BGA751N7

Si-Ge Bipolar 3G/3.5G/4G Single Band LNA

Single Band LNA for Band-20 (791-821 MHz)

Application Note AN394

Revision: Rev. 1.0
2014-04-02

RF and Protection Devices

Application Note AN394
Revision History: 2014-04-02

Previous Revision:

Page	Subjects (major changes since last revision)

Table of Content

List of Figures

List of Tables

1 Introduction

1.1 About 3G and 4G Applications

Recently, demand for wireless data service is growing faster than ever before. Starting from the first 3G technology, Universal Mobile Telecommunications System (LTE), also known as Wideband Code Division Multiple Access (WCDMA) to the 3.5G technologies, High Speed Downlink Packet Access (HSDPA), High Speed Uplink Packet Access (HSUPA), and the combined technology HSPA and HSPA+, the wireless data rate through mobile phone networks increase dramatically. Ever since the rollout of HSDPA networks and flat-rate pricing plans, the wireless industry has seen amazing growth in mobile broadband average revenue per user.

Since middle 2009, further enhancements of the HSPA technology, defines a new OFDMA-based technology through the Long Term Evolution (LTE) start to ramp in the market. The ability of LTE to support bandwidths up to 20MHz and to have more spectral efficiency by using better modulation methods like QAM-64 is of particular importance as the demand for higher wireless data speeds continues to grow fast.

Countries all over the world have released various frequencies bands for the 3G and 4G applications. **Table** 1 and **Table** 2 show the band assignment for the LTE and LTE bands worldwide.

Table 1 LTE/WCDMA Band Assignment

Band No.	Uplink Frequencies (TX)	Downlink Frequencies (RX)	Comment
1	1920 - 1980 MHz	2110 - 2170 MHz	
2	1850 - 1910 MHz	1930 - 1990 MHz	
2 (G)	1850 - 1915 MHz	1930 - 1995 MHz	
2 (H)	1850 - 1920 MHz	1930 - 2000 MHz	
3	1710 - 1785 MHz	1805 - 1880 MHz	
4	1710 - 1755 MHz	2110 - 2155 MHz	
5	824 - 849 MHz	869 - 894 MHz	
6	830 -840 MHz	875 - 885 MHz	
7	2500 - 2570 MHz	2620 - 2690 MHz	
8	880 - 915 MHz	925 - 960 MHz	

Table 2 LTE Band Assignment

Band No.	Band Definition	Uplink Frequency Range	Downlink Frequency Range	FDD/TDD System	Comment
1	Mid-Band	1920-1980 MHz	2110-2170 MHz	FDD	
2	Mid-Band	1850-1910 MHz	1930-1990 MHz	FDD	
3	Mid-Band	1710-1785 MHz	1805-1880 MHz	FDD	
4	Mid-Band	1710-1755 MHz	2110-2155 MHz	FDD	
5	Low-Band	824-849 MHz	869-894 MHz	FDD	
6	Low-Band	830-840 MHz	875-885 MHz	FDD	
7	High-Band	2500-2570 MHz	2620-2690 MHz	FDD	
8	Low-Band	880-915 MHz	925-960 MHz	FDD	
9	Mid-Band	1749.9-1784.9 MHz	1844.9-1879.9 MHz	FDD	
10	Mid-Band	1710-1770 MHz	2110-2170 MHz	FDD	
11		1427.9-1452.9 MHz	1475.9-1500.9 MHz	FDD	
12	Low-Band	698-716 MHz	728-746 MHz	FDD	
13	Low-Band	777-787 MHz	746-756 MHz	FDD	
14	Low-Band	788-798 MHz	758-768 MHz	FDD	
17	Low-Band	704-716 MHz	734-746 MHz	FDD	
18	Low-Band	815-830 MHz	860-875 MHz	FDD	
19	Low-Band	830-845 MHz	875-890 MHz	FDD	
20	Low-Band	832-862 MHz	791-821 MHz	FDD	
21		1447.9-1462.9 MHz	1495.9-1510.9 MHz	FDD	
22		3410-3500 MHz	3510-3600 MHz	FDD	
23	Mid-Band	2000-2020 MHz	2180-2200 MHz	FDD	
24		1626.5-1660.5 MHz	1525-1559 MHz	FDD	
25	Mid-Band	1850-1915 MHz	1930-1995 MHz	FDD	
26	Low-Band	814-849 MHz	859-894 MHz	FDD	
27	Low-Band	807-824 MHz	852-869 MHz	FDD	
28	Low-Band	703-748 MHz	758-803 MHz	FDD	
29	Low-Band	N/A	716-728 MHz	FDD	
33	Mid-Band	1900-1920 MHz		TDD	
34	Mid-Band	2010-2025 MHz		TDD	
35	Mid-Band	1850-1910 MHz		TDD	
36	Mid-Band	1930-1990 MHz		TDD	
37	Mid-Band	1910-1930 MHz		TDD	
38	High-Band	2570-2620 MHz		TDD	
39	Mid-Band	1880-1920 MHz		TDD	
40	High-Band	2300-2400 MHz		TDD	
41	High-Band	2496-2690 MHz		TDD	
42		3400-3600 MHz		TDD	
43		3600-3800 MHz		TDD	
44	Low-Band	703-803 MHz		TDD	

In order to cover different countries with a unique device, mobile phones and 3G data cards are usually equipped with more than one band. Some typical examples are the triple band combination of band 1, 2 and 5 or quad band combination of band 1, 2, 5 and 8. Since last year, some 700MHz bands are released in the US, so that band combination like 4, 13 and 17 are also well visible in the market.

1.2 Applications

Figure 1 shows an example of the block diagram of the front-end of a 3G modem. A SPnT switch connects on one side the modem antenna and on the other sides several duplexers for different 3G bands. Every duplexer is connected to the transmitting (TX) and receiving (RX) paths of each band. The external LNA, here for example BGA735N16, is placed on the RX path between the duplex and the bandpass SAW filter. The output of the SAW filter is connected to the receiver input of the transceiver IC.

Depending on the number of bands designed in a device, various numbers of LNAs are required in a system. It can be 1-, 2-, 3-, or 4-bands. Recently, even mobile devices with 6 bands are under discussion.

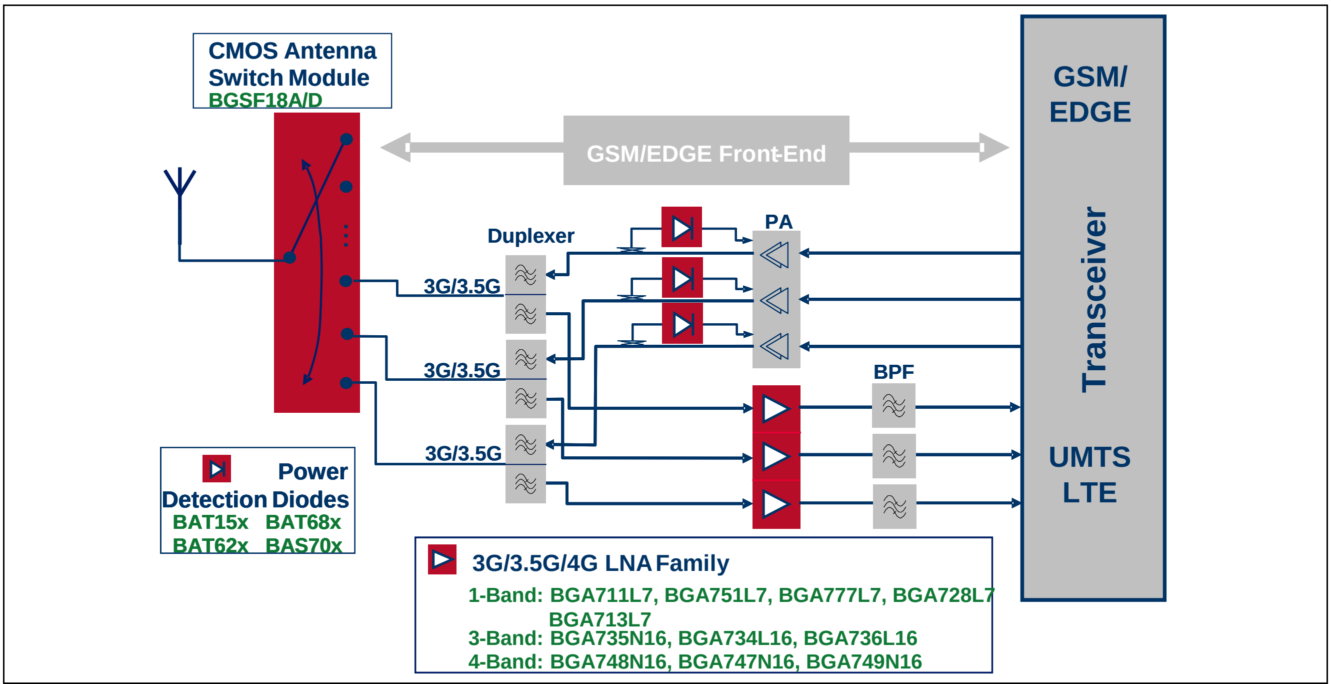

Figure 1 Example of Application Diagram of a 3-band RF front-end for 3G and 4G systems.

