BGA711N7

SiGe Bipolar 3G/3.5G/4G Single-Band LNA

BGA711N7 for LTE Applications Supporting Band 3 and 33 with High Gain of 18dB

Application Note AN353

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RF and Protection Devices

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Table of Content

1 Introduction 4
1.1 About 3G and 4G Applications 4
1.2 Applications 6
1.3 Infineon LNAs for 3G and 4G Applications 7

2 BGA711N7 Overview 10
2.1 Features 10
2.2 Description 10

3 Application Circuit and Performance Overview 13
3.1 Summary of Measurement Results 13
3.2 BGA711N7 as LTE LNA for Band 3 and Band 33 (1805-1920 MHz) 15
3.3 Schematics and Bill-of-Materials 16

4 Measurement Graphs 17

5 Evaluation Board and Layout Information 25

6 Authors 26

7 Remark 26

List of Figures

Figure 1 Example of Application Diagram of a 3-band RF front-end for 3G and 4G systems. 6
Figure 2 BGA711N7 in TSNP-7-1 10
Figure 3 Equivalent Circuit of BGA711N7 11
Figure 4 Package and pin connections of BGA711N7 11
Figure 5 Schematics of the BGA711N7 Application Circuit 16
Figure 6 Insertion Power Gain (Narrowband) of the BGA711N7 for Band-3 and Band-33 Applications 17
Figure 7 Insertion Power Gain (Wideband) of the BGA711N7 for Band-3 and Band-33 Applications 17
Figure 8 Noise Figure of the BGA711N7 for Band-3 and Band-33 Applications 18
Figure 9 Input Matching of the BGA711N7 for Band-3 and Band-33 Applications 18
Figure 10 Input Matching (Smith Chart) of the BGA711N7 for Band-3 and Band-33 Applications 19
Figure 11 Output Matching of the BGA711N7 for Band-3 and Band-33 Applications 19
Figure 12 Output Matching (Smith Chart) of the BGA711N7 for Band-3 and Band-33 Applications 20
Figure 13 Reverse Isolation of the BGA711N7 for Band-3 and Band-33 Applications 20
Figure 14 Stability K-factor of the BGA711N7 for Band-3 and Band-33 Applications 21
Figure 15 Stability Mu1-factor of the BGA711N7 for Band-3 and Band-33 Applications 21
Figure 16 Stability Mu2-factor of the BGA711N7 for Band-3 and Band-33 Applications 22
Figure 17 Input 1dB compression point of the BGA711N7 for Band-3 and Band-33 Applications (HG) 22
Figure 18 Input 1dB compression point of the BGA711N7 for Band-3 and Band-33 Applications (LQ) 23
Figure 19 Input 3rd interception point of the BGA711N7 for Band-3 and Band-33 Applications (HG) 23
Figure 20 Input 3rd interception point of the BGA711N7 for Band-3 and Band-33 Applications (LG) 24
Figure 21 Photo Picture of Evaluation Board (overview) , ... 25
Figure 22 Photo Picture of Evaluation Board (detailed view) 25
Figure 23 PCB layer stack 25

List of Tables

Table 1 LTE/WCDMA Band Assignment 4
Table 2 LTE Band Assignment 5
Table 3 Infineon Product Portfolio of LNAs for new LTE Applications 8
Table 4 Infineon Product Portfolio of LNAs for 3G and 4G Applications 8
Table 5 Pin Assignment of BGA711N7 12
Table 6 Truth Table of BGA711N7 12
Table 7 Electrical Characteristics at *V*CC = 2.8 V (at room temperature) 13
Table 8 Electrical Characteristics at *V*CC = 2.8 V (at room temperature) 14
Table 9 Bill-of-Materials 16

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.	Uplink Frequency Range	Downlink Frequency Range	Comment
1	1920 - 1980 MHz	2110 - 2170 MHz	
2	1850 - 1910 MHz	1930 - 1990 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	
9	1749.9 - 1784.9 MHz	1844.9 - 1879.9 MHz	
10	1710 - 1770 MHz	2110 - 2170 MHz	
11	1427.9 - 1452.9 MHz	1475.9 - 1500.9 MHz	
12	698 - 716 MHz	728 - 746 MHz	
13	777 - 787 MHz	746 - 756 MHz	
14	788 - 798 MHz	758 - 768 MHz	
17	704 - 716 MHz	734 - 746 MHz	
18	815 - 830 MHz	860 - 875 MHz	
19	830 - 845 MHz	875 - 890 MHz	
20	832 - 862 MHz	791 - 821 MHz	
21	1447.9 - 1462.9 MHz	1495.9 - 1510.9 MHz	
33	1900 -1920 MHz	1900 -1920 MHz	
34	2010 - 2025 MHz	2010 - 2025 MHz	
35	1850 - 1910 MHz	1850 - 1910 MHz	
36	1930 - 1990 MHz	1930 - 1990 MHz	
37	1910 - 1930 MHz	1910 - 1930 MHz	
38	2570 - 2620 MHz	2570 - 2620 MHz	
39	1880 - 1920 MHz	1880 - 1920 MHz	
40	2300 - 2400 MHz	2300 - 2400 MHz	

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.

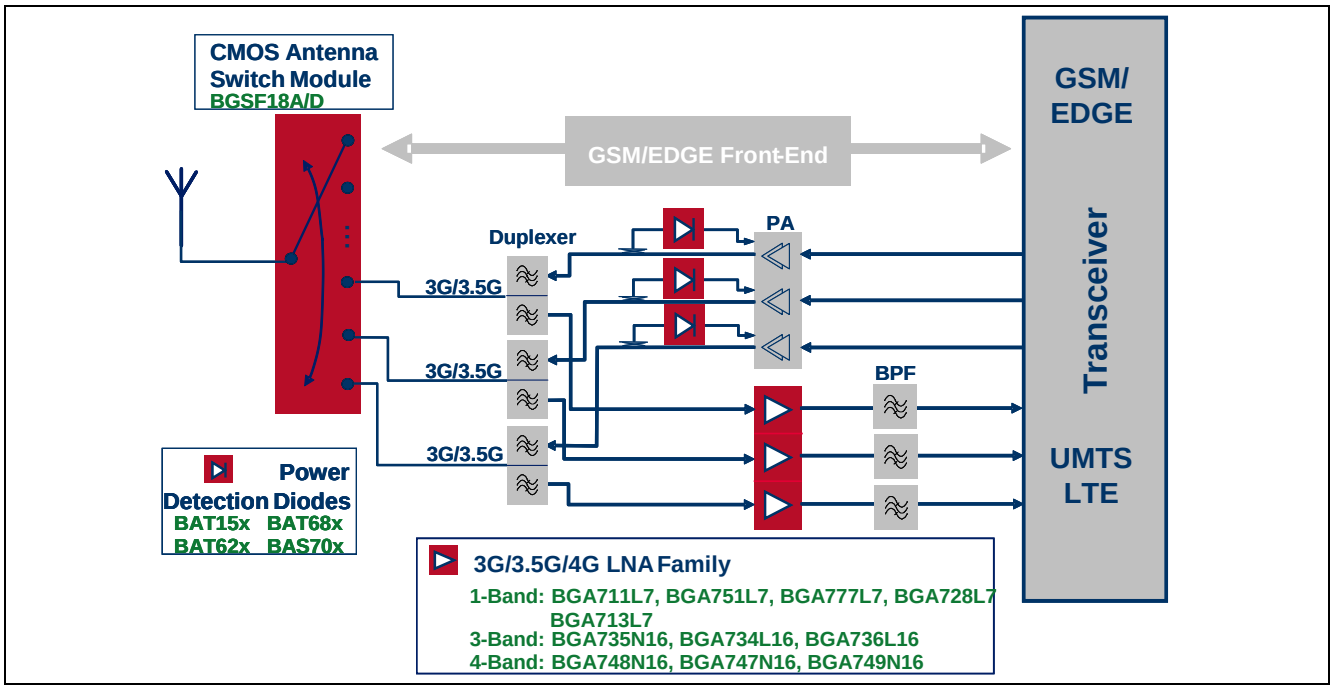

Figure 1 Example of Application Diagram of a 3-band RF front-end for 3G and 4G systems.

