BGA824N6

Temparature Variation of high-Linearity Low Noise Ampifier for Global Navigation Satellite Systems (GNSS)

Application Note AN325

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Application Note AN325
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Previous Revision: None

Page	Subjects (major changes since last revision)

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1 Introduction of Global Navigation Satellite Systems (GNSS)

The BGA824N6 is a front-end Low Noise Amplifier (LNA) for Global Navigation Satellite Systems (GNSS) application. It is based on Infineon Technologies' B7HF Silicon-Germanium (SiGe) technology, enabling a cost-effective solution in a TSNP-6-2 leadless package with ultra low noise figure, high linearity, low current consumption and high gain, over a wide range of supply voltages from 1.5 V up to 3.6 V. All these features make BGA824N6 an excellent choice for GNSS LNA as it improves sensitivity, provide greater immunity against out-of-band jammer signals, reduces filtering requirement and hence the overall cost of the GNSS receiver.

The GNSS satellites are at an orbit altitude of more than 20,000 km away from earth's surface and transmit power in the range of +47 dBm. After taking losses (atmospheric, antenna etc.) into account, the received signal strength at the GNSS device input is very low in the range of -130 dBm. The ability of the GNSS device to receive such low signal strength and provide meaningful information to the end-user depends strongly on the noise figure of the GNSS receives chain. This ability which is called receiver sensitivity can be improved by using a low-noise amplifier with low noise figure and high gain at the input of the receiver chain. The improved sensitivity results in a shorter Time-To-First-Fix (TTFF), which is the time required for a GNSS receiver to acquire satellite signals and navigation data, and calculate a position. Noise figure of the LNA defines the overall noise figure of the GNSS receiver system. This is where BGA824N6 excels by providing noise figure as low as 0.55 dB and high gain of 17 dB, thereby improving the receiver sensitivity significantly.

The ever growing demand to integrate more and more functionality into one device leads to many challenges when transmitter/receiver has to work simultaneously without degrading the performance of each other. In today's smart-phones a GNSS receiver simultaneously co-exists with transceivers in the GSM/EDGE/UMTS/LTE bands. These 3G/4G transceivers transmit high power in the range of +24 dBm which due to insufficient isolation couple to the GNSS receiver. The cellular signals can mix to produce Intermodulation products exactly in the GNSS receiver frequency band. For example, GSM 1712.7 MHz mixes with UMTS 1850 MHz to produce third-order-product exactly at GPS. To quantify the effect, BGA824N6 shows out-of-band input IP3 at GPS of +7 dBm as a result of frequency mixing between GSM

1712.7 MHz and UMTS 1850 MHz with power levels of -20 dBm. Due t this high out-of-band input 3rd order intercept point (IIP3), BGA824N6 is especially suitable for the GPS function in mobile phones.

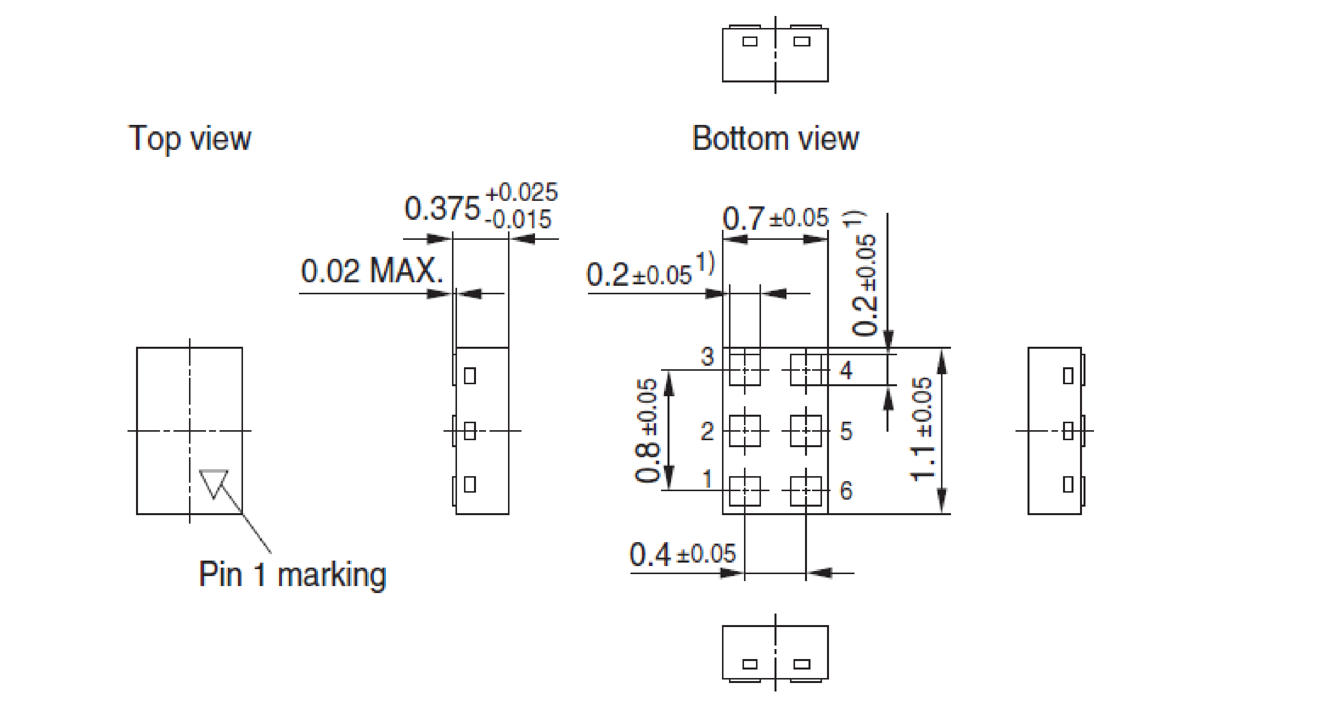

Figure 1 **BGA824N6 TSNP-6-2 leadless Package size**

As the industry inclines toward assembly miniaturization and also surface mount technology matures, there is a desire to have smaller and thinner components. This is especially the case with portable electronics where higher circuit density allows device design flexibility and also optimum use of the limited space available. BGA824N6 has a small package with dimensions of 0.70mm x 1.1mm x 0.375mm and it requires only one external component at its input, the inductor providing input matching. The DC block at input is optional as it is usually provided by the pre-filter before the LNA in many GPS applications. All the device/phone manufacturers implement very good power supply filtering on their boards so that the RF bypass capacitor mentioned in this application circuit may not be needed in the end. The minimal number of external SMD components reduces the application bill of materials, assembly complexity and the PCB area thus making it an ideal solution for compact and cost-effective GNSS LNA. The output of the BGA824N6 is internally matched to 50 Ω, and a DC blocking capacitor is integrated on-chip, thus no external component is required at the output

The device also integrates an on-chip ESD protection which can resist until 2 kV (referenced to Human Body Model) in all pins. The integrated power on/off feature provides for low power consumption and increased stand-by time for GNSS handsets. Moreover, the low current consumption (3.8 mA) makes the device suitable for portable technology like GNSS receivers and mobiles phones.

The Internal circuit diagram of the BGA824N6 is presented in Figure 3. Table 1 show the pin assignment of BGA824N6. Table 2 shows the truth table to turn on/off BGA824N6 by applying different voltage to the PON pin.

