This document provides circuit, layout, BOM and performance information for 2.33 GHz LNA equipped with NXP Semiconductors BFU730F wide-band transistor.
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1. Introduction

The BFU730F is a wideband Silicon Germanium Amplifier transistor for high speed, low noise applications. It is used for LNA applications such as GPS, satellite radio, cordless phone and wireless LAN. The BFU730F comes in a SOT343F package that contains two emitter pins for improved grounding.

The BFU730F is ideal in all kinds of application where cost matters. It also provides the designer with increased flexibility.

BFU730F SiGeC low noise transistor is shown in Figure 1 in a Satellite Digital Audio Radio Service (SDARS) active antenna LNA application. It is intended for use as the first stage in a three stage SIRIUS LNA chain.

The 2.33 GHz LNA evaluation board (EVB) is designed to evaluate the performance of the BFU730F transistor applied as the first stage in a three stage SIRIUS LNA chain. This document provides an application diagram, board layout, bill of material, and some typical results.

Figure 2 depicts the evaluation board.
Fig 2. BFU730F 2.33 GHz LNA evaluation board
2. General description

The BFU730F is a discrete HBT produced in NXP Semiconductors SiGeC QuBIC4x BiCMOS process. SiGeC is in principle a normal silicon germanium process with the addition of Carbon in the base layer of the NPN transistor. The presence of carbon in the base layer suppresses the boron diffusion during wafer processing. This process allows steeper and narrower SiGe HBT base and a heavier doped base. This results in lower base resistance, lower noise and higher cut-off frequency (higher gain). Table 1 provides a summary of the transistor performance in terms of noise and gain is shown.

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>Noise (dB)</th>
<th>Associated gain (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>0.50</td>
<td>25</td>
</tr>
<tr>
<td>1.8</td>
<td>0.50</td>
<td>23.5</td>
</tr>
<tr>
<td>2.4</td>
<td>0.55</td>
<td>21.5</td>
</tr>
<tr>
<td>5.8</td>
<td>0.80</td>
<td>15.0</td>
</tr>
<tr>
<td>12</td>
<td>1.30</td>
<td>11.0</td>
</tr>
</tbody>
</table>

Table 2. Pinning information

<table>
<thead>
<tr>
<th>Pin</th>
<th>Description</th>
<th>Simplified outline</th>
<th>Graphic symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>emitter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>base</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>emitter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>collector</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. Application Board

The BFU730F 2.33 GHz EVB simplifies the evaluation of the BFU730F wideband transistor, for this frequency range. The EVB enables testing of the device performance and requires no additional support circuitry. The board is fully assembled with BFU730F, including input and output matching, to optimize the performance. The input match was a compromise between the best noise figure and a low input return loss. The board is mounted with signal input and output SMA connectors for connection to RF test equipment.

3.1 Application Circuit

Figure 3 provides the application diagram as supplied on the evaluation board.

![Circuit diagram of the evaluation board](fig3.png)
3.2 Board Layout

Figure 3 shows the board layout including components.

![Board Layout Image](aaa-000711)

**Fig. 4.** Printed circuit board of the BUF730F 2.33 GHz evaluation board

3.3 PCB layout

A good PCB Layout is an essential part of an RF circuit design. The EVB of the BFU730F serves as a guideline for laying out a board using the BFU730F. Use controlled impedance lines for all high frequency inputs and outputs. Bypass VCC with decoupling capacitors, preferable located as close as possible to the device. For long bias lines, it may be necessary to add decoupling capacitors in the line further away from the device. Correct grounding of the GND pin is also essential for performance. Either connect the GND pin directly to the ground plane or through vias, or do both.

The EVB is made of FR4 material using the stack shown in Figure 5.

![Stack Image](aaa-000712)

**Fig. 5.** Stack of the PCB material
Material supplier is Isola Duraver; $\varepsilon_r = 4.6$ to 4.9; $\tan \delta = 0.02$.

