# Low Noise SiGe: BGA7H1N6

# Single Band LTE LNA Using BGA7H1N6 Supporting Band-7 (2620- 2690 MHz)

Application Note AN406

## About this document

### Scope and purpose

This application note describes Infineon's Low Noise SiGe: BGA7H1N6 as Low Noise Amplifier (LNA) for LTE Single Band-7 applications.

1. This application note presents the measurement and simulation results of a LNA design from 2620 – 2690 MHz for LTE Single Band application purposes.
2. The LNA design presented in this application notes uses Infineon BGA7H1N6 Low Noise Amplifier.
3. The LNA is to be used in many reference designs of chipset vendors but can also be found in customized solutions to compensate losses due to long PCB-traces from the antenna to the transceiver or improve the own system performance beyond the standard.
4. The LNA desing shown in this application note is to increase the data rate and sensitivity of LTE and LTE-Advanced capable mobile phones and data cards.
5. Key performance paramerters achieved (at 2655 MHz)

    a. Noise figure = 0.78 dB

    b. Gain = 12.4 dB

    c. Input return loss = 12.1 dB

    d. Output return loss =23.2 dB

    e. Output P1dB = 7.5 dBm

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

# 1 Introduction

## 1.1 Introduction About 3G and 4G

The mobile technologies for smartphones have seen tremendous growth in recent years. The data rate required from mobile devices has increased significantly over the evolution modern mobile technologies, starting from the first 3G/3.5G technologies (UMTS & WCDMA, HSPA & HSPA+) to the recently 4G LTE-Advanced (LTE-A). LTE-A can support data rates of up to 1 Gbps.

Advanced technologies such as diversity Multiple Input Multiple Output (MIMO) and Carrier Aggregation (CA) are adopted to achieve such higher data rate requirements. MIMO technology, commonly referred as the diversity path in smartphones, has attracted attention for the significant increasement in data throughput and link range without additional bandwidth or increased transmit power. The technology supports scalable channel bandwidth, between 1.4 and 20 MHz. The ability of 4G LTE to support bandwidths up to 20 MHz and to have more spectral efficiency by using high order modulation methods like QAM-64 is of particular importance as the demand for higher wireless data speeds continues to grow fast. Carrier aggregation used in LTE-Advanced combines up to 5 carriers and widens bandwidths up to 100 MHz to increase the user rates, across FDD and TDD.

Countries all over the world have released various frequencies bands for the 4G applications. **Table 1** shows the band assignment for the LTE bands worldwide.

**Table 1 LTE Band Assignment**

| 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 | |

**Table 1 LTE Band Assignment**

| Band No. | Band Definition | Uplink Frequency Range | Downlink Frequency Range | FDD/TDD System | Comment |
|---|---|---|---|---|---|
| 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 | | 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 | |
| 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 | | 1447.9-1462.9 MHz | 1495.9-1510.9 MHz | FDD | |
| 22 | | 3410-3500 MHz | 3510-3600 MHz | FDD | |
| 23 | Mid-Band | 2000-2020 MHz | 2180-2200 MHz | FDD | |
| 24 | | 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 | |
| 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 | | 3400-3600 MHz | | TDD | |
| 43 | | 3600-3800 MHz | | TDD | |
| 44 | Low-Band | 703-803 MHz | | TDD | |

In order to cover all the bands from different countries in a unique device, mobile phones and data cards are usually equipped more bands and band combinations. Some typical examples are quad-band combinations of band 1/2/5/8, 1/3/5/7 and 3/7/5/17. The frequency bands used by TD-LTE are 3.4–3.6 GHz in Australia and UK, 2.57−2.62 GHz in the US and China, 2.545-2.575 GHz in Japan, and 2.3–2.4 GHz in India and Australia.

## 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 pathes, but also for the diversity pathes, 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.

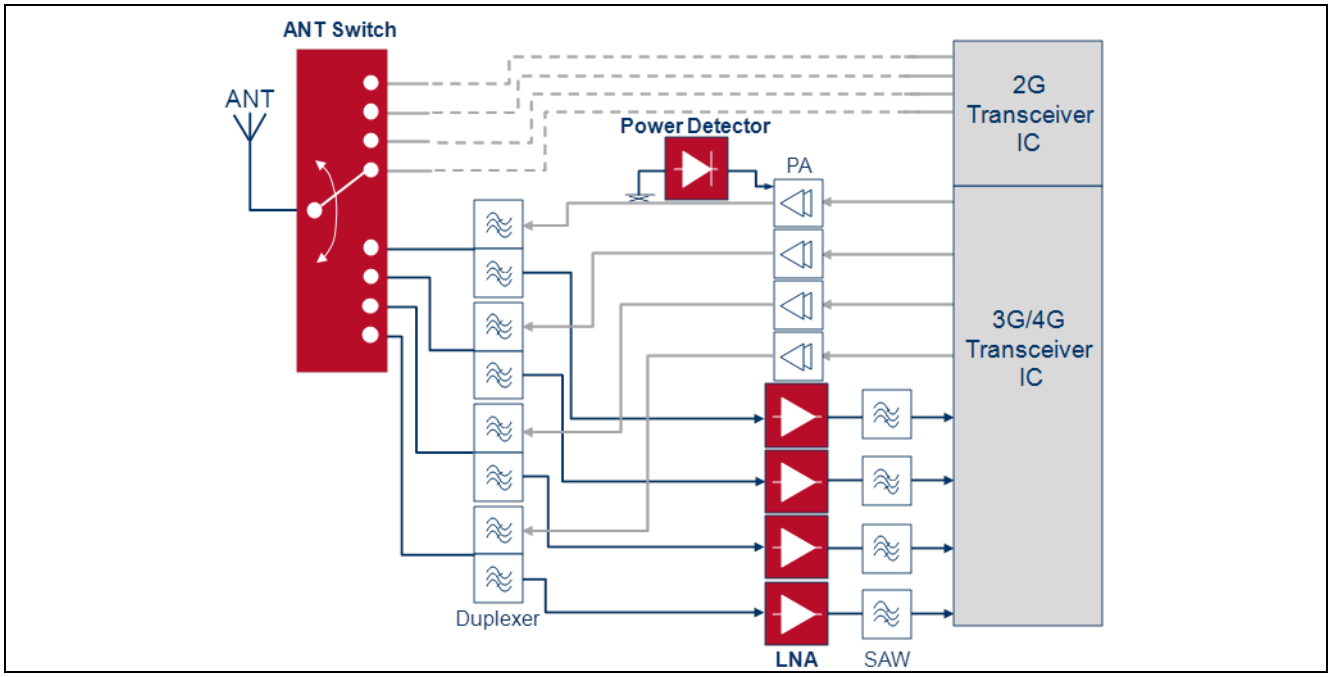



**Figure 1 Example of Application Diagram of RF Front-End for 3G and 4G Systems.**

## 1.3 Infineon LNAs for 3G, 4G LTE and LTE-A 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 can not 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 2**. 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 aggregassion.

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 2 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 | | |
| BGA7L1N6 | | | 1X | |
| **Quad-Band LNA bank** | | | | |
| BGM7MLLH4L12 | 1X | 2X | 1X | |
| BGM7LMHM4L12 | 1X | 2X | 1X | |
| BGM7HHMH4L12 | | 1X | 3X | |
| BGM7MLLM4L12 | 2X | 2X | | |
| BGM7LLHM4L12 | 2X | 1X | 1X | |
| BGM7LLMM4L12 | 2X | 2X | | |

In addition, the older generation of LTE LNAs are featured with gain switching functions which is often helpful for the cases that string or weak signal environment could happen in the field. Error! eference source not found. shows the abailable band combinations:

- Single-band LNAs like BGA777L7 / BGA777N7 for high-band (2300-2700 MHz), BGA711L7 / BGA711N7 for mid-band (MB, 1700-2300 MHz) and BGA751L7 / BGA751N7, BGA728L7/BGA728N7, BGA713L7/BGA713N7 for low-band (LB, 700-1000 MHz) are available.

- Dual-band LNA BGA771L16 supports 1x mid-band (MB, 1700-2300 MHz) and 1x low-band (LB, 700-1000 MHz).

- Triple-band LNAs BGA734N16, BGA735N16 and BGA736N16 are available to cover the most bands. All of the three triple-band LNAs can support designs covering 2x high-bands and 1x low-band.

- Both BGA748N16 and BGA749N16 are quad-band LNAs. BGA748N16 can cover 2x high-and 2x low-bands and BGA749N16 can cover 1x high-band and 3x low-bands.

**Table 3 Infineon Product Portfolio of LNAs for 3G and 4G Applications**

| Frequency Range | 700 MHz – 1 GHz | 1700MHz – 2200MHz | 2100 MHz – 2700 MHz | Comment |
|---|---|---|---|---|
| **Single-Band LNA** | | | | |
| BGA711N7 | | 1X | | |
| BGA713N7 | 1X | | | |
| BGA751N7 | 1X | | | |
| BGA777N7 | | | 1X | |
| BGA728L7 | 1X | 1X | | |
| **Dual Band LNA** | | | | |
| BGA771N16 | 1X | 1X | | |
| **Triple Band LNA** | | | | |
| BGA735N16 | 1X | 1X | 1X | |
| BGA736L16 | 1X | 1X | 1X | |
| **Quad-band LNA** | | | | |
| BGA748L16 | 2X | | 2X | |
| BGA749N16 | 3X | | 1X | |

# 2 BGA7H1N6 Overview

## 2.1 Features

- 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: 1.5 V to 3.3 V
- Digital on/off switch (1V 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
- 2kV HBM ESD protection (including AI-pin)
- Pb-free (RoHS compliant) package

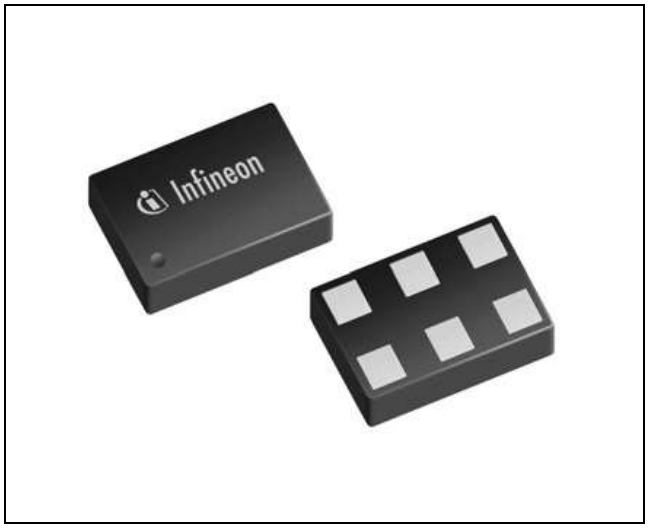



**Figure 2 BGA7H1N6 in TSNP-6-2**

## 2.2 Key Applications of BGA7H1N6

As Low Noise Amplifier (LNA) to support 4G LTE and LTE-A 3G/4G/LTE/LTE-Advanced applications for mobile phones and data cards.

## 2.3 Description

The BGA7H1N6 is a front-end low noise amplifier for LTE 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 3.3 V supply voltage.

