# Silicon Germanium Low Noise Amplifier BGA7L1BN6

## Low Noise Amplifier for LTE Band 17 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 17 (734 MHz – 746 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 17 (734 MHz – 746 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, 740 MHz (High Gain Mode)
   Noise figure = 1.0 dB
   Insertion gain = 14.8 dB
   Input return loss = 11.5 dB
   Output return loss = 14.2 dB
   Input P1dB = -2.9 dBm
   Key performance parameters at 2.8V, 740 MHz (Bypass Mode)
   Insertion loss = 2.2 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).

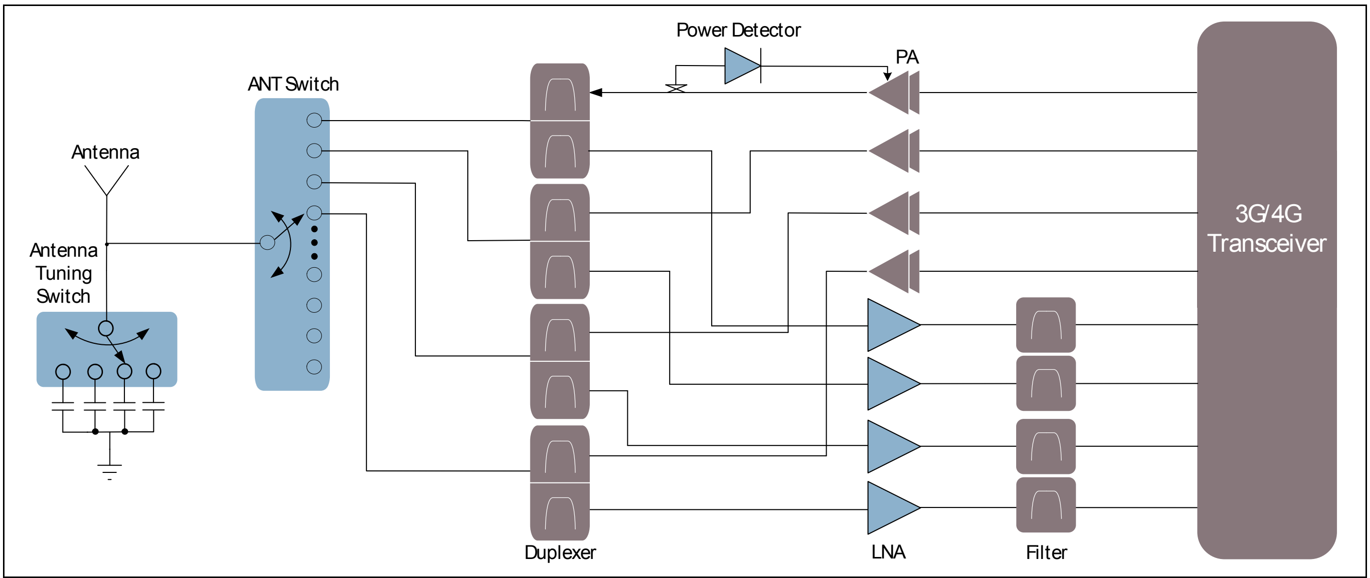


**Figure 1 Block diagram of a 4G LTE RF Frontend**

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 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 | |

| 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 | 462.5-467.5MHz | 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 | |
| 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.

***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 mm$^2$)
- B7HF Silicon Germanium technology
- RF output internally matched to 50 Ω
- Only 1 external SMD component necessary
- Pb-free (RoHS compliant) package

RoHS

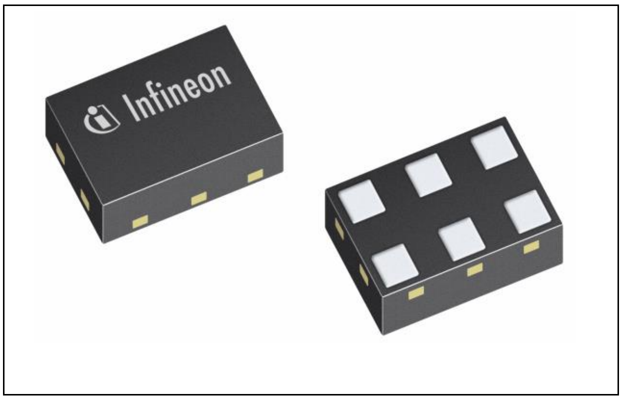


Figure 2 BGA7L1BN6 in TSNP-6-2

**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 |

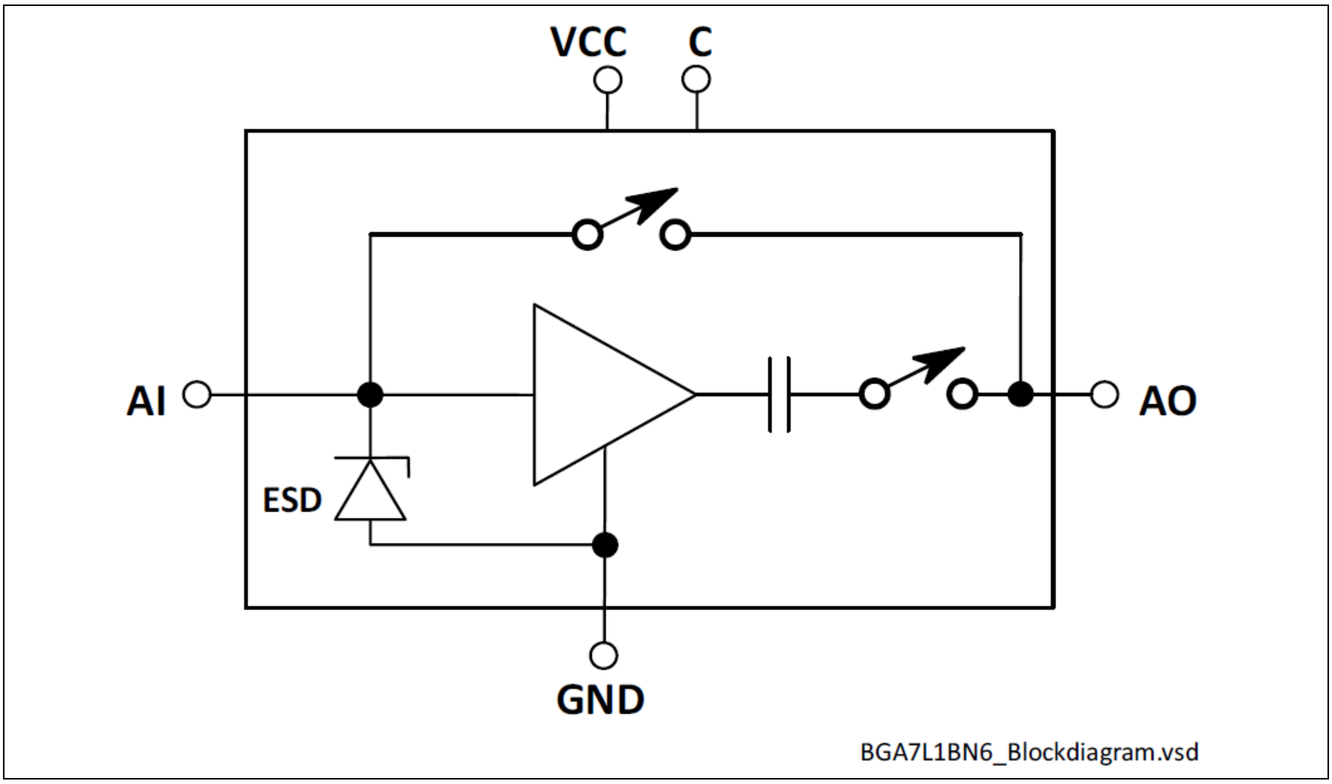


Figure 3 Equivalent Circuit of BGA7L1BN6

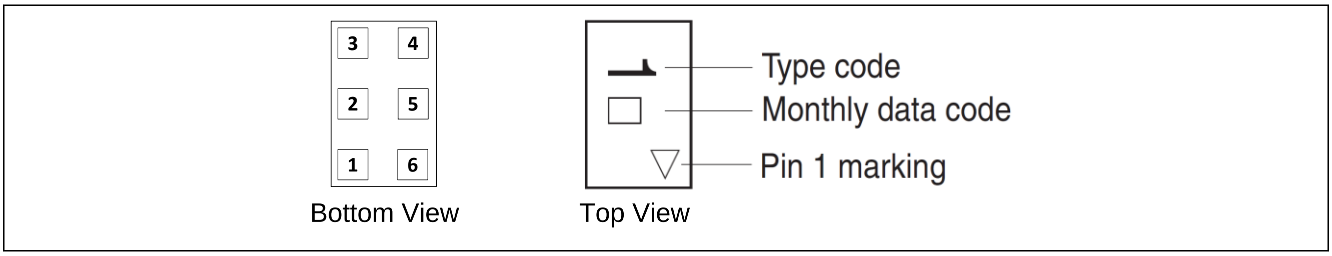


Figure 4 Package and pin connections of BGA7L1BN6

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 17 (734 MHz – 746 MHz) Application Using 0201 Components

**PCB Marking:** M150918

**EVB Order No.:** AN469

## 3.1 Summary of Measurement Results for Band

Ther performance of BGA7L1BN6 for LTE Band 17 (734 MHz – 746 MHz) Application is summarized in the following table.

**Table 2 Electrical Characteristics of the BGA7L1BN6 (at room temperature) for LTE Band 17 in High Gain Mode**

| Parameter | Symbol | Value | | | | | | Unit | Comment/Test Condition |
|---|---|---|---|---|---|---|---|---|---|
| DC Voltage | Vcc | 1.8 | | | 2.8 | | | V | |
| DC Current | Icc | 4.5 | | | 5.0 | | | mA | |
| Frequency Range | Freq | 734 | 740 | 746 | 734 | 740 | 746 | MHz | |
| Gain | G | 14.4 | 14.4 | 14.3 | 14.8 | 14.8 | 14.8 | dB | |
| Noise Figure | NF | 0.95 | 1.00 | 1.00 | 0.95 | 1.00 | 1.00 | dB | Loss of input line 0.05 dB deembedded |
| Input Return Loss | RLin | 10.6 | 10.7 | 10.8 | 11.4 | 11.5 | 11.7 | dB | |
| Output Return Loss | RLout | 13.7 | 13.6 | 13.4 | 14.3 | 14.2 | 14.0 | dB | |
| Reverse Isolation | IRev | 21.9 | 21.9 | 21.8 | 22.5 | 22.4 | 22.3 | dB | |
| Input P1dB | IP1dB | -5.7 | -5.6 | -5.5 | -2.8 | -2.9 | -2.8 | dBm | |
| Output P1dB | OP1dB | 7.7 | 7.8 | 7.8 | 11.0 | 10.9 | 11.0 | dBm | |
| Input IP3 | IIP3 | 2.1 | | | 3.5 | | | dBm | $f_1$ = 740 MHz<br>$f_2$ = 741 MHz<br>$P_{in}$ = -30 dBm |
| Output IP3 | OIP3 | 16.5 | | | 18.3 | | | dBm | |
| Stability | k | >1 | | | | | | -- | Unconditionally stable from 0 to 10 GHz |

**Table 3** Electrical Characteristics of the BGA7L1BN6 (at room temperature) for LTE Band 17 in Bypass Mode

| Parameter | Symbol | Value | | | | | | Unit | Comment/Test Condition |
|---|---|---|---|---|---|---|---|---|---|
| DC Voltage | Vcc | 1.8 | | | 2.8 | | | V | |
| DC Current | Icc | 63 | | | 87 | | | uA | |
| Frequency Range | Freq | 734 | 740 | 746 | 734 | 740 | 746 | MHz | |
| Gain | G | -2.2 | -2.2 | -2.2 | -2.1 | -2.1 | -2.1 | dB | |
| Noise Figure | NF | 4.0 | 3.3 | 3.3 | 3.5 | 3.3 | 3.3 | dB | Loss of input line 0.05 dB deembedded |
| Input Return Loss | RLin | 10.4 | 10.3 | 10.1 | 10.2 | 10.0 | 9.9 | dB | |
| Output Return Loss | RLout | 8.2 | 8.1 | 8.0 | 8.4 | 8.3 | 8.2 | dB | |
| Reverse Isolation | IRev | 2.2 | 2.2 | 2.2 | 2.1 | 2.1 | 2.1 | dB | |
| Input P1dB | IP1dB | 7.2 | 7.1 | 6.9 | 7.1 | 7.1 | 7.4 | dBm | |
| Output P1dB | OP1dB | -10.4 | -10.3 | -10.1 | -10.2 | -10.2 | -10.5 | dBm | |
| Input IP3 | IIP3 | 15.4 | | | 16.5 | | | dBm | $f_1$ = 740 MHz<br>$f_2$ = 741MHz<br>$P_{in}$ = -30 dBm |
| Output IP3 | OIP3 | 13.4 | | | 14.6 | | | dBm | |
| Stability | k | >1 | | | | | | -- | Unconditionally stable from 0 to 10 GHz |

## 3.2 BGA7L1BN6 as 734 MHz – 746 MHz Low Noise Amplifier for LTE Band 17 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 17 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 14.4 dB. The input return loss is 10.7 dB and output return loss is 13.6 dB at 740 MHz. It obtains an input 1dB Compression Point (IP1dB) of -5.6 dBm at 740 MHz. Using two tones of – 30 dBm spacing 1 MHz; the circuit achieves an input Third-order Intercept Point (IIP3) of 2.1 dBm at 740 MHz.