Besides low noise amplifiers, Infineon Technologies also offers system designers solutions for high power highly linear antenna switches as well as power detection diodes for power amplifiers.

1.3 Infineon LNAs for 3G and 4G Applications

With the increasing wireless data speed and with the extended link distance of mobile phones and 3G data cards, the requirements on the sensitivity are much higher. Infineon offers different kind of low noise amplifiers (LNAs) to support the customers for mobile phones and data cards of 3G and 4G to improve their system performance to meet the requirements coming from the networks/service providers.

The benefits to use external LNAs in equipment for 3G and 4G applications are:

- Flexible design to place the front-end components: due to the size constraint, the modem antenna and the front-end can not be always put close to the transceiver IC. The path loss in front of the integrated LNA on the transceiver IC increases the system noise figure noticeably. An external LNA physically close to the ANT can help to eliminate the path loss and reduce the system noise figure. Therefore the sensitivity can be improved by several dB.
- Boost the sensitivity by reducing the system noise figure: external LNA has lower noise figure than the integrated LNA on the transceiver IC.
- Bug fix to help the transceiver ICs to fulfill the system requirements.
- Increase the dynamic range of the power handling.

Infineon Technologies is the leading company with broad product portfolio to offer high performance SiGe:C bipolar transistor LNAs and MMIC LNAs for various wireless applications by using the industrial standard silicon process.

- New generation Band-7like BGA7M1N6 for high-band (HB, 2300MHz-2690MHz), BGA7M1N6 for high-band (1805MHz-2200MHz) or BGA7L1N6 for low-band (LB, 728-960MHz) are available.

- Other single-band LNAs like BGA777L7 / BGA777N7 for high-band (2300MHz-2700MHz), BGA711L7 / BGA711N7 for mid-band (MB, 1700MHz-2300MHz) or BGA751L7 / BGA751N7 for low-band (LB, 700-1000MHz) are available. BGA7M1N6 / BGA7M1N6 is designed for the special LTE bands 12, 13, 14, 17, 18, 19 and 20 in the US.

- Triple-band LNAs BGA734N16, BGA735N16 and BGA736N16 are available to cover the most bands. All of the three triple-band LNAs can support designs covering 2x high-bands and 1x low-band.

- Both BGA748N16 and BGA749N16 are quad-band LNAs. BGA748N16 can cover 2x high- and 2x low-bands and BGA749N16 can cover 1x high-band and 3x low-bands. All of these quad-bands LNAs can support all designs with 3 to 4 bands.

-New generation LTE LNA banks are quard band. There are six different types of these new LTE LNAs which are shown in table 3. All the LNAs have four bands with the combination of high-band (HB, 2300MHz-2690MHz), mid-band (MB, 1700MHz-2300MHz) and low-band (LB, 700-1000MHz).

The broad product portfolio with highest integration and best features in noise figure, switchable gain level and flexible band selection helps designers of mobile phones and data cards to achieve outstanding performance. Therefore Infineon LNAs are widely used by major mobile phone vendors.

Table 3 Infineon Product Portfolio of LNAs for new LTE Applications

Frequency Range	728 MHz – 960 MHz	1805MHz – 2200MHz	2300 MHz – 2690 MHz	Comment
Single-Band LNA				
BGA7L1N6	x			
BGA7M1N6		x		
BGA7H1N6			x	
Quad-band LNA bank				
BGM7MLLH4L12	x	x	x	
BGM7LMHM4L12	x	x	x	
BGM7HHMH4L12		x	x	
BGM7MLLM4L12	x	x		
BGM7LLHM4L12	x	x	x	
BGM7LLMM4L12	x	x		

Table 4 Infineon Product Portfolio of LNAs for 3G and 4G Applications

Frequency Range	700 MHz – 1 GHz	1400MHz – 2200MHz	2100 MHz – 2700 MHz	Comment
Single-Band LNA				
BGA711N7/L7		x		
BGA751N7/L7	x			
BGA777N7/L7			x	
BGA728L7/N7	x	x		
BGA713L7/N7	x			
Dual Band LNA				
BGA771L16	x	x		

Table 4 Infineon Product Portfolio of LNAs for 3G and 4G Applications

Triple Band LNA				
BGA734L16	x	x	x	
BGA735N16	x	x	x	
BGA736N16	x	x	x	
Quad-band LNA				
BGA748N16	x	x	x	
BGA749N16	x	x	x	

2 BGA751N7 Overview

2.1 Features

Main features:

- Gain: 16/-8 dB in high/low gain mode (at 850 MHz)
- Noise figure:1.05 dB in high gain mode (at 850 MHz)
- Supply current: 3.3/0.5 mA in high/low gain mode
- Standby mode (< 2 µA typ.)
- Output internally matched to 50 Ω
- Inputs pre-matched to 50 Ω
- 2 kV HBM ESD protection
- Low external component count
- Small leadless TSNP-7-1 package (2.0 mm x 1.3 mm x 0.39 mm)
- Pb-free (RoHS compliant) package

Figure 2 BGA751N7 in TSNP-7-1

2.2 Description

The BGA751N7 is a low current single-band low noise amplifier MMIC for 3G, 3.5G and 4G. The LNA is based upon Infineon's proprietary and cost-effective SiGe:C technology and comes in a low profile TSNP-7-1 leadless green package. Because the matching is off chip, the RFpath can be easily converted into a 700MHz to 1150MHz path by optimizing the input and output matching network. This document specifies the electrical parameters, pinout, application circuit and packaging of the chip.

