Silicon Germanium Low Noise Amplifier: BGA7H1N6

Low Noise Amplifier for LTE Band-42 (3400–3600 MHz), Using 0201 Components

Application Note AN432

About this document

Scope and purpose

This application note describes Infineon's Low Noise SiGe: BGA7N1N6 used as LNA for LTE Band-42 applications.

1. This application note documents the design of a LTE Band-42 LNA with input matching network.
2. The BGA7H1N6 is used in this design.
3. This design provides a solution to LTE Band-42 receivers where a single band LNA MMIC is required.
4. Key performance parameters for Band-42 at 2.8 V:
   Gain = 10.5 dB,
   NF = 0.95 dB,
   OIP3 = 22.7 dBm and
   IP1dB = 10.9 dBm.

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

1 Introduction of LNA for LTE Application

1.1 Introduction to 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 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).

Moving towards 4G Long-Term Evolution-Advanced (LTE-Advanced), the number of LTE bands has exploded in the last few years. Currently, there are 44 LTE bands worldwide for LTE systems. The following table, derived from the latest release of 3GPP TS 36.101 V12.7.0 “Evolved Universal Terrestrial Radio Access (E-UTRA) - User Equipment (UE) radio transmission and reception” in April 2015, shows the LTE band numbers with up-/down-link frequency ranges and their related multiplexing methods:

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	1475.9-1495.9 MHz	FDD	
12	Low-Band	698-716 MHz	728-746 MHz	FDD	
13	Low-Band	777-787 MHz	746-756 MHz	FDD	

Band No.	Band Definition	Uplink Frequency Range	Downlink Frequency Range	FDD/TDD System	Comment
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	
30	High-Band	2305-2315 MHz	2350-2360 MHz	FDD	
31	Low-Band	452.5-457.5 MHz	462.5-467.5MHz	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	

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

The mobile technologies for smartphones have seen phenomenal growth in recent times. The data rate of mobile devices has increased significantly over the evolution of modern mobile technologies from the first 3G/3.5G technologies (Universal Mobile Telecommunications System (UMTS) and Wideband-Code Division Multiple Access (WCDMA), High-Speed Packet Access (HSPA) and Evolved High-Speed Packet Access (HSPA+)) to 4G LTE-Advanced (LTE-A). The ability of 4G LTE-A to support bandwidths 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 technical features for mobile high-data-rate communication, and advanced wireless connectivities can be summarized as following:

- Inter-operation Frequency Division Duplexing (FDD) + 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) at RF FEs
- Device-to-Device (D2D) communication with LTE (LTE-D)
- High speed wireline connection with USB 3.0, Bluetooth 4.0 etc.

1.2 Applications

Figure 1 shows an example of the block diagram of the front-end of a 4G modem. A SPnT switch connects one side the antenna and several duplexers for different 4G bands on the other side. Every duplexer is connected to the transmitting (TX) and receiving (RX) paths of each band. The external LNA, here for example Infineon single-band LNA BGA7H1N6 is placed on the RX path between the duplex and the bandpass SAW filter. The output of the SAW filter is connected to the receiver input of the transceiver IC.

Depending on the number of bands designed in a device, various numbers of LNAs are required in a system. Recently, even mobile devices with 5 modes 13 bands are under discussion. Not only for the main paths, but also for the diversity paths, the external LNAs are widely used to boost end user experience while using mobile devices for video and audio streaming.

Besides low noise amplifiers, Infineon Technologies also offers solutions for high power highly linear antenna switches, band switches as well as power detection diodes for power amplifiers.

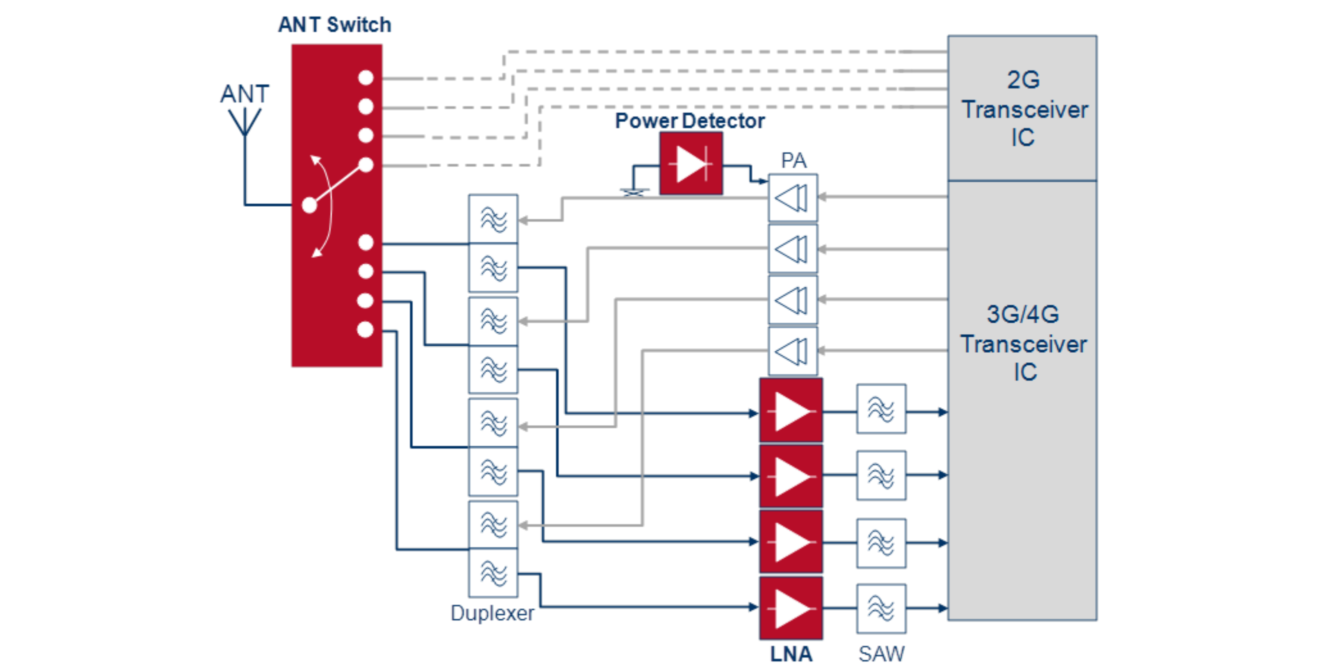

Figure 1 Example of Application Diagram of RF Front-End for 3G and 4G Systems.

1.3 Infineon LNAs for LTE Applications

With the increasing wireless data speed and with the extended link distance of mobile phones and 4G data cards, the requirements on the sensitivity are much higher. Infineon offers different kind of low noise amplifiers (LNAs) to support the customers for mobile phones and data cards of 4G LTE and LTE-A to improve their system performance to meet the requirements coming from the networks/service providers.

The benefits to use external LNAs in equipment for 4G LTE and LTE-A applications are:

- Flexible design to place the front-end components: due to the size constraint, the modem antenna and the front-end cannot be always put close to the transceiver IC. The path loss in front of the integrated LNA on the transceiver IC increases the system noise figure noticeably. An external LNA physically close to the antenna can help to eliminate the path loss and reduce the system noise figure. Therefore the sensitivity can be improved by several dB.
- Support RX carrier aggregation where two LNAs can be tuned on at the same time.

- Boost the sensitivity by reducing the system noise figure: external LNA has lower noise figure than the integrated LNA on the transceiver IC.
- Bug fix to help the transceiver ICs to fulfill the system requirements.
- Increase the dynamic range of the power handling.

Infineon Technologies is the leading company with broad product portfolio to offer high performance SiGe: C bipolar transistor LNAs and MMIC LNAs for various wireless applications by using the industrial standard silicon process. The MMIC LNA portfolio includes:

- New generation single band LTE LNAs like BGA7H1N6 for high-band (HB, 2300-2700 MHz), BGA7M1N6 for mid-band (MB, 1805-2200 MHz) and BGA7L1N6 for low-band (LB, 728-960 MHz) are available.

- New generation LTE LNA Banks are quad-band. Currently there are six different types of these new LTE LNAs which are shown in **Table 1**. Each LNA bank combines four various bands LNA from the high-band (HB, 2300-2700 MHz), mid-band (MB, 1805-2200 MHz) and low-band (LB, 728-960 MHz). Two of the four LNAs in one LNA bank can be turned on at the same time to support carrier aggregation.

The broad product portfolio with highest integration and best features in noise figure and flexible band selection helps designers to design mobile phones and data cards with outstanding performance. Therefore Infineon LNAs and LNA banks are widely used by mobile phone vendors.

