AN11865

BGU6104 Low Noise Amplifier for ISM / LTE bands

Rev. 1.0 — December 12, 2016 Application note

Document information

Info	Content
Keywords	BGU6104 Low Noise Amplifier, 2.4 GHz LNA, 2.4-2.5 GHz ISM, WiFi (WLAN)
Abstract	This document provides circuit schematic, layout, BOM and evaluation board performance for an LNA based on a BGU6104.
Ordering info	BGU610x starter kit OM17057, 12nc 9340 707 07598
Contact information	For more information, please visit: http://www.nxp.com

Revision history

Rev	Date	Description
1.0	December 12, 2016	First version

Contact information

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1. Introduction

The overall intent of this application note is to demonstrate the performance of the BGU6104 in multiple frequency bands.

- 70 - 130 MHz (FM)
- 40 - 1000 MHz (Broadband)
- 169 MHz (ISM)
- 433 MHz (ISM)
- 700 - 930 MHZ (ISM / LTE)
- 2.4 - 2.5 GHz (ISM)
- 1.8 - 2.2 GHz (LTE)

In this application note the ISM/LTE band of 700 – 930 MHz and ISM band of 1.8 – 2.2 GHz are addressed. Key requirements for these applications are gain, noise figure, and input/output return loss.

The transistors of the BGU610X family are promoted with a full promotion package, called “starter kits” (one kit type per device type). Those kits include a BGU610X LNA evaluation board (see figure 1), transistors and simulation model parameters required to perform simulations. See the overview of available starter kits in the table below:

Table 1. Customer evaluation kits

	Basic type	Customer Evaluation kits
1	BGU6101	OM17055, starter kit for BGU6101, ISM/LTE 700-930 MHz and ISM 1.8-2.2 GHz
2	BGU6102	OM17056, starter kit for BGU6102, ISM/LTE 700-930 MHz and ISM 1.8-2.2 GHz
3	BGU6104	OM17057, starter kit for BGU6104, ISM/LTE 700-930 MHz and ISM 1.8-2.2 GHz

The BGU610X LNA evaluation board simplifies the evaluation of the BGU6104 application. The evaluation board enables testing of the device performance and requires no additional support circuitry. The board is fully assembled with the BGU6104 MMIC, and the necessary matching and decoupling components for the associated frequency band.

The board is also supplied with two SMA connectors for input and output connection to RF test equipment. A 50 ohm “through line” is provided at the top of the evaluation board in case the user wishes to verify RF connector and grounded coplanar waveguide losses for de-embedding purposes.

Fig 1. BGU610X Evaluation Board

2. Design and Application

The BGU6104 MMIC is an unmatched wideband MMIC featuring an integrated bias, enable function and wide supply voltage. BGU6104 is part of a family of three products (BGU6101, BGU6102 and BGU6104).

Two applications are evaluated in this application note. One application covers the ISM/LTE band of 700 – 930 MHz and the other covers the ISM band of 1.8 – 2.2 GHz.

Key Benefits:

- Supply voltage range from 1.5 V to 5 V
- Current range up to 40 mA@3 V, 50 mA@5 V
- NF_{min} of 0.8 dB
- Applicable between 40 MHz and 4 GHz
- Integrated temperature-stabilized bias for easy design
- Bias current configurable with external resistor
- Power-down mode current consumption < 6 μA
- ESD protection on all pins up to 3 kV HBM
- Small 6-pin leadless package 2.0 mm × 1.3 mm × 0.35 mm

2.1 Application Circuit Schematic

The PCB is designed to be adaptable for multiple bands. This way, only some components need to be exchanged in order to adjust the board for another frequency band (see figure 2).

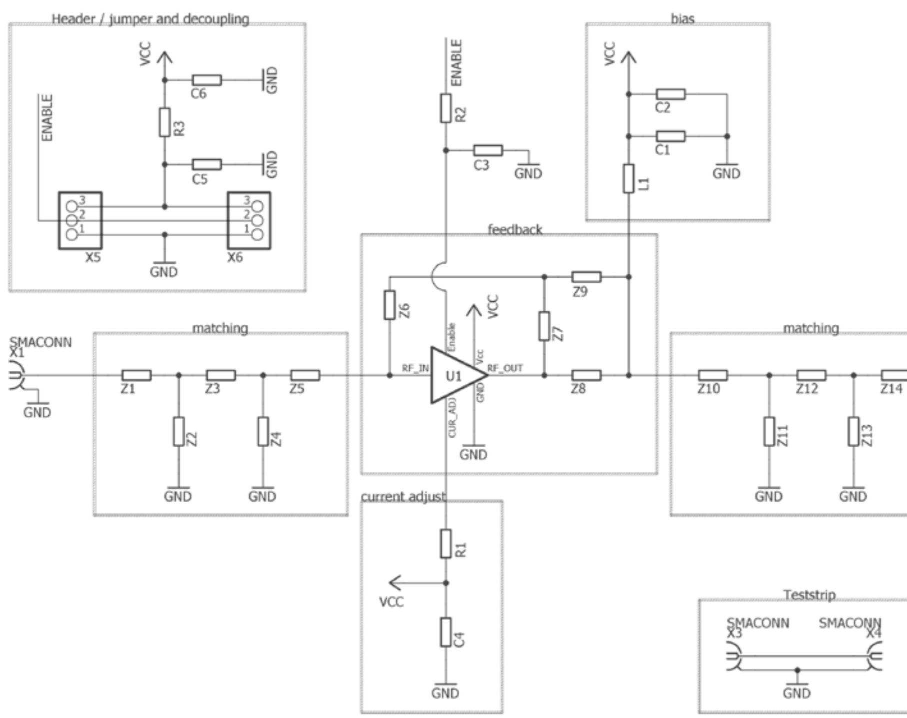

Fig 2. BGU610X Low Noise Amplifier evaluation PCB : Circuit schematic

2.2 Evaluation board Layout

Characteristics of the evaluation board (see figure 3):

