

Silicon Germanium Low Noise Amplifier

BGA7L1BN6

For LTE Band 28 Application Using 0201 Components for Matching

About this document

Scope and purpose

This application note describes Infineon's MMIC: BGA7L1BN6 as Low Noise Amplifier for LTE Band 28 (758 MHz – 803 MHz) applications with 0201 components for matching.

1. The BGA7L1BN6 is a broadband Silicon Germanium Low Noise Amplifier supporting 716 – 960 MHz. It operates both at High Gain and Bypass modes.
2. The target application is LTE Band 28 (758 MHz – 803 MHz) application.
3. In this report, the performance of BGA7L1BN6 is measured on a FR4 board. This device is matched with 0201 size external components.
4. Key performance parameters at 2.8V, 781 MHz (High Gain Mode)
Noise figure = 1.0 dB
Insertion gain = 14.5 dB
Input return loss = 11.9 dB
Output return loss = 15.0 dB
Input P1dB = -3.5 dBm
Key performance parameters at 2.8V, 781 MHz (Bypass Mode)
Insertion loss = 2.0 dB

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

1 Introduction of LTE Application

Mobile phones represent the largest worldwide market in terms of both volume and number of applications on a single platform today. More than 1.5 billion phones are shipped per year worldwide. The major wireless functions in a typical mobile phone include a 2G/3G/4G (GSM/EDGE/CDMA/UMTS/WCDMA/LTE/LTE-A/TD-SCDMA/TD-LTE) cellular modem, and wireless connectivity systems such as Wireless Local Area Network (WLAN), Global Navigation Satellite System (GNSS), broadcasting receivers, and Near-Field Communication (NFC).

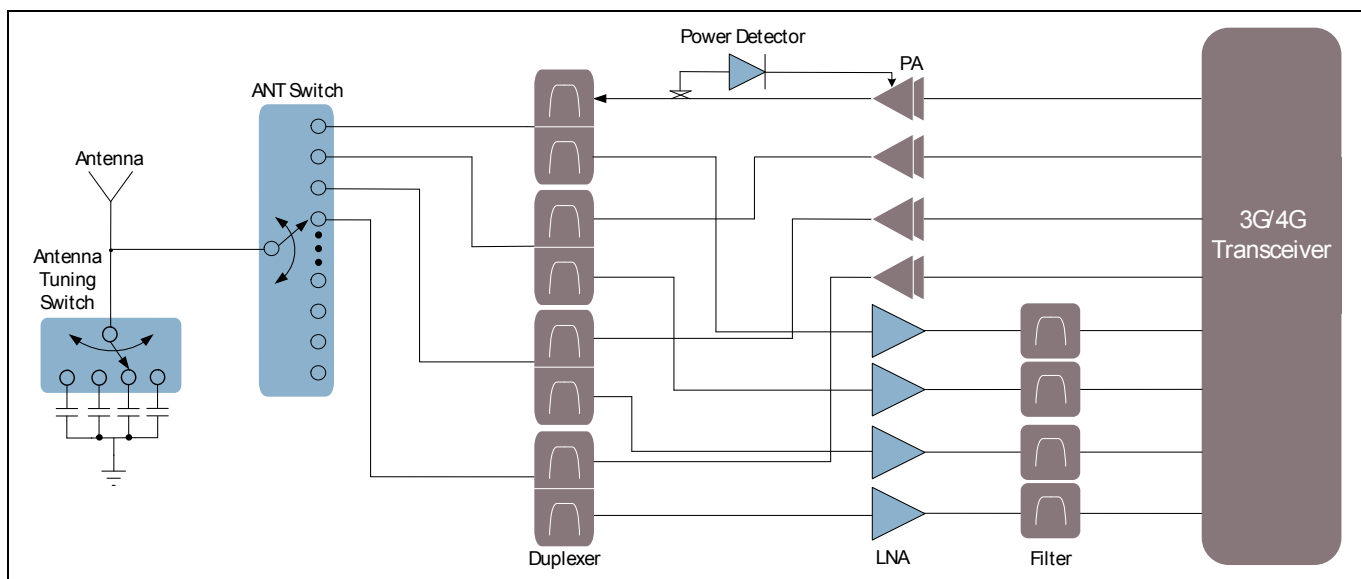


Figure 1 Block diagram of a 4G LTE RF Frontend

Moving towards 4G Long-Term Evolution-Advanced (LTE-A), the number of LTE bands has exploded in the last few years. Currently, there are more than 50 bands in use worldwide. The ability of 4G LTE-A to support single-carrier bandwidth up to 20 MHz and to have more spectral efficiency by using high-order modulation schemes such as Quadrature Amplitude Modulation (QAM-64) is of particular importance as the demand for higher wireless data speeds continues to grow rapidly. LTE-A can aggregate up to 5 carriers (up to 100 MHz) to increase user data rates and capacity for high-speed applications. These new techniques for mobile high-data-rate communication and advanced wireless connectivity include:

- Inter-operation Frequency-Division Duplexing (FDD) and Time-Division Duplexing (TDD) systems
- Down-/uplink Carrier Aggregation (CA)
- LTE-U and LAA at 5 to 6 GHz using link aggregation or carrier aggregation
- Adaptive antenna systems
- Multiple-Input Multiple-Output (MIMO) for RF Front-Ends
- Device-to-Device (D2D) communication with LTE (LTE-D)
- High-speed wireline connection with USB 3.0, Bluetooth 4.0 etc.

The above mentioned techniques drive the industry to develop new concepts for RF Front-Ends and the antenna system and digital interface protection. These require microwave semiconductor vendors to offer

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highly integrated and compact devices with lower loss rates, and more powerful linear performance. The key trends in RF components for mobile phone are:

- Microwave Monolithic Integrated Circuits (MMICs) with smaller form factors
- Higher levels of integration with control buses
- Higher RF power capability
- Ability to handle increased number of bands and operating modes
- Better immunity to interfering signals
- Frequency tuning ability
- Higher integration of various functions in single packages (modulization)

Band No.	Band Definition	Uplink Frequency Range	Downlink Frequency Range	FDD/TDD System	Comment
1	Mid-Band	1920-1980 MHz	2110-2170 MHz	FDD	
2	Mid-Band	1850-1910 MHz	1930-1990 MHz	FDD	
3	Mid-Band	1710-1785 MHz	1805-1880 MHz	FDD	
4	Mid-Band	1710-1755 MHz	2110-2155 MHz	FDD	
5	Low-Band	824-849 MHz	869-894 MHz	FDD	
6	Low-Band	830-840 MHz	875-885 MHz	FDD	
7	High-Band	2500-2570 MHz	2620-2690 MHz	FDD	
8	Low-Band	880-915 MHz	925-960 MHz	FDD	
9	Mid-Band	1749.9-1784.9 MHz	1844.9-1879.9 MHz	FDD	
10	Mid-Band	1710-1770 MHz	2110-2170 MHz	FDD	
11	Mid-Band	1427.9-1452.9 MHz	1475.9-1500.9 MHz	FDD	
12	Low-Band	698-716 MHz	728-746 MHz	FDD	
13	Low-Band	777-787 MHz	746-756 MHz	FDD	
14	Low-Band	788-798 MHz	758-768 MHz	FDD	
15		reserved	reserved	FDD	
16		reserved	Reserved	FDD	
17	Low-Band	704-716 MHz	734-746 MHz	FDD	
18	Low-Band	815-830 MHz	860-875 MHz	FDD	
19	Low-Band	830-845 MHz	875-890 MHz	FDD	
20	Low-Band	832-862 MHz	791-821 MHz	FDD	
21	Mid-Band	1447.9-1462.9 MHz	1495.9-1510.9 MHz	FDD	
22	High-Band	3410-3500 MHz	3510-3600 MHz	FDD	
23	Mid-Band	2000-2020 MHz	2180-2200 MHz	FDD	
24	Mid-Band	1626.5-1660.5 MHz	1525-1559 MHz	FDD	
25	Mid-Band	1850-1915 MHz	1930-1995 MHz	FDD	
26	Low-Band	814-849 MHz	859-894 MHz	FDD	
27	Low-Band	807-824 MHz	852-869 MHz	FDD	
28	Low-Band	703-748 MHz	758-803 MHz	FDD	
29	Low-Band	N/A	716-728 MHz	FDD	

Introduction of LTE Application

Band No.	Band Definition	Uplink Frequency Range	Downlink Frequency Range	FDD/TDD System	Comment
30	High-Band	2305-2315 MHz	2350-2360 MHz	FDD	
31	Low-Band	452.5-457.5 MHz	462.5-467.5 MHz	FDD	
32	Mid-Band	N/A	1452-1496 MHz	FDD	
33	Mid-Band	1900-1920 MHz		TDD	
34	Mid-Band	2010-2025 MHz		TDD	
35	Mid-Band	1850-1910 MHz		TDD	
36	Mid-Band	1930-1990 MHz		TDD	
37	Mid-Band	1910-1930 MHz		TDD	
38	High-Band	2570-2620 MHz		TDD	
39	Mid-Band	1880-1920 MHz		TDD	
40	High-Band	2300-2400 MHz		TDD	
41	High-Band	2496-2690 MHz		TDD	
42	High-Band	3400-3600 MHz		TDD	
43	High-Band	3600-3800 MHz		TDD	
44	Low-Band	703-803 MHz		TDD	
45	Mid-Band	1447-1467 MHz		TDD	
46	Ultra High-Band	5150-5925 MHz		TDD	
...					
64		Reserved			
65	Mid-Band	1920-2010 MHz	2110-2200 MHz	FDD	
66	Mid-Band	1710-1780 MHz	2110-2200 MHz	FDD	
67	Low-Band	N/A	738-758 MHz	FDD	
68	Low-Band	698-728 MHz	753-783 MHz	FDD	

Note: FDD - Frequency Division Duplexing; TDD - Time Division Duplexing.

1.1 Key Requirements on LNAs in LTE Applications

The LTE-Advanced supports data rates of up to 1 Gbps with advanced techniques such as Multiple Input Multiple Output and Carrier Aggregation. LTE-Advanced can support up to 5 bands of carrier aggregation by three component carrier aggregation scenarios: Intra-band contiguous, intra-band non-contiguous and inter-band non-contiguous aggregation. They present new challenges to RF FE designers, such as interference from co-existing bands and harmonic generation. Smart LTE LNAs with the following features can address these requirements to achieve outstanding performance.

Low Noise Figure (NF): An external LNA or LNA module boosts the sensitivity of the system by reducing the overall NF. In addition due to the size constraint, the modem antenna and the receiver FE cannot always be placed close to the transceiver Integrated Circuit (IC). The path loss in front of the integrated LNA on the transceiver IC increases the system NF significantly. An external LNA physically close to the antenna can help to eliminate the path loss and reduce the system NF. The sensitivity can be improved by several dB, which means a significant increase in the connectivity range.

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High Linearity (1-dB compression point $P1dB$ and 3rd-order intercept point $IP3$): An increased number of bands at the receiver input create strong interference, leading to high requirements in linearity characteristics such as high input 1-dB compression point, 2nd intermodulation (IMD2) products and input $IP3$ performance.

Low Power Consumption: Power consumption is even more important in today's smartphones. The latest LTE-Advanced uses enhanced MIMO techniques with up to 8 streams for downlink and 4 streams for uplink. Infineon's LNAs and LNA modules have low supply current and an integrated on/off feature that reduces power consumption and increases standby time for cellular handsets or other portable battery-operated wireless applications.

High Integration and Simple Control Interface: The demand for size and cost reduction and performance enhancement with ease of use and low parts count has become very important in existing and future generation smartphones. Our MMIC LNAs are highly integrated with input and output either matched or pre-matched, built-in temperature and supply voltage stabilization, and a fully ESD-protected circuit design to ensure stable operation and a simple control interface.

