BGA524N6 as Low Noise Amplifier for GPS L5 / Galilieo E5 / GLONASS G3 Bands (1164 - 1214 MHz)

About this document

Scope and purpose

This application note describes Infineon's GNSS MMIC: BGA524N6 as Low Noise Amplifier for GPS L5 / Galileo E5 / GLONASS G3 Band (1164 – 1214 MHz) applications with 0201 size or 0402 size components for matching.

1. The BGA524N6 is a Silicon Germanium Low Noise Amplifier supporting 1550 – 1615 MHz.
2. The target application is GPS L5 / Galileo E5 / GLONASS G3 Band (1164 - 1214 MHz) application.
3. In this report, the performance of BGA524N6 is measured on a FR4 board. Two external components are added at the LNA output to retune the device to L5 band. This device is matched with 0201 size or 0402 size external components.
4. Key performance parameters at 1.8 V, 1189 MHz
   Noise figure = 0.90 dB (with 0402 size LQP03TN inductors for matching)
   Noise figure = 0.70 dB (with 0402 size LQW15 inductors for matching)
   Insertion gain = 18.2 dB
   Input return loss = 13 dB
   Output return loss = 17 dB
   Input P1dB = -15 dBm

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

1 Introduction of Global Navigation Satellite Systems (GNSSs)

1.1 Global Navigation Satellite Systems (GNSSs)

Global Navigation Satellite Systems (GNSSs) are among the fastest growing businesses in the electronic industry. Today, four GNSS systems 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 Galieo navigation system. Among the above systems, BDS and Galieo are expected to be fully operational by 2020. Main market segments include the Personal Navigation Devices (PND) and GNSS-enabled mobile phones.

The main challenges for the growing GNSS-enabled mobile 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 (down to less than -160 dBm) in mobile phones in the vicinity of co-existing high-power cellular signals. In addition, mobile phones must have excellent Electro-Static Discharge (ESD) robustness and low power consumption to ensure long battery usage time.

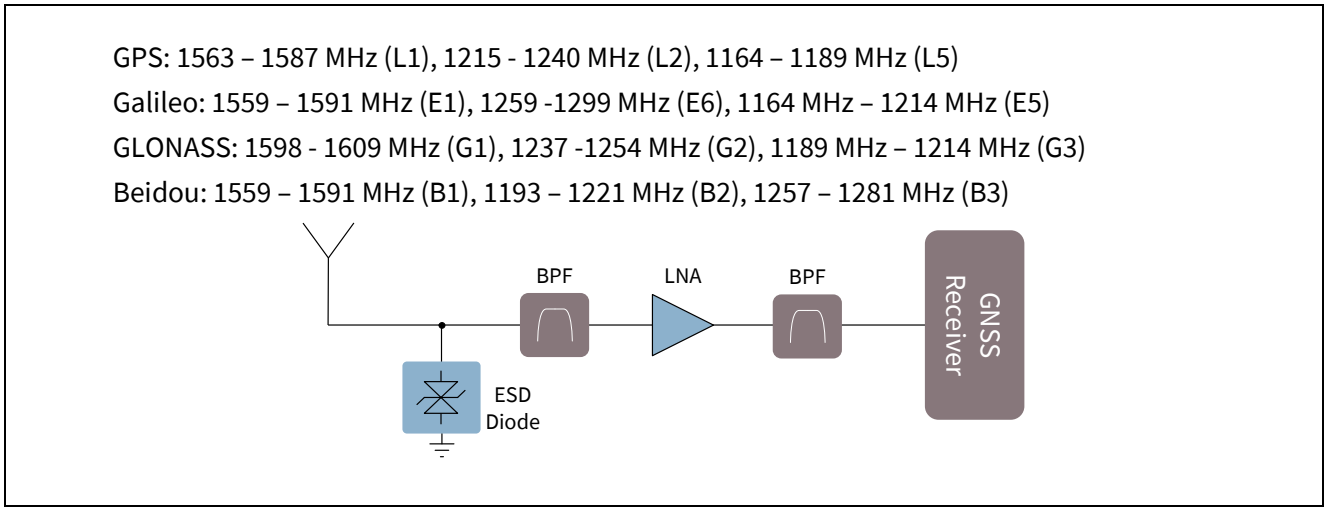


Figure 1 Application Diagram: Receiver Frontend the Global Navigation Satellite System With LNAs and Filter

1.2 Lower L bands (1164 – 1254 MHz) for the GNSS Systems

The GPS L5 band centers at 1176.45 MHz and its frequency ranges from 1164 MHz 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 aircraft precision approach guidance. The Galieo E5 band

centers at 1191.795 MHz, and its frequency ranges from 1164 MHz to 1214 MHz. The GLONASS G3 band centers at 1201 MHz and its frequency ranges from 1189 MHz to 1214 MHz.

The GPS L2 band centers at 1227.6 MHz and its frequency range is from 1215 MHz to 1240 MHz. The Galieo E6 band ranges from 1259 MHz to 1299 MHz. The GLONASS G2 band ranges from 1237 MHz to 1254 MHz.

1.3 Infineon Product Portfolio for GPS Applications

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

- **Low Noise Amplifiers (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 Noise Figure (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 Low Noise Amplifiers

Low Noise Figure & High Gain

The power levels of satellite signals received by a GPS/GNSS receiver are as low as -160 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 mobile 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 GNSS systems, LNAs with high linearity characteristics e.g. IP3, Oob IP3 are required.

Low Current Consumption

Power consumption is an important feature in many GNSS systems 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 (2.5 mA) makes Infineon's LNAs suitable for portable technology such as GNSS enabled handheld devices.

Introduction of Global Navigation Satellite Systems (GNSSs)

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

2 BGA524N6 Overview

2.1 Features

- High insertion power gain: 19.6 dB
- Out-of-band input 3rd order intercept point: -4 dBm
- Input 1 dB compression point: -12 dBm
- Low noise figure: 0.55 dB
- Low current consumption: 2.5 mA
- Operating frequencies: 1550 - 1615 MHz
- Supply voltage: 1.5 V to 3.3 V
- Digital on/off switch (1 V logic high level)
- Ultra small TSNP-6-2 leadless package (footprint: 0.7 x 1.1 mm^2)
- B7HF Silicon Germanium technology
- RF output internally matched to 50
- Only 1 external SMD component necessary
- 2 kV HBM ESD protection (including AI-pin)
- Pb-free (RoHS compliant) package

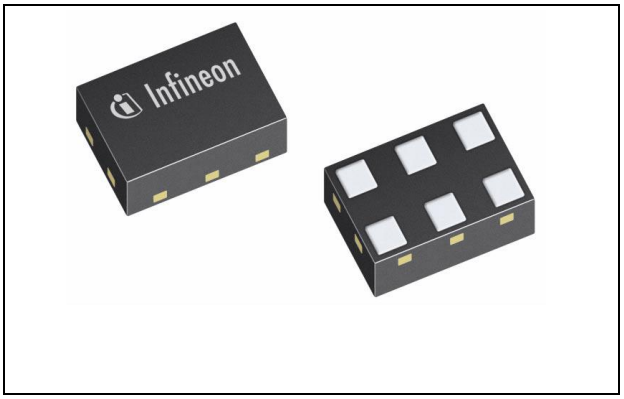


Figure 2 BGA524N6 in TSNP-6-2

2.2 Key Applications of BGA524N6

➢ Ideal for all Global Navigation Satellite Systems (GNSS) applications like

- GPS (US GNSS) working in the L1 band at 1575.42 MHz
- GLONASS (Russian GNSS) working in the L1 band from 1598.0625 MHz to 1605.3125 MHz
- Galileo (European GNSS) working in the E1 band from 1559.052 MHz to 1591.788 MHz
- Beidou (Chinese GNSS) working in E2 band at 1561.098 MHz

2.3 Description

The BGA524N6 is a front-end low noise amplifier for Global Navigation Satellite Systems (GNSS) from 1550 MHz to 1615 MHz like GPS, GLONASS, Galileo, Beidou and others. The LNA provides 19.6 dB gain and 0.55 dB noise figure at a current consumption of 2.5 mA only in the application configuration described in **Chapter 3**. The BGA524N6 is based upon Infineon Technologies B7HF Silicon Germanium technology. It operates from 1.5 V to 3.3 V supply voltage.

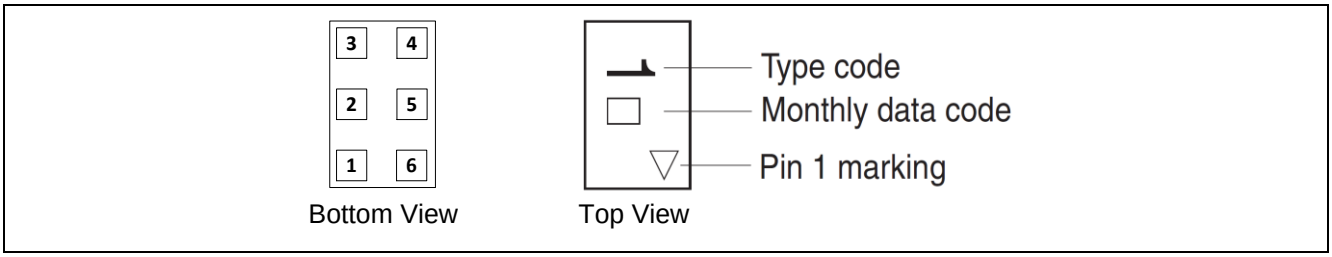


Figure 3 Package and pin connections of BGA524N6

Table 1 Pin Assignment of BGA524N6

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 Mode Selection of BGA524N6

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

Please visit the product page of **BGA524N6** for more information.

