AN11527

BGU8019 GNSS front end evaluation board

Rev. 1 — 19 January 2017 Application note

Document information

Info	Content
Keywords	BGU8019, GNSS, FE, LNA
Abstract	This document explains the BGU8019 GNSS FE evaluation board
Ordering info	Board-number: OM7849 12NC: 9340 682 11598
Contact information	For more information, please visit: http://www.nxp.com

Revision history

Rev	Date	Description
1	20170119	First publication

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1. Introduction

NXP Semiconductors' BGU8019 Global Navigation Satellite System (GNSS) Front-End Evaluation Board (BGU8019 GNSS FE EVB) is designed to evaluate the performance of the GNSS front-end using:

- NXP Semiconductors' BGU8019 GNSS Low Noise Amplifier
- A matching inductor
- A decoupling capacitor
- Two identical GNSS band-pass filters

NXP Semiconductors' BGU8019 is a low-noise amplifier for GNSS receiver applications in a plastic, leadless 6 pin, extremely thin small outline SOT1232 at 1.1 x 0.7 x 0.37mm^3, 0.4mm pitch. The BGU8019 features gain of 18.5 dB and a noise figure of 0.55 dB at a current consumption of 4.6 mA. Its superior linearity performance removes interference and noise from co-habitation cellular transmitters, while retaining sensitivity. The LNA components occupy a total area of approximately 8.4 mm2.

In this document, the application diagram, board layout, bill of materials, and typical results are given, as well as some explanations on GNSS related performance parameters like out-of-band input third-order intercept point O_IIP3, gain compression under jamming and noise under jamming.

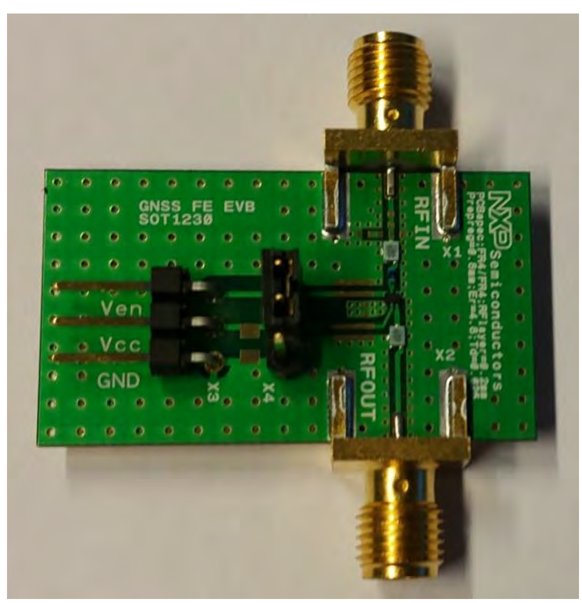


Fig 1. BGU8019 GNSS front-end evaluation board

2. General description

Modern cellular phones have multiple radio systems, so problems like co-habitation are quite common. A GNSS receiver implemented in a mobile phone requires the following factors to be taken into account.

All the different transmit signals that are active in a phone can cause problems like intermodulation and compression.

Since the GNSS receiver needs to receive signals with an average power level of -130 dBm, sensitivity is very important. Currently there are several GNSS chipsets on the market that can be implemented in cell phones, PDAs etc. Although many of these GNSS ICs do have integrated LNA front ends, the noise performance, and as a result the system sensitivity is not always adequate. The GNSS receiver sensitivity is a measure for how accurate the coordinates are calculated. The GNSS signal reception can be improved by a so called GNSS front-end, which improves the sensitivity by filtering out the unwanted jamming signals and by amplifying the wanted GNSS signal with a low-noise amplifier.

The pre-filters and post filters are needed to improve the overall linearity of the system as well as to avoid overdriving the integrated LNA stage of the GNSS receiver.

3. BGU8019 GNSS front-end evaluation board

The BGU8019 front-end evaluation board simplifies the RF evaluation of the BGU8019 GNSS LNA applied in a GNSS front-end that is often used in mobile cell phones. The evaluation board enables testing of the device RF performance and requires no additional support circuitry. The board is fully assembled with the BGU8019, including the input series inductor, decoupling capacitor as well as two SAW filters to optimize the linearity performance. The board is supplied with two SMA connectors for input and output connection to RF test equipment. The BGU8019 can operate from a 1.5 V to 3.1 V single supply and consumes about 4.6 mA.