More information on the LTE LNAs is available at: www.infineon.com/ltelna

More information on the Mobile Phone RF Frontend and related Infineon product portfolio are available in the Application Guide Mobile Communication: www.infineon.com/appguide_rf_mobile

2 BGA7L1BN6 Overview

2.1 Features

- High insertion power gain: 13.6 dB
- Low noise figure: 0.75 dB
- Low current consumption: 4.9 mA
- Operating frequencies: 716 –960 MHz
- Two-state control: Bypass- and High gain-Mode
- Supply voltage: 1.5 V to 3.6 V
- Digital on/off switch (1 V 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
- 2 kV HBM ESD protection (including AI-pin)
- Pb-free (RoHS compliant) package

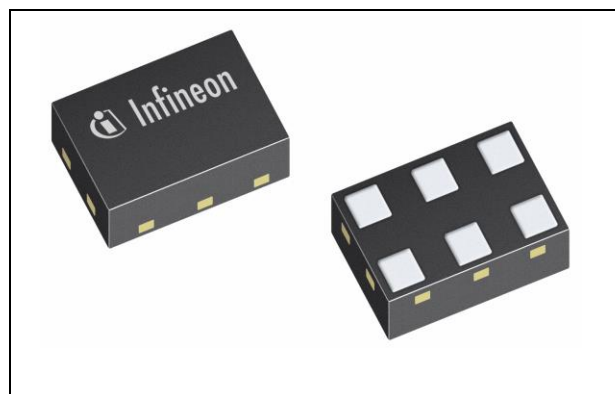


Figure 2 BGA7L1BN6 in TSNP-6-2

Product Validation

Qualified for industrial applications according to the relevant tests of JEDEC47/20/22.

2.2 Description

The BGA7L1BN6 is a front-end low noise amplifier for LTE which covers a wide frequency range from 716 MHz to 960 MHz. The LNA provides 13.4 dB gain and 0.89 dB noise figure at a current consumption of 5.1 mA in the application configuration described in Chapter 3. In bypass mode the LNA provides an insertion loss of -2.4 dB. The BGA7L1BN6 is based upon Infineon Technologies' B7HF Silicon Germanium technology. It operates from 1.5 V to 3.3 V supply voltage. The device features a single-line two-state control (Bypass- and High gain-Mode) and can be controlled via several Infineon devices, e.g. BGAC600. OFF-state can be enabled by powering down Vcc. Please contact Infineon Technologies to get the latest list of available devices which can control this LNA.

Product Name	Marking	Package
BGA7L1BN6	K	TSNP-6-2

BGA7L1BN6 Overview

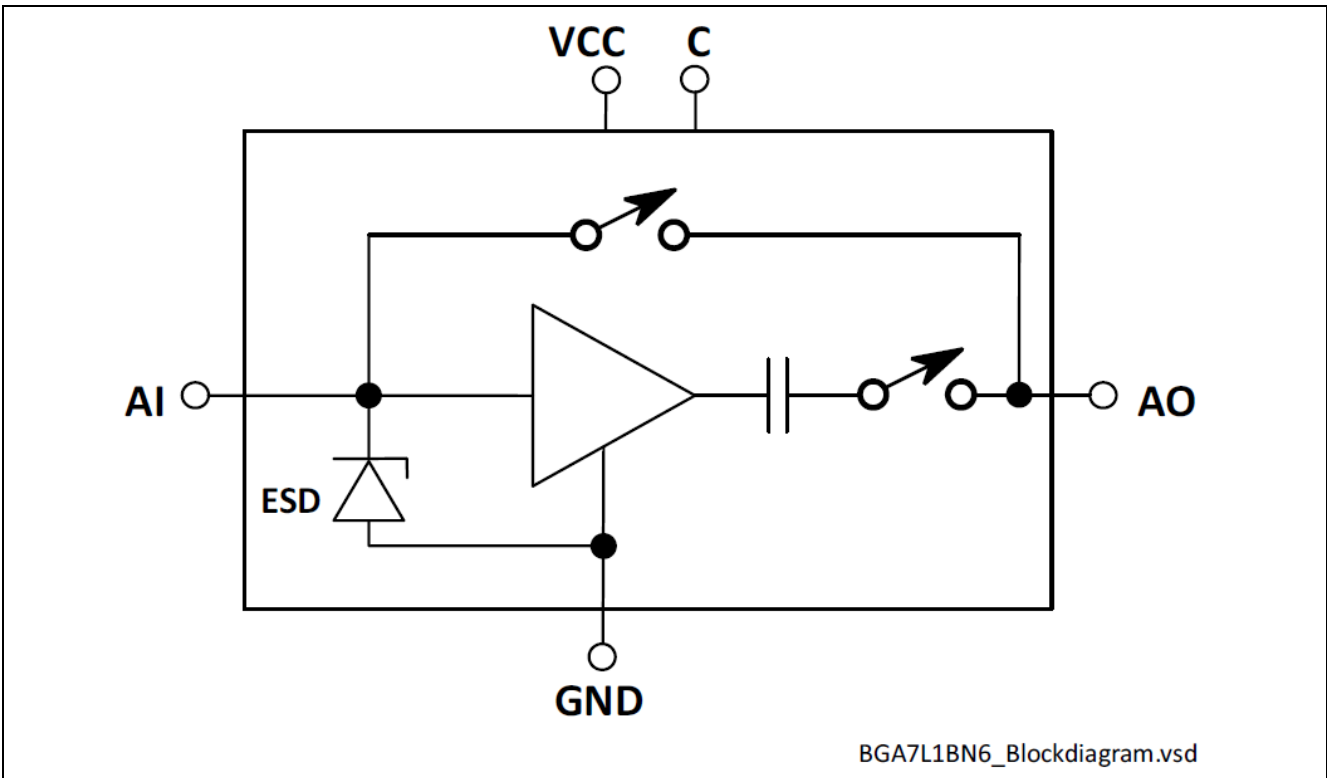


Figure 3 Equivalent Circuit of BGA7L1BN6

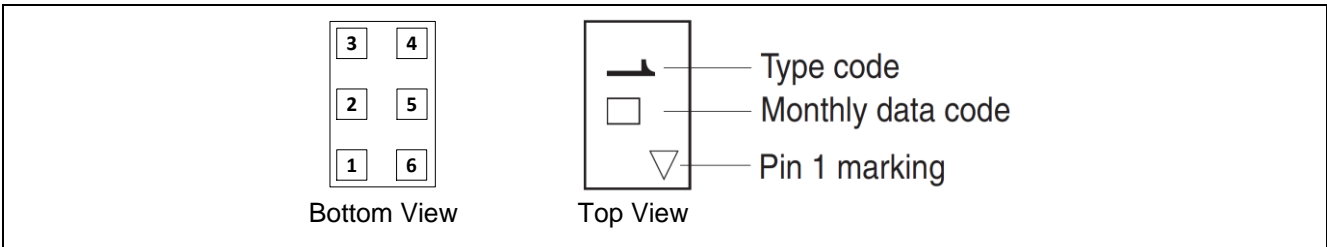


Figure 4 Package and pin connections of BGA7L1BN6

Table 1 Pin Assignment of BGA7L1BN6

Pin No.	Symbol	Function
1	GND	Ground
2	VCC	DC Supply
3	AO	LNA output
4	GND	Ground
5	AI	LNA input
6	C	Control

3 Application Circuit and Performance Overview

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

Device:	BGA7L1BN6
Application:	LNA for LTE Band 28 (758 MHz – 803 MHz) Application Using 0201 Components
PCB Marking:	BGA7x1BN6 V2.0
EVB Order No.:	AN491

3.1 Summary of Measurement Results for Band

The performance of BGA7L1BN6 for LTE Band 28 (758 MHz – 803 MHz) Application is summarized in the following table.

Table 2 Electrical Characteristics of the BGA7L1BN6 (at room temperature) for LTE Band 28 in High Gain Mode

Parameter	Symbol	Value						Unit	Comment/Test Condition
DC Voltage	Vcc	1.8			2.8			V	
DC Current	Icc	4.5			5.1			mA	
Frequency Range	Freq	758	781	803	758	781	803	MHz	
Gain	G	14.3	14.1	13.9	14.7	14.5	14.3	dB	
Noise Figure	NF	1.00	1.00	0.95	1.00	1.00	0.95	dB	Loss of input line 0.05 dB deembedded
Input Return Loss	RLin	10.4	11.0	11.5	11.2	11.9	12.5	dB	
Output Return Loss	RLout	15.1	14.4	13.7	15.7	15.0	14.3	dB	
Reverse Isolation	IRev	21.5	21.2	21.0	22.0	21.7	21.4	dB	
Input P1dB	IP1dB	-5.5	-6.1	-3.7	-2.9	-3.3	-2.8	dBm	
Output P1dB	OP1dB	7.8	7.0	9.2	10.8	10.2	10.5	dBm	
Input IP3	IIP3	3.9			4.1			dBm	f ₁ = 781 MHz f ₂ = 782 MHz P _{in} = -30 dBm
Output IP3	OIP3	18.0			18.6			dBm	
Stability	k	>1						--	Unconditionally stable from 0 to 10 GHz

Table 3 **Electrical Characteristics of the BGA7L1BN6 (at room temperature) for LTE Band 28 in Bypass Mode**

Parameter	Symbol	Value						Unit	Comment/Test Condition
DC Voltage	Vcc	1.8			2.8			V	
DC Current	Icc	60			87			uA	
Frequency Range	Freq	758	781	803	758	781	803	MHz	
Gain	G	-2.0	-2.1	-2.2	-1.9	-2.0	-2.0	dB	
Noise Figure	NF	2.1	2.4	2.4	2.1	2.4	2.4	dB	Loss of input line 0.05 dB deembedded
Input Return Loss	RLin	12.3	11.7	11.1	11.9	11.3	10.7	dB	
Output Return Loss	RLout	9.1	8.8	8.5	9.3	9.0	8.6	dB	
Reverse Isolation	IRev	2.0	2.1	2.2	1.9	2.0	2.1	dB	
Input P1dB	IP1dB	6.5	6.3	6.3	7.0	6.7	7.0	dBm	
Output P1dB	OP1dB	3.5	3.2	3.1	4.1	3.7	4.0	dBm	
Input IP3	IIP3	13.2			14.0			dBm	f ₁ = 781 MHz f ₂ = 782MHz P _{in} = - 10 dBm
Output IP3	OIP3	11.1			12.0			dBm	
Stability	k	>1						--	Unconditionally stable from 0 to 10 GHz

3.2 BGA7L1BN6 as 758 MHz – 803 MHz Low Noise Amplifier for LTE Band 28 Application

The BGA7L1BN6 is a Silicon Germanium Low Noise Amplifier for LTE RF frontend in the range from 716 MHz – 960 MHz. In this application note, the performance of BGA7L1BN6 for LTE Band 28 is investigated at 1.8 V and 2.8 V supply voltages. The circuit uses 0201 size components for matching.

At 1.8 V, high gain mode, the BGA7L1BN6 achieves a noise figure of about 1.0 dB and a gain of 14.1 dB. The input return loss is 11.0 dB and output return loss is 14.4 dB at 781 MHz. It obtains an input 1dB Compression Point (IP1dB) of -6.2 dBm at 781 MHz. The input third order intercept point is 3.9 dBm.

At 1.8 V, bypass mode, the BGA7L1BN6 achieves an insertion loss of 2.1 dB. The input return loss is 11.7 dB and output return loss is 8.8 dB at 781 MHz. It obtains an input 1dB Compression Point (IP1dB) of 7.7 dBm at 740 MHz. The input third order intercept point is 13.2 dBm.

At 2.8V, high gain mode, the BGA7L1BN6 achieves a noise figure of 1.0 dB and a gain of 14.5 dB. The input return loss is 11.9 dB and output return loss is 15.0 dB at 781 MHz. It obtains an input 1dB Compression Point (IP1dB) of -3.5 dBm at 781 MHz. The input third order intercept point is 4.1 dBm.

At 2.8 V, bypass mode, the BGA7L1BN6 achieves an insertion loss of 2.0 dB. The input return loss is 11.3 dB and output return loss is 9.0 dB at 781 MHz. It obtains an input 1dB Compression Point (IP1dB) of 6.9 dBm at 781 MHz. The input third order intercept point is 14.0 dBm.

The circuit is unconditionally stable up to 10 GHz.

