BGA7L1N6

Single Band LTE LNA

Low Noise Amplifier for LTE Band 8 Application (925 - 960 MHz) using 0201 Components

Application Note AN364

Revision: Rev. 1.0
2014-12-18

RF and Protection Devices

Application Note AN364
Revision History: 2014-12-18

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

The mobile technologies for smartphones have seen tremendous growth in recent years. The data rate required from mobile devices has increased significantly over the evolution modern mobile technologies starting from the first 3G/3.5G technologies (UMTS & WCDMA, HSPA & HSPA+) to the recently 4G LTE-Advanced (LTE-A). LTE-A can support data rates of up to 1 Gbps.

Advanced technologies such as diversity multiple input multiple output (MIMO) and carrier aggregation (CA) are adopted to achieve such higher data rate requirements. MIMO technology, commonly referred as the diversity path in smartphones, has attracted attention for the significant increasement in data throughput and link range without additional bandwidth or increased transmit power. The technology supports scalable channel bandwidth, between 1.4 and 20 MHz. The ability of 4G LTE to support bandwidths up to 20 MHz and to have more spectral efficiency by using high order modulation methods like QAM-64 is of particular importance as the demand for higher wireless data speeds continues to grow fast. Carrier aggregation used in LTE-Advanced combines up to 5 carriers and widens bandwidths up to 100 MHz to increase the user rates, across FDD and TDD.

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

Table 1 LTE Band Assignment

Band No.	Uplink Frequency Range (MHz)	Downlink Frequency Range (MHz)	Duplex Mode	Note
1	1920 - 1980	2110 - 2170	FDD	EMEA, Japan
2	1850 - 1910	1930 - 1990	FDD	US PCS
3	1710 - 1785	1805 - 1880	FDD	GSM, DCS1800
4	1710 - 1755	2110 - 2155	FDD	US AWS
5	824 - 849	869 - 894	FDD	US GSM
6	830 - 840	875 - 885	FDD	N/A, ref. Bd.19
7	2500 - 2570	2620 - 2690	FDD	EMEA
8	880 - 915	925 - 960	FDD	GSM900
9	1749.9 - 1784.9	1844.9 - 1879.9	FDD	Japan 1700 Mhz
10	1710 - 1770	2110 - 2170	FDD	Extended AWS

Band No.	Uplink Frequency Range (MHz)	Downlink Frequency Range (MHz)	Duplex Mode	Note
11	1427.9 - 1452.9	1475.9 - 1500.9	FDD	Japan 1500 MHz
12	698 - 716	728 - 746	FDD	US C Spire+USCC-LTE
13	777 - 787	746 - 756	FDD	US VzW-LTE
14	788 - 798	758 - 768	FDD	US FCC Public Safety
15	Reserved	Reserved	FDD	
16	Reserved	Reserved	FDD	
17	704 - 716	734 - 746	FDD	US AT&T-LTE
18	815 - 830	860 - 875	FDD	
19	830 - 845	875 - 890	FDD	
20	832 - 862	791 - 821	FDD	EMEA
21	1447.9 - 1462.9	1495.9 - 1510.9	FDD	Japan
22	3410 - 3500	3510 - 3600	FDD	
23	2000 - 2020	2180-2200	FDD	
24	1626.5 - 1660.5	1525 - 1559	FDD	
25	1850 - 1915	1930-1995	FDD	US AWS-G, Sprint-LTE
26	814 - 849	859-894	FDD	AWS-H
27	807 - 824	852-869	FDD	Sprint / Nextel iDEN
28	703 - 748	758-803	FDD	APAC 700MHz
29	N/A	717 - 728	FDD	Dish Network by 2016
…				
33	1900 -1920		TDD	
34	2010 - 2025		TDD	China Mobile TD-SCDMA
35	1850 - 1910		TDD	
36	1930 - 1990		TDD	
37	1910 - 1930		TDD	
38	2570 - 2620		TDD	Europe, TD-LTE
39	1880 - 1920		TDD	China Mobile TD-SCDMA
40	2300 - 2400		TDD	China Mobile TD-LTE
41	2496 – 2690		TDD	
42	3400 - 3600		TDD	
43	3600 - 3800		TDD	
44	703 - 803		TDD	APAC 700MHz

In order to cover all the bands from different countries into a unique device, mobile phones and data cards are usually equipped more bands and band combinations. Some typical examples are quad-band combination of band 1/2/5/8, 1/3/5/7 and 3/7/5/17. The frequency bands used by TD-LTE are 3.4–3.6 GHz in Australia and UK, 2.57−2.62 GHz in the US and China, 2.545-2.575 GHz in Japan, and 2.3–2.4 GHz in India and Australia.

1.2 Applications

Figure 1 shows an example of the block diagram of the front-end of a 4G modem. A SPnT switch connects one side the modem antenna and several duplexers for different 4G bands on the other side. Every duplexer is connected to the transmitting (TX) and receiving (RX) paths of each band. The external LNA, here for example Infineon quad-band LNA bank BGA7L1N6, 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. Recently, even mobile devices with 5 modes 13 bands are under discussion. Not only for the main pathes, but also for the diversity pathes, the external LNAs are widely used to boost end user experience while using mobile devices for video and audio streaming.

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

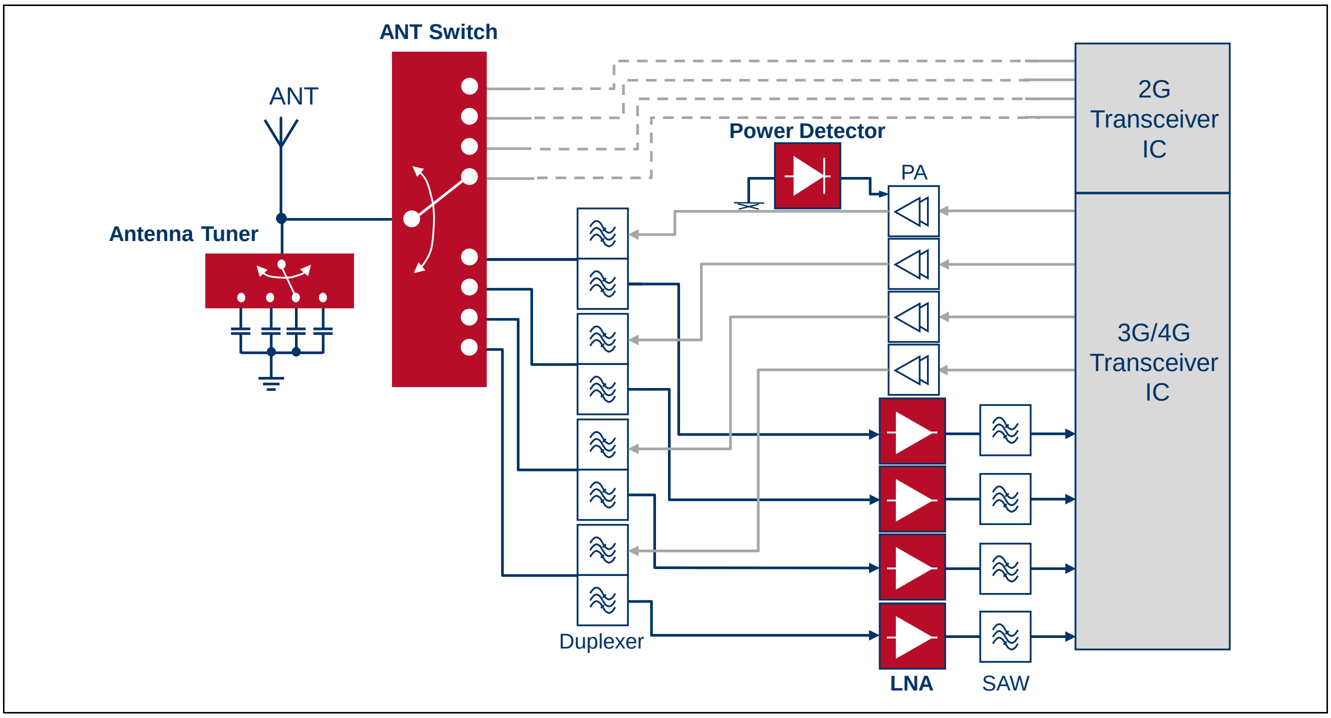

Figure 1 Example of Application Diagram of RF front-end for 3G and 4G systems.

