Low noise amplifier for remote keyless entry (RKE) applications
RF low-power transistor

About this document

Scope and purpose
This application note provides an application circuit design example with Infineon's radio frequency (RF) low-power silicon (Si) transistor BFP460 as low noise amplifier (LNA) for RKE automotive applications. In this document, the BFP460 LNA schematic, PCB layout and measurement results are shown.

Intended audience
This document is intended for engineers who need to design RF LNAs for RKE applications.

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Introduction

1 Introduction

1.1 RKE for automotive applications

The term “RKE” refers to a lock that uses an electronic remote control as a key, which is activated by a handheld device. Widely used in automobiles, an RKE performs the functions of a standard car key without physical contact. When within a few meters of the car, pressing a button on the remote can lock or unlock the doors, and the remote may also perform other functions.

An RKE system consists of an RF transmitter in the keyfob (or key) that sends a signal to the on-board receiver in the vehicle, as shown in Figure 1. In automotive systems, the on-board RKE receiver antenna is usually placed in locations often dictated by cost and practical considerations and may result in increasing path loss and reducing the RKE system range. Furthermore, the antennas used in the RKE receivers typically have poor efficiency. Adding an external LNA between the receiver antenna and the RKE IC is the most cost-effective option to increase the range of the RKE system with minimal increase in power consumption. The wireless carrier frequency used for the RKE systems is 315 MHz in the US/Japan and 433.92 MHz (ISM band) in Europe.

Figure 1 The RKE application in automobiles

1.2 Infineon low-noise Si transistors

Infineon Technologies provides high-performance RF transistors. Infineon’s reliable high-volume RF transistors offer exceptionally low noise figure (NF), high gain and high linearity at low power consumption levels for RF applications. The high-performance low-noise wide-band amplifiers are based on silicon bipolar technology. Their optimized inner transistor cell structure leads to best-in-class power gains and NF. The transistors maximize design flexibility to suit customer requirements.
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2 BFP460 LNA for RKE applications

2.1 Performance overview

The following table shows the RF LNA performance with RF low-power transistor BFP460 for RKE applications. The measurements are performed with network analyzer source power of -40 dBm.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bias voltage</td>
<td>$V_{CC}$</td>
<td>5.0</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Bias current</td>
<td>$I_{CC}$</td>
<td>5.3</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>Frequency range</td>
<td>f</td>
<td>315</td>
<td>434</td>
<td>900 MHz</td>
</tr>
<tr>
<td>Gain</td>
<td>G</td>
<td>16.3</td>
<td>16</td>
<td>14.3 dB</td>
</tr>
<tr>
<td>Input return loss</td>
<td>$R_{L_{in}}$</td>
<td>16.4</td>
<td>14.2</td>
<td>10.3 dB</td>
</tr>
<tr>
<td>Output return loss</td>
<td>$R_{L_{out}}$</td>
<td>24.2</td>
<td>24.6</td>
<td>20.2 dB</td>
</tr>
<tr>
<td>Reverse isolation</td>
<td>$ISO_{rev}$</td>
<td>21.1</td>
<td>21</td>
<td>20.6 dB</td>
</tr>
<tr>
<td>Noise figure</td>
<td>NF</td>
<td>1.6</td>
<td>1.7</td>
<td>1.7 dB</td>
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<tr>
<td>Input 1 dB compression point</td>
<td>$I_{P_{1dB}}$</td>
<td>-20.9</td>
<td>-20.2</td>
<td>dBm 1) Measured at 315 MHz 2) Measured at 434 MHz</td>
</tr>
<tr>
<td>Output 1 dB compression point</td>
<td>$O_{P_{1dB}}$</td>
<td>-5.6</td>
<td>-5.2</td>
<td>dBm 3) Measured at 315 MHz 4) Measured at 434 MHz</td>
</tr>
<tr>
<td>Output third-order intercept</td>
<td>$O_{I_{P_3}}$</td>
<td>6.8</td>
<td>6.7</td>
<td>dBm 5) Input power: -33 dBm per tone, $f_1$=314.5 MHz, $f_2$=315.5 MHz 6) Input power: -33 dBm per tone, $f_1$=433.5 MHz, $f_2$=434.5 MHz</td>
</tr>
<tr>
<td>Stability</td>
<td>K</td>
<td>&gt;1</td>
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<td>Measured from 10 MHz up to 10 GHz</td>
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2.2 Schematic