3.3 Schematics and Bill-of-Materials

The schematic of BGA7L1BN6 for LTE Band 28 Application is presented in **Figure 5** and its bill-of-materials is shown in **Table 4**.

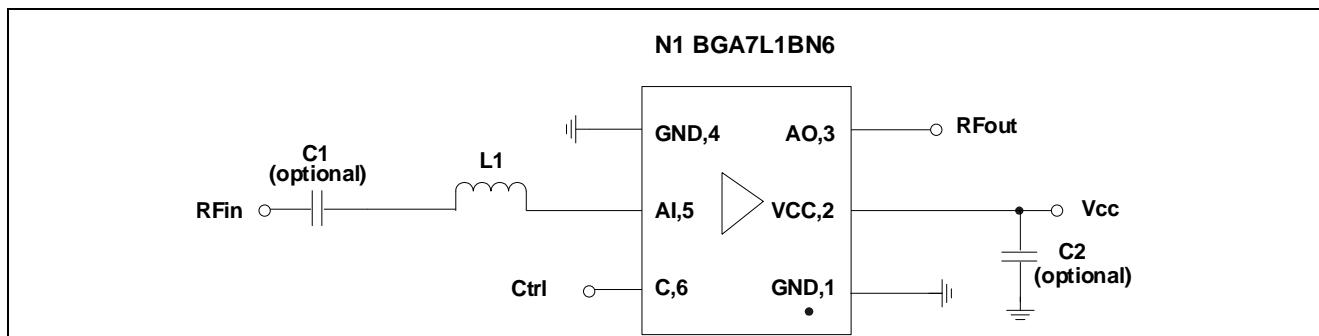


Figure 5 Schematics of the BGA7L1BN6 Application Circuit

Table 4 Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	1	nF	0201	Various	DC block
C2	≥ 1	nF	0201	Various	RF bypass
L1	10	nH	0201	Murata (LQP03T series)	Input matching
Q1	BGA7L1BN6		TSNP-6-2	Infineon Technologies	SiGe LNA

Note: DC block function is NOT integrated at input of BGA7L1BN6. 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.

Measurement Graphs

4 Measurement Graphs

The performance of the application circuit is presented with the following graphs.

4.1 High Gain

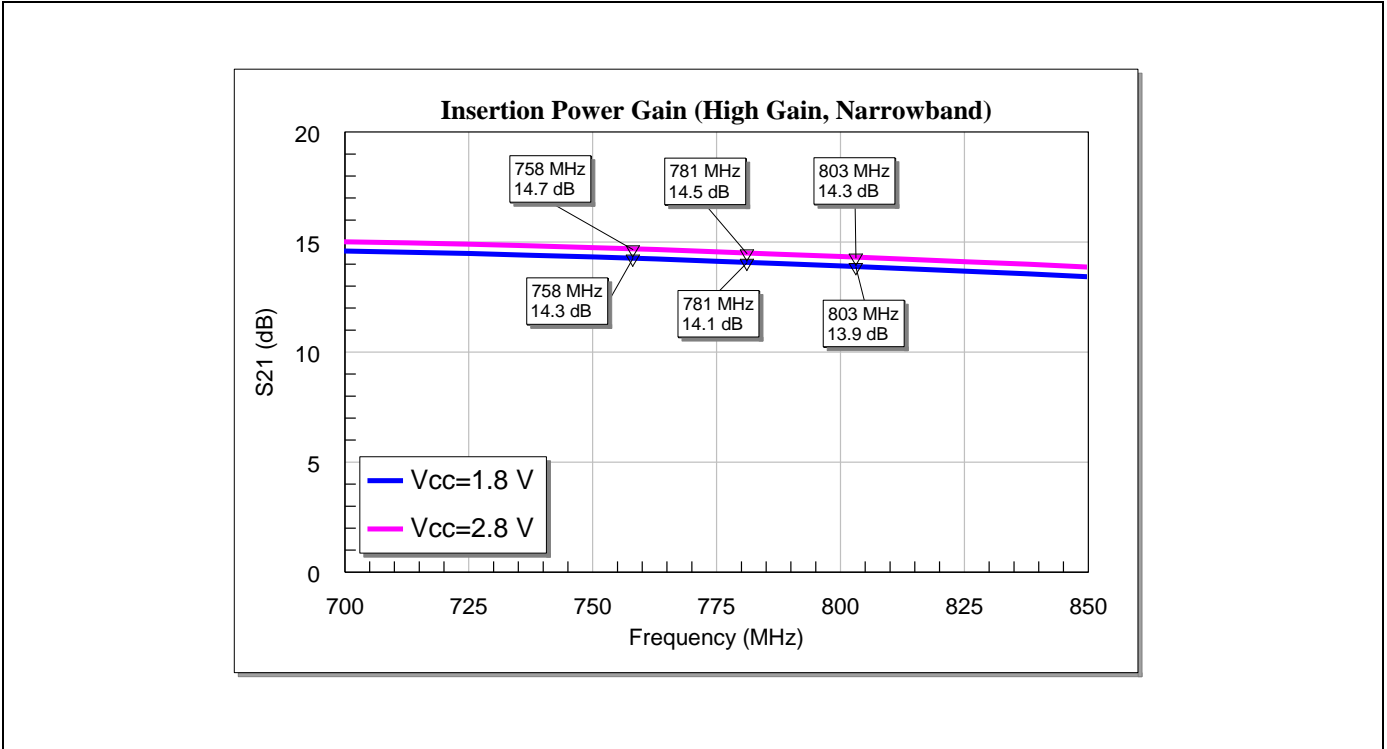


Figure 6 Insertion Power Gain (High Gain, Narrowband) of BGA7L1BN6 for Band 28 Applications

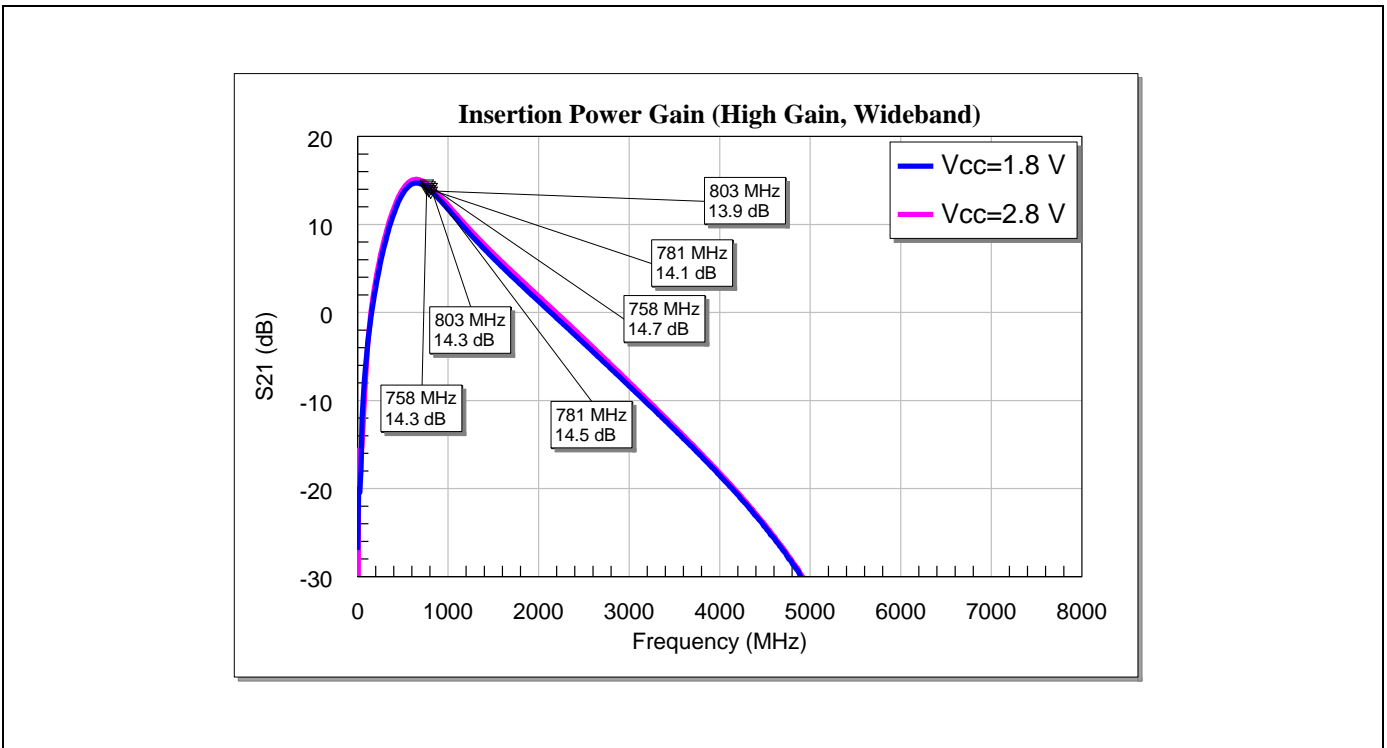


Figure 7 Insertion Power Gain (High Gain, Wideband) of BGA7L1BN6 for Band 28 Applications

Measurement Graphs

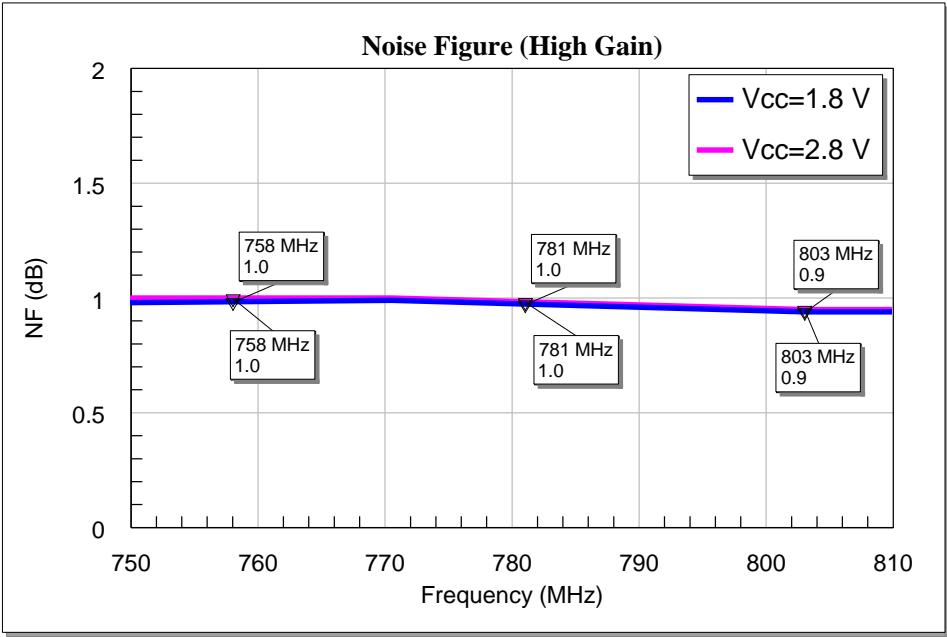


Figure 8 Noise Figure (High Gain) of BGA7L1BN6 for Band 28 Applications

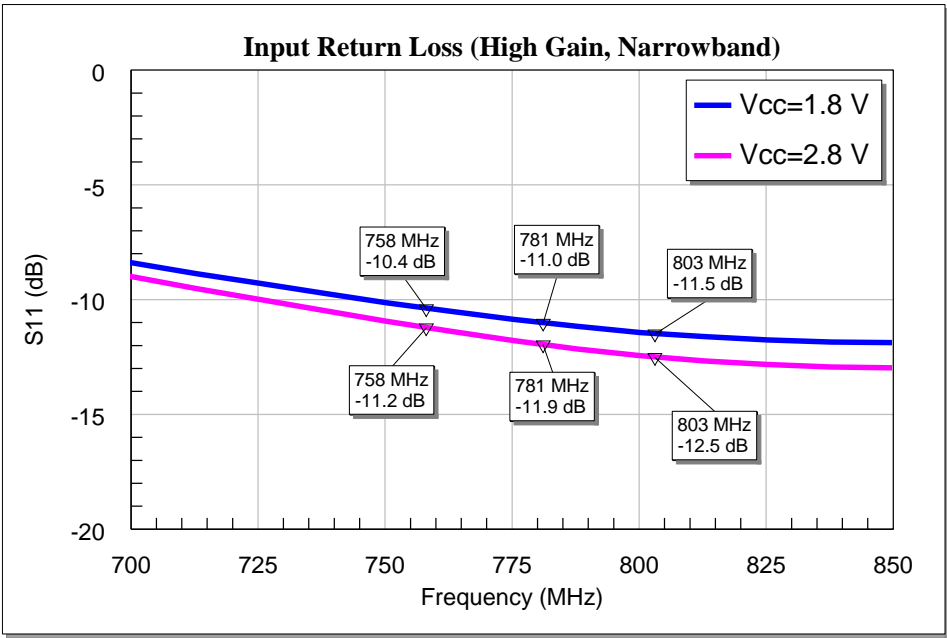


Figure 9 Input Return Loss (High Gain, Narrowband) of BGA7L1BN6 for Band 28 Applications