At 1.8 V, bypass mode, the BGA7L1BN6 achieves an insertion loss of 2.2 dB. The input return loss is 10.3 dB and output return loss is 8.8 dB at 740 MHz. It obtains an input 1dB Compression Point (IP1dB) of 7.7 dBm at 740 MHz. Using two tones of – 30 dBm spacing 1 MHz; the circuit achieves an input Third-order Intercept Point (IIP3) of 15.4 dBm at 740 MHz.

At 2.8V, high gain mode, the BGA7L1BN6 achieves a noise figure of 1.0 dB and a gain of 14.8 dB. The input return loss is 11.5 dB and output return loss is 14.2 dB at 740 MHz. It obtains an input 1dB Compression Point (IP1dB) of -2.9 dBm at 740 MHz. Using two tones of – 30 dBm spacing 1 MHz; the circuit achieves an input Third-order Intercept Point (IIP3) of 3.5 dBm at 740 MHz.

At 2.8 V, bypass mode, the BGA7L1BN6 achieves an insertion loss of 2.1 dB. The input return loss is 10.0 dB and output return loss is 8.3 dB at 740 MHz. It obtains an input 1dB Compression Point (IP1dB) of 7.1 dBm at 740 MHz. Using two tones of – 30 dBm spacing 1 MHz; the circuit achieves an input Third-order Intercept Point (IIP3) of 16.5 dBm at 740 MHz.

The circuit is unconditionally stable up to 10 GHz.

## 3.3 Schematics and Bill-of-Materials

Ther schematic of BGA7L1BN6 for LTE Band 17 Application is presented in **Figure 5** and its bill-of-materials is shown in **Table 4**.

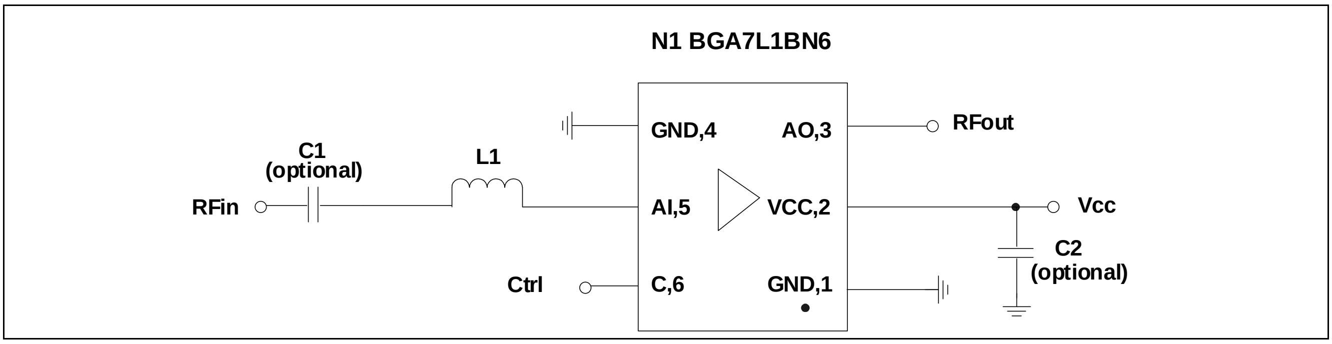


Figure 5 Schematics of the BGA7L1BN6 Application Circuit

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 | 12 | 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.*

