BGA735N16

BGA735N16 for 3G/HSPA/LTE Applications Supporting Bands 1, 2 and 5

with Reference Resistor Rref= 27 kΩ

Application Note AN241

Revision: Rev. 1.0
2010-08-31

RF and Protection Devices

Edition 2010-08-31

Published by
Infineon Technologies AG
81726 Munich, Germany

Legal Disclaimer

The information given in this document shall in no event be regarded as a guarantee of conditions or characteristics. With respect to any examples or hints given herein, any typical values stated herein and/or any information regarding the application of the device, Infineon Technologies hereby disclaims any and all warranties and liabilities of any kind, including without limitation, warranties of non-infringement of intellectual property rights of any third party.

Information

For further information on technology, delivery terms and conditions and prices, please contact the nearest Infineon Technologies Office (**www.infineon.com**).

Warnings

Due to technical requirements, components may contain dangerous substances. For information on the types in question, please contact the nearest Infineon Technologies Office.

Infineon Technologies components may be used in life-support devices or systems only with the express written approval of Infineon Technologies, if a failure of such components can reasonably be expected to cause the failure of that life-support device or system or to affect the safety or effectiveness of that device or system. Life support devices or systems are intended to be implanted in the human body or to support and/or maintain and sustain and/or protect human life. If they fail, it is reasonable to assume that the health of the user or other persons may be endangered.

Application Note AN241
Revision History: 2010-08-31

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 (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 unprecedented 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	
3	1850 - 1915 MHz	1930 - 1995 MHz	
4	1850 - 1920 MHz	1930 - 2000 MHz	
5	1710 - 1785 MHz	1805 - 1880 MHz	
6	1710 - 1755 MHz	2110 - 2155 MHz	
7	824 - 849 MHz	869 - 894 MHz	
8	830 -840 MHz	875 - 885 MHz	
9	2500 - 2570 MHz	2620 - 2690 MHz	
10	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	
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) pathes 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.

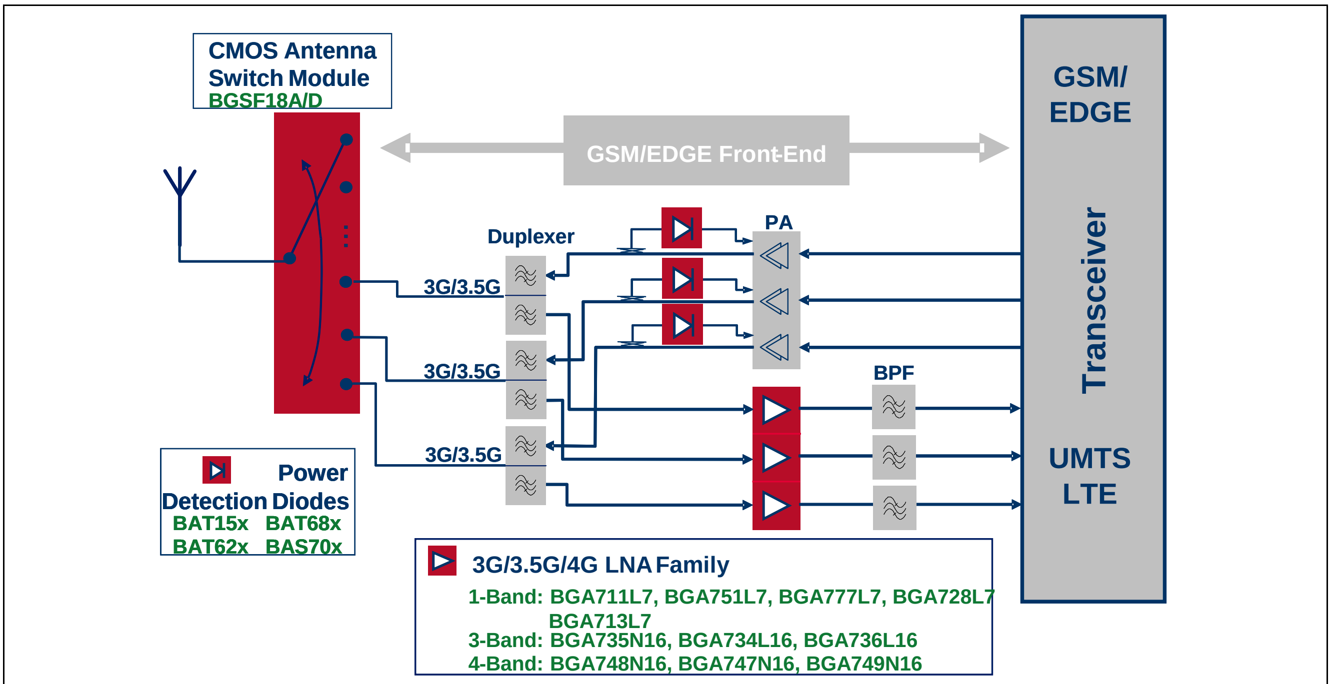

Figure 1 Application Diagram of a 3-band RF front-end for 3G and 4G systems.

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 an 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 always be put close to the transceiver IC. The path loss in front of the integrated LNA on the transceiver IC increases the system noise figure noticeable. 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.

Table 3 shows a list of the MMIC LNA portfolio from Infineon Technologies for the applications of 3G and 4G applications (stand July 2010). Depending on the applications, LNAs with different band combinations are available:

- Single-band LNAs like BGA711L7 for high-band (HB, 1700MHz-2300MHz), BGA777L7 for high-band (2300MHz-2700MHz) or BGA751L7 for low-band (LB, 700-1000MHz) are available. BGA713L7 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. BGA747N16 can cover 3x high-bands and 1x low-band. 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 (Stand July 2010)

Frequency Range	700 MHz – 1 GHz	1400MHz – 2200MHz	2100 MHz – 2700 MHz	Comment
Single-Band LNA				
BGA711L7		x		
BGA751L7	x			
BGA777L7			x	
BGA728L7	x	x		
BGA713L7	x			
Triple Band LNA				
BGA734L16	x	x	x	
BGA735N16	x	x	x	
BGA736N16	x	x	x	
Quad-band LNA				
BGA747N16	x	x	x	
BGA748N16	x	x	x	
BGA749N16	x	x	x	

2 Infineon LNA BGA735N16 for 3G and 4G Applications

This application note focuses on the Infineon's Tri-band LNA BGA735N16 tuned for the band combination of **band 1, 2 and 5**. It presents the performance of BGA735N16 **with an external reference resistor of 27 kΩ** which enables the device to work with a current of **4.4 mA** at single supply voltage of 2.8 V. All the measurements are executed with the standard evaluation board presented at the end of this application note.

2.1 Features of BGA735N16

- High gain and low gain modes
- Low noise figure
- Tunable supply current with external Rref
- 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-16-1 package (2.3 x 2.3 x 0.39 mm)
- Pb-free (RoHS compliant) device

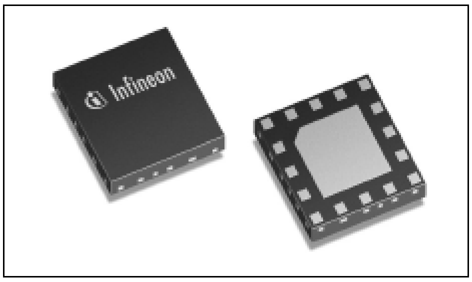

Figure 2 BGA735N16 in TSNP-16 Package

3 Description

Figure 3 shows the internal block diagram of BGA735N16 with the topview of the TSNP-16 and the pin assignment. **Table 4** is the pin assignment of BGA735N16 with the description of their functions accordingly. As shown in the block diagram, BGA735N16 includes 4 LNAs into one device. Each of the LNA can be switched to the high-gain and the low-gain mode. The gain switch can be easily done by switching the VGS pin to Vcc (high-gain mode) or 0 V (low-gain mode). Furthermore, the following functions are integrated into BGA735N16:

- Smart active biasing circuit: to enable the circuit performance over temperature and supply voltage variation.
- Output matching circuits for the standard bands (bands 3, 7, 20 in this case)
- Current setting with only one external resistor Rref.
- Band selection with the two pins VEN1 and VEN2 (Fehler! Verweisquelle konnte nicht gefunden werden.).
- On/off switch of the whole device with one single pin VONFehler! Verweisquelle konnte nicht gefunden werden.).
- All the digital control pins VON, VEN1, VEN2 and VGS are CMOS 2.8V logic compliant.
- ESD protection circuit allaround the device for 2kV HBM.

The RF input pins of the LNAs are connected directly with the base of the major SiGe:C RF transistors to achieve the best nosie figure performance. In addition, the input and the output matching circuits can be tuned to different bands if required.