### 3.4 Bill of materials

Table 3. Bill of materials

<table>
<thead>
<tr>
<th>Designator</th>
<th>Description</th>
<th>Footprint</th>
<th>Value</th>
<th>Supplier name/type</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>capacitor</td>
<td>0402</td>
<td>12 pF</td>
<td>Murata GRM1555</td>
<td>input matching/DC blocking</td>
</tr>
<tr>
<td>C2</td>
<td>capacitor</td>
<td>0402</td>
<td>3.3 pF</td>
<td>Murata GRM1555</td>
<td>input matching/DC blocking</td>
</tr>
<tr>
<td>C3</td>
<td>capacitor</td>
<td>0402</td>
<td>8.2 pF</td>
<td>Murata GRM1555</td>
<td>LF decoupling</td>
</tr>
<tr>
<td>C4</td>
<td>capacitor</td>
<td>0402</td>
<td>10 pF</td>
<td>Murata GRM1555</td>
<td>LF decoupling</td>
</tr>
<tr>
<td>C5</td>
<td>capacitor</td>
<td>0402</td>
<td>10 pF</td>
<td>Murata GRM1555</td>
<td>LF decoupling</td>
</tr>
<tr>
<td>L1</td>
<td>inductor</td>
<td>0402</td>
<td>15 nH</td>
<td>Murata/LQW15A</td>
<td>input matching/DC bias</td>
</tr>
<tr>
<td>L2</td>
<td>inductor</td>
<td>0402</td>
<td>100 nH</td>
<td>Murata/LQW15A</td>
<td>DC bias</td>
</tr>
<tr>
<td>L3</td>
<td>inductor</td>
<td>0402</td>
<td>5.8 nH</td>
<td>Murata/LQW15A</td>
<td>output matching</td>
</tr>
<tr>
<td>R1</td>
<td>resistor</td>
<td>0402</td>
<td>130 $\Omega$</td>
<td>various</td>
<td>bias setting temperature stability</td>
</tr>
<tr>
<td>R2</td>
<td>resistor</td>
<td>0402</td>
<td>30 $\Omega$</td>
<td>various</td>
<td>bias setting</td>
</tr>
<tr>
<td>R3</td>
<td>resistor</td>
<td>0402</td>
<td>100 $\Omega$</td>
<td>various</td>
<td>stability</td>
</tr>
<tr>
<td>R4, R5</td>
<td>resistor</td>
<td>0402</td>
<td>0 $\Omega$</td>
<td>various</td>
<td>backup tune pads</td>
</tr>
<tr>
<td>X1, X2</td>
<td>SMA RF connector</td>
<td>-</td>
<td>-</td>
<td>Johnson, end launch</td>
<td>RF input/RF output</td>
</tr>
<tr>
<td>X3</td>
<td>DC header</td>
<td>-</td>
<td>-</td>
<td>Molex, PCB header, right angle, 1 row, 3-way 90121-0763</td>
<td>bias connector</td>
</tr>
</tbody>
</table>
4. Equipment required

In order to measure the evaluation board the following is required:

- DC power supply up to 30 mA at 3.3 V (up to 15 V for bias control)
- RF signal generator capable of generating an RF signal at the operating frequency of 2.33 GHz.
- RF spectrum analyzer that covers at least the operating frequency of 2.33 GHz as well as a few of the harmonics. A spectrum analyzer that has a noise figure test function which measures up to 8 GHz, is sufficient. This is useful as it eliminates the necessity of having an expensive noise figure analyzer.
- Ammeter to measure the supply current (optional).
- Network analyzer for measuring gain, return loss and reverse Isolation.
- Noise figure analyzer.
5. Connections and setup

The BFU730F, 2.33 GHz EVB is fully assembled and tested. The following procedure is a step-by-step guide to operate the EVB and test the device functions.

1. Set the DC power supply to 3.3 V and connect it to the VCC and GND terminals.
2. Connect the RF signal generator and spectrum analyzer to the RF input and the RF output of the EVB, respectively. Do not turn on the RF output of the signal generator yet but set it to –30 dBm output power at 2.33 GHz. Set the spectrum analyzer to 2.33 GHz center frequency with a reference level of 0 dBm.
3. Turn on the DC power supply and it reads approximately 11 mA.
4. Enable the RF output of the generator; the Spectrum analyzer displays a tone of 2.33 GHz at around –13 dBm.
5. A network analyzer (NWA) can be used, instead of a signal generator and spectrum analyzer, to measure gain for input and output return loss.
6. To evaluate the noise figure, use either a noise figure analyzer or a spectrum analyzer with noise option. The use of a 15 dB noise source, such as the Agilent 364B, is recommended. When measuring the noise figure of the evaluation board, minimize the use of any kind of adaptors or cables between the noise source and the EVB. Cables and adaptors significantly affect the noise performance.

Fig 6. Printed circuit board of the BUF730F 2.33 GHz evaluation board
6. Typical EVB Results

