AN11557

BGU8052[BTS1001M] 1900MHz LNA improved IRL

Rev. 2 — 28 April 2017 1900 MHz LNA

Document information

Info	Content
Keywords	BGU8052 [BTS1001M], 1900 MHz, LNA, BTS
Abstract	This application note provides circuit schematic, layout, BOM and typical evaluation board performance of a 1900 MHz LNA with the use of the BGU8052. The design has been tuned for better input return loss. For the 1700 to 2700 MHz wireless communication bands. Covering LTE FDD bands 1-4,7,9,10,15,16,23-25,30. The performance is given at 3.3 and 5 V supply supporting small cell respectively large cell applications.
Ordering info	Demonstrator boards OM7893, 12NC: 9340 690 55598
Contact information	For more information, please visit: http://www.nxp.com

Revision history

Rev	Date	Description
1	03 September 2015	First publication
2	28 April 2017	Update of the circuit topology to reduce IP3 spread

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1. Introduction

NXPs semiconductors BGU805x series is a family of integrated low noise amplifiers for the 300 MHz to 6000 MHz range. The series consists of the:

- BGU8051 recommended for 300 MHz - 1500 MHz
- BGU8052 recommended for 1500 MHz – 2700 MHz
- BGU8053 recommended for 2500 MHz – 6000 MHz

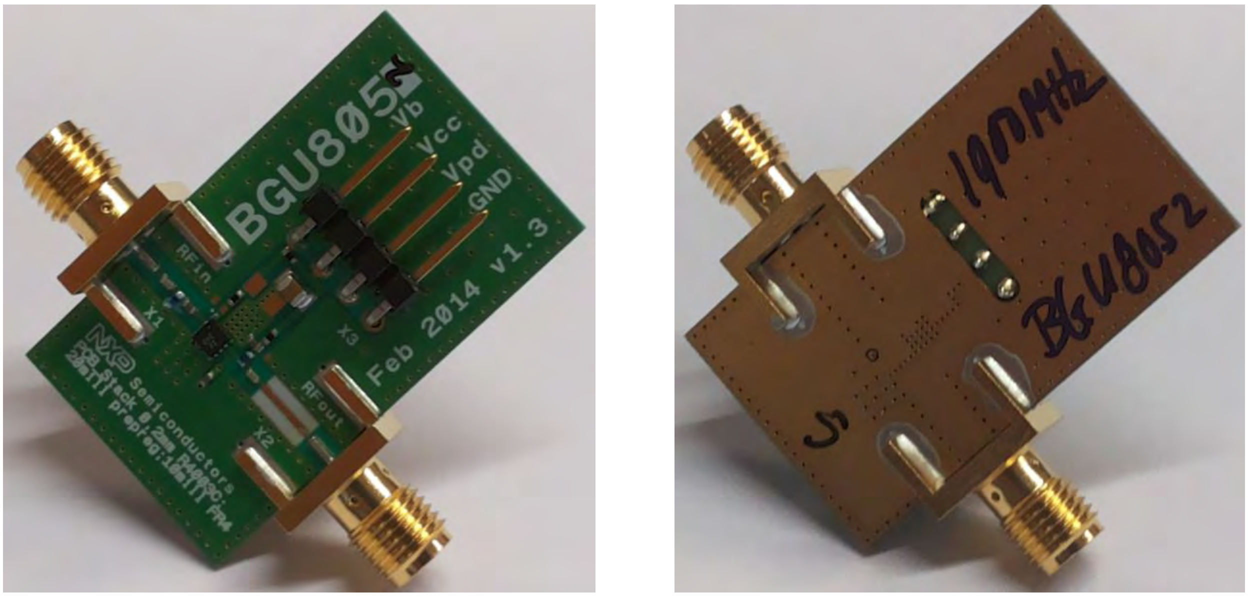
The BGU805X series is a low noise high linearity amplifier family intended for wireless infrastructure applications like BTS, RRH, small cells, but can also be used in other general low noise applications, e.g. active antennas for automotive.

Being manufactured in NXPs high performance QUBiC RF Gen 8 SiGe:C technology, the BGU805X combines high gain, ultra-low noise and high linearity with the process stability and ruggedness which are the characteristics of SiGe:C technology.

BGU805X series comes in the industry standard 2 x 2 x 0.75 mm 8 terminal plastic thin small outline package HVSON8 (SOT1327). The LNA is ESD protected on all terminals.

The 3 types can all use the same PCB layout topology. This enables design in simplicity using one PCB layout for designing LNA’s covering the frequency range from 300MHz to 6000 MHz with one single PCB layout design.

In application note AN11416 the use of the BGU8052 is describes as a wideband LNA for the 1500 to 2700 MHz range with compromised input return loss. In this application note a design procedure is described to improve the input return loss for better filter integration, without NF degradation. Design can be suited for the wireless communication bands from 1700 to 2700 MHz. In Fig 1, the evaluation board described in this application note is shown.



a. Front side b. Back side

Fig 1. BGU8052 1900 MHz evaluation board

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2. Product description

The BGU8052 is a fully integrated low noise amplifier with integrated bias circuit. The MMIC is internally matched to 50 Ω. The BGU8052 also features an integrated shutdown circuit to enable fast turn on/off settling time, enabling switched (time domain duplexing TDD) applications. The device bias current can be set by the value of an external bias resistor R_{BIAS}, which connects the supply voltage to the V_{BIAS} pin, or by an external control voltage applied directly to V_{BIAS} pin 1. This adjustable bias current gives flexibility in biasing the device for the optimum performance on NF or linearity. This feature can be useful in case more than one BGU8052 are cascaded. This bias resistor value changes the bias current directly which can be used to trade of linearity for power saving in battery operated applications.