1.3 Infineon LNAs for 3G, 4G LTE and LTE-A Applications

With the increasing wireless data speed and with the extended link distance of mobile phones and 4G 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 4G LTE and LTE-A to improve their system performance to meet the requirements coming from the networks/service providers.

The benefits to use external LNAs in equipment for 4G LTE and LTE-A 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.
- Support RX carrier aggregation where two LNAs can be tuned on at the same time
- 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. The MMIC LNA portfolio includes:

- New generation single band LTE LNAs like BGA7H1N6 for high-band (HB, 2300-2700 MHz), BGA7M1N6 for mid-band (MB, 1805-2200 MHz) and BGA7L1N6 for low-band (LB, 728-960 MHz) are available.

- New generation LTE LNA Banks are quad-band. Currently there are six different types of these new LTE LNAs which are shown in **Table 2**. All the LNAs combine various four bands from the high-band (HB, 2300-2700 MHz), mid-band (MB, 1805-2200 MHz) and low-band

(LB, 728-960 MHz). Two of the four LNAs in one device can be turned on at the same time to support carrier aggregassion.

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

Table 2 Infineon Product Portfolio of LNAs for 4G LTE and LTE-A Applications

Frequency Range	728 MHz – 960 MHz	1805 MHz – 2200 MHz	2300 MHz – 2690 MHz	Comment
Single-Band LNA				
BGA7L1N6	1X			
BGA7M1N6		1X		
BGA7H1N6			1X	
Quad-Band LNA bank				
BGM7MLLH4L12	1X	2X	1X	
BGM7LMHM4L12	1X	2X	1X	
BGM7HHMH4L12		1X	3X	
BGM7MLLM4L12	2X	2X		
BGM7LLHM4L12	2X	1X	1X	
BGM7LLMM4L12	2X	2X		

In addition, the older generation of LTE LNAs are featured with gain switching functions which is often helpful for the cases that string or weak signal environment could happen in the field. Variuos types of band combinations are available:

- Single-band LNAs include BGA777N7 for high-band (2300-2700 MHz), BGA711N7 for mid-band (MB, 1700-2300 MHz) and BGA751N7 for low-band (LB, 700-1000 MHz).

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

- Both BGA748L16 and BGA749N16 are quad-band LNAs. BGA748L16 is able to cover 2x high-and 2x low-bands and BGA749N16 covers 1x high-band and 3x low-bands.

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

Frequency Range	700 MHz – 1 GHz	1700MHz – 2200MHz	2100 MHz – 2700 MHz	Comment
Single-Band LNA				
BGA711N7		1X		
BGA713N7	1X			
BGA751N7	1X			
BGA777N7			1X	
BGA728L7	1X	1X		
Dual Band LNA				
BGA771N16	1X	1X		
Triple Band LNA				
BGA735N16	1X	1X	1X	
BGA736L16	1X	1X	1X	
Quad-band LNA				
BGA748L16	2X		2X	
BGA749N16	3X		1X	

2 BGA7L1N6 Overview

2.1 Features

- Insertion power gain: 13.0 dB
- Out-of-band input 3rd order intercepts point: +5 dBm
- Input 1 dB compression point: +2 dBm
- Low noise figure: 0.60 dB
- Low current consumption: 4.9 mA
- Operating frequencies: 728 - 960 MHz
- Supply voltage: 1.5 V to 3.6 V
- Digital on/off switch (1V logic high level)
- Ultra small TSNP-6-2 leadless package (footprint: 0.7 x 1.1 mm2)
- B7HF Silicon Germanium technology
- RF output internally matched to 50 Ω
- Only 1 external SMD component necessary
- 2kV HBM ESD protection (including AI-pin)
- Pb-free (RoHS compliant) package

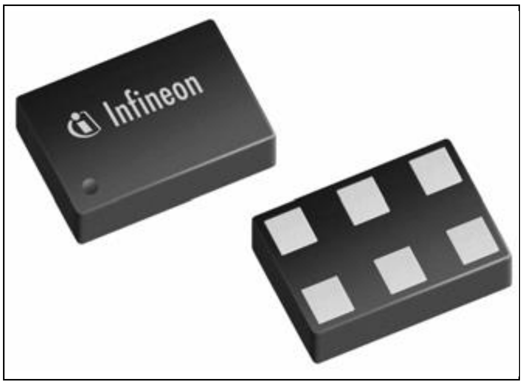

Figure 2 BGA7L1N6 in TSNP-6-2

RoHS

2.2 Description

The BGA7L1N6 is a front-end low noise amplifier for LTE which covers a wide frequency range from 728 MHz to 960 MHz. The LNA provides 13.0 dB gain and 0.60 dB noise figure at a current consumption of 4.9 mA in the application configuration described in **Chapter 3**. The BGA7L1N6 is based upon Infineon Technologies'B7HF Silicon Germanium technology. It operates from 1.5 V to 3.6 V supply voltage.

