BGA713N7

Single-Band UMTS LNA

Low Noise Amplifier using BGA713N7 for UMTS Apllications Supporting Band 20 (791- 821 MHz)

Application Note AN344

Revision: Rev. 1.0
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RF and Protection Devices

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Previous Revision:

Page	Subjects (major changes since last revision)

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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 (UMTS), 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 UMTS and LTE bands worldwide.

Table 1 UMTS/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.

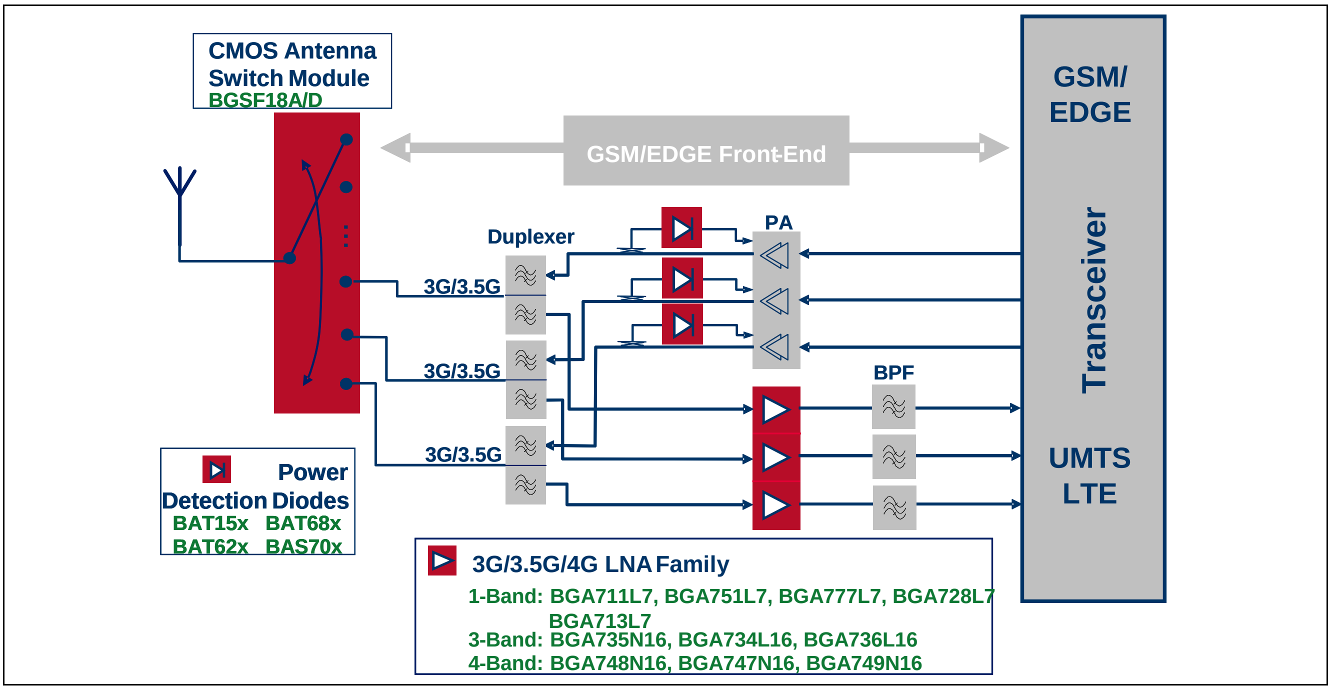

Figure 1 **Example of Application Diagram of a 3-band RF front-end for 3G and 4G systems.**

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.

- Single-band LNAs like BGA711L7 / BGA711N7 for high-band (HB, 1700MHz-2300MHz), BGA777L7 / BGA777N7 for high-band (2300MHz-2700MHz) or BGA751L7 / BGA751N7 for low-band (LB, 700-1000MHz) are available. BGA713L7 / BGA713N7 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.

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 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		
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 BGA713N7 Overview

2.1 Features

- Gain: 16.0 / -8.1 dB in high / low gain mode
- Noise figure: 1.15 dB in high gain mode
- Supply current: 4.8 / 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

RoHS

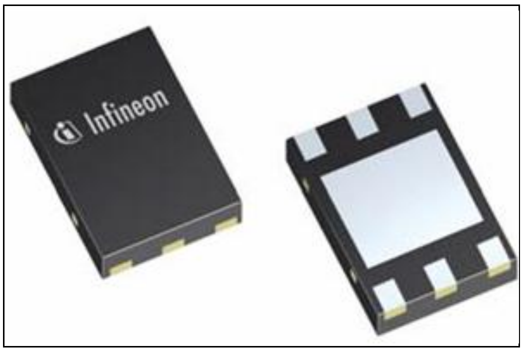

Figure 2 BGA713N7 in TSNP-7-1

2.2 Description

The BGA713N7 is a low current single-band low noise amplifier MMIC for UMTS bands 12, 13, 14, 17 and 20. 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. This document specifies electrical parameters, pinout, application circuit and packaging of the chip.