Table 1 Infineon Product Portfolio of LNAs for 4G LTE and LTE-A Applications

Frequency Range	728 MHz–960 MHz	1805MHz–2200MHz	2300 MHz–2690 MHz	Comment
Single-Band LNA				
BGA7L1N6	1X			
BGA7M1N6		1X		
BGA7H1N6			1X	
Quad-Band LNA bank				
BGM7MLLH4L12	1X	2X	1X	
BGM7LMHM4L12	1X	2X	1X	

Table 1 Infineon Product Portfolio of LNAs for 4G LTE and LTE-A Applications

BGM7HHMH4L12		1X	3X	
BGM7MLLM4L12	2X	2X		
BGM7LLHM4L12	2X	1X	1X	
BGM7LLMM4L12	2X	2X		

2 BGA7H1N6 Overview

2.1 Features

- High insertion power gain: 12.5 dB
- Low noise figure: 0.60 dB
- Low current consumption: 4.7 mA
- Operating frequencies: 2300 – 2690 MHz
- Supply voltage: 1.8 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 mm^2)
- 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 BGA7H1N6 in TSNP-6-2

2.2 Description

The BGA7H1N6 is a front-end low noise amplifier for LTE applications, which covers a wide frequency range from 2300 MHz to 2690 MHz. The LNA provides 12.5 dB gain and 0.60 dB noise figure at a current consumption of 4.7 mA in the application configuration described in **Chapter 3**. The BGA7H1N6 is based upon Infineon Technologies B7HF Silicon Germanium technology. It operates from 1.5 V to 3.6 V supply voltage.

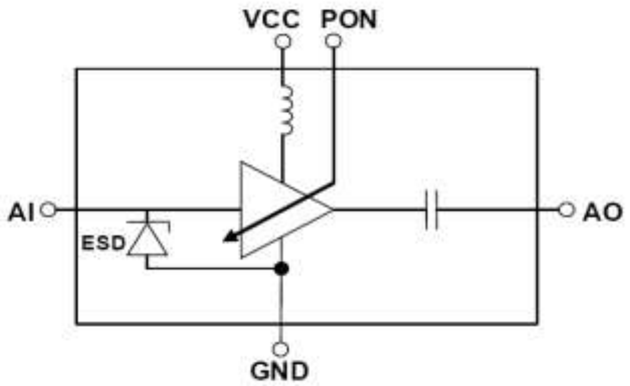

Figure 3 Equivalent Circuit Block diagram of BGA7H1N6

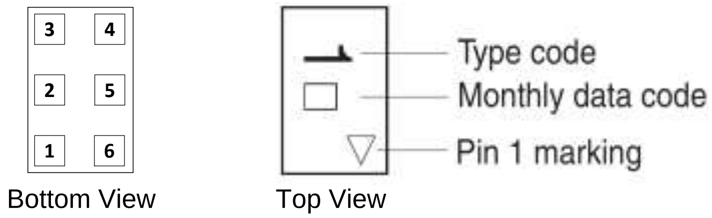

Figure 4 Package and pin connections of BGA7H1N6

Table 2 Pin Assignment of BGA7H1N6

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 3 Pin Assignment of BGA7H1N6

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

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

Device:	**BGA7H1N6**
Application:	**Low Noise Amplifier for LTE Band-42 Applications**
PCB Marking:	**M20150313**
EVB Order No.:	**AN432**

3.1 Summary of Measurement Results

The performance of BGA7H1N6 for LTE LNA Band-42 (3400–3600 MHz) is summarized in the following tables.

Table 4 Electrical Characteristics of the BGA7H1N6 (at room temperature) for LTE Band-42

Parameter	Symbol	Value						Unit	Comment/Test Condition
DC Voltage	Vcc	1.8			2.8			V	
DC Current	Icc	4.7			4.8			mA	
Frequency Range	Freq	3400	3500	3600	3400	3500	3600	MHz	
Gain	G	10.6	10.3	9.8	10.8	10.5	10.1	dB	
Noise Figure	NF	0.94	0.96	0.90	0.95	0.98	0.92	dB	Loss of input line 0.15 dB deembedded
Input Return Loss	RLin	15.8	16.5	18.7	15.8	16.7	19.3	dB	
Output Return Loss	RLout	25.6	16.3	12.5	33.0	17.9	13.5	dB	
Reverse Isolation	IRev	18.0	18.0	18.2	18.3	18.3	18.4	dB	
Input P1dB	IP1dB	-1.9	-1.8	-1.2	1.2	1.3	1.8	dBm	
Output P1dB	OP1dB	7.7	7.5	7.6	11.0	10.8	10.9	dBm	
Input IP3	IIP3	9.9			12.2			dBm	f_1 = 3500 MHz f_2 = 3501 MHz P_{in} = -30 dBm
Output IP3	OIP3	20.2			22.7			dBm	
Stability	k	>1						--	Unconditionally stable from 0 to 10 GHz

3.2 Summary of BGA7H1N6 as LTE LNA for Band-42 (3400–3600 MHz)

This application note describes the LNA performance of LTE Band-42 (3400–3600 MHz). It presents the performance of BGA7H1N6 with 1.8 V and 2.8 V power supply with the operating current of 4.7 mA.

At 1.8 V, the circuit offers a gain of 10.3 dB. It achieves input return loss as well as output return loss better than 12 dB. The input 1 dB compression point is -1.8 dBm at 3500 MHz. Using two tones spacing of 1 MHz, the input third order intercept point (IIP3) reaches 9.9 dBm at 3500 MHz. At room temperature the noise figure is 0.96 dB excluding SMA and PCB losses.

At 2.8 V, the circuit offers a gain of 10.5 dB. It achieves input return loss as well as output return loss better than 13 dB. The input 1 dB compression point is 1.3 dBm at 3500 MHz. Using two tones spacing of 1 MHz, the input third order intercept point (IIP3) reaches 12.2 dBm at 3500 MHz. At room temperature the noise figure is 0.98 dB excluding SMA and PCB losses.

The circuit is unconditionally stable till 10 GHz.

3.3 Schematics and Bill-of-Materials

The schematic of BGA7H1N6 for LTE Band-42 is presented in **Figure 5** and its bill-of-materials is shown in **Table 5**.

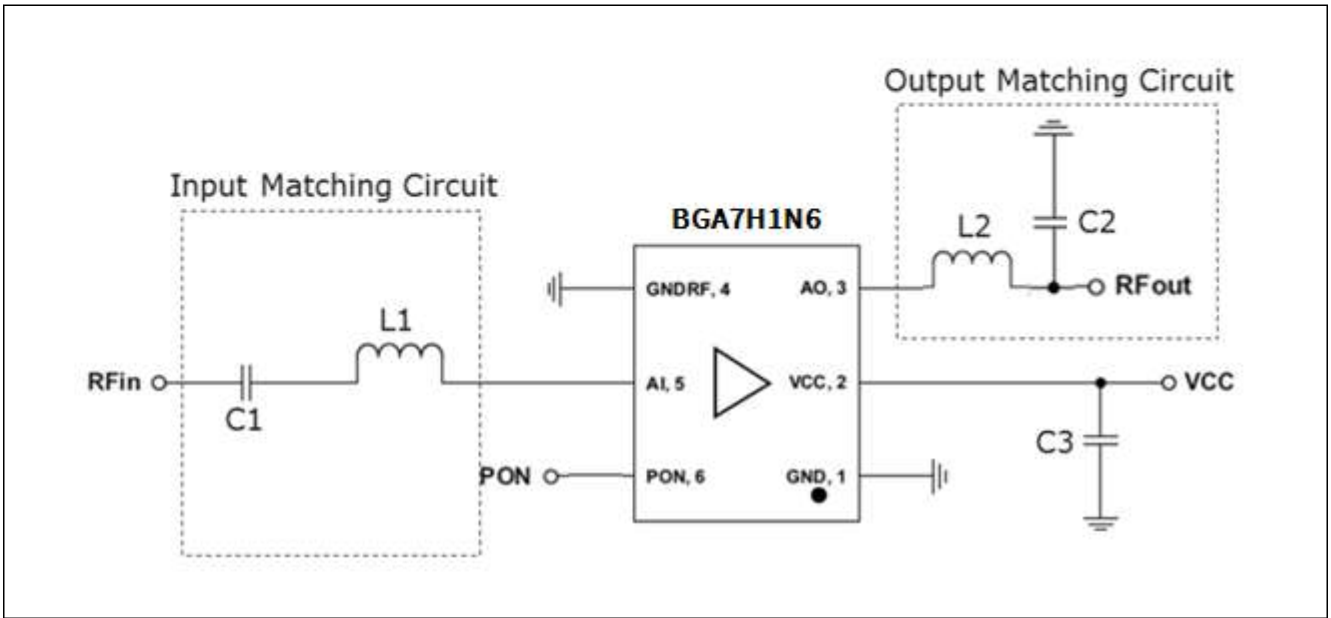

Figure 5 Schematics of the BGA7H1N6 Application Circuit

Table 5 Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
C1 (optional)	1	nF	0201	Various	Input matching
C2	0.5	pF	0201	Various	Output matching
C3(optional)	10	nF	0201	Various	DC block
L1	1.5	nH	0201	Murata LQP Type	Input matching
L2	2.4	nH	0201	Murata LQP Type	Output matching
N1	BGA7H1N6		TSNP-6-2	Infineon	SiGe LNA
PCB					FR4

Note: DC block function is NOT integrated at input of BGA7H1N6. 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 C3 at the DC power supply pin filters out the power supply noise and stabilizes the DC supply. The RF bypass capacitor C3 is not necessary if a clean and stable DC supply can be ensured.

