BGA824N6 as Low Noise Amplifier for GPS L5/ Galileo E5 / GLONASS G3 Bands (1164 - 1214 MHz)

About this document

Scope and purpose

This application note describes Infineon's GNSS MMIC: BGA824N6 as a Low Noise Amplifier (LNA) for GPS L5/Galileo E5/GLONASS G3 bands (1164 to 1214 MHz) applications with 0201 inch or 0402 inch components for matching.

1. The BGA824N6 is a silicon germanium LNA supporting 1550 to 1615 MHz.
2. The target applications are GPS L5/Galileo E5/GLONASS G3 band (1164 to 1214 MHz).
3. In this report, the performance of BGA824N6 is measured on an FR4 board. Two external components are added at the LNA output side to retune the device to L5 band. This device is matched with 0201 inch or 0402 inch external components.
4. Key performance parameters at 2.8 V, 1189 MHz (0201 inch LQP03TN inductors for matching):
   Noise Figure (NF) = 0.90 dB
   Insertion gain = 17.6 dB
   Input return loss = 17.5 dB
   Output return loss = 17.6 dB
   Input P1dB = -9.1 dBm
5. Key performance parameters at 2.8 V, 1189 MHz (0402 inch LQW15 inductors for matching):
   Noise Figure (NF) = 0.70 dB
   Insertion gain = 17.9 dB
   Input return loss = 15.8 dB
   Output return loss = 18.1 dB
   Input P1dB = -9.0 dBm

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

List of tables

1 Introduction of Global Navigation Satellite Systems (GNSSs)

1.1 Global Navigation Satellite Systems (GNSSs)

GNSSs are among the fastest growing applications in the electronic industry. Today, four GNSSs are in operation: the United States' GPS, the Russian GLobal Orbiting NAvigation Satellite System (GLONASS), the Chinese BeiDou Navigation Satellite System (BDS) and the European Union Galileo navigation system. Among the above systems, BDS and Galileo are expected to be fully operational by 2020. Main market segments include Personal Navigation Devices (PNDs) and GNSS-enabled cell phones.

The main challenges for the growing GNSS-enabled cell phone market are to achieve high sensitivity and high immunity defined by government regulations against interference of cellular signals for safety and emergency reasons. This means GNSS signals must be received at very low power levels (e.g. down to -130 dBm) in cell phones in the vicinity of coexisting high-power cellular signals. In addition, cell phones must have excellent ESD robustness and low power consumption to ensure long battery usage time.

GPS: 1563 to 1587 MHz (L1), 1215 to 1240 MHz (L2), 1164 to 1189 MHz (L5)
Galileo: 1559 to 1591 MHz (E1), 1259 to 1299 MHz (E6), 1164 to 1214 MHz (E5)
GLONASS: 1598 to 1609 MHz (G1), 1237 to 1254 MHz (G2), 1189 to 1214 MHz (G3)
BeiDou: 1559 to 1591 MHz (B1), 1193 to 1221 MHz (B2), 1257 to 1281 MHz (B3)

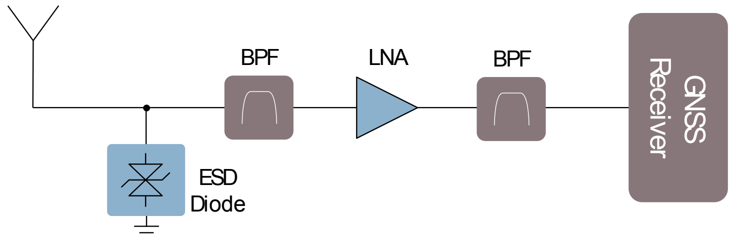

Figure 1 Application diagram: receiver front-end of the GNSS with LNAs and filters

1.2 Lower L bands (1164 to 1254 MHz) for the GNSSs

The GPS L5 band centers on 1176.45 MHz, and its frequency ranges from 1164 to 1189 MHz. It hosts a civilian safety-of-life signal, and is intended to provide a means of radio navigation secure and robust enough for life-critical applications, such as precision aircraft approach guidance. The Galileo E5 band centers on 1191.795 MHz, and its frequency ranges from 1164 to 1214 MHz. The GLONASS G3 band centers on 1201 MHz, and its frequency ranges from 1189 to 1214 MHz.

The GPS L2 band centers on 1227.6 MHz, and its frequency ranges from 1215 to 1240 MHz. The Galileo E6 band ranges from 1259 to 1299 MHz. The GLONASS G2 band ranges from 1237 to 1254 MHz.

1.3 Infineon product portfolio for GNSS applications

Infineon offers a complete product portfolio to all customers designing high-performance flexible RF front-end solutions for GNSSs:

- **LNAs:** Infineon offers a wide range of products such as high-performance Monolithic Microwave Integrated Circuits (MMICs) as well as cost-effective and high-end RF transistors.
- **Transient Voltage Suppression (TVS) diodes:** Infineon devices can protect GNSS antennas reliably up to 20 kV.

Infineon's GNSS MMIC LNA products offer low NF, high gain and low power consumption. In addition they are designed with high out-of-band linearity performance to enhance interference immunity.

1.4 Key features of GNSS LNAs

Infineon's GNSS MMIC LNA products offer the following features:

Low NF and high gain

The power levels of satellite signals received by a GPS/GNSS receiver are as low as -130 dBm. Such systems must be very sensitive. An external LNA with low NF and high gain is required to boost the sensitivity of the system, and Time To First Fix (TTFF).

High linearity

In modern cell phones, GNSS signals coexist with strong interfering cellular signals. The cellular signals can mix to produce intermodulation products in the GNSS receiver frequency band. To enhance interference immunity of the GNSSs, LNAs with high linearity characteristics, e.g. out-of-band IP3, are required.

Low current consumption

Power consumption is an important feature in many GNSSs that are mainly battery operated mobile devices. Infineon's LNAs have an integrated power on/off feature which provides for low power consumption and increased stand-by time for GNSS handsets. Moreover, the low current consumption (e.g. 1.05 mA) makes Infineon's LNAs suitable for portable technology such as GNSS-enabled handheld devices.

Please visit www.infineon.com for more details on LNA products for navigation in cell phones and portable devices.

2 BGA824N6 overview

2.1 Features

- High insertion power gain: 17.0 dB
- Out-of-band input third-order intercept point: +7 dBm
- Input 1 dB compression point: -6 dBm
- Low NF: 0.55 dB
- Low current consumption: 3.8 mA
- Operating frequencies: 1550 to 1615 MHz
- Supply voltage: 1.5 to 3.3 V
- Digital on/off switch (1 V logic high level)
- Ultra-small TSNP-6-2 leadless package (footprint: 0.7 × 1.1 mm²)
- B7HF silicon germanium technology
- RF output internally matched to 50 Ω
- Only one external SMD component necessary
- 2 kV HBM ESD protection (including AI-pin)
- Pb-free (RoHS compliant) package

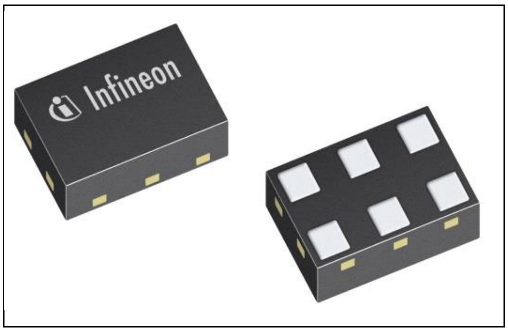

Figure 2 BGA824N6 in TSNP-6-2

RoHS

2.2 Key applications of BGA824N6

Ideal for all GNSSs, such as GPS, GLONASS, BeiDou, Galileo and others.