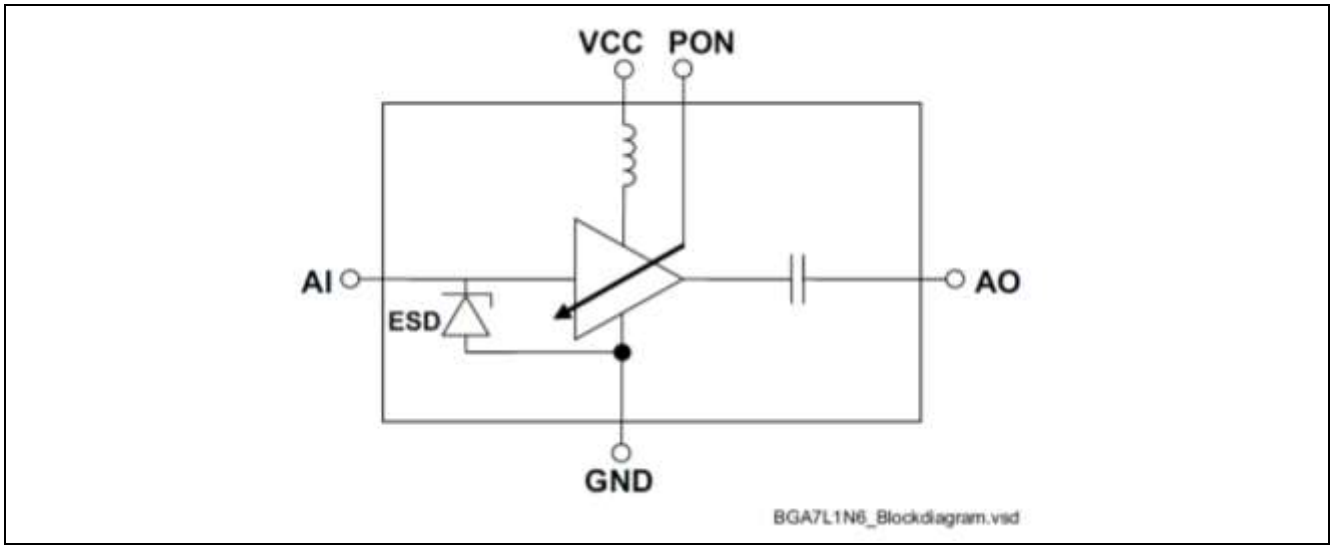



**Figure 1 Equivalent Circuit of BGA7H1N6**

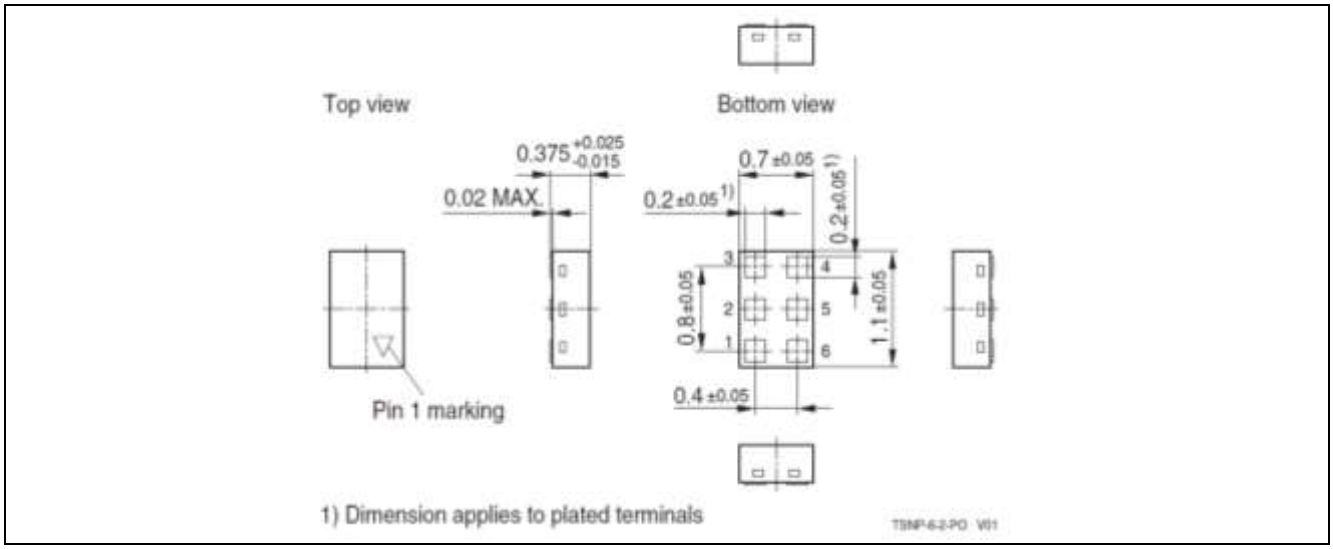



**Figure 2 Package and pin connections of BGA7H1N6**

**Table 4 Pin Assignment of BGA7H1N6**

| Pin No. | Symbol | Function |
|---|---|---|
| 1 | GND | Ground |
| 2 | VCC | Supply Voltage |
| 3 | AO | LNA output |
| 4 | GND | Ground |
| 5 | AI | LNA input |
| 6 | PON | Power on control |

# 3 Application Circuit and Performance Overview

**Device:** **BGA7H1N6**
**Application:** **Low Noise Amplifier for LTE Band 7 Application (2620 – 2690 MHz)**
**PCB Marking:** **BGA7x1N6 V1.0**
**EVB Order No.:** **AN406**

## 3.1 Summary of Measurement Results

**Table 5** **Electrical Characteristics (at room temperature) for Band-7 (2620 – 2690 MHz), $V_{CC}$ = 1.8 V, $V_{PON}$ = 1.8 V**

| Parameter | Symbol | Value | | | Unit | Comment/Test Condition |
|---|---|---|---|---|---|---|
| Frequency Range | Freq | 2620 | 2655 | 2690 | MHz | |
| DC Voltage | Vcc | 1.8 | | | V | |
| DC Current | Icc | 4.8 | | | mA | |
| Gain | G | 12.5 | 12.4 | 12.3 | dB | |
| Noise Figure | NF | 0.79 | 0.78 | 0.78 | dB | PCB and SMA loses 0.1 dB are substracted |
| Input Return Loss | RLin | 11.6 | 12.1 | 12.6 | dB | |
| Output Return Loss | RLout | 20.4 | 23.2 | 25.9 | dB | |
| Reverse Isolation | IRev | 19.4 | 19.3 | 19.2 | dB | |
| Input P1dB | IP1dB | -4.9 | | | dBm | Measured at f = 2655 MHz |
| Output P1dB | OP1dB | 6.5 | | | dBm | Measured at f = 2655 MHz |
| Input IP3 | IIP3 | 5.7 | | | dBm | Power @ Input: -35 dBm $f_1$=2655 MHz, $f_2$=2656 MHz |
| Output IP3 | OIP3 | 18.1 | | | dBm | |
| Stability | k | >1 | | | -- | Measured up to 10 GHz |

**Table 6 Electrical Characteristics (at room temperature) ) for Band-7 (2620 – 2690 MHz), $V_{CC}$ = 2.8 V, $V_{PON}$ = 2.8 V**

| Parameter | Symbol | Value | | | Unit | Comment/Test Condition |
|---|---|---|---|---|---|---|
| Frequency Range | Freq | 2620 | 2655 | 2690 | MHz | |
| DC Voltage | Vcc | 2.8 | | | V | |
| DC Current | Icc | 4.9 | | | mA | |
| Gain | G | 12.6 | 12.5 | 12.5 | dB | |
| Noise Figure | NF | 0.79 | 0.79 | 0.78 | dB | PCB and SMA loses 0.1 dB are substracted |
| Input Return Loss | RLin | 11.9 | 12.4 | 12.9 | dB | |
| Output Return Loss | RLout | 19.5 | 22.7 | 27.2 | dB | |
| Reverse Isolation | IRev | 19.7 | 19.6 | 19.5 | dB | |
| Input P1dB | IP1dB | -1.6 | | | dBm | Measured at f = 2655 MHz |
| Output P1dB | OP1dB | 9.9 | | | dBm | Measured at f = 2655 MHz |
| Input IP3 | IIP3 | 6.3 | | | dBm | Power @ Input: -35 dBm $f_1$=2655 MHz, $f_2$=2656 MHz |
| Output IP3 | OIP3 | 18.8 | | | dBm | |
| Stability | k | >1 | | | -- | Measured up to 10 GHz |

## 3.2 BGA7H1N6 as Low Noise Amplifier for LTE Single Band-7 (2620 – 2690 MHz) Application

This application note focuses on the Infineon's Single-Band LTE LNA, BGA7H1N6 tuned for the Band-7. 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 12.4 dB. It achieves input return loss as well as output return loss better than 11 dB. The input 1 dB compression point is -4.9 dBm at 2655 MHz. Using two tones spacing of 1 MHz, the input third order intercept point (IIP3) reaches 5.7 dBm at 2655 MHz. At room temperature the noise figure is 0.78 dB excluding SMA and PCB losses.

At 2.8 V, the circuit offers a gain of 12.5 dB. It achieves input return loss as well as output return loss better than 11 dB. The input 1 dB compression point is -1.6 dBm at 2655 MHz. Using two tones spacing of 1 MHz, the input third order intercept point (IIP3) reaches 6.3 dBm at 2655 MHz. At room temperature the noise figure is 0.79 dB excluding SMA and PCB losses.

Furthermore, the circuit is measured unconditionally stable till 10 GHz. All the measurements are done with the standard evaluation board presented at the end of this application note.

## 3.3 Schematics and Bill-of-Materials

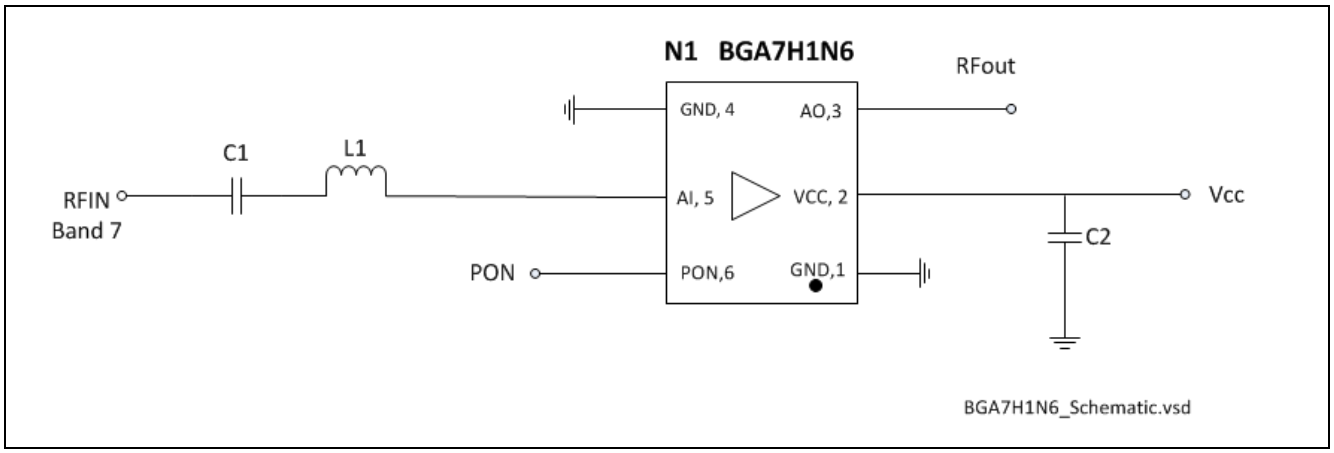



**Figure 3 Schematics of the BGA7H1N6 Application Circuit**

**Table 7 Bill-of-Materials**

| Symbol | Value | Unit | Size | Manufacturer | Comment |
|---|---|---|---|---|---|
| C1 | 1 | nF | 0402 | Various | DC block (optional) |
| C2 | 1 | nF | 0402 | Various | RF to ground (optional) |
| L1 | 3.3 | nH | 0402 | Murata LQW series | Input matching |
| N1 | BGA7H1N6 | TSNP-6-2 | | Infineon | SiGe LNA |