4 Measurement Graphs

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

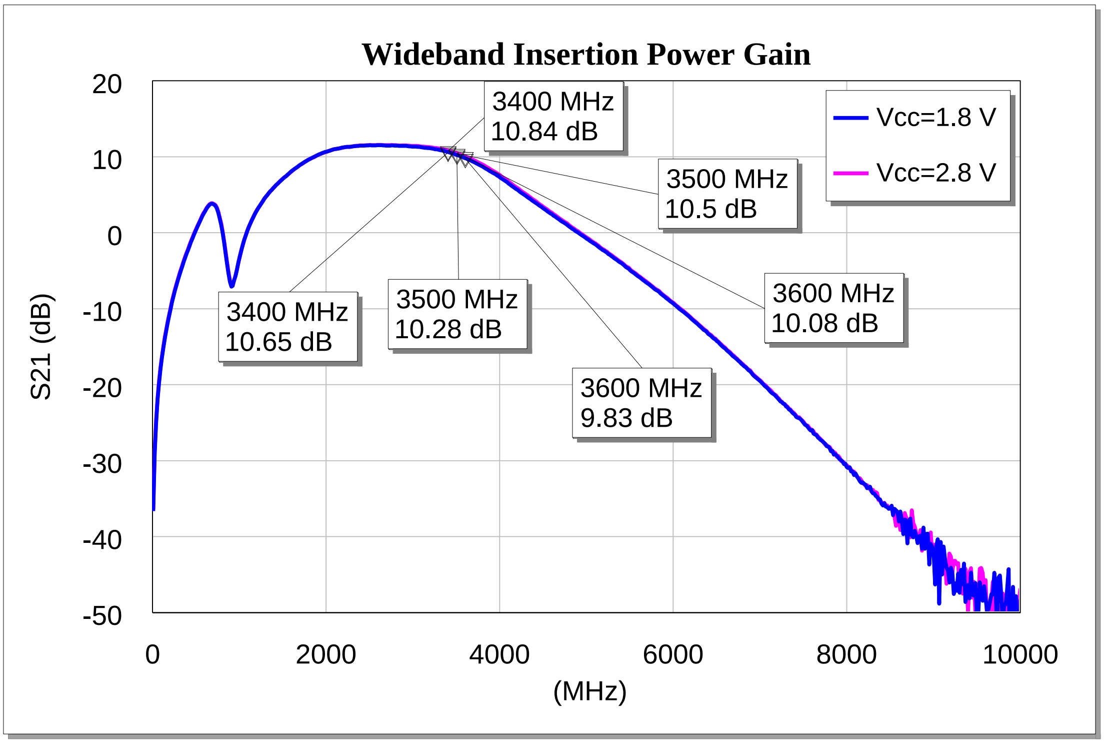

Figure 6 Wideband Insertion Power Gain of the BGA7H1N6 for LTE Band-42

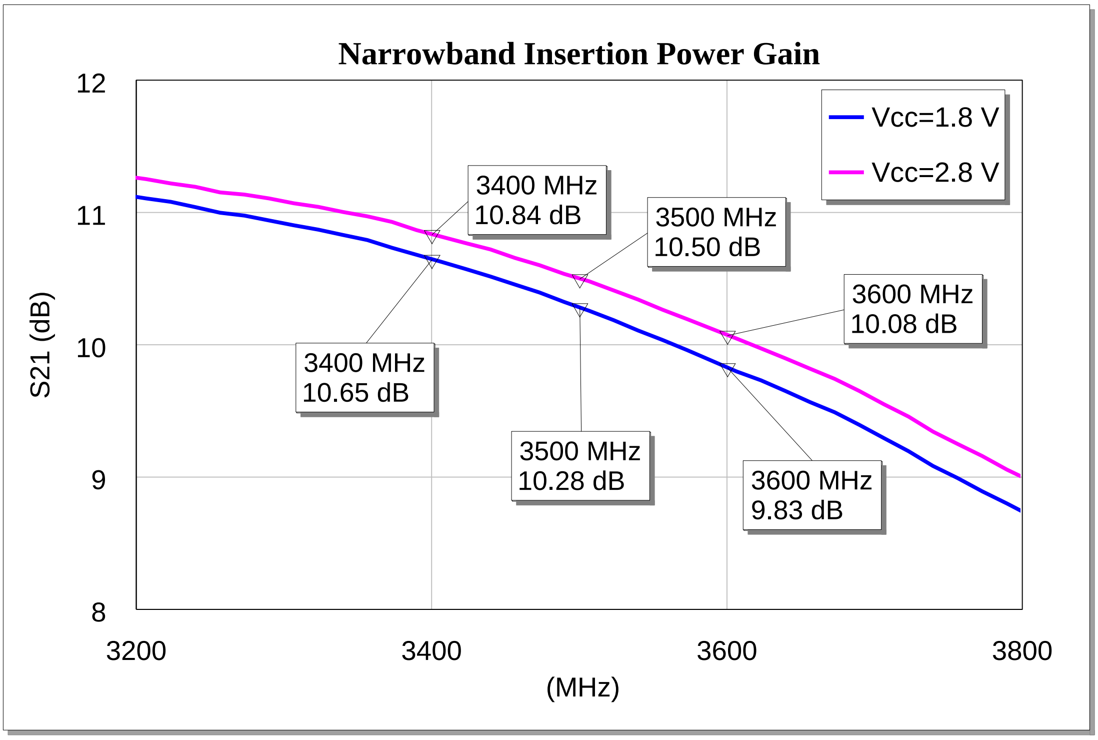

Figure 7 Narrowband Insertion Power Gain of the BGA7H1N6 for LTE Band-42

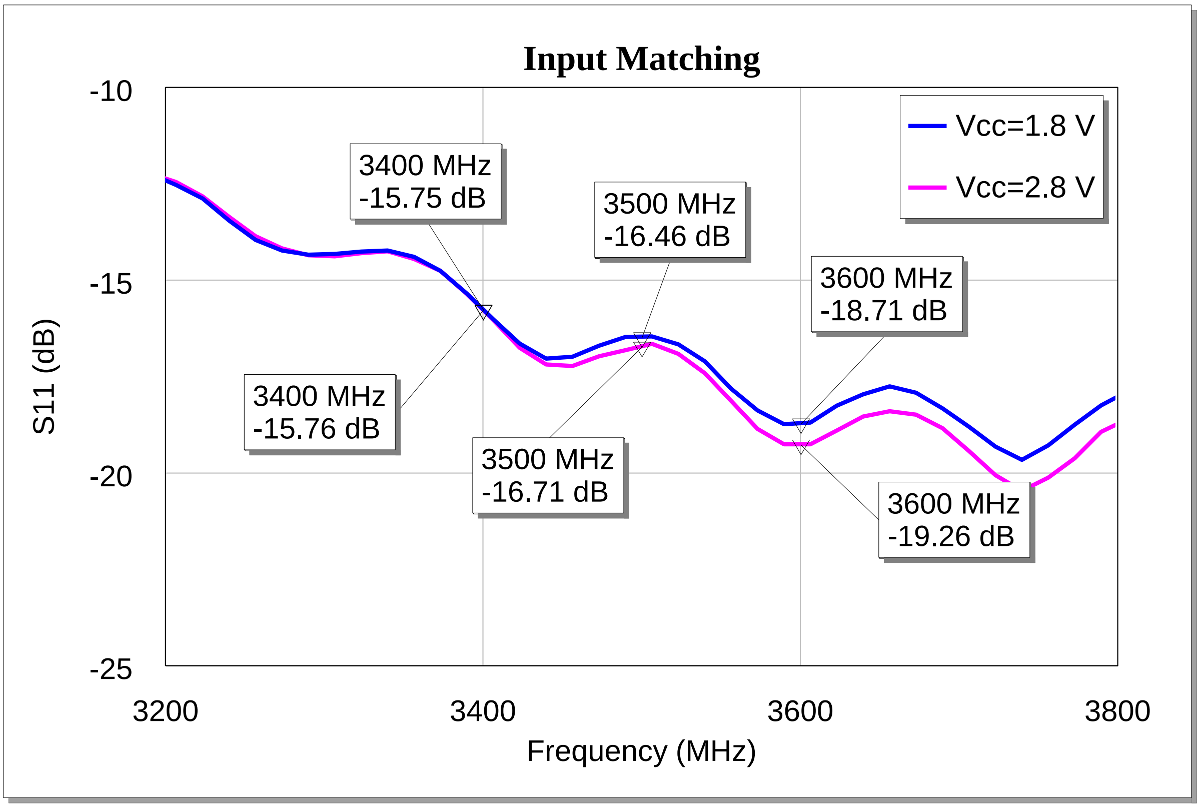

