BGA231N7

Silicon Germanium GNSS Low Noise Amplifier

BGA231N7 Silicon Germanium Low Noise Amplifier for Global Navigation Satellite Systems (GNSS) Applications from 1550 MHz to 1615 MHz

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1 Introduction of Global Navigation Satellite Systems (GNSS)

The BGA231N7 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-7-1 / TSNP-7-2 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 3.3 V. All these features make BGA231N7 an excellent choice for GNSS LNA as it improves sensitivity, provide better 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 BGA231N7 excels by providing noise figure as low as 0.75 dB and high gain of 16 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 band. To quantify the effect, BGA231N7 shows out-of-band input IP3 at GPS band of +5 dBm, as a result of frequency mixing between GSM 1712.7 MHz and UMTS 1850 MHz with power levels of -20 dBm for each tone. Due to this high out-of-band input 3rd order intercept point (IIP3), BGA231N7 is especially suitable for the GPS function in mobile phones.

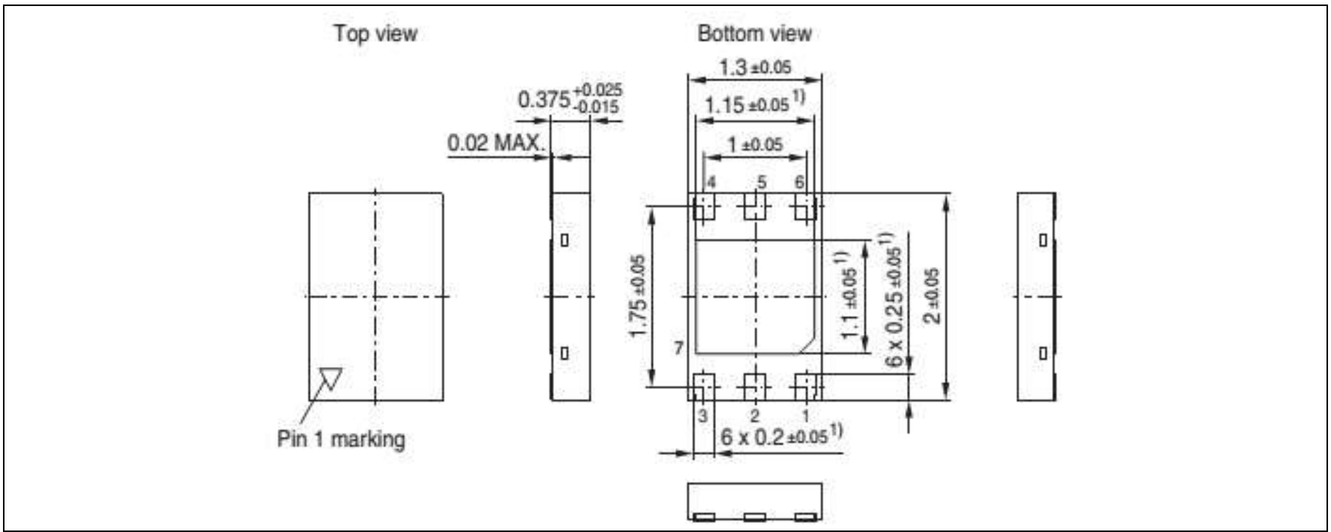

Figure 1 BGA231N7 TSNP-7-1 Package Size

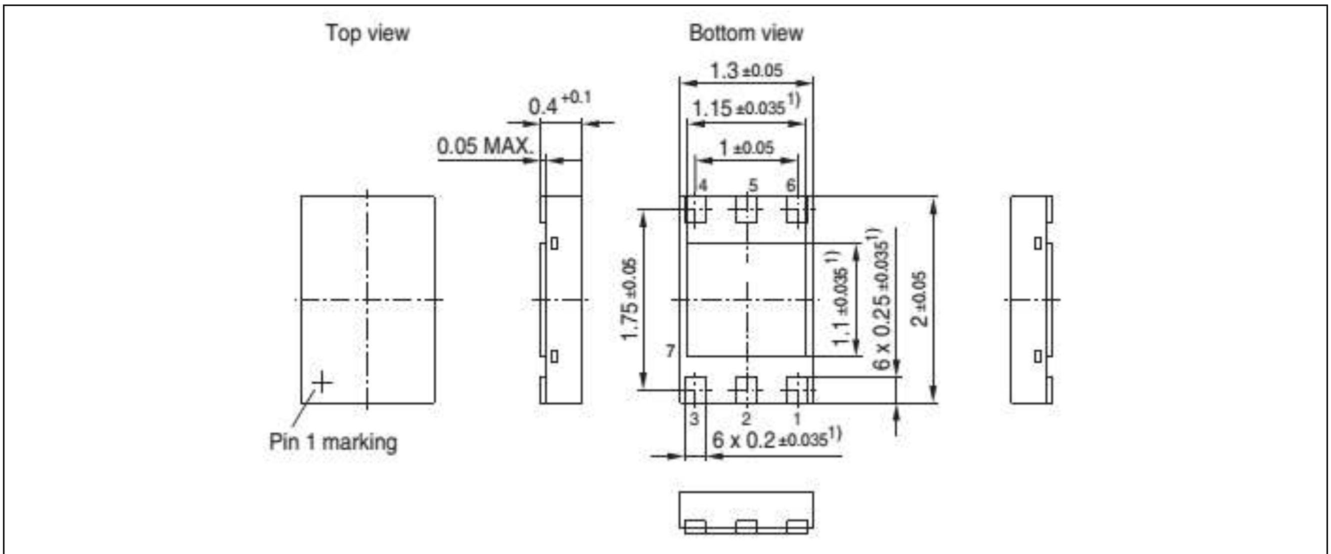

Figure 2 BGA231N7 TSNP-7-2 Package Size

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. BGA231N7 has a small package with dimensions of 1.3mm x 2mm x 0.375mm and it requires only two external components at its input, the inductors providing the input matching and bias feed. The DC block at input is optional as it is usually provided by the pre-filter before the LNA in many GPS applications. Similarly, the RF bypass for power supply noise is also optional. 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 BGA231N7 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 (4.4 mA) makes the device suitable for portable technology like GNSS receivers and mobiles phones.

2 BGA231N7 Overview

2.1 Features

- Insertion power gain: 16.0 dB
- High out of band input 3rd order intercept point at input: +5 dBm
- High input 1 dB compression point: -5 dBm
- Low noise figure: 0.75 dB
- Low current consumption: 4.4 mA
- Operating frequencies: 1550 - 1615 MHz
- Supply voltage: 1.5 V to 3.6 V
- Digital on/off switch(1 V logic high level)
- Tiny TSNP-7-1 / TSNP-7-2 leadless package
- B7HF Silicon Germanium technology
- RF output internally matched to 50 Ω
- Only 2 external SMD components necessary
- 2 kV HBM ESD protection (including AI-pin)
- Pb-free (RoHS compliant) package