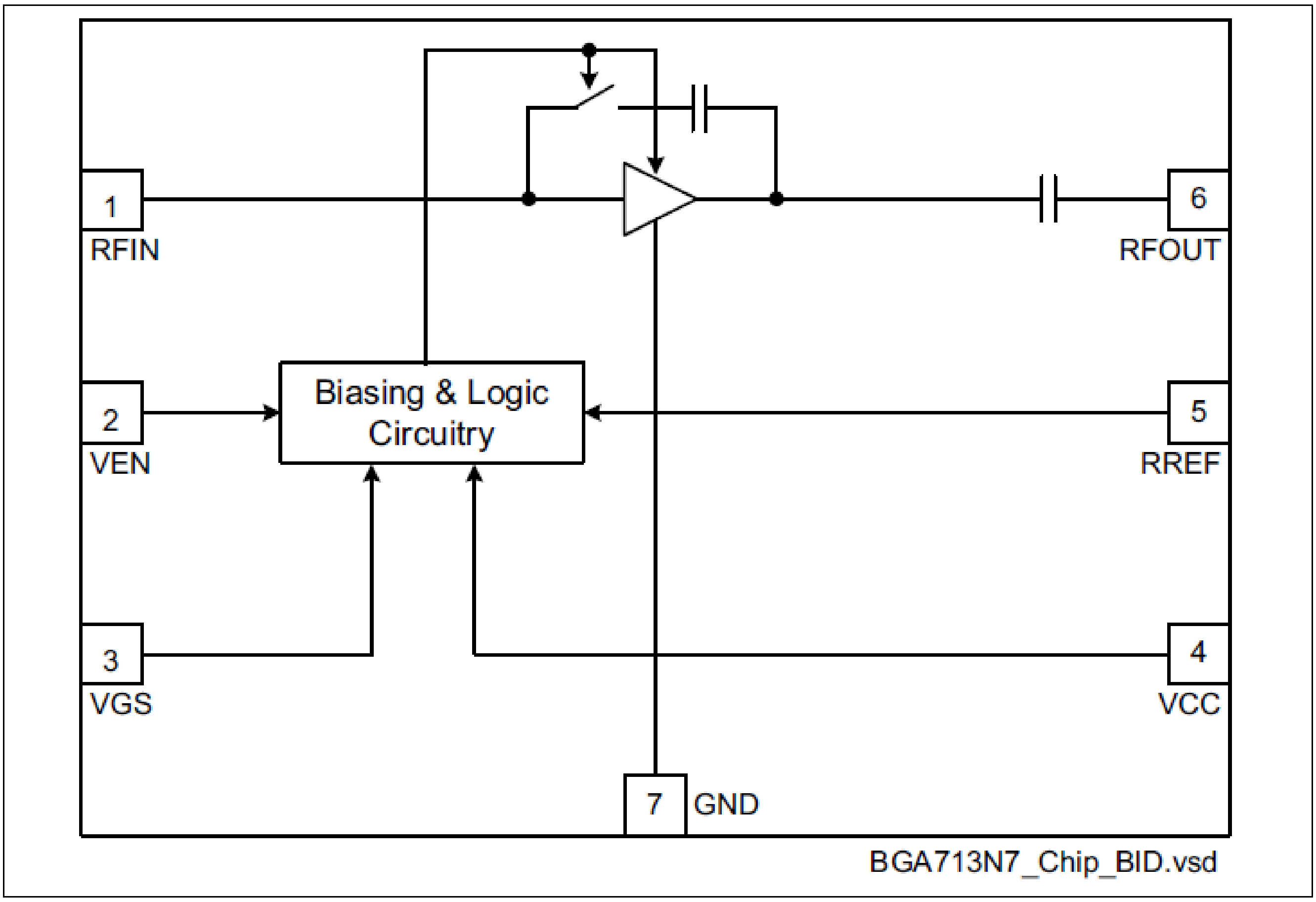

Figure 3 Equivalent Circuit of BGA713N7

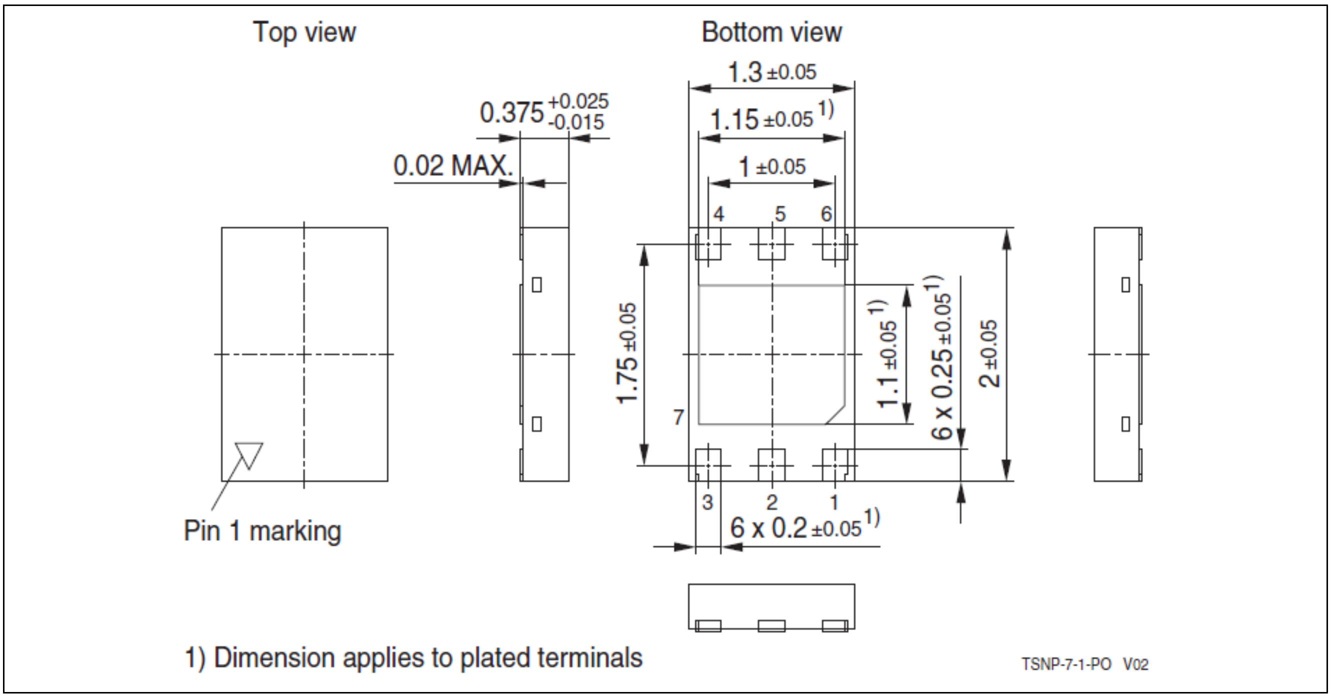

Figure 4 Package and pin connections of BGA713N7

Table 4 Pin Assignment of BGA713N7

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	Ground Package paddle; ground connection and control circuitry

3 Application Circuit and Performance Overview

Device: BGA713N7

Application: Low Noise Amplifier using BGA713N7 for UMTS Apllications Supporting Band 20 (791- 821 MHz)

PCB Marking: BGA713L7 V1.0

3.1 Summary of Measurement Results

Table 5 Electrical Characteristics (at room temperature)
Band 20, T_A = 25 °C, V_{CC} = 2.8 V, V_{EN}=2.8 V, R_{REF} = 5.6 kΩ 1)

Parameter	Symbol	Value		Unit	Comment/Test Condition
Gain Mode		High Gain (V_{GS}=2.8 V)	Low Gain (V_{GS}=0.0 V)		
Frequency Range	Freq	791-821	791-821	MHz	
DC Voltage	Vcc	2.8	2.8	V	
DC Current	Icc	4.8	0.5	mA	
Gain	G	16.0	-8.1	dB	
Noise Figure	NF	1.2	8.1	dB	Loss of input line of 0.05dB included
Input Return Loss	RLin	13.9	14.5	dB	
Output Return Loss	RLout	11.5	23.8	dB	
Reverse Isolation	IRev	8.1	37.9	dB	
Input P1dB	IP1dB	-5.7	-10.3	dBm	Measured @ 806 MHz
Output P1dB	OP1dB	-9.3	-19.4	dBm	
Input IP3	IIP3	-7.8	-0.6	dBm	Power @ Input: -35 dBm (on mode) f_1= 806 MHz, f_2= 807 MHz
Output IP3	OIP3	8.2	-8.7	dBm	
Stability	k	>1	>1	--	Measured up to 10 GHz

3.2 BGA713N7 as 791-821 MHz LNA for UMTS

This application note focuses on the Infineon's Single-Band UMTS LNA BGA713N7 tuned for the band 20. It presents the performance of BGA713N7 with an external reference resistor of 5.6 kΩ which enables the device to work with a current of 4.8 mA (High Gain Mode) or 0.5 mA (Low Gain Mode) at single supply voltage of 2.8 V.