# 4 Measurement Graphs

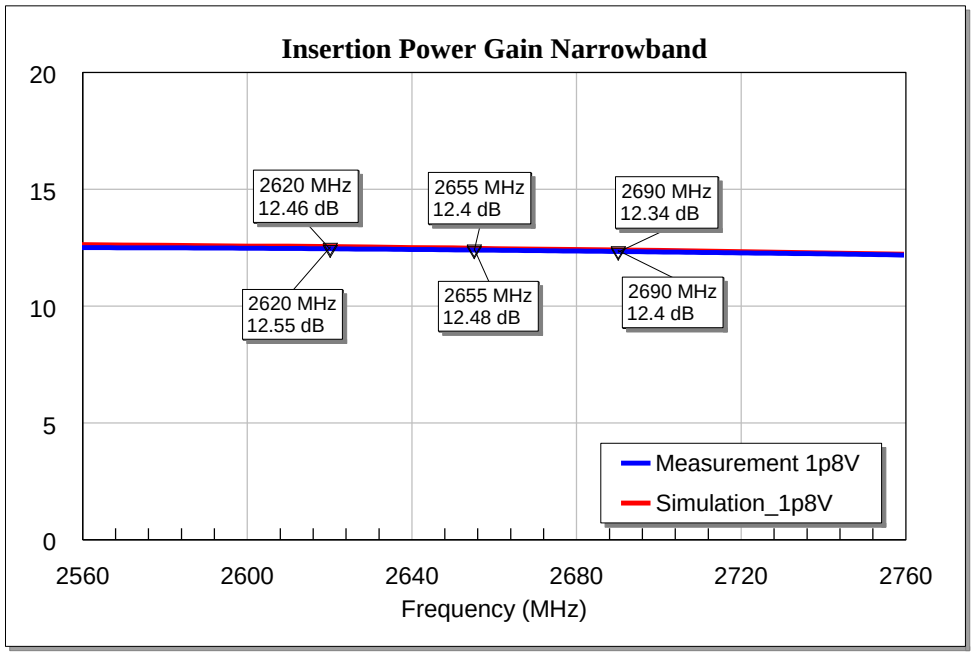



**Figure 4 Insertion Power Gain (Narrowband) of the BGA7H1N6 for LTE Band-7 at Vcc = 1.8 V**

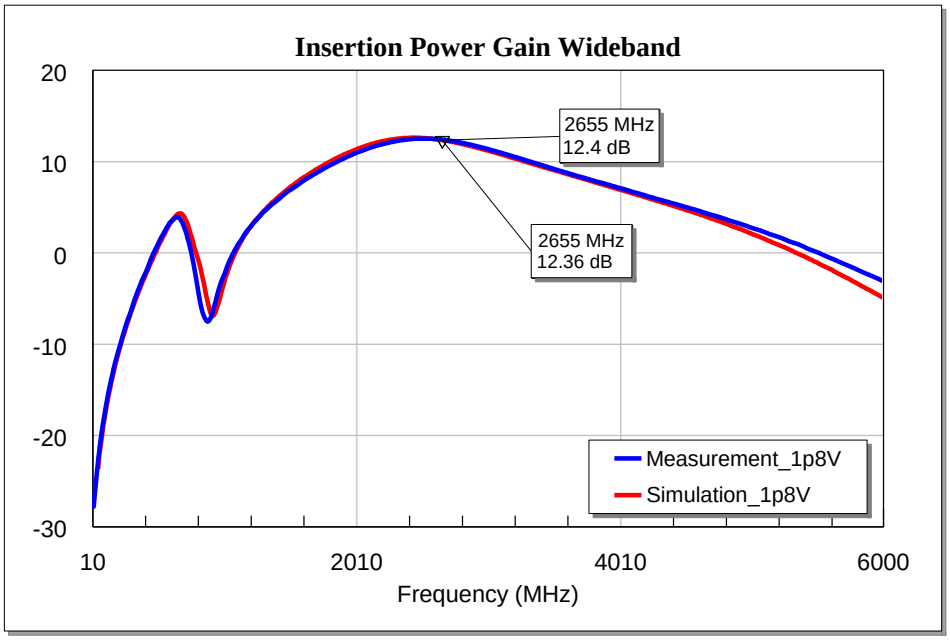



**Figure 5 Insertion Power Gain (Wideband) of the BGA7H1N6 for LTE Band-7 at Vcc = 1.8 V**

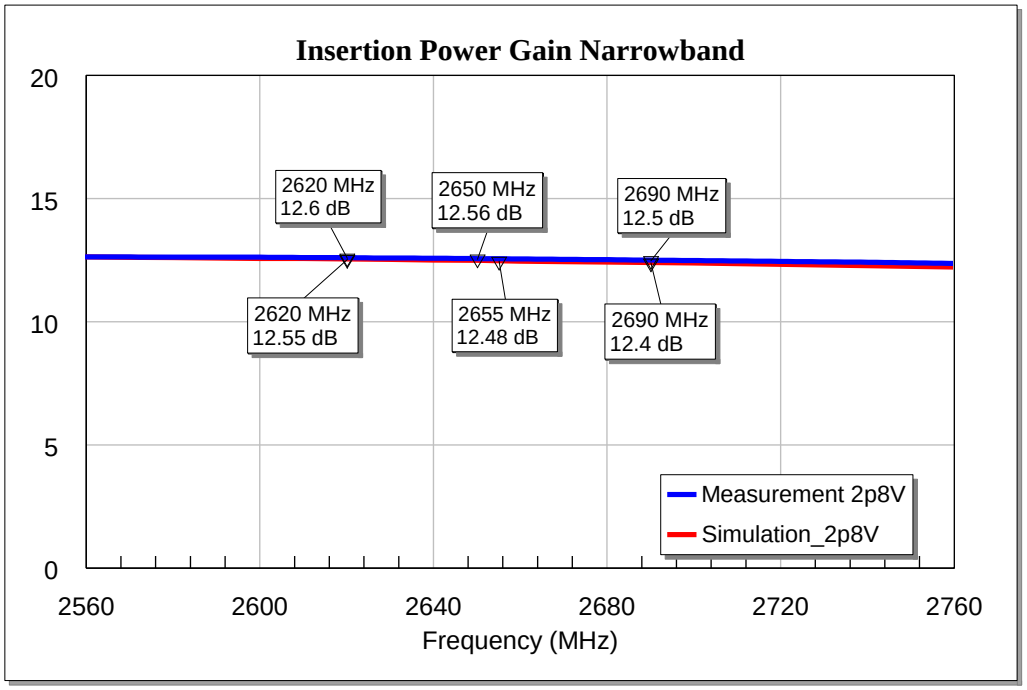



**Figure 6 Insertion Power Gain (Narrowband) of the BGA7H1N6 for LTE Band-7 at Vcc = 2.8 V**

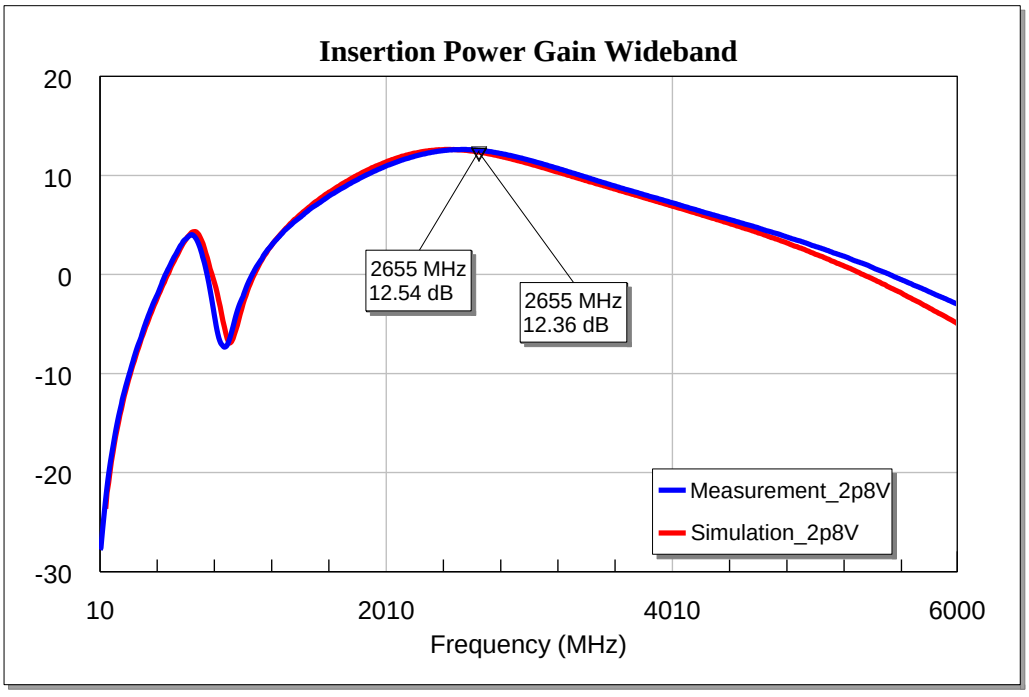



**Figure 7 Insertion Power Gain (Wideband) of the BGA7H1N6 for LTE Band-7 at Vcc = 2.8 V**

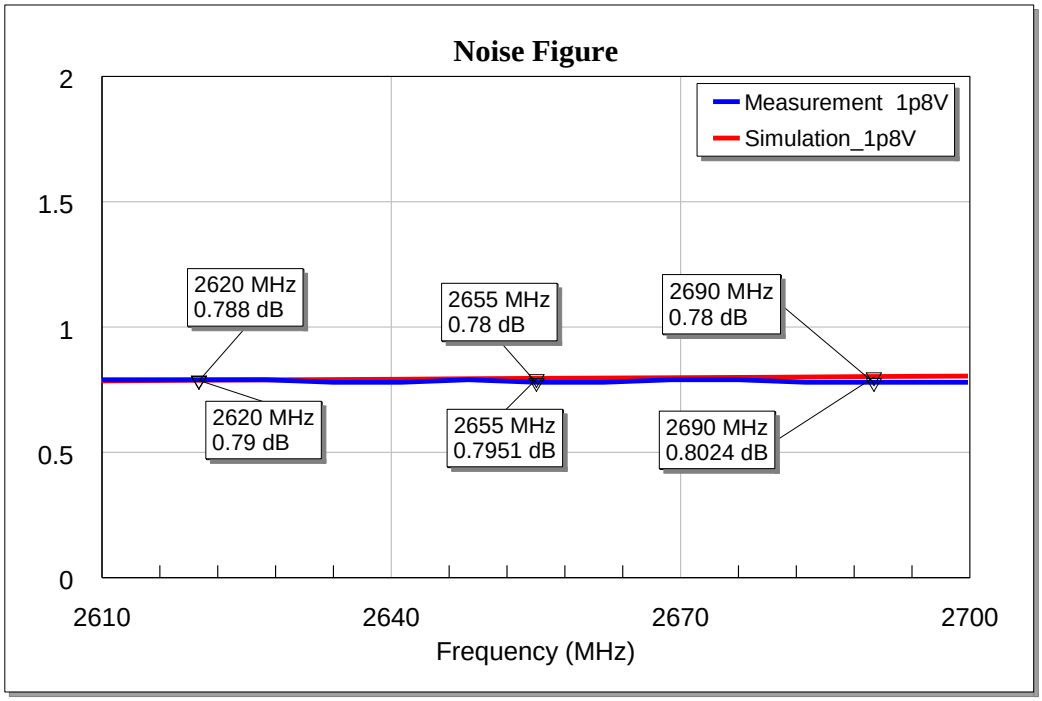



**Figure 8 Noise Figure of the BGA7H1N6 for LTE Band-7 Application at Vcc = 1.8 V**

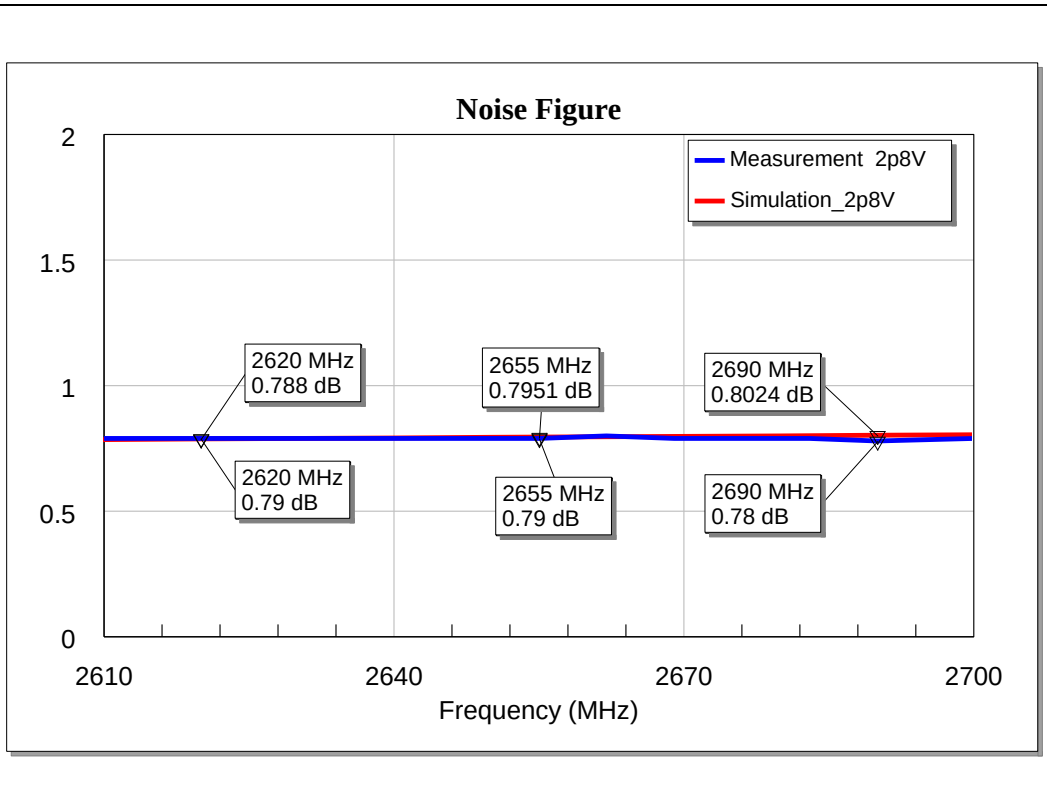