2.3 Description

The BGA824N6 is a front-end LNA for GNSSs from 1550 to 1615 MHz, such as GPS, GLONASS, BeiDou, Galileo and others. The LNA provides 17.0 dB gain and 0.55 dB NF at a current consumption of 4.1 mA in the application configuration described in Chapter 3. The BGA824N6 is based on Infineon Technologies' B7HF silicon germanium technology. It operates from 1.5 to 3.6 V supply voltage.

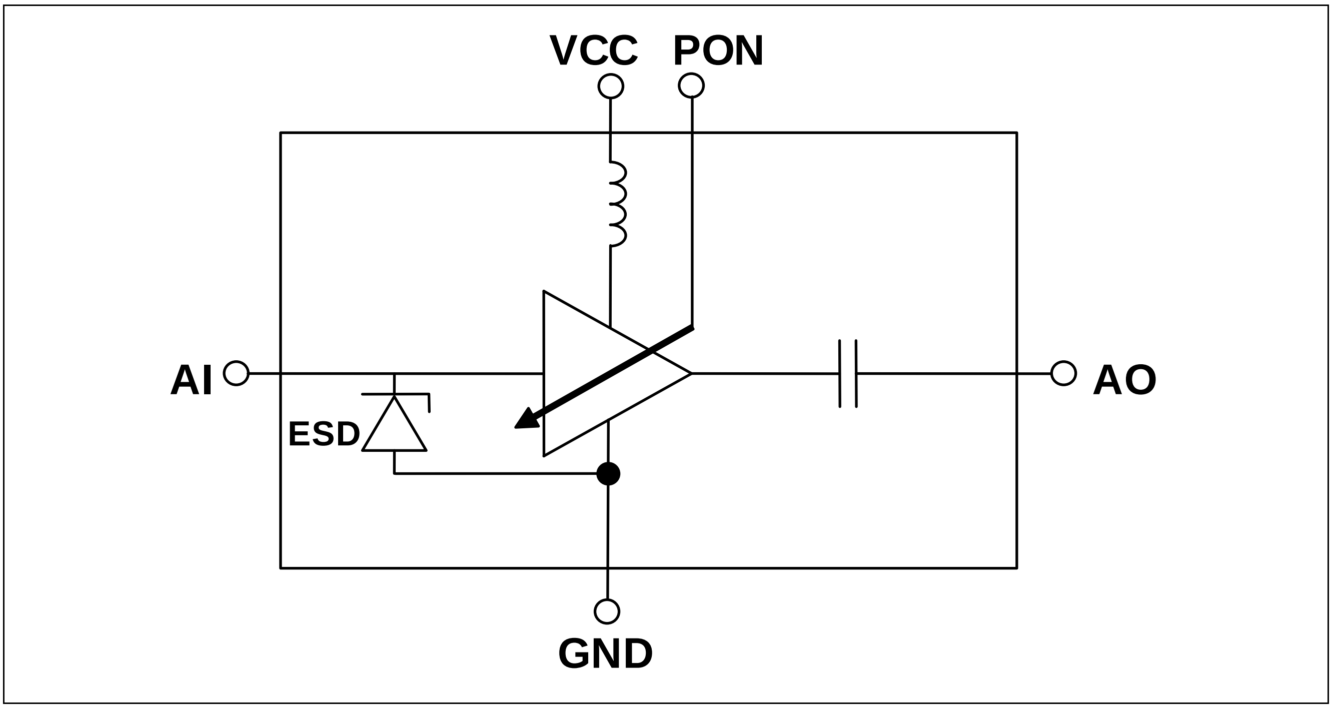

Figure 3 Package and pin connections of BGA824N6

Table 1 Pin assignment of BGA824N6

Pin no.	Symbol	Function
1	GND	Ground
2	V_{CC}	DC supply
3	AO	LNA output
4	GND	Ground
5	AL	LNA input
6	PON	Power on control

3 Application circuit and performance overview

In this chapter the performance of the application circuit, the schematic and Bill of Materials (BOM) are presented.

Device: BGA824N6

Application: **GPS L5/Galileo E5/GLONASS G3 band**

PCB marking: **200814**

EVB order no.: AN533

3.1 Summary of measurement results

The performance of BGA824N6 for GNSS band L5/E5/G3 applications is summarized in the following table.

3.1.1 Measurement results with 0201 size components

The performance of the circuit using 0201 size LQP03TN inductors for matching are presented in the tables below.

Table 2 **Electrical characteristics at 2.8 V (at room temperature)**

Parameter	Symbol	Value			Unit	Comment/Test condition
Frequency range	Freq	1164	1189	1214	MHz	
DC voltage	V_{CC}	2.8			V	
DC current	I_{CC}	4.2			mA	
Gain	G	17.5	17.6	17.4	dB	
Noise Figure	NF	0.90	0.90	0.90	dB	Loss of input line of 0.1 dB is de-embedded
Input return loss	RL_{in}	13.7	17.5	21.6	dB	
Output return loss	RL_{out}	31.1	17.6	12.0	dB	
Reverse isolation	I_{Rev}	27.0	26.7	26.6	dB	
Input P1dB	I_{P1dB}	-9.1			dBm	f = 1189 MHz
Output P1dB	O_{P1dB}	8.4			dBm	
Input IP3	I_{IP3}	-4.2			dBm	Power at input: -30 dBm f1 = 1189 MHz, f2 = 1190 MHz
Output IP3	O_{IP3}	13.3			dBm	
Out-of-band input IP3	Oob_IIP3					Power at input: -25 dBm f1 = 1850 MHz, f2 = 2485 MHz
Out-of-band output IP3						
Stability	K	> 1			–	Measured up to 8 GHz

Table 3 Electrical characteristics at 1.8 V (at room temperature)

Parameter	Symbol	Value			Unit	Comment/Test condition
Frequency range	Freq	1164	1189	1214	MHz	
DC voltage	Vcc	1.8			V	
DC current	Icc	4.1			mA	
Gain	G	17.5	17.5	17.3	dB	
Noise Figure	NF	0.90	0.90	0.90	dB	Loss of input line of 0.1 dB is de-embedded
Input return loss	RLin	13.5	17.5	22.5	dB	
Output return loss	RLout	34.5	16.7	11.5	dB	
Reverse isolation	IRev	26.2	25.9	25.8	dB	
Input P1dB	IP1dB	-11.7			dBm	f = 1189 MHz
Output P1dB	OP1dB	5.8			dBm	
Input IP3	IIP3	-4.2			dBm	Power at input: -30 dBm f1 = 1189 MHz, f2 = 1190 MHz
Output IP3	OIP3	13.2			dBm	
Stability	K	> 1			–	Measured up to 8 GHz

3.1.2 Measurement results with 0402 components

The performance of the circuit using 0402 size, high Q LQW15 inductors for matching are presented in the tables below.