The component values are fine tuned so as to have optimal noise figure, gain, input and output matching. The circuit requires seven 0402 passive components. It has a gain of 16.0 dB in High Gain Mode and -8.1 dB in Low Gain Mode. The circuit achieves input return loss better than 13 dB, as well as output return loss better than 11 dB in High Gain Mode. For Low Gain Mode it accomplishs input return loss of 14 dB and output return loss better than 19 dB. At room temperature the noise figure is 1.2 dB (SMA and PCB losses are subtracted) in High Gain Mode and 8.1 dB in Low Gain Mode.

Furthermore, the circuit is unconditionally stable till 8 GHz for both modes. At Band 20 frequency, using two tones spacing of 1 MHz, the output third order intercept point IIP3 reaches -7.8 dBm in High Gain Mode and -0.6 dBm in Low Gain Mode. Input P1dB of the BGA713N7 LNA is about –5.7 dBm (High Gain Mode) and -10.3 dBm (Low Gain Mode). 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

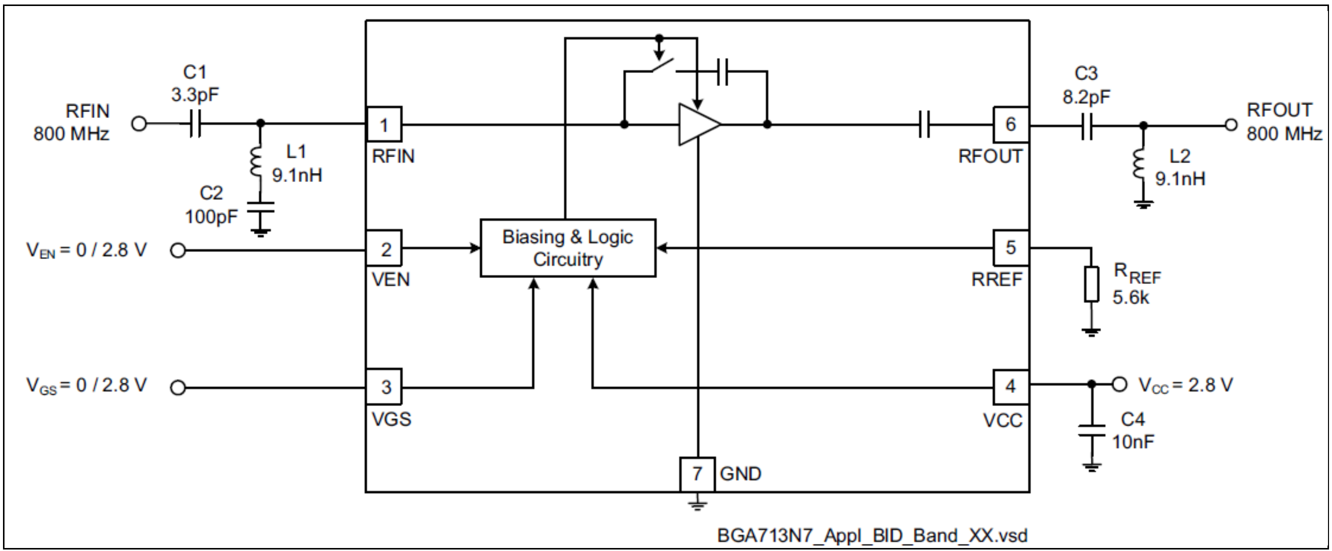

Figure 5 Schematics of the BGA713N7 Application Circuit

Table 6 Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	3.3	pF	0402	Various	Input matching / DC block
C2	100	pF	0402	Various	DC block
C3	8.2	pF	0402	Various	Output matching
C4	10	nF	0402	Various	HF to ground
L1	9.1	nH	0402	Murata LQW series	Input matching
L2	9.1	nH	0402	Murata LQW series	Output matching
R_{Ref}	5.6	kΩ	0402	Various	

4 Measurement Graphs High Gain Mode

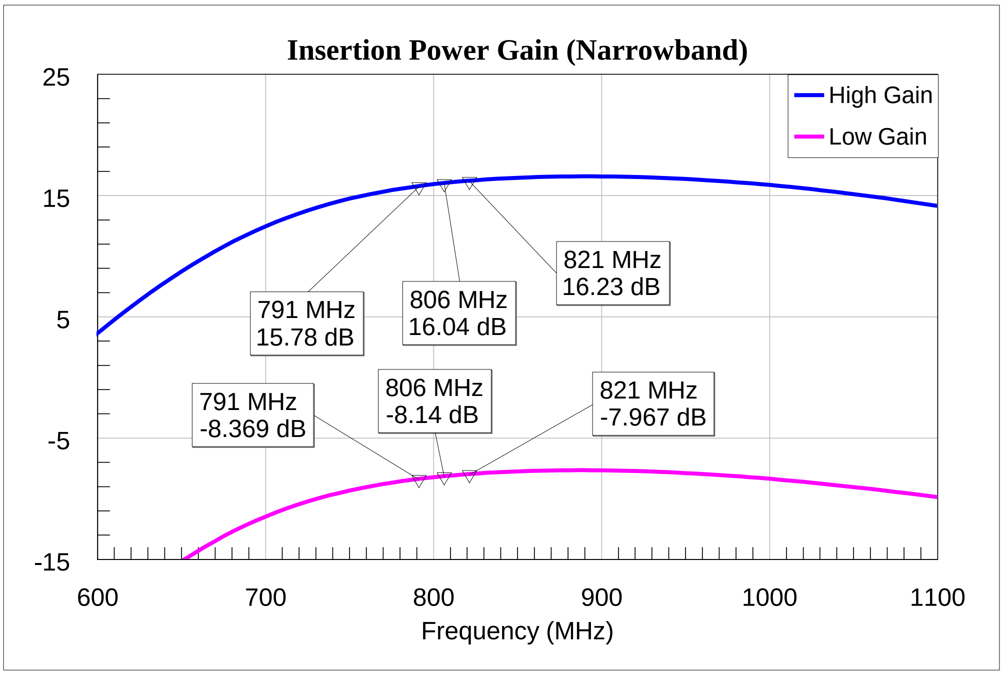

Figure 6 Insertion Power Gain (Narrowband) of the BGA713N7 for Single-Band UMTS LNA Applications at 2.8V

