UM10459

User manual for the BGU7007 GPS LNA evaluation board

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Document information

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Abstract	This document explains the BGU7007 GPS low noise amplifier evaluation board

Revision history

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1. Introduction

NXP Semiconductors' BGU7007 is a low-noise amplifier for GPS receiver applications in a plastic, leadless 6 pin, extremely thin small outline SOT886 package. It has a gain of 18.5 dB and a noise figure of 0.9 dB (incl. board losses) or 0.85 dB (board losses subtracted). It has superior linearity performance to suppress interference and noise from co-habitation cellular transmitters while retaining sensitivity.

The LNA has been designed using NXP Semiconductors' advanced 110 GHz f_T SiGe:C process. The BGU7007 only requires two external components, one series inductor for input matching and one decoupling capacitor. The BGU7007 contains one RF stage and internal bias that is temperature stabilized. It is also supplied with an enable function allowing it to be controlled by a logic signal.

The BGU7007 is ideal for use as GPS LNA in smart phones, feature phones and Portable Navigation Devices.

The GPS LNA evaluation board (EVB), see Fig 1, is designed to evaluate the performance of the BGU7007 applied as a GPS LNA. In this document, the application diagram, board layout, bill of materials, and typical results are given, as well as some explanations on GPS related performance parameters like out-of-band input third-order intercept point, gain compression under jamming and noise under jamming.

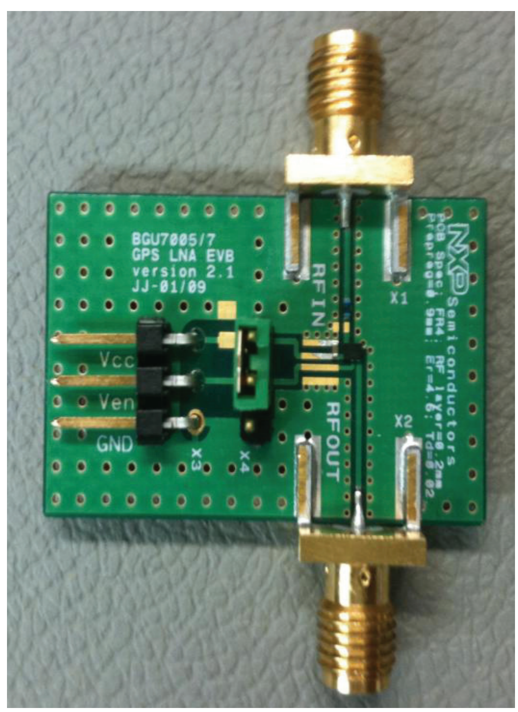

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Fig 1. BGU7007 GPS LNA evaluation board

2. General description

NXP Semiconductors' BGU7007 GPS low noise amplifier is dedicated for the GNSS frequency band (GPS, GLONASS and Galileo positioning systems). The integrated biasing circuit is temperature stabilized, which maintains a constant current over temperature. It also enables the superior linearity performance of the BGU7007. It is also supplied with an enable function that allows it to be controlled with a logic signal. In disabled mode it consumes less than µA.

The output of the BGU7007 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.

Only two external components are required to build a GPS LNA with the following advantages:

- Low noise
- High gain
- High linearity under jamming
- Very low package height 0.5 mm
- Low current consumption
- Short power settling time

The data sheet of the BGU7007 is available, and it is called *"SiGe:C Low Noise Amplifier MMIC for GPS applications"*

3. Application Board

The BGU7007 GPS LNA evaluation board simplifies the evaluation of the BGU7007 GPS LNA for the GPS application. The evaluation board enables testing of the device performance and requires no additional support circuitry. The board is fully assembled with the BGU7007, including the input series inductor as well as a decoupling capacitor to optimize the performance. The board is supplied with two SMA connectors for input and output connection to RF test equipment. The BGU7007 can operate from a 1.5 V to 2.85 V single supply and consumes about 5 mA.

3.1 Application circuit

The circuit diagram of the evaluation board is shown in Fig 2.

With jumper JU1 the enable pin can be controlled to either to V_{cc} or GND.

