# AN11986

## BGU8009 [GPS1201M] tuned for LTE B32 evaluation board

Rev. 1 — 17 July 2017 Application note

**Document information**

| Info | Content |
|---|---|
| **Keywords** | BGU8009, GPS1201M, GNSS, LNA, LTE B32. |
| **Abstract** | This document explains the BGU8009 [GPS1201M] LNA evaluation board tuned for the LTE Band 32 (1452MHz to 1496MHz). |
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# 1. Introduction

Modern cellular phones have multiple radio systems, so problems like co-habitation are quite common. Since the LTE diversity antenna needs to be placed far from the main antenna to ensure the efficiency of the channel, a low noise amplifier close to the antenna is used to compensate the track-losses (and SAW-filter losses when applicable) on the printed circuit board. A LTE receiver implemented in a mobile phone requires a low current consumption and low Noise Figure. All the different transmit signals that are active in smart phones and tablets can cause problems like inter-modulation and compression. Therefore, also a high linearity is required.

The NXP Semiconductors BGU8009, also called GPS1201M used on this evaluation board, is originally designed to use as a GNSS L1-band LNA. It contains internally matched circuitry for this frequency band (1559 MHz to 1610 MHz) whereas only one series inductor at the input is needed to achieve the best RF performance. The operating frequency range can be tuned to the LTE band 32 (1452 MHz to 1496 MHz, see Fig 1) by increasing the external input matching inductor as described in Chapter 2.

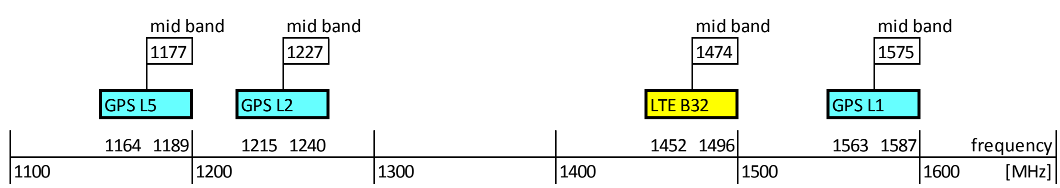



**Fig 1. GPS bands and LTE band 32 frequencies**

The LTE B32 LNA Evaluation Board (see Fig 2) is designed to evaluate the performance of the LTE B32 LNA using:

- NXP Semiconductors GPS1201M Low Noise Amplifier
- Matching inductor at the input
- A decoupling capacitor at the power supply connection

NXP Semiconductors GPS1201M is a low-noise amplifier for GNSS receiver applications in a plastic, leadless 6 pin, extremely thin small outline SOT1230 at 1.1 x 0.9 x 0.5mm$^3$, 0.4mm pitch. At the GNSS L1-band the GPS1201M features gain of 18.5 dB and a noise figure of 0.55 dB at a current consumption of 4.4 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 4.5 mm$^2$.

In this document, the application diagram, board layout, bill of materials, and typical results are given of the GPS1201M LNA board tuned for the LTE B32.

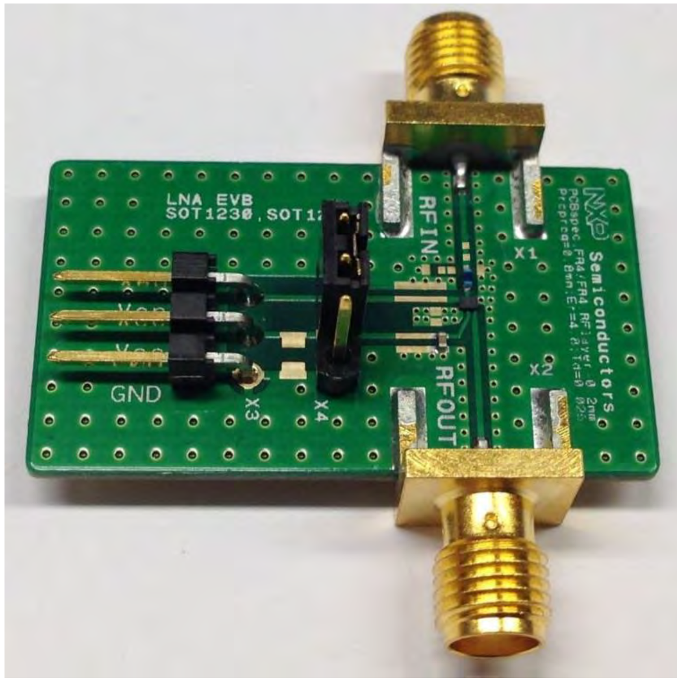



**Fig 2. GPS1201M LTE band 32 LNA evaluation board**

# 2. GPS1201M LTE band 32 LNA evaluation board

The GPS1201M LNA evaluation board simplifies the RF evaluation of the GPS1201M LNA applied in a LTE B32 front-end, 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 GPS1201M including the input series inductor and decoupling capacitor. The board is supplied with two SMA connectors (50 ohms) for input and output connection to RF test equipment. The GPS1201M can operate from a 1.5 V to 3.1 V single supply and consumes typical 4.4 mA.