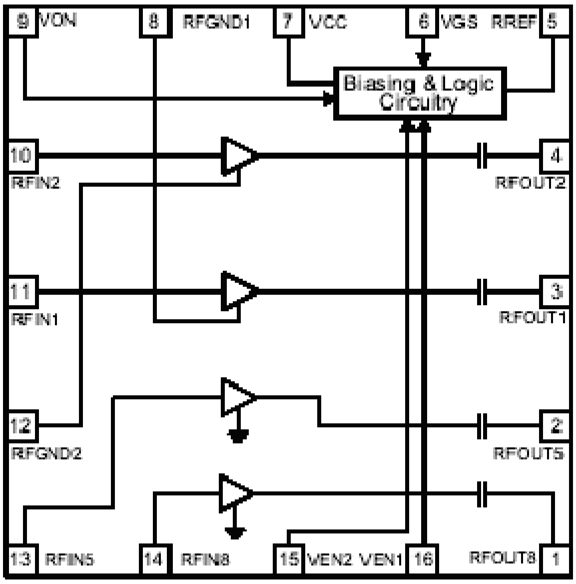

Figure 3 Block diagram and pin assignment of BGA735N16 (topview)

Table 4 Pin Assignment of BGA735N16

Pin No.	Symbol	Function
0	GND	Package paddle; ground connection for low band LNA and control circuity
1	n/c	Not connected
2	VGS	Gain step control
3	VCC	Supply Voltage
4	RFGNDH	High Band LNA emitter ground
5	n/c	Not connected
6	RFINM	Mid Band LNA input (1960 MHz)
7	RFINH	High Band LNA input (2140 MHz)
8	RFGNDM	Mid band LNA emitter ground
9	n/c	Not connected
10	RFINL	Low Band LNA input (880 MHz)
11	VEN2	Band select control
12	VEN1	Band select control
13	RREF	Bias current reference resistor (high gain mode)
14	RFOUTL	Low band LNA output (880 MHz)
15	RFOUTH	High band (2140 MHz) LNA output
16	RFOUTM	Mid band (1960 MHz) LNA output

Table 5 Band selection Truth table(Vcc=2.8V)

Pin control	Band 1	Band 2	Band 5	Stand-by
VEN1	H	H	L	L
VEN2	H	L	H	L

Table 6 Gain control Truth table(Vcc=2.8V)

Pin control	High Gain	Low Gain
VGS	H	L

4 Application Information

Figure 4 shows the application circuit of BGA735N16 for bands 1, 2 and 5.

4.1 Schematics

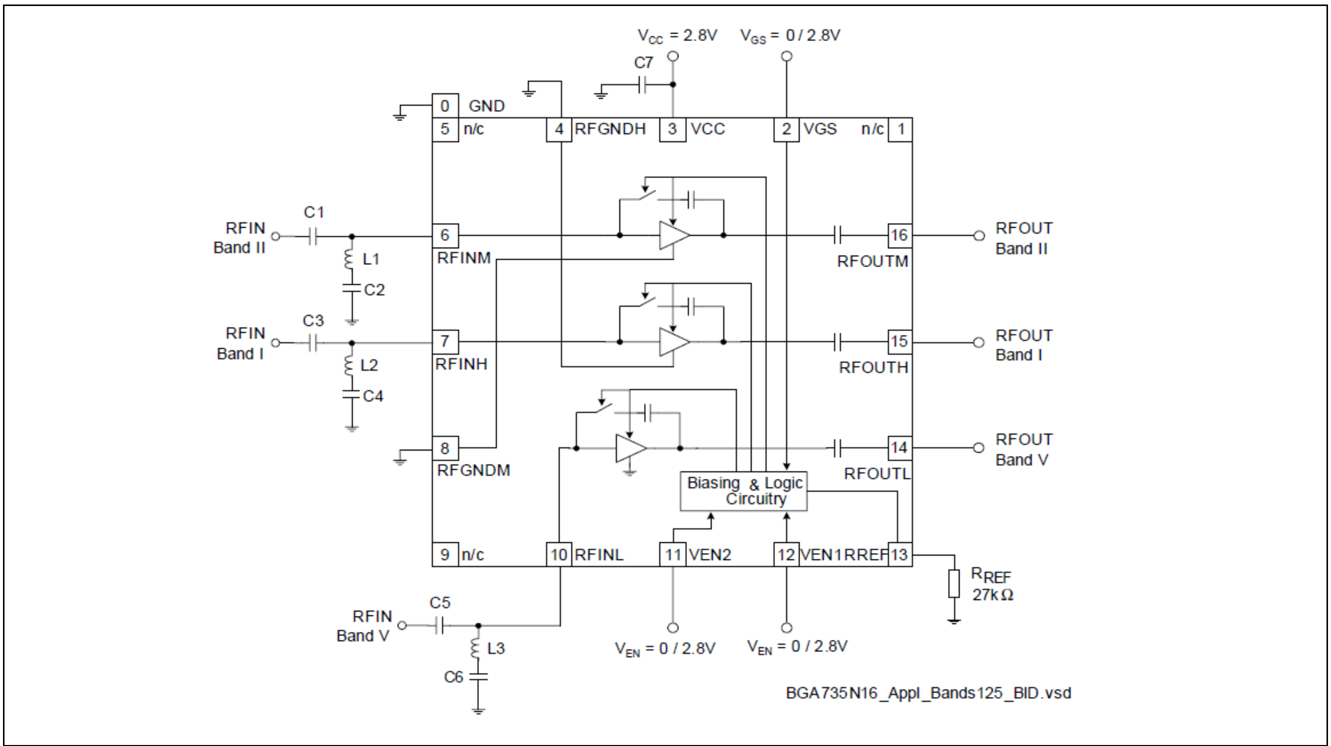

Figure 4 Schematics of the application circuit of BGA735N16 for bands 1, 2 and 5

Table 7 Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	10	pF	0402	Murata GRM15	Input matching / DC block
L1	3.3	nH	0402	Murata LQW15A	Input matching
C2	22	pF	0402	Murata GRM15	Input matching
C3	10	pF	0402	Murata GRM15	Input matching / DC block
L2	2.7	nH	0402	Murata LQW15A	Input matching
C4	22	pF	0402	Murata GRM15	Input matching / DC block
C5	3	pF	0402	Murata GRM15	Input matching
L3	9.1	nH	0402	Murata LQW15A	Input matching
C6	22	pF	0402	Murata GRM15	Input matching
C7	10	nF	0402	Murata GRM15	HF to ground
RREF	27	kΩ	0402	Various	Current settings
Q1			TSNP-16-1	Infineon	SiGe MMIC LNA BGA735N16

5 Typical Measurement Results

5.1 Results of Band 1

Table 8 Electrical Characteristics Band 1 (at room temperature)

Band 1, VGS=0V for low gain mode, VGS=2.8V for high gain mode

Parameter	Symbol	Value		Unit	Comment/Test Condition
Frequency Range	Freq	2110 - 2170		MHz	
DC Supply Voltage	Vcc	2.8		V	
Gain Mode	-	High Gain	Low Gain		
DC Current	Icc	4.2	0.65	mA	
Gain	G	17.5	-7.5	dB	
Noise Figure	NF	1.0	7.7	dB	SMA and PCB losses of 0.2 excluded
Input Return Loss	RLin	16	21.9	dB	
Output Return Loss	RLout	22.6	14.6	dB	
Reverse Isolation	IRev	35.2	7.6	dB	Power@Port2: -30dBm
Input P1dB	IP1dB	-9	-4.5	dBm	
Output P1dB	OP1dB	6.5	-12	dBm	
Input IP3	IIP3	-2.8	3	dBm	Power@Input: -30/-20dBm Δf =1MHz
Output IP3	OIP3	14.7	-4.5	dBm	
Stability	k	2.8		--	Stability measured from 100MHz to 10GHz

5.2 Results of Band 2

Table 9 Electrical Characteristics Band 2 (at room temperature)

Band 2, VGS=0V for low gain mode, VGS=2.8V for high gain mode

Parameter	Symbol	Value		Unit	Comment/Test Condition
Frequency Range	Freq	1930 - 1990		MHz	
DC Supply Voltage	Vcc	2.8		V	
Gain Mode	-	High Gain	Low Gain		
DC Current	Icc	3.4	0.65	mA	
Gain	G	15.5	-8.6	dB	
Noise Figure	NF	1.0	7.7	dB	SMA and PCB losses of 0.3 excluded
Input Return Loss	RLin	19.5	19.6	dB	
Output Return Loss	RLout	12.9	9.5	dB	
Reverse Isolation	IRev	35.3	-8.5	dB	Power@Port2: -30dBm
Input P1dB	IP1dB	-6.2	-5	dBm	
Output P1dB	OP1dB	9.3	-13.6	dBm	
Input IP3	IIP3	-6.8	-4.3	dBm	Power@Input: -30/-20dBm Δf =1MHz
Output IP3	OIP3	8.8	-4.4	dBm	
Stability	K	2.9		--	Stability measured from 100MHz to 10GHz

5.3 Results of Band 5

Table 10 Electrical Characteristics Band 5 (at room temperature)