Table 4 **Electrical characteristics at 2.8 V (at room temperature)**

Parameter	Symbol	Value			Unit	Comment/Test condition
Frequency range	Freq	1164	1189	1214	MHz	
DC voltage	V_{CC}	2.8			V	
DC current	I_{CC}	4.2			mA	
Gain	G	17.9	17.9	17.8	dB	
Noise Figure	NF	0.70	0.70	0.70	dB	Loss of input line of 0.1 dB is de-embedded
Input return loss	RLin	12.6	15.8	19.2	dB	
Output return loss	RLout	26.8	18.1	12.1	dB	
Reverse isolation	IRev	26.5	26.3	26.2	dB	
Input P1dB	IP1dB	-9.0			dBm	f = 1189 MHz
Output P1dB	OP1dB	8.9			dBm	
Input IP3	IIP3	-2.8			dBm	Power at input: -30 dBm f1 = 1189 MHz, f2 = 1190 MHz
Output IP3	OIP3	15.1			dBm	
Stability	K	>1			–	Measured up to 8 GHz

Table 5 Electrical characteristics at 1.8 V (at room temperature)

Parameter	Symbol	Value			Unit	Comment/Test condition
Frequency range	Freq	1164	1189	1214	MHz	
DC voltage	V_{CC}	1.8			V	
DC current	I_{CC}	4.1			mA	
Gain	G	17.9	17.9	17.7	dB	
Noise Figure	NF	0.70	0.70	0.70	dB	Loss of input line of 0.1 dB is de-embedded
Input return loss	RLin	12.4	15.5	19.1	dB	
Output return loss	RLout	30.5	17.1	11.7	dB	
Reverse isolation	IRev	25.9	25.7	25.7	dB	
Input P1dB	IP1dB	-11.6			dBm	f = 1189 MHz
Output P1dB	OP1dB	6.3			dBm	
Input IP3	IIP3	-2.8			dBm	Power at input: -30 dBm f1 = 1189 MHz, f2 = 1190 MHz
Output IP3	OIP3	14.3			dBm	
Stability	K	>1			–	Measured up to 8 GHz

3.2 Schematic and Bill of Materials (BOM)

The schematic of BGA824N6 for GNSS **band L5/E5/G3 applications** is presented in Figure 4 and its BOM is shown in Error! Reference source not found..

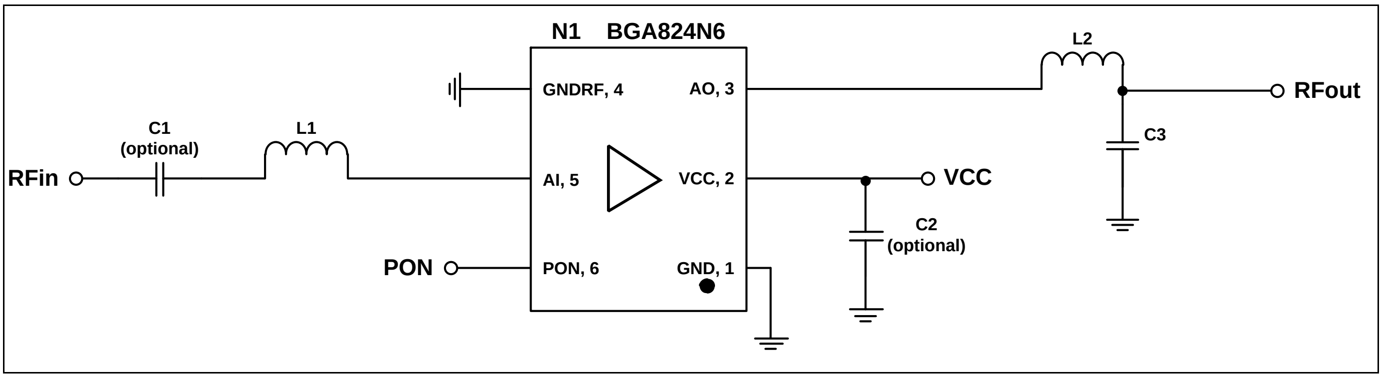

Figure 4 Schematic of the BGA824N6 application circuit

Table 6 BOM

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	>=1	nF	0201/0402	Various	DC block
C2	>=1	nF	0201/0402	Various	RF bypass
C3	4.7	pF	0201/0402	Various	Output matching
L1	12	nH	0201/0402	Murata LQP03TN Murata LQW15	Input matching
L2	3.9	nH	0201/0402	Murata LQP03TN Murata LQW15	Output matching
N1	BGA824N6		TSNP-6-2	Infineon Technologies	SiGe LNA

Note: DC block function is NOT integrated at the input of BGA824N6. The DC block capacitor C1 is not necessary if the DC block function on the RF input line can be ensured by the previous stage.

The RF bypass capacitor C2 at the DC power supply pin filters out the power supply noise and stabilizes the DC supply. The RF bypass capacitor C2 is not necessary if a clean and stable DC supply can be ensured.

4 Measurement graphs (with 0201 size components)

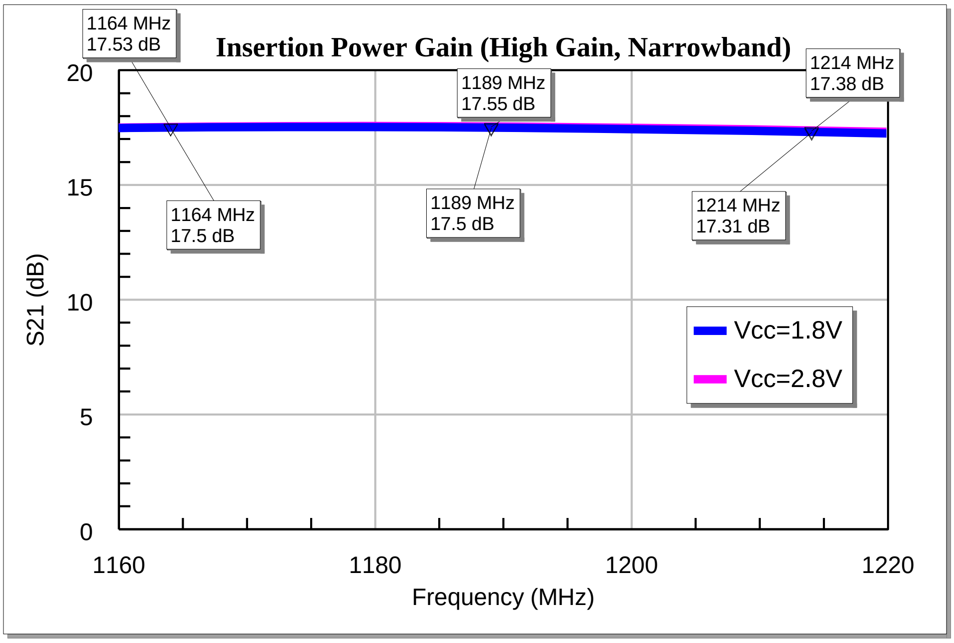

Figure 5 Insertion power gain (high gain, narrowband) of BGA824N6 for band L5/E5/G3 applications