*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

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

## 4.1 High Gain Mode

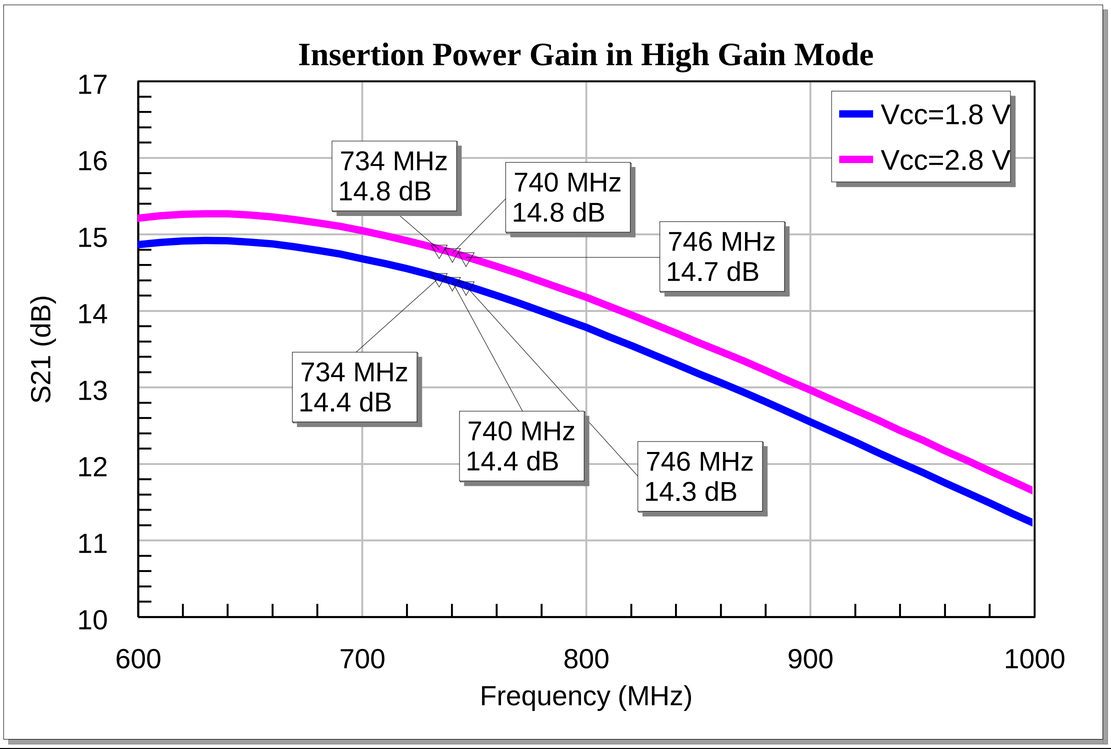


**Figure 6** Insertion Power Gain of the BGA7L1BN6 for LTE Band 17 Application

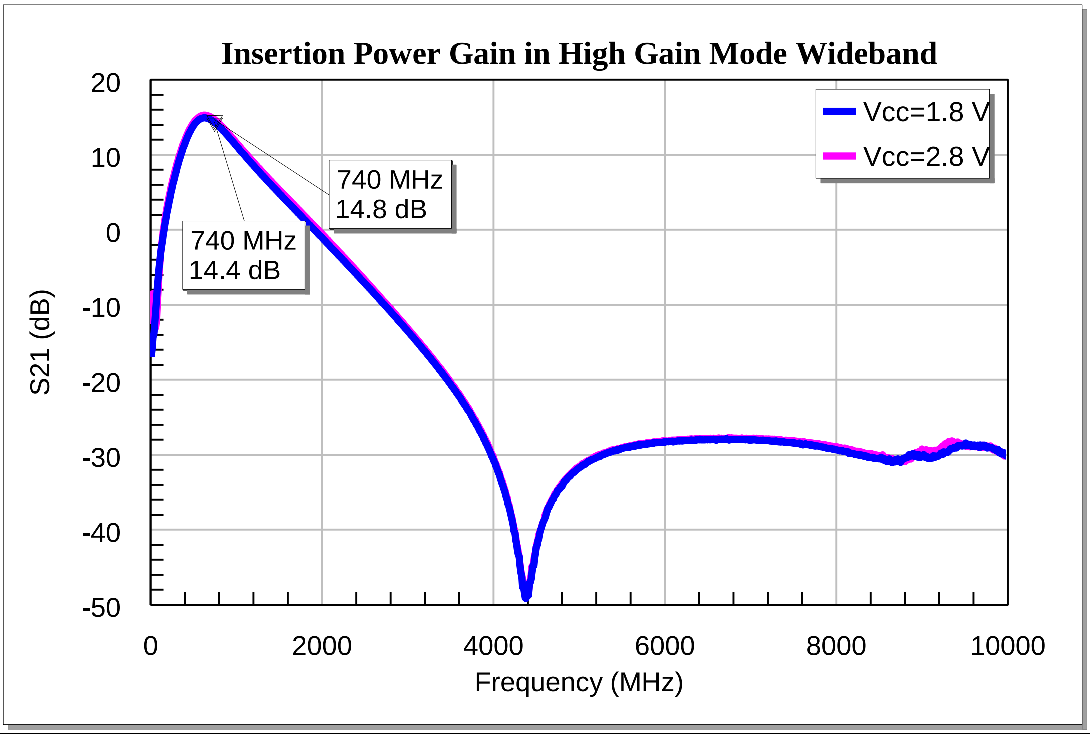


**Figure 7** Insertion Power Gain (Wideband) of the BGA7L1BN6 for LTE Band 17 Application

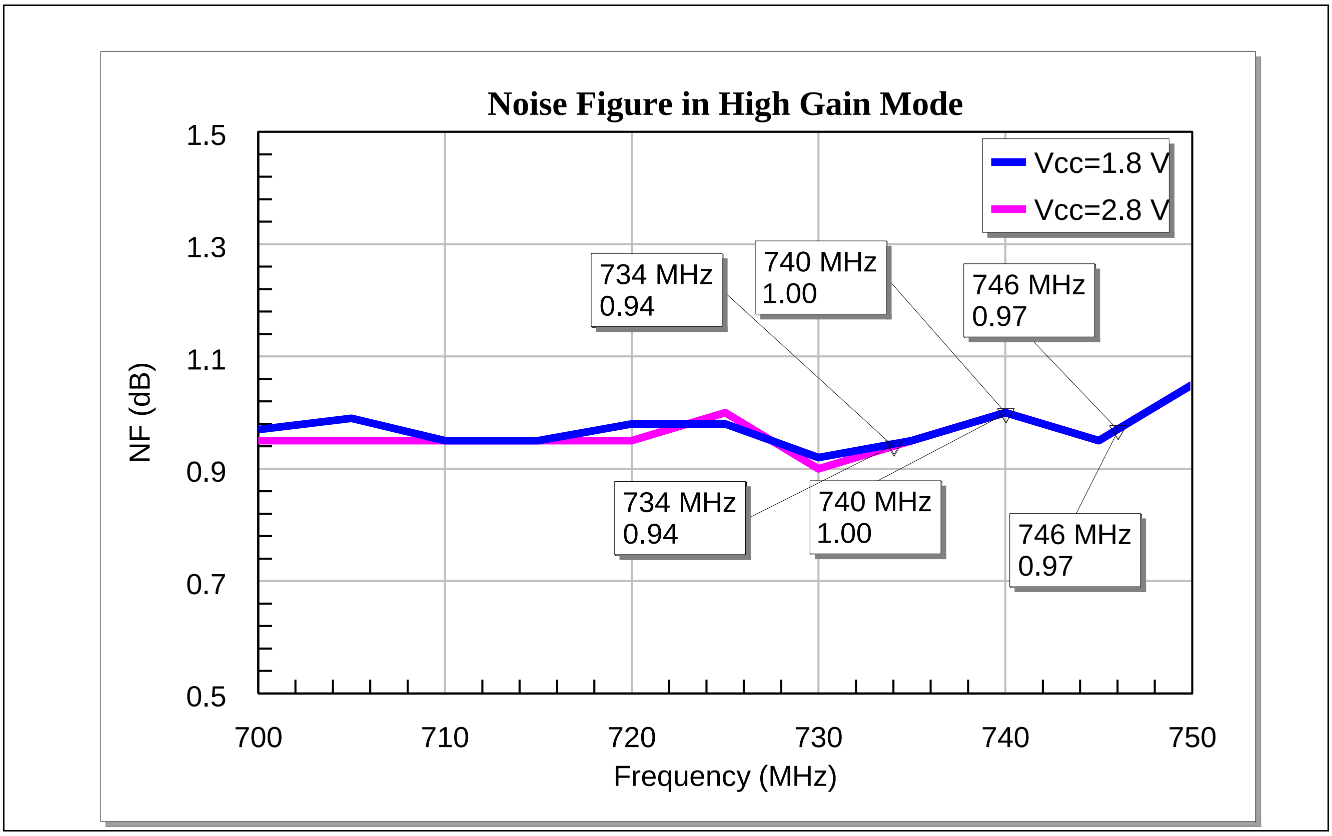


**Figure 8** Noise Figure (SMA and connector loss deembedded) of the BGA7L1BN6 for LTE Band 17 Application

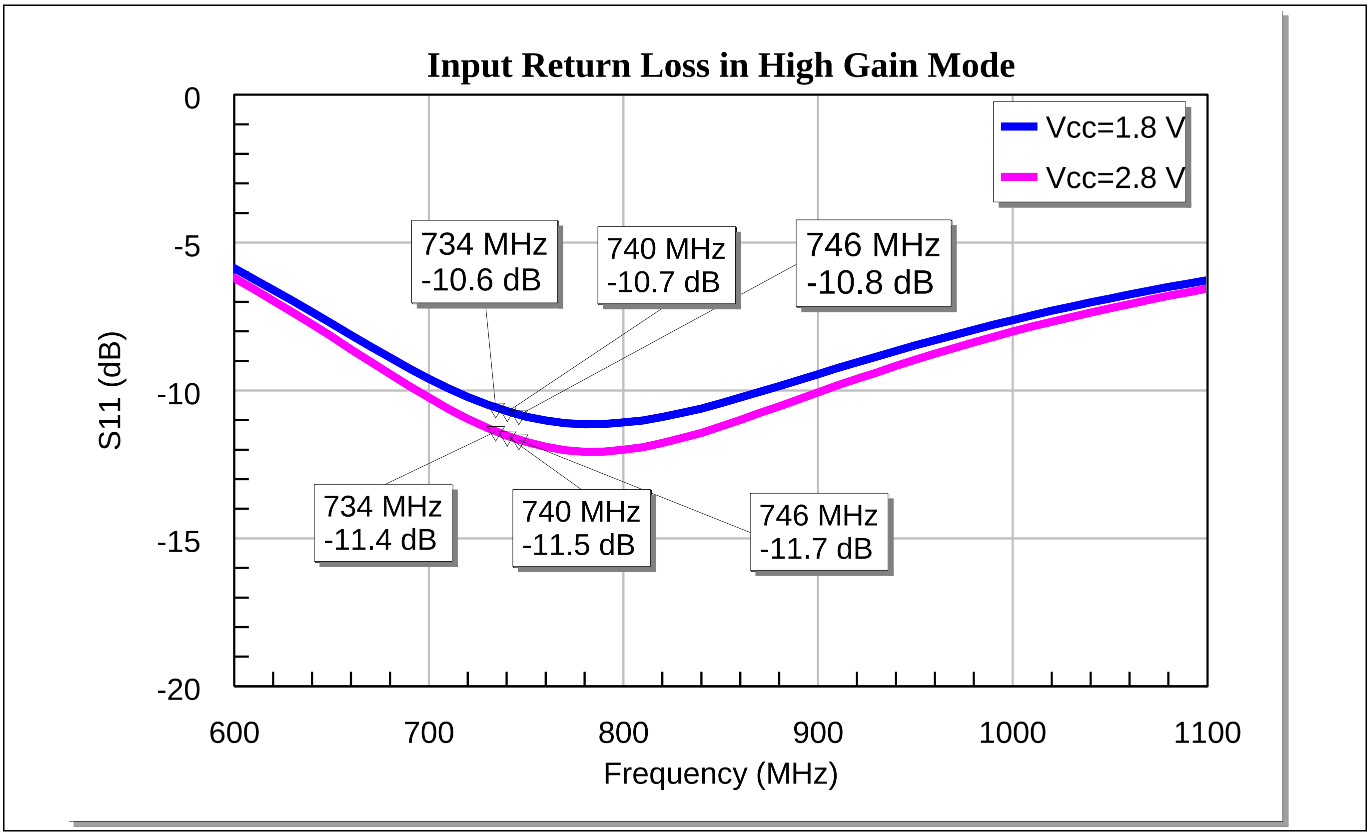


**Figure 9** Input Return Loss of the BGA7L1BN6 for LTE Band 17 Application

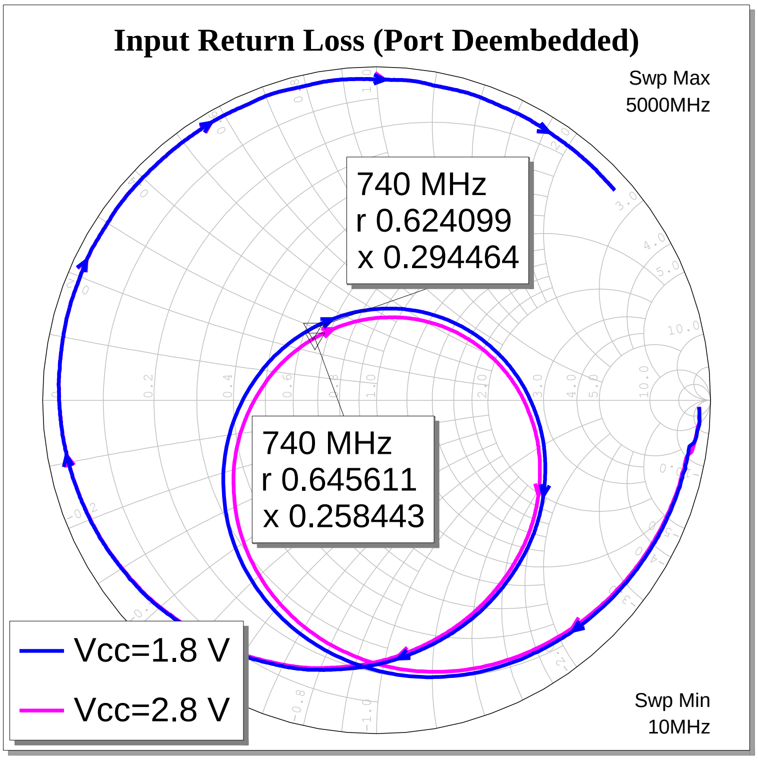