3 Application Circuit and Performance Overview

In this chapter the performance of the application circuit, the schematic and bill-of-materials are presented.

Device: **BGA524N6**

Application: **LNA for GPS L5/Galileo E5 / GLONASS G3 Bands**

PCB Marking: **161214**

EVB Order No.: **AN537**

3.1 Summary of Measurement Results

Ther performance of BGA524N6 for GNSS Bands L5/ E5/ G3 applications is summarized in the following table.

Table 3 Electrical Characteristics at 1.8V (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		2.5		mA	
Gain	G	17.6	18.2	18.4	dB	Loss of input/output line of 0.10dB are included
Noise Figure[1)]	NF	0.90	0.90	0.90	dB	[1)]with 0201 size external matching, loss of input line of 0.1 dB is deembeded
Noise Figure [2)]	NF	0.70	0.70	0.70	dB	[2)]with 0402 size external matching, loss of input line of 0.1 dB is deembeded
Input Return Loss	RLin	11.8	12.8	13.5	dB	
Output Return Loss	RLout	15.4	17.4	13.8	dB	
Reverse Isolation	IRev	45.4	45.4	45.5	dB	
Input P1dB	IP1dB		-15.4		dBm	f = 1189 MHz
Output P1dB	OP1dB		1.8		dBm	
Input IP3	IIP3		-11.2		dBm	Power @ Input: -30 dBm f1 = 1189 MHz, f2 = 1190 MHz
Output IP3	OIP3		7.0		dBm	
Out-of-band IIM3	Oob_IIM3		-92.1		dBm	Power @ Input: -25 dBm f1 = 1850 MHz, f2 = 2485 MHz
Out-of-band OIM3	Oob_OIM3		-73.7		dBm	
Stability	k		>1		--	Measured up to 8 GHz

Note: Out-of-band Input IM3 = Out-of-band Input IM3 – Gain @ the measured frequency

Table 4 Electrical Characteristics at 2.8V (at room temperature)

Parameter	Symbol	Value			Unit	Comment/Test Condition
Frequency Range	Freq	1164	1189	1214	MHz	
DC Voltage	Vcc		2.8		V	
DC Current	Icc		2.5		mA	
Gain	G	17.6	18.1	18.3	dB	Loss of input/output line of 0.10dB are included
Noise Figure [1)]	NF	0.90	0.90	0.85	dB	[1)]with 0201 size external matching, loss of input line of 0.1 dB is deembedded
Noise Figure [2)]	NF	0.70	0.70	0.70	dB	[2)]with 0402 size external matching, loss of input line of 0.1 dB is deembeded
Input Return Loss	RLin	11.9	12.8	13.6	dB	
Output Return Loss	RLout	14.9	17.2	14.0	dB	
Reverse Isolation	IRev	46.4	45.0	45.0	dB	
Input P1dB	IP1dB		-15.1		dBm	f = 1189 MHz
Output P1dB	OP1dB		2.0		dBm	
Input IP3	IIP3		-11.9		dBm	Power @ Input: -30 dBm f1 = 1189 MHz, f2 = 1190 MHz
Output IP3	OIP3		6.2		dBm	
Out-of-band IIM3	Oob_IIM3		-72.9		dBm	Power @ Input: -25 dBm f1 = 1850 MHz, f2 = 2485 MHz
Out-of-band OIM3	Oob_OIM3		-91.2		dBm	
Stability	k		>1		--	Measured up to 8 GHz

Note: Out-of-band Input IM3 = Out-of-band Input IM3 – Gain @ the measured frequency

3.2 Schematics and Bill-of-Materials

The schematic of BGA524N6 for GNSS Band L5/ E5 / G3 applications is presented in **Figure 4** and its bill-of-materials is shown in **Table 5**.

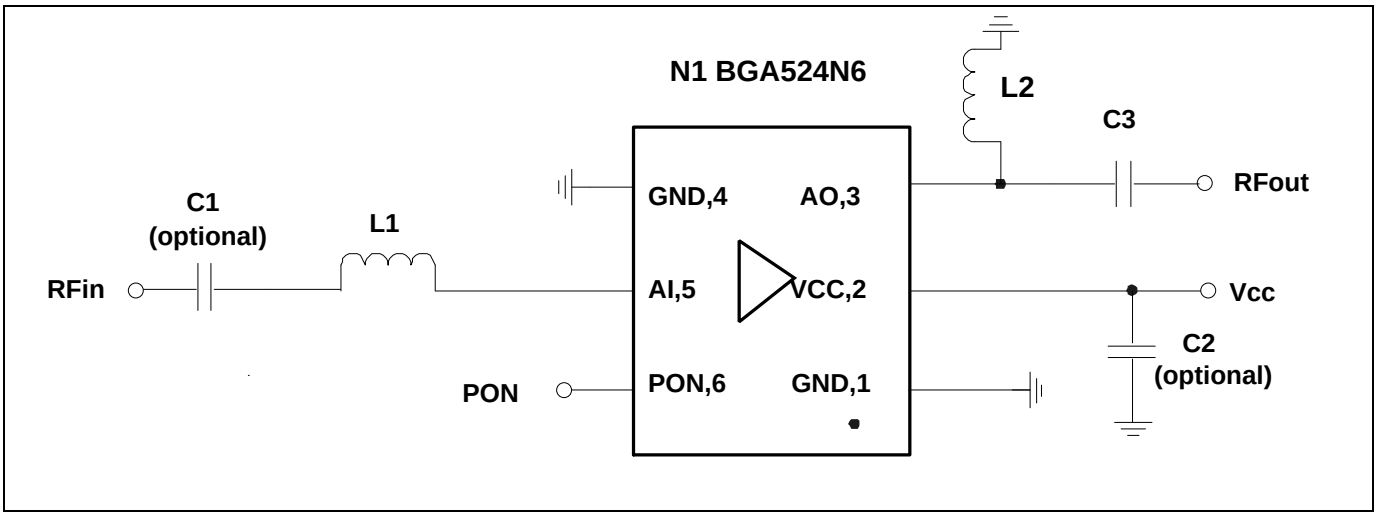


Figure 4 Schematics of the BGA524N6 Application Circuit

Table 5 Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	>=1	nF	0201/ 0402	Various	DC block
C2	>=10	nF	0201/ 0402	Various	RF bypass
C3	3.0	pF	0201 /0402	Various	Output Matching
L1	12	nH	0201/ 0402	Murata LQP03TN Murata LQW15	Input Matching
L2	3.0	nH	0201/ 0402	Murata LQP03TN Murata LQW15	Output Matching
N1	BGA524N6	TSNP-6-2		Infineon Technologies	SiGe LNA

Note: DC block function is NOT integrated at input of BGA524N6. 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.

Note: 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 external components)

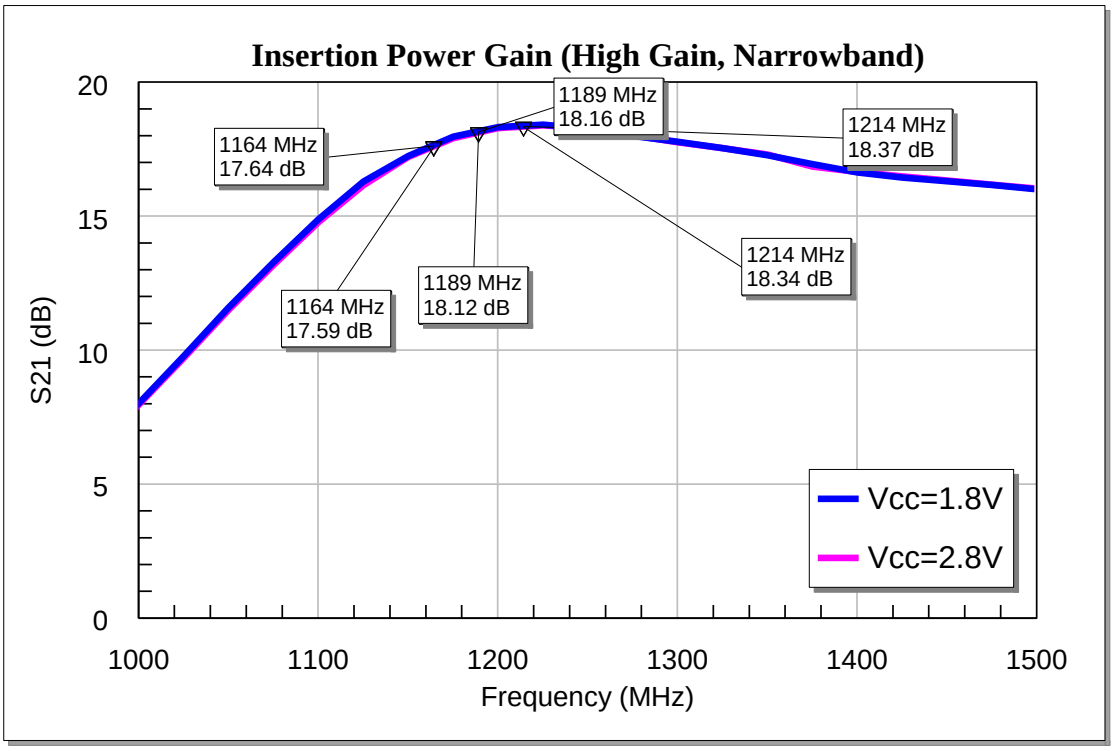


Figure 5 **Insertion Power Gain (High Gain, Narrowband) of BGA524N6 For Band L5/E5/G3 Applications**