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 BGA711N7 Overview

2.1 Features

- Gain: 17 / -8 dB in high / low gain mode (f.e. at 2.14GHz)
- Noise figure: 1.1 dB in high gain mode (f.e. at 2.14GHz)
- Supply current: 3.6 / 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 x 1.3 x 0.39 mm)
- Pb-free (RoHS compliant) package

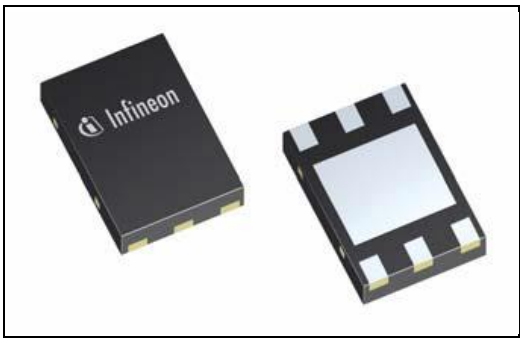

Figure 2 BGA711N7 in TSNP-7-1

2.2 Description

The BGA711N7 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 RF path can be easily converted into a 1.8GHz to 2.7GHz path by optimizing the input and output matching network. This document specifies the electrical parameters, pinout, application circuit and packaging of the chip.

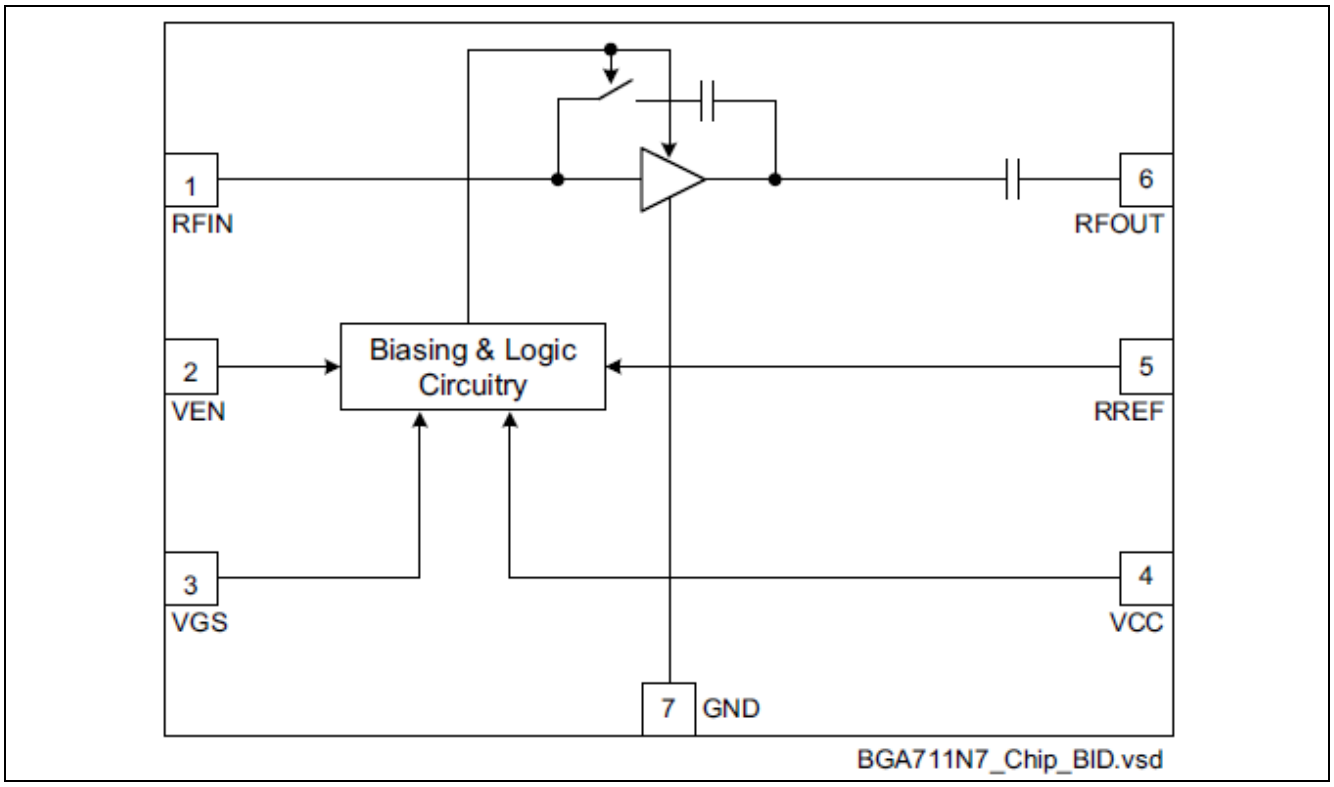

Figure 3 Equivalent Circuit of BGA711N7

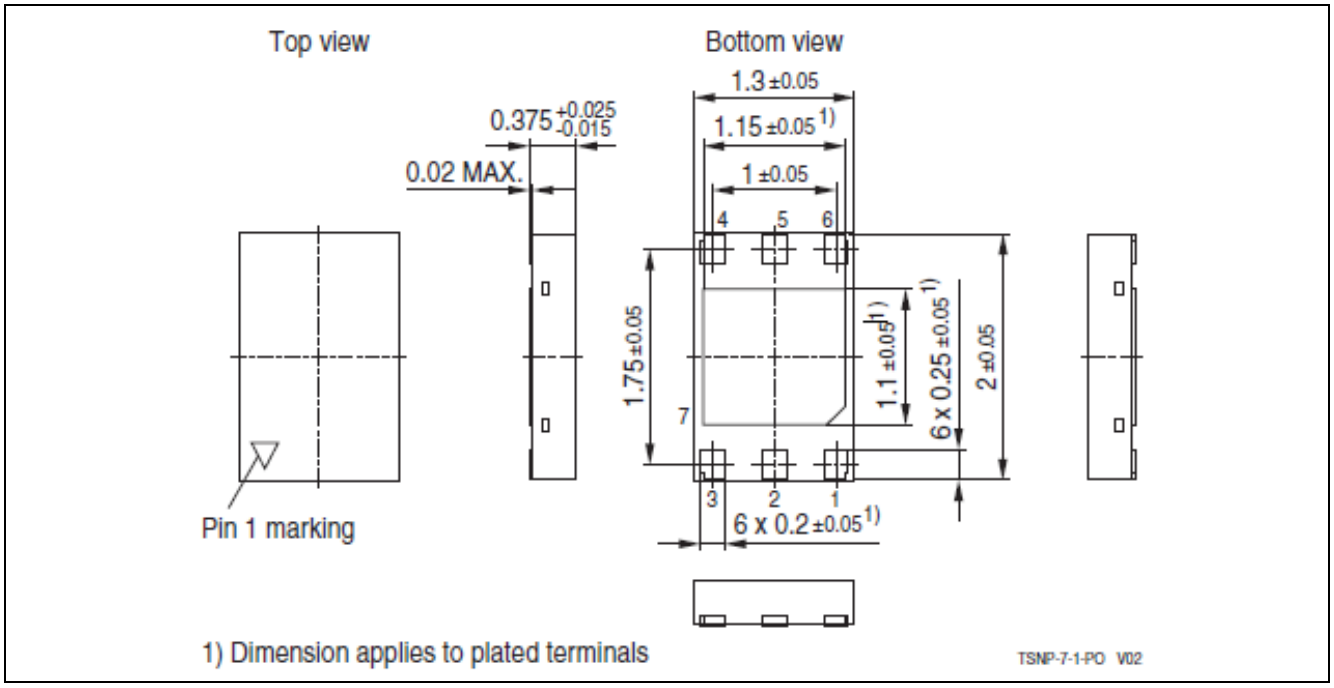

Figure 4 Package and pin connections of BGA711N7

Table 5 Pin Assignment of BGA711N7

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 for LNA and control circuitry

Table 6 Truth Table of BGA711N7

Control Voltage			
VEN	**VGS**	**HG**	**LG**
H	L	OFF	ON
H	H	ON	OFF
L	L	STANDBY	
L	H		