Measurement Graphs

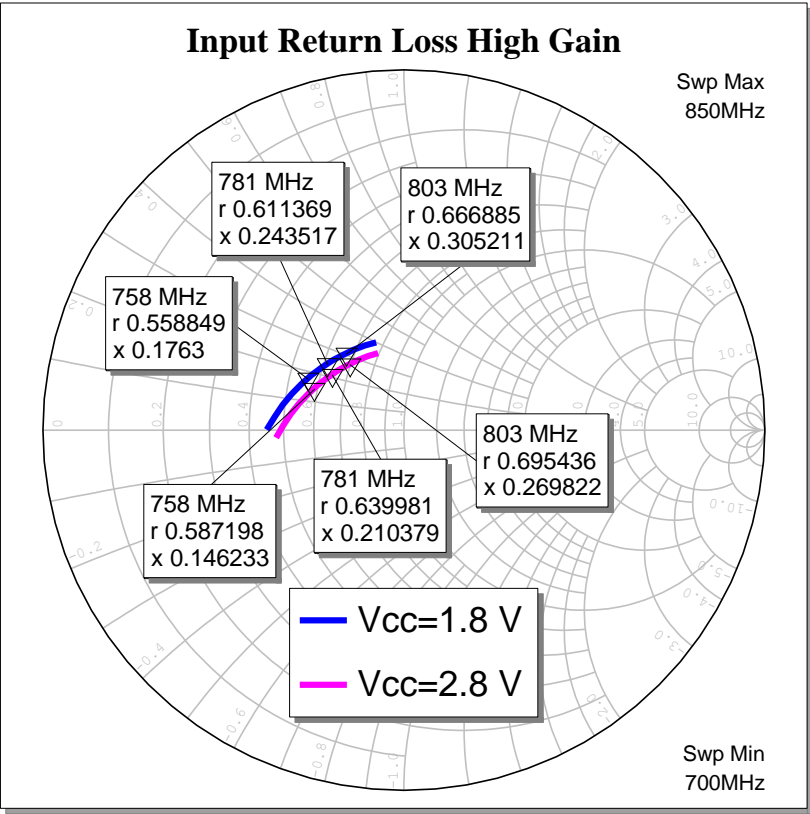


Figure 10 Input Return Loss (High Gain, Smith Chart) of BGA7L1BN6 for Band 28 Applications

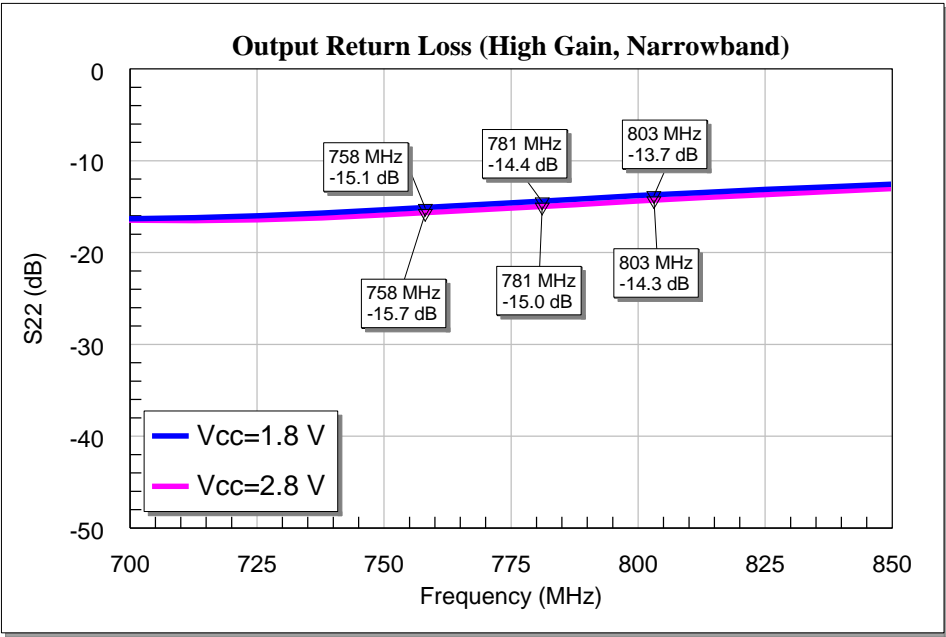


Figure 11 Output Return Loss (High Gain, Narrowband) of BGA7L1BN6 for Band 28 Applications

Measurement Graphs

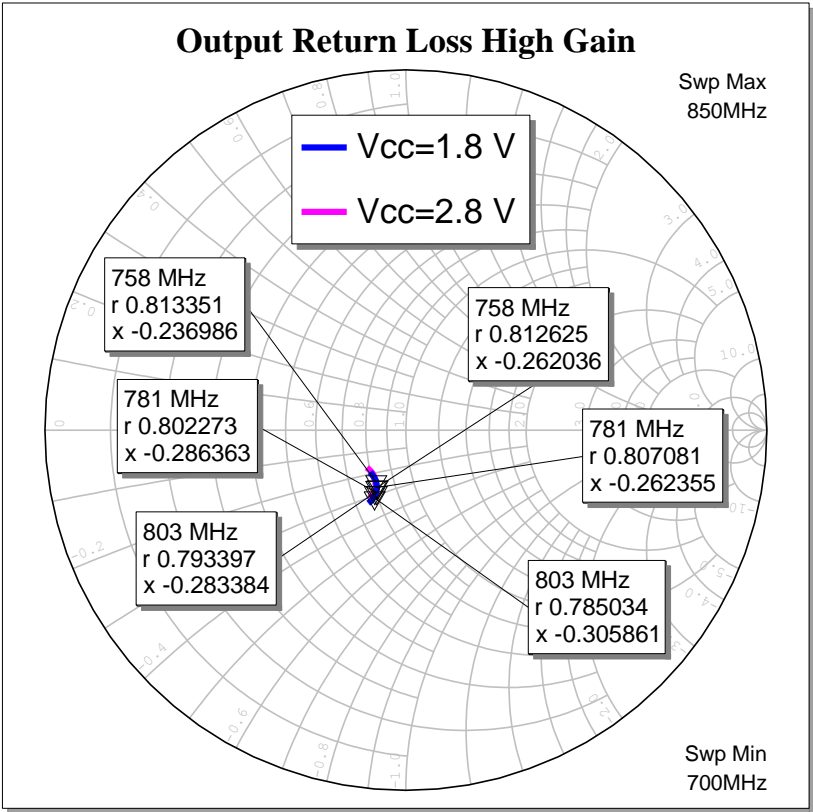


Figure 12 Output Return Loss (High Gain, Smith Chart) of BGA7L1BN6 for Band 28 Applications

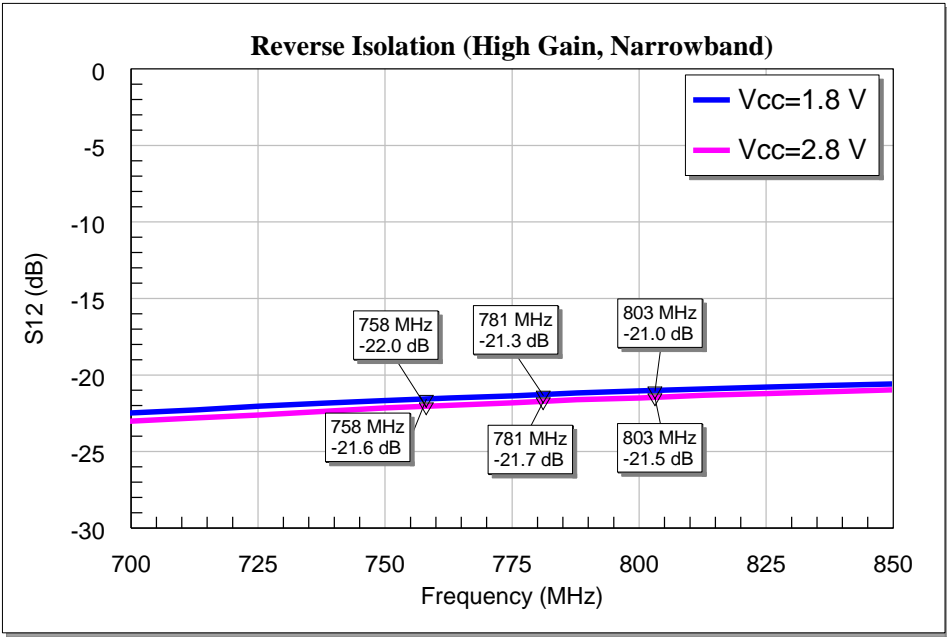


Figure 13 Reverse Isolation (High Gain, Narrowband) of BGA7L1BN6 for Band 28 Applications

