User's Guide
TRF0206-SP Evaluation Module

TEXAS INSTRUMENTS

ABSTRACT

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

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1 Description

The TRF0206-SP evaluation module (EVM) is used to evaluate the TRF0206-SP device. TRF0206-SP 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 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

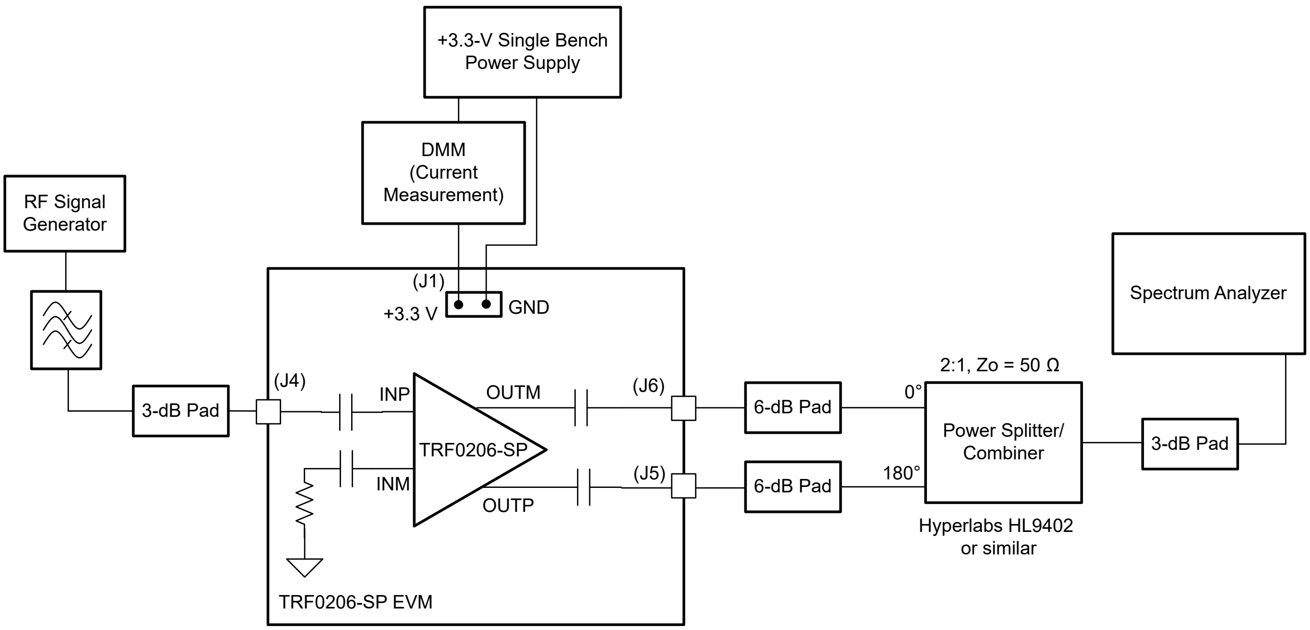


Figure 1-1. Single Tone Setup for Gain and Output P1dB

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. Set the DC output power supply to +3.3 V before connecting the power-supply cables to the EVM.
    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. Turn on the DC power supply of VCC = +3.3 V now. The supply current (I_Q) drawn from the power supply is approximately 135 mA.
    e. If the supply current is low, then check 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 is 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 can 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.