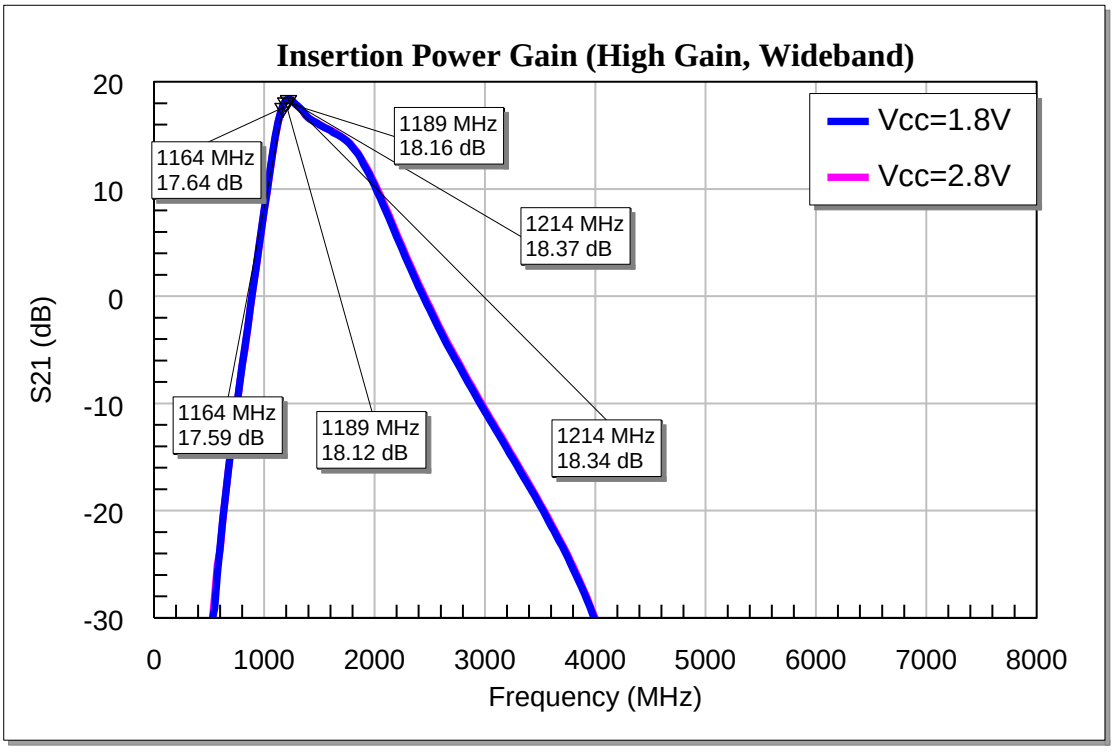


Figure 6 Insertion Power Gain (High Gain, Wideband) of BGA524N6 For Band L5/E5/G3 Applications

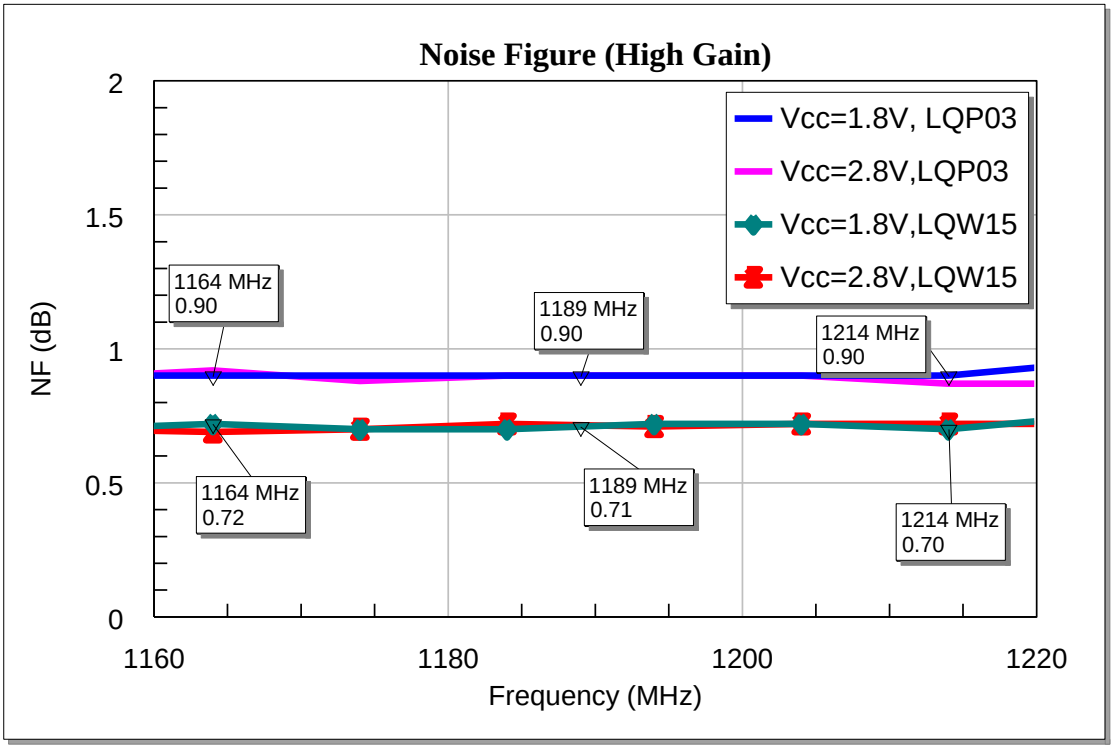


Figure 7 Noise Figure (High Gain) of BGA524N6 For Band L5/E5/G3 Applications (incl. NF performance with LQW components for matching)

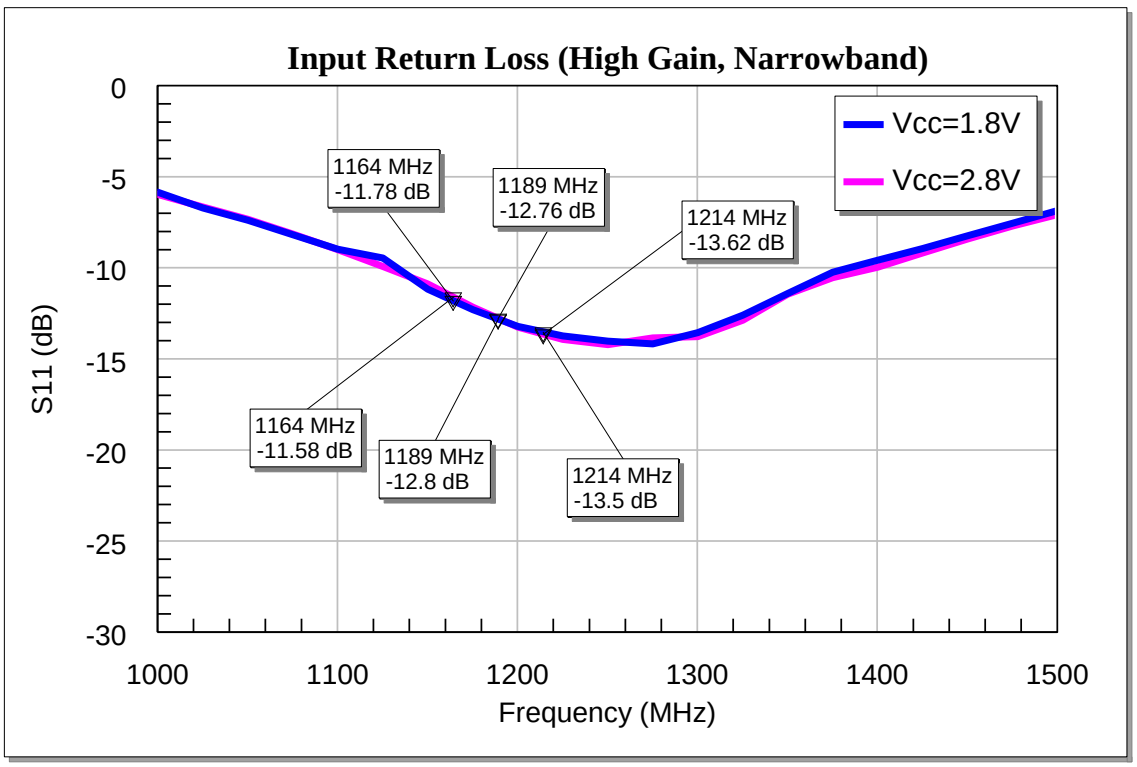


Figure 8 Input Return Loss (High Gain, Narrowband) of BGA524N6 For Band L5/E5/G3 Applications