- 3 layer PCB
- PCB material FR4 (ε_r=4.6)
- 20 x 35 mm
- RF layer thickness 0.254 mm (critical)
- Surface finish ENIG (Electroless Nickel Immersion Gold)
- Soldermask
- SMD components (0402 formfactor)

Top view Bottom view

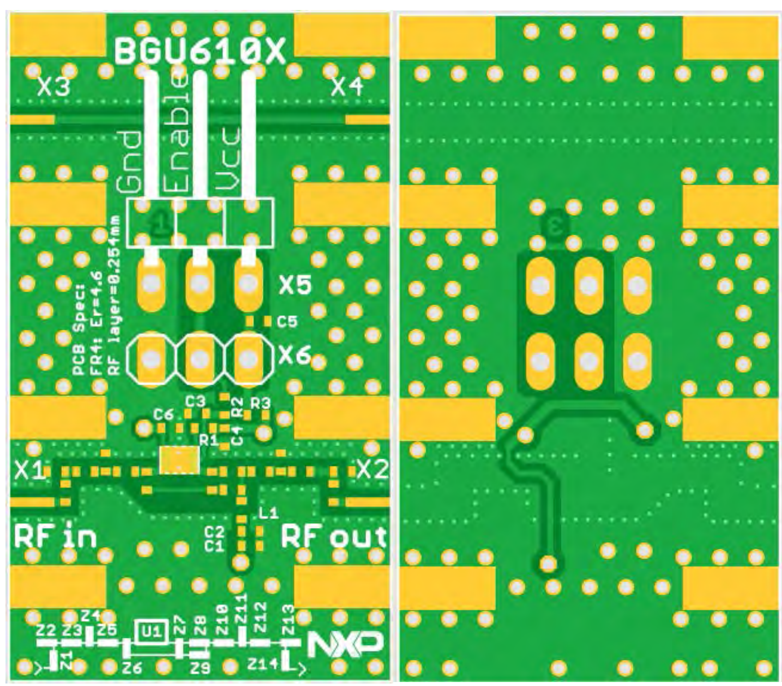

Fig 3. BGU610X Low Noise Amplifier evaluation board

Figure 4 shows the PCB stack-up. The PCB consists of 3 layers, where the first two, RF signal layer and RF ground are between a critical dielectric layer in order to ensure 50 ohm coplanar waveguide transmission lines. Through vias are used to connect the different layers.

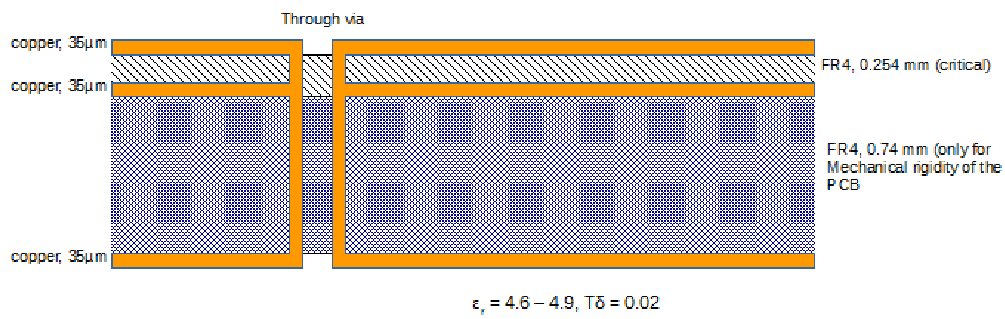

Fig 4. PCB Stack-up

2.3 Application board Bill-Of-Material

Table 2. Bill-Of-Material ISM / LTE 700 – 930 MHz

Item	Quantity	Reference	Part Number	Value	Vendor
1	4	Z1,Z6,Z10,C1	GRM1555C1H680GA01D	68pF	Murata
2	1	Z2	GJM1555C1H2R5WB01D	2.5pF	Murata
3	1	Z4	GJM1555C1H3R2BB01D	3.2pF	Murata
4	1	Z11	GJM1555C1H1R5BB01D	1.5pF	Murata
5	5	C2,C3,C4,C5,C6	GRM155R71A104KA01D	100nF	Murata
6	1	Z3	LQW15AN3N9B00D	3.9nH	Murata
7	1	Z5	LQW15AN3N4C10D	3.4nH	Murata
8	1	Z12	LQW15AN4N1B00D	4.1nH	Murata
9	1	L1	LQW15CNR27J10D	270nH	Murata
10	1	Z14	667-ERJ-2RKF10R0X	10	Panasonic - ECG
11	1	Z7	667-ERJ-2RKF8200X	820	Panasonic - ECG
12	1	Z8	667-ERJ-2GE0R00X	0	Panasonic - ECG
13	1	R1	667-ERJ-2RKF6801X	6.8k	Panasonic - ECG
14	2	R2,R3	667-ERJ-2RKF10R0X	10	Panasonic - ECG
15	1	U1	BGU6104	-	NXP
16	2	X1,X2	142-0701-841	SMA	Cinch Connectivity
17	1	X5	538-22-28-8030	header	Molex
18	1	X6	538-22-28-4030	header	Molex

Note: Customer can choose their preferred vendor but should be aware that the performance could be affected.