RoHS

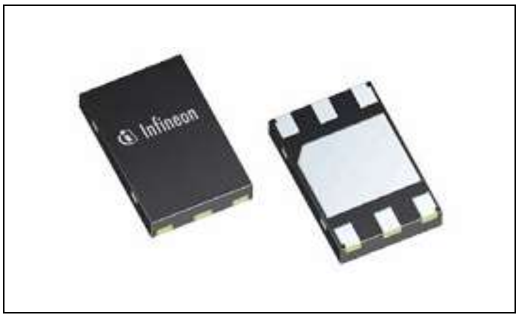

Figure 3 BGA231N7 in TSNP-7-1

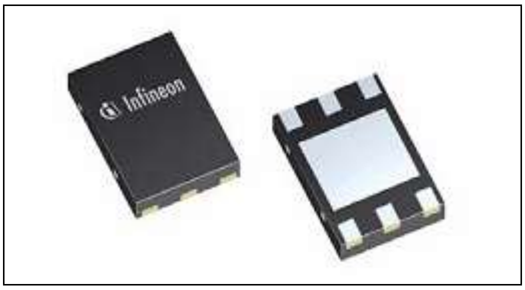

Figure 4 BGA231N7 in TSNP-7-2

2.2 Key Applications of BGA231N7

➢ 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 BGA231N7 is a front-end low noise amplifier for Global Navigation Satellite Systems (GNSS) from 1550 MHz to 1615 MHz like GPS, Galileo, GLONASS, COMPASS and others. The LNA provides 16.0 dB gain and 0.82 dB noise figure at a current consumption of 4.4 mA in the application configuration described in Chapter 3. The BGA231N7 is based upon Infineon Technologies' B7HF Silicon Germanium technology. It operates from 1.5 V to 3.6 V supply voltage.

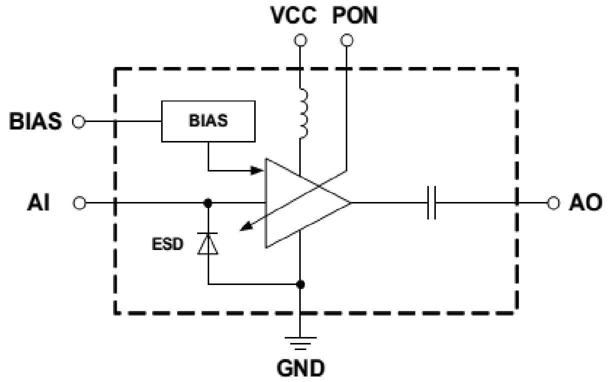

Figure 5 Equivalent Circuit Block diagram of BGA231N7

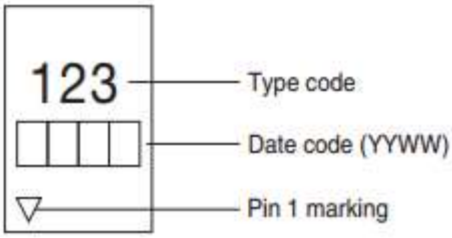

Figure 6 Package of BGA231N7 in TSNP-7-1

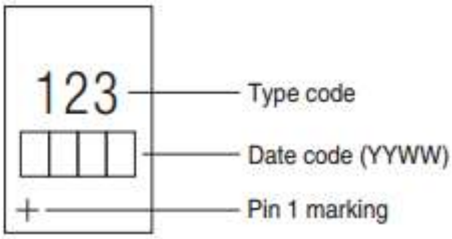

Figure 7 Package of BGA231N7 in TSNP-7-2

Table 1 Pin Assignment of BGA231N7

Pin No.	Symbol	Function
1	PON	Power on control
2	AI	LNA input
3	BIAS	DC bias
4	n.c	Not connected
5	AO	LNA output
6	VCC	DC supply
7	GND	RF and DC ground

3 Application Circuit and Performance Overview

Device: BGA231N7

Application: BGA231N7 Silicon Germanium Low Noise Amplifier for Global Navigation Satellite Systems (GNSS) Applications from 1550 MHz to 1615 MHz

PCB Marking: BGA231N7 V1.0

3.1 Summary of Measurement Results

Table 2 Electrical Characteristics for COMPASS/Galileo at Vcc = Vpon = 1.8 V

Parameter	Symbol	Value			Unit	Comment/Test Condition
DC Voltage	Vcc	1.8			V	
DC Current	Icc	4.3			mA	
Navigation System	Sys	COMPASS/ Galileo	GPS	GLONASS		
Frequency Range	Freq	1559-1593	1575.42	1598-1606	MHz	
Gain	G	15.9	15.9	15.8	dB	
Noise Figure	NF	0.84	0.81	0.83	dB	PCB and SMA losses 0.08 dB are substracted
Input Return Loss	RLin	-10.9	-11.3	-11.7	dB	
Output Return Loss	RLout	-19.5	-22.1	-29.2	dB	
Reverse Isolation	IRev	-22.6	-22.5	-22.3	dB	
Input P1dB	IP1dB	-7.6	-7.2	-7.6	dBm	f_{gal} = 1559 MHz f_{gps} = 1575.42 MHz $f_{GLONASS}$ = 1605 MHz
Output P1dB	OP1dB	7.3	7.7	7.2	dBm	
Input IP3 In-band	IIP3		-1		dBm	f_{1gps} = 1575.42 MHz, f_{2gps} = 1576.42 MHz Input power= -30 dBm
Output IP3 In-band	OIP3		14.9		dBm	
LTE band-13 2nd Harmonic	H2-iput referred	-43.7			dBm	f_{IN} = 787.76 MHz, P_{IN} = -25 dBm; f_{H2} = 1575.52 MHz
Input IP3 Out-of-band	$IIP3_{OOB}$	2.1			dBm	f_1 = 1712.7 MHz, P_{1IN} = -25 dBm; f_2 = 1850 MHz, P_{2IN} = -65 dBm; f_{IIP3} = 1575.4 MHz
Stability	k	>1			--	Unconditionnally Stable from 0 to 10GHz

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

Parameter	Symbol	Value			Unit	Comment/Test Condition
DC Voltage	Vcc	2.8			V	
DC Current	Icc	4.4			mA	
Navigation System	Sys	COMPASS/ Galileo	GPS	GLONASS		
Frequency Range	Freq	1559-1593	1575.42	1598-1606	MHz	
Gain	G	16.0	16.0	15.9	dB	
Noise Figure	NF	0.84	0.82	0.81	dB	PCB and SMA losses 0.08dB are substracted
Input Return Loss	RLin	-11.3	-11.6	-12.1	dB	
Output Return Loss	RLout	-17.4	-19.4	-23.9	dB	
Reverse Isolation	IRev	-23.1	-23.0	-22.8	dB	
Input P1dB	IP1dB	-4.4	-4.1	-4.3	dBm	f_{gal} = 1559 MHz f_{gps} = 1575.42 MHz $f_{GLONASS}$ = 1605 MHz
Output P1dB	OP1dB	10.6	10.9	10.6	dBm	
Input IP3 In-band	IIP3		-0.8		dBm	f_{1gps} = 1575.42 MHz, f_{2gps} = 1576.42 MHz Input power= -30 dBm
Output IP3 In-band	OIP3		15.2		dBm	
LTE band-13 2^{nd} Harmonic	H2-input referred	-44.1			dBm	f_{IN} = 787.76 MHz, P_{IN} = -25 dBm; f_{H2} = 1575.52 MHz
Input IP3 Out-of-band	$IIP3_{OOB}$	2.6			dBm	f_1 = 1712.7 MHz, P_{1IN} = -25 dBm; f_2 = 1850 MHz, P_{2IN} = -65 dBm; f_{IIP3} = 1575.4 MHz
Stability	k	>1			--	Unconditionnally Stable from 0 to 10GHz

3.2 Summary BGA231N7 as 1550-1615 MHz LNA for GNSS

This application note describes the performance of BGA231N7 for GNSS appliactions for 1.8 V and 2.8 V operating voltage. The circuit requires only two 0201 passive components. And the component values are fine tuned for optimal noise figure, jammer rejection, gain and input matching.