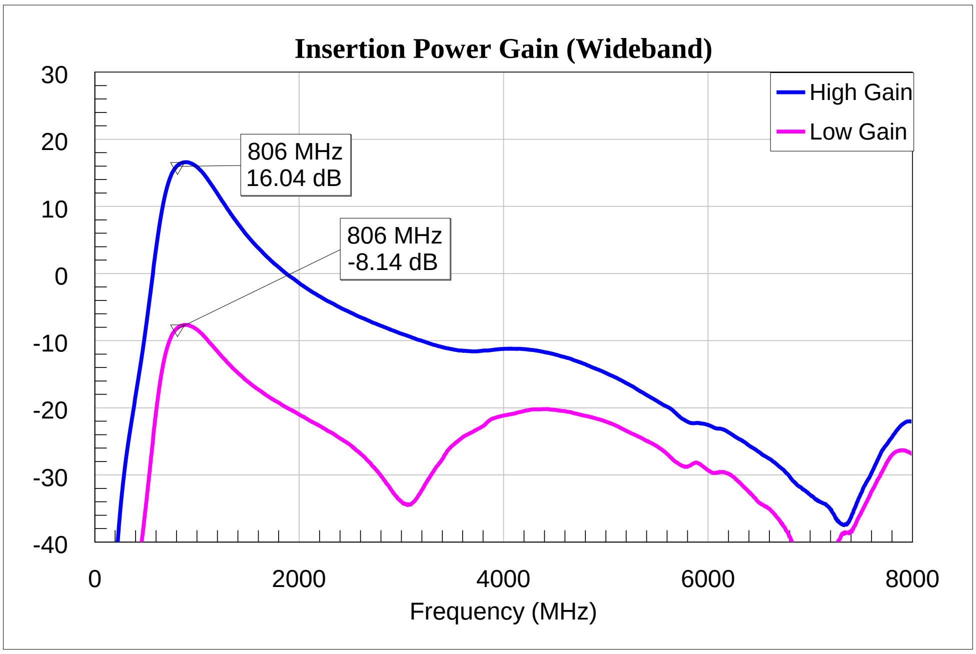

Figure 7 Insertion Power Gain (Wideband) of the BGA713N7 for Single-Band UMTS LNA Applications at 2.8V

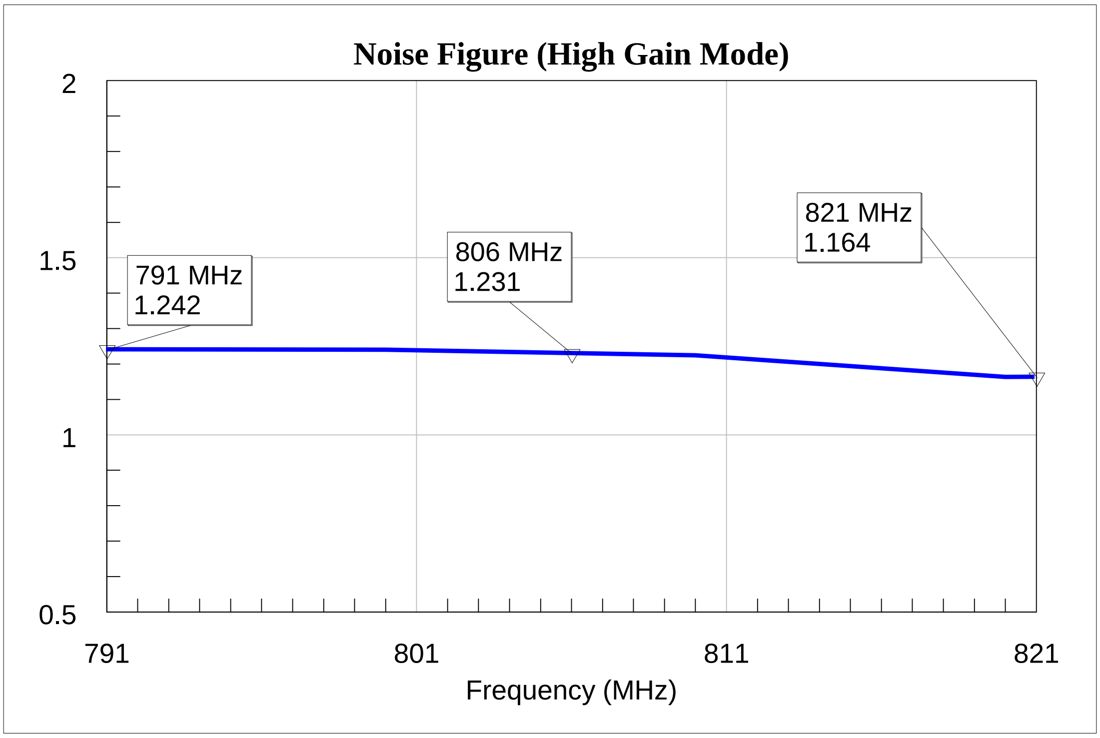

Figure 8 Noise Figure of the BGA713N7 for Single-Band UMTS LNA Applications at 2.8V

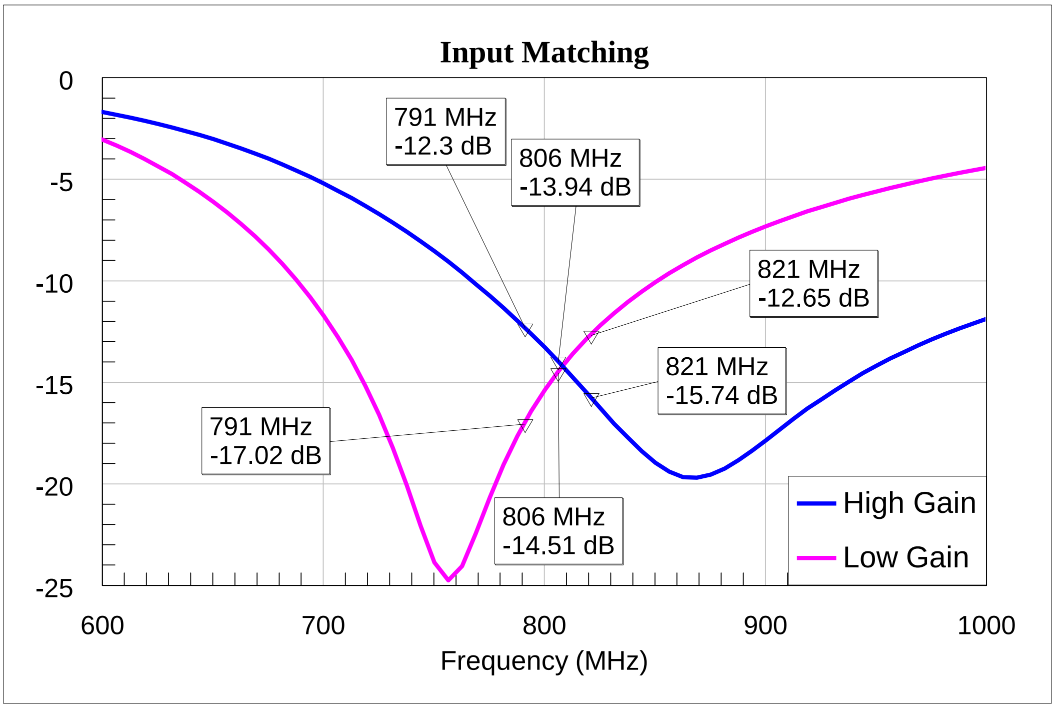

Figure 9 Input matching of the BGA713N7 for Single-Band UMTS LNA Applications at 2.8V