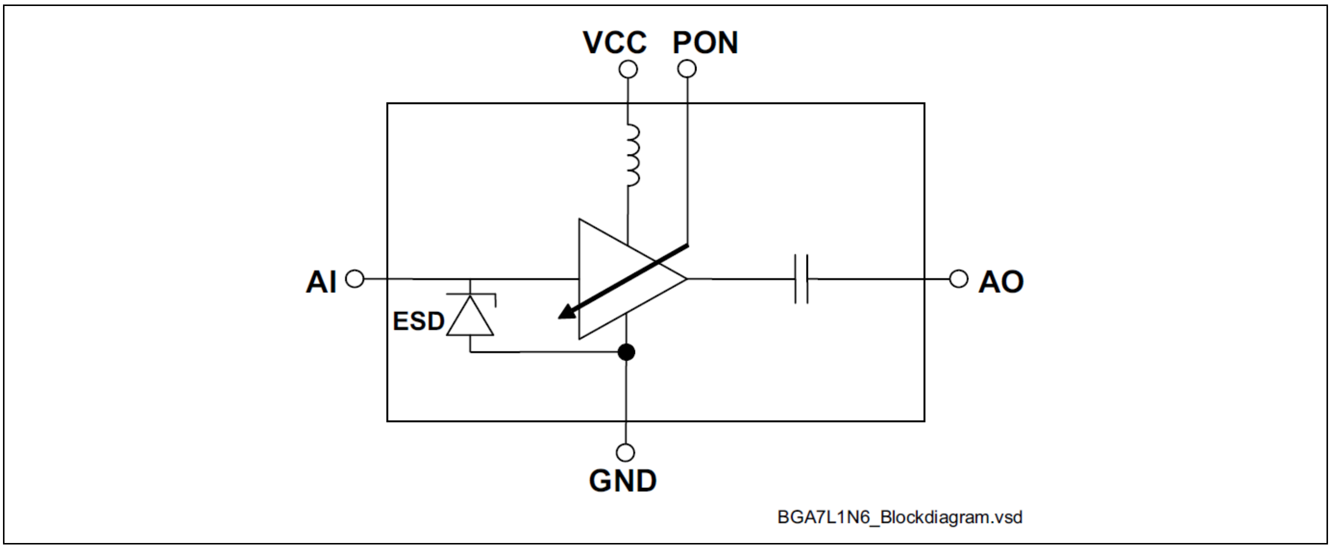

Figure 3 Equivalent Circuit of BGA7L1N6

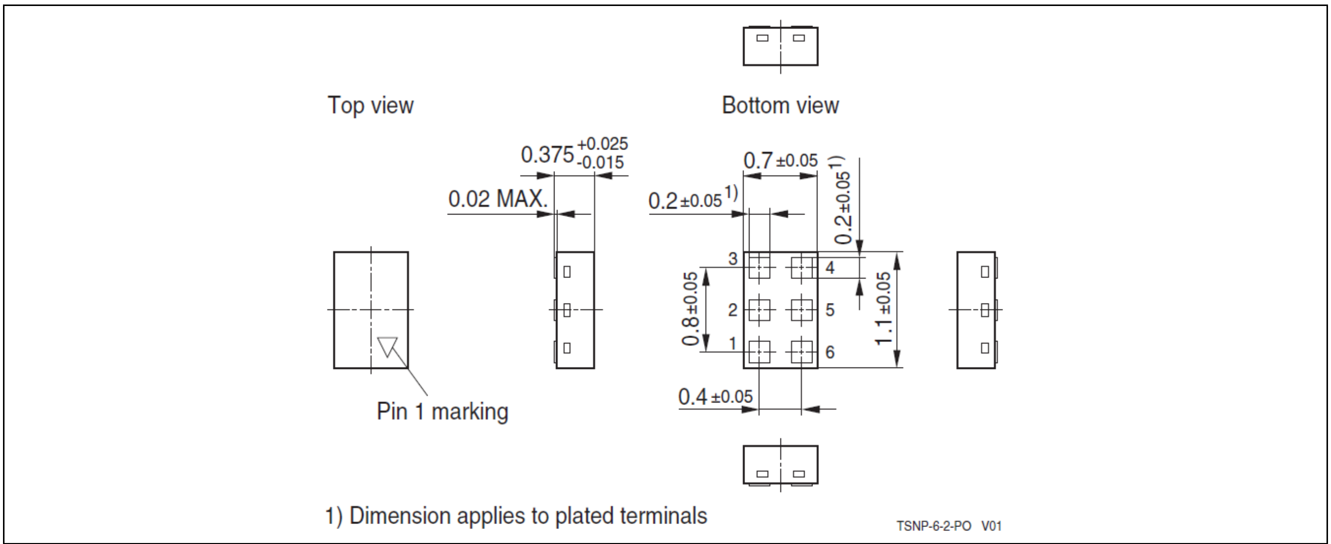

Figure 4 Package and pin connections of BGA7L1N6

Table 4 Pin Assignment of BGA7L1N6

Pin No.	Symbol	Function
1	GND	Ground
2	VCC	Supply Voltage
3	AO	LNA output
4	GND	Ground
5	AI	LNA input
6	PON	Power on control

3 Application Circuit and Performance Overview

Device: BGA7L1N6

Application: Low Noise Amplifier for LTE Band 8 Application (925 - 960 MHz) using 0201 Components

PCB Marking: BGA7x1N6 V1.0

3.1 Summary of Measurement Results

Table 5 Electrical Characteristics at room temperature (T_A = 25 °C) for Band-8 (925 – 960 MHz), V_{CC} = 1.8 V, V_{PON} = 1.8 V

Parameter	Symbol	Value			Unit	Comment/Test Condition
DC Voltage	Vcc	1.8			V	
DC Current	Icc	4.4			mA	
Frequency Range	Freq	925	942	960	MHz	
Gain	G	12.8	12.7	12.7	dB	
Noise Figure	NF	1.06	1.12	1.11	dB	Measured in a shielding box, SMA and line losses of 0.05 dB are subtracted
Input Return Loss	RLin	25.5	21.7	18.7	dB	
Output Return Loss	RLout	23.0	26.0	28.1	dB	
Reverse Isolation	IRev	20.8	20.6	20.4	dB	
Input P1dB	IP1dB	-6.1	-6.1	-6.2	dBm	
Output P1dB	OP1dB	+5.7	+5.6	+5.5	dBm	
Input IP3	IIP3	+1.6			dBm	Power @ Input: -30 dBm f_1=942 MHz, f_2=943 MHz
Output IP3	OIP3	+14.4			dBm	
Stability	k	>1			--	Measured up to 10 GHz

Table 6 Electrical Characteristics at room temperature (T_A = 25 °C) for Band-8 (925 – 960 MHz), V_{CC} = 2.8 V, V_{PON} = 2.8 V

Parameter	Symbol	Value			Unit	Comment/Test Condition
DC Voltage	Vcc	2.8			V	
DC Current	Icc	4.5			mA	
Frequency Range	Freq	925	942	960	MHz	
Gain	G	12.9	12.8	12.8	dB	
Noise Figure	NF	1.12	1.14	1.19	dB	Measured in a shielding box, SMA and line losses of 0.04 dB are subtracted
Input Return Loss	RLin	28.5	24.1	20.0	dB	
Output Return Loss	RLout	19.8	22.0	25.6	dB	
Reverse Isolation	IRev	21.3	21.1	20.9	dB	
Input P1dB	IP1dB	-2.8	-2.7	-2.5	dBm	
Output P1dB	OP1dB	+9.1	+9.1	+9.3	dBm	
Input IP3	IIP3	+2.0			dBm	Power @ Input: -30 dBm f_1=942 MHz, f_2=943 MHz
Output IP3	OIP3	+14.9			dBm	
Stability	k	>1			--	Measured up to 10 GHz

3.2 BGA7L1N6 as LTE LNA for Band-8 (925-960 MHz)

This application note focuses on the Infineon's Single-Band LTE LNA, BGA7L1N6 tuned for the band-8. It presents the performance of BGA7L1N6 with 1.8V and 2.8V power supply with the operating current of 4.5 mA.

The application circuit requires as few as one 0201 inductor for input matching. The component value is fine tuned so as to have optimal noise figure, gain, input and output matching.

At 1.8 V, the circuit offers a gain of 12.7 – 12.8 dB. It achieves input return loss as well as output return loss better than 10 dB. The input 1dB compression point is -6.1 dBm at 942 MHz. Using two tones spacing of 1 MHz, the input third order intercept point (IIP3) reaches 1.6 dBm at 942 MHz. At room temperature the noise figure is 1.1dB excluding SMA and PCB losses.

At 2.8 V, the circuit offers a gain of 12.8 – 12.9 dB. It achieves input return loss as well as output return loss better than 10 dB. The input 1dB compression point is -2.7 dBm at 942 MHz. Using two tones spacing of 1 MHz, the input third order intercept point (IIP3) reaches 2.0 dBm at 942 MHz. At room temperature the noise figure is 1.1dB excluding SMA and PCB losses.

Furthermore, the circuit is measured unconditionally stable till 10 GHz. 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

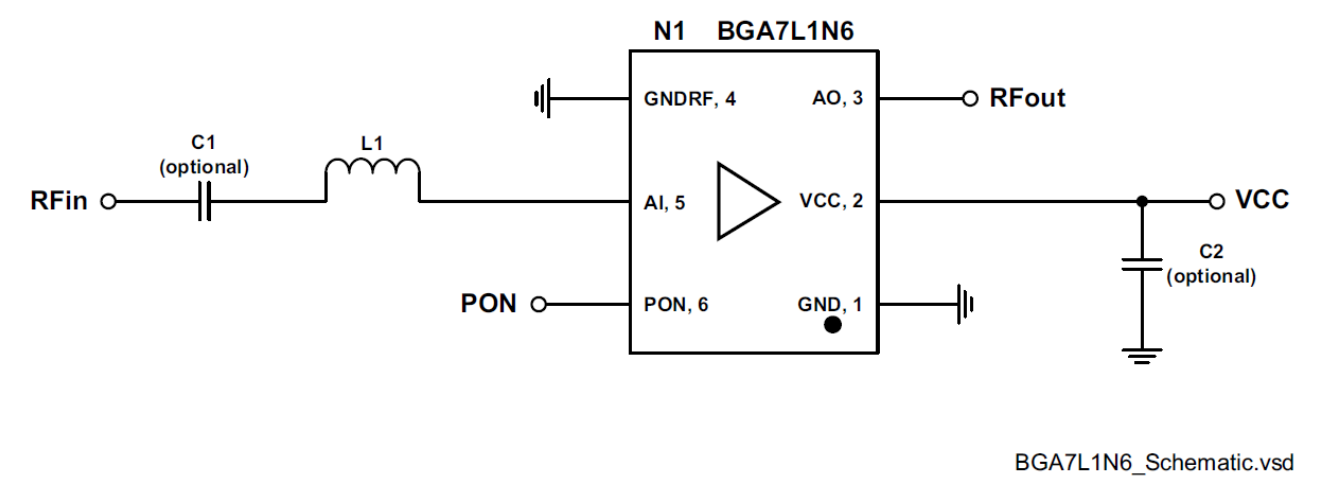

Figure 5 Schematics of the BGA7L1N6 Application Circuit

Table 7 Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	≥ 1	nF	0201	Various	DC block (optional)
C2	≥ 1	nF	0201	Various	RF to ground (optional)
L1	18	nH	0201	Murata LQP series	Input matching
N1	BGA7L1N6	TSNP-6-2		Infineon	SiGe LNA

Note: DC block capacitor C1 may be removed if a DC blocking device such as SWA filter is available in front of the LNA.