**Figure 9 Noise Figure of the BGA7H1N6 for LTE Band-7 Application at Vcc = 2.8 V**

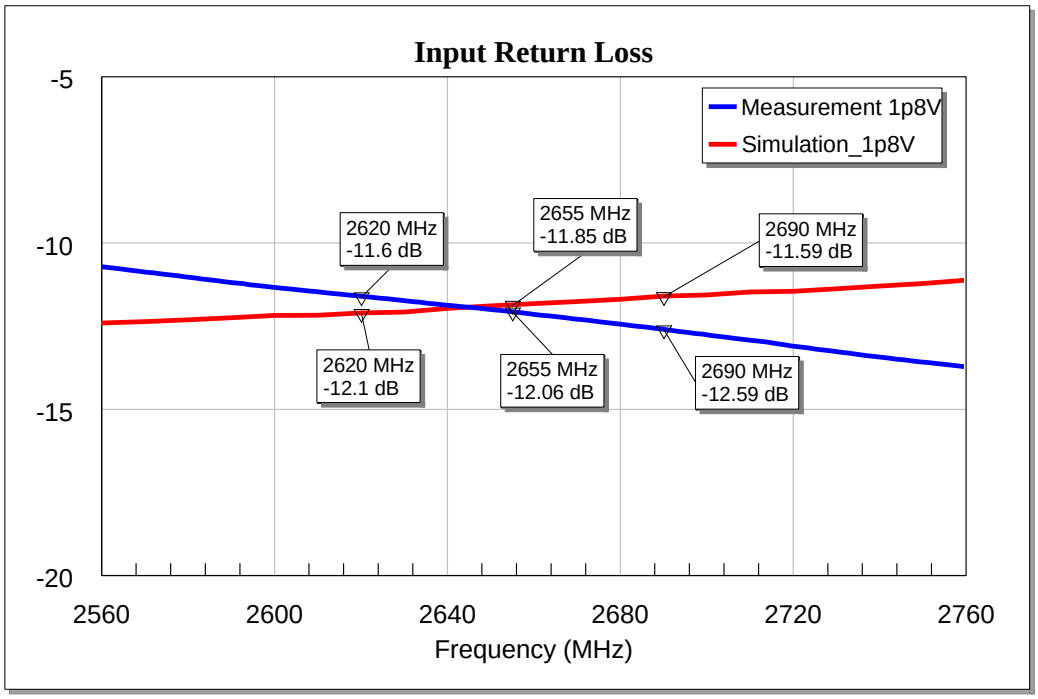



**Figure 10 Input Matching of the BGA7H1N6 for LTE Band-7 Application at Vcc = 1.8 V**

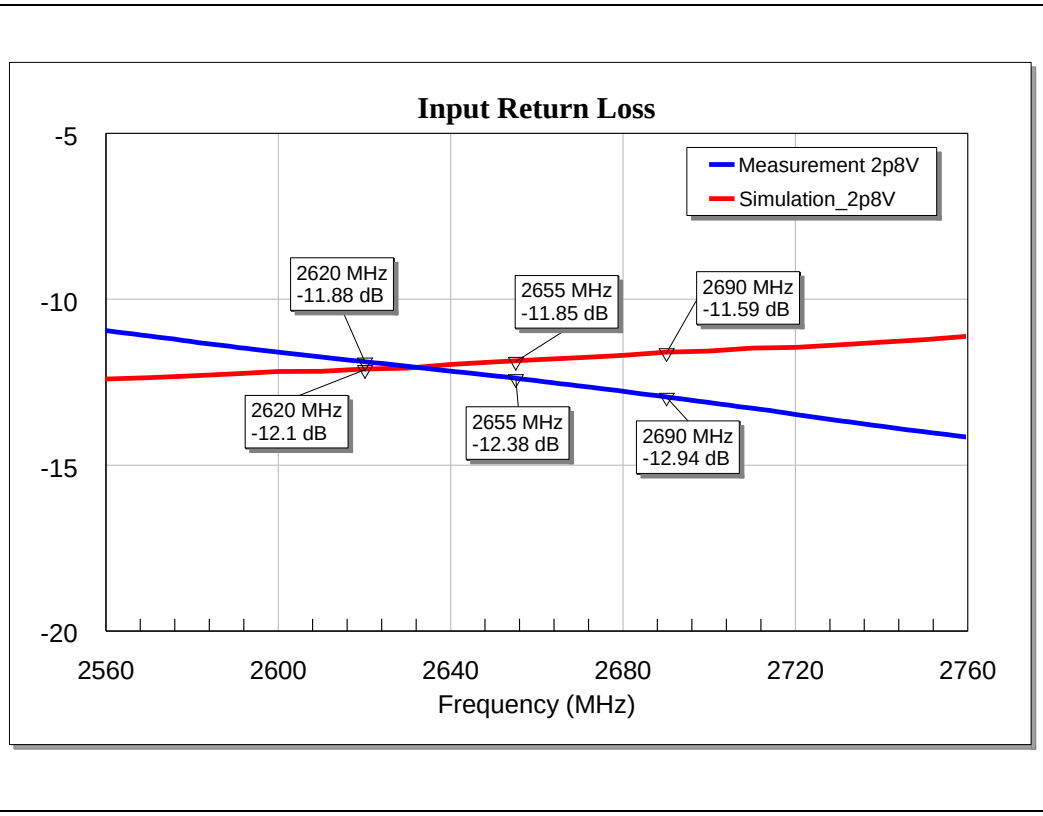



**Figure 11 Input Matching of the BGA7H1N6 for LTE Band-7 Application at Vcc = 2.8 V**

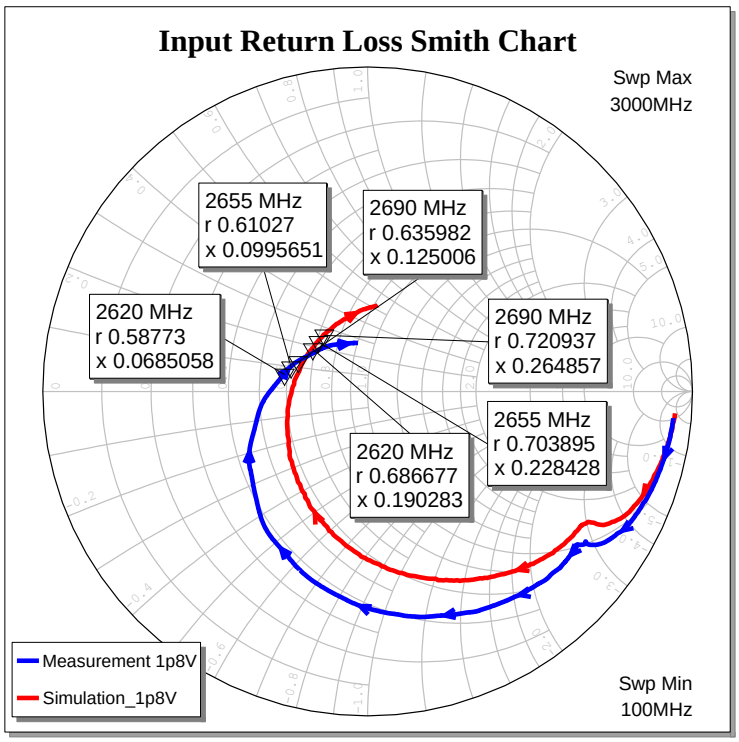



**Figure 12 Input Matching (Smith Chart) of the BGA7H1N6 for LTE Band-7 Application at Vcc = 1.8 V**

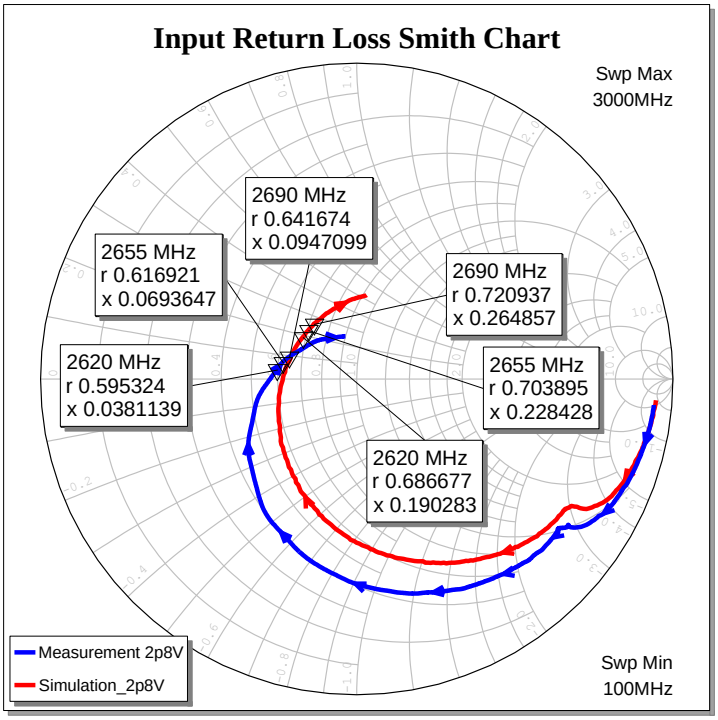



**Figure 13 Input Matching (Smith Chart) of the BGA7H1N6 for LTE Band-7 Application at Vcc = 2.8 V**

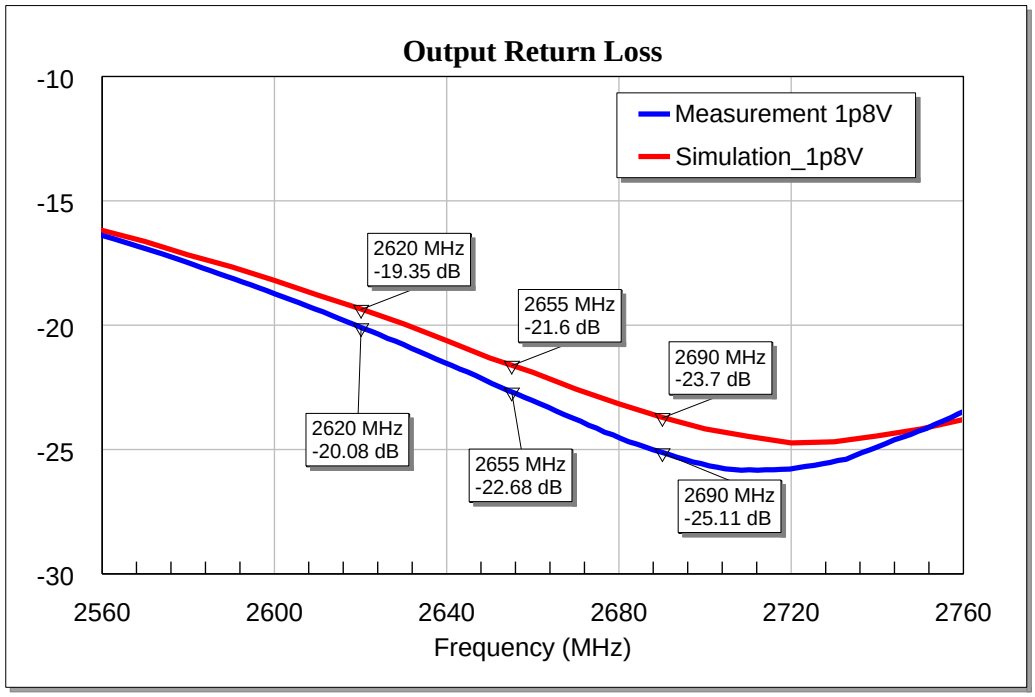