3 Application Circuit and Performance Overview

Device: BGA711N7

Application: BGA711N7 for LTE Applications Supporting Band 3 and 33 with High Gain of 18dB

PCB Marking:

3.1 Summary of Measurement Results

Table 7 Electrical Characteristics at V_{CC} = 2.8 V (at room temperature)
Band 3 (1805 – 1880 MHz), Band 33 (1900 – 1920 MHz), T_A = 25 °C, V_{CC} = V_{EN} =V_{GS} =2.8 V,

Parameter	Symbol	Value			Unit	Comment/Test Condition
DC Voltage	Vcc	2.8			V	
DC Current	Icc	4.2			mA	
Frequency Range	Freq	1805	1880	1920	MHz	
Gain	G	17.6	18	17.8		
Noise Figure	NF	1.01	1.05	1.03	dB	Loss of SMA and line of 0.11dB are substracted
Input Return Loss	RLin	13.5	14.5	14.5	dB	
Output Return Loss	RLout	11.2	17.5	11.9	dB	
Reverse Isolation	IRev	40	38.7	38.5	dB	
Input P1dB	IP1dB	-8.5	-7.8	-8.2	dBm	
Output P1dB	OP1dB	8.1	9.2	8.6	dBm	
Input IP3	IIP3	-4.7				f_1=1879 MHz, f_2=1880 MHz P_{in1}=P_{in2}=-30 dBm
Output IP3	OIP3	13.3			dBm	
Stability	k	>1			--	Measured up to 10 GHz

Table 8 Electrical Characteristics at V_{CC} = 2.8 V (at room temperature)
Band 3 (1805–1880 MHz), Band 33 (1900–1920 MHz), T_A = 25 °C, V_{CC} = V_{EN} =2.8 V, V_{GS} =0 V

Parameter	Symbol	Value			Unit	Comment/Test Condition
DC Voltage	Vcc	2.8			V	
DC Current	Icc	0.5			mA	
Frequency Range	Freq	1805	1880	1920	MHz	
Gain	G	-13	-10.9	-10.3		
Noise Figure	NF	13	10.9	10.3	dB	Loss of SMA and line of 0.11 dB are substracted
Input Return Loss	RLin	13.5	11.6	10.6	dB	
Output Return Loss	RLout	9.9	22.6	16.1	dB	
Reverse Isolation	IRev	13	10.9	10.2	dB	
Input P1dB	IP1dB	>10	>10	>10	dBm	
Input IP3	IIP3	3.3			dBm	f_1=1879 MHz, f_2=1880 MHz P_{in1}=P_{in2}=-25 dBm
Output IP3	OIP3	-7.6			dBm	
Stability	k	>1			--	Measured up to 10 GHz

3.2 BGA711N7 as LTE LNA for Band 3 and Band 33 (1805-1920 MHz)

This application note focuses on the Infineon's Single-Band LTE LNA, BGA711N7 tuned for the band 3 and band 33. It presents the performance of BGA711N7 with 2.8V power supply with high gain mode current 4.2 mA and 0.5 mA current for low gain mode.

The application circuit requires only five 0402 passive component. The component value is fine tuned to have optimal noise figure, gain, input and output matching. It has a gain of 18 dB in high gain mode and -10.9 dB gain in low gain mode. The circuit achieves input return loss better than 13.3 dB in high gain mode and 9.9 dB in low gain mode. The circuit also achieves output return loss better than 11.2 dB in high gain mode and 10.2 dB in low gain mode. At room temperature the noise figure is 1.05 dB (SMA and PCB losses are subtracted).

Furthermore, the circuit is unconditionally stable till 10 GHz. At Band 3 frequency, using two tones spacing of 1 MHz, the output third order intercept point, OIP3 reaches 13.3 dBm in high gain mode. Input P1dB of the BGA711N7 LNA is about -7.8 dBm at 1880 MHz for high gain mode and for low gain mode it is higher than 10 dBm. 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

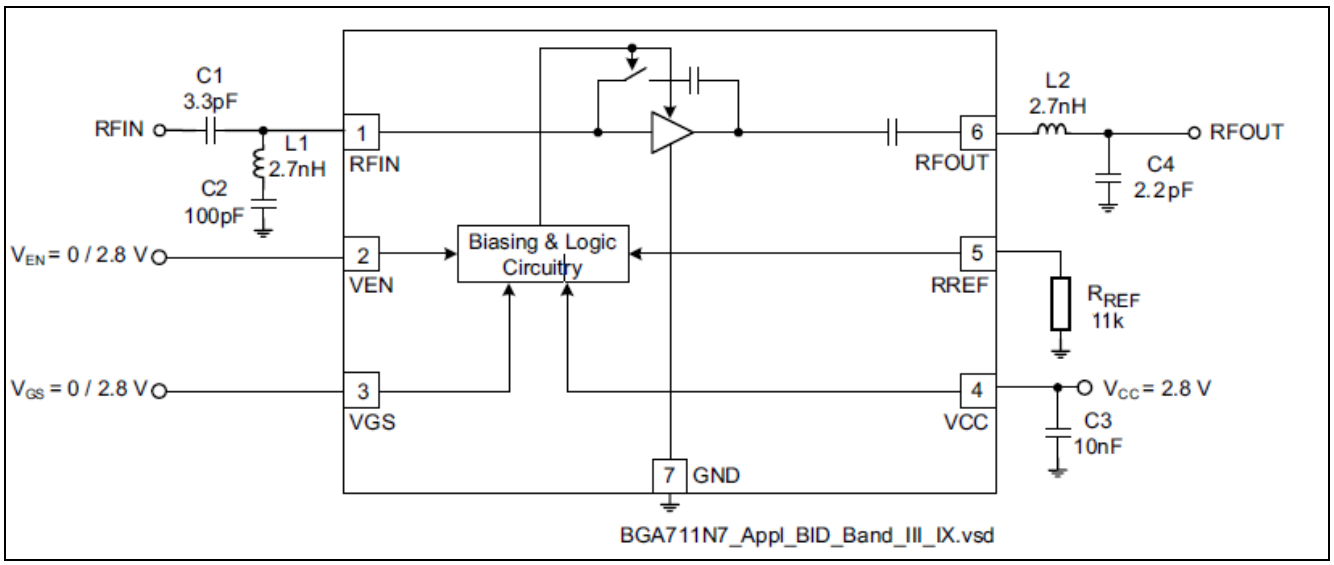

Figure 5 Schematics of the BGA711N7 Application Circuit

Table 9 Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	3.3	pF	0402	Various	DC block and Input matching
C2	100	pF	0402	Various	DC block
C3	10	nF	0402	Various	HF to ground
C4	2.2	pF	0402	Various	Output matching
L1	2.7	nH	0402	Murata LQW series	Input matching
L2	2.7	nH	0402	Murata LQW series	Output matching
R_{REF}	11	kΩ	0402	Various	Bias current Setting
N1	BGA711N7	TSNP-6-2		Infineon	SiGe LNA