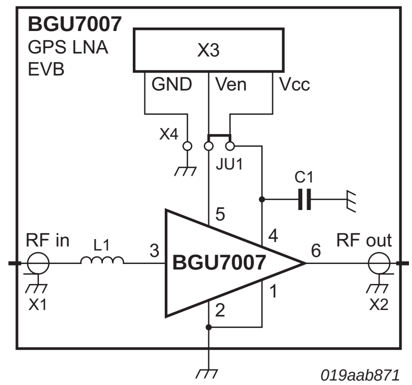

Fig 2. Circuit diagram of the BGU7007 evaluation board

3.2 Board layout

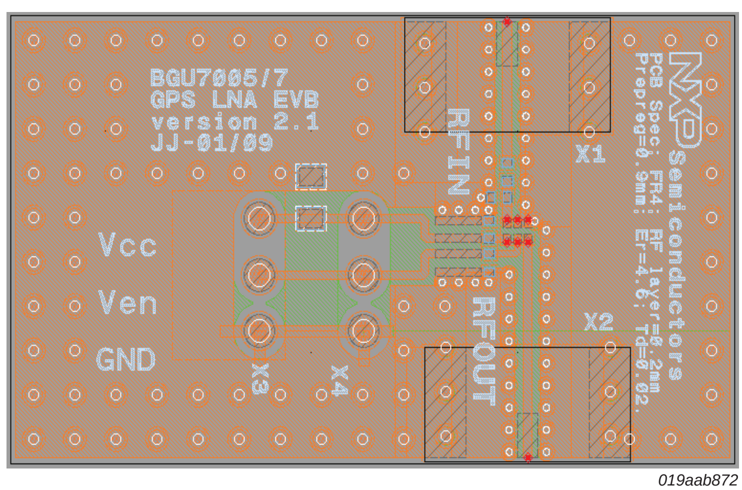

Fig 3. Printed circuit board lay-out of the BGU7007 GPS LNA evaluation board

3.3 PCB layout

A good PCB layout is an essential part of an RF circuit design. The evaluation board of the BGU7007 can serve as a guideline for laying out a board using the BGU7007. Use controlled impedance lines for all high frequency inputs and outputs. Bypass V_{cc} 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. The material that has been used for the evaluation board is FR4 using the stack shown in Fig 4

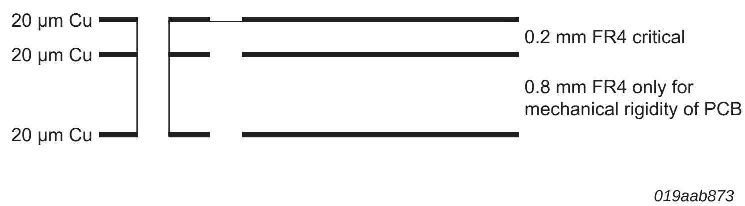

Fig 4. Stack of the PCB material

Material supplier is ISOLA DURAVER; $\varepsilon r = 4.6 - 4.9$: $\mathrm{Tan}\delta = 0.02$

3.4 Bill of materials

Table 1. BOM of the BGU7007 GPS LNA EVB v2.1

Designator	Description	Footprint	Value	Supplier Name/type	Comment
Ac	BGU7007	1.45 mm x 1.1 mm	-	-	LNA MMIC
PCB	v2.1	35 mm x 20 mm	BGU7007 GPS LNA EVB	-	-
C1	Capacitor	0402	1 nF	Murata GRM1555	Decoupling
L1	Inductor	0402	5.6 nH	Murata/LQW15A High Q low Rs	Input matching
X1,X2	SMA RF 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 V_{en} to V_{cc} or separate V_{en} voltage
JU1	Jumper	-	-	-	-

3.4.1 Series inductor

The evaluation board is supplied with Murata LQW15series inductor of 5.6 nH. 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.

4. 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 2.85 V
- Two RF signal generators capable of generating an RF signal at the operating frequency of 1575.42 MHz, as well as the jammer frequencies 850 MHz, 1713.42 MHz, 1850 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, so 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.

5. Connections and setup

The BGU7007 GPS LNA evaluation board is fully assembled and tested. Please follow the steps below for a step-by-step guide to operate the evaluation board and testing the device functions.