## 2.1 Application Circuit

The circuit diagram of the evaluation board is shown in Fig 3. With jumper JU1 the enable input can be connected either to $V_{cc}$ or GND.

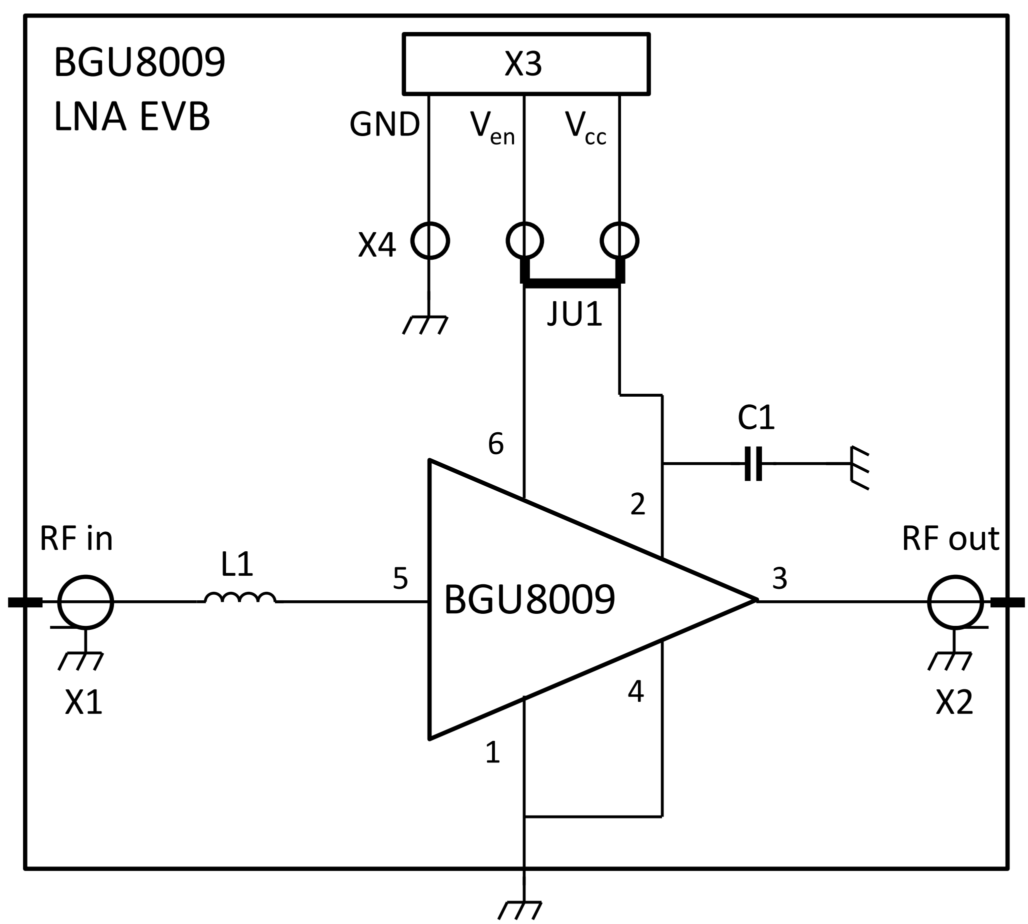



Fig 3. Circuit diagram of the GPS1201M [BGU8009] LTE band 32 LNA evaluation board

## 2.2 PCB Layout

A good PCB layout is an essential part of an RF circuit design. The LNA evaluation board of the GPS1201M can serve as a guideline for laying out a board using the GPS1201M (see Fig 4). 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.