4 Measurement Graphs

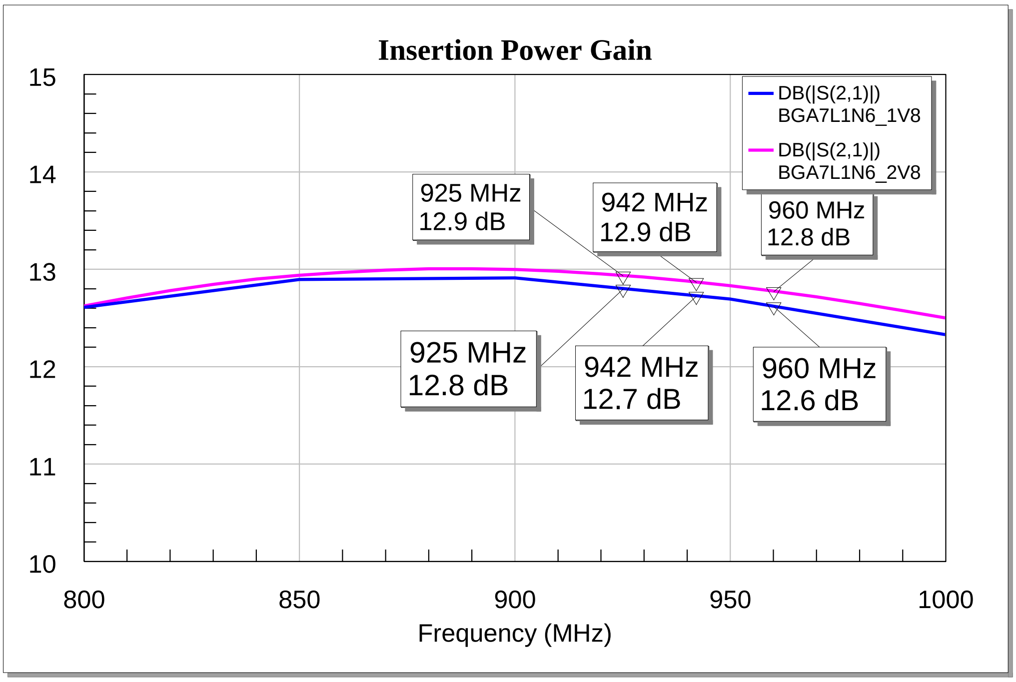

Figure 6 Insertion Power Gain (Narrowband) of the BGA7L1N6 for LTE Band-8 Application

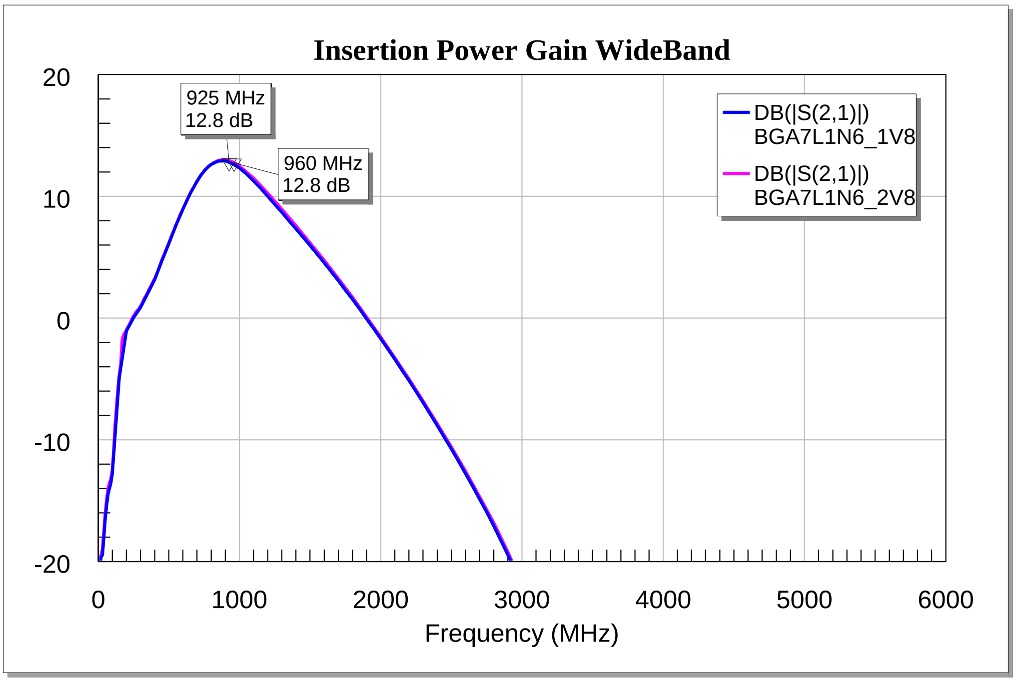

Figure 7 Insertion Power Gain (Wideband) of the BGA7L1N6 for LTE Band-8 Application