Measurement Graphs

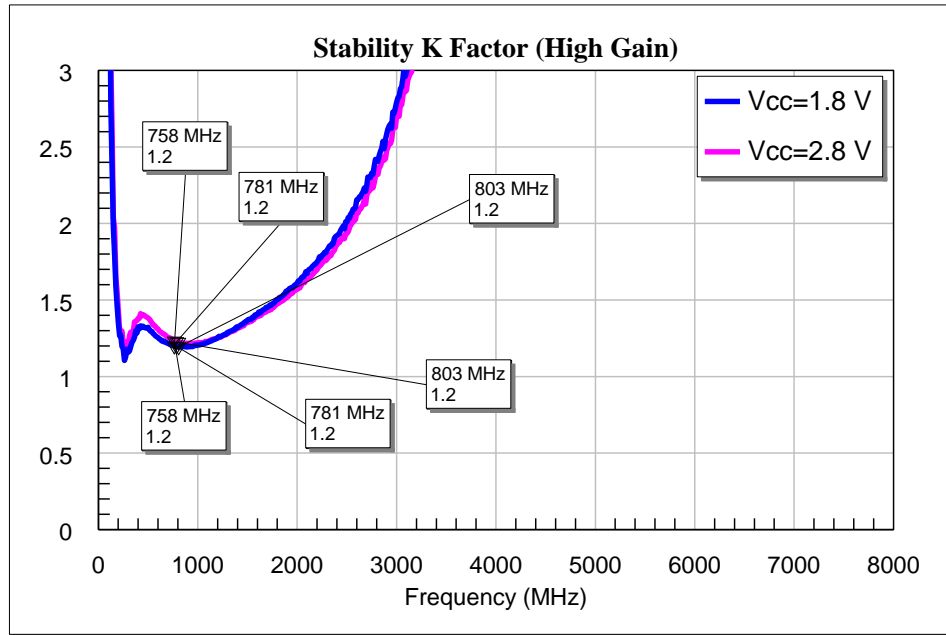


Figure 14 Stability K-factor (High Gain) of BGA7L1BN6 for Band 28 Applications

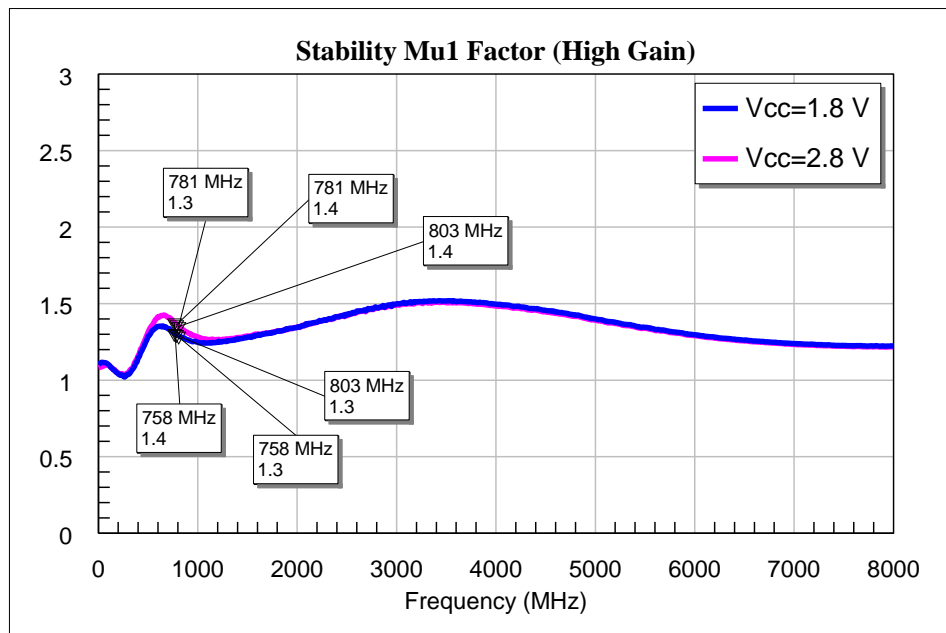


Figure 15 Stability Mu1-factor (High Gain) of BGA7L1BN6 for Band 28 Applications

Measurement Graphs

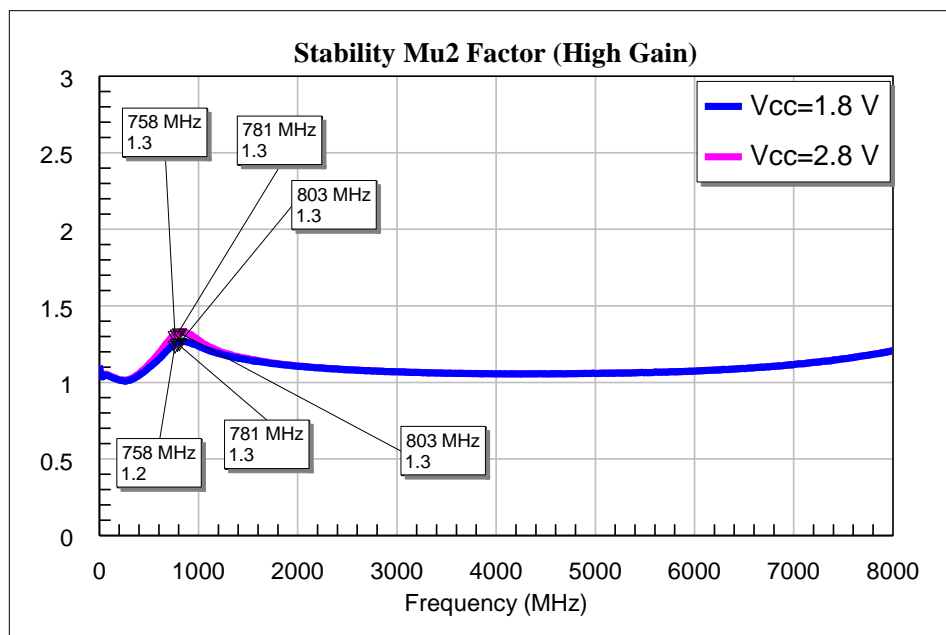


Figure 16 Stability Mu2-factor (High Gain) of BGA7L1BN6 for Band 28 Applications

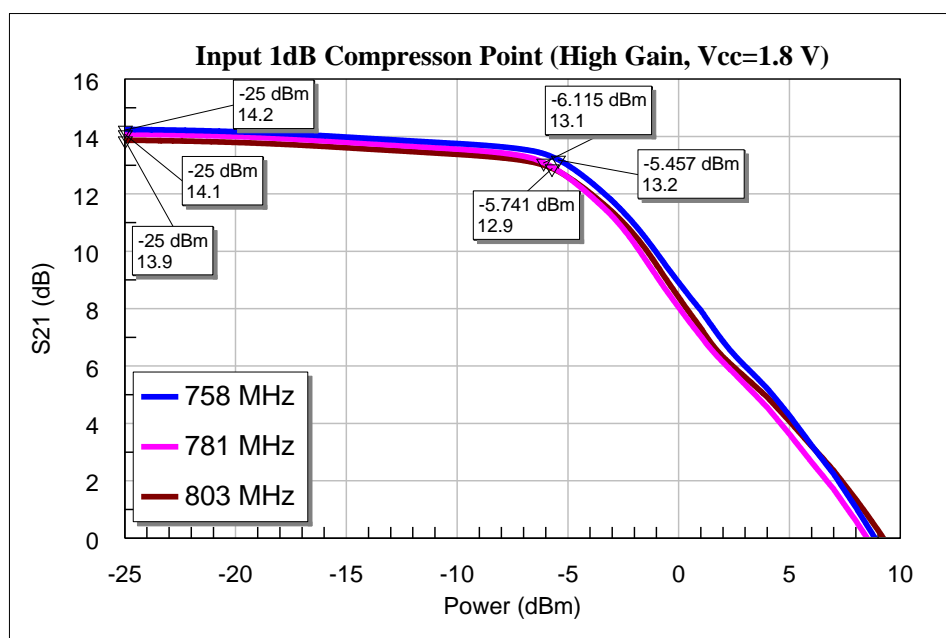


Figure 17 Input 1dB Compression Point (High Gain, 1.8 V) of BGA7L1BN6 for Band 28 Applications

Measurement Graphs

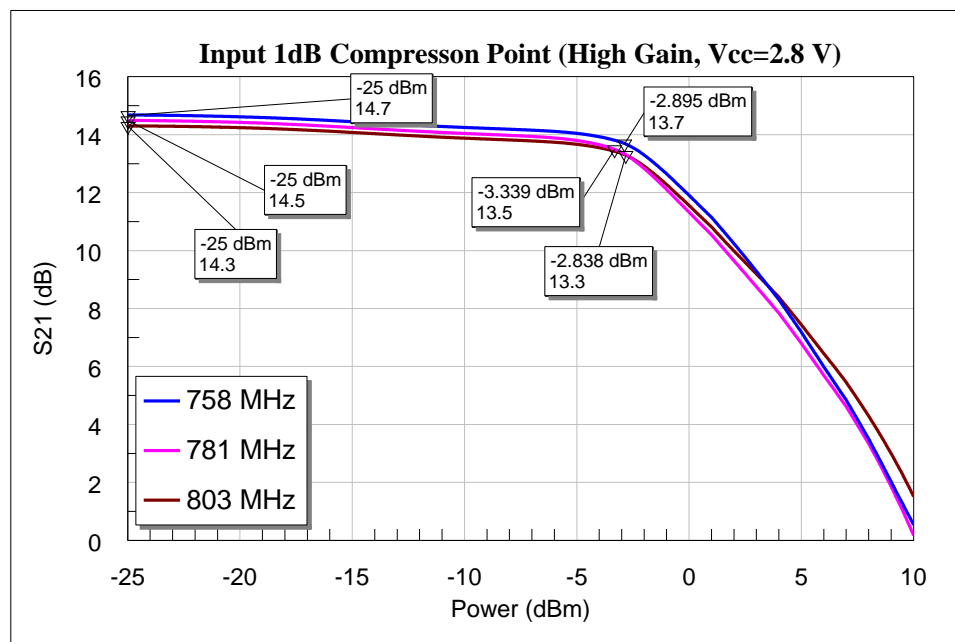


Figure 18 Input 1dB Compression Point (High Gain, 2.8 V) of BGA7L1BN6 for Band 28 Applications

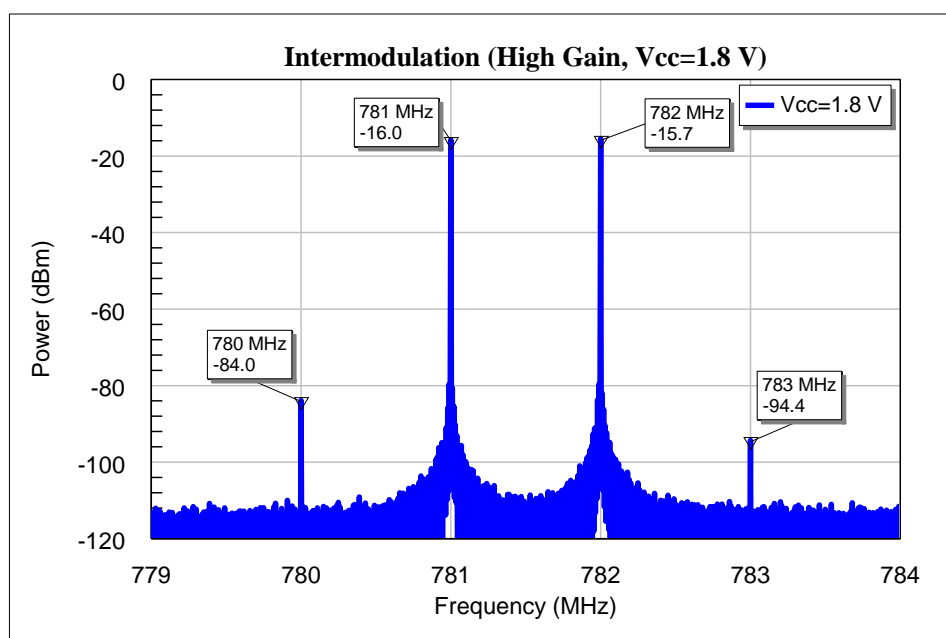


Figure 19 Third-order Interception Point (High Gain, 1.8 V) of BGA7L1BN6 for Band 28 Applications

Measurement Graphs

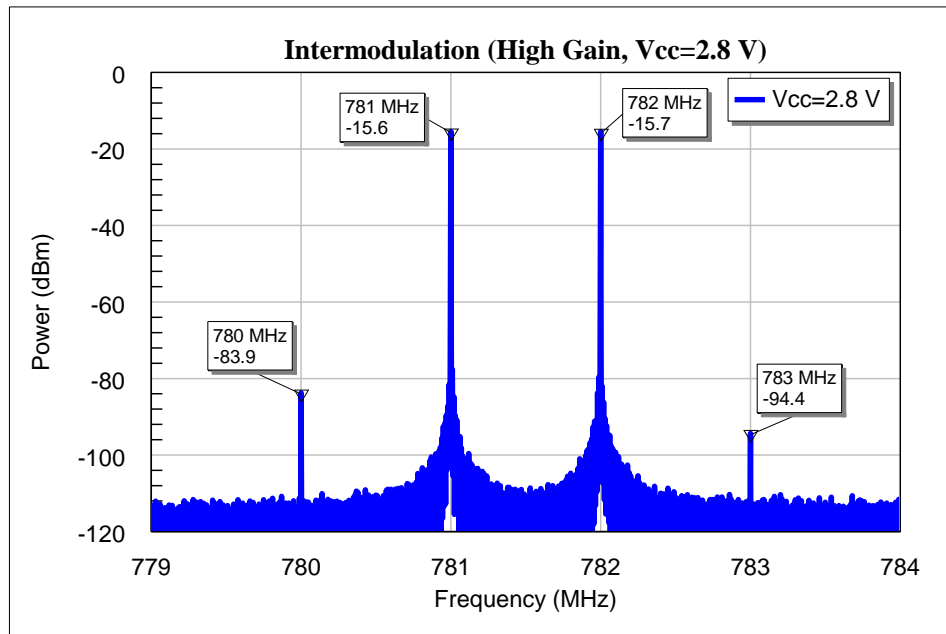


Figure 20 Third-order Interception Point (High Gain, 2.8 V) of BGA7L1BN6 for Band 28 Applications