Band 5, VGS= 2.8 V for low gain mode, VGS= 0 V for high gain mode

Parameter	Symbol	Value		Unit	Comment/Test Condition
Frequency Range	Freq	869 - 894		MHz	
DC Supply Voltage	Vcc	2.8		V	
Gain Mode	-	High Gain	Low Gain		
DC Current	Icc	3.5	0.65	mA	
Gain	G	15.5	-7.9	dB	
Noise Figure	NF	1.1	7.5	dB	SMA and PCB losses of 0.15 excluded
Input Return Loss	RLin	15.7	18.3	dB	
Output Return Loss	RLout	11.8	11	dB	
Reverse Isolation	IRev	36.9	7.9	dB	Power@Port2: -30dBm
Input P1dB	IP1dB	-5.2	-8.2	dBm	
Output P1dB	OP1dB	10.4	-16.1	dBm	
Input IP3	IIP3	-9	0.1	dBm	Power@Input: -30/-20dBm Δf =1MHz
Output IP3	OIP3	6.5	-7.8	dBm	
Stability	k	2.8		--	Stability measured from 100MHz to 10GHz

6 Measured Graphs

6.1 Graphs of Band 1

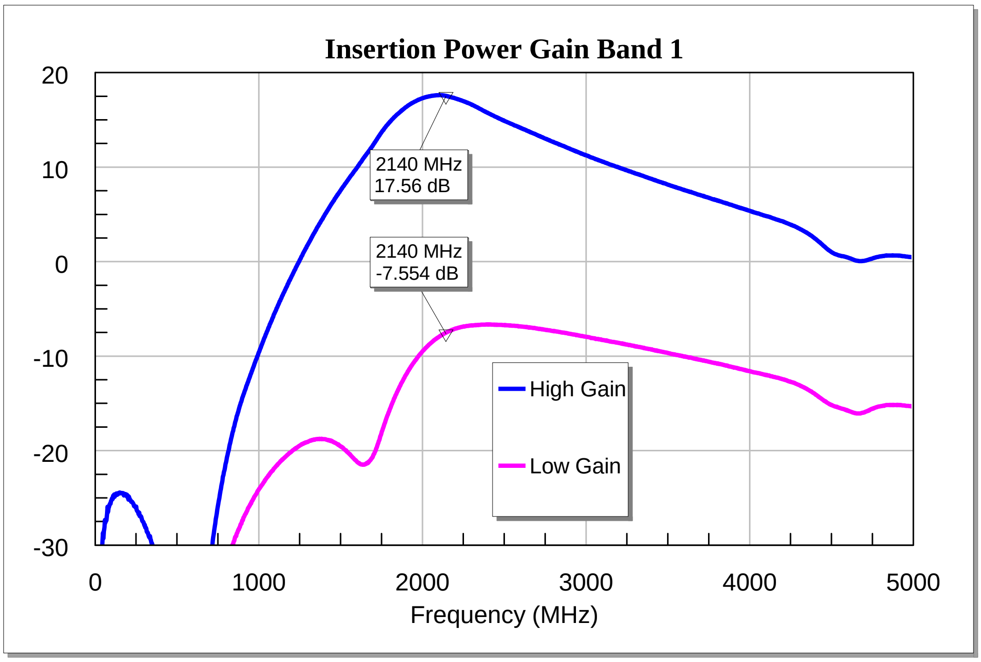

