BGA524N6 as Low Noise Amplifier for GNSS Applications with LTE B13/B14 Rejection

About this document

Scope and purpose

This application note describes Infineon’s GNSS MMIC: BGA524N6 as a Low-Noise Amplifier (LNA) for GNSS applications (1550 to 1615 MHz) with LTE B13/B14 rejection using 0201 size components for matching.

1. The BGA524N6 is a silicon germanium LNA supporting 1550 to 1615 MHz.
2. The target application is GNSS applications (1550 to 1615 MHz).
3. In this report, the performance of BGA524N6 for LTE B13/B14 rejection is measured on a FR4 board. This device is matched with 0201 size external components. For comparison purposes, the Noise Figure (NF) with 0402 size LQW15 inductor component in the circuit is also presented.
4. Key performance parameters at 1.8 V, 1575 MHz
   - NF with LQP03T inductor = 1.05 dB
   - NF with LQW15 inductor = 0.95 dB
   - Insertion gain = 19.1 dB
   - Insertion gain at 787 MHz = -37 dB
   - Input return loss = 11.5 dB
   - Output return loss = 17.2 dB
   - Out-of-band output IM3 = -48.1 dBm
5. Key performance parameters at 2.8 V, 1575 MHz
   - NF with LQP03T inductor = 1.05 dB
   - NF with LQW15 inductor = 0.95 dB
   - Insertion gain = 19.0 dB
   - Insertion gain at 787 MHz = -37 dB
   - Input return loss = 11.5 dB
   - Output return loss = 17.4 dB
   - Out-of-band output IM3 = -49.2 dBm
BGA524N6 as Low Noise Amplifier for GNSS Applications with LTE B13/B14 Rejection

Introduction of Global Navigation Satellite Systems (GNSSs)

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1) The graphs are generated with the simulation program AWR Microwave Office®.
Introduction of Global Navigation Satellite Systems (GNSSs)


1.1 **Global Navigation Satellite Systems (GNSSs)**

Global Navigation Satellite Systems (GNSSs) are among the fastest-growing businesses in the electronic industry. Today, four GNSS systems are in operation: the United States GPS, the Russian GLobal Orbiting Navigation Satellite System (GLONASS), the Chinese BeiDou Navigation Satellite System (BDS) and the European Union Galileo navigation system. Main market segments include the Personal Navigation Devices (PNDs), GNSS-enabled mobile phones and GNSS-enabled portable devices.

The main challenges for the growing GNSS-enabled mobile phone segment are to achieve high sensitivity and high immunity defined by government regulations against interference of cellular signals for safety and emergency reasons. This means GNSS signals must be received at very low power levels (down to less than -130 dBm) in mobile phones in the vicinity of co-existing high-power cellular signals.

The main challenges for the GNSS-enabled portable devices are to obtain a long battery operation time, and low Time-To-First Fix (TTFF) to quickly locate the device.

![Figure 1](image-url)  
**Figure 1** Application diagram: receiver front-end of the Global Navigation Satellite System

1.1.1 **LTE band 13/band 14 interference**

The second harmonic of LTE band 13 and band 14 (777 MHz/788 MHz) is located in the GNSS band at 1574 MHz/1576 MHz. Figure 2 shows the interference measurement of LTE band 13 with the GNSS band of 1575 MHz.

Considering a worst-case isolation of 15 dB between both the antennas, jammer frequency $f_{LTE} = 787.76$ MHz, the power of the LTE band 13 jammer is -32 dBm at the input of GNSS LNA. After inserting a band 13 rejection filter at the LNA input, the second harmonic at $f_{H2} = 1575.52$ MHz will be reduced to -110 dBm at the LNA output.
**BGA524N6 as Low Noise Amplifier for GNSS Applications with LTE B13/B14 Rejection**

**Introduction of Global Navigation Satellite Systems (GNSSs)**

**Figure 2**  Block diagram for the LTE band 13 second harmonic interference

1.1.2  Out-of-band interference

Because GNSS and cellular systems coexist in a compact area in a mobile phone, coupling from the cellular transmitter to the GNSS receive path results in the intermixing of other high-frequency signals in GNSS FE devices; for example, intermodulation between LTE band 2 and band 3 signals, intermodulation between LTE band 5 and WLAN 2.4 GHz signals, etc.