Table 4. Typical measurement results measured on the evaluation board

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>NF</td>
<td>noise figure</td>
<td>0.8</td>
<td>dB</td>
</tr>
<tr>
<td>Gp</td>
<td>power gain</td>
<td>17.6</td>
<td>dB</td>
</tr>
<tr>
<td>RL_{in}</td>
<td>input return loss</td>
<td>9.4</td>
<td>dB</td>
</tr>
<tr>
<td>RL_{out}</td>
<td>output return loss</td>
<td>22.5</td>
<td>dB</td>
</tr>
<tr>
<td>a_{isol(r)}</td>
<td>reverse isolation</td>
<td>29.4</td>
<td>dB</td>
</tr>
<tr>
<td>P_{G(1dB)}</td>
<td>input 1 dB Gain Compression</td>
<td>-15</td>
<td>dBm</td>
</tr>
<tr>
<td>P_{L(1dB)}</td>
<td>output 1 dB Gain Compression</td>
<td>1.7</td>
<td>dBm</td>
</tr>
<tr>
<td>IP_{3I}</td>
<td>Input third order intercept point</td>
<td>4.7</td>
<td>dBm</td>
</tr>
<tr>
<td>IP_{3O}</td>
<td>output third order intercept point</td>
<td>22.6</td>
<td>dBm</td>
</tr>
</tbody>
</table>

[1] The NF and gain figures are measured at the SMA connectors of the EVB, so the connectors and PCB losses are not subtracted. When they are subtracted, the NF improves by approximately 0.1 dB.

6.1 Noise figure

Fig 7. Plot of noise figure

2290 MHz to 2370 MHz, center of plot (x-axis) is 2330 MHz
6.1.1 Noise figure tabular data

Table 5. Frequency list results

<table>
<thead>
<tr>
<th>RF (GHz)</th>
<th>NF (dB)</th>
<th>Noise temperature (K)</th>
<th>Gain (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.290</td>
<td>0.825</td>
<td>60.701</td>
<td>17.736</td>
</tr>
<tr>
<td>2.300</td>
<td>0.827</td>
<td>60.840</td>
<td>17.694</td>
</tr>
<tr>
<td>2.310</td>
<td>0.825</td>
<td>60.650</td>
<td>17.662</td>
</tr>
<tr>
<td>2.320</td>
<td>0.832</td>
<td>61.259</td>
<td>17.639</td>
</tr>
<tr>
<td>2.330</td>
<td>0.822</td>
<td>60.425</td>
<td>17.644</td>
</tr>
<tr>
<td>2.340</td>
<td>0.821</td>
<td>60.378</td>
<td>17.641</td>
</tr>
<tr>
<td>2.350</td>
<td>0.812</td>
<td>59.642</td>
<td>17.643</td>
</tr>
<tr>
<td>2.360</td>
<td>0.834</td>
<td>61.426</td>
<td>17.632</td>
</tr>
<tr>
<td>2.370</td>
<td>0.819</td>
<td>60.216</td>
<td>17.609</td>
</tr>
</tbody>
</table>

[1] From Rohde and Schwarz FSU

6.2 Power gain compression test

$V_{cc} = 3.3$ V network analyzer is set to CW mode - for example, set to a single frequency, with power sweep. Input power is swept from $-25$ dBm to $-5$ dBm at 2332.5 MHz. Amplifier reaches input 1 dB compression point ($P_{I(1dB)}$) at $-15.02$ dBm input power. Output $P_{L(1dB)} = -15.02$ dBm + 16.77 dB gain at $P_{L(1dB)}$ point ≥ $+1.75$ dBm, or 1.5 mW.

![Fig 8. Plot of gain compression test](aaa-000715)
6.3 Input return losses (10 MHz to 6 GHz)

6.3.1 Log Mag

Fig 9. Plot of input return losses

![Graph showing input return losses](image)

6.3.2 Smith chart

Fig 10. Smith chart of input return losses

Reference plain = input SMA connector on PCB

![Graph showing Smith chart](image)
6.3.3 Forward gain - wide sweep

Fig 11. Plot of forward gain

6.4 Reverse isolation

Fig 12. Plot of reverse isolation
6.5 Output return losses (10 MHz to 6 GHz)

6.5.1 Log Mag

Fig 13. Plot of output return losses

6.5.2 Smith chart

Fig 14. Smith chart of output return losses

Reference plain = input SMA connector on PCB
6.6 Two-tone test (2332 MHz)

6.6.1 Input stimulus for amplifier two-tone test

- $f_1 = 2332 \text{ MHz}$
- $f_2 = 2333 \text{ MHz}$
- $-24.37 \text{ dBm for each tone}$

Fig 15. Plot of amplifier two-tone test at 2332 MHz
6.6.2 LNA response to two-tone test

- Output IP3 = 22.625 dBm
- Input IP3 = 22.625 dBm – (24.37 – 6.46) dBm = 4.7 dBm

Fig 16. Plot of LNA response to two-tone test
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8. Tables

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Fig 5. Stack of the PCB material.

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Fig 8. Plot of gain compression test.

Fig 9. Plot of input return losses.

Fig 10. Smith chart of input return losses.

Fig 11. Plot of forward gain.

Fig 12. Plot of reverse isolation.

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Fig 14. Smith chart of output return losses.

Fig 15. Plot of amplifier two-tone test at 2332 MHz.

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