Figure 5 Measured Power Gain of BGA735N16 in Band 1 with Rref= 27 kΩ

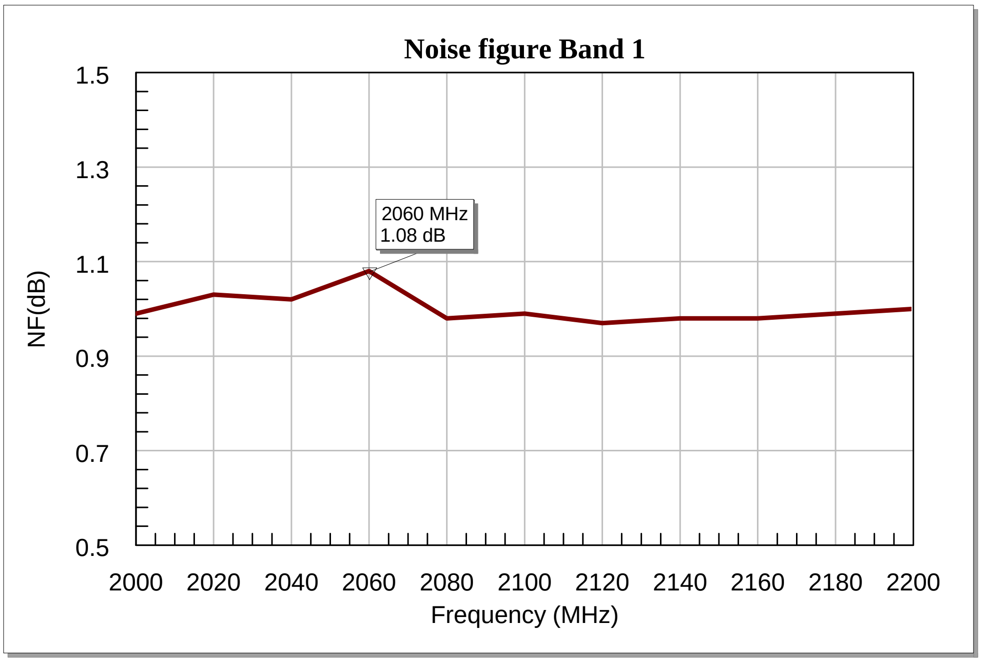

Figure 6 Measured Noise Figure of BGA735N16 in Band 1 with Rref= 27 kΩ

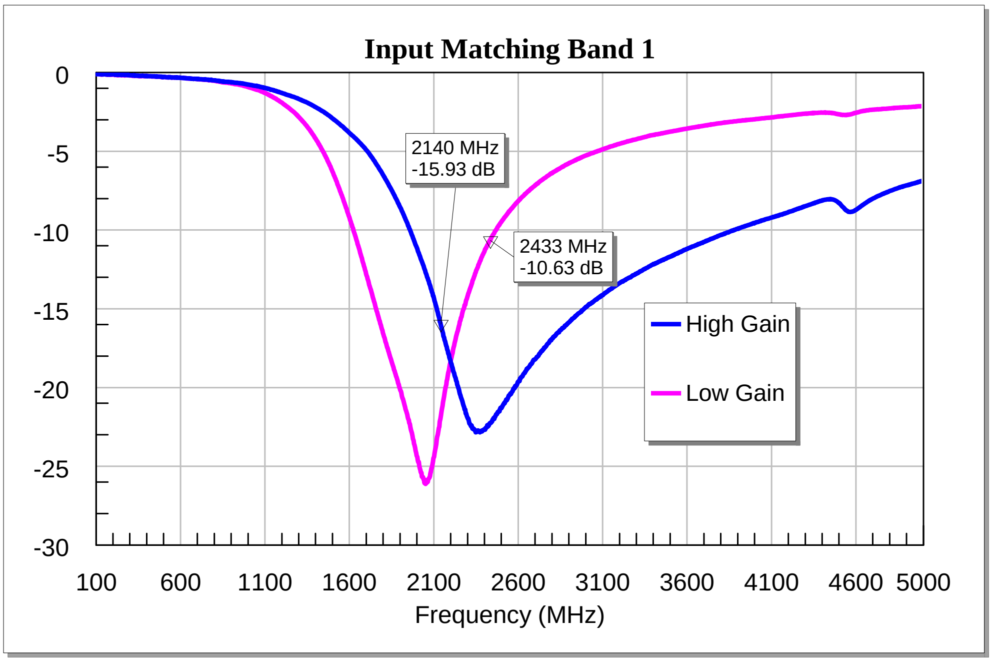

Figure 7 Measured input insertion loss of BGA735N16 in Band 1 with Rref= 27 kΩ

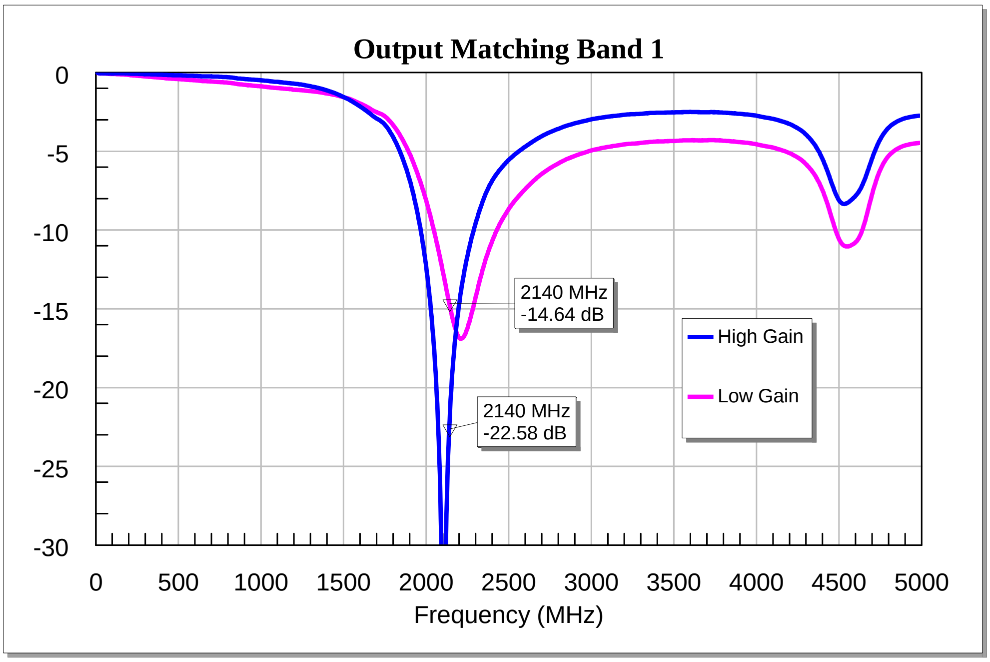

Figure 8 Measured output insertion loss of BGA735N16 in Band 1 with Rref= 27 kΩ

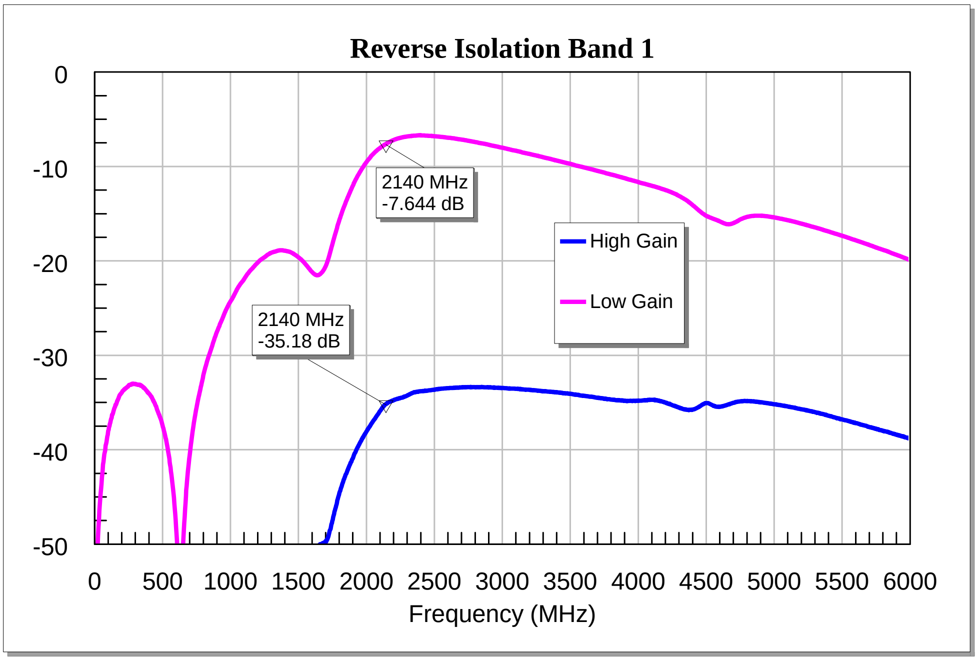

Figure 9 Measured reverse isolation of BGA735N16 in Band 1 with Rref= 27 kΩ

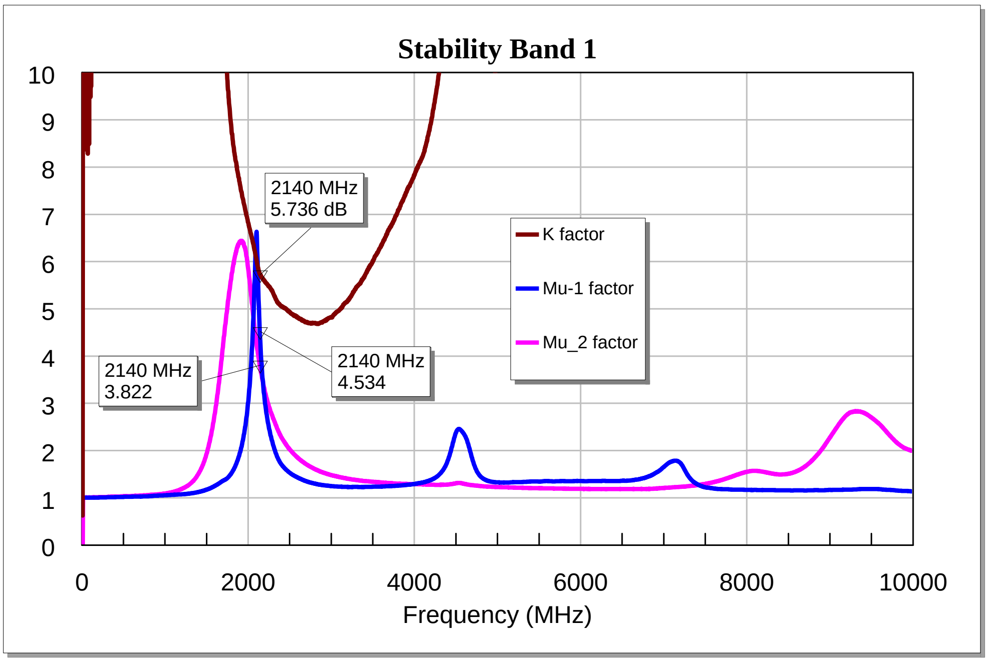

Figure 10 Measured stability factor of BGA735N16 in Band 1 with Rref= 27 kΩ

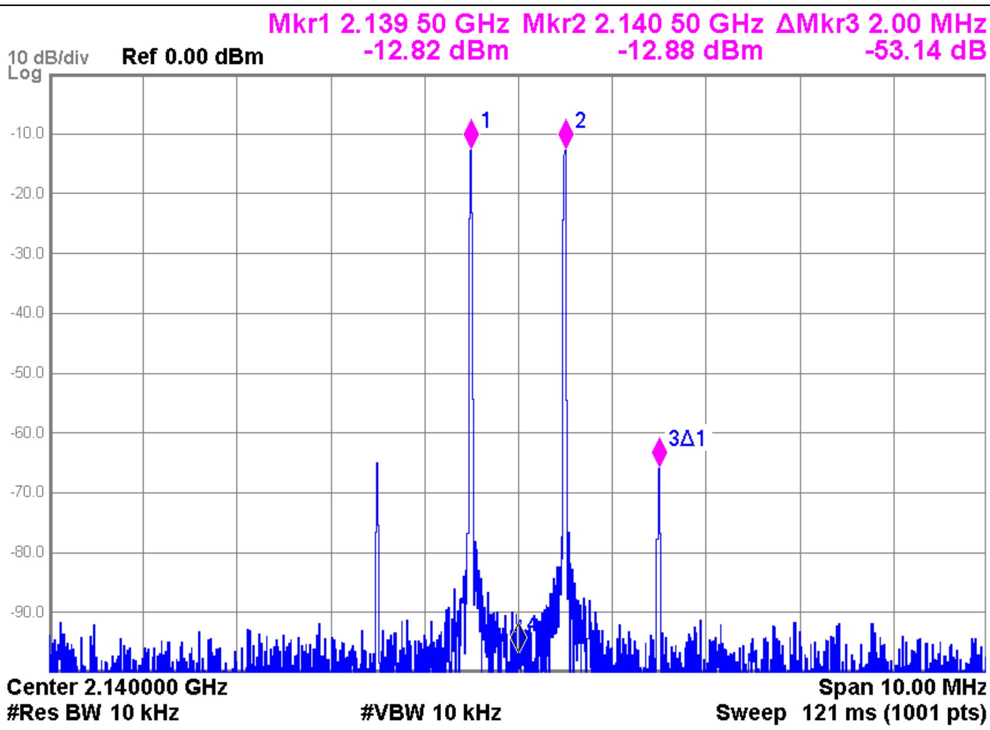

Figure 11 Measured input IP3 of BGA735N16 in middle of Band 1 with Rref= 27 kΩ (High Gain Mode)