**Figure 10** Input Return Loss (Smith Chart) of the BGA7L1BN6 for LTE Band 17 Application

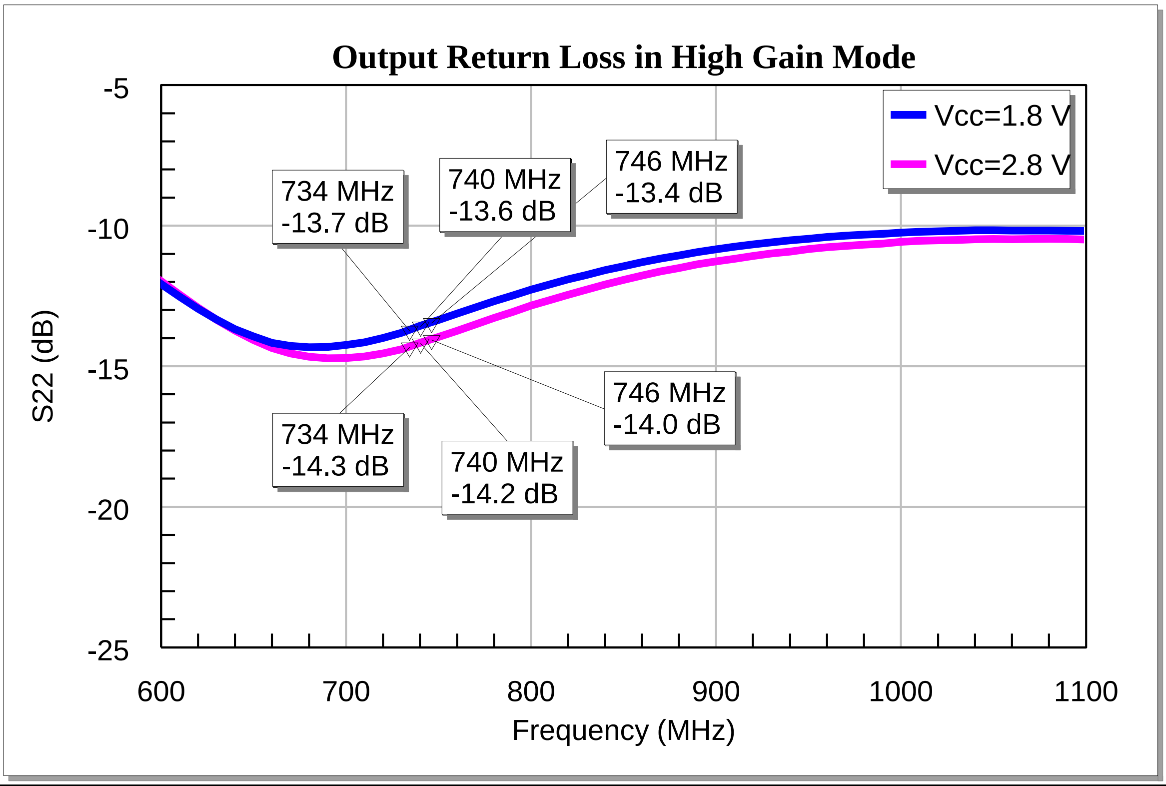


**Figure 11** Output Return Loss of the BGA7L1BN6 for LTE Band 17 Application

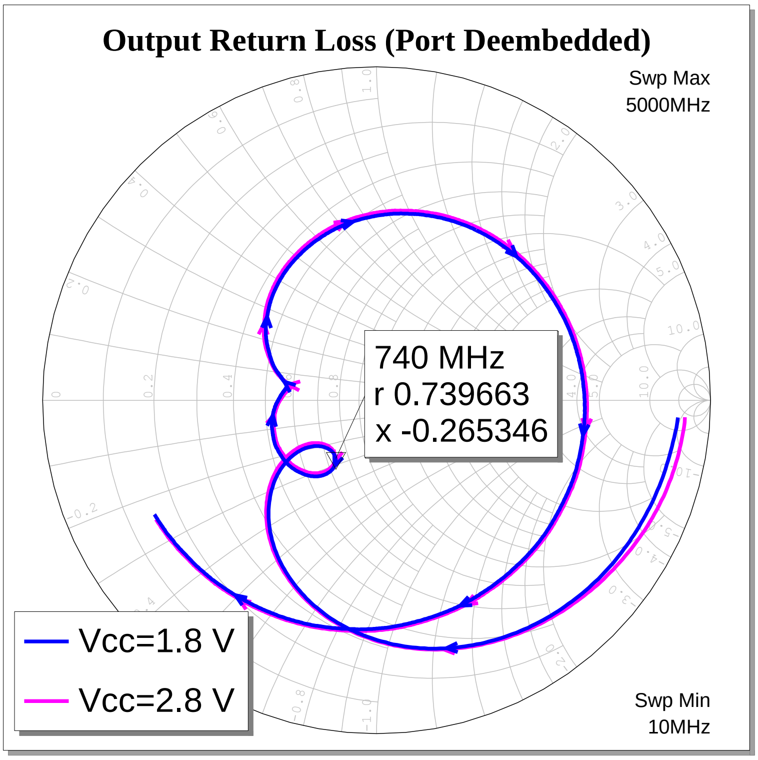


**Figure 12** Output Return Loss (Smith Chart) of the BGA7L1BN6 for LTE Band 17 Application

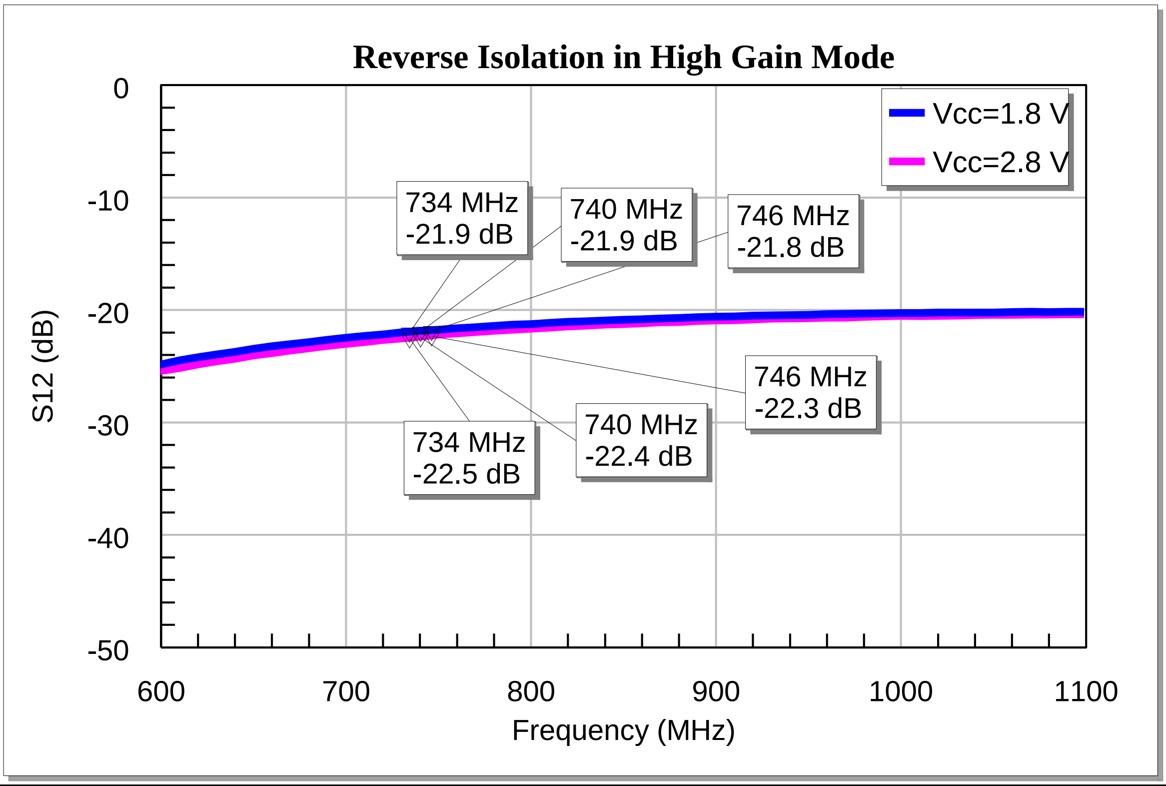


**Figure 13** Reverse Isolation of the BGA7L1BN6 for LTE Band 17 Application

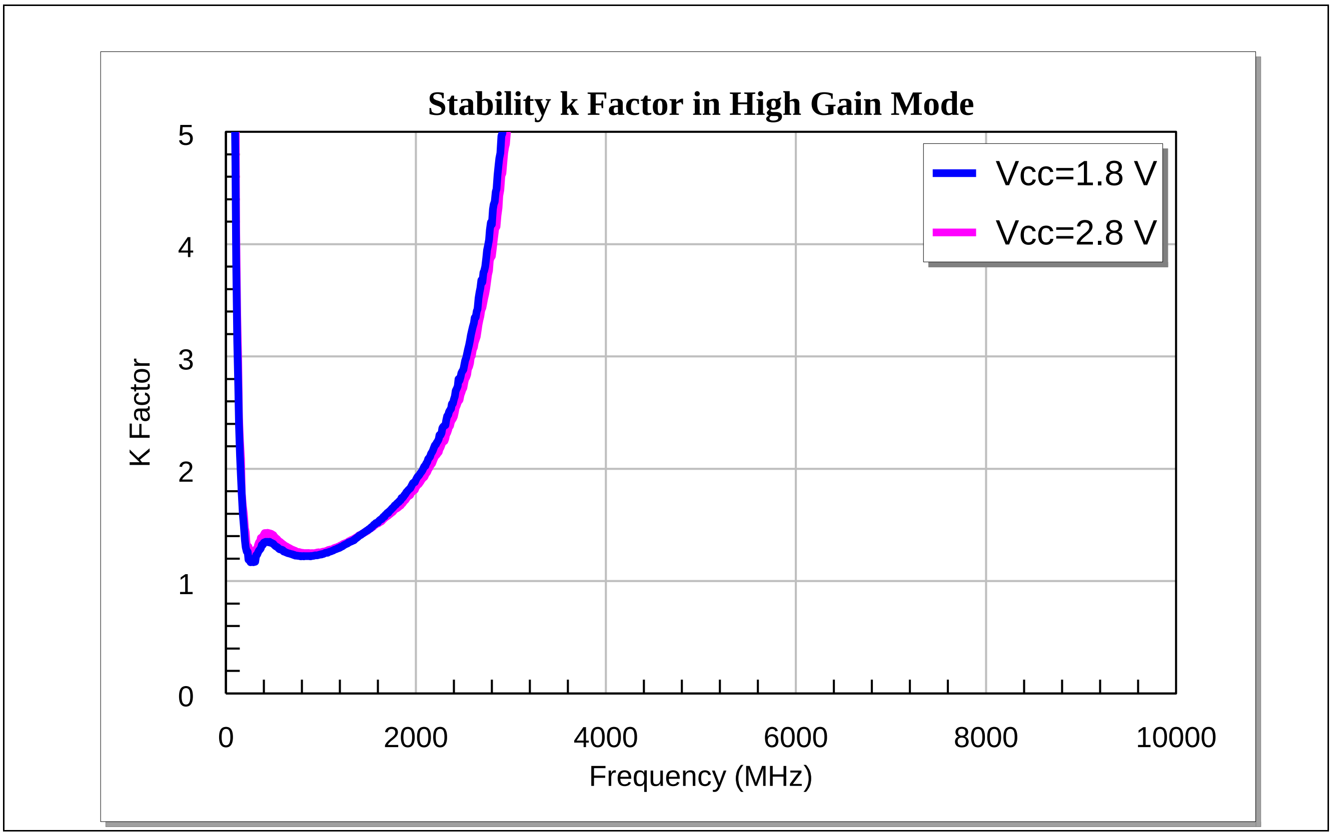


**Figure 14** Stability K-factor of the BGA7L1BN6 for LTE Band 17 Application

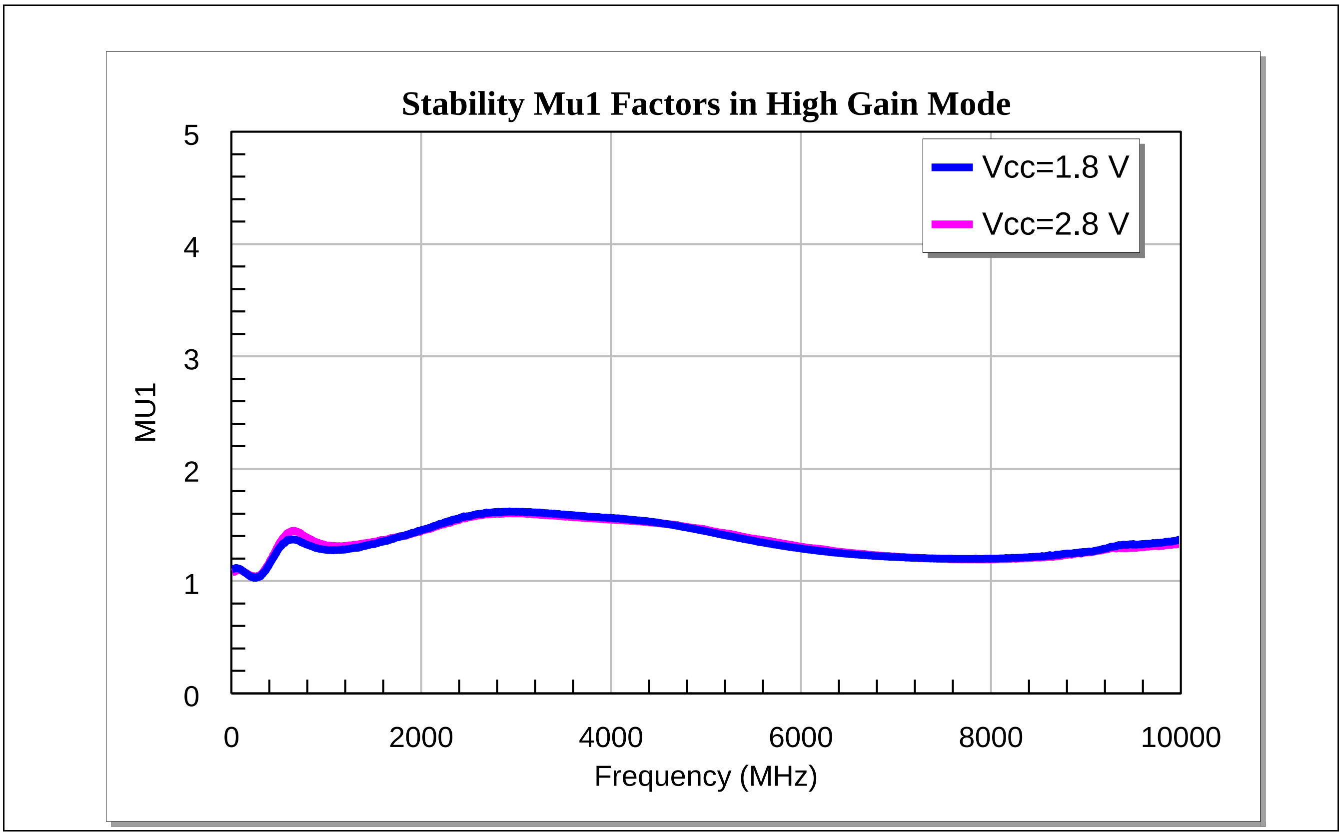


**Figure 15** Stability Mu1 factor of the BGA7L1BN6 for LTE Band 17 Application

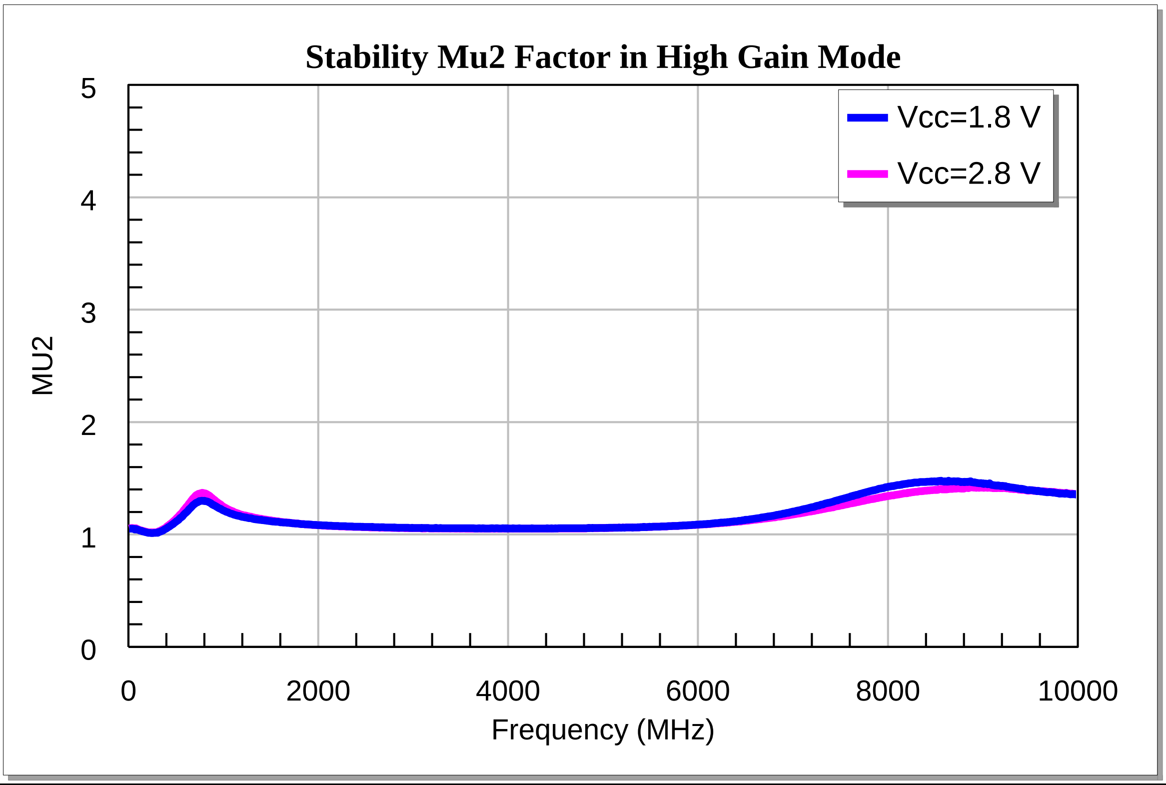