4 Measurement Graphs

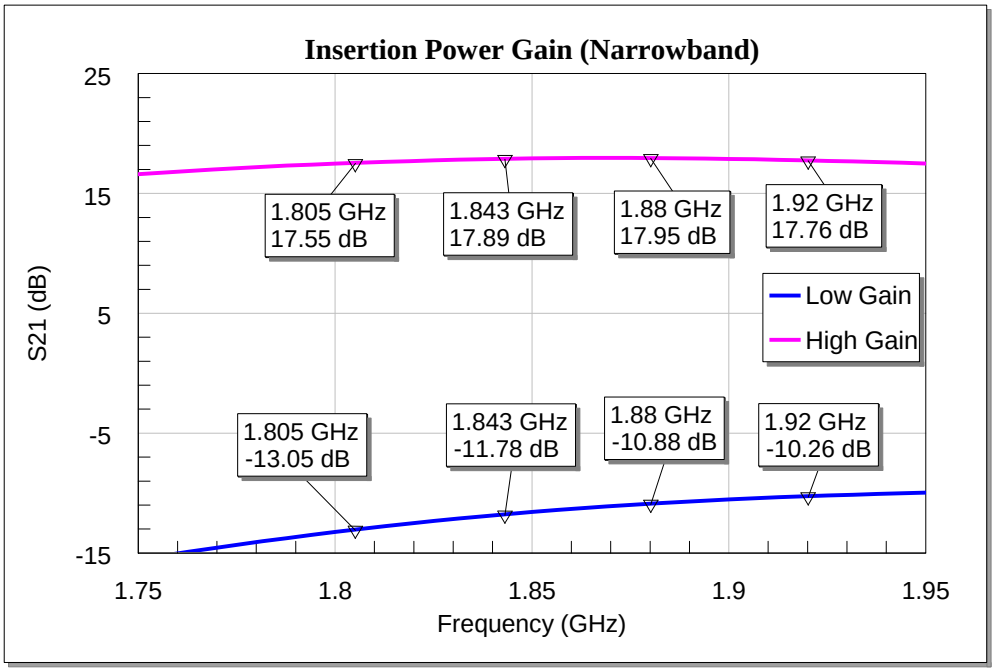

Figure 6 Insertion Power Gain (Narrowband) of the BGA711N7 for Band-3 and Band-33 Applications

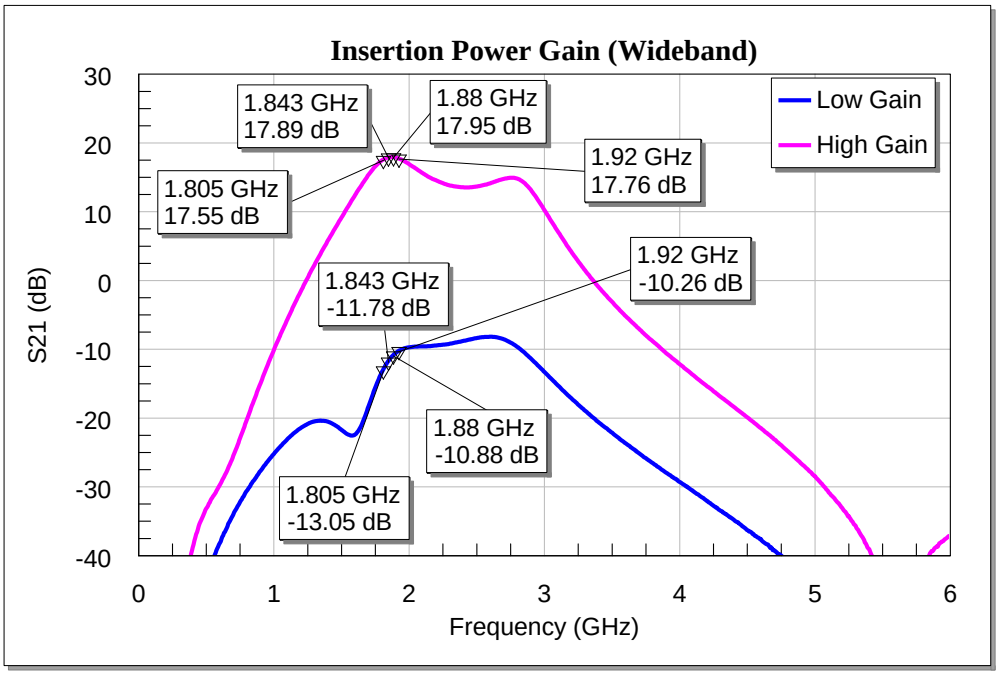

Figure 7 Insertion Power Gain (Wideband) of the BGA711N7 for Band-3 and Band-33 Applications