The following figure shows the schematic of BFP460 LNA for RKE applications. In the schematic, resistors R1, R2 and R3 stand for transistor voltage and current bias; meanwhile, R1 and R3 form a negative DC feedback mechanism to stabilize the transistor bias points in various conditions. R2 and C2 serve as the negative feedback to improve input and output impedance matching. Capacitors C3 and C4 serve as the RF bypass. The transistor input matching is achieved by C1. The output matching network is formed by C5 and R4.
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Figure 2  **BFP460** LNA schematic for RKE applications

2.3  **Bill of materials (BOM)**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
<th>Package</th>
<th>Manufacture</th>
<th>Comment</th>
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<tr>
<td>Q1</td>
<td><strong>BFP460</strong></td>
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<td>SOT343</td>
<td>Infineon</td>
<td>Low-power Si transistor</td>
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<tr>
<td>C1</td>
<td>390</td>
<td>pF</td>
<td>0402</td>
<td>various</td>
<td>DC block and input matching</td>
</tr>
<tr>
<td>C2</td>
<td>390</td>
<td>pF</td>
<td>0402</td>
<td>various</td>
<td>DC block for feedback network</td>
</tr>
<tr>
<td>C3</td>
<td>220</td>
<td>nF</td>
<td>0402</td>
<td>various</td>
<td>RF bypass</td>
</tr>
<tr>
<td>C4</td>
<td>390</td>
<td>pF</td>
<td>0402</td>
<td>various</td>
<td>RF bypass</td>
</tr>
<tr>
<td>C5</td>
<td>390</td>
<td>pF</td>
<td>0402</td>
<td>various</td>
<td>DC block and output matching</td>
</tr>
<tr>
<td>R1</td>
<td>82</td>
<td>kΩ</td>
<td>0402</td>
<td>various</td>
<td>Base DC bias</td>
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<tr>
<td>R2</td>
<td>430</td>
<td>Ω</td>
<td>0402</td>
<td>various</td>
<td>Feedback resistor</td>
</tr>
<tr>
<td>R3</td>
<td>130</td>
<td>Ω</td>
<td>0402</td>
<td>various</td>
<td>DC bias and DC negative feedback</td>
</tr>
<tr>
<td>R4</td>
<td>300</td>
<td>Ω</td>
<td>0402</td>
<td>various</td>
<td>Collector DC bias and output matching</td>
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</tbody>
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2.4  **Evaluation board and layout information**

The evaluation board for **BFP460** LNA for RKE applications:

- PCB material: FR4
- PCB marking: BFP460 V2.0

Images of the evaluation board and the PCB stack information are shown in the following figures.
Figure 3  The photo of BFP460 LNA for RKE applications

Figure 4  PCB stack information for the evaluation board
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3 Measurement results of **BFP460** LNA for RKE applications

![Graph showing small signal gain of BFP460 LNA for RKE applications.](image)

**Figure 5** Small signal gain of **BFP460** LNA for RKE applications

![Graph showing input return loss of BFP460 LNA for RKE applications.](image)

**Figure 6** Input return loss of **BFP460** LNA for RKE applications

*Note: The graphs are generated with the AWR electronic design automation (EDA) software Microwave Office®.*
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Figure 7  Output return loss of **BFP460** LNA for RKE applications

Figure 8  Reverse isolation of **BFP460** LNA for RKE applications
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Figure 9  Input 1 dB compression point of BFP460 LNA for RKE applications

Figure 10  Output third-order intermodulation products of the BFP460 LNA at 315 MHz with -33 dBm input power per tone for RKE applications
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**Figure 11**  Output third-order intermodulation products of the **BFP460** LNA at 434 MHz with -33 dBm input power per tone for RKE applications

**Figure 12**  NF measurement of **BFP460** LNA for RKE applications
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Figure 13  K-factor measurement of BFP460 LNA for RKE applications
4 Author

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Revision history

<table>
<thead>
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<th>Document version</th>
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