AN11006
Single stage 2.3-2.7GHz LNA with BFU730F
Rev. 4.0 — 21 June 2016

Application note

Table: Info | Content
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Keywords | BFU730F, LNA, 2.3-2.7 GHz, WiMAX, WLAN, ISM, LTE, High linearity.
Abstract | The document provides circuit, layout, BOM and performance information on 2.3-2.7 GHz LNA equipped with NXP’s BFU730F wide band transistor.

This Application note is related to evaluation board OM7690/BFU730F,598 12nc 934065627598
Contact information

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1. Introduction

The BFU730F is a discrete HBT that is produced using NXP Semiconductors' advanced 110 GHz fT SiGe:C BiCMOS process. SiGe:C is 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 allows steeper and narrower SiGe HBT base and a heavier doped base. As a result, lower base resistance, lower noise and higher cut off frequency can be achieved.

The BFU730F is one of a series of transistors made in SiGe:C. BFU710F, BFU760 and BFU790 are the other types, BFU710 is intended for ultra low current applications. The BFU760F and BFU790F are high current types and are intended for application where linearity is key.

The BFU7XXF are ideal in all kind of applications where cost matters. It also gives design flexibility.

2. Requirements and design of the 2.3-2.7GHz LNA

The BFU730 2.3-2.7GHz LNA EVB simplifies the evaluation of the BFU730 wideband transistor, for this frequency range, in which e.g. WLAN, Bluetooth, WiMax, LTE etc systems are present. The EVB enables testing of the device performance and requires no additional support circuitry. The board is fully assembled with BFU730, including input- and output matching, to optimize the performance. The input match is a compromise between best noise figure and good Input return loss. The board is supplied with two SMA connectors for input and output connection to RF test equipment.

Table 1. Target spec.

<table>
<thead>
<tr>
<th>Vcc</th>
<th>Icc</th>
<th>NF</th>
<th>Gain</th>
<th>IRL</th>
<th>ORL</th>
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<tr>
<td>3</td>
<td>10</td>
<td>&lt;1dB</td>
<td>&gt;18</td>
<td>&gt;10</td>
<td>&gt;10</td>
</tr>
<tr>
<td>V</td>
<td>mA</td>
<td>dB</td>
<td>dB</td>
<td>dB</td>
<td>dB</td>
</tr>
</tbody>
</table>

3. Design

The 2.3_2.7 GHz LNA consists of one stage grounded emitter BFU730F amplifier. For this amplifier 11 external components are used, for matching, biasing and decoupling.

The design has been conducted using Agilent's Advanced Design System (ADS). The 2D EM Momentum tool has been used to co-simulate the PCB. Results are given in paragraph 4.5. The LNA shows a gain of 20 dB, NF of 0.8 dB, input P1dB of –16.5 dBm and an input IP3 of 1.5 dBm.

The LNA shown in this application note is unconditional stable 10 MHz-20 GHz.
3.1 BFU730F 2.3-2.7 GHz LNA-ADS Simulation circuit

Fig 1. ADS simulation circuit for 2.3-2.7 GHz LNA
3.2 BFU730F 2.3-2.7 GHz LNA - ADS Gain and match simulation results

Fig 2. ADS Gain and match simulation results for 2.3-2.7 GHz LNA
3.3 BFU730F 2.3-2.7 GHz LNA - ADS NF simulation results

Minimum NF and NF with 50 ohm terminations

Fig 3. ADS Noise Figure simulation results for 2.3-2.7 GHz LNA
3.4 BFU730F 2.3-2.7 GHz LNA - ADS Stability simulation results

If either mu_source or mu_load is >1, the circuit is unconditionally stable.

![Graph showing ADS stability simulation results for 2.3-2.7 GHz LNA](image)

(1) As K ≥ 1 and Mu ≥ 1, the LNA is unconditionally stable for the whole frequency band

Fig 4. ADS stability simulation results for 2.3-2.7 GHz LNA
4. Implementation

4.1 Schematic

Fig 5. BFU730F 2.3-2.7 GHz LNA schematic
4.2 Layout and assembly

Fig 6. Layout and assembly information for BFU730F 2.3-2.7 GHz LNA EVB
Table 2.  Bill of materials

<table>
<thead>
<tr>
<th>Designator</th>
<th>Description</th>
<th>Size</th>
<th>Value</th>
<th>Type</th>
<th>Note</th>
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<tr>
<td>Q1</td>
<td>BFU730F</td>
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<td></td>
<td>NXP Semiconductors</td>
<td>HBT</td>
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<tr>
<td>PCB</td>
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<td>20X35mm</td>
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<td></td>
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<td>0402</td>
<td>100 pF</td>
<td>MurataGRM1555</td>
<td>DC block</td>
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<tr>
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<td>Bias Decoupling</td>
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<td>C6</td>
<td>Capacitor</td>
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<td>3.3 pF</td>
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<td>output match</td>
</tr>
<tr>
<td>C7</td>
<td>Capacitor</td>
<td>0402</td>
<td>4.7 pF</td>
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<td>output match</td>
</tr>
<tr>
<td>L1</td>
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<td>1.5 nH</td>
<td>Murata LQW15</td>
<td>input match</td>
</tr>
<tr>
<td>L2</td>
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<td>0402</td>
<td>8.7 nH</td>
<td>Murata LQW15</td>
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<tr>
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<td>4.7 nH</td>
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<td>output match</td>
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<tr>
<td>L4</td>
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<td>3.6 nH</td>
<td>Murata LQP15</td>
<td>output match</td>
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<td>Resistor</td>
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<td>37 K</td>
<td></td>
<td>Bias Setting</td>
</tr>
<tr>
<td>R2</td>
<td>Resistor</td>
<td>0402</td>
<td>100 R</td>
<td></td>
<td>Bias Setting</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hfe and Temp spread cancellation</td>
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<tr>
<td>R3</td>
<td>Resistor</td>
<td>0402</td>
<td>10 Ohm</td>
<td></td>
<td>Stability</td>
</tr>
<tr>
<td>R4</td>
<td>Resistor</td>
<td>0402</td>
<td>0 R</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>X1,X2</td>
<td>SMA RF connector</td>
<td>-</td>
<td></td>
<td>Johnson, End launch SMA 142-0701-841</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>