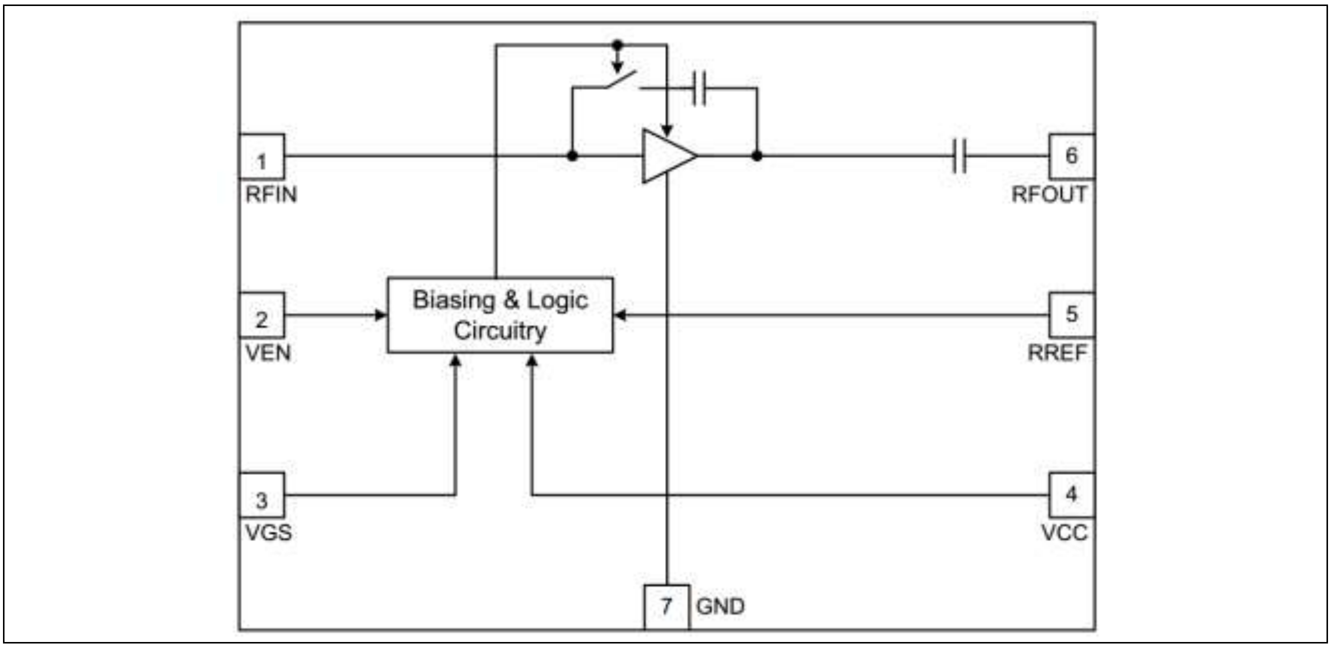

Figure 3 Equivalent Circuit of BGA751N7

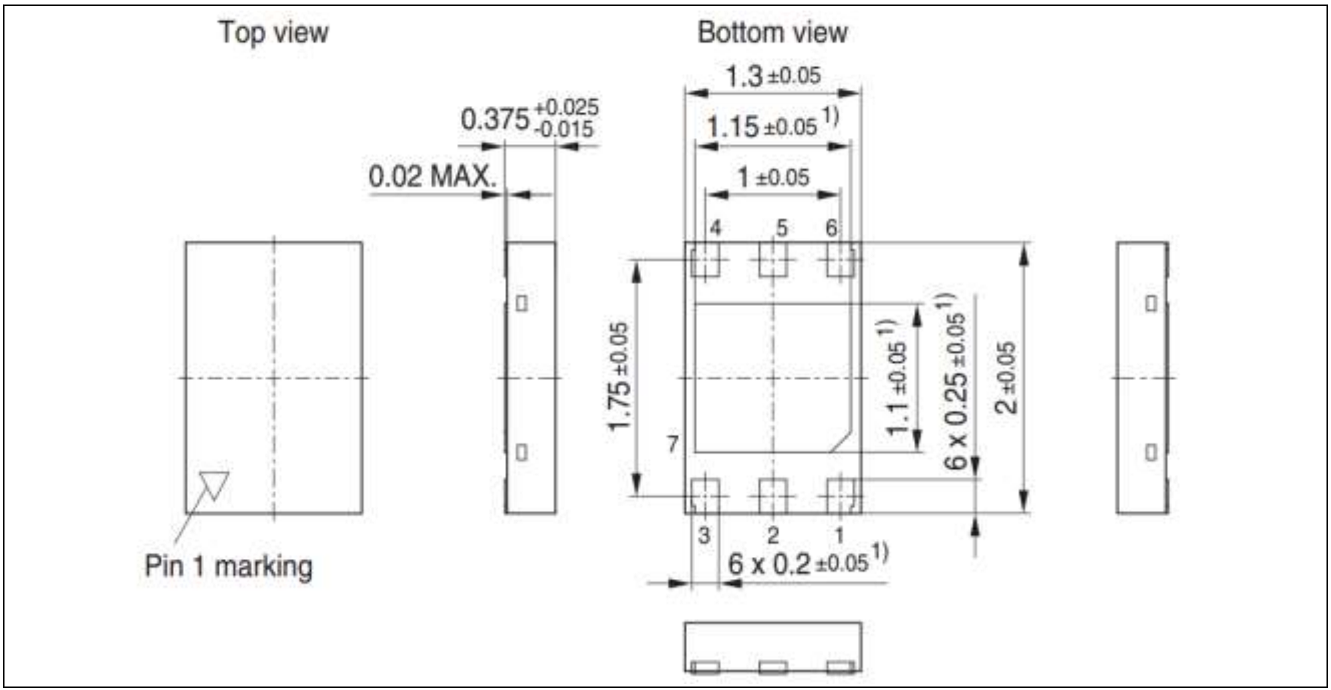

Figure 4 Package and Pin Connections of BGA751N7

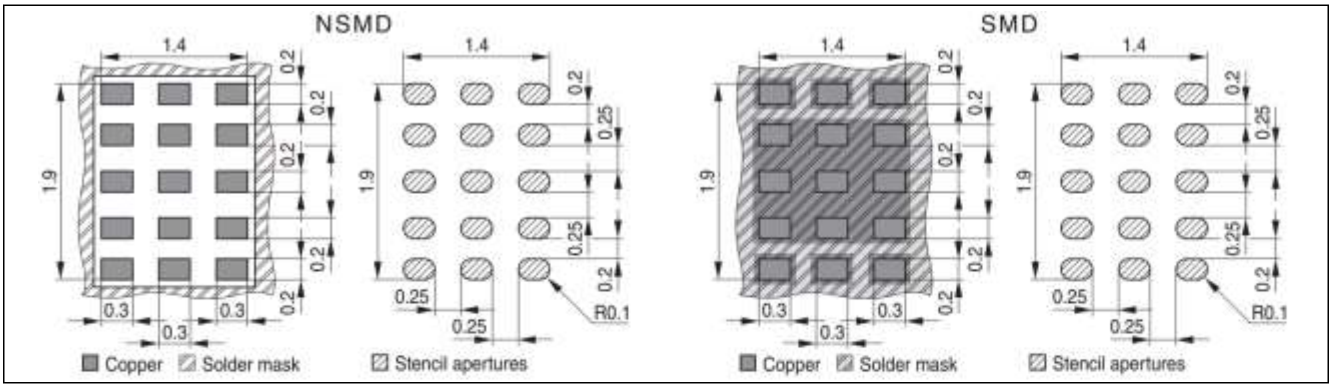

Figure 5 Footprint Recommendation 1 for the BGA751N7 Package

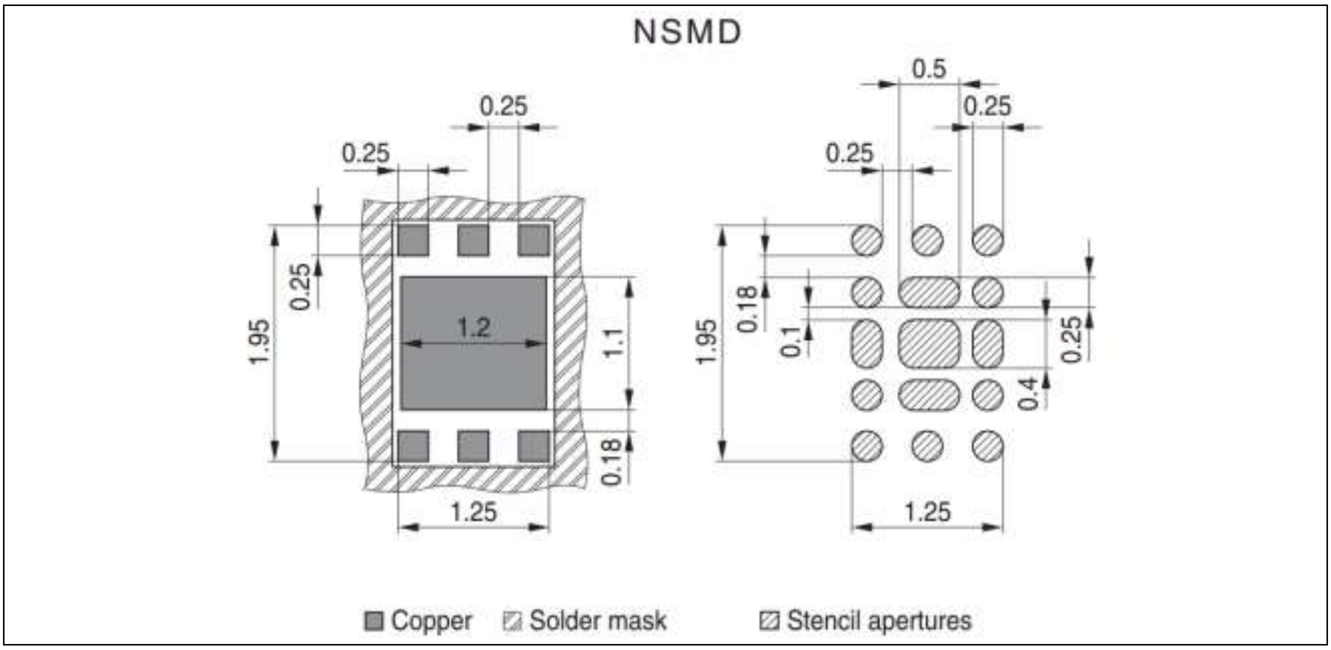

Figure 6 Footprint Recommendation 2 for the BGA751N7 Package

Table 5 Pin Assignment of BGA751N7

Pin No.	Symbol	Function
1	RFIN	LNA Input
2	VEN	Band Select Control
3	VGS	Gain Step Control
4	VCC	Supply Voltage
5	RREF	Bias Current Reference Resistor (high gain mode)
6	RFOUT	LNA Output
7	GND	Package Paddle; Ground Connection and Control Circuitry

3 Application Circuit and Performance Overview

Device: BGA751N7
Application: Single Band LNA for Band-20 (791-821 MHz)
PCB Marking: BGA713L7/N7 V1.0

3.1 Summary of Measurement Results

Table 6 Electrical Characteristics of BGA751N7 at High Gain Mode for Band-20
V_{CC} = 2.8 V, V_{EN} = 2.8 V, V_{GS} = 2.8 V, T_A = 25 °C

Parameter	Symbol	Value			Unit	Comment/Test Condition
DC Voltage	Vcc	2.8			V	
DC Current	Icc	5			mA	
Frequency Range	Freq	791	800	821	MHz	
Gain	G	15.5	15.7	16	dB	
Noise Figure	NF	1.28	1.22	1.11	dB	Loss of SMA and line of 0.05 dB is subtracted
Input Return Loss	RLin	12.9	14.2	17.2	dB	
Output Return Loss	RLout	12.7	15.2	11.2	dB	
Reverse Isolation	IRev	38.8	38.6	38.1	dB	
Input P1dB	IP1dB	-5.6	-5.4	-5.5	dBm	
Output P1dB	OP1dB	8.9	9.3	9.5	dBm	
Input IP3	IIP3	-7.2			dBm	Power @ Input: -30 dBm f_1=805 MHz, f_2=806 MHz
Output IP3	OIP3	8.5			dBm	
Stability	k	>1			--	Measured up to 10 GHz

Table 7 Electrical Characteristics of BGA751N7 at Low Gain Mode for Band-20
V_{CC} = 2.8 V, V_{EN} = 2.8 V, V_{GS} = 0 V, T_A = 25 °C

Parameter	Symbol	Value			Unit	Comment/Test Condition
DC Voltage	Vcc	2.8			V	
DC Current	Icc	0.5			mA	
Frequency Range	Freq	791	800	821	MHz	
Gain	G	-8.9	-8.7	-8.5	dB	
Noise Figure	NF	8.9	8.7	8.5	dB	Loss of SMA and line of 0.05 dB is subtracted
Input Return Loss	RLin	19.2	16.8	13.5	dB	
Output Return Loss	RLout	23.9	25	23.3	dB	
Reverse Isolation	IRev	8.9	8.8	8.5	dB	
Input P1dB	IP1dB	-9.9	-9.7	-9.4	dBm	
Output P1dB	OP1dB	-19.8	-19.4	-18.9	dBm	
Input IP3	IIP3	-0.8			dBm	Power @ Input: -30 dBm f_1=805 MHz, f_2=806 MHz
Output IP3	OIP3	-9.5			dBm	
Stability	k	>1			--	Measured up to 10 GHz

3.2 BGA751N7 LNA for LTE Band-20 (791-821 MHz)

This application note focuses on the Infineon's Single-band LNA, BGA751N7 tuned for the LTE Band-20. It presents the performance of BGA751N7 with 2.8 V voltage for both high and low gain mode. This application circuit requires seven 0402 passive components. The components values are fine tuned for optimal noise figure, gain, input and output matching.