The circuit has in band gain of 16 dB. The circuit achieves input return loss better than 11.5 dB, as well as output return loss better than 19 dB. At room temperature the noise figure is 0.82 dB (SMA and PCB losses are subtracted) for the GPS frequecncy. Furthermore, the circuit is unconditionally stable till 10 GHz.

At GPS frequency, using two tones spacing of 1 MHz, the Output Third-order Intercept point for the GPS frequency band reaches up to 15.2 dBm. Input P1dB of the GNSS LNA is about -4.1 dBm for the GPS frequency and -4.3 dBm for GLONASS frequency band. And this circuit shows very good input reffered H2 performance of -44 dBm for GPS frequency.

3.3 Schematics and Bill-of-Materials

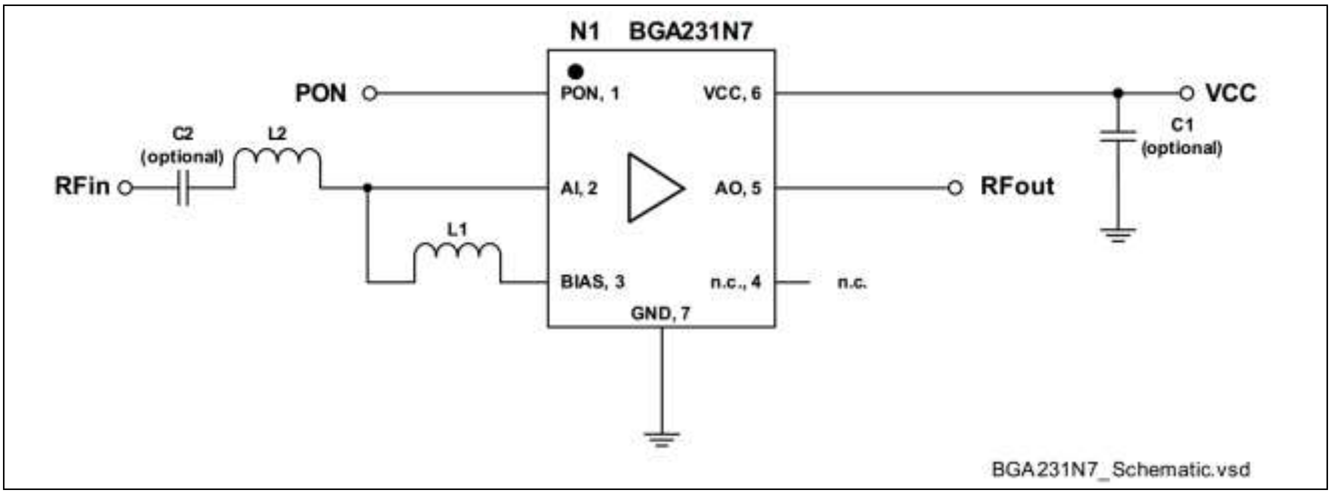

Figure 8 Schematic of the BGA231N7 Application Circuit

Table 4 Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
C1 (optional)	100	nF	0201	Various	RF block[1)]
C2 (optional)	33	pF	0201	Various	DC block[2)]
L1	39	nH	0201	Murata LQP03T	Bias feed and RF choke
L2	6.8	nH	0201	Murata LQP03T	Input matching
N1	BGA231N7		TSNP-6-2	Infineon	SiGe LNA

1. RF bypass recommended to mitigate power supply noise
2. DC block might be realized with pre-filter in GNSS applications

4 Measurement Graphs

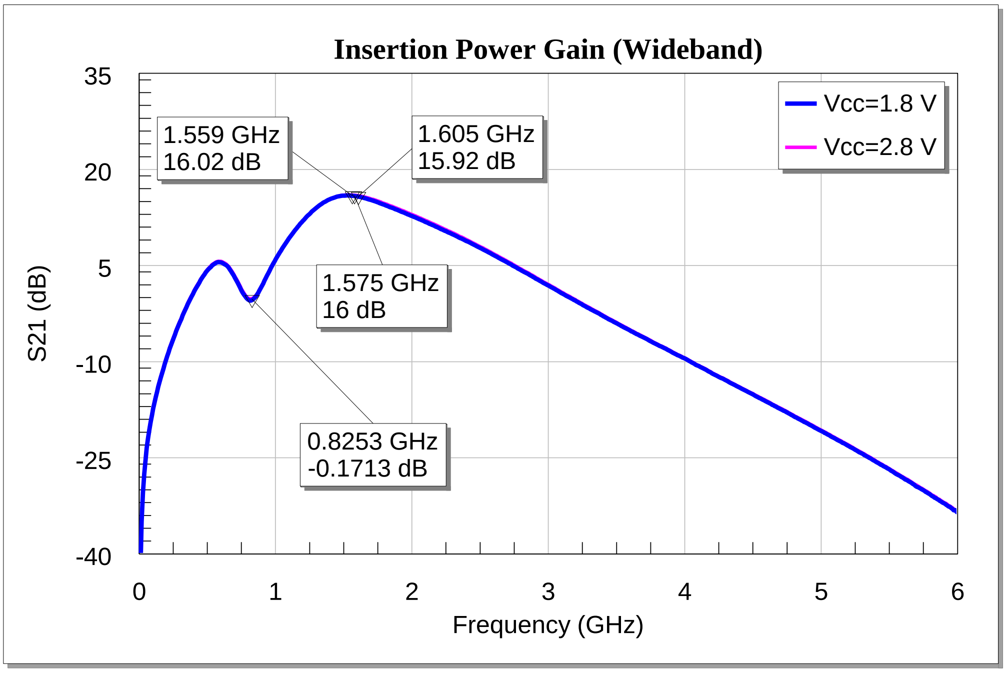

Figure 9 Power Gain of BGA231N7 for COMPASS, Galileo, GPS and GLONASS Bands

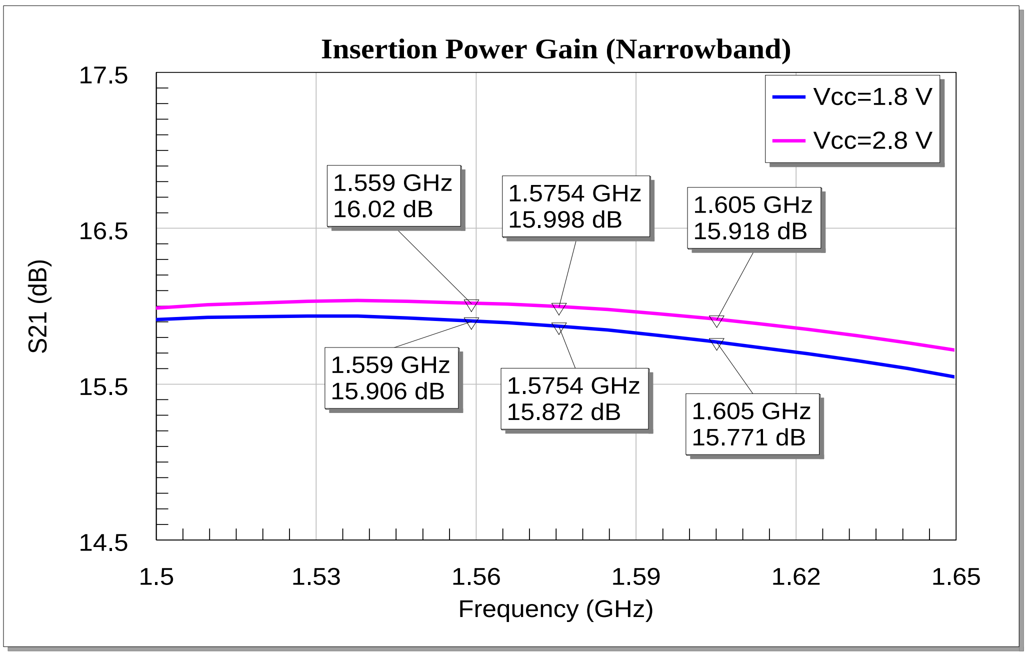

Figure 10 Narrowband Power Gain of BGA231N7 for COMPASS, Galileo, GPS and GLONASS Bands