The BGU8052 key features and benefits at 1900MHz are;

- Low noise performance: NF = 0.57 dB
- High linearity performance: $IP3_O$ = 36.6 dBm
- High output power at 1dB gain compression P_L1dB = 18.5 dBm
- High input return loss RL_{in} = 21 dB
- High out return loss RL_{out} = 17dB
- Unconditionally stable up to 20 GHz
- Max RF input power of +20 dBm
- ESD protection on all pins

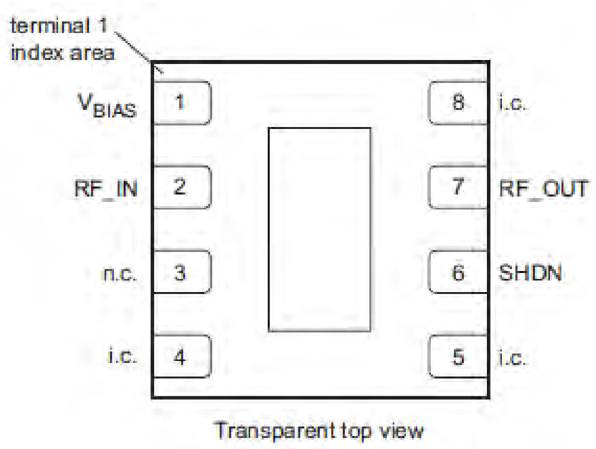

Fig 2. BGU8052 Pin description

In Fig 2 the pin out of the BGU8052 is given, the n.c. and i.c pin are recommended to connect to ground, which is the case on the evaluation boards.

3. 1900 MHz LNA improved input return loss evaluation board.

The 1900MHz improved return-loss evaluation board simplifies the RF evaluation of the BGU8052. The EVB enables testing the device RF performance and requires no additional support circuitry. The EVB is fabricated on a 35 x 20 x 1mm 4 layer PCB that uses 0.2 mm (8 mill) R4003C for the RF performance. The board is fully assembled with

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the BGU8052, including the external components. The board is supplied with two SMA connectors to connect input and output to the RF test equipment. The EVB is also enabled with the possibility to evaluate the BGU8052 at different bias currents.

3.1 Application circuit

The BGU8052 has been characterized for S-parameter and Noise-parameters at different bias settings. This data can be downloaded from NXPs website as a zip file. The S2P files you can find in this zip file have been used as a small signal model to design this 1900MHz LNA. The low pas matching structure that is created by means of L2 and C8, improves the input return loss for better filter integration.

The application board circuit diagram that is implemented on the EVB is shown in Fig 3

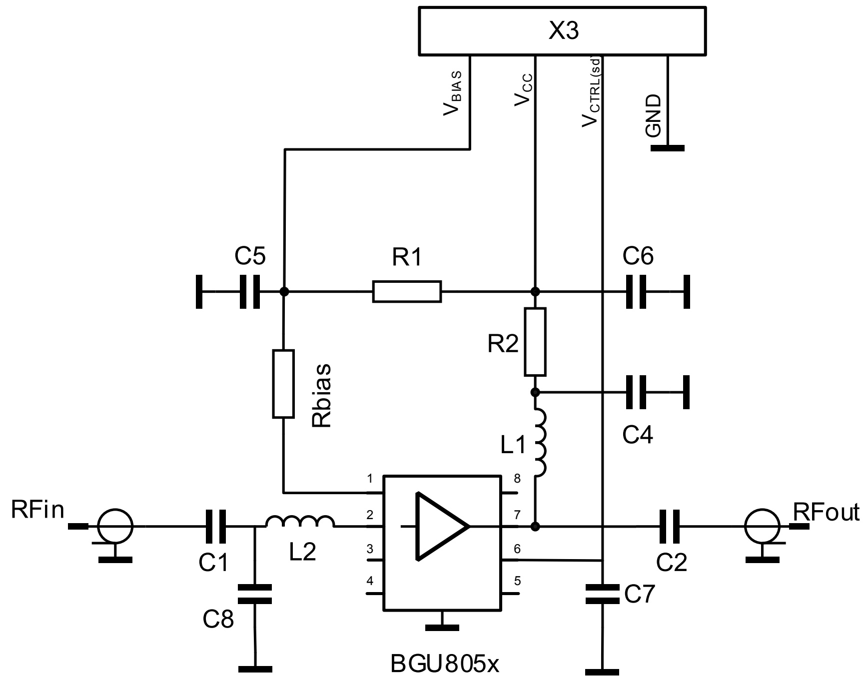

Fig 3. BGU8052 1900 MHz imp RL application board circuit diagram

As already indicated the bias current of the BGU8052 can be set by the value R_{BIAS}. The evaluation boards are supplied with a 5.1 kΩ bias resistor (I_{CC} = 48 mA +/-5 mA @ V_{CC}=5V). If however it is required to evaluate the BGU8052 at different bias currents, resistor R1 which is 0 Ω can be removed and an external control voltage can be applied to V_{BIAS} (V_b pin) on the bias header X3, see Fig 3.

By applying this separate bias voltage on the V_{BIAS} pin of the bias header X3, the I_{CC} current can be swept without changing R_{BIAS}. With bias voltage window from 1.5 to 6 V on V_{BIAS} while keeping the V_{CC} pin on 5 V, I_{CC} can be varied from 5-60 mA. In Fig 4 the relation between I_{cc} and R_{BIAS} at V_{CC} = 5 V as well as the relation between I_{CC} and V_{BIAS} with R_{BIAS} = 5k1 is shown. In Fig 4 you can also find the bias resistor values when applying the BGU8052 at lower supply voltages. Which indicates the BGU805x series can also be biased with lower voltage e.g. 3.3V which makes it excellent suitable for small cells. In paragraph 4.1 typical performance of the LNA @ 3.3V 48mA is also included.