Measurement Graphs

4.2 Bypass

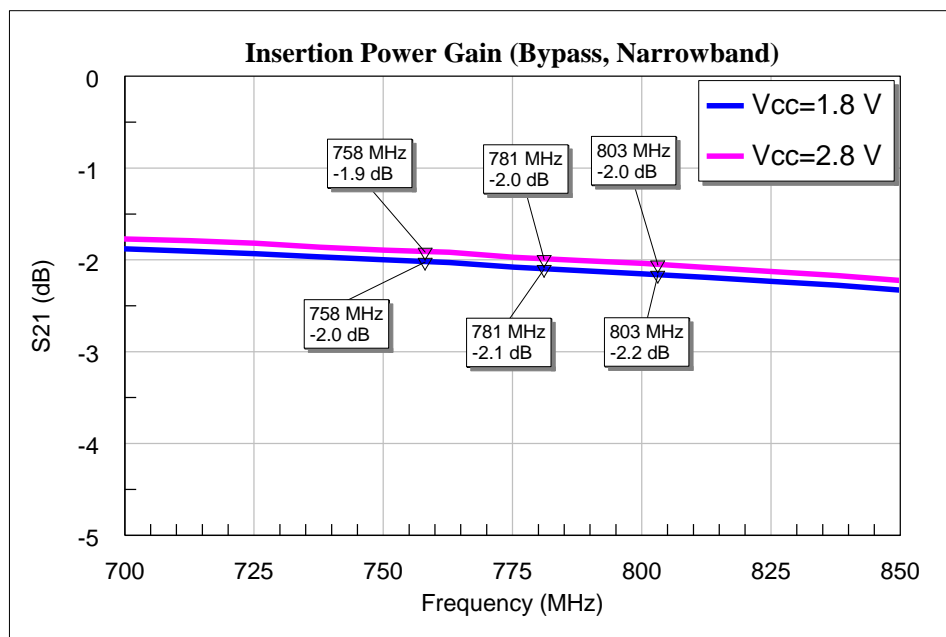


Figure 21 Insertion Power Gain (Bypass, Narrowband) of BGA7L1BN6 for Band 28 Applications

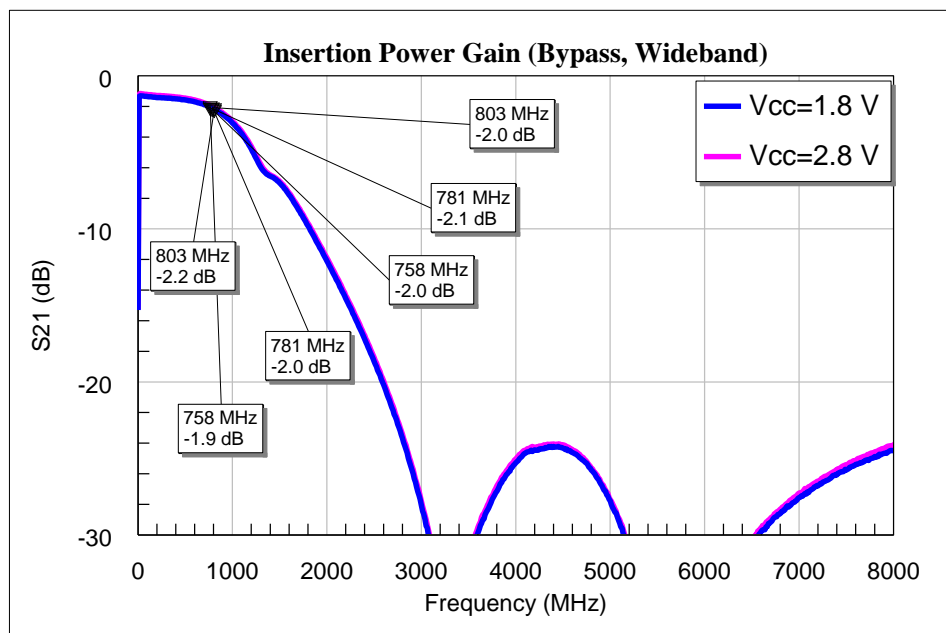


Figure 22 Insertion Power Gain (Bypass, Wideband) of BGA7L1BN6 for Band 28 Applications

Measurement Graphs

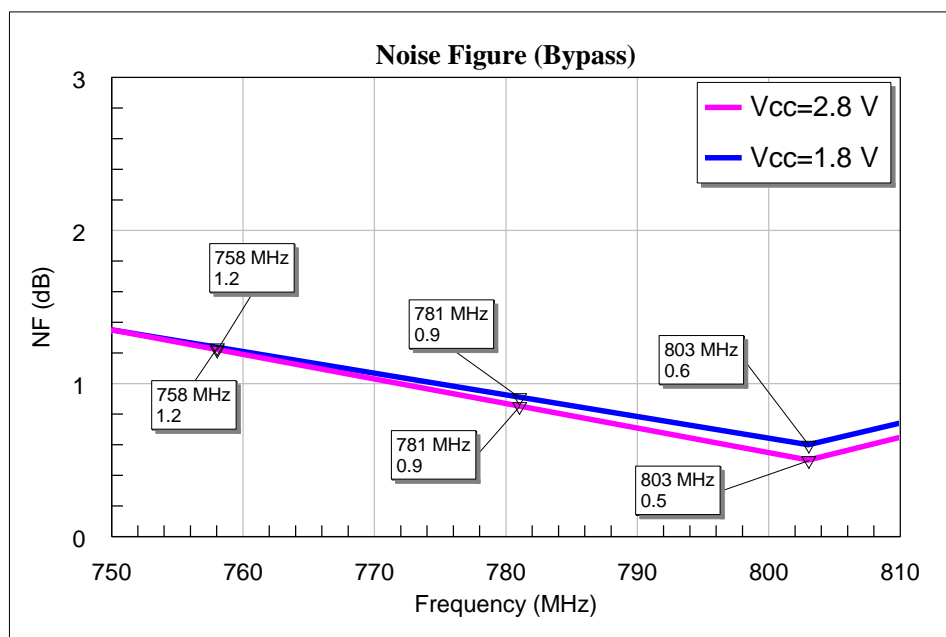


Figure 23 Noise Figure (Bypass) of BGA7L1BN6 for Band 28 Applications

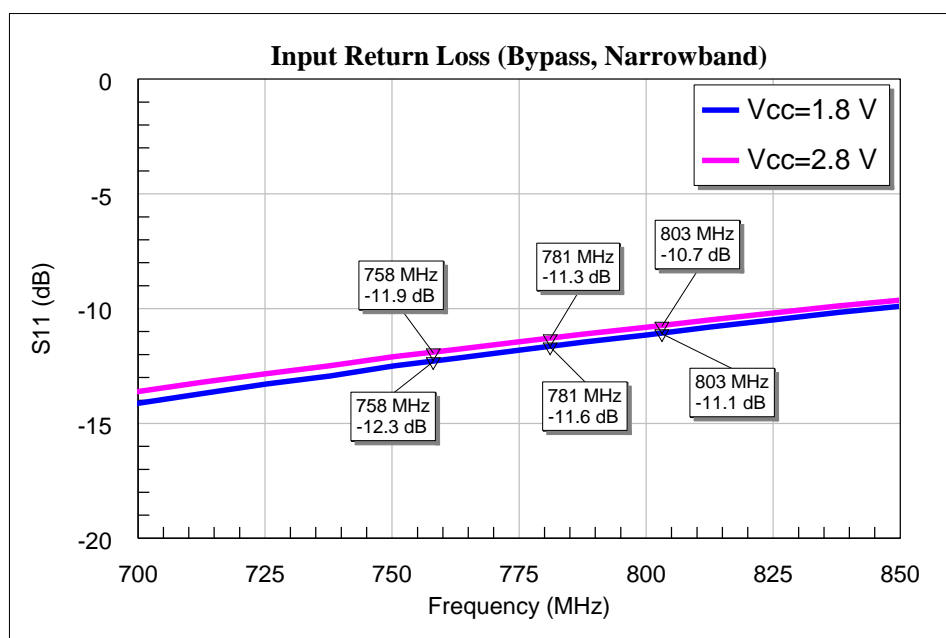


Figure 24 Input Return Loss (Bypass, Narrowband) of BGA7L1BN6 for Band 28 Applications

Measurement Graphs

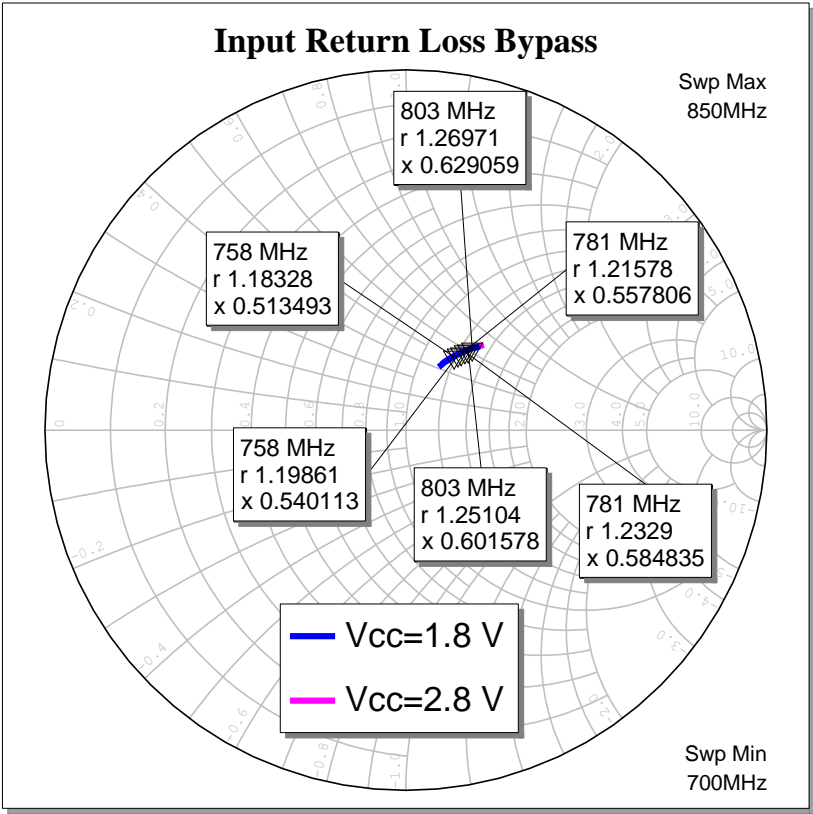


Figure 25 Input Return Loss (Bypass, Smith Chart) of BGA7L1BN6 for Band 28 Applications

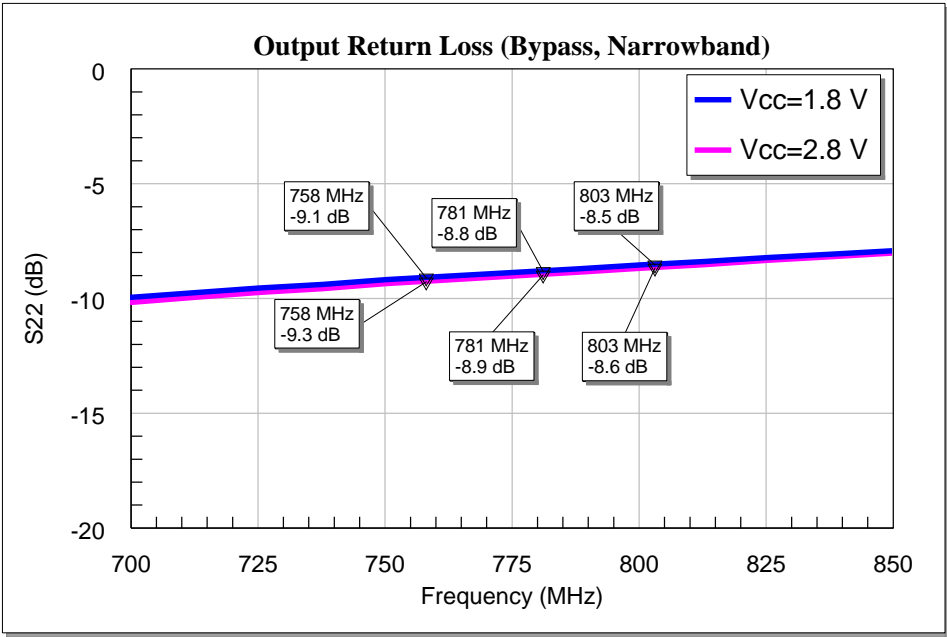


Figure 26 Output Return Loss (Bypass, Narrowband) of BGA7L1BN6 for Band 28 Applications