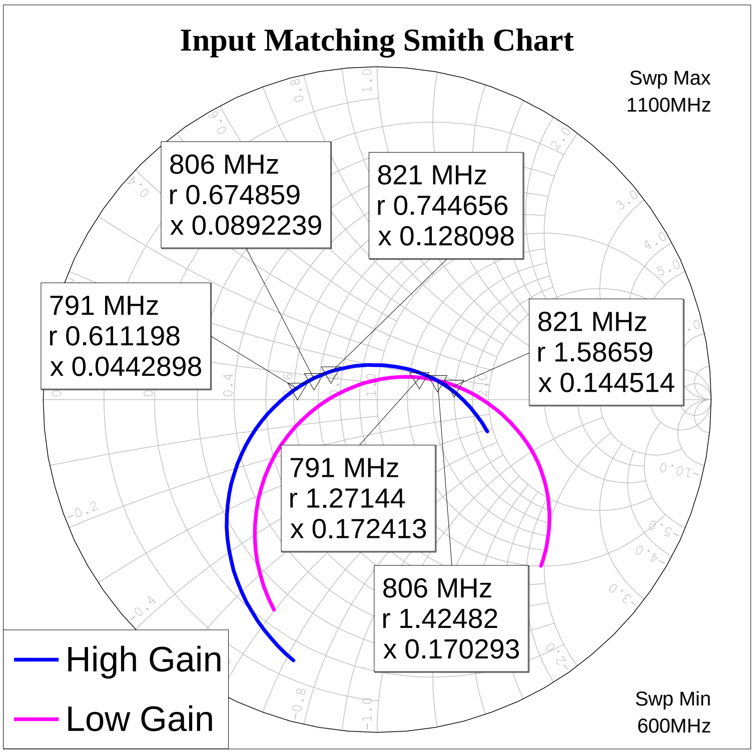

Figure 10 Input matching (Smith Chart) of the BGA713N7 for Single-Band UMTS LNA Applications at 2.8V

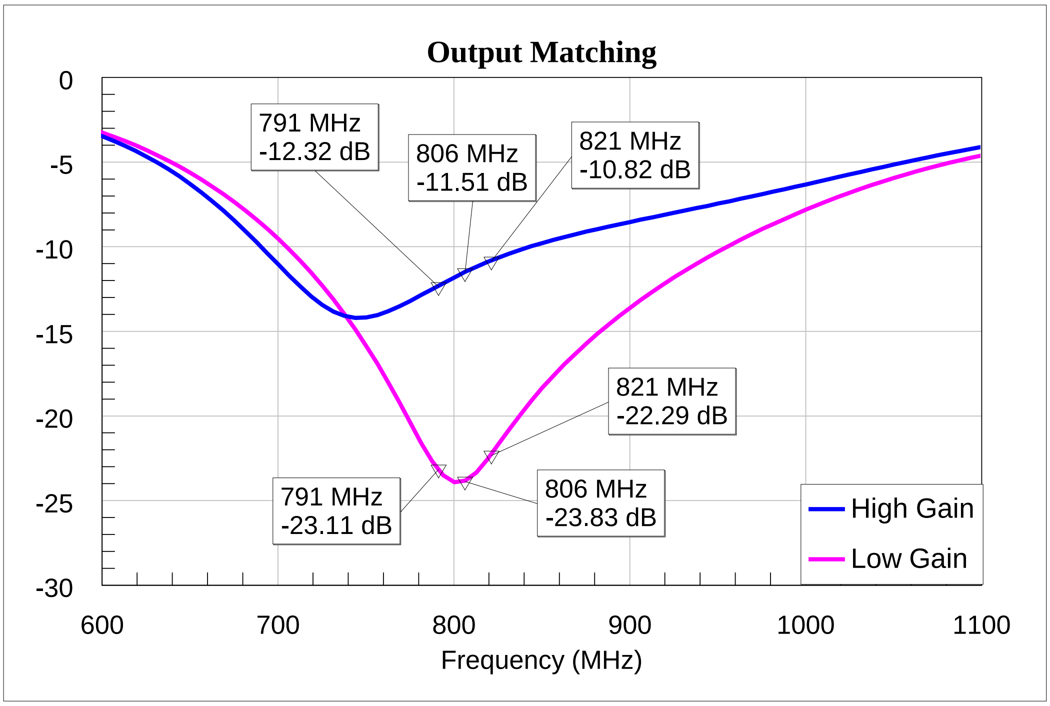

Figure 11 Output matching of the BGA713N7 for Single-Band UMTS LNA Applications at 2.8V

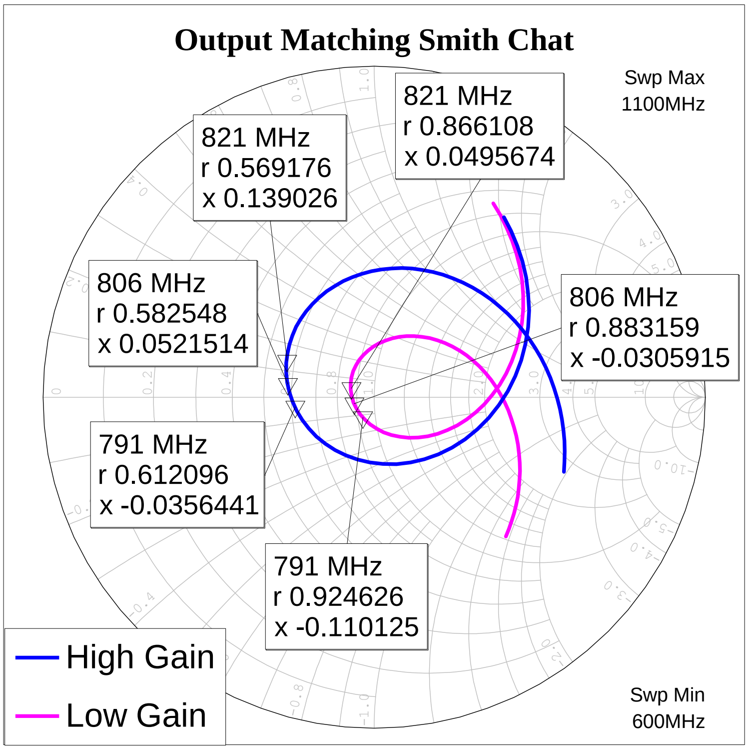

Figure 12 Output matching (Smith Chart) of the BGA713N7 for Single-Band UMTS LNA Applications at 2.8V