2 BGA824N6 Overview

2.1 Features

- High insertion power gain: 17.0 dB
- Out-of-band input 3rd order intercept point: +7 dBm
- Input 1 dB compression point: -6 dBm
- Low noise figure: 0.55 dB
- Low current consumption: 3.8 mA
- Operating frequencies: 1550 - 1615 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

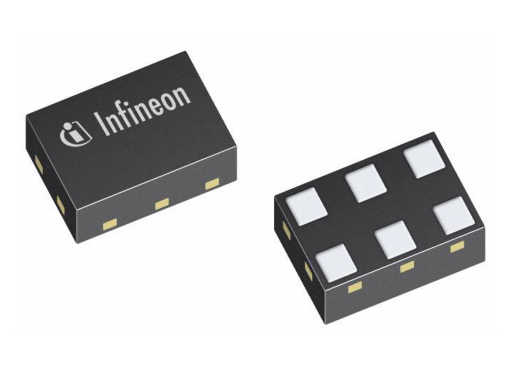

Figure 2 BGA824N6 in TSNP-6-2

RoHS

2.2 Key Applications of BGA824N6

- Ideal for all Global Navigation Satellite Systems (GNSS) like
  - GPS (Global Positioning System) working in the L1 band at 1575.42 MHz
  - GLONASS (Russian GNSS) working in the L1 band from 1598.06 MHz to 1605.38 MHz
  - Galileo (European GNSS) working in the E2-L1-E1 band from 1559 MHz to 1592 MHz
  - COMPASS (Chinese Beidou Navigation System) working in E2 band at 1561.10 MHz and E1 band at 1589.74 MHz

2.3 Description

The BGA824N6 is a front-end low noise amplifier for Global Navigation Satellite Systems (GNSS) from 1550 MHz to 1615 MHz like GPS, GLONASS, Beidou, Galileo and others. The LNA provides 17.0 dB gain and 0.55 dB noise figure at a current consumption of 3.8 mA in the application configuration described in **Chapter 3**. The BGA824N6 is based upon Infineon Technologies B7HF Silicon Germanium technology. It operates from 1.5 V to 3.6 V supply voltage.

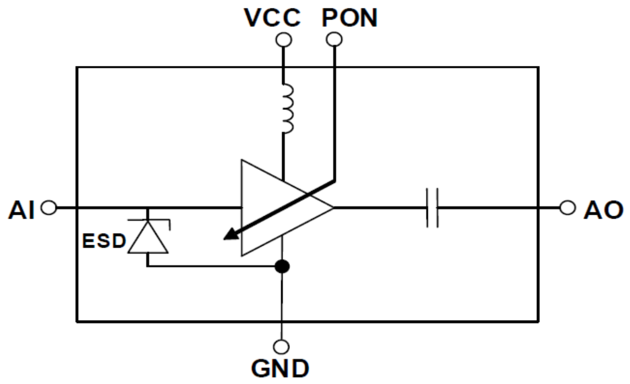

Figure 3 Equivalent Circuit of BGA824N6

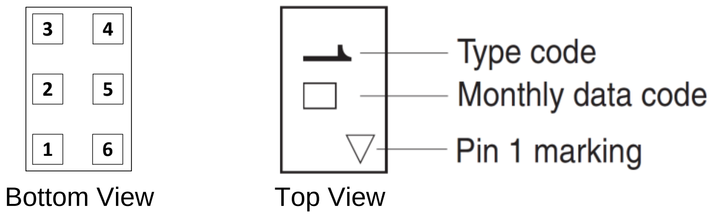

Figure 4 Package and pin connections of BGA824N6

Table 1 Pin Assignment of BGA824N6

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

Table 2 Pin Assignment of BGA824N6

LNA Mode	Symbol	ON/OFF Control Voltage at PON pin	
		Min	Max
ON	PON, on	1.0 V	VCC
OFF	PON, off	0 V	0.4 V

3 Application Circuit and Performance Overview

Device: BGA824N6

Application: Temparature Variation of high-Linearity Low Noise Ampifier for Global Navigation Satellite Systems (GNSS)

PCB Marking: BGA824N6

3.1 Summary of Measurement Results

Table 3 Electrical Characteristics for COMPASS/Galileo at Vcc = Vpon = 2.8 V

Parameter	Symbol	Value					Unit	Comment/Test Condition
Frequency Range	Freq	1559-1593					MHz	
DC Voltage	Vcc	2.8					V	
Temparature	T	-40	-15	0	25	85	°C	
DC Current	Icc	4.1	4.1	4	3.9	3.7	mA	
Gain	G	18	17.7	17.5	17.2	16.2	dB	
Noise Figure	NF	0.4	0.47	0.52	0.59	0.88	dB	PCB and SMA losses 0.05dB are substracted
Input Return Loss	RLin	14.5	14.2	14	13.6	12	dB	
Output Return Loss	RLout	26.4	25.1	24.3	23.6	23	dB	
Reverse Isolation	IRev	23.1	23.1	23.2	23.2	23.2	dB	
Input P1dB	IP1dB	-7.3	-7.2	-7.2	-7.2	-7.1	dBm	$f_{galileo}$ = 1559 MHz
Output P1dB	OP1dB	10.7	10.4	10.3	10	9.3	dBm	
Input IP3 In-band	IIP3	3.3	3	2.7	1.6	0.1	dBm	
Output IP3 In-band	OIP3	21.1	20.7	20.2	19.8	17.3	dBm	f_{1gal} = 1559 MHz f_{2gal} = 1560MHz Input power= -30dBm
Stability	k	>1					--	Unconditionnally Stable from 0 to 10GHz

Table 4 Electrical Characteristics for GPS at Vcc = Vpon = 2.8 V

Parameter	Symbol	Value					Unit	Comment/Test Condition
Frequency Range	Freq	1575.42					MHz	
DC Voltage	Vcc	2.8					V	DC Voltage
Temparature	T	-40	-15	0	25	85	°C	
DC Current	Icc	4.1	4.1	4	3.9	3.7	mA	
Gain	G	17.9	17.6	17.4	17	16	dB	
Noise Figure	NF	0.43	0.48	0.52	0.59	0.87	dB	PCB and SMA losses 0.05dB are substracted
Input Return Loss	RLin	15.5	15.1	14.9	14.5	12.7	dB	
Output Return Loss	RLout	21.8	21.1	20.5	20	19.7	dB	
Reverse Isolation	IRev	23	23.1	23.1	23.2	23.2	dB	
Input P1dB	IP1dB	-7.2	-7.1	-7.1	-7.1	-7	dBm	$f_{galileo}$ = 1575.42 MHz
Output P1dB	OP1dB	10.6	10.4	10.3	10.1	9.3	dBm	
Input IP3 In-band	IIP3	3.7	3.4	3.1	2	0.5	dBm	
Output IP3 In-band	OIP3	21.6	21	20.4	19	16.5	dBm	f_{1gps} = 1575 MHz f_{2gps} = 1576MHz Input power= -30dBm
LTE band-13 2nd Harmonic	H2 – input referred				-28.2		dBm	f_{IN} = 787.76 MHz P_{IN} = -25 dBm f_{H2} = 1575.52 MHz
Input IP3 out-of-band	$IIP3_{OOB}$	11.3	10.7	10.1	8.2	5.9	dBm	f_1 = 1712.7 MHz f_2 = 1850 MHz Input power = -20dBm f_{IIP3} = 1575.4 MHz
Output IM2 Out-of-band	IM2				-36.6		dBm	f_1 = 827 MHz , P_{IN1} = -28 dBm f_2 = 2402 MHz, P_{IN2} = -28 dBm
Output IM2 Out-of-band	IM2				-35.9		dBm	f_1 = 897 MHz , P_{IN1} = -28 dBm f_2 = 2472 MHz, P_{IN2} = -28 dBm
Stability	k	>1					--	Unconditionnally Stable from 0 to 10GHz

