has ac-coupling capacitors at the input and output. The EVM is ready to connect to a +3.3-V power supply, signal source, and test instruments for the measurements.

1.1 Features

- Operates on a single +3.3-V supply.
- Designed for a single-ended 50-Ω input matching.
- Simple interface to the inputs and output through onboard SMA connectors.
- Power down option is available onboard using a jumper connector.

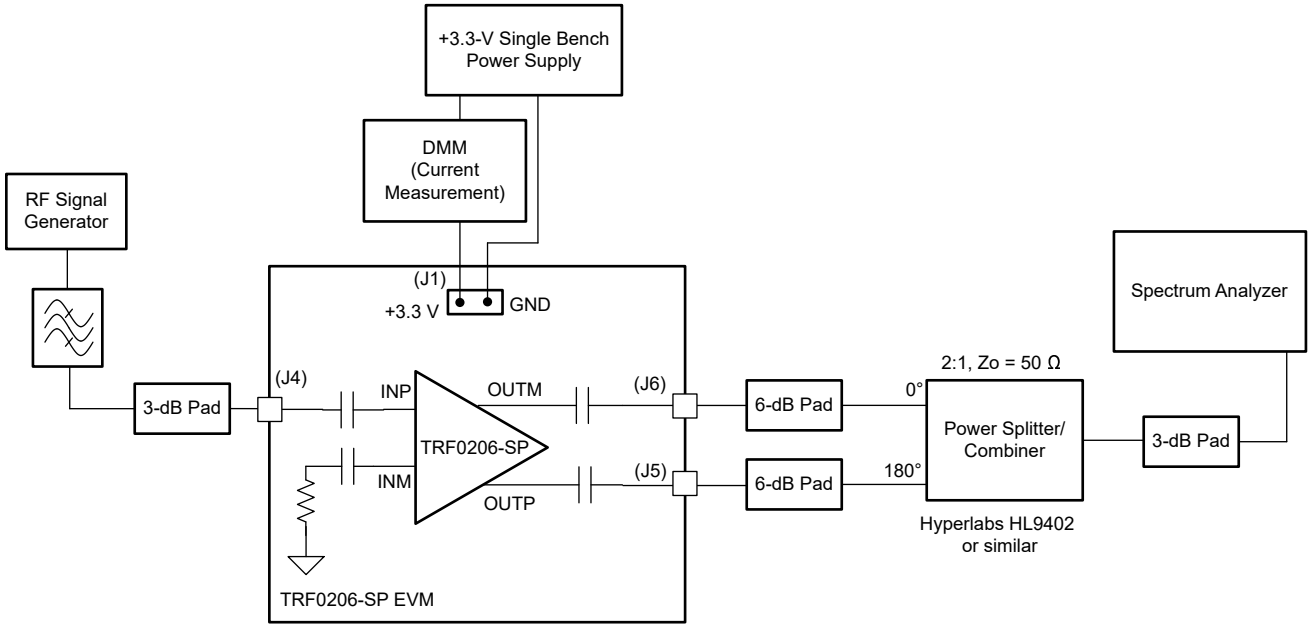


Figure 1-1. Single Tone Setup for Gain and Output P1dB

1.2 General Usage Information

This section provides general usage information for the TRF0206-SP EVM. Figure 1-1 shows 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 +3.3 V.
   b. Set the current limit of the DC output power supply at 250 mA.
   c. Turn off the supply then connect the power supply cables to the J1 connector of the EVM.
   d. Now turn on the DC power supply of VCC = +3.3 V. The supply current (I_Q) drawn from the power supply should be approximately 135 mA.
   e. If the supply current is low, then ensure that the device is not disabled by the PD pin.
2. Power-down option:
   a. Connect +1.8 V (logic-1) on the PD pin to power-down the chip. Ground the PD pin to enable the chip.