Figure 8 Input Matching of the BGA7H1N6 for LTE Band-42

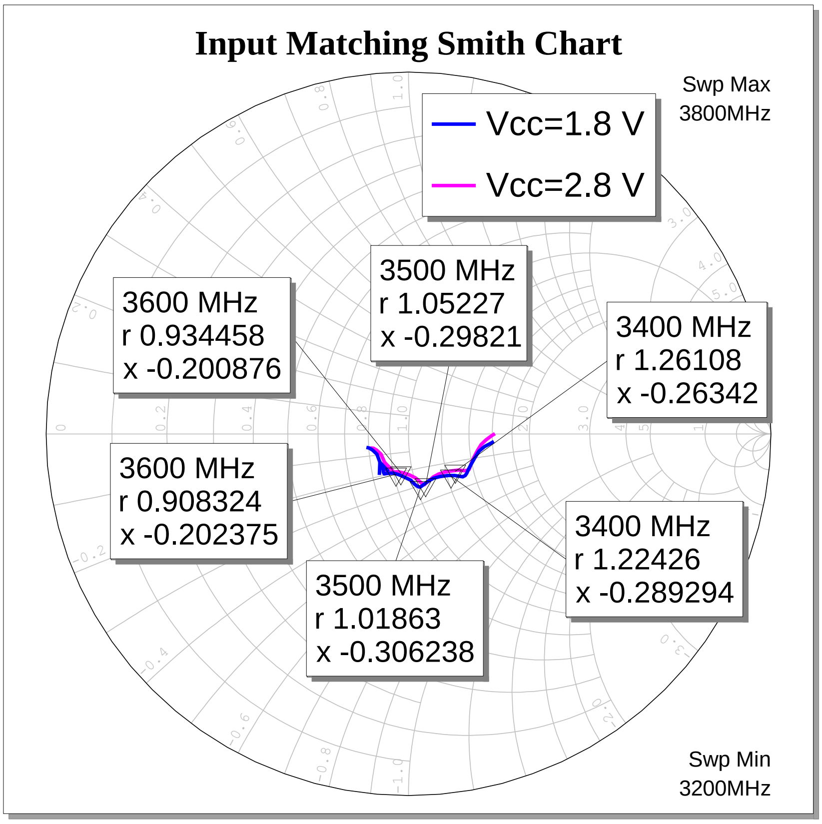

Figure 9 Input Matching (Smith Chart) of the BGA7H1N6 for LTE Band-42

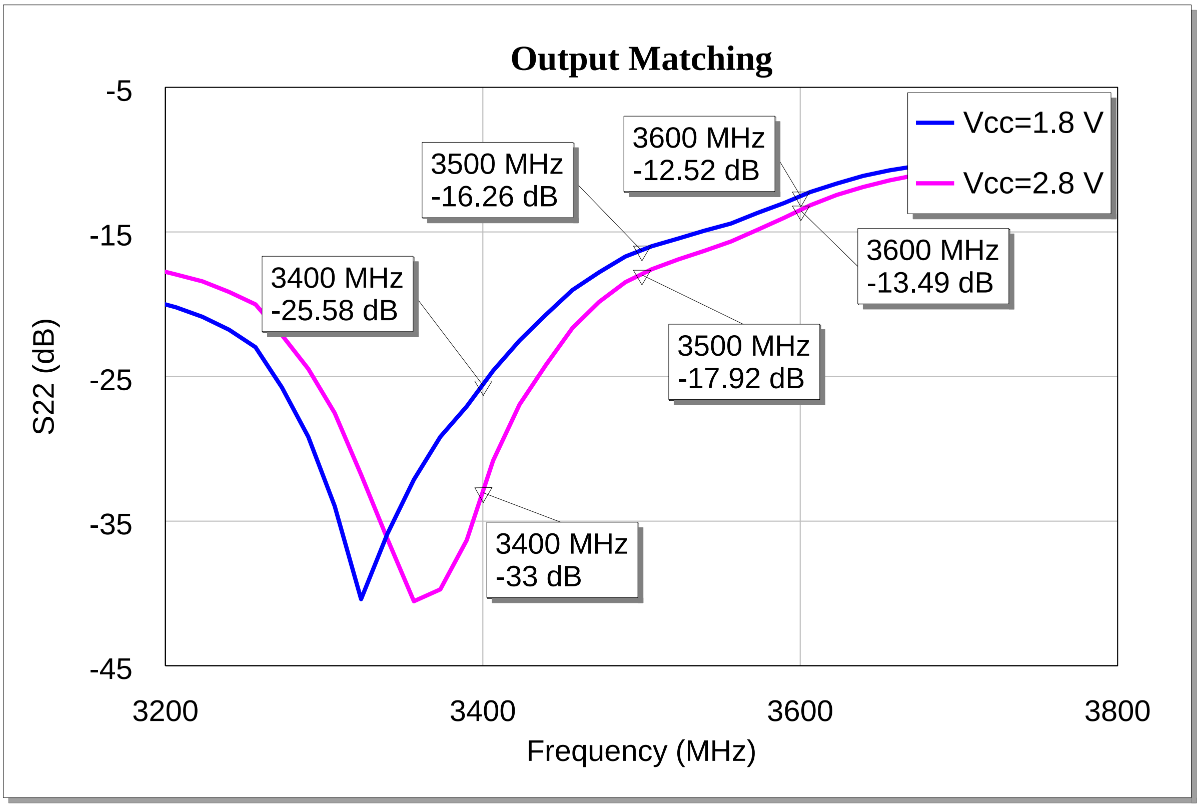

Figure 10 Output Matching of the BGA7H1N6 for LTE Band-42

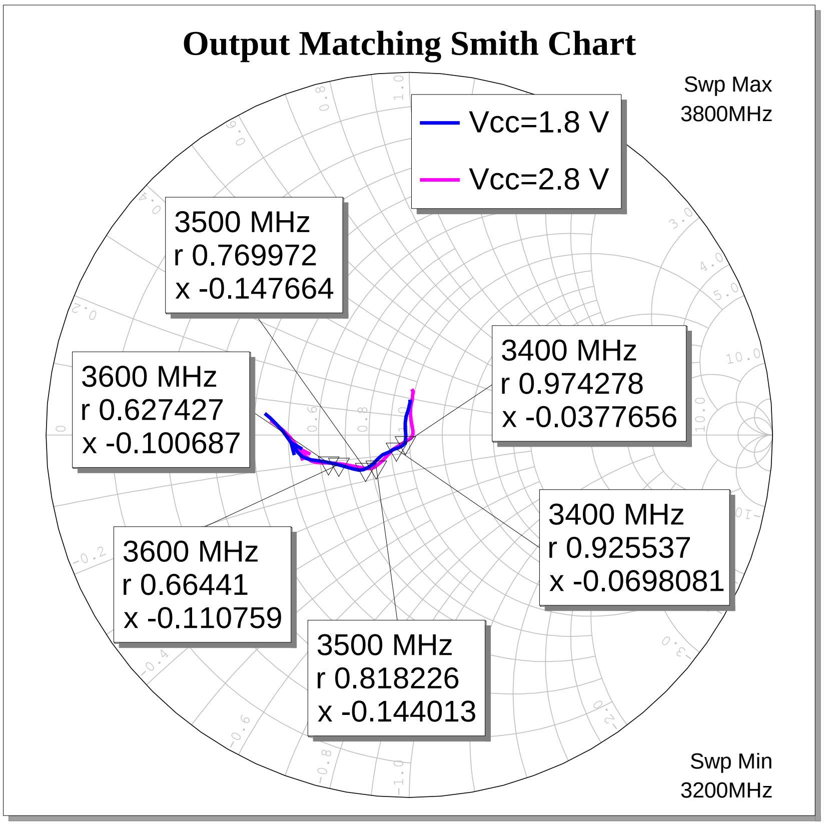

Figure 11 Output Matching (Smith Chart) of the BGA7H1N6 for LTE Band-42