Table 3. Bill-Of-Material LTE 1.8 – 2.2 GHz

Item	Quantity	Reference	Part Number	Value	Vendor
1	4	Z1,Z6,Z12,C1	GRM1555C1H150JA01D	15pF	Murata
2	1	Z2	GJM1555C1HR40WB01D	0.4pF	Murata
3	2	Z4	GJM1555C1H3R2BB01D	3.2pF	Murata
4	1	Z11	GJM1555C1HR70WB01D	0.7pF	Murata
5	5	C2,C3,C4,C5,C6	GRM155R71A104KA01D	100nF	Murata
6	1	Z14	LQW15AN4N7B00D	4.7nH	Murata
7	1	Z3	LQG15HN2N4S02D	2.4nH	Murata
8	1	Z8	LQW15AN5N1B00D	5.1nH	Murata
9	1	L1	LQW15CNR27J10D	270nH	Murata
10	1	Z5	ERJ-2GE0R00X	0	Panasonic - ECG
11	1	Z9	ERJ-2RKF8200X	820	Panasonic - ECG
12	1	Z10	ERJ-2RKF20R0X	20	Panasonic - ECG
13	1	R1	667-ERJ-2RKF6801X	6.8k	Panasonic - ECG
14	2	R2,R3	667-ERJ-2RKF10R0X	10	Panasonic - ECG
15	1	U1	BGU6104	-	NXP
16	2	X1,X2	142-0701-841	SMA	Cinch Connectivity
17	1	X5	538-22-28-8030	header	Molex
18	1	X6	538-22-28-4030	header	Molex

Note: Customer can choose their preferred vendor but should be aware that the performance could be affected.

3. Measurement results ISM / LTE 700 – 930 MHz

This section presents the results of the BGU6104 Low Noise Amplifier. Unless otherwise noted, all measurement references are at the SMA connectors on the evaluation board and are performed at an ambient temperature of 25 degrees Celsius. The circuit is biased with Vcc=4V, Icc=20 mA.

Next measurements are performed:

- S-parameters
- Noise figure
- RF-power characteristics
- Stability
- On/Off switching (Power-down)