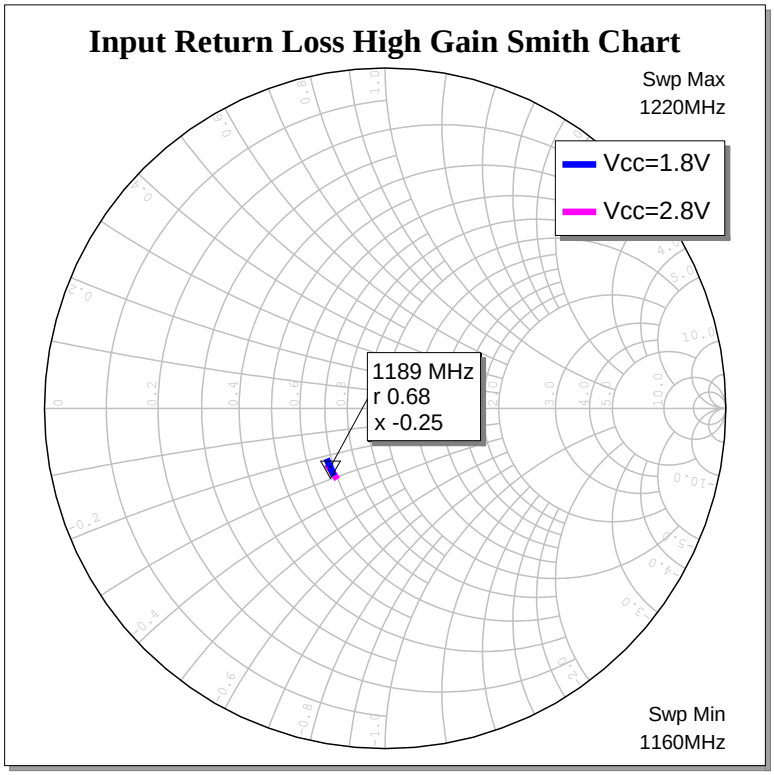


Figure 9 Input Return Loss (High Gain, Smith Chart) of BGA524N6 For Band L5/E5/G3 Applications

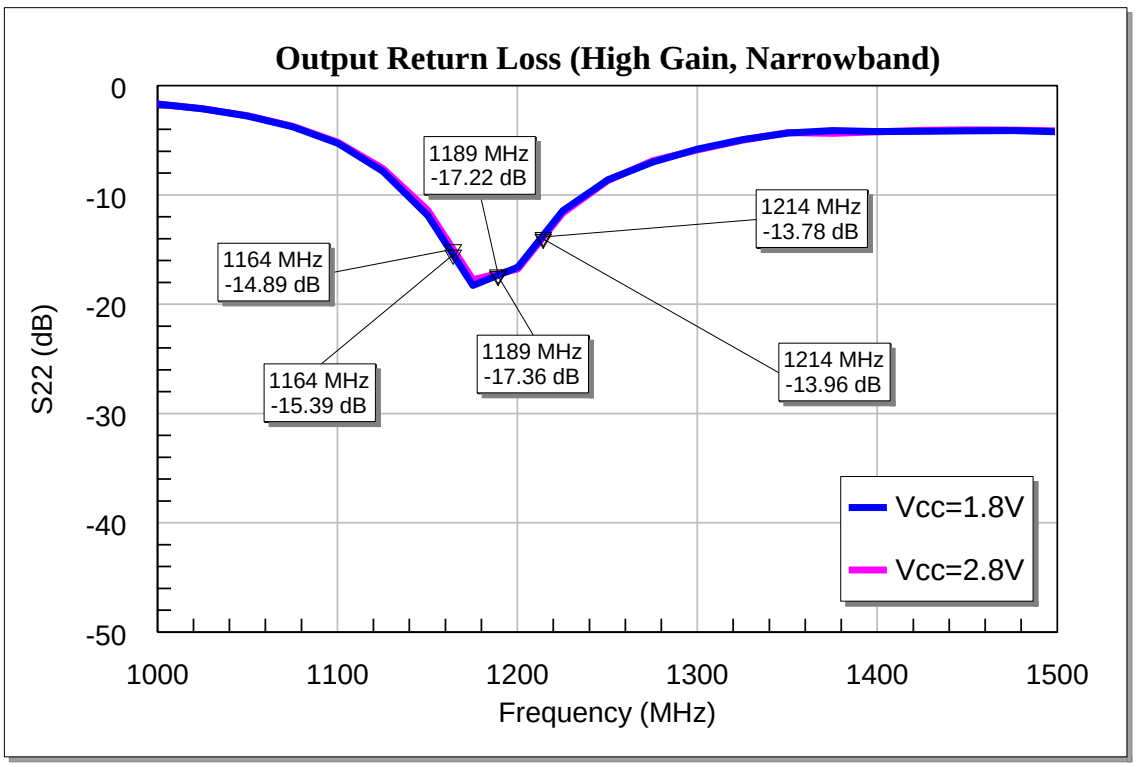


Figure 10 Output Return Loss (High Gain, Narrowband) of BGA524N6 For Band L5/E5/G3 Applications

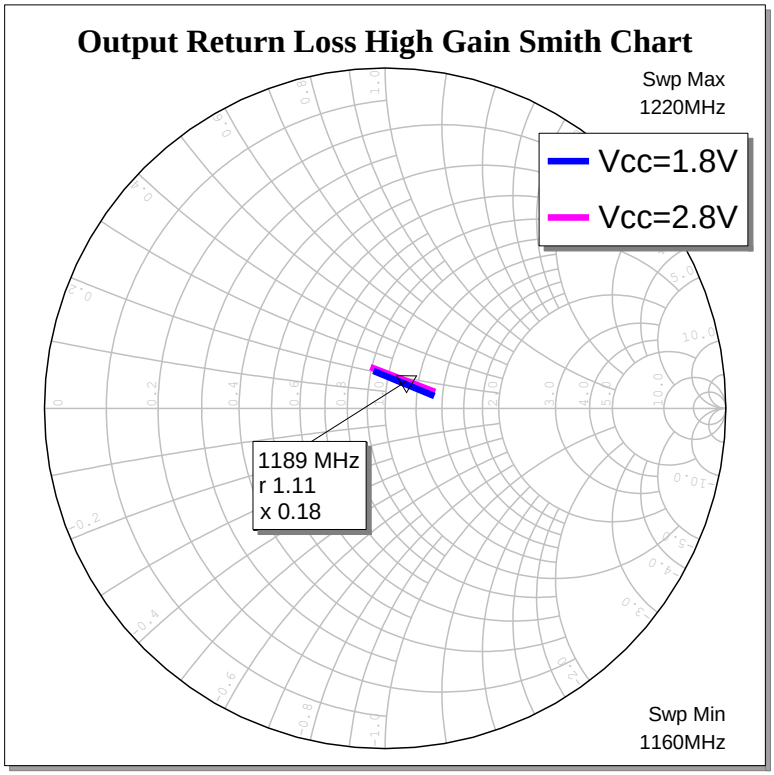


Figure 11 Output Return Loss (High Gain, Smith Chart) of BGA524N6 For Band L5/E5/G3 Applications

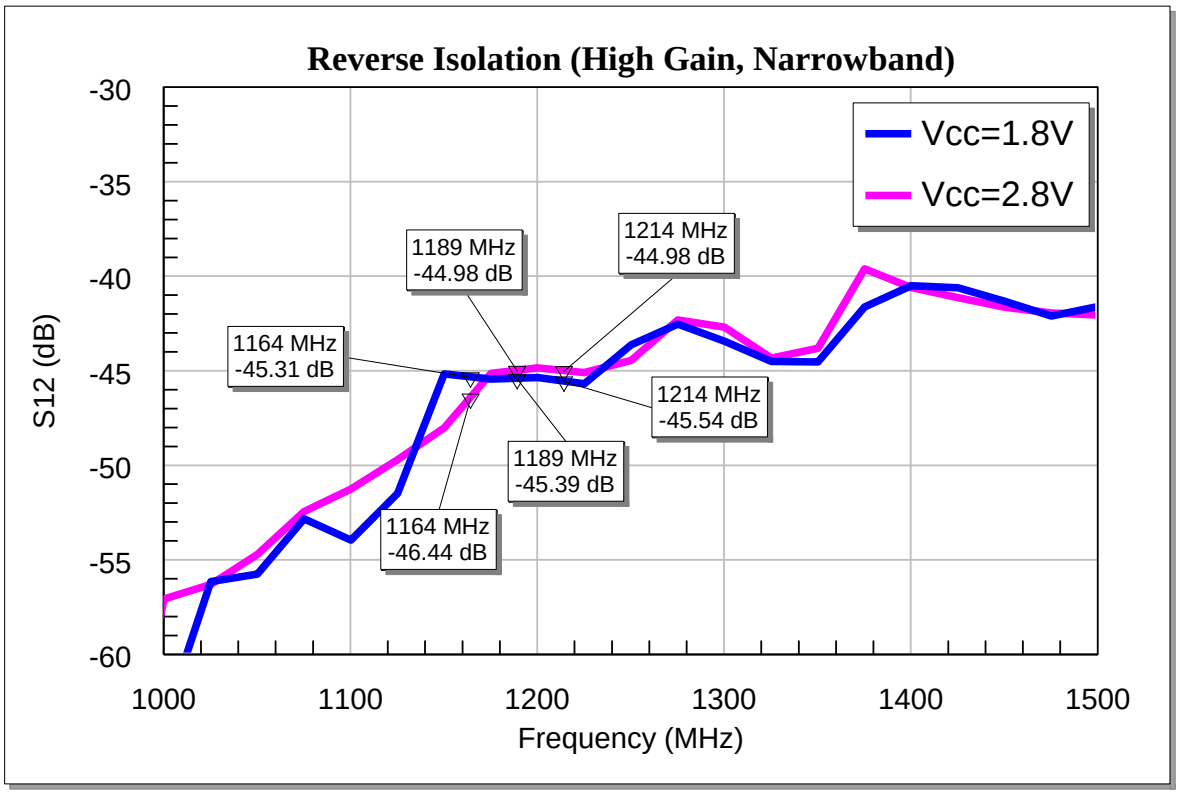


Figure 12 Reverse Isolation (High Gain, Narrowband) of BGA524N6 For Band L5/E5/G3 Applications