In high gain mode, it has an in-band gain of 15.7 dB. The circuit achieves input return loss better than 12.9 dB, as well as the output return loss better than 11.2 dB. At room temperature the noise figure is 1.22 dB (SMA and PCB losses are subtracted). Furthermore, the circuit is measured unconditionally stable till 10 GHz. At Band-20, using two tones spacing of 1 MHz, the output third order intercept point, OIP3 reaches 8.5 dBm. Input P1dB of the BGA751N7 LNA is about –7.2 dBm at 800 MHz.

In low gain mode, it has an attenuation of 6.9 dB. The circuit achieves input return loss better than 13.5 dB, as well as the output return loss better than 23.3 dB. Moreover, the circuit is also unconditionally stable till 10 GHz. At Band-20, using two tones spacing of 1 MHz, the input third order intercept point, IIP3 reaches -0.8 dBm. Input P1dB of the BGA751N7 LNA is about -9.7 dBm at 800 MHz. All the measurements are done with the standard evaluation board presented at the end of this application note.

3.3 Schematics and Bill-of-Materials

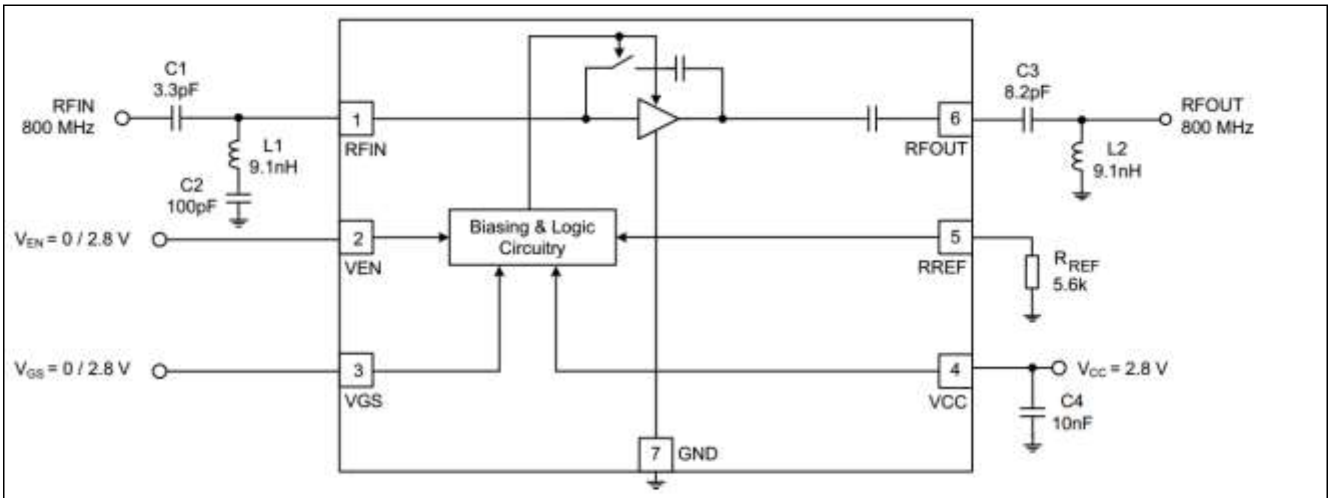

Figure 7 Schematics of the BGA751N7 Application Circuit

Table 8 Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	3.3	pF	0402	Various	
C2	100	pF	0402	Various	
C3	8.2	pH	0402	Various	
C4	10	nH	0402	Various	
L1	9.1	nH	0402	Murata LQW series	Wirewound, Q ≈ 50
L2	9.1	nH	0402	Murata LQW series	Wirewound, Q ≈ 50
RREF	5.6	kΩ	0402	Various	
N1	BGA751N7	TSNP-7-1		Infineon	SiGe LNA

4 Measurement Graphs

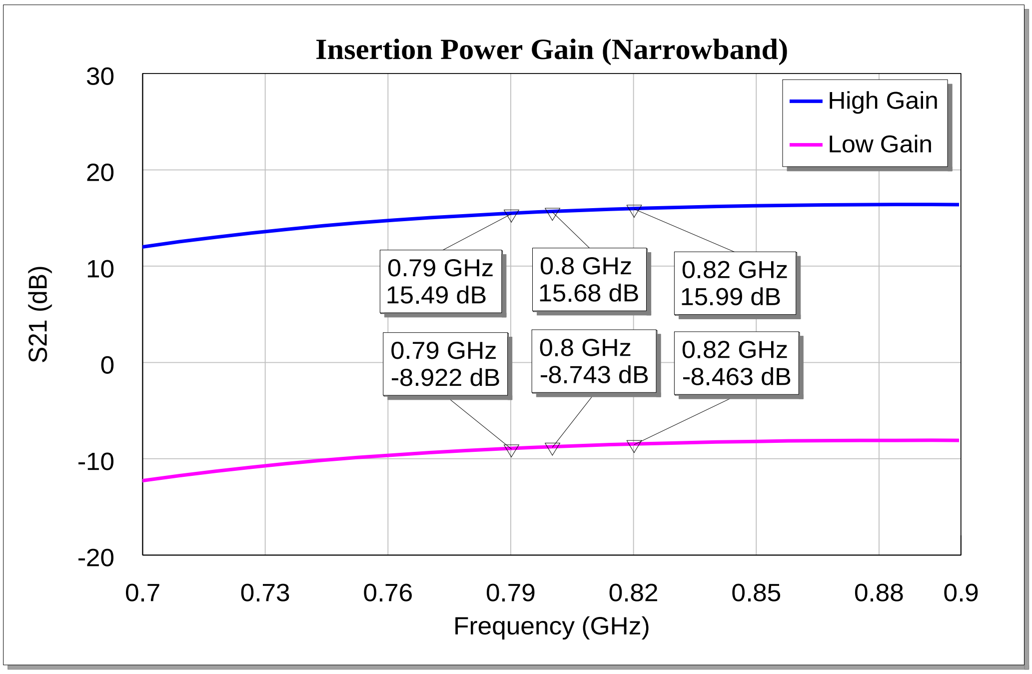

Figure 8 Insertion Power Gain (Narrowband) of the BGA751N7 for Band-20 Applications

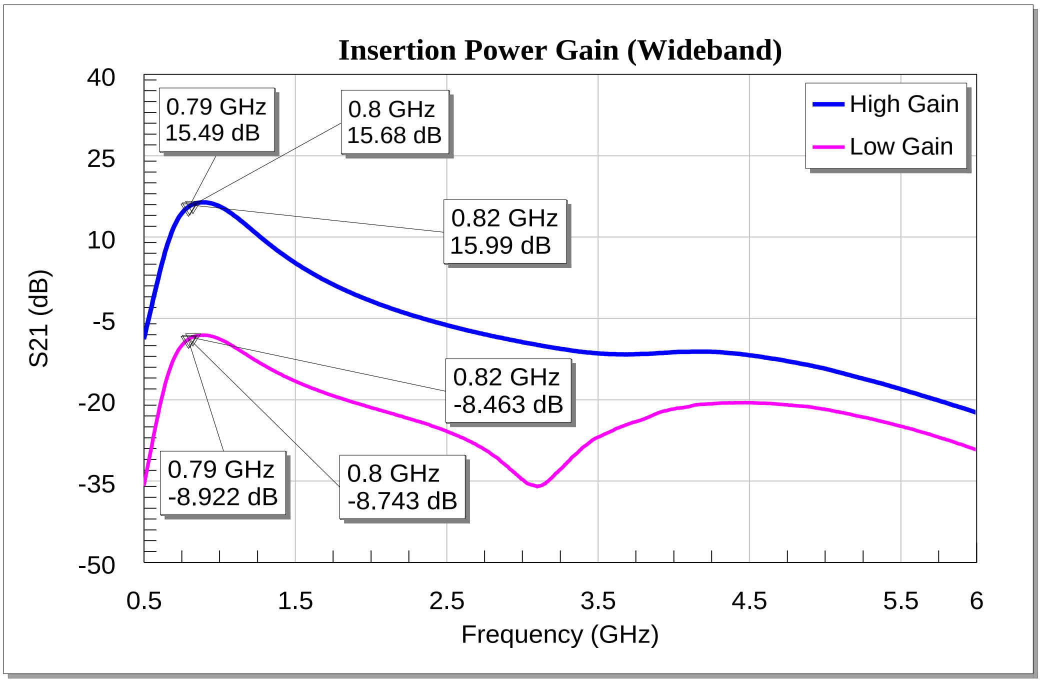

Figure 9 Insertion Power Gain (Wideband) of the BGA751N7 for Band-20 Applications