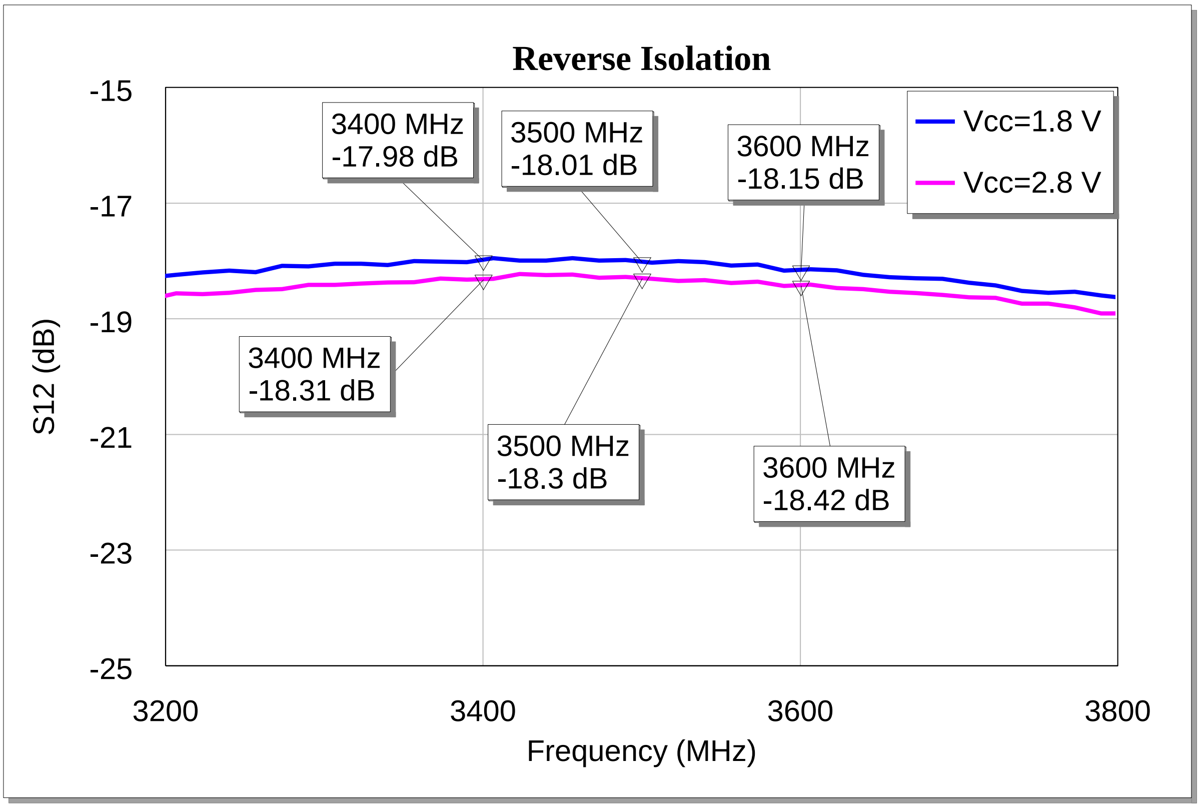

Figure 12 Reverse Isolation of the BGA7H1N6 for LTE Band-42

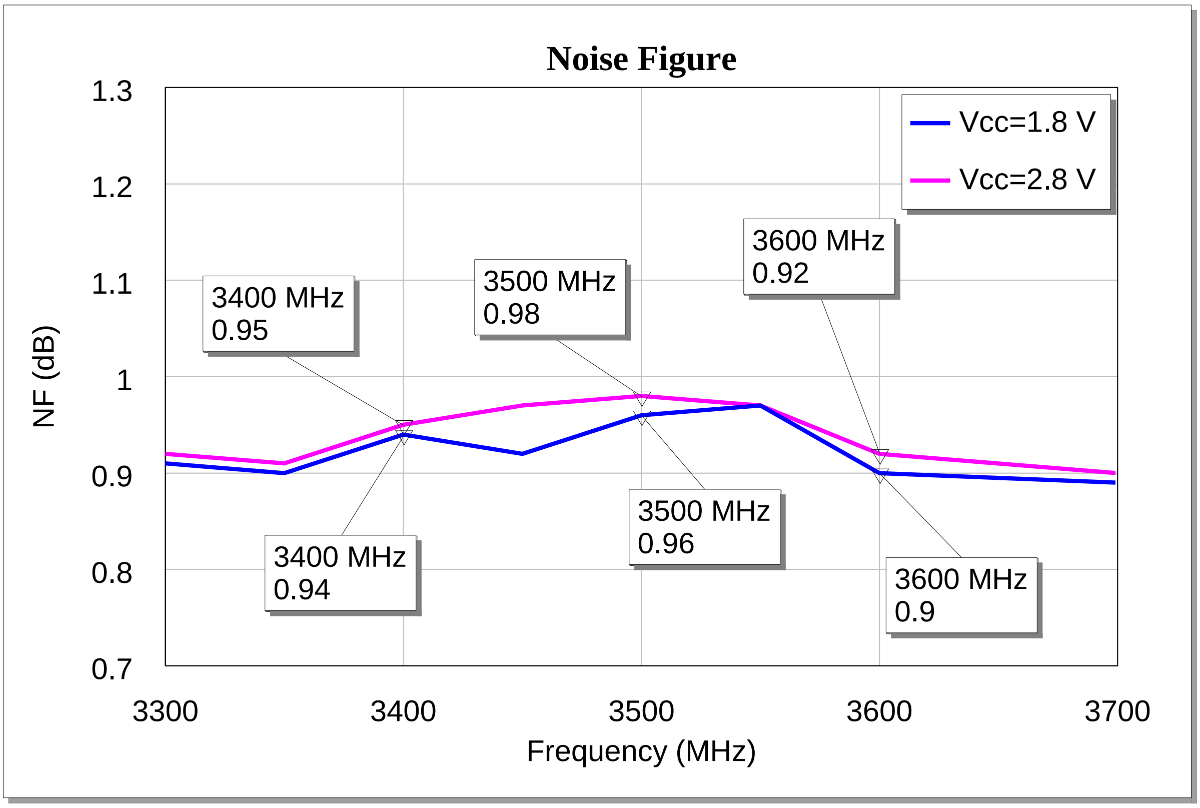

Figure 13 Noise Figure of the BGA7H1N6 for Band-42

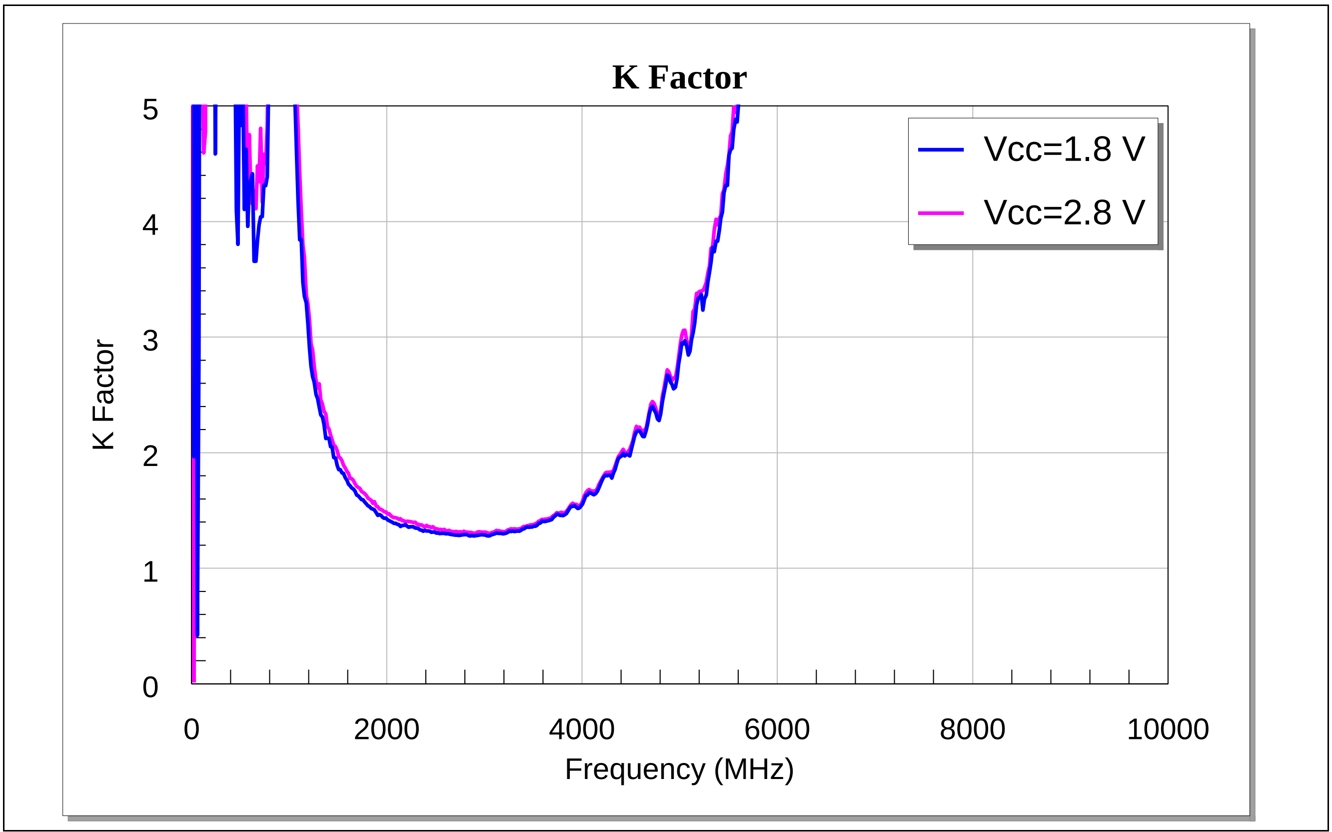

Figure 14 Stability K Factor and Delta Factor of the BGA7H1N6 for LTE Band-42

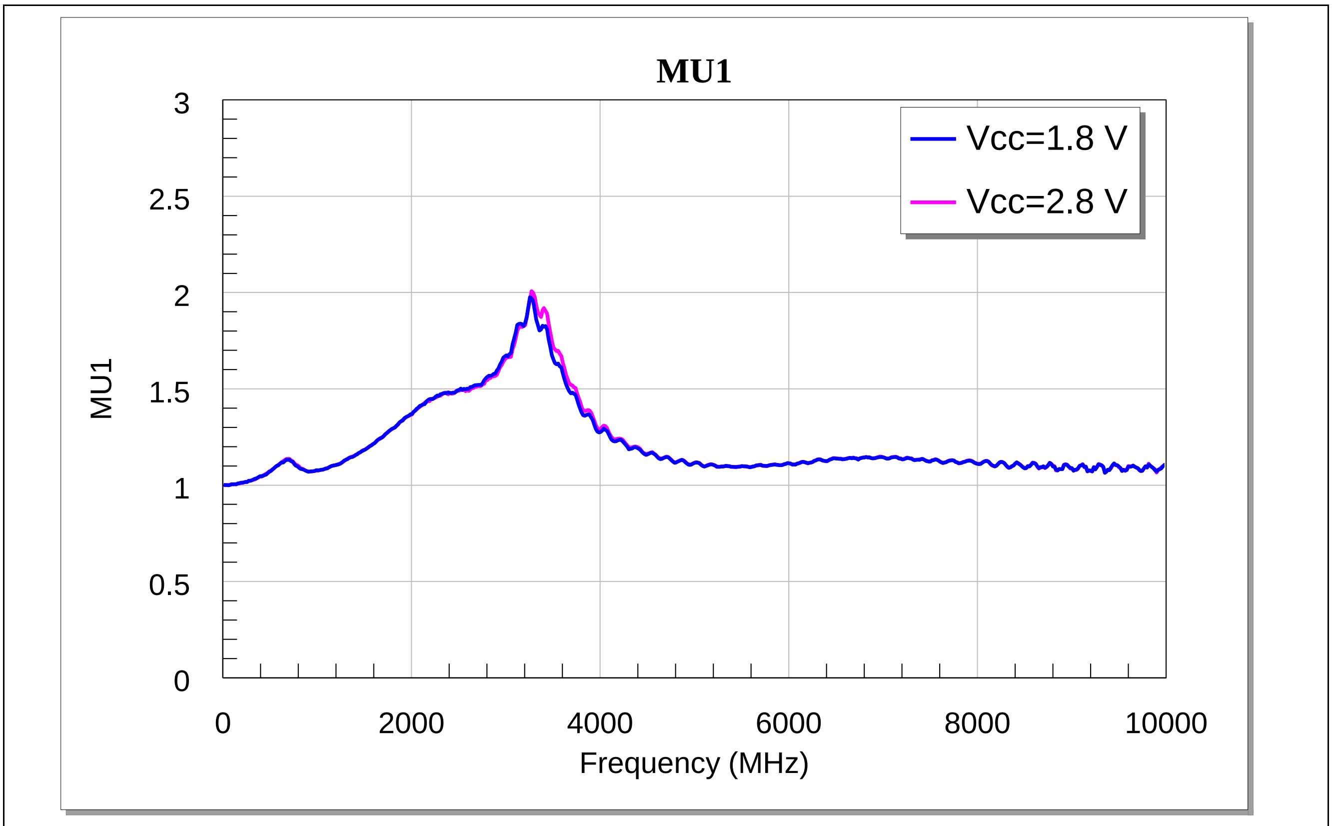