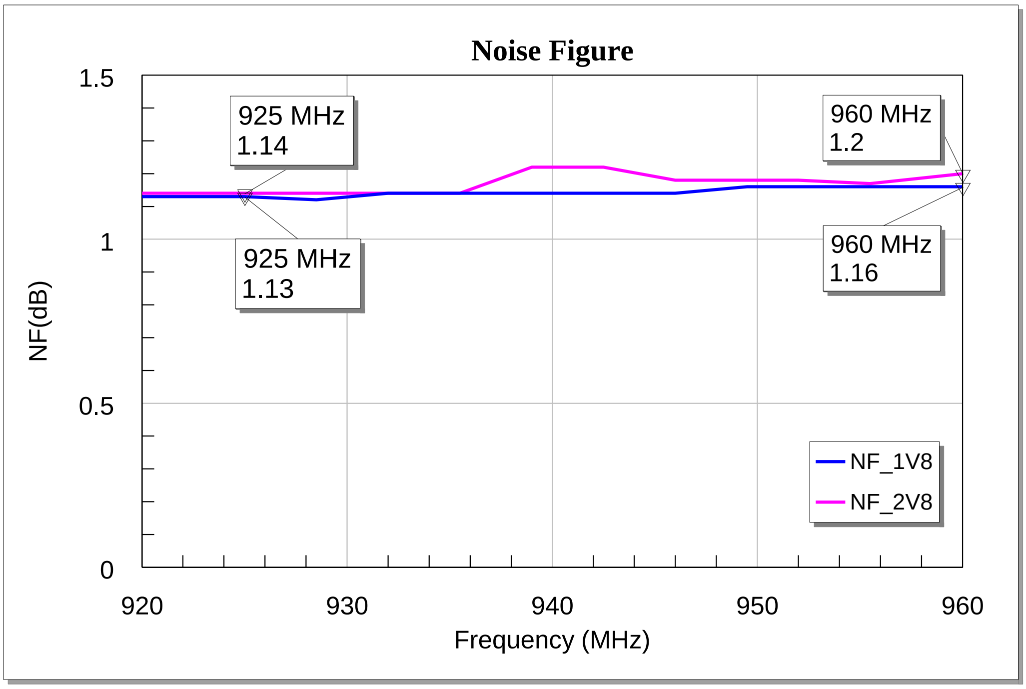

Figure 8 Noise Figure of the BGA7L1N6 for LTE Band-8 Application

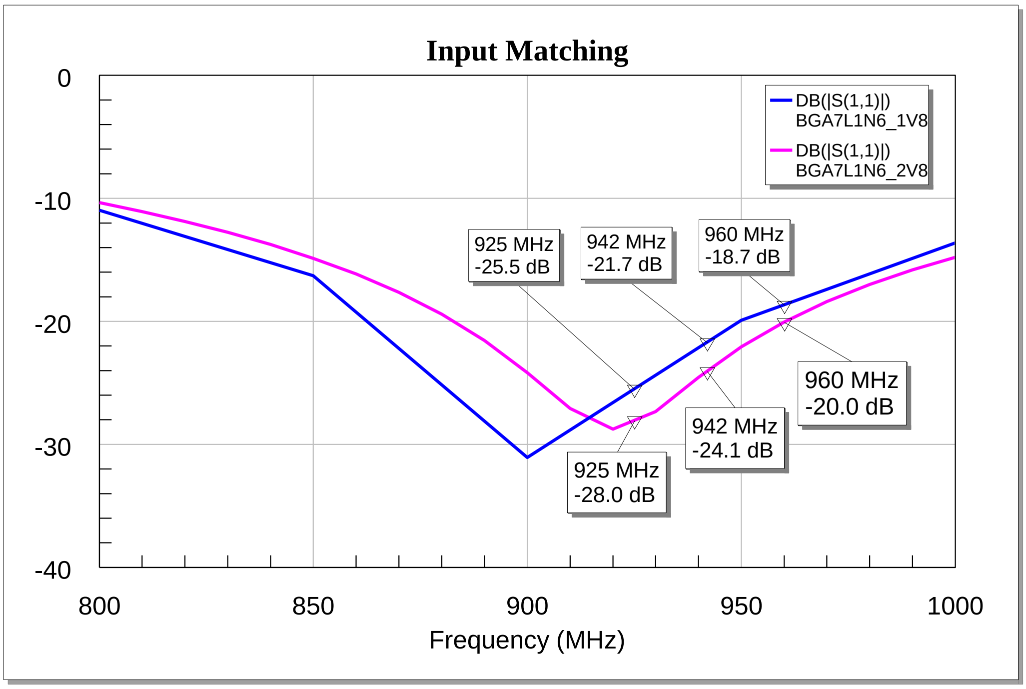

Figure 9 Input Matching of the BGA7L1N6 for LTE Band-8 Application

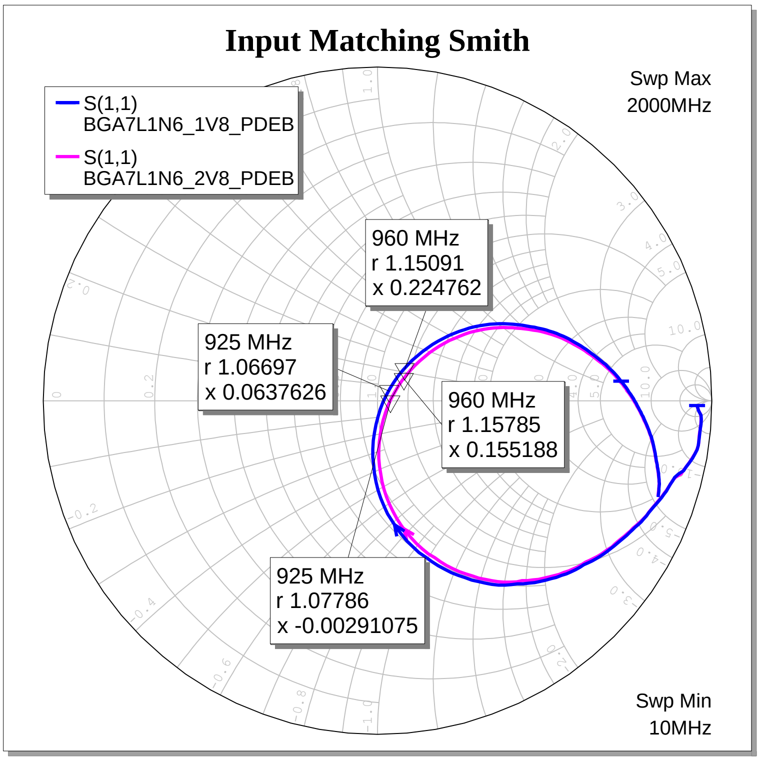

Figure 10 Input Matching (Smith Chart) of the BGA7L1N6 for LTE Band-8 Application

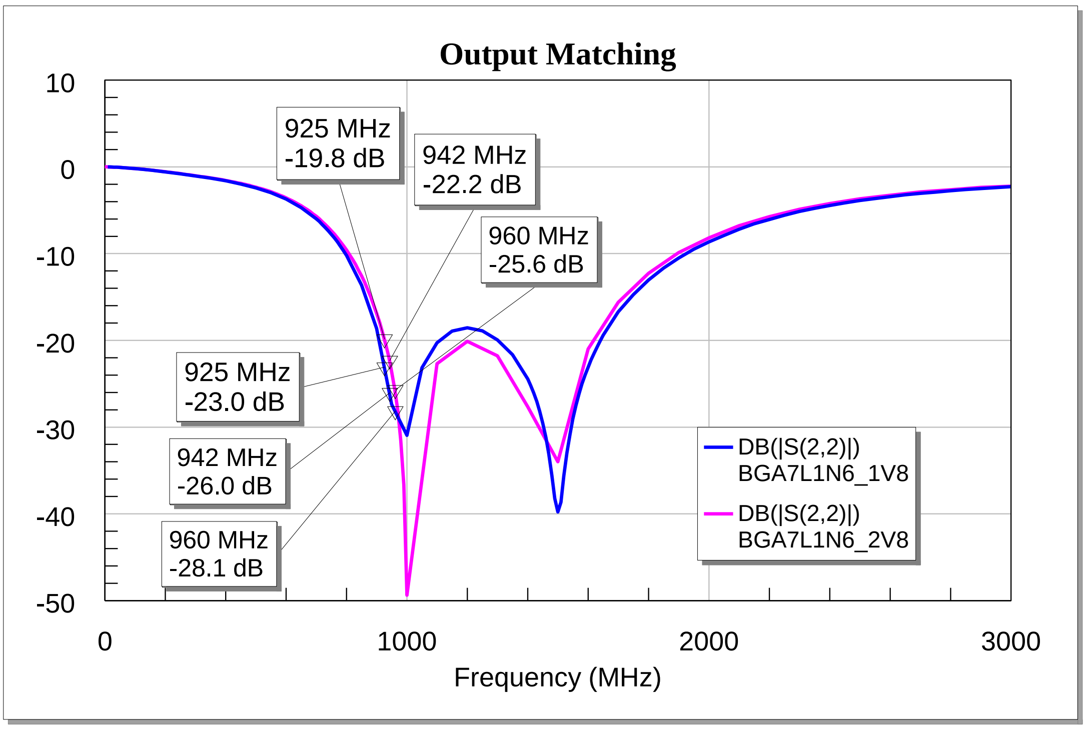

Figure 11 Output Matching of the BGA7L1N6 for LTE Band-8 Application

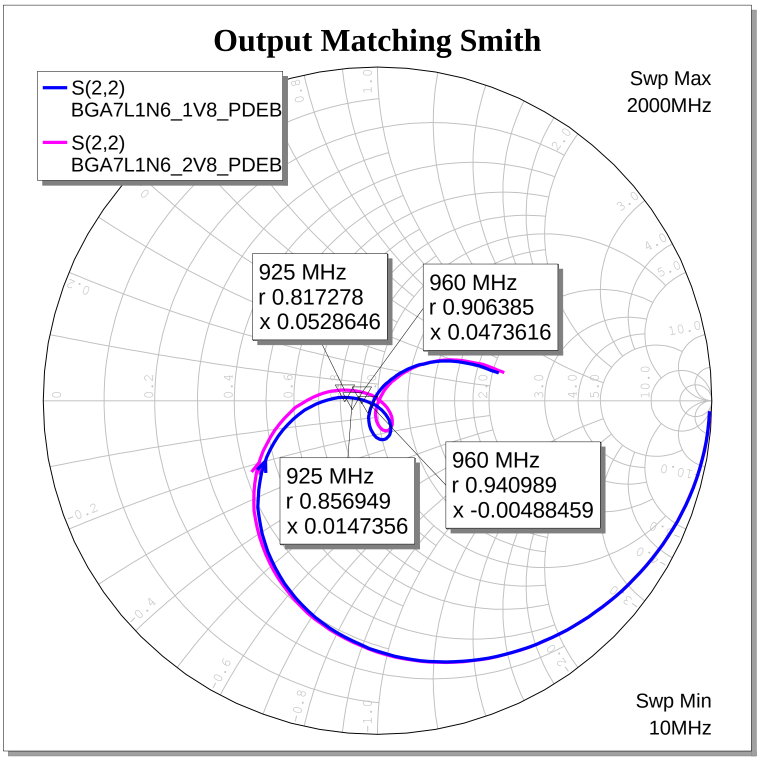

Figure 12 Output Matching (Smith Chart) of the BGA7L1N6 for LTE Band-8 Application