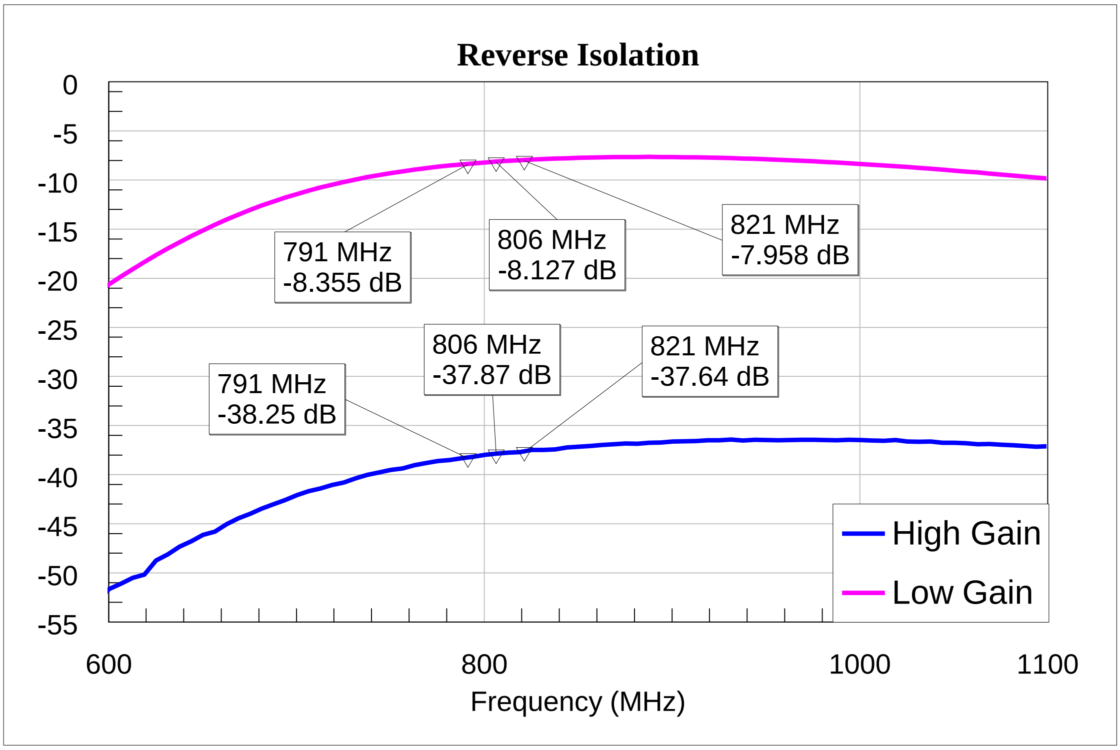

Figure 13 Reverse isolation of the BGA713N7 for Single-Band UMTS LNA Applications at 2.8V

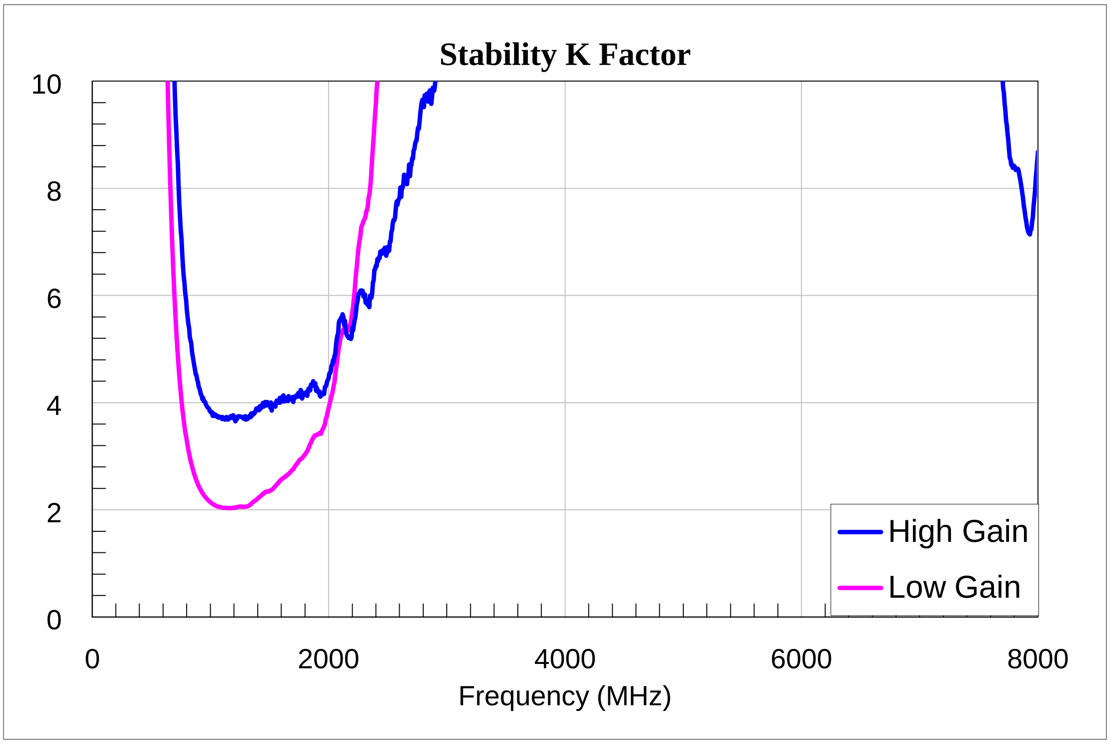

Figure 14 Stability K-facetor of the BGA713N7 for Single-Band UMTS LNA Applications at 2.8V

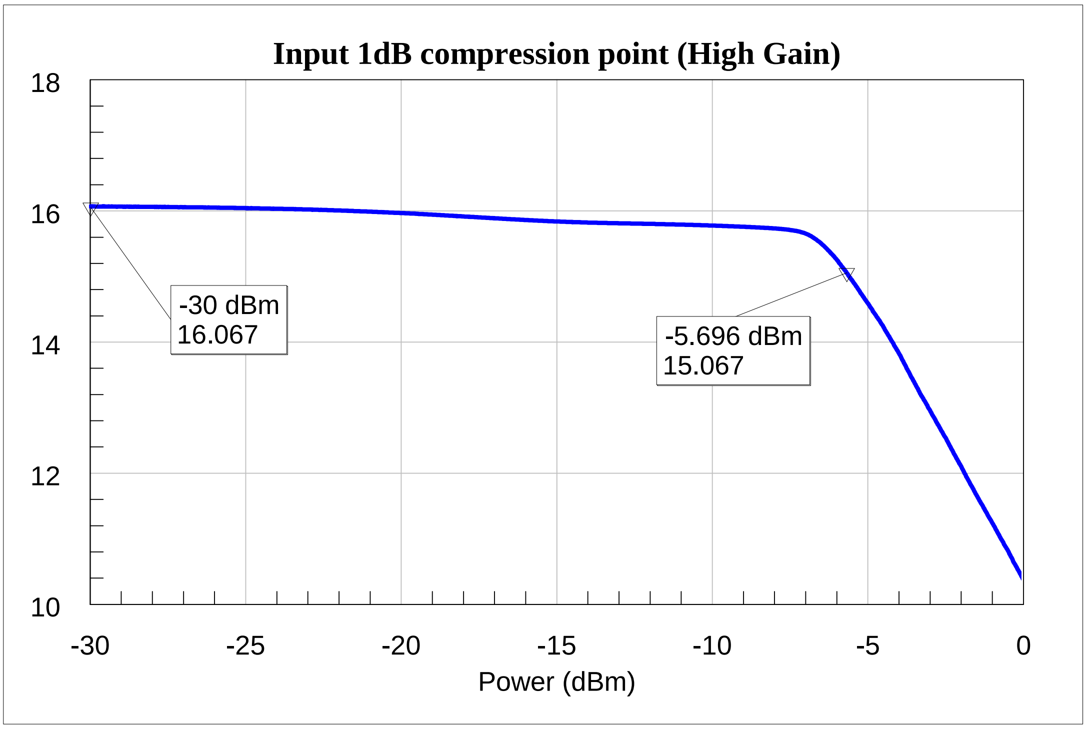

Figure 15 Input 1dB compression point (High Gain Mode) of the BGA713N7 for Single-Band UMTS LNA Applications at 2.8V