1. Measure the cable- and directional coupler losses at the frequencies which are used during the evaluation (1575 MHz, 850 MHz and 1850 MHz). These losses are used to correct the measured power levels.
2. 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 2.85 V, but never exceed 3.1 V as it might damage the BGU7007.
3. Jumper JU1 is connected between the V_{cc} terminal of the evaluation board and the V_{en} pin of the BGU7007.
4. To evaluate the power on settling time ton and the power off settling time t_{off}, it is also possible to use a separate voltage on the V_{en}, eventually this voltage can be supplied by a pulse generator. In this case jumper JU1 should be removed. The definition of ton is the time from 10 % to 90 % of the maximum signal level and for t_{off} the time from 90 % to 10 % of the maximum signal level.
5. 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.
6. Turn on the DC power supply and it should read approximately 5 mA.
7. Enable the RF output of the generator; the spectrum analyzer displays a tone of around –25 dBm at 1575.42 MHz. 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.
8. 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 performance.

9. For noise under jamming conditions, the following is needed. A 15 dB ENR noise source, a directional coupler, GPS band pass filter, a noise-figure analyzer or a spectrum analyzer with noise option can be used. See Fig 11.

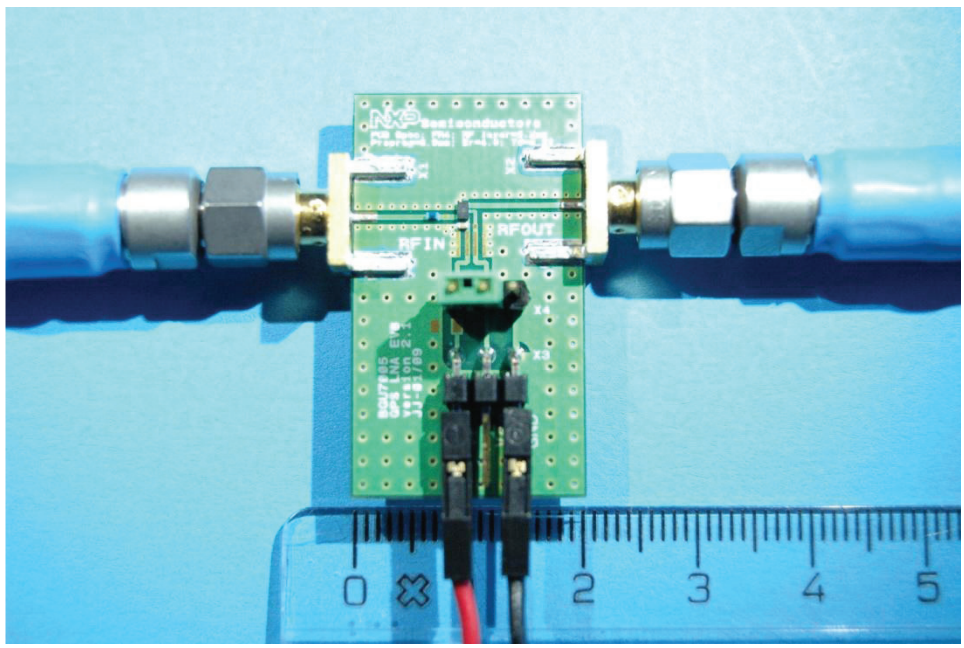

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Fig 5. GPS LNA evaluation board including its connections

6. Linearity

At the average power levels of –130 dBm that have to be received by a GPS receiver, the system will not have in-band intermodulation problems caused by the GPS-signal itself. Strong out-of-band cell phone TX jammers however can cause linearity problems, and result in third-order intermodulation products in the GPS frequency band. In this chapter the effects of these Jammer-signals on the Noise and Gain performance of the BGU7007 are described. The effect of these Jammers on the In-band and Out-of-Band Third-Order Intercept points are described in more detail in a separate User Manual: *UM10453: 2-Tone Test BGU7005 and BGU7007 GPS LNA*.

6.1 1 dB gain compression at 1575 MHz with 850 MHz or 1850 MHz jammers

As already stated before, signal levels in the GPS frequency band of –130 dBm average will not cause linearity problems in the GPS band itself. This of course is also valid for the 1 dB gain compression in-band. The 1 dB compression point at 1575 MHz caused by cell phone TX jammers however is important. Measurements have been carried out using the set-up shown in Fig 6. The jammer signal is coupled via a directional coupler to the DUT. For the P1dB measurements this not required, but connecting it this way the setup can also be used for NF-measurements as described in the next paragraph.