Table 5 Electrical Characteristics for GLONASS at Vcc = Vpon = 2.8 V

Parameter	Symbol	Value					Unit	Comment/Test Condition
Frequency Range	Freq	1598-1606					MHz	
DC Voltage	Vcc	2.8					V	
Temparature	T	-40	-15	0	25	85	°C	
DC Current	Icc	4.1	4.1	4	3.9	3.7	mA	
Gain	G	17.7	17.4	17.2	16.9	15.9	dB	
Noise Figure	NF	0.42	0.47	0.53	0.61	0.9	dB	PCB and SMA losses 0.05dB are substracted
Input Return Loss	RLin	16.9	16.5	16.3	15.9	13.9	dB	
Output Return Loss	RLout	17.1	16.7	16.3	16	15.7	dB	
Reverse Isolation	IRev	-23	-23.1	-23.1	-23.1	-23.2	dB	
Input P1dB	IP1dB	-6.9	-6.8	-6.8	-6.7	-6.4	dBm	$F_{GLONASS}$ = 1605.38 MHz
Output P1dB	OP1dB	10.8	10.6	10.4	10.2	9.5	dBm	
Input IP3 In-band	IIP3	4	3.7	3.3	2.4	0.9	dBm	
Output IP3 In-band	OIP3	21.7	21.1	20.5	19.3	16.8	dBm	$f_{GLONASS}$ = 1602 MHz $f_{GLONASS}$ = 1603MHz Input power= -30dBm
Stability	k	>1					--	Unconditionnally Stable from 0 to 10GHz

3.2 Summary BGA824N6 as 1550-1615 MHz LNA for GNSS

This application note presents the high linearity low noise amplifier for Global Navigation Satellite Systems (GNSS) using BGA824N6.

The circuit requires only one 0402 passive component. It has in band gain of 17dB. The gain flatness over the whole temperature range (-40°C to 85°C) is less than 2dB. The circuit achieves input return loss better than 12dB and output return loss more than 15.7 dB for the whole temperature range. In room temperature noise figure is 0.6dB (SMA and PCB losses are subtracted) and it increases to 0.93dB for 85°C. Furthermore, the circuit is unconditionally stable till 10 GHz.

At 1575 MHz, using two tones spacing of 1 MHz, the output third order intercept point OIP3 reaches 19 dBm. OIP3 varies form 16.5 dBm to 21.6 dBm for the whole frequency range. Input P1dB of the GNSS LNA is about -7dBm and it is almost constant over the whole temaprature range. The out of band OIP3 reaches 8.2 dBm at room temperature at 1575.4 MHz frequency. And this circuit shows very good H2 performance -28.2 dBm for GPS frequency.

3.3 Schematics and Bill-of-Materials

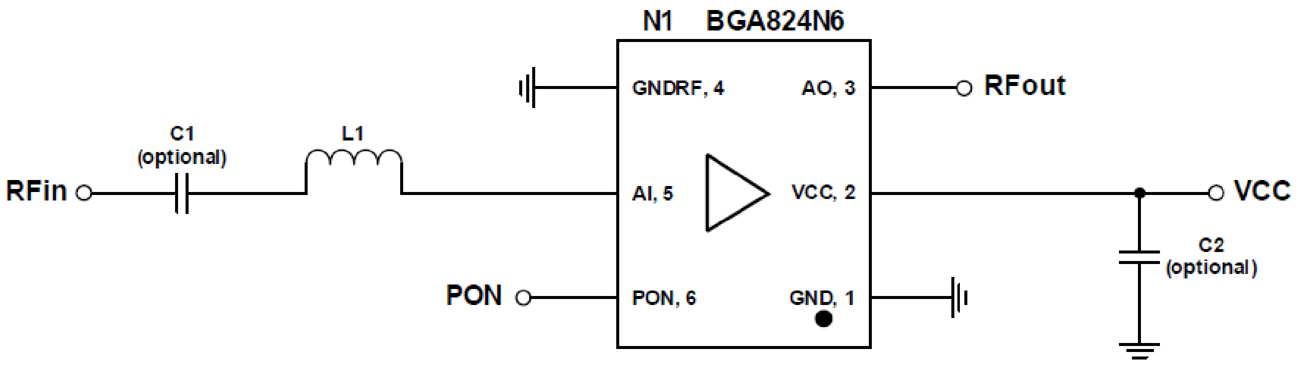

Figure 5 Schematics of the BGA824N6 Application Circuit

Table 6 Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
C2 (optional)	1	nF	0402	Various	DC block
C2 (optional)	>10	nF	0402	Various	RF bypass
L1	6.8	nH	0402	Murata LQW type	Input matching
N1	BGA824N6		TSNP-6-2	Infineon	SiGe LNA