3.1 S-Parameters

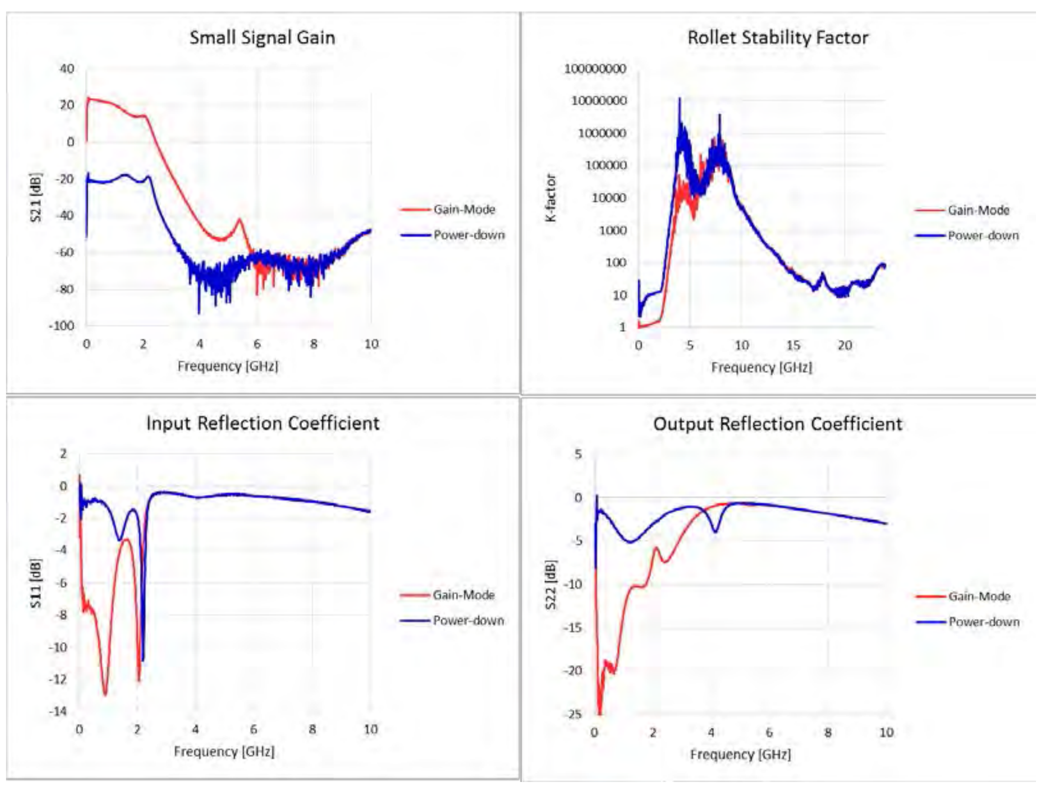

Fig 5. S-Parameters 700 – 930 MHz Band, Vcc=4V, Icc=20mA

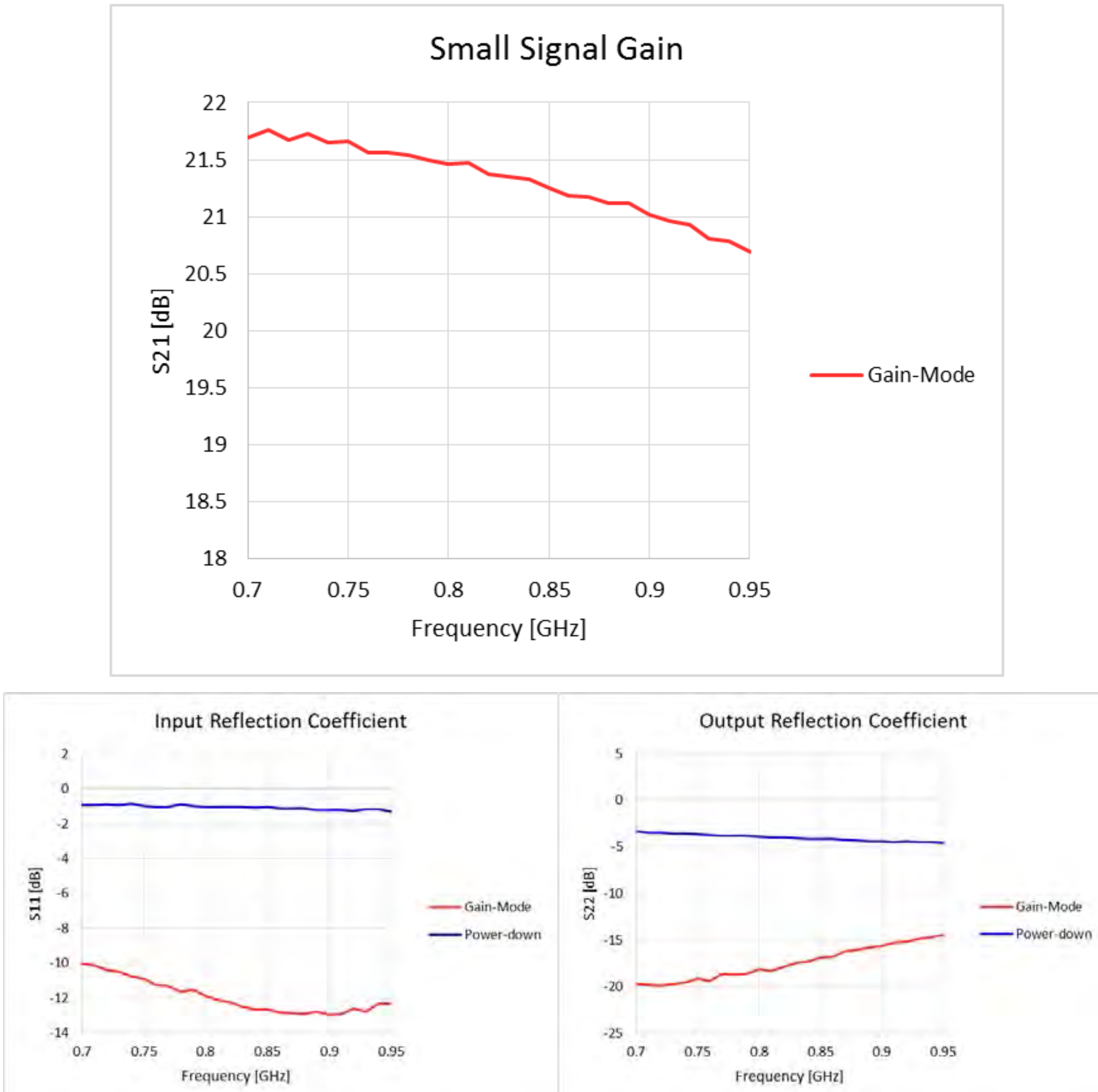

Fig 6. BGU6104 S-Parameters (typical values). Gain mode and Power-down mode (Frequency range zoomed in), Vcc=4V, Icc=20mA

3.2 Noise figure

The noise figure is physically measured at the SMA connectors of the evaluation board.

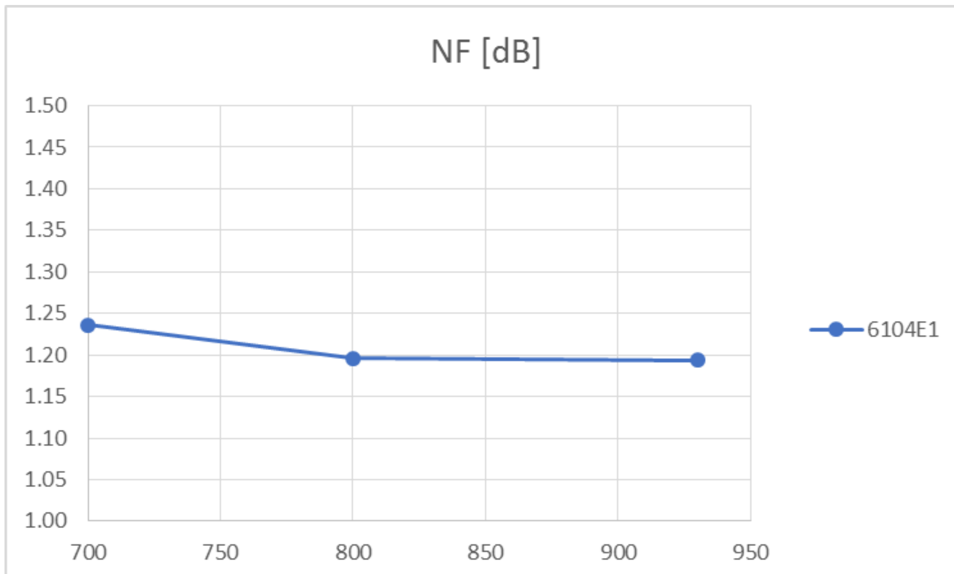

Fig 7. BGU6104 Low Noise Amplifier Noise Figure 700 – 930 MHz, Vcc=4V, Icc=20mA

3.3 RF-power characteristics

Next paragraphs contains the linearity related characteristics of the BGU6104. The circuit is biased with Vcc=4V, Icc=20 mA.