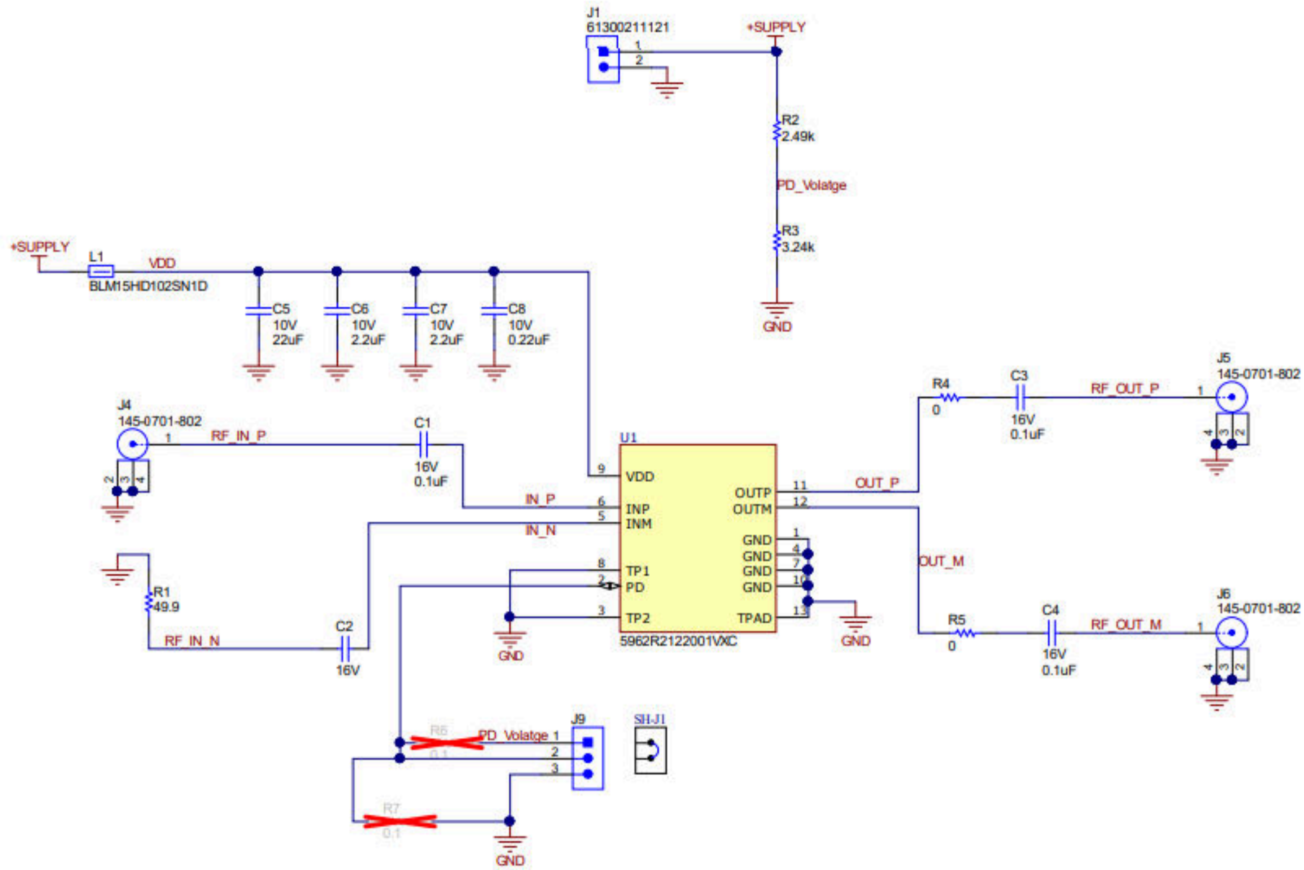


Figure 2-1. TRF0206-SP EVM Schematic

2.2 PCB Layers

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

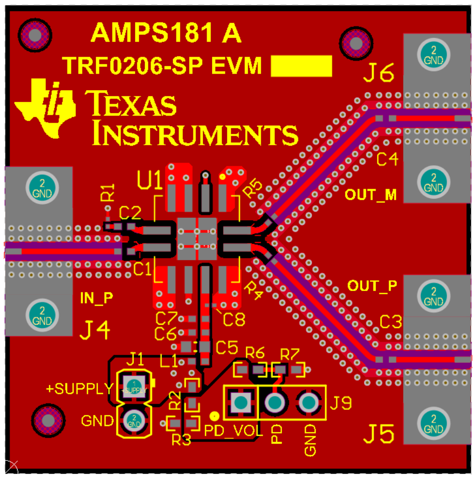


Figure 2-2. Top Layer

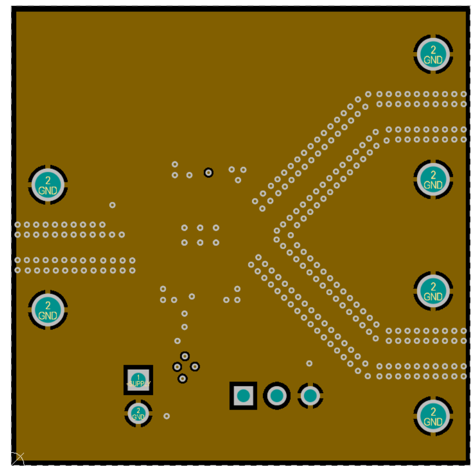


Figure 2-3. Layer 2

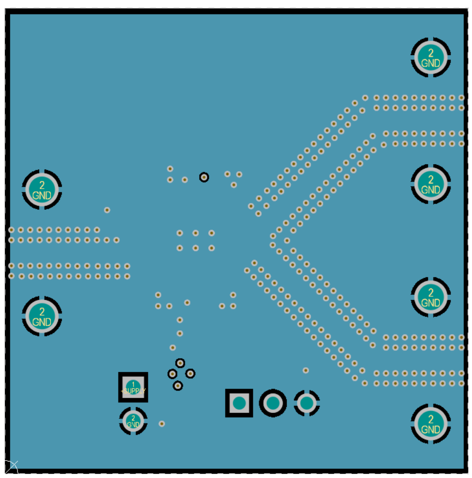


Figure 2-4. Layer 3

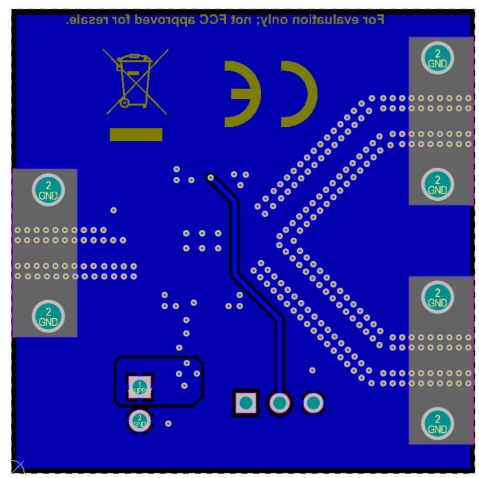


Figure 2-5. Bottom Layer

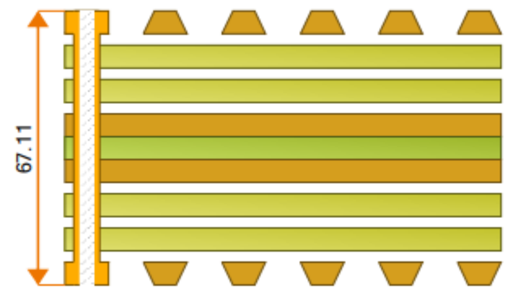
2.3 TRF0206-SP EVM Bill of Material

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		TRF0206FFM/EM	Texas Instruments	TRF0206FFM/EM	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

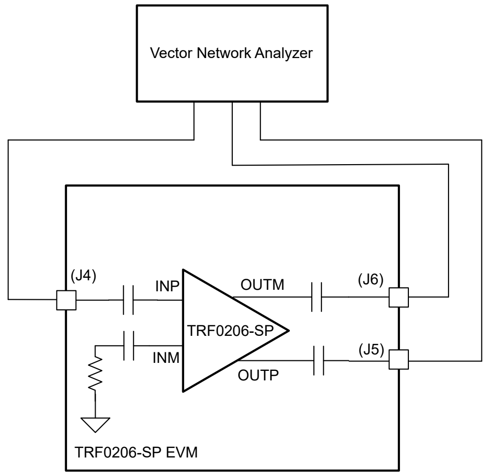


Figure 3-1. S-Parameter Test Setup

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. Determine 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 the adequate sweep time for the measurement.
4. Accounting for board trace losses at the input and output side of the device during gain measurements is important. Figure 3-2 gives typical input and output trace losses measured on the EVM.