6.2 Graphs of Band 2

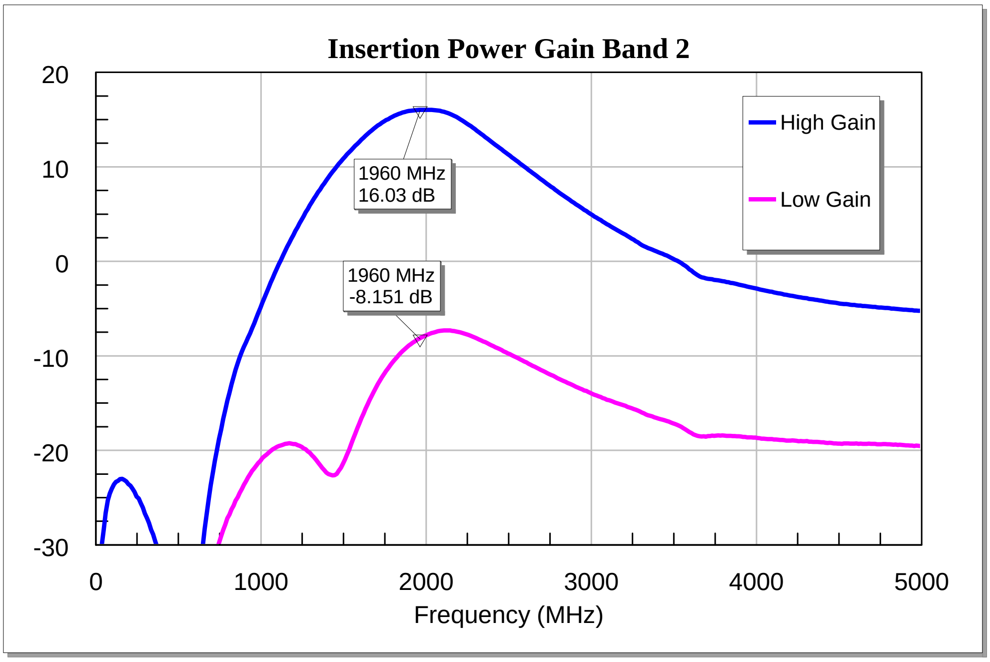

Figure 12 Measured Power Gain of BGA735N16 in Band 2 with Rref= 27 kΩ

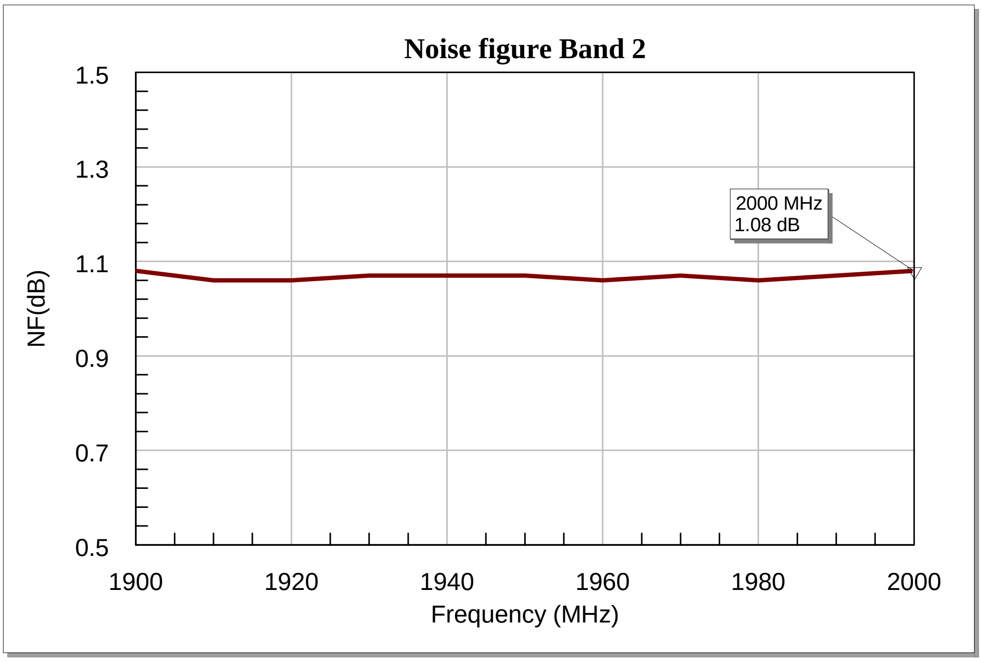

Figure 13 Measured Noise Figure of BGA735N16 in Band 2 with Rref= 27 kΩ

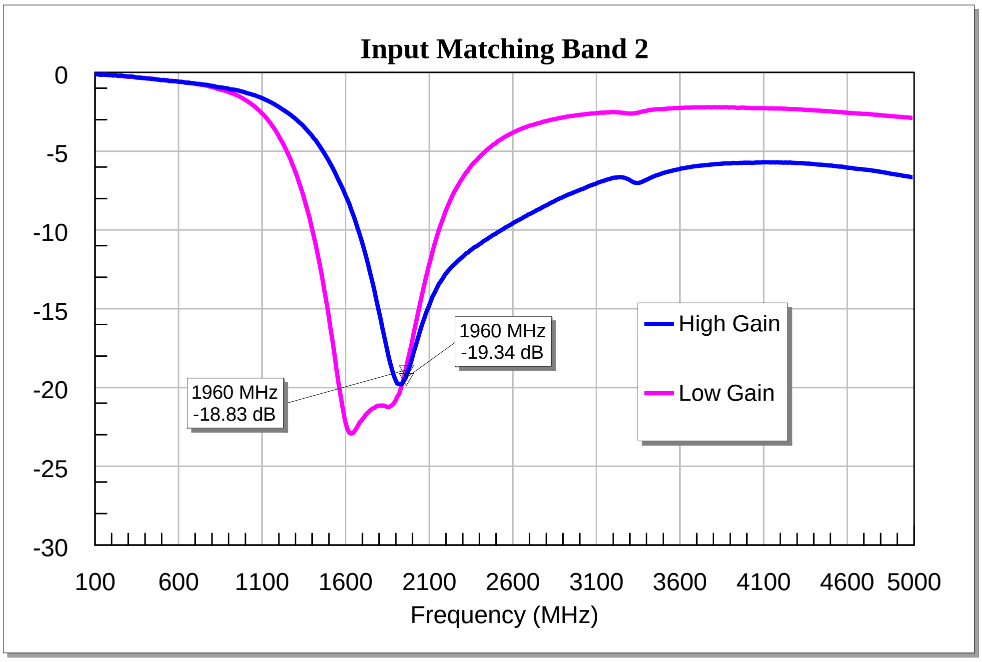

Figure 14 Measured input insertion loss of BGA735N16 in Band 2 with Rref= 27 kΩ

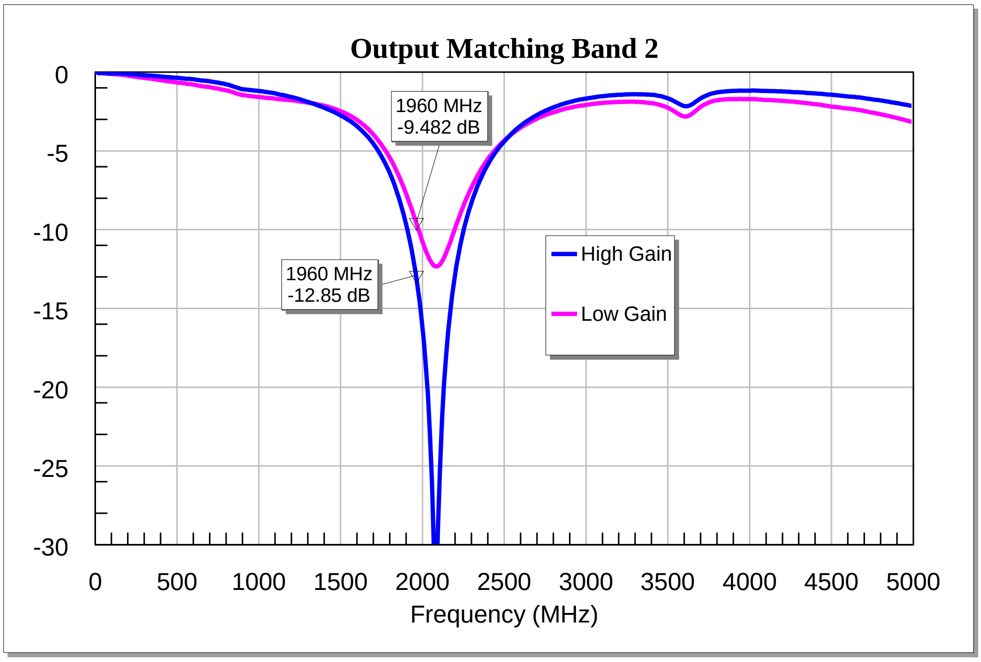