**Figure 16** Stability Mu2 factor of the BGA7L1BN6 for LTE Band 17 Application

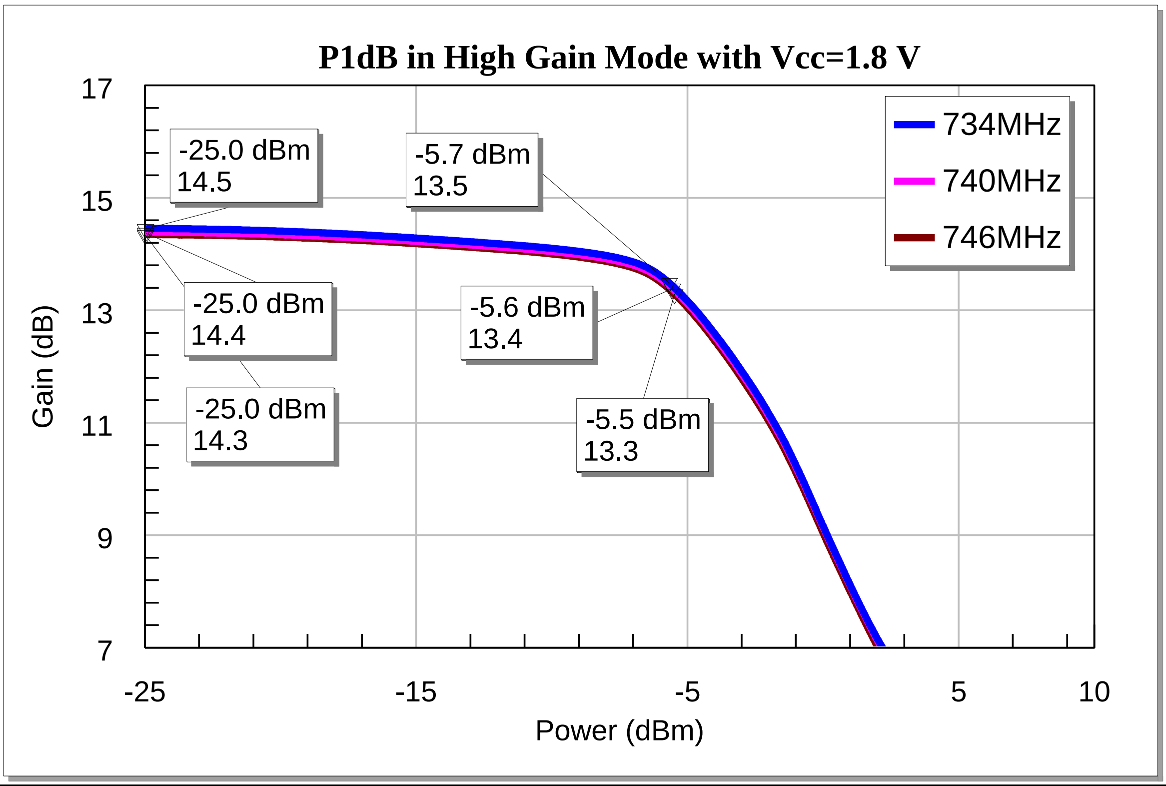


**Figure 17** Input 1dB Compression Point of the BGA7L1BN6 for LTE Band 17 Application, 1.8V

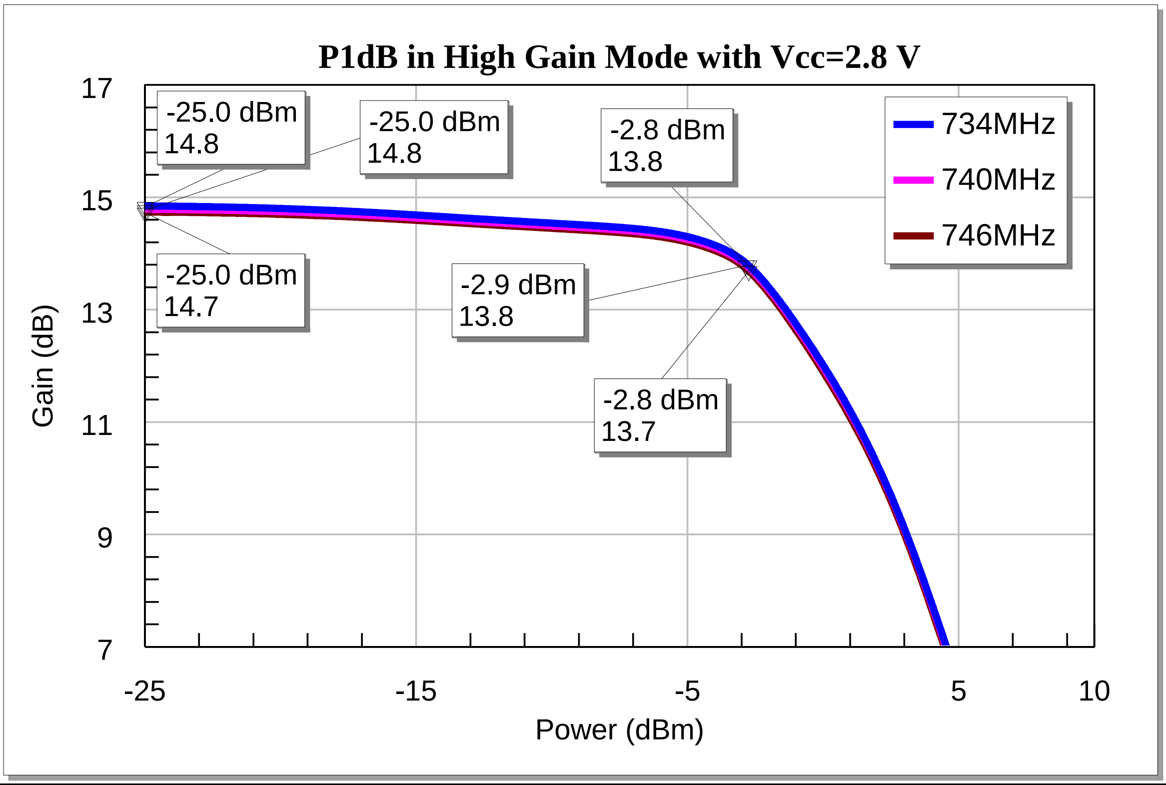


**Figure 18** Input 1dB Compression Point of the BGA7L1BN6 for LTE Band 17 Application, 2.8V

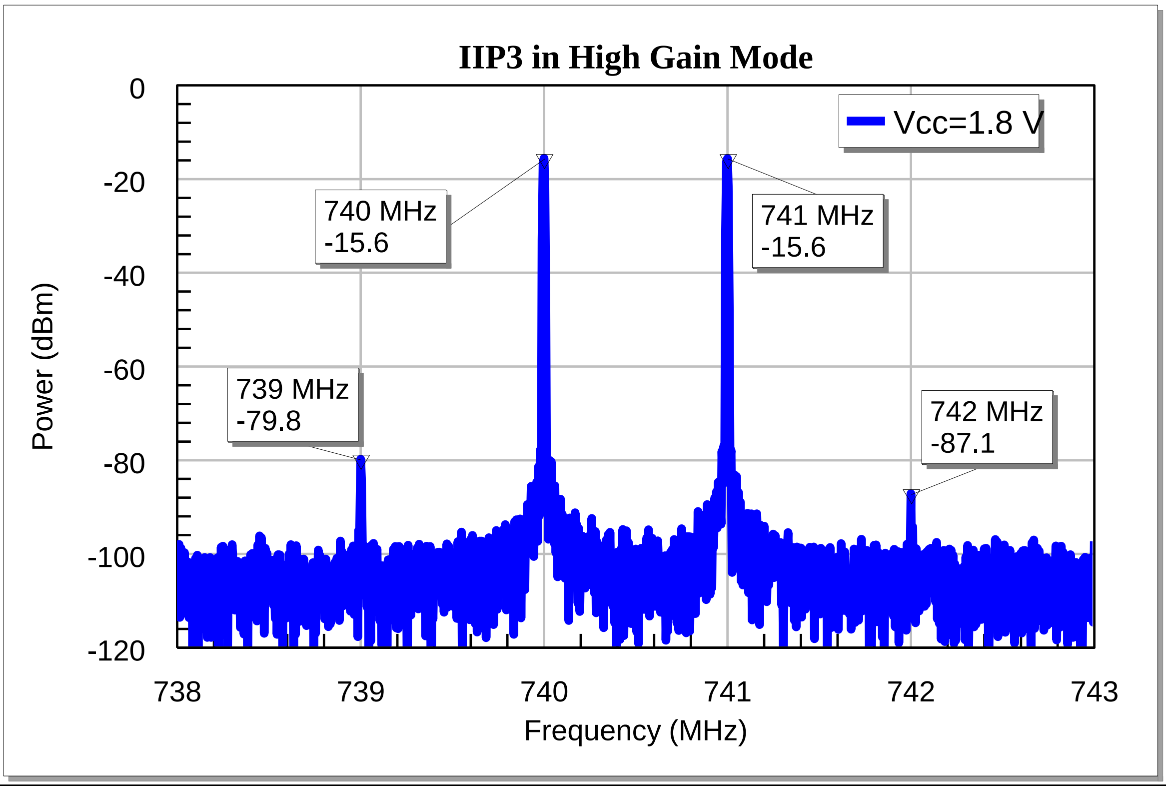


**Figure 19** Third-order Interception Point of the BGA7L1BN6 for LTE Band 17 Application, 1.8 V

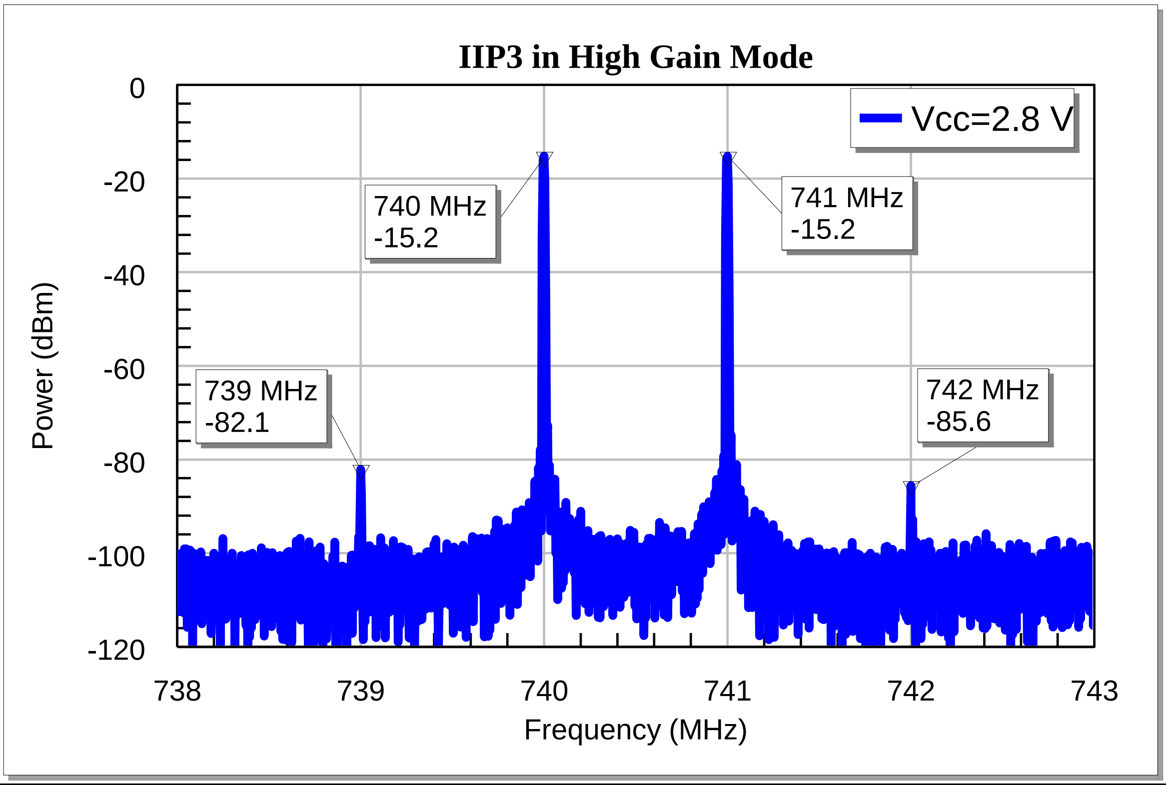


**Figure 20** Third-order Interception Point of the BGA7L1BN6 for LTE Band 17 Application, 2.8 V

## 4.2 Bypass Mode

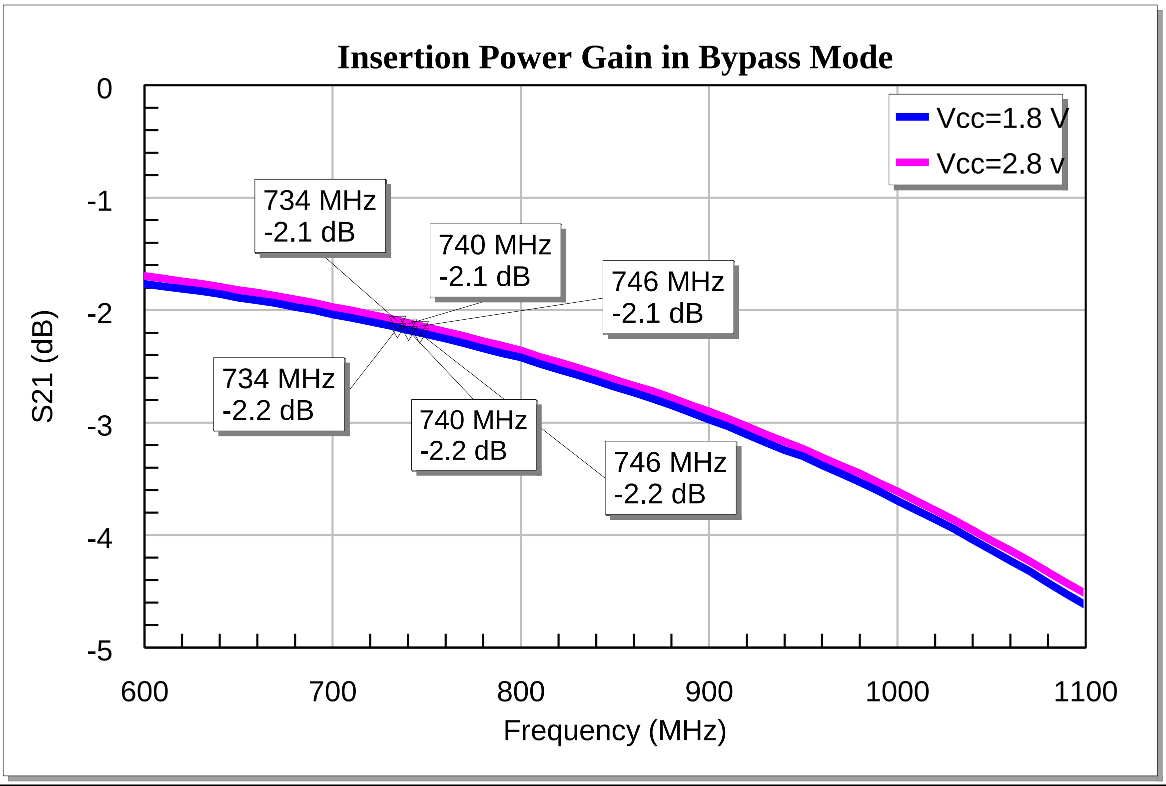