In the example below, the LTE band 3 signal ($f_{IN1}$) and LTE band 2 signal ($f_{IN2}$) produce third-order intermodulation products at GPS frequencies. This effect desensitizes the GPS receiver and decreases its performance. When $f_{IN1} = 1712.7$ MHz and power $P_{IN1} = -25$ dBm, and $f_{IN2} = 1850$ MHz and power $P_{IN2} = -25$ dBm are used, the third-order intermodulation product, $2 \times f_{IN1} - f_{IN2}$, is located at 1575.4 MHz. This signal is referred to as Out-of-band Output IM3 (OoB OIM3). The Out-of-Band Input IM3 (OoB IIM3) can be calculated as:

$$OoB\ IIM3 = OoB\ OIM3 - Gain\ at\ 1575.4\ MHz$$

As an example, if the OoB OIM3 of the device at 1575.4 MHz is -48.1 dBm and the gain of the amplifier at 1575.4 MHz is 19.1 dB, then the OoB IIM3 is calculated as:

$$OoB\ IIM3 = -48.1 - 19.1 = -67.2\ dBm$$

1.2  Infineon product portfolio for GNSS applications

Infineon offers the following product portfolio to all customers designing high-performance flexible RF front-end solutions for all GNSS systems:

- **Low-Noise Amplifiers (LNAs):** Infineon offers a wide range of products such as high-performance Monolithic Microwave Integrated Circuits (MMICs) as well as cost-effective and high-end RF transistors.

- **Transient Voltage Suppression (TVS) diodes:** Infineon devices can protect GNSS antennas reliably up to 20 kV.

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Introduction of Global Navigation Satellite Systems (GNSSs)

1.3 Key features of GNSS low-noise amplifiers

Infineon Technologies is among the market leaders in GNSS LNAs for navigation applications. The GNSS MMIC LNA products offer the following features:

Low Noise Figure & High Gain

The power levels of satellite signals received by a GNSS receiver are as low as -130 dBm. An external LNA with exceptionally low NF and good gain helps to boost the signal-to-noise ratio of the system. The existing LNA portfolio includes devices with various gain levels to tailor to customer’s RF systems.

High robustness against coexistence of out-of-band jammer signals

In the presence of very weak GNSS satellite signals, there is no inband interference signal in the GNSS receiver frontends.

In case of mobile phone systems, GNSS signals coexist with strong jammer signals from other RF applications, e.g. 3G/4G, wireless LAN, etc. The above out-of-band jammer signals can mix to produce intermodulation products in the GNSS receiver frequency band. Compared with the received signal level from GNSS satellites, the resulted intermodulation products are significant interference, LNAs with high robustness against out-of-band interference signals are required.

Low Current Consumption

Power consumption is an important feature in many GNSS systems that are mainly battery-operated mobile devices. Infineon's LNAs have an integrated power on/off feature which provides for low power consumption and increased stand-by time for GNSS handsets. Moreover, the recent development has focused on low current (e.g. 1.1 mA) and low supply voltage (1.2 V), making the LNAs suitable for portable devices such as GNSS enabled wearables and connected IoT devices.

Please visit www.infineon.com for more details on LNA products for navigation in mobile phones and portable devices.
BGA524N6 as Low Noise Amplifier for GNSS Applications with LTE B13/B14 Rejection

BGA524N6 overview

1.4 Features

- Operating frequencies: 1550 to 1615 MHz
- Ultra-low current consumption: 2.5 mA
- Wide supply voltage range: 1.5 to 3.3 V
- High insertion power gain: 19.6 dB
- Low NF: 0.55 dB
- 2 kV HBM ESD protection (including AI pin)
- Ultra-small TSNP-6-2 leadless package (footprint: 0.7 x 1.1 mm²)
- RF output internally matched to 50 Ω
- Only one external SMD component necessary
- Pb-free (RoHS compliant) package
- B7HF silicon germanium technology

Figure 3 BGA524N6N6 in TSNP-6-2

1.5 Key applications of BGA524N6

BGA524N6 is designed to enhance GNSS signal sensitivity, especially in wearables and mobile cellular IoT devices. With 19.6 dB gain and only 0.55 dB NF it ensures high system sensitivity. The current needed is only 2.5 mA, which is critical to help to conserve batteries. The wide supply voltage range of 1.5 to 3.3 V ensures flexible design and high compatibility. It supports all GNSS systems including GPS, GLONASS, BeiDou and Galileo.