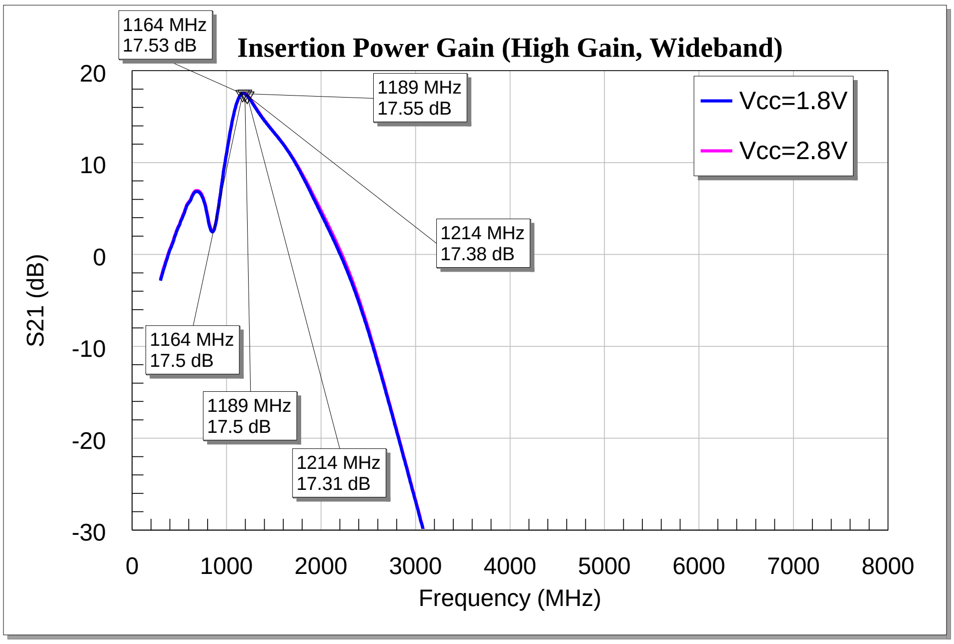

Figure 6 Insertion power gain (high gain, wideband) of BGA824N6 for band L5/E5/G3 applications

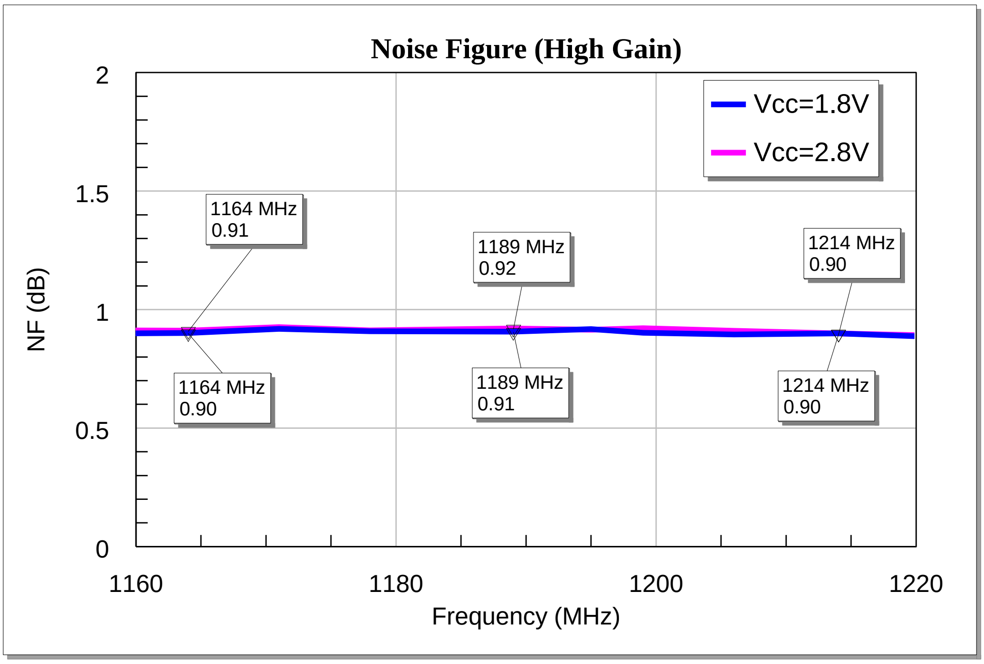

Figure 7 NF (high gain) of BGA824N6 for band L5/E5/G3 applications (with LQP03TN inductor for matching)

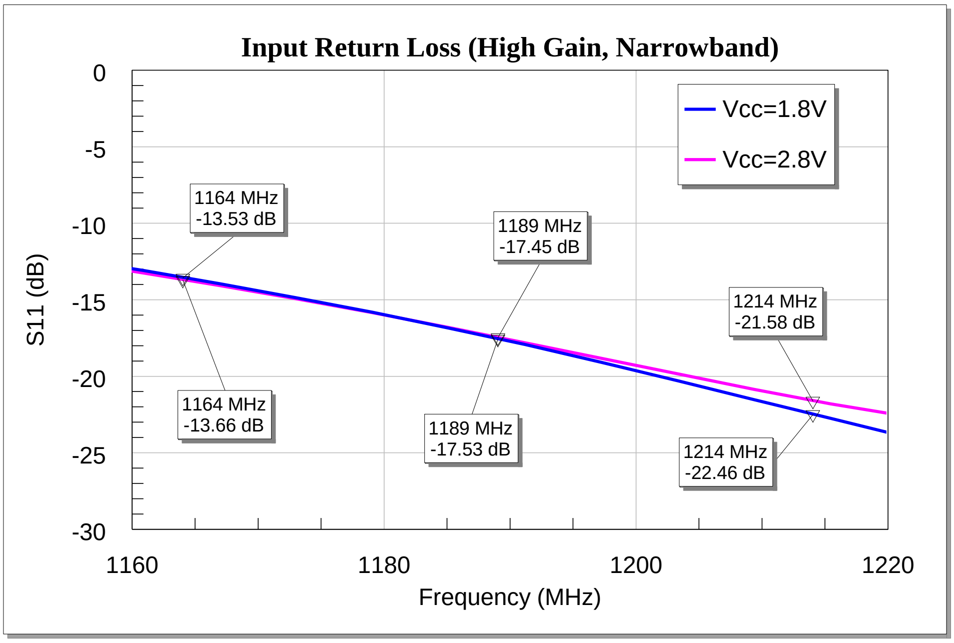

Figure 8 Input return loss (high gain, narrowband) of BGA824N6 for band L5/E5/G3 applications

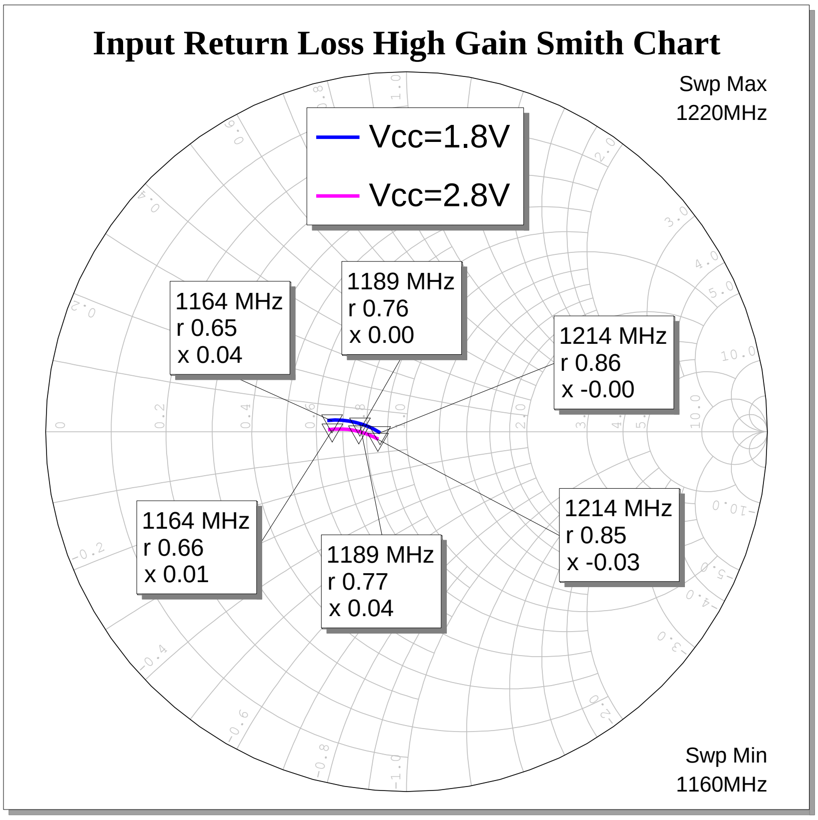

Figure 9 Input return loss (high gain, Smith chart) of BGA824N6 for band L5/E5/G3 applications