3. Single tone measurement setup recommendation:
   a. Connect an RF signal generator to input SMA connector, J4.
      As shown in Figure 1-1, use an RF band pass filter when measuring single tone distortion.
   b. The RF signal generator used must support up to 12-GHz signal frequency for testing the TRF0206-SP EVM.
   c. The TRF0206-SP device input is 50-Ω in the pass-band.
      To minimize signal reflections due to impedance mismatch, TI recommends using an attenuator pad of approximately 3-dB to 6-dB between the source and J4 SMA input.
   d. The EVM outputs are fully differential (or 180° out-of-phase) at J5 and J6 SMA connectors.
      The TRF0206-SP device has low output impedance at dc and low frequencies.
   e. When connecting to a spectrum analyzer, the differential signal out of the EVM should be converted to a single-ended signal using an external passive balun as shown in Figure 1-1.
      Usage of an attenuator pad of approximately 3-dB to 6-dB is recommended at the three terminals of the passive balun to minimize reflections.
   f. Lastly, it is recommended 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. TRF0206-SP is a wide-band amplifier and it receives 50-Ω input matching over its operating bandwidth up to about 7 GHz. A signal generator or noise source that drives this EVM will have 50-Ω impedance over a wideband width. But, if this EVM is driven by a narrow-band driver or a source that has non 50-Ω matching, then there may be instability issues with the amplifier. To avoid such issues, additional matching may be required at the input. For more information, see the *TRF0206-SP Single Channel, 10 MHz to 6.5 GHz 3-dB BW, ADC Driver Amplifier* data sheet.
   b. As mentioned earlier, the TRF0206-SP device has low output impedance, and zero-ohm series resistors are used in the EVM. When the EVM outputs are connected to a balun, it is recommended to use attenuator pads to minimize reflections.

2 EVM Overview

This section includes the schematic diagram, a bill of materials (BOM), PCB layer prints, and EVM stack-up information.

2.1 Schematic

Figure 2-1 shows the TRF0206-SP EVM schematic.