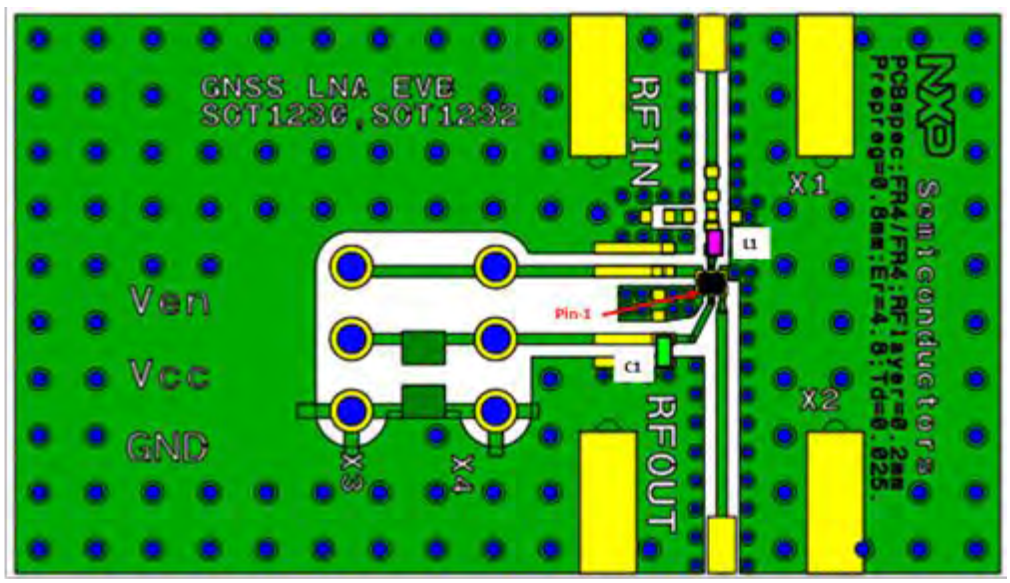
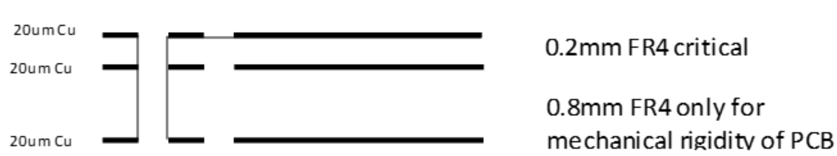



**Fig 4. Printed-Circuit Board layout of the GPS1201M LNA evaluation board**

The material that has been used for the evaluation board is FR4 using the stack shown in Fig 5.




[1] Material supplier is ISOLA DURAVER; εr = 4.6-4.9: Tδ = 0.02

**Fig 5. Stack of the PCB material**

## 2.3 Bill of materials

**Table 1. BOM of the GPS1201M LTE B32 LNA evaluation board**

| Designator | Description | Footprint | Value | Supplier Name/type | Comment |
|---|---|---|---|---|---|
| A | GPS1201M | 1.1 x 0.9 x 0.5mm$^3$, 0.4mm pitch | | NXP | SOT1230 |
| PCB | | 20 x 35mm | | GPS1201M GNSS LNA EV Kit | |
| C1 | Capacitor | 0402 | 1nF | Murata GRM1555 | Decoupling |
| L1 | Inductor | 0402 | 9.1 nH | Murata LQW15 | Input matching |
| 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 $V_{en}$ to $V_{cc}$ or separate $V_{en}$ voltage |
| JU1 | JUMPER | | | | |

## 2.4 GPS1201M product description

NXP Semiconductors GPS1201M 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 GPS1201M. The GPS1201M 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 GPS1201M 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. In this application, the GPS1201M is tuned for the LTE band 32.

It requires only two external components to build a LTE band 32 LNA having the following advantages:

- Low noise
- System optimized gain
- High linearity under jamming
- 1.1 x 0.9 x 0.5mm$^3$, 0.4mm pitch: SOT1230
- Low current consumption
- Short power settling time

## 2.5 Inductors

The evaluation board is supplied with a Murata LQW15 series inductor L1 of 9.1 nH at the input. L1 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.

**Table 1. Series Inductor options**

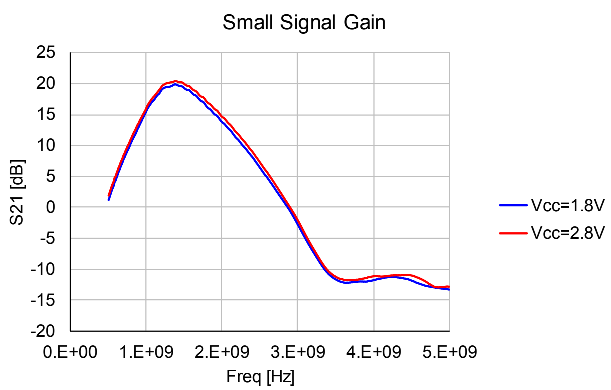
| Type | Murata | Size 0201 | Size 0402 | Size 0603 | Comment |
|---|---|---|---|---|---|
| Multilayer Non-Magnetic Core | LQG | | 15H NF↑↑ | 18H NF↑ | |
| Film | LQP | 03T NF↑↑ | 15M NF↑ | | |
| Wirewound Non-Magnetic Core | LQW | | 15A **Default** | 18A NF↓ | Lowest NF |