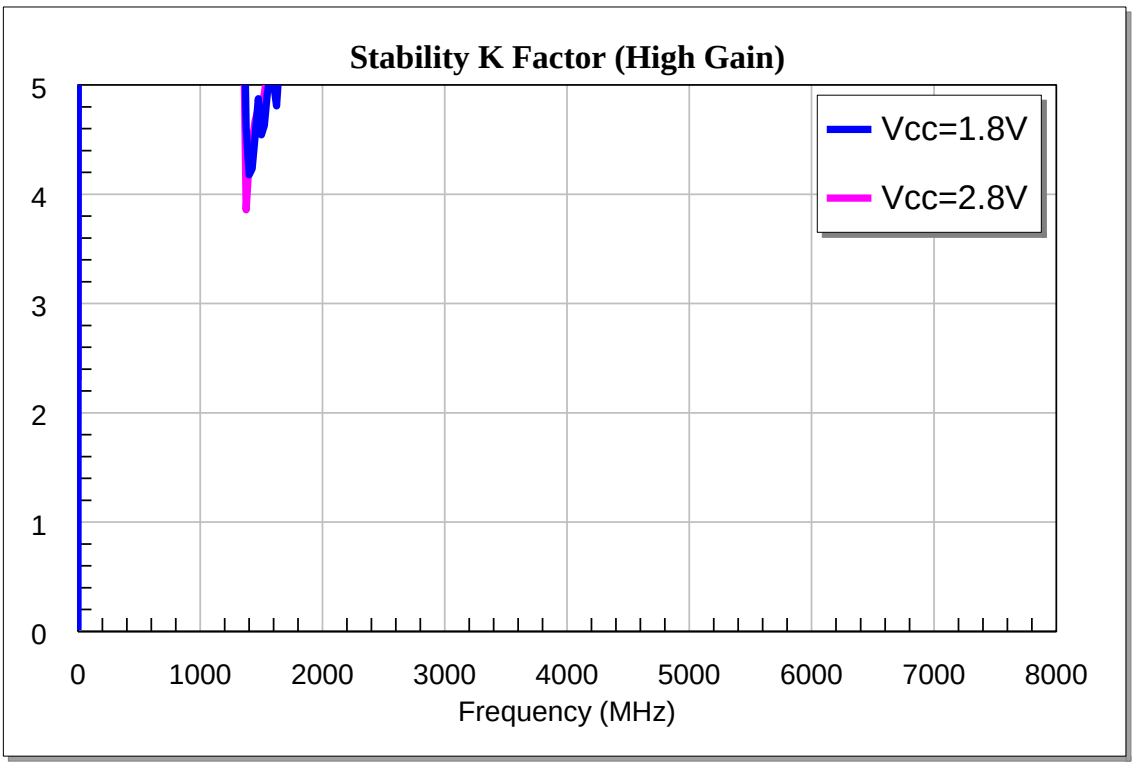


Figure 13 Stability K-factor (High Gain) of BGA524N6 For Band L5/E5/G3 Applications

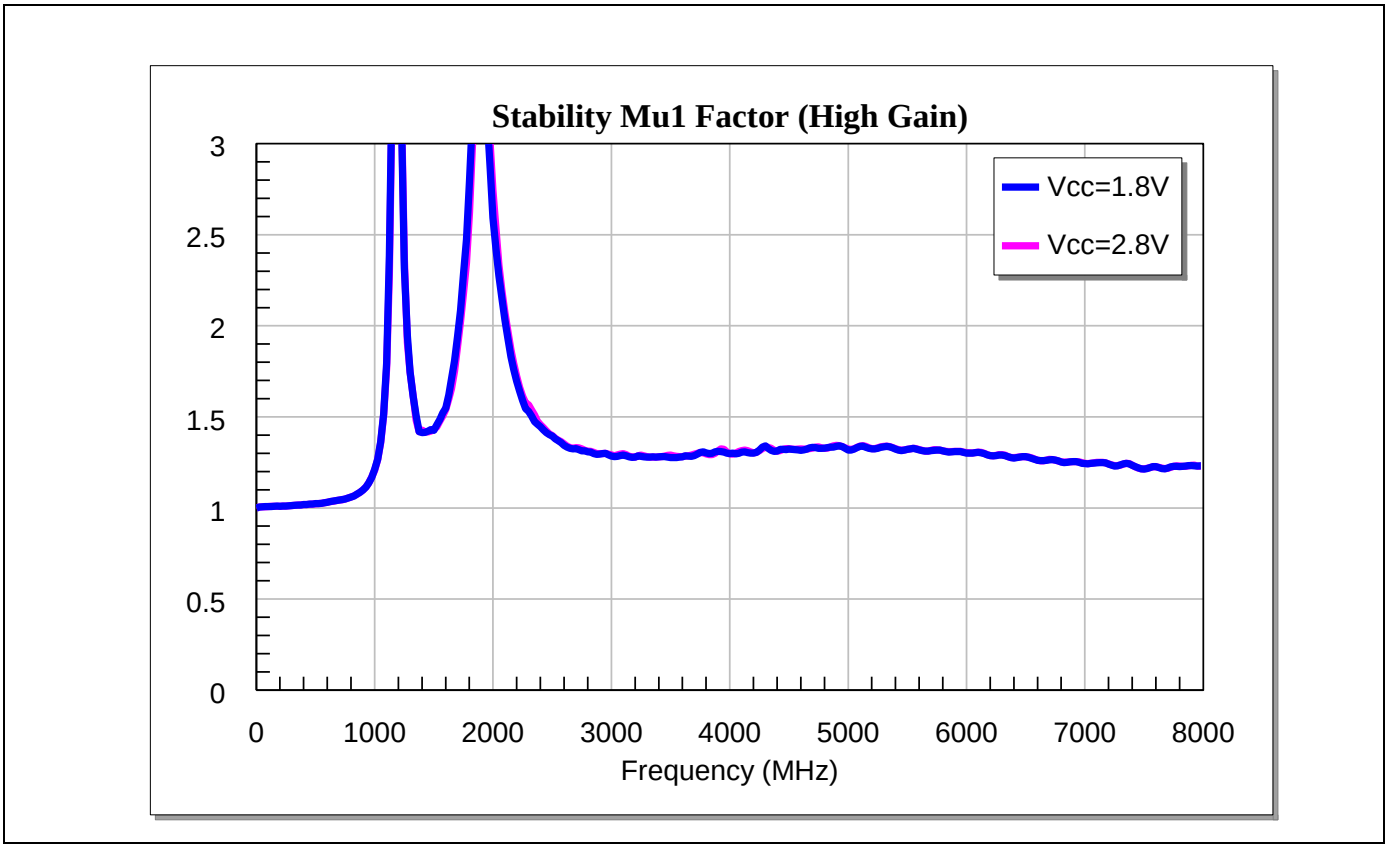


Figure 14 Stability Mu1-factor (High Gain) of BGA524N6 For Band L5/E5/G3 Applications