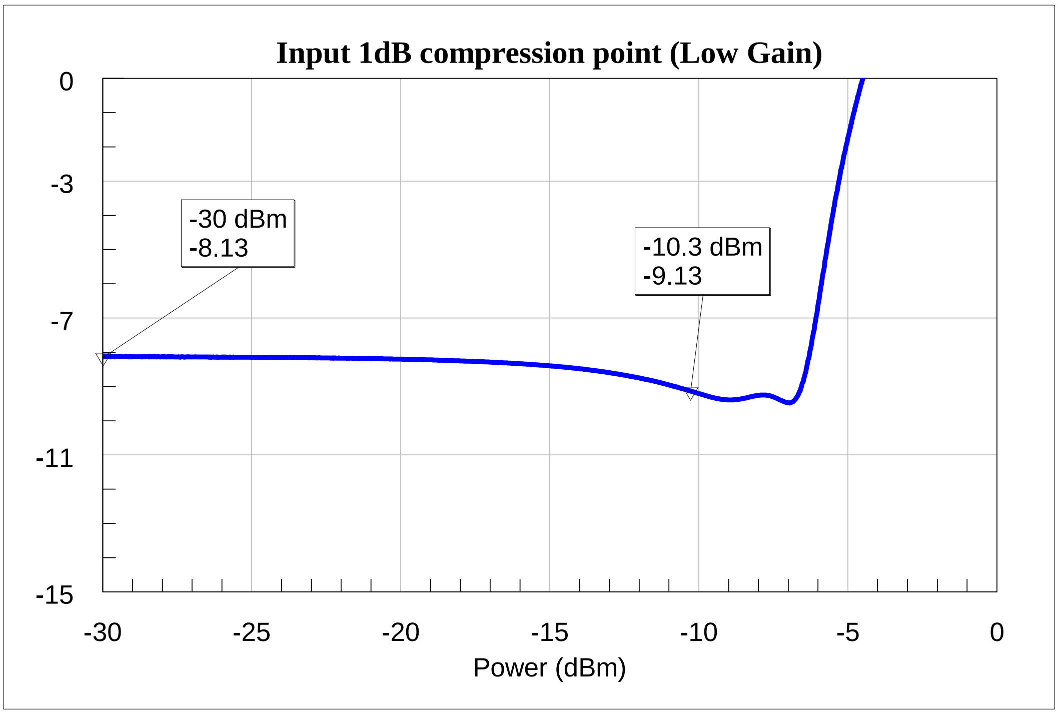

Figure 16 **Input 1dB compression point (Low Gain Mode) of the BGA713N7 for Single-Band UMTS LNA Applications at 2.8V**

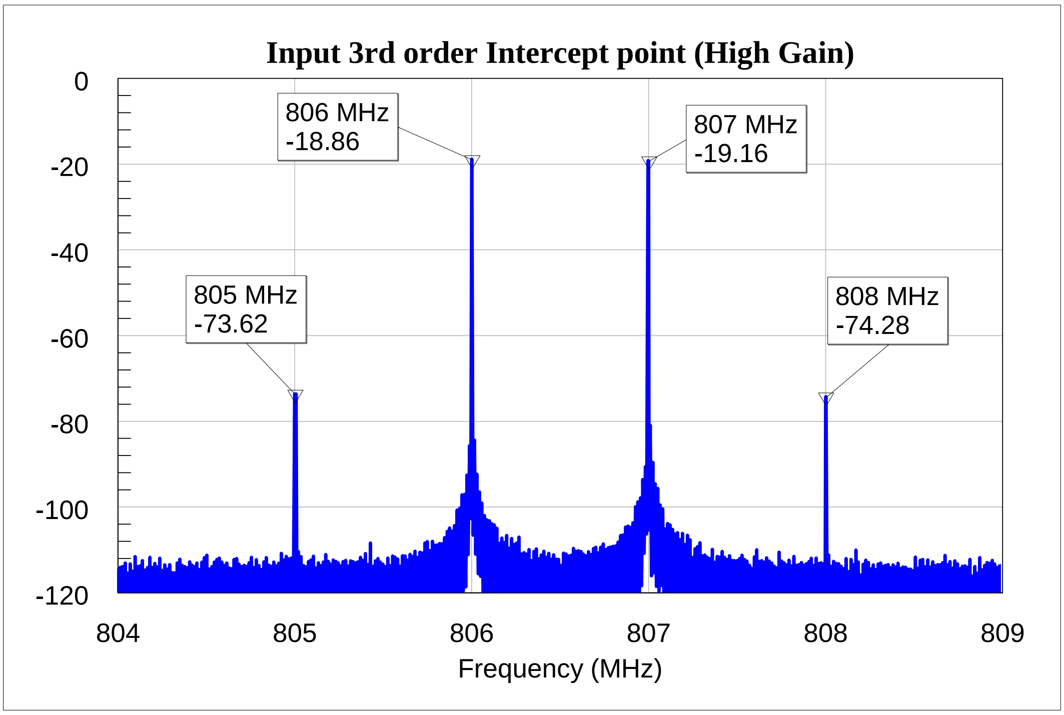

Figure 17 **Input 3rd interception point of the BGA713N7 for Single-Band UMTS LNA Applications at 2.8V**

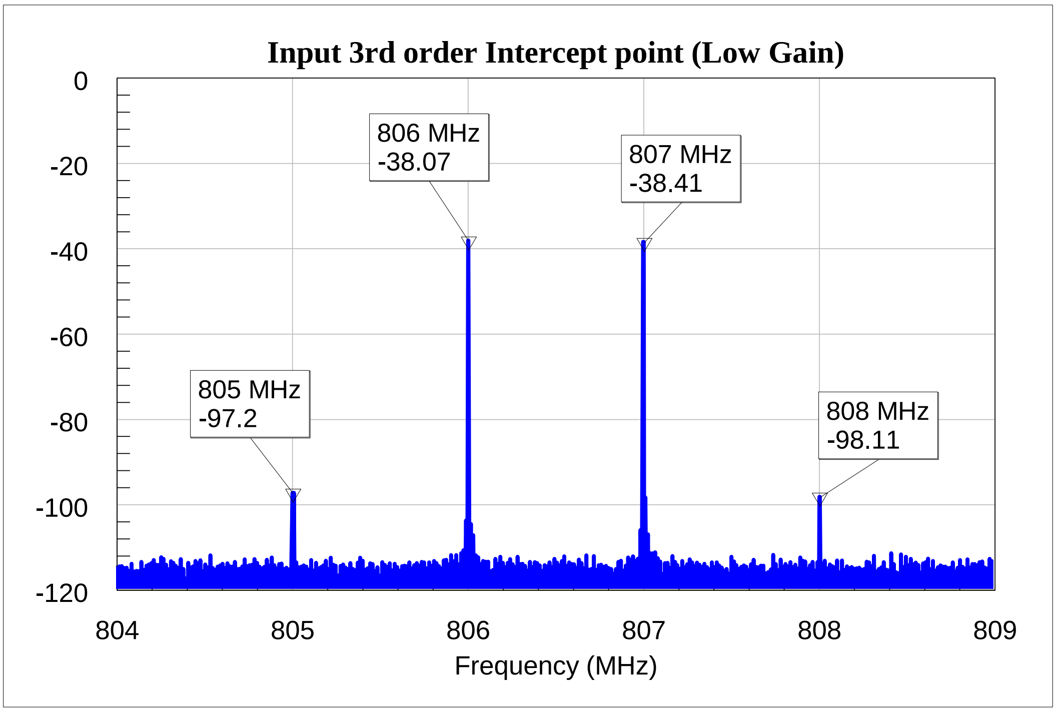

Figure 18 **Input 3rd interception point of the BGA713N7 for Single-Band UMTS LNA Applications at 2.8V**