**Figure 14 Output Matching of the BGA7H1N6 for LTE Band-7 Application at Vcc = 1.8 V**

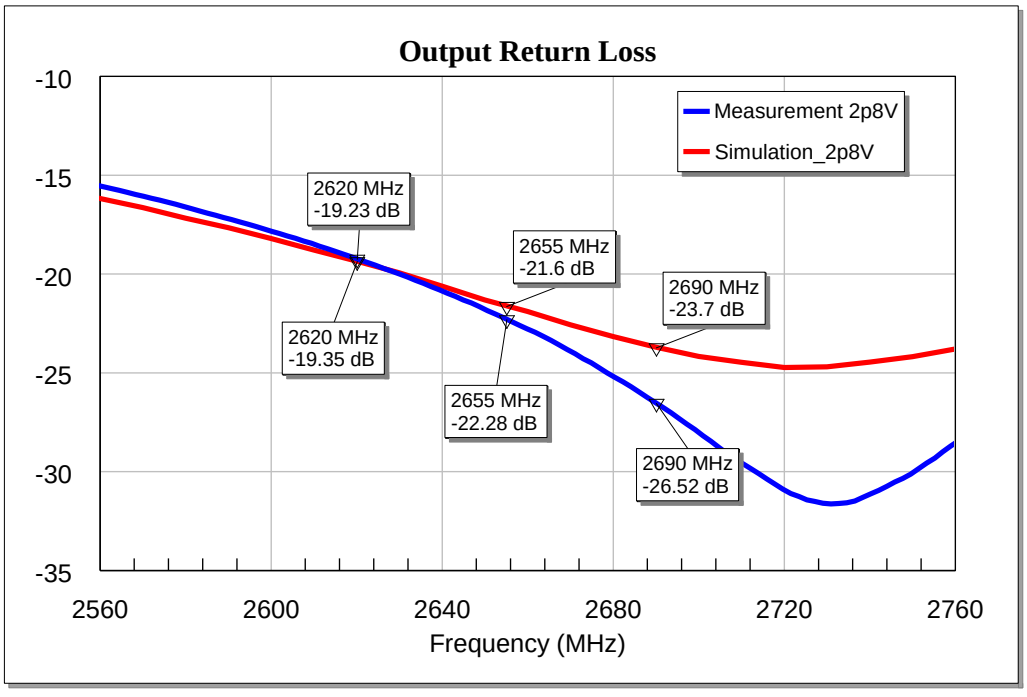



**Figure 15 Output Matching of the BGA7H1N6 for LTE Band-7 Application at Vcc = 2.8 V**

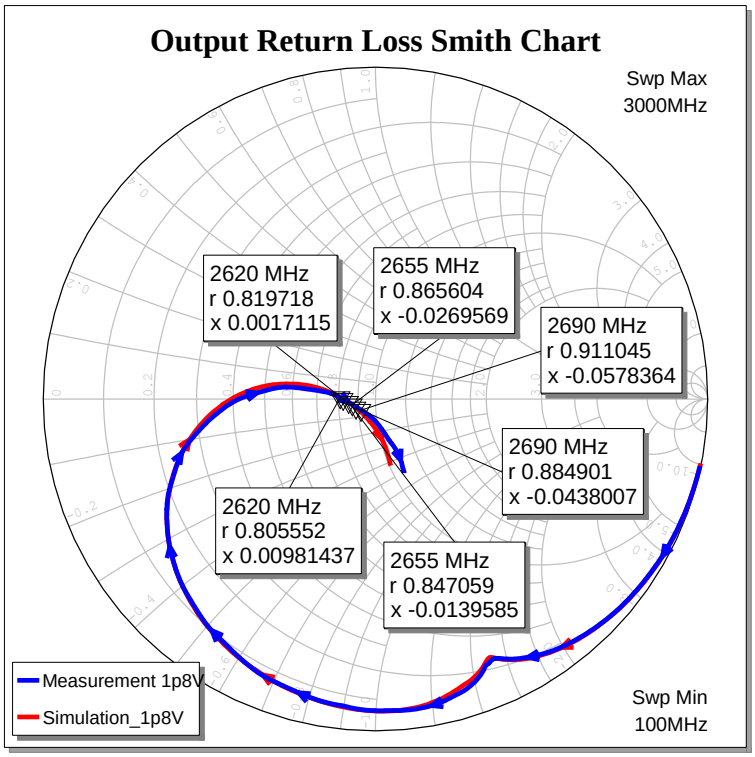



**Figure 16 Output Matching (Smith Chart) of the BGA7H1N6 for LTE Band-7 Application at Vcc = 1.8 V**

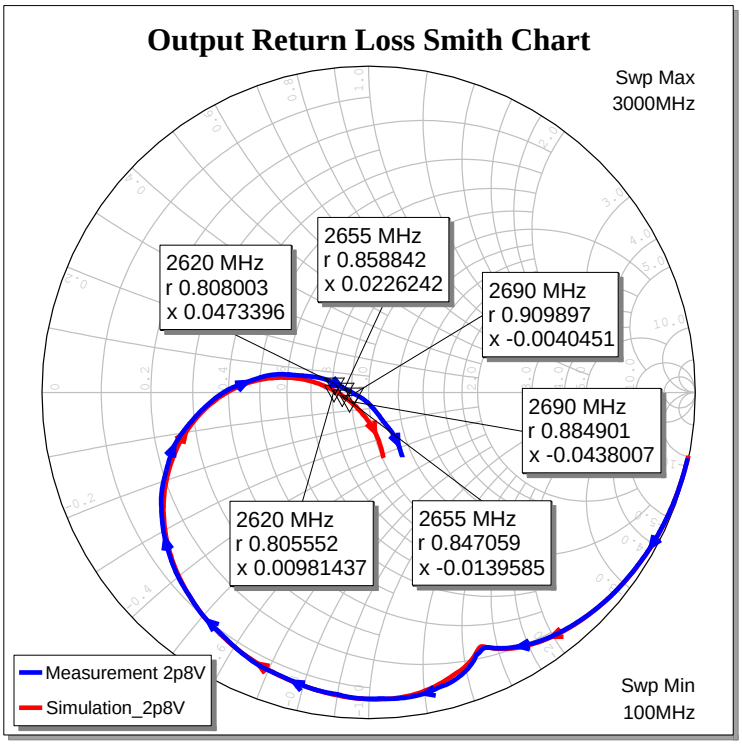



**Figure 17 Output Matching (Smith Chart) of the BGA7H1N6 for LTE Band-7 Application at Vcc = 2.8 V**

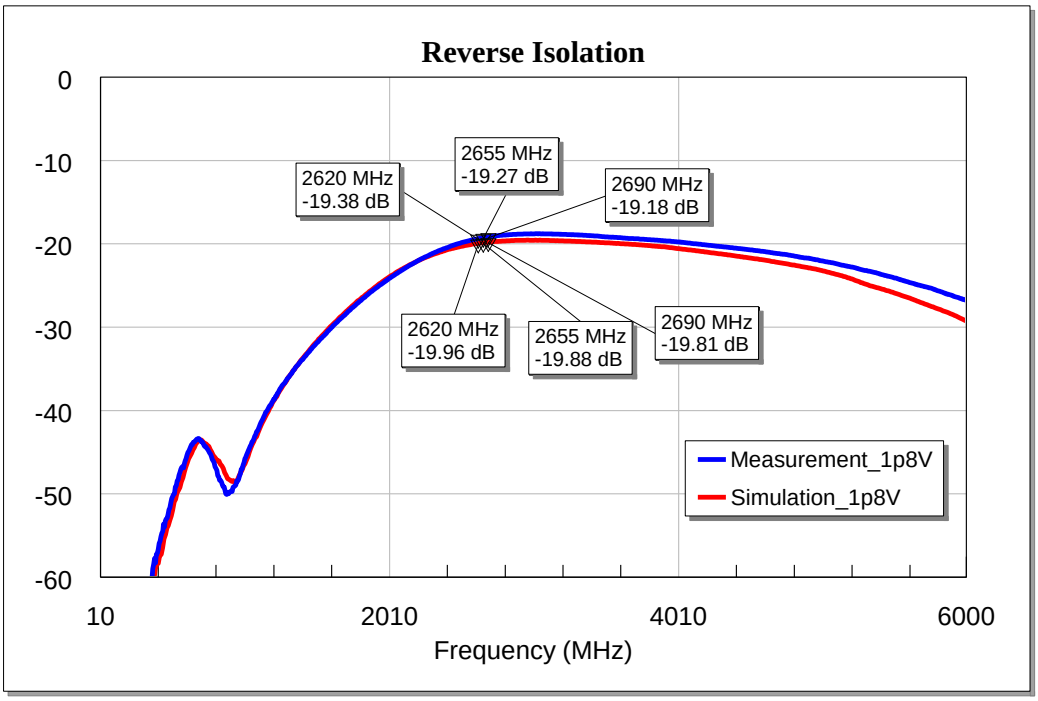



**Figure 18 Reverse Isolation of the BGA7H1N6 for LTE Band-7 Application at Vcc = 1.8 V**

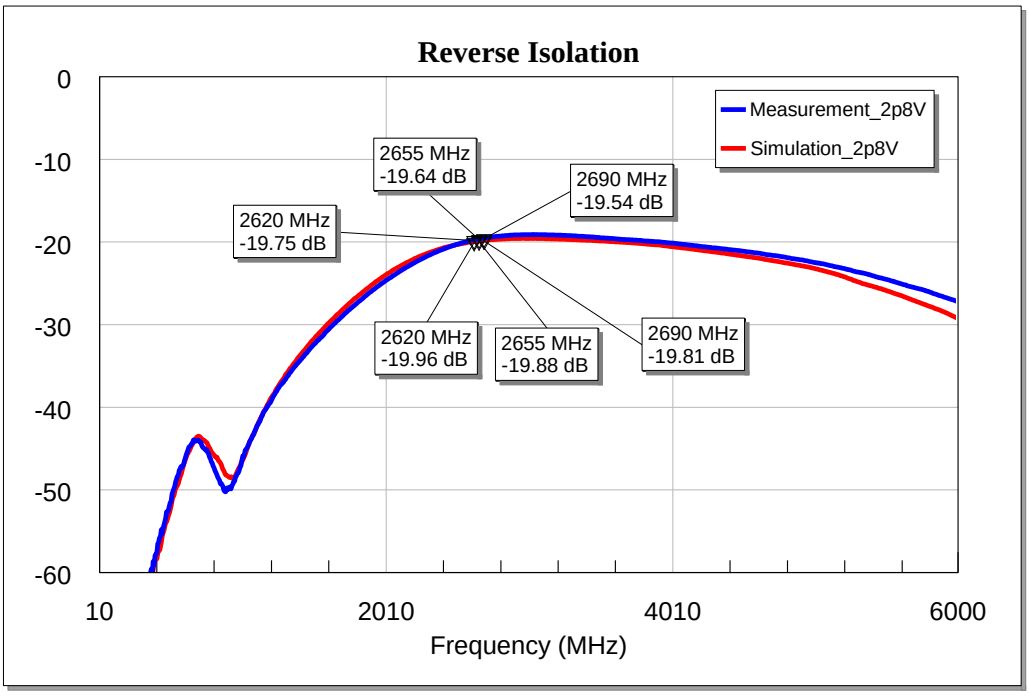



**Figure 19 Reverse Isolation of the BGA7H1N6 for LTE Band-7 Application at Vcc = 2.8 V**

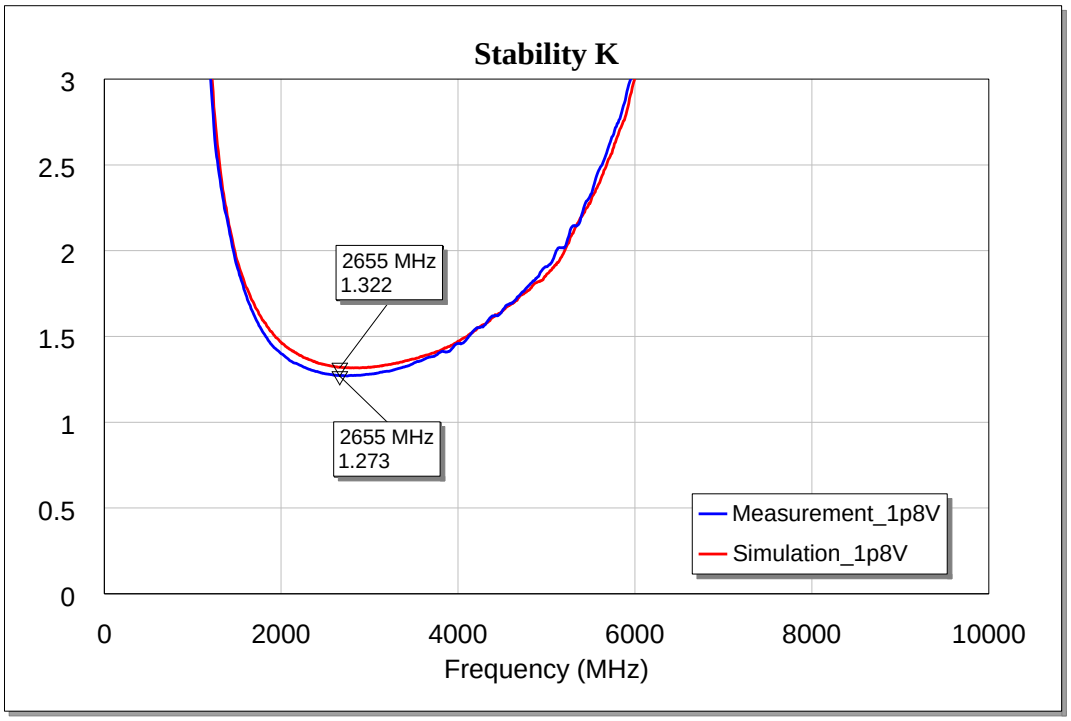