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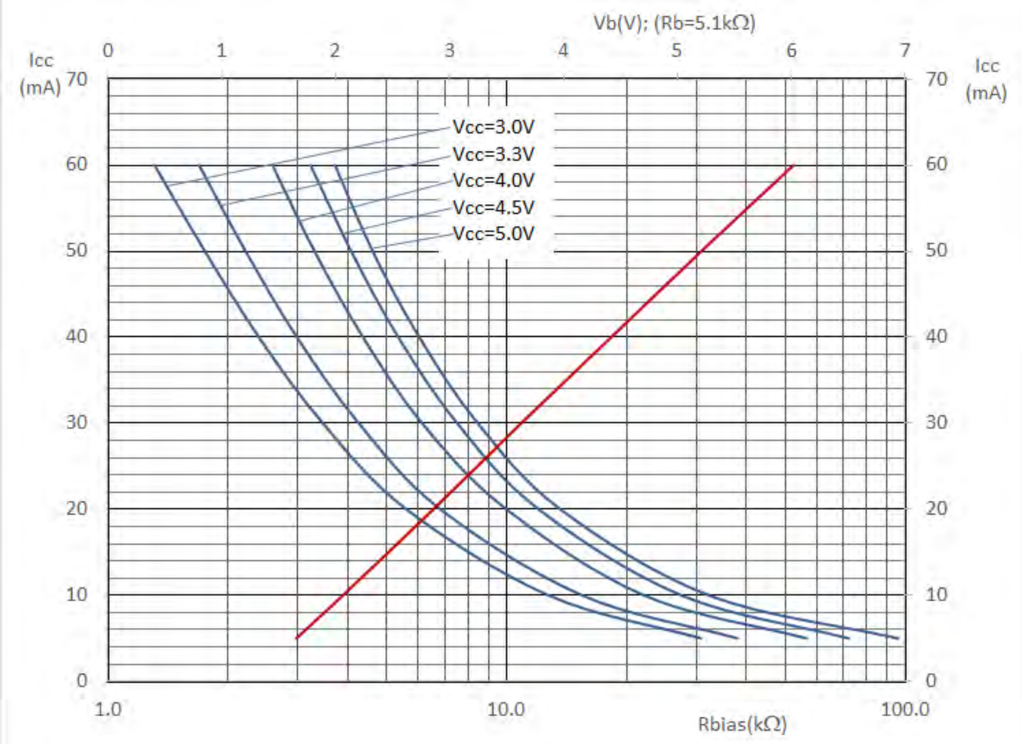

(1) Blue curve corresponds with the left Y axis and the lower X axis. Giving the I_{CC} versus the value of R_{BIAS}.

(2) Red curve corresponds with the right Y axis and the upper X axis. Giving the I_{CC} versus the voltage applied to the V_b pin with R_{BIAS} = 5k1 in place.

Fig 4. Relation of I_{CC} with R_{BIAS} and V_b

3.2 PCB Layout information

- A good PCB layout is an essential part of an RF circuit design. The LNA evaluation board can serve as a guideline for laying out a board using the BGU8052.
- The evaluation board uses micro strip coplanar ground structures for controlled impedance lines for the high frequency input and output lines.
- V_{CC} is decoupled by C4 and C6 decoupling capacitors, C4 should be located as close as possible to the device, to avoid AC leakage via the bias lines. For long bias lines it may be necessary to add decoupling capacitors along the line further away from the device.
- The self-resonance frequency of inductor L1 should be chosen above frequency band of interest for good choking. In this case the Murata LQW15 series has been used.
- Inductor L2 and capacitor C8 are creating the low pass matching structure and are in that sense critical, to the input return loss at the frequency of interest.
- C1 and C2 are DC blocking capacitors, C1 needs to be in the range of 100nF to keep the provided input source impedance for low frequencies low impedance. [1]
- C5 is not mounted on the evaluation boards, but can be used as additional V_{CC} decoupling, but is not critical to the RF performance.

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- C7 is used to decouple the shutdown pin
- R2 increases the low frequency stability
- 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 layout and component placement of the BGU8052 evaluation board is given in Fig 5