Figure 15 Measured output insertion loss of BGA735N16 in Band 2 with Rref= 27 kΩ

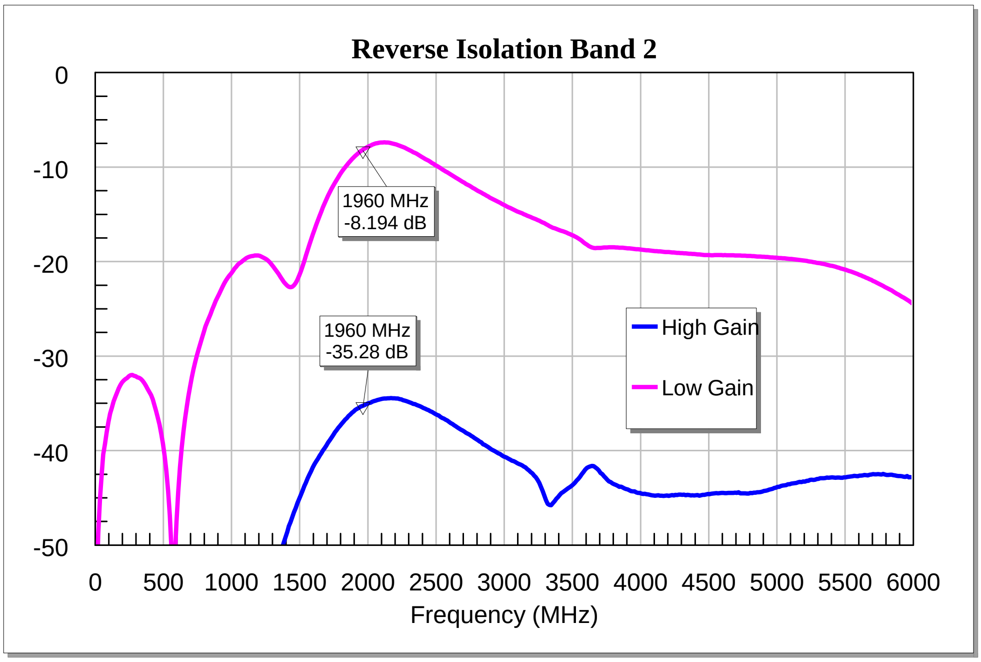

Figure 16 Measured reverse isolation of BGA735N16 in Band 2 with Rref= 27 kΩ

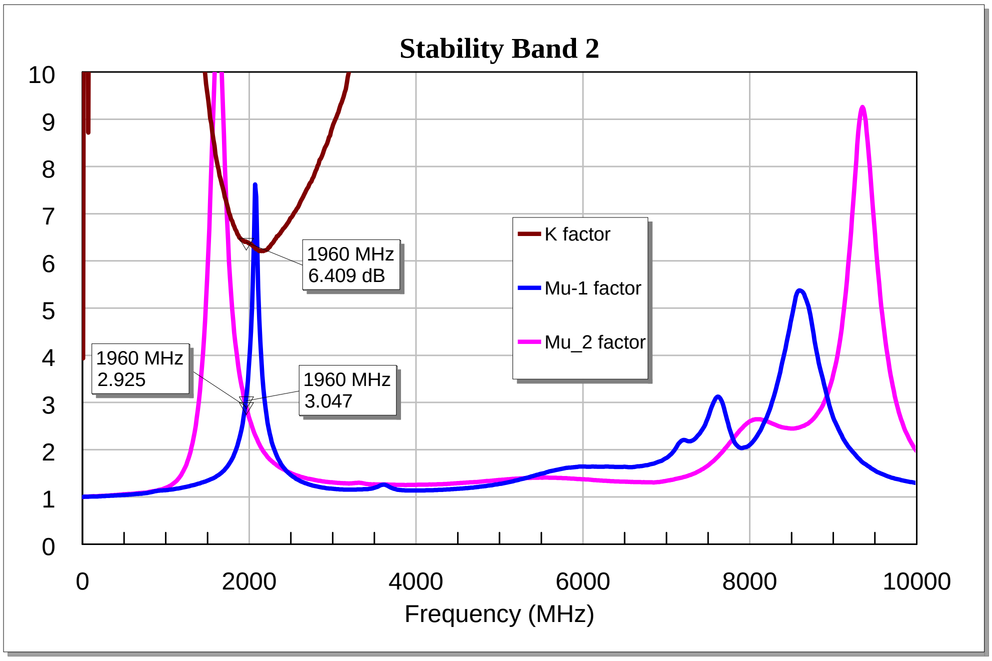

Figure 17 Measured stability factor of BGA735N16 in Band 2 with Rref= 27 kΩ

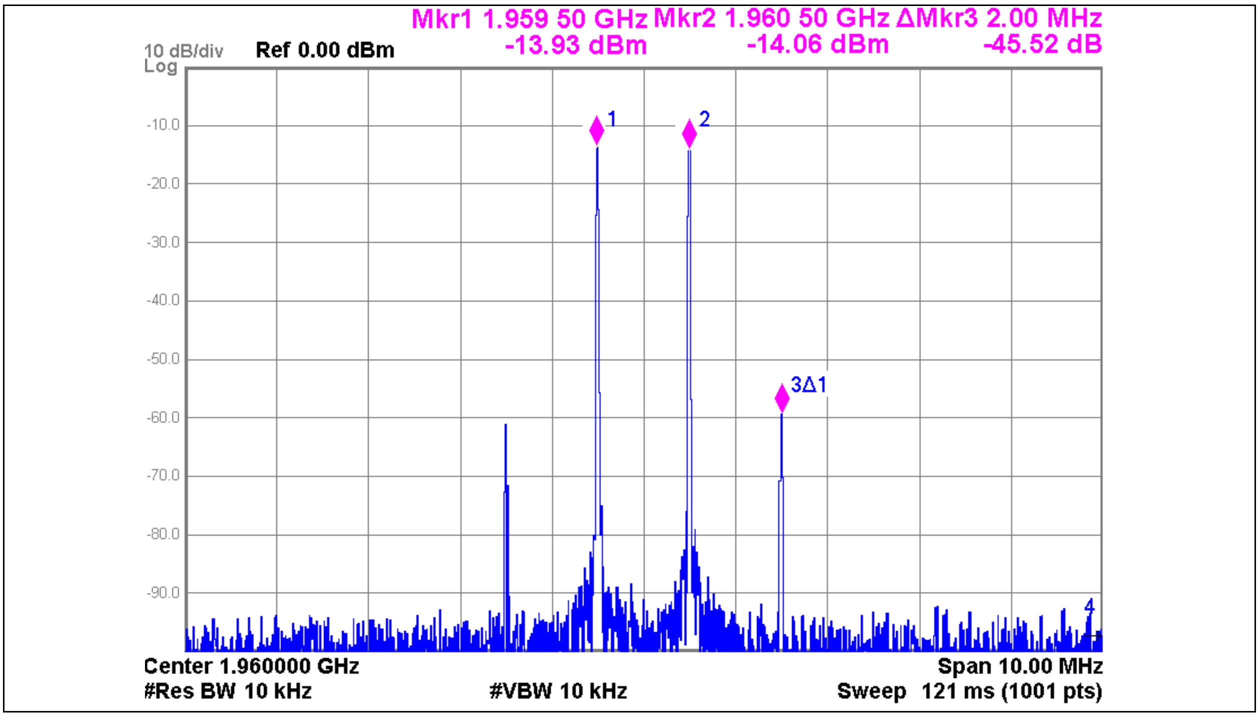

Figure 18 Measured input IP3 of BGA735N16 in middle of Band 2 with Rref= 27 kΩ (High Gain Mode)