4 Measurement Graphs

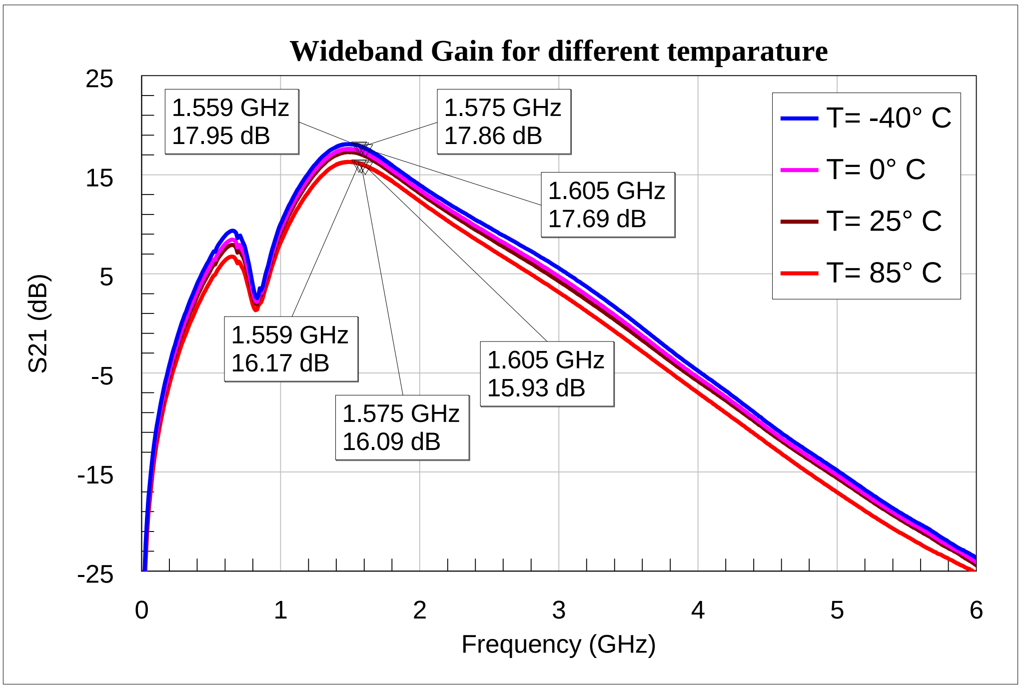

Figure 6 Power gain of BGA824N6 for COMPASS, Galileo, GPS and GLONASS bands

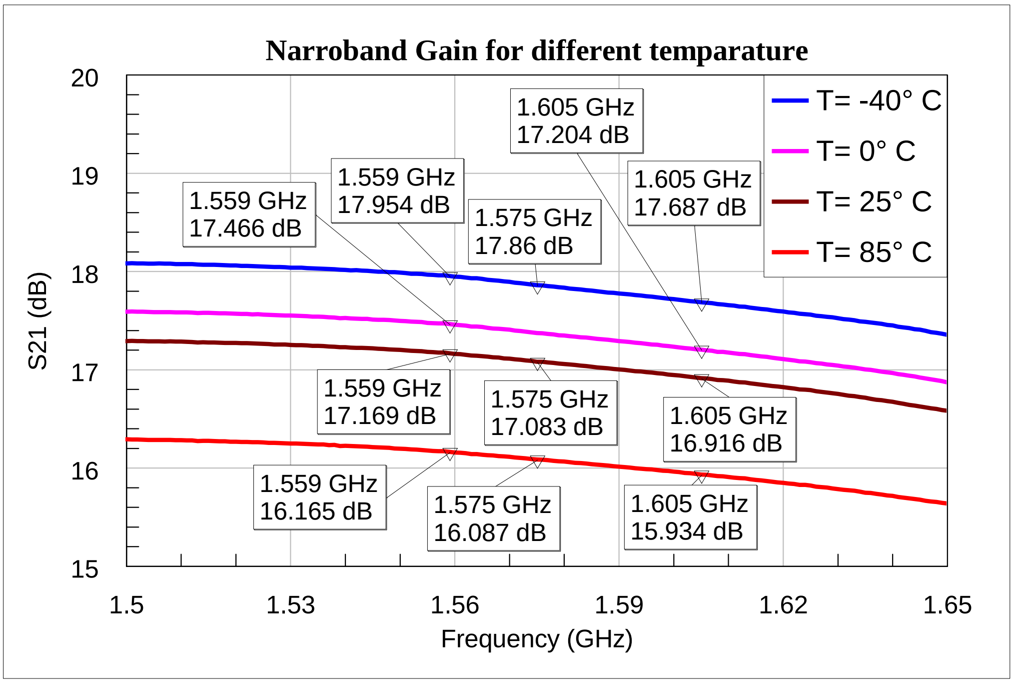

Figure 7 Narrowband power gain of BGA824N6 for COMPASS, Galileo, GPS and GLONASS bands