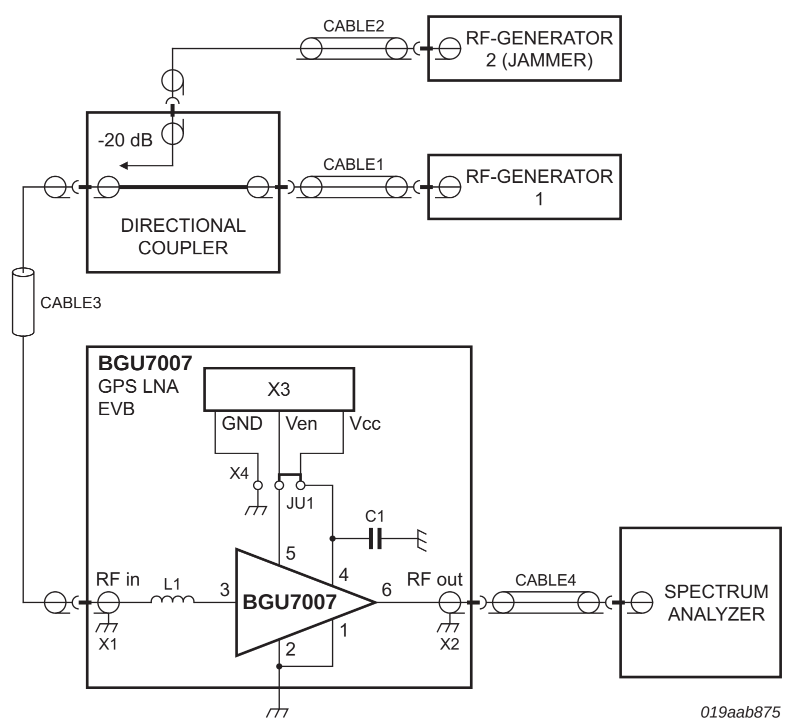
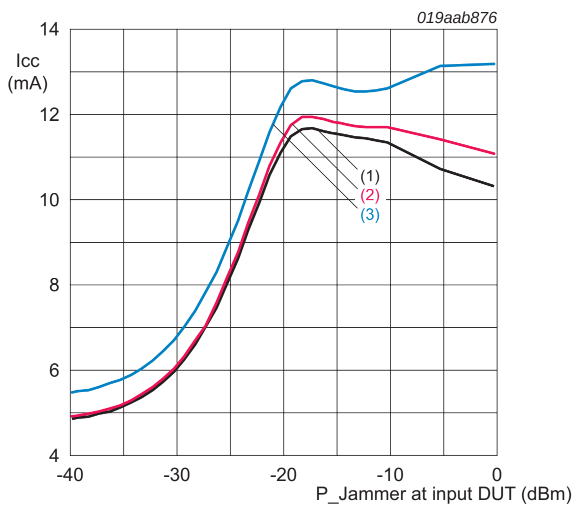


Fig 6. Setup for 1 dB compression with jammers

The gain of the DUT was measured between port RFin and RFout of the EVB at the GPS frequency 1575 MHz, while simultaneously a jammer power signal was swept at the 20 dB attenuated input port of the Directional Coupler. Please note that the drive power of the jammer is 20 dB lower at the input of the DUT caused by the directional coupler.

The figures below show the supply-current (I_{cc}) and gain compression curves with 850 MHz and 1850 MHz jammers. At 1 dB Gain drop the Jammer-Generator read out for 850 MHz jammer is +5.6 dBm (V_{cc} = 2.85 V). Taking into account the approx 20 dB attenuation of the directional coupler this means Pi1 dB = –14.74 dBm (Fig 8). For 1850 MHz the Jammer-Generator read out is +12.8 dBm (V_{cc} = 2.85 V. Taking into account the approx 20 dB attenuation of the directional coupler this means Pi1 dB = – 7.54 dBm). (Fig 10).