# 3. Typical LNA evaluation board results

At the average power levels of –130 dBm that have to be received by a GNSS receiver, the system will not have in-band intermodulation problems caused by the GNSS-signal itself. Third-Order Intercept points are described in more detail in a separate User Manual: UM10453: 2-Tone Test BGU7005 and BGU7007 GNSS LNA.
For the LTE B32 application higher input power levels are used. Therefore, the BGU8009 LTE B32 EVB’s described in the Application Note have been evaluated with an input power of -30dBm.

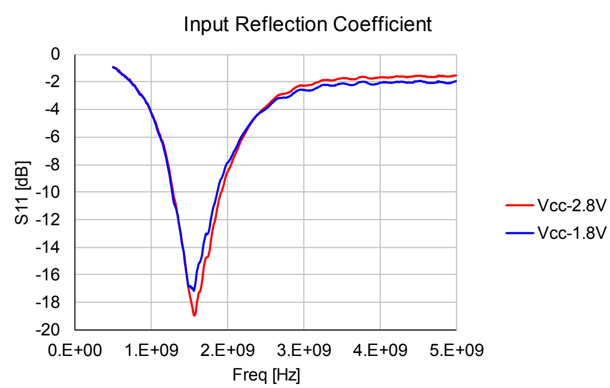
## 3.1 S-parameters

The S-parameters are measured at the SMA connectors of the application board. Next figures (Fig 6, Fig 7, Fig 8 and Fig 9) depicts the measurement result of the 2-port S-parameter measurement between 500MHz and 5GHz.



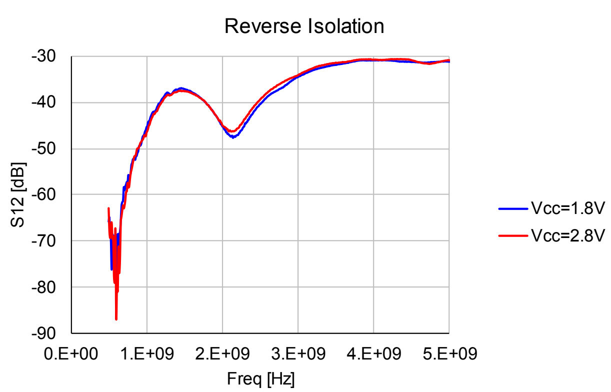

Pin = -30 dBm

**Fig 6. Small signal gain (S21)**



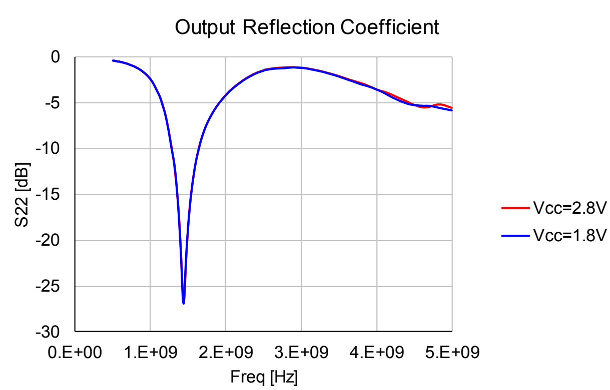

Pin = -30 dBm

**Fig 7. Input Reflection Coefficient (S11)**




Pin = -30 dBm

**Fig 8. Reverse Isolation (S12)**




Pin = -30 dBm

**Fig 9. Output Reflection Coefficient (S22)**

Fig 10, Fig 11, Fig 12 and Fig 13 show the measurement result around the LTE B32 frequencies between 1.4GHz and 1.555GHz (the LTE Band 32 is located between 1452MHz and 1496MHz).