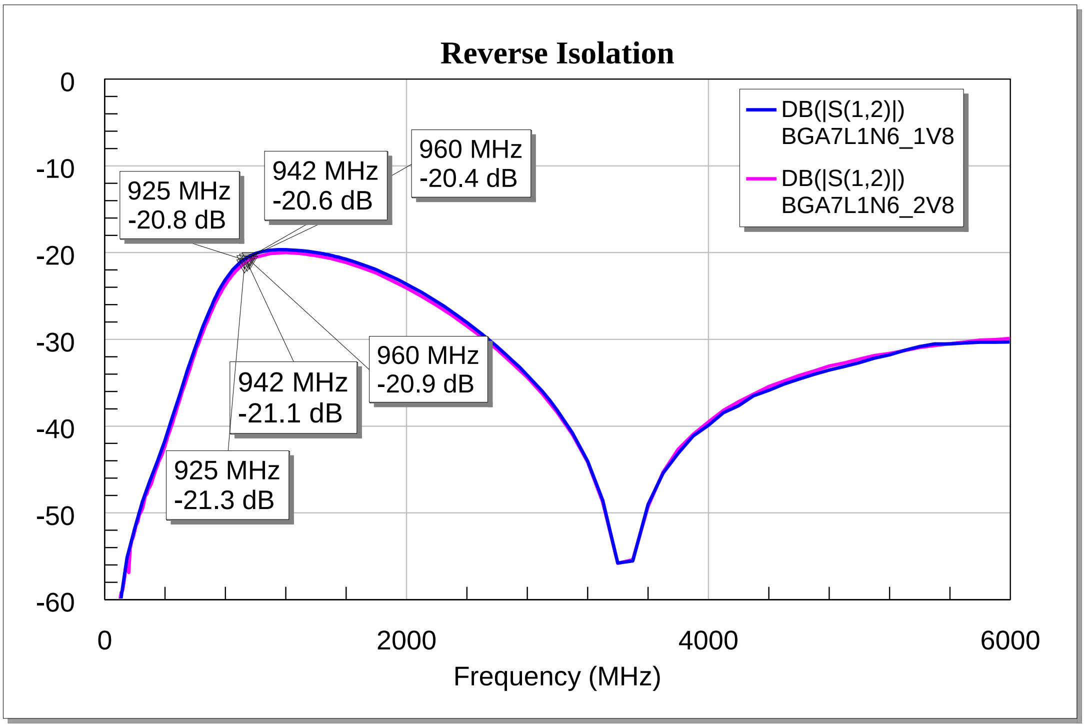

Figure 13 Reverse Isolation of the BGA7L1N6 for LTE Band-8 Application

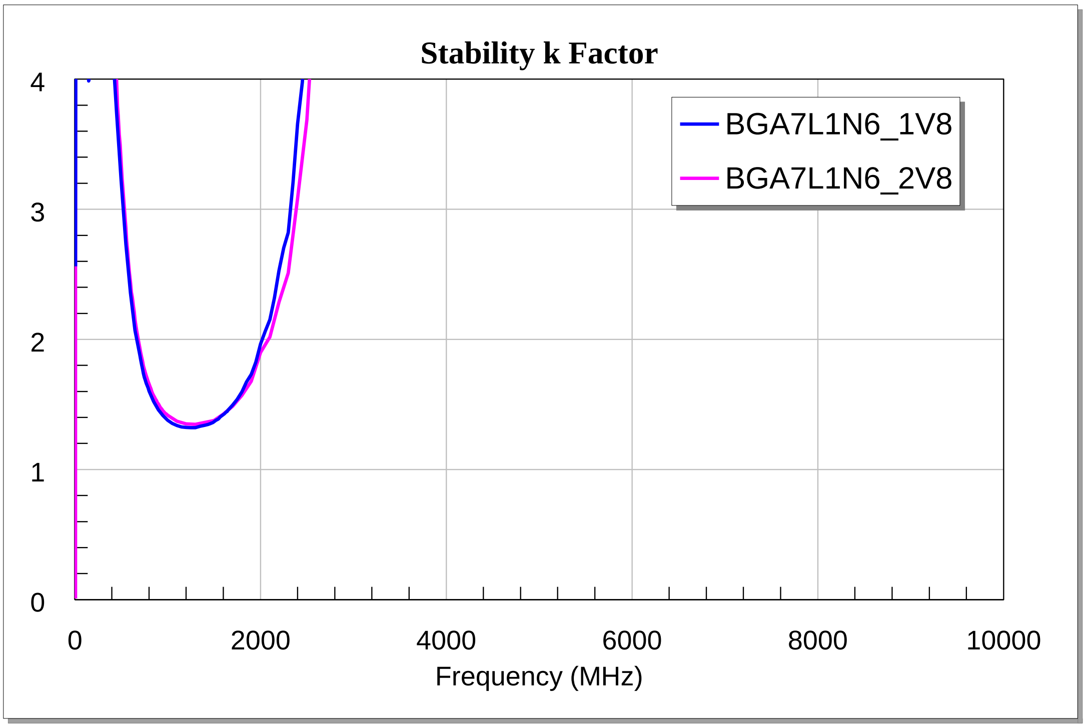

Figure 14 Stability K-factor of the BGA7L1N6 for LTE Band-8 Application

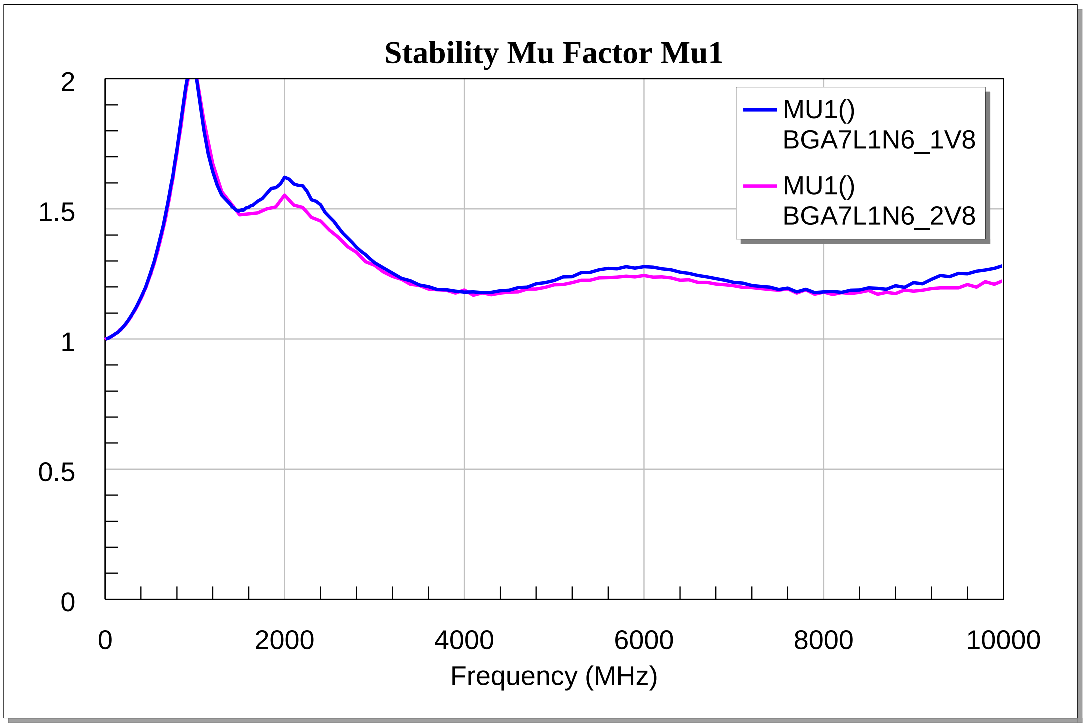

Figure 15 Stability Mu1-factor of the BGA7L1N6 for LTE Band-8 Application

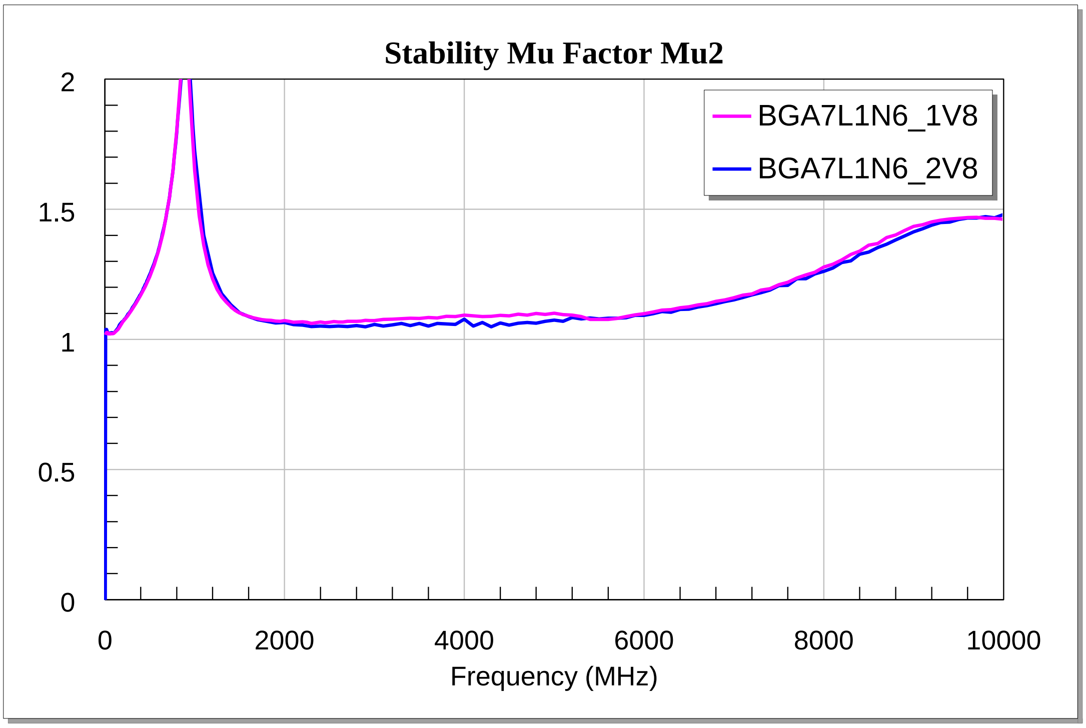