6.3 Graphs of Band 5

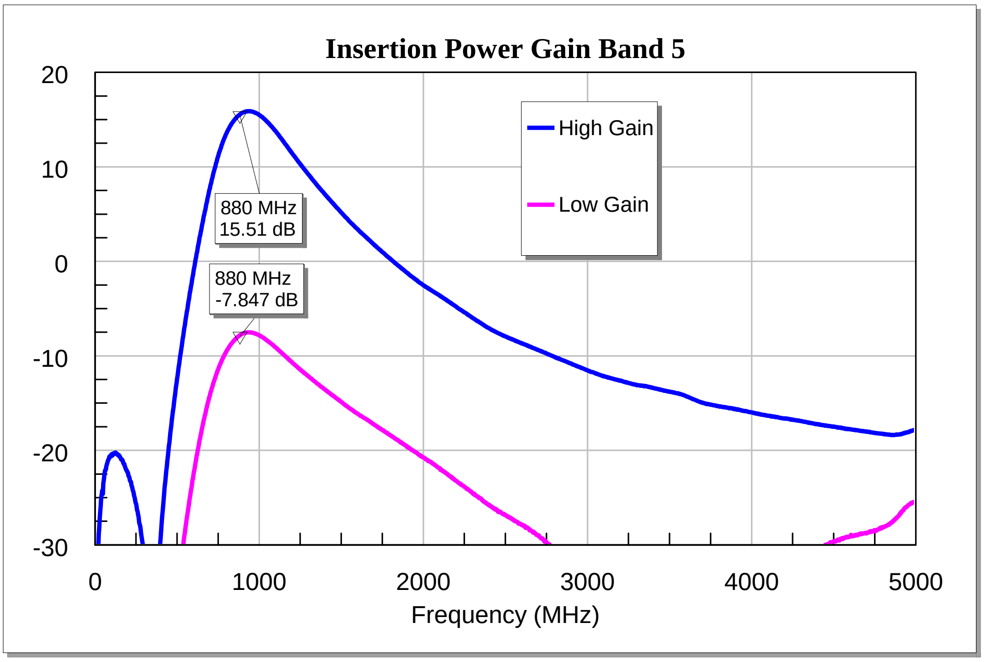

Figure 19 Measured Power Gain of BGA735N16 in Band 5 with Rref= 27 kΩ

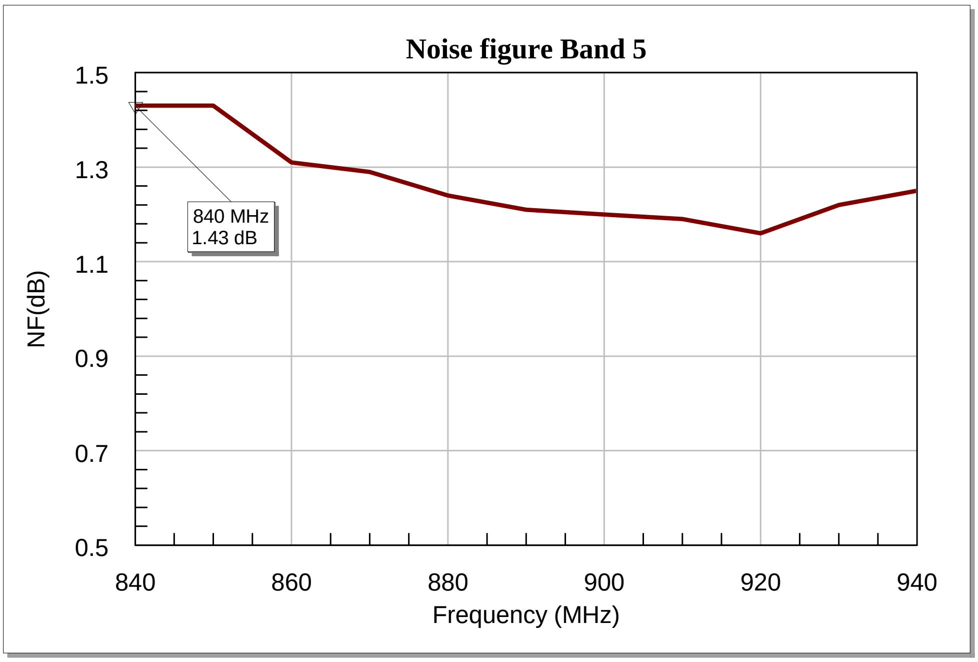

Figure 20 Measured Noise Figure of BGA735N16 in Band 5 with Rref= 27 kΩ

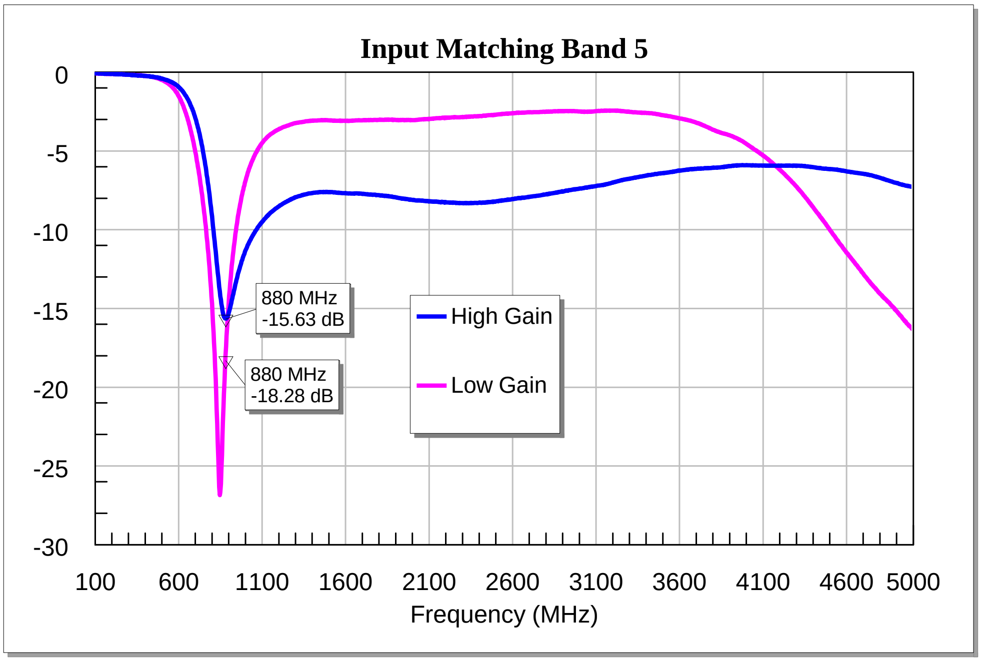

Figure 21 Measured input insertion loss of BGA735N16 in Band 5 with Rref= 27 kΩ

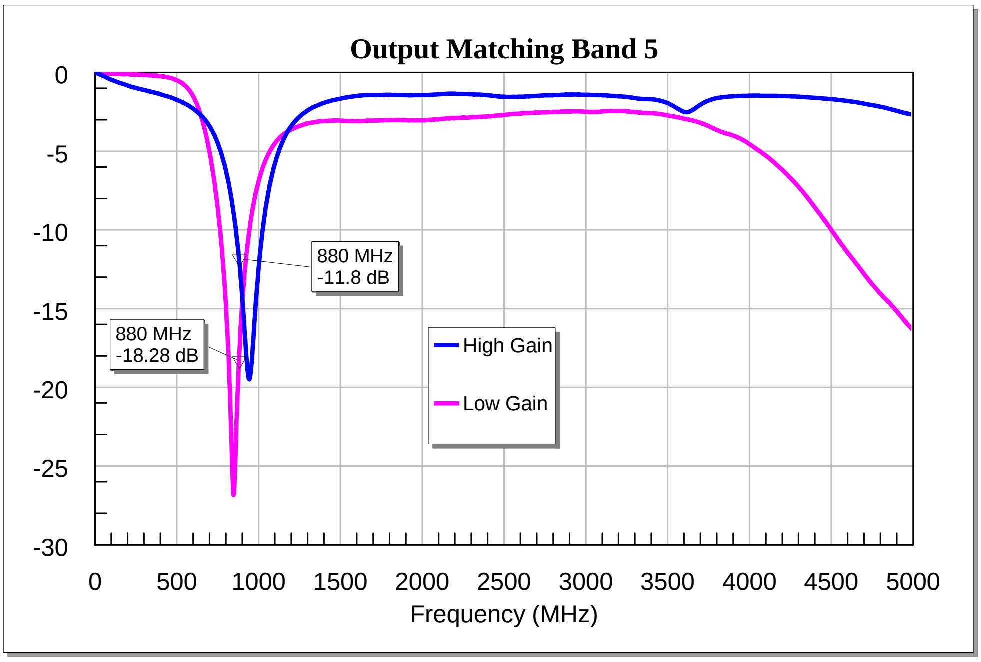

Figure 22 Measured output insertion loss of BGA735N16 in Band 5 with Rref= 27 kΩ

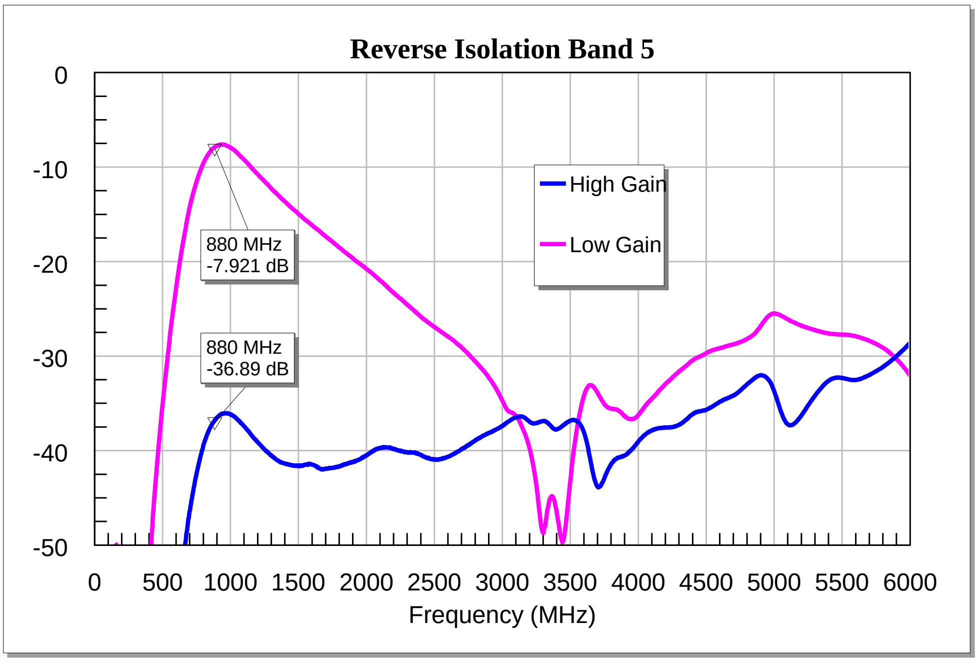

Figure 23 Measured reverse isolation of BGA735N16 in Band 5 with Rref= 27 kΩ

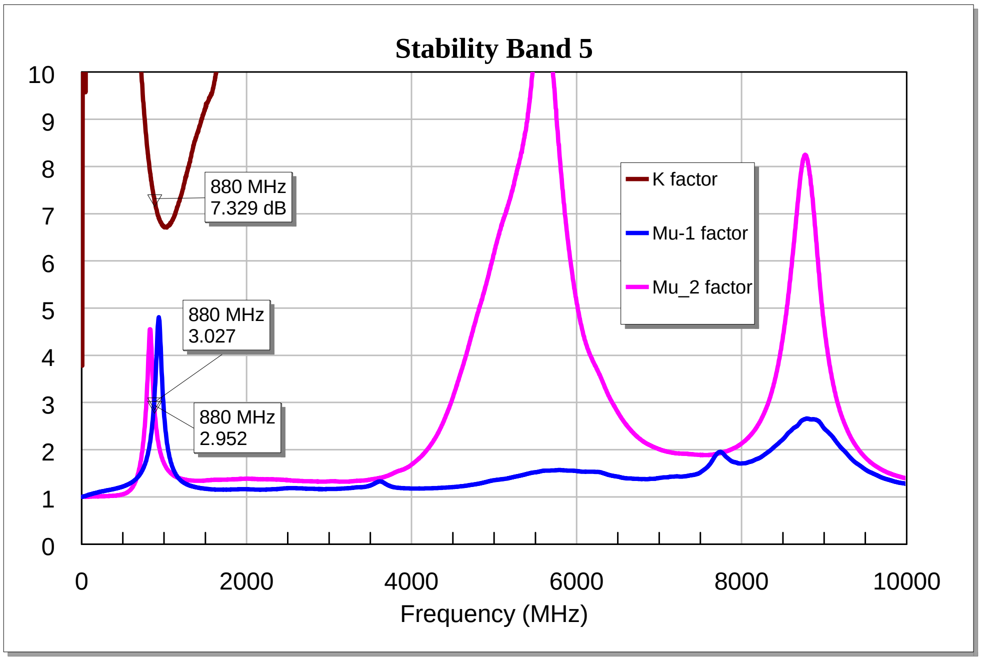

Figure 24 Measured stability factor of BGA735N16 in Band 5 with Rref= 27 kΩ