1.6 Description

The BGA524N6 is an ultra-low-noise amplifier for Global Navigation Satellite Systems (GNSSs), which covers all GNSS frequency bands from 1550 to 1615 MHz, such as GPS, GLONASS, BeiDou, Galileo and others. The LNA provides 19.6 dB gain and 0.55 dB NF at a current consumption of only 2.5 mA in the application configuration described in Figure 5. The BGA524N6 is based on Infineon Technologies' B7HF silicon germanium technology. It operates from 1.5 to 3.3 V supply voltage.
BGA524N6 as Low Noise Amplifier for GNSS Applications with LTE B13/B14 Rejection

BGA524N6 overview

Figure 4  Package and pin connections of BGA524N6

Table 1  Pin assignment of BGA524N6

<table>
<thead>
<tr>
<th>Pin no.</th>
<th>Symbol</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>2</td>
<td>VCC</td>
<td>DC supply</td>
</tr>
<tr>
<td>3</td>
<td>AO</td>
<td>LNA output</td>
</tr>
<tr>
<td>4</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>5</td>
<td>AI</td>
<td>LNA input</td>
</tr>
<tr>
<td>6</td>
<td>PON</td>
<td>Power on control</td>
</tr>
</tbody>
</table>
Application circuit and performance overview

In this chapter the performance of the application circuit, the schematic and Bill of Materials are presented.

Device: BGA524N6
Application: LNA for GNSS applications with LTE B13/B14 rejection
PCB marking: M110705
EVB order no.: AN575