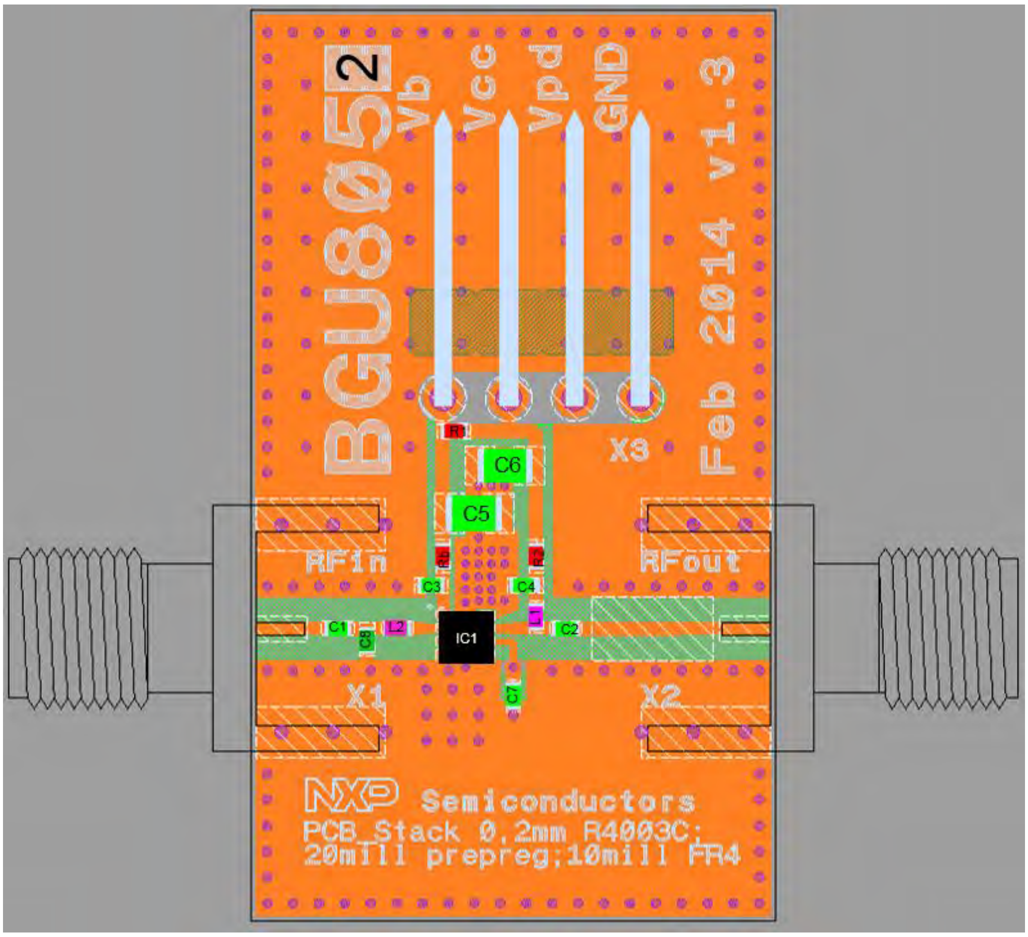

Fig 5. BGU8052 1900MHz evaluation board component placement

3.2.1 PCB stack and recommended footprint.

The PCB material used to implement the LNA is a 0.2 mm (8 mil) RO4003C low loss printed circuit board which is merged to a 0.51 mm (20 mil) prepreg and a 0.254 mm (10 mil) FR4 layer for mechanical stiffness. See Fig 6a

The official drawing of the recommended footprint can be found on the PIP page of the BGU8052. If micro strip coplanar PCB technology is used it is recommended to use at least 4 ground-via holes of 300 um, this is also used on the EVBs as shown inFig 6b.

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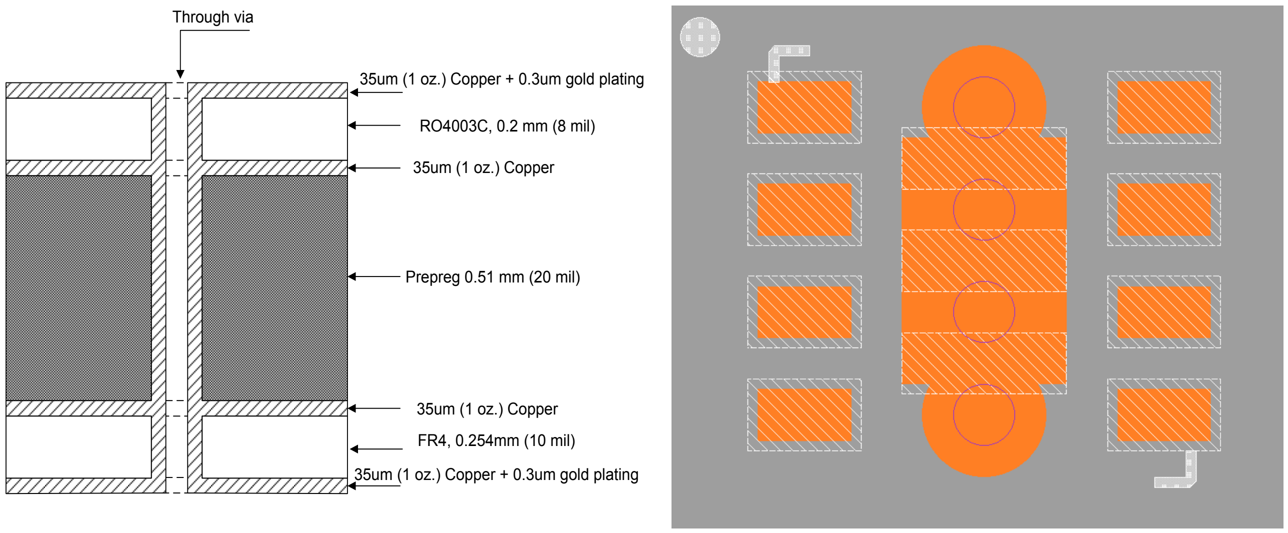

c. Cross section of the PCB Layer stack.

d. Recommended footprint.

Fig 6. PCB stack and footprint information.

3.3 Bill of materials

Table 1 gives the bill of materials as is used on the EVB.

Table 1. BOM

Designator	Description	Footprint	Value	Supplier Name/type	Comment/function
IC1	BGU8052				
PCB	20x35x1mm			KOVO	RO4003C PCB v 1.3
C1	Capacitor	0402	100nF	Various	DC block
C2	Capacitor	0402	100pF	Various	DC block
C4	Capacitor	0402	1nF	Various	RF decoupling
C5	Capacitor	0806	4.7uF	Various	Optional
C6	Capacitor	0806	4.7uF	Various	LF Decoupling
C7	Capacitor	0402	10pF	Various	Decoupling
C8	Capacitor	0402	0.9pF	Murata GJM15	Input match
L1	Inductor	0402	15nH	Murata LQW15	Bias choke/Output match
L2	Inductor	0402	1.8nH	Murata LQP15	Input match
R1	Resistor	0402	0Ohm	Various	
R2	Resistor	0402	10Ohm	Various	stability
Rbias	Resistor	0402	5k1	Various	Bias setting
X1,X2	SMA RF connector			Johnson, End launch SMA 142-0701-841	RF connections
X3	DC header			Molex, PCB header, right angle, 1 row 4 way	DC connections

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4. Measurement results

4.1 Typical board performance

The values given in Table 2 are typical values of >25 boards measured.

Table 2. Typical board performance using the BOM given in Table 1

T_{amb}=25°C; input and output 50 Ω; R_{bias}=5.1 kΩ.