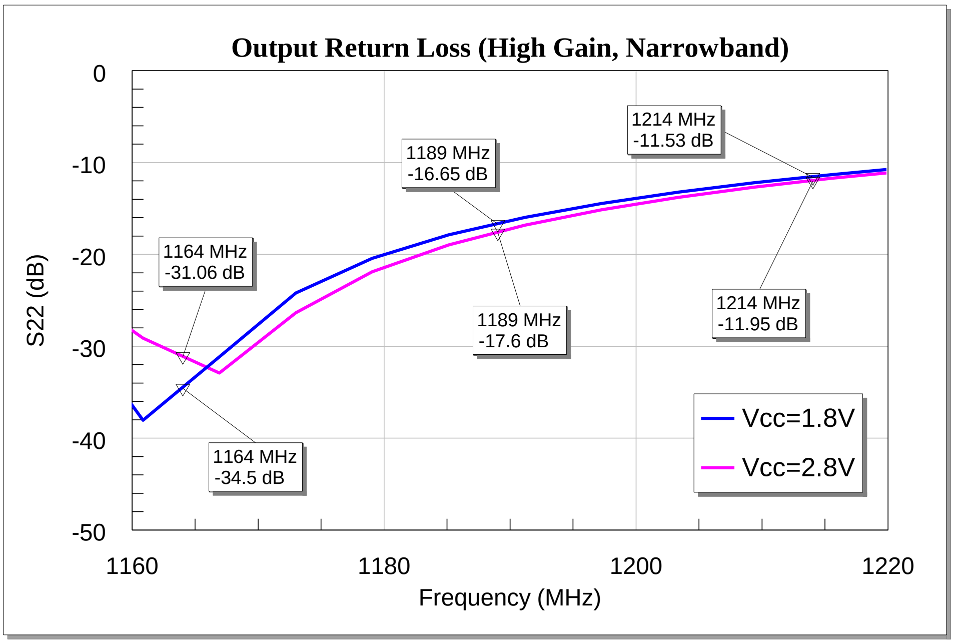

Figure 10 Output return loss (high gain, narrowband) of BGA824N6 for band L5/E5/G3 applications

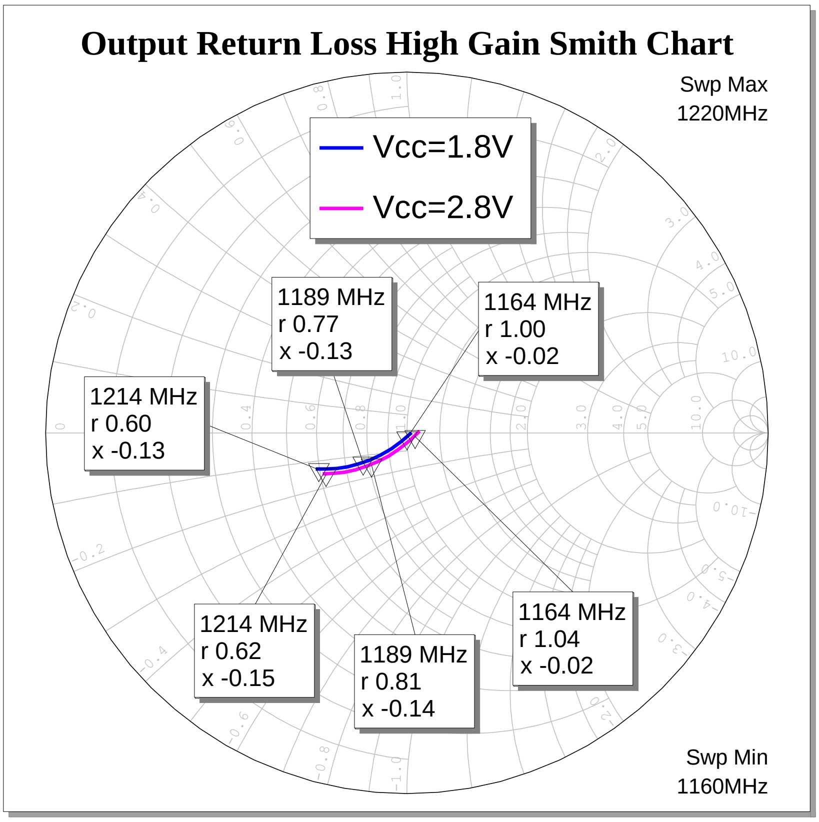

Figure 11 Output return loss (high gain, Smith chart) of BGA824N6 for band L5/E5/G3 applications

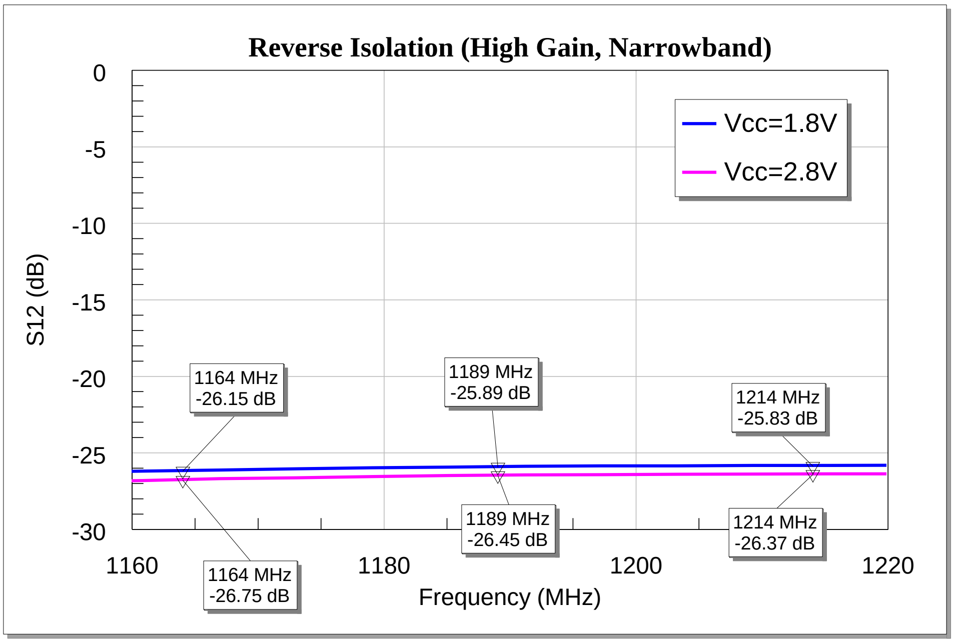

Figure 12 Reverse isolation (high gain, narrowband) of BGA824N6 for band L5/E5/G3 applications