Figure 15 Stability µ1 Factor of the BGA7H1N6 for LTE Band-42

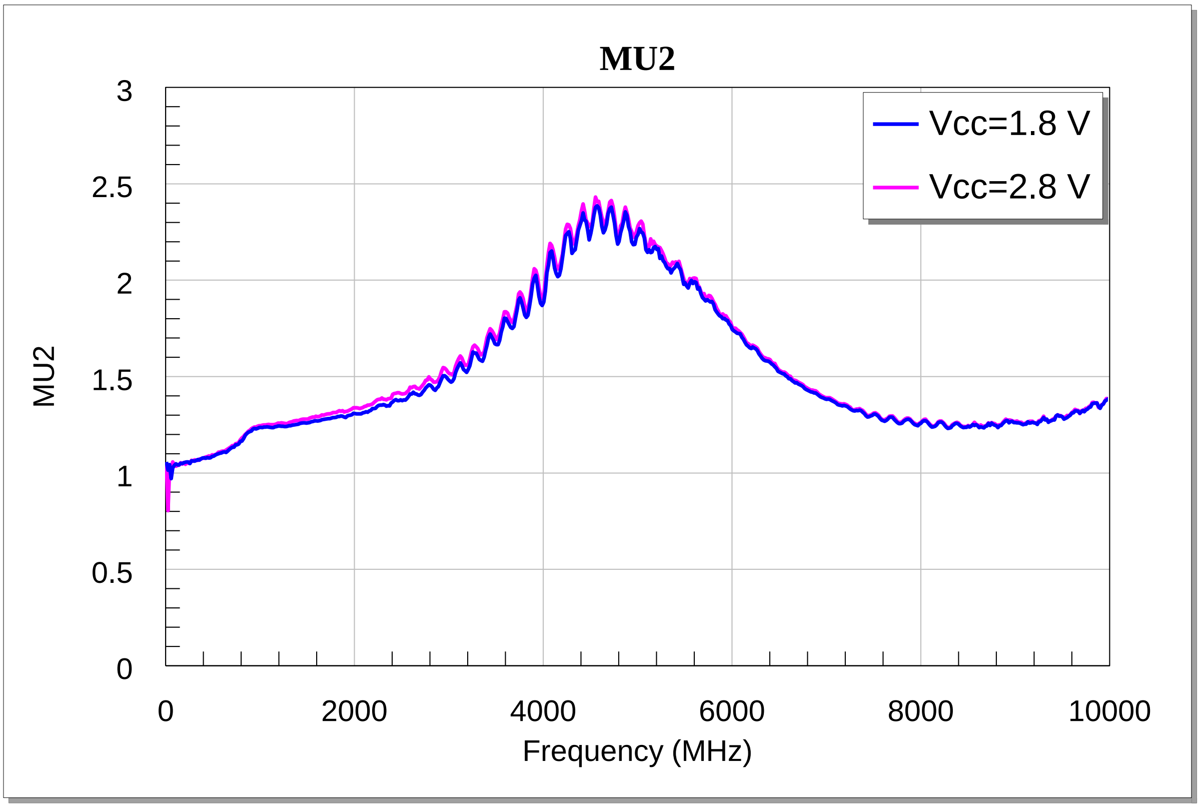

Figure 16 Stability µ2 Factor of the of the BGA7H1N6 for LTE Band-42

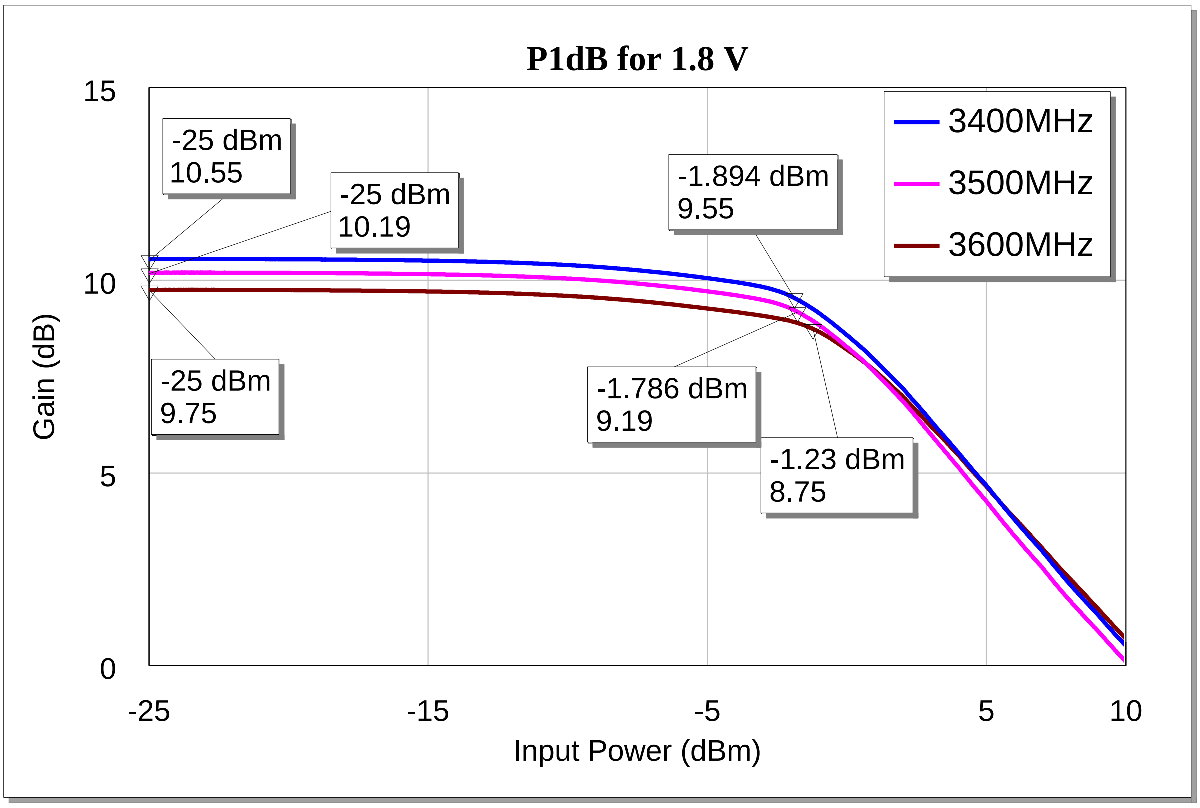

Figure 17 IP1dB of the BGA7H1N6 for LTE Band-42 with 1.8 V power supply

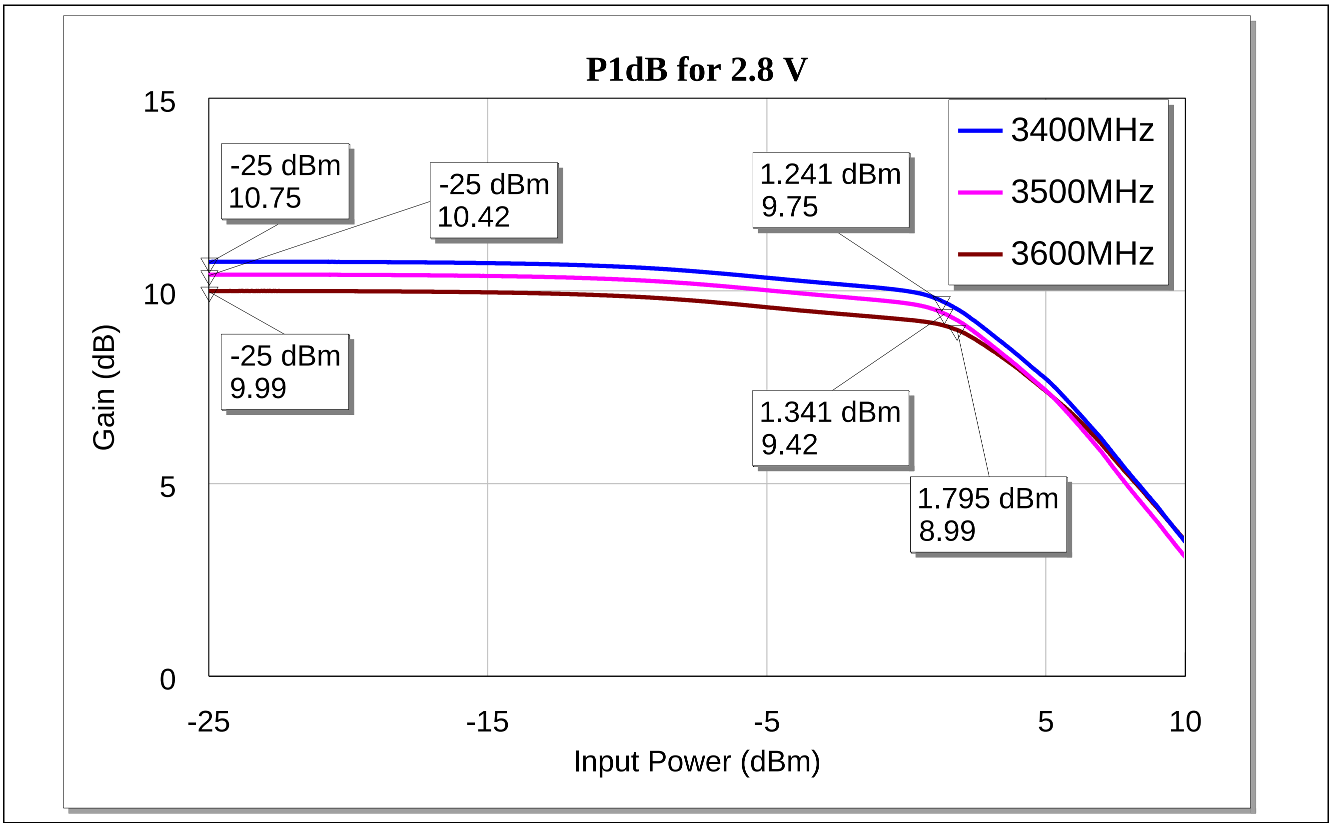