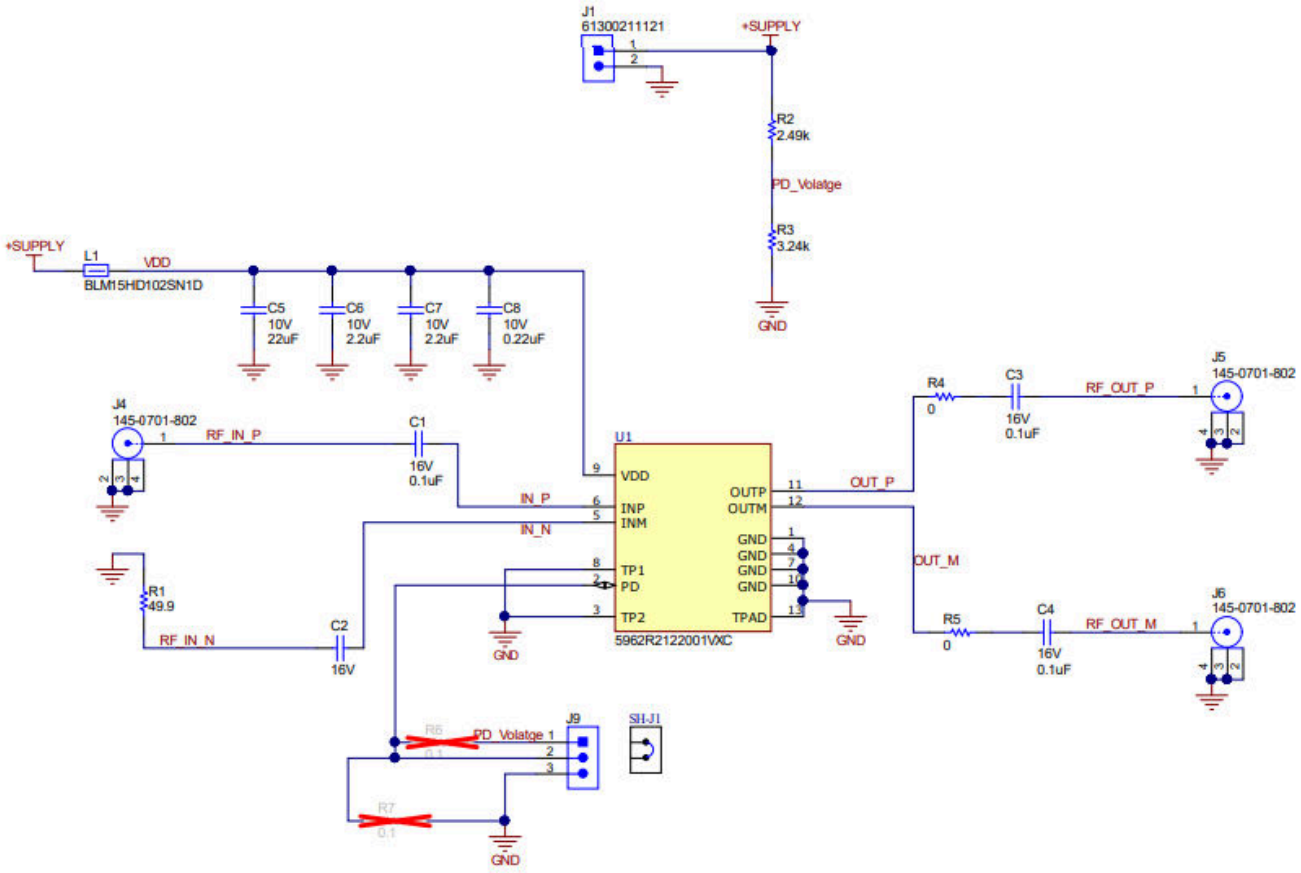


Figure 2-1. TRF0206-SP EVM Schematic

2.2 PCB Layers

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

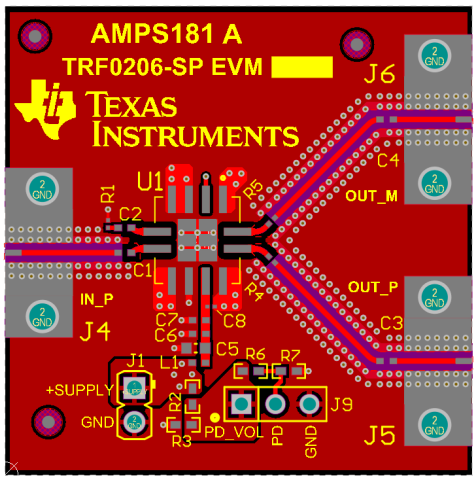


Figure 2-2. Top Layer

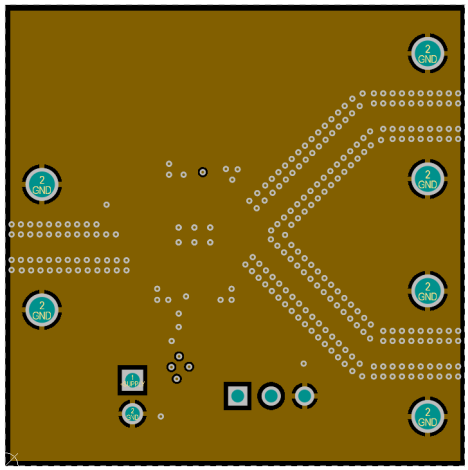


Figure 2-3. Layer 2

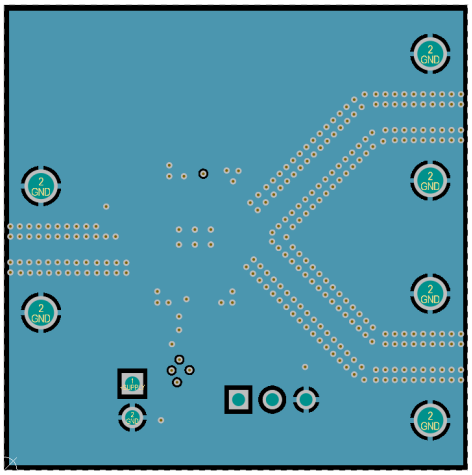


Figure 2-4. Layer 3

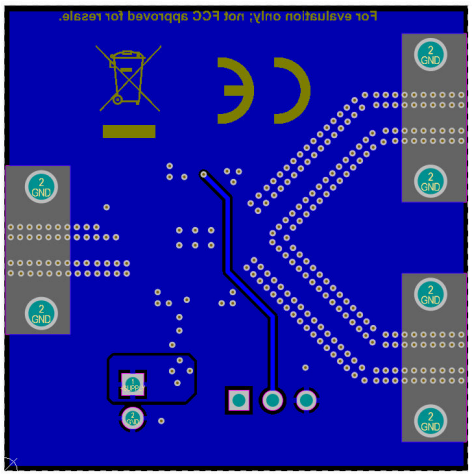


Figure 2-5. Bottom Layer

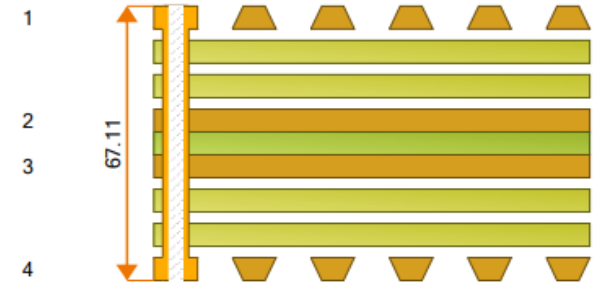
2.3 TRF0206-SP EVM Bill of Material

Table 2-1. TRF0206-SP EVM BOM

Item #	Designator	Quantity	Value	Part Number	Manufacturer	Description	
1	!PCB	1		AMPS181	Any	Printed Circuit Board	
2	C1, C2, C3, C4	4	0.1 µF	ATC530L104KT16T	AT Ceramics	CAP, CERM, 0.1 µF, 16 V, ± 10%, X7R, 0402	0402
3	C5	1	22 µF	CL10A226MP8NUNE	Samsung Electro-Mechanics	CAP, CERM, 22 µF, 10 V, ± 20%, X5R, 0603	0603
4	C6, C7	2	2.2 µF	C1005X7S1A225K050BC	TDK	CAP, CERM, 2.2 µF, 10 V, ± 10%, X7S, 0402	0402
5	C8	1	0.22 µF	LMK063BJ224MP-F	Taiyo Yuden	CAP, CERM, 0.22 µF, 10 V, ± 20%, X5R, 0201	0201