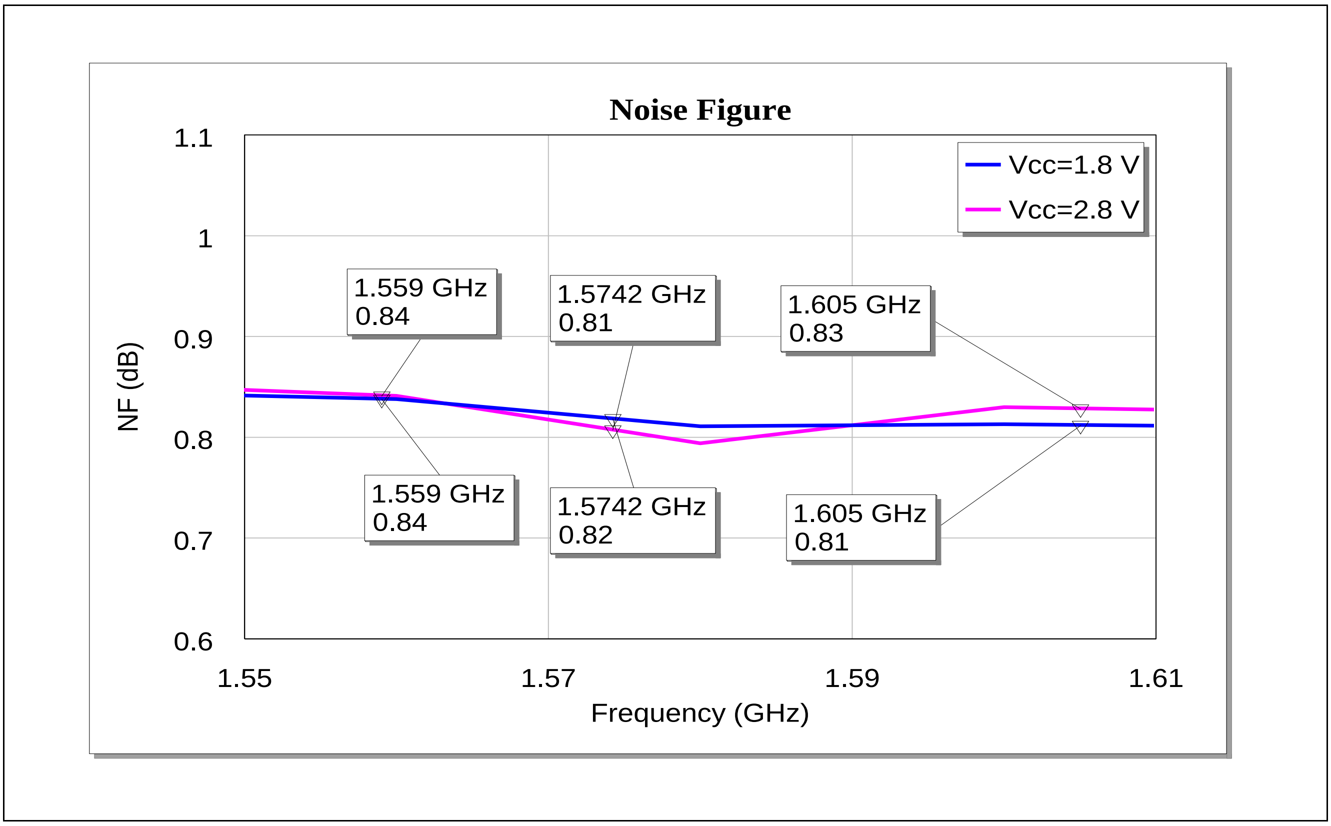

Figure 11 Noise Figure of BGA231N7 for COMPASS, Galileo, GPS and GLONASS Bands

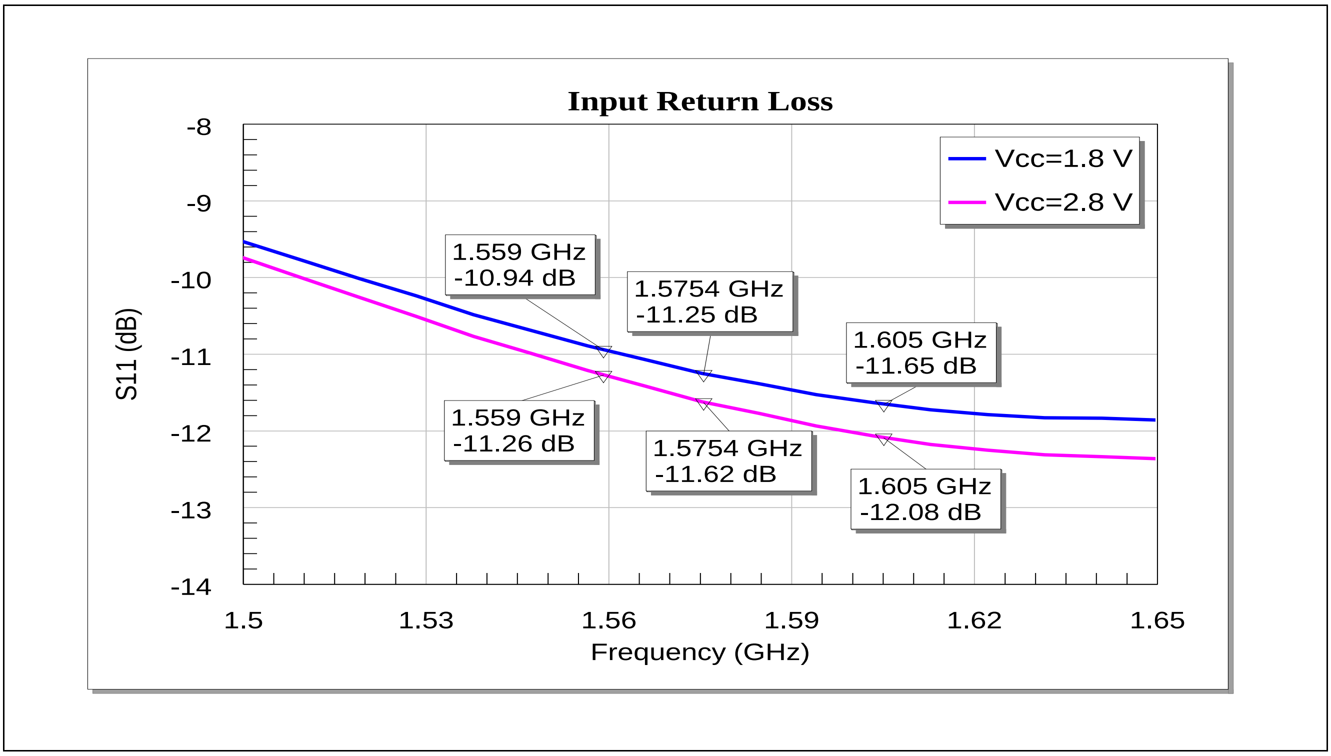

Figure 12 Input Matching of BGA231N7 for COMPASS, Galileo, GPS and GLONASS Bands

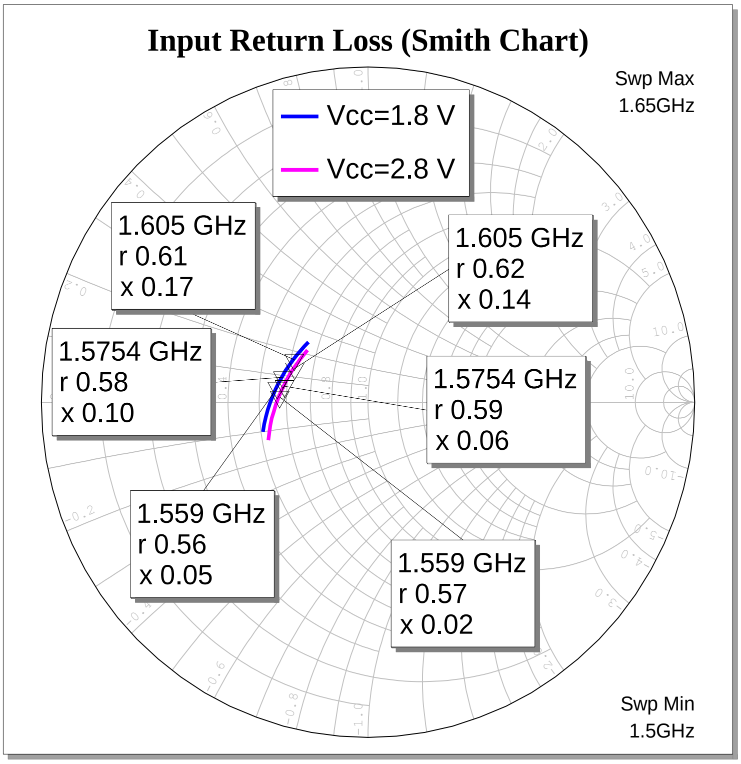