3.1 Application Circuit

The circuit diagram of the evaluation board is shown in Fig 2. With jumper JU1 the enable input can be connected either to Vcc or GND.

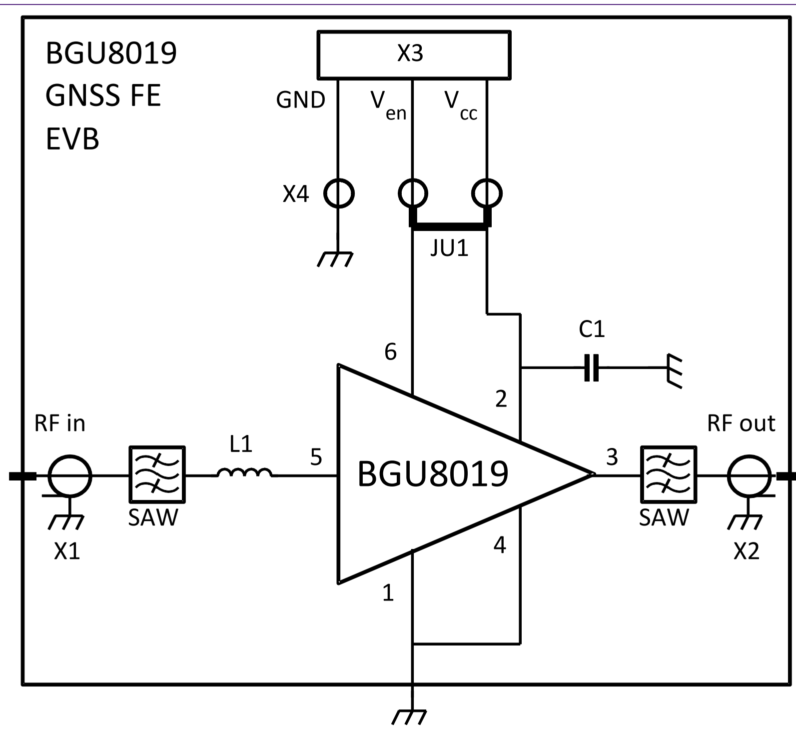


Fig 2. Circuit diagram of the BGU8019 front-end evaluation board

3.2 PCB Layout

A good PCB layout is an essential part of an RF circuit design. The front-end evaluation board of the BGU8019 can serve as a guideline for laying out a board using the BGU8019. Use controlled impedance lines for all high frequency inputs and outputs. Bypass Vcc with decoupling capacitors, preferably located as close as possible to the device. For long bias lines it may be necessary to add decoupling capacitors along the line further away from the device. Proper grounding of the GND pins is also essential for good RF performance. Either connect the GND pins directly to the ground plane or through vias, or do both, which is recommended. The out-of-band rejection of the SAW filters also depends on the grounding of the filter. The material that has been used for the evaluation board is FR4 using the stack shown in Fig 4. The input circuit has also SMD-positions for optional input filtering circuits (not used in this version of the FE-EVB).