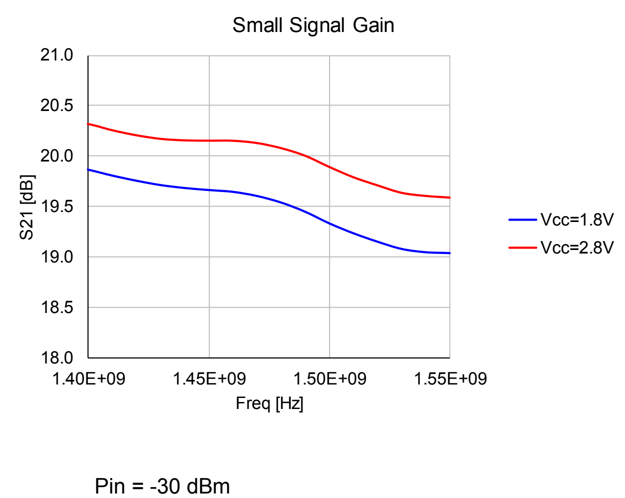



**Fig 10. Small signal gain (S21)**

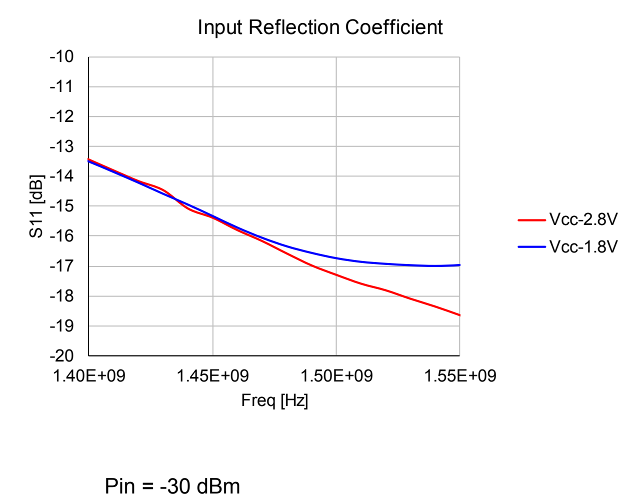



**Fig 11. Input Reflection Coefficient (S11)**

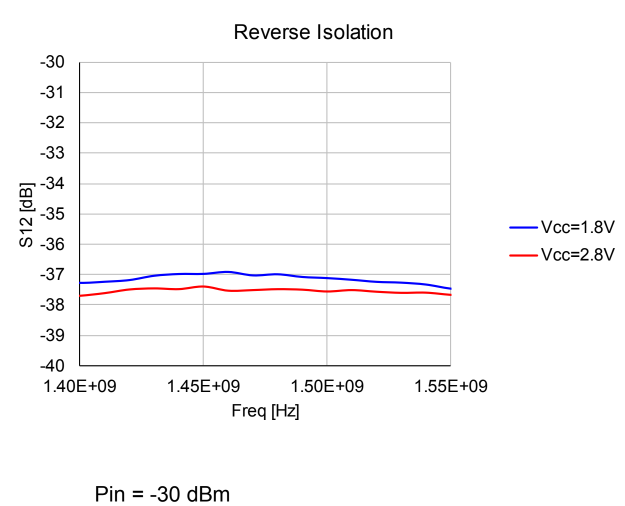



**Fig 12. Reverse Isolation (S12)**

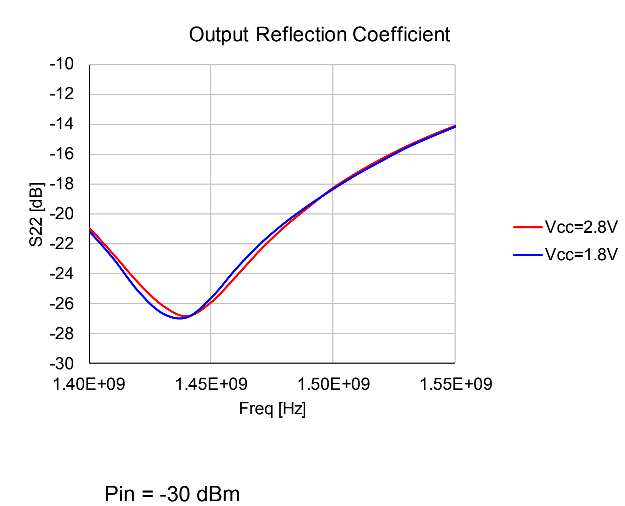



**Fig 13. Output Reflection Coefficient (S22)**

## 3.2 Stability factor

The stability factor “K” can be calculated with use of the S-parameter data. Stability factors less than one, indicates a possible instability issue of the circuit. Next figure (Fig 14) shows the stability factor “K” up to a frequency of 5 GHz. Below approximately 500 MHz, the stability factor becomes noisy and is therefore unsuitable as an indicator of instability and can be neglected.