Measurement Graphs

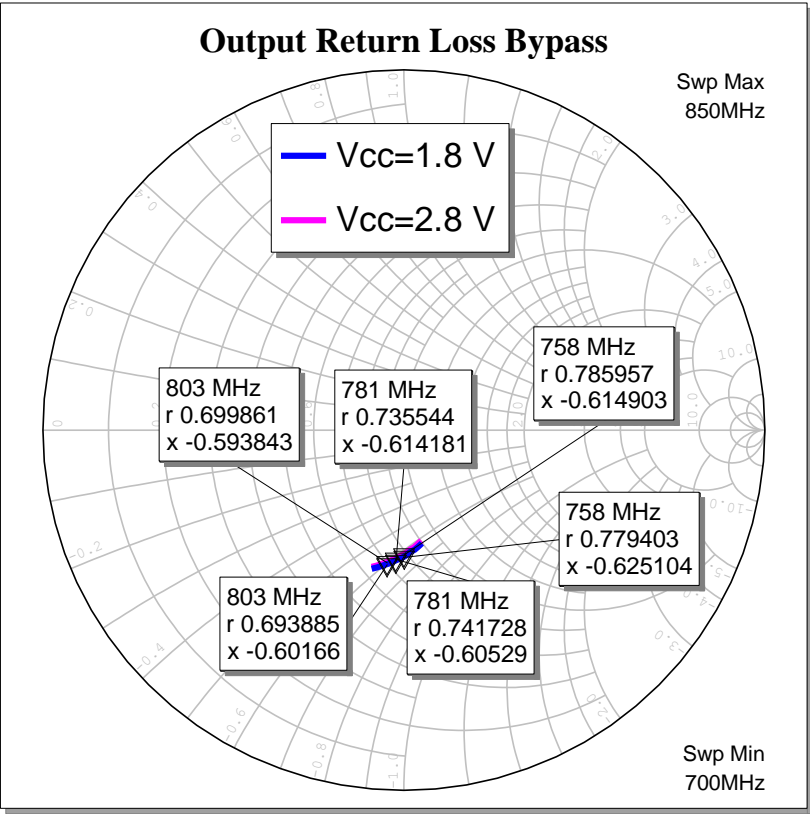


Figure 27 Output Return Loss (Bypass, Smith Chart) of BGA7L1BN6 for Band 28 Applications

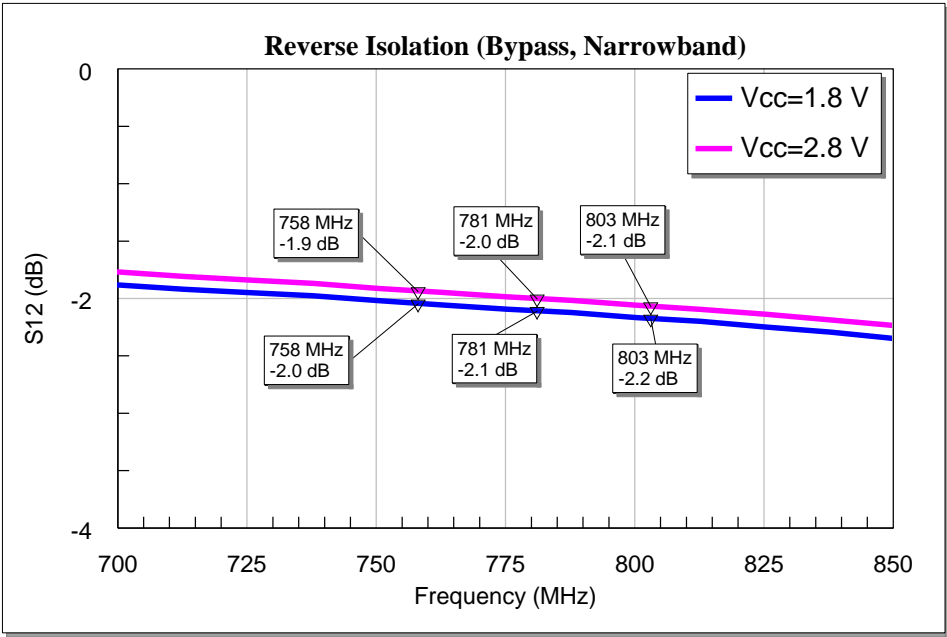


Figure 28 Reverse Isolation (High Gain, Narrowband) of BGA7L1BN6 for Band 28 Applications

Measurement Graphs

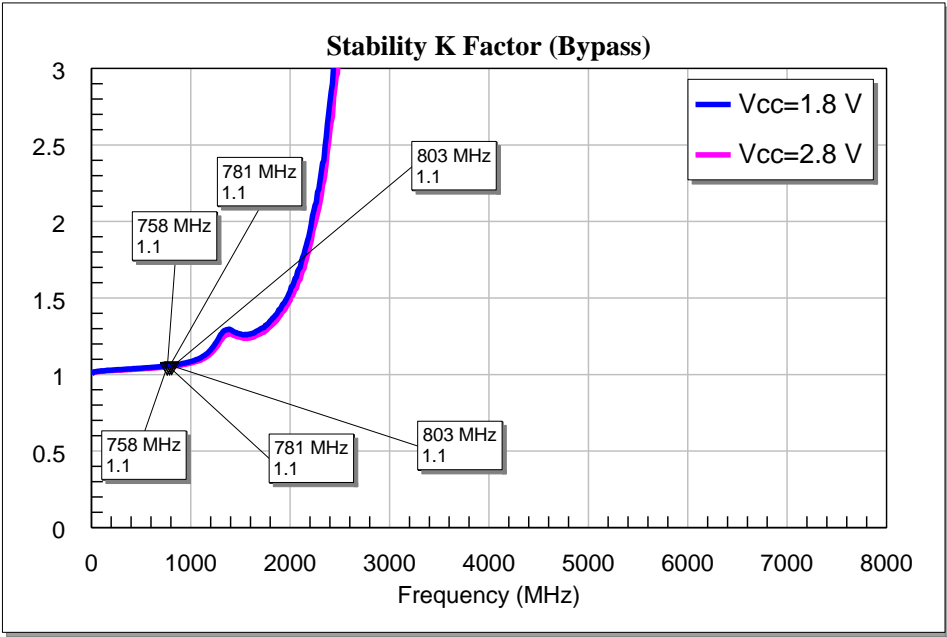


Figure 29 Stability K-factor (Bypass) of BGA7L1BN6 for Band 28 Applications

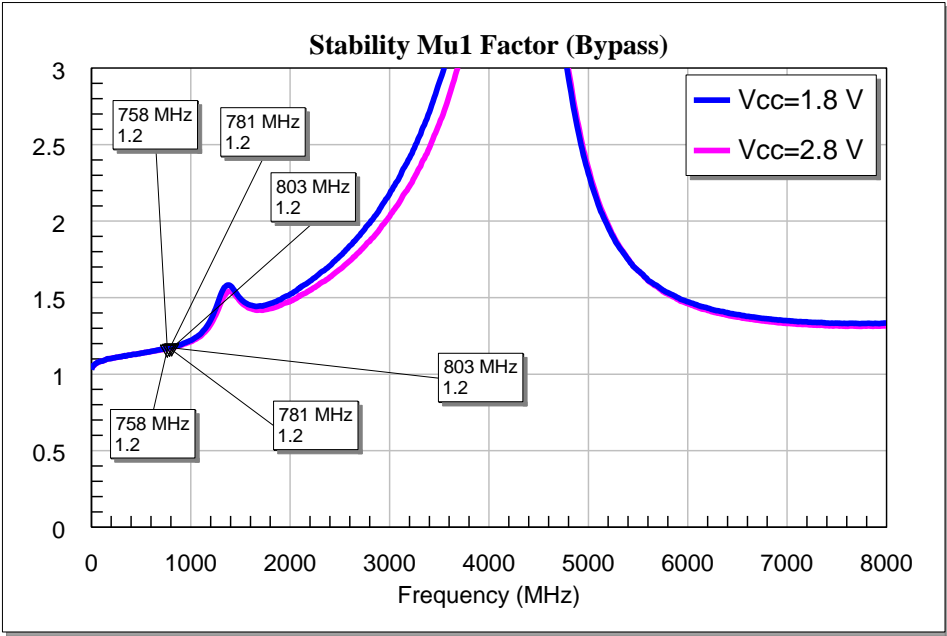


Figure 30 Stability μ_1 -factor (Bypass) of BGA7L1BN6 for Band 28 Applications

Measurement Graphs

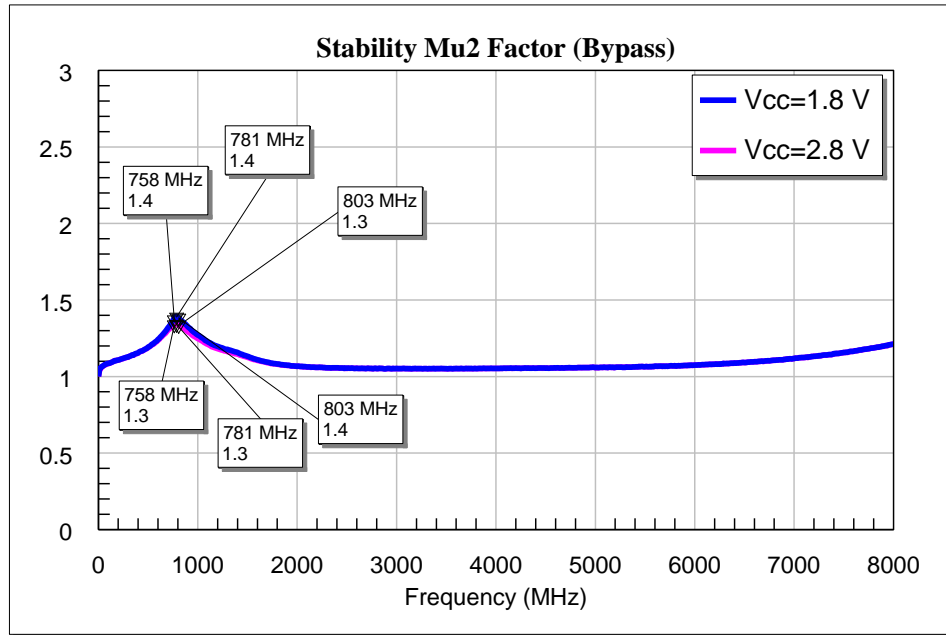


Figure 31 Stability Mu2-factor (Bypass) of BGA7L1BN6 for Band 28 Applications

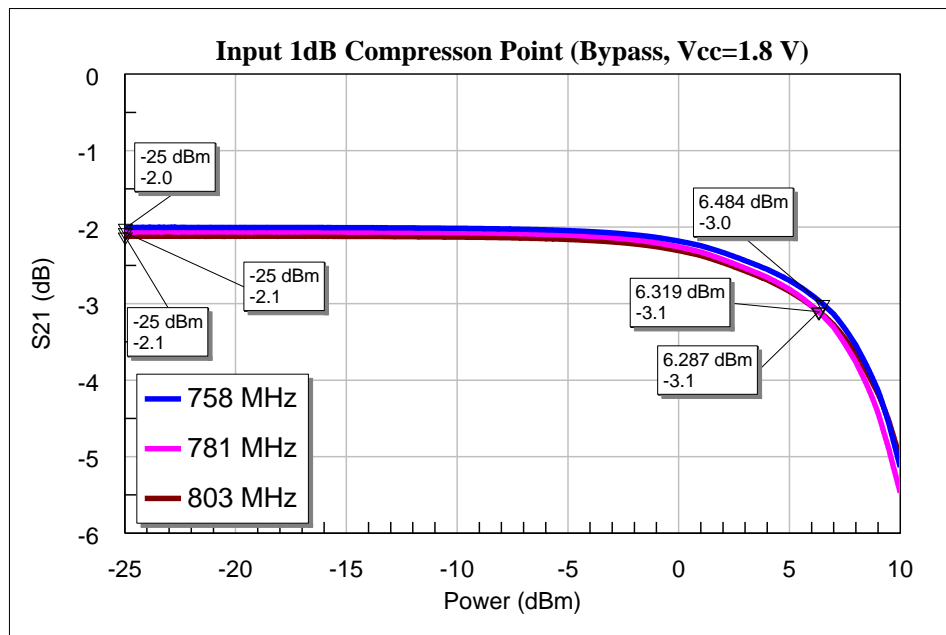


Figure 32 Input 1dB Compression Point (Bypass, 1.8 V) of BGA7L1BN6 for Band 28 Applications