3.3 Board Layout

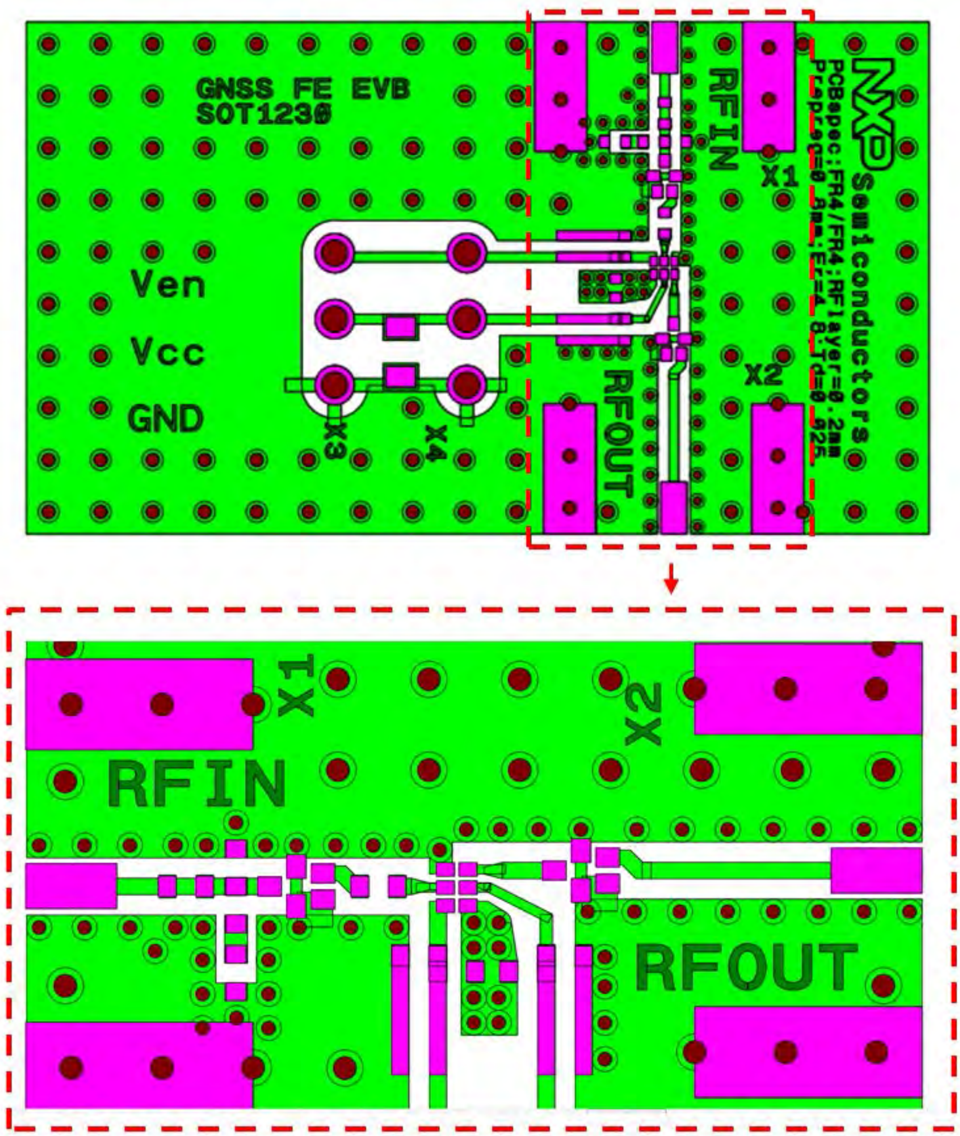
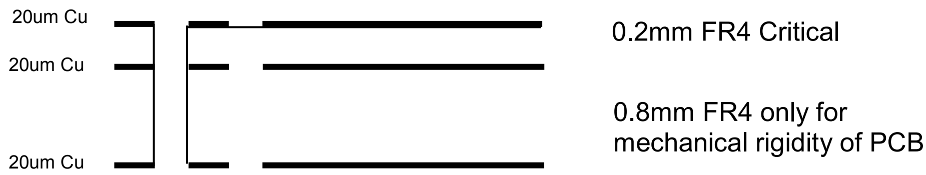


Fig 3. Printed-Circuit Board layout of the BGU8019 front-end evaluation board



(1) Material supplier is ISOLA DURAVER; εr = 4.6-4.9: $T\delta = 0.02$

Fig 4. Stack of the PCB material

4. Bill of materials

Table 1. BOM of the BGU8019 GNSS front-end evaluation board

Designator	Description	Footprint	Value	Supplier Name/type	Comment
Marking code: A	BGU8019	1.1 x 0.7 x 0.37 mm^3 0.4 mm pitch		NXP	SOT1232
PCB		20 x 35 mm^2		BGU8019 GNSS FE EV Kit	
C1	Capacitor	0402	1nF	Murata GRM1555	Decoupling
L1	Inductor	0402	6.8nH	Murata LQW15	Input matching
JK	SAW BPF	1.4 x 1.1 x 0.4 mm^3		EPCOS B8313	[1]
X1, X2	SMA RD connector	-	-	Johnson, End launch SMA 142-0701-841	RF input/ RF output
X3	DC header	-	-	Molex, PCB header, Right Angle, 1 row, 3 way 90121-0763	Bias connector
X4	JUMPER Stage	-	-	Molex, PCB header, Vertical, 1 row, 3 way 90120-0763	Connect Ven to Vcc or separate Ven voltage
JU1	JUMPER				

[1] Although in this case the EPCOS B8313 is used, the performance as given in this document can also be achieved with the use of GNSS SAW filters from other suppliers. See paragraph 4.2

4.1 BGU8019

NXP Semiconductors' BGU8019 GNSS low noise amplifier is designed for the GNSS frequency band. The integrated biasing circuit is temperature stabilized, which keeps the current constant over temperature. It also enables the superior linearity performance of the BGU8019. The BGU8019 is also equipped with an enable function that allows it to be controlled via a logic signal. In disabled mode it consumes less than 1 µA.