6	J1	1		61300211121	Wurth Elektronik	Header, 2.54 mm, 2x1, Gold, TH	Header, 2.54mm, 2x1, TH
7	J4, J5, J6	3		145-0701-802	Cinch Connectivity	50 Ω JACK, SMT	50 Ω JACK, SMT
8	J9	1		PEC03SAAN	Sullins Connector Solutions	Header, 100mil, 3x1, Tin, TH	Header, 3 PIN, 100mil, Tin
9	L1	1	1000 Ω	BLM15HD102SN1D	MuRata	Ferrite Bead, 1000 Ω at 100 MHz, 0.25 A, 0402	0402
10	R1	1	49.9	ERJ-1GEF49R9C	Panasonic	RES, 49.9, 1%, 0.05 W, AEC-Q200 Grade 1, 0201	0201
11	R2	1	2.49k	CRCW04022K49FKED	Vishay-Dale	RES, 2.49 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402
12	R3	1	3.24k	CRCW04023K24FKED	Vishay-Dale	RES, 3.24 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402
13	R4, R5	2	0	ERJ-1GN0R00C	Panasonic	RES, 0, 5%, .05 W, AEC-Q200 Grade 0, 0201	0201
14	SH-J1	1	1x2	SNT-100-BK-G	Samtec	Shunt, 100mil, Gold plated, Black	Shunt
15	U1	1		5962R2122001VXC	Texas Instruments	5962R2122001VXC	LCCC12
16	FID1, FID2, FID3	0		N/A	N/A	Fiducial mark. There is nothing to buy or mount.	N/A
17	R6, R7	0	0.1	ERJ2BWFR100X	Panasonic	RES, 0.1, 1%, 0.25 W, 0402	0402