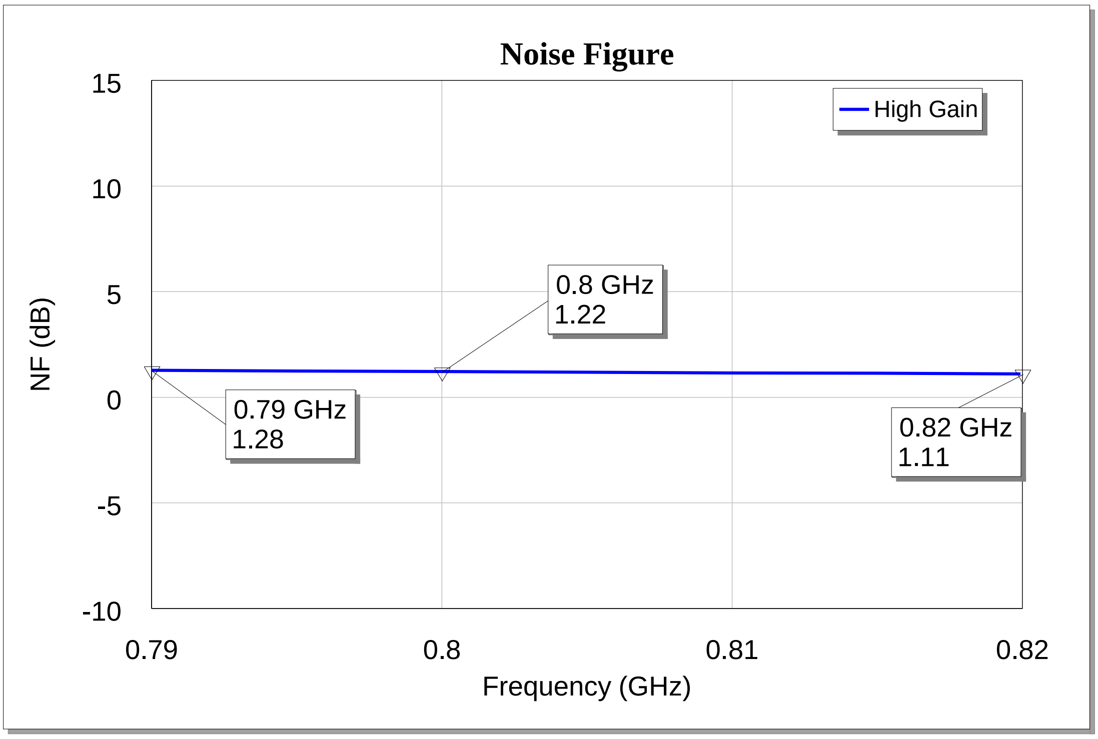

Figure 10 Noise Figure of the BGA751N7 for Band-20 Applications

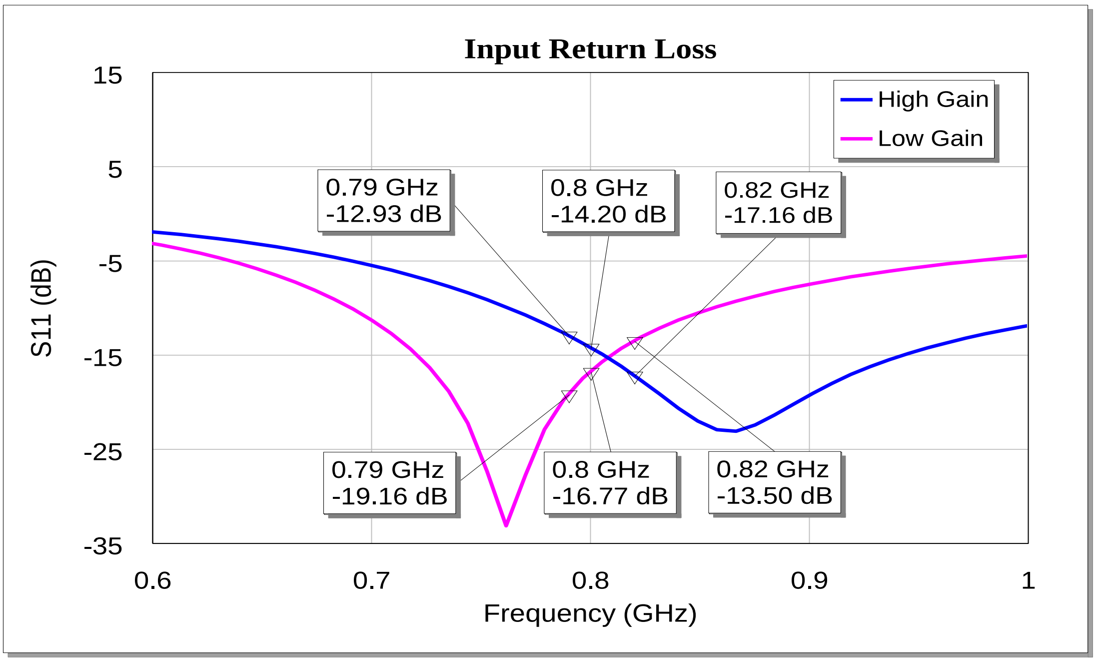

Figure 11 Input Matching of the BGA751N7 for Band-20 Applications

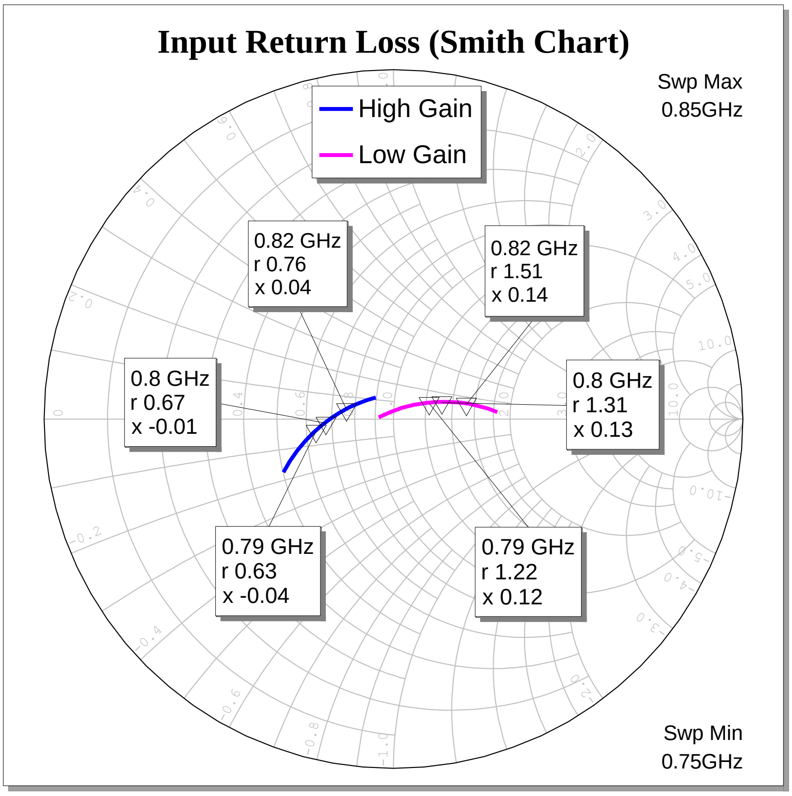

Figure 12 Input Matching (Smith Chart) of the BGA751N7 for Band-20 Applications

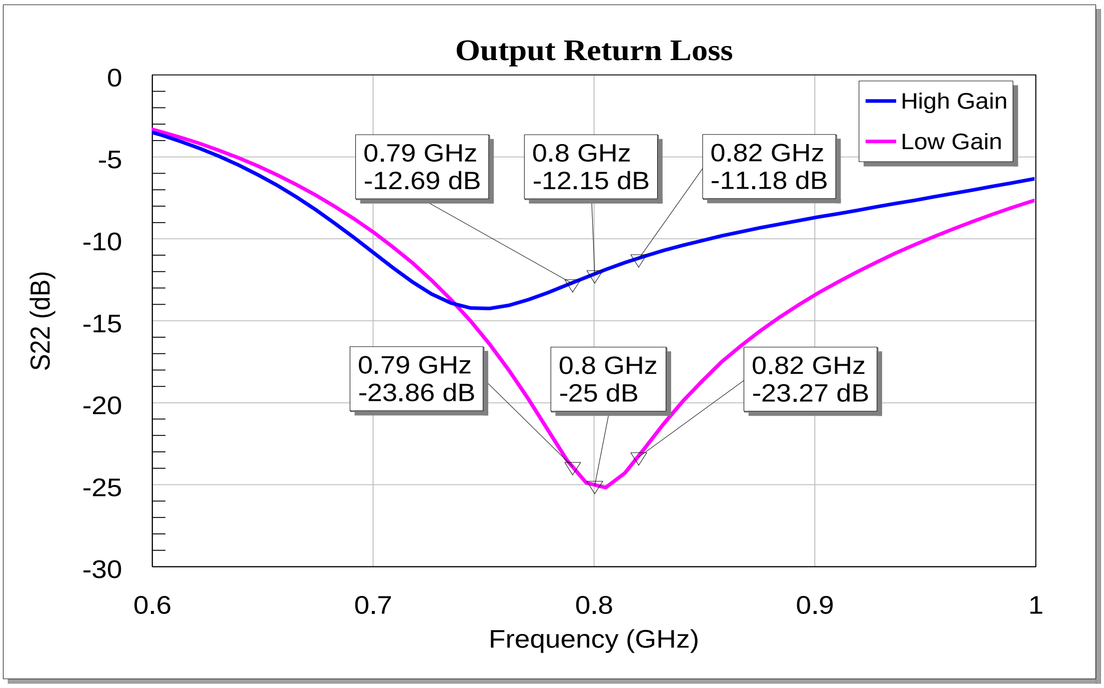

Figure 13 Output Matching of the BGA751N7 for Band-20 Applications