The output of the BGU8019 is internally matched for 1575.42 MHz whereas only one series inductor at the input is needed to achieve the best RF performance. Both the input and output are AC coupled via an integrated capacitor.

It requires only two external components to build a GNSS LNA having the following advantages:

- Low noise
- High gain
- High linearity under jamming
- 1.1 x 0.7 x 0.37, pitch 0.4mm^3, SOT1232
- Low current consumption
- Short power settling time

4.2 Band pass filters

The band-pass filters that are implemented in the GNSS front-end evaluation board are key components regarding the overall system linearity and sensitivity. Currently there are different suppliers on the market that have SAW filters for the GNSS band available. One of the key performance indicators of these filters is having very high rejection at the different cell phone TX frequencies, and simultaneously having low insertion loss in the GNSS pass-band. Although the evaluation board is supplied with two EPCOS B8313 SAW-filters (GPS, COMPASS, Galileo and GLONASS), the following alternatives can be considered:

1. Murata SAFA1G57KH0F00
2. Murata SAFA1G57KB0F00 low loss variant
3. Fujitsu FAR-F6KA-1G5754-L4AA
4. Fujitsu FAR-F6KA-1G5754-L4AJ

All these filters can use the same footprint. In order to be able to achieve the rejection level as indicated in the data sheet of these filters, it is necessary that the filters are properly grounded. In the layout of the front-end evaluation board the suppliers' recommendations have been followed. See Fig 5, please note that every GND pin has its own ground-via and there is a ground path between the input and the output.

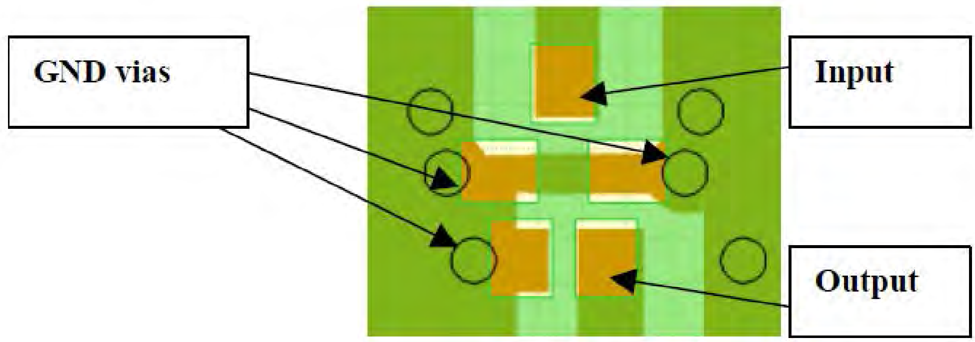


Fig 5. SAW filter footprint

4.3 Series inductor

The evaluation board is supplied with Murata LQW15 series inductor of 6.8nH. This is a wire wound type of inductor with high quality factor (Q) and low series resistance (Rs). This type of inductor is recommended in order to achieve the best noise performance. High Q inductors from other suppliers can be used. If it is decided to use other low cost inductors with lower Q and higher Rs the noise performance will degrade.

5. Required Equipment

In order to measure the evaluation board the following is necessary:

- ✓ DC Power Supply up to 30 mA at 1.5 V to 3.1 V
- ✓ Two RF signal generators capable of generating RF signals at the operating frequency of 1575.42 MHz, as well as the jammer frequencies 1713.42 MHz and 1851.42 MHz
- ✓ An RF spectrum analyzer that covers at least the operating frequency of 1575.42 MHz as well as a few of the harmonics. Up to 6 GHz should be sufficient.
  "Optional" a version with the capability of measuring noise figure is convenient
- ✓ Amp meter to measure the supply current (optional)
- ✓ A network analyzer for measuring gain, return loss and reverse isolation
- ✓ Noise figure analyzer and noise source
- ✓ Directional coupler
- ✓ Proper RF cables

6. Connections and setup

The BGU8019 GNSS front-end evaluation board is fully assembled and tested. Please follow the steps below for a step-by-step guide to operate the front-end evaluation board and test the device functions.