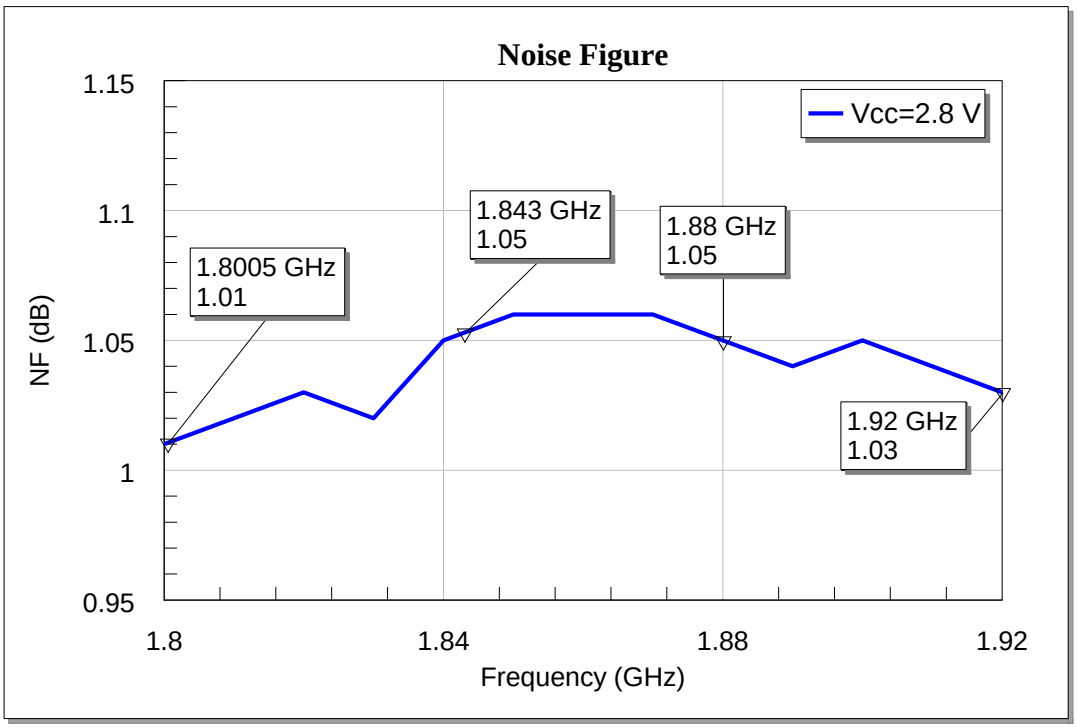

Figure 8 Noise Figure of the BGA711N7 for Band-3 and Band-33 Applications

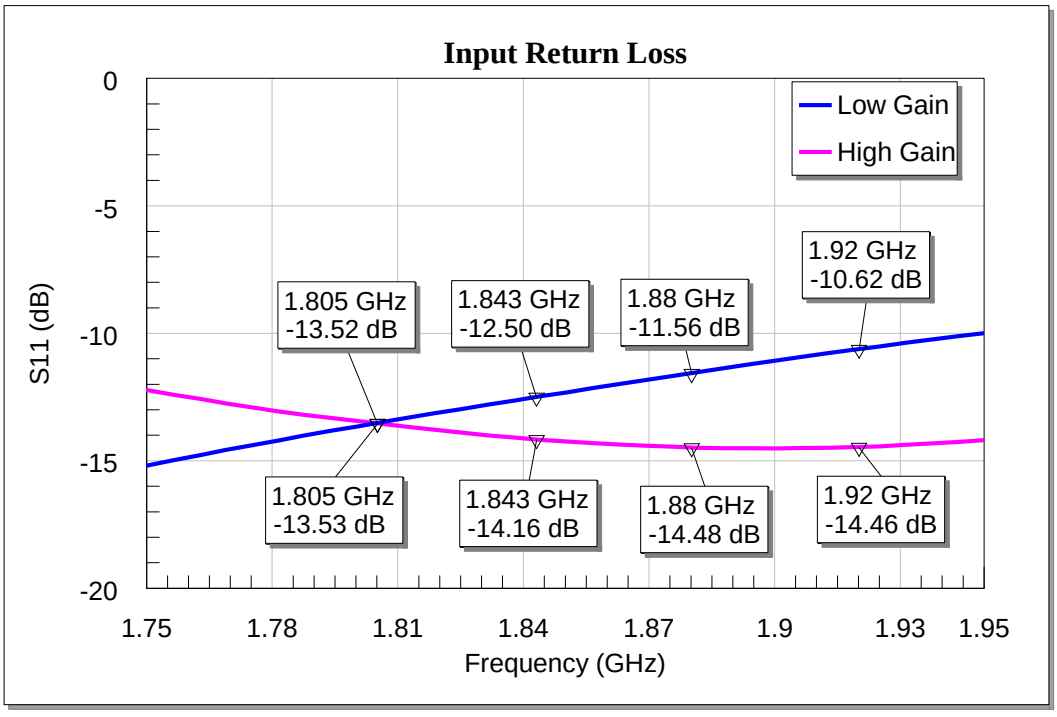

Figure 9 Input Matching of the BGA711N7 for Band-3 and Band-33 Applications

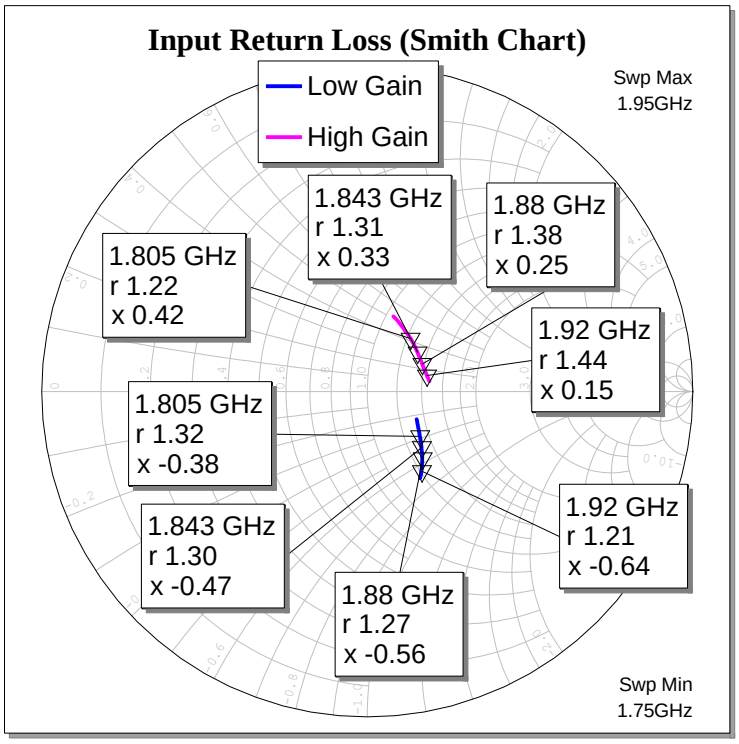

Figure 10 Input Matching (Smith Chart) of the BGA711N7 for Band-3 and Band-33 Applications

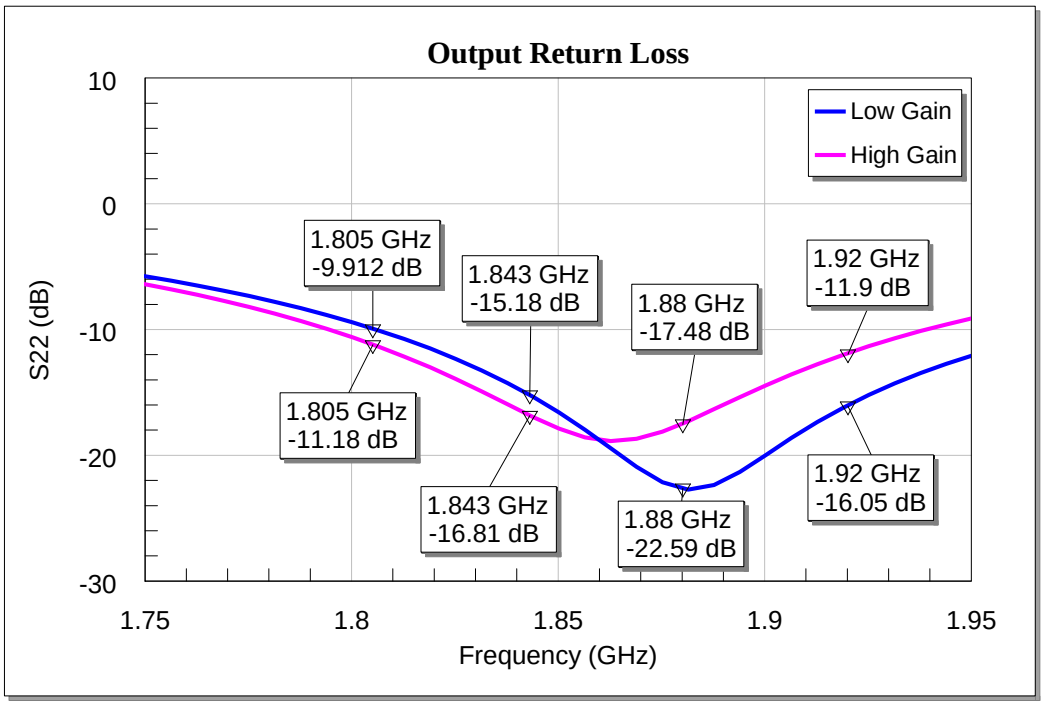

Figure 11 Output Matching of the BGA711N7 for Band-3 and Band-33 Applications

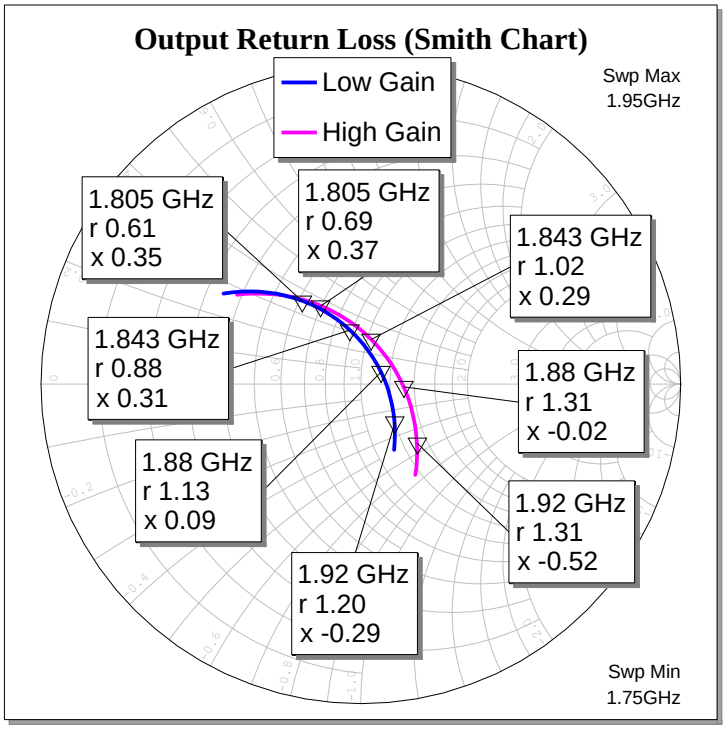

Figure 12 Output Matching (Smith Chart) of the BGA711N7 for Band-3 and Band-33 Applications