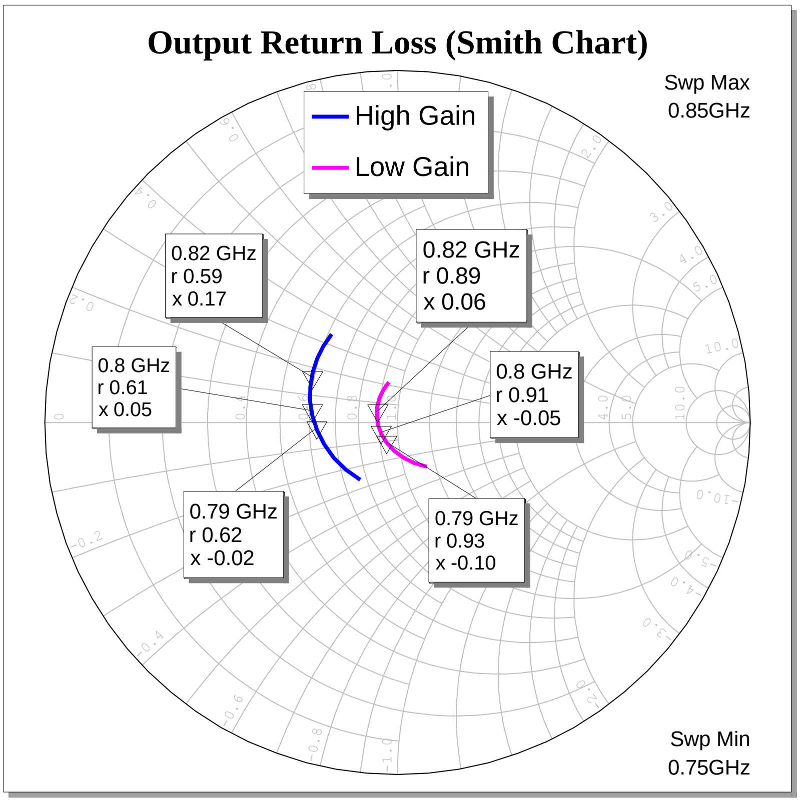

Figure 14 Output Matching (Smith Chart) of the BGA751N7 for Band-20 Applications

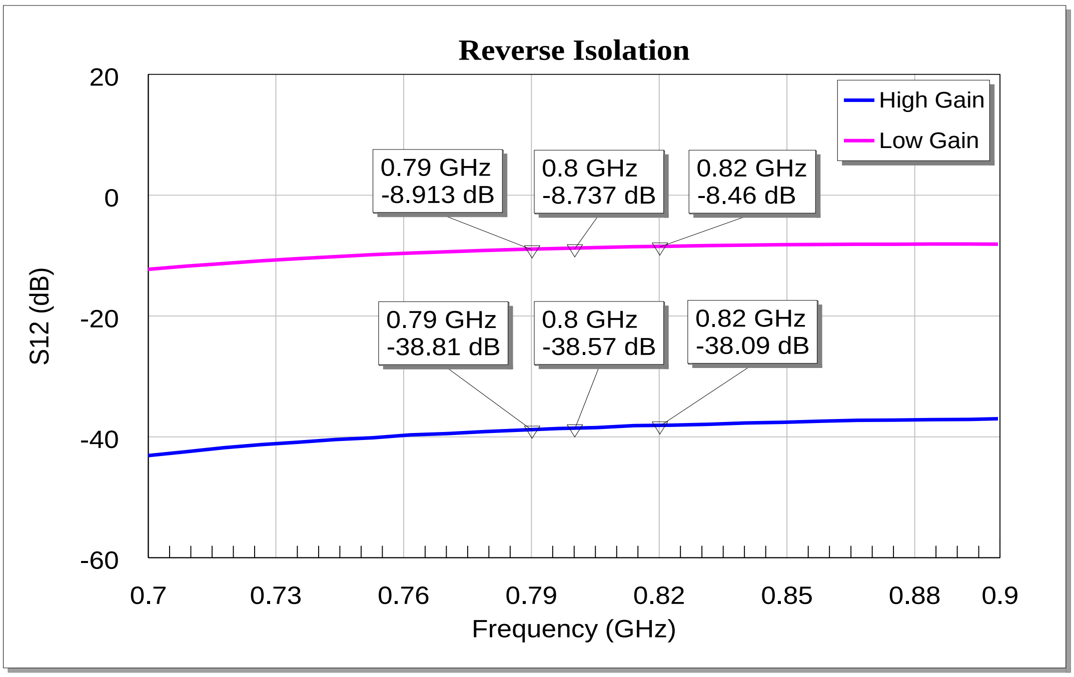

Figure 15 Reverse Isolation of the BGA751N7 for Band-20 Applications

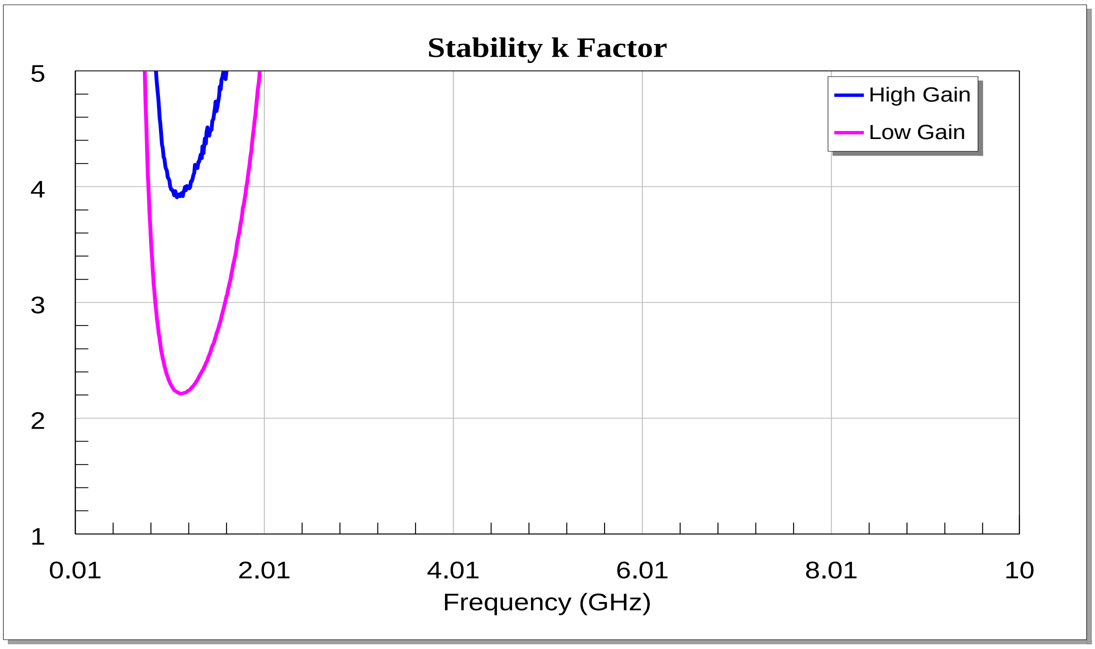

Figure 16 Stability K-factor of the BGA751N7 for Band-20 Applications

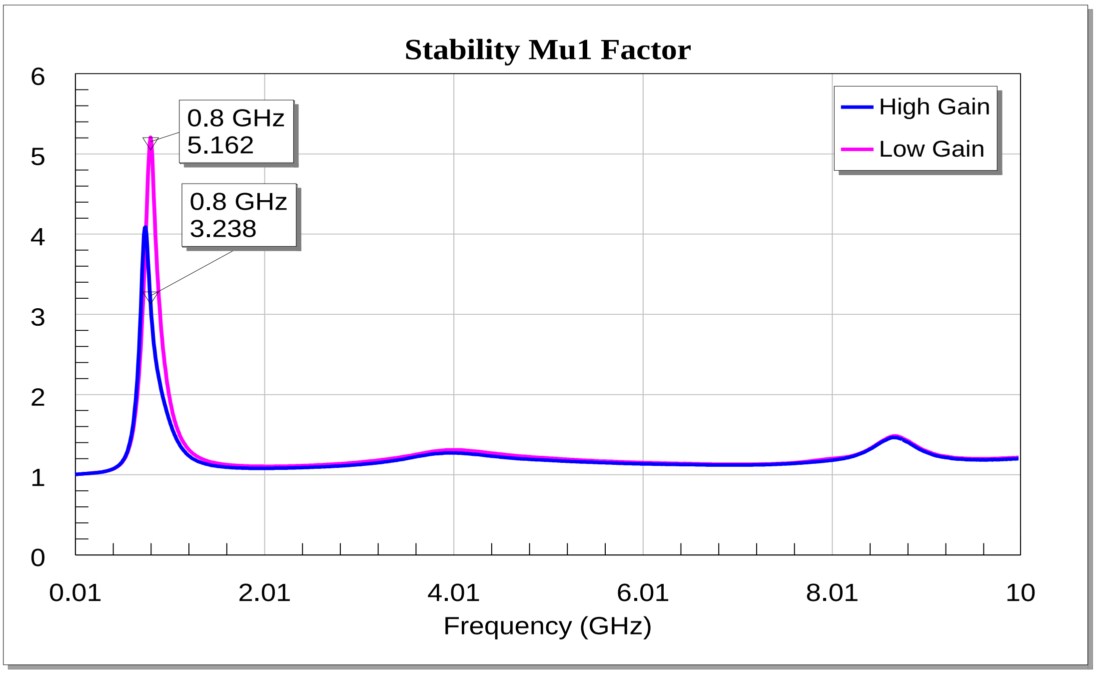