2.1 Summary of measurement results

The performance of BGA524N6 for GNSS applications is summarized in the following table.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
<th>Comment/test condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency range</td>
<td>Freq</td>
<td>1550</td>
<td>1575</td>
<td>1615 MHz</td>
</tr>
<tr>
<td>DC voltage</td>
<td>VCC</td>
<td>1.8</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>DC current</td>
<td>ICC</td>
<td>2.6</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>Gain</td>
<td>G</td>
<td>19.1</td>
<td>19.1</td>
<td>18.9 dB</td>
</tr>
<tr>
<td>Gain at 787 MHz</td>
<td>G_B13</td>
<td>-37</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>Noise Figure(^1)</td>
<td>NF</td>
<td>1.10</td>
<td>1.05</td>
<td>1.05 dB</td>
</tr>
<tr>
<td>Noise Figure(^1)</td>
<td>NF</td>
<td>0.95</td>
<td>0.95</td>
<td>0.95 dB</td>
</tr>
<tr>
<td>Input return loss</td>
<td>RL_{in}</td>
<td>12.6</td>
<td>11.5</td>
<td>10.1 dB</td>
</tr>
<tr>
<td>Output return loss</td>
<td>RL_{out}</td>
<td>11.8</td>
<td>17.2</td>
<td>24.8 dB</td>
</tr>
<tr>
<td>Reverse isolation</td>
<td>I_{Rev}</td>
<td>37.7</td>
<td>37.6</td>
<td>37.9 dB</td>
</tr>
<tr>
<td>Input P1dB</td>
<td>IP1dB</td>
<td>-15.2</td>
<td>dBm</td>
<td></td>
</tr>
<tr>
<td>Output P1dB</td>
<td>OP1dB</td>
<td>3.9</td>
<td>dBm</td>
<td></td>
</tr>
<tr>
<td>LTE band 13 second harmonic input referred</td>
<td>B13 IHD2</td>
<td>-68.3</td>
<td>dBm</td>
<td>Power at input: -25 dB f = 787.7 MHz, HD2 measured at 1575.4 MHz</td>
</tr>
<tr>
<td>LTE band 13 second harmonic output referred</td>
<td>B13 OHD2</td>
<td>-49.2</td>
<td>dBm</td>
<td></td>
</tr>
<tr>
<td>Input IP3</td>
<td>IIP3</td>
<td>-12.1</td>
<td>dBm</td>
<td>Power at input: -30 dB f1 = 1575 MHz, f2 = 1576 MHz</td>
</tr>
<tr>
<td>Output IP3</td>
<td>OIP3</td>
<td>6.9</td>
<td>dBm</td>
<td></td>
</tr>
<tr>
<td>Out-of-Band Input IM(^3)</td>
<td>OoB_{IIM3}</td>
<td>-67.2</td>
<td>dBm</td>
<td>Power at input: -25 dB f1 = 1712.7 MHz, f2 = 1850 MHz OoB_{IIM3} measured at 1575.4 MHz</td>
</tr>
<tr>
<td>Out-of-Band Output IM(^3)</td>
<td>OoB_{OIM3}</td>
<td>-48.1</td>
<td>dBm</td>
<td></td>
</tr>
<tr>
<td>Stability</td>
<td>K</td>
<td>&gt; 1</td>
<td>–</td>
<td>Measured up to 10 GHz</td>
</tr>
</tbody>
</table>
### Table 3  Electrical characteristics at 2.8 V (at room temperature)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
<th>Comment/test condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency range</td>
<td>Freq</td>
<td>1550</td>
<td>1575</td>
<td>1615 MHz</td>
</tr>
<tr>
<td>DC voltage</td>
<td>V&lt;sub&gt;CC&lt;/sub&gt;</td>
<td>2.8</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>DC current</td>
<td>I&lt;sub&gt;CC&lt;/sub&gt;</td>
<td>2.7</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>Gain</td>
<td>G</td>
<td>19.2</td>
<td>19.0</td>
<td>18.9 dB</td>
</tr>
<tr>
<td>Gain at 787 MHz</td>
<td>G&lt;sub&gt;_B13&lt;/sub&gt;</td>
<td>-37</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>Noise Figure&lt;sup&gt;1)&lt;/sup&gt;</td>
<td>NF</td>
<td>1.10</td>
<td>1.05</td>
<td>1.05 dB</td>
</tr>
<tr>
<td>Noise Figure&lt;sup&gt;2)&lt;/sup&gt;</td>
<td>NF</td>
<td>0.95</td>
<td>0.95</td>
<td>0.90 dB</td>
</tr>
<tr>
<td>Input return loss</td>
<td>RL&lt;sub&gt;in&lt;/sub&gt;</td>
<td>12.7</td>
<td>11.5</td>
<td>10.1 dB</td>
</tr>
<tr>
<td>Output return loss</td>
<td>RL&lt;sub&gt;out&lt;/sub&gt;</td>
<td>11.9</td>
<td>17.4</td>
<td>24.9 dB</td>
</tr>
<tr>
<td>Reverse isolation</td>
<td>I&lt;sub&gt;_rev&lt;/sub&gt;</td>
<td>37.6</td>
<td>37.6</td>
<td>37.8 dB</td>
</tr>
<tr>
<td>Input P1dB</td>
<td>IP1dB</td>
<td>-11.5</td>
<td>dBm</td>
<td></td>
</tr>
<tr>
<td>Output P1dB</td>
<td>OP1dB</td>
<td>7.6</td>
<td>dBm</td>
<td></td>
</tr>
<tr>
<td>LTE band 13 second harmonic input referred</td>
<td>B13 IHD2</td>
<td>-68.3</td>
<td>dBm</td>
<td>Power at input: -25 dBm f = 787.7 MHz, measure HD2 at 1575.4 MHz</td>
</tr>
<tr>
<td>LTE band 13 second harmonic output referred</td>
<td>B13 OHD2</td>
<td>-49.2</td>
<td>dBm</td>
<td></td>
</tr>
<tr>
<td>Input IP3</td>
<td>IIP3</td>
<td>-12.1</td>
<td>dBm</td>
<td></td>
</tr>
<tr>
<td>Output IP3</td>
<td>OIP3</td>
<td>7.0</td>
<td>dBm</td>
<td></td>
</tr>
<tr>
<td>Out-of-Band Input IM&lt;sup&gt;3)&lt;/sup&gt;</td>
<td>OoB_iIM3</td>
<td>-68.2</td>
<td>dBm</td>
<td>Power at input: -25 dBm f&lt;sub&gt;1&lt;/sub&gt; = 1712.7 MHz, f&lt;sub&gt;2&lt;/sub&gt; = 1850 MHz OoB_IIM3 measured at 1575.4 MHz</td>
</tr>
<tr>
<td>Out-of-Band Output IM3</td>
<td>OoB_OIM3</td>
<td>-49.2</td>
<td>dBm</td>
<td></td>
</tr>
<tr>
<td>Stability</td>
<td>K</td>
<td>&gt; 1</td>
<td>–</td>
<td>Measured up to 10 GHz</td>
</tr>
</tbody>
</table>

<sup>1)</sup> LQP03T inductor for matching, loss of input line of 0.05 dB is de-embedded<sup>1)</sup>

<sup>2)</sup> LQW15 inductor for matching, loss of input line of 0.05 dB is de-embedded<sup>2)</sup>

<sup>3)</sup> Out-of-band Input IM<sub>x</sub> = IM level output referred – Gain @ the measured frequency
### 2.2 Schematic and BOM

The schematic of BGA524N6 for GNSS applications is presented in Figure 5 and its BOM is shown in Error! Reference source not found..