Figure 16 Stability Mu2-factor of the BGA7L1N6 for LTE Band-8 Application

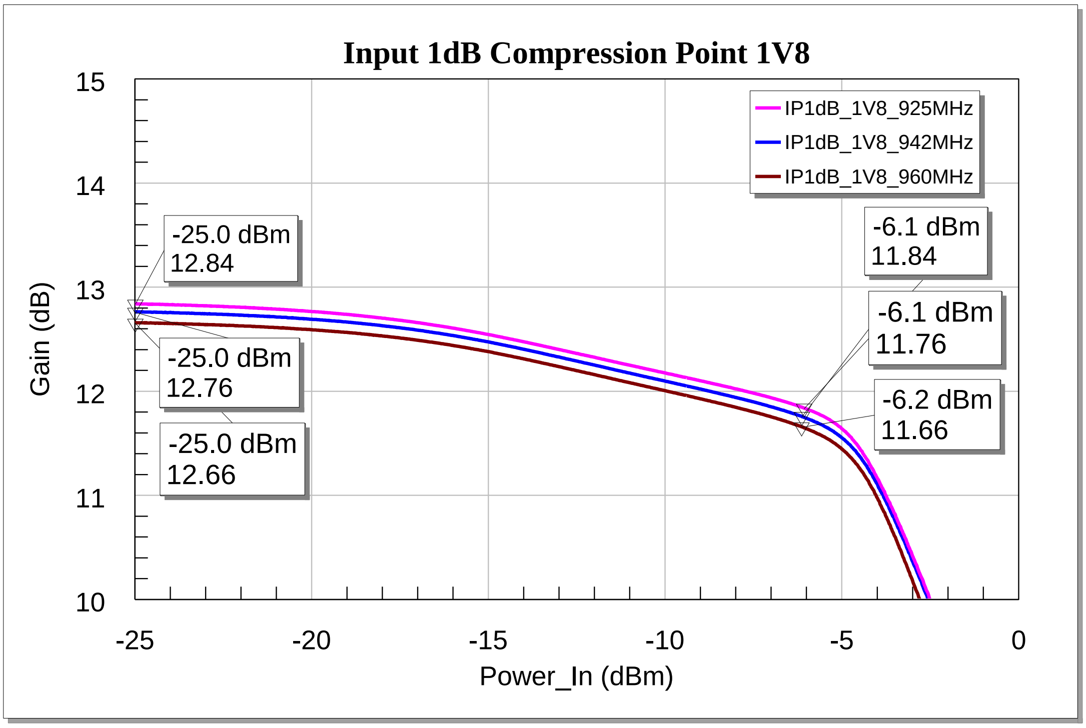

Figure 17 Input 1dB compression point of the BGA7L1N6 for LTE Band-8 Application at Vcc=1.8V

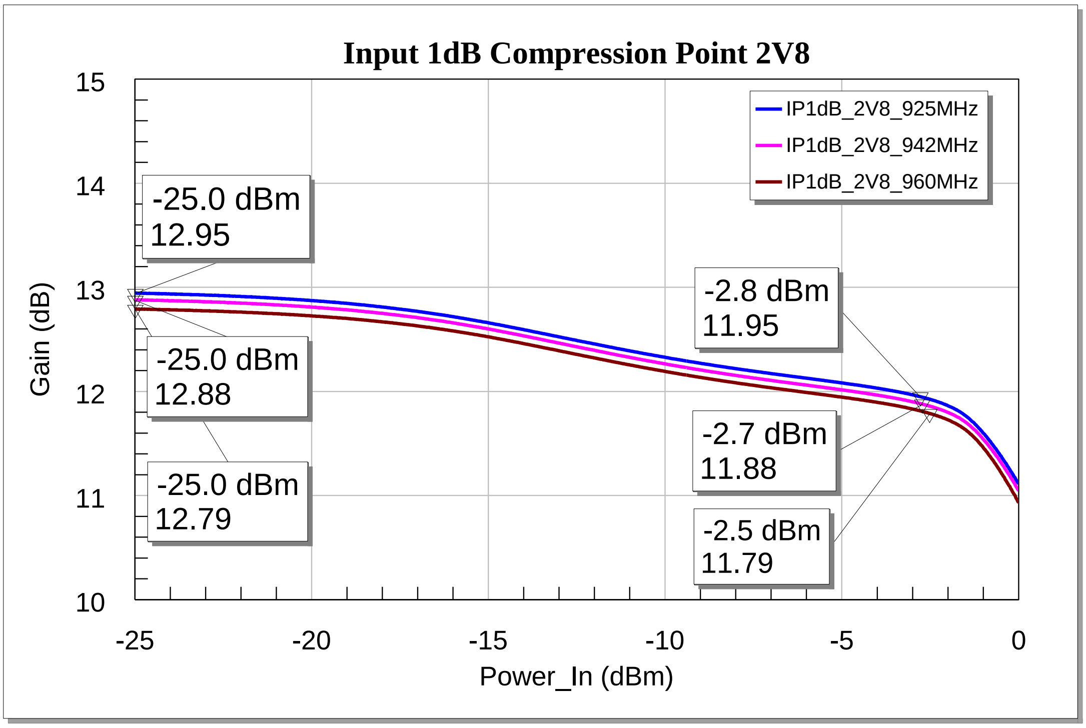

Figure 18 Input 1dB compression point of the BGA7L1N6 for LTE Band-8 Application at Vcc=2.8V