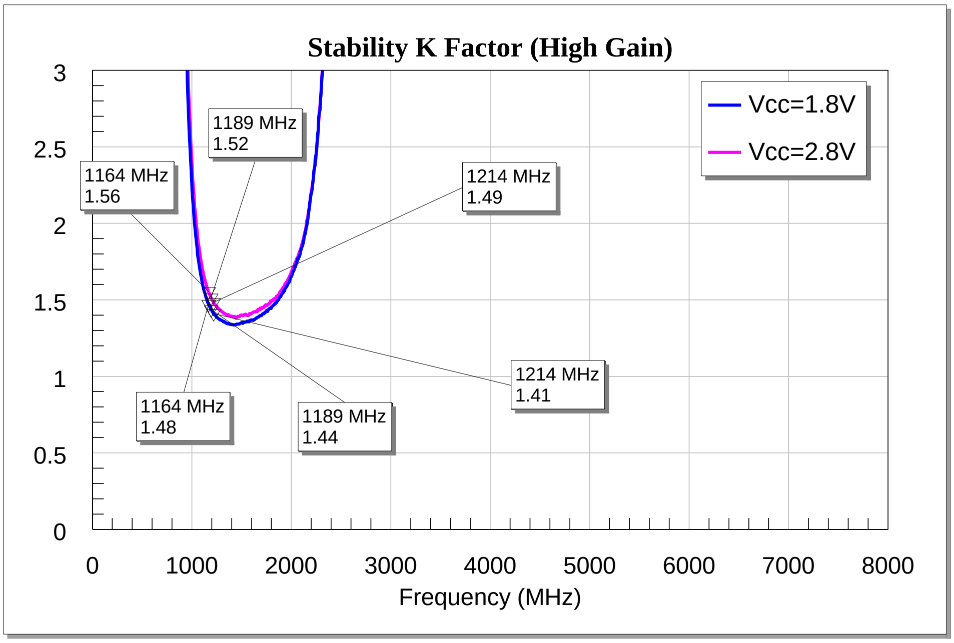

Figure 13 Stability K-factor (high gain) of BGA824N6 for band L5/E5/G3 applications

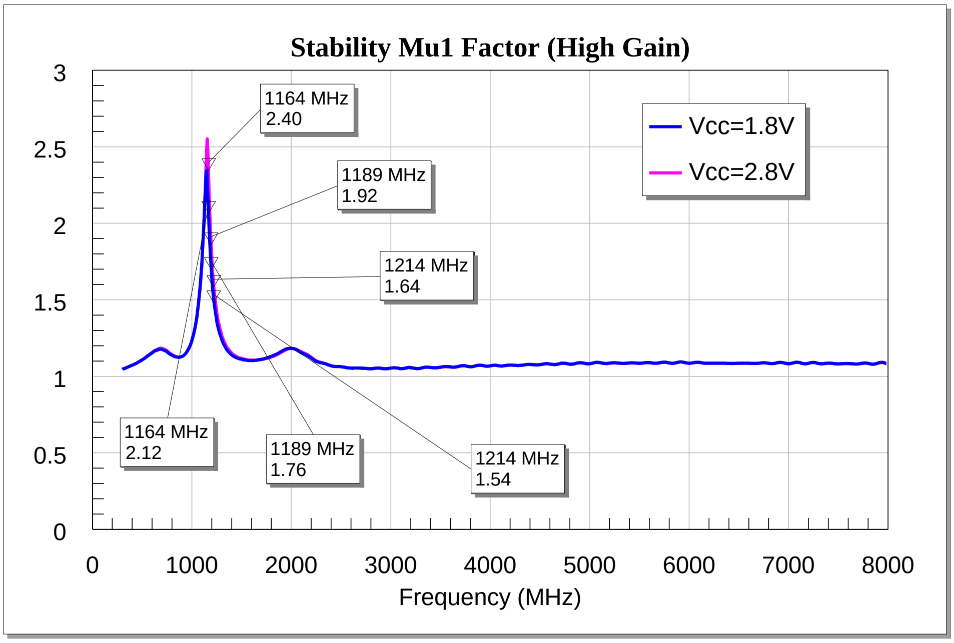

Figure 14 Stability Mu1-factor (high gain) of BGA824N6 for band L5/E5/G3 applications

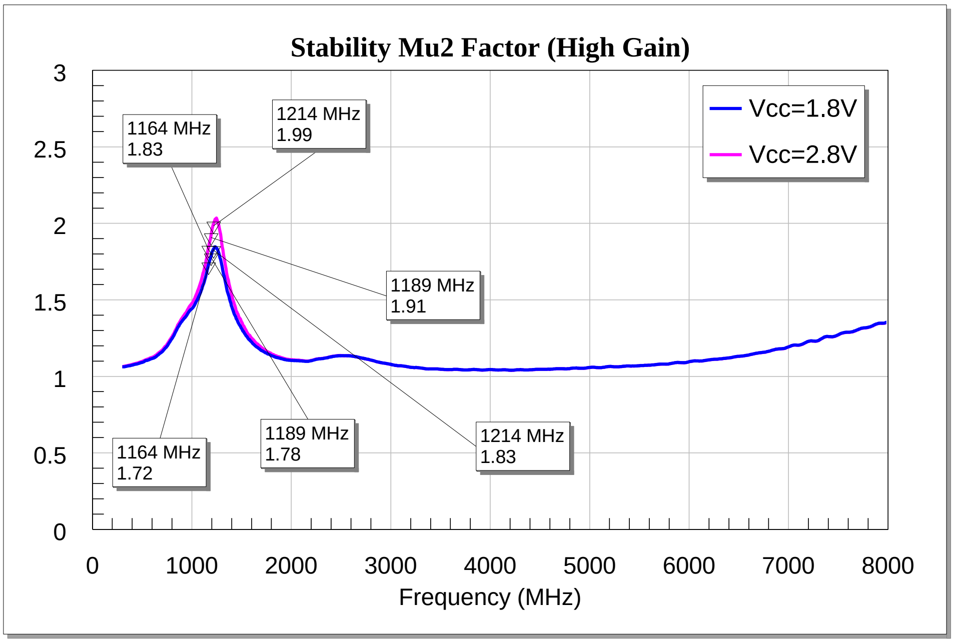

Figure 15 Stability Mu2-factor (high gain) of BGA824N6 for band L5/E5/G3 applications

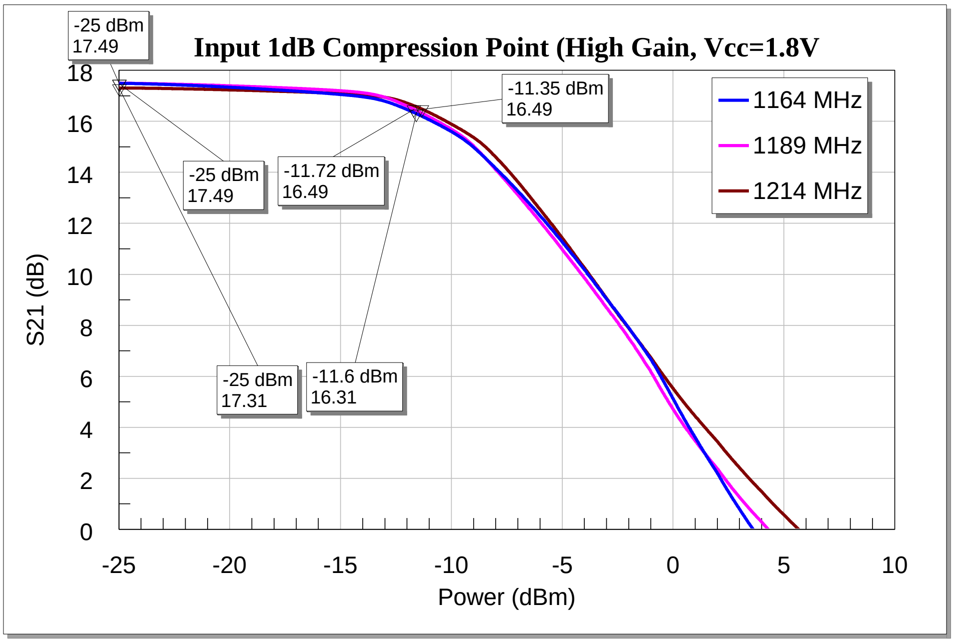

Figure 16 Input 1 dB compression point (high gain, 1.8 V) of BGA824N6 for band L5/E5/G3 applications