Symbol	Parameter	Conditions		Min	Typ	Max	Typ	Unit
V_{CC}	Supply voltage			5	5	5	3.3	V
I_{cc}	Supply current			46.9	49.1	51.6	49.7	mA
G_{ass}	Associated gain		1500MHz 1900MHz	20.3 18.2	20.4 18.3	20.6 18.5	20.4 19.3	dB
NF	Noise figure	Error! Reference source not found.	1500MHz 1900MHz	0.48 0.55	0.52 0.57	0.56 0.61	0.58 0.63	dB
$P_{L((1dB)}$	Output power at 1dB gain compression		1500MHz 1900MHz	17.4 18.0	17.9 18.5	18.3 18.9	14.4 15.0	dBm
$IP3_O$	Output third-order intercept point	2-tone; tone spacing = 1MHz; Pi = -15dBm per tone	1500MHz 1900MHz	36.2 36.2	36.5 36.6	36.8 37.0	34.7 34.7	dBm
RL_{in}	Input return loss		1500MHz 1900MHz	14.7 18.7	15.4 21.4	16.0 22.8	16.0 22.0	dB
RL_{out}	Output return loss		1500MHz 1900MHz	18.3 15.1	20.5 17.2	21.5 18.2	20.9 17.6	dB
ISL	Isolation		1500MHz 1900MHz	25.2 23.6	25.3 23.7	25.5 23.9	25.3 23.7	dB

[1] Board losses have not been de-embedded.

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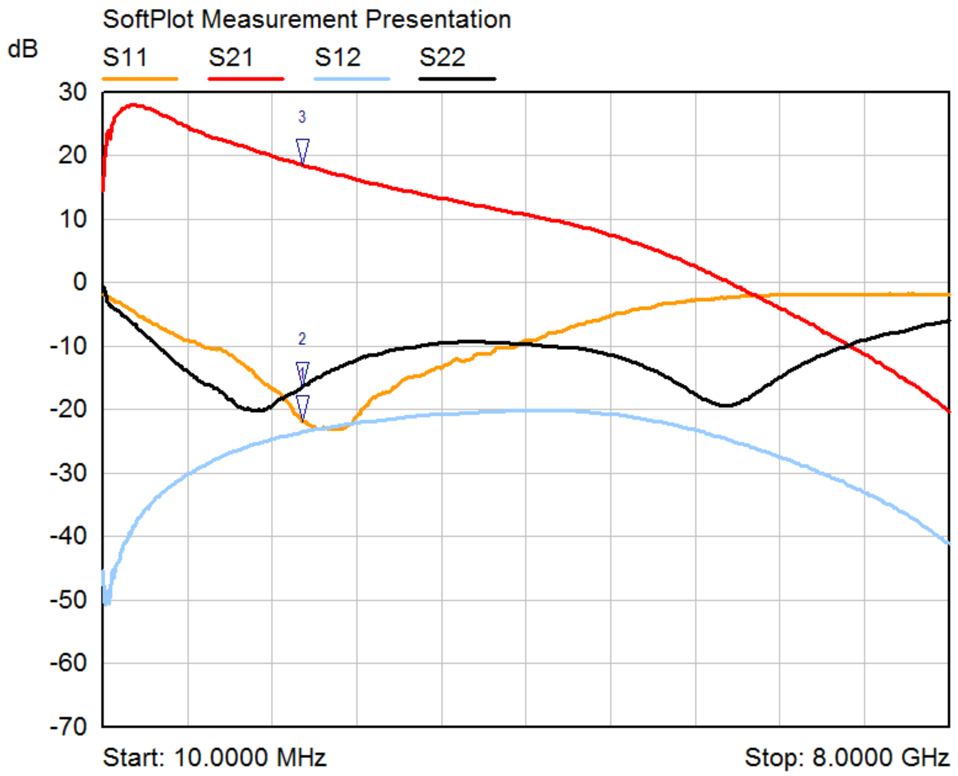
4.2 S_Parameters

The measured S-parameters are given in Fig 7. For the measurements, a typical BGU8052 1900 MHz EVB is used. All the S-parameter measurements have been carried out using the setup in Fig 12a



Mkr	Trace	X-Axis	Value	Notes
1	S11	1.9000 GHz	-21.85 dB	
2	S22	1.9000 GHz	-16.54 dB	
3	S21	1.9000 GHz	18.50 dB	

V_{CC} = 5 V; T_{AMB} = 25 °C; I_{CC} = 49 mA

Fig 7. BGU8052 1900 MHz LNA S-parameters

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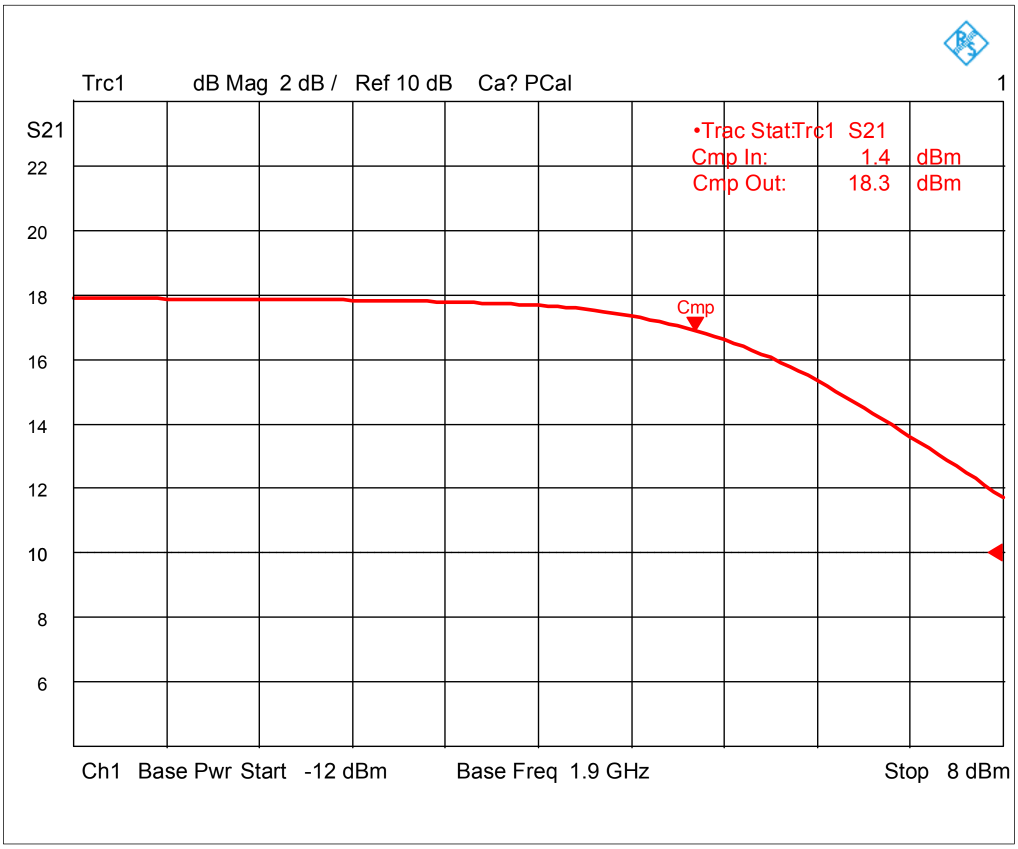
4.3 1dB Gain compression point.