Figure 18 IP1dB of the BGA7H1N6 for LTE Band-42 with 2.8 V power supply

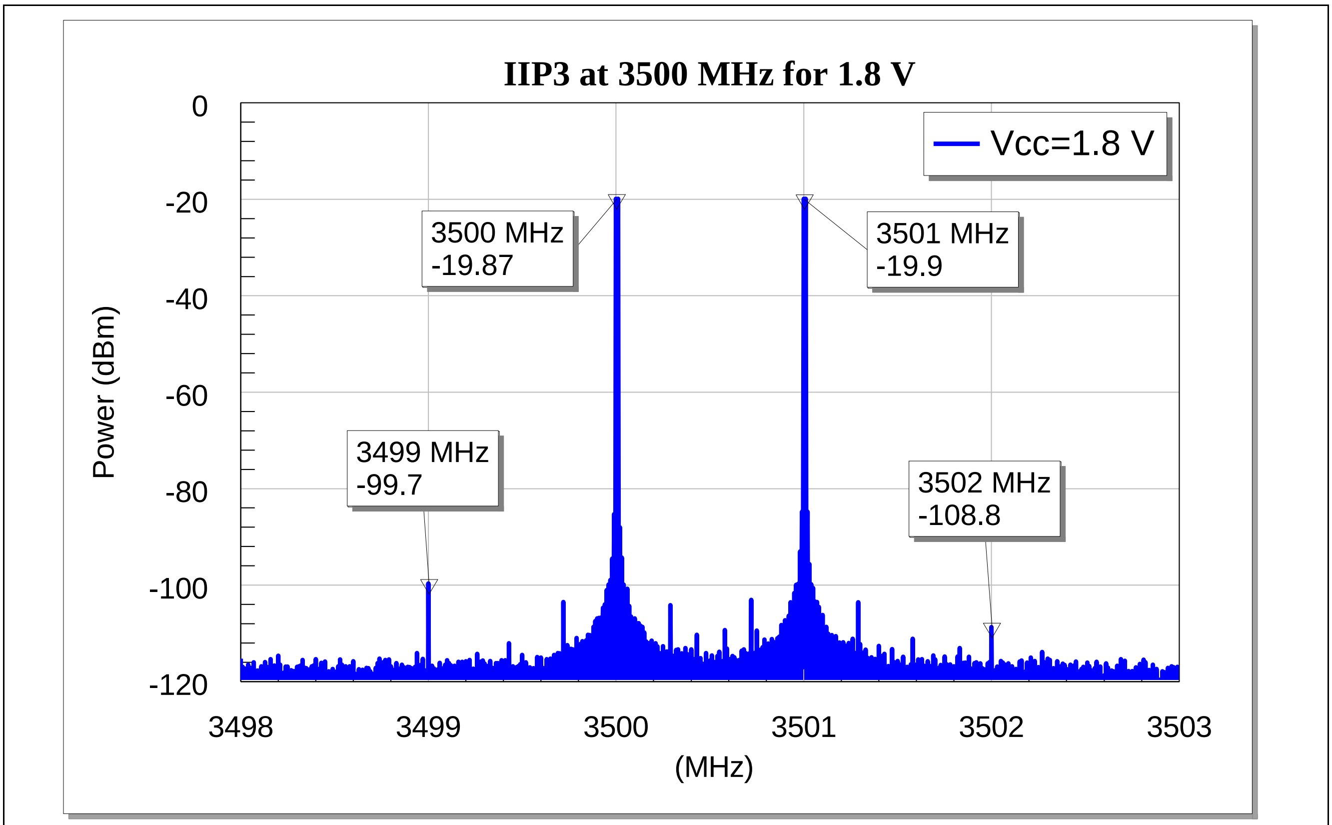

Figure 19 IIP3 Measurement of the BGA7H1N6 for LTE Band-42 with 1.8 V power supply

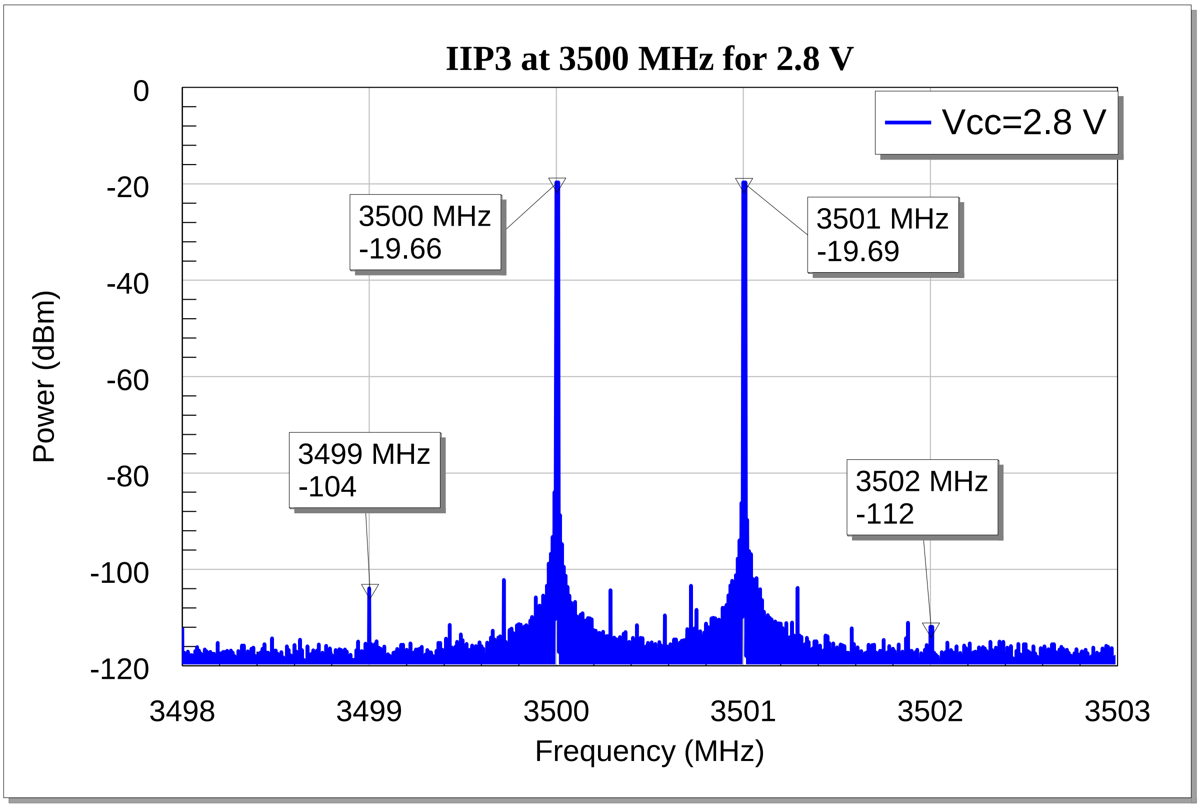

Figure 20 IIP3 Measurement of the BGA7H1N6 for LTE Band-42 with 2.8 V power supply

5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB Marking: **M20150313**