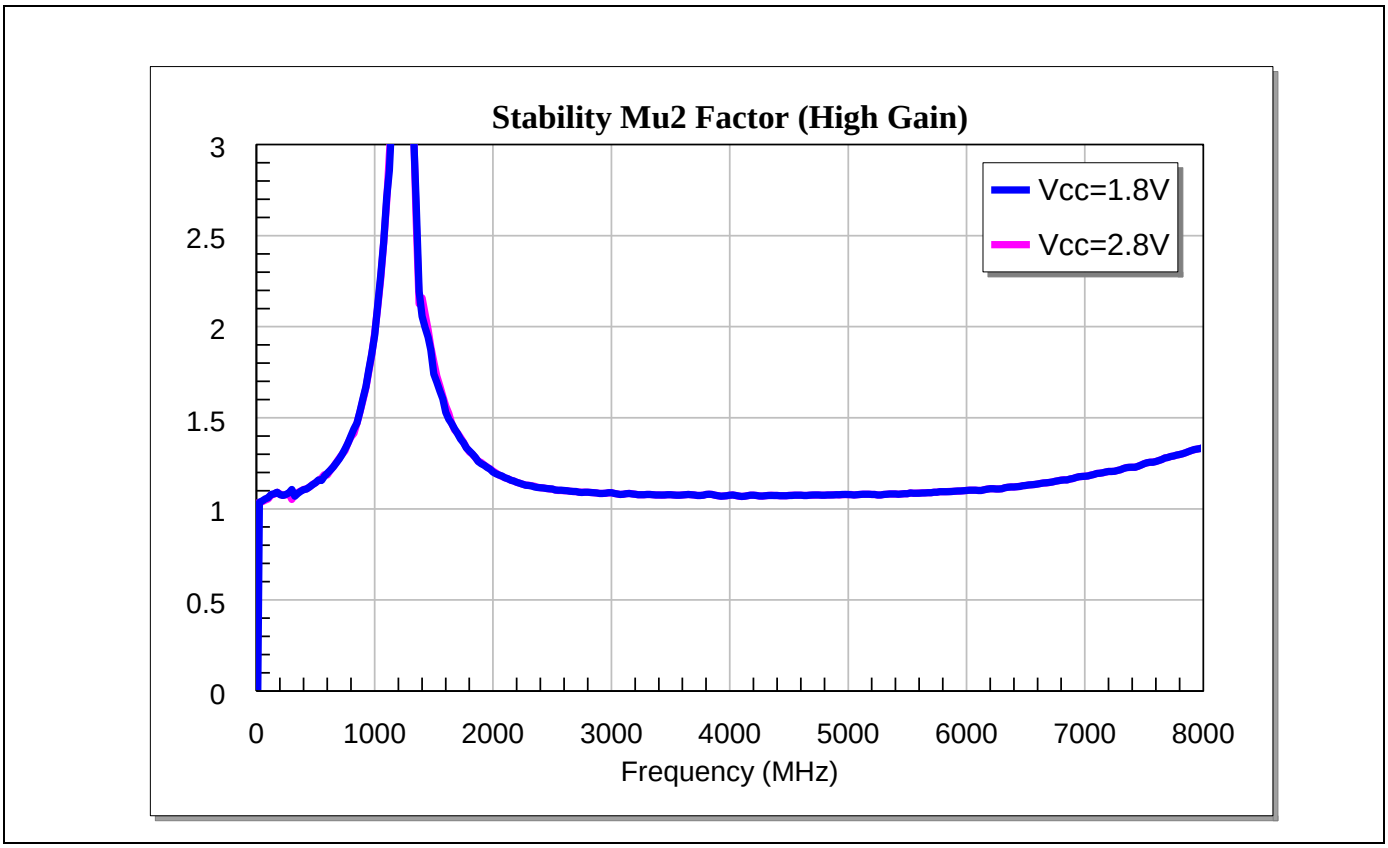


Figure 15 Stability Mu2-factor (High Gain) of BGA524N6 For Band L5/E5/G3 Applications

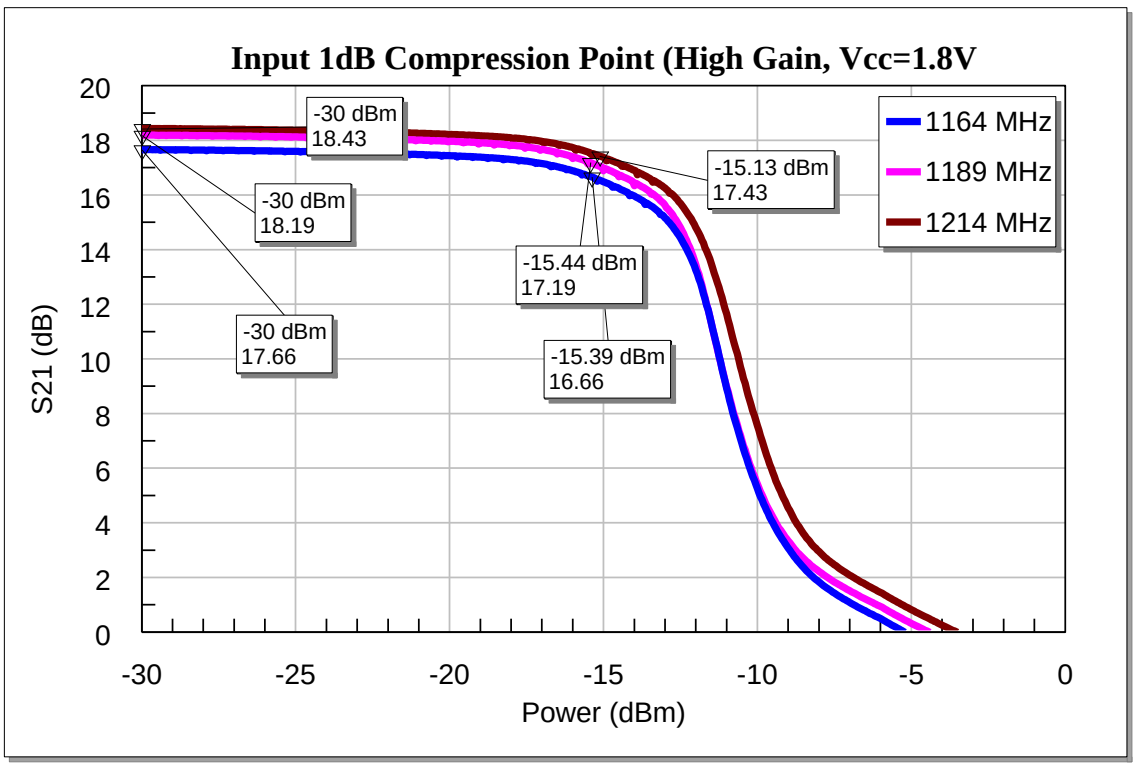


Figure 16 **Input 1dB Compression Point (1.8V) of BGA524N6 For Band L5/E5/G3 Applications**

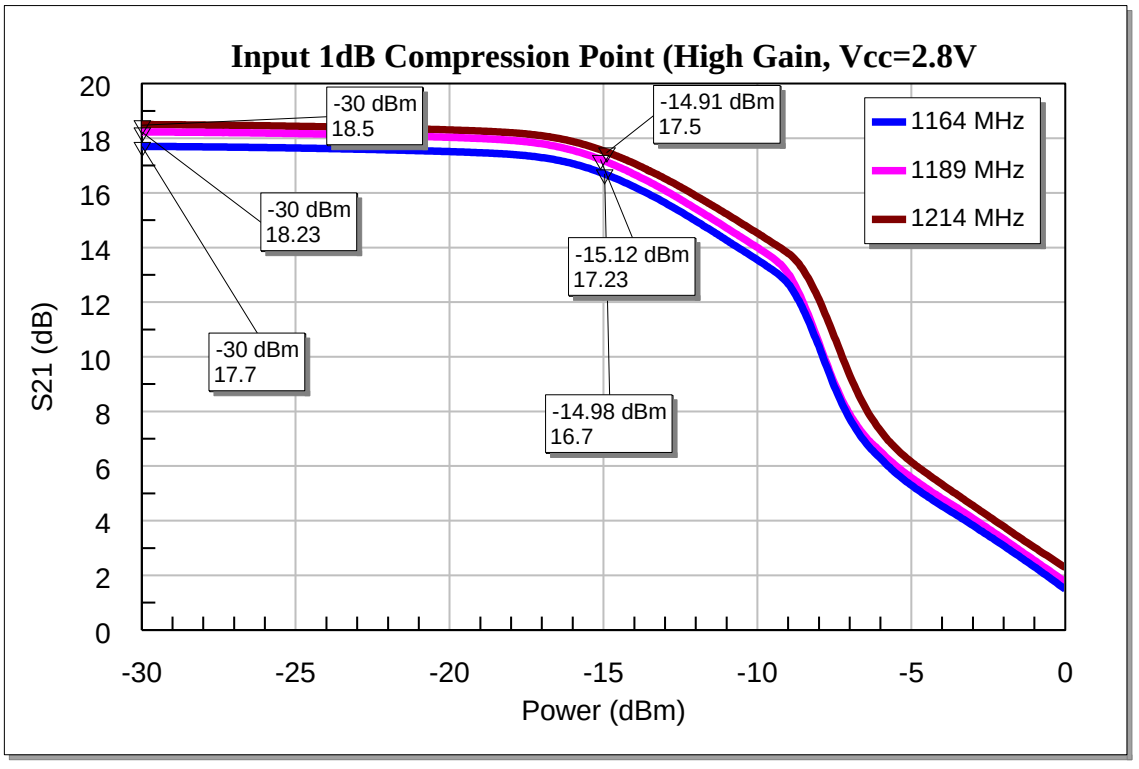


Figure 17 **Input 1dB Compression Point (2.8V) of BGA524N6 For Band L5/E5/G3 Applications**