Measurement Graphs

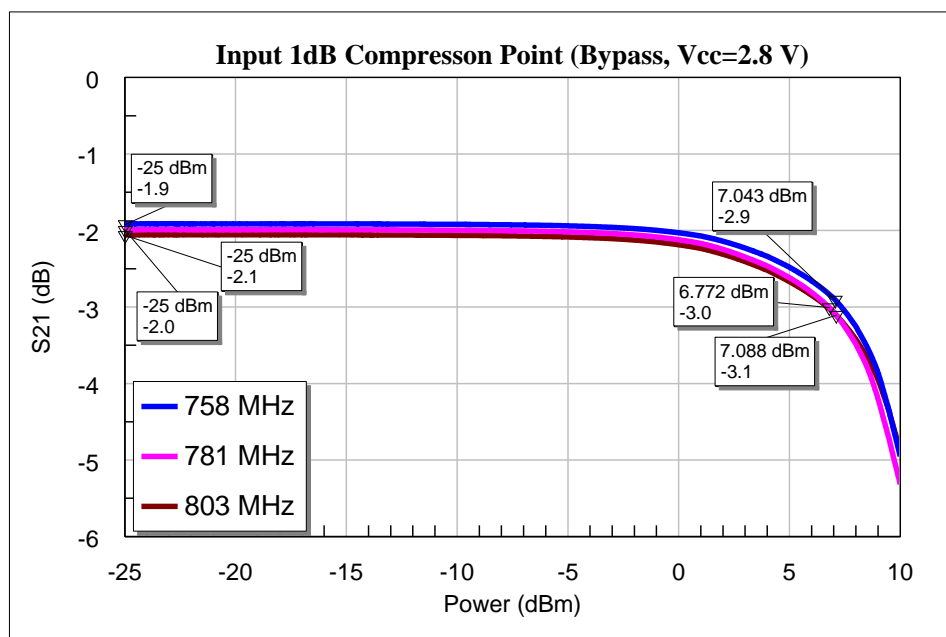


Figure 33 Input 1dB Compression Point (Bypass, 2.8 V) of BGA7L1BN6 for Band 28 Applications

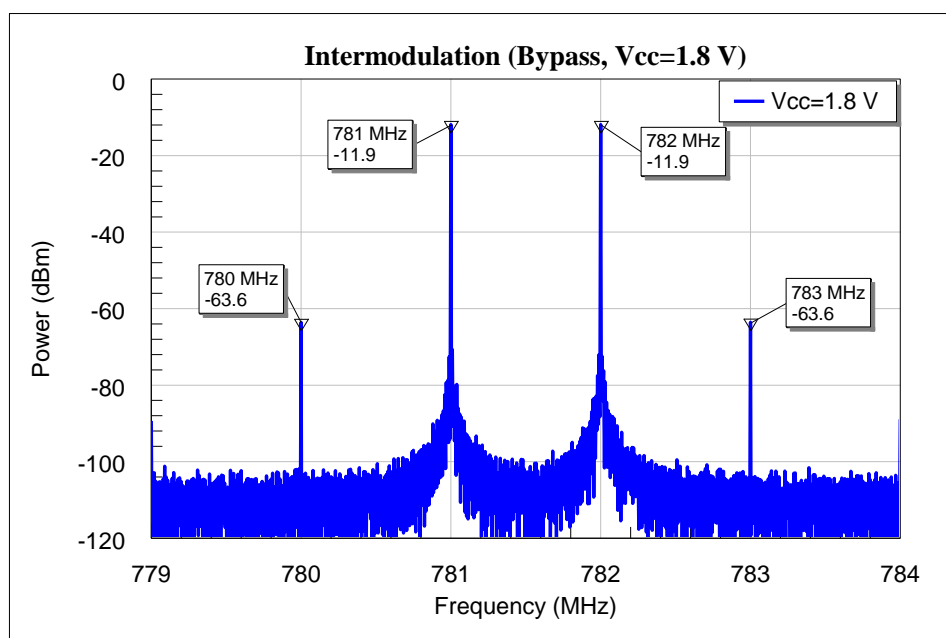


Figure 34 Third-order Interception Point (Bypass, 1.8 V) of BGA7L1BN6 for Band 28 Applications

Measurement Graphs

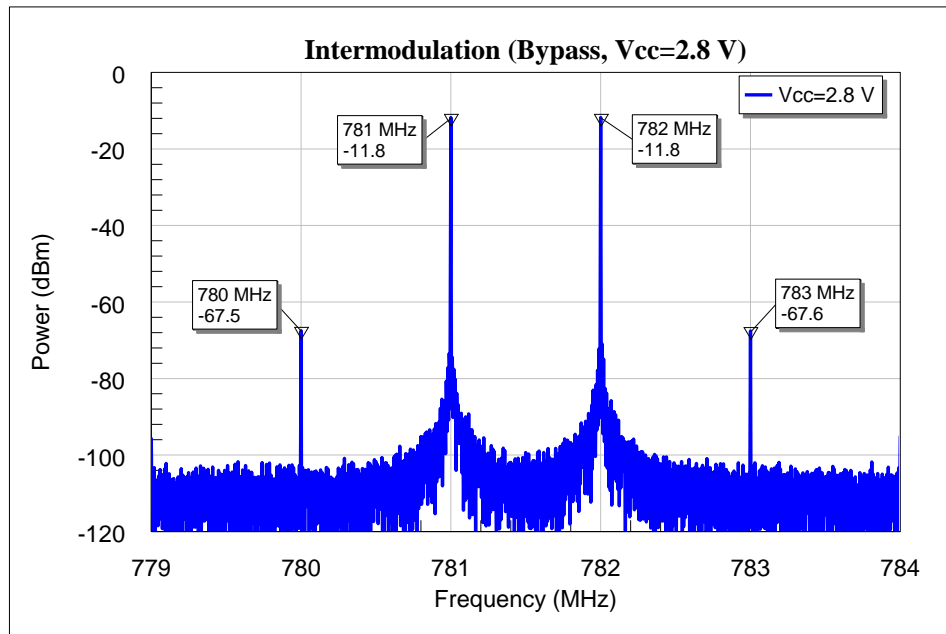


Figure 35 Third-order Interception Point (Bypass, 2.8 V) of BGA7L1BN6 for Band 28 Applications

5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB Marking: **BGA7x1BN6 V2.0**

PCB material: **FR4**

ϵ_r of PCB material: **4.8**



Figure 36 Photo Picture of Evaluation Board (overview) <PCB Marking M150918 Rev. 2.0>

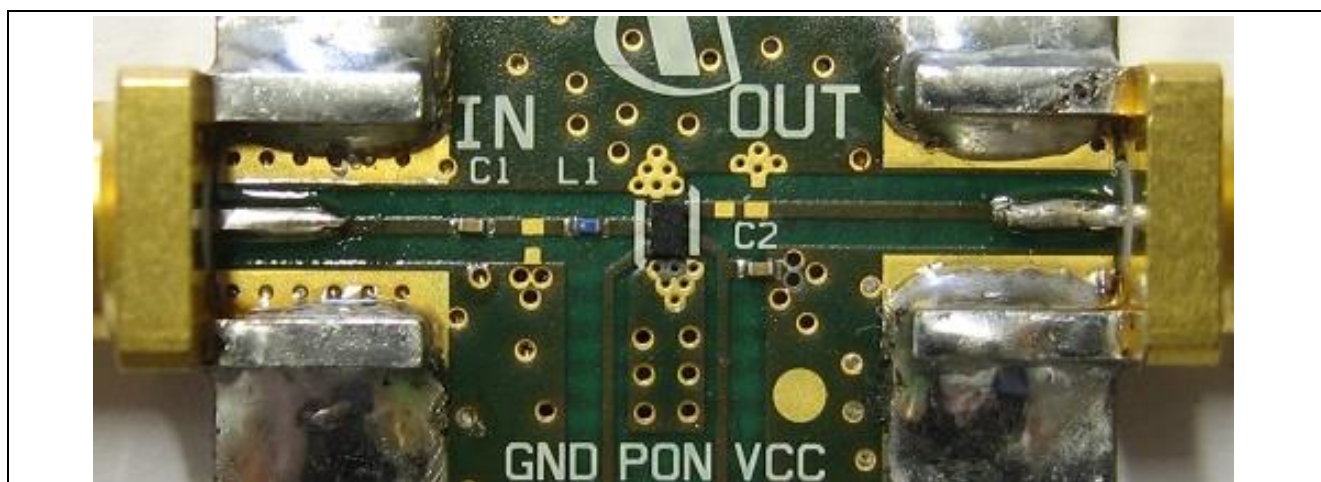


Figure 37 Photo Picture of Evaluation Board (detailed view)

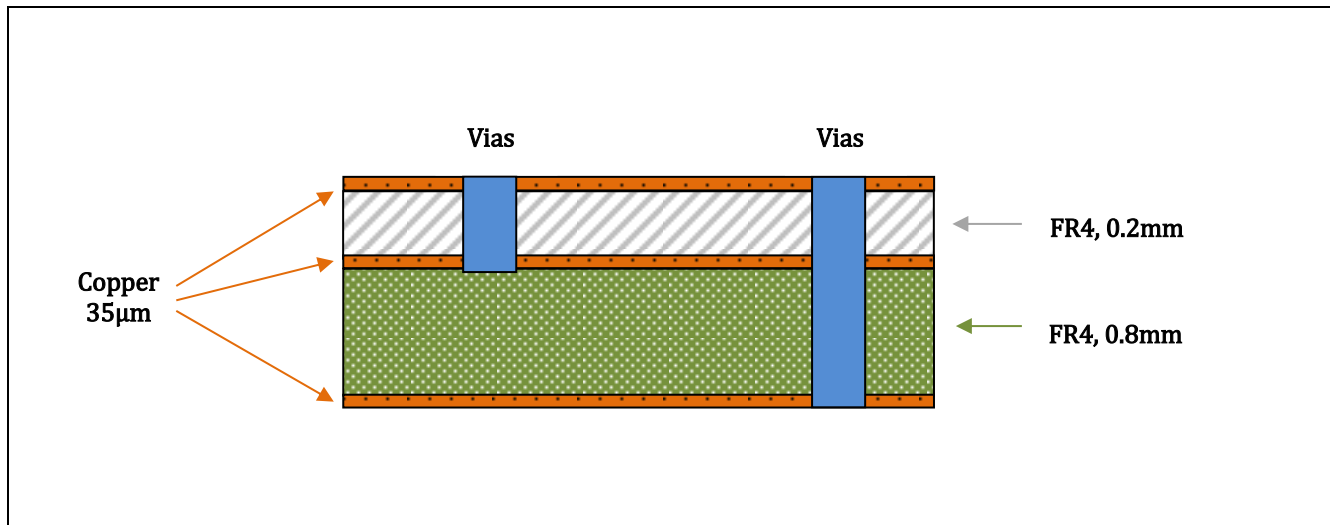


Figure 38 PCB Layer Information

6 Authors

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

7 Reference

[1] Application Guide for Mobile Communication, Infineon Technologies, Business Unit "Radio Frequency and Sensors" http://www.infineon.com/appguide_rf_mobile

Revision History

Major changes since the last revision (2016-08)

Page or Reference	Description of change
4 - 7	Updated introduction of LTE application
10	Updated insertion gain at 1.8V, high gain, updated P1dB values

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