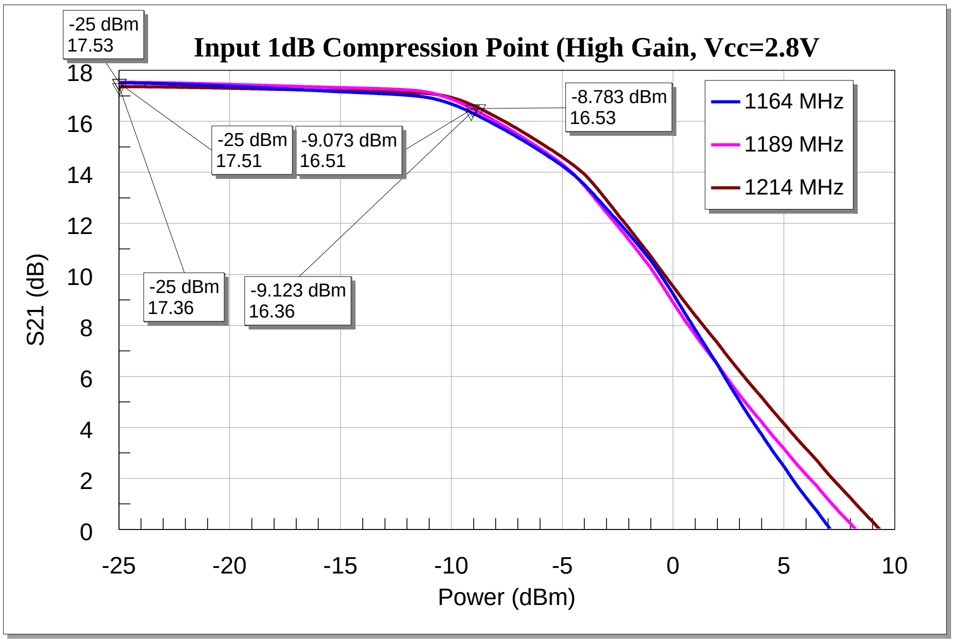

Figure 17 Input 1 dB compression point (high gain, 2.8 V) of BGA824N6 for band L5/E5/G3 applications

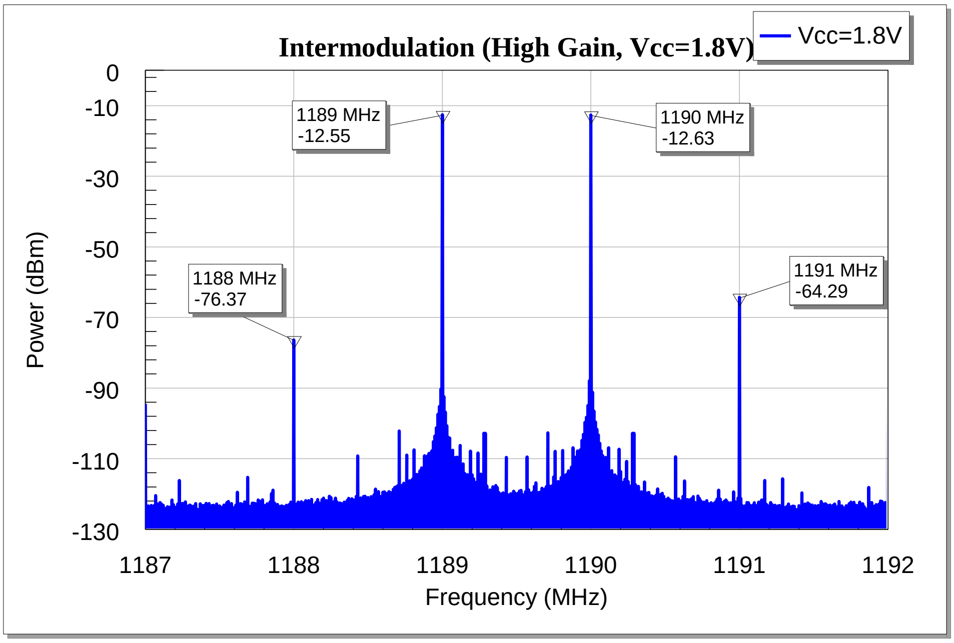

Figure 18 Third-order interception point (high gain, 1.8 V) of BGA824N6 for band L5/E5/G3 applications

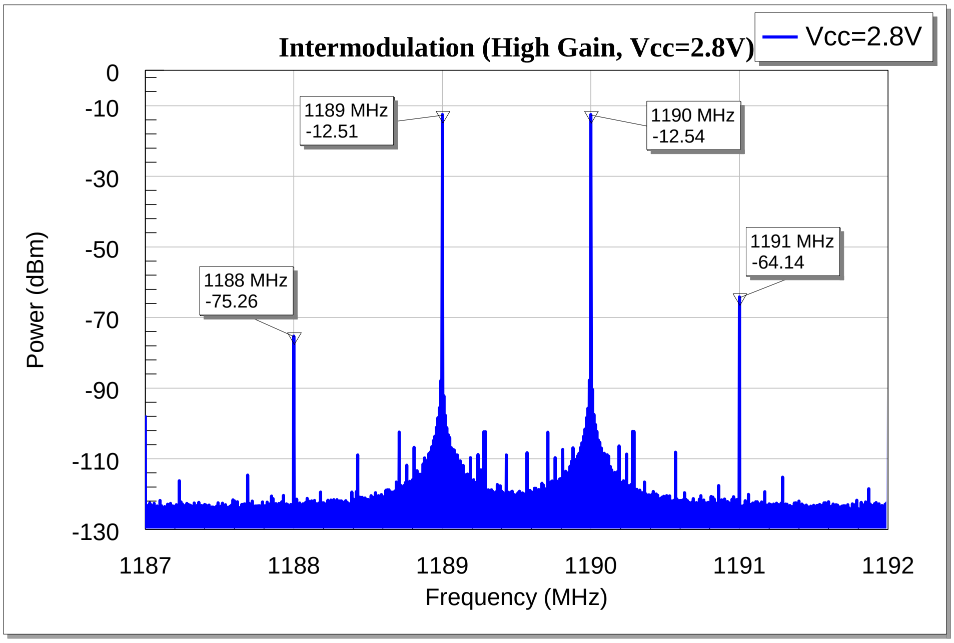

Figure 19 Third-order interception point (high gain, 2.8 V) of BGA824N6 for band L5/E5/G3 applications

5 Evaluation board and layout information

In this application note, the following PCB is used:

PCB marking: 200814

PCB material: FR4

εr of PCB material: 4.8

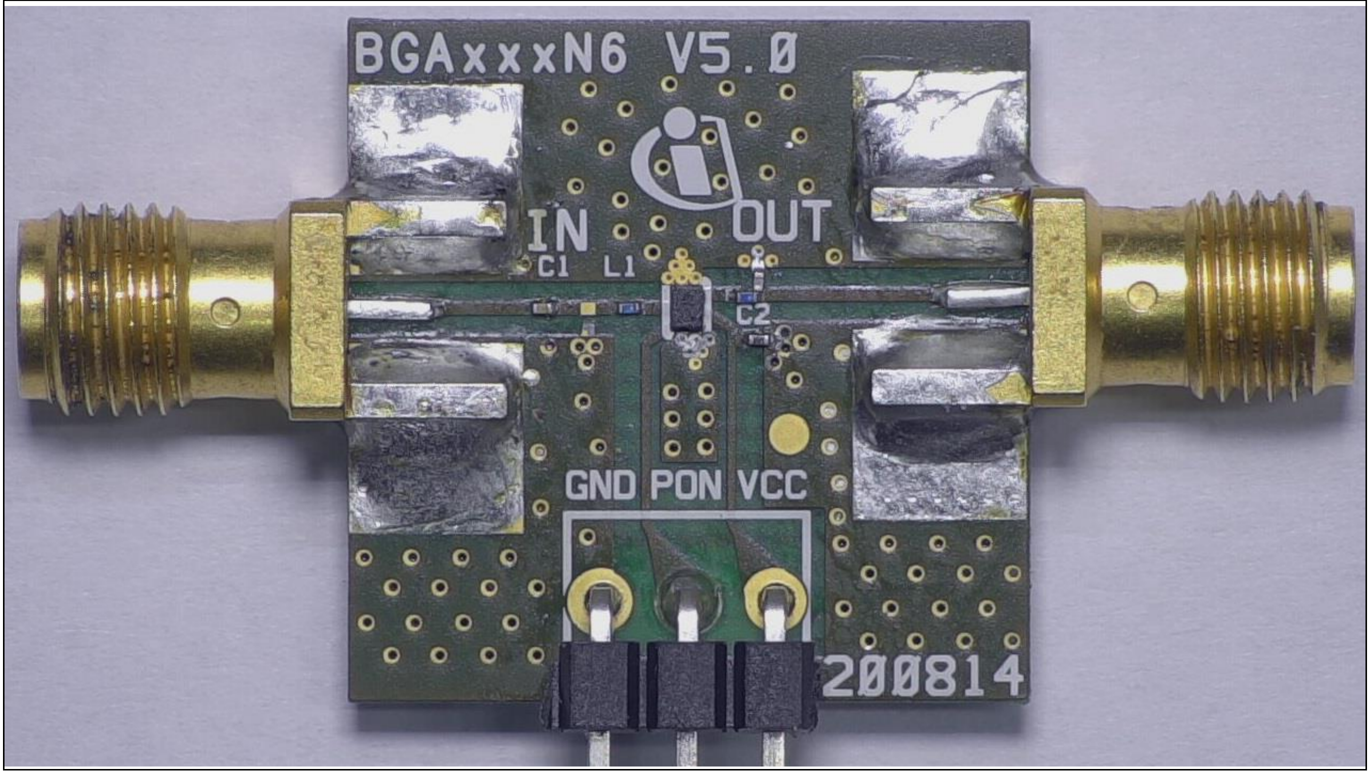

Figure 20 Photo of evaluation board (overview)

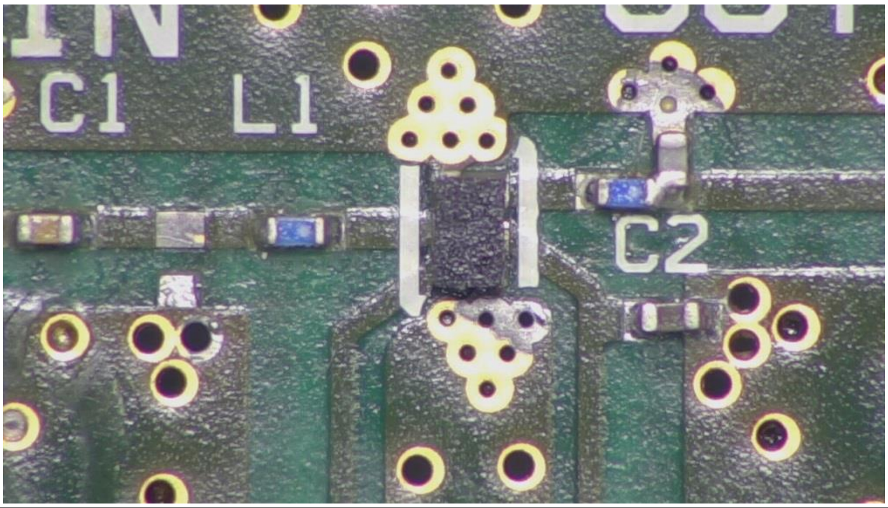

Figure 21 Photo of evaluation board (detailed view)

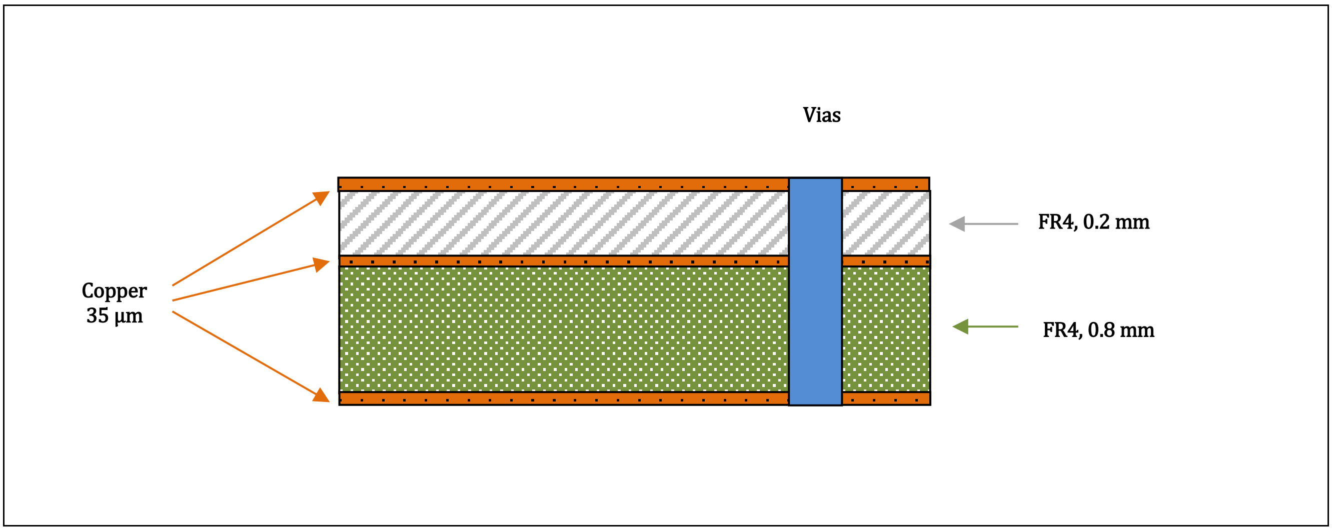

Figure 22 PCB layer information

6 Authors

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Mark Schmidt, Working Student of Business Unit "Radio Frequency and Sensors"

7 References

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2. https://en.wikipedia.org/wiki/GPS_signals
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5. http://gpsworld.com/innovation-glonass-11405/

Revision history

Major changes since the last revision, Rev. 1.1 2017-12-20

Page or reference	Description of change
1	Added performance results with 0402 external components
8 to 11	Added performance results with 0402 external components
8, 9	Table 2, Table 3, corrected the SMA and connector losses and noise figure values
12	Added performance results with 0402 external components
14	Updated the noise figure graph

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