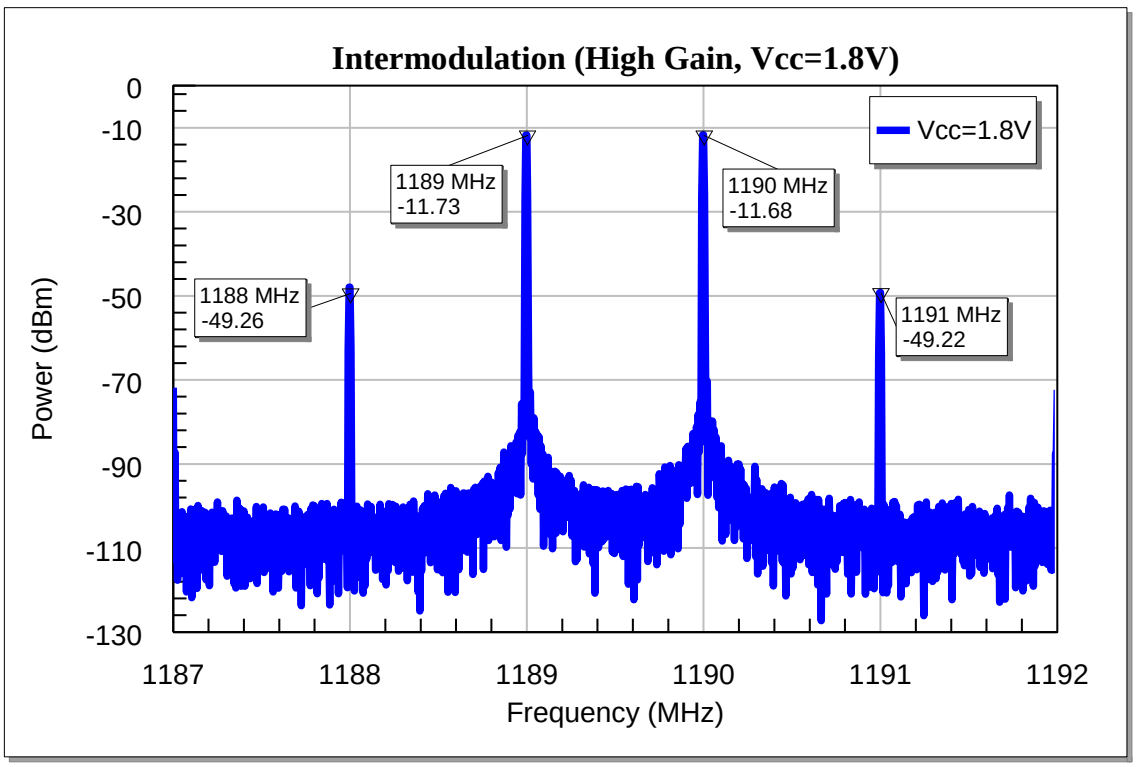


Figure 18 Third-order Interception Point (1.8V) of BGA524N6 For Band L5/E5/G3 Applications

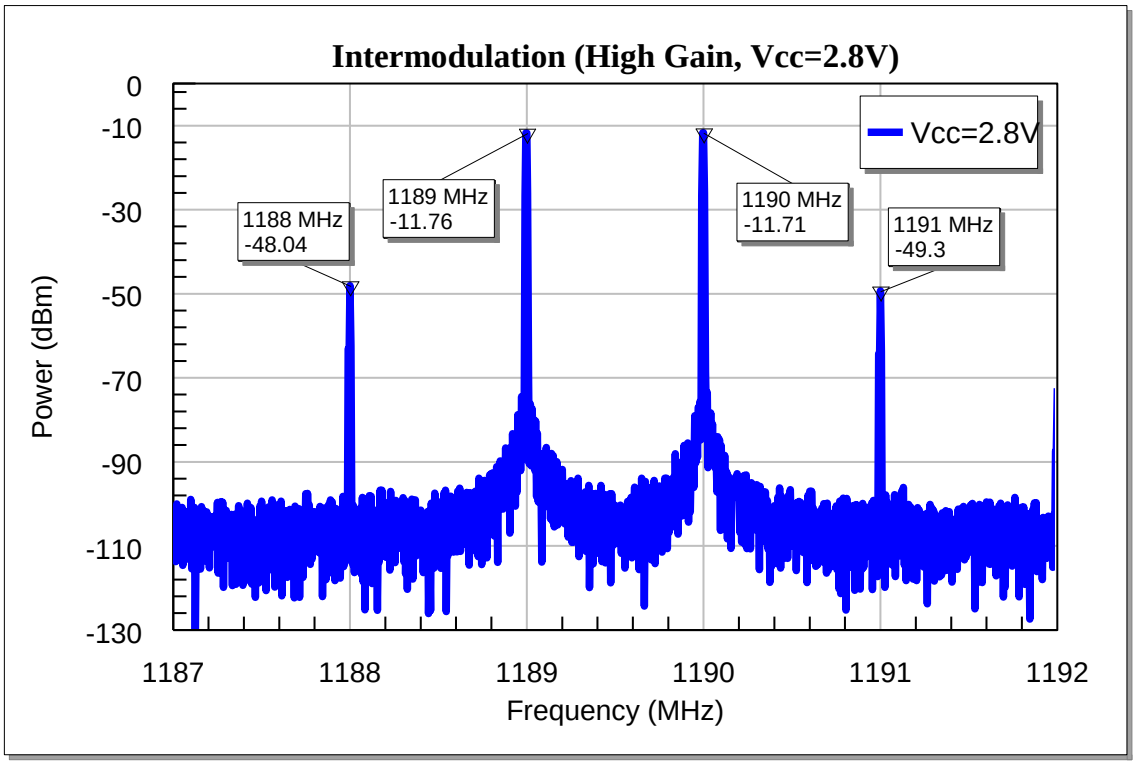


Figure 19 Third-order Interception Point (2.8V) of BGA524N6 For Band L5/E5/G3 Applications

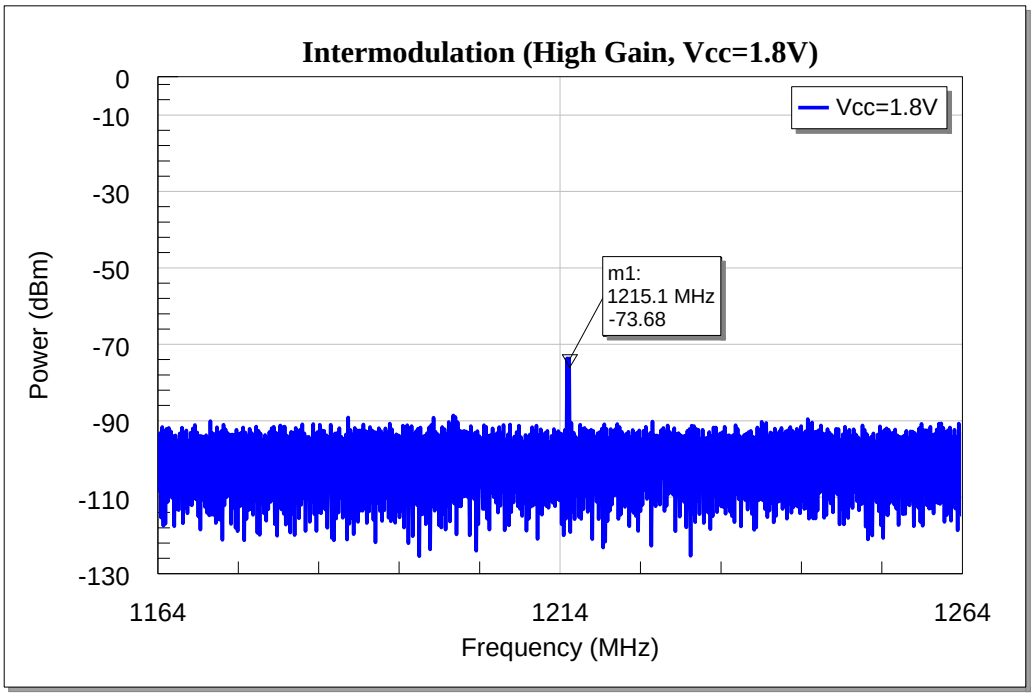


Figure 20 Out-of-band Intermodulation (1.8V) of BGA524N6 For Band L5/E5/G3 Applications

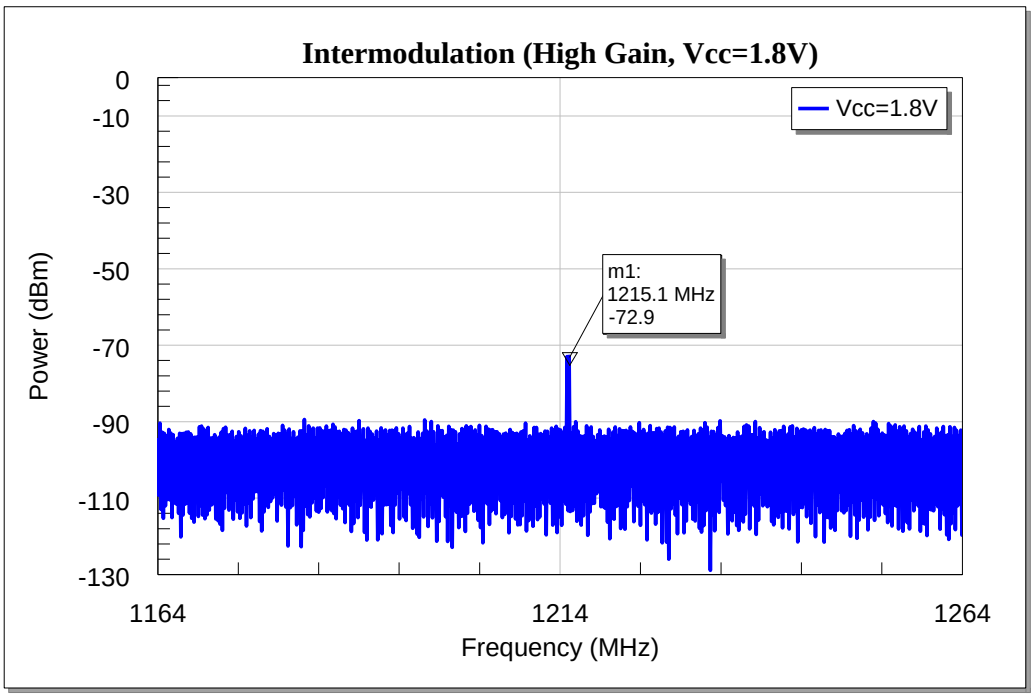


Figure 21 Out-of-band Intermodulation (2.8V) of BGA524N6 For Band L5/E5/G3 Applications