Figure 17 Stability Mu1-factor of the BGA751N7 for Band-20 Applications

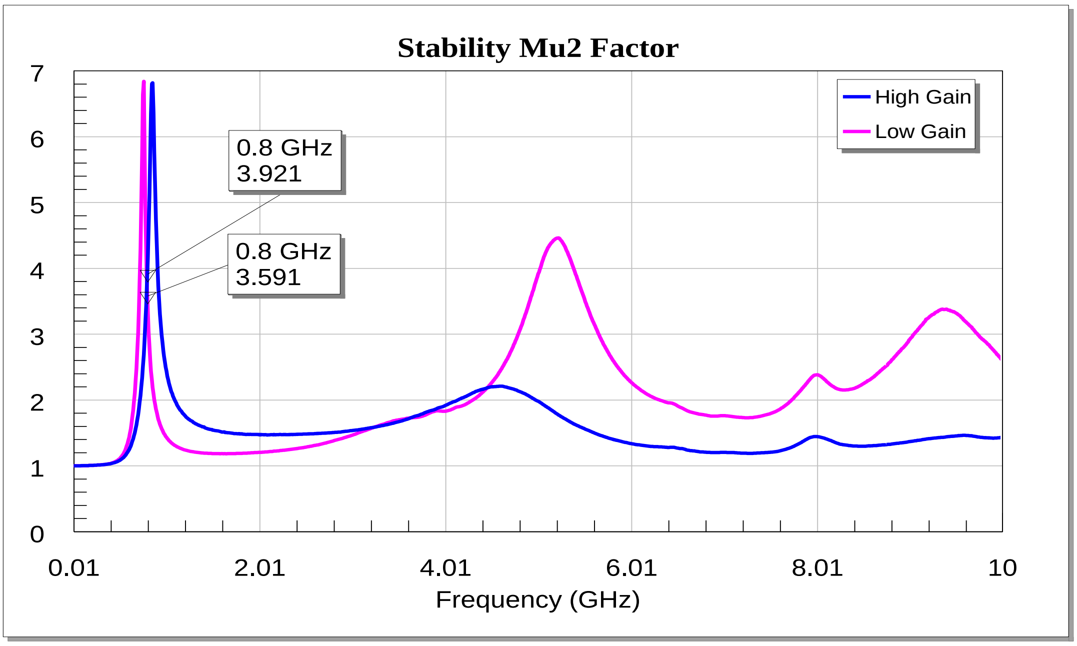

Figure 18 Stability Mu2-factor of the BGA751N7 for Band-20 Applications

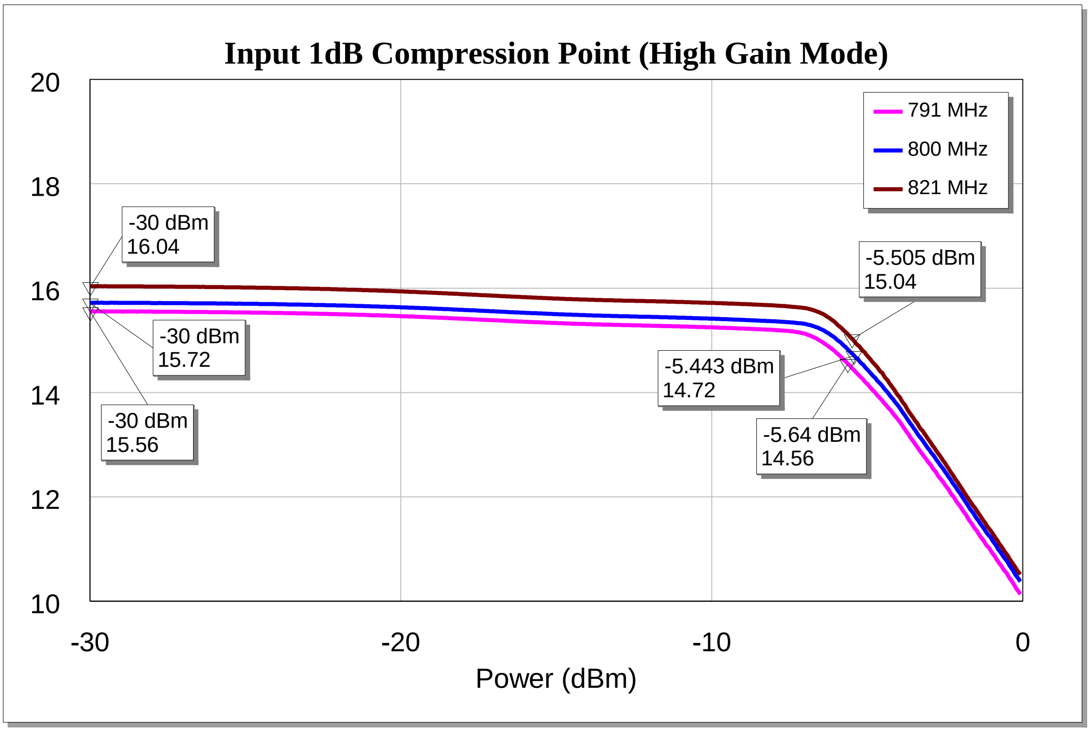

Figure 19 Input 1dB Compression Point of the BGA751N7 for Band-20 Applications (High Gain Mode)

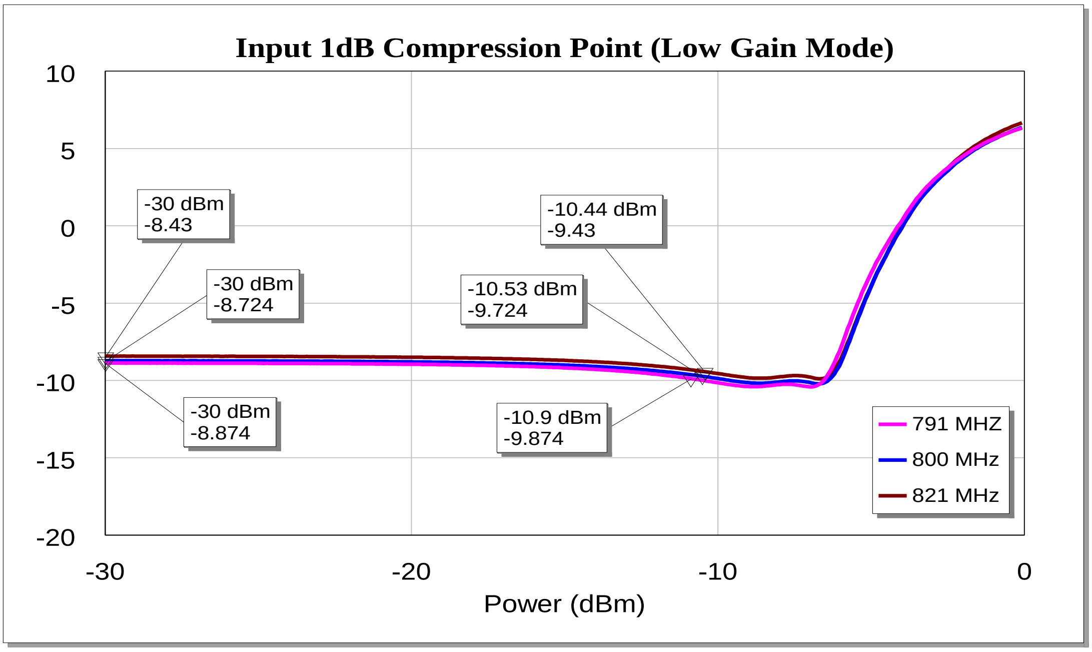

Figure 20 Input 1dB Compression Point of the BGA751N7 for Band-20 Applications (Low Gain Mode)