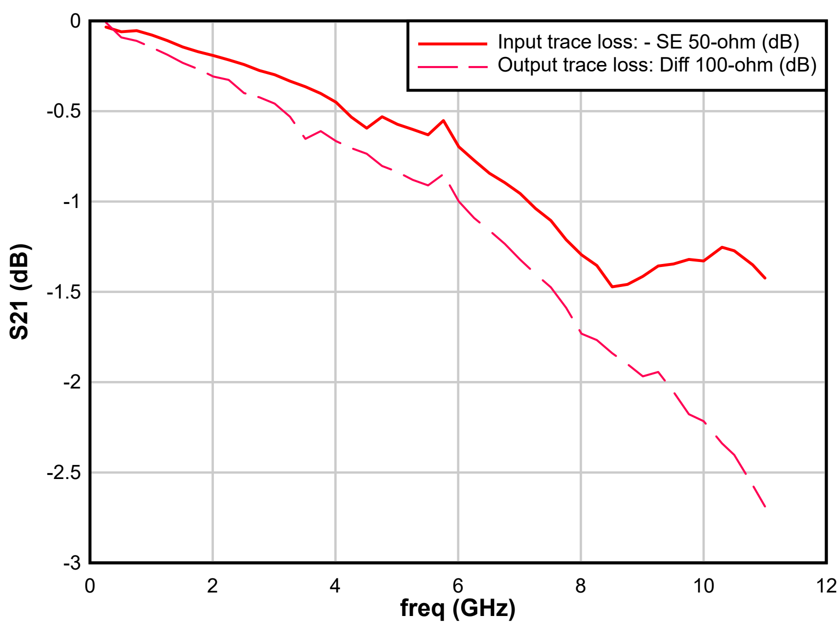


Figure 3-2. PCB Trace Loss vs Frequency

3.2 Noise Figure Test Setup

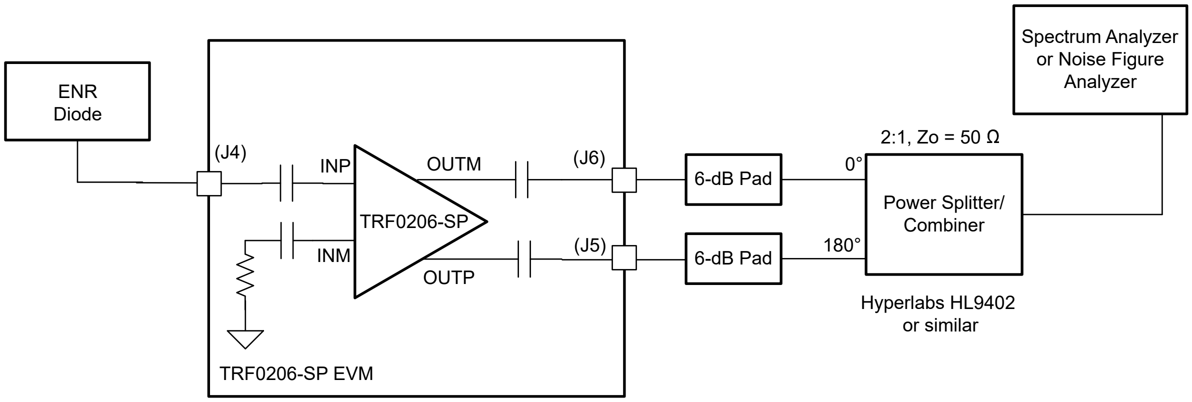


Figure 3-3. Noise Figure Test Setup

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 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, factoring the output loss into the NF measurement is important. Use the *Friis* equation to calculate the NF of the device from the total measured NF.

3.3 Two-Tone OIP3 Test Setup

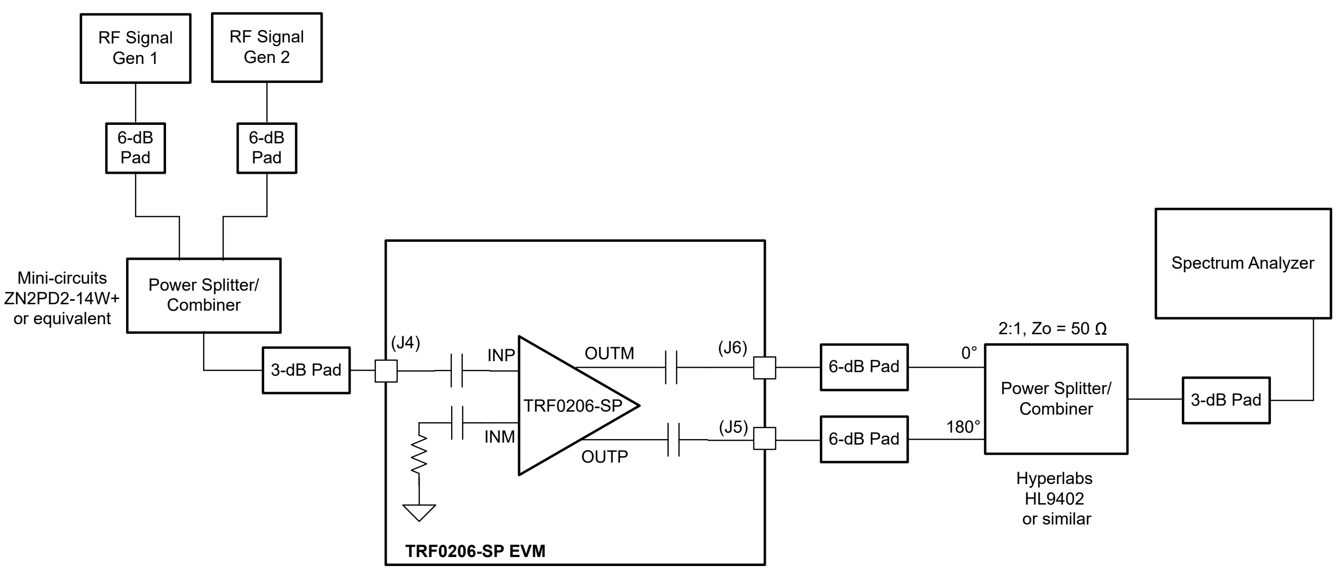


Figure 3-4. OIP3 Test Setup

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.

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

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.

5 Revision History

Changes from Revision * (October 2022) to Revision A (November 2023) **Page**

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