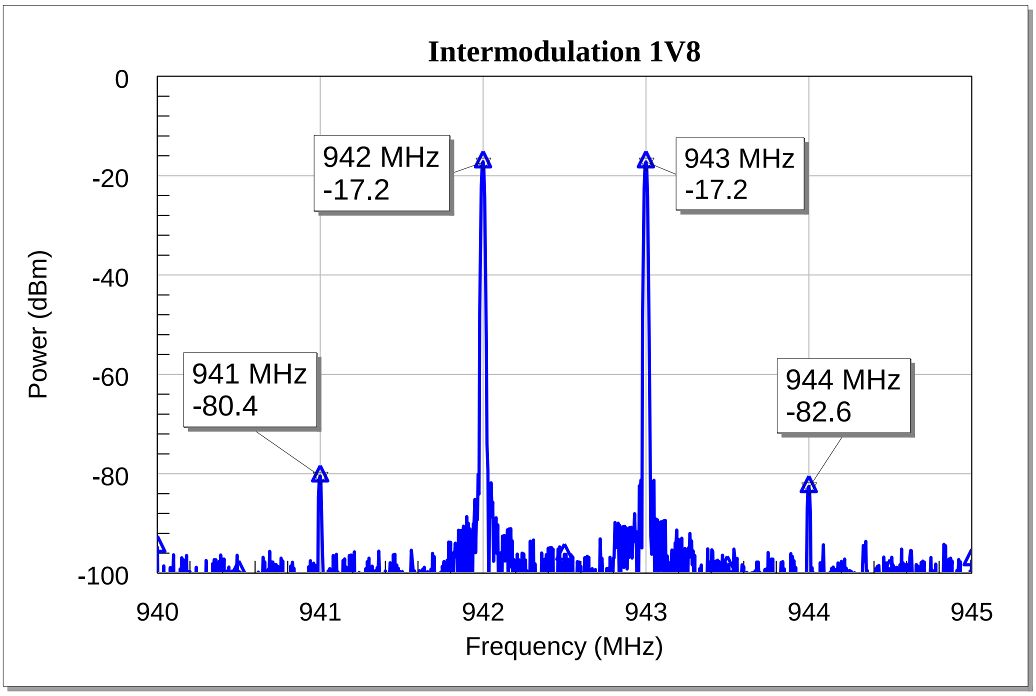

Figure 19 Input 3rd interception point of the BGA7L1N6 for LTE Band-8 Application at Vcc=1.8V

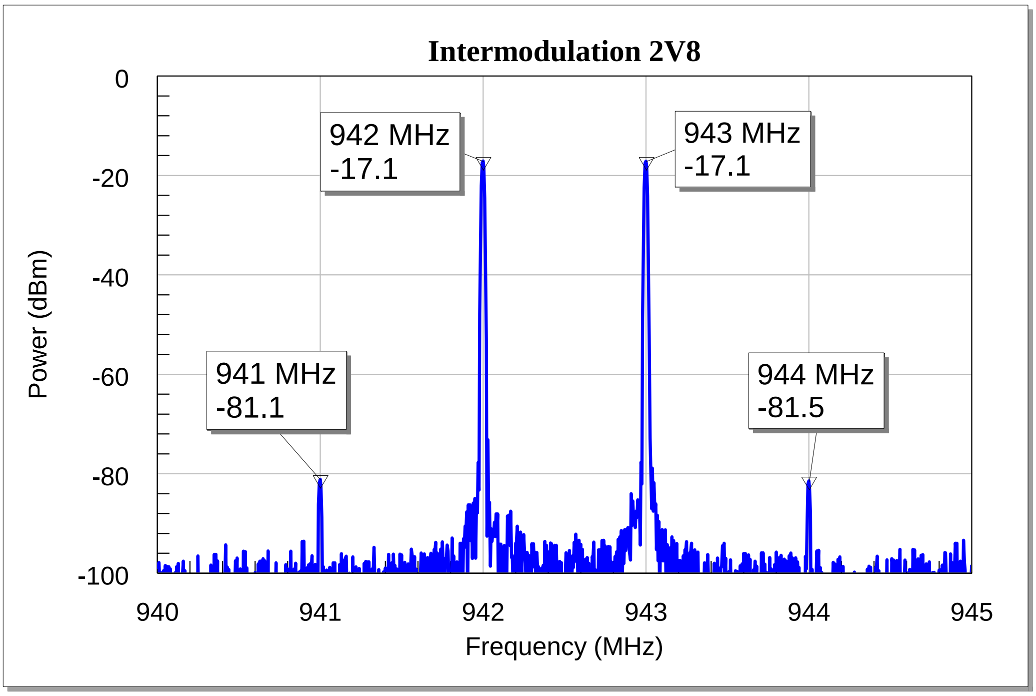

Figure 20 Input 3rd interception point of the BGA7L1N6 for LTE Band-8 Application at Vcc=2.8V

5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB Marking: BGA7x1N6 V1.0 **091213**

PCB material: FR4

ε_r of PCB material: 4.3

Figure 21 Photo Picture of Evaluation Board (overview)

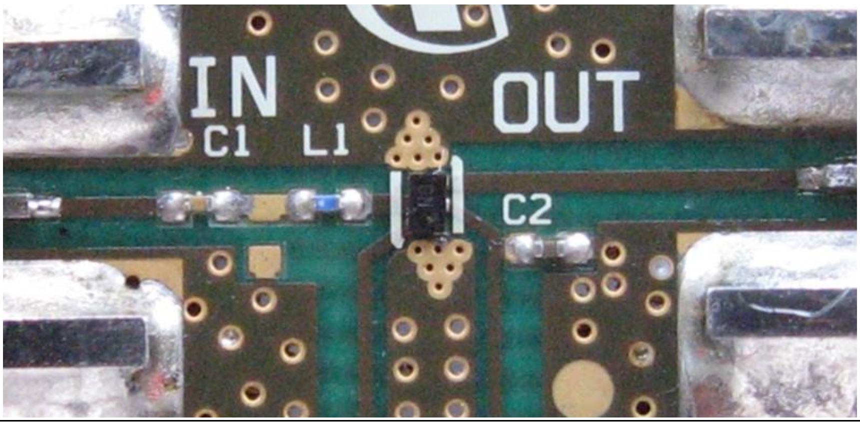

Figure 22 Photo Picture of Evaluation Board (detailed view)

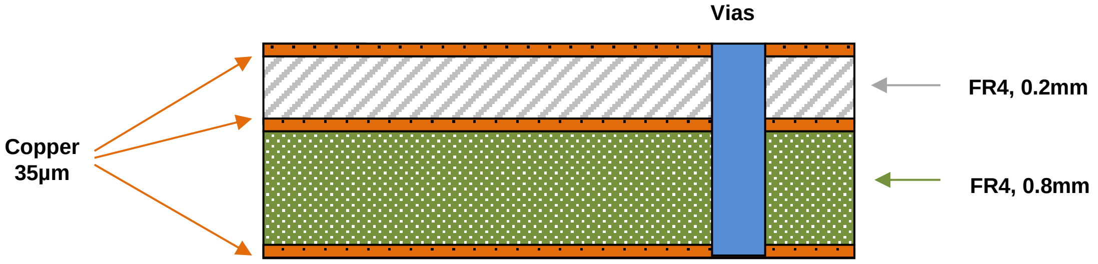

Figure 23 PCB layer stack

6 Authors

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

7 Remark

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

8 Reference

[1] Application Guide RF & Protection Devices, Mobile Communication Application, Edition 2014. Infineon Technologies, **www.infineon.com**

w w w . i n f i n e o n . c o m

Published by Infineon Technologies AG AN364