This document provides circuit simulation, schematic, layout, BOM and typical EVB performance for a broadband WiFi (WLAN) LNA.
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 a 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, BFU760F and BFU790F are the other types. BFU710F is intended for ultra low current applications. The BFU760F and BFU790F are high current types and are intended for application where linearity is key.

New 6th & 7th Generation Wideband transistors from NXP offer best RF noise figure / gain tradeoff at 12GHz drawing lowest current which means best signal reception at low power, enabling products to be more sensitive in noisy environments and friendlier to the environment.

Key Benefits:

• Application up to 18 GHz and higher
• Broad choice of parts for the perfect fit in the application
• Lowest current consumption meaning greener products
• SOT343F package for high performance and easy manufacturing
2. Requirements and design of the 2.4-5.9GHz broadband WiFi LNA

The circuit shown in this application note is intended to demonstrate the performance of the BFU730F in a 2.4-5.9 GHz LNA for e.g. 802.11a/b/g & 802.11n “MIMO” WiFi (WLAN) applications.

Key requirements for this application are:

- Broadband Frequency 2.4 – 5.9GHz
- Gain
- Input/output Match
- Linearity
- NF
- Turn ON/OFF Time
# Table 1. Broadband WiFi LNA Design Target Spec

<table>
<thead>
<tr>
<th>VCC</th>
<th>Icc</th>
<th>NF</th>
<th>Gain</th>
<th>IP1dB</th>
<th>IIP3</th>
<th>ORL</th>
<th>IRL</th>
<th>Turn ON/OFF Time</th>
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<td>3.3</td>
<td>12</td>
<td>&lt;2</td>
<td>&gt;10</td>
<td>&gt;-14</td>
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<td>mA</td>
<td>dB</td>
<td>dB</td>
<td>dBm</td>
<td>dBm</td>
<td>dB</td>
<td>dB</td>
<td>nS</td>
</tr>
</tbody>
</table>

## 3. Design and Simulation

The 2.4-5.9 GHz broadband WiFi LNA consists of one stage BFU730F amplifier. For this amplifier 12 external components are used for broadband matching, DC biasing and decoupling.

The design has been simulated using Agilent's Advanced Design System (ADS), and the simulation results are given in the following figures.

The LNA shows a Gain of 20dB @2.4GHz with NF 0.7dB and 10dB @5.9 GHz with best-in-class NF of 1.2 dB. With only 12mA it shows a high input P1 dB compression of –8dBm@5.9GHz, as well as high input IP3 of +3dBm. The designed LNA is unconditionally stable at 10 MHz-20 GHz.
3.1 BFU730F 2.4-5.9GHz Broadband WiFi LNA Simulation

![BFU730F 2.4-5.9GHz Broadband WiFi LNA Simulation: Circuit](image_url)
3.2 BFU730F WiFi Broadband LNA Simulation Result

3.2.1 Gain and Match in 2.4GHz and 5.9GHz Band

Fig 3. BFU730F 2.4-5.9GHz Broadband WiFi LNA Simulation: Gain and Match
3.2.2 Noise Figure in 2.4GHz and 5.9GHz Band

Fig 4. BFU730F 2.4-5.9GHz Broadband WiFi LNA Simulation: Noise Figure

3.2.3 Stability

Fig 5. BFU730F 2.4-5.9GHz Broadband WiFi LNA Simulation: Stability
4. Application Board

The 2.4-5.9GHz broadband WiFi LNA evaluation board simplifies the evaluation of the BFU730F application. The evaluation board enables testing of the device performance and requires no additional support circuitry. The board is fully assembled with the BFU730F transistor, including input and output matching components, to optimize performance.

The board is supplied with two SMA connectors for input and output connection to RF test equipment.

4.1 Application Circuit Schematic

Fig 6. BFU730F 2.4-5.9GHz Broadband WiFi LNA: Schematic
### 4.2 Application Board Bill-Of-Material

Table 2. BFU730F 2.4-5.9GHz Broadband WiFi LNA Part List

*Customer can choose their preferred vendor but should be aware that the performance could be affected.*

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Reference</th>
<th>Part Number</th>
<th>Vendor</th>
<th>Value</th>
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<td>C1</td>
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<td>Murata</td>
<td>2pF</td>
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<td>2</td>
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<td>GRM1555C1HR50CZ01</td>
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<td>0.5pF</td>
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<td>5</td>
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<td>90120-0762</td>
<td>Molex</td>
<td>CON-2PIT</td>
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<tr>
<td>6</td>
<td>2</td>
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<td>Amphenol</td>
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<td>Coilcraft</td>
<td>2.2nH</td>
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<tr>
<td>8</td>
<td>1</td>
<td>L2</td>
<td>0402CS-3N3X_LU</td>
<td>Coilcraft</td>
<td>3.3nH</td>
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<td>9</td>
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<td>LQG15HN5N6S02</td>
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<td>5.6nH</td>
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<td>4.7nH</td>
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<td>BFU730F</td>
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<td>R1</td>
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<td>Panasonic - ECG</td>
<td>39K</td>
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<td>13</td>
<td>1</td>
<td>R2</td>
<td>ERJ-2RF10R0X</td>
<td>Panasonic - ECG</td>
<td>10</td>
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<tr>
<td>14</td>
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<td>R3</td>
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<td>R6</td>
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4.3 Typical Application Board Test Result

4.3.1 S-Parameter – Gain and Match

**Fig 7.** BFU730F 2.4-5.9GHz Broadband WiFi LNA: S-Parameter

4.3.2 P1dB

**Fig 8.** BFU730F 2.4-5.9GHz Broadband WiFi LNA: P1dB
4.3.3 Linearity/IP3

Tone spacing: 1MHz

Fig 9. BFU730F 2.4-5.9GHz Broadband WiFi LNA: IP3

4.3.4 Stability

K Factor

Fig 10. BFU730F 2.4-5.9GHz Broadband WiFi LNA: Stability
4.3.5 Noise Figure Measurement

A network analyzer is used to measure the loss between the connector to the first matching component of the device. The measured return loss is 0.2-0.4dB across the band, therefore a 0.1-0.2dB input loss must be de-embedded to get device noise figure.