5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB Marking: **161214**

PCB material: **FR4**

ε_r of PCB material: **4.8**

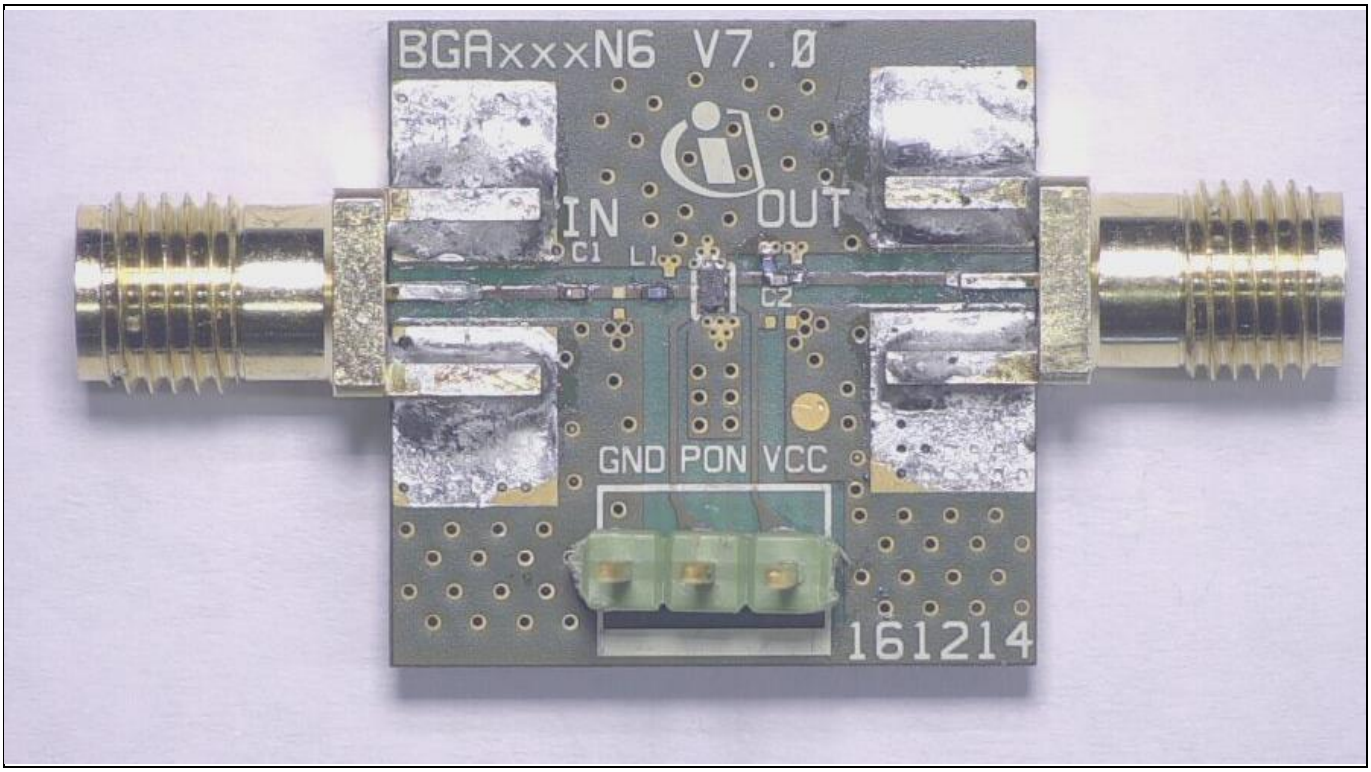


Figure 22 Photo Picture of Evaluation Board (overview)

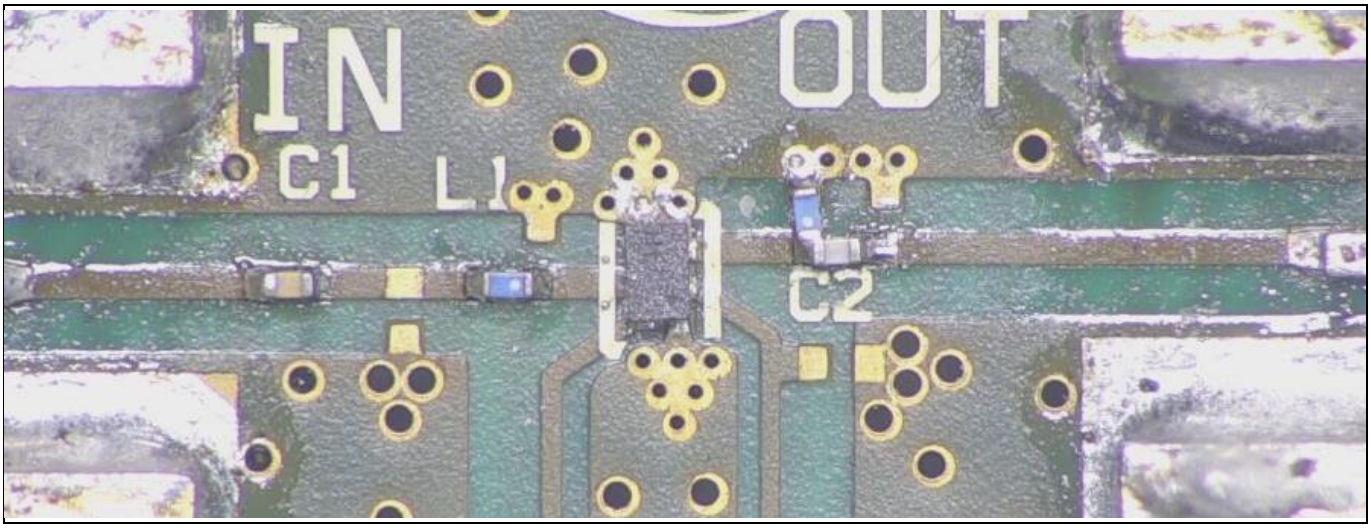


Figure 23 Photo Picture of Evaluation Board (detailed view)

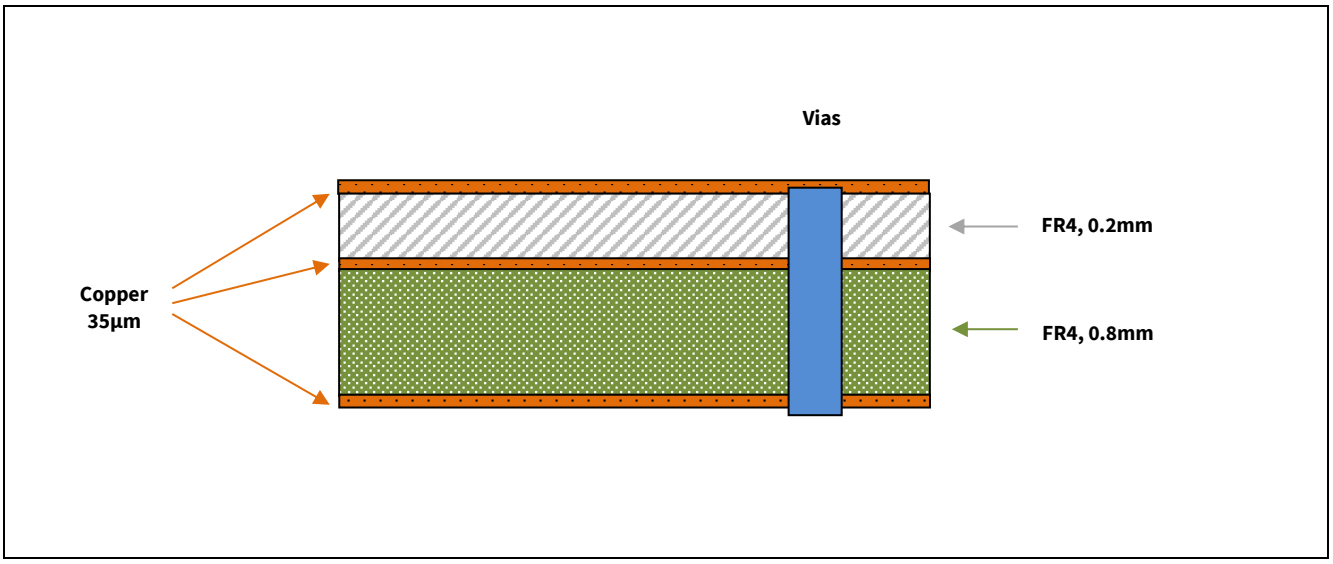


Figure 24 PCB Layer Information

6 Authors

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7 Reference

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Revision History

Major changes since the last revision Rev 1.1 2018-04-06

Page or Reference	Description of change
8,9, 20	Added the Oob_IM3 performance data
Cover page, 8,9	Updated the 1.8 V to be main supply voltage instead of 2.8 V

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