**Figure 20 Stability K-factor of the BGA7H1N6 for LTE Band-7 Application at Vcc = 1.8 V**

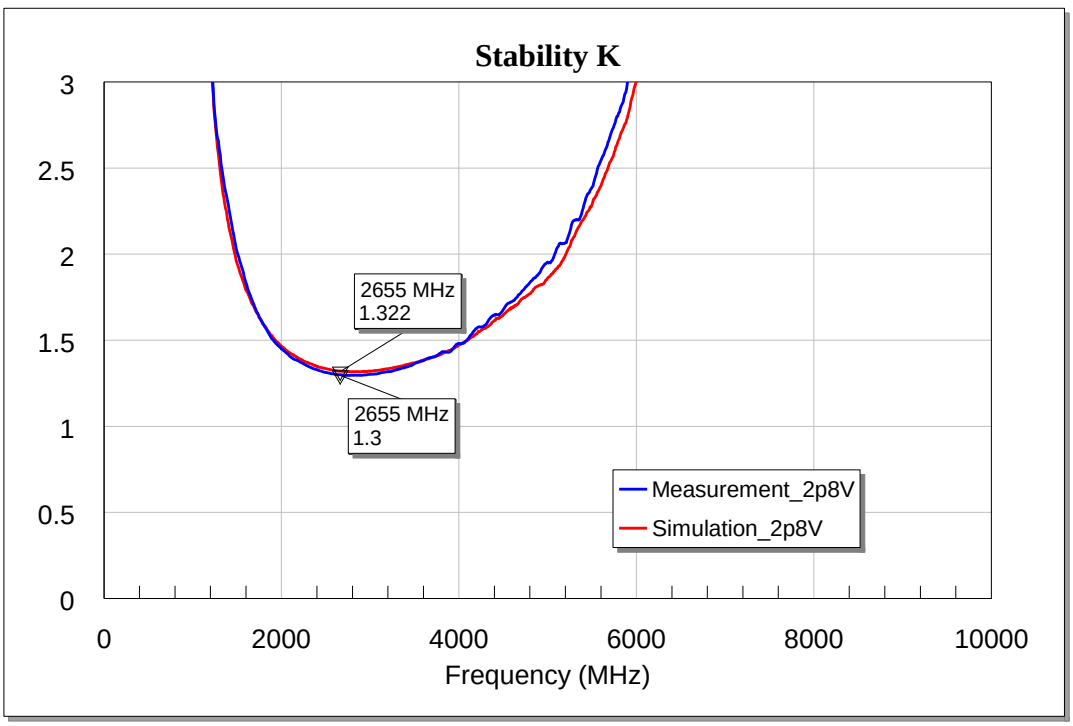



**Figure 21 Stability K-factor of the BGA7H1N6 for LTE Band-7 Application at Vcc = 2.8 V**

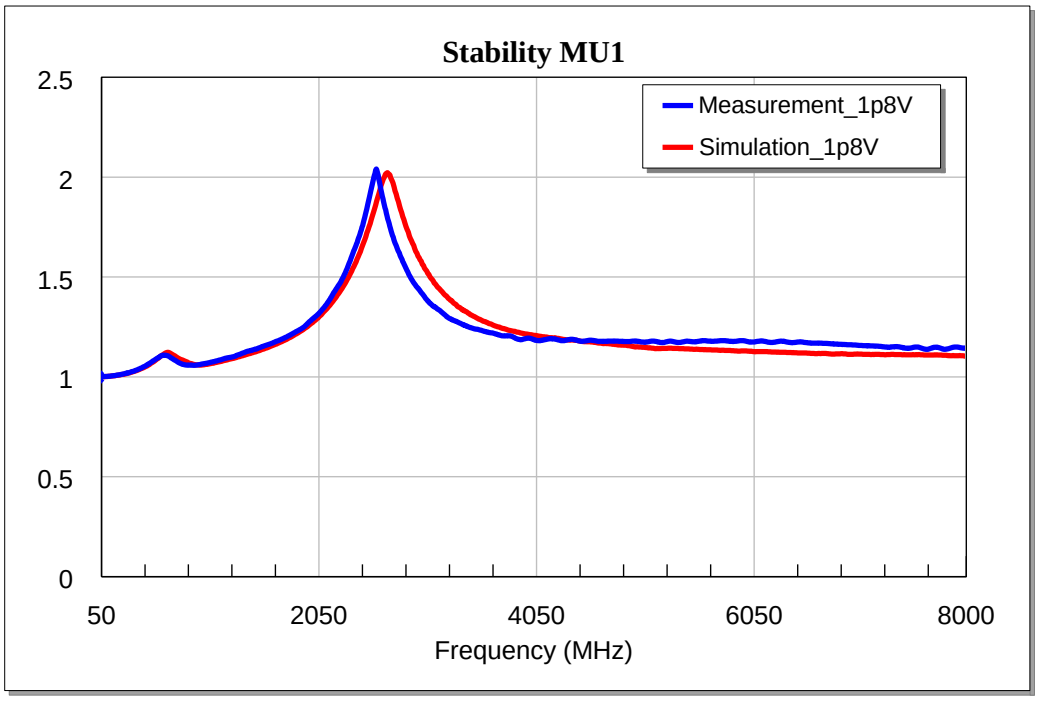



**Figure 22 Stability Mu1-factor of the BGA7H1N6 for LTE Band-7 Application at Vcc = 1.8 V**

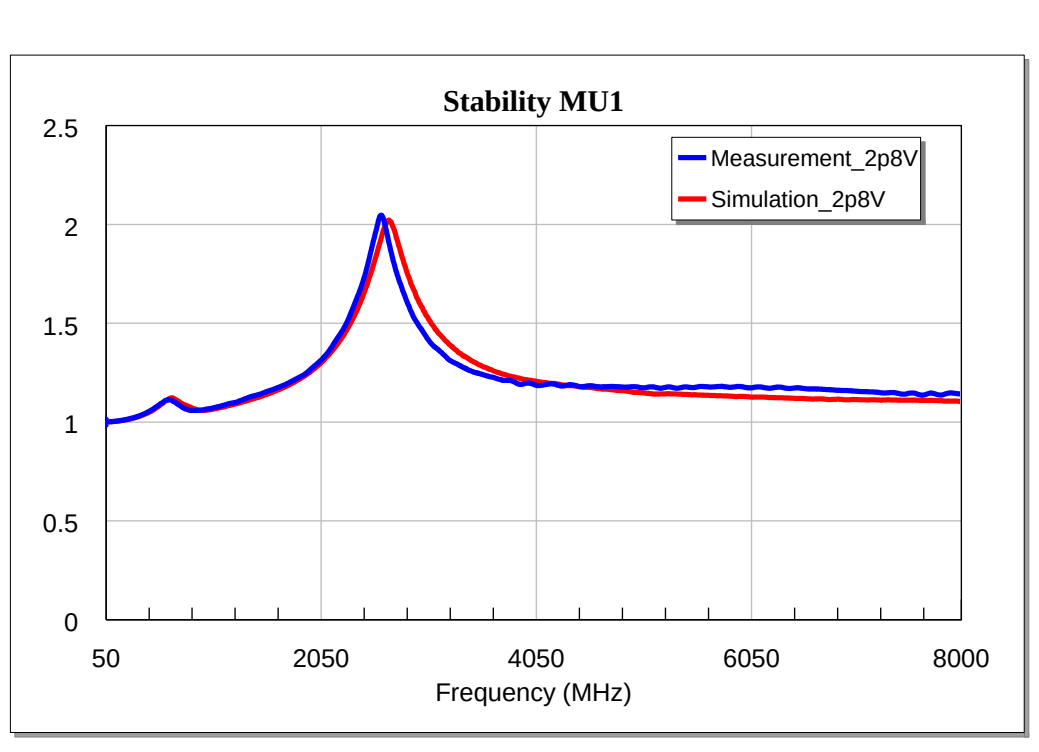



**Figure 23 Stability Mu1-factor of the BGA7H1N6 for LTE Band-7 Application at Vcc = 2.8 V**

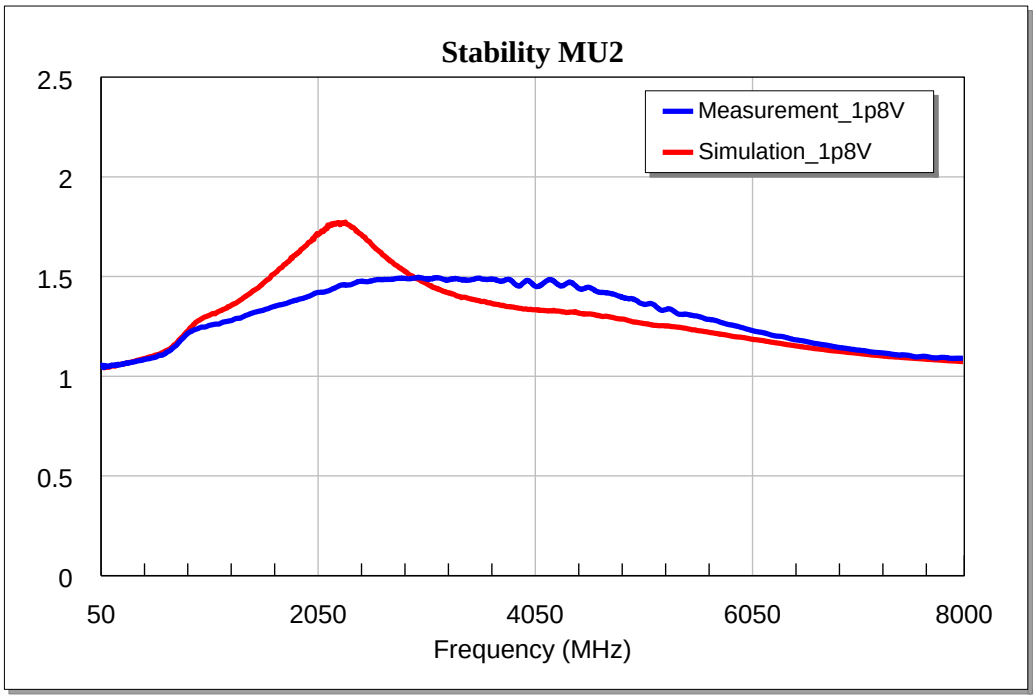



**Figure 24 Stability Mu2-factor of the BGA7H1N6 for LTE Band-7 Application at Vcc = 1.8 V**

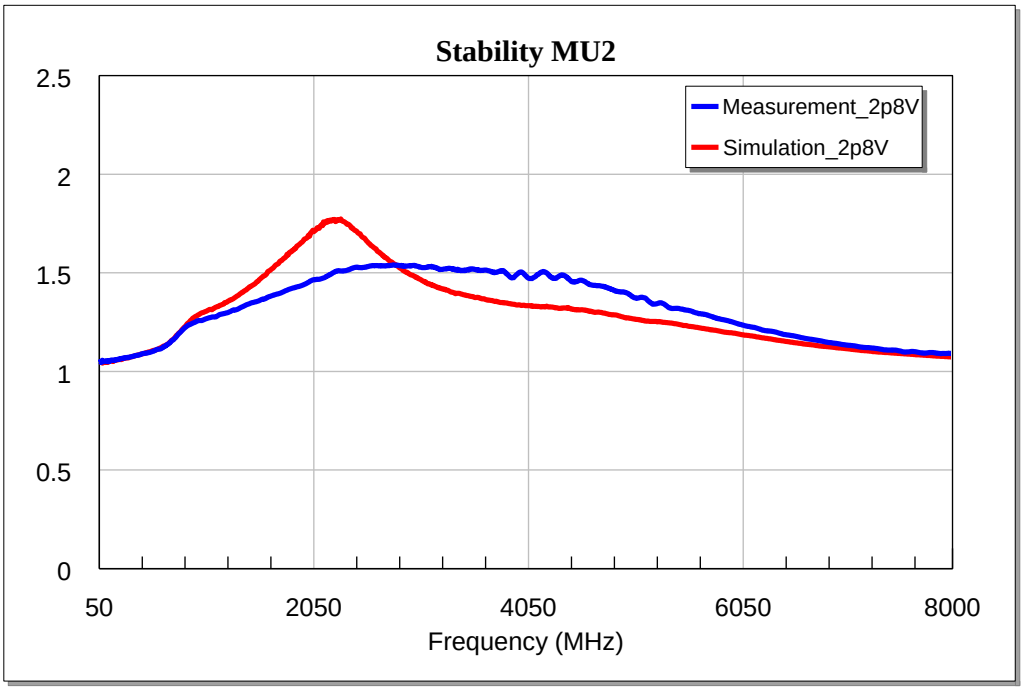