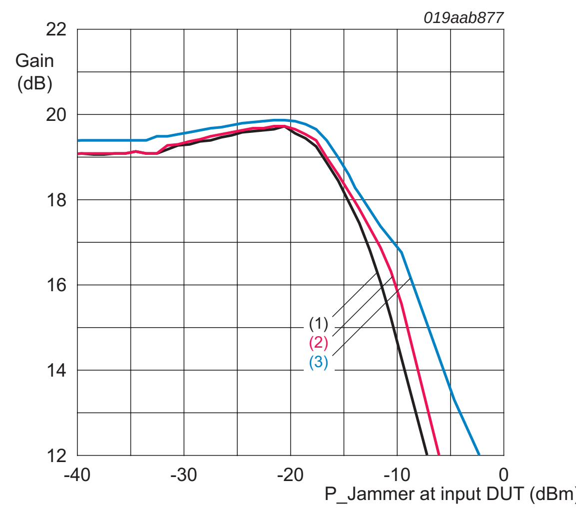
(1) Vcc = 1.5 V

(2) Vcc = 1.8 V

(3) Vcc = 2.85 V

(Pin 1575 MHZ = -45 dBm)

Fig 7. Icc versus jammer power at 850 MHz



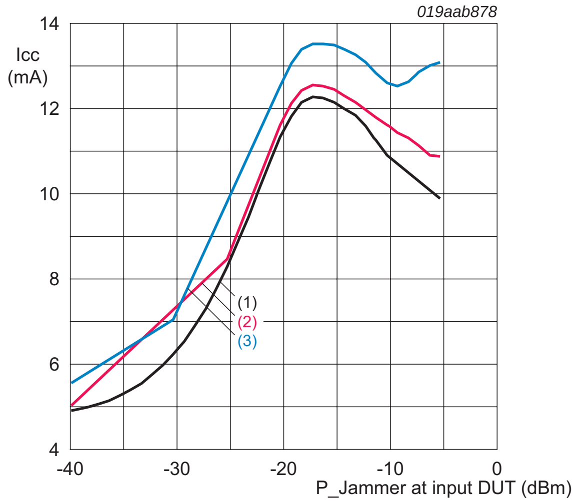
(1) Vcc = 1.5 V

(2) Vcc = 1.8 V

(3) Vcc = 2.85 V

(Pin 1575 MHZ = -45 dBm)

Fig 8. Gain versus jammer power at 850 MHz



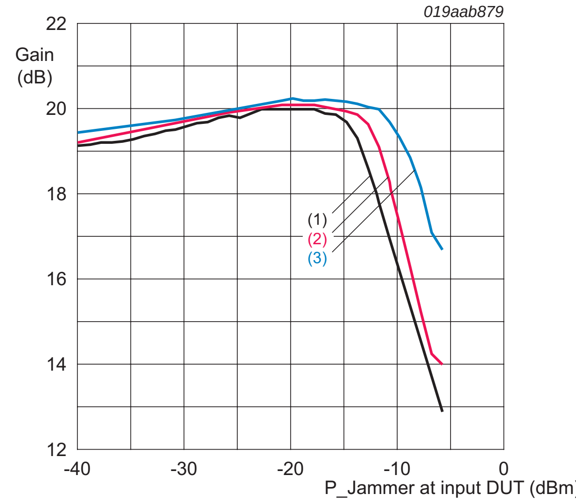
(1) Vcc = 1.5 V

(2) Vcc = 1.8 V

(3) Vcc = 2.85 V

(Pin 1575 MHZ = -45 dBm)

Fig 9. Icc versus jammer power at 1850 MHz



(1) Vcc = 1.5 V

(2) Vcc = 1.8 V

(3) Vcc = 2.85 V

(Pin 1575 MHZ =-45 dBm)

Fig 10. Gain versus jammer power at 1850 MHz

7. Noise figure as function of jammer power at 850 MHz and 1850 MHz

Noise figure under jamming conditions is a measure of how the LNA behaves when e.g. a GSM TX interfering signal is at the input of the GPS antenna. To measure this behavior the setup shown in Fig 11 is used.

The jammer signal is coupled via a directional coupler to the DUT: this is to avoid the jammer signal damaging the noise source. The GPS BPF is needed to avoid driving the second-stage LNA in saturation.