3.3.1 P1dB

Frequency [MHz]	iP1dB [dBm]	oIP1dB [dBm]
700	-12.7	7.4
800	-12.7	7.2
930	-12.6	6.8

3.3.2 IP3

The output-referred IP3 level for the BGU6104 is measured at -30dBm per tone with a frequency spacing of 1MHz at 700, 800 and 930MHz.

Frequency [MHz]	iIP3 [dBm]	oIP3 [dBm]
700	-2.1	18.0
800	-0.8	18.1
930	-1.0	18.4

3.4 Stability

The stability factor K is calculated from the measured S-parameters. To check for instabilities out of band, the S-parameters are measured over an extended frequency range.

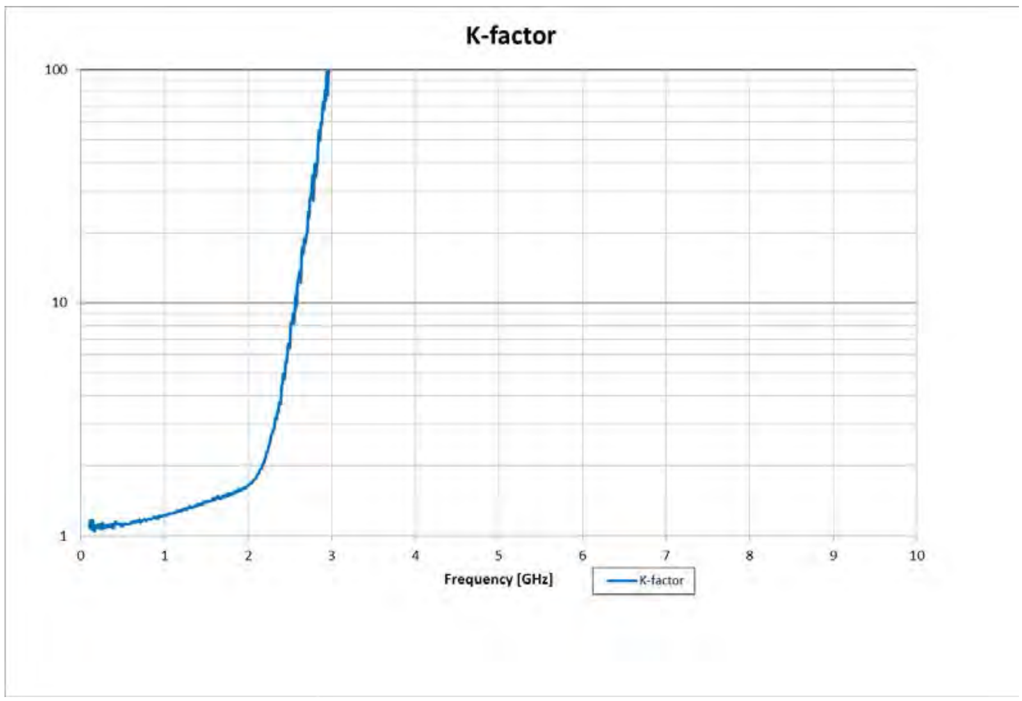

Fig 8. BGU6104 Low Noise Amplifier Broadband K Factor (Rollett Stability Factor) V_{CC}=4V, Icc=20mA, 25°C ambient temperature

3.5 LNA Turn ON-OFF Time

The evaluation board contains an RC low pass filter at the enable signal. This RC circuit introduces an extended on-off time and masks the on-off time of the device itself.

On-time = 1.3 us, Off-time = 4.5 us.

Conditions:

- trigger signal 0-4V 50% duty cycle, 200 Hz
- trigger level @ 50%
- input CW -20 dBm@900 MHz

The following diagram shows the setup to test LNA Turn ON and Turn OFF time.

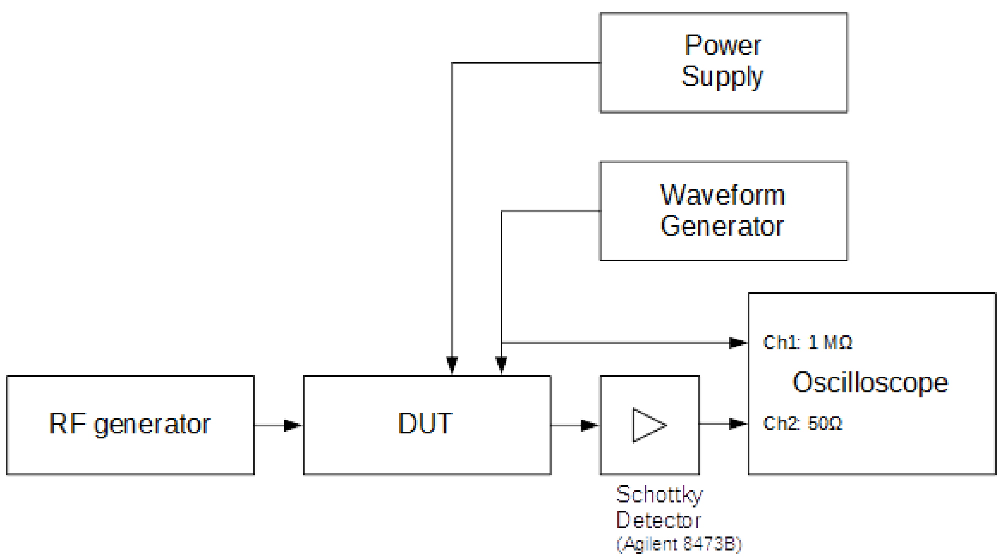

Fig 9. BGU6104 Low Noise Amplifier Turn On and Turn Off time test setup

4. Measurement results LTE 1.8 – 2.2 GHz

This section presents the results of the BGU6104 Low Noise Amplifier for the LTE 1.8 – 2.2 GHz. Unless otherwise noted, all measurement references are at the SMA connectors on the evaluation board and are performed at an ambient temperature of 25 degrees Celsius. The circuit is biased with Vcc=4V, Icc=20mA.