Figure 13 Input Matching Smith Chart for COMPASS, Galileo, GPS and GLONASS Bands

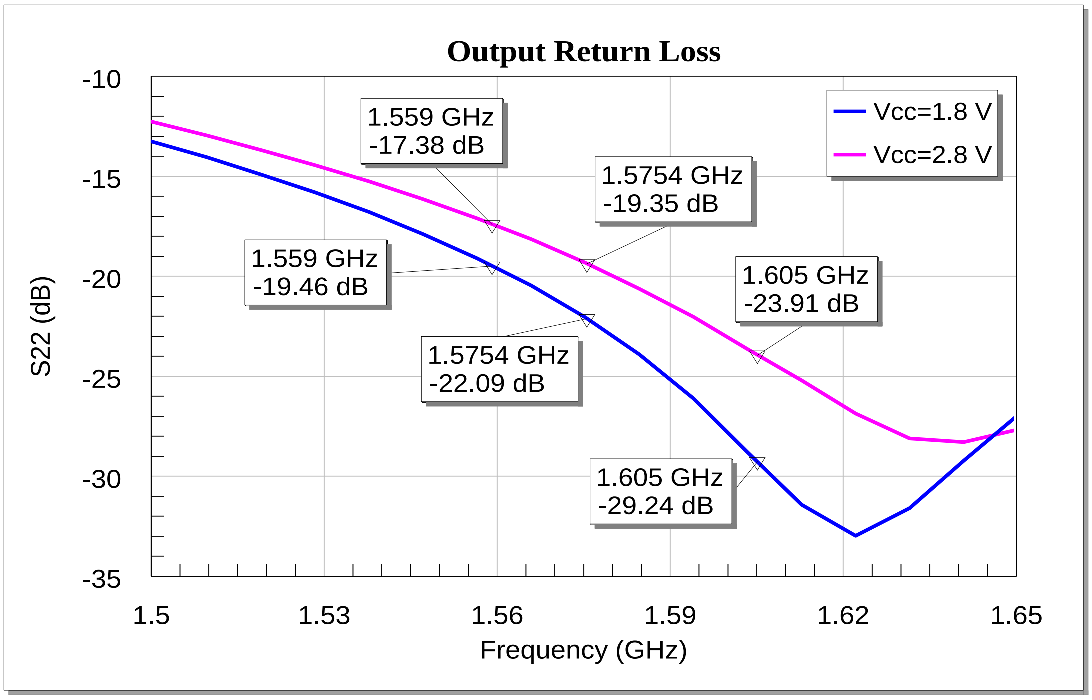

Figure 14 Output Matching of BGA231N7 for COMPASS, Galileo, GPS and GLONASS Bands

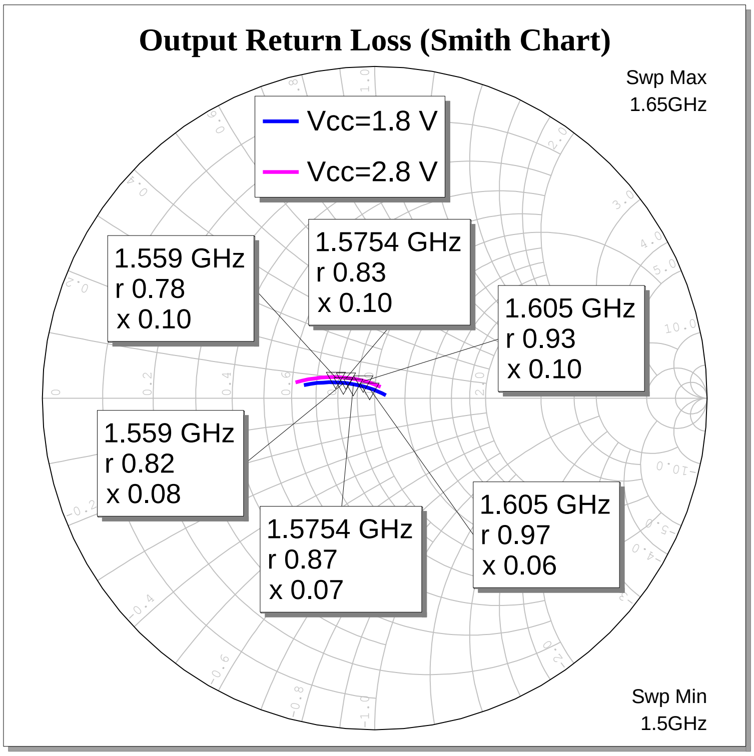

Figure 15 Output Matching Smith Chart for COMPASS, Galileo, GPS and GLONASS Bands