5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB Marking: BGA713L7 V1.0

PCB material: FR4

ε_r of PCB material: 4.3

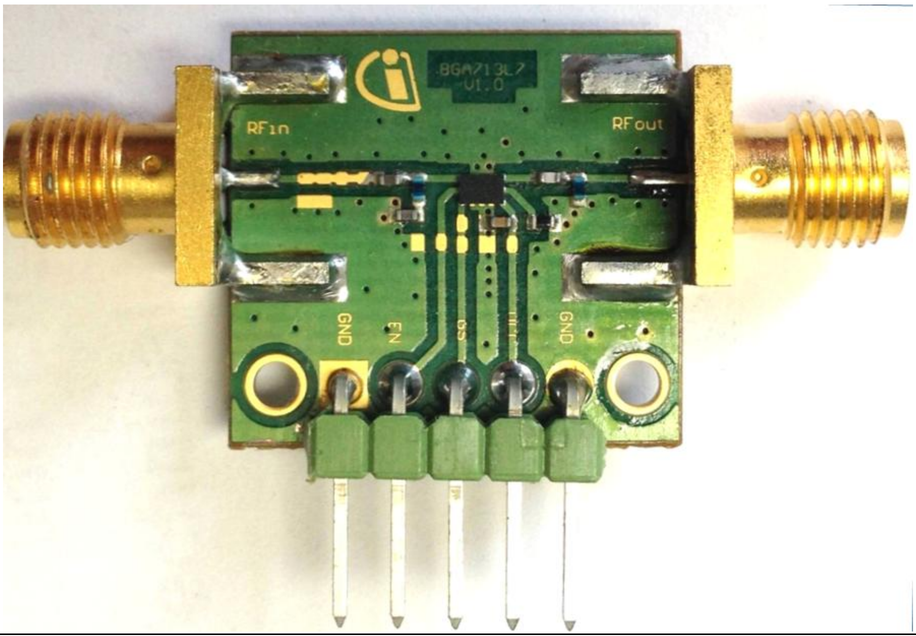

Figure 19 Photo Picture of Evaluation Board (overview) , BGA713L7 V1.0

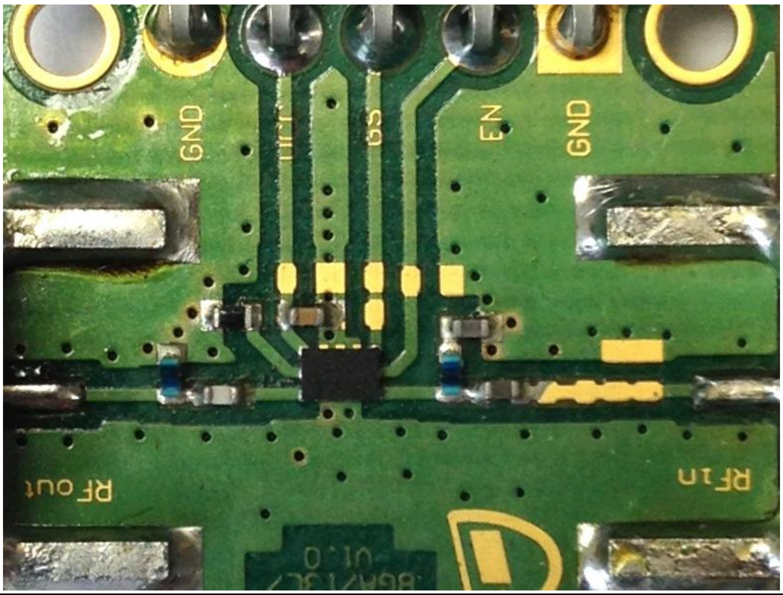

Figure 20 Photo Picture of Evaluation Board (detailed view)

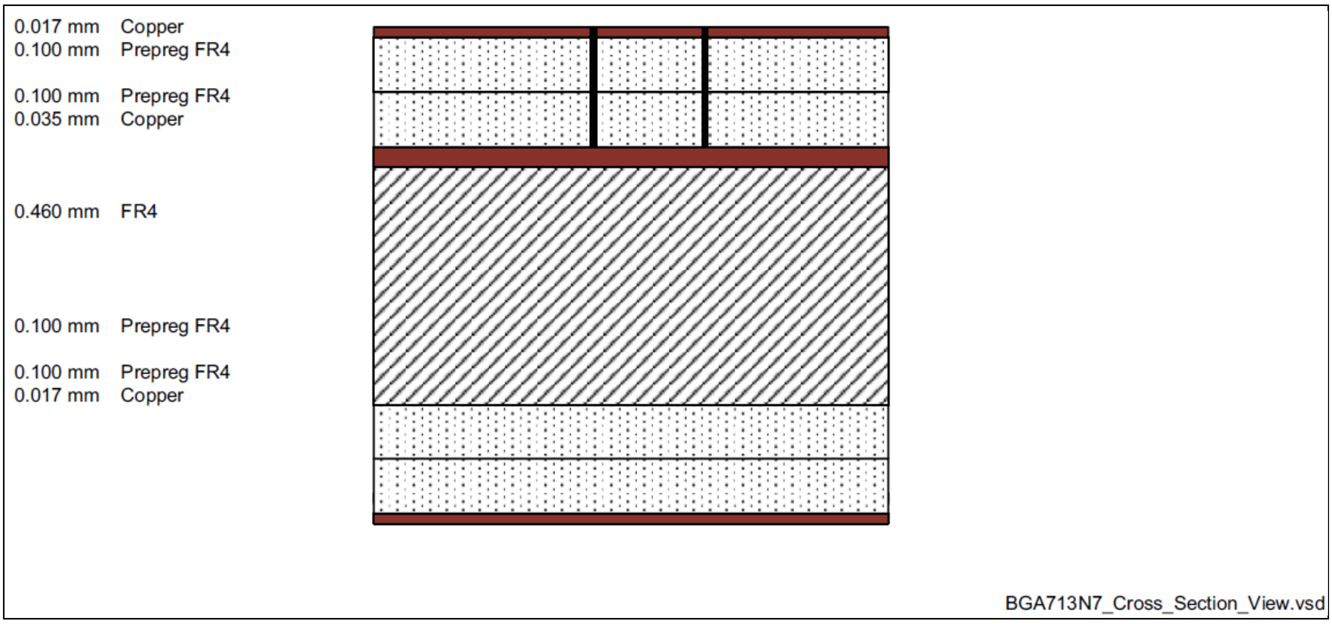

Figure 21 PCB Layer Information

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 program AWR Microwave Office®.

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