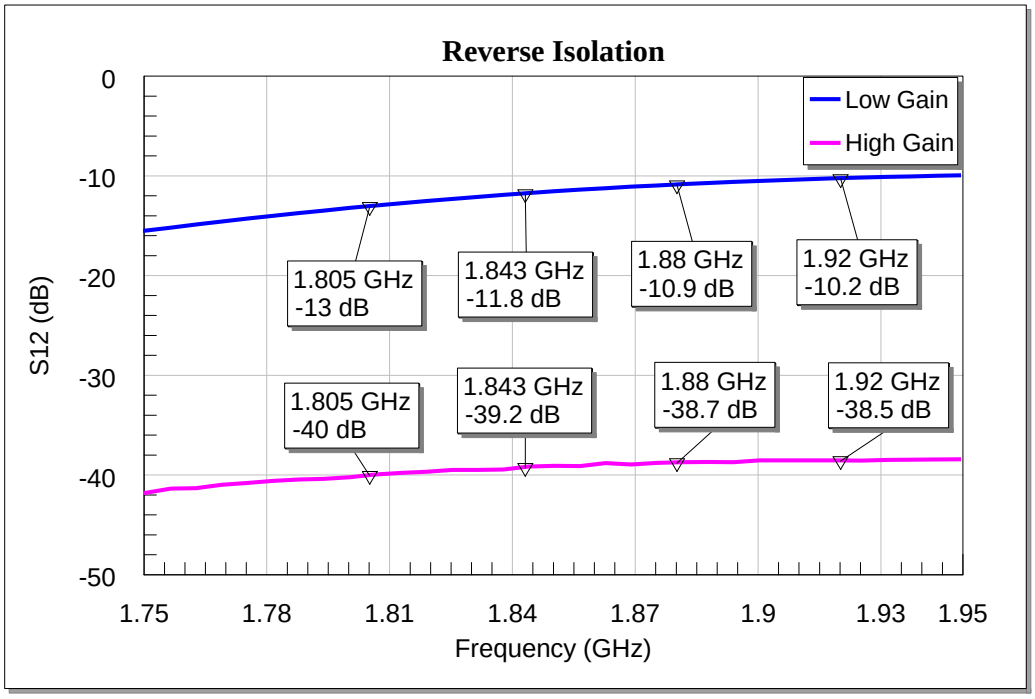

Figure 13 Reverse Isolation of the BGA711N7 for Band-3 and Band-33 Applications

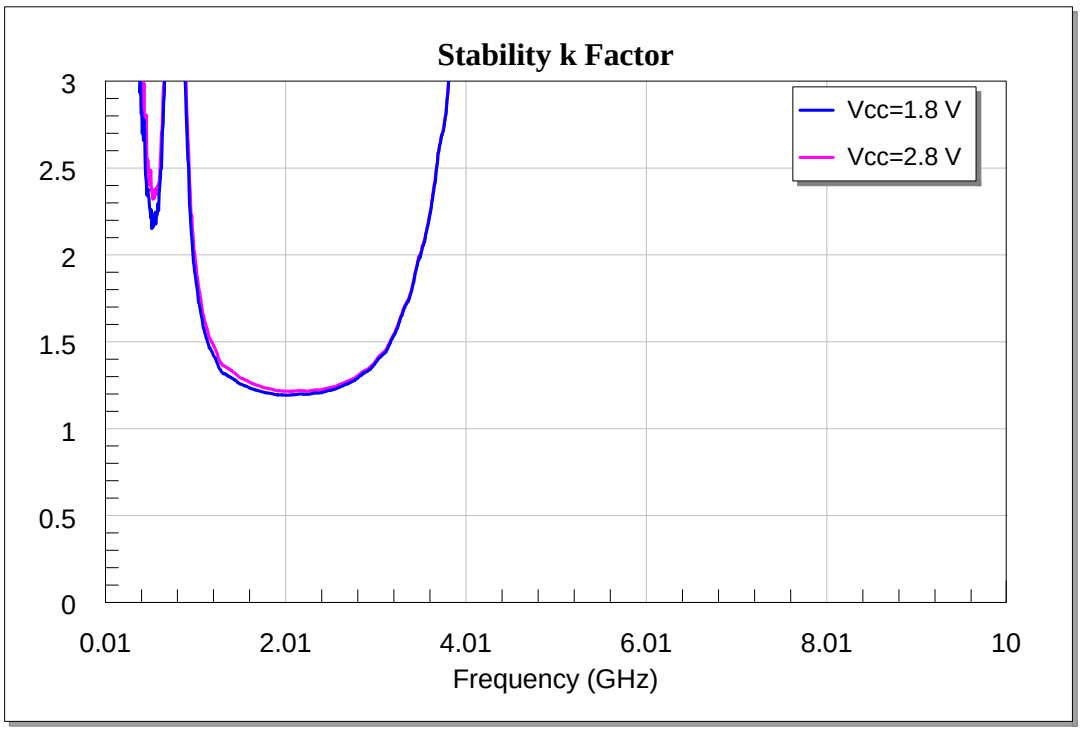

Figure 14 Stability K-factor of the BGA711N7 for Band-3 and Band-33 Applications

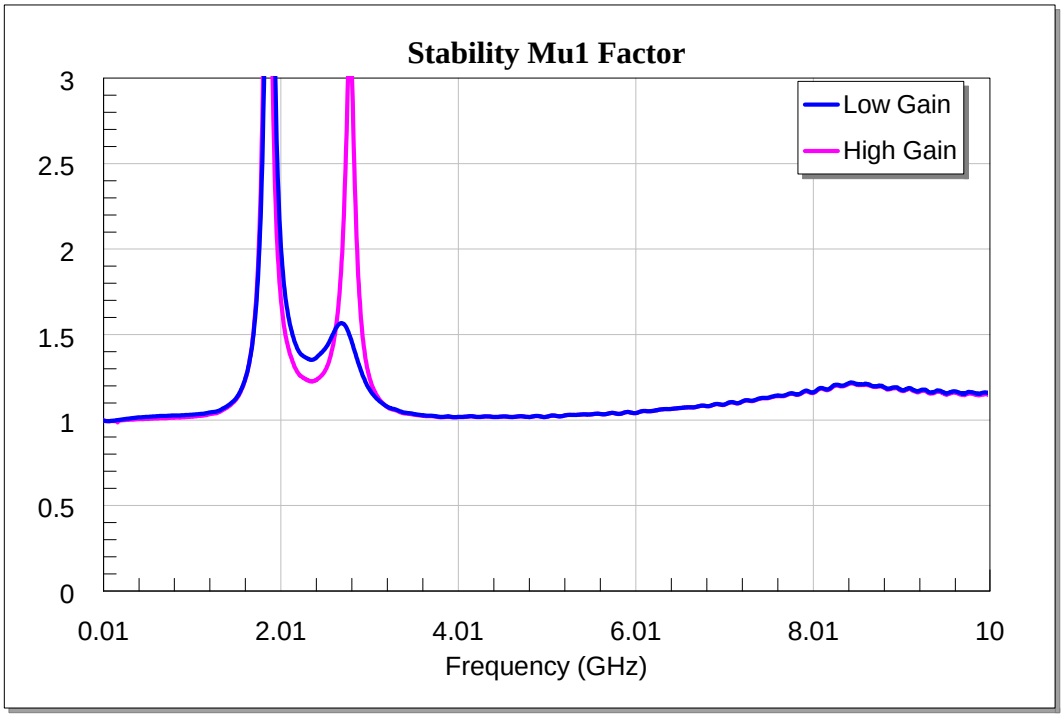

Figure 15 Stability Mu1-factor of the BGA711N7 for Band-3 and Band-33 Applications