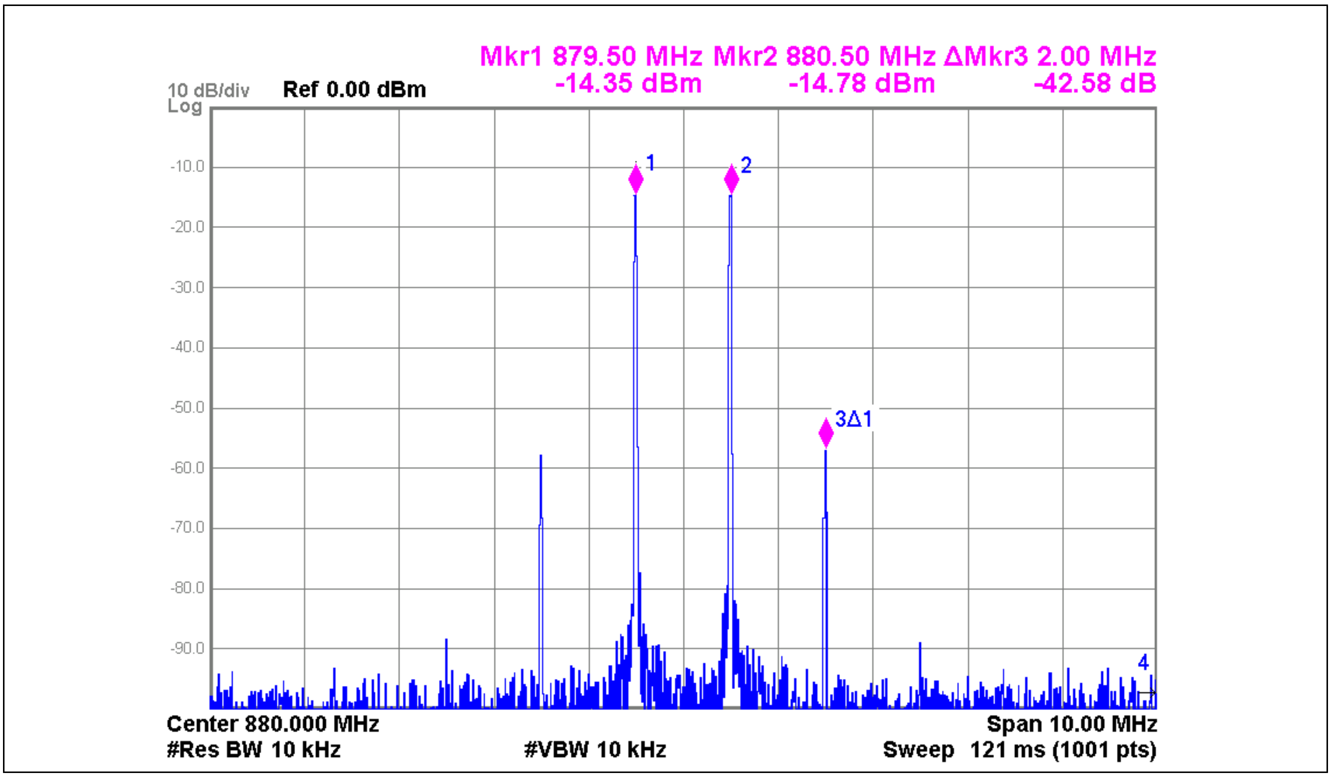

Figure 25 Measured input IP3 of BGA735N16 in middle of Band 5 with Rref= 27 kΩ (High Gain Mode)

7 Evaluation Board and Layout Information

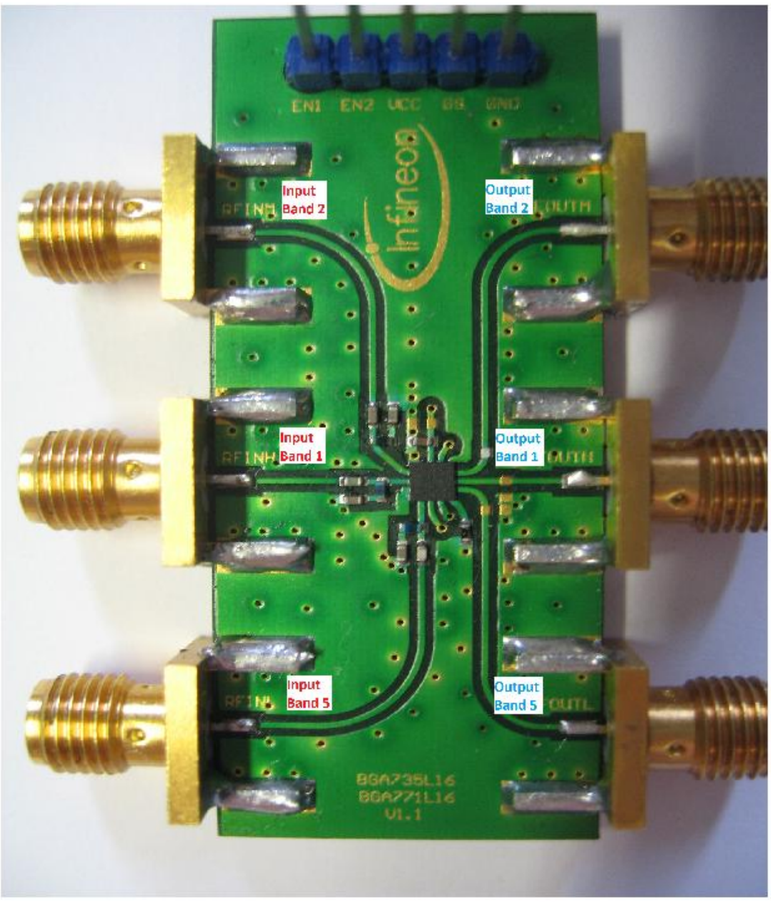

Figure 26 Photo Picture of Evaluation Board of BGA735N16

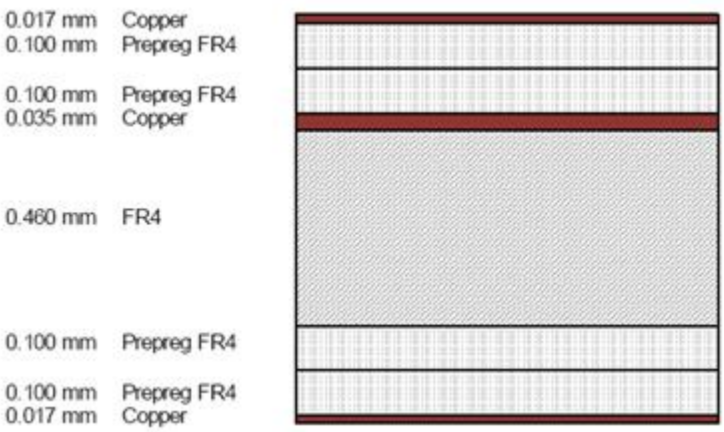

Figure 27 PCB Layer Information of BGA735N16

Authors

André Dewai, RF Engineer of Business Unit “RF and Protection Devices”

Dr.Chih-I Lin, Senior Staff engineer of Business Unit “RF and Protection Devices”

Anthony Thomas, RF Engineer of Business Unit “RF and Protection Devices”

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

Published by Infineon Technologies AG AN241