2.4 Stack-Up and Material

The TRF0206-SP EVM is a 67-mil, 4-layer board whose material type is Isola® 185HR. 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 50 Ω. 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
		ISOLA	185HR	#2116	5.000	4.966	4.320
2					1.378	1.378	
		ISOLA	185HR	1.00 1.0/1.0	39.370	39.370	4.420
3					1.378	1.378	
		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 2-6. TRF0206-SP EVM Stack-Up (Units in Mils)

3 Test Setup Diagrams

This section includes general recommendations for S-parameter, noise figure, and two-tone OIP3 setup while measuring the TRF0206-SP EVM.

3.1 S-Parameter Test Setup

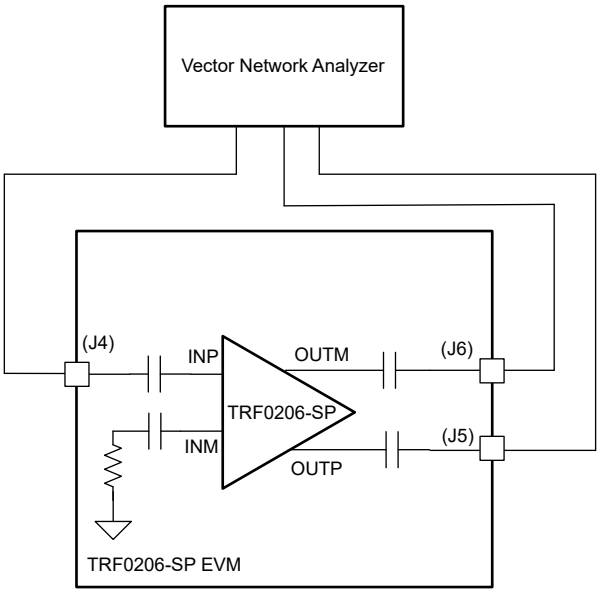


Figure 3-1. S-Parameter Test Setup

Use the following guidelines for S-parameter measurement:

1. As Figure 3-1 shows, the S-parameter is typically measured using a Vector Network Analyzer (VNA). For measuring the TRF0206-SP EVM, a 3-port VNA is recommended which can generate single-ended and receive differential signals at the input and output ports of the 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 TRF0206-SP devices. The resolution bandwidth (RBW) and dynamic range of the VNA can be adjusted to give optimum sweep time for the measurement.
4. It is important to 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.