4.3 PCB layout

A good PCB Layout is an essential part of an RF circuit design. The EVB of the BFU730 can serve as a guideline for laying out a board using either the BFU730 or one of the other SiGe.C HBTs in the SOT343F package. Use controlled impedance lines for all high frequency inputs and outputs. Bypass VCC with decoupling capacitors, preferably located as close as possible to the device. For long bias lines it may be necessary to add decoupling capacitors along the line further away from the device. Proper grounding the emitters is also essential for the performance. Either connect the emitters directly to the
ground plane or through vias, or do both. The material that has been used for the EVB is FR4 using the stack shown in Fig 7.

Fig 7. PCB material stack

Material supplier is Isola Duraver; Er=4.6-4.9 Tδ=0.02
4.4 LNA View

Fig 8. 2.3_2.7 GHz LNA
4.5 Measurement results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage</td>
<td>V_{cc}</td>
<td>3</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Supply Current</td>
<td>I_{cc}</td>
<td>10</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>Noise Figure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>NF[1]</td>
<td>0.8</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>Power Gain 2.3 GHz</td>
<td></td>
<td>21.2</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>Power Gain 2.5 GHz</td>
<td>G_{p}</td>
<td>21</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>Power Gain 2.7 GHz</td>
<td></td>
<td>20.5</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>Input return Loss</td>
<td>I_{RL}</td>
<td>7.9</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>Output return Loss</td>
<td>O_{RL}</td>
<td>17.5</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>Input 1dB Gain compression Point</td>
<td>P_{i1dB}</td>
<td>-16.5</td>
<td>dBm</td>
<td></td>
</tr>
<tr>
<td>Output 1dB Gain compression Point</td>
<td>P_{o1dB}</td>
<td>+3.7</td>
<td>dBm</td>
<td></td>
</tr>
<tr>
<td>Input third order intercept point</td>
<td>I_{P3i}</td>
<td>+1.5</td>
<td>dBm</td>
<td></td>
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<tr>
<td>Output third order intercept point</td>
<td>I_{P3o}</td>
<td>+22.5</td>
<td>dBm</td>
<td></td>
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<tr>
<td>Power settling time</td>
<td>T_{on}</td>
<td>430</td>
<td>ns</td>
<td></td>
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<tr>
<td></td>
<td>T_{off}</td>
<td>24</td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>

[1] The NF and gain figures are being measured at the SMA connectors of the evaluation board, so losses of the connectors and the PCB of approximately 0.1 dB are not substracted

4.5.1 Faster Switching time <1 μs

If no switching speed is required in the application, the recommendation is to keep the BOM as is presented in this application note. However if the LNA is applied in e.g. a WLAN application where power settling time is required to be <1 μs, the value of C1 an C3 should be changed to 27pF. This will result in a Ton power settling time of 860ns and the Toff power settling time stays 24ns. However this change in capacitor values will result in about 5-10dB of degradation of the IP3 figures reported in Table 3.
4.5.2 Gain and match - typical values

Fig 9. Typical Gain and match measured values
4.5.3 NF and Gain- typical values

![ NF and Gain- typical values graph]

Measurement Complete

Date: 26 DEC 2010 15:15:01

(1) NF and Gain measurements correction applied see §5 for values

Fig 10. Typical NF curve
4.5.4 Stability

Fig 11. Stability typical measurement results
4.5.5 1dB compression point typical values.

Fig 12. Typical 1 dB compression point curve.

(1) $P_{1dB} = -16.4$ dBm   $P_o1dB = 3.7$ dBm
4.5.6 Linearity IP3 – typical values

Fig 13. IM3 - typical values

(1) \[ IP_{3o} = \frac{(72-8.9)}{2} + 22.6 \text{ dBm} \]
\[ IP_{3i} = -30 \text{ dBm} + \frac{63.1}{2} = -30 + 31.55 = +1.55 \text{ dBm} \]
4.5.7 Power settling time

Fig 14. $t_{on}$ Power settling time

(1) curve 1 is power supply; curve 2 is the output of the detection diode.
5. NF measurement corrections

There are two types of errors and losses that have been taken into account to correct the NF measurement results: (1) Own system error for NF measurement and (2) insertion losses accounted to RF IN and RF OUT connectors, microstrip feed lines used at the input of the LNA in NF measurements.

5.1 NF measurement system error

A Miteq professional amplifier, rated as NF=0.41 dB, Gain=30 dB, has been used as reference for NF measurement system correction. Its manufacturer data is in Fig 16.
Fig 16. Miteq amp 1228664

Miteq 1228664 amplifier measured with the NF setup used to qualify the BFU730F 2.3-2.7GHz LNA has the NF performances listed in Fig 17. The system correction factor, NFsys, is the difference between the NF measured and the 0.42 dB value from the catalog. At 2GHz this difference is about 0.3 dB and at 3 GHz around 0.15 dB.
(2) \( NF_{sys} = (NF \text{ in Fig 17} - NF \text{ in Fig 16}) \) represents the NF system correction factor: average value = 0.2 dB

Fig 17. Miteq 1228664 amplifier NF and Gain

5.2 Insertion losses.

Insertion losses have not been taken in to account so measurements are referenced to the SMA connectors.
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