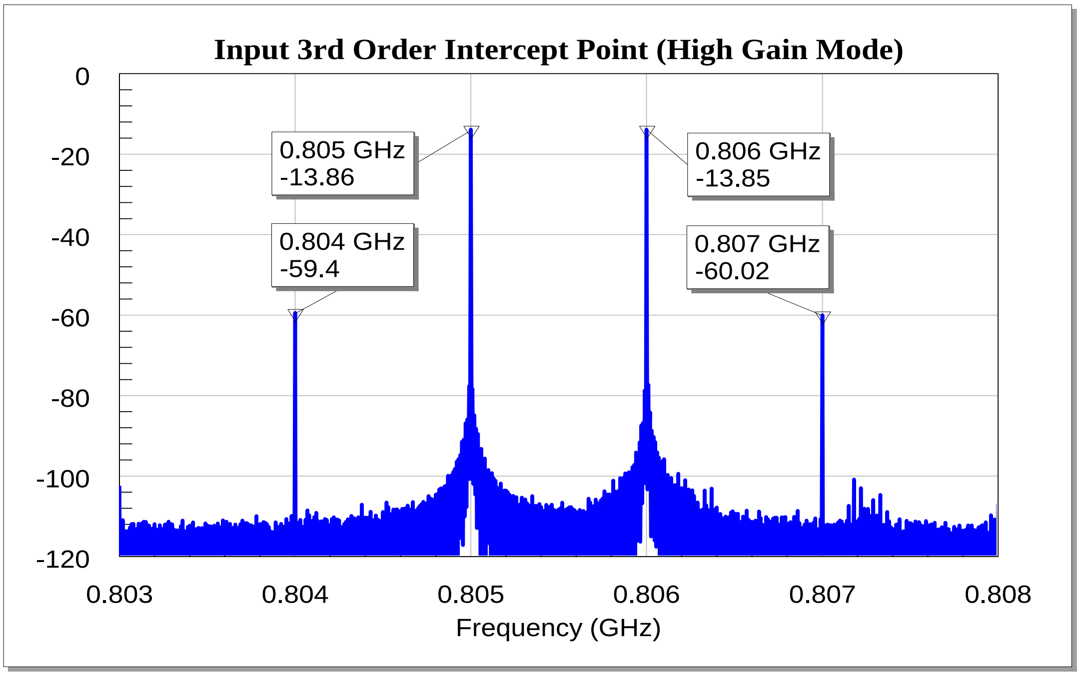

Figure 21 Input 3rd Intercept Point of the BGA751N7 for Band-20 Applications (High Gain Mode)

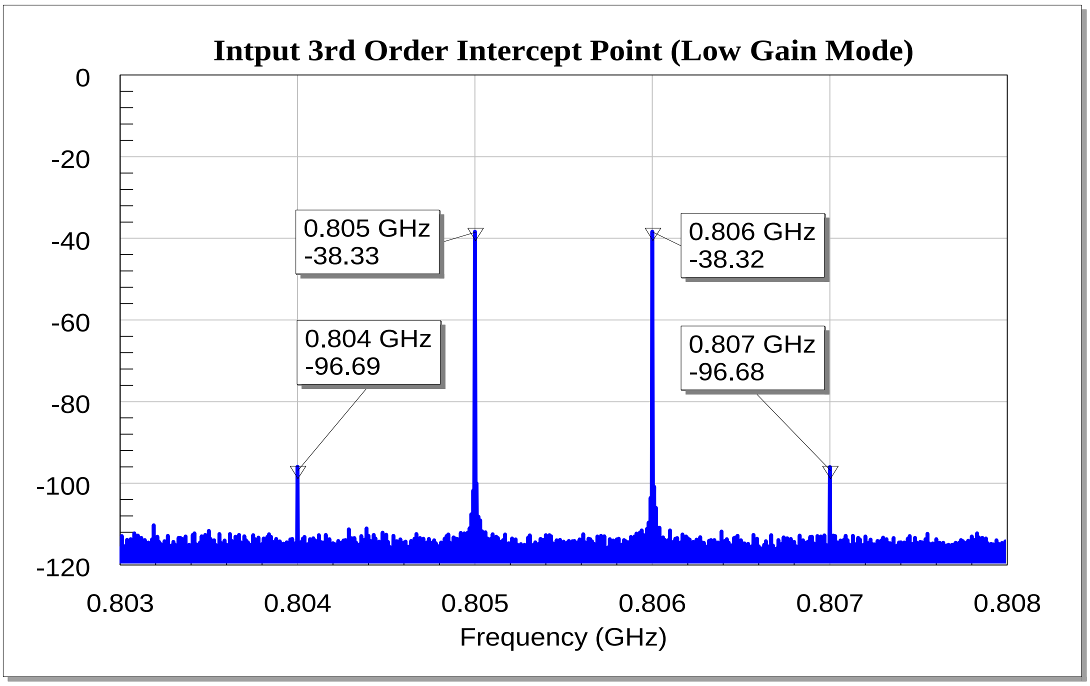

Figure 22 Input 3rd Intercept Point of the BGA751N7 for Band-20 Applications (Low Gain Mode)

5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB Marking: BGA713L7/N7 V1.0

PCB material: FR4

ε_r of PCB material: 4.3

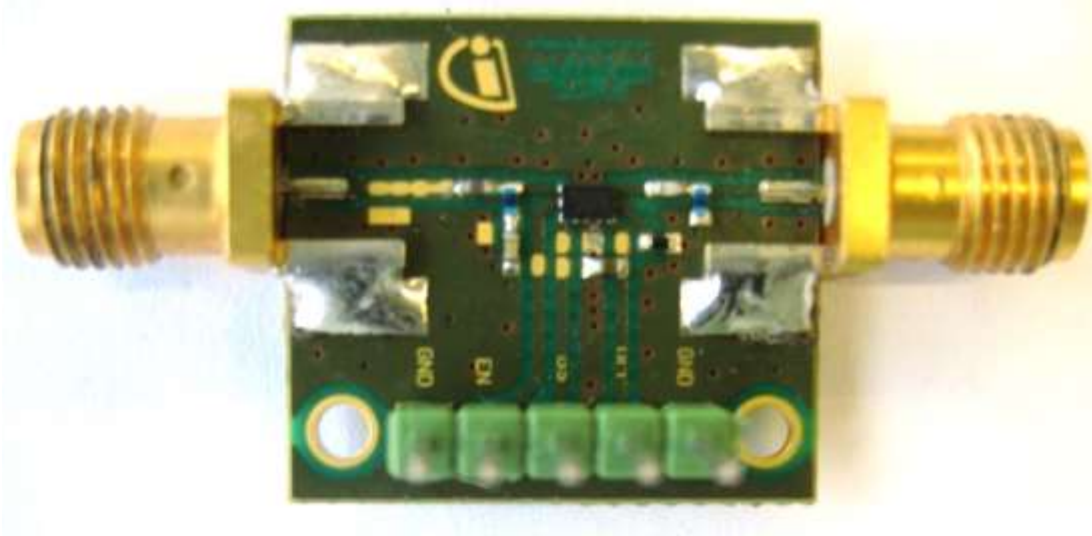

Figure 23 Picture of Evaluation Board (Overview) of BGA751N7 V1.0

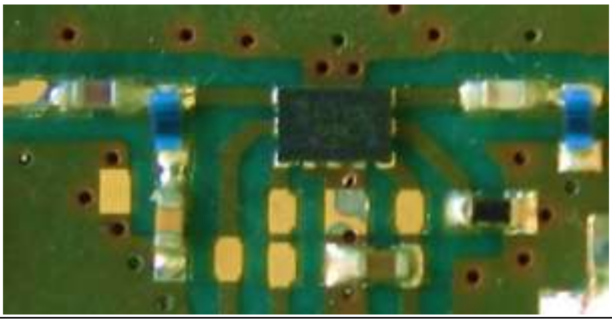

Figure 24 Picture of Evaluation Board (Detailed View) of BGA751N7 V1.0

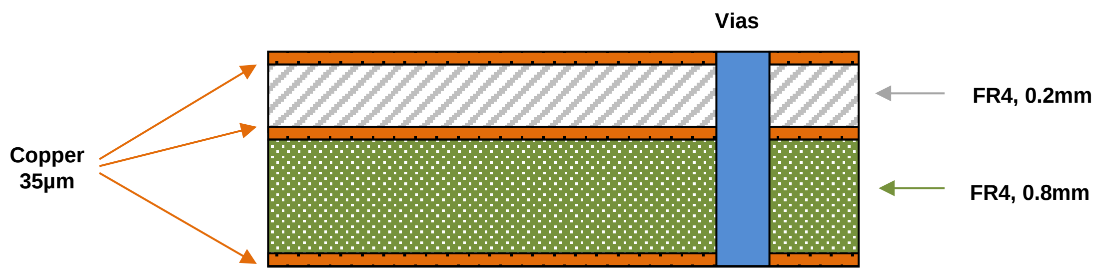

Figure 25 PCB Layer Stack

6 Authors

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Moakhkhrul Islam, RF Application Engineer of Business Unit “RF and Protection Devices”

7 Remark

The graphs are generated with the simulation software AWR Microwave Office®.

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