Next measurements are performed:

- S-parameters
- Noise figure
- RF-power characteristics
- Stability
- On/Off switching

4.1 S-Parameters

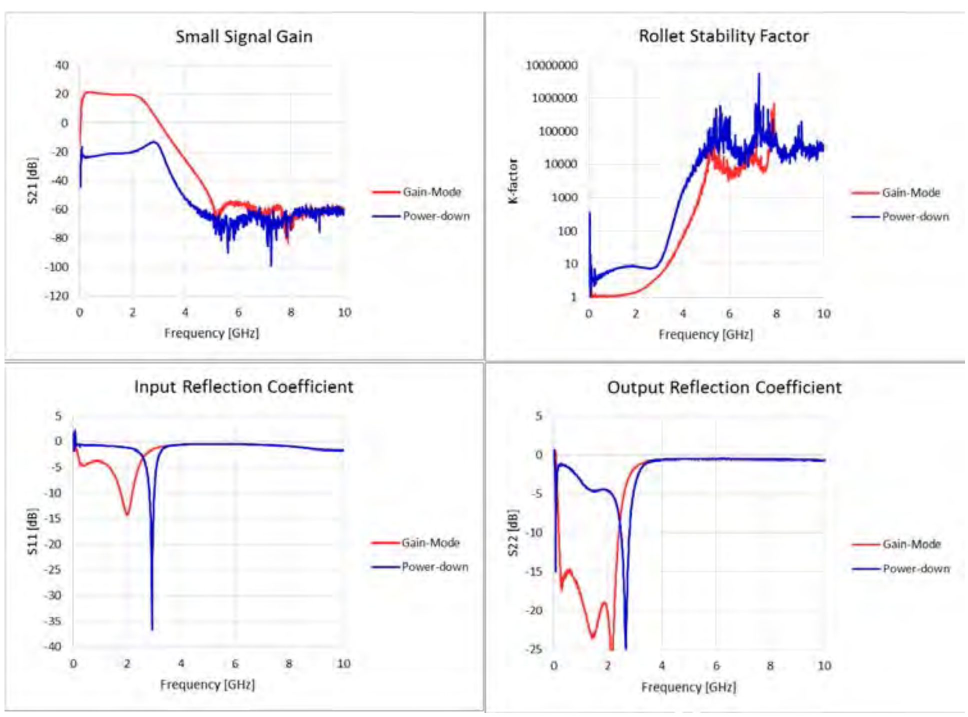

Fig 10. S-Parameters 1.8 – 2.2 GHz Band, Vcc=4V, Icc=20mA

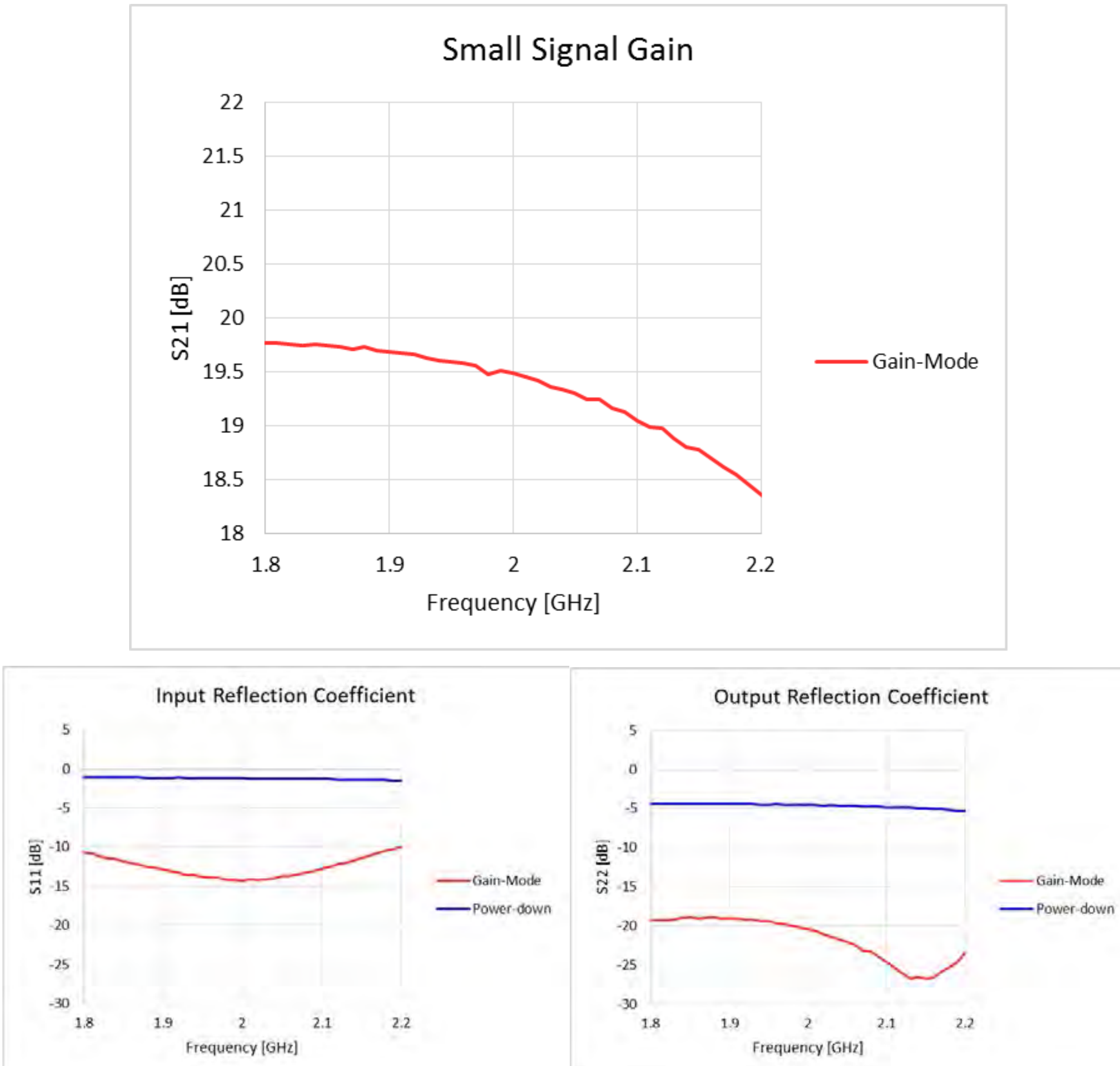

Fig 11. BGU6104 S-Parameters (typical values). Gain mode and Power-down mode (Frequency range zoomed in), Vcc=4V, Icc=20mA

4.2 Noise figure

The noise figure is physically measured at the SMA connectors of the evaluation board.

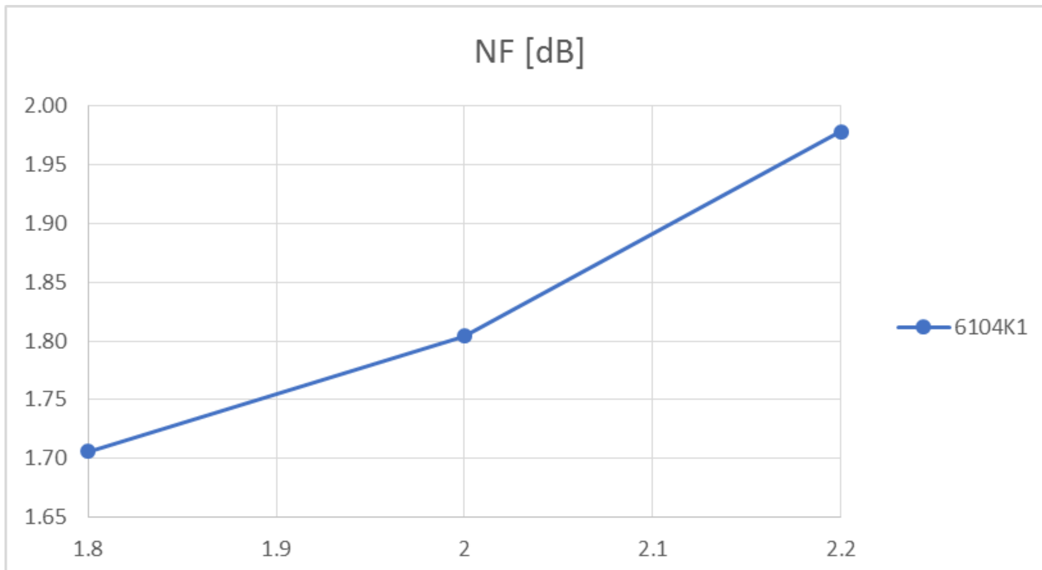

Fig 12. BGU6104 Low Noise Amplifier Noise Figure 1.8 – 2.2 GHz, Vcc=4V, Icc=20mA

4.3 RF-power characteristics

Next paragraphs contains the linearity related characteristics of the BGU6104. The circuit is biased with Vcc=4V, Icc=20 mA.

4.3.1 P1dB

Frequency [GHz]	iP1dB [dBm]	oIP1dB [dBm]
1.8	-11.0	7.9
2.0	-9.6	8.9
2.2	-6.5	10.8

4.3.2 IP3

The output-referred IP3 level for the BGU6104 is measured at -30dBm per tone with a frequency spacing of 1MHz at 1.8, 2.0 and 2.2GHz.

Frequency [GHz]	iIP3 [dBm]	oIP3 [dBm]
1.8	-0.9	18.0
2.0	-0.1	18.4
2.2	2.0	19.3

4.4 Stability

The stability factor K is calculated from the measured S-parameters. To check for out of band instabilities, the S-parameters are measured over an extended frequency range.