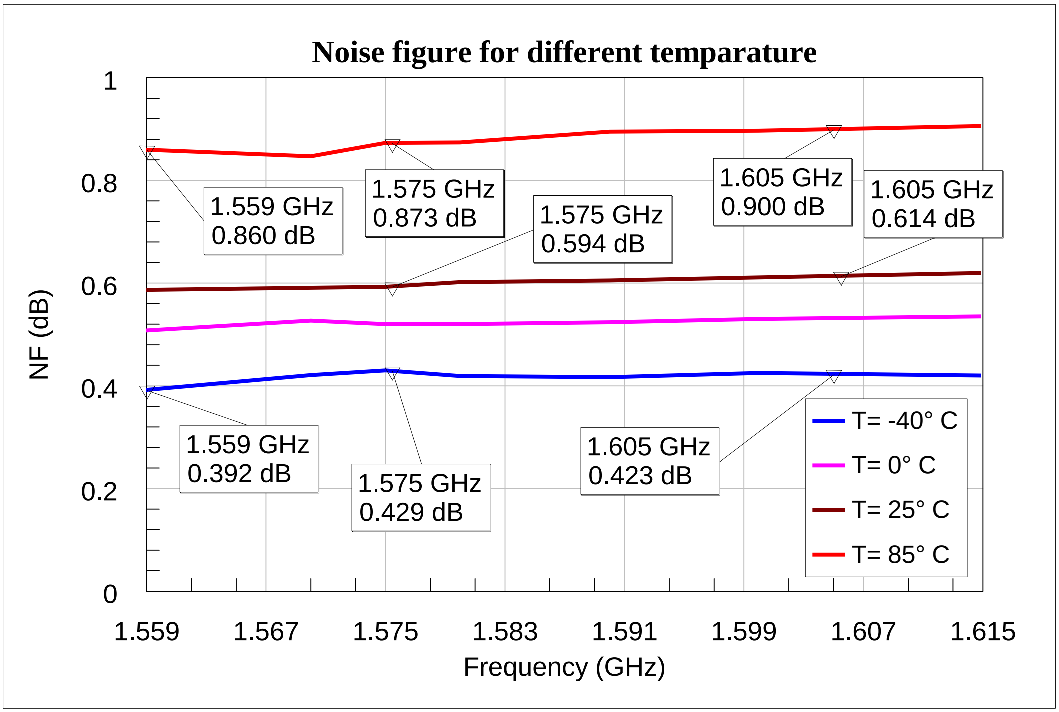

Figure 8 Noise figure of BGA824N6 for COMPASS, Galileo, GPS and GLONASS bands

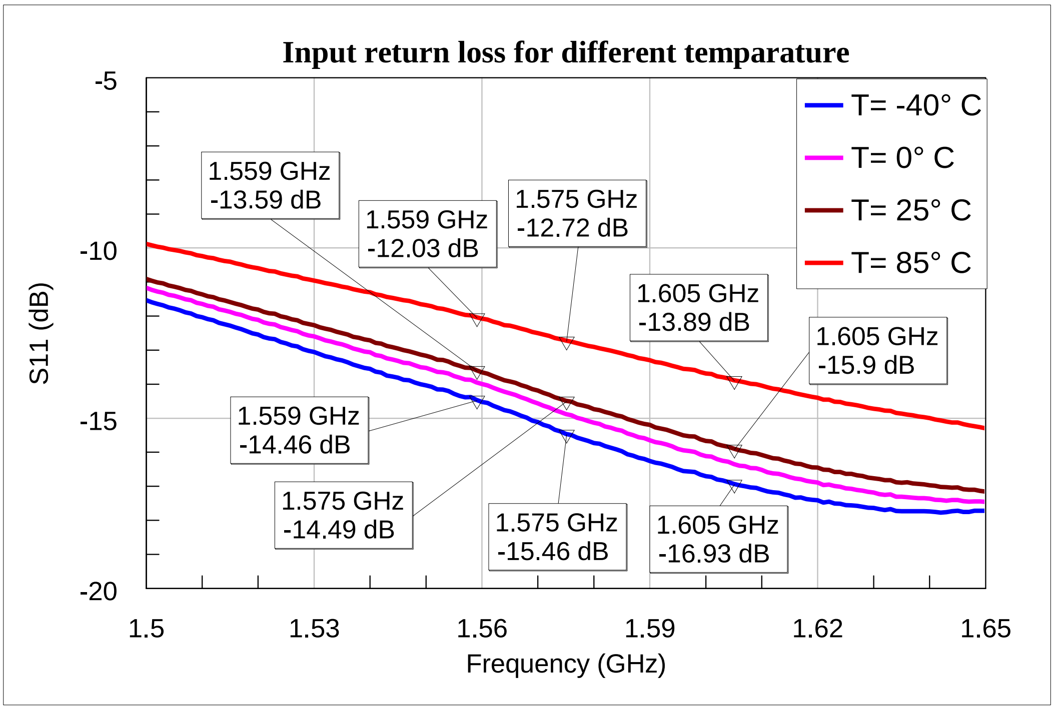

Figure 9 Input matching of BGA824N6 for COMPASS, Galileo, GPS and GLONASS bands

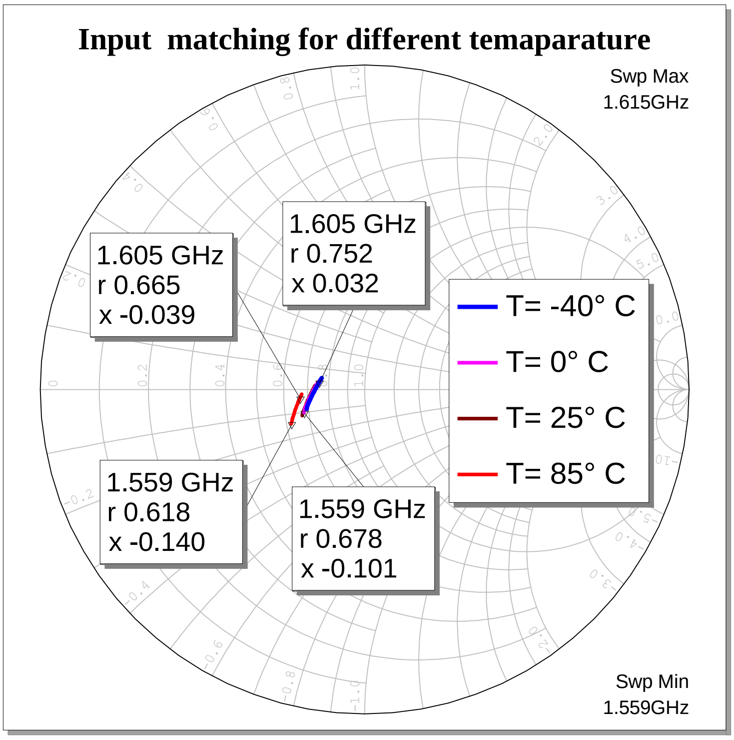

Figure 10 Input matching smith chart for COMPASS, Galileo, GPS and GLONASS bands

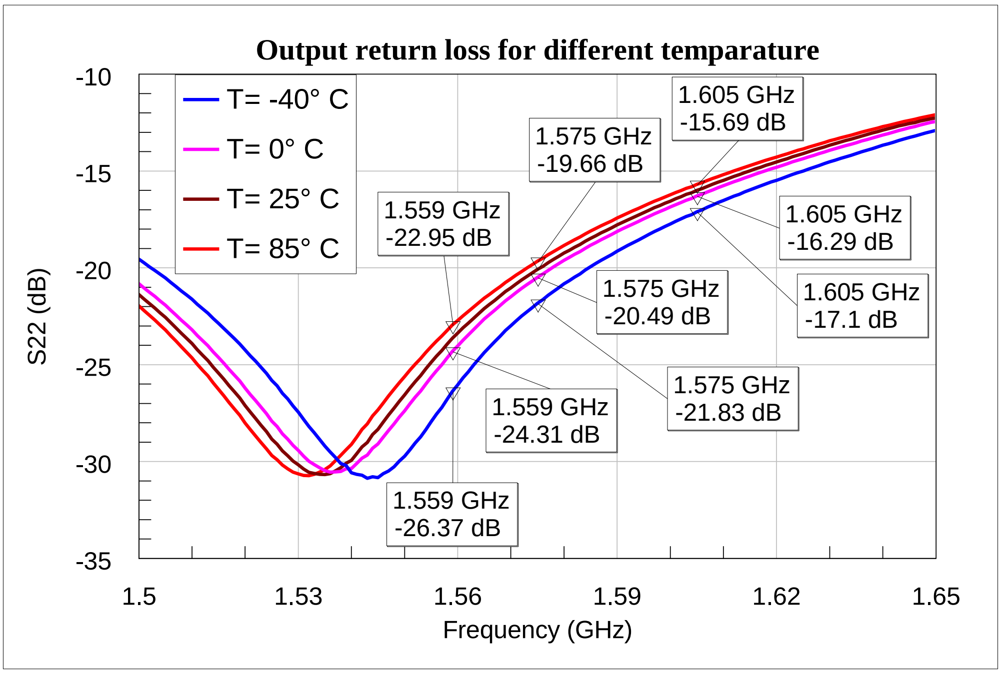

Figure 11 Output matching of BGA824N6 for COMPASS, Galileo, GPS and GLONASS bands

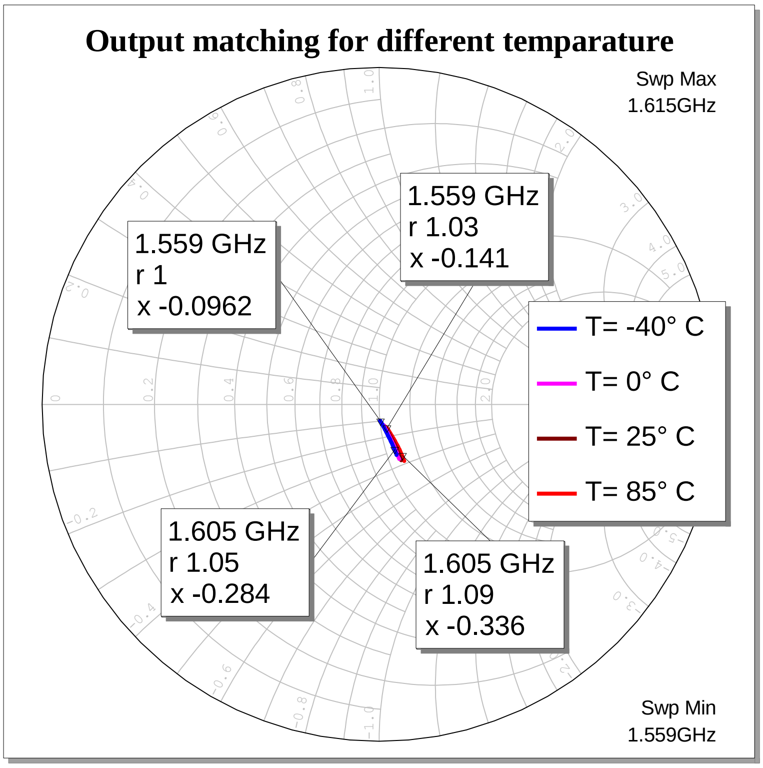

Figure 12 Output matching smith chart for COMPASS, Galileo, GPS and GLONASS bands