The measured Gain versus input power is given in Fig 8 for the measurements, a typical BGU8052 1900 MHz EVB is used. All the P1dB measurements have been carried out using the setup in Fig 12a.



(1) V_{CC} = 5V; T_{AMB} = 25 °C; I_{CC} = 49.1 mA

(2) P_i1dB = 1.4 dBm; P_L1dB = 18.3 dBm

Fig 8. BGU8052 1900 MHz LNA 1dB gain compression

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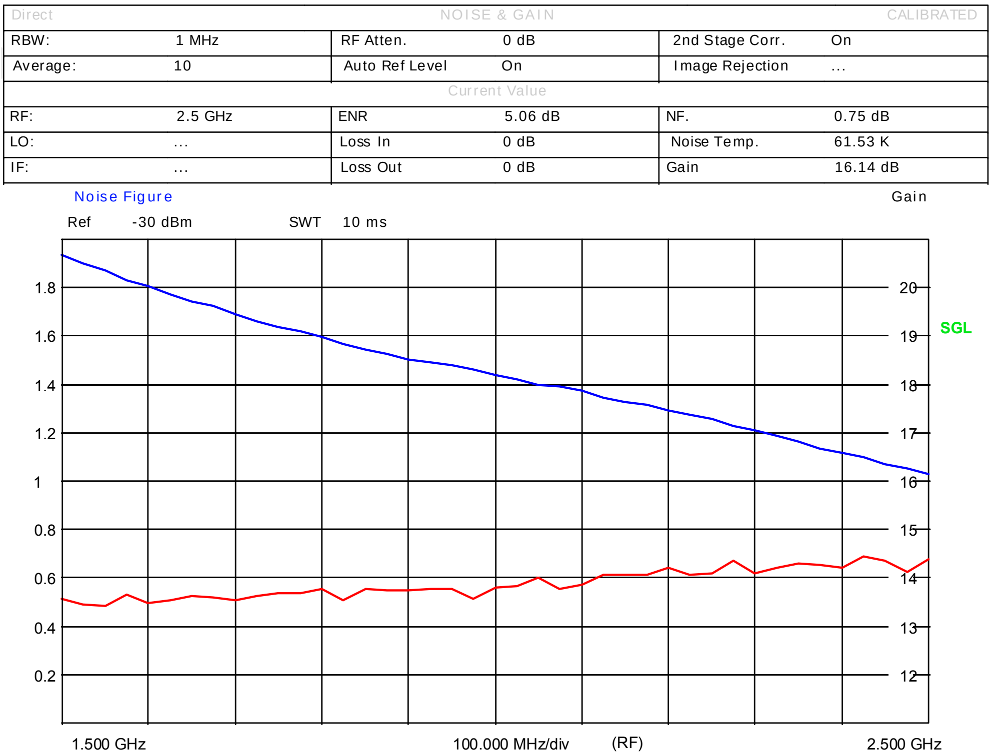
4.4 Noise figure

The measured noise figure are given in Fig 9 . For the measurements, a typical BGU8052 1900MHz EVB is used. The noise figure measurement have been carried out using the setup in Fig 12b



V_{CC} = 5 V; T_{AMB} = 25 °C; I_{CC} = 48 mA

(1) Measured at the evaluation boards SMA connectors PCB losses are not de-embedded.

Fig 9. BGU8052 1900 MHz LNA typical noise figure performance.

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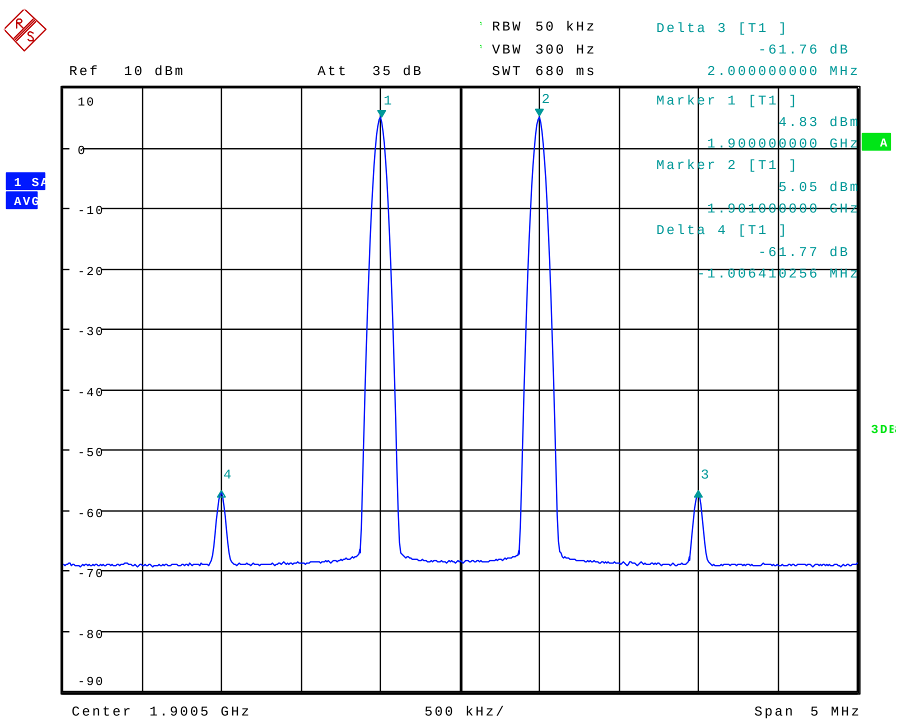
4.5 3rd order intercept point, output referred

The evaluation board provided in the customer evaluation kit is automatically measured on linearity using the set-up shown in Fig 12a. Alternatively the setup given in Fig 12c can be used, which is done for the spectrum plot in Fig 10. For the measurements, a typical BGU8052 1900 MHz EVB is used.