**Figure 21** Insertion Power Gain of the BGA7L1BN6 for LTE Band 17 Application

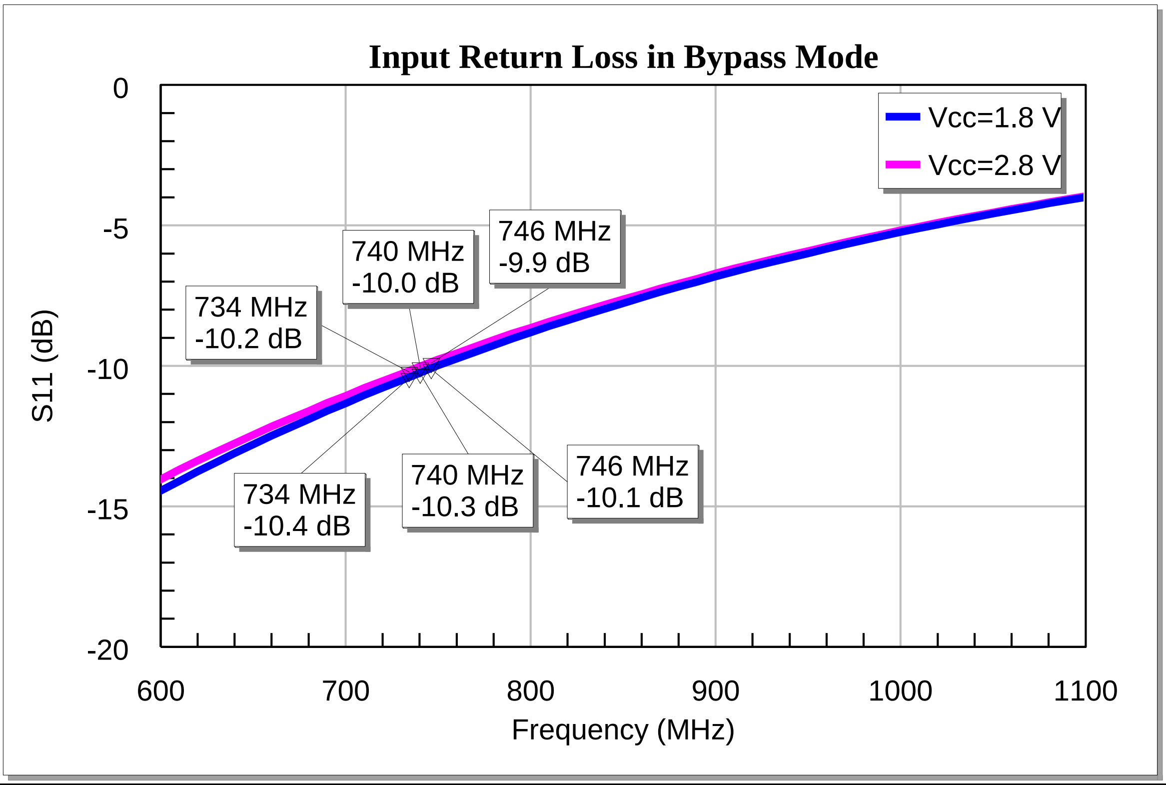


**Figure 22** Input Return Loss of the BGA7L1BN6 for LTE Band 17 Application

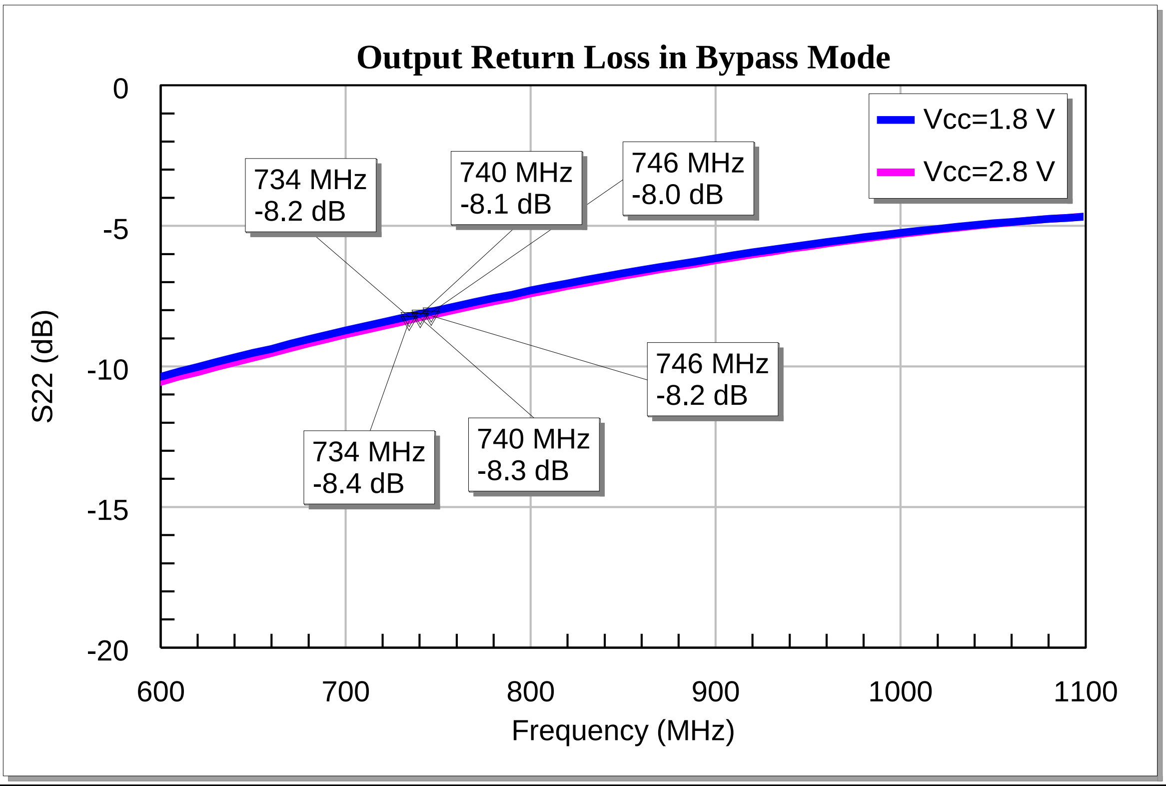


**Figure 23** Output Return Loss of the BGA7L1BN6 for LTE Band 17 Application

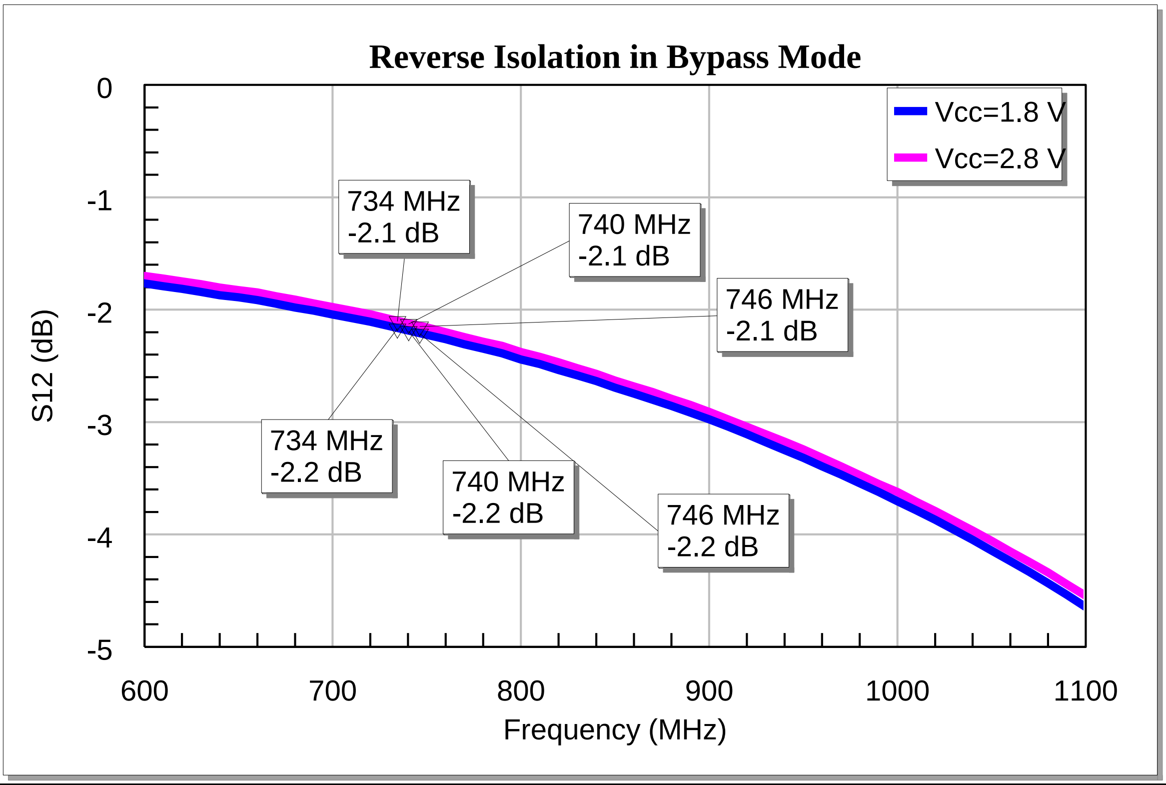


**Figure 24** Reverse Isolation of the BGA7L1BN6 for LTE Band 17 Application

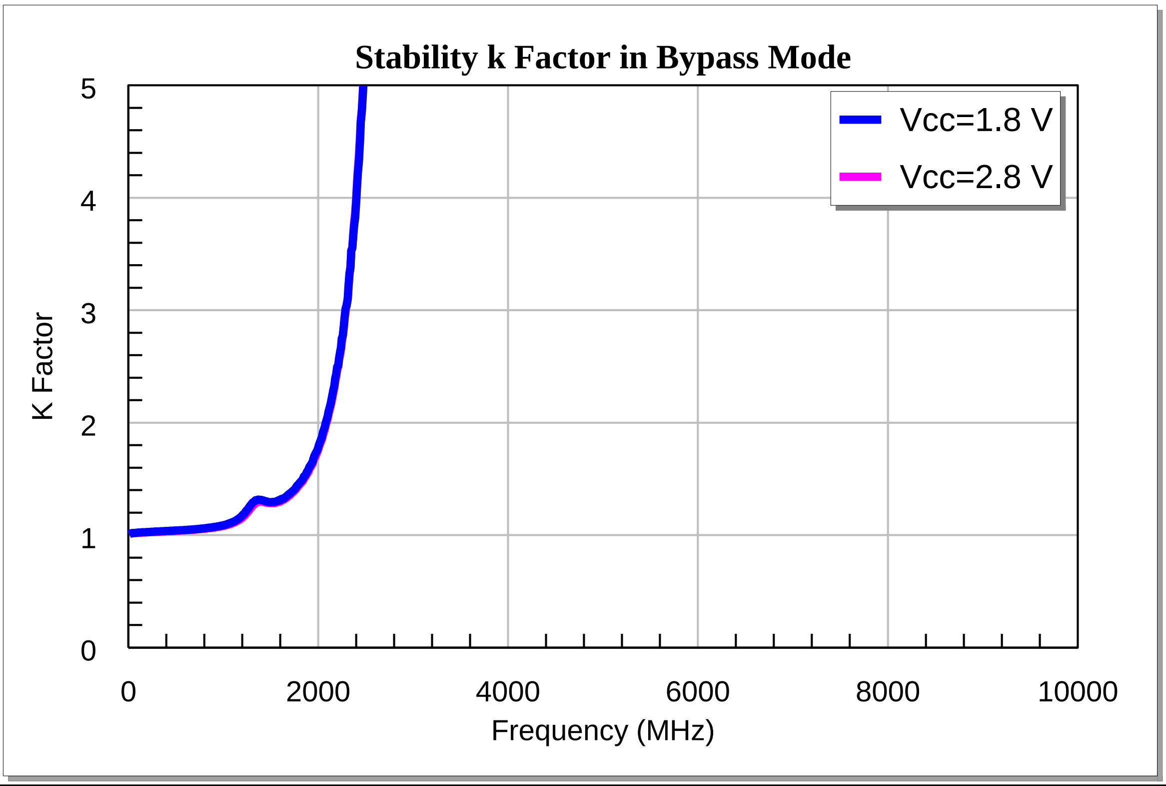


**Figure 25** Stability K-factor of the BGA7L1BN6 for LTE Band 17 Application

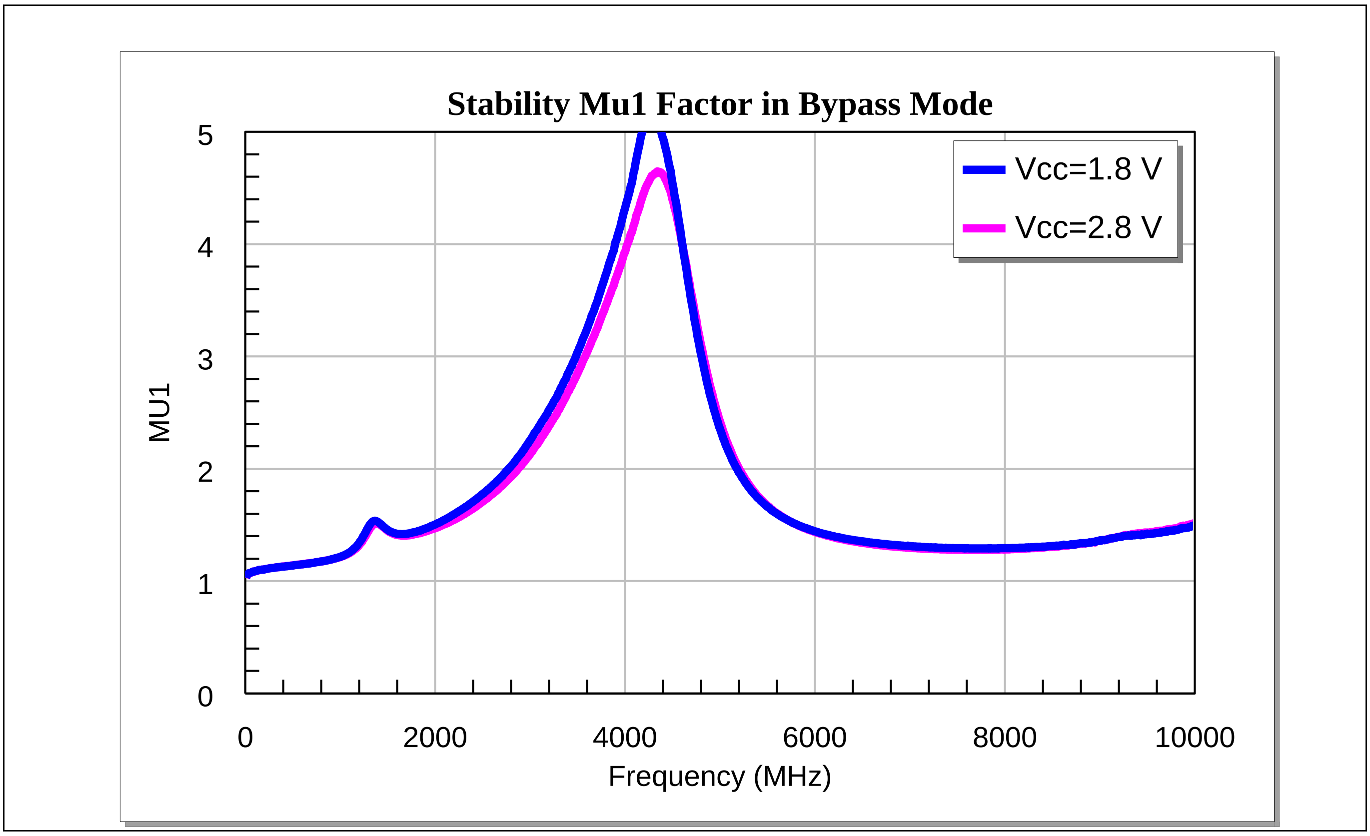


**Figure 26** Stability Mu1 factor of the BGA7L1BN6 for LTE Band 17 Application

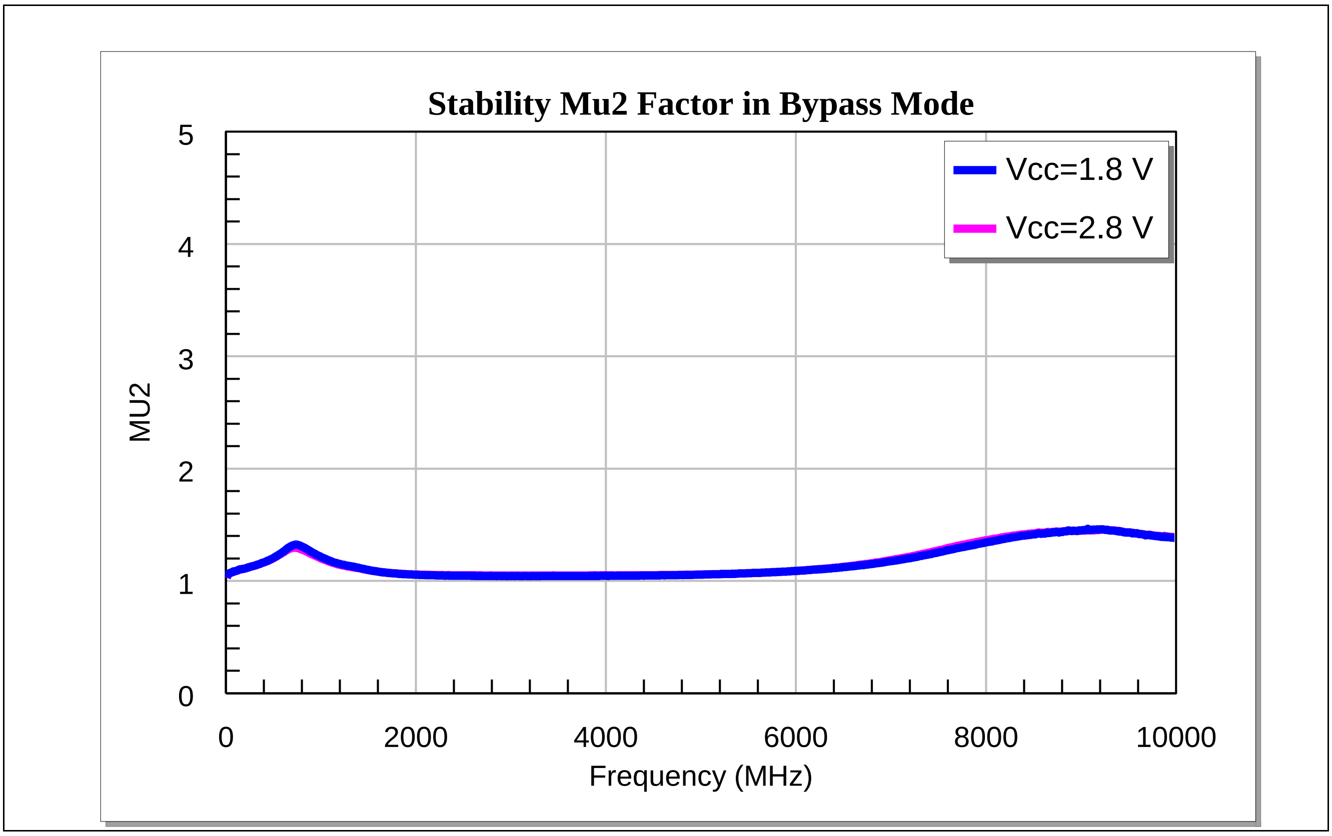