**Figure 25 Stability Mu2-factor of the BGA7H1N6 for LTE Band-7 Application at Vcc = 2.8 V**

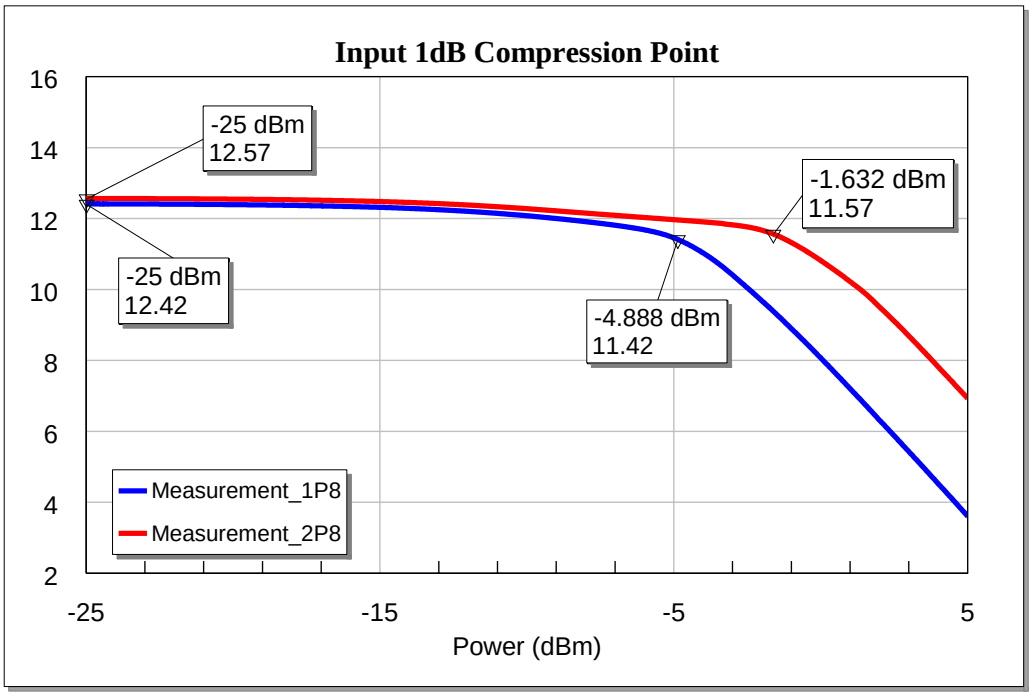



**Figure 26 Input 1dB compression point of the BGA7H1N6 for LTE Band-7 Application**

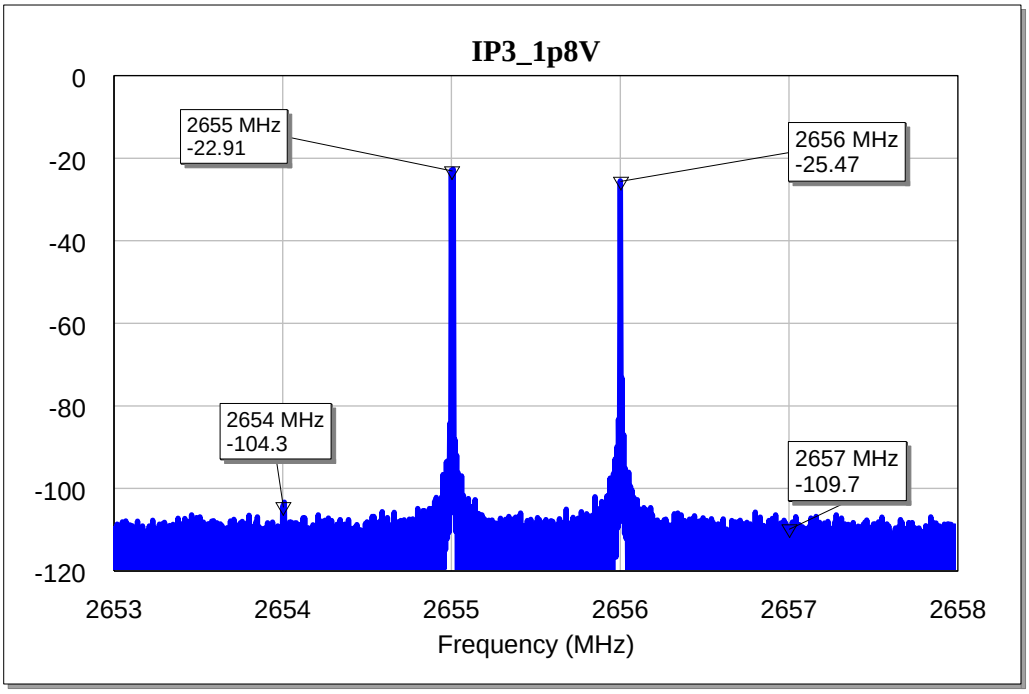



**Figure 27 Input 3rd interception point of the BGA7H1N6 for LTE Band-7 Application at Vcc=1.8 V**

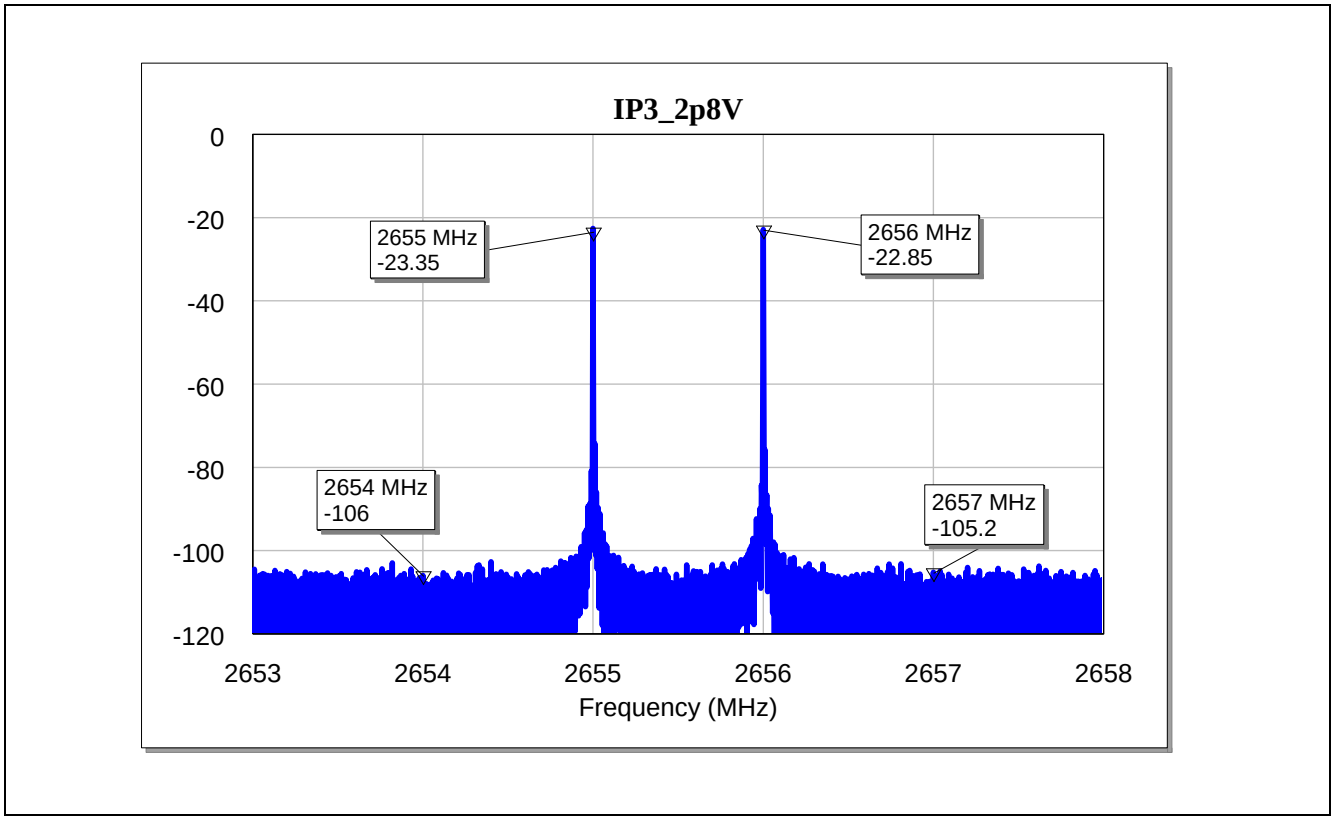



**Figure 28 Input 3rd interception point of the BGA7H1N6 for LTE Band-7 Application at Vcc=2.8 V**

# 5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB Marking: **BGA7x1N6 V1.0**

PCB material: **Rogers 4003**

$\varepsilon_r$ of PCB material: **3.6**

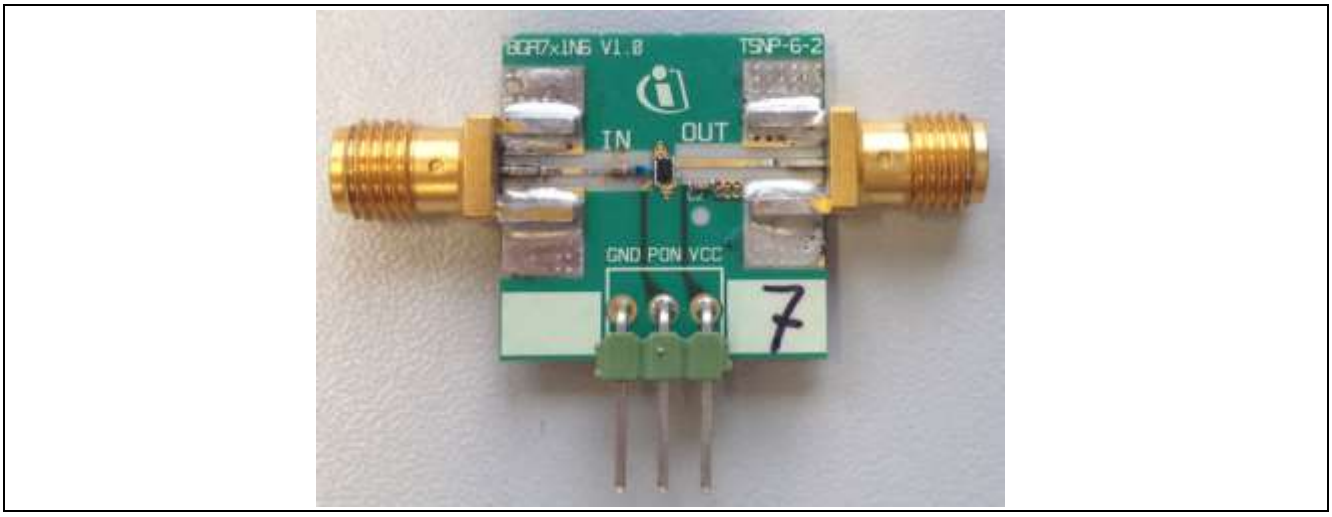



**Figure 29 Photo of Evaluation Board (overview)**

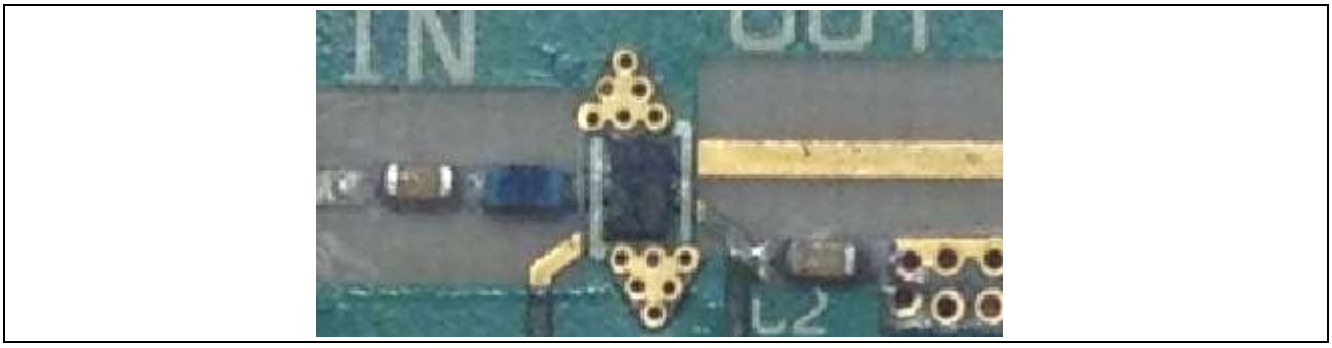