(1) $IP3_O$ LSB = (63.7)/2+4.82 = 36.7 dBm; $IP3_O$ USB = (63.7)/2+5.03 = 36.9 dBm

(2) $IP3_i = IP3_O$ -Gain = 36.7 - 18.3 = 18.4 dBm

Fig 10. BGU8052 1900 MHz LNA Typical OIP3 spectrum

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4.6 Stability Factor

Due to the low pass shape of the input matching circuit the low frequency gain becomes high. This might introduce potential instability issues. Proper selection of the output bias choke together with the 10 Ohm resistance R1 avoids this. **Error! Reference source not found.** shows the rollet stability factor plots of 10 EVBs with the improved input return loss BOM.

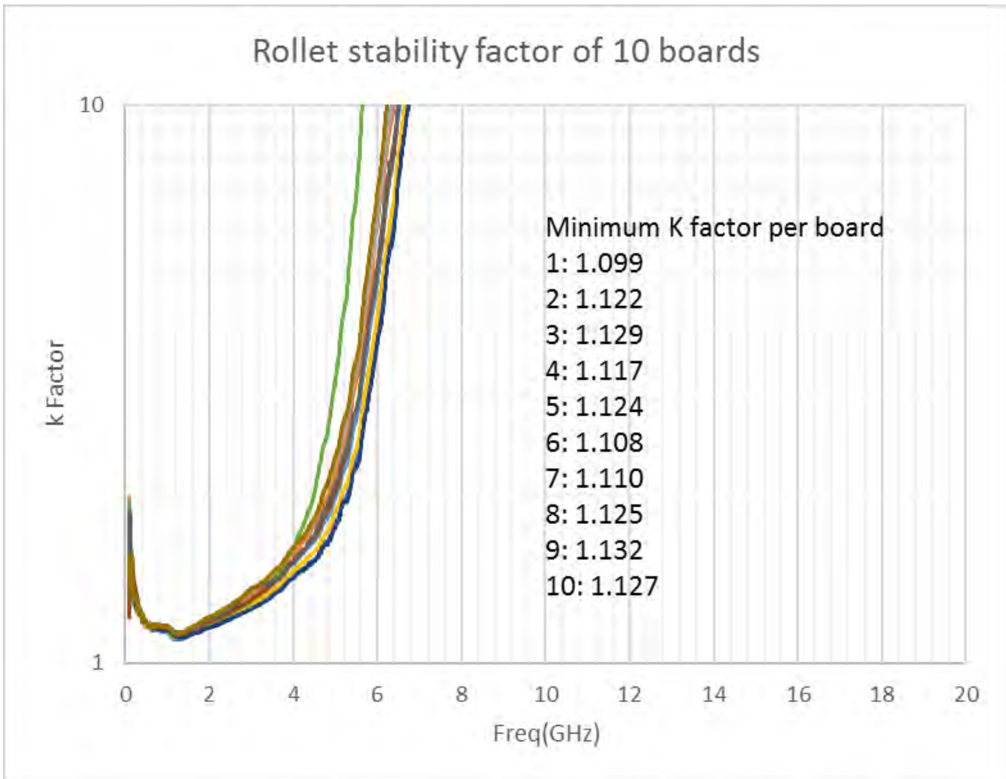

Fig 11. Rollet Stability factor

5. Measurement methods and setups.

5.1 Required Measurement Equipment

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

- ✓ 2 (channel) DC Power Supply up to 100 mA at 5 V, to set V_{CC} and eventual Vbias.
- ✓Two RF signal generators capable of generating RF signals up to 2 GHz
- ✓An RF spectrum analyzer that covers at least the operating frequencies and a few of the harmonics. Up to 6 GHz should be sufficient.
- ✓A network analyzer for measuring gain, return loss and reverse isolation
- ✓Noise figure analyser and noise source
- ✓Proper RF cables with male SMA connectors.

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5.2 Connection and setup

The typical values shown in this report have been measured on the fully automated test setups shown in Fig 12. 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 5V
2. 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 approximately -30 dBm output power at the center frequency of the wanted frequency band and set the spectrum analyzer at the same center frequency and a reference level of 0 dBm.
3. Turn on the DC power supply and it should read approximately 48 mA.
4. Enable the RF output of the generator: The spectrum analyzer displays a tone around -11.5 dBm.
5. 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 and P1dB (see Fig 12a)
6. 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 (see Fig 12b).