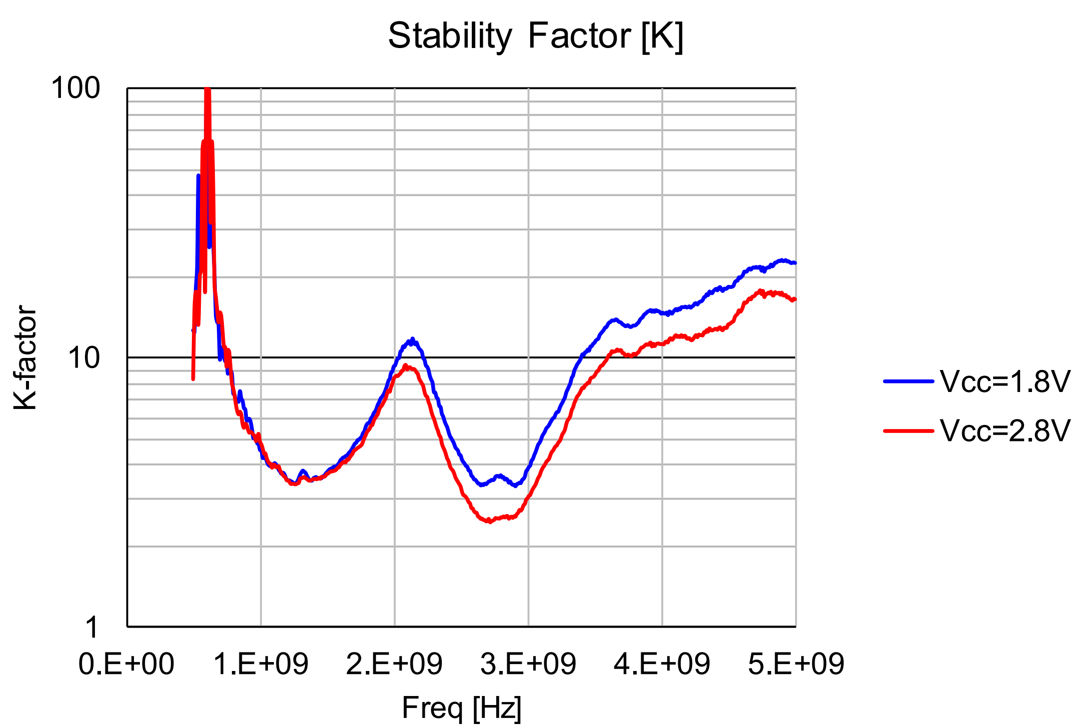



**Fig 14. Stability factor (K)**

## 3.3 In-band 1dB gain compression

The 1dB compression point depends on the supply voltage. Next figure (Fig 15) gives the 1dB compression point at a frequency of 1500 MHz at different supply voltages. Before the application enters the compression region, a gain expansion is noticed due to the adaptive biasing of the circuit.

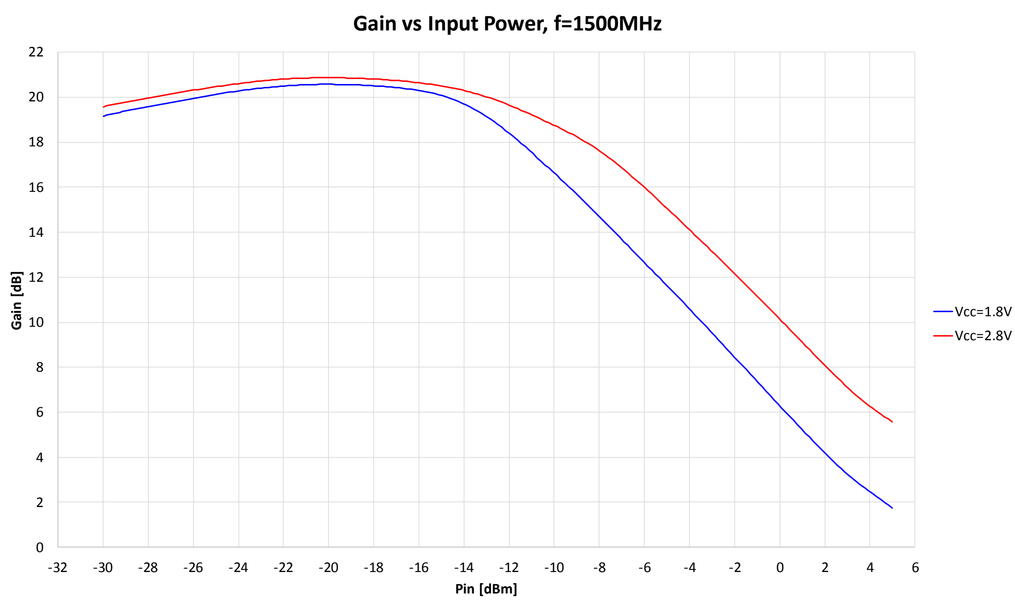



**Fig 15. 1 dB compression point (P1dB)**

The calculated P1dB (Input-P1dB and Output-P1dB) values at different supply voltages are shown in Table 2.