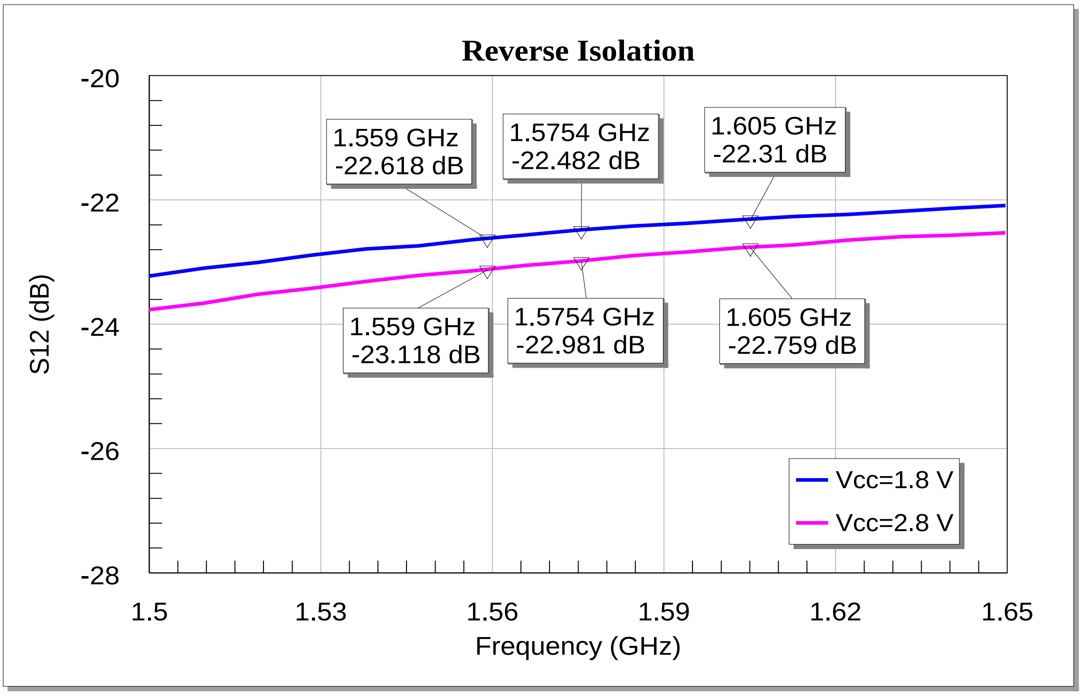

Figure 16 Reverse Isolation of BGA231N7 for COMPASS, Galileo, GPS and GLONASS bands