For the Jammer-Generator a low Phase-Noise type is advised. This is to avoid extra noise caused by the Jammer-Generator at measurement frequency (1575 MHz).

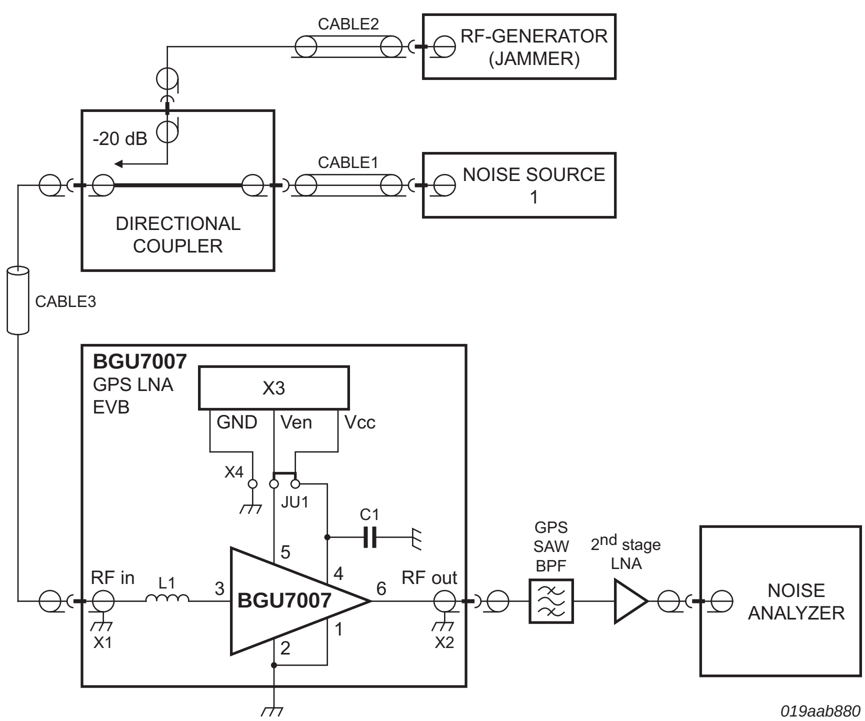
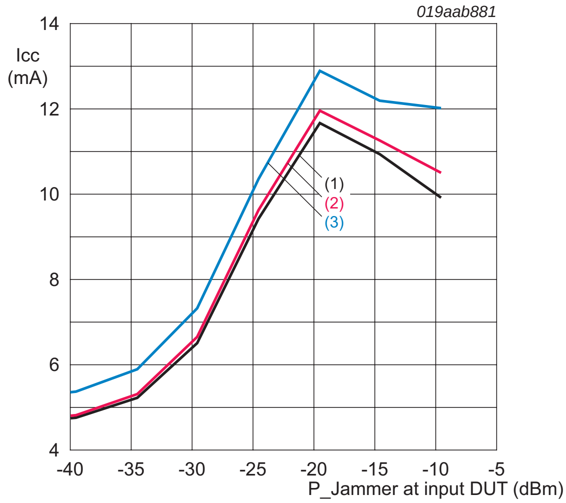


Fig 11. Noise under jamming measurement setup

In the figures below the supply-current (I_{cc}), the noise figure (NF) and gain as function of jammer power are given for 850 MHz and 1850 MHz jammer signals.