The Noise figure data in the graphic below is the noise figure after de-embedding the connector and input loss.

![Noise Figure Measurement](image)

**Fig 11. BFU730F 2.4-5.9GHz Broadband WiFi LNA: Noise Figure**
4.3.6 LNA Turn ON/OFF Time

The following diagram shows the setup to test LNA Turn ON and Turn OFF time. The LNA Turn ON and Turn OFF time are mainly determined by the R-C time constant of the biasing circuitries: on the Base bias path the $\tau_1 = R3*C3$ and on the Collector bias path $\tau_2 = (R2+R3)*C12$.

Set the waveform generator output to square mode and the output amplitude at 3Vrms with high output impedance. The waveform generator has adequate output current to drive the LNA therefore no extra DC power supply is required which simplifies the test setup.

Set the RF signal generator output level to -25dBm at 2.4GHz and increase its level until the output DC on the oscilloscope is at 25mV on 5mV/division, the signal generator RF output level is approximately -13dBm.

It is very important to keep the cables as short as possible at input and output of the LNA so the propagation delay difference on cables between the two channels is minimized.

It is also critical to set the oscilloscope input impedance to 50ohm on channel 2 so the diode detector can discharge quickly to avoid a false result on the Turn OFF time testing.

Fig 12. LNA Turn ON and Turn OFF time test setup
4.3.6.1 LNA Turn ON Time

3.3Vrms, 100KHz and 50% duty cycle pulse applied on VCC pin, measured from 50% of input pulse to 90% of max. output power

Fig 13. BFU730F 2.4-5.9GHz Broadband WiFi LNA: Turn ON time
4.3.6.2 LNA Turn OFF Time

3.3Vrms, 100KHz and 50% duty cycle pulse applied on VCC pin, measured from 50% of input pulse to 10% of max. output power

Fig 14. BFU730F 2.4-5.9GHz Broadband WiFi LNA: Turn OFF time

4.3.7 Summary Of the Typical Evaluation Board Test Result

Table 3. Typical results measured on the BFU730F 2.4-5.9GHz Broadband WiFi LNA Evaluation Board

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
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<tr>
<td>Supply Voltage</td>
<td>Vcc</td>
<td>3.3</td>
<td>V</td>
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<tr>
<td>Supply Current</td>
<td>Icc</td>
<td>12</td>
<td>mA</td>
</tr>
<tr>
<td>Noise Figure @2.4GHz</td>
<td>NF</td>
<td>0.7</td>
<td>dB</td>
</tr>
<tr>
<td>Noise Figure @5.9GHz</td>
<td>NF</td>
<td>1.2</td>
<td>dB</td>
</tr>
<tr>
<td>Power Gain @2.4GHz</td>
<td>Gp</td>
<td>20.9</td>
<td>dB</td>
</tr>
<tr>
<td>Power Gain @5.9GHz</td>
<td>Gp</td>
<td>10.6</td>
<td>dB</td>
</tr>
<tr>
<td>Input Return Loss @2.4GHz</td>
<td>IRL</td>
<td>11.8</td>
<td>dB</td>
</tr>
<tr>
<td>Input Return Loss @5.9GHz</td>
<td>IRL</td>
<td>13.8</td>
<td>dB</td>
</tr>
<tr>
<td>Output Return Loss @2.4GHz</td>
<td>ORL</td>
<td>9.7</td>
<td>dB</td>
</tr>
<tr>
<td>Output Return Loss @5.9GHz</td>
<td>ORL</td>
<td>19.7</td>
<td>dB</td>
</tr>
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<td>Parameter</td>
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<td>Value</td>
<td>Unit</td>
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<tr>
<td>---------------------------------------</td>
<td>--------------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>Reverse Isolation</td>
<td>@2.4GHz ISLrev</td>
<td>28.5</td>
<td>dB</td>
</tr>
<tr>
<td></td>
<td>@5.9GHz ISLrev</td>
<td>25.8</td>
<td>dB</td>
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<td>Input 1dB Gain Compression Point</td>
<td>@2.4GHz Pi1dB</td>
<td>-13.1</td>
<td>dBm</td>
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<tr>
<td></td>
<td>@5.9GHz Pi1dB</td>
<td>-7.6</td>
<td>dBm</td>
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<td>Output 1dB Gain Compression Point</td>
<td>@2.4GHz PL1dB</td>
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<td></td>
<td>@5.9GHz PL1dB</td>
<td>1.7</td>
<td>dBm</td>
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<tr>
<td>Input Third Order Intercept Point</td>
<td>@2.4GHz IIP3</td>
<td>-4.3</td>
<td>dBm</td>
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<tr>
<td>@1MHz tone spacing</td>
<td>@5.9GHz IIP3</td>
<td>3.8</td>
<td>dBm</td>
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<td>Output Third Order Intercept Point</td>
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<td>dBm</td>
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<td>@1MHz tone spacing</td>
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<td>LNA Turn ON/OFF Time</td>
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<td>nS</td>
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<tr>
<td></td>
<td>Toff</td>
<td>19</td>
<td>nS</td>
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