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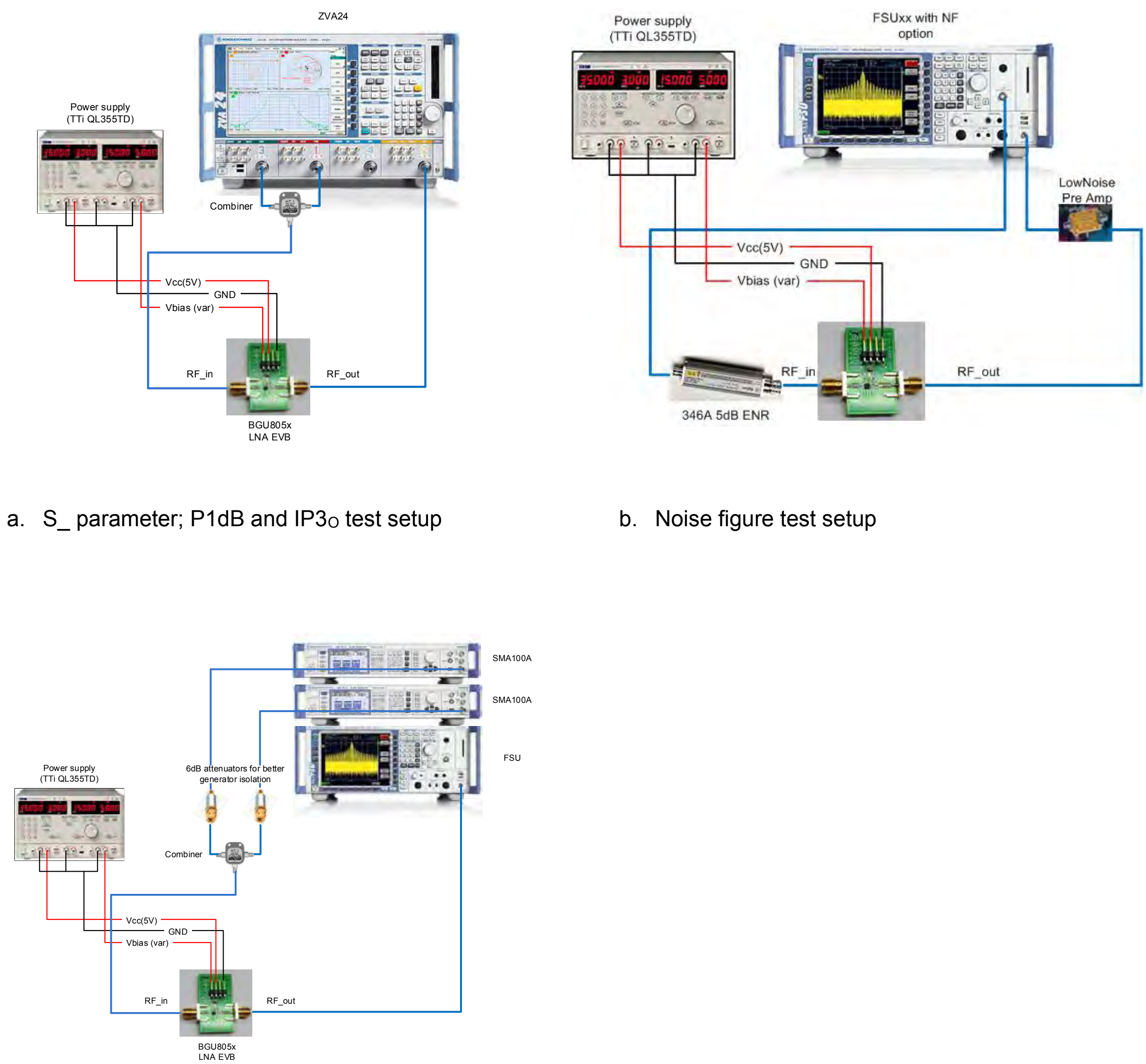

a. S_ parameter; P1dB and IP3o test setup

b. Noise figure test setup

c. Third order intercept point test setup

Fig 12. Characterization measurements setups.

5.3 Noise figure measurement setup

In Fig 12b the noise figure measurement set-up is shown, this is intended as a guide only, substitutions can be made. For sub 1 dB noise figure levels like the BGU8052 has it is recommended to perform the noise-measurements in a Faraday's cage or at least put the DUT in a shielded environment. This is recommended to avoid any interference of cellular frequencies that are in the same frequency range. A spectrum analyzer with noise option. A 5dB ENR noise source was used. To achieve the lowest possible setup-noise figure an external pre-amplifier is also recommended. The Noise figure value in Fig 9 is the value measured at the evaluation board SMA connectors. Correcting for the connector and PCB loss will end up in 0.1dB lower noise figure.

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5.4 Third order intercept

In [1] the effect on linearity of SiGe BiCMOS BJTs and the advantage of using low source impedances at the low frequencies of the 2nd order mixing terms is described. To make the application unsensitive to IP3 spread (magnification, cancelation of the IM3 components) the source impedance seen by the input of the BGU8052 needs to be low-impedance. This is achieved with the C8, L2 and C1, and give the best linearity performance with the lowest IP3 spread. Small drawback is that the circuit as presented is not fast enough to be applied in TDD platforms. When measuring the high OIP3 values it is essential check the capabilities of the used measurement equipment. Be aware that the measurement set-up itself is not generating dominating IM3 levels. Advised is to do a THRU measurement without a DUT first.

6. References

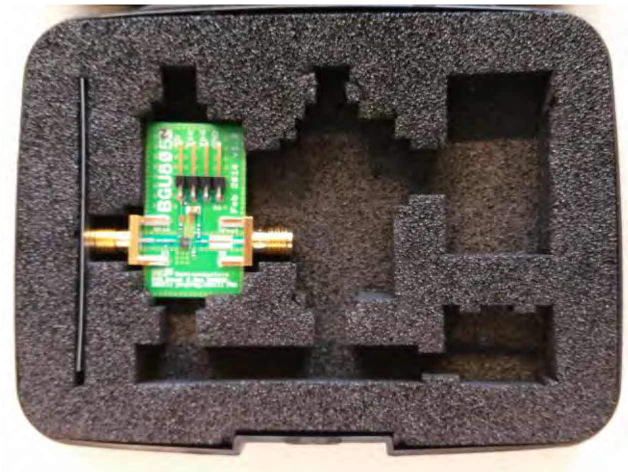
[1] Vladimir Aparin, Lawrence E. Larson, "Linearization of monolithic LNAs Using Low-Frequency Low-Impedance Input Termination". IEEE 0-7 803-8 108-4/03 ©2003

7. Customer Evaluation Kit

In the customer evaluation kit you will find;

- One 1900MHz improved return loss EVB
- 10 loose samples.

a.



b.

Fig 13. BGU8052 1900 MHz imp RL customer evaluation KIT

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Date of release: 28 April 2017
Document identifier: AN11557