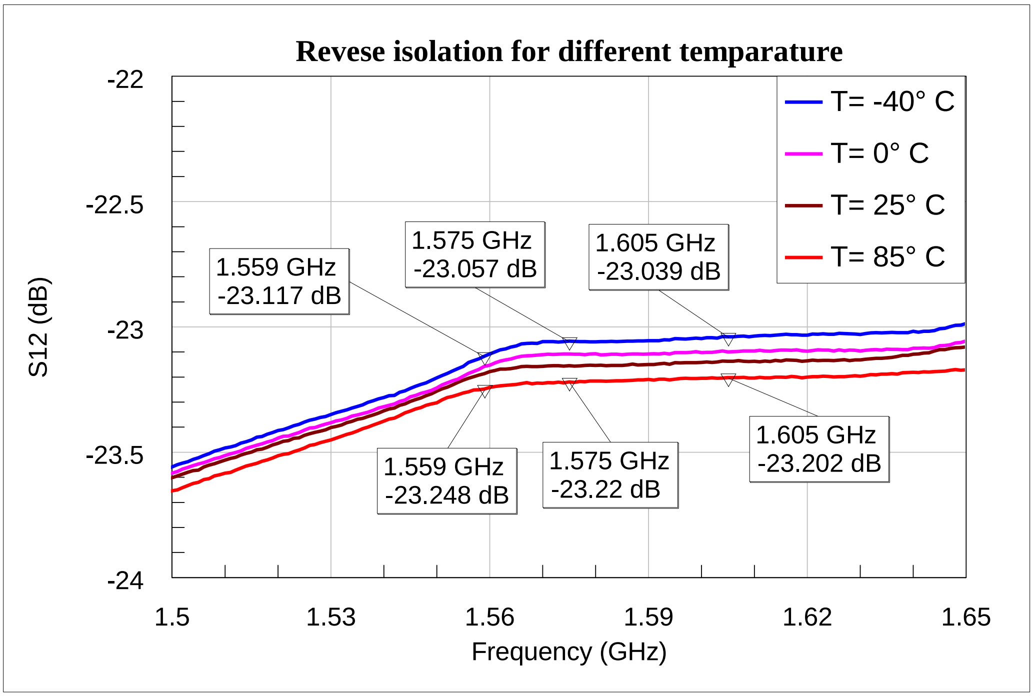

Figure 13 Reverse isolation of BGA824N6 for COMPASS, Galileo, GPS and GLONASS bands