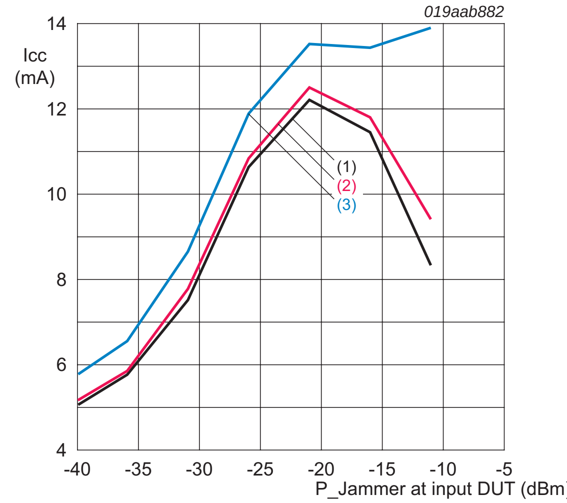


(1) Vcc = 1.5 V

(2) Vcc = 1.8 V

(3) Vcc = 2.85 V

Fig 12. Icc versus jammer power at 850 MHz

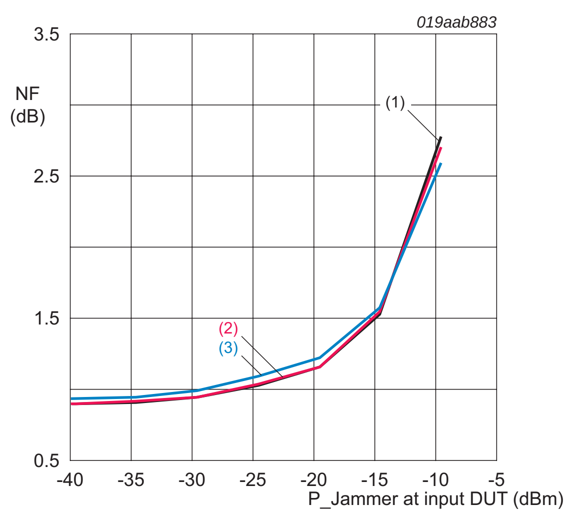


(1) Vcc = 1.5 V

(2) Vcc = 1.8 V

(3) Vcc = 2.85 V

Fig 13. Icc versus jammer power at 1850 MHZ

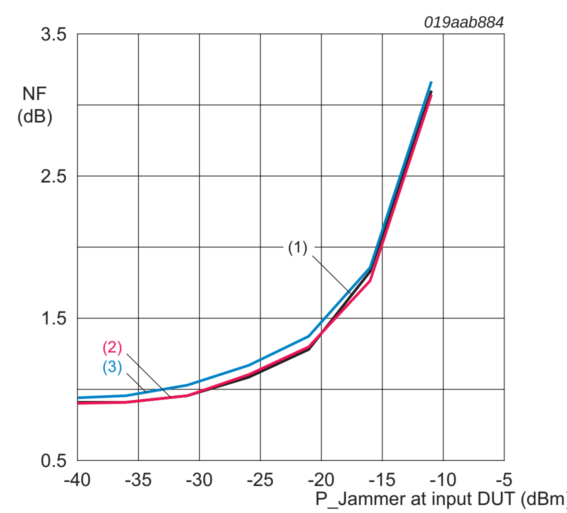


(1) Vcc = 1.5 V

(2) Vcc = 1.8 V

(3) Vcc = 2.85 V

Fig 14. NF at 1.575 GHz versus jammer power at 850 MHz



(1) Vcc = 1.5 V

(2) Vcc = 1.8 V

(3) Vcc = 2.85 V

Fig 15. NF at 1.575 GHz versus jammer power at 1850 MHz

8. Typical 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	BGU7007	BGU7007	BGU7007,	Unit	Remarks
Supply Voltage	V_{cc}	1.5	1.8	2.85	V	-
Supply Current	I_{cc}	3.4	4.8	6.1	mA	-
Noise Figure	NF [1]	0.9	0.9	0.9	dB	P_{in} < -40 dBm, no jammer
Power Gain	G_p	16.5	18.5	20.5	dB	P_{in} < -40 dBm, no jammer
Input Return Loss	RL_{in}	5	7	-	dB	P_{in} < -40 dBm, no jammer
Output Return Loss	RL_{out}	12	18	-	dB	P_{in} < -40 dBm, no jammer
Reverse Isolation	ISL_{rev}	22	24	-	dB	P_{in} < -40 dBm, no jammer
Input 1dB Gain Compression	P_i1dB	-13	-12	-11	dBm	-
Input third order intercept point	$IP3_i$ [2]	4	4	5	dBm	-

[1] The NF and Gain figures are being measured at the SMA connectors of the evaluation board, so the losses of the connectors and the PCB of approximately 0.1dB are not subtracted.

[2] Jammers at f_1 = f+138 MHz and f_2 = f+276 MHz, where f = 1575.42 MHz

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