**Figure 27** Stability Mu2 factor of the BGA7L1BN6 for LTE Band 17 Application

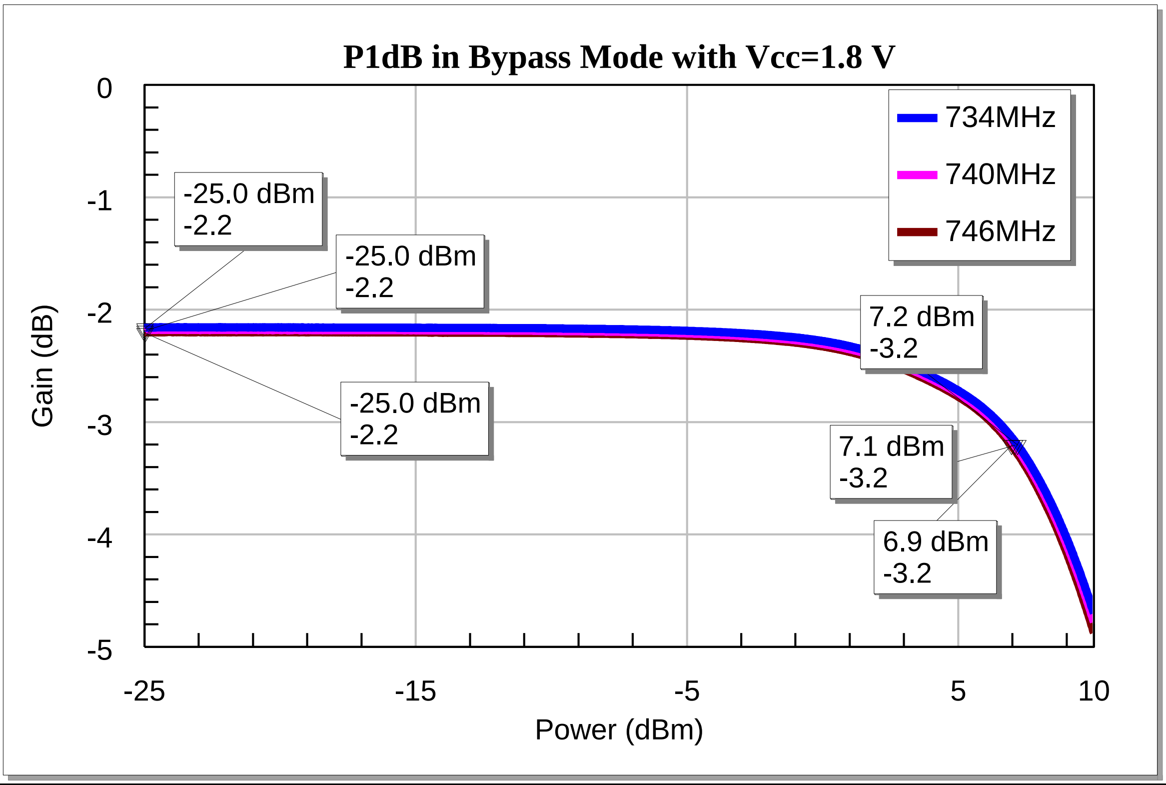


**Figure 28** Input 1dB Compression Point of the BGA7L1BN6 for LTE Band 17 Application, 1.8V

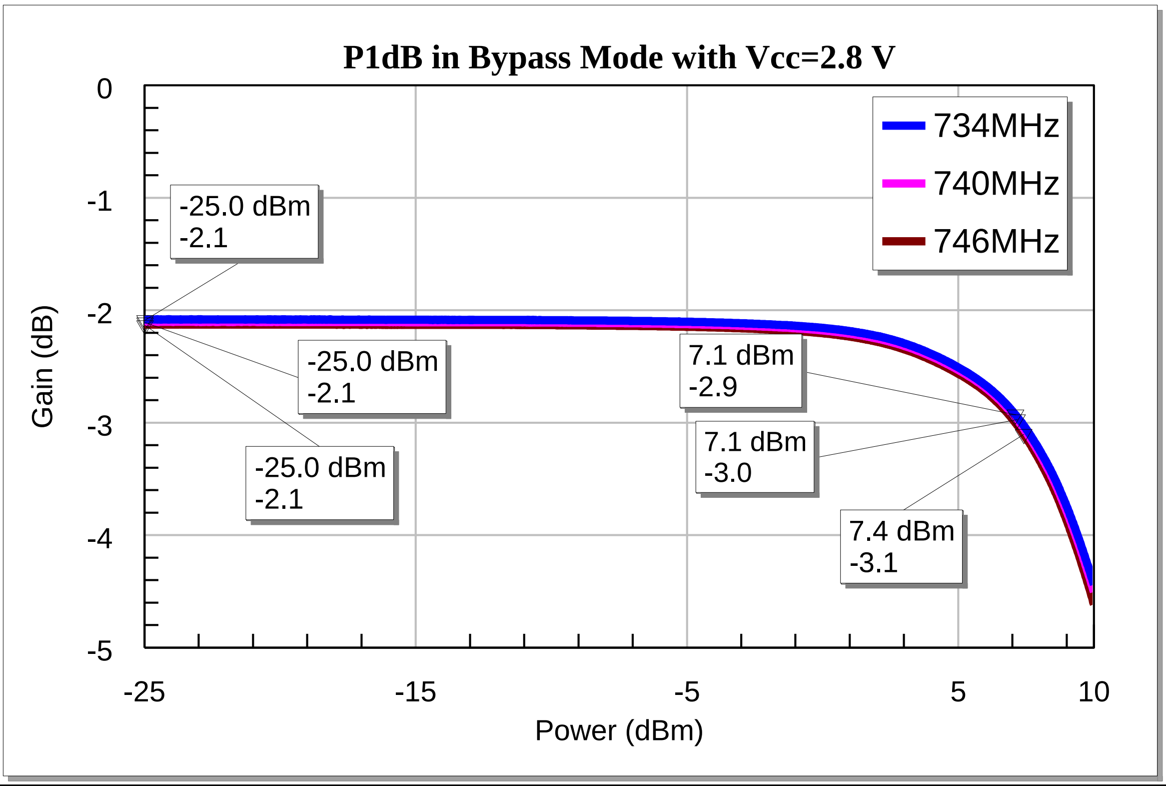


**Figure 29** Input 1dB Compression Point of the BGA7L1BN6 for LTE Band 17 Application, 2.8V

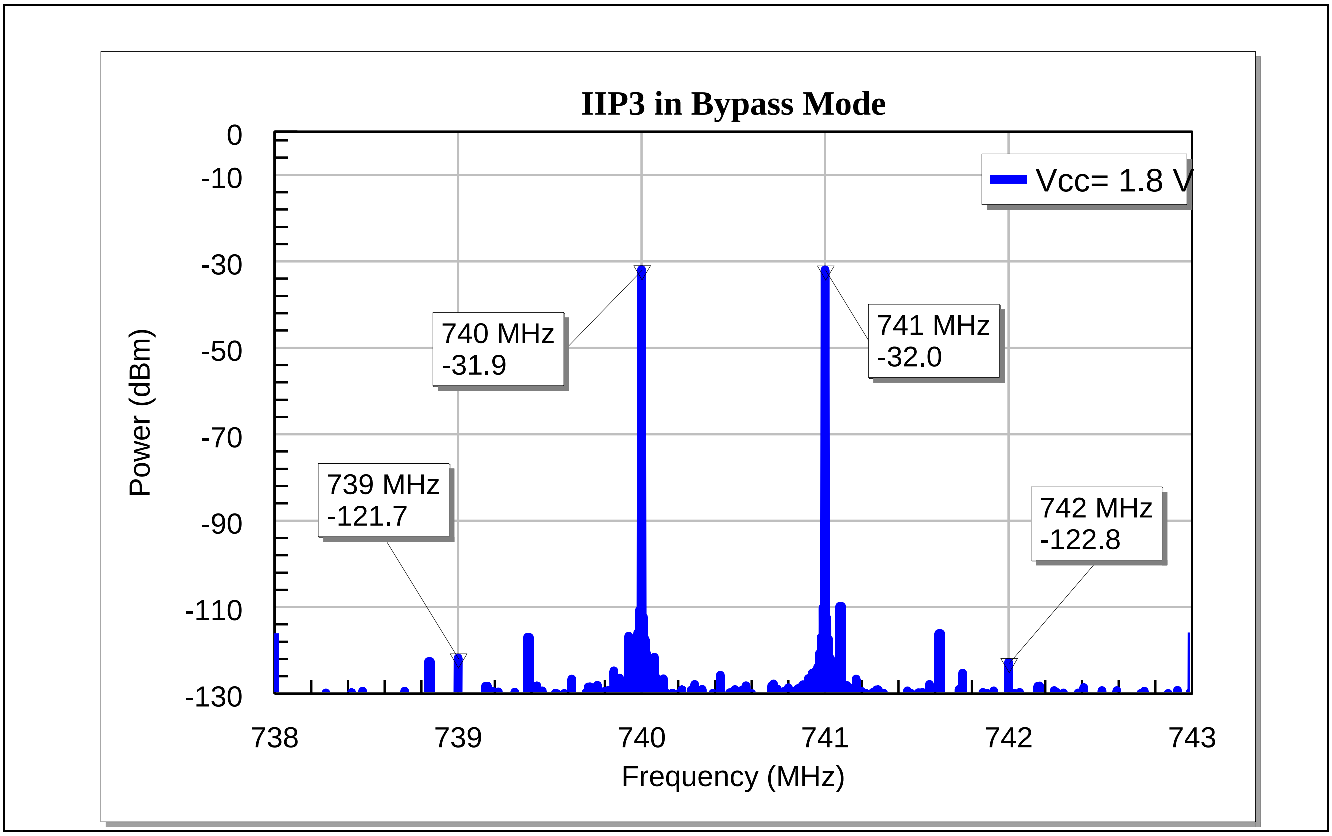


**Figure 30** Third-order Interception Point of the BGA7L1BN6 for LTE Band 17 Application, 1.8 V

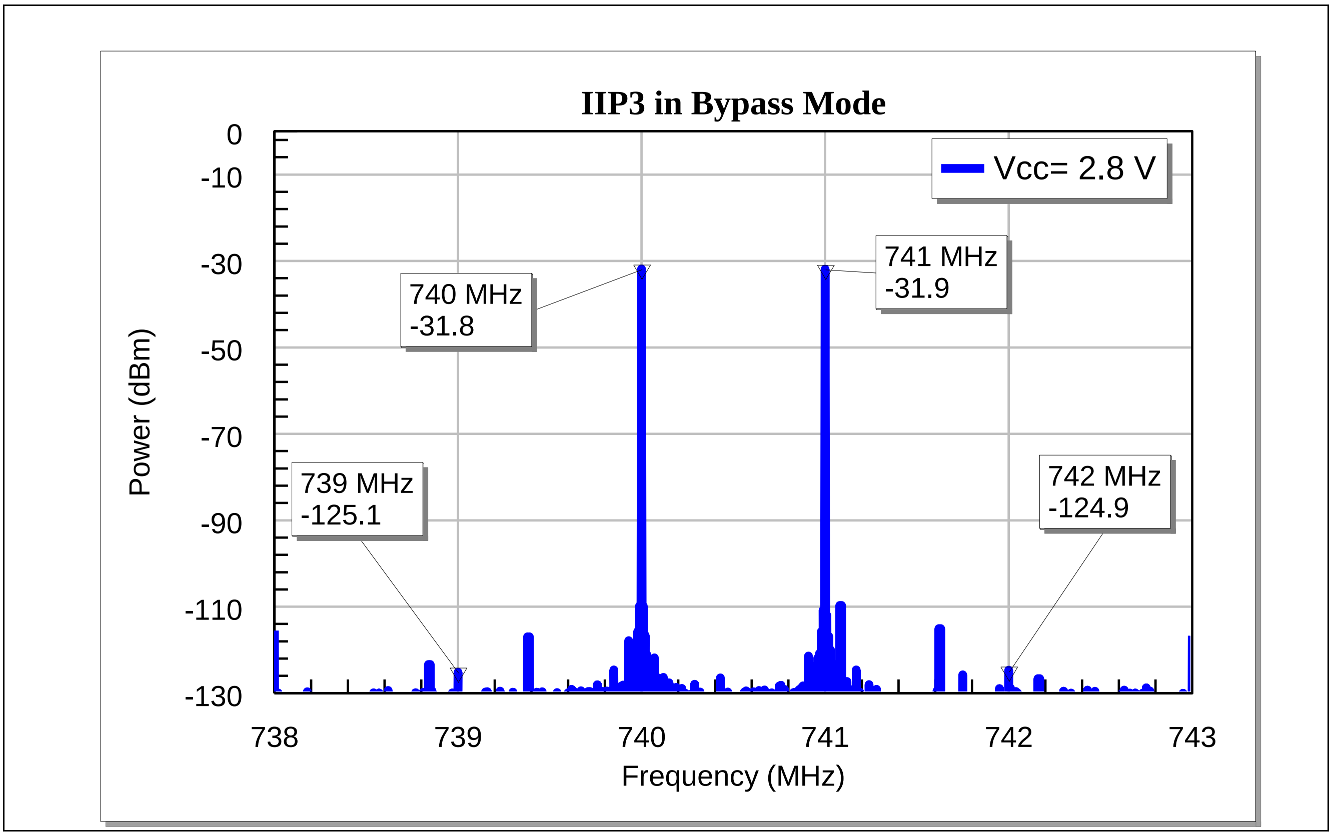


**Figure 31** Third-order Interception Point of the BGA7L1BN6 for LTE Band 17 Application, 2.8 V

# 5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB Marking: **M150918**

PCB material: **FR4**

$\varepsilon_r$ of PCB material: **4.8**