**Table 2. P1dB compression points at different supply voltages**

| Supply Voltage | IP1dB | OP1dB | Unit |
|---|---|---|---|
| 1.8 V | -11.7 | 6.5 | dBm |
| 2.8 V | -9.7 | 8.9 | dBm |

### 3.4 Intermodulation distortion

The IM3 measurement is performed with two-tones with a separation of 1 MHz.

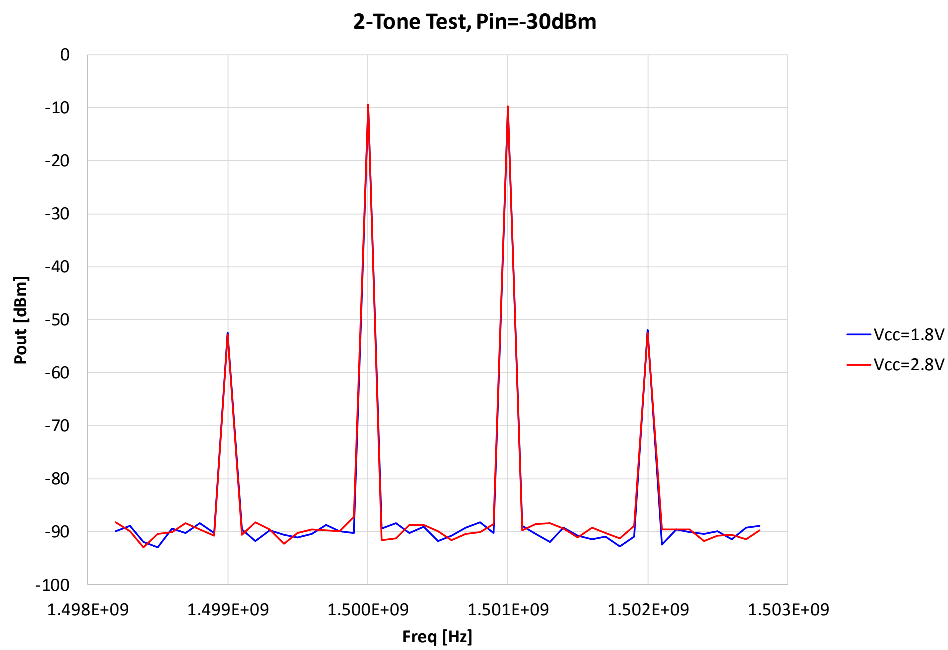



**Fig 16. IM3 measurement**

The calculated Output-IP3 values at different supply voltages are shown in Table 3.

**Table 3. Calculated OIP3 at different supply voltages**

| Supply Voltage | LSB_OIP3 | USB_OIP3 | Unit |
|---|---|---|---|
| 1.8 V | 11.5 | 10.8 | dBm |
| 2.8 V | 12.2 | 11.6 | dBm |

### 3.5 Noise figure

The Noise Figure is measured at different supply voltage levels at an ambient temperature of 25°C, see Fig 17. PCB losses are not subtracted.

The Noise Figure levels are comparable with the GPS1201M GNSS LNA for the L1 band.