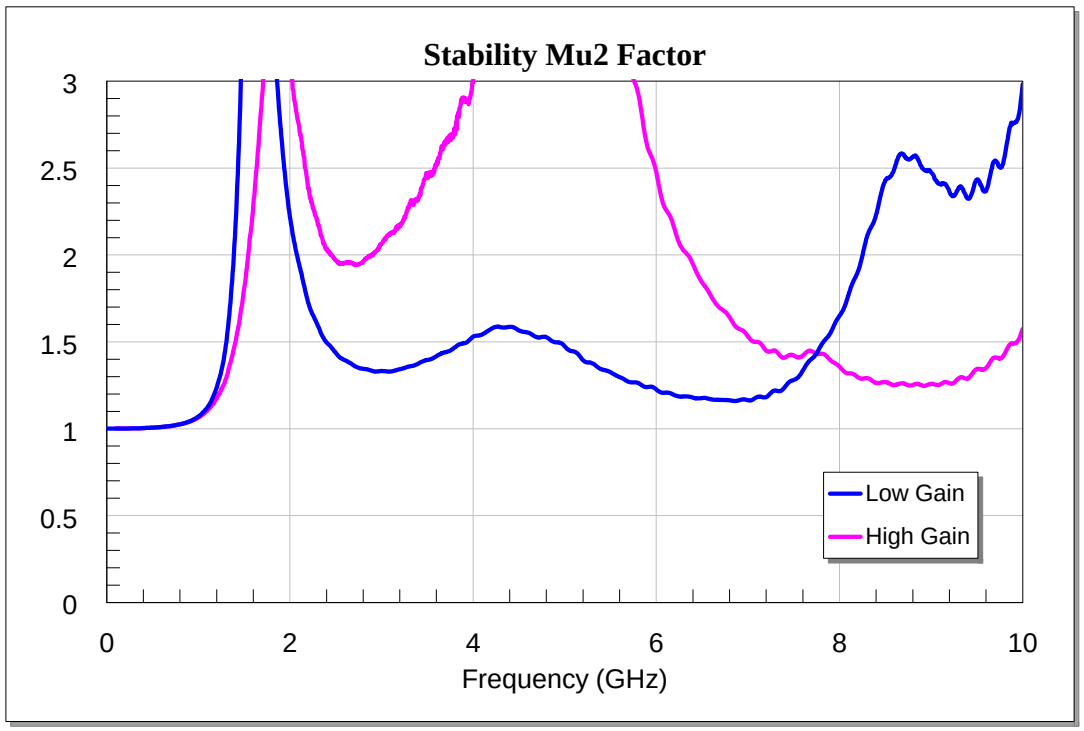

Figure 16 Stability Mu2-factor of the BGA711N7 for Band-3 and Band-33 Applications

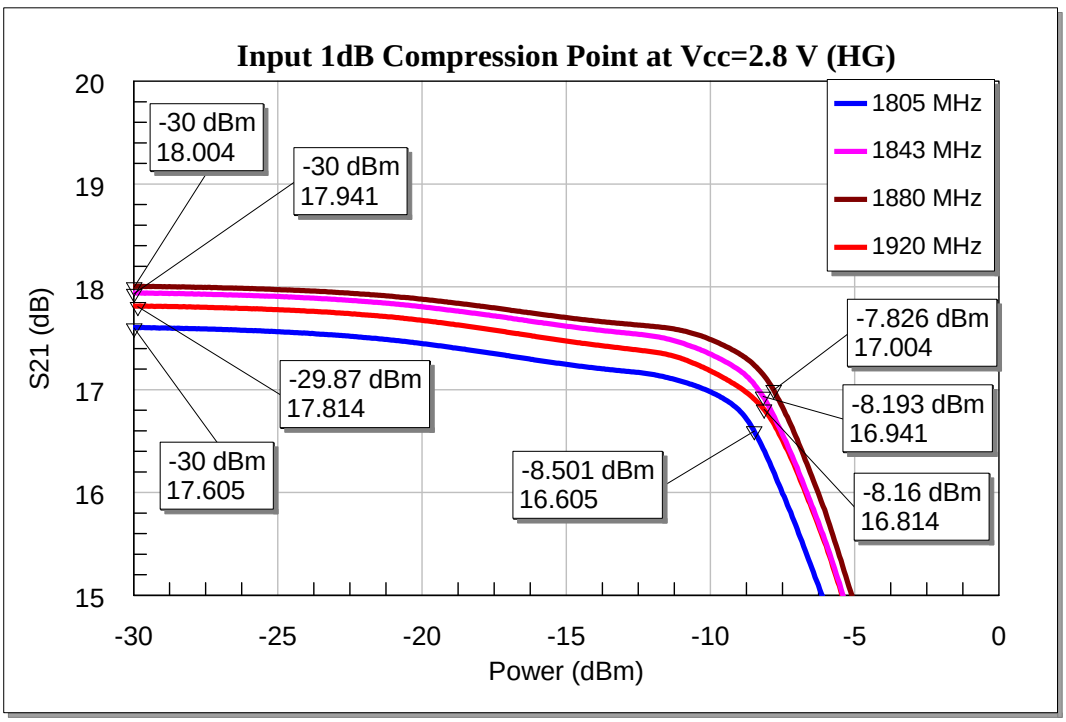

Figure 17 Input 1dB compression point of the BGA711N7 for Band-3 and Band-33 Applications (HG)

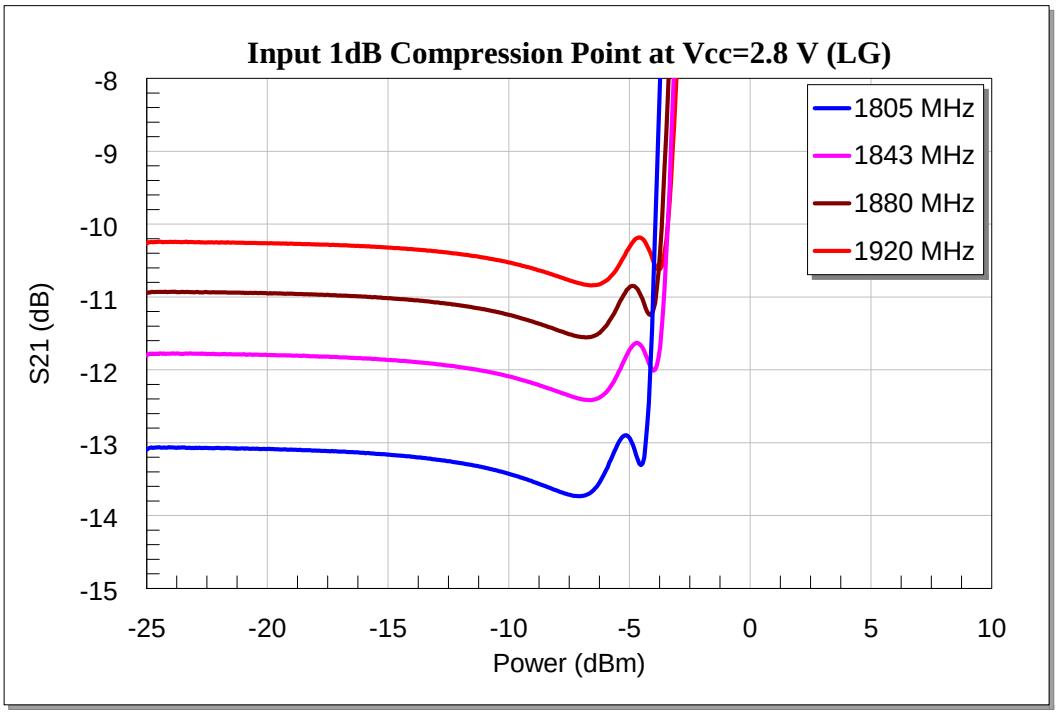

Figure 18 Input 1dB compression point of the BGA711N7 for Band-3 and Band-33 Applications (LQ)

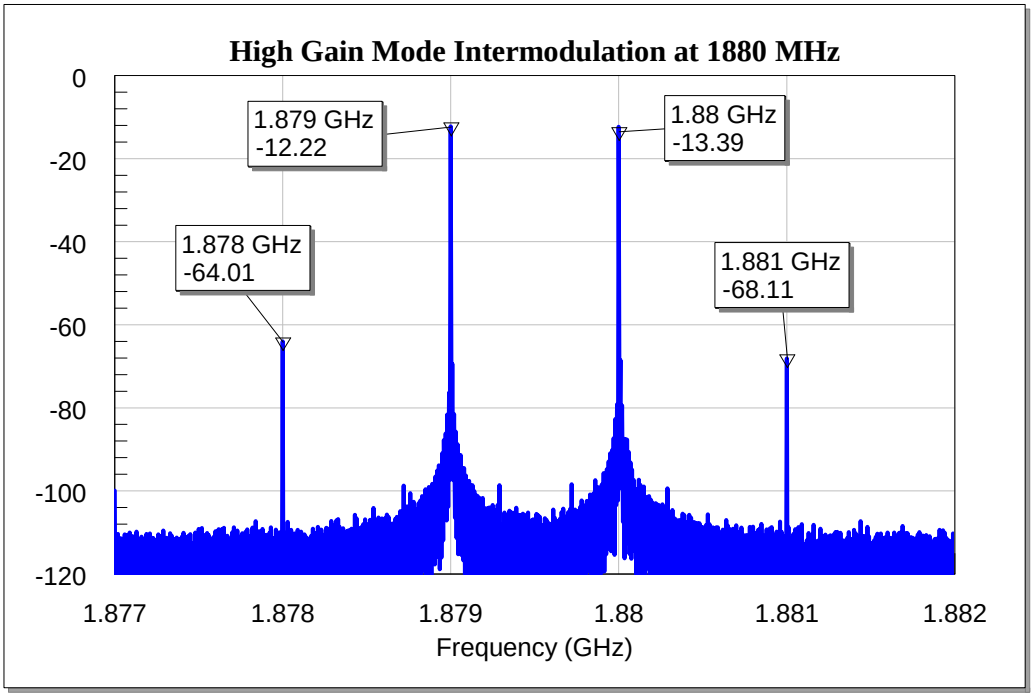

Figure 19 Input 3rd interception point of the BGA711N7 for Band-3 and Band-33 Applications (HG)