#### Figure 5  Schematic of the BGA524N6 application circuit

#### Table 4  BOM

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
<th>Size</th>
<th>Manufacturer</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1.5(^1)/1.6(^2)</td>
<td>pF</td>
<td>0201</td>
<td>Various</td>
<td>Input matching</td>
</tr>
<tr>
<td>C2</td>
<td>6.8</td>
<td>pF</td>
<td>0201</td>
<td>Various</td>
<td>B13/B14 notch filter</td>
</tr>
<tr>
<td>C3</td>
<td>Greater than or equal to 1</td>
<td>nF</td>
<td>0201</td>
<td>Various</td>
<td>RF bypass</td>
</tr>
<tr>
<td>L1</td>
<td>6.2</td>
<td>nH</td>
<td>0201/0402</td>
<td>Murata LQP03T/Murata LQW15</td>
<td>B13/B14 notch filter</td>
</tr>
<tr>
<td>N1</td>
<td>BGA524N6</td>
<td></td>
<td></td>
<td>Infineon Technologies</td>
<td>SiGe LNA</td>
</tr>
</tbody>
</table>

Note: 1) \( C1 = 1.5 \text{ pF} \) used for matching when LQW15 inductor is used as a filter component

2) \( C1 = 1.6 \text{ pF} \) used for matching when LQP03T inductor is used as a filter component

3) Measurements have been presented using 0201 components

Note: DC block function is NOT integrated at the input of BGA524N6. The DC block might be realized with pre-filter in GNSS applications.

Note: The RF bypass capacitor C3 at the DC power supply pin filters out the power supply noise and stabilizes the DC supply. The C3 is not necessary if a clean and stable DC supply can be ensured.
3 Measurement graphs

Figure 6  Insertion power gain (narrowband) of BGA524N6 for GNSS applications

Figure 7  Insertion power gain (wideband) of BGA524N6 for GNSS applications
BGA524N6 as Low Noise Amplifier for GNSS Applications with LTE B13/B14 Rejection

Measurement graphs

Figure 8  NF of BGA524N6 for GNSS applications (without SMA and connector losses)

Figure 9  Input return loss of BGA524N6 for GNSS applications
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Measurement graphs

Figure 10  Output return loss of BGA524N6 for GNSS applications

Figure 11  Reverse isolation of BGA524N6 for GNSS applications
Figure 12  Stability K-factor of BGA524N6 for GNSS applications

Figure 13  Stability Mu1-factor, Mu2-factor of BGA524N6 for GNSS applications
**BGA524N6 as Low Noise Amplifier for GNSS Applications with LTE B13/B14 Rejection**

**Measurement graphs**

**Figure 14**  Input 1dB compression point of BGA524N6 for GNSS applications

**Figure 15**  Second harmonic of LTE band 13 of BGA524N6 for GNSS applications
Figure 16  Third-order interception point (1.8 V) of BGA524N6 for GNSS applications

Figure 17  Third-order interception point (2.8 V) of BGA524N6 for GNSS applications
BGA524N6 as Low Noise Amplifier for GNSS Applications with LTE B13/B14 Rejection

Measurement graphs

Figure 18  Out-of-band interception point (1.8 V) of BGA524N6 for GNSS applications

Figure 19  Out-of-band third-order interception point (2.8 V) of BGA524N6 for GNSS applications
4 Evaluation board and layout Information

In this application note, the following PCB is used:

PCB marking: M110705
PCB material: FR 4
εr of PCB material: 4.3

Figure 20 Photo of evaluation board (overview)

Figure 21 Photo of evaluation board (detailed view)
Evaluation board and layout Information

Figure 22  PCB layer information

Copper 35 µm

FR4, 0.2 mm

FR4, 0.8 mm
5 Authors

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6 Reference

[4] https://www.infineon.com/dgdl/AN267.pdf?folderId=db3a304313b8b5a60113d4239297042f&fileId=db3a3043327f13e30132a509789d4359

Revision history

Major changes since the last revision Rev 1.0 from 2019-2-22

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<tr>
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<td>Updated GNSS frequency allocations in Fig 1</td>
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