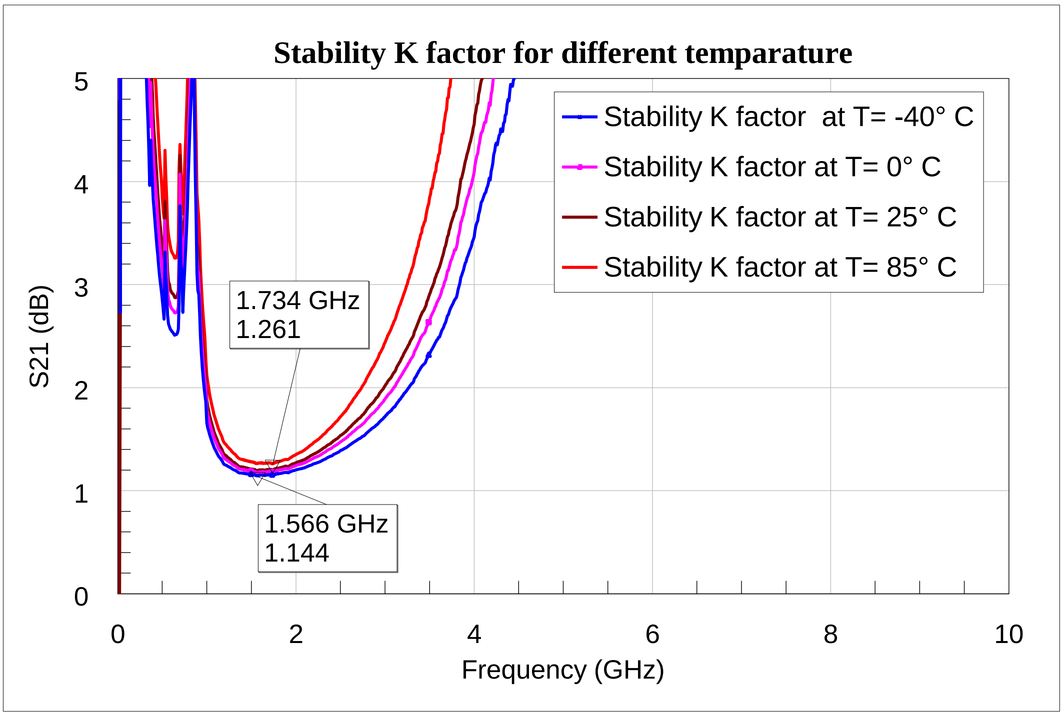

Figure 14 Stability factor k of BGA824N6 upto 10GHz

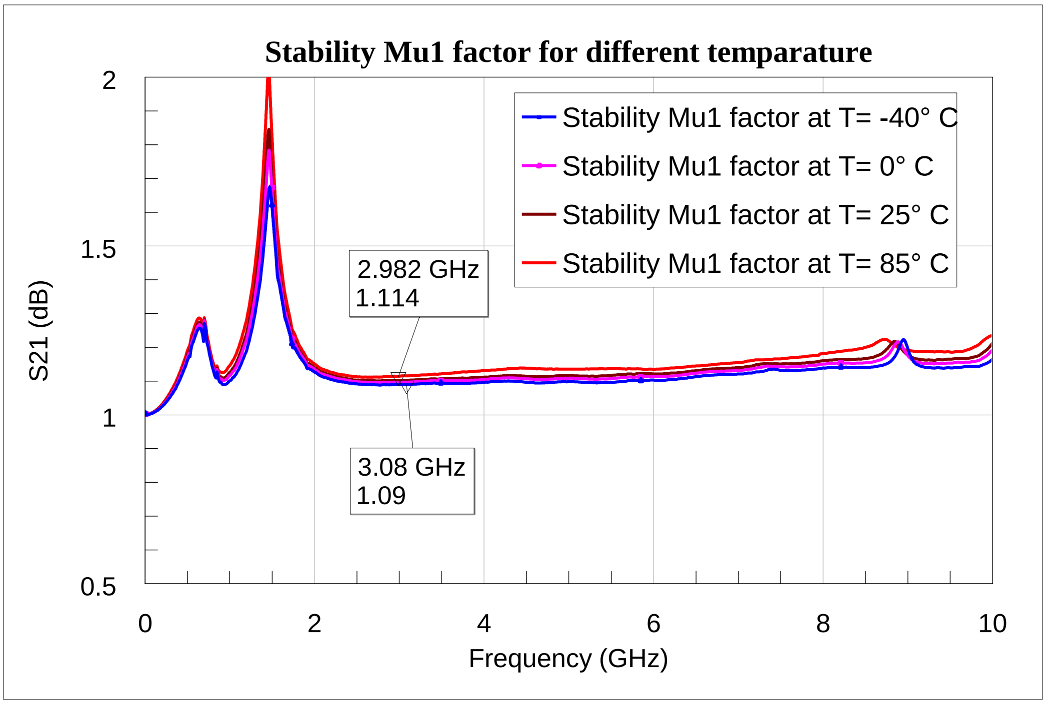

Figure 15 Stability factor μ1 of BGA824N6 upto 10GHz

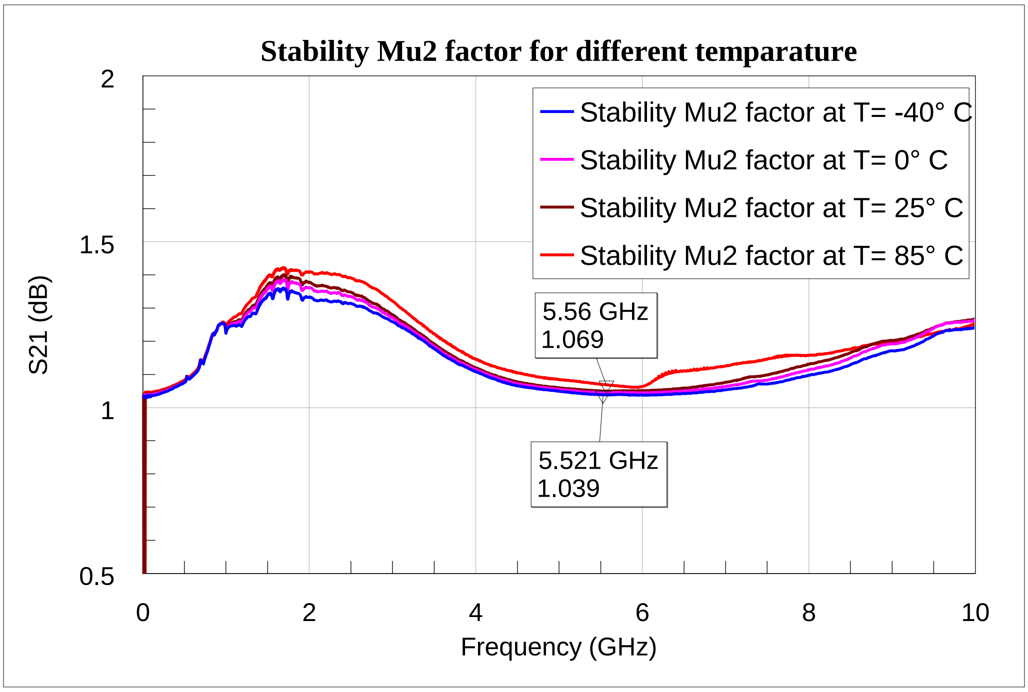

Figure 16 Stability factor µ2 of BGA824N6 upto 10GHz

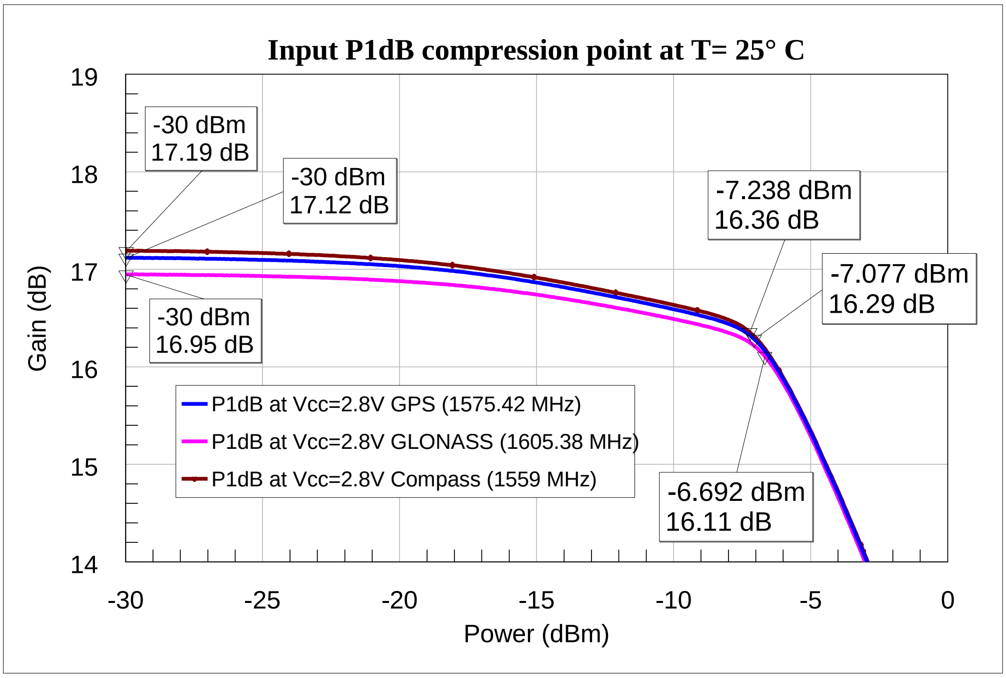

Figure 17 Input 1 dB compression point of BGA824N6 at supply voltage of 2.8V for COMPASS, Galileo, GPS and GLONASS bands