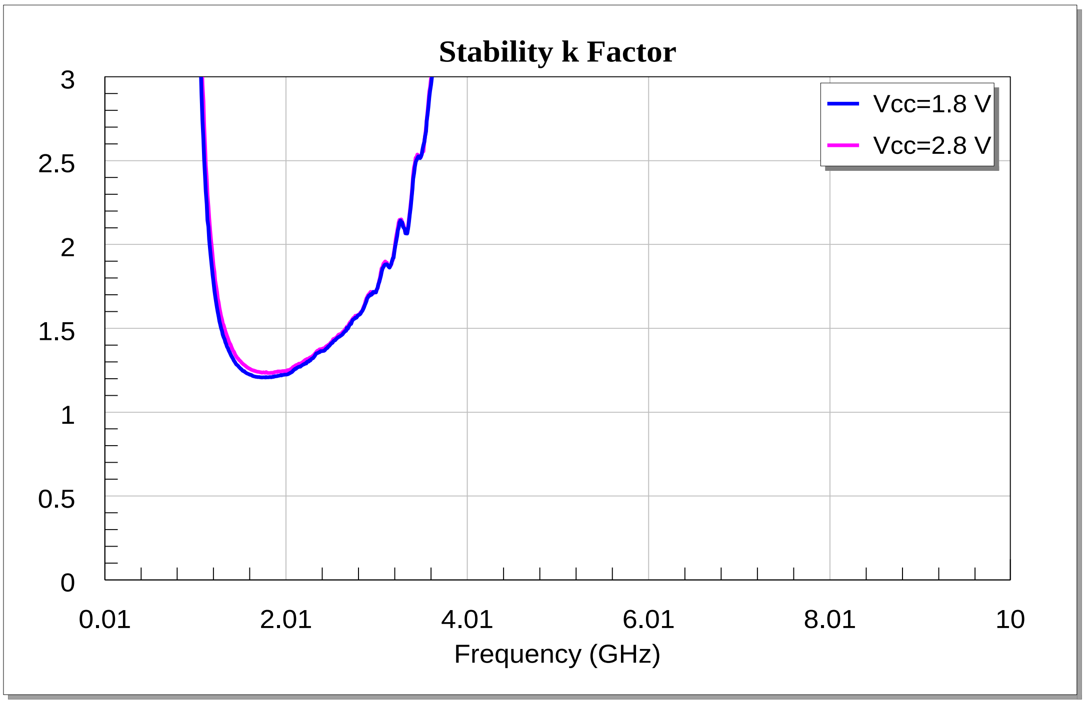

Figure 17 Stability factor k of BGA231N7 upto 10 GHz

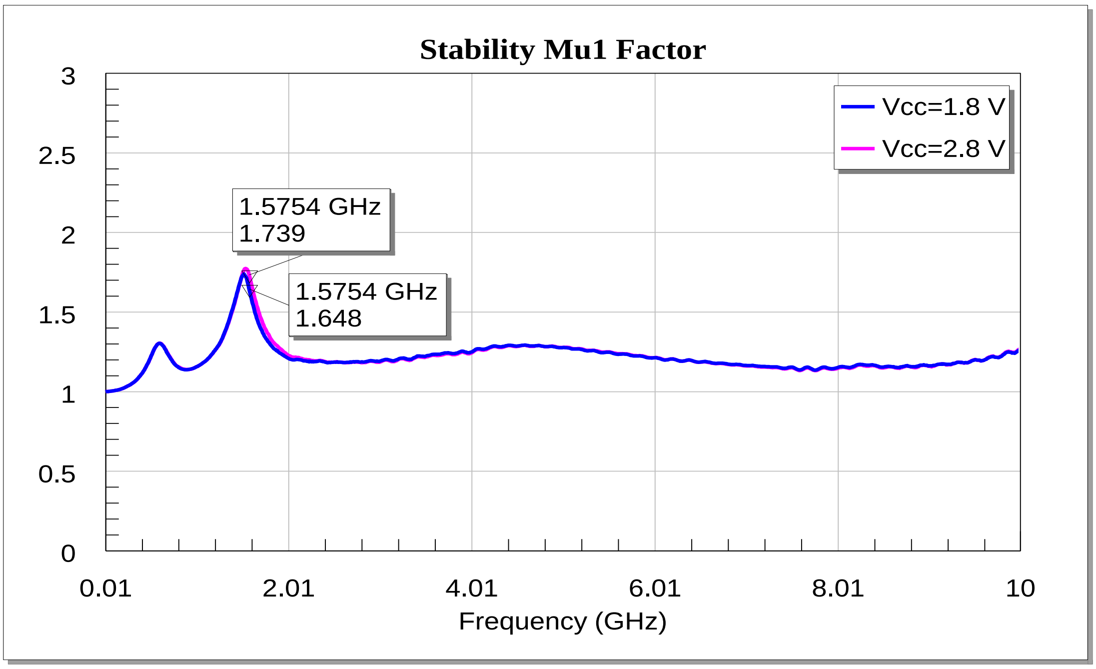

Figure 18 Stability Factor µ1 of BGA231N7 upto 10 GHz

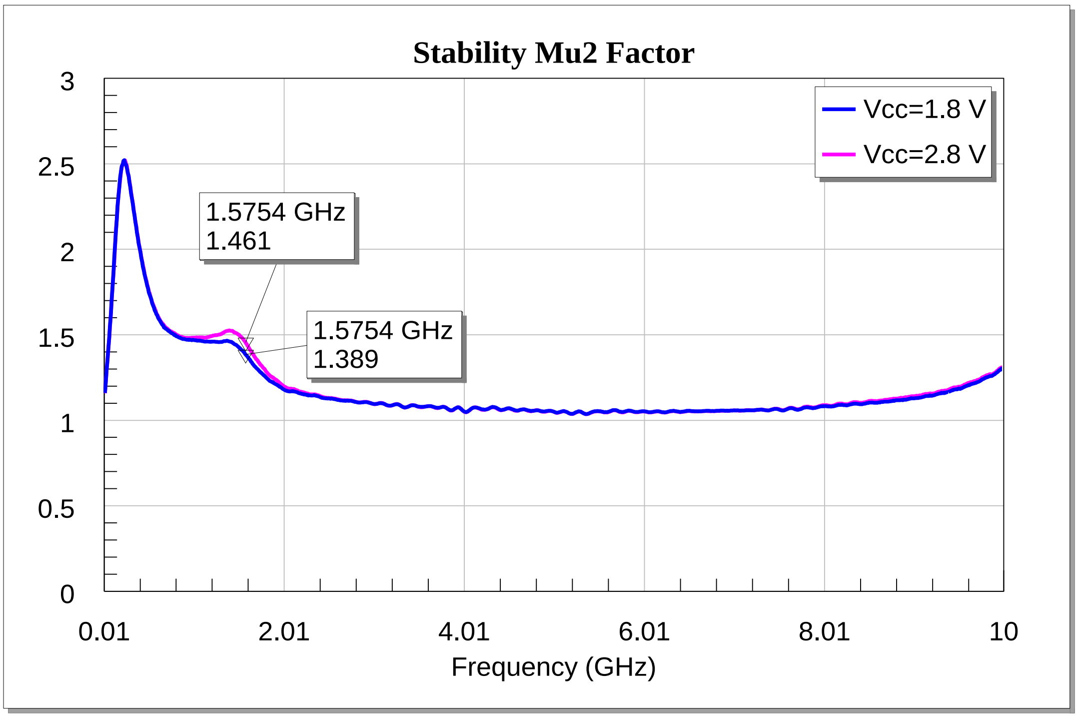

Figure 19 Stability Factor µ2 of BGA231N7 upto 10 GHz

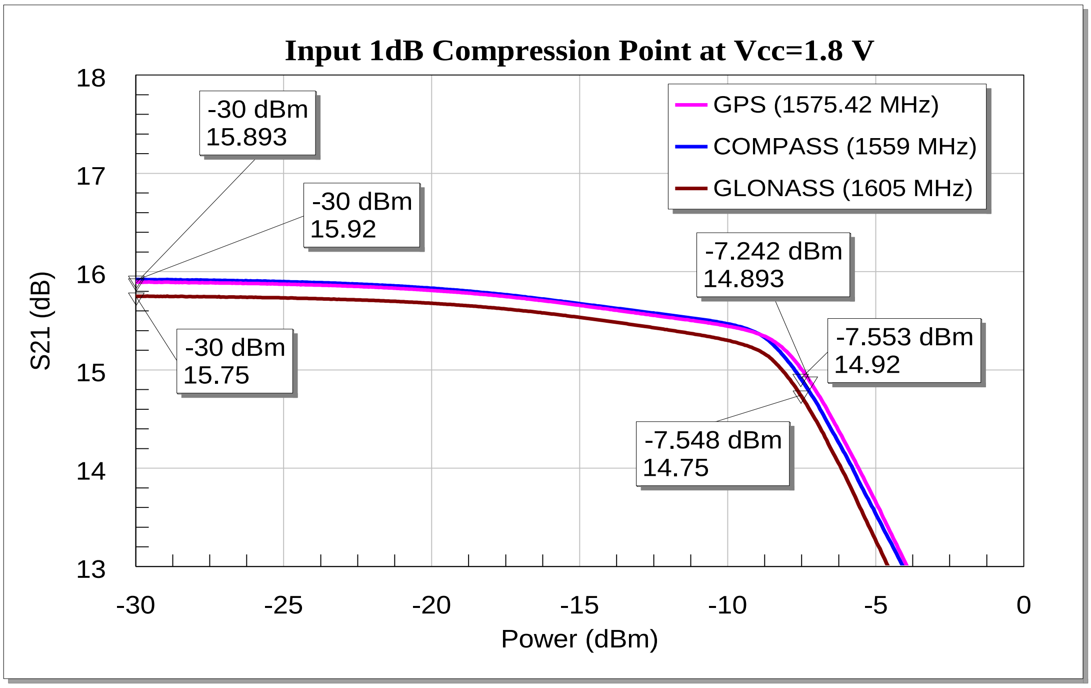

Figure 20 Input 1 dB Compression Point of BGA231N7 at Supply Voltage of 1.8 V for COMPASS, Galileo, GPS and GLONASS Bands

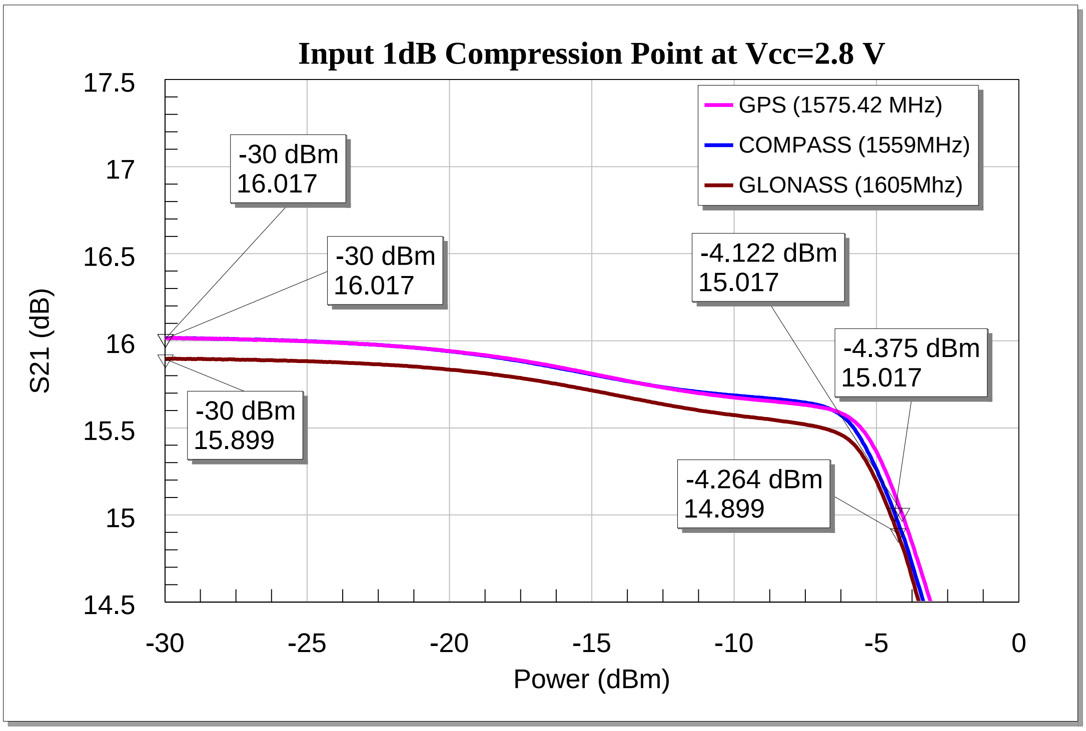

Figure 21 Input 1 dB Compression Point of BGA231N7 at Supply Voltage of 2.8 V for COMPASS, Galileo, GPS and GLONASS Bands