1. Connect the DC power supply to the V_{cc} and GND terminals. Set the power supply to the desired supply voltage, between 1.5 V and 3.1 V, but never exceed 3.1 V as it might damage the BGU8019.
2. Jumper JU1 is connected between the V_{cc} terminal of the evaluation board and the V_{en} pin of the BGU8019.
3. Connect the RF signal generator and the spectrum analyzer to the RF input and the RF output of the evaluation board, respectively. Do not turn on the RF output of the signal generator yet, set it to -40 dBm output power at 1575.42 MHz, set the spectrum analyzer at 1575.42 MHz center frequency and a reference level of 0 dBm.
4. Turn on the DC power supply and it should read approximately 4.4mA.
5. Enable the RF output of the generator: The spectrum analyzer displays a tone around –25 dBm at 1575.42 MHz.
6. Instead of using a signal generator and spectrum analyzer one can also use a network analyzer in order to measure gain as well as in- and output return loss.
7. For noise figure evaluation, either a noise figure analyzer or a spectrum analyzer with noise option can be used. The use of a 15 dB noise source, like the Agilent 364B is recommended. When measuring the noise figure of the evaluation board, any kind of adaptors, cables etc between the noise source and the evaluation board should be avoided, since this affects the noise figure.

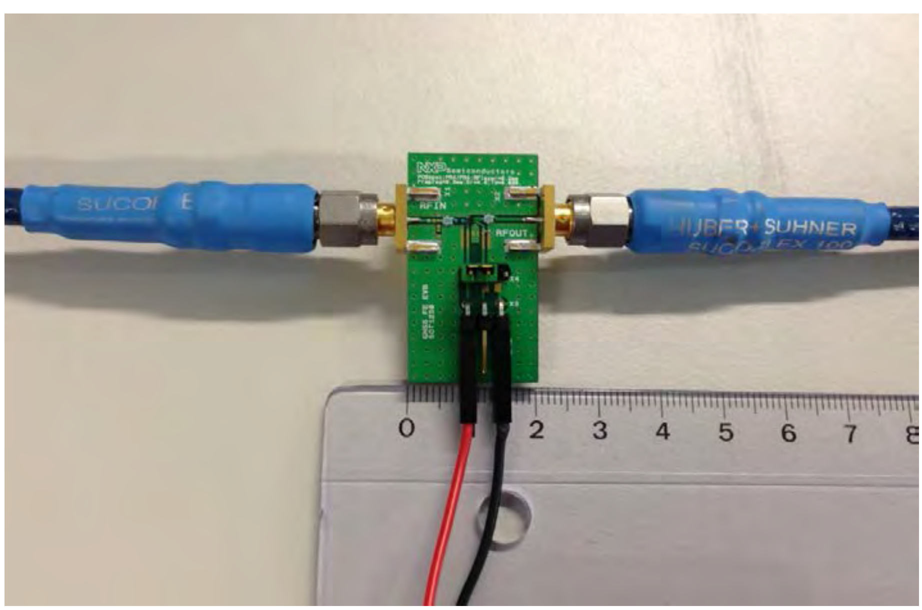


Fig 6. Evaluation board including its connections

7. TX rejection levels

When measuring the front-end evaluation board the input level of the network analyzer has to be on -45 dBm to avoid activating the adaptive biasing. This low input level results in a very inaccurate measurement result of the TX rejection. Fig 7 and Fig 8 show the typical TX rejection levels measured more accurate due to segmented power calibration.