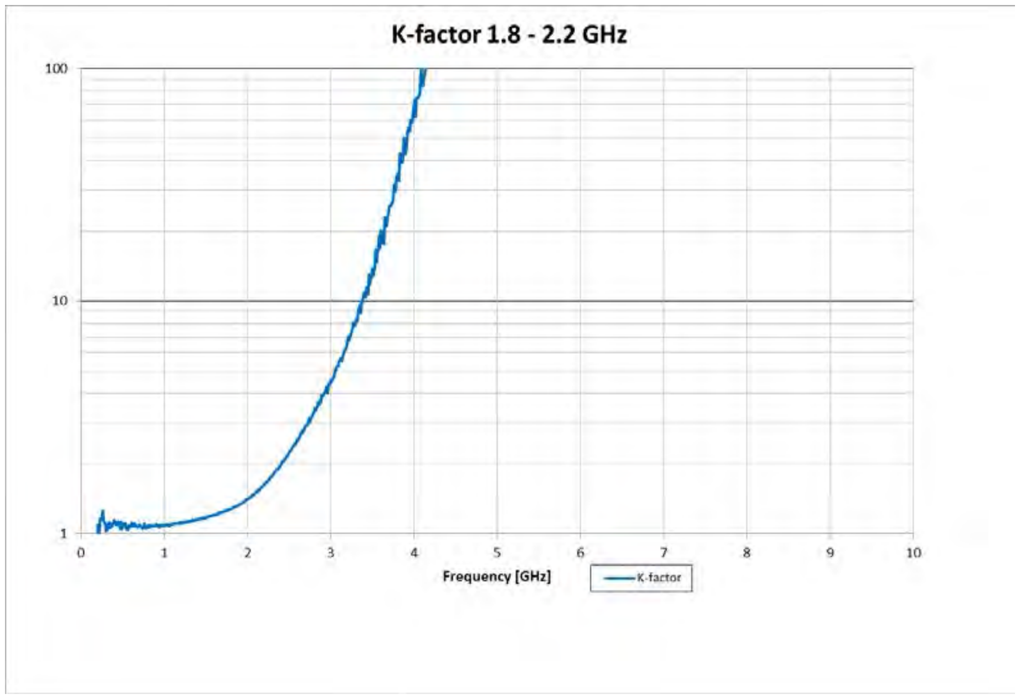

Fig 13. BGU6104 Low Noise Amplifier Broadband K Factor (Rollett Stability Factor) V_{CC}=4V, Icc=20mA, 25°C ambient temperature

4.5 LNA Turn ON-OFF Time

See paragraph 3.5 for the LNA turn ON-OFF time due to circuit similarity.

5. Summary measurement results ISM / LTE 700 – 930 MHz

Table 4. Results measured on the BGU610X Low Noise Amplifier Evaluation Board for ISM / LTE 700 – 930 MHz

Tamb = 25 °C; Ven = 4 V; Icc(tot) = 20 mA

Parameter		Symbol	Value	Unit
Supply Voltage		Vcc	4	V
Supply Current		Icc	20	mA
Noise Figure [1]	@ 700 MHz	NF	1.2	dB
	@ 930 MHz	NF	1.2	dB
Power Gain	@ 700 MHz	Gp	21.7	dB
	@ 930 MHz	Gp	20.8	dB
Input Return Loss	@ 700 MHz	IRL	10.1	dB
	@ 930 MHz	IRL	12.3	dB
Output Return Loss	@ 700 MHz	ORL	19.7	dB
	@ 930 MHz	ORL	14.5	dB
Reverse Isolation	@ 700 MHz	ISLrev	28.4	dB
	@ 930 MHz	ISLrev	27.8	dB
Input 1dB Gain Compression Point	@ 800 MHz	iP1dB	-12.7	dBm
Output 1dB Gain Compression Point	@ 800 MHz	oP1dB	7.2	dBm
Input Third Order Intercept Point [2]	@ 800 MHz	iIP3	-0.8	dBm
Output Third Order Intercept Point [2]	@ 800 MHz	oIP3	18.1	dBm
Stability (100 MHz - 10 GHz)		K	>1	
LNA Turn ON/OFF Time		Ton	1.3	µs
		Toff	4.5	µs

[1] PCB and connector losses excluded.

[2] The third order intercept point is measured at -30 dBm per tone at RF_IN (f_1 = 800 MHz; f_2 = 801 MHz)

6. Summary measurement results LTE 1.8 – 2.2 GHz

Table 5. Results measured on the BGU610X Low Noise Amplifier Evaluation Board for LTE 1.8 – 2.2 GHz

Tamb = 25 °C; Ven = 4 V; Icc(tot) = 20 mA

Parameter		Symbol	Value	Unit
Supply Voltage		Vcc	4	V
Supply Current		Icc	20	mA
Noise Figure [3]	@ 1.8 GHz	NF	1.7	dB
	@ 2.2 GHz	NF	2.0	dB
Power Gain	@ 1.8 GHz	Gp	19.8	dB
	@ 2.2 GHz	Gp	18.4	dB
Input Return Loss	@ 1.8 GHz	IRL	10.8	dB
	@ 2.2 GHz	IRL	10.0	dB
Output Return Loss	@ 1.8 GHz	ORL	19.3	dB
	@ 2.2 GHz	ORL	23.4	dB
Reverse Isolation	@ 1.8 GHz	ISLrev	30.2	dB
	@ 2.2 GHz	ISLrev	29.4	dB
Input 1dB Gain Compression Point	@ 2.0 GHz	iP1dB	-9.6	dBm
Output 1dB Gain Compression Point	@ 2.0 GHz	oP1dB	8.9	dBm
Input Third Order Intercept Point [4]	@ 2.0 GHz	iIP3	-0.1	dBm
Output Third Order Intercept Point [4]	@ 2.0 GHz	oIP3	18.4	dBm
Stability (100 MHz - 10 GHz)		K	>1	
LNA Turn ON/OFF Time		Ton	1.3	µs
		Toff	4.5	µs

[3] PCB and connector losses excluded.

[4] The third order intercept point is measured at -30 dBm per tone at RF_IN (f_1 = 2.000 GHz; f_2 = 2.001 GHz)

7. Application recommendations

The BGU6104 can be used for other application than the applications mentioned in this application note. Only the matching components need to be changed (see schematic diagram of figure 2). The biasing components can be changed to improve the linearity performance.

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