**Figure 32 Photo Picture of Evaluation Board (overview) <PCB Marking M150918 Rev. 2.0>**

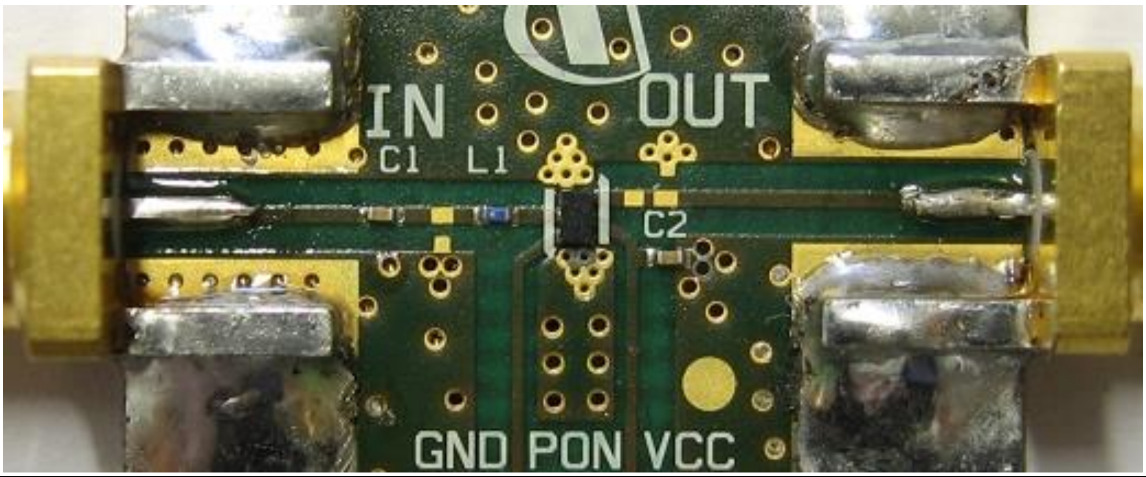


**Figure 33 Photo Picture of Evaluation Board (detailed view)**

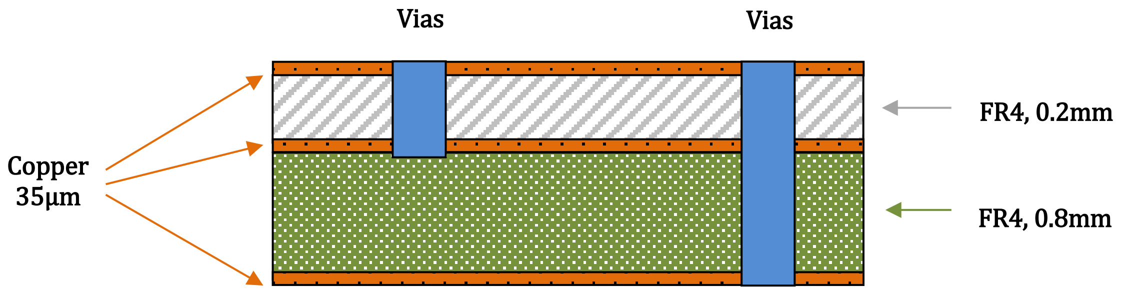


Figure 34 PCB Layer Information

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# 7 Reference

[1] Application Guide for Mobile Communication 2015, Infineon Technologies, PMM RFS

## Revision History

**Major changes since the last revision (Rev 1.0 2016-01)**

| Page or Reference | Description of change |
|---|---|
| 4 - 7 | Updated introduction of LTE application |
| 8 | Inserted product validation statement |
| | |

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