PCB material: **FR4**

ε_r of PCB material: **4.3**

Figure 22 Photo Picture of the Evaluation Board (overview)

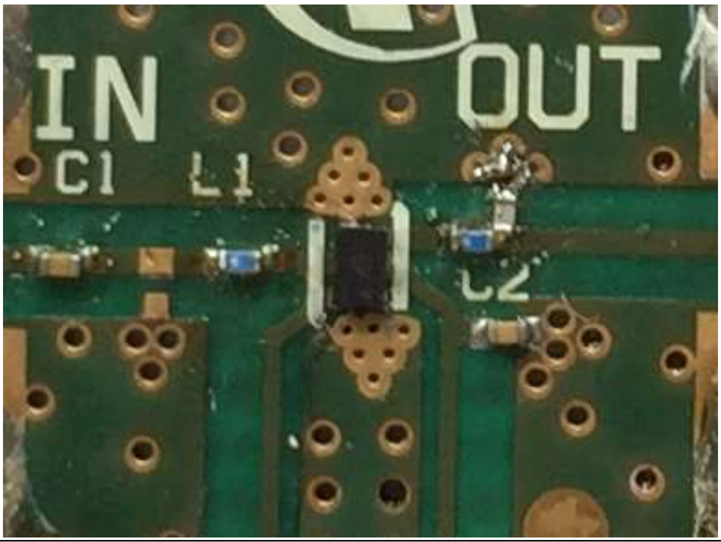

Figure 23 Photo Picture of the Evaluation Board (detailed view)

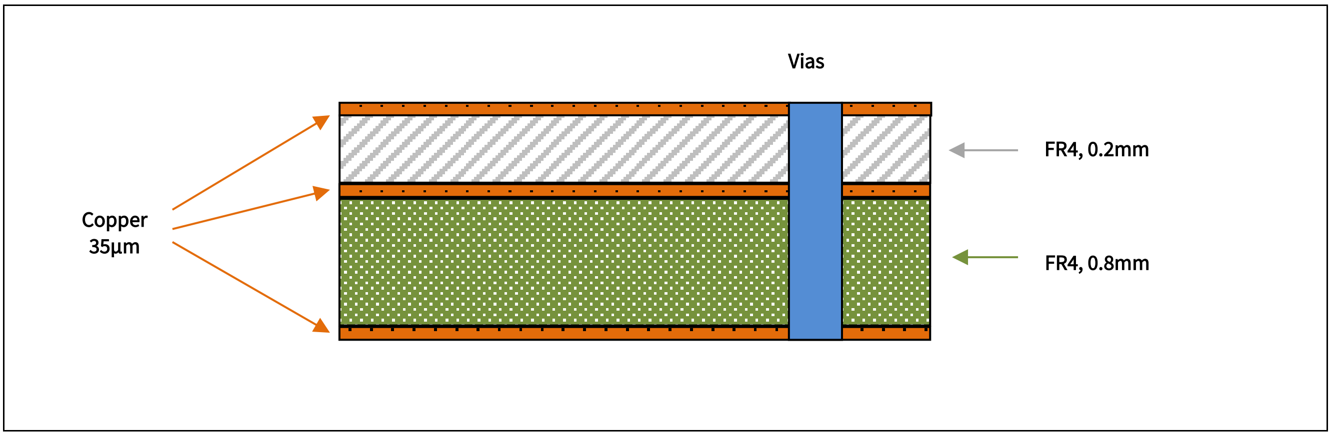

Figure 24 PCB Layer Information

6 Author

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