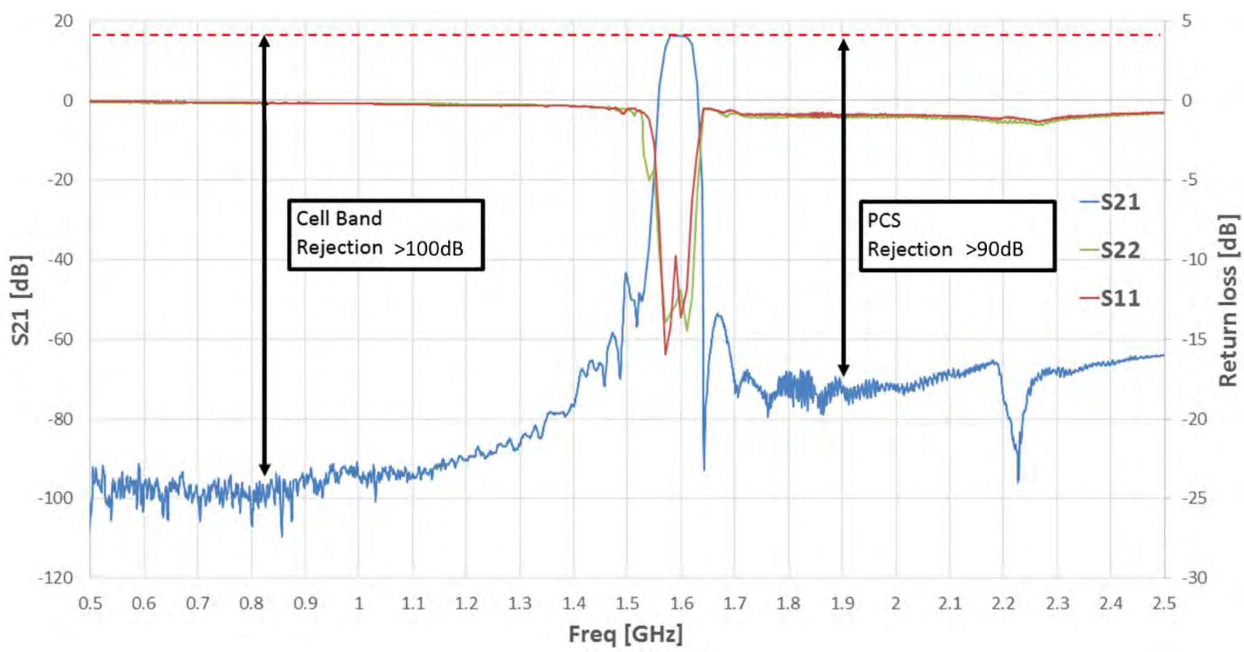


Fig 7. Typical S-parameter plot at Vcc = 2.85 V

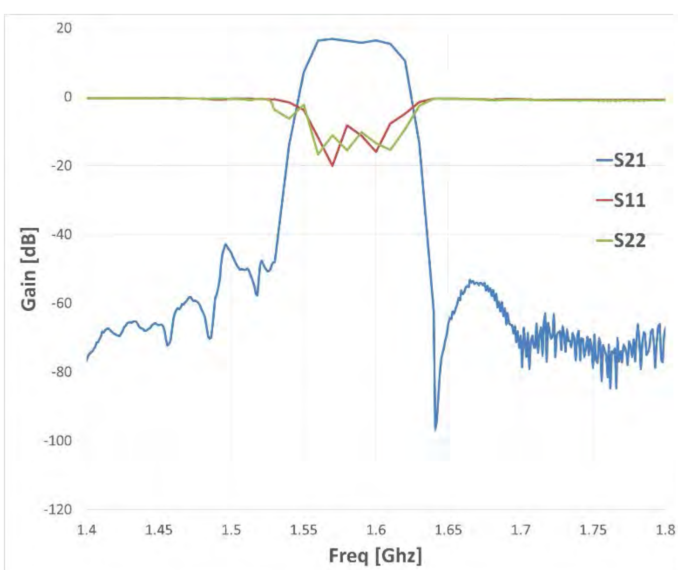


Fig 8. Typical pass band response at Vcc = 2.85 V

8. Typical front-end evaluation board results

Table 2. Typical results measured on the evaluation boards
Operating Frequency is f = 1575.42 MHz unless otherwise specified; Temp = 25 °C

Parameter	Symbol	FE EVB	FE EVB	FE EVB	FE EVB	Unit	Remarks
Supply Voltage	V_{CC}	1.5	1.8	2.85	3.1	V	
Supply Current	I_{CC}	4.2	4.3	4.5	4.6	mA	
Noise Figure	NF	1.45	1.45	1.4	1.4	dB	[1]
Power Gain	G_p	15.7	16.0	16.3	16.4	dB	
Input Return Loss	RL_{in}	7.9	8.0	8.4	8.3	dB	
Output Return Loss	RL_{out}	14.5	14.6	14.6	14.7	dB	
Reverse Isolation	ISO_{rev}	33.1	33.2	33.2	33.3	dB	
Input 1dB Gain Compression	P_i1dB	-11.5	-9.6	-6.5	-6.1	dBm	
Output 1dB Gain Compression	P_o1dB	3.3	5.4	8.8	9.3	dBm	
Power settling time	T_{on}	< 2	< 2	< 2	< 2	μs	
	T_{off}	< 1	< 1	< 1	< 1	μs	

[1] The noise figure and gain figures are measured at the SMA connectors of the evaluation board. The losses of the connectors and the PCB of approximately 0.1dB are not subtracted. Measured at T_{anb} = 25 °C.

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10. List of figures

11. List of tables

12. Contents

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Date of release: 19 January 2017
Document identifier: AN11527