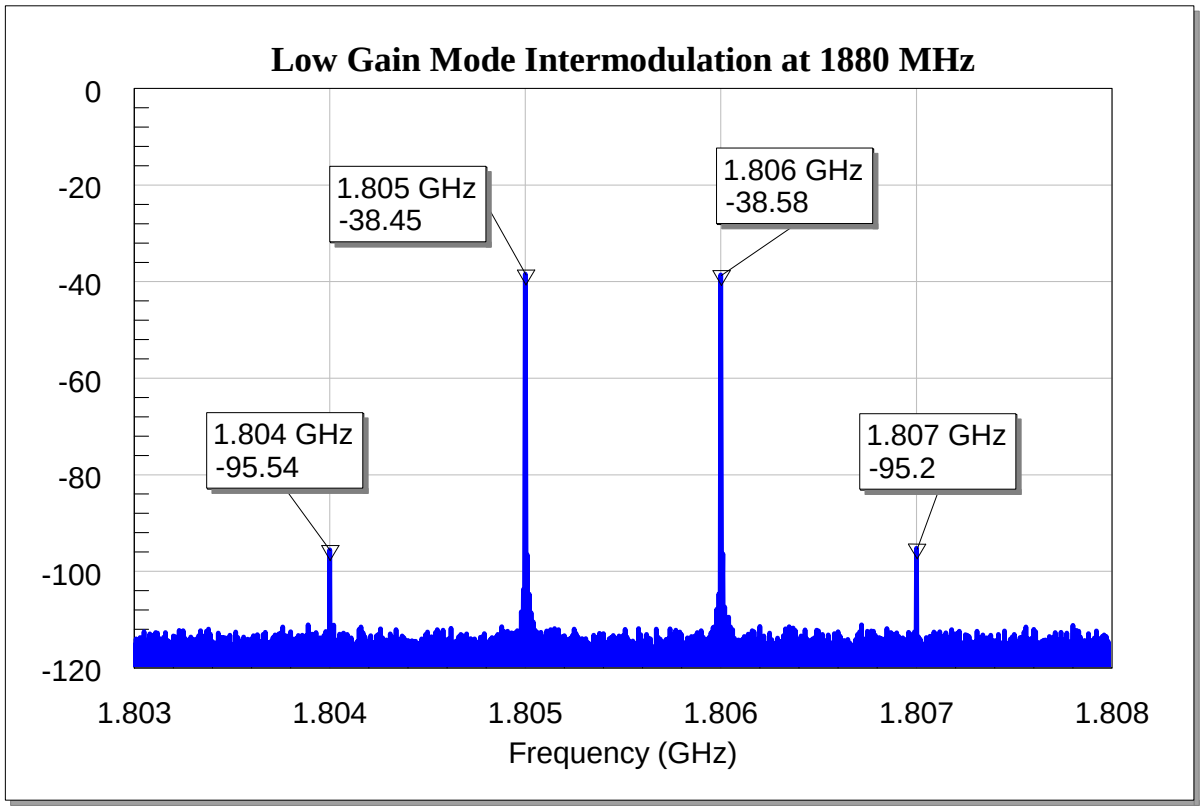

Figure 20 Input 3rd interception point of the BGA711N7 for Band-3 and Band-33 Applications (LG)

5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB Marking:

PCB material: FR4

ε_r of PCB material: 4.3

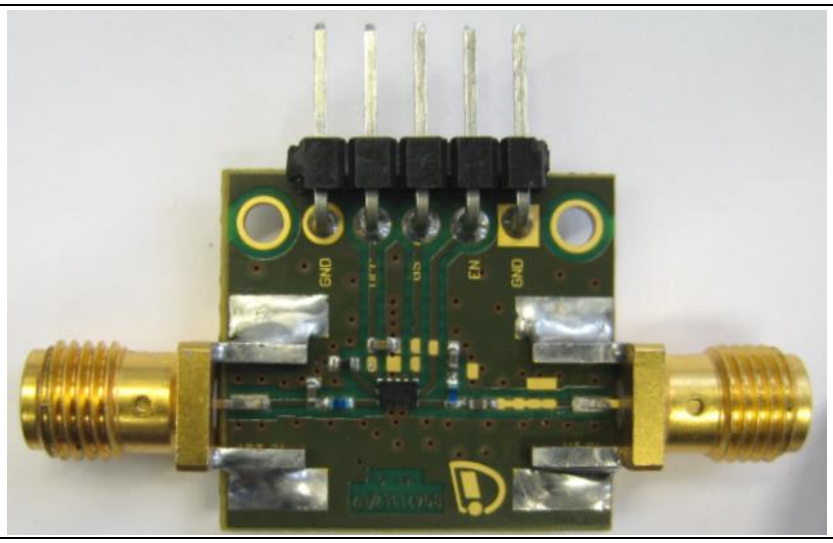

Figure 21 Photo Picture of Evaluation Board (overview) ,

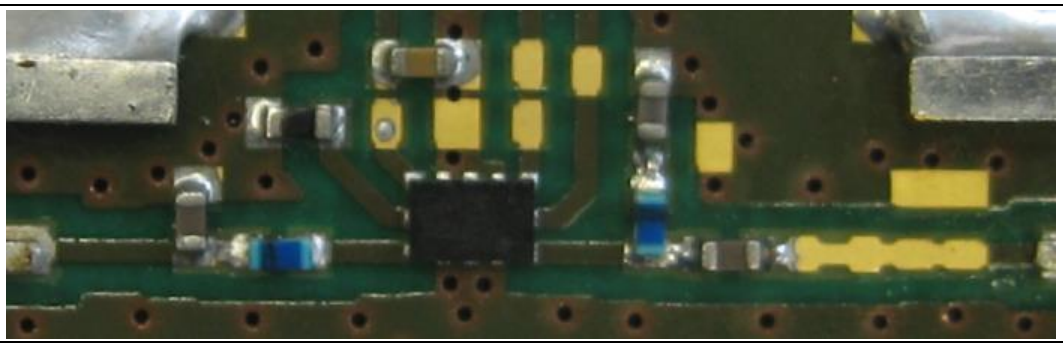

Figure 22 Photo Picture of Evaluation Board (detailed view)

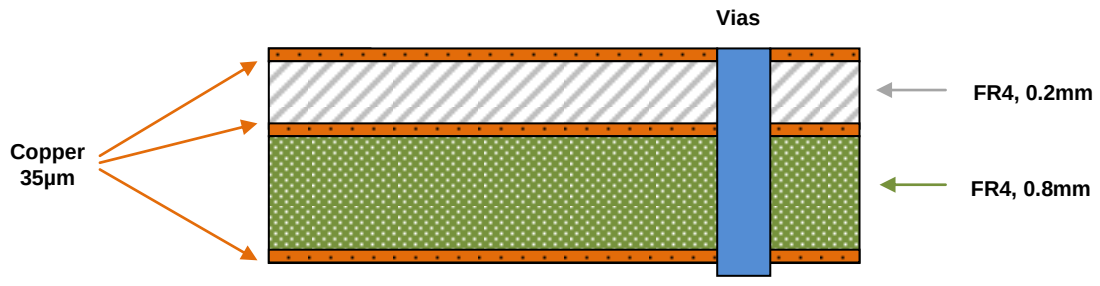

Figure 23 PCB layer stack

6 Authors

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7 Remark

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

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