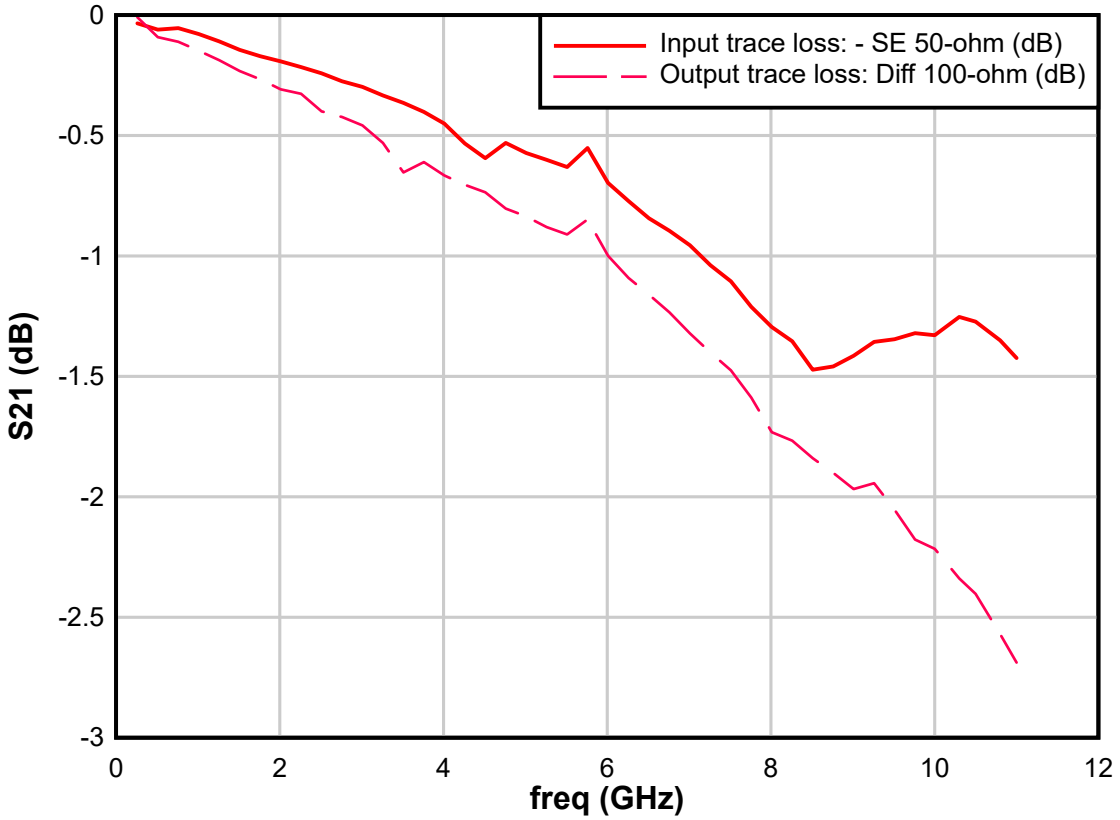


Figure 3-2. PCB Trace Loss vs Frequency

3.2 Noise Figure Test Setup

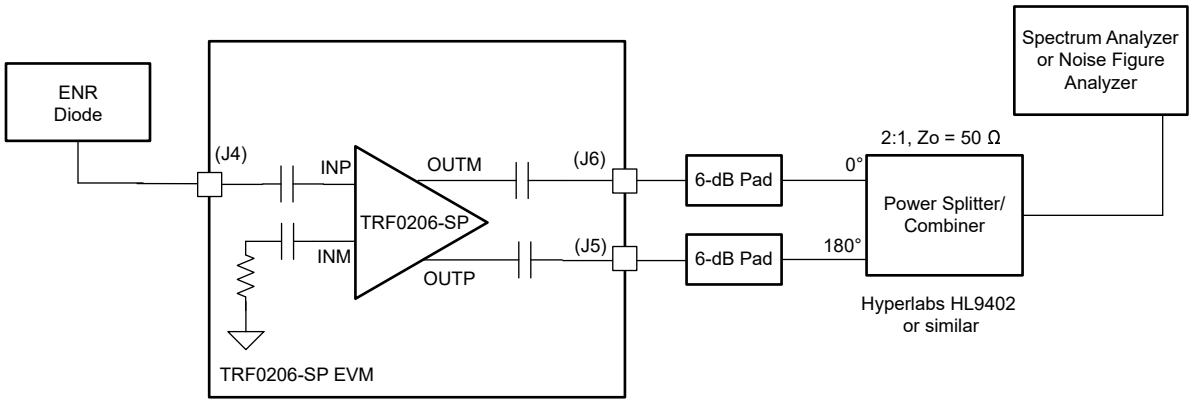


Figure 3-3. Noise Figure Test Setup

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 will result 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 it is important to factor the output loss into the NF measurement. Use the *Friis* equation to calculate the NF of the device from the total measured NF.