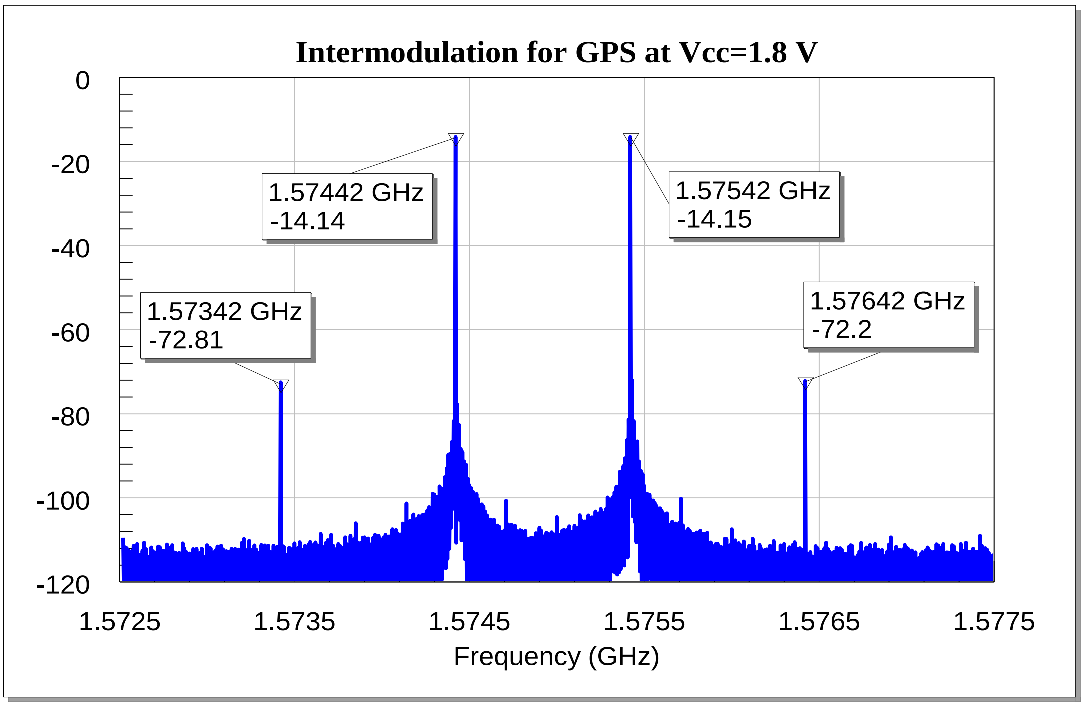

Figure 22 Carrier and Intermodulation Products of BGA231N7 for GPS Band at Vcc=1.8 V

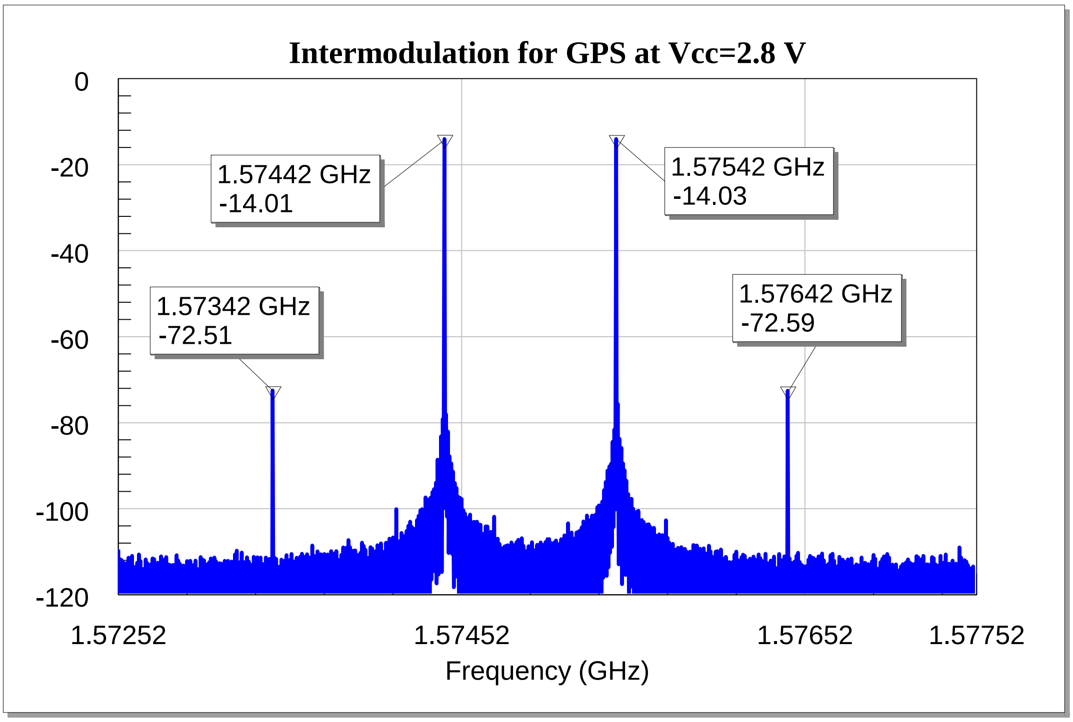

Figure 23 Carrier and Intermodulation Products of BGA231N7 for GPS Band at Vcc=2.8 V

5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB material: FR4

ε_r of PCB material: 4.3

Figure 24 Picture of Evaluation Board (overview)

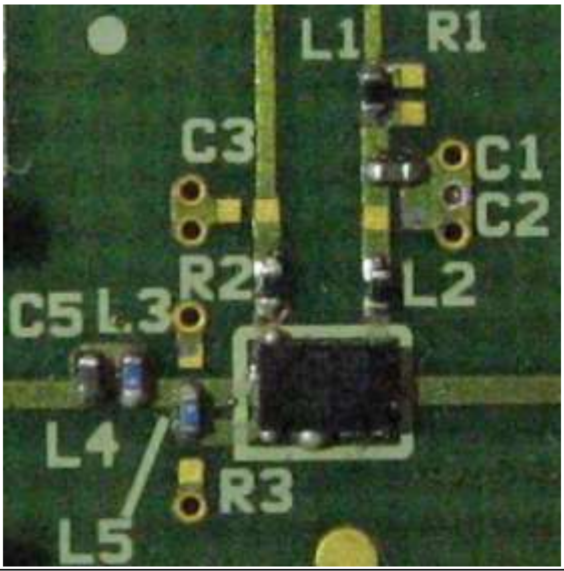

Figure 25 Picture of Evaluation Board (detailed view)

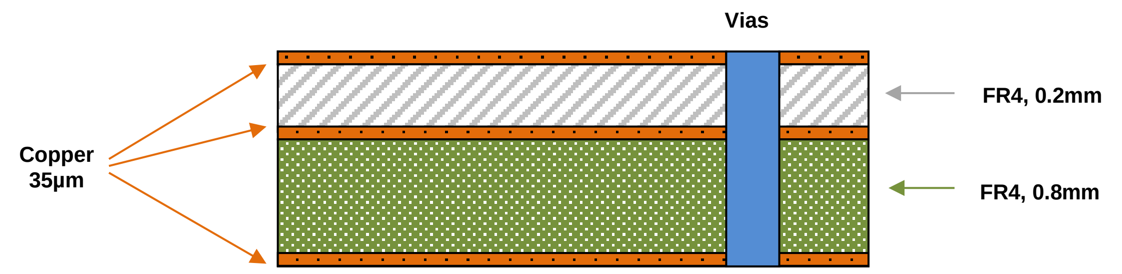

Figure 26 PCB Layer Information

6 Authors

Asheque Mohammad Zaidi, Werkstudent of Business Unit “RF and Protection Devices”.
Moakhkhrul Islam, 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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