**Figure 30 Photo of Evaluation Board (detailed view)**

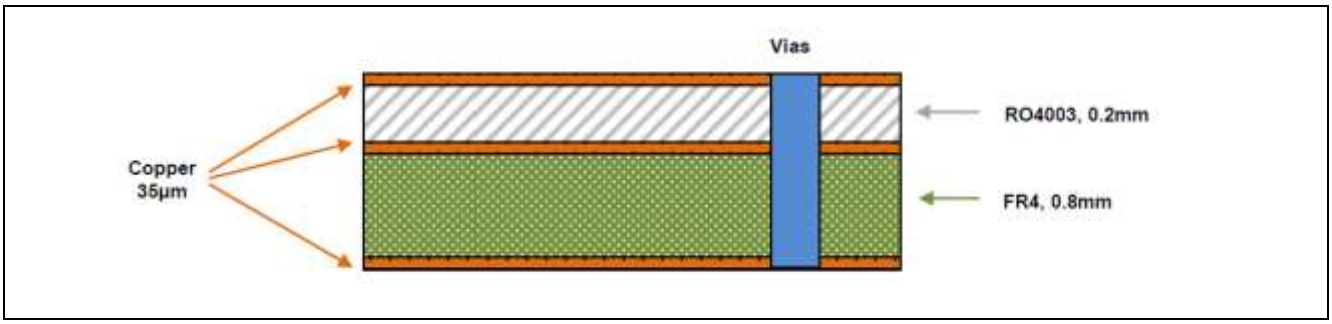



**Figure 31 PCB Layer Information**

# 6 Authors

Wenxin Pei, Working Student of Business Unit “RF and Protection Devices”
Islam Moakhkhrul, RF Application Engineer of Business Unit “RF and Protection Devices”

# 7 Reference

[1] A Reference. See the code examples at **www.infineon.com**

# Revision History

**Major changes since the last revision**

| Page or Reference | Description of change |
|---|---|
| | |
| | |
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| | |

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AN_201412_PL32_004

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