3.3 Two-Tone OIP3 Test Setup

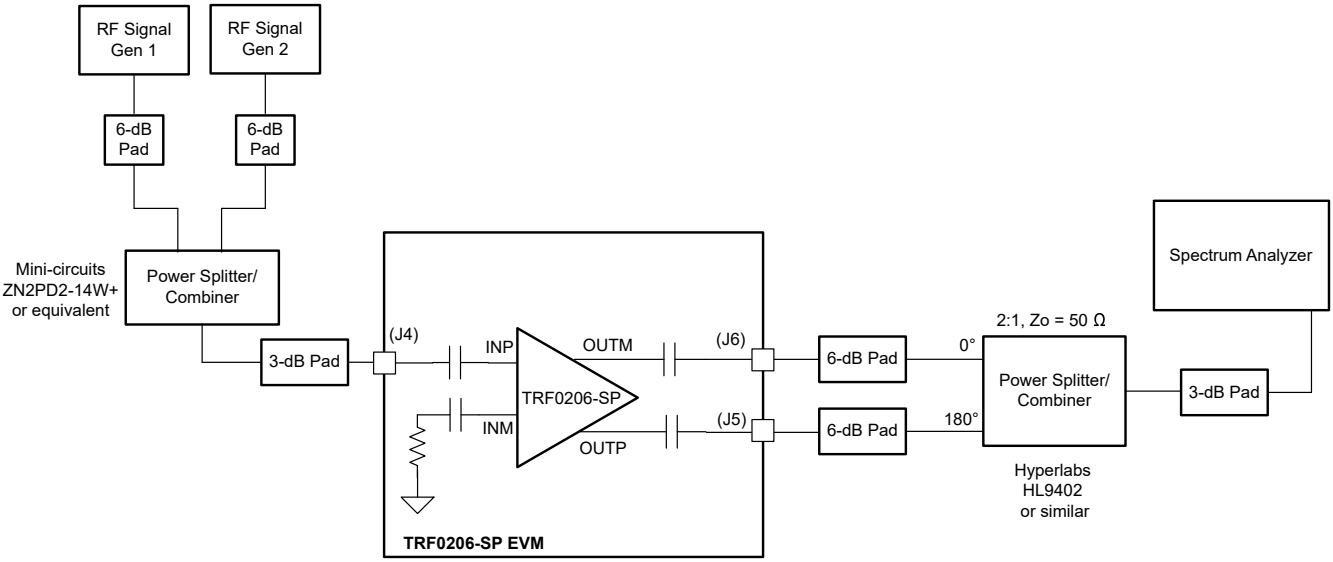


Figure 3-4. OIP3 Test Setup

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 6-dB 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 it yields the desired output power (P_{OUT}) at the device.
3. It is recommended for the output power level to remain within the linear operation range of the TRF0206-SP device. For example, if the total desired output power at the device is 8 dBm, then set the signal generators so that each of the fundamental output power results in 2 dBm per tone. As a general rule, it is recommended to keep the total output power level approximately 6 to 8 dB lower than the 1-dB 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 TRF0206-SP device output to the spectrum analyzer input. The combined power loss is due to PCB output trace, RF coax cable, 0/180° passive balun, and any attenuator pad used for external matching purposes. The calculated OIP3 is given in Equation 1.

$$\text{Output IP3} = (P_{IN\_SA} - \text{IMD3}) / 2 + P_{IN\_SA} + P_{LOSS} \quad (1)$$

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 2f1 – f2 or 2f2 – f1

8. In Equation 1, $P_{IN\_SA} + P_{LOSS} = P_{OUT}$ is the amplifier output power per tone.

4 Related Documentation

For related documentation, see the following:

- Texas Instruments, *TRF0206-SP Single Channel, 10 MHz to 6.5 GHz 3-dB BW, ADC Driver Amplifier* data sheet

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   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.

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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 DEGREDATION 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/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page
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/lsds/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:*

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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