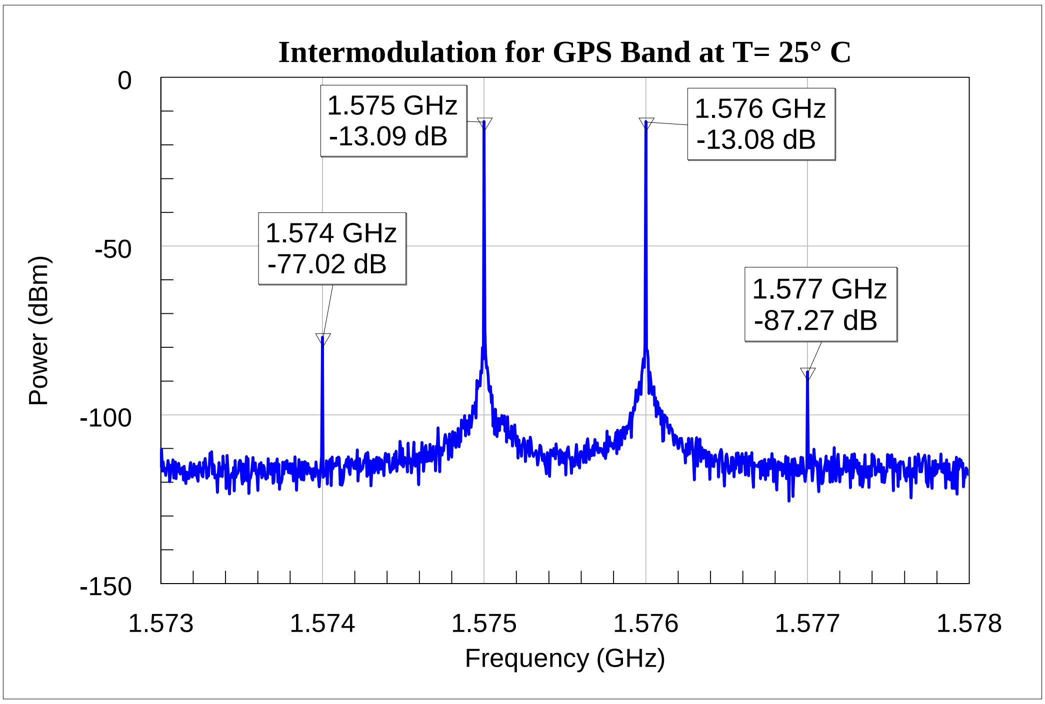

Figure 18 Carrier and intermodulation products of BGA824N6 for GPS band

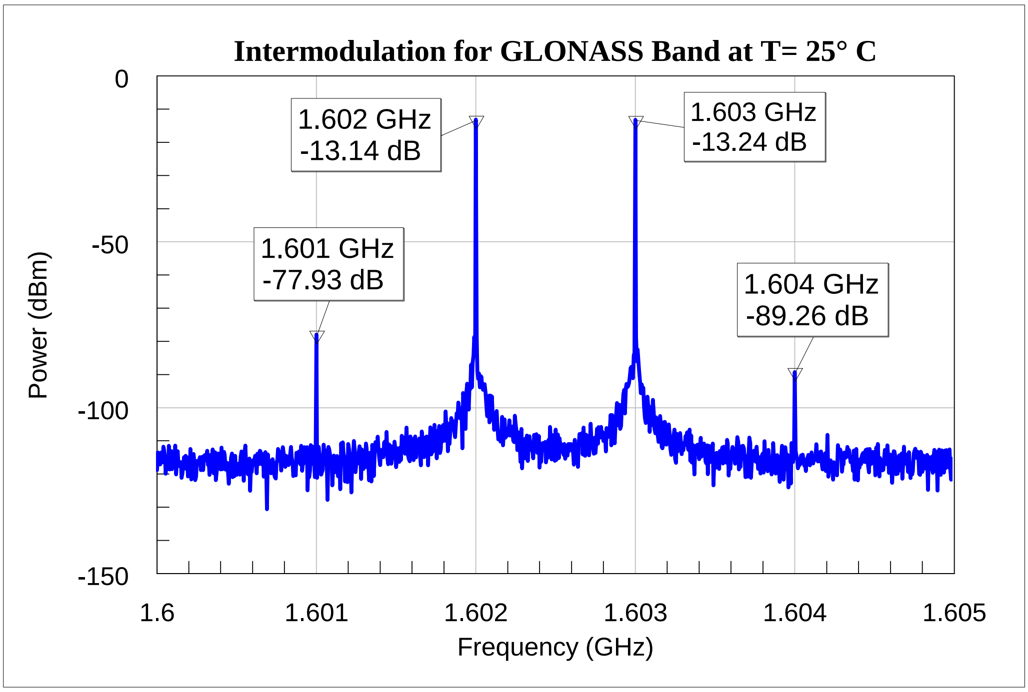

Figure 19 Carrier and intermodulation products of BGA824N6 for GLONASS band

5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB Marking: BGA824N6

PCB material: FR4

ε_r of PCB material: 4.3

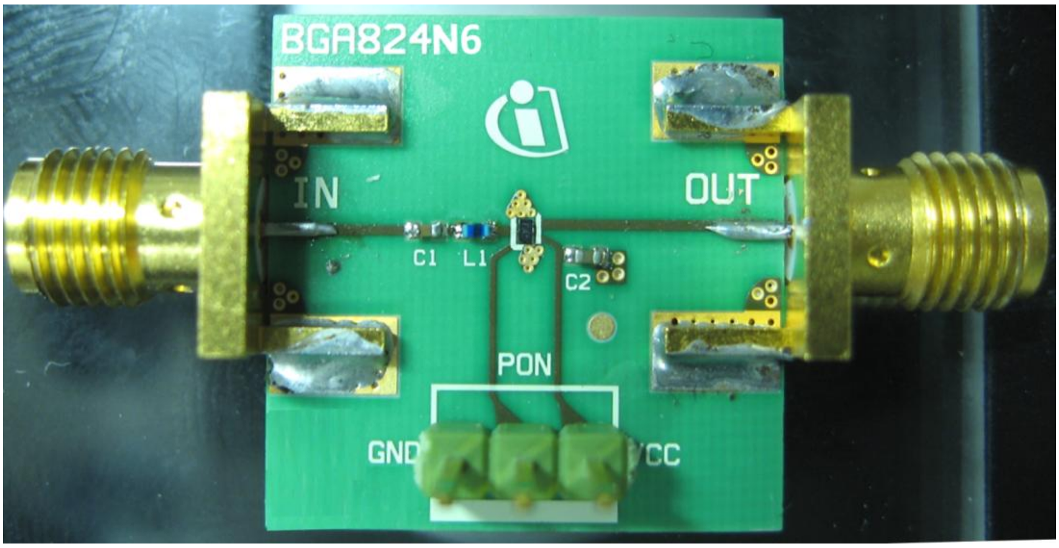

Figure 20 Photo Picture of Evaluation Board (overview) <PCB Marking Myymmdd Rev. x.x>

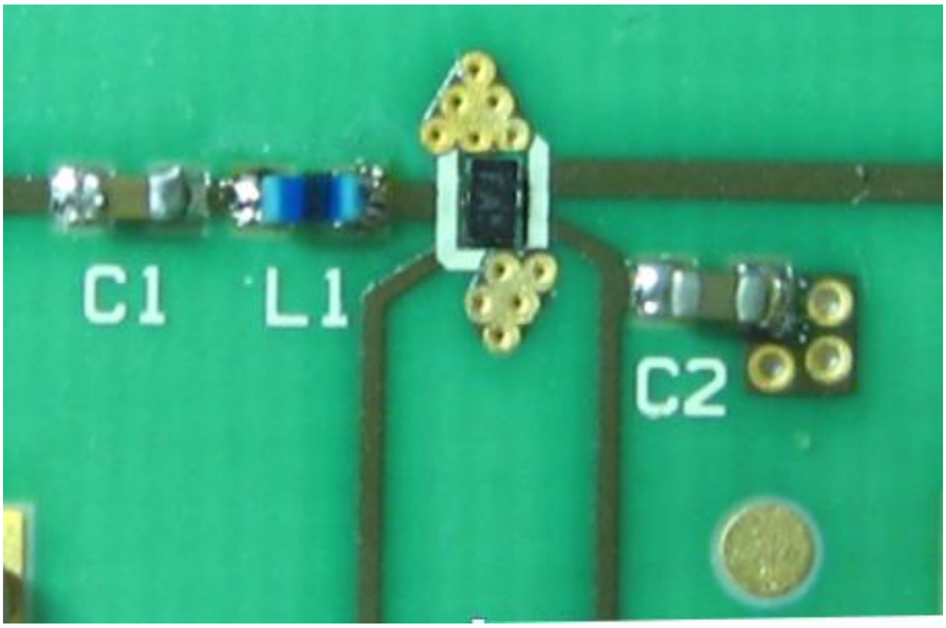

Figure 21 Photo Picture of Evaluation Board (detailed view)

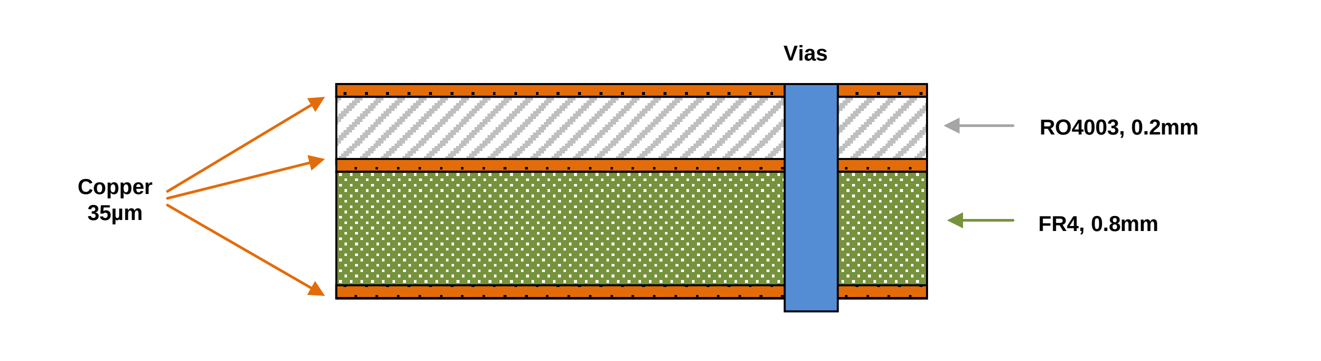

Figure 22 PCB Layer Information

6 Authors

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Dr. Chih-I Lin, Senior Staff 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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