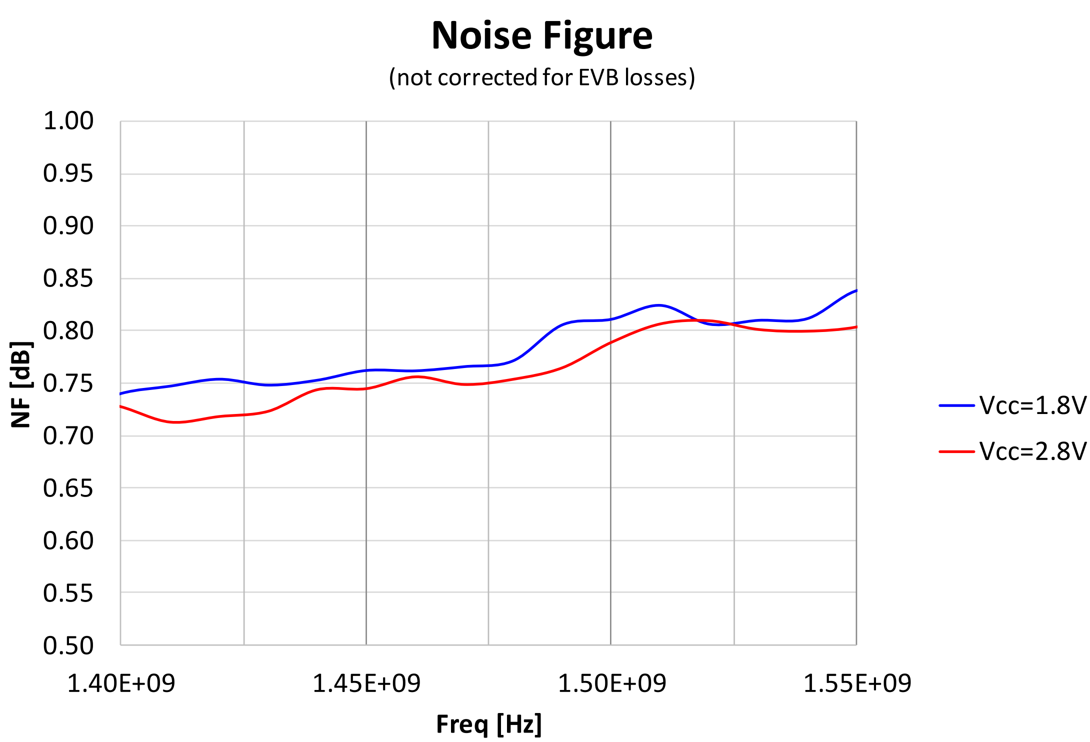



**Fig 17. Noise Figure (NF), PCB losses are not subtracted.**

# 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 3.1 V
- ✓ Two RF signal generators capable of generating RF signals at the operating frequency of 1400 MHz to 1500 MHz.
- ✓ An RF spectrum analyzer that covers at least the operating frequency of 1400 MHz to 1500MHz 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

## 5. Connections and setup

The GPS1201M GNSS LNA evaluation board is fully assembled and tested. Please follow the steps below for a step-by-step guide to operate the LNA evaluation board and testing 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 GPS1201M.
2. Jumper JU1 is connected between the $V_{cc}$ terminal of the evaluation board and the $V_{en}$ pin of the GPS1201M.
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 -30 dBm output power at 1475 MHz, set the spectrum analyzer at 1475 MHz center frequency and a reference level of 0 dBm.
4. Turn on the DC power supply and it should read approximately 4.4 mA.
5. Enable the RF output of the generator: The spectrum analyzer displays a tone around –10 dBm at 1475 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 5 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 minimized, since this affects the noise figure.

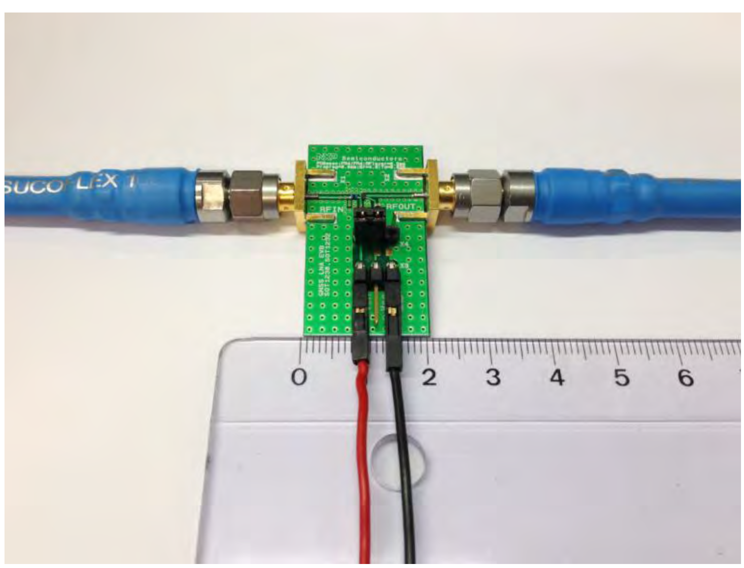



Fig 18. Evaluation board including its connections

# 6. Legal information

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# 7. List of figures

# 8. List of tables

# 9. Contents





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